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Investigation of a water supply near Encino, New Mexico in relation to nearby high-energy detonations

By

F. C. Koopman, J. A. Basler, and E. G. Lappala

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Prepared in cooperation with the Air Force Weapons
Laboratory (WLCD-D)
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Introduction

The U.S. Air Force has made tests using conventional explosives at a site near Encino, Torrance County, N. Mex., on a ranch owned by Mr. Gene Harvey. The initial high-energy detonation test was made at the site on October 3, 1968. Soon thereafter, Mr. Harvey expressed concern that the detonation may have adversely affected a nearby surface-water supply used for watering stock. The water supply is contained in two ponds, which have formed in holes scoured in an arroyo about 250 feet south of the test site.

At the request of the Air Force, personnel of the U.S. Geological Survey and the Air Force visited the site on November 5, 1968 to make a reconnaissance and field inspection. Preliminary data collected by Geological Survey personnel were noted in a letter to the record transmitted to the Air Force on November 8, 1968. Soon thereafter the Air Force Weapons Laboratory (WLCD-D), Kirtland Air Force Base, N. Mex., requested the Geological Survey to make a more thorough investigation of the water supply to determine if it could have been affected by test explosions.

The Air Force test site and the impounded water supply are located in the SE¼NE¼ sec. 7, T. 5 N., R. 12 E., Torrance County, about a quarter of a mile south of U.S. Highway 60 between Willard and Encino (fig. 1).

The Geological Survey acknowledges the assistance of the Biology Department of the University of New Mexico for identification of the aquatic life found in the ponds. Mr. Harvey, the land owner, was most congenial in permitting the Geological Survey to install instrument shelters, to conduct tests on the site, and to have freedom of access to the property for the periodic observations.

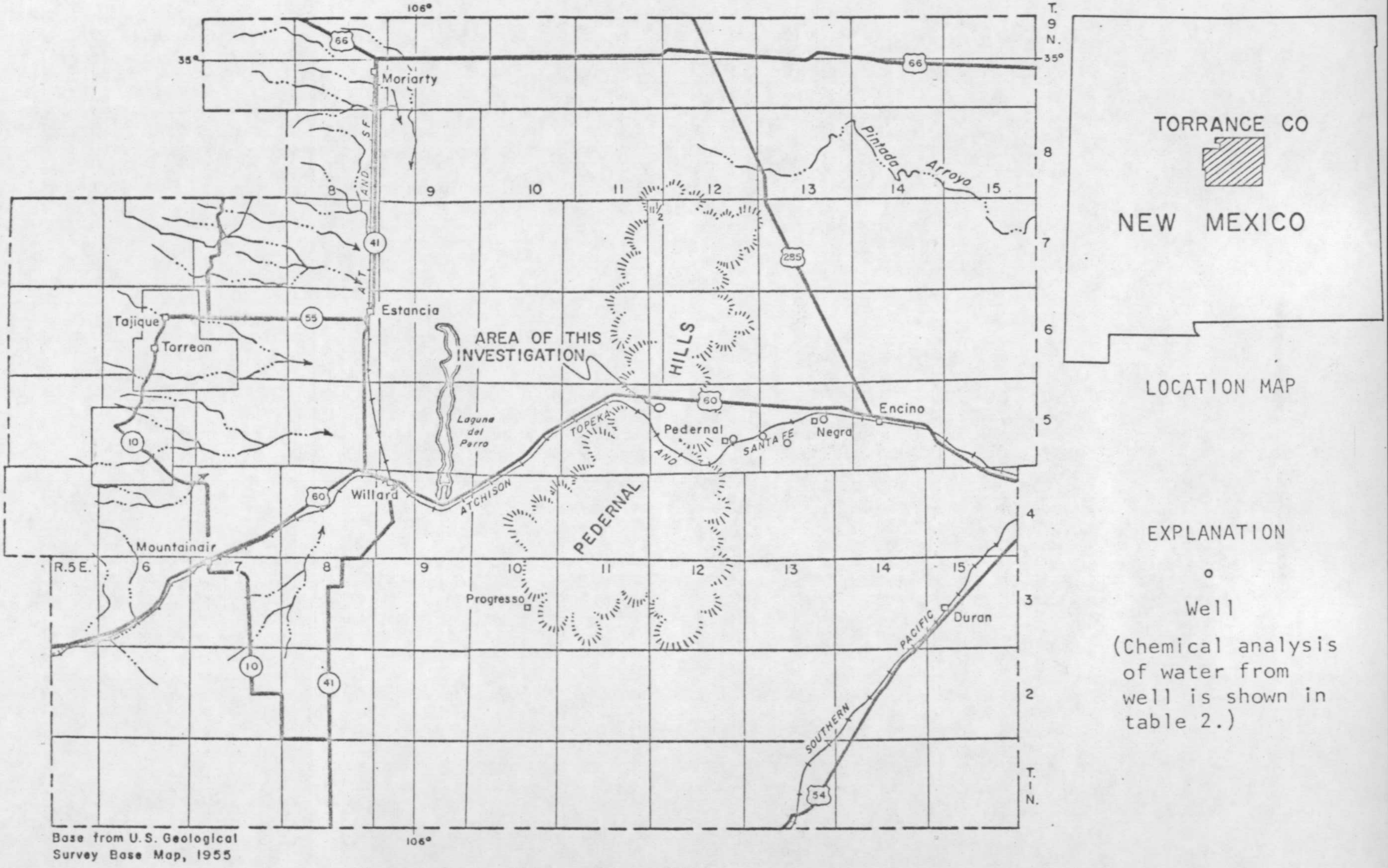


Figure 1.--Index map.

Description of the ponds

For the purpose of this report the term "pond" is used to imply a permanent or temporary water supply that is impounded in holes scoured on the surface of hard rock.

The two ponds near the test site, which furnish stock water for this section of the Harvey ranch, are formed in holes scoured in an arroyo about 250 feet south of the test site. They are known as the "upper" and "lower" ponds and are about 100 feet apart in the arroyo (fig. 2). Details of the upper pond are shown in figure 3, and figure 4 shows details of the lower pond. The lower and largest of the two ponds, has been developed, in part, by the construction of a low rock wall across the lower part of the arroyo channel downstream from the pond. When full the lower pond contains about 645 cubic feet of water; the upper pond about 80 cubic feet.

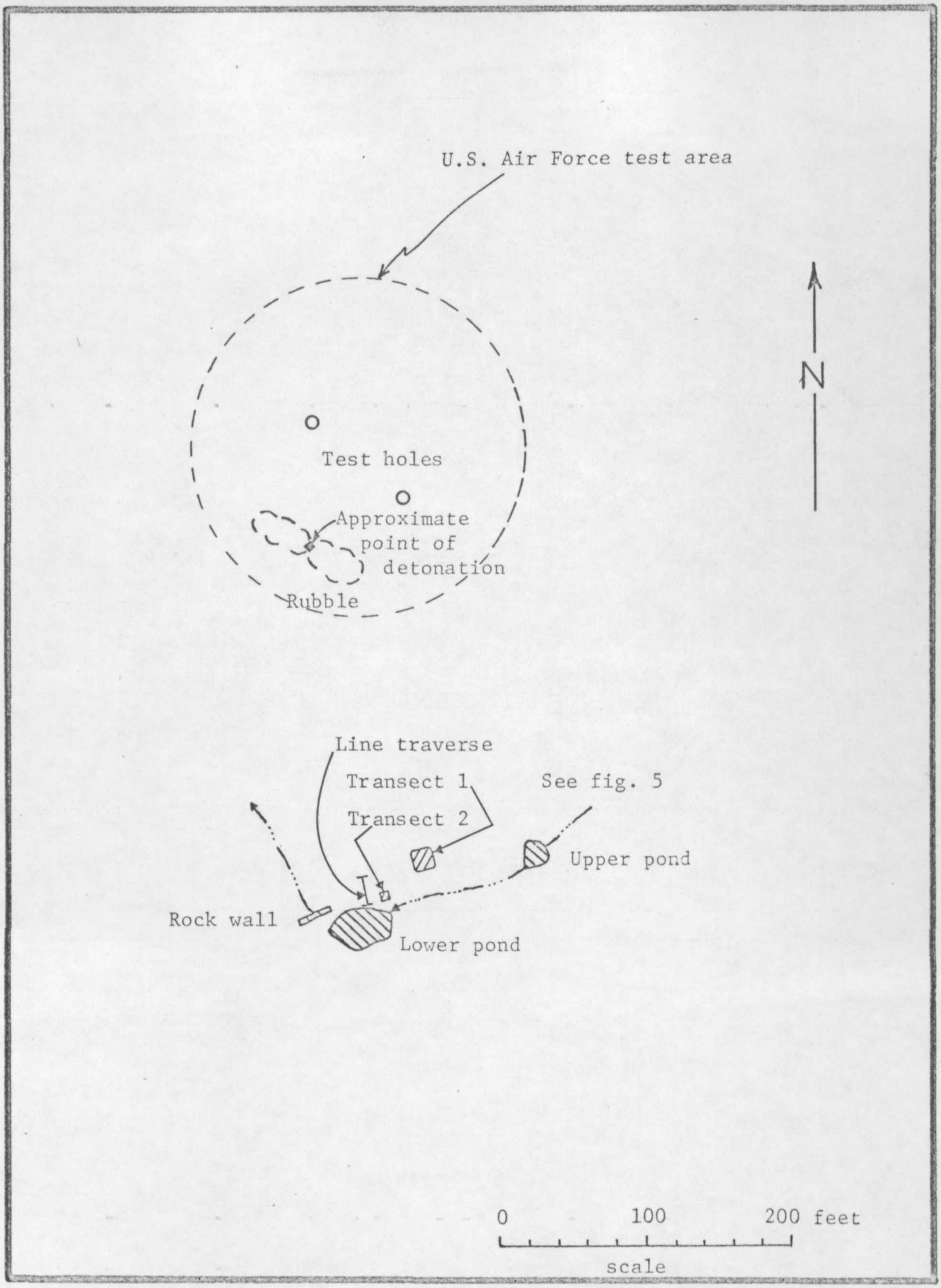


Figure 2.--Location map of ponded area and Air Force test area 20 miles east of Willard, N. Mex.

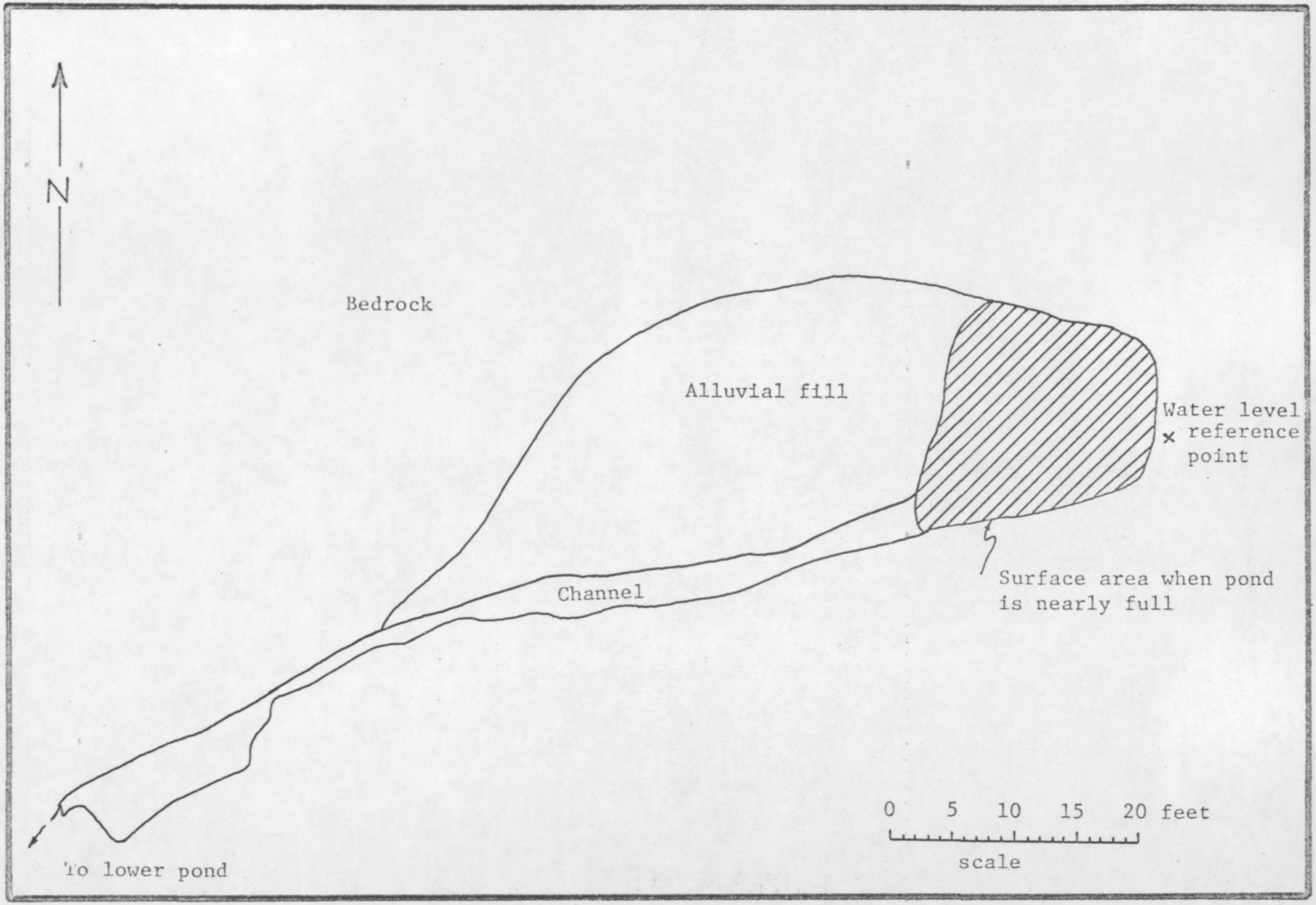


Figure 3.--Map of upper pond area.

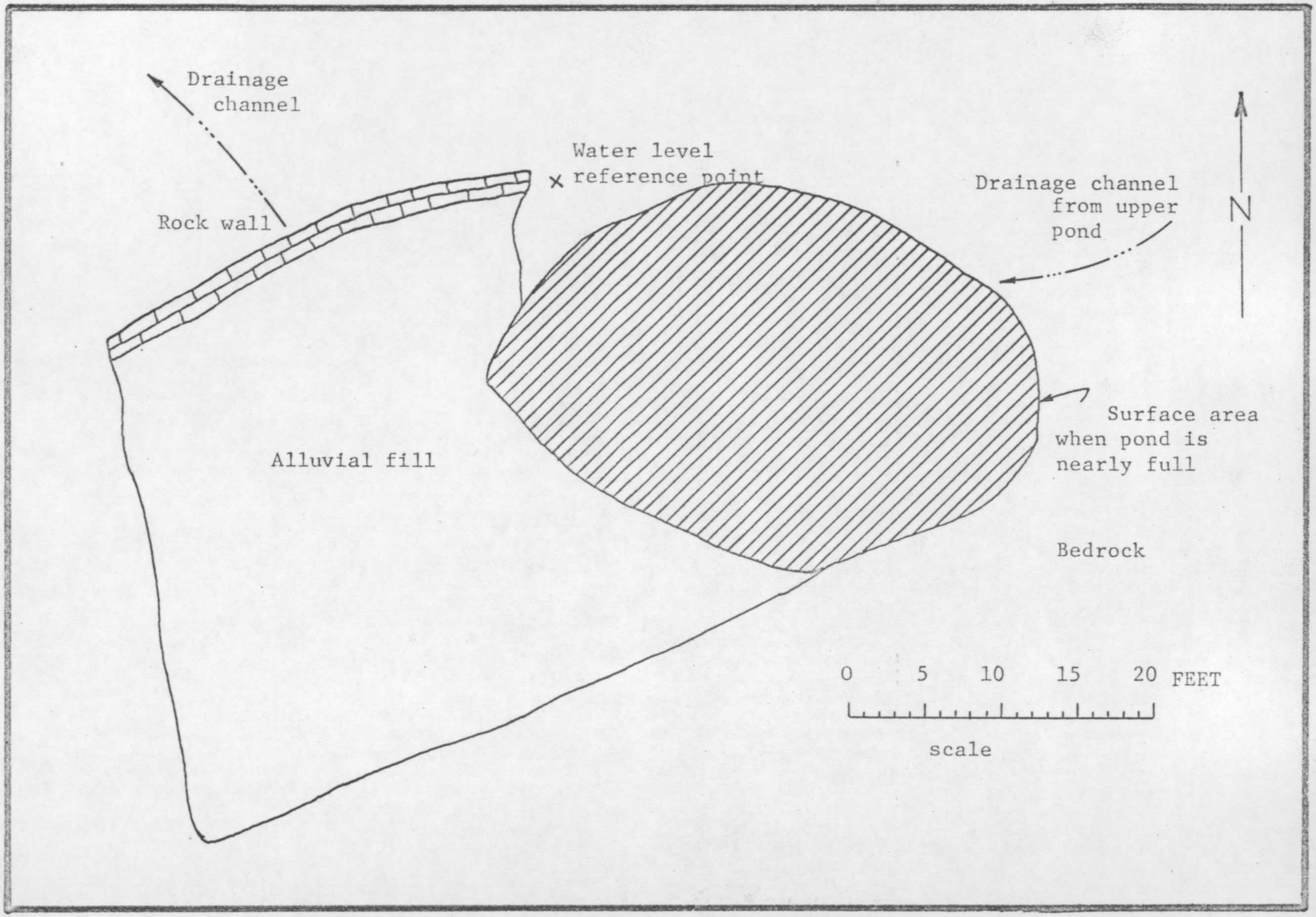


Figure 4.--Map of lower pond area.

Instrumentation and test equipment

Two Esterline Angus, single-pen recorders were used to record the fluid level and strain-gage transducers were used to sense the water level in the ponds. The transducers, mounted on concrete blocks in each pond, were attached to four-conductor shielded cables that transmitted the signals from each transducer to the recorders.

One of the recorders was modified and fitted with an event pen to record the time of receipt of each 0.12 inch of precipitation. This was done by capturing the precipitation in a standard tipping-bucket type precipitation-gage that transmitted a signal at the time each 0.12 inch of precipitation was received. Precipitation was noted by the event pen on the recorder and tallied on a counter that registered the total precipitation. The recorders were housed in a steel shelter, as was the fuel-cell-type electrical generator used for powering the instruments. Precipitation at the site was monitored by recording equipment from April 26 through October 21, 1969, with the exception of the period August 13 through September 23.

Flood flows were of sufficient velocity at times to completely dislocate the transducers and move the concrete blocks placed around them some distance downgradient, resulting in a loss of record. The automatically recorded information was supplemented initially and eventually replaced by field observations made by Geological Survey personnel on frequent trips to the site. Temperatures of the ponds were taken by hand-held mercury thermometers.

Geography

Topography and drainage

The area of the test site and water-supply ponds is in the Pedernal Hills (fig. 1). This range of hills is characterized by gentle grass-covered slopes with scattered outcrops of quartzite Precambrian rocks. The Pedernal Hills range in altitude from 6,200 to 7,600 feet and mark the boundary between the Basin and Range Province and the Great Plains Province (Smith, 1957, p. 10).

Water drains westward and collects in playas after heavy rains. Because of the large area and shallow depth of water the evaporation rate from the playas is high--consequently the playas are dry most of the year.

The drainage area above the study site is about 1.4 square miles. The arroyo in which the ponds are located is incised into quartzite and it parallels a major joint system. The bottom of the arroyo is rough and is characterized by innumerable scoured holes which contain water after runoff events.

Land use

The principal use of the land before the test site was established was for stock raising, including cattle and sheep. The land owner reported that the ponds near the test site were the only watering places in that particular pasture. It was reported by Andrew Gordon, U.S. Corps of Engineers, that the ponds were an important source of water many years ago for the salt-haulage teams that passed nearby with their payload of salt obtained from the playas to the west.

Climate

The climate of the area is semiarid. The average-annual precipitation from U.S. Weather Bureau records at Estancia, is 12 inches; at Pedernal 4E, 11 inches; and at Progresso, 13 inches. The estimated average-annual precipitation at the site, using the three nearby stations for reference, is about 11 inches. Precipitation is greatest during July and August. More than half of the precipitation falls as thunderstorm showers from June to September when temperatures and evaporation rates are highest, (table 1). Data collected at the site show that 9 inches of precipitation occurred from May to October; this is more than 80 percent of the average-annual precipitation.

Precipitation and evaporation is at the minimum during the winter months; temperatures may drop to as low as -20°F. The average date for a killing frost is probably October 17 at the site--this has little or no effect on the vegetation in the upper drainage of the site.

The average-annual evaporation from a free-water surface is estimated from 1966 - 1968 evaporation data at Estancia to be 76 inches. The average evaporation during the period, May through September, is about 0.29 inches per day.

Table 1.--Total evaporation and average temperature from Weather Bureau Stations near the site of investigation.

	May		June		July		August		September	
Year	Evaporation (inch)	Temperature (°F)	Evaporation (inch)	Temperature (°F)	Evaporation (inch)	Temperature (°F)	Evaporation (inch)	Temperature (°F)	Evaporation (inch)	Temperature (°F)
1966	10.2	58.8	9.2	65.8	8.8	73.4	7.6	67.4	5.7	63.3
1967	11.4	57.4	8.9	65.6	9.8	72.1	-	66.2	-	-
1968	8.1	56.5	9.9	68.2	7.7	69.7	7.1	66.6	6.5	60.9
1969	8.1	57.5	8.6	65.0	8.4	52.1	6.9	71.5	4.9	63.0

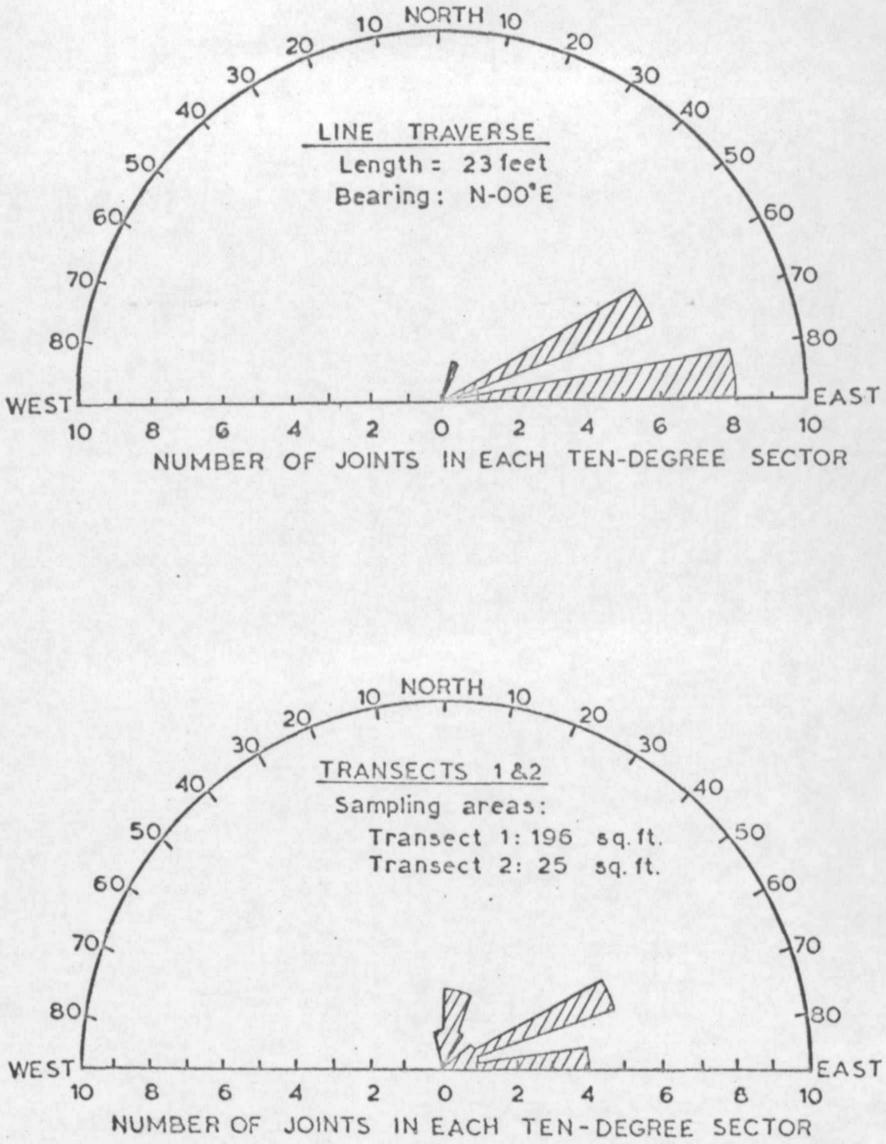
Total evaporation per month at Estancia, New Mexico
Average monthly temperatures at Pedernal, New Mexico

Geology

Alluvium overlies quartzite bedrock at the study site. The alluvium is unconsolidated and consists of clastic material largely derived locally from the quartzite. The alluvium several hundred-feet upgradient from the ponds is as much as 10-feet thick; immediately above the ponds it is very thin. Boulders and coarse gravels, with some thin sand lenses, are deposited on quartzite in the arroyo near the ponds where the velocity during flooding is not sufficient to carry it downgradient. Several cubic yards of gravel, boulders, and sand are present as fill material west of the lower pond where a low wall of rocks constructed across the arroyo caused flood flows to lose velocity. Some windblown material has accumulated in the grass-covered portion of the drainage area.

The bedrock in which the ponds have been scoured is a quartzite of Precambrian age (Smith, 1957). It is hard, dense, fine grained, pink to reddish in color, and contains some chlorite inclusions along the original bedding plane.

Primary joints in the quartzite strike from due east to N. 65°E. (fig. 5) and dip to the north at angles ranging from 50° to vertical. A secondary joint system strikes almost due north, with dips ranging from 75° to the west to vertical. Distance between joints ranges from one to two feet. A minor tertiary joint system strikes N. 25°E.



Note: Locations of line traverse and transects are shown on fig. 2.

Figure 5.--Diagrams showing directional characteristics of joint system in the quartzite underlying the study area.

An inspection by Geological Survey personnel, on November 5, 1968, of quartzite exposures between the test site and the ponds (a distance of more than 200 feet) indicated that the quartzite beyond 50 feet from the rubble accumulated from the detonation test in the area contained no significant openings caused by the detonation.

The estimated porosity of the unweathered and unfractured quartzite is less than one percent, with permeability so low as to be almost negligible. The naturally occurring joints or fractures cause an increase in both permeability and porosity of the quartzite; however, the porosity and permeability represented by these joints or fractures decrease with depth, as joints commonly become smaller and less numerous with depth. At some depth they become incipient--there is actually no opening in the rock but joints will develop later as the overlying rock is removed by erosion or excavation.

Ground water

Small amounts of ground water may be held temporarily in the thin alluvial layer at the study site after a rainfall. Discharge of the water would soon occur, either by evapotranspiration where vegetation exists in the upper portion of the drainage, or down-gradient along the interface between the alluvium and quartzite where it would be evaporated or added to the surface flow. A permanent ground-water supply does not exist in the alluvium in the drainage above the ponds.

The quartzite may contain a trace of ground water near the surface within the joint system; the joints are non-conductive to water below a few feet of the surface. Test holes drilled by the Air Force prior to the detonations, to depths of 20 feet (fig. 2) in the quartzite north of the ponds and at higher elevation than the ponds, contain water that has collected from runoff during 1969 summer showers. The retention of water in these drill holes demonstrates the inability of the quartzite to transmit water a few feet below the surface.

The surface of the water in the drill holes is as much as 7 feet above that of the upper pond and 25 feet above that of the lower pond. As the drill holes are at a slightly higher elevation and nearer to the point of detonation (less than 100 feet) than are the ponds (more than 200 feet), the containment of water in the drill holes suggests that there was no uniformly widespread disturbance of water-transmission properties of the natural-joint system at the ponds.

The slope of the land surface and infiltration characteristics of the soil in the drainage area above the ponds are such that only a limited amount of recharge could occur in the thin alluvial material; practically no recharge could occur in the joint system of the quartzite. This condition is unfavorable for the storage of major amounts of ground water to supply wells or springs, but it does provide a relatively efficient rainfall-harvesting area for runoff water to the ponds. A study of aerial photographs shows that about 12 percent of the drainage area is exposed quartzite. The quartzite surface offers a natural paving for water harvesting and subsequent storage in the scour holes. Efficiencies for rainfall recovery can be as much as 80 percent for artificially paved areas at White Sands Missile Range, N. Mex. (Ballance and Basler, 1967) which probably compares favorably with runoff expected from a crystalline rock surface. However, surface roughness of the quartzite and a thin alluvial cover indicate that runoff efficiency over most of the drainage area of the ponds would be considerably less than 80 percent.

Quality of water

Samples of water were collected periodically from the ponds and analyzed for constituents thought to be the most likely indicators of the type of water in the ponds. The water was badly polluted with algae, moss, some aquatic life, and animal excrement. All these forms of pollutants were evident when the ponds were full, and more so when evaporation had nearly depleted the water supply. An attempt was made to determine whether there was evidence of a ground-water source to the ponds. The difference in chemical constituents from one sampling period to another does not indicate any source of water change during the period of observation. Soon after rainfall, the new water that flows into the ponds is the same quality as older water in the ponds.

About four pounds of the quartzite from the area between the two ponds was crushed and soaked in distilled water for about ten days under laboratory conditions. The water was drained from the rock and the results compared by pictorial diagram (fig. 6). The water in the pool has the same general chemical character as that generated by soaking the host rock in distilled water. The chemical constituent ratios were about the same but the total amount of dissolved solids was less-possibly because of insufficient leaching time.

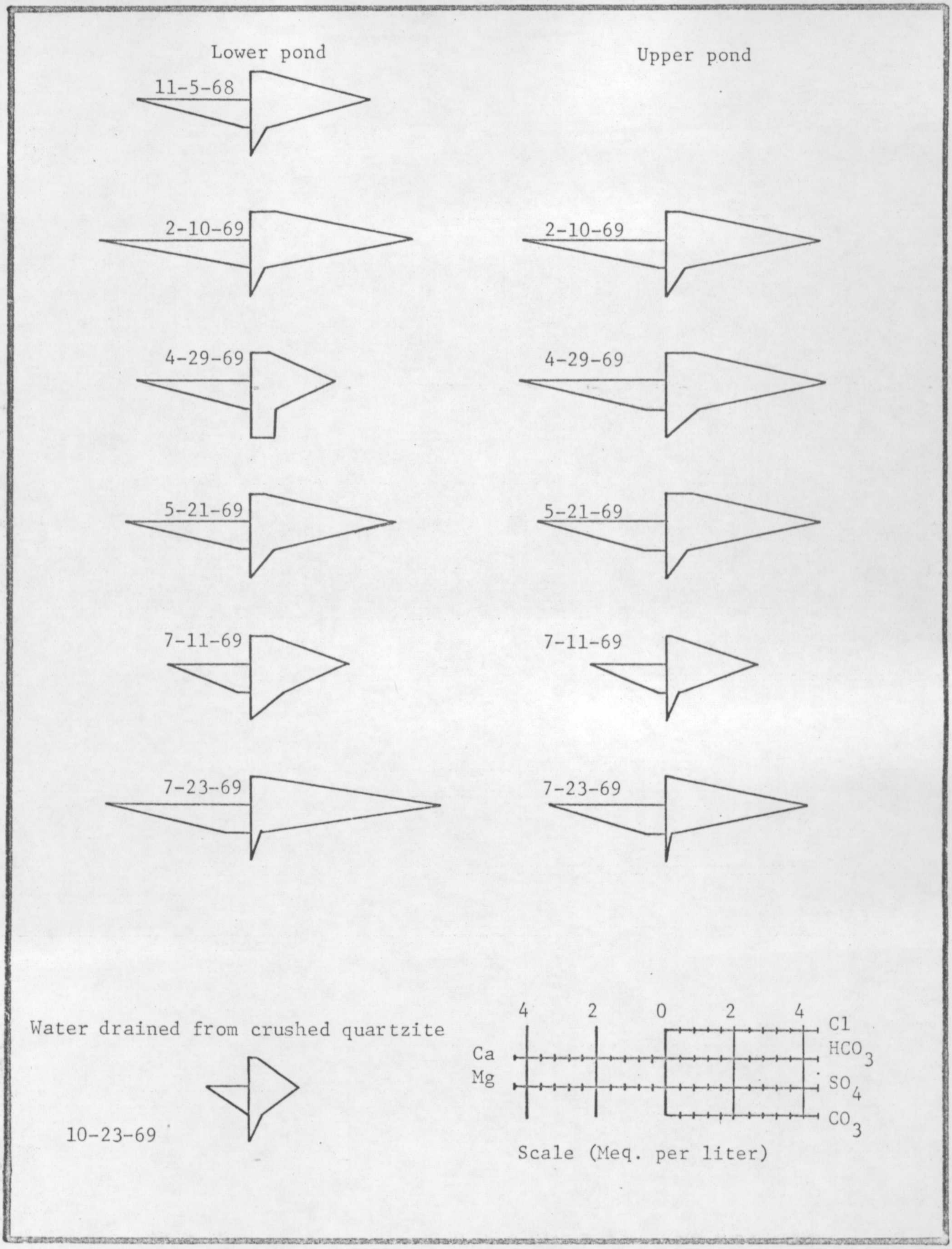


Figure 6.--Diagrams showing relative concentrations of chemical constituents in water collected from upper and lower ponds, and water drained from crushed quartzite.

The water from wells in the area has a specific conductance of more than 600 micromhos. Smith (1957, pl. 2) indicates that the specific conductance of typical ground water from a well or spring in the same general area as the ponds is about 750 micromhos. The specific conductance of water samples from the ponds ranged from 183 to 358 micromhos. This low conductance value suggests that the water in the ponds is from surface runoff. Analyses of ground water from wells near Pedernal (fig. 1) and those analyses of samples collected from the ponds during 1969 are shown in table 2. The water from the ponds has a lower concentration of magnesium, sulfate, chloride, fluoride, and dissolved solids than does water from wells. This is significant in differentiating between ground water in the area and the water found in the ponds. A comparison of the ponded water and ground water from wells can be made by comparing figures 6 and 7. A substantial difference in the quality of the water from the two sources is shown by the shapes of the chemical constituent arrays.

Pond water in residence for some time should reflect an increased total dissolved-solids per unit-volume because of loss of pure water by evaporation; conversely a slug of precipitation runoff should decrease the total-solids per unit-volume. Because of seepage losses and overflow of the ponds, the dilution and concentration of dissolved solids as determined from the samples does not correlate directly with field measurements of precipitation and changes in pond levels.

Table 2.--Chemical analyses of water from the upper and lower ponds at the study site, from crushed quartzite, and from wells in the Pedernal area, N. Mex. (Analyses by the U.S. Geological Survey, Chemical constituents are in milligrams per liter).

Location	Date of collection	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids
SW¼,NE¼, Sec. 27, T. 5N., R. 12E	7/18/50	659	19	87	23	16	152	153	43	0.2	1.7	418
NW¼,SW¼, Sec. 14, T. 5N., R. 13E	7/? /50	906	17	62	34	92	233	228	42	2.4	1.6	594
SW¼,NW¼, Sec. 28, T. 5N., R. 13E	7/19/50	669	16	48	25	63	207	146	22	2.4	.2	425
NW¼,NW¼, Sec. 30, T. 5N., R. 13E	7/18/50	593	18	50	21	46	188	117	21	1.8	.5	368
Upper Pond*	11/ 5/68	231	5.7	33	1.8	9.0	103	11	6.7	.2	4.3	123
Upper Pond*	2/10/69	276	1.0	44	0.0	14.0	138	8.4	12.0	.2	.4	148
Lower Pond	2/10/69	271	1.2	42	.2	13	133	12	8.4	.3	.6	143
Upper Pond	4/29/69	198	7.1	33	.1	13	73	18	8.5	.4	1.1	128
Lower Pond	4/29/69	324	6.7	43	3.0	18	140	21	14	.5	2.0	177
Upper Pond	5/21/69	255	16	36	2.2	14	128	14	6.8	--	.0	152
Lower Pond	5/21/69	358	30	38	3.2	26	162	15	12	--	.0	204
Upper Pond	7/11/69	226	11	24	2.2	--	86	22	8.9	.4	.6	137
Lower Pond	7/11/69	183	9.7	22	1.5	--	80	9.2	2.7	.2	.6	96
Upper Pond	7/23/69	288	25	42	4.6	--	166	6.8	4.3	.6	.8	193
Lower Pond	7/23/69	223	22	34	3.4	--	126	4.0	2.8	.3	.5	143
Lab test on quartzite	10/23/69	102	7.2	13	.4	--	44	8.2	3.8	--	.8	62

*Both Upper and Lower Ponds are located in SE¼,NE¼, Sec. 7, T. 5N., R. 12E

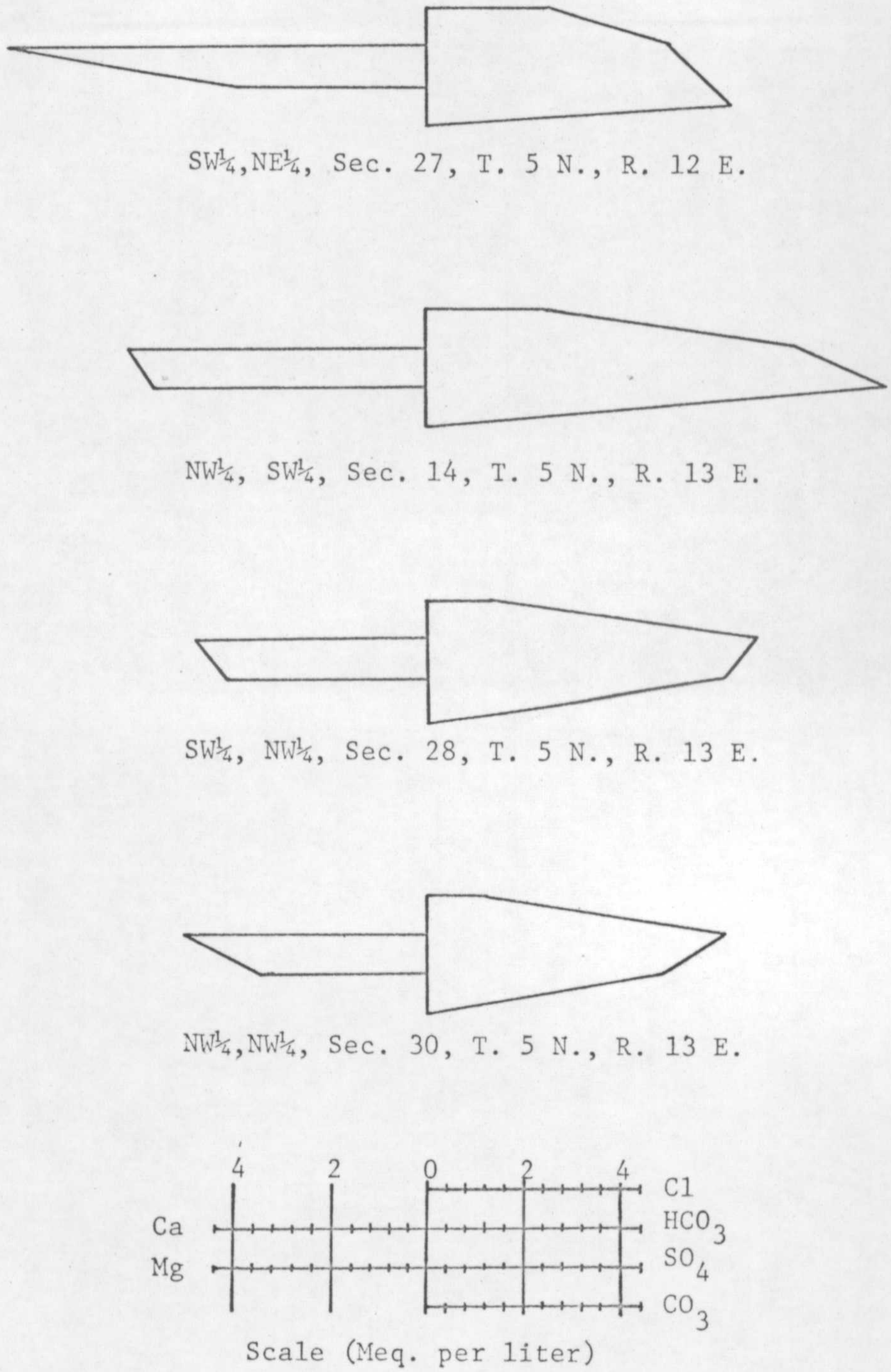


Figure 7.--Diagrams showing relative concentrations of chemical constituents in water from wells near the study area.

If a major portion of the sustained flow to the pools were from ground-water sources as spring flow, the chemical character of water in the ponds would be similar to the quality of water from wells near the area.

Observations of the ponds

Aquatic life

Aquatic life in the ponds observed during November 1968 consisted of young salamanders in the swimming larvae stage ranging from two to three inches in length and of two kinds of aquatic beetles. Aquatic plantlife was observed through October 1969. The aquatic life observed in the ponds is commonly found in temporary ponds and therefore does not suggest permanency of water in the ponds.

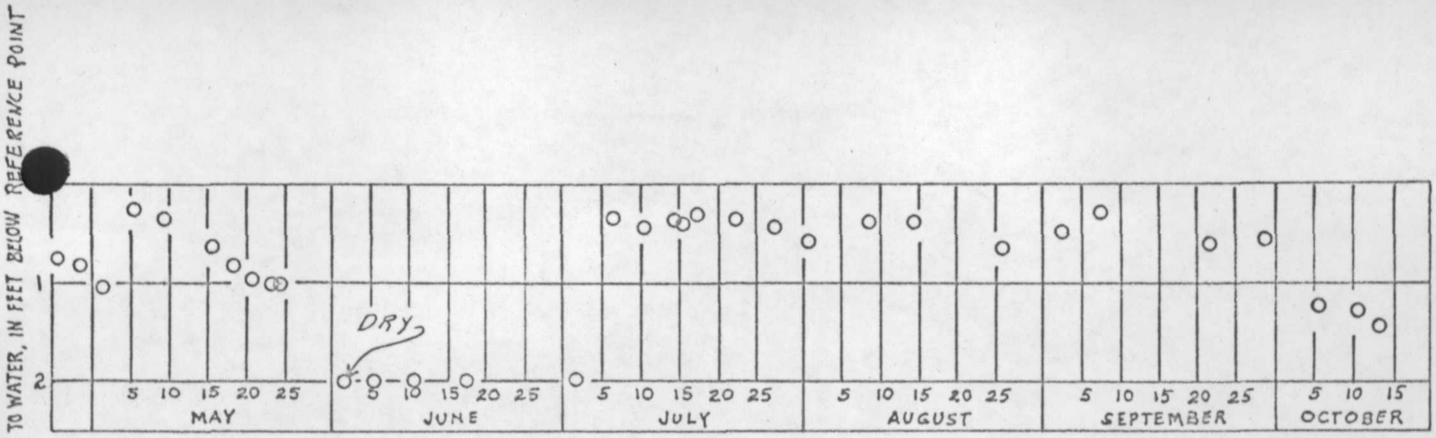
Low temperature periods

The ponds do freeze solid, as noted in January and February 1969. Such freezing of the entire body of pond water is an indication that the ponds are probably not maintained by spring flow. If spring water entered the ponds, it would be of a temperature above the freezing point and would create circulation of water in the pond which would prevent freezing of some of the pond water.

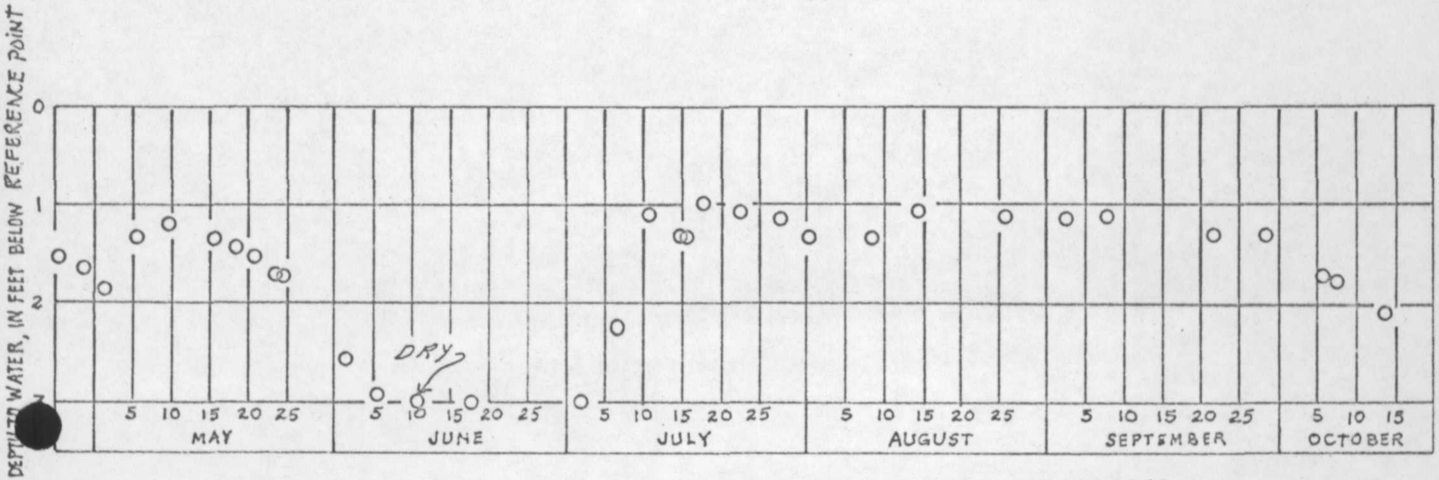
Fluctuation of water level

The relation of precipitation to water level in the two ponds is shown on figures 8, 9, and 10. The reference datum for depth-to-water measurements shown in figure 8 is a point on the quartzite a few inches above the estimated maximum water level of the pond (figs. 3 and 4). No precipitation was recorded at the site during the period May 24 through July 4, 1969. The lack of precipitation during this period when evaporation rate is about 0.29 inches per day, caused the ponds to dry up. Some water may have been consumed by animals grazing in the area. Water in the upper pool completely evaporated early in June 1969 and no water was visible in the lower pool from June 7 through July 3, 1969. However, there was evidence of a very small seep of less than two or three gallons per day below the rock wall downgradient from the lower pond. The seep was probably supported by water slowly draining out of the alluvium on the west side of the pond. Rains during the second week in July 1969 filled the ponds and the ponds have contained water to date (December 1969).

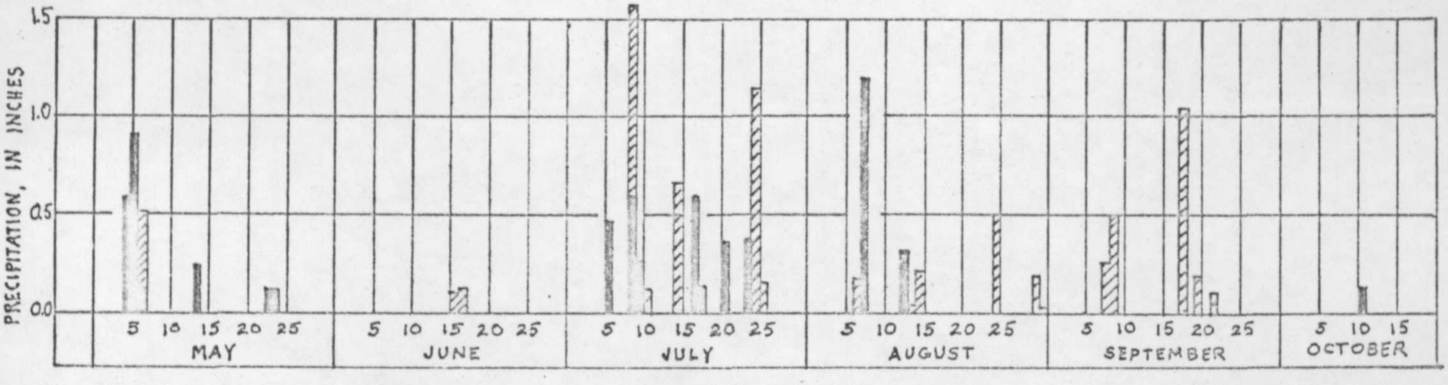
Failure of the precipitation-monitoring equipment from mid-August to the last part of September, 1969 resulted in loss of record; however, some accumulation of rainfall, noted in the reservoir below the tipping-bucket drainage, indicated that about an inch of rainfall had occurred during this period. This figure is in fair agreement with the rainfall records of the Weather Bureau station Pedernal 4E, located four miles east of Pedernal and about eight miles east-southeast of the site.



A.--Depth to water in upper pond, May through October 1969.



B.--Depth to water in lower pond, May through October 1969.



C.--Precipitation at site of investigation (solid bar) and precipitation at Pedernal.

Figure 8.--Graphs showing the relation of precipitation to water level in the two ponds, May through October 1969.

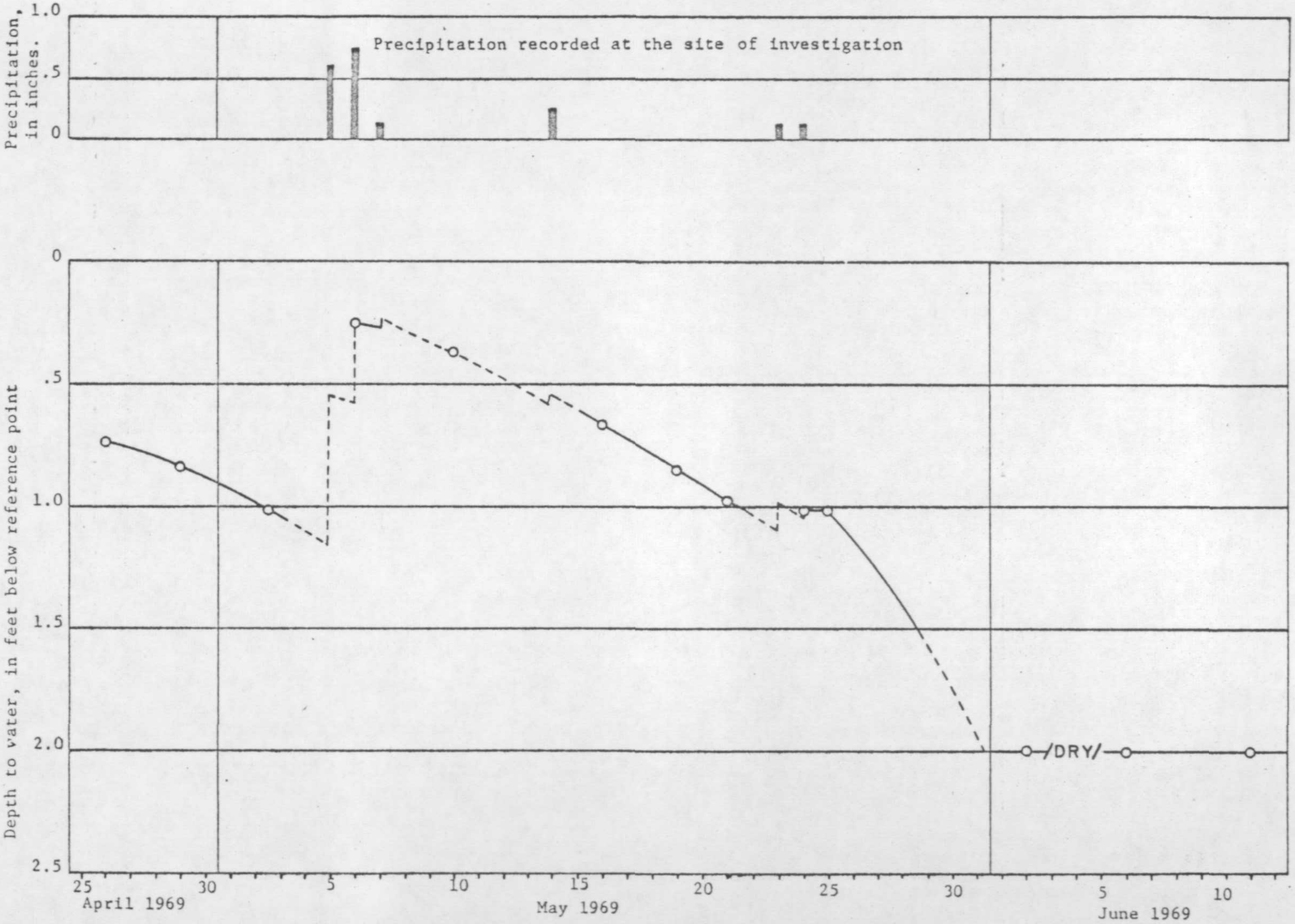


Figure 9.--Graphs showing the effect of precipitation on water level in the upper pond.

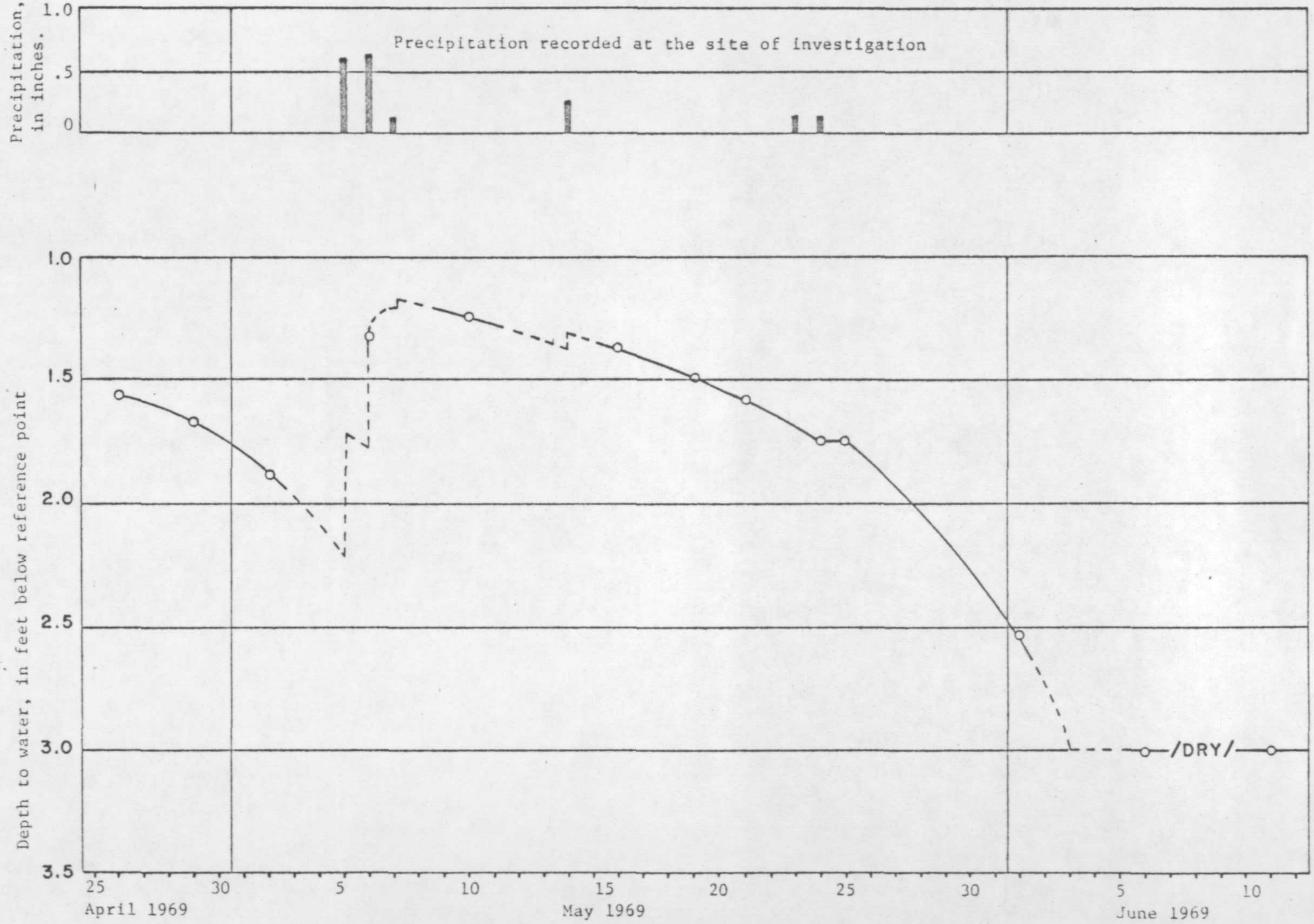


Figure 10.--Graphs showing the effect of precipitation on water level in the lower pond.

The total volume of water when the ponds are full is about 80 cubic feet for the upper pond and 645 cubic feet for the lower pond. The surface areas relative to volume of water in the ponds are shown in figures 11 and 12. The decrease of volume of water in the pond by evaporation and seepage causes a decrease in effective area of the free-water surface for evaporation. However, the wetted area around the ponds is effective for further dissipation of water by evaporation from the wetted perimeters by about the same rate per unit area as from the free-water surface.

About 250 cubic feet of water was removed from the lower pond on October 8, 1969 and stored temporarily in a nearby tank for about 24 hours and then returned to the pond. This caused a drop in water level of the pond of 0.35 feet. The water level was monitored with a sensitive recorder for the duration of the test to determine if there was any recharge to the pond from ground-water sources. Figure 13, which is a copy of the pen trace from the recorder, indicates that no water entered the pond area during the test. No precipitation occurred during the period of the test.

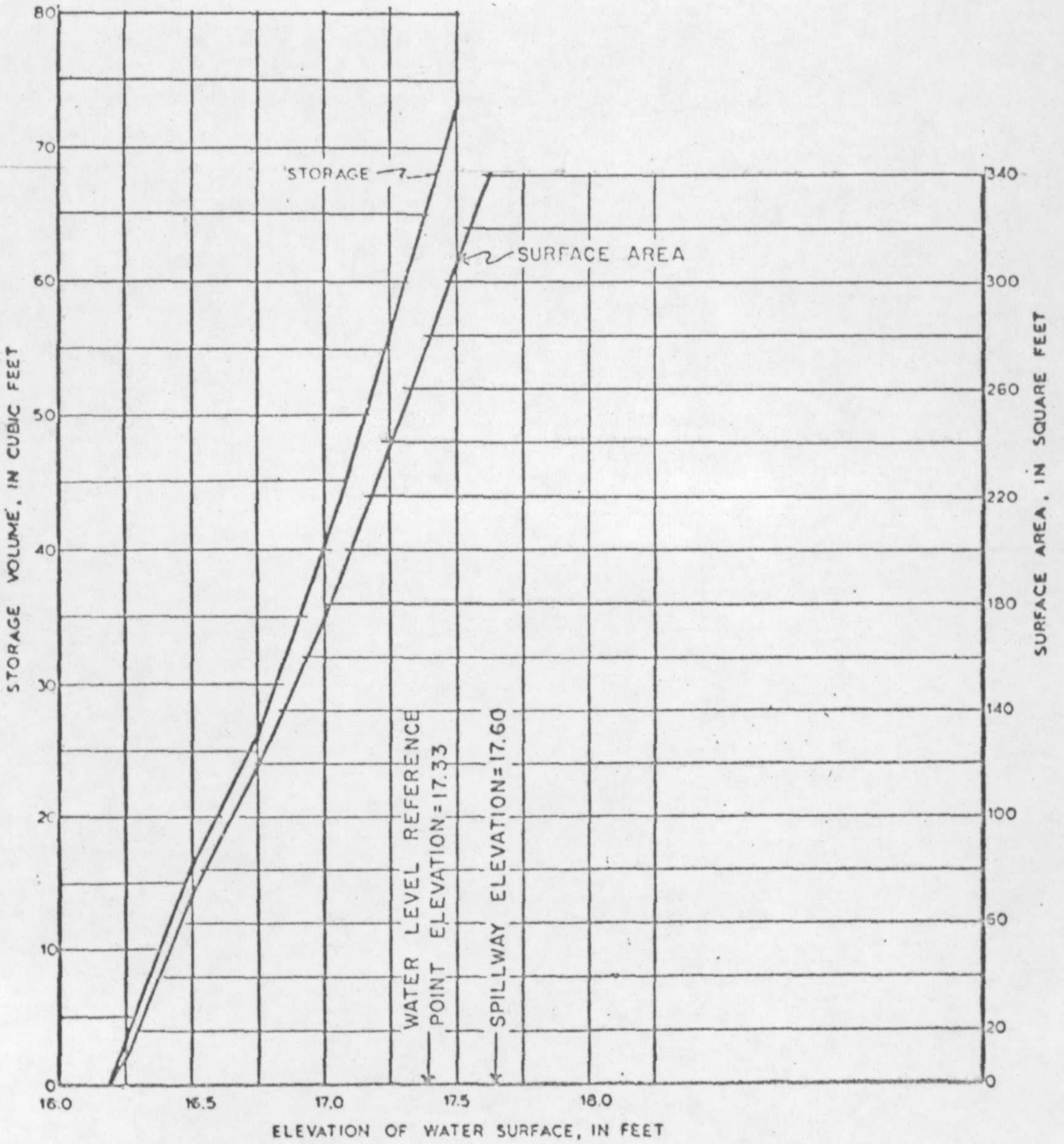


Figure 11.--Storage and surface area of upper pond as a function of the elevation of the water surface.

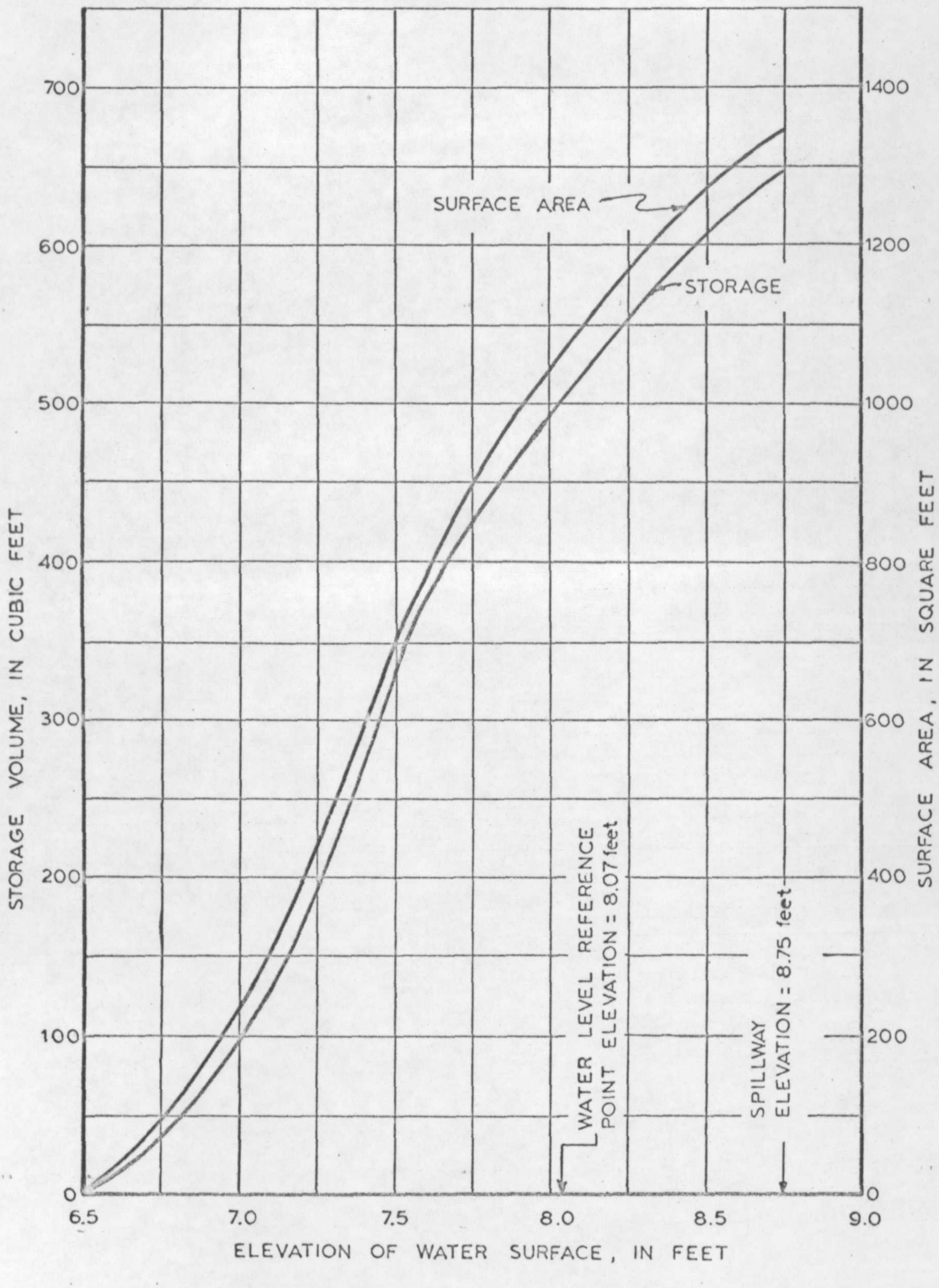


Figure 12.--Storage and surface area of lower pond as a function of the elevation of the water surface.

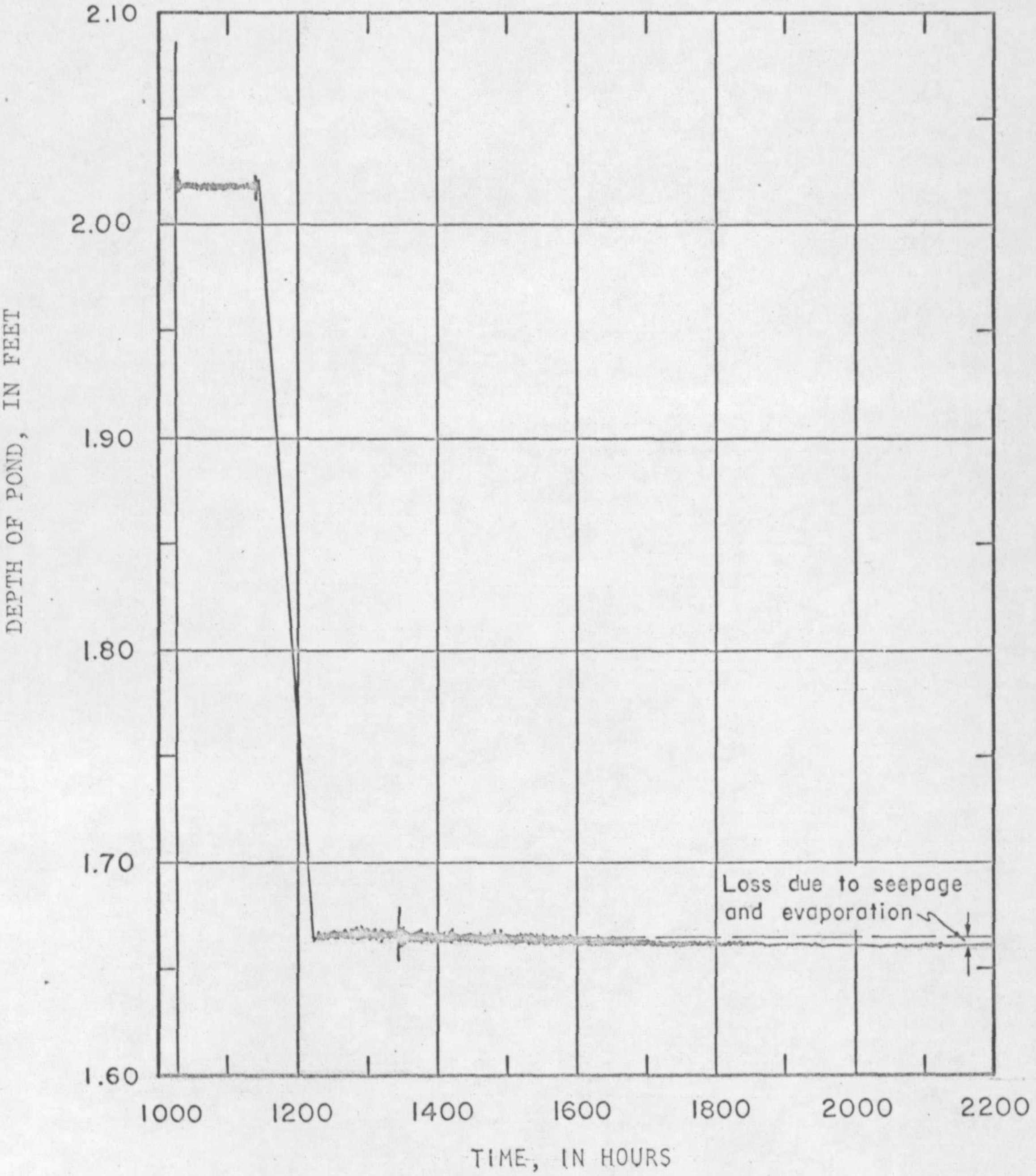


Figure 13.--Water level change in the lower pond as a result of removing 250 cubic feet of water on Oct. 8, 1969.

Figure 14 shows the monthly precipitation at Pedernal 4E during the period 1960-1969, and the departure from the long-term daily average for the same period. Records for those months of high-evaporation potential suggests that during May 1962, 1963, and 1964, the ponds must have been nearly dry, or dry. An effort was made to obtain photographs taken or documents that may have been prepared during the time the ponds were most likely to have been dry. Several aerial photographs were obtained; however, the photographs were all taken during a period when rainfall had been sufficient to maintain the ponds. Photographic enlargements were made of high-altitude photos to discern the presence or absence of water in the ponds but this proved futile because no better definition of the ponds resulted. The Atchison, Topeka, and Santa Fe Railway headquarters in Amarillo, Tex. was contacted to see if they had noted the ponds in any of their records or considered the site as a potential water supply for the railway constructed less than a quarter mile from the ponds. The records were searched and officials of the railway reported that reference was made in their files only to supplies from the well drilled for the railway north of Negra, N. Mex., about 10 miles east of the ponds.

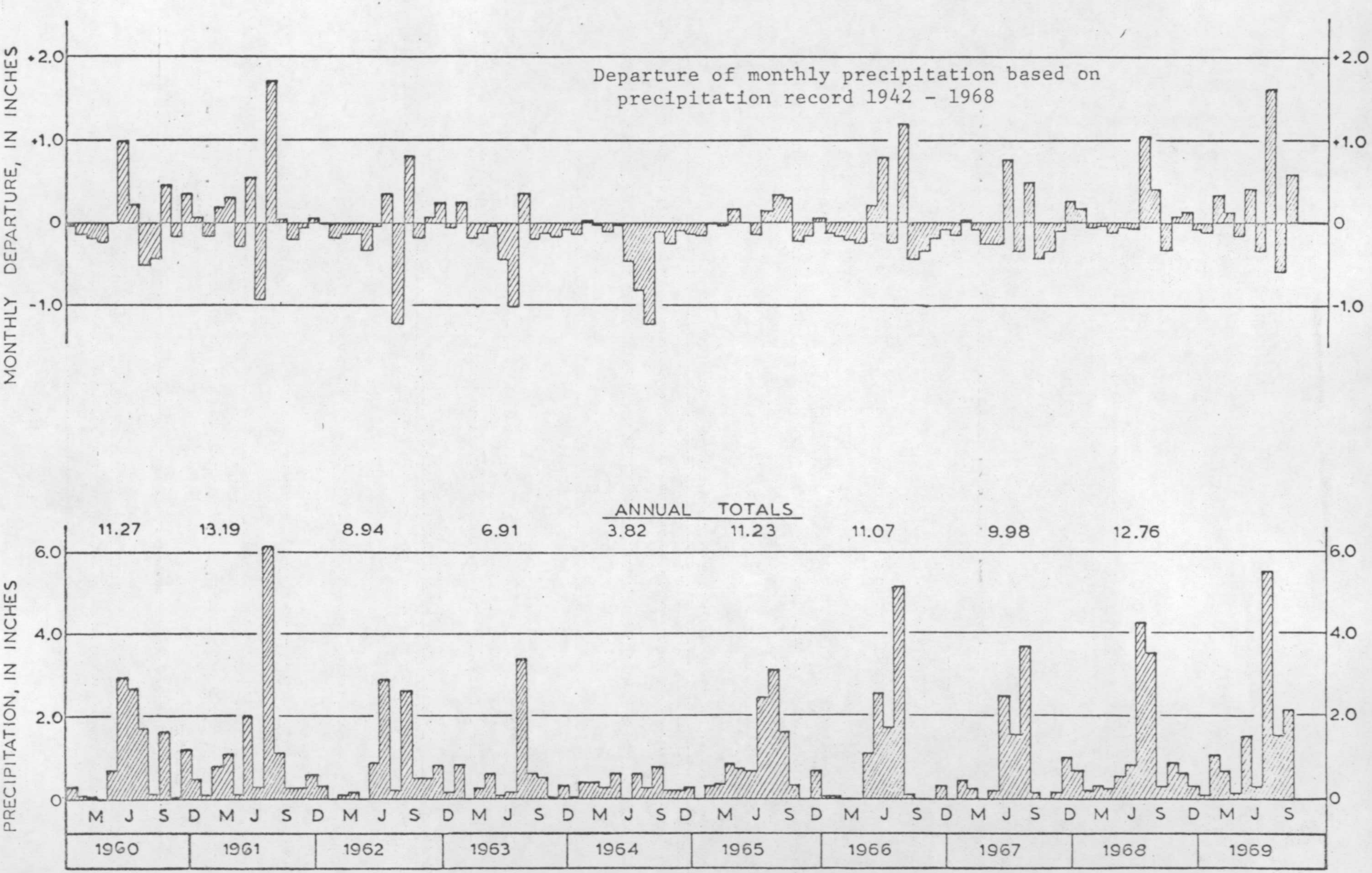


Figure 14.--Graph showing monthly precipitation compared with a graph of the monthly departure, Pedernal 4 E, Weather Bureau Station, New Mexico.

Summary and conclusions

Investigations indicate that the ponds near the Air Force test site are supported by runoff from precipitation. The water levels in the ponds are sensitive to precipitation because of relatively high efficiency of effective runoff from the hard-rock surface in the watershed. It was evident during the period of observation in 1969 that periodic showers were sufficient to support the water supply in the ponds; however, absence of precipitation for a period of one or two weeks resulted in a serious depletion of the supply. A period of no rainfall longer than three weeks during May through October, when evaporation rates are hight, plus a few animals watering at the ponds will result in complete dryness of tne pond areas.

No evidence was found of fracturing from the high-energy detonations which could cause leakage through the host rock. Water loss from the depression can be accounted for by evaporation, by stock watering, and at the lower pond by the small discharge that takes place through the artificial rock wall.

The quality of water from the pond area does not resemble the quality of ground water from wells drilled in the quartzite. This quality difference makes it doubtful that any significant amount of ground water discharges to the ponds. A test was conducted in the laboratory by putting distilled water in a container with four pounds of crushed quartzite for about 10 days. The quality of the liquor from the container resembled that of the water from the ponds. It is most probable that the pond water is precipitation runoff that has been in contact with the quartzite.

Three joint systems are obvious in the pond areas. The joints generally transmit water at a lesser rate with increased depth. The accumulation of rainfall runoff in drill holes about 250 feet north and 25 feet higher than the lower pond indicates the low permeability of the quartzite. These drill holes are only a short distance from an area of disturbed quartzite caused by the detonation. It is not likely that this same detonation could have caused damage to the water-supply ponds at a lower elevation and more than 200 feet away.

The alluvium in the area is thin and the underlying bedrock appears to be tight within a few feet of the surface. This environment is not favorable for the existence of a perennial ground water body at shallow depth. No ground water inflow to the ponds was observed and there was no evidence that suggests the ponds have been maintained in part by ground-water inflow--that is, by inflow of spring water.

The possible damage to the pond-area water supply was reported about October 1968 by the land owner. Visits to the area by Geological Survey personnel for more than a six-month period found water or ice in the pond area. The ponds did not dry up until there was a period of no rainfall starting in June 1969. If the high-energy detonation had caused joints to open or fractures to develop in the rock around the pond, in such a manner as to substantially increase the rock permeability and cause a diversion of flow from the pond, then this postulated increase in permeability in the host rock also should have caused an increase of ground-water flow to the pond or an increase in leakage of collected surface water from the pond. The water-level change caused by a permeability change from the detonation should be greatest immediately after the detonation--not several months later.

An inspection trip to the ponds in November 1968 showed no biological evidence supporting the permanent existence of the pools through historical times. The swimming larvae of salamanders and aquatic beetles, plus aquatic plantlife found in the ponds, are common in temporary ponds.

An intensive search was unsuccessful for photographic or documented evidence depicting dry-pond conditions at some time before the Air Force tests.

References

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