UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

POTENTIAL SITES FOR A SPENT UNREPROCESSED FUEL FACILITY (SURFF), SOUTHWESTERN PART OF THE NEVADA TEST SITE

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ABSTRACT

In the absence of specific criteria, the topography, geomorphology, and geology of Jackass Flats and vicinity in the southwestern part of the Nevada Test Site are evaluated by arbitrary guidelines for a Spent Unreprocessed Fuel Facility. The guidelines include requirements for surface slopes of less than 5 percent, 61 m of alluvium beneath the site, an area free of active erosion or deposition, lack of faults, a minimum area of 5 km^2, no potential for flooding, and as many logistical support facilities as possible.

The geology of the Jackass Flats area is similar to the rest of the Nevada Test Site in topographic relief (305-1,200 m), stratigraphy (complexly folded and faulted Paleozoic sediments overlain by Tertiary ash-flow tuffs and lavas overlain in turn by younger alluvium), and structure (Paleozoic thrust faults and folds, strike-slip faults, proximity to volcanic centers, and Basin and Range normal faults). Of the stratigraphic units at the potential Spent Unreprocessed Fuel Facility site in Jackass Flats, only the thickness and stability of the alluvium are of immediate importance. Basin and Range faults and a possible extension of the Mine Mountain fault need further investigation.

The combination of a slope map and a simplified geologic and physiographic map into one map shows several potential sites for a Spent Unreprocessed Fuel Facility in Jackass Flats. The potential areas have slopes of less than 5 percent and contain only desert pavement or segmented desert pavement--the two physiographic categories having the greatest geomorphic and hydraulic stability.

Before further work can be done, specific criteria for a Spent Unreprocessed Fuel Facility site must be defined. Following criteria definition, potential sites will require detailed topographic and geologic studies, subsurface investigations (including geophysical methods, trenching, and perhaps shallow drilling for faults in alluvium), detailed surface hydrologic studies, and possibly subsurface hydrologic studies.

INTRODUCTION

Development of a safe method of disposing of high-level radioactive wastes--safe not only for this generation but for as long as a million years--is estimated to be more than 10 years in the future. To provide safe temporary storage of such wastes until a permanent disposal method is developed and publicly accepted, DOE (U.S. Department of Energy, formerly U.S. Energy Research and Development Administration) has proposed the SURFF (Spent Unreprocessed

Fuel Facility) concept. The SURFF concept is similar to the concept for storage of reprocessed nuclear waste (U.S. Atomic Energy Commission, 1974) which would encase the waste in large concrete monoliths to be stored on the surface. Other possible methods of temporary storage, some involving burial of waste at relatively shallow depths, are also under study, but they are not considered here.

This report presents a compilation of available geologic and physiographic data on the southwestern part of the NTS (Nevada Test Site) and indicates several areas that warrant further detailed study as potential disposal sites. It is limited to a discussion of the geologic character of the alluvium at and near the surface and of young faults in or below the alluvium, movement on which might affect a surface storage facility. Another report and as yet unpublished data are complementary to this report, and an understanding of all three bodies of data is necessary for decisions on the desirability of siting a SURFF within the study area. The published report concerns the seismic hazard of the NTS region (Rogers and others, 1977), and unpublished data concerns the hydrology of the southwestern part of the NTS.

The study area includes all of NTS Area 25, site of the now inactive NRDS (Nuclear Rocket Development Station), plus small areas surrounding Area 25. The study area was limited to Area 25 and vicinity primarily because its use for waste storage would not interfere with weapons testing or other activities in other parts of the NTS, and because some NRDS facilities may be adaptable to SURFF use. Other parts of the test site, however, contain equally acceptable potential sites for a SURFF. Some of those that would deserve study in case siting within the present study area proves infeasible are: Frenchman Flat, Yucca Flat, Mid Valley, Rock Valley, and possibly Mercury Valley. All of the latter are shown on figure 1, but none is discussed further here.

Guidelines for SURFF Site Selection

Specific criteria for selection of a SURFF site have not yet been determined. For purposes of this compilation, a set of arbitrary guidelines is adopted. These guidelines serve to determine the physiographic, geologic, and hydrologic factors that must be evaluated in the search for a site. Some of the criteria are drawn from general discussions of RSSF (Retrievable Surface Storage Facility) siting (U.S. Atomic Energy Commission, 1974), but some are based on knowledge of local conditions within the study area. The arbitrary criteria follow:

1. Surface of site and vicinity must be nearly level, with no slopes greater than 5 percent (2°52'). This requirement is partly to facilitate construction, but mainly to permit rail or highway haulage of heavy, concentrated loads.
2. Surface must be underlain by at least 200 feet (60 m) of alluvium, with no bedrock highs at or near surface. One purpose of this requirement is to provide foundations that can be excavated easily but possess sufficient bearing strength to support concentrated loads; a second purpose is to provide a sorption barrier to downward migration of water or other fluids.

3. Surface should be stable (with little or no active deposition or erosion) and with few, if any, active washes or gullies.
4. Actual or potential surface faults must be avoided within the site.
5. Specific sites should have minimum areas of 518 ha (5 km^2 or 2 mi^2), but the larger the surrounding areas that meet criteria 1-3, the better.
6. Sites must not be subject to floods unless engineering means of diverting stream or sheetfloods are available.
7. Existing roads, communication lines, and other facilities are desirable but not required.

Conclusions and Recommendations

Many parts of the study area meet the basic requirements for a SURFF site embodied in the arbitrary guidelines adopted here. Of them all, those in Jackass Flats appear to offer the best potential sites. It is recommended, therefore, that further search be narrowed to Jackass Flats. Firm guidelines for siting a SURFF should be established. Once these are available, detailed studies should be made of each of the areas within the flats that are shown on figure 5 as favorable. These studies should include hydrologic and seismic investigations as well as geologic. Together, they will almost certainly result in identification of one or more sites that meet the requirements fully. If the Jackass Flats sites so identified prove to be infeasible for any reason, the search can be extended to other parts of the NTS, either in the study area or outside it.

PHYSIOGRAPHIC AND TOPOGRAPHIC SETTING

The major physiographic features in and near the NTS are shown on figure 1. The test site lies in the Basin and Range physiographic province, which consists primarily of alluvium-filled valleys between northerly trending mountain ranges. Most of the valleys trend north or northeast; Mercury Valley, which trends northwest along the line of the Las Vegas Valley shear zone, is an exception.

Topographic relief at NTS generally ranges from 305 to 1,220 m. The lowest point in the test site, at the southwest corner, is 820 m; the highest point, on Rainier Mesa near the center of the test site's northern boundary, is 2,340 m. Within the study area of this report, altitudes range from 820 m in the southwest corner to nearly 1,830 m on Skull Mountain.

Mountains and hills are mostly rugged, with steep slopes and canyons and almost continuous exposures of bedrock. They have been carved by intermittent streams that have filled the intermontane area with alluvial debris carried from the mountains.

The alluvial fill in the valleys and flats ranges in thickness from a few inches along the sides to several thousand feet in the deeper parts. Surface slopes on the fill are far flatter than those in the mountains, and range from horizontal to as much as 10 percent (5°43'). Some of the flattest areas, such as those of Frenchman and Yucca Flats, are marked by playas, which are covered with water for a few hours or even days after heavy precipitation. No playas lie within the study area.

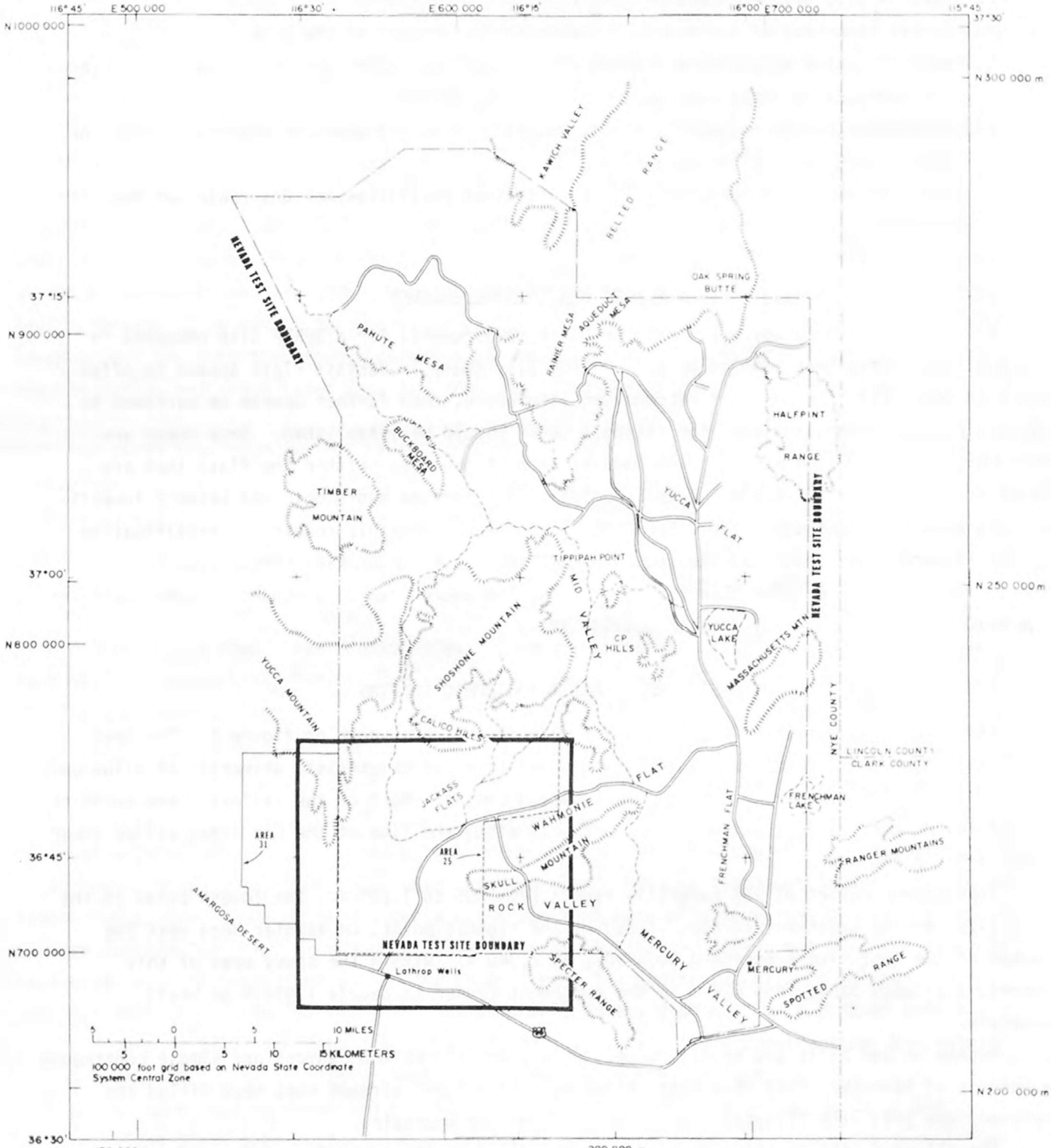

Figure 1.--Index map showing topographic features in the Nevada Test Site and vicinity. Heavy outline defines area shown on figures 2, 3, and 4.

The deep valleys, such as Yucca Flat, were formed by faulting of great blocks of rock and by relative uplift of the mountain masses. The resultant valleys were then filled by accumulation of debris from the mountains. Generally, the topography of the Basin and Range physiographic province thus consists of a series of mountainous islands that are being buried in sand seas of their own debris. Degradation of the mountains and filling of the valleys are still in progress. In some areas, however, such as parts of Jackass Flats, the two processes have approached equilibrium and alluviated surfaces are relatively stable.

GEOLOGY

Rocks

Given the arbitrary requirements for a SURFF site as listed above, the bedrock geology has comparatively little bearing on the suitability of alluvial surfaces for sites. Such bearing as there is has to do with the ability of the bedrock masses to transmit earthquake stresses (discussed by Rogers and others, 1977) and the possibility that movements on old or new bedrock faults may also affect the alluvium. This possibility is discussed in the section on structure.

The NTS and the area surrounding it is underlain by a thick series of old, complexly folded and faulted sedimentary rocks--quartzites, argillites, limestones, and others. Their eroded surfaces are overlain by a much younger series of extrusive volcanic rocks and are cut in a few places by relatively small bodies of intrusive igneous rocks. The volcanic rocks, mostly ash-flow and ash-fall tuffs and lavas of variable composition, were derived from a few scattered volcanic centers, such as the complex caldera of Timber Mountain. The volcanic rocks are themselves faulted but not as intensely as the older sedimentary rocks. They are, in turn, overlain by young alluvium. The alluvium is thin or nonexistent in the mountains, but very thick in the valleys. Characteristically coarse and angular in the mountainous source areas, it becomes progressively finer grained downslope toward the valley centers.

The geology of the study area is like that just described for the entire NTS. It is shown at 1:24,000 [1 in=2,000 ft (610 m)] on a series of geologic quadrangle maps (fig. 2) and is described on these maps and in numerous other reports listed in the bibliography. All the geologic quadrangle maps depict alluvium as well as bedrock, but the amount of detail shown for the alluvium varies from one map to another.

For convenience in use of this report, references to the maps that cover the study area are listed:

Jackass Flats, GQ 368; McKay and Williams, 1964
Lathrop Wells, GQ 883; McKay and Sargent, 1970
Skull Mountain, GQ 387; Ekren and Sargent, 1965
Specter Range NW, GQ 884; Sargent and Stewart, 1971
Striped Hills, GQ 882; Sargent and others, 1970
Topopah Spring SW, GQ 439; Lipman and McKay, 1965

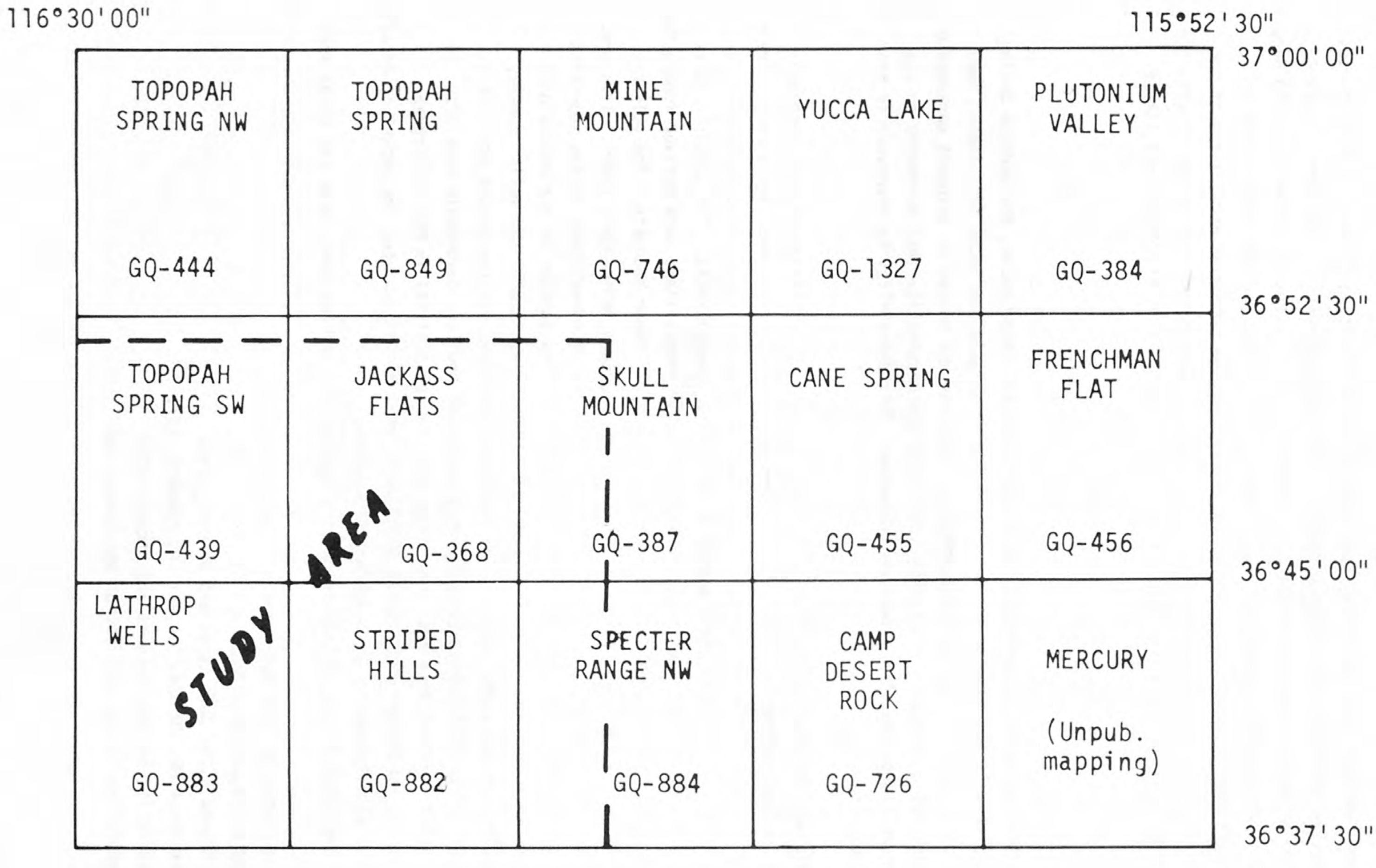

Figure 2.--Index map showing available geologic quadrangle maps in southern part of the Nevada Test Site, with outline of the area covered by this study. All maps are 1:24,000 scale.

Structure

The predominant structural features in the NTS and vicinity are (1) complex folds and major thrust faults in Precambrian and Paleozoic rocks; (2) strike-slip faults and fault zones, some of them very extensive; (3) volcanic centers; and (4) Basin and Range normal faults. None of the folds, or thrust faults, or volcanic centers, are believed to have any bearing on the present study, but a few strike-slip and normal faults are young enough to affect the alluvium. Should renewed movements occur on these, they might damage surface structures or topple waste-filled canisters placed above or near them.

Structure of the alluvium is far simpler than that of the underlying bedrock. Individual beds and lenses within it reflect the attitudes of the surfaces on which the alluvium was deposited. Thus, the beds dip gently from the surrounding hills at ever decreasing angles toward the central parts of the valleys,where they are nearly or quite horizontal.

Drill-hole data elsewhere on the NTS indicate that the bedrock beneath the valley is as complexly faulted as that in the mountainous areas. Some of the faults in underlying bedrock, perhaps many of them, affect the alluvium too. Faults in alluvium are difficult to find, however, and few are shown on geologic maps of any part of the test site. Some of the difficulty lies in the fact that many faults that may have displaced older and deeper parts of the alluvial fill die out upward. That is, movement along them stopped before all the alluvium had been deposited, or else the loose, incoherent sands and silts were incompetent to transmit the fault stresses and propagate them upward. In addition, the almost total lack of recognizable marker beds within the alluvium and the tendency toward smoothing and erasure of surface evidence by erosion both add to the difficulty of identifying faults.

Only a few natural fault scarps have been identified at the NTS. The Yucca fault and the Rock Valley fault have the most prominent scarps. Scarps of a few smaller faults are known; still others are suspected, but their existence is not yet proved. Air photos and other available evidence indicate that the alluvium surface in much of the southwest part of NTS, particularly in Jackass Flats, contains fewer faults than anywhere else on the test site.

POTENTIAL SURFF SITES

Much of the study area meets the basic physical requirements for a SURFF site--large areas having gentle slopes and underlain by at least 200 feet (60 m) of alluvium with stable, relatively smooth surfaces.

The facts needed for pinpointing the most promising potential sites within the vast alluvial valleys of the study area are summarized on two maps, figures 3 and 4. One of these, figure 3, shows only surface slopes, in three categories. The first two of these, slopes of less than 2 percent and those of 2-5 percent, fall within the arbitrary criteria adopted for this report. The areas in the third category, slopes of greater than 5 percent, are too steep to be acceptable for a SURFF and are not considered further. It must be expected that locally, as along the steep banks of washes, slopes may exceed the limits set for the first two categories.

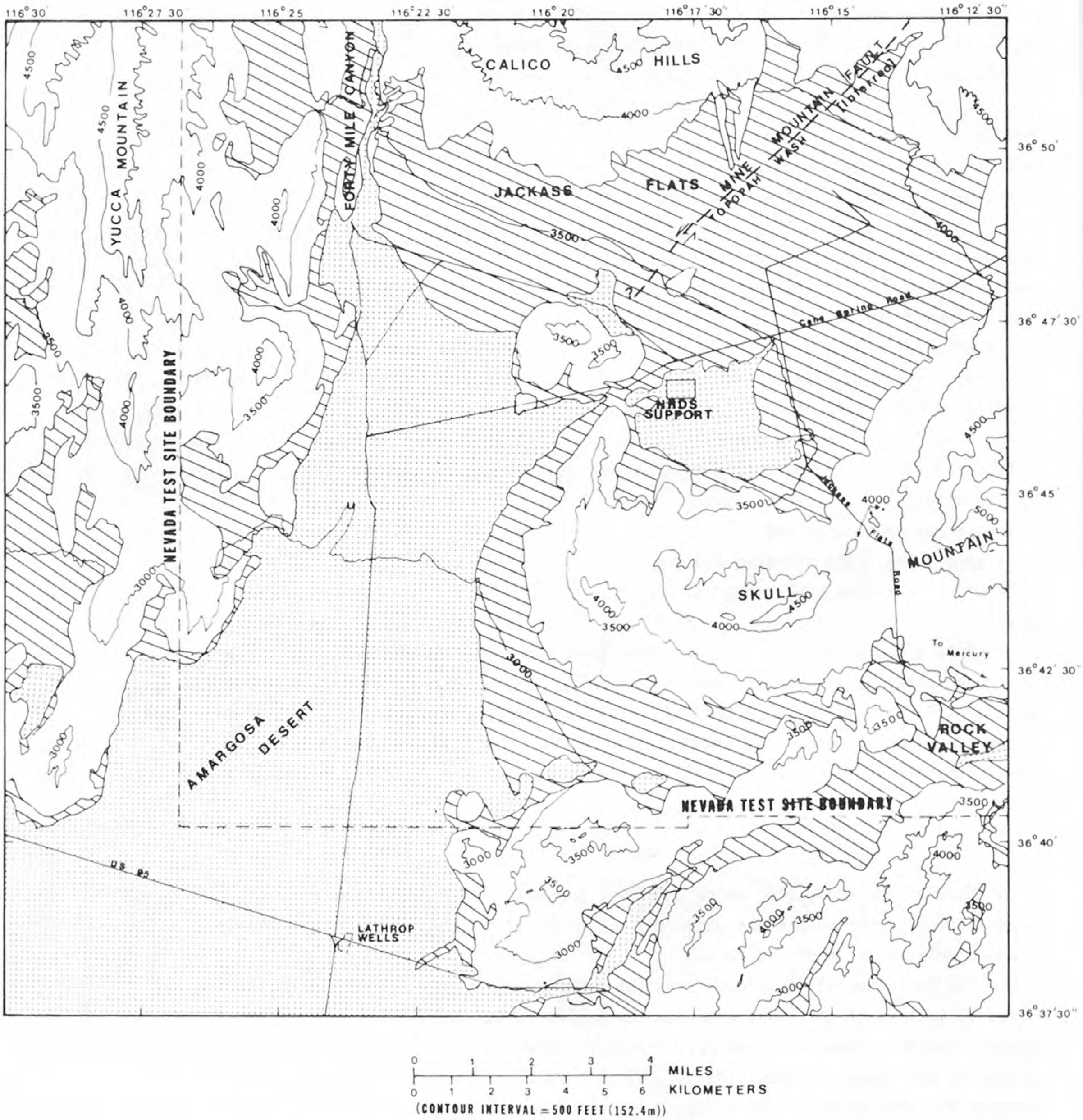

Figure 3.--Map of southwest NTS showing surface slopes. Locally, slopes may be steeper or flatter than the limits shown. Existing railroad lines between NRDS (Nuclear Rocket Development Station) facilities and several improved and unimproved roads not shown. Slope data derived from U.S. Geological Survey topographic maps. Base from U.S. Geological Survey topographic maps (see fig. 2).

EXPLANATION

SLOPES LESS THAN 2 PERCENT (1°9')

SLOPES 2-5 PERCENT (1°9'-2°52')

SLOPES GREATER THAN 5 PERCENT (2°52')--Includes nearly all mountains and a few small areas in valleys

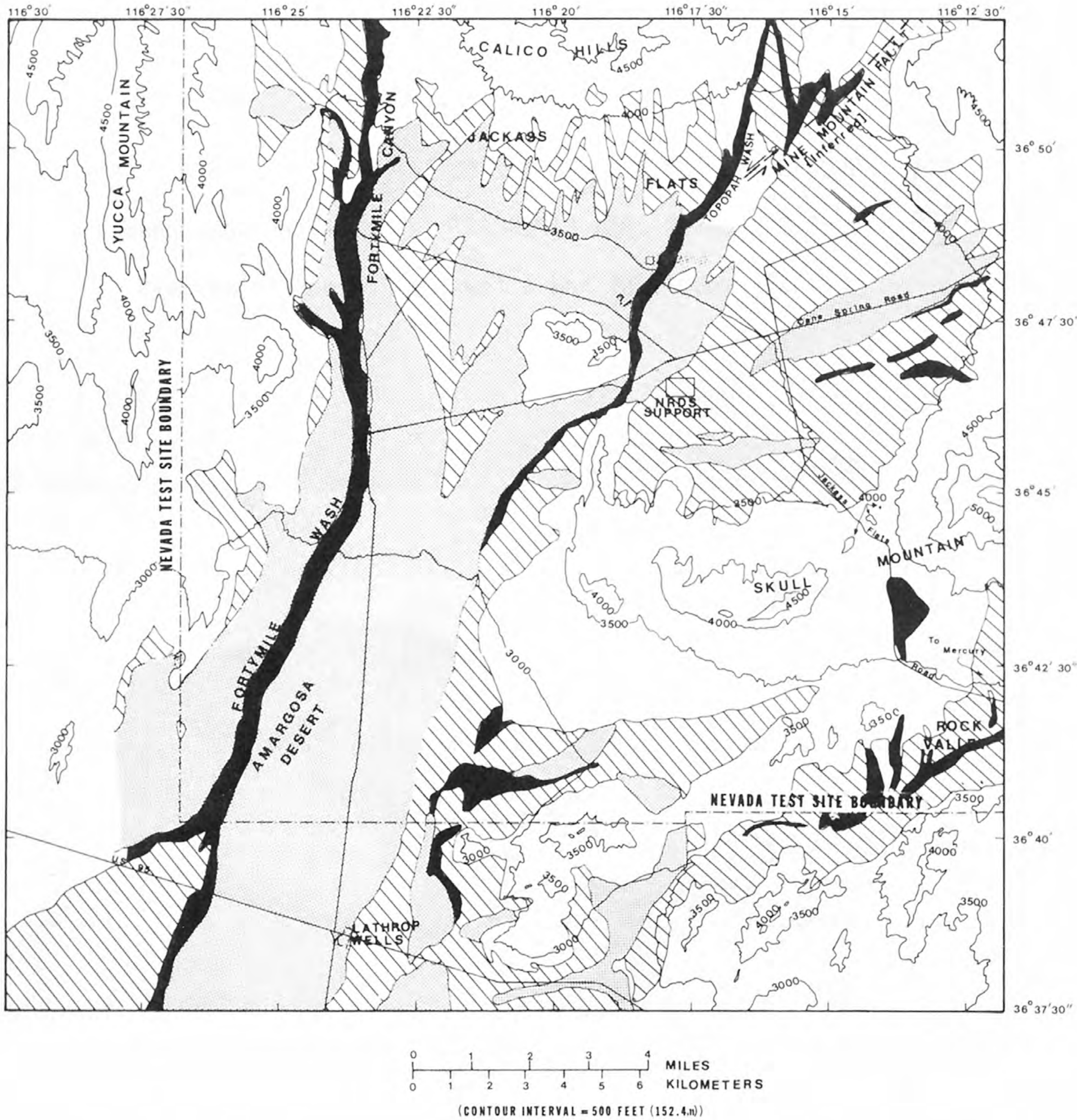

Figure 4.--Geologic and physiographic map of surface materials in southwest NTS. Derived from U.S. Geological Survey geologic quadrangle maps and aerial photographs.

EXPLANATION

Favorable for SURFF site

DESERT PAVEMENT--Stable, smooth surface covered by pebble- to boulder-sized fragments of rock. Cut by few, if any, shallow washes

SEGMENTED DESERT PAVEMENT--Like desert pavement, but cut by numerous washes, active and abandoned

Unfavorable for SURFF site

ACTIVE WASHES--Contain intermittent streams; subject to floods; surfaces unstable; valley walls may be steep in places

MOUNTAINOUS TERRAIN WITH BEDROCK AT OR VERY NEAR SURFACE--Most slopes too steep for easy construction or transport; includes deeply dissected alluvial fans in northern part of map area

Figure 4 is a highly simplified map that shows the geologic and physiographic character of the surface. The first two categories, both considered favorable for siting a SURFF, are characterized by desert pavement and segmented desert pavement. Desert pavements are those parts of an alluvial fill whose surfaces are covered by a pavement of pebble- to boulder-sized fragments embedded in soil. Surfaces are smooth and drainage channels are subdued. Because runoff from rainfall directly on the surfaces is the only important agent of erosion, areas of desert pavement are stable and undergo minimal erosion or flooding over periods of several hundred to perhaps several thousand years. Evidence for such stability is provided by desert varnish on upper surfaces of exposed boulders and pebbles. This varnish is a thin brown to black coating of iron and manganese oxides which forms in desert climates. Archeological evidence (C. B. Hunt, 1954; A. P. Hunt, 1960) indicates that most desert varnish may be 2,000 or more years old. Rarely, however, it may be much younger (Engel and Sharp, 1958). The two categories of desert pavement shown in figure 4 differ only in the regularity of their surfaces. Areas mapped as desert pavement are cut by few or no active washes, which are commonly less than 60 m wide; density of shallow, abandoned washes is variable. Segmented desert pavement is similar to desert pavement, except that it is cut by active and abandoned washes that may be as much as 6 m deep and commonly less than 305 m apart. Floods may occur more frequently than on unsegmented desert pavement, but will still be relatively rare. Reasons for the unsuitability of the other two categories of surface--large, active washes and mountainous areas or highly dissected alluvium--are self-evident.

Numerous potential SURFF sites in the southwest NTS are shown on figure 5. Produced by superposition of figures 3 and 4, it combines considerations of slope and of surface character. The first two categories present smooth, stable, relatively undissected desert pavement surfaces on low slopes. The difference between the two lies only in the steepness of slope, and decisions as to whether sites should be sought in only one or both kinds of area must rest on engineering decisions as to the amount of slope that can be tolerated. Areas in the third category, excluded from further consideration, are undesirable as sites because of steep slopes, surface characteristics, or both.

Jackass Flats

Most of Jackass Flats, including the area along Fortymile Wash and the Amargosa Desert, fit the guidelines adopted in this report. Several other smaller areas also appear at first glance to meet the requirements, but they are considered less desirable as candidates because of their small size, lack of thick alluvial fill, or for other reasons. That part of the Amargosa Desert that lies within the test site contains many ideal potential sites that have nearly flat slopes, thick alluvium, and physiographically stable surfaces. It is less desirable than Jackass Flats because of its proximity to the NTS boundary and Lathrop Wells. Any contaminated material, either on the surface or in the subsurface, that might be accidentally released from a SURFF would travel off government-controlled land faster from the Amargosa Desert than it would from the more northerly parts of Jackass Flats.

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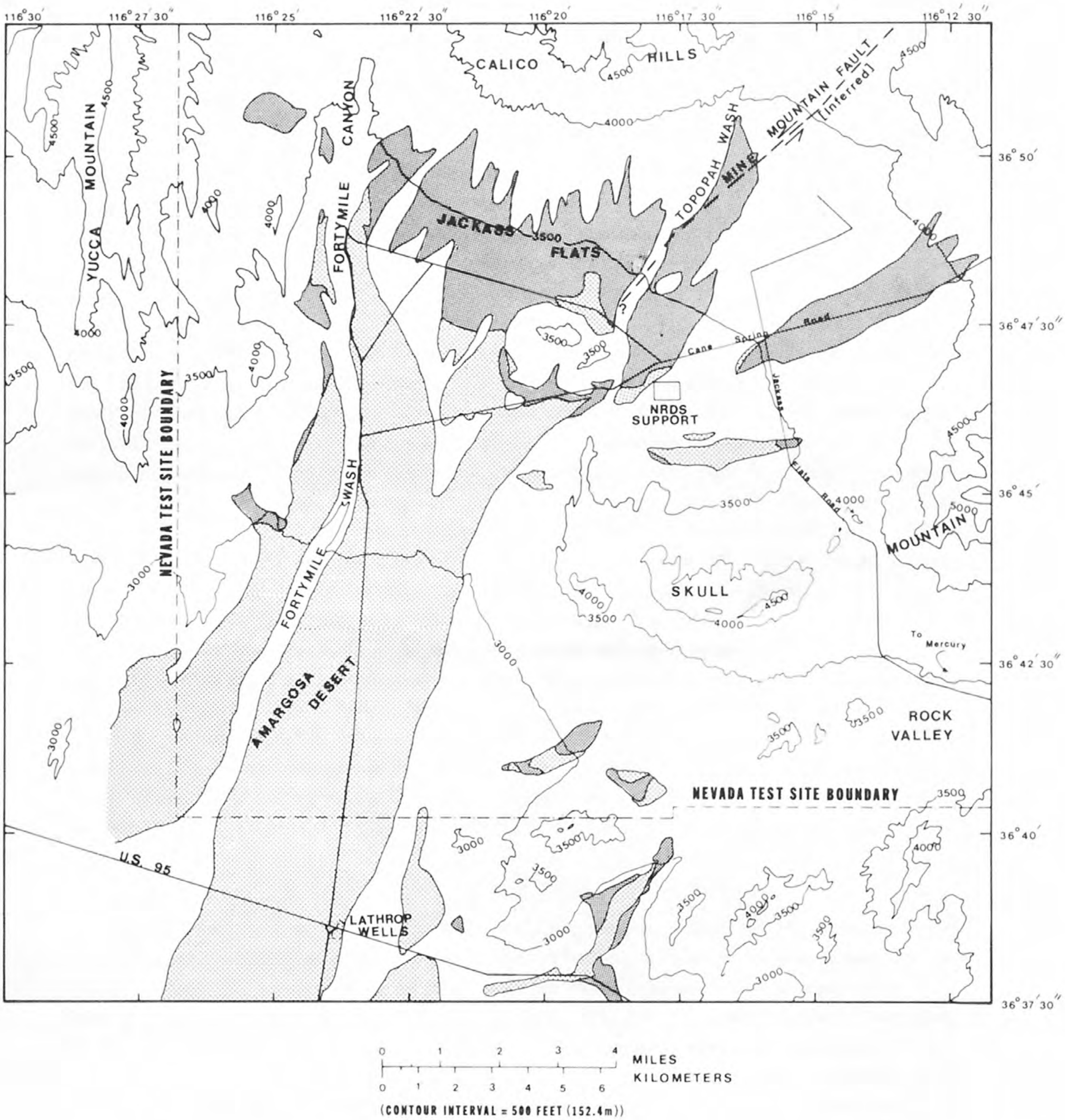

Figure 5.--Map of southwest NTS showing potential SURFF sites. Derived from superposition of figures 3 and 4. All potential areas shown require further detailed study before final judgments can be made.

EXPLANATION

Potential site areas

- DESERT PAVEMENT (UNSEGMENTED) WITH SLOPES LESS THAN 2 PERCENT (1°9')--Stable surface, cut by very few washes, alluvium probably at least 200 feet (60 m) thick, with no known faults
- DESERT PAVEMENT (UNSEGMENTED) WITH 2-5 PERCENT SLOPES--Only slightly less favorable for SURFF site than pavement with <2 percent slopes

Undesirable for further study

- UNFAVORABLE AREAS--Because of too-steep slopes, unstable surfaces, or both

For the reasons just given, Jackass Flats seems to warrant the most attention within the study area in the search for potential sites.

Jackass Flats, including most of Fortymile Wash, is a large, oval basin, filled by alluvium and surrounded by mountains and hills on nearly all sides. Like the Amargosa Desert within the NTS boundaries, all of the surface and probably the subsurface drainage of Jackass Flats escapes beyond the boundaries, but the flow path is longest.

Despite drill-hole data from hydrologic test holes, the subsurface geology of Jackass Flats is not known in detail. Toward the center of the flats the alluvium is more than 305 m thick (McKay and Williams, 1964) and is at least 157 m thick in the Fortymile Wash area (Lipman and McKay, 1965). It is very probable that at least 60 m of alluvium is present in all of the areas shown as favorable on figure 5.

The alluvium is unconsolidated (or partly cemented by caliche near the surface). It consists of lenses and discontinuous sheets of sand, silt, and sandy gravel with pebble- to boulder-sized fragments of subrounded to subangular fragments of volcanic and sedimentary rocks. Grain size tends to become progressively finer toward the center of the basin and southward along Fortymile Wash.

At least one fault is strongly suspected to exist in the alluvium of Jackass Flats, but others may and probably do exist. The one suspected fault is an extension of the Mine Mountain fault, a southwest-trending strike-slip fault that extends from near the southwest edge of Yucca Flat through Mid Valley (figs. 3-5) and into Jackass Flats near the E-MAD complex along Topopah Wash. Indirect evidence for its existence in the alluvium rests only in otherwise unexplained breaks in surface slopes and in a sharp bend in the course of Topopah Wash. Its presence cannot be regarded as confirmed, but the possibility is great enough to justify detailed search for more evidence of its existence or absence.

In summary, any of the areas within Jackass Flats shown on figure 5 as favorable should yield one or more potential sites for a SURFF.

FURTHER STUDIES NEEDED

Several areas that will probably yield SURFF sites that meet most of the arbitrary criteria defined here are outlined by this study (fig. 5). Final selection of a site or sites, however, should be preceded by detailed field studies of each of the suggested areas so as to permit valid comparisons between them.

Official definition of the geologic, hydrologic, and geophysical requirements for an acceptable SURFF site is regarded as prerequisite to any further studies. Once the criteria are established, studies can begin. The evaluation of potential SURFF sites in Jackass Flats should include:

1. Detailed topographic studies to detect faults, using larger scale maps.
2. Detailed geologic mapping of selected areas to determine geomorphic stability, evidence of previous flooding, and to detect faults.
3. Subsurface exploration by geophysical methods, trenching, and, possibly, shallow drilling to detect faults and to determine depth to bedrock.
4. Detailed surface hydrologic studies of selected areas to determine flooding potential.

5. Subsurface hydrologic studies may be required. These studies are detailed in the unpublished hydrologic data.

Despite the paucity of direct or indirect evidence of faults, determined efforts to find faults, or better, to demonstrate their absence conclusively, must be included in any detailed studies of specific sites. Direct evidence of faults, such as scarps or displacements of recognizable geologic units, is probably nonexistent, else they would have been found during earlier geologic mapping. Indirect evidence, such as otherwise unexplained shifts in stream courses or breaks in slopes, may be found by a variety of techniques. Detailed studies of aerial photographs (particularly in stereo), drilling, trenching, magnetic or gravity geophysical measurements, and more detailed slope measurements than were applied in this compilation, may all be needed. Such techniques, singly or in combination, would probably serve to detect faults having vertical components of movement, but they would almost certainly be less conclusive in detecting horizontal displacements, as along strike-slip faults.

Should all potential sites within Jackass Flats be rejected for any reason, the search could then be extended to other alluvial valleys in this study area or to other parts of the NTS.

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