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Environmental Assessment

Tonopah Test Range
Tonopah, Nevada

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I. SUMMARY

This Omnibus Environmental Assessment describes the ongoing operations of the Sandia Laboratories at the Tonopah Test Range and evaluates the actual and possible impacts on the environment that continuation of these operations entails. Since the Range predates the National Environmental Policy Act of 1969 (NEPA) by 12 years, there has been no overall formal retrospective environmental assessment of its facilities and operations, although each construction project that postdates NEPA has been assessed for potential environmental impact.

All Range activities are discussed herein, except that this assessment does not evaluate the consequences of possible terrorist activity against the Range facilities, nor does it detail security safeguards or concern itself with transportation hazards outside the Range.

Background

The Sandia Laboratories operates government-owned facilities in Albuquerque, New Mexico; Livermore, California; and Tonopah, Nevada. This assessment concerns itself with only the Tonopah operations. Sandia's principal responsibility is engineering, research, and development on nuclear ordnance. At the Tonopah Test Range, because of its isolation, Sandia carries out field tests of greater hazard than can be accommodated at its Albuquerque or Livermore sites.

The Tonopah Test Range dates from 1957, when it came into limited use after similar facilities at the Salton Sea Test Base, California, and at Yucca Flat in the Nevada Test Site became inadequate. Originally the Range was used for measurements of weapon ballistics; its functions have since been expanded to include rocket and gun firings and various kinds of tests with conventional chemical explosives.

Description and Activities of the Range

The Tonopah Test Range is located in Nye County, Nevada, about 30 air miles southeast of Tonopah and 140 air miles northwest of Las Vegas, Nevada. The 624 square miles occupied by the Range is military land, used by permit from, and by operating agreement with the Air Force. The Range is bounded on three sides by restricted areas of the Nellis AFB Bombing and Gunnery Range, and on the north by land controlled by the Bureau of Land Management. The combination of the Tonopah Test Range, the Nellis AFB Bombing and Gunnery Range, and the Nevada Test Site is one of the largest unpopulated land areas of the contiguous United States.

In general appearance the Range is a broad desert valley (Cactus Flat) between two low mountain ranges, with a string of dry lakes down its center. There are two main centers of activity, Areas 3 and 9, and numerous smaller ones.

Area 3 is the Control Point Area, housing administration, operational control, a computer, telemetry playback equipment, and maintenance. Area 9 is a center for rocket and gun firings, with impact areas to the southeast.

A series of targets in the dry lakes is used for air drops of ballistic shapes. A rocket static test stand (the C4 site) has been built for the Navy on the east side of the valley, but the test program for which it was constructed is in abeyance. Tests are carried out on one of the smaller dry lakes in a program for the design of shipping containers that will retain the shrapnel and gaseous products such as might be produced by the planned demolition of a nuclear weapon. Earth penetrator experiments are carried out wherever the proper ground or rock conditions can be found.

On either side of the valley are many stations for fixed and portable radars, telescopes, and phototheodolites.*

Future Construction

Only two future construction projects are in view: a rebuilding of the airstrip and erection of an equipment maintenance building.

The Environment

The Tonopah Test Range is located in the mountain desert of the Basin-and-Range Province of the western United States, an area characterized by north-south trending mountain ranges and broad valleys with no external surface drainage. Together with the Nellis AFB Bombing and Gunnery Range and the Nevada Test Site, it constitutes a large, wholly unpopulated area in the midst of an area of generally low population density. The nearest town, Goldfield, is 26 air miles to the west of the Range Control Point (CP), and the nearest metropolitan area (Las Vegas) is well over a hundred air miles to the southeast.

The valley in which practically all the Range activities take place is high desert, hot in the summer and cold in the winter, sparsely covered with range grasses and low bushes such as budsage and shadscale. The fauna of the valley consists of such animals as kangaroo rats, coyotes, lizards, and a variety of birds. The vegetation grades into larger bushes, Joshua trees, and juniper as one ascends the slopes at the sides of the valley and into the low mountains. There are no perennial streams and only a few permanent springs, the water from which evaporates or percolates back underground within a few hundred feet.

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*Optical tracking devices with photographic recording of field of view and azimuth and elevation angles.

The climate is mild and usually dry, but is given to large diurnal and seasonal changes in temperature, from a record high of 102°F to a record low of -24°F. Clear, sunny days with light to moderate winds are the rule. Rainfall is about 5 inches a year in the valley and is probably higher in the mountains, though records have never been taken. The rain comes principally in August thunderstorms, though on the average there is some rainfall in every month of the year. Dust storms are common in the spring, and strong dust devils occur in the summer.

Environmental Impact

Normal Operation

The impacts of normal operation of the Tonopah Test Range consist of scarring of the land by roads and shrapnel impact, the use of resources and energy, noise, debris, some scattered toxic or radioactive materials, and economic effects on nearby communities.

Sandia was not the first user of the land. There are old roads, buildings near the various springs, prospectors' holes in the hills, and even some artifacts from prehistoric occupation by Paiute Indians. The land is still being grazed, and perhaps even overgrazed, albeit on a non-permit basis. For the most part, today's use of the land is re-use of roads and tracks formed previously; it includes also new cross-country tracks made in looking for and picking up debris from rocket and gun shots, impact scars, and a gradual accumulation of test debris.

Resources used are electricity, petroleum fuels, water, construction materials, and the supplies needed for the ongoing work of the Range.

Various activities of the Range result in soil or metal debris being thrown about from impacts or explosions. There is also noise from aircraft flyovers (especially on low or supersonic runs), from rocket exhausts on takeoff, from gun shots, and from explosions.

There are three areas on the Range (the Roller Coaster sites) that are contaminated with plutonium from tests carried on in 1963. These areas are well fenced, and there is no indication of migration of this surface contamination outside the fence, let alone outside the Range; nor is there any indication that this plutonium has entered significantly into local biological systems or foodchains. No future tests of this sort involving plutonium are contemplated.

A current set of tests of explosions in shipping containers have scattered and may yet scatter some beryllium and depleted uranium.*

Sanitary wastes are disposed of in septic tanks and privies. Solid wastes are disposed of in landfills. Explosive wastes are burned in the open.

*Depleted uranium is uranium from which most of the isotope U-235 has been removed.

The demographic effects of the Tonopah Test Range are significant, mostly because of the small population nearby. The 50 support people and their families who live in Tonopah constitute 12 percent of the town's population and contribute nearly a million dollars a year in payroll income to the local economy.

Accident Analyses

In addition to these impacts from normal operation, the existence and operation of the Range entails the risk of accidents, even though measures are taken to avoid them or mitigate their effects as far as possible.

The worst accident that might occur would be a crash of either military craft during a low-level air drop or rocket-shooting mission or of the commuter plane that four times a week takes the technical staff from Las Vegas to the Range and back again. In addition to the human tragedy, the environmental consequences could be significant: a large impact scar and perhaps a fuel fire. A fire in a valley would not spread because of the sparseness of the vegetation cover, but a fire in one of the two nearby wooded mountain areas might.

A rocket being launched either from Area 9 or from an airplane could go astray and even land outside the Range and the surrounding Nellis land. The probability of this happening is small, and the resultant impact scar and debris would be confined to the impact area.

A drop device might be inadvertently or prematurely released, impacting off the Range. If this were to happen, it would probably be in the open BLM land to the north of the Range.

A gun shell containing toxic or radioactive material might break up either in the gun barrel or in flight. The residual contamination would be contained within the boundaries of the Range.

A rocket motor might explode. Again the resultant crater and scattered debris would be contained within the boundaries of the Range.

If the C4 site (a static rocket test stand) were eventually put to the use for which it is designed, it is possible that some day a rocket motor could break loose of its restraints. It would then skitter randomly about the surface nearby, but could not go farther than a mile from where it started; the resultant scarring would remain well within the boundaries of the Range.

Unavoidable Adverse Environmental Impacts

Environmental impacts that are unavoidable adverse consequences of the operation of the Tonopah Test Range are the use of the land, the irrecoverable use of some natural resources, the generation of noise and dust, and the exposure of the working staff and the native flora and fauna to the hazard of accidents.

Alternatives

The alternatives to continuing the operation of the Tonopah Test Range are: complete cessation of the work, transfer of some or all of the functions elsewhere, reducing the pace of testing, and changing operational methods.

Discontinuing the work done at the Range would be against the national interest, as it would mean not doing a necessary part of work that the nation, speaking through the Congress, has said should be done. Removing operations to another place would merely transfer impacts elsewhere. The Range could in principle be decommissioned, but the cost would be great, and the fact that the land occupied is by permit from the Air Force means that closing the Range would probably not release the land to the public domain. Shutting the Range down or moving its operations elsewhere would also have an adverse impact on the economy of the Tonopah area.

In recent years there has been a reduction of the pace of testing on the Range. The net effect is to decrease the rate of accumulation of environmental damage in the Cactus Flat valley.

Several possible changes in operational methods have surfaced during this assessment. It would seem that less damage to the environment would be done if as many gun-fired projectiles as experimental needs permit were not recovered by digging with a back-hoe, but were recovered with an auger or left buried at their points of impact.

The decrease in rate of testing at TTR may require changes in procedure such as part-time operation.

Relationship Between Short-Term Use and Long-Term Productivity

The present use of the Tonopah Test Range does not preclude its long-term use for grazing livestock; witness the number of cattle found there now.

Relationship to Land Use Plans

Neither Nye County nor the state of Nevada has any land use plans or policies that conflict with the operation of the Range.

Commitment of Resources

Few commitments of resources at the Tonopah Test Range are absolutely irreversible and irretrievable. The use of fuels, most construction materials, and supplies used in the maintenance and operation of the Range are irretrievable. The human resources that have been invested in the past are also irretrievable.

The use of water is not irretrievable, since the water used is from a recharged underground water reservoir, and is returned to the biosphere by evaporation and transpiration.

The use of the land is not absolutely irreversible, although return to its pristine state would be difficult and expensive.

Cost-Benefit Analysis

The costs of the operation of the Tonopah Test Range are the use of resources (although the operations carried out anywhere else would use as many); the use of the land, precluding its current possible use for other purposes; the generation of noise and missiles; and the exposure of the working staff and the native flora and fauna to the hazards of potential accidents.

The principal benefit to the United States from the continued operation of the Tonopah Test Range is its contribution to the national defense, through its part in Sandia's mission with nuclear ordnance. As a side effect, the effect on the economy of the town is positive.

The various alternatives studied have great economic costs and few environmental benefits, except that there is a reduction of the pace of testing at the Range, and except that some alternate ways of carrying on the operations of the Range may be slightly less environmentally damaging.

Conclusion

These costs and these benefits imply that as long as the nation chooses to maintain an up-to-date nuclear weapon stockpile, some facility such as the Tonopah Test Range must continue to exist. Because this Range does exist as an operating entity, and because it is well isolated from man and his works, from an environmental point of view, the operation of the Range should be permitted to continue. The environmental costs inherent in the work are small and reasonable for the benefits received.

II. BACKGROUND

Introduction

History and Objectives of the Operation

The Tonopah Test Range (TTR) is operated by the Sandia Laboratories for the U. S. Energy Research and Development Administration.*

The land occupied by TTR is military land for which the Department of the Air Force has issued a 10-year permit which will expire March 31, 1979. Interagency arrangements are detailed in an Operating Agreement with Nellis Air Force Base, dated April 25, 1969. These documents (Appendix A) gave the AEC, now ERDA, acting through the Sandia Laboratories, first priority use of the land and facilities and the right to construct or modify facilities at its sole discretion.

Sandia's principal responsibility is research and development on nuclear ordnance: the arming, fuzing, and firing systems used in U. S. nuclear bombs and warheads. Components in these systems developed by Sandia include power supplies and timing mechanisms, radars, switches, and other parts and circuitry which make up the intricate actuating and control systems of those bombs and warheads. In addition, Sandia designs bomb casings for the weapons which would be dropped from aircraft. In the case of warheads, Sandia's job is one of team-play with missile designers to assure compatibility of each device with its delivery vehicle.

The Tonopah Test Range dates from 1957, when it came into limited use after similar facilities at Salton Sea Test Base, California, and at Yucca Flat on the Nevada Test Site became inadequate. It had been a bombing range during World War II.

TTR was originally designed and equipped to gather raw data on aircraft-delivered inert test vehicles coming under AEC cognizance. Over the years, the facilities and capabilities at TTR have been expanded to accommodate tests related to the AEC weapons development program, varying from simple tests of hardware components, or systems needing only limited support, to rocket launches or air drops of test vehicles requiring full range support.

*All Sandia Laboratories facilities are owned by the U. S. government and operated by the Bell System through a contract of the Western Electric Company with ERDA (the successor to the AEC).

When not required for ERDA tests, TTR is available on a reimbursable basis to other government agencies or contractors. In this role, the Range provides regular support for Air Force, Army and Navy operational and test groups, and for some defense contractors.

Investment in buildings and improvements totals $6.3 million; in equipment, $14 million.

Description of the Range

Tonopah Test Range (TTR) is located in the high desert region of west central Nevada (Figures 1 and 2), covering 624 square miles of dry lakes and rolling hills. It is about 140 air miles (225 km) northwest of Las Vegas and about 35 highway miles (56 km) southeast of Tonopah. It lies along a string of dry lakes (Cactus Flat) and is between two low mountain ranges, the Kawich Range to the east and the Cactus Range to the west. Three sides are protected by the restricted areas of Nellis Air Force Base Bombing & Gunnery Range, the fourth by arid range land controlled by the Bureau of Land Management (BLM). The nearest occupied community is Goldfield, 26 miles (42 km) to the west.

The normal approach to the Range is by driving east from Tonopah on U. S. Highway 6 for 17 miles, then to the right on a marked, but restricted, hard-surfaced road to the Main Gate. With prior permission, private or charter aircraft may enter from the north and land at the airstrip.

The site was chosen because it is one of the least populated regions of the United States, it has a reasonably good climate for year-around operations, and it was already government land as a part of a military range.

Since the Range is unfenced, several hundred cattle continue to drift in, graze off the sparse vegetation and gather around the occasional and impermanent water holes, barrow ditches and dry lakes (playas). Weekend roundups are permitted twice yearly and frequently a rancher is permitted to check on his stock.

The main road from the Main Gate to the Control Point (CP) is paved; several others have been oiled to control dust for better telephotography. Still others are graded and frequently maintained. There are many primitive roads left over from WW II days that are rarely traveled or maintained.

Areas 3 and 9 (Figures 3, 4, and 5) are two main centers of activity. Area 3 (the CP) has about a dozen buildings and is conveniently close to the 6600-foot (2000 m) airstrip. Activities related to administration, operation control, computer analysis and control, telemetry decoding and recoding, and maintenance of instrument equipment and vehicles are centered here.

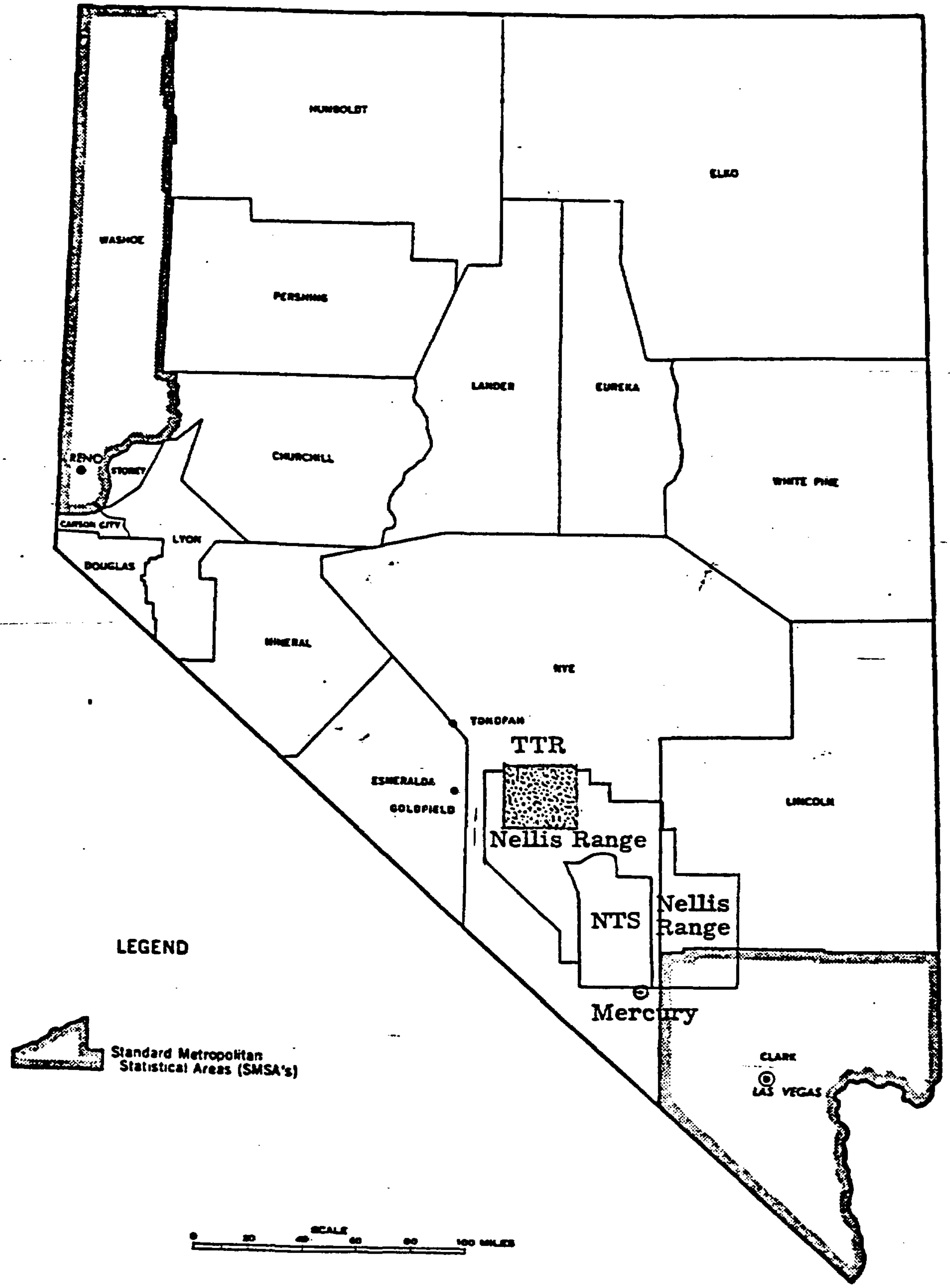

Figure 1. Map of Nevada, showing location of Tonopah Test Range.

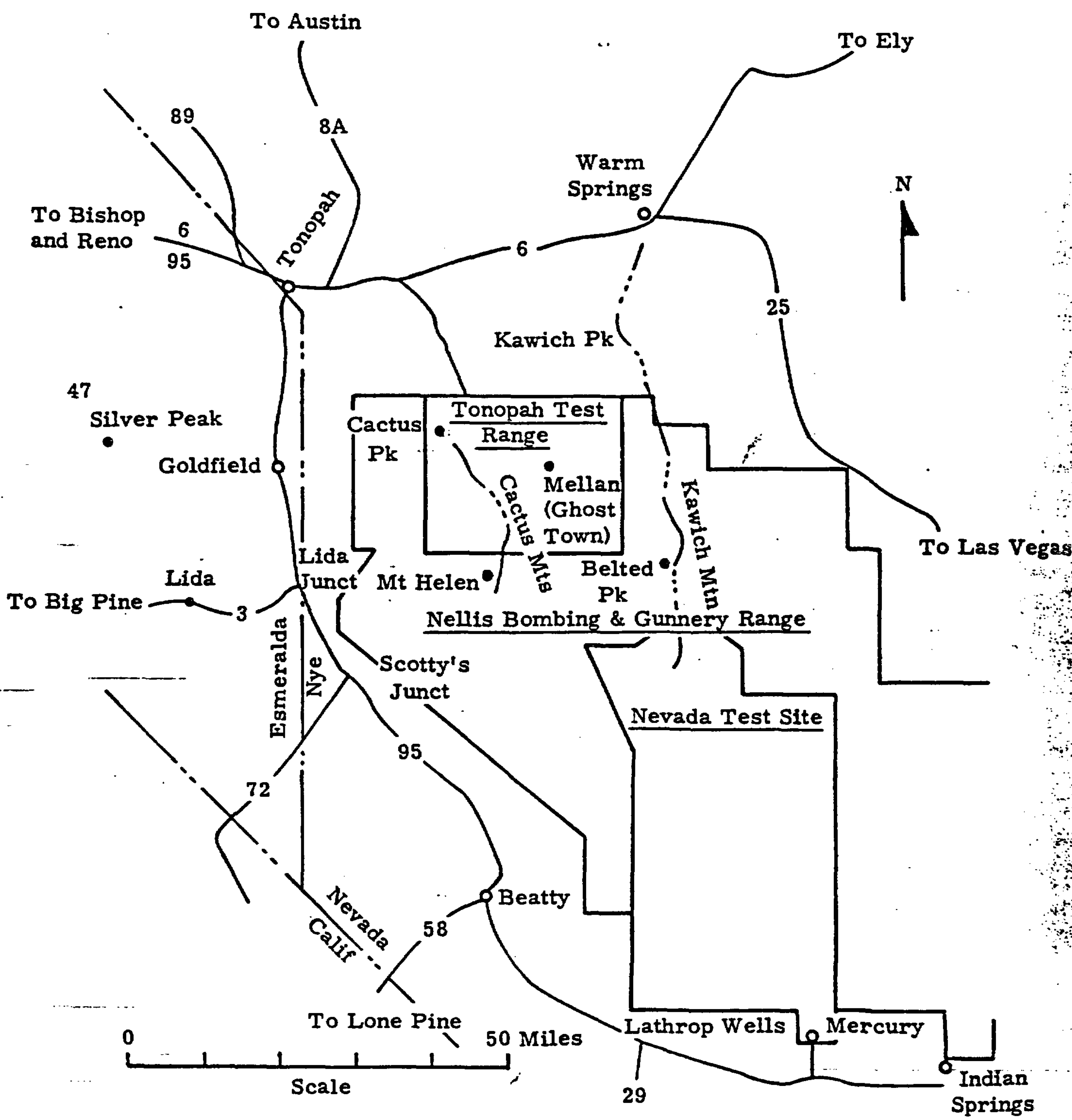

Figure 2. Map of Tonopah Test Range and environs

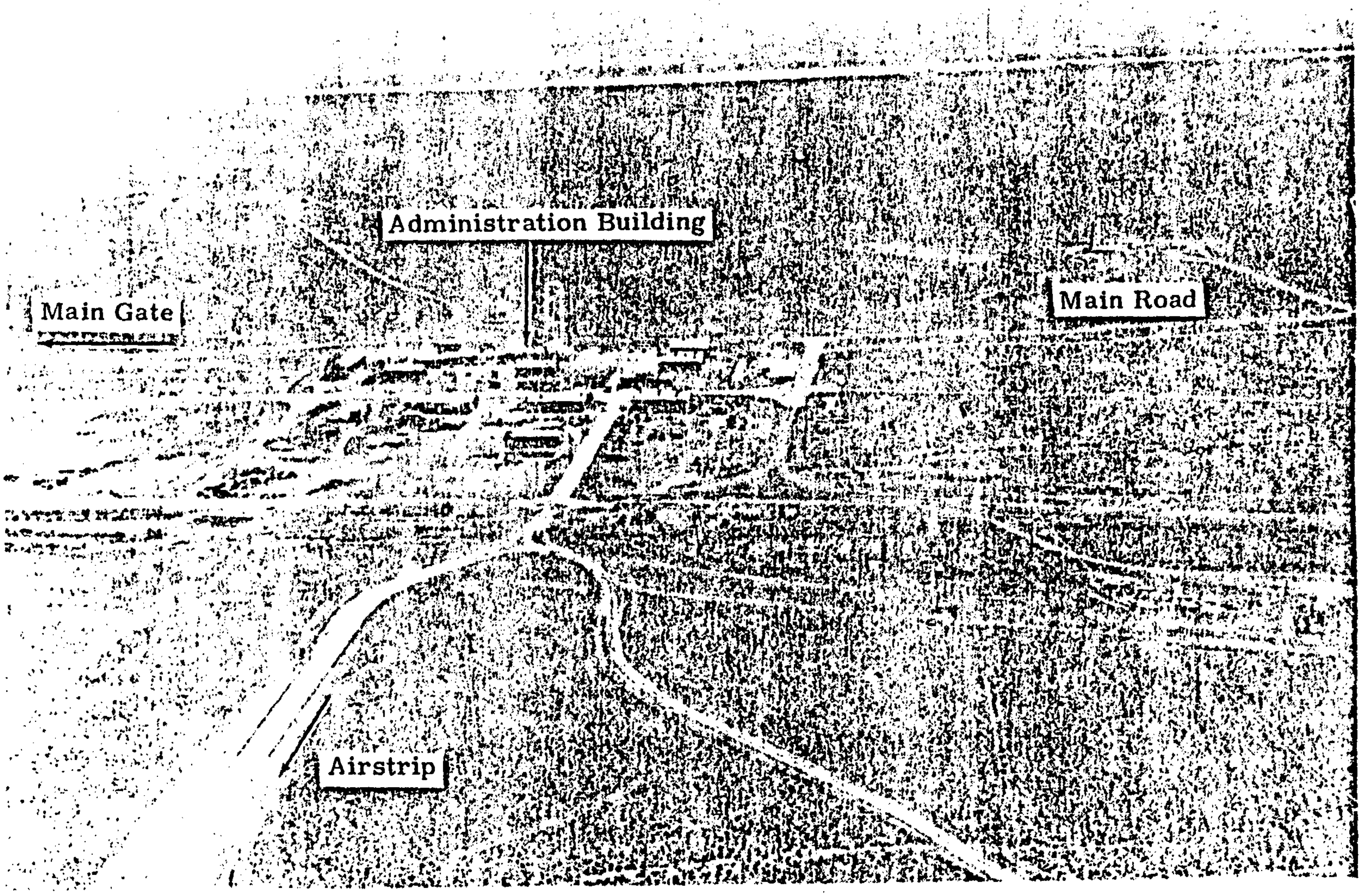

Figure 4. Area 3—The Control Point Area

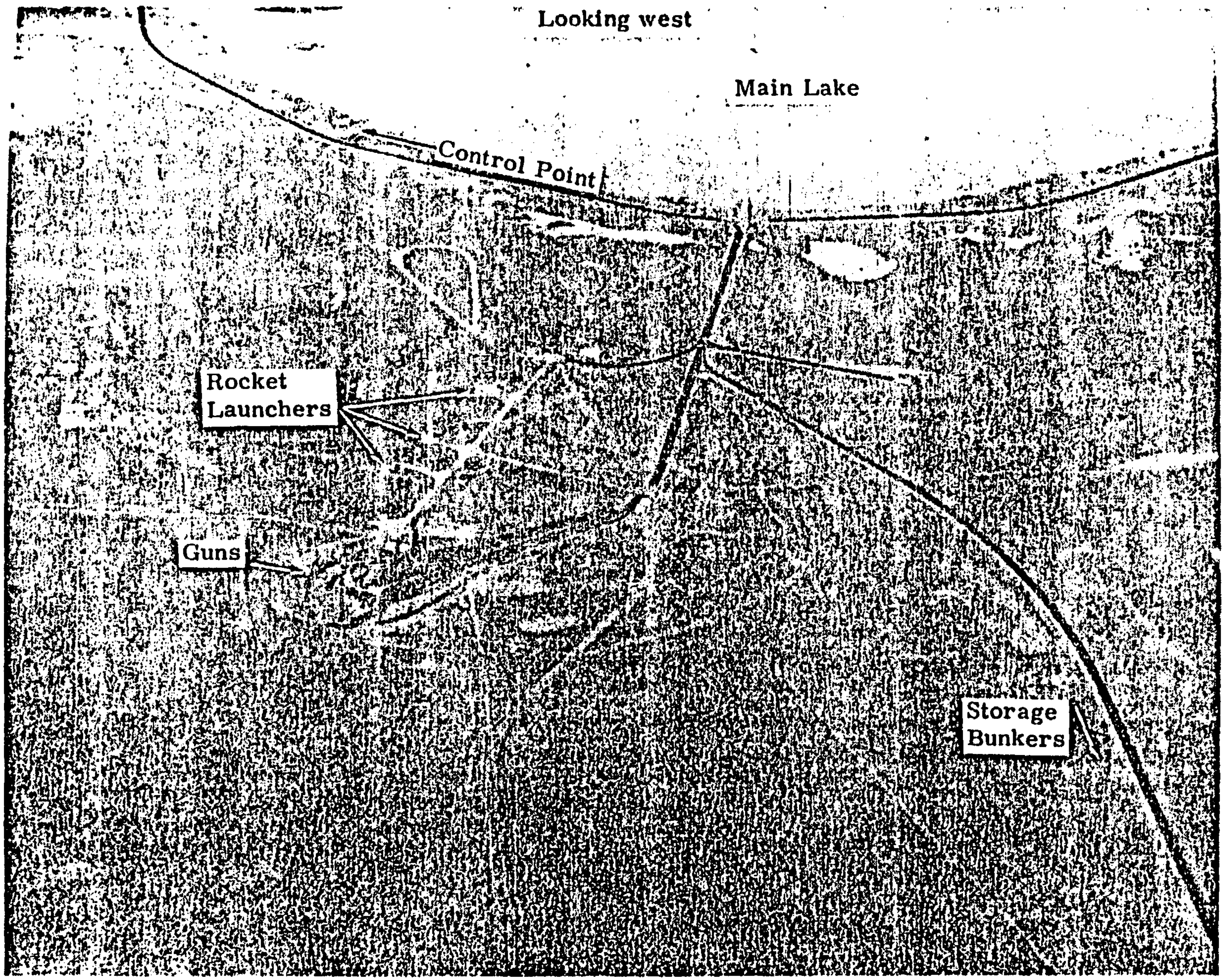

Figure 5. Area 9—The Gun and Rocket Firing Area

Area 9 is the rocket launching and gun firing center. It has four large buildings, three blockhouses, and numerous explosives storage facilities. In addition, there are four launchers for rockets like the Nike and Talos and two mounts for gun barrels up to 8 inches in diameter. There are three towers to support cameras and telemetry antennas and one 300-foot (90-m) meteorological tower.

Starting at Main Lake (2.2 square miles) near Area 9 and continuing southward for about 13 miles (21 km), there is a series of mile-high dry lakes (playas) ending with Antelope Lake (3.2 square miles). About a dozen drop targets are in use, most of which are hard dry earth targets on or near the lakes. The flight line (347° true) is about parallel to these targets and centers on the Main Lake Target. There is a concrete target on the southern edge of Main Lake, a soft target to the northwest of Main Lake, and a rock target south of Mt. Helen.

There is a weather station balloon building near Main Lake, as well as a Contraves (phototheodolite) maintenance building.

On either side of the Range and at various distances from the Flight Line are many stations for telescopes (up to 24-inch-diameter reflector), phototheodolites (Contraves), radars (target tracking), and telemetry (C&L band). Six of the Contraves stations are permanent cylindrical towers of steel and concrete about 30 feet high. A dozen or so stations for radars and portable Contraves have sophisticated concrete pads at first-order surveyed locations. Finally there are a few dozen cleared areas for portable tracking telescopes.

Since satellite tracking was once done with radio-interferometer signals, six antenna arrays consisting of short antenna towers in a crosslike configuration are located around the periphery of the Range.

On the east side of the Range just off the Cedar Pass road is the C4 (Trident) site, a rocket static test pad with a removable building over it. Surrounding the pad are several underground instrument and camera bunkers, a bunkered power plant, and a World War II bunker that has been converted to a Control Bunker. The C4 site has never been used; it remains on a standby basis for Trident (Type C4) rocket motor testing.

The NEDS (Nonviolent Explosives Destruct System) Site is in the center of a small dry lake 6 miles south of Main Lake. Partially or fully contained explosive tests are conducted on expendable wooden stands and are observed through several bunkered camera and instrument stations nearby. At the north end of the lake, an instrumentation and control trailer is partially buried and bunkered.

Benefits for National Defense

The Sandia Laboratories is one of three weapons laboratories of the former United States Atomic Energy Commission, the other two being the Los Alamos Scientific Laboratory and the Lawrence Livermore Laboratory. The Tonopah Test Range is an intrinsic part of the Sandia Laboratories' work, required for field tests of greater hazard than can be accommodated at Sandia's principal locations, Albuquerque and Livermore. Sandia's responsibility, in contrast to the nuclear physics laboratories, is the ordnance engineering of U.S. nuclear weapons. The U.S. Senate, in giving its assent to the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (the so-called limited test ban treaty), specified that the U. S. shall maintain "modern nuclear laboratory facilities and programs in theoretical and exploratory nuclear technology which will attract, retain, and ensure the continued application of our human scientific resources to these programs in which continued progress in nuclear technology depends." (Com. For. Rel., U.S. Senate, 1963, p. 274). The Sandia Laboratories is an integral part of this posture.

Other programs of national interest are also carried on at TTR, such as cratering tests with conventional explosives carried on for the Plowshare program (the investigation into non-military uses of nuclear explosions) and air-drops for the military services.

Major Activities

Test Activities

The test activities at TTR can be divided into seven general categories:

1. Air Drops -- TTR range instrumentation is configured to cover the trajectories of simulated bombs or weapons aimed at several designated targets along the chain of dry lakes running through the center of the Range. Units containing beryllium and/or high explosives are sometimes included. The average number of air drops per year is approximately 130. Of these, 30 to 35 contain HE or beryllium. Most deliveries are subsonic; a few (less than ten a year) are supersonic.

2. Gun Firings -- TTR conducts about 150 gun firings (155 mm and 8 inch) per year. A few (less than ten) of the projectiles contain radioactive or toxic materials (depleted uranium, plutonium, or beryllium) or HE, but not both in the same unit. The impacts are generally 7000 feet (2100 m) at an azimuth of 147 degrees true from their firing points in Area 9. Another impact area is about 40,000 feet (12,200 m) in that direction. Many rounds have parachute recovery systems. Wind measurements are taken before each firing of such rounds to assure that they will land on the Range in places easily accessible for recovery.

3. Ground-Launched Rockets -- On the average, eight rockets per year of the antiaircraft type are launched from Area 9, most containing scientific instruments or test objects for aero-ballistic or materials properties measurements. A few (averaging less than one per year, and none since 1970) contain as much as 5 pounds of explosives used to disperse sodium or barium compounds into the upper atmosphere for the purpose of mapping the earth's magnetic field or high-altitude winds. The latter reach altitudes of 300,000 feet or more; the former, altitudes of not over 70,000 feet. In such launches there have been as many as three rocket stages plus the payload, all of which impact at various locations on TTR, generally toward or beyond the ghost town of Mellan.

4. Air-Launched Rockets -- About six times a year, as a service for the military, the TTR is used for the launching of rockets from aircraft. These are medium-altitude releases, generally about 6000 feet above the terrain. Flight paths and launches may be either from the south or from the north (not from the east or west because of wind and terrain limitations), releasing over the TTR for impact on Nellis land to the south, or vice versa. A very few releases are from the north, with their release points outside the range and with trajectories to impact on or past the TTR.

5. Explosion Effects -- A series of tests (the NEDS tests) is being carried out in a program for the design of shipping and storage containers that will retain the shrapnel, radioactive and toxic debris, and gaseous products such as might be produced in the planned demolition of a nuclear weapon. In 1963, a series called the Roller Coaster tests was carried out to study the spread of plutonium from the nonnuclear detonation of nuclear weapons; Roller Coaster type tests are not expected to be conducted again.

6. Static Rocket Tests -- As an assist to the Navy in developing the Trident submarine program, the Range constructed a static rocket motor test pad and is holding the facility on a standby basis.

7. Earth Penetrator Tests -- The Range conducts about ten tests a year for the Sandia Terradynamics Program, a pioneering study of earth surfaces using high-velocity penetrators. Earth or rock penetrating shapes are dropped from aircraft, sometimes with rocket boosters to increase their impact velocities, or fired vertically downward from guns. The pattern of their deceleration in the ground or rock is diagnostic of the hardness and layering of these surfaces Applications are as esoteric as measuring the thickness of ice in the polar seas.

Radioactive Sources

The only radioactive source at TTR, other than radioactive material contained in tests mentioned above, is a 30-Curie ^{60}Co sealed source for radiographic inspection of test objects.

Electromagnetic Radiation

Two G-band (5.4 to 5.9 GHz) radars with peak power outputs of up to one megawatt and two I-band (8.9 to 9.6 GHz) radars with peak power outputs of up to one-quarter megawatt are included in the Range instrumentation capability. The maximum average power of the largest radar is 640 watts.

Various types of radio transmission equipment are used for local and distant communications: A 1-KW voice high-frequency (HF) transmitter for contact with incoming aircraft at sea or across the continent; 20-W ultrahigh-frequency (UHF) equipment for in-close contact; for local and mobile contacts, two 100-W master and dozens of 20-W mobile very high frequency (VHF) transmitters; and for navigational purposes, a 1-W VHF localizer and a 50-W low-frequency (LF) beacon.

To check out telemetry stations, there are 5-W master transmitters for the A band (215 to 315 MHz), D band (1430 to 1540 MHz) and E band (2200 to 2300 MHz) systems. Telemetry transmitters relaying information from test devices in these same bands have a 5-W maximum output.

Future Projects

Runway Improvement

Structural condition and adequacy of the aircraft runway at TTR are of concern because test borings indicate some distress and deterioration of both subbase and base courses along the landing pattern. Current appraisal, based on these data and visual observation of surface conditions, is that some structural failure is occurring along wheel paths in the center portion after 3 years of operation of the F-27 airplane.

The runway is used during each day of Range operation (normally Tuesday through Friday) by an ERDA-owned F-27 airplane and, on occasion, by other lighter aircraft for transport of regular employees and official visitors between Las Vegas, Nevada, and the Range.

In order to assure that the airstrip is kept in a condition that is suitable for this kind of aircraft operation, the runway is scheduled for resurfacing in Fiscal Year 1976, at a cost of $495,000. No additional environmental impact is expected from this action because the land concerned is already paved.

Heavy Equipment Maintenance Building

This project is for the construction of a 4000-square-foot building in Area 3 for heavy-equipment maintenance. The building will be a rigid-frame, metal, panel-covered building 40 feet wide by 100 feet long, set on a reinforced concrete slab, with an eave height sufficient to clear vehicular doors 14 feet high by 12 feet wide.

Fiscal year 1977 construction is planned for this project. The only environmental impact of this project will be the result of construction and will be small because the land to be used is already entirely denuded.

Roller Coaster Tests

Description of the Experiment

Roller Coaster is the name given to a joint U.S.-British series of four tests carried out in mid-1963 to study plutonium dispersal from accidental nonnuclear explosions of plutonium-bearing weapons.

The first test, called Double Tracks, was executed west of the Cactus Range in the Nellis AFB Bombing and Gunnery Range; the other three, called Clean Slates I, II, and III, were executed at Cactus Flat in the middle of the Tonopah Test Range at the positions shown in Figures 3 and 6. Double Tracks was a detonation simulating an accident involving only one weapon on a hard surface with minimum entrainment of soil. The three Clean Slate tests were multiple bursts, of 9, 19, and 19 units, respectively, of which only one unit in each test contained plutonium; the remaining units had depleted uranium substituted for plutonium. Clean Slate I was fired in the open on a concrete pad; Clean Slates II and III were in igloolike structures with 2 and 8 feet of earth cover, respectively. Thus they simulated accidents in open storage and in magazines with varying amounts of protection.

The amount of plutonium involved in each test was in the low kilograms.

The tests were extensively instrumented. Each was at the apex of a large 90-degree field sector as shown in Figure 6. Extensive air sampling and deposition measurements were made on all shots.

Subsequent History of the Sites

The Roller Coaster test experiments were of short duration, and the interests of the test group did not go beyond the end of 1963. The inner areas of highest residual contamination (i.e., to levels of 1000 $\mu g/m^2$ and above) were fenced to facilitate their control of access (Figure 7), and there was an extensive cleanup and pickup of contaminated debris. Responsibility for monitoring these sites rests with the Nevada Operations Office of ERDA, which sends monitors back at least annually for radiation surveys and checks of fences.

In 1970, there was renewed concern about these Roller Coaster contaminated areas, and expert advice was sought about possible further cleanup. It was decided not to undertake cleanup, lest the required denudation be worse than leaving the areas in their naturally vegetated state. However, an

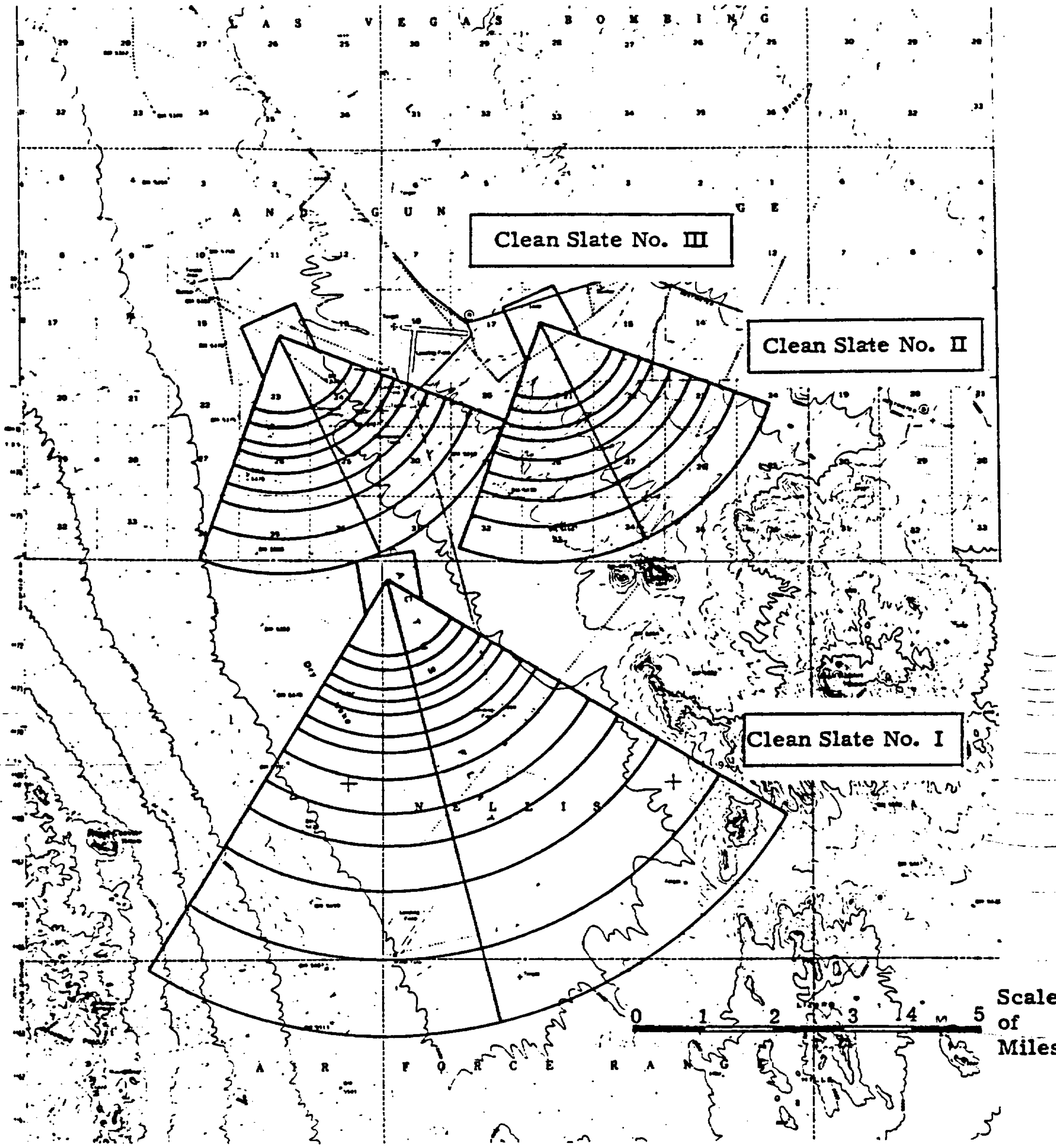

Figure 6. Roller Coaster site plan

extensive program was instituted on these and other TTR plutonium-contaminated areas, studying the ecological dynamics of plutonium in the desert environment. (These studies are being carried on on an unclassified basis; the most recent reports on the findings of these studies are Dunaway and White (1974) and White and Dunaway (1975). Although further decontamination was not initiated, new fences were built around larger areas than originally enclosed, for better control of access.

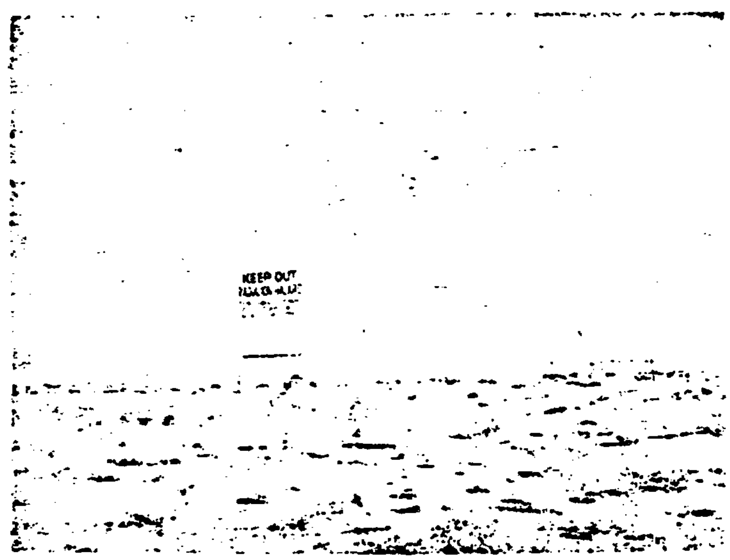

Figure 7. Warning sign at inner enclosure, Clean Slate III.

The present status of the Roller Coaster sites and some of the results of the ecological program being carried on there are taken up in Chapter III of this report.

Disposition of the Roller Coaster Debris

On the Clean Slate shots, especially the second and third, the debris consisted of large volumes of earth scattered to distances of about 100 yards, and pieces of concrete and metal thrown to much greater distances. The debris in the vicinity of each ground zero and fragments out to a range of 2500 feet were collected and buried in a trench inside the fenced ground-zero area. The contaminated surface of the compacted areas around each ground zero and areas contaminated by jetting were scraped to a depth of several inches. This soil was put into the same trench as the debris, the trench was covered with several feet of earth, and the whole watered and compacted (Burnett et al., 1964).

During the Roller Coaster operation, a temporary decontamination station was established where vehicles and equipment, and if necessary people as well, could be checked and cleaned of alpha contamination on leaving the area. This station was at the intersection of the main north-south road and the Cactus Springs road, where it could serve all four tests of the Roller Coaster series. The area remains fenced and posted with standard radiation safety signs.

The only piece of debris that was returned to the Nevada Test Site was a large steel plate that had been at the ground zero of the Double Tracks shot; all the rest of the Roller Coaster contaminated debris remains buried on or near the Tonopah Test Range. Because ground water is at least 90 feet below the surface and percolation is almost nonexistent, there is believed to be only a small probability that the remaining debris will contaminate ground water systems of central Nevada (see Hydrology section below).

Waste Disposal

All of the solid and sanitary liquid wastes generated at TTR are disposed of on the Range. Most of the waste is produced in Area 3 with a somewhat smaller amount in Area 9.

Solid wastes are disposed of using the sanitary landfill method; it meets the guidelines set forth by the Environmental Protection Agency in the Federal Register, Vol. 39, No. 158, dated August 14, 1974 (40 CFR 241). There are two disposal cells about 1500 feet from Area 3. One is partially covered with a screen to control wind blown paper. The other one is for large objects such as boxes, crates, etc. There is one cell 2000 feet (600 m) from Area 9 for large objects.

Sanitary liquid waste is disposed of in underground septic tanks and privies. There are three septic tanks around the periphery of Area 3 and one in Area 9. Privies are used at 12 remote locations. Every few years the septic tanks are pumped out and the sludge and scum is buried in a hole approximately 1 m in diameter and 15 m deep and backfilled.

No liquid, solid, or gaseous radioactive wastes are normally generated as a result of present TTR operations. The exception is the NEDS tests. During fiscal year 1975, 66 kg (29 mCi) of depleted uranium was collected from them for burial, as well as 5.4 kg of beryllium. These wastes are buried at a government-owned, ERDA-approved burial facility at the NTS.

Occasionally test units containing depleted uranium and/or beryllium are deliberately destructed using specific Safe Operating Procedures. All fragments and waste material are carefully collected, packaged, marked, and shipped to the test originator using current Department of Transportation requirements.

Whenever explosives have deteriorated or are obsolete or defective, they are disposed of at an open burn pad about 2000 m from Area 9. These consist of high explosives (Comp C), gun or howitzer propellants, electric igniters, and solid-fuel rocket motors. Safe Operating Procedures based upon Army Ordnance Command manuals are used by qualified personnel to burn off the explosive materials. The residue is inspected and disposed of in the sanitary landfill cell nearby.

Environmental Monitoring

Environmental monitoring at the TTR consists of sampling of drinking water semi-monthly for bacterial content, and monitoring of individual tests according to the hazard they may represent.

In addition, the National Environment Research Center of the Environmental Protection Agency (NERC/EPA) makes a number of relevant measurements. The TTR is on their list of water sampling points, but no analysis was made in 1974, the latest year reported on. The NERC/EPA indicates that the background radiation dose at the TTR is 110 mrem per year. The NERC/EPA also maintains continuously operating air samplers about the NTS-Nellis-TTR area, in nearby communities and on intermediate points on the roads between them. For 1974, they report some radioactivity, primarily radioxenon, released intermittently as a result of NTS activities, with a maximum whole-body dose (calculated) to an individual of 11 μrem. No airborne radioactivity from TTR operations is detectable offsite (EPA, 1975).

The four Roller Coaster sites on and near the TTR are reinspected at least annually to assure that the control fences remain intact and to determine whether activity has spread.

Individual experiments are carried on at the TTR involving such materials as beryllium and uranium. These are monitored to insure personnel safety and to meet the scientific purposes of each experiment. There is no single pattern for monitoring these various experiments; each monitoring scheme is tailored to its experiment. By way of example, consider the NEDS tests and burn tests.

The NEDS (Nonviolent Explosive Destruct System) experiments are part of a program to design, fabricate, and test a transportable container that will retain the shrapnel, radioactive and toxic debris, and gaseous products produced by the one-point initiation of the high explosives in a nuclear weapon. In the mock-ups used in the TTR development testing, fissile materials are not present, but there may be as much as 10 kg of depleted uranium or a kilogram of beryllium present. These may be dispersed downwind from such a test if the container fails.

The NEDS tests are normally conducted in the late morning hours while the winds are moderate in order to keep atmospheric potential gradients below 1600 V/m. Two high-volume air samplers are deployed in the upwind and downwind camera bunkers about 75 feet away. Thirty-minute samples are taken prior to, during, and after each test. The filters are analyzed for gross alpha with portable instruments immediately after re-entering the area. The re-entry party, which delays 5 minutes after the test before re-entering, wears protective clothing and full face respirators until it is established that no appreciable contamination exists. In the event of possible beryllium contamination, a swipe analysis is made in the field; but in any case, the filters and swipe samples are removed to Sandia Livermore for a more accurate alpha, beta-gamma, and beryllium level determinations.

In March 1970, a burn test of a unit containing HE and beryllium was conducted at the TTR. The unit was suspended over a diesel fire, expecting the high explosives in it to detonate, in which case there would be an excellent opportunity to collect data on the spread of beryllium and uranium under accident conditions. However, the explosives burned rather than detonated. (That they only burned in this test is no indication that a detonation is not possible under such circumstances.)

Eighty-seven air samplers were deployed on two 90-degree arcs at 3000 and 5000 feet from the burn test, spaced at 150-foot intervals. Twenty-two fallout trays were placed at about 100-foot intervals on 90-degree arcs at 500 and 1000 feet from the burn pit, and six more were scattered about 100 feet from the pit. Twelve parachute-borne air samplers were to have been dropped from an airplane into the cloud expected to be produced by the explosion, but since an explosion did not occur, these were not dropped. Soil samples were taken at the four sides of the burn pit approximately 50 feet out from each side of the pit.

Emergency Response Capability

Fire

All high-monetary-value facilities of the Tonopah Test Range are protected by sprinkler systems or by Halon fire-extinguishing systems.

There is no fire department on the Range, but fire suppression equipment is available at the CP. This equipment is normally manned by the guard staff, all of whom as well as all the rest of the Range staff are trained in its use.

Range fires are not considered a possible hazard in Cactus Flat or in the Cactus Range because the ground cover is too sparse. Rhoads, for instance, indicates (1974, p. 127) that the ground cover in the middle of the valley near the Clean Slate sites is no more than 15 percent. However, in some ranges nearby, such as the Kawich Range and Stonewall Mountain—all with extensive areas above 7000 feet elevation—there is enough pinon-juniper woodland to support a forest fire.

Medical

On the support staff of the Range is a full-time paramedic, backed up by an ambulance and a fully equipped aid room. He is further backed up by the capability for evacuating a patient by ambulance to the hospital in Tonopah 35 miles away, or by air to Las Vegas. The paramedic can also, of course, consult with doctors in Tonopah, the Nevada Test Site, or Las Vegas by telephone.

Air Crashes

Because of the special hazards of aircraft landings and takeoffs, the aircraft ground controller and the paramedic do not work the normal hours of the support staff, but report to work at the Range before the commuter plane arrives in the morning and remain until it departs in the evening.

The Range is acquiring a military type of search radar designed to further enhance the reliability of aircraft control.

Topography

The range is about 24 miles (39 kilometers) wide and 26 miles (42 kilometers) long with a total land area of approximately 624 square miles (1616 square kilometers). The central area of about 45 percent of the total is a valley containing several square miles of dry lake beds lying along a north-south line approximately through the middle of the range (see Figure 3). The valley has an elevation of approximately 5300 feet MSL. This area is bounded on the west side by the Cactus Range, a series of low, rocky mountains with the highest peak 7480 feet MSL. Along the east boundary is another group of mountains known as the Kawich Range whose peaks range up to 9400 feet MSL. The slopes leading to these mountains consist of alluvium derived from the mountains, which themselves are generally igneous in origin. The general appearance is of great barrenness. The dry lake beds support no vegetation at all; the valleys support a thin cover of range grass, sagebrush, and shadscale; and the lower slopes and mountains support more brush, and some Joshua trees and juniper. Only the highest areas, generally those over 7000 feet MSL and almost none of this on the TTR itself, bear any appreciable amount of woodland.

Airspace

The Tonopah Test Range airspace is referred to on SAC charts as Cactus Flat and on aeronautical sectional charts as R4809 (Figure 8). The airspace is restricted and is both used and controlled by ERDA. Air traffic is handled during working hours by a controller on the Range, using the call signal "Silverbow."

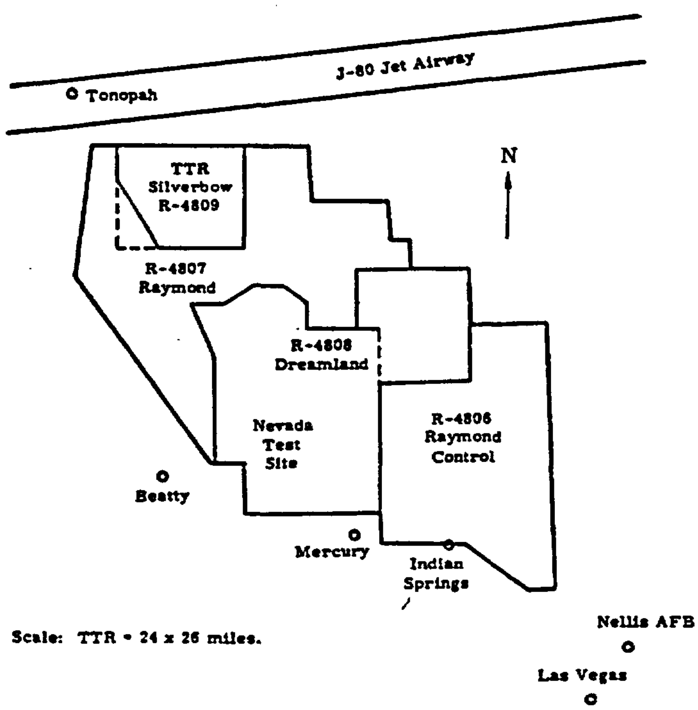

Figure 8. Tonopah sectional map with air control designations. From Sjovold et al., 1974.

By agreement with the USAF on Nellis AFB, at all times when the airspace is not scheduled for use by the Range, it is available for their use. However, coordination and notification of intent to use must be made.

An informal agreement with the Federal Aviation Administration (FAA) has stipulated that commercial aircraft may be routed over the range during periods when the range is not in use. A hot-line exists between the TTR and the FAA Salt Lake City Air Route Traffic Control Center for emergency control.

North of the range, jet route J-80 links the radio navigation aids at Metford, Utah, and Coaldale, Nevada. J-80 is the major east-to-west jet route which terminates in the San Francisco Bay area.

Economy and Demography

In general, the area surrounding TTR is characterized by economies based upon government activity, mining, tourism, and small amounts of ranching. The Nevada Employment Security Department estimates the 1972 total work force of Nye County (in which the TTR lies) at 6,580 persons with an unemployment rate of 1.5 percent.

Tonopah, with a 1970 population of 1,716, is the nearest town by road to TTR. The range draws upon this population for construction and guard support.

Tonopah owes its beginning to the mining industry. When silver was discovered near Tonopah in 1900, it triggered a bonanza that stimulated mining in the West for a decade and awoke Nevada from hard times and declining population. By autumn 1902, the town had 3,000 inhabitants. It became the hub of railroad service for the region and the seat of county government. By 1907 Tonopah was a modern mining town of more than 20,000 inhabitants with "five banks, modern hotels....., cafes, opera house, school, lavish gambling palaces, electric and water companies, and an array of other businesses housed in fine stone edifaces [sic], a few reaching four and five stories." Tonopah became the outfitting point for prospectors and the distribution and supply point for new camps as they developed (Paher, 1966).

Tonopah reached its peak in 1910-1914 and continued to have many good years until the Depression. Its four principal companies continued operation until World War II. In 1947, the local railroad was abandoned. As one observer put it, "Tonopah as a historic spot has been immortalized—and justly so. Virginia City had put Nevada on the map; Tonopah kept it there."

Tonopah survived the decline of mining for a number of reasons. Situated on the main highway about midway between Reno and Carson City in the north and Las Vegas in the south, it continued as a service center for the nearby ranching and agricultural interests. During World War II the military services constructed an airbase nearby for purposes of tactical instruction. Tonopah also became a headquarters for tourists visiting the mountain deserts and for several conventions a year.

The 1970 census found Tonopah with a population of 1,716, almost a third of the total population of Nye County. There are six motels and one hotel having a total of 400 rooms, a 40-bed hospital, seven churches, one bank, one weekly newspaper, and radio and cable TV service. There are two schools, one elementary and one secondary. Bus and truck service are available. There is the usual assortment of services; service stations, restaurants, bars, and a bowling alley.

Tonopah has continued to benefit as well as to suffer from activities of the federal government. The 866th Radar Squadron of the U. S. Air Force was stationed there until 1969 but was then transferred to Las Vegas. The result was a population loss of 500 persons.

Mining continues to be an important activity in the area. The search for mineral wealth has made Nye County the only oil producing area of any importance in Nevada. With rising prices for minerals and, therefore, renewed interest in exploration and development, it may well be that Tonopah could experience a new mining boom. However, the consequences are unlikely to be those of the early twentieth century. Today's mining operations are highly mechanized and are not likely to create the demand for labor that characterized the earlier days.

Tonopah is extremely vulnerable to the changes in the activities and spending policies of the federal government. Ninety percent of the land in Nye County is owned by the federal government. Of that total, 58 percent is managed by the Bureau of Land Management, 15 percent by the Forest Service, and 27 percent by "others," largely the Department of Defense.

The dominant industry of Nye County is government, but the leading employer in the County is the service industry, accounting for 28 percent of the employment. A good portion of the service industry directly supports ERDA activities. Government follows with 20 percent, and mining is third with 14 percent. Tourism presumably will figure very strongly in Tonopah's future. A community center capable of holding 400 persons serves as a convention center for the many state organizations that like Tonopah because of its central location. A list of populated places surrounding the TTR-Nellis-NTS area, together with their populations, their distances, and their directions from the TTR Control Point, is given in Table I.

Geology

The Tonopah Test Range (TTR) is in the western part of the basin-and-range geophysical province, about 50 miles east of the Cordilleran eugeosyncline as defined by Gilluly (1965). The area west of this border is characterized by large granitic plutons of Mesozoic age that are related to the intrusion of the Sierra Nevada batholith. Granite plutons are present east of the line, but they are relatively small and widely scattered. The TTR lies east of a zone of transcurrent faulting and shear, called the Walker Lane to the northwest and the Las Vegas Valley shear zone to the southeast. The exact nature and location of the shear zone near the TTR are problematical.

Shawe (1965) prefers to extend one of the major transcurrent faults through Tonopah and southeastward from there through the Cactus Range on the TTR. Ekren et al. (1971) found no unequivocal evidence of strike-slip motion in the area southeast of Tonopah but said that the prominent northwest-trending grain of the Cactus Range and the occurrence of numerous volcanic centers along a line extending southward from the Cactus Range into the Nevada Test Site (Figure 9) tend to suggest that a major crustal rift is present in the area along which magmas, generated at great depth, moved upward during Mesozoic times. That this zone is a major transcurrent fault may never be proved, they say, but it must be considered a reasonable possibility.

TABLE I

Populated Places Around the Tonopah Test Range

	Distance (mi)	Direction	Population (1970)
Warm Springs	37	NE	15
Tonopah	31	NW	1716
Silver Peak	49	W	45
Goldfield	26	W	300
Lida Junction	30	SW	4-20
Scotty's Junction	36	SSW	0
Beatty	61	S	800
Lathrop Wells	83	SSE	40
Mercury, NTS	66	SSE	*
Area 12 Camp, NTS	60	SE	*
Area 51**	66	SE	*
Indian Springs	104	SSE	2000

*Transient quarters available for several hundred, but no permanent population at these places.

**An Air Force installation northeast of NTS.

The stratigraphy and structure of the TTR area has been studied by Ekren et al. (1971) as part of an aborted consideration of the northern part of the Nellis AFB Bombing and Gunnery Range for expansion of the Nevada Test Site. Rocks of Precambrian age with an aggregate thickness of over 8000 feet are overlain by about 20,000 feet of Paleozoic sedimentary and carbonate rocks. A thrust fault system of Mesozoic age causes Mesozoic rocks to be missing in the section, except as they appear in small exposures of granite in the Cactus Range and in the southern Kawich Range south-southeast of the TTR. Above the resultant unconformity lie about 20,000 feet of Tertiary rocks, consisting for the most part of widespread ash-flow tuffs that range in age from 27 to 7 m.y. (million years), thick piles of variegated lavas, and several sequences of interbedded tuffs and sedimentary rocks. Above all this, over half of the TTR is blanketed by alluvium and colluvium of Quaternary and Tertiary age. The alluvial material is thickest in the major basins, such as Cactus Flat, but the actual thicknesses there are unknown. The stratigraphy is summarized in Table II. Geologic sections are not available because the TTR area is at the extreme, least interesting part of the area studied by Ekren et al.

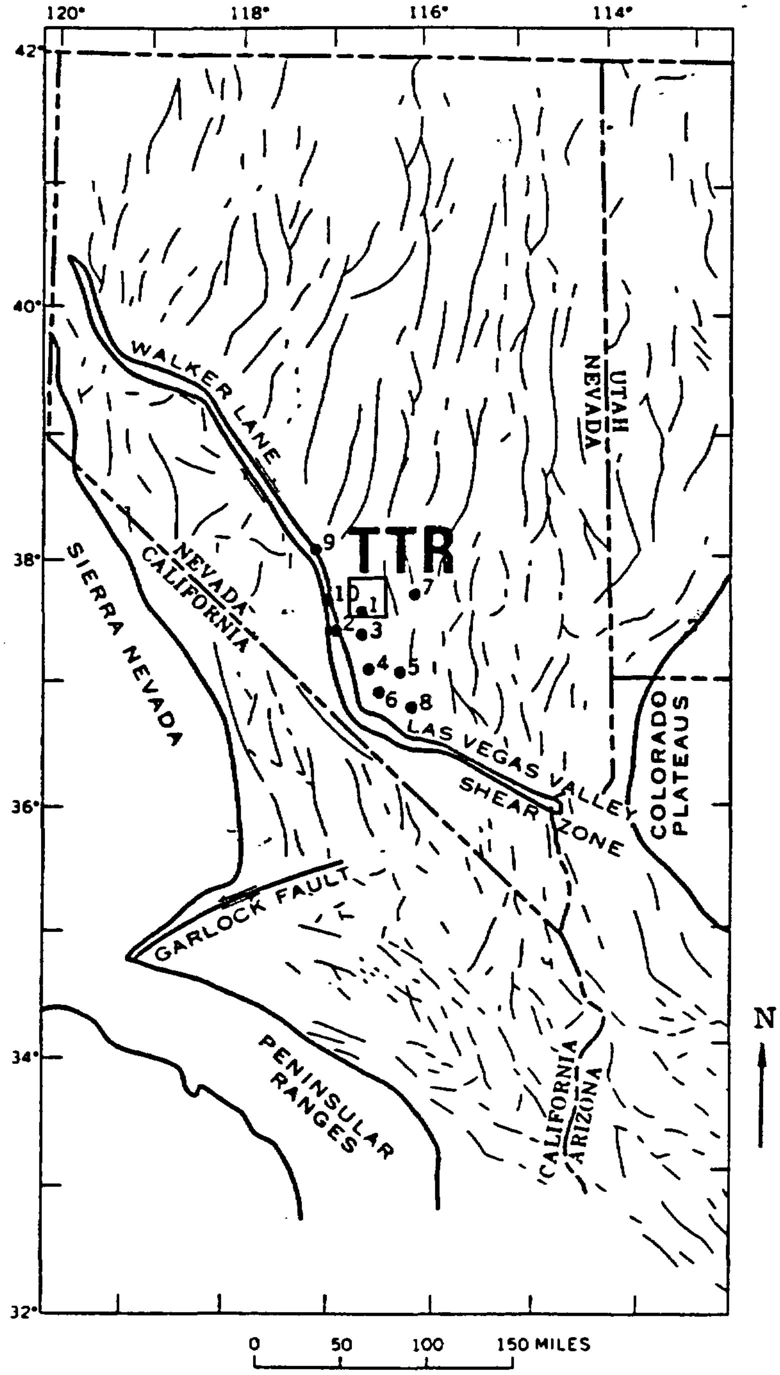

Figure 9. The Walker Lane-Las Vegas shear zone. Dots indicate location of major volcanic centers: 1, Cactus Range; 2, Stonewall Mountain; 3, Mount Helen; 4, Black Mountain; 5, Pahute Mesa; 6, Timber Mountain; 7, Cathedral Range; 8, Wahomoni; 9, Tonopah; 10, Goldfield. Modified from Burchfiel, 1965. Trends of the ranges in the Basin and Range Province are indicated by fine lines.

TABLE II

Major Geologic Rock Units in the Northern Nellis AFB Bombing and Gunnery Range

Age	Rock unit	Stratigraphic thickness (feet)	Lithologic character
Quaternary and late Tertiary	Alluvium and colluvium	0-3,000+	Valley and stream alluvium, terrace and pediment gravels, talus and landslide debris.
	Basalt	0-100	Lava flows; a few dikes and one small cinder cone.
Pliocene	Basalt	0-100	Lava flows; many dikes.
	Thirsty Canyon Tuff	0-500	Trachyte, trachytic sodic rhyolites, comendite, and pantellerite.
	Timber Mountain Tuff: Ammonia Tanks Member	0-350	Rhyolitic welded tuff.
	Timber Mountain Tuff: Rainier Mesa Member	0-600	Do.
Miocene	Paintbrush Tuff	0-500	Rhyolitic ash-fall tuff and intercalated rhyolite lavas.
	Rhyolite lavas and tuffs	0-1,000	Sodic rhyolite lava flows, welded tuff, ash-fall tuff.
	Belted Range Tuff and associated lavas	0-1,000	Comendite, trachytic sodic rhyolite, trachyte.
	Tuff of Tolicha Peak	0-400	Rhyolitic welded tuff.
	Rhyolite	0-1,600	Lava flows and numerous dikes and plugs of rhyolite and rhyodacite.
	Sedimentary rocks	0-800	Ash-fall tuff, tuffaceous sediment, and thin-bedded lake sediment.
	Fraction Tuff	0-7,200	Rhyolitic welded tuff, composite ash-flow sheet.
	Lavas of intermediate composition	0-3,000	Lava flows, dikes, plugs, and small stocks.
	Tuff of Wilsons Camp and bedded tuff	0-500+	Rhyolitic welded tuff, ash-fall tuff, and tuffaceous sedimentary rock.
	Tuff of White Blotch Spring	0-3,000	Rhyolitic welded tuff.
	Shingle Pass Tuff	0-1,000	Rhyolitic welded tuff.
	Tuffs of Antelope Springs	0-4,000+	Rhyodacitic and rhyolitic welded tuff; several cooling units.
Oligocene	Monotony Tuff.	0-2,300	Rhyodacitic welded tuff.
	Unconformity		
Mississippian and Late Devonian	Eleana Formation	5,000±	Argillite, quartzite, and conglomerate; some limestone and limestone conglomerate at base.
Middle Devonian	Limestone and dolomite	1,285+	Limestone, silty limestone, and dolomite.
Middle and Early Devonian	Nevada Formation	1,000+	Dolomite, sandy dolomite, and dolomitic sandston with subordinate limestone, siltstone, and cher.
Early Devonian and Late and Middle Silurian	Dolomite of the Spotted Range	1,415	Dolomite; sandy at top, and locally cherty.
Late and Middle Ordovician	Ely Springs Dolomite	340	Dolomite, with abundant chert.
Middle Ordovician	Eureka Quartzite	315	Quartzite; gradational into overlying and underlying units.
Middle and Early Ordovician	Pogonip Group	3,010±	Limestone and dolomite, silty in part; subordinate calcareous siltstone, chert, and shale.
Late Cambrian	Nopah Formation: Smoky Member	950±	Limestone and dolomite; scattered chert.
	Nopah Formation: Halfpint Member	1,900±	Limestone and dolomite; laminae of silty limestone and dolomite; abundant chert.
	Nopah Formation: Dunderberg Shale Member	200±	Shale; intercalated limestone.

From Ekren et al, 1971

Cactus Flat, which constitutes the basic working area of the TTR, is surrounded by the Cactus Range, the northern portion of the Kawich Range, and the Mellan Hills.

The Cactus Range is a northwest-trending raised structural block, one of at least five that lie along the Las Vegas Valley-Walker Lane lineaments. In these mountain masses, volcanic rocks of Tertiary age are steeply tilted, highly faulted, and invaded by numerous intrusive masses. The central core of the Cactus Range is composed of minor Paleozoic sedimentary rocks, one small exposure of Mesozoic granite, and a thick sequence of widespread Tertiary extrusive and sedimentary rocks. These central core rocks are flanked by volcanic and sedimentary rocks that are downdropped along known or inferred faults that tend to gird the range.

Cactus Range was a major volcanic center during the Miocene, early in which there were two series of extensive eruptions of tuffs with subsequent collapse. Later, in mid-Miocene times, there was extensive intrusive activity. Lavas and tuffs flanking the northern part of the range probably erupted concomitantly with the emplacement of these intrusive masses. During the latter part of this period, the range was uplifted to its present level.

The hills south of Mellan are a series of north-northwest-trending topographically subdued lava ridges separated by valleys of soft tuffs. Despite low elevations and a consequent lack of vegetation, the hills have the poorest exposures of any bedrock area in the Bombing and Gunnery Range. This is due to the abundance of rubble-weathering flow breccias in the lava piles and the tectonic breccias that formed as the lava ridges were faulted, tilted, and shifted eastwards by northwest-trending very-low-angle faults.

The northern segment of the Kawich Range is a horst,* consisting predominantly of Tertiary igneous rocks. Except for three small masses of Paleozoic sedimentary rocks, it consists of Tertiary tuff, lava, and intrusive masses of early Miocene tuff. The horst is poorly defined south of Cedar Pass, where it contains a well-defined rhyolite volcano.

Hydrology

All the steams in and near TTR are intermittent and end in closed basins. The TTR is almost coincident with the Cactus Flat drainage area, although in the northwest the TTR laps over into the Stone Cabin Valley drainage area, in the west to the Stonewall Flat drainage area, and in the southeast into the Gold Flat drainage area (Figure 10).

All the working areas of the TTR lie in about 400 square miles (1000 km^2). Along the axis of the valley lie a string of playas (dry lake beds), conspicuous by their light-colored surface sediments, high content of soluble minerals, and lack of vegetation. These lie at elevations of a little under 5400 feet (1650 m). Except for a few days each year after rain in the nearby mountains, these playas are dry, but during the Pleistocene glacial period there was a lake here, the shorelines of which can still be faintly seen.

*A horst is a raised block of the earth's crust separated by faults from adjacent relatively depressed blocks.

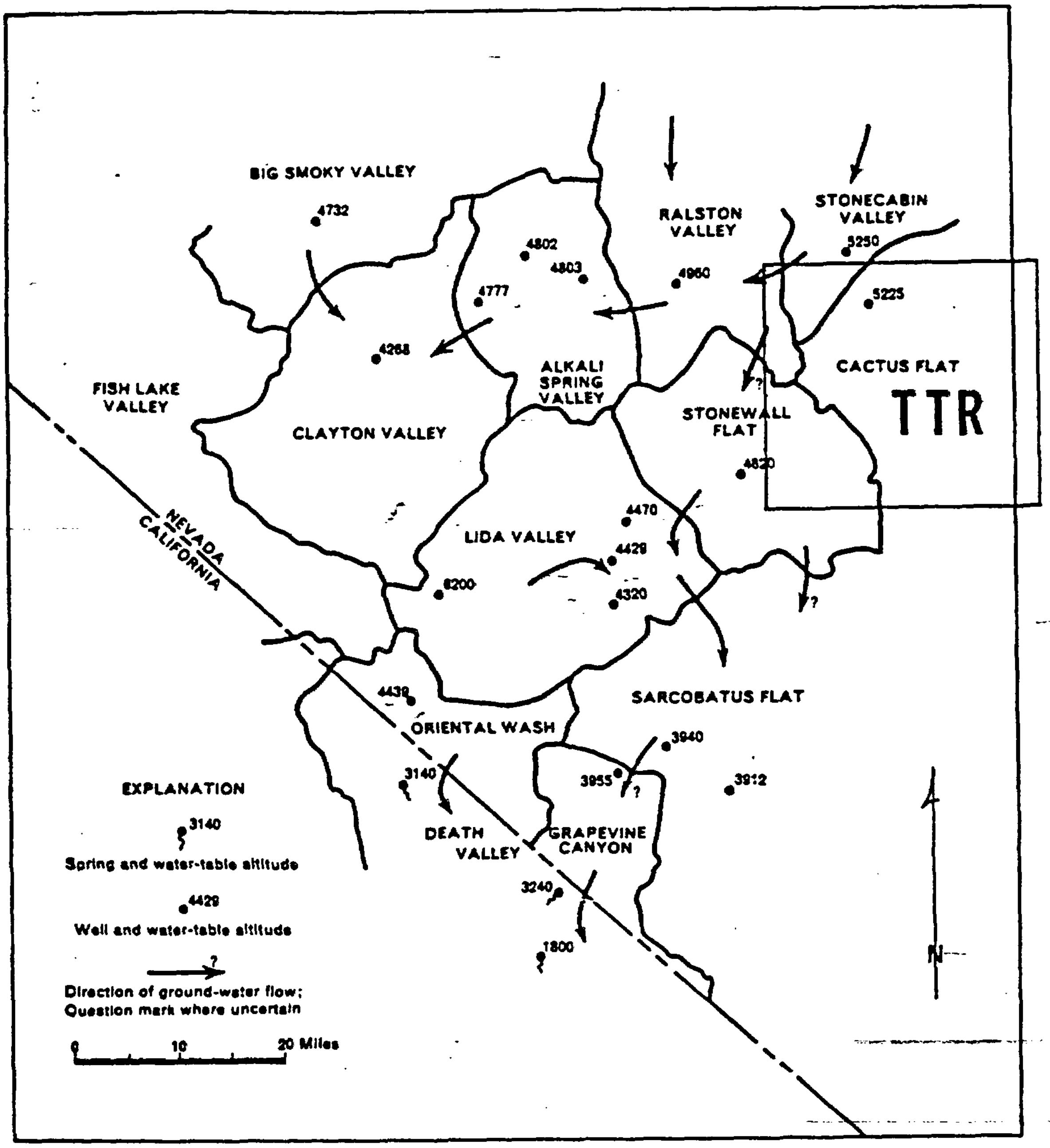

Figure 10. Generalized map of inter-valley ground-water flow as interpreted from water-level data. From Rush, 1968.

the state, and only since 1932 does the University of Nevada feel that "accurate seismological records based on instrumental observations are... available and complete for the entire western United States" (Ryall et al., 1966). For earlier years, magnitudes and epicenters have had to be estimated from the area over which an earthquake was felt and its intensity at the center of this area. Nevertheless, the earlier data are consistent in their general implications with the instrumentally derived data of the last 40 years. In California the data go back two centuries, but the period of good instrumental observations is only slightly longer than in Nevada.

This century of data, taken together with earthquake data from other western states, indicates that there is a zone of high seismicity extending from Ventura, California, to Winnemucca, Nevada, passing just to the west of the TTR. This zone is shown in a regional context in Figure 11, and within the state of Nevada in Figure 12. (Figure 11 is not the usual plot of earthquake epicenters, but a map of "tectonic flux,"* i.e., density of earthquake strain releases accumulated during the period from 1932 to 1961.) This zone has come to be called the Nevada Seismic Zone.

The Nevada Seismic Zone has experienced some of the largest earthquakes on record. Near where the zone crosses the better-known San Andreas Fault, an earthquake occurred on January 9, 1857, that was of larger magnitude than the famous San Francisco earthquake of 1906, and only less destructive because of the slightly developed nature of the country where it occurred. Farther north in the Owens Valley, an even larger earthquake occurred on March 26, 1872, that left fault scarps up to 23 feet in height. Shocks along the Nevada portion of the zone have been smaller; the most notable of these are listed in Table III. The Cedar Valley earthquake of 1932 was about where the Nevada Seismic Zone crosses the Walker Lane described in the Geology Section.

TABLE III

Larger Earthquakes in Nevada

Date	Time (GMT)	Locality	Lat N	Long W	Intensity	Magnitude
1903		Wonder			VIII	†
1910 11 21	23:23	Fish Lake Valley	38	118	VIII	
1915 10 03	06:53	Pleasant Valley	40.5	117.5	X	7.8†
1932 12 21	06:10:04	Cedar Mountain	38.8	118.0	X	8.2†
1934 01 90	20:16:35	Excelsior Mountain	38.3	118.4	VIII	6.3†
1954 07 06	11:13:20	Rainbow Mountain	39.4	118.5	IX	6.8†
1954 07 06	22:07:41	Rainbow Mountain	39.3	118.5	VIII	6.0
1954 08 24	05:51:32	Rainbow Mountain	39.4	118.5	VIII	6.8†
1954 12 16	11:07:11	Fairview Peak	39.3	118.1	X	7.3†
1954 12 16	11:11:34	Dixie Valley	39.8	118.1		6.9†

†Accompanied by surface faulting.
Sources: Slemmons et al., 1965. Ryall et al., 1966. Coffman and von Hake, 1973.

*As defined by Ryall et al., 1966.

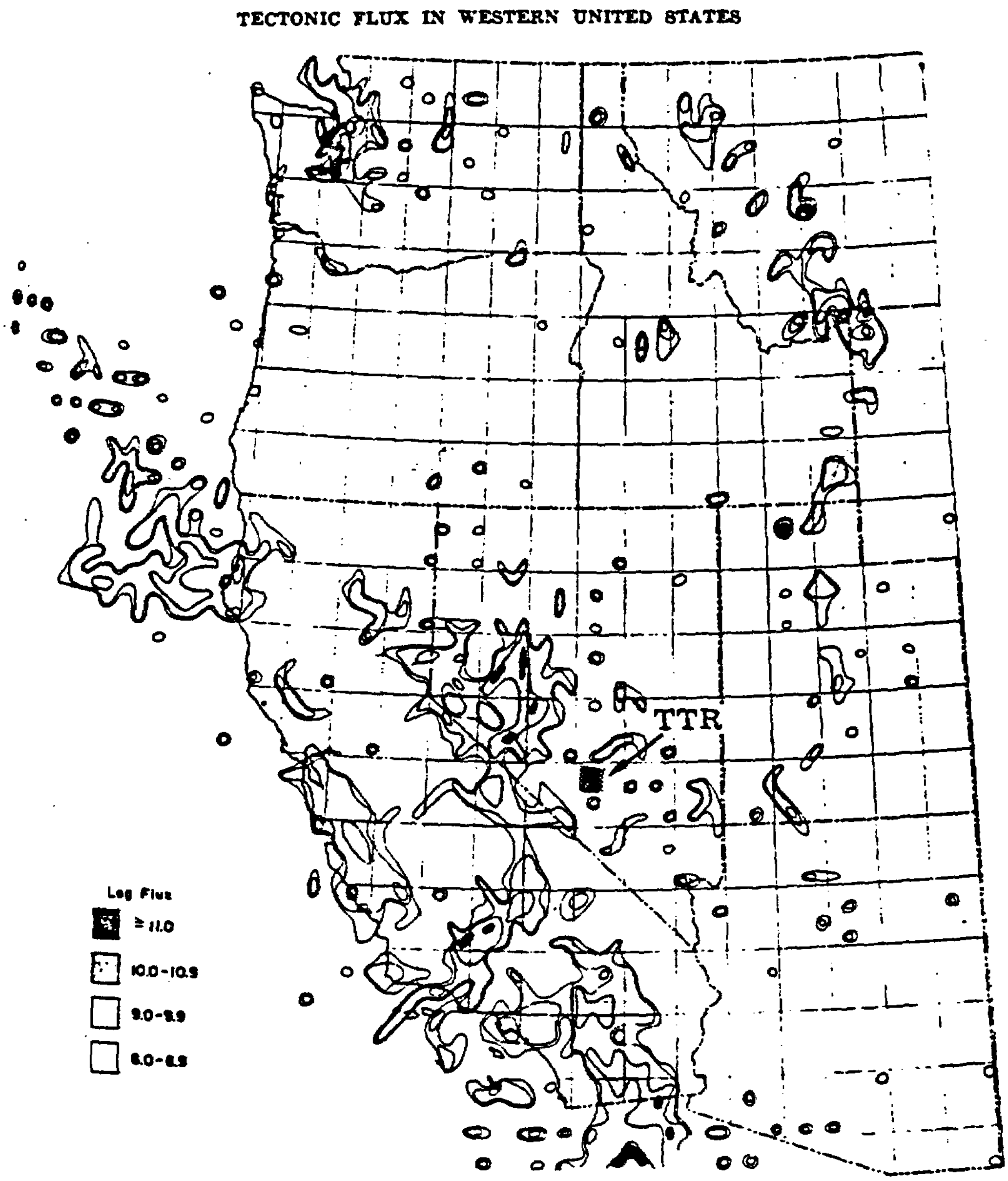

Figure 11. Map of tectonic flux for the western United States, for the period 1932-1961. From Ryall et al., 1966.

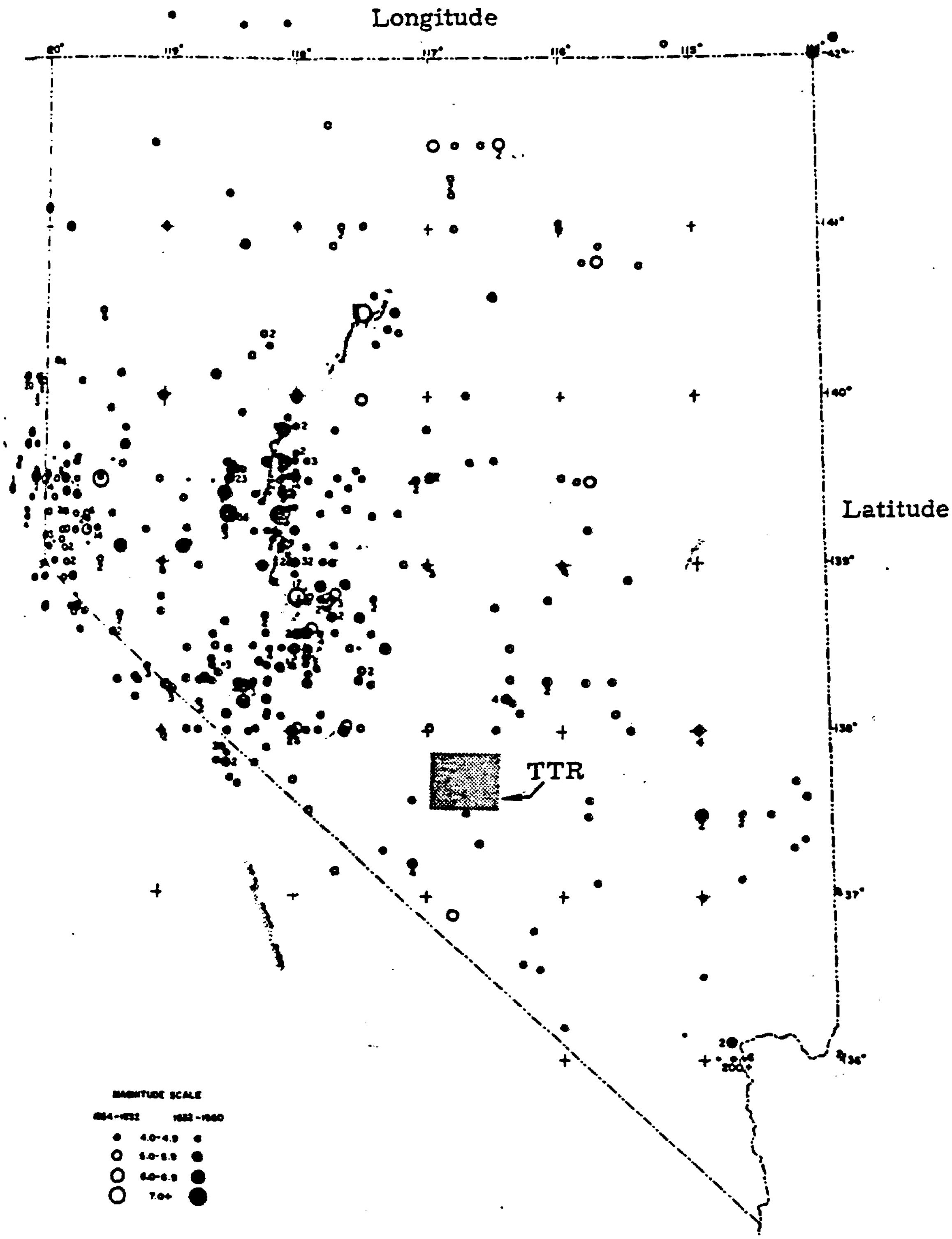

Figure 12. Map of Nevada earthquake epicenters, 1852-1960. Where two or more epicenters coincide, the symbol for the higher Richter magnitude is used and the number of coincident events is noted. Magnitudes for earthquakes not measured instrumentally are inferred from intensity and/or area over which they were felt. From Slemmons et al., 1965.

Thus the Nevada Seismic Zone crosses two of the more prominent geological features of the western United States, which would seem to be in conflict with geological explanations for its existence. Also, since the zone does not conform to the boundary of a tectonic plate, plate tectonics theory does not seem to explain it.

Gumper and Scholz (1971) have used microseismicity, focal mechanism solutions, and previously published focal parameter data to study the tectonics of the Nevada Seismic Zone. Microseisms (very small earthquakes), though more frequent, follow the same distribution pattern as the earthquakes shown in Figures 11 and 12. Of particular interest are microseisms in the Cedar Valley area, that being along Walker Lane. From them a composite focal mechanism was determined, that is, the strike and drip of the apparent slip plane along which these microseisms operated. Of the two planes possible, one with a strike of N 27°W is in good agreement with horizontal movements inferred from the 1932 Cedar Valley earthquake. These 1932 movements were the basis on which earlier investigators considered the Walker Lane to be an active tectonic feature, but Gumper and Scholz conclude that "the seismic pattern that has developed since 1932 indicates that the Cedar Valley earthquake is part of the Nevada Seismic Zone that cuts across the Walker Lane near Cedar Valley [instead of being part of a seismic zone extending along Walker Lane]. Considering the seismicity and the composite focal mechanism for the Cedar Valley area..., the data indicate that the 1932 Cedar Valley earthquake does not provide evidence of current tectonic activity along the Walker Lane" (ibid. p. 1424).

Gumper and Scholz gathered focal mechanism parameters for earthquakes on the Nevada Seismic Zone to the north of Walker Lane. Despite some scatter, the results indicate a persistent NW-SE orientation for the tension axes of these earthquakes. A similar orientation has been obtained for aftershocks of nuclear explosions on the Nevada Test Site. This result implies that the western portion of the basin-and-range province, where the TTR is, is in a state of tension and is spreading.

Finally, Gumper and Scholz adduce studies of Cenozoic vulcanism in the region, which indicate a westward movement, to conclude that there is probably also a westward expansion of the zone of normal faulting within the Great Basin. If so, this would explain the present low seismicity of east-central Nevada.

Gumper and Scholz quote Slemmons (1967) as noting that the seismic zone is at or near the easternmost extent of Cretaceous granitic plutons associated with the Sierra Nevada batholith. They are led to conclude that the Nevada Seismic Zone is due to an interaction between the forces within the mantle below the earth's crust that caused the outward migration of vulcanism and the boundary of the Sierra Nevada batholith. Crustal thickening is implied, and it begins farther east, close to the Nevada Seismic Zone. High stresses would be developed at this boundary by any impinging westward-moving material below the crust of the western basin-and-range province.

Thus Gumper and Scholz conclude "that the seismic zone is caused by a westward flow of mantle material beneath the crust of the basin-and-range province impinging against the boundary of the Sierra Nevada batholith. In addition to high stresses being produced by this interaction, the boundary probably represents a zone of weakness between the more rigid crust beneath the Sierra Nevada and the thinner crust beneath the main part of the Basin and Range Province" (ibid, p. 1428).

So far as the TTR is concerned, the relevant conclusion is that there are and will continue to be many small earthquakes to the west, some occurring in the Cactus Range itself. No present or past activities of the TTR can affect this seismicity; but the presence of that seismicity is consistent with the TTR being within Seismic Risk Zone 3 (ICBO, 1970), and construction and activities at the TTR have to be undertaken with this risk in mind.

Climate

The Basin-and-Range Province as a whole is the driest in the United States. In many parts of it, annual precipitation is less than 10 inches. There is a shortage of perennial streams, and evaporation rates are high.

Weather in the Great Basin is the result of three prevailing circulation patterns (Houghton, 1969): transitory frontal systems moving inland from the Pacific and controlled to a certain extent by the jet stream; continental cyclones developing over the Great Basin; and convection associated with moist air from the Gulf of Mexico. The last two operate year-round, while the first is confined to the summer season. It should be noted that an important feature of the climate in this region is the existence of a semipermanent high-pressure area. It is this feature that primarily accounts for the good weather, but it also offers a potential for air pollution. Precipitation comes with great variation in strength and frequency; thus the vegetation of the Great Basin has had to adapt to an irregular supply of water.

Winters are cold, and most of the precipitation then occurs as snow. Standing water is almost nonexistent and consists of only a few natural areas fed by fresh-water springs. Man-made reservoirs (none near TTR) add to this and constitute areas characterized by relatively heavy recreational use.

The Tonopah Test Range itself is a region of low precipitation and moderate winds. Schaeffer (1968) has summarized seven years of meteorological data from 1961 through 1967 taken in mid-valley on the Range. Tables IV through VI are taken from this report. Daily average temperatures range from 28°F (-2°C) in January to 74°F (+23°C) in July; extremes during the period were -24°F (-31°C) and +102°F (+39°C) (Figure 13). Precipitation averaged 4.92 inches (12.5 cm) a year (including 19 inches of snow), the bulk of it coming in the late spring and summer in thunderstorms (Figure 14). On the average there were 37 days a year on which there was measurable precipitation, and 7 days a year of fog (Figures 15 and 16). Winds were bimodal from the west-northwest and from the south-southeast (Table VI, Figure 17). Dust storms are common in spring and dust devils in the summer.

TABLE IV*

Surface Temperature (^{o}F) at TTR, 1961-1967

	Averages			Extremes				Average Number of Days			
								Maximum		Minimum	
	Daily max	Daily min	Monthly	Highest	Date	Lowest	Date	90 and above	32 and below	32 and below	0 and below
January	44	13	28	65	17/61	-24	24/62	0	3	30	3
February	49	20	34	70	5/63 7/63	-5	27/62	0	1	26	1
March	52	24	38	78	31/66	1	1/62	0	0	28	0
April	62	31	47	82	17/62 18/62	9	20/66	0	0	17	0
May	71	40	56	92	22/67	19	7/64	0	0	4	0
June	79	48	65	102	21/61	30	2/67	6	0	0	0
July	90	54	74	100	24/64 2/67	41	28/65	19	0	0	0
August	88	54	72	98	6/66 8/66 9/66 10/66	40	29/62 26/63	15	0	0	0
September	79	44	62	91	18/62	28	30/61 19/65	1	0	2	0
October	70	36	53	87	1/63 5/64	15	23/61	0	0	12	0
November	54	25	38	74	2/62 3/62	-3	19/64 20/63	0	2	24	1
December	45	17	29	64	24/64	-15	20/67 21/67	0	4	30	1
Year	65	34	50	102	21/61	-24	24/62	41	10	173	6

*From Schaeffer, 1968, p. 18.

TABLE V*

Precipitation at TTR, 1961-1967

	Total Precipitation (Inches)	Total Snow, sleet (Inches)	Number of Days: Precipitation 0.01 inch or more	Snow, sleet 1.0 inch or more	Thunderstorms	Fog
January	0.19	2	1	1	0	1
February	0.24	3	2	1	0	1
March	0.19	3	4	2	1	1
April	0.49	4	5	2	1	1
May	0.56	3	4	1	1	1
June	0.54	0	4	0	2	0
July	0.30	0	3	0	1	0
August	1.06	0	5	0	1	0
September	0.61	0	2	0	1	0
October	0.11	1	1	0	0	0
November	0.40	2	4	1	0	1
December	0.23	1	2	1	0	1
Year	4.92	19	37	9	8	7

*From Schaeffer, 1968, p. 20.

TABLE VI*

Surface Winds at TTR, 1961-1967
(Percent Frequency and Average Speed)

Direction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
N	%	3.5	7.4	4.7	4.7	4.6	5.7	1.9	2.8	3.0	3.7	2.8	4.4	4.1
	Av	6	7	9	8	6	6	6	4	6	8	6	6	6
NNE	%	0.9	1.9	1.7	1.7	1.8	2.6	0.9	1.3	2.1	1.8	1.2	1.3	1.6
	Av	6	7	8	6	7	6	6	7	7	8	6	6	7
NE	%	0.4	0.8	0.7	0.5	0.8	0.7	0.9	1.0	0.7	0.7	0.6	0.4	0.7
	Av	2	4	5	4	4	5	6	6	6	5	5	3	5
ENE	%	0.3	0.3	0.5	0.4	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4
	Av	3	3	5	4	6	4	6	4	4	4	2	2	4
E	%	0.9	1.1	1.3	1.1	1.2	0.7	1.1	1.6	1.0	1.1	0.6	0.6	1.0
	Av	5	4	5	5	6	6	4	6	6	6	5	4	5
ESE	%	2.3	2.6	3.9	2.8	3.1	2.5	4.0	3.9	3.2	3.1	3.2	1.7	3.0
	Av	5	6	6	6	6	6	6	6	5	6	6	7	6
SE	%	7.1	7.6	8.1	7.2	8.2	6.3	11.8	10.2	8.9	8.2	10.4	8.1	8.5
	Av	7	7	8	7	7	6	7	6	6	7	7	6	7
SSE	%	6.4	7.5	9.1	8.0	8.8	7.3	11.9	10.0	8.7	9.0	12.2	7.6	8.9
	Av	8	9	10	9	8	8	8	7	6	8	8	9	8
S	%	5.2	4.9	9.8	11.9	12.2	12.0	20.4	15.2	14.0	9.2	9.2	5.4	10.8
	Av	9	9	13	12	12	11	10	10	9	8	10	8	10
SSW	%	2.0	3.0	4.3	5.7	6.5	7.7	10.4	10.6	7.0	4.4	2.8	2.0	5.5
	Av	6	8	11	10	10	10	10	10	9	7	6	8	9
SW	%	1.1	1.5	2.1	2.6	3.8	3.5	3.7	4.6	2.3	2.4	1.6	1.1	2.5
	Av	4	6	6	8	8	7	8	8	6	6	4	6	6
WSW	%	1.5	1.8	1.7	2.2	3.0	3.7	2.4	2.5	2.0	2.2	1.7	1.6	2.2
	Av	3	4	5	6	6	6	6	6	5	5	4	3	5
W	%	7.6	6.2	6.0	6.3	6.9	7.1	4.4	4.8	5.6	6.1	5.4	6.8	6.1
	Av	7	7	8	6	8	7	7	5	5	6	7	7	7
WNW	%	14.8	14.3	12.4	12.7	10.8	11.6	4.7	4.8	7.3	9.5	10.1	12.8	10.5
	Av	9	9	10	11	9	8	7	7	6	7	8	8	8
NW	%	12.7	15.0	14.3	14.0	12.2	11.0	4.5	5.0	7.8	9.3	8.3	11.4	10.5
	Av	8	10	10	11	9	8	6	6	6	6	7	7	8
NNW	%	5.7	7.6	6.3	6.2	6.2	6.1	2.7	3.6	4.1	5.2	4.2	5.5	5.3
	Av	6	6	7	8	7	6	6	5	5	5	6	5	6
CALM	%	27.6	16.5	13.1	11.8	9.3	11.1	13.9	17.7	22.0	23.8	25.4	29.0	18.4

*From Schaeffer, 1968, p. 21.

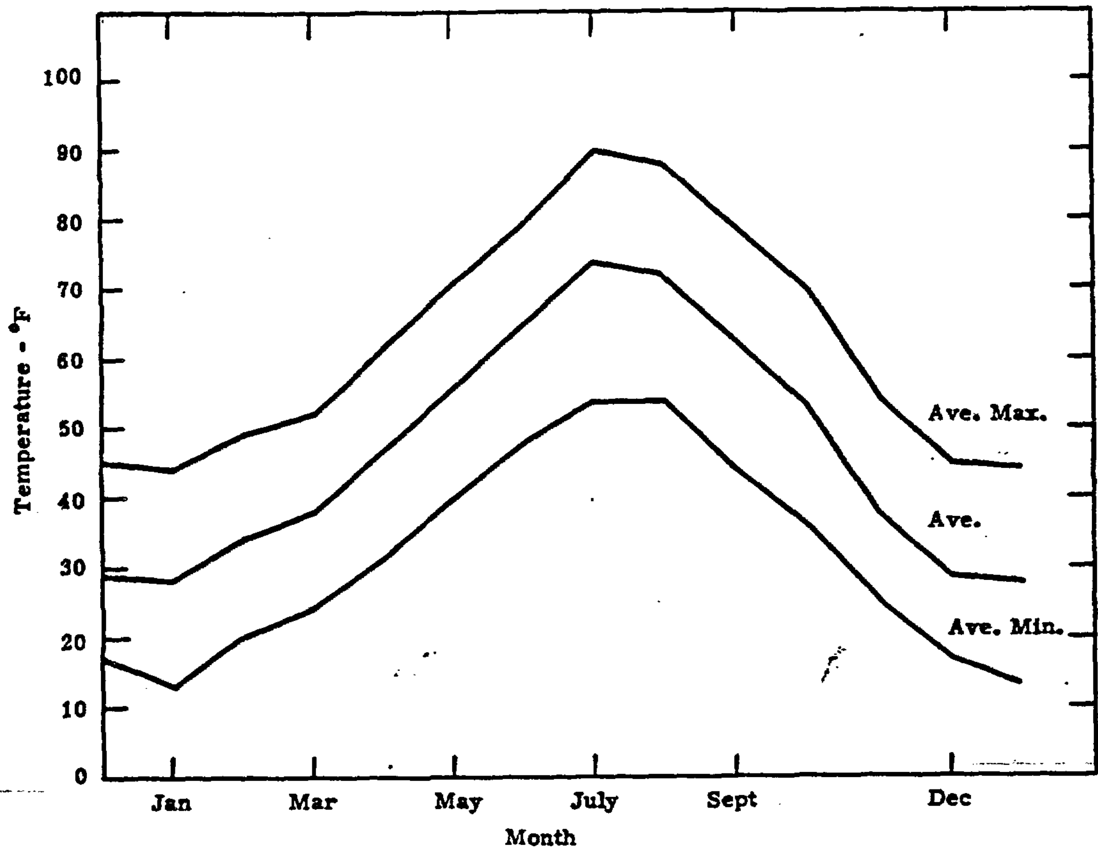

Figure 13. Average surface temperatures vs month of the year

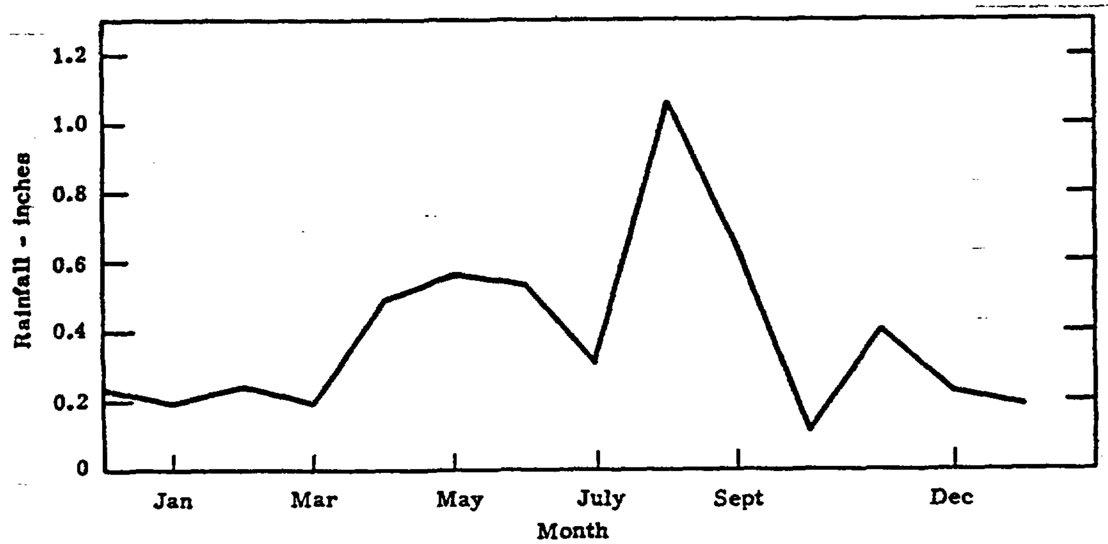

Figure 14. Average precipitation vs month of the year

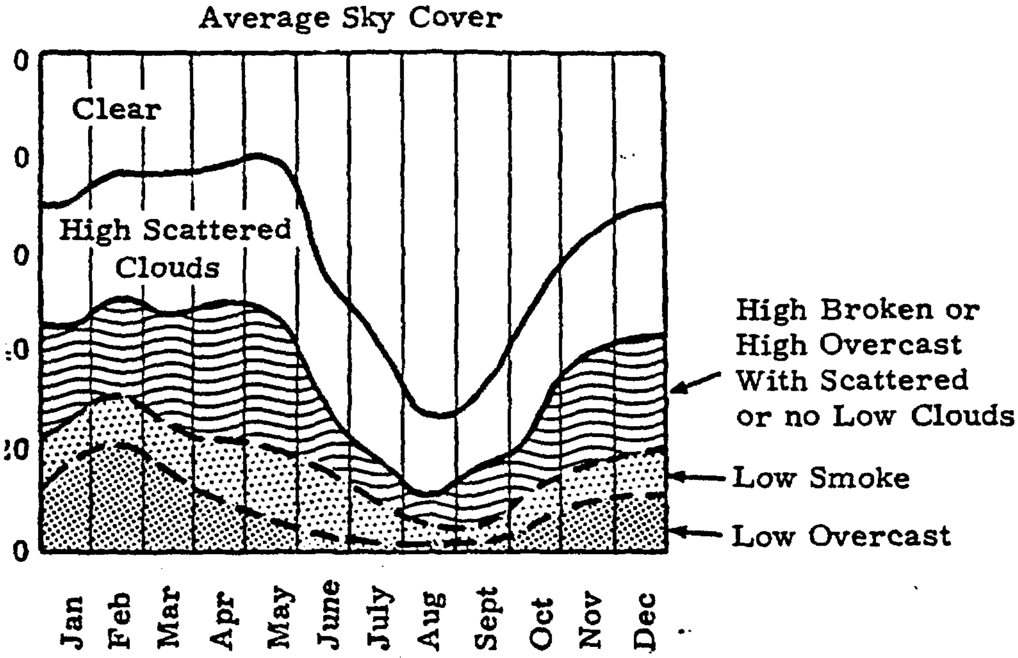

Figure 15. Proportion of various sky conditions at TTR

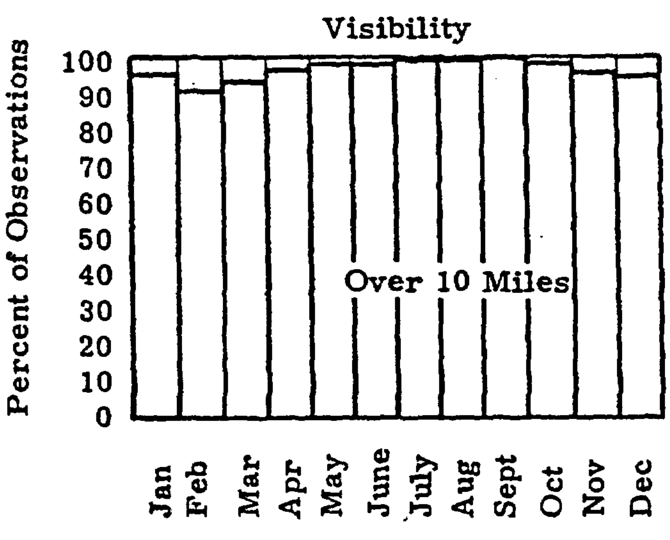

Figure 16. TTR sky cover and visibility

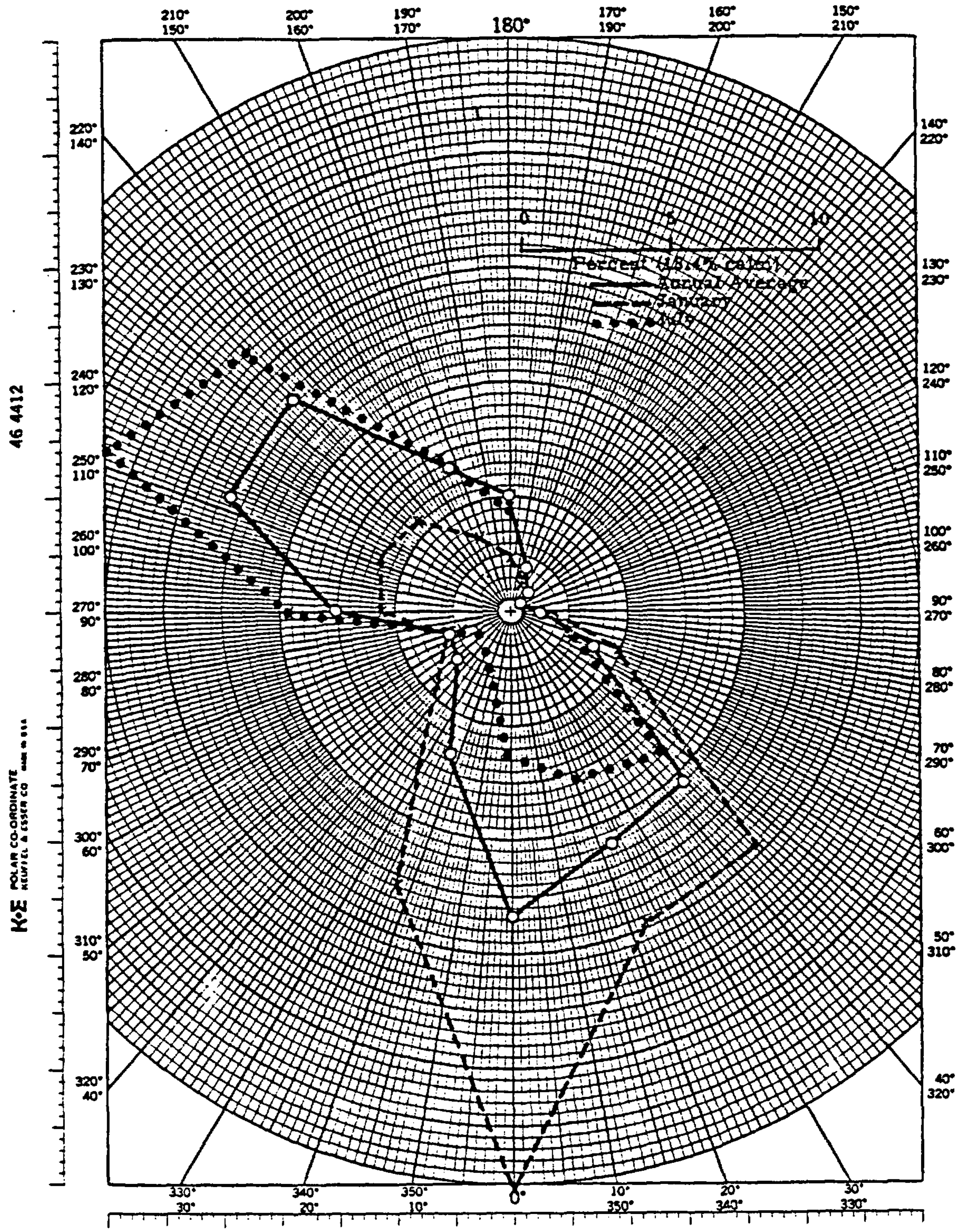

Figure 17. Annual wind rose for TTR

Biology

Ecological Determinants -- The Tonopah Test Range appears to many to be a dry, desolate desert valley between two almost bare ranges of low hills. This appearance is deceptive, for there is a wide variety of plants and animals native to the area that are well adapted to its dryness, extremes of temperature, and occasional dust and high winds. It is true, nevertheless, that the productivity of a mountain desert such as this is much less than it is in moister parts of the United States.

Tonopah Test Range is in the Basin-and-Range region of the western United States, characterized by north-south mountains, broad valleys, closed drainage systems, and playas (or dry lake beds). However, only a few thousand years ago in the Pleistocene era, the Great Basin was not desert, but rather, since the climate was wet enough, supported lakes several hundreds of feet deep. Only a few remnants of these lakes remain,such as Pyramid Lake in northwestern Nevada. (The distribution of Pleistocene lakes is closely correlated with the contemporary Salt Desert Shrub vegetation defined below.) Another consequence of this earlier moister climatic regime is the occurrence throughout the Great Basin of relict populations, especially of small rodents, that now constitute separate species, and some of which are listed on the Secretary of the Interior's List of Rare and Endangered Species. (None of these however, to the best of our knowledge, occurs within the bounds of the Tonopah Test Range.)

In the western mountain deserts, moisture and soil conditions are all-important in determining the plant and animal communities to be found in any given place. Because elevation is strongly correlated with rainfall and temperature, there are sharp altitudinal gradients in ecosystems, and in what follows plant and related animal communities are described in terms of the mountains and valleys in which they occur.

In the valleys where most of the activities of the TTR take place, the surface soils have a gravelly texture and are classified as gravelly sandy loam. All the soils are alkaline, ranging in pH from 7 to 9. The wind has had a dominant influence on the surface texture of the soil. It has moved the fine-textured soils, creating bare areas between the plants and depositing the fines around the base of the brush or vegetation. If water were available, most of the soils would be potential agricultural land (Leavitt, 1974).

Vegetation -- The numerous mountain ranges and valleys of the Great Basin have provided for the development of diverse flora and funa, often changing with sharp ecotones as elevations change or from valley to valley; but, generally, the communities within the Tonopah Test Range may be characterized as: Salt Desert Shrub, Northern Desert Shrub, and Pinon-Juniper Woodland (Sjovold et al., 1974).

Salt Desert Shrub

This is the community found in such valley floors as Cactus Flat. It consists of a uniform but thinly spread distribution of a rather depauperate flora of shrubs, forbs, and grasses. The common shrubs are white sage (winter-fat), shadscale, four-wing saltbush, greasewood, spiny hopsage, and black sagebrush. Also to be found in these areas are Russian thistle (tumbleweed), Indian ricegrass, haletogen, and the grass galleta. Rhoads (1974) indicates no more than 15 percent ground cover in the center of Cactus Flat near the Clean Slate sites. Four-wing saltbush, winter-fat, and galleta are the vegetation species among these that livestock prefer to any others that grow on the desert range (Leavitt, 1974). The forb haletogen is oxalate-containing and poisonous at all stages of growth, though the plant is usually so unpalatable that only under unusual circumstances will animals consume enough to produce poisoning. Haletogen is particularly to be found on disturbed areas such as within the Clean Slate inner enclosures where decontamination took place in 1963. Other plants listed as sometimes poisonous are shadscale and greasewood (Brown and Smith, 1966). Table VII lists those plants which Sjovold et al. (1974) indicate are common in areas of Salt Desert Shrub.

Northern Desert Shrub

This is the community found at the edges of the valley and in the low foothills, including much of the Cactus Range. Important plant species include sagebrush, rabbitbrush, wheatgrass, squirreltail, and Nevada bluegrass. Of these, rabbitbrush is poisonous under some conditions. Sjovold et al. (1974) do not mention the Joshua tree. This spectacular tree is found around the edges of Cactus Flat in the well-drained slopes leading up to the Cactus and Kawich Ranges (see Figure 18). Also, the Cactus Range does not fit their description of Northern Desert Shrub (or of the Pinon-Juniper Woodland) in that juniper are moderately common, but there are no pine. One also finds hydrophilous vegetation around such springs as Cactus Springs (Figure 19), but the areas watered by such springs are so small that the overall impact on the vegetational picture of the TTR is almost negligible. Still, there is one cottonwood tree, probably introduced, at Cactus Springs (Figure 20), and the presence of this and other springs makes possible a population of large mammals.

Pinon-Juniper Woodland

This community is normally found above the Northern Desert Shrub in the mountains; at the TTR it is found only in the Kawich Range. As its name indicates, the principal and dominant species are pinon pine and Utah juniper.

TABLE VII

Vegetation Commonly Found at the TTR

		Salt Desert Shrub	Northern Desert Shrub	Pine-Juniper Woodland
Gymnospermae				
Pinaceae - Pine family				
Pinon pine	Pinus monophylla			X
Cupressaceae - Cypress family				
Utah juniper	Juniperus osteosperma			X
Angiospermae - Monocotyledonae				
Gramineae - Grass family				
Galleta	Hilaria jamesii	X		
Bluebunch wheatgrass	Agropyron spp		X	
Squirreltail	Sitanion hystrix		X	
Indian ricegrass	Oryzopsis hymenoides	X		
Nevada bluegrass	Poa nevadensis		X	
Agavaceae - Agave family				
Joshua tree	Yucca brevifolis		X	
Angiospermae - Dicotyledoneae				
Salicaceae - Willow family				
Fremont's cottonwood	Populus fremontii			X
Chenopodiaceae - Goosefoot family				
White sage (winter-fat)	Eurotia lanata	X		
Four-wing saltbush	Atriplex canescens	X		
Shadscale	Atriplex confertifolia	X		
Haletogen	Haletogen glomeratus	X		
Bailey's greasewood	Sarcobatus baileyi	X		
Greasewood	Sarcobatus vermiculatus	X		
Russian thistle (tumbleweed)	Salsola kali	X		
Compositae - Aster family				
Black sagebrush	Artemisia nova	X		
Bud sagebrush	Artemisia spinescens	X		
Big sagebrush	Artemisia tridentata		X	
Rubber rabbitbrush	Chrysothamnus nauseosus		X	
Green rabbitbrush	Chrysothamnus viscidiflorus	X	X	
Spiny hopsage	Grayia spinosa	X		

Figure 18. Joshua trees at the Tonopah Test Range

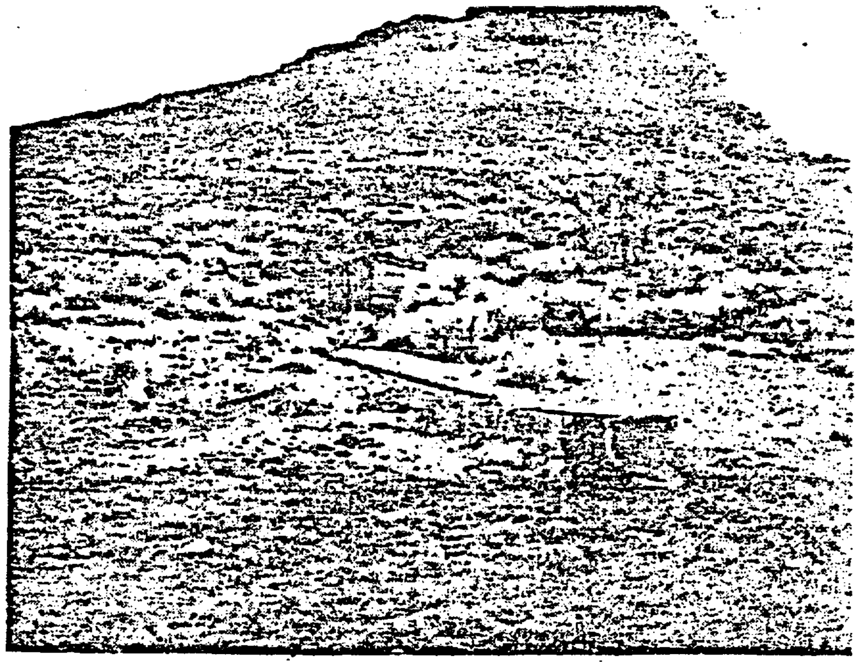

Figure 19. Springhouse at Cactus Springs

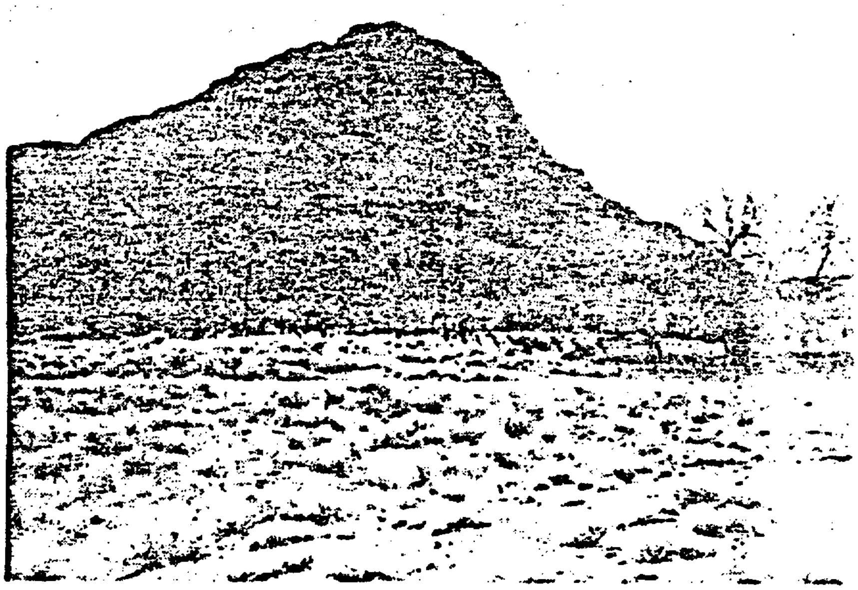

Figure 20. Cottonwood tree at Cactus Springs

Animals -- With each vegetational community is associated a faunal assemblage characteristic of it. Only a few species such as the coyote and the rattlesnake occur in all local vegetational communities (see Table VIII).

In the Salt Desert Shrub are to be found many rodents, kit foxes, coyotes, badgers, and jackrabbits. There are lizards and rattlesnakes. Common birds are the horned lark, the sage thrasher, brewer's and vesper sparrows, and the mourning dove.

In the Northern Desert Shrub, there are rodents, a somewhat different set than in the Salt Desert Shrub, lizards, snakes, and some different species of birds, including the golden eagle, the sage grouse, and the raven.

In the Pinon-Juniper Woodland of the Kawich Range in the northeast corner of the TTR there are also cottontail and mule deer. This woodland has the greatest variety of wildlife of any of the vegetational associations to be found on the TTR.

Range Cattle

The Great Basin is used by cattle as winter or summer range, and sometimes as continuous-use range, depending on the management system used by individual ranchers (see Figure 21). The carrying capacity of these lands is low. For instance, the Bureau of Land Management (BLM) has established the Animal Unit Month for Nye and Esmeralda counties to be one animal per 52 acres. Strictly speaking, the Tonopah Test Range is not open to grazing; all grazing permits once applying to this land have been canceled. Nevertheless, there are cattle here; Nevada state law says that land not fenced off is open range land, and the cost of fencing TTR and other parts of the Nellis AFB Range is prohibitive. At last count (April 1974) there were about 800 cattle on the Range. Trespass cattle remain a problem that the ERDA and the BLM have not been able to resolve with the ranchers who own these cattle.

Wild Horses

The April count also indicates some 375 feral horses on the TTR (see Figure 22). Feral horses consist of animals that have escaped the close domestic management of man and now graze freely throughout much of Nevada, and the western United States. These animals are still escaping into the wild; thus their populations are a mixture of animals that have been long removed from man's management and those that are essentially domestic but free grazing.

In recent years, wild horses have caught the attention and imagination of many North Americans, so much so that legislation has recently been passed to protect them. Since there is essentially no management of these horses, little is known about their biology or space requirements. Their exposure to Range activities has apparently had little effect on their population or grazing habits.

TABLE VIII

Fauna Commonly Found at the TTR

		Salt Desert Shrub	Northern Desert Shrub	Pine-Juniper Woodland
Mammals				
Audubon cottontail	Silvilagus audubonii			X
Black-tailed jackrabbit	Lepus californicus		X	
Cliff chipmunk	Eutamias dorsalis		X	
Least pocket mouse	Perognathus longimembris	X		
Great Basin pocket mouse	Perognathus parvus		X	
Dark kangaroo mouse	Microdipodops megacephalus	X		
Ord kangaroo rat	Dipodomys ordii	X	X	X
Chisel-toothed kangaroo rat	Dipodomys microps	X	X	
Western harvest mouse	Reinthrodontomys megalotis		X	
Canyon mouse	Peromyscus crinitus			X
White-footed deer mouse	Peromyscus maniculatus	X	X	X
Pinon mouse	Peromyscus truei			X
Northern grasshopper mouse	Onychomys leucogaster		X	
Desert wood rat	Neotoma lepida			X
Coyote	Canis latrans	X	X	X
Kit fox	Vulpes macrotis	X	X	
Badger	Taxidea taxus	X		
Bobcat	Lynx rufus	X	X	X
Mule deer	Odocoileus hemionus			X
Reptiles				
Desert horned-lizard (horned toad)	Phrynosoma platyrhinos	X		
Sagebrush lizard	Sceloporus graciosus		X	
Western fence lizard	Sceloporus occidentalis			X
Side-blotched lizard	Uta stansburiana	X	X	X
Whip-tailed lizard	Cnemidophorus tigris	X		
Gophersnake	Pituophis catenifer		X	
Speckled rattlesnake	Crotalus mitchelli	X	X	X
Birds				
Golden eagle	Aquila chrysaetos		X	
Sage grouse	Centrocercus urophasianus		X	
Mourning dove	Zenaidura macroura	X		X
Poor-will	Phalaenoptilus nuttallii			X
Dusky flycatcher	Empidonax oberholseri			X
Horned lark	Eremophila alpestris	X	X	
Raven	Corvus corax		X	
Mountain chickadee	Parus gambeli			X
Bushtit	Psaltriparus minimus			X
White-breasted nuthatch	Sitta carolinensis			X
Bewick's wren	Thryomanes bewickii			X
Sage thrasher	Oreoscoptes montanus	X	X	
Gray vireo	Vireo vicinor			X
Black-throated gray warbler	Dendroica nigrescens			X
Vesper sparrow	Pooecetes gramineus	X		
Lark Sparrow	Chondestes grammacus		X	
Black-throated sparrow	Amphispiza bilineata		X	
Brewer's sparrow	Spizzela breweri	X		

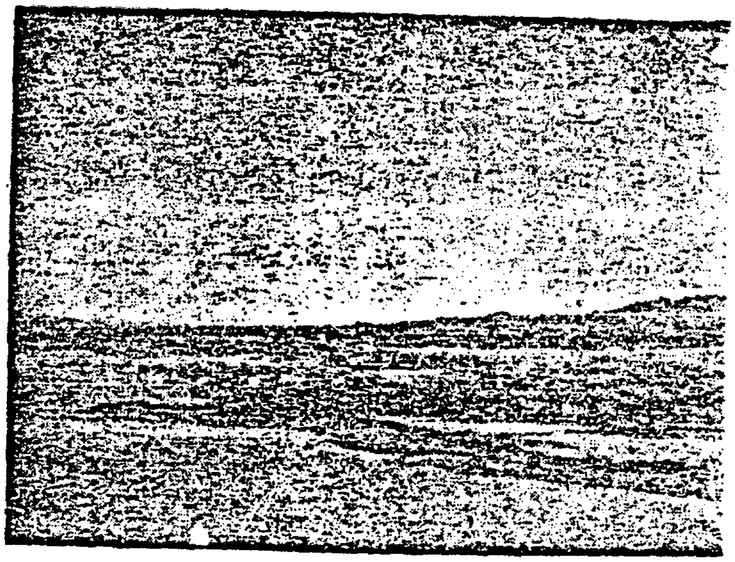

Figure 21. Cattle on the Tonopah Test Range

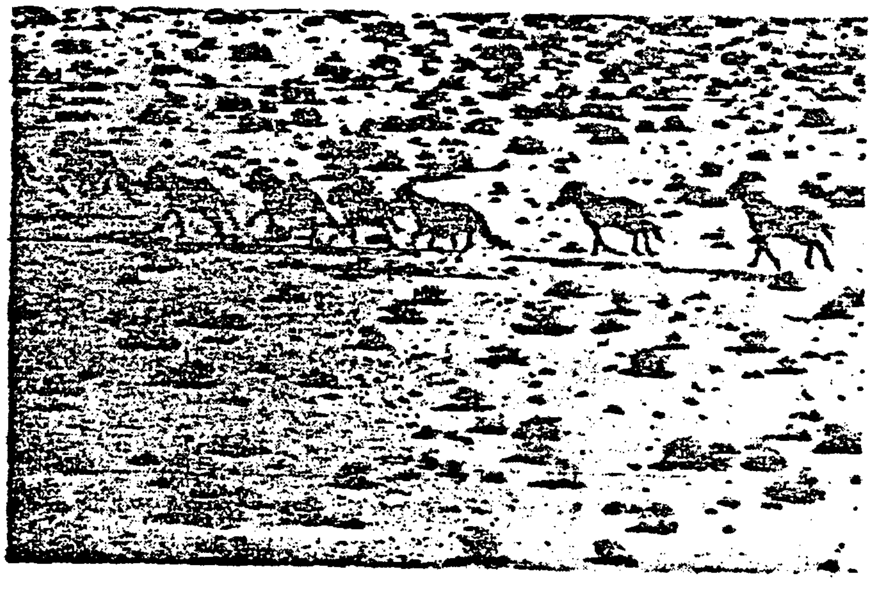

Figure 22. Wild horses on the Tonopah Test Range

Archaeological and Historical Considerations

Before the arrival of the white man, this part of the West was occupied by a very thinly spread population of aboriginal Indians. At the time of contact, these Paiutes had a hunter-gatherer economy of life. In spite of their apparently sparse population, these people exploited the local resources to the limit that their methods permitted, and it is safe to say that at one time or another they were everywhere within the bounds of the present Tonopah Test Range, as is attested to by the fact that arrowheads can be found almost anywhere in the area. Naturally, however, their remains are most common near the three springs in the TTR: Cactus and Antelope Springs in the central and southern portions of the Cactus Range on the west side of the TTR, and Silverbow Springs in the northeast corner of the TTR in the foothills of the Kawich Range.

After the arrival of the white man, the open plains of the area were gradually taken over as range land, and the mountains were intensely prospected for minerals. From this period there remains a variety of old roads and trails not completely obliterated by returning vegetation, cabins near all of the springs mentioned, and innumerable prospectors' probe holes in the mountains.

None of the historical remains on the TTR are listed on the National Register of Historical Sites.

There has never been a survey of the TTR for sites of historic or archaeological interest and value, as defined in the Antiquities Act of 1906, as amended. According to that act, such sites should be preserved or "salvaged" before use of the land on which they lie destroys them. However, there has been no indication that construction of the existing facilities on the TTR has accomplished any such destruction, because those facilities are in the open plain, and most of the sites are believed to be in the mountains near the springs mentioned above.

III. ENVIRONMENTAL IMPACT

Land Use

The land occupied by the Tonopah Test Range has had several previous occupants. The aboriginal Indians left very few marks, if any, but did leave broken arrowheads and spear points, mainly near the several springs in the surrounding hills. The early settlers built a few shacks and made a few wagon trails, many of which are still visible.

At the turn of the century, the prospector and miner made the first real impact on the land. About a dozen abandoned mines and numerous prospecting holes are to be found in the surrounding hills. State Highway 25 was built essentially down the middle of the Range, with many side roads leading to the various mines and springs.

By the beginning of World War II, virtually all of the mines had been abandoned and the Army Air Corps set up a bombing range in the general area. Hangars, barracks and airstrips were set up in Ralston Valley just east of Tonopah. Numerous targets were propped into the ground and two additional airstrips were added. Many more miles of roads were constructed, as well as spotting towers and bunkers. The Army Air Corps has been gone for over 25 years; but most of the roads are discernible (many are now paved or well graded); almost all towers have been moved and revitalized; and the airstrip near Tonopah (along with one hangar and a few small buildings) has been improved and is the FAA-approved city airport. The two airstrips in the central and southern portion of the TTR have received little care but could be restored for temporary or special use. Two observation bunkers have been modified, one for propellant storage and another for a fire control bunker. There is a small mound of spent practice bomb casings, and a 30-caliber bullet can be found occasionally.

Although the land became a part of the reactivated Nellis Air Force Base Gunnery and Bombing Range in early 1950, there was virtually no activity until late 1956. In November 1956, Sandia started construction of a temporary test range which in 1959 was to become TTR. Early construction consisted of the erection of a few metal buildings (now a part of Area 3) and some camera towers. Two portable radars were brought in. A county road was extended and wells were dug near Area 3. The Range was operated on a part-time basis beginning in early 1957.

In early 1959 it was decided to make the Range permanent and contracts were let to improve roads, construct a concrete target on the main lake, erect permanent theodolite stations, and drill additional wells. In the ensuing years, the rocket-launching and gun-firing facilities in Area 9 were completed and expanded, and additional buildings were erected in Area 3 for administration, computers, etc.

In 1963, the Range was used for the Roller Coaster series of nuclear safety tests described in Chapter II. Many temporary roads were constructed in these areas and a trailer camp was set up near the intersection of the main north-south road and the Cactus Spring road. The camp is now gone, but the roadways are still quite evident, although seldom used. There are four fenced-in contaminated areas (several acres apiece) that are periodically monitored, as indicated in Chapter II.

In the early 1960's several interferometer antenna arrays were constructed. These consisted of many short concrete pillars covering a 100-foot (30-meter) square area and interconnected by underground cables. One site (Station 25) has an underground instrument bunker.

A 6600-foot (2000-meter) hard-surfaced aircraft runway was constructed about a mile west of Area 3. Continuing use of the Range is for the most part re-use of land already disturbed by these previous uses, but there are some incremental impacts: natural revegetation is slow, so that even only very occasional use of an old road or track will discourage or prevent its return to its natural state. Where some tracks cross natural drainage paths, they are subject to erosion greater than on the surrounding undisturbed land. New cross-country tracks are produced whenever a gun or rocket firing is carried out, in order to recover the major fragments of such shots for the information implicit in them. Conversely, whatever fragments are not recovered add to the miscellaneous junk and debris scattered over the land. Finally, new construction projects in previously unused areas mean new denudation, new access roads, and the like. (The most recent such construction in a previously unused area was the C4 rocket testing stand; as Chapter II states, no such work in new areas is now contemplated.)

Use of Energy and Resources

Except for roadway materials and underground water, all of the energy and resources needed for construction, maintenance, and operation are obtained off the range. There are two gravel pits, each less than an acre in size, for building roadways. Initially, all the electricity was generated where needed by portable or stationary diesel-electric units. In late 1970, the commercial power system (1500 KVA max) was completed and now about three-fourths of the electrical energy is provided by the Sierra Pacific Power Co. Approximately 200 kilowatt-hours are consumed monthly on the average. The consumption rate does not change much with the season because the heating load of winter just about equals the cooling load of summer. Projected use will remain about the same.

Most of the electrical generating equipment has been retained, since there are several power interruptions per month. There are about 25 portable units used in remote locations.

Although some electricity is used for space heating (small buildings and portable equipment trailers), most buildings are heated by burning liquified petroleum gas (propane), of which 90,000 to 100,000 gallons are consumed per year.

Most of the 80 vehicles on the Range are light-duty pickup trucks. They consume from 25,000 to 35,000 gallons of gasoline per year. The half-dozen diesel trucks and portable generators consume 40,000 to 50,000 gallons per year.

The underground water at the Range is soft, tasty, and plentiful for Range needs. There are wells in various places, two of which were never very productive and are capped. Two wells (in Areas 3 and 9) have chlorinators and are used for drinking purposes as well as sanitation. Stored in three tanks in Area 3 are 200,000 gallons of water to assure adequate pressure for fire protection. Two untreated wells provide water for dust control. The rate of consumption is estimated at 3.65 million gallons/year (none of the wells are metered). Other than drinking and sanitation water for 80 to 100 persons and an occasional fire drill, the only other use is 500- to 600-tank truck loads (5000 gallons each) each year for dust control and concrete mixing. There is no indication that the water table has dropped or that any well has been reduced in pumping capacity.

Impacts Expected from Normal Operations

Target Areas for Rockets and Cannon Shells

A variety of rockets, rocket assemblies, and cannon shells have been and will continue to be launched from an area on the Range known as Area 9. Prior to any launch, a thorough and careful analysis is made to determine potential impact areas assuming individual and collective failures of subsystems. These areas are combined into one area which is known as the impact footprint. From this study and its results, a determination is made regarding direction of firing, allowable weather conditions, etc.

Rockets are usually launched in a southeasterly direction, to impact in isolated areas "swept" for intruders before each launch. Recovery of the residual pieces of each rocket is made to assess test results.

Guns are normally fired in a near vertical condition so that shells and shell components may be recovered through the use of parachutes. A network of equipment, including geophone nets and radars, provides a means of determining actual impact points so that shells may be recovered.

The scars left by impacting rocket motors are superficial, but have been as much as 40 feet in length (Figure 23). Since most shells impact nearly vertically, their resulting scars are no more than a foot in diameter. Most of these shells are recovered by excavation which, after back filling, leaves scars as large as 5 feet in diameter.

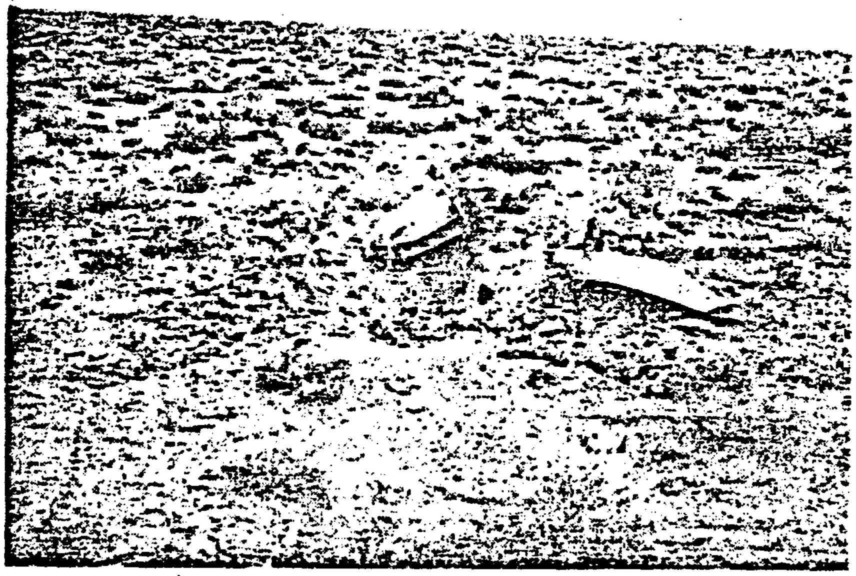

Figure 23. An impact scar at the Tonopah Test Range

Residual Debris

The normal operation of a range such as the TTR produces over the years a widespread accumulation of what can only be called junk. Included are probably also small quantities of live or inert explosives left from Army Air Corps use during World War II, and from rocket and shell firings from airplanes and from Area 9 guns. Up to three years ago, rocket motors were not recovered, but were left lying where they impacted; but since that time all motors fired have been recovered immediately after the test they were used on, and there has been a concerted campaign to find and pick up old rocket motors. Shells from Area 9 guns bury themselves where they impact, if they are not parachute retarded, and are recovered now, but large numbers remain from previous years that are considered impractical to recover. Indeed, so far as shells are concerned, the process of digging them out produces a larger hole than if they were not disturbed.

One must also cite under this heading miscellaneous debris such as paper and film packs and wrappers, which are often thrown away in a careless manner to blow with the winds. Standard instructions forbid this, but they are not always obeyed.

Altogether, however, the Range is so large and so generally empty that the presence of miscellaneous junk, though real, is not particularly evident as one drives about the Range roads.

Spread of Beryllium and Depleted Uranium

Uranium is a naturally occurring element which in nature is composed of 99.3% ^{238}U (half-life 4.5 x 10^9 years), 0.7% ^{235}U (half-life 7.1 x 10^8 years), and 0.006% ^{234}U (half-life 2.5 x 10^5 years). Each of these alpha-emitting isotopes begins a series of decay products that ends in a stable isotope of lead. Biological concentration of uranium along food chains does not seem to occur (BEIR, 1972, pp 29, 33). The chief effects noted with animals and plants are attributed to the chemical toxicity of uranium rather than its radioactivity. The chemical toxicity of uranium in humans relates to effects on kidney function. At lower levels, these changes are reversible in that they disappear when exposure stops.

In dispersal of large pieces, plant toxicity may occur at soil concentrations near 50 ppm (50 μg U/g soil) near the roots and acute toxicity may occur at levels ten times this. When airborne, the Threshold Limit Value (TLV) for occupational exposure to uranium is 200 $\mu g/m^3$ (ACGIH, 1974).

Beryllium is a nonradioactive element presenting two potential hazards to health. If inhaled over an extended time, beryllium may lessen the efficiency of an individual's lungs and in severe cases be fatal. If beryllium enters a break in the skin, a slowly healing ulcer may form until the beryllium is surgically removed. Beryllium enters the body almost entirely by inhalation. The experimental evidence is that little beryllium is absorbed through the intestinal wall. Animals fed the metal or the oxide at a level of 5% of the diet absorbed the beryllium so poorly that no effect on growth occurred over long periods of feeding. (Tabershaw, 1972, pp 6, 22)

When airborne, the TLV for occupational exposure to beryllium is 2 $\mu g/m^3$.

In some of the tests carried on at the TTR, beryllium and depleted uranium may be spread about, especially in the NEDS tests described in Chapter II. In these tests, quantities of beryllium of the order of a kilogram and uranium of the order of 10 kilograms are used.

The NEDS tests are carried out under wind conditions where the resulting cloud will not pass over the persons carrying out or observing the tests, or over people working elsewhere on the Range, which is to say with a wind from the north. The earliest tests were carried out unconfined, studying what forces containment casks would have to withstand. In these, the uranium was scattered in large pieces, which could be recovered; but most of the beryllium was dispersed as a particulate too small to recover. In present tests containment casks are used, but some fail. In these, about 80 percent of the uranium and 75 percent of the beryllium are in large enough pieces to recover.

Soil samples collected after a total of 18 NEDS tests indicate that beryllium levels in the soil at the point of detonation and up to 100 feet downwind are less than the limit of detection (5 mg Be/g soil), presumably because of the very small size of particles formed.

Air samplers downwind of the earlier, uncontained explosions, drawing in 50 liters/min, picked up of the order of 8 μg of beryllium as a result of cloud passage. Inasmuch as Standard Man breathes 17 liters/min, a man in the same position as one of these air samplers would have breathed in 2.7 μg of beryllium. For beryllium there is no stated maximum permissible body burden, but the TLV permits those occupationally exposed to breathe 16 μg of beryllium a day.

Experience indicates, therefore, that neither the uranium nor the beryllium released by the NEDS test is a residual hazard in the soil nor more than a transient hazard for short distances in the air. Nevertheless, whatever uranium or beryllium remains on the surface in pieces large enough to pick up is picked up, and the scene of a just-fired test is approached with caution.

Noise from Aircraft

All the aircraft that land and take off at the TTR airstrip are of the nonhigh-performance type and create little noise. There are from 100 to 150 operations a year involving high-performance aircraft such as the F-111, F-104, A7, and B-52. About half of the time there will be a second chase plane as well.

About 20 percent of the time, the aircraft become supersonic on the Range, generally at less than 1000 feet (300 m) above the terrain. Only two or three times a year do they become supersonic before reaching the Range and then at more than 20,000 feet (6000 m) above the terrain.

Less than 20 percent of the aircraft approach the Range from the unrestricted airspace to the north, and virtually all of these are subsonic. Many of these approaches are over Beatty, Nevada (population 300), at cruise altitude; the aircraft then turn in over Lida Junction (population 4 by day and 20 at night), then to Mud Lake, and in to the Range. If it were an F-14 at approach power as low as 15,000 feet (4500 m) above Lida Junction, the people there might experience as much as 75-decibel effective perceived noise level (EPN db). This would be clearly noticeable.

On the Range there is not only the noise of the jet engine, but occasionally the boom of supersonic flight. Before authorizing each supersonic flight, meteorological data are analyzed to make sure there is no temperature inversion to adversely focus the sonic blast. On one occasion an aircraft inadvertently exceeded Mach 1 while flying over Area 3; several windows were broken, and one person was slightly injured. This practice was then prohibited and has not been repeated.

Many times the Range operators are as close as 3000 ft (900 m) from the flight path and experience a significant amount of jet noise and sonic boom pressure. The engine noise is probably 100 to 115 EPN db, which is quite loud, but is within the established threshold limit values (TLV's) for short exposures (ACGIH, 1974). The sonic boom pressures are less than 0.2 psi (1700 Pascal). These levels being less than the TLV's, they do not require the use of earplugs, but the operators do use them as a matter of good operating practice.

Explosion Shocks, Missiles, and Dust

Normal operation of the Tonopah Test Range involves detonation of as much as 20 pounds of chemical explosives and use of as much as 50 pounds of propellants in gun firings. Operating personnel and other observers not in bunkers are kept at a distance of at least a mile from such firings.

OSHA standards limit exposure of people in the open to 1/4 psi from single, unrepeated shocks such as these explosions or firings constitute. For a surface detonation of 50 pounds of explosives, 1/4 psi will be at about 450 feet. According to the usual formula 600 $W^{1/3}$*, soil will be thrown as far as 2200 feet, and experience indicates that some case fragments will fly as far as 4000 feet. Thus shock and debris ranges are well within the bounds of the TTR and are also safely less than the distances to observers.

Surface explosions also raise dust clouds whenever the soil is at all dry, i.e., most of the time. Experience indicates that these dust clouds dissipate to invisibility within a mile or so of travel downwind, and are much smaller and less dense than dust storms that occur many times during the spring and summer during periods of high winds.

Transportation of Heavy Equipment

Because of the variety of activities at the Range, it is often necessary to move radars or telescopes and guns, weighing up to 40 tons, to new or even off-Range locations. This may require that new roadways or pad sites be built. These are generally minimal in quality and often abandoned after the first use. The roadways are about 20 feet wide and the pad sites much less than an acre in area. The land in these areas is cleared, and drainage or erosion control steps are taken when needed, though the need is rare.

Effects of Electromagnetic Radiation

The operation of the Tonopah Test Range entails the continued use of a number of electromagnetic radiators. The spectrum of operating frequencies and the wide range of radiated power levels requires that an examination be made of the impact these radiations can have on the surrounding environment.

Numerous studies have been undertaken to establish living tissue tolerance levels to electromagnetic radiation. This type of radiation is propagated energy, which, if intercepted and absorbed, ultimately results in generation of heat and elevated temperatures in the absorbers. The production of heat in living tissue due to microwave absorption is well established and documented. This mechanism appears to be the dominant effect in the interaction of microwaves with living tissue and is known as the thermal threat (Michaelson, 1972).

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*Safe separation distance in feet = 600 x (cube root of charge size in pounds).

With respect to thermal effects, the bloodstream is important in distributing and dissipating heat, and it can be expected that the regions of the body with poorly developed vascular sys- ; (in particular, lenses of the eye) would be especially liable to thermal damage. For example, sure levels of 100 mW/cm^2 for one hour to microwave radiation causes thermal coagulation ns protein and cataract formation in rabbits.

Considerations of these effects have formed the basis of tolerance limits and standards in J. S. The first protection guide used in this country was established by the Navy in 1953, and set at 10 mW/cm^2, with no time limit set. Subsequent guides have relaxed this guide, allow- ıigher irradiation levels for short periods (6 to 10 minutes).

The national criteria for the safe level of exposure (ACGIH, 1974) are as follows:

1. 10 mW/cm^2, average power, continuous for an 8-hour day.
2. 10-25 mW/cm^2 for any 10-minute period in 60 minutes.
3. Greater than 25 mW/cm^2, no exposure.

A tolerance limit for flora is not possible to set because little is known about plants' absorp- y and tolerance to heat. It is reasonable to assume as with animals that the tolerance is re- l to the maximum whole volume temperature, and hence is a function of temperature rise above ımbient. Their tolerances on a hot day may therefore be much less than on a cold day. Further- e, tolerances probably vary from species to species. We can note, however, that the desert ːs of the TTR are adapted to the sun's maximum irradiance of about 100 mW/cm^2, in a spectral on that is more highly absorbed than microwaves. Thus even in the absence of a formal stand- the 10 mW/cm^2 limit accepted for people should protect plants as well.

Operating procedures on the Range protect the people there by keeping them out of areas where r and other radiators create irradiation levels above 10 mW/cm^2. It is, of course, impossible xclude wild animals from these areas, and it is possible that some individual animals are dam- by electromagnetic radiation. It is believed their numbers are small and that the populations ived are at no hazard because the exposures are short and there is a large safety factor in the ıW/cm^2 figure. Some of the species of rodents and other small animals are nocturnal and are exposed.

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Most dust and particulate matter that enters the human (or other mammalian) lung is readily expelled. Moist passages catch dust, and the cilia on the surfaces of these passages remove particles settling on them within minutes. Only the smallest of particles—for plutonium oxide, those of diameters less than 3μm—penetrate deep into the lung and remain there. These latter are slowly eliminated by uptake into the blood and lymphatic system, with an effective biological half-life of 500 days (TGLD, 1966). It therefore follows that when dust containing plutonium is stirred up, only the small-particle fraction of it is important in carrying plutonium into the body.

Present Studies at the Sites

As indicated in Chapter II, the Roller Coaster and other plutonium-contaminated areas on and near the Nevada Test Site (NTS) have become the subject of extensive research on the dynamics of plutonium in the desert environment. The first priority study has been the delineation of the areas of present contamination. From this work come Figures 24 through 26, indicating contours of plutonium contamination at the three Clean Slate sites as indicated by FIDLER surveys made in 1974 (Gilbert et al., 1975). The FIDLER is an instrument designed to make radiation surveys of areas contaminated with trans-uranium nuclides. It is selective in measuring low energy gamma rays emitted during radioactive decay.

The fences indicated in Figures 24 through 26 are the outer fences referred to in Chapter II, the ones built in 1970 to include the 100-$\mu g/m^2$ contamination contours (≈ 0.3 nCi/g if all in the top centimeter of soil). A proposed interim standard for plutonium soil contamination is 0.4 nCi/g (Healy, 1974).

Another priority study is determining the extent to which the plutonium from the Roller Coaster and other sites is migrating away from its original location, either by resuspension or by entering into natural biological systems. Three aspects of these studies are related to spread by physical means: changes in surface distribution patterns, quantities of plutonium found by air samplers, and direct studies of the resuspension process. As to the first, the logical procedure would be to compare recent distribution patterns (Figures 24 through 26) with those determined in 1963 as part of the Roller Coaster experiments. These comparisons are as yet inconclusive; patterns are grossly similar, but since 1963 there has been migration of plutonium downwards into the soil so that the original methods of surface detection are no longer applicable, and the necessary analysis of soil samples is not complete. In any event, this method is insensitive to movements of small quantities of plutonium from the source.

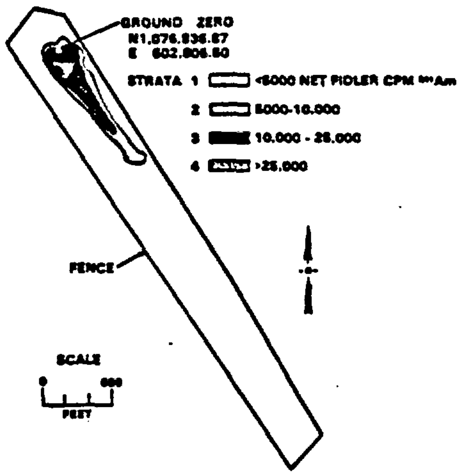

Figure 24. Strata used in sampling for inventory - TTR - Clean Slate I Site

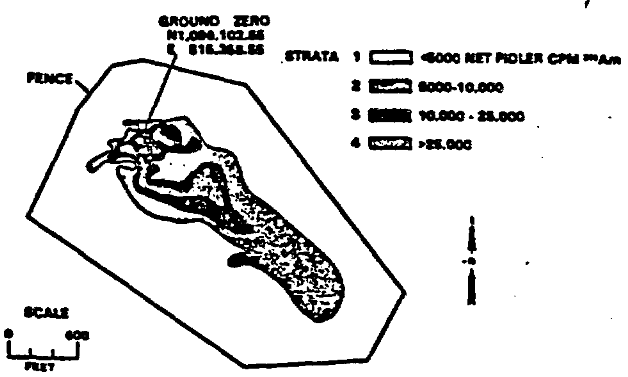

Figure 25. Strata used in sampling for inventory - TTR - Clean Slate II Site

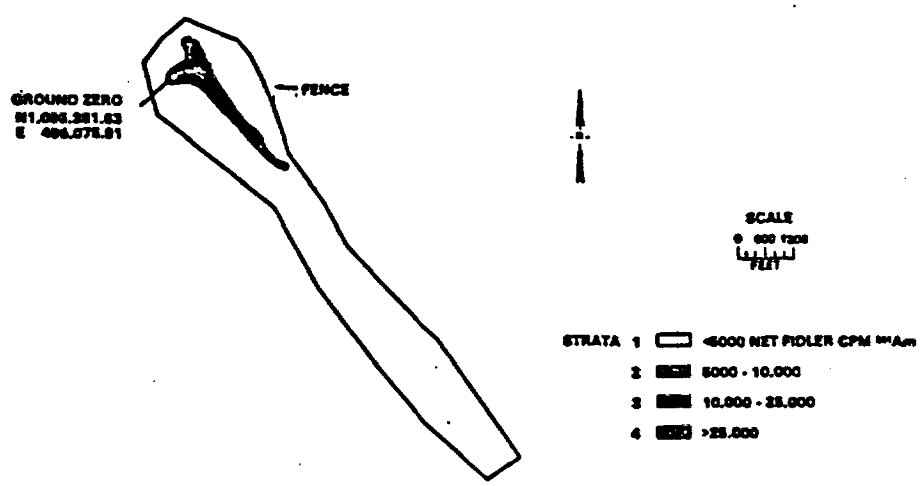

Figure 26. Strata used in sampling for inventory - TTR - Clean Slate III Site
The above three figures are from Gilbert et al., 1975.

Current air-sampling data gathered at offsite points around the NTS and the TTR indicate annual average concentrations less than one percent of the Radiation Protection Standard for airborne plutonium. The studies of resuspension have been carried on at plutonium-contaminated areas other than the Roller Coaster sites, in particular at the so-called GMX site on the NTS, a site contaminated in the period from 1954 to 1956. Air samplers at the corners of the GMX site yield an average resuspended air concentration of about 300 aCi/m^3 (= 0.0003 pCi/m^3). (Phelps and Anspaugh, 1974). By way of comparison the Radiation Protection Guide for insoluble plutonium for the general public exposed 168 hours a week is 0.1 pCi/m^3. Thus, right on the border of the GMX site, the average air concentration is 0.3 percent of the standard. These results imply that the hazard to on-site mammals at the TTR is very small.

Numerous studies of the resuspension process carried on in freshly contaminated fields have indicated an initial rapid decrease in resuspended material, with an effective half-time of 35 to 70 days. This decrease cannot be explained by the relatively minor loss of material from its initial site of deposition, but is presumably caused by the migration of material into the soil. Over a long time period, the rate of decrease diminishes, so that resuspension factors measured today at the GMX site are much greater than a simple extrapolation of the early decrease would indicate (being of the order of 10^{-9} m^{-1}). The present low resuspension factors are reflected in the low air concentrations described in the previous paragraph (Anspaugh, 1974).

All these results lead Dunaway and White to conclude (1974, p. 368) that "large quantities of plutonium and americium are not being moved rapidly from the study sites by wind."

On the other hand, soil fungi studied in vitro were quite efficient in absorbing plutonium from the agar in which they were grown, the discrimination factor being only a factor of 4. For comparison, the discrimination factor of plutonium oxide transferred from soils to plants is of the order of 10^4 to 10^6. The uptake by fungi was in an experiment where the agar pH was adjusted to 2.5 (very acid) to keep the plutonium ionic and therefore soluble. (Desert soil tends towards alkalinity rather than acidity.) This suggests that the discrimination against plutonium uptake by plants depends greatly on the chemical and physical properties of the soil (Au, 1974, p. 137).

Direct measurement of plutonium in kangaroo rats taken from contaminated areas showed a discrimination of 10^3 between plutonium concentrations in the GI tract (indicative of concentrations of what they eat) and in the carcass (indicative of the amount retained) (Dunaway and White, 1974, p. 364; Moor and Bradley, 1974).

Preliminary modeling studies of uptake in man based on the results of various experimenters, assuming that the man gains his whole sustenance from such contaminated areas, indicates that inhalation accounts for all the radiation dose to the lungs and pulmonary lymph nodes and about

56 percent of the dose to the bone, kidney, liver, and whole body; while ingestion of soil, vegetation, milk, and beef (from the contaminated area) accounted for all the radiation dose to the GI tract, and 44 percent of the dose to the bone, kidney, liver, and whole body, indicating that perhaps the relative importance of inhalation has been overstressed, and that of ingestion understressed (Martin et al., 1974).

Two other findings of the studies are worth mentioning. Rhoads and Mullen (1974) note that fencing the Clean Slate sites from grazing has resulted in a much better condition of the grasses within the enclosures than outside. They also note more subtle differences. The co-dominant species of shrubs nearby are budsage and shadscale. Within the enclosures, shadscale is dominant almost to the exclusion of budsage. They are not convinced that grazing is the cause of this latter difference, since neither shrub is grazed outside the fences, and are inclined to think that the 1963 soil disturbances are the cause.

The cattle on the TTR are there without permission, a result of the open-range, unfenced nature of central Nevada. They are excluded from areas of appreciably over-background levels of plutonium contamination by the fences, but nevertheless do accumulate low levels of uranium and plutonium in their tissues. Smith (1974) reports that ^{239}Pu was about 20 times higher in femurs from cattle that have grazed on the TTR near the Roller Coaster areas than in cattle from an area 200 miles away to the south. This ratio was lower in edible tissues. "Using the maximum concentrations observed in beef tissue, the hypothetical maximum bone dose for a man ingesting 250 g/day for 50 years was calculated to be 9.7 mrem from beef muscle or 36.4 mrem for beef liver." This is an insignificant fraction of the 8500 mrem background dose accumulated from natural sources by residents at 5000-foot elevation in that time.

Thus far, the conclusion about the handling of the Roller Coaster and other plutonium-contamination areas is, leave them alone but keep track of them. If there is a problem with these areas, it is one involving slow processes, and waiting a few years or a decade will produce little or no change in the problem.

Credible Accidents

TTR operations are conducted in a manner which will normally prevent impact or scattering of test-object debris outside the TTR onto the Nellis Bombing and Gunnery Range or onto public lands. Abnormal operations that might occur are discussed below.

Errant Rocket Flight

Most of the rockets are of the ballistic type and are ground launched. They are carefully aimed to impact in a specified area of the Range. If the fin or thrust alignments of a rocket were accidentally changed at launch, there is a small chance (0.011) that it would impact off the Range. There is at least a 20-mile (32-km) buffer zone (the Nellis Range) beyond the TTR which reduces the probability of impact on public lands even further to 0.0001.

Occasionally, an internally guided rocket is air-launched. The plane's altitude and guidance system is carefully monitored, but if after launch the rocket's guidance system should fail and a purely random course be taken, the impact point could be anywhere within a 100- or 200-mile radius.

At its impact point, the damage area is less than an acre and consists of an impact crater and metal and soil debris.

Inadvertent or Premature Release of a Drop Device from an Aircraft

In almost all cases, the authorization to unlock an aircraft's release rack is given after the plane has entered the TTR or is over the Nellis Range and near enough to be sure that an inadvertent release at that time would result in impact on the TTR. There have been (and probably will continue to be) a few high-altitude parachute drops that require release outside the TTR because of wind conditions. In these cases the release racks are unlocked only a few miles ahead of the intended release point and, if prematurely released, the parachute would still carry it to the TTR. If the parachute were to fail, the device would impact off the Range. Again, at its impact point, the damage area would be less than an acre, and would consist of an impact crater and metal and soil debris.

Structural Failure of Test Devices Containing Depleted Uranium, Plutonium, or Beryllium

Less than a dozen devices of this type have been tested, and their number is expected to be similarly few in the future. These are gun projectiles fired nearly vertically under wind conditions that will carry any aerosol particles away from the gun area. The accident here postulated consists of structural failure of a projectile intended to stay together. There are two points in its trajectory where the stress on a projectile is greatest: in the barrel during its initial firing, and near the top of its trajectory at the time of parachute deployment. The former is the more serious.

If the postulated failure were to occur in the gun barrel, the source of potential contamination would be myriad particles of small size spewing out of the barrel, falling back to the ground from low altitude (since the propellant gases would vent past them to the atmosphere rather than stay confined behind the emerging projectile). A device fired in a test of this type may contain depleted uranium and beryllium and either plutonium or high explosive, but not both of the last two on the same test unit. The possible quantities of depleted uranium and beryllium are no greater than discussed above in the context of the NEDS experiments; the problem with these materials is therefore no greater than discussed there.

Any high explosive in a projectile that fails in the gun barrel will add to the force of the accident, either by burning, in which case its energy may double the forces ejecting other materials involved, or by exploding, in which case the gun barrel itself may rupture. A ruptured gun barrel, although costly to replace, would not appreciably change the hazard from other materials being released.

Any plutonium in a projectile that fails in the gun barrel will burn and be distributed downwind as plutonium oxide, probably (because of its chemical properties) plated on particles of other materials. The maximum amount of plutonium present in such a test is in the order of a few kilograms. The results of the 1959 Vixen trials (in which plutonium was burned in a gasoline-fired chimney) indicate that very little of the plutonium would be released downwind as respirable particles. In these tests, 200-gram rods of plutonium were suspended in a 4-foot square chimney, 11 feet high. One such rod was heated by a gasoline fire to 805°C for 30 minutes, and another heated slowly to 600°C in an hour. The releases of plutonium oxide were measured by weight loss, integration of ground deposition contours, and integration of downwind concentrations (Jordan, 1963).

In reporting the results of the trials, Stewart concluded that (1961, p. 27-28):

- "The larger value of 0.05 percent is clearly a satisfactory safe value to use in estimation of the airborne hazard downwind from a fire involving plutonium.
- "Therefore, no significant inhalation hazard would be produced at 200 yards and beyond downwind as the result of burning several kilograms of metal."

Thus the hazard of inhalation from such an accident is negligible at the TTR, since there would be no people immediately downwind of such an accident in any case, and the proportion of the population of any rodent or other small animal would be very small indeed. The principal hazard would be with the residual ground contamination, which from the same Vixen trials is estimated to be perhaps 2-1/2 acres of land contaminated above the recently suggested limit of 8 $\mu Ci/m^2$ (Healy, 1974). The land so contaminated would have to be either isolated from future use or decontaminated by removal of the surface soil and vegetation.

Rocket Motor Explosion

Most of the rocket motors used are of the Nike or Talos type, which are in the 2,000- to 4,000-pound weight class. The TTR is also capable of static testing (at the C4 site) first-stage motors of the Poseidon or Trident type, which contain up to 40,000 pounds of propellant. If a rocket motor of the latter size were to burst or explode, the effects would be similar to those of an explosion of 10 tons of TNT. Damage would be extensive to the facilities in the test-stand area. There would be a crater; in unprotected alluvium it would be 35 feet in radius. An overpressure of 5 psi would extend to 400 feet; this level may break a man's eardrums, while rodents and other small mammals are presumably more resistant because of their smaller size. Dirt and other debris might be thrown as far as a mile, distributing a layer of soil 0.2 inch thick or more to a distance of 150 feet; within this distance some smothering of the native vegetation might be expected.

Accidental Detachment of a Rocket Motor

The worst case of this would be a Trident-type first stage breaking loose from its stand during static test. Because of its nonaerodynamic shape, such a motor could not launch itself. Its few hundred thousand pounds of thrust would last about a minute, and during this time it would skitter about on the ground in random direction. It might end up as far as a mile from the test stand. In thus skittering about, a long scar would be created, consisting of torn ground and disrupted vegetation. Perhaps some of the vegetation would catch fire, but such a fire would not spread because of the thinness of the vegetation cover.

Airplane Crash

Each year there are from 100 to 150 operations at TTR involving aircraft. About half of these have two planes, and a few three or more. In addition, the 44-passenger F-27 brings the Las Vegas crew to the Range four days a week. Several times a month other aircraft bring passengers or material in. Several times a month military helicopters will refuel in transit. A few times a year some unannounced military plane will cross the Range.

There have been minor accidents. A T-39 executive jet landed but was unable to stop before running off the end of the runway and into the brush, damaging the landing carriage. An L-19 observation plane had fuel problems and landed on the desert with minor damage to a wheel.

Although these happened on the Range, it is also quite possible for an aircraft to fail on the approach to the Range and to crash beyond the buffer zone. Possibly the worst crash for damage to the environment would be for a high-performance supersonic aircraft such as an F-111 or a subsonic bomber such as a B-52 to crash while on a low-level mission. The damaged area, although narrow would extend for several thousands of feet, and would consist of a long scar of ripped ground and torn vegetation, with metal and other debris scattered about. It is quite probable that in such an event the fuel carried by the aircraft would catch fire: in most areas near the TTR, such a fire would not spread because of the thinness of ground cover, but if such a crash took place in one of the few areas with Pinon-Juniper Woodland, such as the Kawich Range or Stonewall Mountain, a forest fire could ensue. How far such a fire would spread would depend on weather, wind, and terrain conditions. Judging from the sparse cover characteristic of pinon-juniper woodland, it is estimated that such a fire would be no larger than 100 acres. No fires have occurred within 150 miles of the TTR in recent years. The nearest forest-fire fighting capability is maintained by the U.S. Forest Service for the Toiyabe National Forest to the north.

The worst personnel tragedy, of course, would be for the F-27 to crash with its crew of 3 and its passengers, who could number as many as 44.

Premature or Accidental Detonation of Explosives

There are from 100 to 500 pounds of high explosives (HE) and 10,000 to 50,000 pounds of propellants used each year. These are stored in bunkers, each of which has a storage limit of up to 50,000 pounds. It is conceivable that these stored materials could accidentally catch on fire and detonate, most probably while being loaded into or being taken out of the bunkers. The arrangement of the bunkers is such that a detonation in one will not propagate to the next. If a bunker were filled to capacity with HE and the explosive went high order instead of burning, it would destroy that facility alone. The tamping effect of the bunker would make its overpressure and missile effects like that of the rocket motor explosion postulated above.

An accident could also happen while explosive material is being assembled into a test unit or being transported to a test site (such as the NEDS site) or while being instrumented. Aside from damage to people, the damage would be much less than for an explosion in a bunker.

IV. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

Environmental effects described in Chapter III that are unavoidable consequences of the existence and continued use of the Tonopah Test Range are:

Land use
Use of resources and energy
Impacts of normal operation
Exposure to the risk of accidents

Land Use

Since the 624 square miles of the Tonopah Test Range are used by permit from the Air Force, presumably if the Range were closed the land would revert to the Air Force for whatever use they would put it to, probably as a part of the Nellis AFB Bombing and Gunnery Range. This land is therefore precluded from other potential uses in any case. The bulk of the land remains approximately in its natural state, the only all-pervasive effect being the nonpermit grazing now taking place. The Range buildings and facilities take up a small, widely scattered fraction of the land area. Continued use of the land implies hindrance of natural revegetation on test areas and roads among them, the accumulation of new tracks, and a gradual increase in the miscellaneous (but not ordnance) debris to be found on it.

Use of Resources and Energy

Electric power is consumed at the Range at the rate of about 2.4 GWhr/year. Since this power is generated by burning fossil fuels, it represents the consumption of an irreplaceable resource. Fossil fuels are used directly as liquified petroleum gas and motor fuel at the rate of about 175,000 gal/year (4000 barrels/year). Something like 3.65 million gallons (11 acre-feet, 14,000 m^3) of water is used per year, pumped from the underground aquifer underlying the Range, but this is much less than the 600 acre-feet per year of natural recharge. These consumption rates are expected to remain about the same in the near future.

Impacts of Normal Operation

Probably the most serious impact on the Range environment aside from land use itself is the disruption caused by and the debris left from rocket and shell impacts. Individually these are small in area, but there have been several thousand of these through the years. As yet, however, their cumulative impact is not very evident to the casual eye. Air drops also mean noise, especially if the aircraft is flying supersonically; this noise (or these sonic booms) are confined to unpopulated areas and thus do not affect humans; what effect they have on the natural biota is not known. Explosions and rocket exhausts carry with them varying amounts of blast waves or noise, dust, and missiles. These effects are entirely contained within the boundaries of the Range, and even within them are quite localized. Finally, certain of the tests, particularly the NEDS tests, scatter beryllium and depleted uranium.

Exposure to the Risk of Accidents

The most serious accident possible at the Tonopah Test Range is an aircraft crash, either of a drop aircraft on a low-level approach or of the commuter plane. Aside from the deaths of some or all of the people on such planes, which would be a tragedy by itself, there would be a very large scar on the landscape, very likely compounded by fire in the plane's fuel. A range fire is extremely unlikely if the crash were to take place in the valley, because of the thinness of cover, but if the crash were to take place in a forested mountain region (of which there are two nearby), there might be some spread of such a fire.

One might also postulate a rocket flight going astray or a premature or errant drop of a device from an aircraft. An errant rocket flight is more important, since (with a low probability) it could impact anywhere within a 100- or 200-mile radius. A premature drop, considering the flight paths that are used, would almost surely mean an impact at least within the larger TTR-Nellis-NTS area. In any of these cases, the net impact, wherever it might be, would be local and would consist of a small area of scarred land, torn vegetation, and scattered debris.

The possibility of the use of the C4 rocket testing stand being put to use as designed means that there is some possibility, however remote, that a rocket motor being tested there would break loose. In skittering about, the motor could reach any point within a mile of the stand, but the stand is many miles from the boundaries of the Range, so the resultant land scarring would be entirely confined to the Range.

V. ALTERNATIVES

Alternatives to be considered with regard to any on-going operation are complete discontinuation of the work, complete or partial transfer of functions elsewhere, reducing the pace of the effort, and changing operational methods.

Consideration of alternative action presupposes already existing adverse impacts; and, indeed, it would be unusual if a critical review of any industrial operation did not uncover some problem areas.

Complete Discontinuation of the Work

To completely shut down the operations of the Tonopah Test Range and not do the work anywhere would seriously detract from the quality of the work being done in the development and maintenance of items for the nation's stockpile of nuclear weapons and thus would detract from the nation's posture of national defense. As long as the nation has decided through its Congress to maintain strong nuclear development laboratories, the resulting product must be tested in some remote area. However, if the work were to be completely discontinued, the accumulation of impacts listed in Chapter IV would cease.

Transfer of Functions Elsewhere

The more hazardous of the operations of the Sandia Laboratories and related ERDA laboratories are carried out at the Tonopah Test Range. To consider moving all or a part of the operations elsewhere, one must find another area comparably remote and safe to operate in. Two such areas have been considered in the past: the Nevada Test Site and the White Sands Missile Range in New Mexico.

From one point of view, there would be no net environmental gain in moving TTR operations to the Nevada Test Site, for that is an area that is biologically much like the Tonopah Test Range, and the impacts of the operations would be much the same. What might perhaps be gained would be to concentrate the insult to the environment in one place, leaving the other to accumulate no further damage other than what its subsequent use would entail.

If any great proportion of the TTR work were to be moved to the Nevada Test Site, the move would probably have to be carried out in a portion of the NTS not presently being used, so that the net result in the latter case would be environmental impacts on parts of Nevada not now being affected.

If, on the other hand, the level of work were to decrease at the NTS and the TTR, it might be possible to carry on the remaining work of both ranges in the same general areas of the NTS.

It must be recognized that the test facilities that have been built up at the TTR do not exist at the NTS, so that their relocation would entail an undetermined but not small economic cost.

The White Sands Missile Range (WSMR) in southern New Mexico though smaller than the TTR-Nellis-NTS area and hence less isolated and less safe to operate in as far as projects requiring buffer zones are concerned, has much of the range equipment installed and operational that is deployed by the TTR. Work done there would be closer to Albuquerque, and would be more convenient to Albuquerque-based engineering staff, but would be less convenient to Livermore-based engineering staff. Another problem with moving all or part of the TTR operations to the WSMR is that the WSMR is a very busy range, and the scheduling problems would be large, unless a presently unused portion of the WSMR were dedicated to the transferred work. If operations were to be moved to WSMR, the environmental effects would be similar to those at TTR, for WSMR is also a desert area.

Reducing the Pace of the Effort

In principle the pace of the effort at the TTR could be reduced either by decreasing the number of tests required in each engineering development or by decreasing the number of engineering developments. Economic considerations already cause a close scrutiny of tests carried out by the TTR in support of any particular engineering effort and coincide with the interest in minimizing environmental impact in wanting to keep those tests to a minimum.

Beyond that, however, the pace of testing at the TTR is slowing down. By way of concrete example, the size of the Sandia and support staff assigned to the TTR has decreased from 100 to the present 76 since 1969, and the number of tests carried out is decreasing year by year (Figure 27).

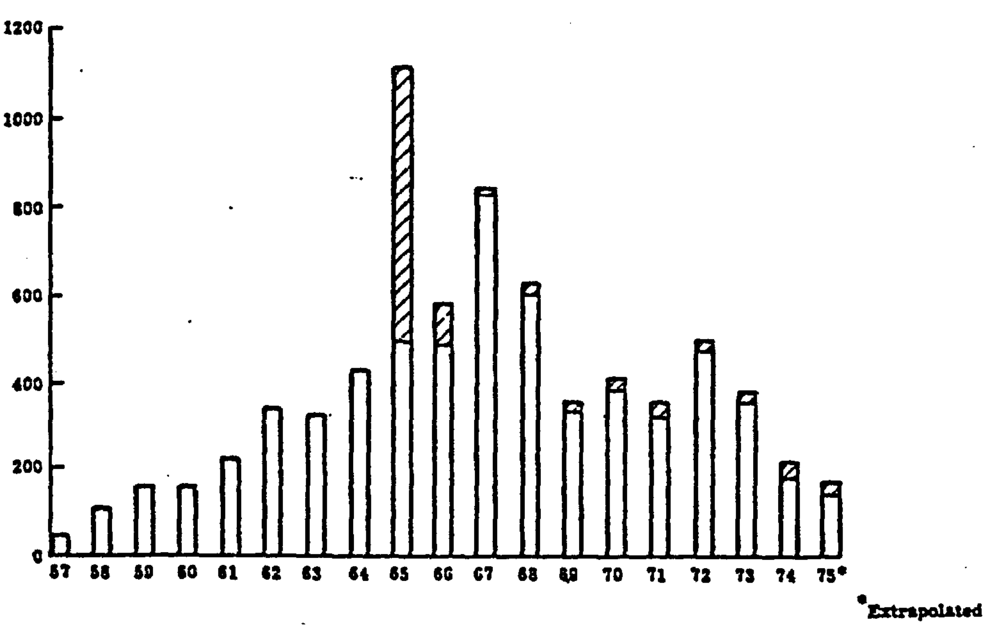

Figure 27. Total tests per year at the Tonopah Test Range (fly-arounds are cross-hatched)

Changing Operational Methods

In general terms there is little choice in the way operations at the TTR are carried out. Air drops, for instance, must be guided in by radar-informed traffic controllers, and the configurations dropped by the aircraft must be closely followed by radar and by tracking cameras. Moreover, the flight paths to be used are dictated by geography, and the positions of radars and tracking cameras are dictated by the geometry of the situation once a particular target on the playas is chosen.

The most obvious change in operational methods suggested by the discussion of the foregoing material is greater care in recovering debris from air drops, gun and rocket shots, and high-explosive detonations. Up to a few years ago there was no concerted effort to recover debris from the shots then going on or from previous activities of the Army Air Corps during World War II, except where classified shapes and technological answers were involved. Today, all rocket motors and other kinds of scrap are recovered, and old debris is picked up as people come across it.

Generally speaking, the tracking systems used are accurate enough to guide pickup crews right to the large pieces of debris, and from the nearest road. Even when a rocket or shell breaks up, the resulting pieces, being high-drag pieces, fall together in the same general area. Occasionally, perhaps once a year, a detailed search must be made for a classified shape or a fragment with potentially valuable information inherent in it. Then there is an environmental price to be paid in searching for it. A general technique used when only the general location of a fragment is known is to drive cross-country with a number of trucks thirty or forty feet apart. Such a search necessarily means new, aesthetically unpleasing tracks across the desert and broken shrubs along the way.

Another possible change has to do with the present practice of recovering dummy rounds fired from the Area 9 guns. These make a small hole going into the ground; digging them out with a back-hoe leaves a much bigger hole, and these holes are not always filled back in. Two alternatives suggest themselves, using a tractor-mounted auger to get these dummy shells back, or not recovering them at all. Either practice would reduce the scar left by the recovery operation. (Classified or explosives-containing shells must be recovered in any case; the only debatable question is how.)

Finally, as indicated above, the pace of testing at the TTR is slowing down. Further decrease in the work to be done at the TTR may require changes in operational methods, such as the technical crew operating out of Albuquerque (or Livermore) and coming to the TTR periodically as the backlog of tests to be done at the Range accumulates. Such a change would not change the environmental impact of Range operations, because it would not per se change the number or nature of tests required.

VI. RELATIONSHIP BETWEEN SHORT-TERM USE AND LONG-TERM PRODUCTIVITY

Before World War II the land now being used for the Tonopah Test Range was used for grazing. During the war it was taken over by the Military as a bombing and gunnery range, but the land continues to be used for grazing on a nonpermit basis.

If it were thought desirable, the Range could be stripped of its buildings and facilities and allowed to revert to the wild. Revegetation, however, would be very slow without supplemental water. Denuded areas would remain scarred for many decades.

The fact that the Tonopah Test Range exists by use permit from the Air Force means that if the Range were to be closed down permanently, the land would revert to the Air Force for whatever use they might see fit. This use would most likely be as part of the existing Nellis AFB Bombing and Gunnery Range.

VII. RELATION OF PRESENT ACTION TO LAND USE PLANS, POLICIES AND CONTROLS

Neither Nye County nor the state of Nevada has an existing formal land use plan, although the State has within the last several years set up a Land Use Planning Committee, which presumably will soon come out with such a plan. Therefore, the continued operation of the Tonopah Test Range is not in conflict with any known land use plans of State or local entities.

Operations have been continuous for 18 years as the Tonopah Test Range and for about as long before that as a military bombing and gunnery range; it is unlikely that any plan drawn up by the State in the future will do other than accept the existence of the Range as it is.

VIII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Few commitments of resources at the Tonopah Test Range are absolutely irreversible and irretrievable. Fuels for energy production, most construction materials, and other consumables used in the operation and maintenance of the Range are irretrievable. In a less tangible but equally real way, the human resources invested in the past in the Range and its programs are also irretrievable.

The use of fuels has been discussed in Chapters II and IV. Electrical power generated by the burning of fossil fuels is used at the Range at the rate of about 2.4 GWhr/year. Other fossil fuels are used directly on the Range at the rate of about 175,000 gallons per year.

The use of water at the Range is not considered irretrievable, inasmuch as all water used is recycled in nature by evaporation and transpiration, and this use of ground water is much less than the natural recharge.

The use of land is also not absolutely irretrievable, although in practice it would be extremely difficult to restore this land to its pristine condition, because of the slowness of revegetation naturally, the uneconomic nature of such an action, and the fact that the land would revert to the Air Force and not to the public domain. In the yet unused portions of the Range no irreversible or irretrievable changes are known to have occurred in the overall ecological patterns of the area as the result of the existence and operation of the Range.

IX. COST-BENEFIT ANALYSIS

A basic principle established in the National Environmental Policy Act of 1969 is that all costs and benefits of a proposed action are to be considered, even if some of them are only qualitative in nature and not measurable in economic terms. A cost-benefit analysis is therefore somewhat philosophical in nature.

The costs of the operation of the Tonopah Test Range are several in addition to its pure monetary cost.

The Range uses these resources: fossil fuels at the rate of about 175,000 gallons/year (660 m^3/year); electricity at the rate of about 2.4 GWhr/year; water at the rate of about 3.65 million gallons/year (11 acre-feet/year or 14,000 m^3/year); and materials and supplies used in construction and operation.

Use of the 624 square miles (1600 km^2) of the Range precludes its use for possible other purposes, particularly for grazing (although some non-permit grazing on the land does occur).

The normal operation of the Range entails a gradual accumulation of surface disruptions and scars from gun and rocket impacts and from the cross-country tracks made in recovering the resultant debris. Explosions and rocket firings also entail blast waves, noise, and dust. There are occasional sonic booms, their effects confined to the Range.

Finally, the existence and operation of the Range bring with them the risk of accidents, some common to all industrial operations, and some peculiar to the kind of work carried on there. These have been detailed in Chapter III, but two possible accidents bear repeating. The worst accident possible from Range operations in human and environmental terms would be an aircraft crash. This could be either of the daily commuter plane or of an aircraft performing a low-altitude drop mission. In either case the loss of life would be a human tragedy: there could be as many as 47 people involved. Also, the impact scar and possible fuel fire would be environmentally significant locally. The scar could be as large as five acres (2 ha) in size. A fuel fire could cover as large an area; such a fire would not spread if it occurred on the Range, but if the impact were in one of the small forested areas near the Range, it could become as large as 100 acres (40 ha). Second, there is a remote possibility of a rocket going astray and, in the extreme, impacting anywhere within 100 or 200 miles (160-320 km) of its launching point, which is to say possibly well outside the TTR-Nellis-NTS area. The odds of actually hitting something important are very low, but are non-zero, even admitting that the effects on impact would be very limited in area.

The principal benefit to the United States from the operation of the Sandia Laboratories is its contribution made to the national defense in the ordnance engineering of nuclear weapons. This work is carried on in response to long-stated national policy and must be carried out somewhere. Until that policy is changed the question is not whether, but where and how. The Tonopah Test Range's work is an essential part of that mission. There must be a place with sufficient isolation to permit carrying out there the more hazardous tests needed in testing the components and systems resulting from this ordnance engineering. Again, the question is not whether, but where and how.

As a side effect, the economy of the Tonopah-Nye County area benefits from the employment of about 50 persons and an annual payroll of about a million dollars injected into the local economy.

The various alternatives of Chapter V, when analyzed from a cost-benefit point of view, generally have high economic costs and little or no environmental benefit. For other reasons there is a continuing reduction in the pace of operations at the Range and this reduces the environmental impact of its operation. The consideration of alternatives did surface the matter of recovery of dummy shells, in which more environmental damage is often done than would be incurred in leaving them in place.

These costs and benefits lead to these conclusions: As long as the nation mandates an up-to-date nuclear weapons stockpile, some facility such as the Tonopah Test Range must exist to do the more hazardous testing associated with weapons development. Because the Tonopah Test Range already exists as a well equipped facility for carrying out these tests, and because it is well isolated from man and his works, from an environmental point of view the operation of the Tonopah Test Range should be permitted to continue. The environmental costs inherent in the work of the Range are small and reasonable for the benefits received.

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APPENDIX A

PERMIT AND OPERATING AGREEMENT WITH THE DEPARTMENT OF THE AIR FORCE

COPY COPY

DEPARTMENT OF THE AIR FORCE
PERMIT TO OTHER FEDERAL GOVERNMENT DEPARTMENT OR AGENCY
TO USE PROPERTY ON

NELLIS AIR FORCE RANGE, NEVADA NO. DACA09-4-70-43

THE ATOMIC ENERGY COMMISSION, hereinafter referred to as the Permittee, is hereby granted a permit for a term of ten (10) years,

beginning 1969 April 01 , 19 and ending 1979 March 31, 19 but revocable at will only at Secretary of the Air Force level or above to use and occupy for testing purposes that area referred to as the Tonopah Test Range, at the location

as shown substantially in red on Drawing No. 256-K-1, marked Exhibit B, attached hereto and made a part hereof, and described

An area approximately 24 by 26 miles starting from a point on the northern boundary of the Nellis Air Force Range at approximately 37° 53' N - 116° 26' W., thence 26 miles West to approximately 37° 53' N - 116° 55' W, thence South to approximately 37° 33' N - 116° 55' W, thence 26 miles East to approximately 37° 33' N - 116° 26' W, thence 24 miles North to point of beginning.

Containing 369,280 acres, more or less.

THIS PERMIT is granted subject to the following conditions:

1. That the use and occupation of the said premises shall be without cost or expense to the Department of the Air Force, under the general supervision and subject to the approval of the officer having immediate jurisdiction over the premises, and subject also to such rules and regulations as he may from time to time prescribe. Not Applicable

2. That the permittee shall, at its own expense and without cost or expense to the Department of the Air Force, maintain and keep in good repair and condition the premises herein authorized to be used.

3. That any interference with or damage to property under control of the Department of the Air Force incident to the exercise of the privileges herein granted shall be promptly corrected by the permittee to the satisfaction of the said officer. Not Applicable

4. That the permittee shall pay the cost, as determined by the Department of the Air Force, of producing and/or supplying any utilities and other services furnished by the Department of the Air Force or through Department of the Air Force facilities for the use of the permittee.

5. That no additions to or alternations of premises shall be made without the prior consent of the said officer. Not Applicable

6. That if for any reason it should be deemed necessary or expedient for the Department of the Air Force to perform functions and/or render services which are the responsibility of the permittee, the Department of the Air Force may, in lieu of reimbursement, require the permittee to furnish the personnel and/or materials required for the performance of said functions and/or for the rendering of said services. In addition to furnishing personnel and/or materials, the permittee shall reimburse the Department of the Air Force for any costs incurred by the Department of the Air Force in connection with said functions and/or services, such as for supervision and/or equipment furnished. Selection of such personnel will be subject to the approval of the Department of the Air Force.

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7. That on or before the date of expiration of this permit ot its relinquishment by the permittee, the permittee shall vacate the said premises, remove its property therefrom, and restore the premises to a condition satisfactory to the said officer, ordinary wear and tear and damage beyond the control of the permittee excepted. If, however, this permit is revoked, the permittee shall vacate the premises, remove its property therefrom, and restore the premises as aforesaid within such time as the Secretary of the Air Force may designate.

Not Applicable

13. That prior to execution of this permit, the following changes were made:

Revised:	Granting clause and Conditions Nos. 4 and 6.
Added:	Conditions Nos. 8 through 13. Conditions Nos. 8 through 12 are contained in Exhibit A, attached hereto and made a part hereof.
Deleted:	Conditions Nos. 1, 3, 5 and 7.

IN WITNESS WHEREOF I have hereunto set my hand by authority of the Secretary of the Air Force

this 30th day of July, 1969.

/S/ John Houston
JOHN HOUSTON
ACTING CHIEF, REAL ESTATE DIVISION
U. S. ARMY ENGINEER DISTRICT,
LOS ANGELES

8. That operating details for use and occupancy of the Tonopah Test Range shall be delineated in a separate "Operating Agreement" to be negotiated between Nellis Air Force Base and the permittee's Albuquerque Operations Office. The "Operating Agreement" shall reflect the following conditions:

a. That the permittee's use of the Tonopah Test Range shall take precedence over the use by the Department of the Air Force.

b. That the Department of the Air Force may use the Tonopah Test Range on a noninterference basis at any time the Tonopah Test Range has not been scheduled for use by the Manager, Tonopah Test Range.

c. That the Department of the Air Force shall control the use of the restricted air space, designated as R-4809, but shall give priority to the permittee's requirements.

d. That permittee and Department of the Air Force shall assume responsibility and accountability for the property, within Tonopah Test Range, for which they have funded.

9. That the permittee may make additions to its buildings and facilities in, or alternations of, the Tonopah Test Range without the prior consent of the Department of the Air Force.

10. That the Department of the Air Force may conduct bombing and gunnery training on a noninterference basis on ranges to be constructed in a mutually acceptable Tonopah Test Range area.

11. That the permittee shall be responsible for the disposal of all Tonopah Test Range property for which the permittee funded, in accordance with applicable laws and regulations.

12. That this permit succeeds Permit No. SFRE-(3)-727 dated 1956 November 09, and Amendments Nos. 1 and 2 thereto, which terminated by its own terms on 1969 March 31.

The Atomic Energy Commission
Nellis Air Force Range, Nevada
Permit No. DACA09-4-70-43

EXHIBIT A

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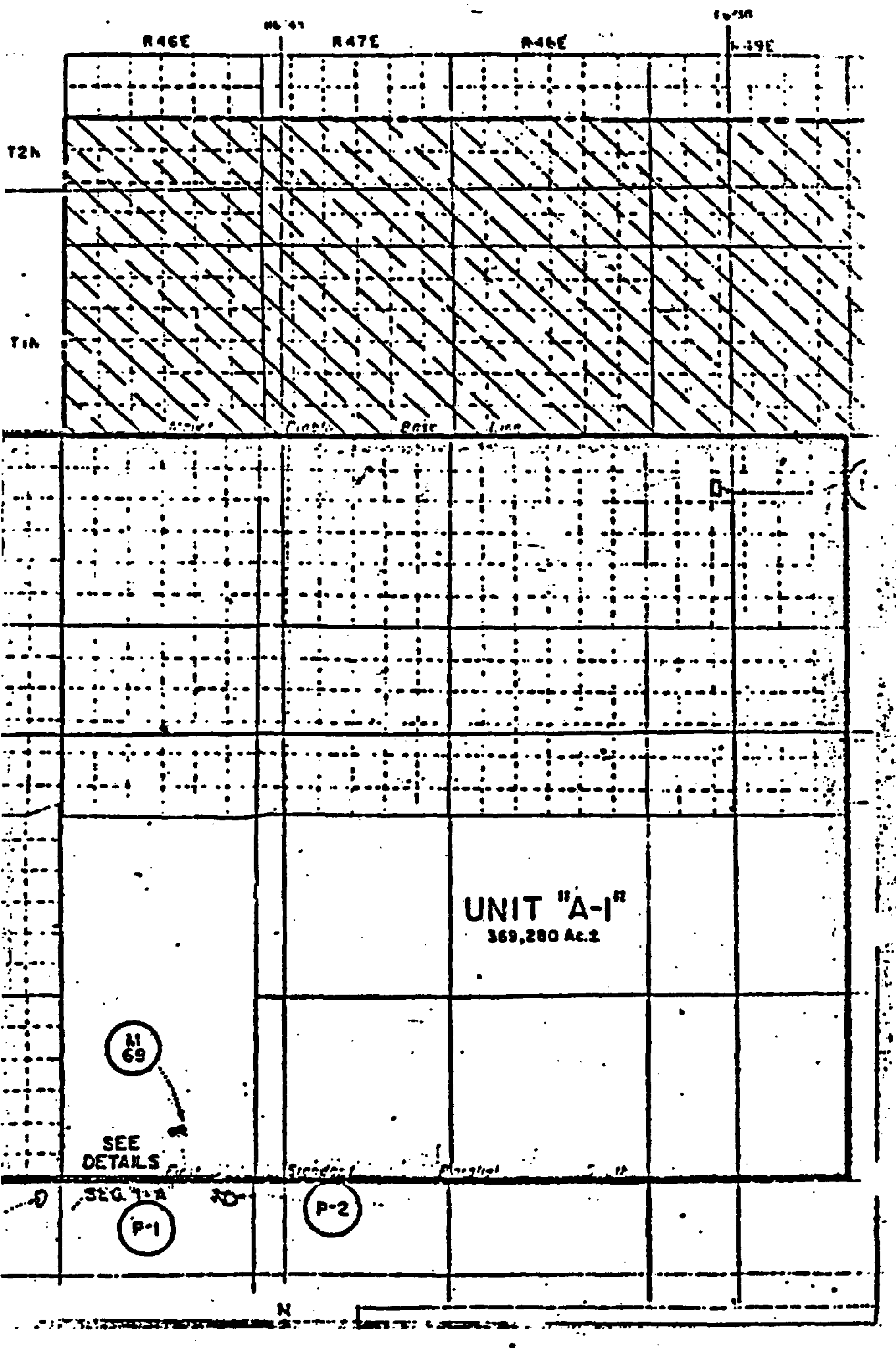

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No. AT(29-2)-2747

B. This Agreement will be reviewed by the parties during the first quarter of each calendar year.

C. This Agreement terminates when the Permit referenced in Article II above is terminated.

D. The effective date of this Agreement is the later of the dates on which the parties sign below.

NELLIS AIR FORCE BASE
DEPARTMENT OF THE AIR FORCE

BY: /S/ R. G. Taylor

TITLE: Commander, Nellis AFB

DATE: 22 April 1969

ALBUQUERQUE OPERATIONS
UNITED STATES ATOMIC
ENERGY COMMISSION

BY: Original signed by H. C. Donnelly

TITLE: Manager, ALO

DATE: April 25, 1969