Documentation for
SELECT PRECIPITATION/RUNOFF
EVENT DATA SETS
from the USDA-ARS
Walnut Gulch Experimental Watershed
near Tombstone, Arizona 4/13/93

Documentation for

SELECT PRECIPITATION/RUNOFF EVENT DATA SETS

Data Sets of Runoff and Associated Precipitation Collected at the U.S.D.A. - ARS Walnut Gulch Experimental Watershed Tombstone, Arizona

Compiled by

Southwest Watershed Research Center
U.S.D.A. - ARS

in cooperation with the
Flood Control District of Maricopa County

1993

ACKNOWLEDGEMENT

The sincerest appreciation is extended to the staff of the Southwest Watershed Research Center and the Tombstone field office. Their diligent and dedicated efforts have made the existence of high-quality, long-term data records of the Walnut Gulch Experimental Watershed possible.

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I. INTRODUCTION

A. Purpose of the Document

In March 1992, the Flood Control District of Maricopa County (FCDMC) and the United States Department of Agriculture, Agricultural Research Service (ARS) entered into a cooperative agreement for the purpose of establishing a program to temporarily facilitate the analysis of hydrologic data already collected by the ARS. Specifically, the ARS would select subsets of data in the areas of rainfall/runoff, watershed infiltration, and channel transmission losses from which runoff, soil hydraulic, and channel loss parameters would be developed and reported to the FCDMC.

One of the project tasks (Task 5.3) within the cooperative agreement was the selection of a subset of high quality rainfall and runoff data collected at Walnut Gulch. The quality criteria for the data set to be supplied to the FCDMC as specified in Task 5.3 are as follows:

Task 5.3: Check raw data from Walnut Gulch Experimental Watershed (WG), select a subset of high quality data, and develop a set of runoff data over a range of scales.

1. Prepare a program to reformat database rainfall and runoff data into a format acceptable to the DISTRICT (the Flood Control District of Maricopa County.)
2. Prepare and check data for each sub-watershed:
   a. select roughly 30 target events that cover a range of event sizes based on runoff.
   b. check the runoff record for each target event to ensure that
      1. each of the events occurred under comparable management and instrumentation conditions.
      2. less than 10% of the hydrograph was estimated.
      3. clock timing errors are < +/- 10 minutes.
   c. list all raingages associated with the sub-watershed under investigation.
   d. for each of the target events, check to see that 90% of the associated raingages were operating properly under the following criteria:
      1. less than 10% of the hyetograph was estimated.
      2. clock timing errors are < +/- 10 minutes.
   e. reformat all data in a format acceptable to the DISTRICT.
3. Repeat procedures in step 2 for sub-watersheds of increasing size.

This document serves as documentation of the process developed and final data sets collected and presented to the FCDMC in fulfillment of Task 5.3, and constitutes a portion of the Final Report of the Flood Control District of Maricopa County and USDA-ARS Cooperative Agreement (submitted under a separate cover) and is to be presented to the FCDMC on April 6, 1993.

B. Organization of the Document

Part II begins with a description of the research carried out at the Walnut Gulch Experimental Watershed (Walnut Gulch). This is followed by a brief description of Walnut Gulch, the instrumentation there, the processing of Walnut Gulch data, and the resulting ARS database from which the precipitation/runoff data sets were selected. It is important to note that due to its location, the data collected at Walnut Gulch is associated with warm-weather monsoon-type, intense but highly localized convective precipitation which is the predominate precipitation pattern in southeastern Arizona. This type of precipitation produces usually brief, intense, silt-laden flows within the steep, normally dry stream channels. The data sets supplied to FCDMC reflect these conditions.

Part III pertains to the select high-quality data sets provided to the FCDMC. Definitions, assumptions, and checking procedures used to select appropriate data sets are described. A description of the format of the data is presented as well as a description of the file, record, and field structure of the data sets.

In Part IV, each of the sub-watersheds within Walnut Gulch for which data were collected is described, figures illustrating the sub-watershed and raingage configurations are presented, and pertinent information regarding each sub-watershed is noted.

Appendices referred to within this document are contained in a separate document. The appendices contain runoff gage and raingage locations (UTM coordinates), sub-watershed and pond areas, tables summarizing the runoff data for each sub-watershed, graphical representations of each selected event for each sub-watershed, and tables which list the daily precipitation totals for a five-day period prior to the selected events for each sub-watershed. A hard-copy of all the selected data sets is also contained within the appendices. A 3½-inch high density write-protected diskette which contains the data sets, antecedent precipitation tables, and runoff summary tables is located inside the back cover of the document containing the appendices.

Any questions regarding the selected data sets can be referred to Dr. David C. Goodrich, Southwest Watershed Research Center, USDA-ARS located at 2000 E. Allen Road, Tucson, Arizona, 85719-1596, (602)670-6481 (phone) or (602)670-5550 (FAX).

II. THE WALNUT GULCH EXPERIMENTAL WATERSHED AND ITS DATA

A. The Walnut Gulch Experimental Watershed

1. Mission Statement

Establishment of the Walnut Gulch Experimental Watershed was initiated in 1954 with the purpose of researching the role of watershed management on downstream water yield. Generally, scientist conduct research on technology to enhance conservation and optimize resource utilization in arid and semiarid regions. The research involves developing fundamental principles of the plant-soil-water-animal relationships and tools for transferring the technology to areas having little or no research data. Emphasis is on understanding processes and developing:

* Point and areal precipitation characteristics and their relationships to plant growth and runoff and erosion processes.

* Models of plant-soil-water-air-animal interactions of the rangeland biotic components under conditions of limited moisture and nutrient supplies.

* New technology for vegetation manipulation on rangelands and abandoned farmlands for conservation of soil and water resources.

* Models to describe the hydraulics of runoff from complex watersheds for predicting flood and water yield characteristics.

* Improved models for erosion prediction technology applicable on arid and semiarid watersheds.

* Technology for assessing erosion rates and evaluating the influence of erosion control methods on runoff, water quality, and soil productivity.

* Principles describing sediment, chemical, and nutrient transport, channel morphology, and spatially varied flow in alluvial channels and sediment yield from arid and semiarid watersheds.

* Models to quantify responses from management systems; to make management decisions; and to transfer data and ideas to other areas.

Examples of the uses of the information from the studies include: establish soil, water, and land management systems; increase and stabilize plant cover; determine the present and future water resource potential of arid and semiarid regions; provide design concepts and criteria for flash flood and sediment control; manage the yield and quality of water for competing local and downstream users.

The research team includes agronomists, soil scientists, hydraulic engineers, hydrologists, mathematicians, and computer scientists. Research is conducted in active cooperation with other federal, state and local agencies, universities, national laboratories and private individuals.

2. Watershed Description

The following description is excerpted from Renard, et. al (1993), (unit conversions in parenthesis have been added):

> The Walnut Gulch Experimental Watershed encompasses the 150 square kilometers (about 58 square miles or 37000 acres) in southeastern Arizona, U.S.A. (31°43'N, 110°41'W) (Figure 1) that surrounds the historical western town of Tombstone. The watershed is representative of approximately 60 million hectares of brush and grass covered rangeland found throughout the semiarid southwest and is a transition zone between the Chihuahuan and Sonoran Deserts. Elevation of the watershed ranges from 1250 m (4100 ft.) to 1585 m (5200 ft.) MSL. (Figure 2) Cattle grazing is the primary land use with mining, limited urbanization, and recreation making up the remaining uses. Within the USDA-ARS national hydrologic database, Walnut Gulch is designated as Location 63. With this convention Watershed 1 at Walnut Gulch is designated as Watershed 63.001, and so on for the other sub-watersheds...
>
> *Geology*
>
> The Walnut Gulch watershed is located primarily in a high foothill alluvial fan portion of the larger San Pedro River watershed. Cenozoic alluvium is very deep and is composed of coarse-grained fragmentary material, the origin of which is readily traceable to present-day mountain flanks on the watershed. The alluvium consists of clastic materials ranging from clays and silts to well-cemented boulder conglomerates with little continuity of bedding. This alluvial fill material is more than 400 m (1300 ft) deep in places and serves as a huge ground water reservoir. Depth to ground water varies greatly in the watershed ranging from 50 m (150 ft) at the lower end to 145 m in the central parts of the watershed (Libby et al., 1970). Topographic expression of the alluvium is that of low undulating hills dissected by present stream channels whose routes are controlled by geologic structures. Upland slopes can be as great as 65% while slopes in the lower lying areas can be as small as 2 to 3%. Major channel slopes average about 1% with smaller tributary channels averaging 2 to 3%.
>
> The remaining mountainous portion of the watershed consists of rock types ranging in age from pre-Cambrian to Quaternary, with rather complete geologic sections. Rock types range from ridge-forming limestone to weathered granite intrusions. The geologic structural picture of the mountainous area is complex, with much folding and faulting. This folding and faulting, along with igneous intrusions has resulted in large areas of shattered rock, which influence the watershed hydrology.
>
> The watershed hydrology is, in places, controlled by past geologic events and structures. Intrusive igneous dikes in the Tombstone Hills influence ground water movement, as well as change the surface drainage. The Schieffelin granodiorite alters the course of the Walnut Gulch main stream, acts as a probable ground water barrier between the ground water in the Tombstone Hills and the deep alluvial basin, and has caused numerous small perched water tables along its perimeter. Highly compacted conglomerate beds greatly alter the path of stream channels and, in places, divert streams at more than right angles. High angle faults form new paths for streamflow, making channels arrow-straight in some places and causing diversions in others.

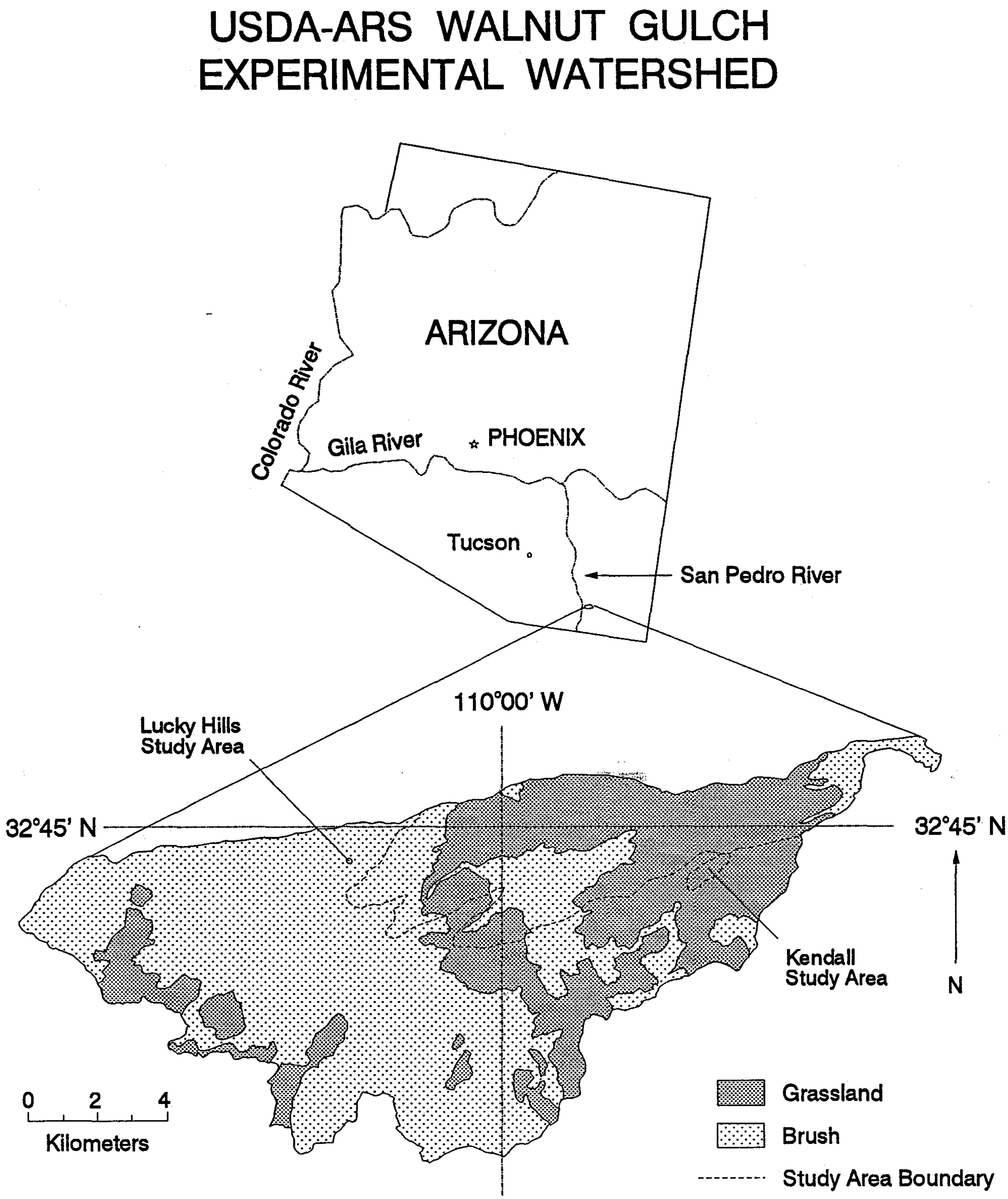


Figure 1. Location Map

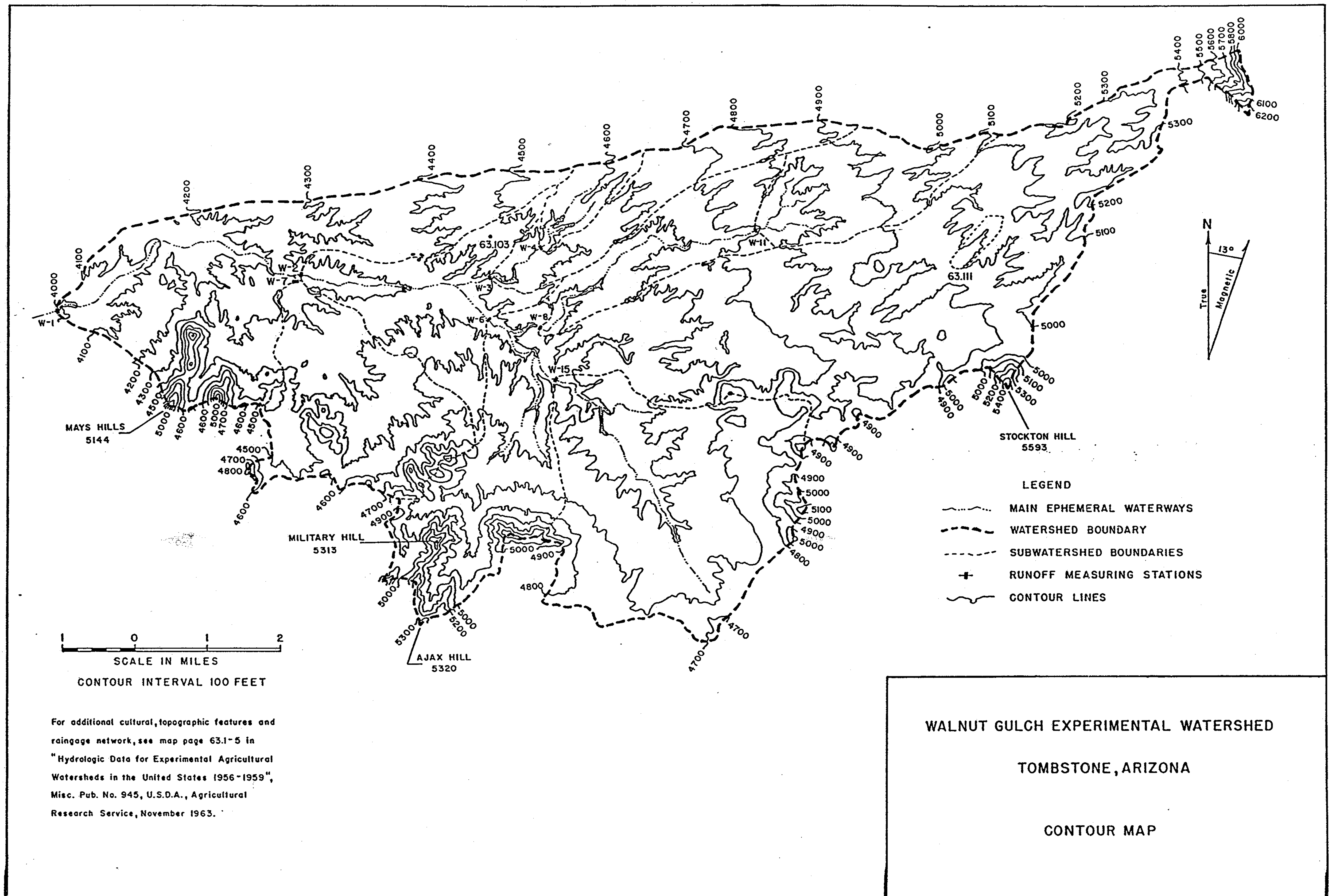

WALNUT GULCH EXPERIMENTAL WATERSHED
TOMBSTONE, ARIZONA
CONTOUR MAP
LEGEND
MAIN EPHEMERAL WATERWAYS
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARIES
RUNOFF MEASURING STATIONS
CONTOUR LINES
SCALE IN MILES
CONTOUR INTERVAL 100 FEET
For additional cultural, topographic features and raingage network, see map page 63.1-5 in "Hydrologic Data for Experimental Agricultural Watersheds in the United States 1956-1959", Misc. Pub. No. 945, U.S.D.A., Agricultural Research Service, November 1963.
MAYS HILLS
5144
MILITARY HILL
5313
AJAX HILL
5320
STOCKTON HILL
5593
N
True
Magnetic
13°
W-1
W-2
W-3
W-4
W-6
W-7
W-8
W-11
W-15
63.103
63.111

Figure 2

Soils

Soils on the Walnut Gulch Experimental Watershed reflect the geologic parent material from which they developed. The limestone influenced alluvial fill parent material is dominate on the watershed. The soils that developed from this material are generally well drained, calcareous, gravelly loams with large percentages of rock and gravel at the soil surface (Gelderman, 1970). Soil surface rock fragment cover (erosion pavement) can range from nearly 0% on shallow slopes to over 70% on the very steep slopes (Simanton et al. in press). The major soil series presently defined on this area are Bernardino (fine, mixed, thermic *Ustollic haplargid*), Cave (loamy, mixed, thermic, shallow *Typic paleorthid*), Hathaway (loamy-skeletal, mixed, thermic *Aridic calciustoll*), and Rillito (coarse-loamy, mixed, hyperthermic *Typic calciorthid*). The uppermost 10 cm of the soil profiles contain up to 60% gravel, and the underlying horizons usually contain less than 40% gravel. The remaining soils developed from igneous intrusive materials and are generally cobbly, fine textured, shallow soils.

Vegetation

Although historical records indicate that most of the watershed was grassland approximately 95 years ago; now shrubs dominate the lower two-thirds of the watershed (Hastings and Turner, 1965). Major watershed vegetation includes the shrub species of creosote bush (*Larrea tridentata*), white-thorn (*Acacia constricta*), tarbush (*Flourensia cernua*), snakeweed (*Gutierrezia sarothrae*), and burroweed (*Aplopappus tenuisectus*); and grass species of black grama (*Bouteloua eriopoda*), blue grama (*B. gracilis*), sideoats grama (*B. curtipendula*), bush muhly (*Muhlenbergia porteri*), and Lehmann lovegrass (*Eragrostis lehmanniana*). Shrub canopy cover ranges from 30 to 40% and grass canopy cover ranges from 10 to 80%. Average annual herbaceous forage production is approximately 1200 kg/ha (1070 lbs/ac).

Climate

The climate of Tombstone, Arizona and the surrounding Walnut Gulch Experimental Watershed is classified using the modified Koppen's method (Trewartha, 1954) and data collected at Tombstone from 1941 - 1970 (Sellers and Hill, 1974). Mean annual temperature at Tombstone is 17.6°C (63.7°F) and mean annual precipitation is 324 mm (13 in). The climate is classified as arid or desert (BW) if mean annual temperature is less than 18°C (64.4°F) and mean annual rainfall is less than 318 mm (12.5 in), and semiarid or steppe (BS) if mean annual rainfall is greater than 318 mm (12.5 in). With a mean annual precipitation of 324 mm (13 in), the climate at Tombstone is semiarid or steppe, BS, but close to an arid or desert climate, BW. The BS climates are further distinguished as hot (h) or cold (k). Using the original Koppen's classification, Tombstone is classified as BSk because the mean annual temperature is less than 18°C (64.4°F). Using the modified Koppen's scheme the climate at Tombstone is classified as BSh.

Therefore, the climate at Tombstone can be classified as semiarid or steppe, hot, with a dry winter (BSh) but is quite close to being an arid or desert climate and is near the temperature boundary for hot (h) or cold (k).

Precipitation

Precipitation varies considerably from season to season and from year to year on the Walnut Gulch Experimental Watershed. Osborn (1983) reported, based on records from 1956-80, that annual precipitation varied from 170 mm (6.7 in) in 1956 to 378 mm (14.9 in) in 1977; summer rainfall varied from 104 mm (4.1 in) in 1960 to 290 mm (11.4 in) in 1966; and winter precipitation varied from 25 mm (1 in) in 1966-67 to 233 mm (9.2 in) in 1978-79. Approximately two--thirds of the annual precipitation on the Walnut Gulch Watershed occurs as high intensity, convective thunderstorms of limited areal extent. The moisture source for these thunderstorms is primarily the Gulf of Mexico, although Pacific Ocean storms from southwest of Arizona also produce moisture surges that result in convective storms.

Winter rains (and occasional snow) are generally low-intensity events associated with slow-moving cold fronts, and are generally of greater areal extent than summer rains. Convective storms can occur during the winter as well. Runoff on the Walnut Gulch Watershed results almost exclusively from convective storms during the summer season.

Instrumentation

The initial rainfall and runoff instrumentation on Walnut Gulch was installed in 1954-55. The initial network of 20 precipitation recording gages was expanded in the early 1960's to the 85 gage network currently in place on the watershed (Osborn and Reynolds, 1963). [Refer to Appendix A for network gage locations in UTM coordinates, and gage elevation in feet.] Five supercritical precalibrated flumes were constructed prior to 1955 to measure runoff from the heavily sediment laden ephemeral streams of Walnut Gulch. All five flumes failed or were badly damaged within two years. They failed for hydrologic, hydraulic, and structural reasons. Following extensive hydraulic model research at the Agricultural Research Service (ARS) Outdoor Hydraulic Structures Laboratory in Stillwater, Oklahoma, the original five flumes were rebuilt using a design known as the Walnut Gulch Supercritical flume (Gwinn, 1970; Smith et al., 1982). Six additional flumes were added later. (Figure 3) [Refer to Appendix A for runoff gage locations in UTM coordinates and elevation.]

Runoff from small (< 40 ha, 100 ac) watersheds is measured using various gauging structures. These structures include broad-crested V-notch weirs, H-flumes, and supercritical flow flumes. Currently 10 small watersheds are monitored. Runoff from watersheds larger than 200 ha (500 ac) is measured with large supercritical flow flumes (Smith et al., 1982). The largest flume, at the outlet of the Walnut Gulch watershed has a flow capacity of 650 m^3s^{-1} (23,000 cfs). Sediment from small watersheds monitored with V-notch weirs is sampled with automatic pump samplers (Allen et al., 1976) and sediment traps above the weirs (Osborn et al., 1978). Sediment from small watersheds equipped with supercritical flow flumes is sampled with a total-load automatic traversing slot sampler (Renard et al., 1986). Soil moisture within various vegetation/soil complexes throughout the watershed is measured using time domain reflectometry (Zegelin et al., 1989). Permanent vegetation plots and transects have been established to evaluate the impacts of management practices and global change on vegetation.

B. Description of Precipitation and Runoff Data

1. Data Collection

The data collection system on Walnut Gulch (WG) consists of mechanical weighing recording raingages (Belfort Universal precipitation gages) and mechanical recording stage gages for runoff. By convention, the recording raingages number 1 - 99 for 24-hr recording gages, 300's for 6-hour gages and 500's for weekly gages. Major flumes defining the major sub-watersheds within Walnut Gulch are numbered 1 - 15; smaller sub-watersheds within the major sub-watersheds are designated by 100's; ponds are designated by 200's. Also, by convention, all runoff gage numbers designate sub-watersheds. For example, Flume 11 measures runoff from sub-watershed 11, while weir 104 measures runoff from sub-watershed 104 (Figure 3).

ARS field personnel stationed in Tombstone, Arizona have primary responsibility for maintaining the data collection equipment within the Walnut Gulch Experimental Watershed. Site visits to the recording instruments vary according to type of recorder and weather

USDA-ARS WALNUT GULCH EXPERIMENTAL WATERSHED RAINGAGE AND SUBWATERSHED LOCATIONS

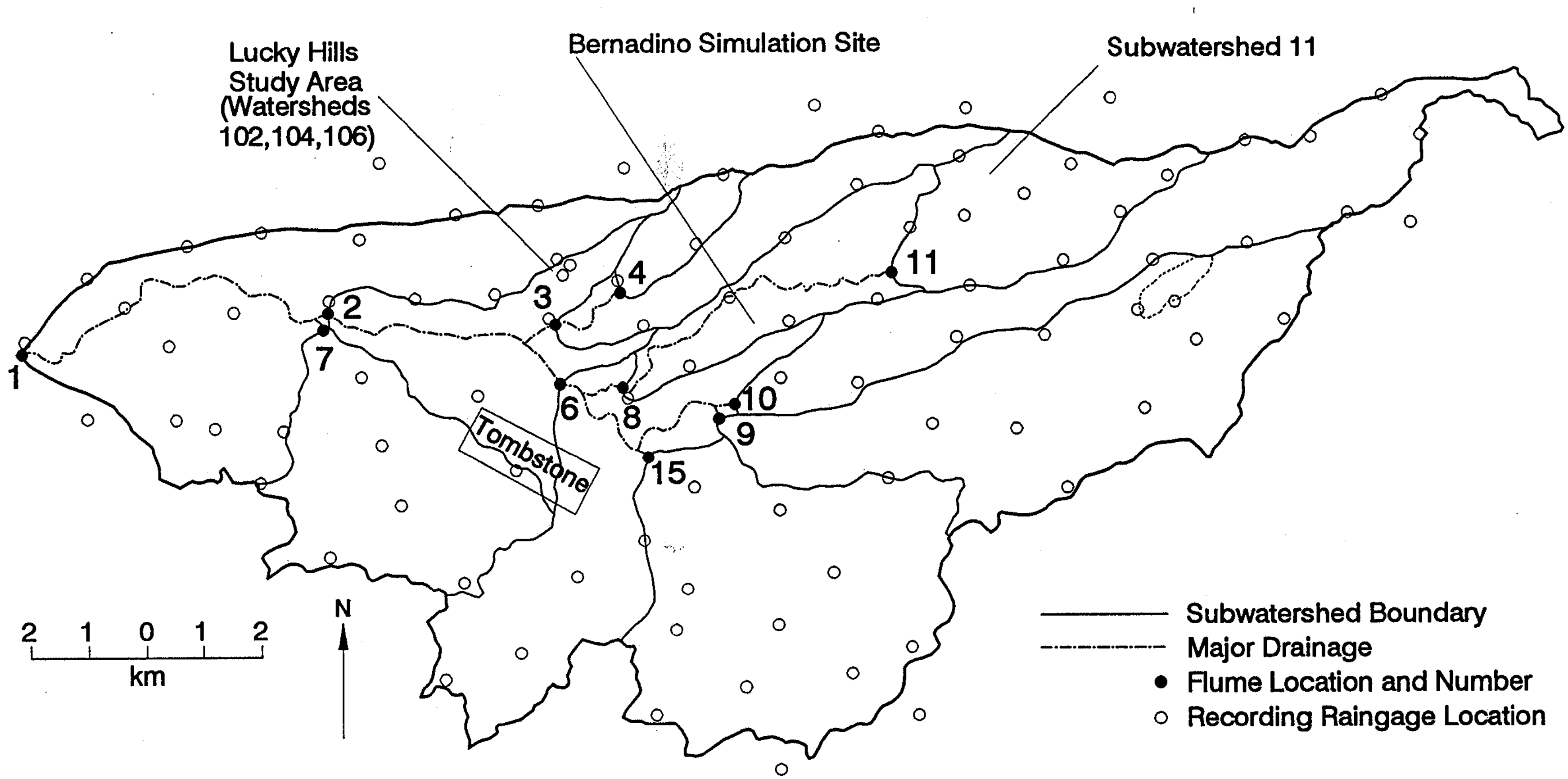


Figure 3

conditions. Generally, raingage charts are changed weekly. Runoff gage charts at the major flumes are time-checked (ensuring chart time and real time coincide) approximately weekly and, if possible, are changed after major runoff events. Site visits occur more frequently and charts are changed more frequently during the summer rain season.

During runoff events, ARS personnel attempt to visually observe flow and add significant observations to the recording charts. For example, time, depth of flow, symmetry of flow, and high water marks may be noted. These observations are often critical in interpretation of the data record and in assessing the integrity of the data record and recording instrument.

2. Data Processing and Estimates

Recording charts collected by field personnel are entered into a computer by ARS personnel in Tucson. First, data charts are encoded; start and stop times for the event are noted, breakpoints (slope changes) in the precipitation record are demarcated, as are time and peak stage for runoff events. Consistency between chart data and field observations is checked. Incomplete data charts--which can occur if, for example, the clock stops and the recording drum stops rotating, the recording pen falls off the drum or gets stuck, or the pen simply runs out of ink--are interpreted by scientists and their staff, and estimated points are inserted on the charts and noted as estimates. Second, chart data points are digitized and entered into a computer.

For precipitation data, at least two points are digitized. In some cases, only two points are digitized if the depth of precipitation is small and no breakpoints are evident or if, due to recorder problems, only the start or stop of an event is evident, or no start or stop time is evident but that precipitation occurred at the gage is known. In these cases, the start or stop of the event is estimated from nearby gages, but the times and/or depth points are marked with estimate codes.

Many of the estimates associated with runoff occur during the recession of the flow due to silting of the intakes to the stilling wells where the recording equipment is located. Silted intakes are especially common after large flow events. In recognition of this problem, the intakes for the larger flumes were modified. At the same time redundant FW-1 runoff stage recorders (with different time/depth resolutions from the original A35 stage recorders) were installed and a regular program of clearing the intakes after each runoff event was implemented. In some cases, when the primary charts contain missing data or silted intakes were obvious, hydrograph ordinates from the backup gages have been substituted into the data. The ARS policy on whether or not these substituted values are to be considered estimates is currently under evaluation.

Once the digital data is entered into the computer a variety of checks are performed. Simple data checks include checking that years, months, and days are reasonable (i.e. data entry errors), and that a minimum number of points were digitized. However, due to its nature, further checking of precipitation and runoff data is somewhat different.

Precipitation data are checked that start times, intensities, and depths are consistent basin-wide. Although it is possible that during highly localized summer precipitation, a particular raingage might record no precipitation while nearby raingages report significant amounts of precipitation, it is not probable, and ARS data processing personnel are alerted to the situation and recheck the charts and digitized data.

The analysis of the runoff data collected is less developed than for precipitation data mostly due to the absence of any established non-interpretative runoff characterizations. Runoff response (both in time and amount) to precipitation is more interpretative than the probable spatial and temporal distribution of precipitation and is thus more difficult to check. Prior to the early 1970's, because of the amount of data and time, personnel, and fiscal constraints, precipitation and runoff data were processed separately. Since then, more emphasis has been placed upon more interactive precipitation and runoff processing. Still, the event description process described in Part III which was developed to select data sets for the FCDMD has led to the development of additional procedures to alert data processing personnel of probable timing errors and gross volume errors within digitized runoff data.

3. Definitions and Interpretation of Precipitation and Runoff Data

Precipitation. Raingage recording charts record cumulative precipitation over a continuous time base. However, continuous data is difficult to utilize and some discretization is necessary. ARS personnel have developed a spatial/temporal criteria to define a precipitation event for a particular raingage. A precipitation event for a raingage starts when the recording line on the chart begins to increase and ends when the recording line ceases to increase. If another episode of precipitation begins not long after the previous event, the second episode may or may not be considered part of the first event depending upon whether any precipitation occurred on the rest of the watershed. If **no raingage within the Walnut Gulch raingage network records any precipitation within a 60-minute interval**, then the second episode of precipitation would be considered a separate precipitation event. Otherwise, the second precipitation episode would be considered part of the first event. Thus, some precipitation events may be relatively long but include only sporadic episodes of precipitation. This discretization is necessary to define blocks of precipitation within the ARS precipitation database. By linking consecutive precipitation events for a single raingage, the original precipitation record is reproduced. It is important to note that the same blocks of precipitation, or precipitation events, are used within the FCDMC data set.

Runoff. Like the precipitation recording charts, the runoff recording charts record depth of flow over a continuous time base. Some interpretation is required when very small flows occur alone or immediately prior to a large runoff event because the large impervious surface area of the flumes can act like raingages. Local precipitation on the flume can fill the intakes and is recorded as runoff on the recording charts. However, distinguishing separate runoff events is somewhat more simple and obvious than for precipitation. Generally, a gap of at least one hour of no flow separates runoff events at a particular gage.

4. The ARS Precipitation and Runoff Databases

The ARS has two separate databases--one database for precipitation data, and one for runoff--but the overall format is the same for both. Both databases are event-based; only the discretized events are available, but the events include all precipitation or runoff which occurred on Walnut Gulch. Also, the data in the databases are on two record types. The first record type is a single header record which contains event identification and event summary information. The second record type contains breakpoint or hydrograph ordinate points which were digitized from the recording chart. Obviously, several breakpoint or hydrograph ordinate records are associated with each precipitation or runoff header record. Of particular significance are the estimate codes entered in both the header record and/or breakpoint or ordinate data records indicating whether a start time or data point was estimated or not. These estimate codes were heavily relied upon in the event data selection process.

III. THE SELECT PRECIPITATION/RUNOFF EVENT DATA SETS

In Part II, the ARS Walnut Gulch data was described as were the definitions, interpretations, and databases used by ARS personnel. However, in fulfillment of the FCDMC agreement, some additional data processing, definitions, and assumptions were necessary. This section describes the specific definitions and assumptions necessary to select data sets, and the final format of the data sets collected and supplied to the FCDMD.

A. Precipitation/Runoff Event Definition

The main objective of the FCDMC data sets was to link runoff data to related precipitation data for selected sub-watersheds. First, several sub-watersheds within Walnut Gulch, ranging in size from over 3000 acres to less than one acre, were selected with approval from FCDMC. Second, raingages that were within each sub-watershed or which would record precipitation which would contribute to runoff at the sub-watershed outlet were identified. Third, ARS personnel developed a definition of a combined precipitation/runoff (p/ro) event based upon observed data and which would provide the necessary parameters with which to search the ARS databases and extract data. A combined p/ro event within a sub-watershed is based upon the runoff event and is designated by the date of the runoff event. For any sub-watershed, it is assumed that any precipitation events which are recorded at any raingage associated with the sub-watershed that **starts six hours prior to the start time of the runoff event** possibly contributed to the runoff. Additionally, any precipitation event at an associated raingage that **starts during the runoff event** is also considered to have possibly contributed to the runoff. All precipitation within a sub-watershed that meet either of these criteria, together with the resulting runoff, is considered a combined p/ro event. This definition of a p/ro event was adhered to throughout the selection of possible data set events with only one exception. It was found that six-hours from the start of runoff was insufficient to adequately encompass all possible associated precipitation for the sub-watershed 8 runoff event of August 18, 1986, and an eight-hour interval prior to runoff was used.

B. Event Selection and Checking

First, runoff instrumentation records as well as available sub-watershed historical notes were searched to determine time periods during which management and instrumentation conditions remained unchanged. For the larger sub-watersheds chosen (7, 8, 11), fences were installed immediately upstream of the flumes to direct flows symmetrically into the flumes in late 1972 to early 1973. Thus, the search interval was 1973 to the present for the larger flumes. Several instrument changes and herbicide applications for vegetative/runoff studies were made within the smaller sub-watersheds chosen (102, 104, 106) together with changes in location to one of the two recording gages associated with these sub-watersheds, narrowed the acceptable data period to five years, from 1972 to 1977.

Second, once the ARS databases were searched and several p/ro events were defined for each sub-watershed, the runoff data for each p/ro event was searched for estimates. In accordance with the FCDMC criteria, if the total amount of runoff volume estimated equalled or exceeded ten percent, the entire p/ro event was dropped from consideration. An additional criteria imposed upon the runoff data was that none of the runoff volume prior to and/or including the peak was acceptable, even if the total estimated volume was less than ten percent.

Third, the precipitation data for each p/ro event was searched for estimates. If more than ten percent of the associated precipitation gages which reported precipitation for an event had more than ten percent of the total precipitation depth estimated, the entire p/ro event was considered unacceptable and deleted from consideration. For example, if a sub-watershed had 17 associated raingages which reported precipitation during a p/ro event and the data from one raingage (1 is less than 10% of the 17 raingages) was entirely estimated, the entire p/ro event would still be considered acceptable. If, for a different p/ro event within the same watershed more than ten percent of the total precipitation depth recorded per gage was estimated for 5 of the 17 raingages (5 is greater than 10% of the 17 raingages), then the entire p/ro event was considered unacceptable. The same ten-percent criteria included estimated precipitation start times.

Fourth, once several p/ro events had been identified which met the FCDMC criteria, the original flume charts were checked for notes regarding timing corrections. (For both precipitation and runoff data, any discrepancies in chart time versus real time are distributed linearly throughout the chart data.) In the case of the precipitation data, any modifications to the start time of a precipitation event would result in a start time estimate code which would have to pass the previously described 10% criteria.

Finally, FCDMC personnel stated that emphasis should be on selecting the largest p/ro events. Therefore acceptable p/ro events were sorted according to peak discharge and volume, and the largest approximately 30 p/ro events were selected as acceptable data sets for FCDMC. The data within the selected p/ro event data sets were then converted into units agreed upon by the FCDMC.

C. Data Set Format

Individual p/ro events are contained within separate files identified by the date of the runoff - the file name is a six-digit number in a year-month-day (yymmdd) format with a ".DAT" extension. If two p/ro events occur on the same day, the second event has the letter "B" appended to the file name. All selected p/ro event data is available on a single write-protected 3½-inch high density diskette located inside the back cover of the appendices. The data sets for each sub-watershed are located within a subdirectory identified by the sub-watershed number. Thus, the p/ro event data sets for Walnut Gulch sub-watershed 7 are in the subdirectory WG007.

The p/ro event data is in ASCII format with data fields separated by commas and quotes. Numeric data is separated by commas, and text data are enclosed by double quotes (") and separated by commas. The comma-and-quote format allows all data to be imported into and correctly interpreted by most commercially available spreadsheet software.

The p/ro event data format is a modification of the ARS database formats. Each p/ro event file includes a single runoff header record which begins with a header code of "Q" or "P" indicating whether the record is a runoff or precipitation header (useful for data searches.) The 96-character header also contains the runoff gage number (sub-watershed number), event date and time, summary of the runoff, the number of associated hydrograph ordinates, the number of associated precipitation events for the p/ro event, a field indicating whether or not estimates are present within the data, and an event identification code. The event identification code identifies the sub-watershed, event date and time particular to each p/ro event and is included in all header records associated with that event. The identification code was added to the data sets to identify associated precipitation and runoff should the data become separated. The single runoff header record is followed by several hydrograph ordinate records which contain elapsed time from the start of the runoff and discharge. Table 1 details the runoff record and data field formats.

Immediately following the runoff records are the precipitation event data associated with the runoff. Like the runoff data, the precipitation data consists of a single precipitation event header record which contains fields for start date and time of precipitation, total depth and duration of precipitation, number of breakpoints, and the same event identification code as the runoff. A final field is allotted to identify whether any of the precipitation breakpoint data is estimated. Following the precipitation header record are several breakpoint records, each of which includes elapsed time from the start of the precipitation, depth of precipitation, and intensity of precipitation. The single precipitation header and associated breakpoint record format is repeated for each precipitation event associated with the defined p/ro event. Table 2 details the precipitation record and data field formats.

D. Special Notes Regarding the Precipitation/Runoff Data Sets

1. Independence of the Events

Each p/ro event is considered separate from and independent of all other p/ro events for a sub-watershed within the data sets. This is due to the fact that the p/ro event data sets do not contain precipitation or runoff which may have occurred between selected p/ro events. Some exceptions do exist in the case of nested sub-watersheds. For example, about one-half of the selected p/ro events for sub-watershed 8 are coincident with those in sub-watershed 11 which is nested within sub-watershed 8. Also, all the p/ro events for the nested sub-watersheds 102, 104, and 106 are coincident.

Naturally, however, most precipitation/runoff events are not independent. Therefore, tables showing the five-day antecedent precipitation totals for each associated raingage within each sub-watershed for each p/ro event have been developed. These tables are included in

TABLE 1
Field Definition for Runoff Data in Event Data Files

Data are in a comma-and-quote separated format; i.e., numeric data fields are separated by commas, alphanumeric text fields are separated by commas and double quotes ("). No blank lines exist within the data files, and associated precipitation data immediately follows the runoff breakpoint data.

Below is a description of the fields, units, and Fortran format specifications for a portion of the runoff data including header and sample breakpoints.

Header

```
Field →      "Q", 8,830926,1537, 3276.666,   9.70308, 209.05,  9.50, 158.5, 44,28,"008-830926-1537","E"
Field No. →   1.  2.  3.    4.      5.          6.        7.      8.     9.  10. 11.      12.          13.
```

Hydrograph Ordinates

```
Field →       0.00,   0.00
              1.00,  83.78
              1.50, 129.78,"E"
Field No. →    1.      2.    3.
```

Header Field No.	Header Field Description	Field Units	Fortran Format
1.	Runoff identification code		A3
2.	Walnut Gulch sub-watershed number		I3
3.	Start date of runoff	yymmdd	I6
4.	Start time of runoff (military time)	hhmm	I4
5.	Sub-watershed contributing area	acres	F9.3
6.	Total event runoff volume	acre-feet	F11.5
7.	Peak discharge	cfs	F8.2
8.	Time to peak	minutes	F7.2
9.	Total event duration	minutes	F6.1
10.	Number of ordinates (time-discharge pairs)		I4
11.	Number of associated precipitation gages		I2
12.	Event id ("watershed-event date-event time")		A17
13.	Estimate code (only if estimates are present)		A3
Ordinate Field No.	**Ordinate Field Description**	**Ordinate Units**	**Fortran Format**
1.	Elapsed time from start time	minutes	F9.2
2.	Discharge	cfs	F8.2
3.	Estimate code (only if estimates are present)		A3

TABLE 2
Field Definition for Precipitation Data in Event Data Files

Data are in a comma-and-quote separated format; i.e., numeric data fields are separated by commas, alphanumeric text fields are separated by commas and double quotes ("). No blank lines exist within the data files, and associated precipitation data immediately follows the runoff breakpoint data.

Below is a description of the fields, units, and Fortran format specifications for a portion of the precipitation data including header and sample breakpoints.

Header

```
Field →     "P", 54,830926,1418, 0.12,  27,  4,"008-830926-1537","E"
Field No. →  1.  2.   3.     4.   5.    6.   7.        8.          9.
```

Breakpoints

```
Field →       0, 0.00,  0.0000
              6, 0.03,  0.3000
              9, 0.11,  1.6000
             27, 0.12,  0.0333,"E"
Field No. →   1.  2.     3.    4.
```

Header Field No.	Header Field Description	Field Units	Fortran Format
1.	Precipitation identification code		A3
2.	Precipitation gage number		I3
3.	Start date of precipitation	yymmdd	I6
4.	Start time of precipitation (military time)	hhmm	I4
5.	Total precipitation depth	inches	F5.2
6.	Duration of precipitation	minutes	I4
7.	Number of breakpoints (time-depth pairs)		I3
8.	Event id ("watershed-event date-event time")		A17
9.	Estimate code (only if estimates are present)		A3
Breakpoint Field No.	**Breakpoint Field Description**	**Field Units**	**Fortran Format**
1.	Elapsed time from start time	minutes	I4
2.	Accumulated precipitation depth	inches	F5.2
3.	Precipitation intensity	inches/hour	F8.4
4.	Estimate code (only if estimates are present)		A3

Appendix C and on the data set diskette. On the diskette, the file name is identified by "ANTE" followed by the sub-watershed number. The file extension is ".TAB". The file name for the antecedent precipitation table for the selected p/ro events for sub-watershed 7 is "ANTE007.TAB". Due to the size and nesting of sub-watersheds 102, 104, and 106, and because all p/ro events for those sub-watersheds are coincident, only one antecedent precipitation table common to p/ro events for those watersheds has been developed and included in Appendix C. The file name for this table is "ANTE100.TAB".

2. Contributing Areas and Pond Spillage

Ponds 216 and 218 (stockponds) occupy the upper end of sub-watershed 11. Pond 216 is instrumented with a float-stage recorder and a 50-foot sharp-crested weir. Records of pond water level have been maintained there since 1966 and indicate periodic pond spillage. Upstream of pond 216 is pond 218 which is ungaged. The combined contributing area of the two ponds is 371.5 acres, approximately 24% of the total contributing area of sub-watershed 11.

Research indicates that pond spillage can have an effect upon watershed outflow - usually in terms of delaying the peak at the watershed outlet. Additionally, if pond spillage volume is significant (greater than about 5% the total runoff volume at the watershed outlet), then the area contributing runoff measured at the watershed outlet must include the watershed area contributing to the pond.

However, transmission losses within semi-arid ephemeral stream channels can be significant. Lane (1983) calculates the average transmission loss along the 4.1 mile channel between Walnut Gulch flumes 011 and 008 is 1.902 acre-feet per channel mile, or 11.5% of the original volume lost per channel mile. Jordan (1977) states that channel transmission losses are not linearly distributed between gaging stations and are, in fact, higher for the first mile and decrease downstream. Therefore, Walters (1990) calculates a mean first-mile transmission loss on the same reach as Lane (11 to 8) using Lane's data as 2.4 acre-feet per channel mile. Both estimates appear reasonable based upon other figures derived for nearby channel reaches within Walnut Gulch of transmission losses ranging from 11% to 20% of the original volume lost per channel mile. (Lane, 1983; El-Shinnawy, 1993). To assess the effect of pond 216 spillage on discharge measured at flume 11, the conservative figure of transmission losses equalling approximately 1.902 acre-feet per channel mile (11.5% of total flow lost per channel mile) was adopted. Thus, if the pond spill volume is less than the volume of runoff lost through transmission losses, then the spill volume does not significantly affect watershed runoff volume calculated at the watershed outlet and can be ignored.

Additionally, it can be posited that the spill volume replenishes the watershed runoff volume normally reduced by transmission losses. Again, if the spill-augmented watershed runoff is less than conceivable measurement error (5%) then the pond contributing area must be excluded from the total watershed contributing area.

Pond 216 records were checked for any spillage that occurred during the selected p/ro events for sub-watershed 11. If spillage occurred, the total spill volume was calculated. The maximum spill volume for pond 216 was about 5.2 acre-feet. Subtracting the transmission losses assumed for sub-watershed 11 of 1.902 acre-feet per channel mile for the approximate 1 mile channel length between pond 216 and flume 11, resulted in about 3.3 acre-feet of pond spillage contributing to runoff at flume 11. Put another way, about 3.8% of the outflow measured at flume 11 was contributed by water spilled from pond 216. This amount was considered insignificant (within conceivable measurement error), thus the areas contributing to ponds 216 and 218 were excluded from the contributing area of sub-watershed 11 for all events.

While sub-watershed 8 encompasses sub-watershed 11 and ponds 216 and 218, spills from pond 216 that occurred during p/ro events selected for sub-watershed 8 were checked for, but were considered insignificant contributions to runoff there (<<5%) due to the increased distance between pond 216 and flume 8.

No gaged ponds exist within sub-watershed 7. However, a mining operation at the upper, southern end of the sub-watershed has existed throughout the period of selected p/ro events. No records are available detailing the type and extent of changes to the sub-watershed characteristics especially runoff. Measurements taken from aerial photographs of the operation indicate that the disturbed mining area constitutes about 4% the total sub-watershed area.

Additionally, the majority of the City of Tombstone lies within the boundaries of sub-watershed 7. Relatively little activity possibly affecting runoff (increased paved area, for example) has occurred within Tombstone over the period for which the p/ro event data was collected.

3. Area Calculations

In an attempt to update Walnut Gulch data, the entire watershed has recently been photosurveyed to obtain 1:5000-scale orthophoto maps at a five-meter contour interval upon which the boundaries have been checked and digitized. These redigitized boundaries and subsequently recalculated areas are to be considered updated figures but vary slightly from previously published figures. (Digitized boundaries in UTM coordinates have been supplied to FCDMC as have the 1:5000 orthophoto quads in response to the cooperative agreement. Refer to the Final Report.)

All of the larger sub-watershed areas within the p/ro event data sets include the updated areas. However, since the areas for sub-watersheds 102, 104, and 106 were previously digitized from more precise larger-scale maps (1" = 40') for special studies, the areas used by Goodrich (1991) are included in the p/ro event data sets.

All sub-watershed areas to be used with the p/ro event data sets are found in Appendix A. Note that sub-watershed areas in Appendix A are inclusive; that is, the area for sub-watershed 8, for example, includes the area of sub-watershed 11 and all ponds within sub-watershed 11. The sub-watershed areas reported in the p/ro event data sets include **contributing area only**.

4. Antecedent Conditions

Tables showing the event day (ED) and previous five-day (ED-1...ED-5) rainfall totals for each raingage for each selected p/ro event within selected sub-watersheds are included in Appendix C. Note that if a runoff event began early into a new day (less than six hours, for example), the total precipitation for that day is, more than likely, not representative of conditions antecedent to the runoff. Therefore, to ensure that the same amount of precipitation information antecedent to the runoff is presented for all events, precipitation totals for six days prior to runoff are presented if runoff begins less than six hours into the new day.

5. Zeros in the Runoff Data

The discharge associated first and last hydrograph ordinate points within the runoff data are zeros - that is, no flow occurred. Other zeros immediately prior to the last hydrograph ordinate usually indicate that some flow occurred but in quantities smaller than can be reported by the two significant figure format used in the data sets. If zeros are reported during the event, no such assumptions apply. In other words, intermediate zeros in the data could indicate no flow, or they could indicate flows too small to be represented by two significant figures.

IV. SELECT DATA SET SUB-WATERSHED DESCRIPTIONS AND PERTINENT INFORMATION

A. Sub-watershed 7

FLUME 007
LOCATION: Latitude 31°44'02" N, Longitude 110°05'55" W

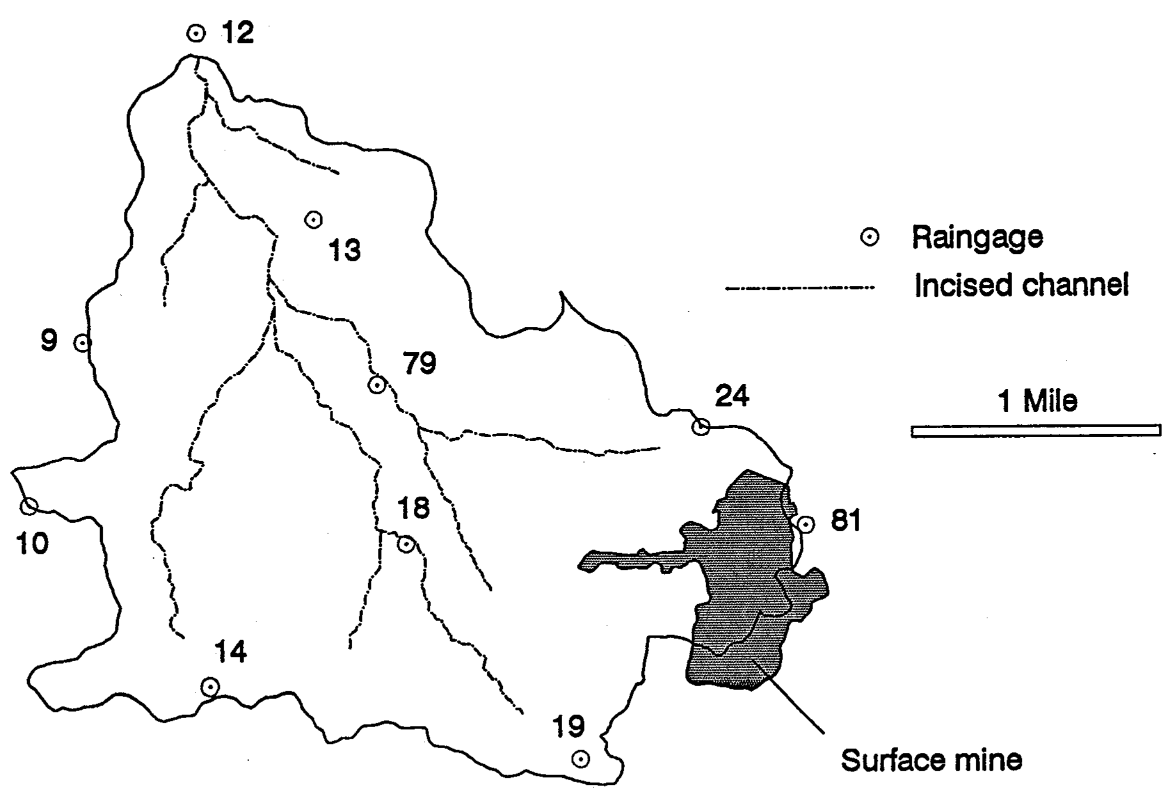
SUB-WATERSHED AREA: 3367 acres

PERIOD OF RECORD: On 1966 to January 1971. Off January 1971 to install fences to prevent asymmetric flows. On January 1971 to present.

GAGE: Walnut Gulch supercritical flume with a capacity of 8000 cfs. Recorder type is an A35 analog recorder using strip charts. Back-up FW-1 recorder installed on June 8, 1982.

RUNOFF: A summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A, and in the WG007 subdirectory on the event diskette with the title "QSUM007.TAB".

Map of Walnut Gulch Subwatershed 7 Showing Recording Raingages and Major Drainage Network



Special Notes for Sub-watershed 7

Soils Celler rocky sandy loam and House Mountain very rocky loam (Entisols) comprise 24% of the area; Sonoita sandy loam, Chiricahua very gravelly clay loam. Cave-Rillito gravelly loam, Laveen loam, and Nickel gravelly loam (Aridisols) comprise 33% and Tortugas rocky loam and Comoro sandy loam (Mollisols) comprise 43% of the area. (ARS, 1966) (Note that a new survey of soils within the Walnut Gulch is currently underway by the Soil Conservation Service. The results of the survey will be supplied to the FCDMC as stated in the cooperative agreement when they become available.)

Vegetation Desert shrubs (whitethorn, creosote bush, tarbush, and mortonia) occupy approximately 75% of the watershed. The remaining 25% of the area is grass. Most prevalent grasses are black grama, curly mesquite, side oats grama, blue grama, and tobosa grass. (ARS, 1966) This description coincides with the general vegetative boundaries digitized for Walnut Gulch and presented in the Final Report.

Selection The precipitation and runoff data for sub-watershed 7 was chosen because of the hilly topography and fan-shaped contributing area. The majority of the City of Tombstone exists within the boundaries of sub-watershed 7 as does a small mining operation. Sub-watershed 7 also includes a portion of the Tombstone Hills which, within the sub-watershed boundaries, reach an approximate elevation of 4900 feet.

Baseflow Baseflow persisting sometimes several days has been recorded at Flume 007. Due to basaltic intrusions associated with the Tombstone Hills, small, isolated perched aquifers are not uncommon in the immediately surrounding area. In fact, the same phenomenon occurs on the south side of the Tombstone Hills where the U.S. Geological Survey stream gage on the San Pedro River near Charleston records year-round flows. It is probable, however, that construction of flume 007 increased the occurrence of baseflow within the channel, as the toe-down for the concrete flume structure reaches to bedrock forcing subsurface flow to the surface.

Event graphs Graphs showing the distribution of precipitation at the central raingage within the sub-watershed (raingage 79) and the resulting hyrdograph, and spatial distribution of precipitation depths are found in Appendix B. Two exceptions must be noted. First, the data for the central raingage within sub-watershed 7, raingage 79, is estimated for the event of 900914 (Sept. 14, 1990) and the data from nearby raingage, raingage 13, is plotted instead. Second, the event of 730727 (July 27, 1973) includes baseflow for several days. For the sake of simplicity, only the main runoff episode and associated precipitation are shown on the graph.

Associated Raingages The raingages associated with sub-watershed 7 are:

9, 10, 12, 13, 14, 18, 19, 24, 79, 81

B. Sub-watershed 8

FLUME 008

LOCATION: Latitude 31°43'23" N, Longitude 110°02'39" W

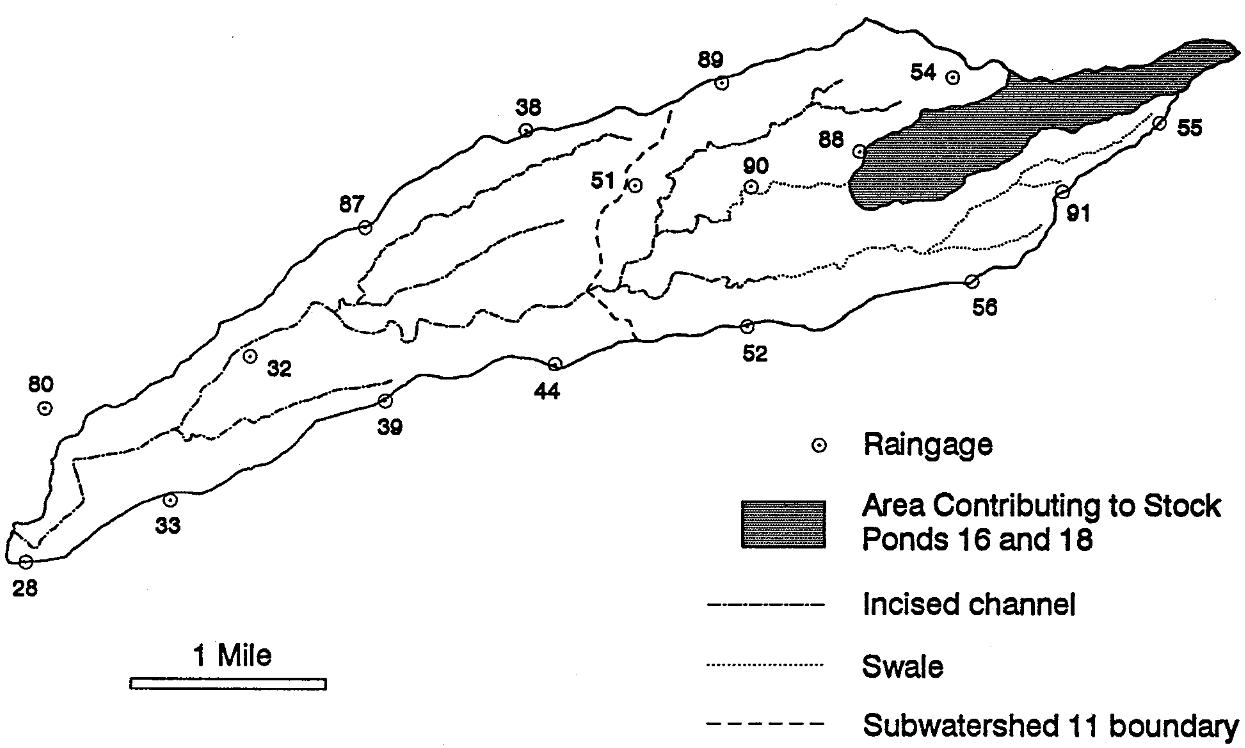
SUB-WATERSHED AREA: 3277 acres excluding pond 216 contributing area; 3648 acres including pond contributing area.

PERIOD OF RECORD: On August 1963 to April 1972. Off April 1972 to install fences to prevent asymmetric flows. On April 1972 to 1990.

GAGE: Walnut Gulch supercritical flume with a capacity of 8000 cfs. Recorder type is an A35 analog recorder using strip charts. Backup FW-1 recorder installed on May 9, 1972.

RUNOFF: A summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A and in the WG008 subdirectory on the event diskette with the title "QSUM008.TAB".

Map of Walnut Gulch Subwatersheds 8 and 11 Showing Recording Raingages, Major Drainage Network, and Area Contributing to Stock Ponds



Special Notes for Sub-watershed 8

Soils Detailed description not available at this time.

Vegetation (Includes sub-watershed 11) Approximately one-third of the area is dominated by desert shrubs (whitethorn, creosotebush, tarbush) with a crown spread of approximately 30% and an understory of grasses with less than 1% basal area. The remaining two-thirds of the area is dominated by grasses (black grama, curly mesquite grass, sideoats grama), with a basal area of about 2.5%, interspersed by desert shrubs with a crown spread of about 5%. (USDA-ARS, 1966)

Selection Precipitation and runoff data from sub-watershed 8 were chosen because sub-watershed 11, another selected sub-watershed, is contained within sub-watershed 8. In fact, some p/ro event data sets were chosen such that they were coincident between sub-watershed 8 and sub-watershed 11.

Event graphs Graphs showing the distribution of precipitation at the central raingage within the sub-watershed (raingage 51) and the resulting hyrdograph, and spatial distribution of precipitation depths are found in Appendix B. All event graphs for sub-watershed 8 show the precipitation at raingage 51. However, due to estimated data for raingage 51 during the event of 840816 (August 16, 1984), the graph for this event shows the precipitation intensities for raingage 87 **not** raingage 51.

Event data An interval of six hours prior to the start time of the runoff of event 860818 (August 18, 1986) did not adequately capture all the precipitation which could be associated with the runoff on that date. Due to the size and elongated shape of sub-watershed 8, it was conceivable that the amount of time in which the runoff would respond to precipitation could be longer than six hours. When the interval was increased to eight hours for this particular event, ARS personnel decided that all precipitation within sub-watershed 8 which could be related to runoff on August 18, 1986 was accounted for. It is interesting to note that, other than for this particular event, the six-hour interval served quite well as a temporal criteria to define related runoff and precipitation over all the basin sizes for which the p/ro event data sets were collected.

Associated raingages The raingages associated with sub-watershed 8 are:

28, 32, 33, 38, 39, 44, 51, 52, 54, 55, 56, 80, 87, 88, 89, 90, 91

C. Sub-watershed 11

FLUME 011
LOCATION: Latitude 30°44'32" N, Longitude 109° 59'35" W

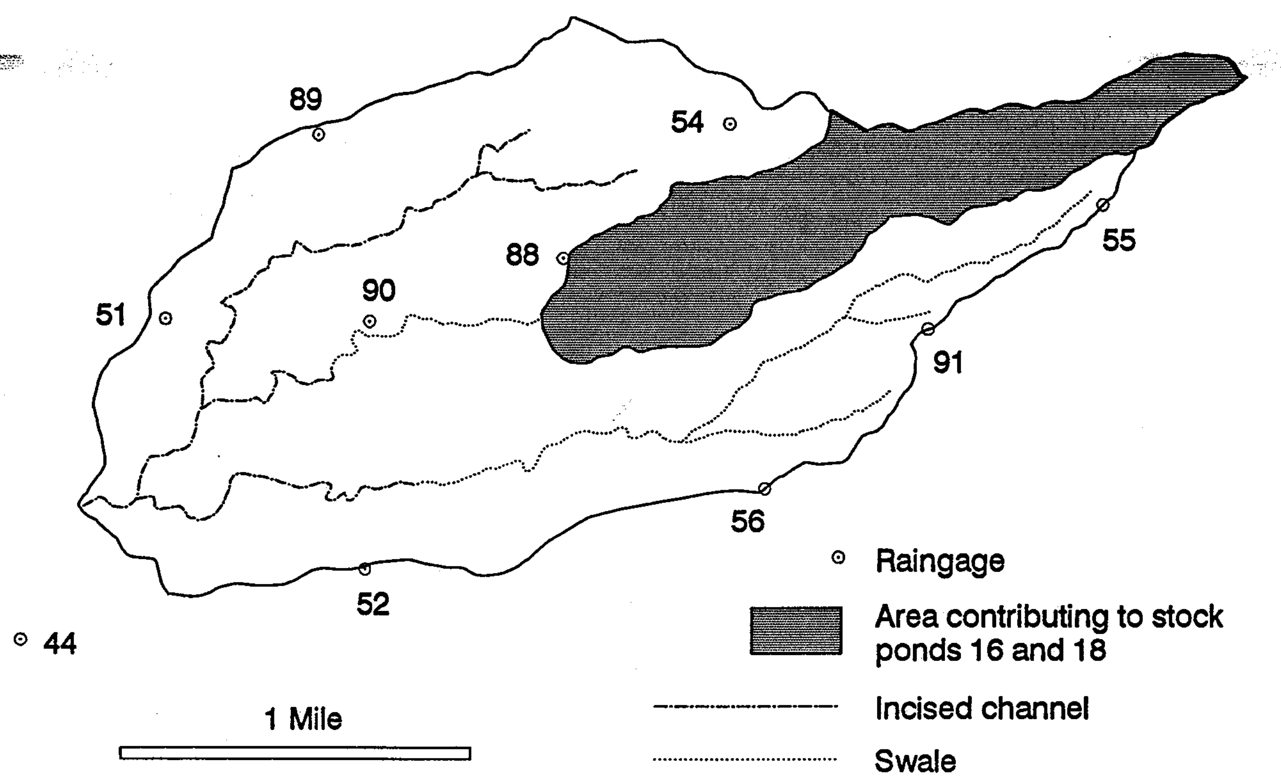
SUB-WATERSHED AREA: 1569 acres excluding pond 216 and pond 218 contributing area; 1941 acres including pond contributing areas.

PERIOD OF RECORD: On March 1963 to December 1971. Off December 1971 to install fences to prevent asymmetric flows. On January 1971 to present.

GAGE: Walnut Gulch supercritical flume with a capacity of 6000 cfs. Recorder type is an A35 analog recorder using strip charts. Back-up FW-1 recorder installed on March 29, 1982.

RUNOFF: A summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A and in the WG011 subdirectory on the event diskette with the title "QSUM011.TAB".

Map of Walnut Gulch Subwatershed 11 Showing Recording Raingages, Major Drainage Network, and Area Contributing to Stock Ponds



Special Notes for Sub-watershed 11

Soils Detailed description not available at this time.

Vegetation Approximately 20% of the area is dominated by desert shrubs (whitethorn, creosotebush, tarbush) with a crown spread of approximately 30% cover and an understory of grasses with basal area of less than 1%. The remaining 80% of the area supports a grass cover (black grama, curly mesquite grass, sideoats grama) with a basal cover of about 2.5% interspersed with desert shrubs averaging less than 5% crown cover. (USDA-ARS, 1966)

Selection Sub-watershed 11 was chosen as an event data set sub-watershed due to the predominate grass-dominated vegetative cover. Additionally, sub-watershed 11 is entirely within sub-watershed 8, and approximately one-half the selected p/ro events are coincident between the two sub-watersheds.

Ponds The areas contributing runoff to two stockponds--pond 216 which is gaged and pond 218 which is ungaged--comprise the upper approximate one-fourth of the sub-watershed. (The contributing area of pond 218 is contained entirely within pond 216). The total contributing area to Pond 216 is approximately 371 acres, 150 acres of which comprise the contributing area to pond 218. Pond 216 has been surveyed periodically and pond depth/volume relationships have been developed as have pond discharge rating tables. The recording charts for pond 216 were examined for each of the selected p/ro event data sets for sub-watershed 11 to determine whether or not the pond spilled, and if so, the volume of spill was calculated. ARS personnel determined that pond spillage had a minor, if any, effect upon runoff volume measured at Flume 11, certainly within error of 5%. Following is a list of events for which pond 216 spilled, and approximate spill volumes.

Event date (yymmdd)	Spill volume (ft^3)	Spill volume (acre-ft)
750913	16461	0.4
820827	228224	5.2
820911	146093	3.4
860817	34422	0.8
860829	18355	0.4

Event graphs Graphs showing the distribution of precipitation at the central raingage within the sub-watershed (raingage 90) and the resulting hyrdograph, and spatial distribution of precipitation depths are found in Appendix B. Note that there are three branches to the channel within sub-watershed 11, and multi-peaked hydrographs are not uncommon.

Associated raingages The raingages associated with sub-watershed 11 are:

44, 51, 52, 54, 55, 56, 88, 89, 90, 91

D. Sub-watersheds 102, 104, and 106

FLUME 102
LOCATION: Latitude 31°44'28" N, Longitude 110° 03'10" W

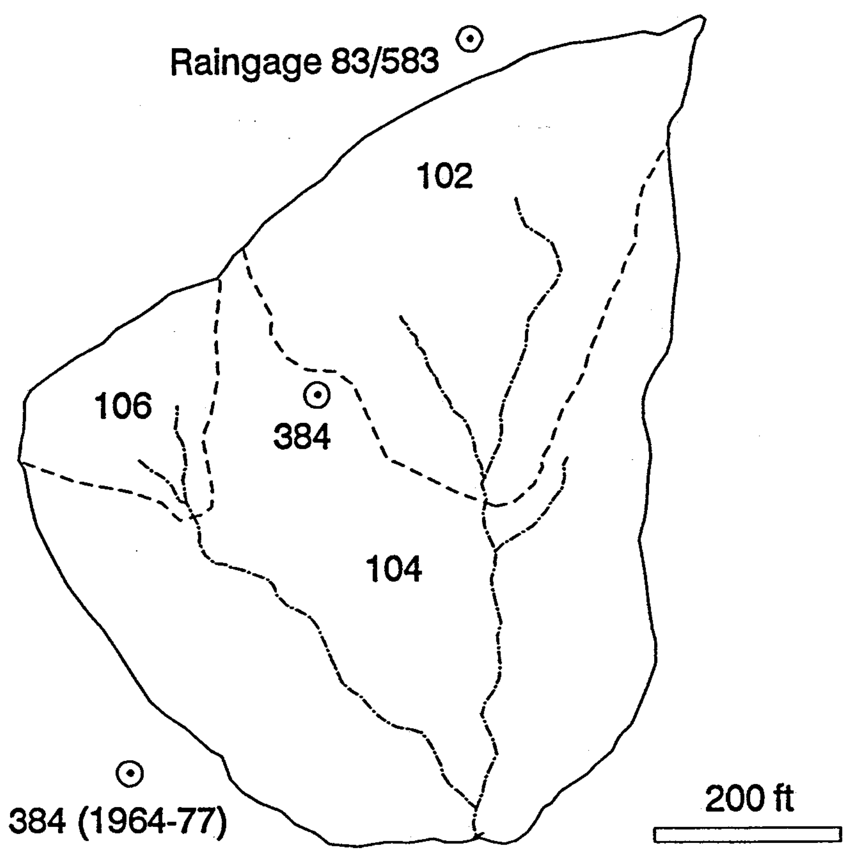
SUB-WATERSHED AREA: 3.62 acres (obtained from large-scale 1" = 40' maps, 1990)

PERIOD OF RECORD: Activated as a weir June 1963. Replaced with flume March 1973 to present.

GAGE: Originally, 2:1 V-notch weir with FW-1 6-hour recorder. Replaced with Smith-type concrete flume.

RUNOFF: A single summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A, and in the WG102 subdirectory on the event diskette with the title "QSUM102.TAB".

Map of Lucky Hills Watersheds 102, 104, and 106 Showing Boundaries, Recording Raingages, and Major Drainage Network



FLUME 104
LOCATION: Latitude 31°44'22" N, Longitude 110° 03'10" W

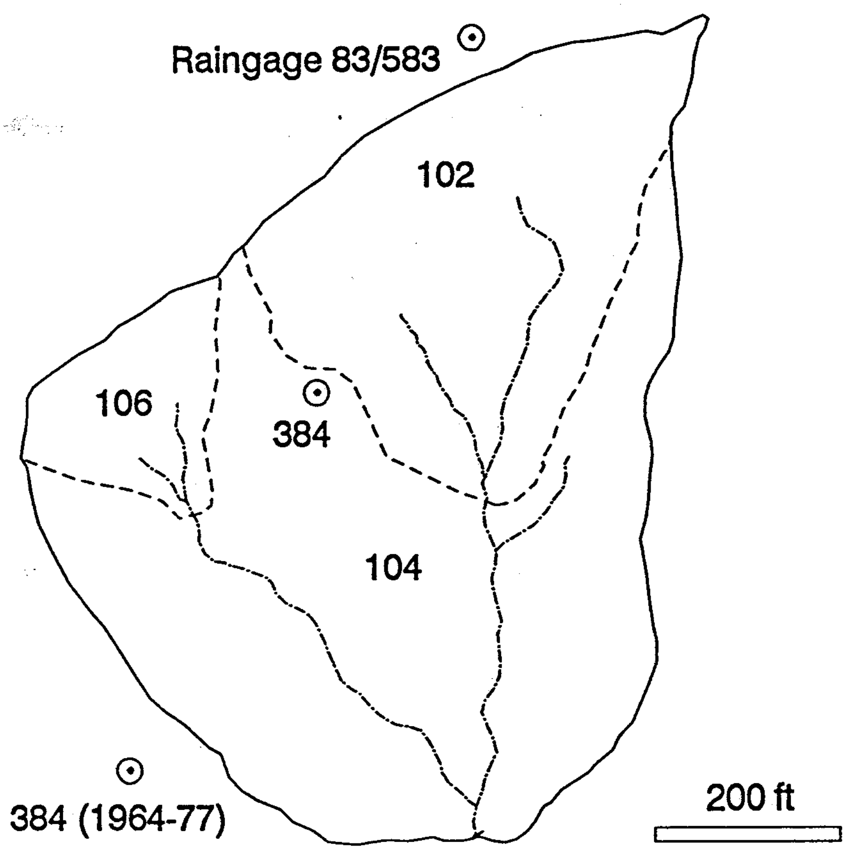
SUB-WATERSHED AREA: 10.90 acres (obtained from large-scale 1" = 40' maps, 1990)

PERIOD OF RECORD: Activated as a weir June 1963. Replaced with 50 cfs Smith-type flume March 1978 to present.

GAGE: Originally, 2:1 V-notch weir with FW-1 6-hour recorder. Replaced with Smith-type concrete flume.

RUNOFF: A single summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A, and in the WG104 subdirectory on the event diskette with the title "QSUM104.TAB".

Map of Lucky Hills Watersheds 102, 104, and 106 Showing Boundaries, Recording Raingages, and Major Drainage Network



FLUME 106
LOCATION: Latitude 31°44'25" N, Longitude 110° 03'13" W

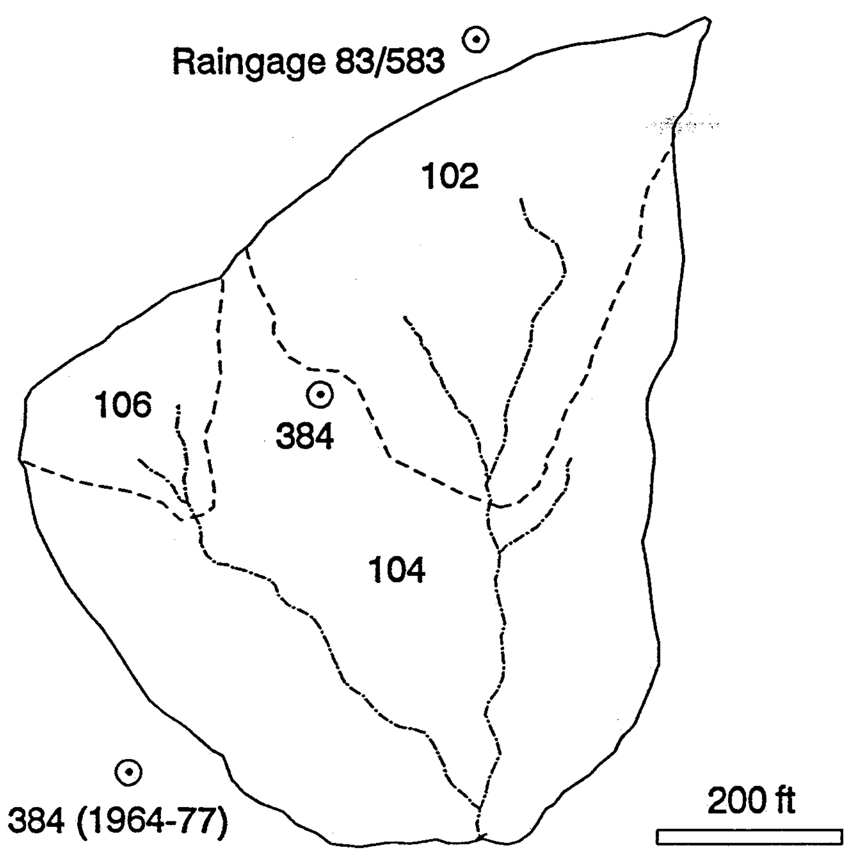
SUB-WATERSHED AREA: 0.90 acres (obtained from large-scale 1" = 40' maps, 1990)

PERIOD OF RECORD: Activated June 1965 to present.

GAGE: 3.0-foot H-Flume with FW-1 6-hr recorder.

RUNOFF: A single summary of the time to peak, peak, and total discharge of runoff for each of the selected p/ro events is found in Appendix A, and in the WG106 subdirectory on the event diskette with the title "QSUM106.TAB".

Map of Lucky Hills Watersheds 102, 104, and 106 Showing Boundaries, Recording Raingages, and Major Drainage Network



Special Notes for Sub-watersheds 102, 104, and 106

The "Lucky Hills" sub-watersheds Sub-watersheds 102, 104, and 106 are small nested experimental watersheds commonly referred to as the "Lucky Hills" sub-watersheds. Sub-watersheds 102 and 106 are independent and are contained within sub-watershed 104. Experimental treatments and/or modelling studies usually involve the combined use of data from all three sub-watersheds.

Sub-watershed management Raingage 384 was moved in July of 1978. Herbicide was applied to sub-watersheds 102 and 106 in 1981, and land imprinting studies were conducted there.

The accompanying sub-watershed diagram reflects the position of raingage 384 during the period for which p/ro events were selected. The UTM gage coordinates for the pre-1978 location is noted as "384 *" in Appendix A.

Event selection All events for sub-watersheds 102, 104, and 106 are concurrent, except that mechanical problems for then-weir 104 prevented the collection of acceptable p/ro event data for sub-watershed 104 for the events of 741022 and 750705.

The same two raingages are associated with sub-watersheds 102, 104, and 106. Therefore, each selected p/ro event for each sub-watershed contains separate runoff response data to the same precipitation.

Event graphs Graphs showing the distribution of precipitation at the nearest raingage (both associated raingages in the case of sub-watershed 104) to the sub-watersheds and the resulting hyrdograph are found in Appendix B. Due to the sub-watershed configurations and instrument locations, the raingage nearest to the sub-watershed is plotted in the event graphs for sub-watersheds 102 and 106, **not** the central raingage as in other sub-watershed event graphs. Both raingages (83 and 384) near the sub-watersheds are plotted in event graphs for sub-watershed 104.

No plot of the spatial distribution of precipitation depths were created for the p/ro events for sub-watersheds 102, 104, and 106 due to the small size of the watersheds and to the fact that more than two raingages are necessary to realistically interpolate the data.

Rating adjustments During the period for which p/ro events were selected, runoff from sub-watershed 104 was measured by weir data. The runoff rating tables for weir 104 were adjusted due to the steep approach and pond siltation, and do not represent the data currently available on the ARS database for sub-watershed 104 for the period 1972 - 1977.

Associated raingages The raingages associated with sub-watersheds 102, 104, and 106 are:

83, 384

V. REFERENCES

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