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THE HYDROMETEOROLOGIC GROUND TRUTH FACILITY AT WHITE SANDS MISSILE RANGE, NEW MEXICO

By

William J. Stone

Captain, Signal Corps

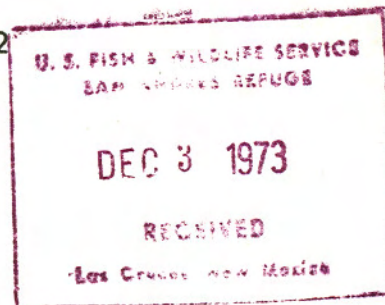
Atmospheric Sciences Laboratory

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White Sands Missile Range, New Mexico 88002

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13. ABSTRACT		
In preparation for the launch of a geosynchronous meteorologic satellite, SMS/GOES-A, several ground truth facilities are being established at White Sands Missile Range, New Mexico. One of these facilities, consisting of two instrumented watersheds on the western piedmont slope of the San Andres Mountains, Dona Ana County, New Mexico, will provide basic hydrometeorologic data. Instruments used include: eight recording rain gages, nine nonrecording rain gages, five recording, flood stage stream gages, five self-siphoning sediment samplers, one recording water well monitor, and three evaporation stations. All equipment, except that for the evaporation stations, is provided, operated, and maintained under contract by the US Geological Survey, Albuquerque. Data provided by these instruments will be used to study the hydrometeorologic controls of soil trafficability and to investigate the possibility of predicting trafficability from hydrometeorologic conditions.		

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PREFACE

The author wishes to thank Dr. Carlton Herbel, Range Scientist at New Mexico State University and the Agricultural Research Service at Las Cruces for granting access to the study area, for providing local rainfall and evaporation records, and for making the various resources of the Jornada Experimental Range available during the installation of the instruments. Thanks are also due the personnel of the Jornada Experimental Range and the San Andres Wildlife Refuge for their cooperation and help during the first field season. The author is also grateful to Mr. Ernest Cobb, Assistant District Chief, and Mr. Pat Borland, Project Supervisor, of the Water Resources Division, U.S. Geological Survey, Albuquerque, for their assistance in both the planning and operational stages of the project. Sincere appreciation is extended to Mr. Richard Smith, Soil Conservation Service, Las Cruces, who kindly furnished air photomosaics and peak discharge estimates for the watersheds under study. The author is also indebted to Drs. K. G. Renard, Director, and H. B. Osborn, Hydraulic Engineer, of the Agricultural Research Service, Southwest Watershed Research Center, Tucson, for a tour of their Walnut Gulch Experimental Watershed and helpful discussions of the Jornada project.

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INTRODUCTION

Satellites have shown great promise as platforms from which atmospheric and ground conditions across large areas of the earth's surface may be remotely sensed on a real-time basis. The verification of such satellite observations, however, requires ground truth, i.e., surface information. In preparation for the launch of a geosynchronous meteorologic satellite, SMS/GOES-A, to be positioned over the equator at 100° west longitude, various kinds of ground truth stations and facilities are being established at White Sands Missile Range (WSMR), New Mexico, by the Atmospheric Sciences Laboratory (ASL). These will provide the surface information necessary for evaluation and application of the satellite data. One of these facilities will permit collection of basic hydrometeorologic data. The purpose of this report is to define the research objectives, characterize the geologic and climatic setting, and describe the instrumentation of the hydrometeorologic ground truth facility at WSMR.

Data collected includes: precipitation, flood stage, soil moisture, suspended sediment load, position of water table, and evaporation. From these observations, values for storm intensity, runoff, transmission loss, sediment discharge, and ground water recharge may also be derived. Although this information will constitute hydrometeorologic ground truth for use in studies of arid microclimates and in general applications of meteorological satellite observations, it will be mainly used in research on hydrometeorologic controls of soil trafficability. The hydrometeorologic data obtained in this investigation will be used to construct models of the typical arid watersheds in the study area. Such models are used to predict the response of a watershed to given hydrometeorologic conditions. Trafficability for a given soil and terrain setting varies with moisture content, which is in turn controlled by other hydrometeorologic variables. Therefore, if the response of a watershed to given hydrometeorologic conditions can be predicted, corresponding changes in soil moisture and trafficability can also be predicted.

REGIONAL SETTING

The hydrometeorologic ground truth facility or study area is located about 25 miles northeast of Las Cruces, Dona Ana County, New Mexico, and lies wholly within the boundary of WSMR (Figure 1). It includes parts of the missile range land used by two United States Department of Agriculture agencies: The Agricultural Research Service, Jornada Experimental Range, and the San Andres National Wildlife Refuge (Plate 1, inside back cover).

The study area is situated on the western flank of the San Andres Mountains at the eastern edge of the Jornada del Muerto, a typical, southwestern bolson. The San Andres Mountains rise about 4,000 feet

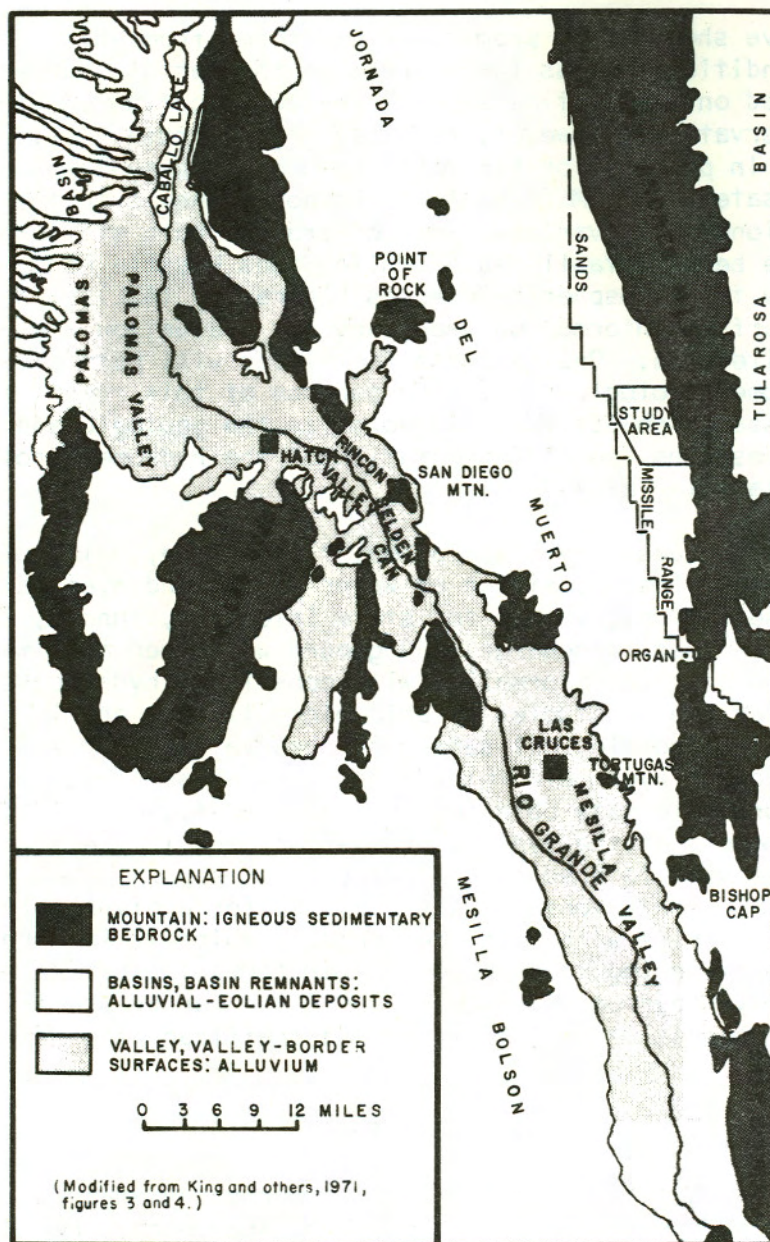


Figure 1. Generalized physiographic/geologic map of region.

above the adjacent basin floor and reach a maximum elevation of 8,239 feet at San Andres Peak, about 2 miles east of the study area (see Plate 1). The minimum elevation of the Jornada basin occurs at Lake Tank (4,289 feet), about 10 miles southwest of the study area.

The piedmont slopes of the San Andres Mountains, as well as those of other local ranges, are quite complex and consist of numerous constructional and destructional surfaces or terraces. At least a dozen such geomorphic surfaces have been recognized in the Las Cruces area by previous workers [1, 2, 3]. The caliche horizons of various thicknesses which are associated with each of these geomorphic surfaces play a significant role in controlling infiltration and groundwater movement and thus exert a major influence on runoff and the hydrologic cycle of these slopes in general. A seismic survey conducted in the summer of 1973 should reveal not only the depth of bedrock but also the number and vertical distribution of the caliche layers present beneath the channels of the watersheds instrumented.

The piedmont slopes and the basin floor consist of various bolson fill materials, principally alluvial sand and gravel. Eolian sand and dunes cover the surface in the northern half of the study area (Figure 2). Filling of the Jornada and adjacent basins was probably accomplished by mid-Pleistocene time [4].

The San Andres range is a westward-tilted fault block bounded on the east by the Tularosa Basin and on the west by the Jornada del Muerto Syncline [5]. The structural setting along the western flank of the range, as indicated by records [6] from water wells at the NASA White Sands Test Facility (formerly the Apollo Test Site), is shown in Figure 3. The San Andres Mountains consist mainly of Paleozoic carbonates, sandstones, and mudstones; however, Tertiary conglomerate, andesite, monzonite and rhyolite, as well as Precambrian pegmatite, granite, and schist are also present in places (Figure 2).

Soils of the study area include mollisols in the stable areas along the mountain front, aridisols on the stablest portion of the piedmont slope and basin floor, vertisols in small local playas, and entisols on the young, steep, less stable slopes. The specific soils present include the Nickel-Tencee-Del Norte, the Berino-Pintura, and the Headquarters-Jal associations [7]. According to Gile *et al.* [4], the Nickel and Jal are calciorthids, the Tencee and Del Norte are typic paleorthids, the Berino is a typic haplargid, the Pintura is a typic torripsamment, and the Headquarters is a ustollic haplargid.

The vegetation covering a 144,475 acre portion of the Jornada Experimental Range was surveyed in 1963 [8]. Mesquite was found to be the dominant plant, constituting 50.3% of the vegetation present; creosote accounted for 14.2%, and tarbush 8.6%. The remaining 26.9% of the vegetation included various other shrubby plants, cacti, yuccas and grasses.

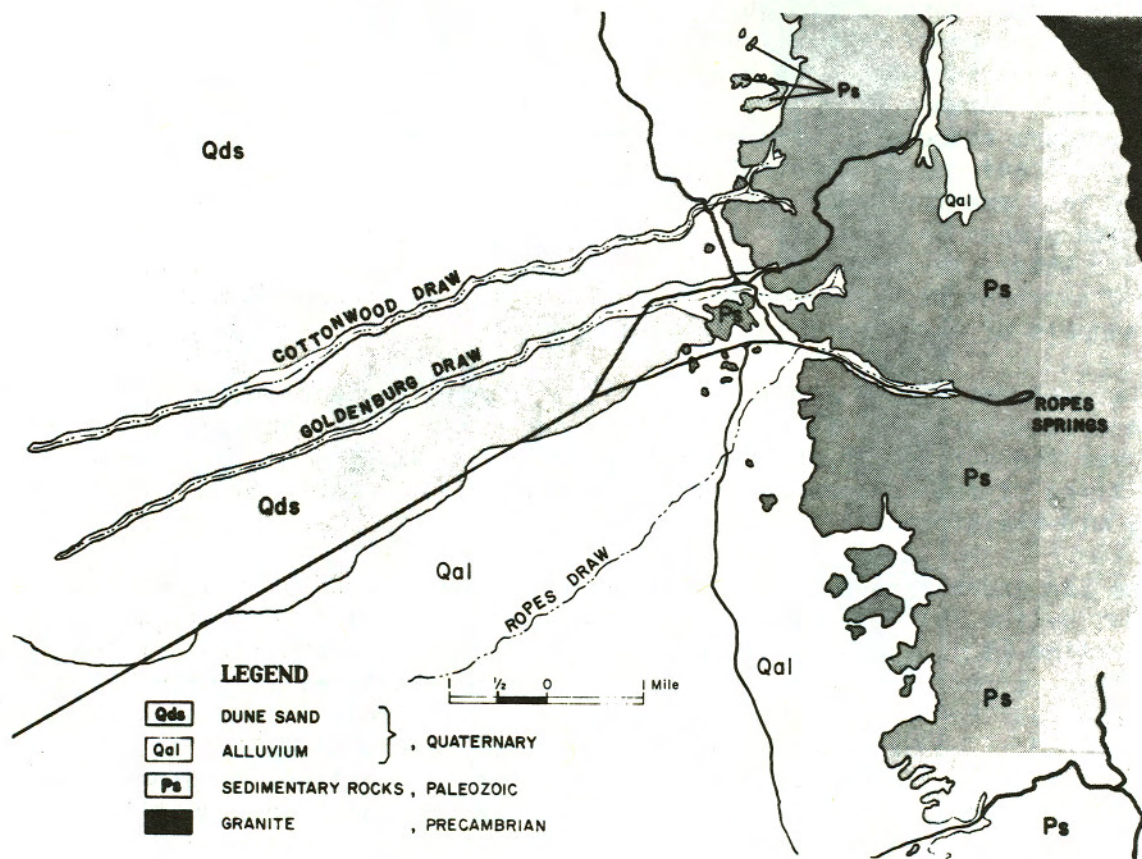


Figure 2. Geologic map of study area (modified from Bachman and Myers [3]).

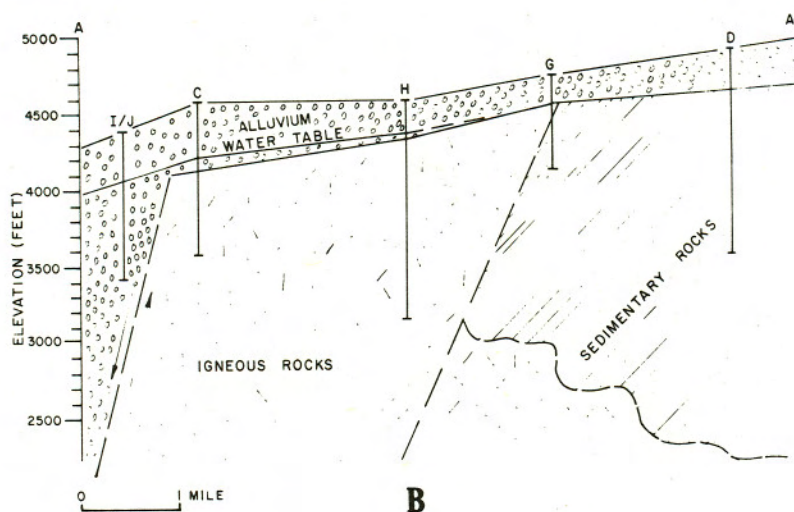
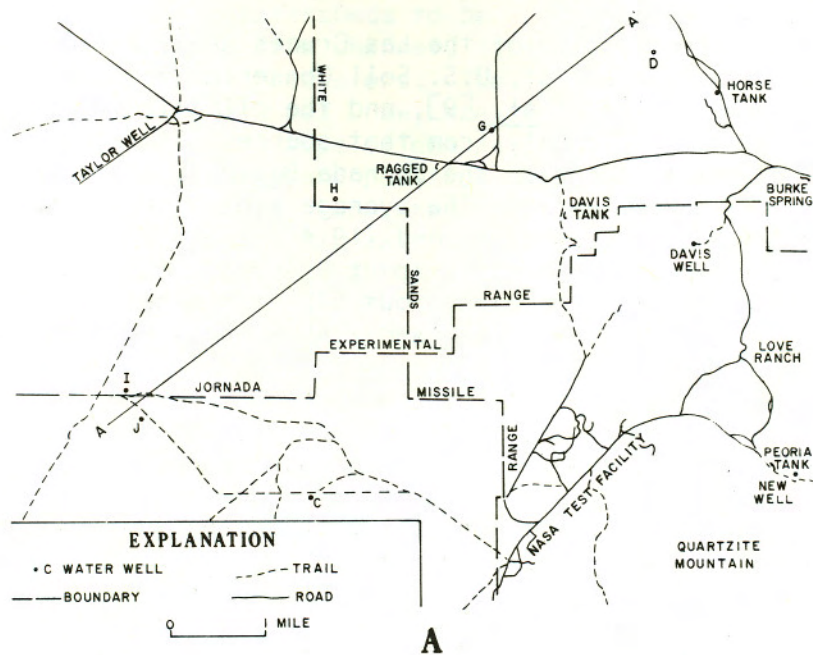


Figure 3. Subsurface geology in the vicinity of the NASA Test Facility (data from Doty [6]): a) location of wells used, b) cross-section.

A good summary of the climate of the Las Cruces area, as compiled by Leland H. Gile, soil scientist, U.S. Soil Conservation Service, Las Cruces, was given in King et al. [9], and the climatic information which follows was drawn largely from that source. The study area includes two types of climate: the Jornada Basin is arid, and the San Andres Mountains are semi-arid. The average annual precipitation in the basin, based on 52 years of record (1914 - 1966) at the Jornada Experimental Range Headquarters, is about 9 inches. The months of July, August and September provide about 54% of the annual rainfall, with monthly averages of 1.75, 1.68 and 1.45 inches, respectively.

The average annual relative humidity, measured at New Mexico State University (NMSU), Las Cruces, is less than 50%, and ranges from an average of 30% during the warmest hours of spring and early summer days to an average of about 60% in some early morning hours. Pan evaporation averages 97 inches per year at NMSU and 90 inches at the Jornada Experimental Range Headquarters.

The average annual temperature is 60°F with an average daily range of 30°F. Summer daytime temperatures reach 90°F or higher about 101 days a year or 28% of the time. The record high temperature at WSMR (during the period 1950 - 1968) is 105°F, which has been recorded in both June and July [10]. The coolest month is January, during which the average daily minimum is 25°F and the maximum 57°F. The record low temperature for the area is -10°F, which occurred on 11 January 1962.

SITE SELECTION

The western flank of the San Andres Mountains was selected as the study area for several reasons. This area is separated from the main part of the missile range by mountains, and access is therefore not interrupted by test firings. Likewise, the use of aircraft and photography are less restricted on this part of the range. Furthermore, because of this easier access, previous studies of the geology, groundwater, soils, and vegetation in the area have been carried out, and useful published reports and maps are available.

Another advantage to conducting hydrometeorologic studies in this area is the close proximity to the Jornada Experimental Range. Rainfall data have been collected at various sites on this range since 1935 and at the Headquarters since 1914. An evaporation station has been in operation at the Headquarters since 1929. Furthermore, numerous water wells on the Jornada Range, as well as at the NASA White Sands Test Facility, provide essential groundwater information. Roads in the area are unimproved but fairly well maintained by the Wildlife Refuge and Jornada agencies. The supporting literature, backlog of hydrometeorologic data, network of water wells, and system of roads found here are not available anywhere else on the missile range.

Selection of the specific watersheds to be instrumented was based on the condition and length of the channel, type of channel sediment, ease of access, and position of headwaters. The two watersheds selected for study, Cottonwood Draw and Ropes Draw, are representative of drainage in the study area as regards type of channel sediment, surficial sediment adjacent to the channel, and position of headwaters. Cottonwood Draw is approximately 10 miles long, has its source in the foothills or front range of the San Andres Mountains, and flows across an area dominated by eolian sand and dunes (Figure 2). Ropes Draw is about 9 miles long, has its source in the main range of the San Andres Mountains, and flows mainly through gravel (Figure 2). Although the two watersheds have somewhat different shapes, both have an area of about 9 square miles (Figure 4).

To insure records of as many flows as possible, individual stream gages were placed along relatively straight reaches of the channels on the bank which seemed to be favored by low flows. The sites of the upper Cottonwood and middle Ropes stream gages were selected such that they would be downstream from the intersections of the major tributaries. The site for the upper Ropes gage, although above some major tributaries, was selected because it lies at the upper edge of the piedmont slope, where discharge of this stream may be measured as it leaves the mountains and before appreciable transmission loss occurs from flow across the porous piedmont alluvium. The lowermost stream gages were installed as far downstream from the last station above as possible to facilitate the study of transmission loss. Limiting factors included condition of the channel and ease of access by travel down the channels. The upper and lower Cottonwood stream gages are about 3 miles apart and the lower two gages on Ropes Draw are about 1 mile apart.

INSTRUMENTATION

The instruments constituting the WSMR hydrometeorologic ground truth facility are spread over a 50-square-mile area and include eight recording rain gages, nine nonrecording rain gages, five recording, flood stage stream gages, five self-siphoning sediment samplers, one recording water well monitor, three evaporation stations, and six runoff plots, three at each of two sites. In addition to the equipment listed above, there are 26 cased holes for measurement of soil moisture with a neutron probe. All of this equipment, except that in the evaporation stations and runoff plots, is provided, operated, and maintained under contract by the United States Geological Survey (USGS), Albuquerque. The distribution of the instruments is shown in Figure 4 and on Plate 1.

Rain Gages

The recording rain gages used were designed by the USGS and consist of a standpipe and float apparatus connected to a battery-operated, Fischer and Porter Series 35-1540 recorder (Figure 5). With these devices, the

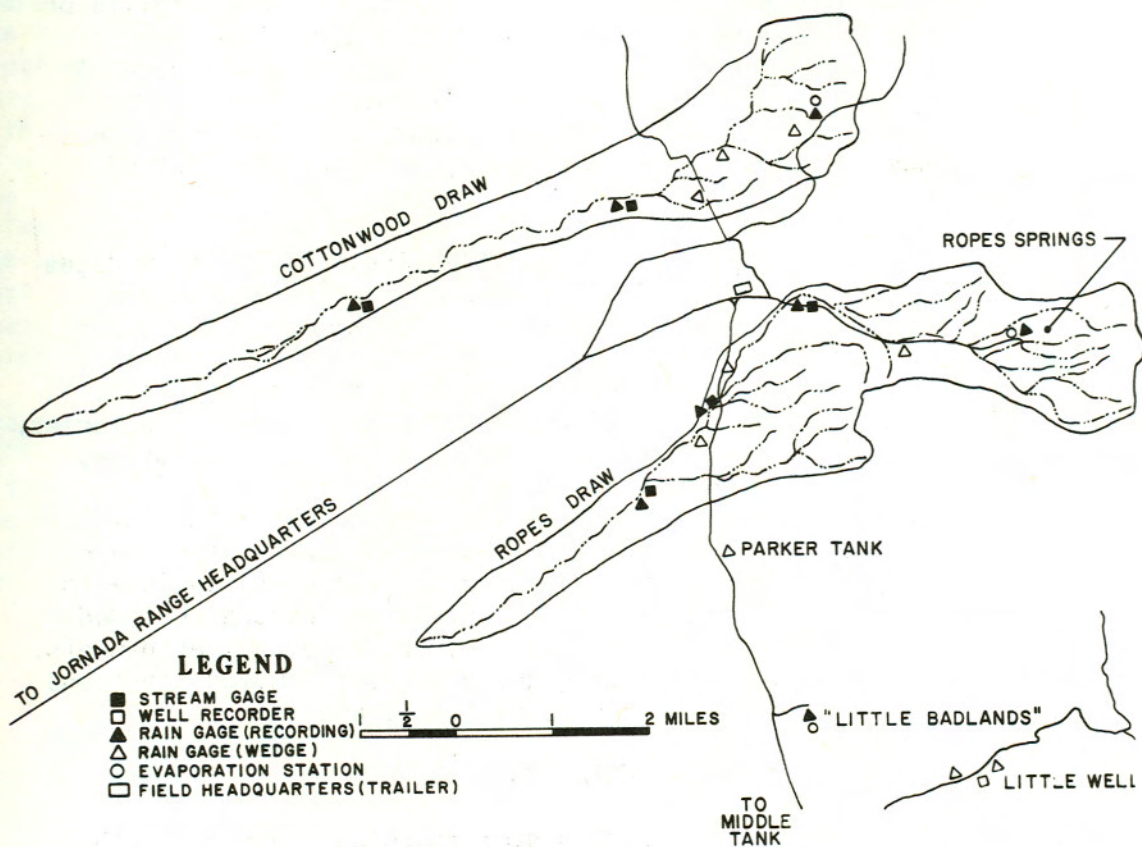


Figure 4. Map of watersheds under study showing distribution of instruments.

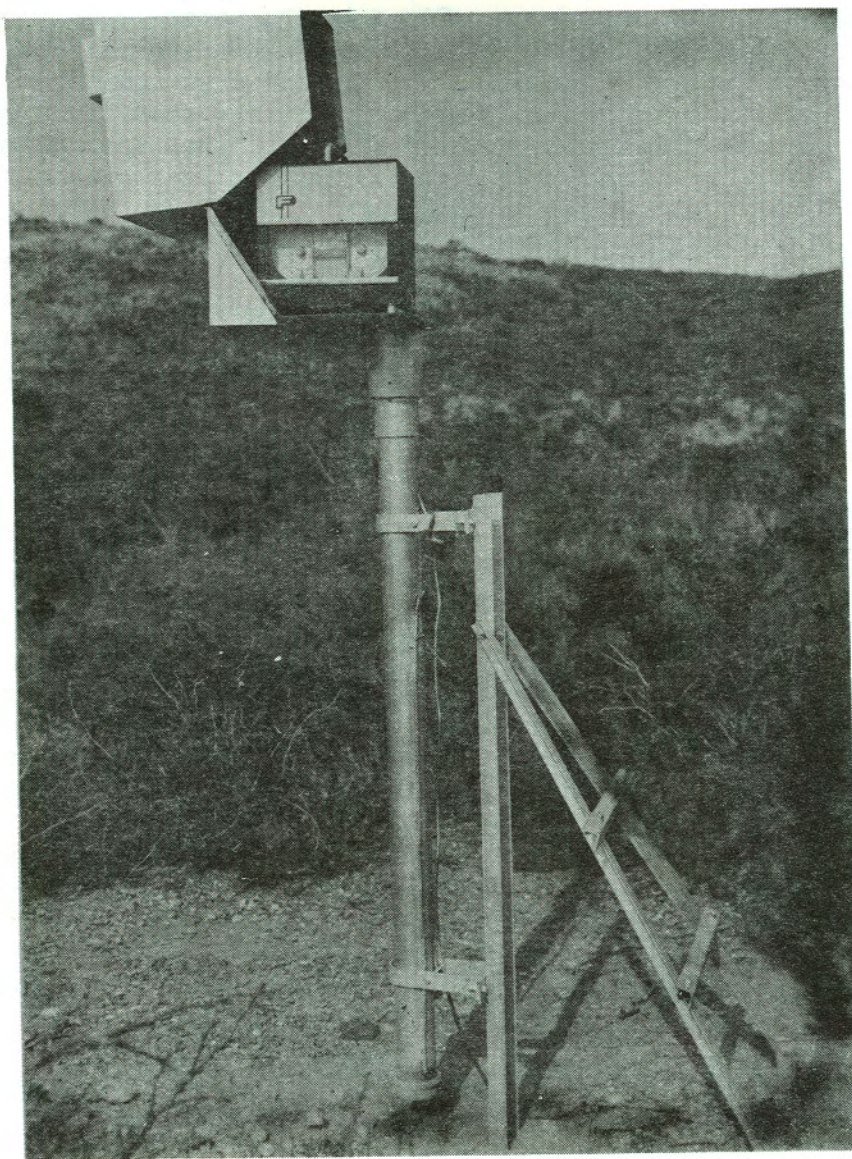


Figure 5. Typical recording rain gage at the upper Ropes Draw Site with shelter lid raised to show the recorder.

position of the water level in the standpipe is continuously punched onto paper tape (Figure 6). During the summer rainy season, the data are punched every 5 minutes; in the dry winter months, the precipitation data are only recorded every hour. Rises in the water level in the standpipe correspond to precipitation. Eight recording rain gages of this type were installed: one at each of the five stream gage sites, where both the rain and stream gages are run by the same clock to assure synchronous records; two in the mountains, one at the upper extremity of each of the two watersheds under study; and one in the area of intense erosion and badlands development in the southern part of the study area, hereafter called the "Little Badlands."

To supplement this network of recording rain gages, nine nonrecording "Tru-Check," plastic, wedge-type rain gages (Figure 7) were placed at various positions throughout the study area: three in the Cottonwood Draw watershed, four in the Ropes Draw watershed, one in the vicinity of the "Little Badlands," and one at Little Well, the site of the recording water well monitor. Rainfall data is therefore provided by a network of 17 gages. The overall spacing of these gages ranges from less than a half mile to about 3 miles; within a given watershed, gages are about 1 mile apart.

Stream Gages

The stream gages are identical to the recording rain gages, except that the water level they monitor is that in the adjacent stream channel during intermittent flow events. During such flows water enters the standpipe through holes at the bottom (Figure 8). Five stream gages were installed: two in the Cottonwood Draw watershed and three in the Ropes Draw watershed (Figure 4). As a precaution against washout, the legs of the stream gages were anchored in a cubic yard of concrete. Each stream gage is accompanied by a recording rain gage (Figure 9) and a crest stage gage (added summer 1973).

Soil Moisture Sites

Antecedent soil moisture data are provided by Troxler neutron probe equipment (a Model 1255 Depth Gage and a Model 2601 Scaler) and twenty-six 20-foot holes. Twenty-one of these are utilized for channel moisture measurements and are distributed at three sites: one on Cottonwood Draw and two on Ropes Draw (Figure 4 and Plate 1). These sites consist of seven holes each, drilled in a cross-shaped pattern: three of the holes aligned along the middle of the channel, and two holes on each bank of the channel opposite the middle channel hole. All holes are spaced 1 channel-width apart. Each hole is cased with plastic pipe and capped top and bottom (Figure 10). For protection against damage by large boulders, the tops of the pipes in the channel were enclosed in a 3-foot length of cast-iron pipe set in concrete (Figure 11). Access to the holes is gained through removable caps on both the cast-iron and plastic pipes.

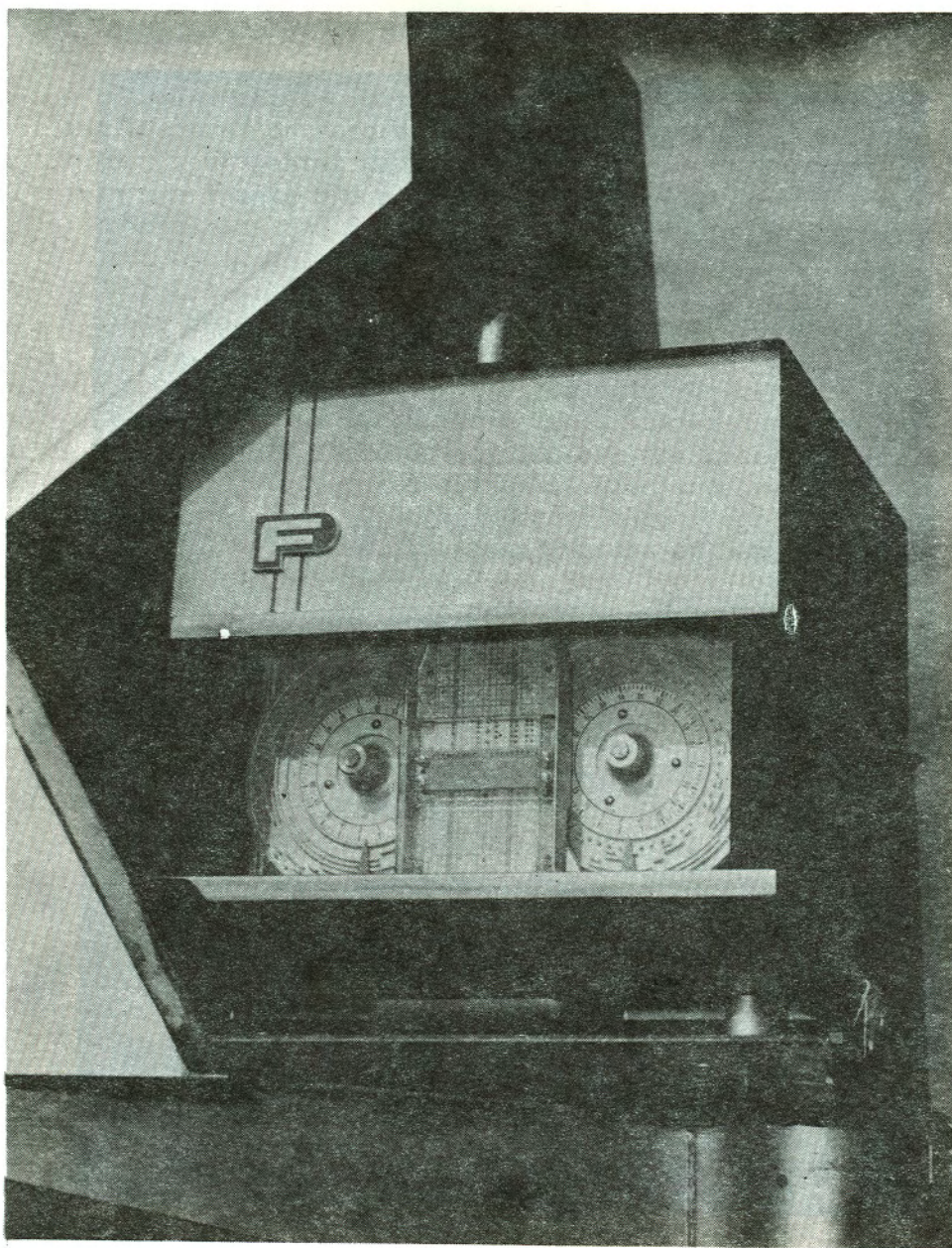


Figure 6. Close-up of Fisher and Porter paper tape recorder as used in both the recording rain gages and stream gages.



Figure 7. Plastic, wedge-type, non-recording rain gage, at Parker Tank Site, as used to supplement the recording rain gage network.



Figure 8. Typical stream gage at the middle Ropes Draw Site, with shelter lid raised to show the recorder and upper end of the float mechanism; channel water enters the floatation tube through the small holes at the bottom.

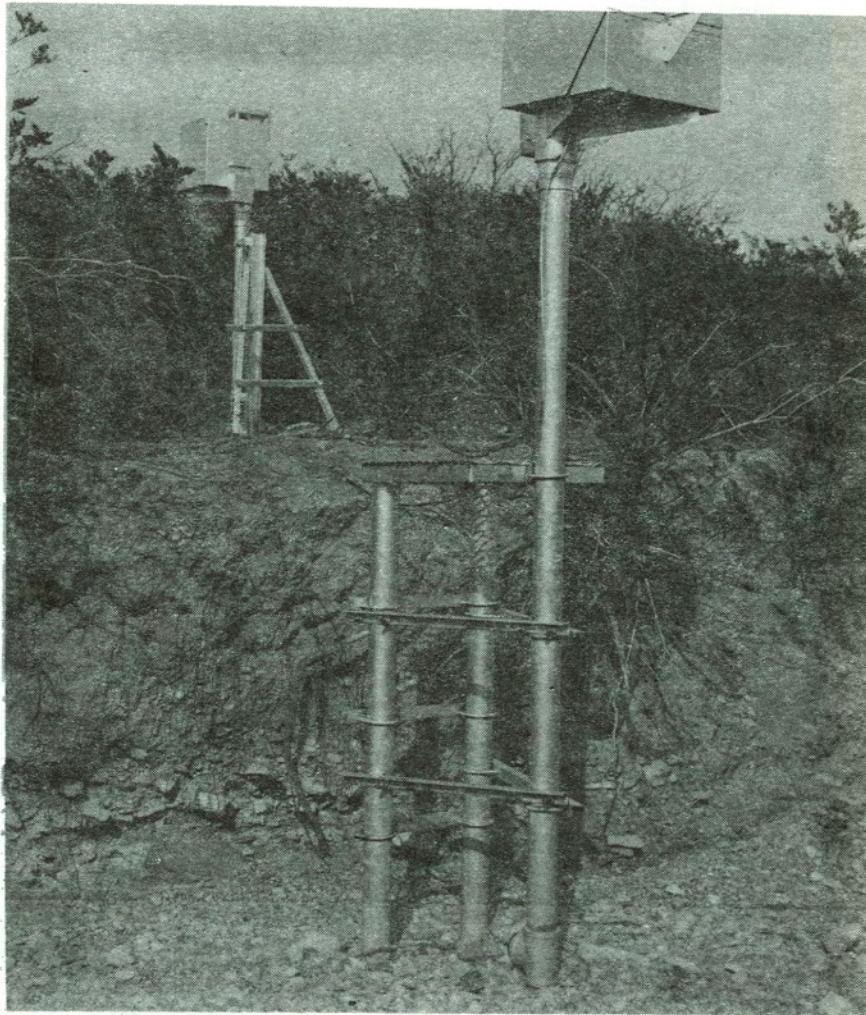


Figure 9. Typical stream and rain gage combination at the middle Ropes Draw Site; both gages are operated by the same clock for synchronous precipitation/runoff records.



Figure 10. Close-up of upper end of soil moisture tube as installed on bank adjacent to channel at upper Ropes Draw Site showing plastic pipe with which hole is cased.



Figure 11. Close-up of upper end of soil moisture tube as installed in channel at upper Ropes Draw Site showing cast-iron sleeve added to prevent washout.

In addition to these channel sites, five soil moisture holes were drilled at the "Little Badlands" erosion study site; one at the overflow of an earthen dam on the main channel of the adjacent drainage, three holes respectively positioned 100, 120, and 140 feet east of the headwall of the badlands, and one hole located about 120 feet west of a north-south trending earthen structure at the western edge of the badlands.

Calibration of the depth gage will be facilitated by the use of a "mini-geophysical logger" belonging to the USGS. Neutron, gamma, and gamma-gamma logs made with this instrument will also aid in determining both the position and lithology of moisture-bearing zones to be regularly monitored with the depth gage. Plans are also under way to obtain a Troxler Model 1207 surface soil moisture gage for measurements in the channels near the cased holes and elsewhere, especially adjacent to rain gages. This additional tool is required because the depth gage does not give reliable readings in the upper foot or so of the cased holes.

Sediment Samplers

Self-siphoning sediment samplers, designed by the USGS, were installed at each of the five stream gage sites. They consist of a series of glass, pint milk bottles fastened to the back of a piece of large, heavy-duty angle-iron erected vertically in the channel with its apex pointing upstream (Figure 12). The intake of sediment-laden water and exhaust of air from a given bottle are accomplished simultaneously with two pieces of 1/2-inch diameter copper tubing which pass through holes in the angle-iron and have their open ends upstream (Figure 12). The bottles are arranged so as to collect suspended sediment at 1-foot intervals above the stream bed. As installed, the samplers stand 5 feet high and thus permit the collection of five samples. To prevent washout, the angle-iron rests in a cubic foot of concrete. In addition to providing suspended sediment data, these samplers also serve as checks of maximum water height during a flow.

Water Well Monitors

When the work for the first field season (summer 1972) was being planned, it was hoped that the water level could be monitored in at least three wells on the western San Andres piedmont slope. However, as might be expected, any wells having sufficient water to monitor were pumped daily with windmills, thus ruling out the use of float-type recording instruments. Although these wells cannot be monitored continuously, they provide useful information during periodic ground water surveys (summer and winter). The single recording instrument used during the first field season was installed at Little Well in the mountains near the mouth of Ash Canyon (Figure 13). This is an old well consisting of a 4-foot square hand-dug shaft. The water surface generally lies at a depth



Figure 12. Typical self-siphoning sediment sampler in channel at upper Ropes Draw Site. Upstream is toward the right; intake tubes are one-foot apart.



Figure 13. General view of Little Well, the site of the water-level recorder.

of 10 feet below the surface. The water level is recorded by means of a Stevens Type A-30 continuous water-level recorder, which consists of a float mechanism attached to a strip chart recorder (Figure 14).

Evaporation Stations

Evaporation information is provided by three modified Weather Bureau Class A evaporation stations installed at the upper Cottonwood Draw, upper Ropes Draw, and "Little Badlands" recording rain gage sites. In addition to these recording rain gages, each evaporation station consists of a standard 4-foot diameter pan resting on a standard 4-foot square platform, an MRI model 1071 recording mechanical weather station (which gives wind run, wind direction, and temperature), and a nonrecording rain gage (Figure 15). The water level in each pan is measured by means of a hook gage in a stilling well (Figure 16). Water temperature is given by a floating maximum/minimum thermometer. Wind run at pan level is provided by a recording anemometer.

At each station, all instruments except the recording rain gage are located inside a 20-foot square barbed wire enclosure. The taller instruments have been placed on the north side of the enclosures to avoid shadows across the pans. The fence is 4 feet high and "rodent-proofed" by the presence of 3 feet of chicken wire around the base of the fence, the lower foot of which has been bent away from the fence and buried parallel to the surface. To avoid the problem of rodent burrowing at gates, entrance to the enclosures is provided by stiles rather than gates.

Runoff Plots

An evaluation of runoff/infiltration conditions in the study area is made possible by two sets of runoff plots installed in the summer of 1973, one on the sandy surficial sediment in the Cottonwood Draw watershed and one on the gravelly surficial material in the Ropes Draw watershed. Both sites are located on south facing slopes of similar magnitude and at similar elevations or positions on the piedmont slope. The Cottonwood Draw runoff plot site is located near the Cottonwood Springs wedge gage just south of the sideroad to Cottonwood Springs about 3/4-mile north of the adobe ruins of the old Goldenburg Ranch (Plate 1). The Ropes Draw site is located south of the main road to Ropes Springs, directly opposite its intersection with the road to the northern sites, about midway between the trailer used as the project field office and the upper Ropes Draw Stream gage site (Plate 1).

Each runoff plot site consists of three 6x12-foot sheet metal plots, three nonrecording, plastic wedge-type, rain gages, and a recording weather station as used at evaporation stations. Runoff from each plot is caught in a 50-gallon drum, where it is measured by means of a Stevens Type F, float-type water level strip-chart recorder attached to the drum. Soil moisture in the plots will be measured with the Troxler Model 1207 neutron type surface moisture gage mentioned above.

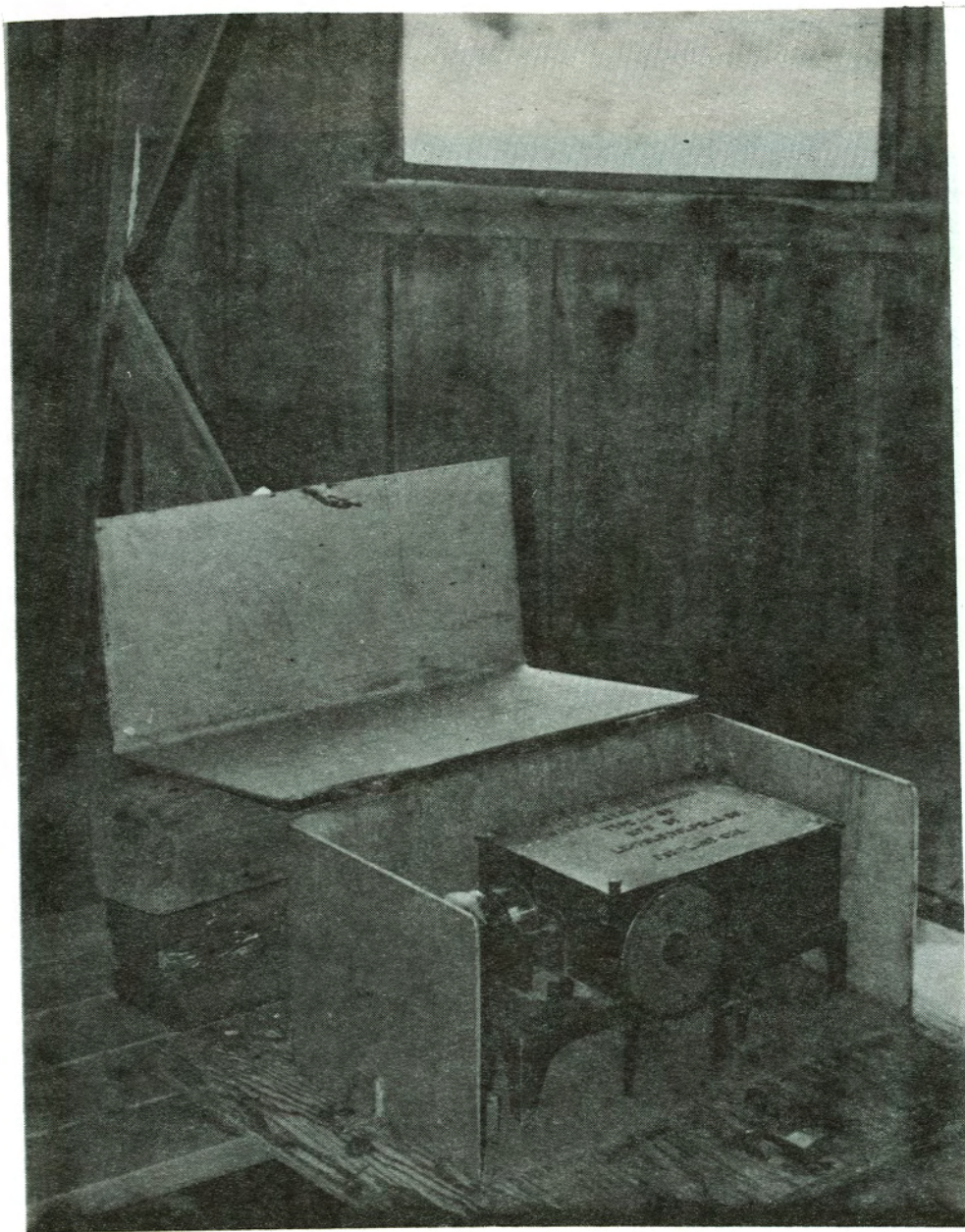


Figure 14. Close-up of the water-level recorder at Little Well.



Figure 15. General view of a typical evaporation station at the upper Cottonwood Draw Site.



Figure 16. Close-up of the pan and recording weather station at the upper Cottonwood Draw Site.

The design of the plots was modified from plans provided by the ARS Southwest Watershed Research Center, Tucson, Arizona, and the plots used in this study are therefore similar to those in use at the ARS Walnut Gulch Experimental Watershed, Tombstone, Arizona.

Radar Support

Valuable support of the data collection effort will be provided by an AN/CPS-9 storm detection ground radar. This will be used to sense potential rain-producing storms over the study area such that field personnel may be alerted in time to be on hand to make necessary flow velocity measurements. The radar has the capability of plotting precipitation areas within a 250-mile radius of its fixed position (tentatively planned to be the Las Cruces Municipal Airport) and can be operated 23 hours per day over extended periods.

MAINTENANCE AND DATA HANDLING

During the first field season (summer 1972), the USGS maintained their instruments with several field teams of two technicians each. A given team was at the facility a week at a time with a new team starting each Monday. In addition to maintaining the recording instruments, these teams read the nonrecording rain gages each morning, took direct velocity measurements and made slope-area surveys of flows, whenever possible, and collected the suspended sediment samples after each flow.

The type and format of all data provided by the WSMR hydrometeorologic ground truth facility are summarized in Table I. Data from the first field season includes that punched on paper tape by the recording rain and stream gages and that collected from the nonrecording instruments. Data from the digital recording instruments are being put onto magnetic tape by the USGS, Washington. Data from the strip chart recorders and the nonrecording instruments are being punched onto cards at WSMR for transfer to magnetic tape. Equipment is now being built by engineers of the Meteorological Satellite Technical Area, ASL, which will permit the transfer of data from the punched paper recorder tapes to standard magnetic computer tape at WSMR. This will eliminate the long turnaround time required for the data to go through processing by the USGS, Washington. Plans are also under way to develop the capability of recording the data with cassette type magnetic tape recorders and then transferring this data to standard magnetic tape at WSMR.

Copies of all data are provided to ASL, WSMR, the USGS, Albuquerque, and the Agricultural Research Service (Jornada Experimental Range) at Las Cruces. The surface water data will be published by the USGS in their annual "Water Resources Data for New Mexico, Part I, Surface Water Records." Interpretive and data reports will be prepared by ASL, WSMR. The modeling of the watersheds will involve the use of a modification of the Stanford parametric watershed model, possibly that used by the USGS [11]. A number of other such models are also currently under consideration.

TABLE I

SUMMARY OF TYPE AND FORMAT OF DATA PROVIDED BY THE WSMR HYDROMETEOROLOGIC GROUND TRUTH FACILITY

Parameter	Instrument	Number	Frequency of Measurement	Raw Data Format
RAINFALL	Recording: USGS Float-type gages with Fisher and Porter Series 35-1540 digital punched tape recorders.	8	Tapes changed monthly; partial tapes may be collected at any time; cumulative total may be read at any time.	Punched paper tape.
	Nonrecording: Plastic wedge-type gages.	9	Read daily in early morning and after all storms.	Hand written data sheet.
STREAMFLOW	Recording: USGS Float-type gages with Fisher and Porter Series 35-1540 digital punched-tape recorders.	5	Tapes changed monthly; partial tapes may be collected at any time; cumulative total may be read at any time.	Punched paper tape.
	Nonrecording: Crest stage gages (powdered cork and staff in pipe).	5	Flood crest height read after each storm for which flow occurs.	Hand written data sheet.
SOIL MOISTURE	Depth: Troxler model 1255 neutron depth probe and model 2601 scaler.	1	Readings taken weekly; frequency dependent upon rate of moisture movement and storm frequency.	Hand written data sheet.
	Surface: Troxler model 1207 surface moisture gage and model 2601 scaler.	1	Readings taken weekly; frequency dependent upon rate of moisture movement and storm frequency.	Hand written data sheet.

TABLE I (Con.)

Parameter	Instrument	Number	Frequency of Measurement	Raw Data Format
SUSPENDED SEDIMENT	USGS Self-siphoning sediment samplers.	5	Bottles collected after each flow.	Samples analyzed by USGS Albuquerque; data consists of total sediment load in ppm.
WATER TABLE	Stevens type A-30 Float type water level strip chart recorder.	1	Charts changed monthly.	Strip chart of water level.
EVAPORATION	Water Loss: Hook gages in stilling wells.	3	Read weekly.	Hand written data sheet.
	Water surface temperature: Floating max/min thermometers.	3	Read weekly.	Hand written data sheet.
	Pan level wind run: Recording anemometers.	3	Read weekly.	Hand written data sheet.
	Basic weather data: Automatic recording MRI weather stations.	3	Charts changed monthly.	Strip chart of wind direction & velocity & temperature.
RUNOFF	6x12-foot plots with Stevens type F float-type water level strip chart recorders installed in collection barrels.	6	Charts changed weekly.	Strip chart of water level in collection barrels.

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ATTN: Code 6530, H. Shenker
Washington, D. C. 20390

Mr. E. F. Corwin
Head, Met Research Branch
Meteorological Division
Naval Air Sys Cmd (AIR-5401)
Washington, D. C. 20360

Commanding Officer
US Army Combat Dev Cmd
Intelligence Agency
ATTN: CDCINT-P, Cpt Thoresen
Ft. Huachuca, Arizona

Director
US Army Advanced Materiel Concepts Agency
2461 Eisenhower Avenue
Alexandria, VA 22314

University of Oklahoma
Research Institute
Field Artillery Research Off
P. O. Box 3124
Ft. Sill, OK 73503

Dir US Naval Research Lab
ATTN: CODE 6530, H. Shenker
Washington, D. C. 20390

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