STORM RAINFALL-RUNOFF RELATIONS

IN

WILSON CREEK WATERSHED, MANITOBA

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ABSTRACT

Although the intense, short duration summer rainstorms falling on the Wilson Creek Watershed in Manitoba, result in a rapid storm runoff, indicating the possibility of a quick impulse-response linear relationship, the scatter of points on a simple correlation of rainfall-runoff indicates some large effects of other hydrologic parameters. This study attempts to determine the major parameter affecting this storm rainfall - storm runoff relationship.

Three techniques of groundwater separation are considered for derivation of direct storm runoff values. An arbitrary groundwater separation technique with the aid of a composite recession curve is selected in the final analysis.

The findings point out that the antecedent basin moisture, as represented by a depth to groundwater table parameter, is the major parameter affecting the storm rainfall - runoff process in the Wilson Creek Watershed.

A preliminary attempt to derive a unit hydrograph for the basin indicates that both the peak and its time distribution are variable.

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CHAPTER I

INTRODUCTION

The operation of flood, erosion, and sediment silting control projects constructed prior to 1957 on several streams originating in the Riding Mountain Escarpment gave indication of future high maintenance costs and pointed out the need for more information on basic causes. This need of discovering the basic causes to the aforementioned problems resulted in the establishment of the Committee on Headwater Flood and Erosion Control in 1957. The Committee was charged with determining the extent, the causes, and the steps required to alleviate the problems of flooding, silting, and erosion caused by action in the headwaters. The Wilson Creek Watershed, located on the eastern slopes of the Riding Mountain, (Figure 1), was selected by the Committee for intensified studies of the abovementioned problems.

Owing to the greater simplicity of conditions and the possibility of obtaining or measuring components of the hydrologic cycle more accurately due to a more dense network of measuring stations, studies of runoff from small drainage basins such as Wilson Creek are better adapted to the determination of the underlying laws and principles of runoff phenomena than studies of larger drainage basins.

The actual program of investigations on Wilson Creek has been discussed fairly extensively in the paper by Mackay and Stanton (1964).

One of the main aspects of the program is the collection of rainstorm and storm runoff data for the establishment of a storm rainfall-runoff relationship. The derivation of a procedure for computing runoff from precipitation provides more insight into the occurrence and control of floods.

The rapid response of runoff to the frequent short duration summer rainstorms on Wilson Creek Watershed, with intensities as high as 6 inches per hour (Newbury et al., 1969) indicates the possibility of a quick impulse-response linear relationship.

Several complex and interdependent processes, however, affect the movement of water from rainfall before it enters streamflow. One of the major problems in determining a storm rainfall-runoff relationship is the separation of the quick response runoff from the long term groundwater flow.

This thesis attempts to discover the major parameter affecting the storm rainfall-runoff relationship in the Wilson Creek Watershed. An initial description of the Wilson Creek storms and the basic data collection in the watershed, in Chapter II, is followed by a general discussion of the factors affecting the runoff phenomena in Chapter III. Several techniques of groundwater separation from the streamflow hydrograph are presented in Chapter IV. The method of chemical base flow separation presently being investigated on the watershed is briefly compared to other methods of base flow separations. The unit hydrograph principle which indicates the time distribution of runoff is discussed. The technique to be used in the thesis for correlation of storm rainfall-runoff is presented along with effects of other parameters.

The data gathered on Wilson Creek Watershed is then analyzed through the aforementioned techniques and a preliminary graphical relationship of storm rainfall-runoff is achieved. A mathematical representation of the graphical relationship is then derived and a comparison between computed and actual flow is obtained. An attempt is also made to determine a unit hydrograph from several storms.

The conclusions presented in the thesis indicate that the antecedent basin moisture as represented by a depth to groundwater table in Well #5 is the major parameter affecting the storm rainfall runoff process in the Wilson Creek Watershed. The findings concluded herein also indicate where future research should be directed or where improvement in the data collection is required.

CHAPTER II

THE WILSON CREEK STORMS

2.1 General Description of Basin

The Wilson Creek Watershed is situated along the eastern boundary of Riding Mountain National Park, on the Manitoba Escarpment, approximately 150 miles northwest of Winnipeg in the vicinity of the town of McCreary (Figure 1). The headwaters of this pear-shaped, 8.5 square mile watershed, begin at about elevation 2400 feet. From a relatively flat plateau in the upper catchment area, the land falls rapidly, dropping about 1300 feet in four miles. A profile and a geologic cross-section from the headwaters down to the weir may be observed in Figure 2. The sloping portion of the watershed along the escarpment is deeply incised and cut by a large number of drains and coulees tributary to the main water courses.

Cox (1968) divides the Wilson Creek Watershed into four distinct physiographic regions with:

(a) the Western Upland comprised of an undulating plain with numerous beaver ponds, muskeg, and kettle holes.

(b) the Upper Escarpment extending down to approximately 1900 feet elevation and composed entirely of glacial deposits.

(c) the Lower Escarpment containing high rising shale banks and

(d) the Manitoba Lowlands located at the foot of the escarpment in the form of an alluvial fan.

The drainage density of 2.9 for Wilson Creek Watershed was determined using a total stream length of 24.78 miles (Cox, 1968).

The drainage densities of the Bald Hill Creek and Packhorse Creek sub-basins are 2.45 and 3.26 respectively while the drainage density of Wilson Creek basin excluding the Bald Hill and Packhorse Basins is given at 5.15 (Cox, 1968). This increase in value may be caused by a small area in the lower basin accompanied by a considerable meanding of the creek.

A soil survey of the Wilson Creek Watershed in 1958 (Mackay and Stanton, 1964) disclosed that the upper portion consisting of finer textured soils indicates a large contribution to surface runoff while the middle portion, comprising the steep slopes of the escarpment and consisting of very permeable soils may keep surface runoff at a low level.

Detailed studies of the vegetative cover of the watershed, as carried out by J. C. Ritchie in 1958, (Mackay and Stanton, 1964), indicate that the forest cover of the watershed is comprised of both coniferous and deciduous species. The more open decadent forest of hardwoods and spruces is more prominent in upper portion of the watershed. The escarpment is covered predominantly with mixed forest in the upper slopes and deciduous trees in the lower slopes. The lower portion of the watershed is covered by a mixture of hardwood and coniferous forest.

2.2 Wilson Creek Watershed Basic Data

2.2.1 Rainfall Data Network

The extreme variation in elevation across the escarpment indicated the necessity of establishing a fairly dense network of rain gauges before attempting to achieve a rainfall-runoff relationship. By September, 1969, 34 rain gauges had been installed throughout the watershed (Thomlinson, 1970). The location of both the 26 standard rain gauges and the 8 recording rain gauges are shown in Figure 1.

The total storm rainfall for the basin is determined by the isohyetal method using data from all rain gauges. Rainfall analysis by the isohyetal method may be observed in Figure 24. Sydor (1970) found the Thiessen polygon method to produce similar results.

Although the average seasonal rainfall, from May to September, has averaged only 14.22 inches from 1959 to 1969 (Thomlinson, 1970) rainfall on the basin is frequent and intensities as great as 6 inches per hour have been recorded (Newbury et al., 1969).

To obtain hourly increments of rainfall for each storm, data from the 8 automatic rain gauges is averaged and adjusted by comparison with the storm rainfall value obtained from the isohyetal analysis using all rain gauges.

The hourly rainfall and runoff data for each storm is presented as Appendix A. Hyetographs of storm rainfall have also been plotted with the storm hydrographs and may be observed in Appendix B.

During each annual period from May to September the basin has been averaging 50 days of rainfall for the past 11 years with the months of June and August having an average maximum 11 days and September averaging only 8 days of rainfall (Thomlinson, 1970).

An average of 5 storms per season with 1 inch of rainfall or higher occurred on the watershed with 1961 having a minimum of 1 storm while 1965 contained a maximum of 9 storms (Thomlinson, 1970).

The maximum 48-hour rainstorm from 1959 to 1969 occurred on June 25 to 27, 1969, and produced an average rainfall of 4.93 inches over the watershed (Thomlinson, 1970).

2.2.2 Streamflow Data Network

Streamflow records on the Wilson Creek Watershed are collected at six gauging stations. These include Packhorse Creek, Bald Hill Dam, Ridge Dam, and the two weirs on Conway Creek in addition to the main gauging station at the Wilson Creek Weir which provides records of streamflow from the whole basin. The location of the stage recorders at the above sites may be observed in Figure 1.

The Wilson Creek Weir was constructed to obtain a stable cross-section necessary for defining a reliable stage-discharge relationship.

The trapezoidal concrete control structure consists of a base width of 30 feet, side slopes of 3:1, a section length of 20 feet and a 2-foot wide notch to rate low flows.

A continuous record of stage is obtained from a Stevens A-35 water level recorder sitting on top of a bank type well installation connected to the stream by intake pipes. The lowest well intake pipe is extended into the 2-foot low flow notch in the concrete weir.

Sediment deposits at the control section cause difficulties in obtaining accurate low flow records especially below 2 or 3 cfs.

Medium and large flows are not significantly affected. The occasional breakdown of the stage recorder, however, also adds to the problem of obtaining accurate records even at high flows.

Generally speaking, the streamflow at the Wilson Creek responds very quickly to rainfall on the watershed. The streamflow hydrograph at the outlet frequently begins to rise only 2 or 3 hours from beginning of rainfall.

The storm discharge hydrographs exhibit sharp rising limbs, high peaks of very short duration and a fairly quick recession. It was hoped that this quick response of the watershed to bypass storm runoff from each storm rainfall may lead to a quick impulse - quick response type of rainfall-runoff relation at Wilson Creek.

The quick response has produced several streamflow hydrographs of over 100 cfs peak values on the watershed with the storm of June 25 to June 27, 1969 reaching a maximum instantaneous peak of 700 cfs. As a comparison the 11-year average daily discharge during the open water season is approximately only 6.0 cfs (Thomlinson, 1970).

2.2.3 Soil Moisture Measurements

Estimates of the moisture content of soil in the basin are generally made weekly using a one-inch tube sampler. The moisture content of the soil samples are estimated by feel at increments of 6 inches up to a depth of 3 feet. These estimates are made at seven sites within the basin.

Laboratory tests have indicated that the soil moisture holding capacity when dry is 3-inches per foot. Once the soil moisture estimate is obtained at each site and the soil capacity is known, the soil moisture deficit may be determined. Values from the seven sites are then averaged to obtain a mean basin soil moisture deficit.

Although the accuracy of this method appears to be questionable, it has provided a fairly reliable estimate for forecasting the possibility of high runoff following a storm rainfall. The estimate of soil moisture deficits prior to some heavy storms have helped to explain the size of the resulting storm runoff.

2.2.4 Groundwater Network

Instrumentation to measure groundwater in the basin was not installed until 1965. The present network of wells and piezometer nests are shown on Figure 1.

Wells #1, #2, and #5 are equipped with continuous automatic recorder charts which require changing only once a month. The piezometers are checked on a weekly basis.

Initial reasons for establishing the groundwater investigations were:

(a) the apparent significance of the groundwater recharge and discharge in the overall water balance of the watershed,

(b) to determine the possibility of fairly rapid subsurface flow, especially in the areas of loose shale, and,

(c) to determine the effect of groundwater flow on the sediment movement adjacent to the streams.

In 1968, preliminary studies were undertaken (Newbury, Cherry, and Cox, 1969) to:

(a) determine the hydrochemical characteristics of the surface and groundwater flow systems,

(b) identify groundwater discharge derived from in-basin and out-of basin sources, and

(c) investigate the use of hydrochemical methods of separating stream hydrograph components.

Analysis of the collected data by Newbury et al.(1969) indicates "that the groundwater flow beneath the uplands above the confluence of Packhorse Creek and Bald Hill Creek and beneath the outlet of the basin is characterized by a downward hydraulic gradient."

Observation of Figure 8, indicates greater fluctuations in Wells #1 and #5 than in Well #2. Both Well #1 and #5 show very quick responses to rainfall in their area with Well #5 appearing to be the most sensitive with the largest fluctuations.

Well #1, set in fill, and Well #5, set in shale, are located in recharge areas well above the nearest stream channel. Well #2 is apparently located in a discharge area.

It is interesting to note in Figure 8 that although Well #5 is located in a recharge area while Well #2 is in a discharge area, the water level in Well #5 rises to within 1.3 feet from the ground surface as a result of the large rainstorm in June, 1969 while the water level in Well #2 only rises to within 6 feet from the ground surface.

2.2.5 Additional Meteorologic Data

The importance of measuring meteorologic data in addition to rainfall for use in water budget and rainfall-runoff studies has not been overlooked. Instrumentation has been installed on the watershed to measure temperature, relative humidity, barometric pressure, wind, pan evaporation, and solar radiation.

The importance of this additional meteorological data shows up when observing the average pan evaporation for the months of May and September for the period 1961 to 1969. Although the average monthly temperatures during that period were higher in September than in May, thus indicating the possible occurrence of higher evaporation in September also, the actual average pan evaporation of 2.54 inches in September is much less than the 4.36 inches in May.

CHAPTER III

FACTORS OF THE RUNOFF PHENOMENA

Generally speaking this chapter deals with a discussion of the runoff phenomena and a qualitative analysis of the factors or parameters which affect runoff.

There is no intention in this thesis to present a quantitative analysis of all these factors and the formulas for deriving their values are thus not presented.

3.1 The Runoff Phenomena

There are many variations in "runoff" definitions found in hydrologic literature.

Bruce and Clark (1966) define runoff from an area as the "integrated result of all hydrological and meteorological factors operative in a drainage area."

Hoyt ,(Chow, 1964),described the "runoff phenomena" in terms of a runoff cycle comprised of five phases, which are briefly described in this section.

Phase 1 - Rainless periods. Groundwater level decreases.

Phase 2 - Initial period of rainfall. Little overland flow or evapotranspiration.

Phase 3 - Continuation of rainfall. Overland flow occurs. Groundwater level rises and increases base flow.

Phase 4 - Continuation of rainfall. Natural storage satisfied. Overland flow and subsurface flow continue.

Phase 5 - Period past termination of rain. Evapotranspiration is active. Streamflow sustained by water from channel and subsurface storage.

Chow, (1964) states that "runoff is that part of precipitation which is collected from a drainage basin as it appears at the outlet." An extensive qualitative explanation of the interrelationship of the various hydrologic phenomena before, during, and after a rain in graphical form is presented by Linsley, Kohler, and Paulhus (1949).

3.2 Components of the Runoff Phenomena

In most hydrology books streamflow is usually split into surface runoff, subsurface runoff and groundwater runoff.

Surface Runoff, or overland flow, is that part of the runoff which travels over the ground surface and through channels and reaches the basin outlet fairly promptly.

The Subsurface Runoff, also known as interflow, is the runoff due to that part of the precipitation which infiltrates the surface soil and moves laterally through the upper soil horizons towards the stream channels. This portion also enters the streams fairly promptly.

The Groundwater Runoff, or base flow, is that part of the runoff due to deep percolation of the infiltrated water which has passed into the ground, has become groundwater, and has been discharged into the stream. This portion is usually called the long term component of streamflow.

For many practical purposes the surface runoff and the prompt subsurface runoff are usually grouped under the term direct runoff, the portion of streamflow used in rainfall-runoff and unit hydrograph analysis. Direct runoff is obtained by subtracting the groundwater or base flow from the total streamflow.

3.3 Factors or Parameters Affecting Runoff

The actual runoff process is very complicated and variable since it is affected by numerous factors. These factors will be considered under three groups -- climatic, physiographic and other hydrologic factors.

3.3.1 Climatic Factors

(a) Rainfall

The quantity and character of streamflow relies heavily on the total amount of rainfall, but the extent to which it does will depend upon the interaction of other characteristics of rainfall such as:

(i) Rainfall intensity

Heavy rain falling in excess of the infiltration capacity of the soil surface will largely contribute to surface runoff and will, therefore, tend to reach the stream very rapidly, while rain falling at lower intensities will be largely absorbed by the soil. Although this may eventually reach the groundwater body, its addition to streamflow will be considerably delayed (Ward, 1967). This indicates that streamflow peaks should vary with the rainfall intensity.

Kohler (1964) states that intensity effects are of great importance in semiarid plains region where severe thunderstorms are prevalent and where an inch of runoff may cause serious flooding.

Because of short time of concentration, runoff from small areas such as Wilson Creek Watershed may be very sensitive to changes in rainfall intensity.

(ii) Rainfall Duration

Rainfall duration is significant when considered in relation to the time taken for a drop of rainfall from the farthest point on the watershed to reach the outlet. This duration determines whether the runoff is being contributed from the whole watershed.

Rainfall duration is also important since the infiltration capacity of the soil tends to decrease through a period of rainfall (Ward, 1967). Thus, the longer duration of rainfall will gradually increase surface runoff to the stream.

(iii) Rainfall Distribution

Consideration of areal rainfall distribution is important since it determines whether the runoff contribution is from the whole watershed.

Since rainfall total or intensity are never uniform over the whole watershed, the difference in location of the concentrated higher intensity rainfall between the steeper headwaters and the low lying downstream section will have a different effect on the time distribution and possibly the peak of runoff.

(b) Other climatic factors such as temperature, humidity, wind, and insolation are significant due to their effect on total evaporation, soil moisture and vegetation which in turn affect runoff.

3.3.2 Physiographic Factors

Most textbooks of hydrology generally discuss similar physiographic factors. Chow (1964) further subdivides these into the following two groups:

(a) Basin Characteristics

(i) Geometric factors - size, shape, slope, orientation, elevation.

(ii) Physical factors - land use and cover, soil type, geologic conditions.

Ward (1967) considers watershed area size the most important factor since it determines the total amount of rainfall to fall on the watershed.

(b) Channel Characteristics

(i) Carrying capacity - size and shape of cross-section, slope, length, and tributaries.

(ii) Storage capacity - backwater effect.

Channel characteristics are related mostly to hydraulic properties of the channel which govern the movement of streamflows and determine channel storage capacity (Chow, 1964).

Chow (1964) further adds, however, that peak runoff on small watersheds is more dominantly affected by overland flow than by channel flow.

3.3.3 Other Hydrologic Factors

(a) Interception

Interception is the process by which precipitation is caught and stored on leaves and stems of the vegetation cover.

Linsley et al. (1949) state that the rate of interception at the beginning of rain is quite high, especially during summer in densely vegetated areas.

Chow (1964) estimates the annual interception by forests to be approximately 25% of annual precipitation.

(b) Evapotranspiration

Evapotranspiration deals with evaporation from soil and water and the withdrawal of water from soil by plants which also evaporates into the atmosphere from its leaf surfaces.

Chow (1964) points out the importance of transpiration from plants when he states that while surface evaporation commonly affects only the upper 6 to 15 inches, plants can withdraw water from considerably deeper soil. Riggs (1963) in his discussion of studies in Brandywine Creek, U.S.A., indicates that differences in summer recession curves on that basin are the result of differences in losses to the atmosphere.

During a storm rainfall period, evapotranspiration occurs at an almost negligible rate since the lower atmosphere is either saturated or nearly so.

During rainless periods evapotranspiration may contribute to the gradual lowering of the groundwater table.

(c) Infiltration

Infiltration is the flow or movement of water from the surface of the ground through the pores and openings of the soil mass, as a result of rainfall on the watershed.

Once the water has infiltrated into the soil mass, its movement through the soil to the groundwater table is known as percolation.

The rate of infiltration is at a maximum when a soil is fairly dry. When water is added from rainfall, the pore spaces in the soil become full and the rate of entry of additional water declines to a low steady rate shortly after beginning of rainfall.

When rainfall rate falling on the ground surface exceeds the infiltration capacity, the rate at which water will be absorbed by a soil surface runoff will occur.

The water which infiltrated into the soil will stay as soil moisture in the ground, move as subsurface flow or percolate to the water table, increasing groundwater flow.

Infiltration indices have been used to estimate an average rate at which rainfall is lost to runoff during specific storms.

Chow (1964) ,however, suggests caution in their use since unequal distribution of rainfall and differences in vegetation cover may affect the derivation and application of these indices.

(d) Soil Moisture

Soil moisture refers to the water in the zone above the water table. The soil moisture content at any time can be expressed as soil moisture deficit in percentage of the field capacity. Field capacity is the amount of water held in the soil after excess gravitational water has drained away and the rate of downward movement has materially decreased.

Since the greater part of soil moisture deficiency is satisfied before significant surface runoff takes place (Linsley et al, 1949) the soil moisture content prior to a rainstorm has a large effect on the amount of the resulting storm runoff.

Since soil moisture content is difficult to measure accurately, several indices have been proposed (Chow, 1964)

(i) groundwater flow prior to rainfall

(ii) antecedent precipitation

(iii) basin evaporation

(iv) groundwater table levels

(e) Depression and Groundwater Storage

Depression storage is water retained in ponds, puddles, ditches and other depressions in the soil surface during rainfall.

Since water collects in depression storage as soon as the ground rainfall rate exceeds infiltration, the amount and duration of surface runoff is effectively reduced (Linsley et al, 1949).

Linsley et al.(1949) further state that, "the combined elements of surface retention may be of sizeable magnitude, ranging from 0.5 to 1.5 inches, for cultivated fields, grasslands, and forests."

Groundwater storage and groundwater movement are affected by a wide variety of topographic geologic and soil conditions. Since these conditions remain fairly constant for each basin, the groundwater occurrence, storage and movement will vary with meteorologic conditions.

Chow (1964) states that differences in rainfall intensity, duration, and areal distribution produce different amounts of recharge from similar amounts of rainfall, thus resulting in close correlations between rainfall variations and groundwater levels.

CHAPTER IV

STORM RUNOFF ANALYSIS AND CORRELATION TECHNIQUES

4.1 Streamflow Hydrograph Analysis

A stream hydrograph, as defined by Bruce and Clark (1966), "is a chronological representation of a discharge of a river. Each storm on the basin, or part of the basin, creates a flood wave of a magnitude which varies with the intensity of the storm, its location on the basin and the dryness of the soil prior to the storm." The effects of these and other factors on the stream hydrograph shape is discussed in the following sub-section.

4.1.1 Factors Affecting Hydrograph Shape

During analysis, a stream hydrograph is generally divided into 3 parts or segments.

(a) the rising limb

(b) the peak segment, and

(c) the recession limb or segment

Linsley et al.(1958) consider the characteristics of the rain-storm causing the rise to be the main influence on the shape of the rising limb.

The peak of a hydrograph, however, may be influenced not only by the storm characteristics but also by seasonal vegetation changes and antecedent basin moisture conditions. Linsley et al.(1949) mention that occurrence of high intensity rainfall early in the storm produces a peak before the end of the rain. This will depend, however, on the storm duration.

Regarding the stream hydrograph recession, Bruce and Clark (1966), and Linsley et al.(1949) consider the shape of the recession limb to be generally independent of the characteristics of the rainstorm although variations in areal rainfall distribution may slightly affect the recession shape.

Riggs (1963) and Bruce and Clark (1966) indicate that the hydrograph recession is affected by seasonal variations in climate and basin vegetation cover and that recession is greater in summer than in winter due to higher evapotranspiration. Riggs (1963) also infers that some lack of consistency of the hydrograph recession segments may be an indication of the existence of two or more groundwater aquifers having different discharge characteristics. Singh (1968), in his studies also noted variations in hydrograph recessions as a result of differences in groundwater aquifers discharge characteristics.

Thus, both Riggs (1963) and Singh (1968) conclude that the theoretical straight line semilog recession curve is not applicable to all streams.

4.1.2 Streamflow Hydrograph Separation

The streamflow hydrograph is generally considered to consist of three runoff components -- surface runoff, subsurface runoff, and groundwater or baseflow. These components are defined in Section 3.2. In studies of floods, the prompt surface and subsurface flow is combined and termed direct runoff, which is the major contribution to flood volume and peaks. To determine the amount of direct runoff, the base flow component is separated from the streamflow hydrograph. Several procedures for separating the hydrograph into base flow and direct runoff have been developed. Fairly extensive reviews of base flow separations have been presented by Chernaya (1964) and Hall (1968).

It is of interest to note some of the differences in the concepts or approaches to base flow separation.

Riggs (1963) states that conventional procedures for separating base flow from direct flow during flood periods usually are based on the assumption that groundwater inflow to the stream continues or even increasss during the flood rise. However, it has been recognized by Linsley et al. (1949) that some streams become influent at flood stages.

A study by Kulandaiswamy and Seetharaman (1969) indicates that some of the methods of base flow separation do not clearly indicate their consideration of interflow. The only two methods mentioned by the authors which provide a clear division of interflow are Barnes method and the recent chemical methods of separation. These are discussed in the following sections.

In all these procedures there is difficulty in determining the time base of direct runoff, that is the terminal point of direct runoff, the size and the time of occurrence of the base flow peak. Linsley et al. (1958) suggest the possible use of a constant time base from storm to storm which may be approximated by using the equation:

$$N = A^{0.2}$$

where N is in days

and A is the drainage area in square miles

Bruce and Clark (1966) qualify this statement by stating that "the time base of direct runoff remains relatively constant for storms of the same duration." Bruce and Clark (1966) and Linsley et al. (1958) indicate that the time base may be determined better by inspection of a number of hydrographs.

Regarding the time of base flow peak, Brater (1940) states that this point probably occurs near the end of surface runoff or about halfway between the peak of the hydrograph and the end of surface runoff. Chow (1964) and Linsley et al. (1958) indicate the location of peak groundwater could also be located under the inflection point of the falling limit of a hydrograph.

Once a method has been chosen and the baseflow has been separated, the volume of direct runoff can then be obtained by planimetering the area under the graph. This volume which is expressed in cfs - days or cfs - hours is then converted to inches of runoff spread over the whole basin.

In this thesis three methods of base flow separation are considered and they are described in the following subsections.

(a) Arbitrary Base Flow Separation With Aid of a Composite Groundwater Depletion Curve

Arbitrary separations of base flow are usually made by drawing of straight lines from the beginning of direct runoff to end of direct runoff. Assumptions have to be made on the increase or decrease of groundwater flow, the time of groundwater flow rise and the peak of groundwater flow. The point of intersection of an arbitrary base flow separation line and the hydrograph recession, which indicates the end of direct runoff, may be determined with the aid of a composite groundwater recession curve and by observation of the hydrograph recession.

A composite groundwater recession curve is commonly derived from segments of several storm hydrograph recessions. Data for a composite recession curve should be selected during periods when it is reasonably certain that no direct runoff is included. Discussions on this method are presented in many hydrologic publications (Bruce and Clark, 1966; Linsley et al., 1949; Riggs, 1963; and others).

(b) Barnes Method of Baseflow Separation

This method of base flow separation was presented by Barnes in 1939 and referred to later in a discussion of Linsley and Ackerman's investigations (1942). Since then, this method has been included in standard hydrological publications (Linsley et al, 1949; Chow, 1964; and others). In this method of separation the total streamflow hydrograph recession is plotted on semi-logarithmic paper. Barnes suggests than that surface runoff, interflow and groundwater flow can then be approximated by three straight lines. As a straight line, the groundwater recession may then be extended back under the hydrograph. Variations from this straight line concept have been noted by Riggs (1963) and Singh (1968). The time of groundwater peak and the rising limb is estimated (Linsley et at, 1949). Ward (1967) suggests locating of the groundwater peak to an approximate point under the peak of the hydrograph.

Linsley and Ackerman (1942) in their study of stream hydrographs in Tennessee Valley by the procedure suggested by Barnes, did not find the results sufficiently consistent. Kulandaiswamy and Seetharaman (1969) in their application of the Barnes method to six storm hydrographs, conclude that Barnes method of separation "is likely to yield direct values of runoff that may be considerably lower than those obtained by using other methods." They also point out the extreme importance of the location of the groundwater peak in this method since the magnitude of the groundwater flow before the peak depends on the position of that peak.

(c) <u>Chemical Methods of Base Flow Separation</u>

Numerous investigators such as Kunkle (1965), Durum (1963), Hendrickson and Krieger (1960), and Toler (1965), have shown the existence of an inverse relation between water discharge and the concentration of dissolved solids in streams. During low flows when the water in the stream is provided by groundwater discharge the concentration of dissolved solids is relatively high. During storm runoff, the direct runoff dilutes the storm water and the concentration of dissolved solids decreases. Pinder and Jones (1969) determined the groundwater component of three Nova Scotia streams during high flows from the chemical characteristics of stream water. A similar inverse relation has been noted between specific conductance, which is a measure of the resistivity of the ionized material in the water, (Hem, 1959), and the streamflow discharge. Kunkle (1965) used specific conductance to compute groundwater discharge to small streams in Iowa.

In studies of the groundwater - streamflow systems of Wilson Creek Watershed, Newbury et al. (1969) observed similar relations of chemical dilution during storm runoff. A relationship between storm runoff and the dilution of $SO_4^=$ concentration was determined to enable the derivation of groundwater flow during summer storms. Examples of the chemical base flow separations on Wilson Creek are presented in Figure 5. This preliminary analysis indicated that the dilution techniques for separating base flow may help to achieve a reasonable rainfall - runoff correlation on the basin.

4.2 Unit Hydrograph

The unit hydrograph developed by Leroy Sherman in 1932 is defined by Chow (1956) as "the hydrograph of direct surface runoff resulting from 1 inch of precipitation excess generated uniformly over the watershed area at a uniform rate during a specified period of time." Unit hydrographs provide a method for a quick calculation of peak flood discharges and the distribution of runoff with time and thus may be used to great advantage in studying and forecasting flood flows.

4.2.1 Basic Assumptions

The unit hydrograph is based on three basic assumptions.

(a) The ordinates of a unit hydrograph are proportional to the total volume of direct runoff from rainfall of uniform intensity and of equal duration, irrespective of the amount of the rain;

(b) The base of time duration of the hydrograph of direct runoff, due to an excess rainfall for a given duration, is practically constant regardless of the volume of runoff;

(c) The ratio of volume of runoff during a particular interval of time to the total runoff is the same for all unit hydrographs of direct runoff derived from the same basin. Based on these assumptions it can be stated that identical storms with the same antecedent conditions produce identical hydrographs.

Bruce & Clark (1966) stipulate that none of these assumptions, however, are precisely fulfilled in nature. Regarding assumption "(b)" on the time base of floods, Linsley et al. (1949) state "that the time required for flows to recede to some fixed value increased with the initial flow." Studies in Dry Creek, California (Kohler, 1964) indicate that difference in seasons and rainfall intensity affect both the peaks and time basis of unit hydrographs. Ward (1967) suggests that for areas smaller than 3000 square miles, variation rainfall patterns may not be significant.

4.2.2 Derivation of the Unit Hydrograph

Procedures for deriving unit hydrographs are presented in most hydrologic textbooks. The procedure used in this study of Wilson Creek storms, is that presented by Linsley et al. (1949) which is included below.

"a. Separate the groundwater flow, and measure the volume of direct runoff from the storm.

b. Divide the ordinates of direct runoff by the runoff volume (expressed in inches over the drainage area). The resulting hydrograph is a unit graph for the basin.

c. Determine the effective duration of runoff- producing rain for which the unit graph is applicable by a study of the rainfall records."

Linsley et al. (1949) also state that a mean unit hydrograph may be determined by averaging several unit hydrographs from similar storms. The average peak size and time location are determined and a mean graph having an area equal to one inch of runoff resembling the individual graphs is sketched in by trial and error. The authors also note that large variations in areal storm distribution or nonuniform intensities may require the development of several unit hydrographs.

Bruce & Clark (1966) and Linsley et al.(1949) indicate that use of storms in excess of 1 inch of runoff tends to diminish the errors in the unit hydrograph because of the reduction to 1 inch. Conversely, the use of storms with very low storm runoff tends to increase the errors in the unit hydrograph.

4.2.3 Deviations from Basic Assumptions

Studies by various investigators (Linsley et al, 1949; Scully and Bender, 1969; Brater, 1940; and Bruce and Clark, 1966) indicate that some deviations from basic assumptions may occur and that variable storm rainfall characteristics such as intensity, duration and areal distribution along with the amount of runoff cause variations in the shape of the resulting unit hydrographs.

Sherman (1940) in a discussion of Brater's investigations, (1940), indicates that areal distribution and thus location of storm center is significant only on larger areas.

Linsley et al.(1958) mention that rainfall variations caused by topographic controls are relatively fixed characteristics of the basin and suggest that it is departures from the normal pattern which caused variations. They also note that effects of rainfall intensities are dependent on basin area size. Regarding effects of rainfall duration, Linsley et al, state that an increase in rainfall duration will lengthen the time base and lower the unit hydrograph peak. Bruce & Clark (1966) indicate that unit hydrograph peaks are generally somewhat higher for extreme floods than for moderate floods. Despite its limitations, however, the unit hydrograph has been frequently used, and many investigations have been attempted to improve its accuracy and applicability.

4.3 Rainfall - Runoff Correlation Techniques

Correlation analysis is a method of showing the relationship between two or more variables. In a simple correlation analysis of rainfall-runoff, two variables indicate a cause and effect relationship to one another.

A graphical plot of runoff against corresponding values of rainfall results in a scatter diagram, the shape of which indicates the nature of the relationship.

Linsley et al. (1958) show that a graphical correlation relation for rainfall-runoff is typically curved, indicating an increasing percentage of runoff with increasing rainfall. The simple method of correlation of only rainfall-runoff is found to be unsatisfactory due to the large scatter of points caused by the effects of other factors on this relationship.

Recent methods as described by Linsley et al. (1949), Miller and Paulhus (1957), Witherspoon (1963), Bruce & Clark (1966), and other investigators generally suggest the use of coaxial-correlation relations with the aid of climatic and physiographic parameters. The most frequently quoted parameters are antecedent precipitation index, storm duration, storm intensity, week or month of the year, soil moisture deficit, days to last significant rainfall, baseflow prior to storm, and others.

Witherspoon (1963) in a study of storm runoff from small agricultural watersheds in Ontario used effective rainfall duration and effective rainfall depth as parameters in a graphical rainfall-runoff relation. He defines effective storm duration as the duration in minutes of effective rainfall which is the depth of rainfall causing runoff. Only rainfall intensities in excess of 0.5 inches per hour were considered.

In studies of rainfall-runoff prediction, Linsley and Ackerman (1942) omitted insignificant amounts of rainfall before or after the main storm to arrive at rainfall duration values. Linsley et al. (1949) suggest that insignificant amounts of rainfall prior to storm could be included with an antecedent precipitation index if such an index is used. Osborn and Lane (1969), using simple linear regression models for predicting total volume of runoff, have indicated, however, that runoff volume was most strongly correlated to total precipitation.

Although numerous studies involving rainfall and runoff are being done today by computers (Betson et al., 1969; Knisel et al., 1969; Osborn and Lane, 1969; and others), Kohler (1964) states that "graphical correlation permits greater flexibility in the selection of the functional form employed and in fact can be employed without consideration of the equation involved."

The procedure used to determine a graphical coaxial correlation relation for rainfall runoff is well described by Linsley et al. (1958), Ezekiel (1941), Richards (1964), and Beard (1962). If the scope of the problem does not justify a complex correlation, Linsley et al. (1949) suggest the use of a three way relationship between rainfall, runoff and either a groundwater flow index parameter or a soil wetness condition parameter.

4.4 Effects of Selected Basin Moisture Parameters on the Rainfall-Runoff Correlation

The volume of storm runoff resulting from storm rainfall is highly dependent on the soil moisture conditions over the basin prior to each storm.

Leroy Sherman (1942) states in his discussion on rainfall-runoff factors that the quantity of moisture in the soil materially governs the intake of rainfall and consequently affects the quantity of surface runoff.

Minshall (1960) also found that runoff was positively correlated to antecedent soil moisture on small experimental watersheds in Illinois, U.S.A. He concluded that these relationships may also apply to several other midwestern states.

The direct determination of soil moisture conditions throughout the basin at the beginning of the storm is fairly difficult, however, since direct soil moisture measurements do not always provide a representative value due to limited areal coverage, length of record and time of observation prior to a storm.

Linsley et al. (1949) suggest that use of an indirect index may provide considerable improvement in rainfall-runoff correlations.

The most common index used for estimating soil moisture is the antecedent precipitation index "API." It is computed from the equation

$$P_t = Pok^t$$

where Po = initial antecedent precipitation index

P_t = reduced value of the antecedent precipitation index "t" days later, and "k" is a depletion factor.

Linsley et al. (1958) suggest a normal usage range for "k" between 0.85 and 0.98. Any rainfall falling on the basin is added to each daily value of API. Bruce & Clark (1966) used a modification of the API by combining it with the week number of the year and terming the resulting values as a seasonal precipitation index, SPI. Linsley and Ackerman (1942) mention that pan evaporation may sometimes be used in the computation of a moisture index. For their studies they concluded that the field moisture deficiency at any time was equal to 0.9 times the total pan evaporation since the ground was last saturated, less any additions made to the field moisture by intervening rains. The maximum possible value was found to be 0.8 inches. Other indices that have been used to represent moisture conditions on the basin are groundwater flow or base flow and the ϕ - index or "Fav" index.

Jones (1967) in his investigations of groundwater-streamflow interactions mentions the use of groundwater flow rated to mean groundwater by Rasmussen and Andreasen (1959), and Schicht and Walton (1961), as indicator of the base flow contribution of a stream.

Regarding the use of the ϕ-index, Linsley et al.(1949) state that "this index is based on the assumption that for a specified storm with given initial conditions, the rate of basin recharge remains constant throughout the storm period. Thus if a time intensity graph of rainfall is constructed, the ϕ-index is the average rainfall intensity above which the volume of rainfall equals the volume of observed runoff."

It appears that the use of any of these basin moisture parameters may be governed by local conditions and attempts should be made to consider two or three of these prior to deciding which parameter may be most useful in any analysis.

CHAPTER V

RAINFALL-RUNOFF ANALYSIS OF WILSON CREEK STORMS

5.1 Rainstorm Analysis

All rainstorm data used in this thesis were computed by the staff of the Wilson Creek Experimental Watershed. The average total rainfall for each rainstorm on the whole basin has been computed using the isohyetal method. The method is described in many hydrology books including those by Bruce and Clark (1966), and Linsley et al. (1949). Two examples of rainstorms with isohyetal lines drawn over the Wilson Creek Basin are shown in Figure 24. Hourly values of rainfall during each rainstorm are obtained by adjusting the average value of the recording rain gauges to the average rainfall over the whole basin which is computed from all rain gauges over the watershed. This hourly rainfall data is presented in Appendix A and is also plotted with the storm runoff hydrographs in Appendices B and C. The rainfall over the watershed occurs as sharp, intense thunderstorms. The quick response of this watershed to high intensity runoff producing rainfall is clearly visible in the above-mentioned Appendices B and C, although this response also depends on the wetness of the soil in the basin. As seen in Figure 24, the amount of rainfall varies over the watershed. Generally speaking, more rain falls in the headwaters of the watershed than at the outlet although there are instances when the storm center occurs in the lower portion of the watershed.

5.2 Analysis of Storm Runoff Computations

Data on hourly storm runoff values are presented in Appendix A. Hydrographs of streamflow following storm rainfall over the watershed are shown in Appendices B and C. The hourly values of streamflow were provided by the Watershed Committee and were computed by using hourly values of stage at the concrete control structure at basin outlet and derived annual stage-discharge curves. In the determination of the hourly values of streamflow, however, there is possibility of several errors.

a. Streamflow measurement errors

b. Drawing of stage-discharge relation curves

c. Extension of rating curves to compute high discharges

d. Faulty recording of stage

e. Change in stage-discharge relationship caused by sediment deposits on the control structure

On large rivers the errors caused by the above possibilities may not affect the final computation of streamflow to any great extent. In a small research watershed stage errors of .01 or .02 foot in the lower portion of the stage-discharge relation may be appreciably large, percentage wise. Thus, although the amount of field data from a research watershed, may be adequate, there is still some possibility of error in this data and this should be considered when applying the data in a numerical or graphical analysis.

5.3 Basin Soil Moisture Indicators Prior to Rainstorms

Three methods of determining the soil moisture in the basin prior to each rainstorm were investigated.

These included the method of obtaining actual field moisture estimates and two methods for computing an index of the basin soil moisture. Field estimates of the soil moisture content have been made weekly during the summer months on the Wilson Creek Watershed since 1963 (Thomlinson, 1970).

Seven-point measurements are obtained throughout the watershed to determine an average estimate of the soil moisture content.

A description of the test procedure and value of the data as presented in the 1969 Annual Report, (Thomlinson, 1969), is given below.

"In the test procedure a one-inch tube sampler is used to take soil samples at increments of six inches down to a depth of three feet. The moisture content of each sample is estimated by feel and recorded. These tests are made at seven locations in the watershed. Laboratory tests have indicated that the water content of the soil between field capacity and wilting point is about three inches per foot of soil.

The weekly estimates of the soil moisture are used to forecast the possibility of high runoff following a storm. Although the method does not provide accurate values, it has helped to explain why some heavy rainstorms have produced relatively little runoff. During the dry summer of 1967, the tests showed the extreme dryness of the soil, while in 1968 they showed that the soil was nearly saturated until the middle of September. This indicates that the heavy precipitation in 1968 was largely stored in the soil rather than emerging as surface runoff at the Wilson Creek Weir."

During preliminary analysis of the effect of soil moisture content on the storm rainfall-runoff relationship of the Watershed, it was realized that although the weekly moisture data gives a general indication of the possible quantity of runoff it is not precise enough for any numerical analysis. These estimates of the moisture content may have been obtained several days or even a week before the rainstorm. Thus, values of soil moisture content immediately prior to the storm had to be computed by estimating soil moisture depletion between rainstorms (Figure 11).

As a result of possible large percentage errors in the estimated soil moisture content using two other techniques for comparison purposes in the rainfall-runoff analysis. The two indices chosen were the Antecedent Precipitation Index and the Depth to Groundwater Table Index.

The procedure for computing the Antecedent Precipitation Index (API) is described in most hydrology books including Linsley, Kohler and Paulhus, 1949, and the formula used for the computation was

$$P_{at} = P_{ao}Kt$$

To obtain day-by-day value of the index "t" equals unity and;

$$P_{a1} = KP_{ao}$$

The antecedent precipitation index Pa_1 for any day is then equal to the constant "K" times the index of the day before. As mentioned in Section 4.4, Linsley et al (1958) state that a value for "k" from 0.85 to 0.98 is applicable over most of the central portions of the United States.

In the computations carried out in this thesis, a value of "k" of 0.90 was used. An example of daily values of the antecedent precipitation index for 1969 is presented in Figure 11. The computed values of the antecedent precipitation moisture prior to each rainstorm used in the analysis are given in Table 2.

Prior to deciding on the third technique, two possibilities were considered. One would be to consider the flow in the stream prior to storm runoff and the other to use the depth to groundwater table. Since streamflows have to be computed from stage-discharge curves which contain a large scatter of points at low flows, it was decided to use the parameter of Depth to the Groundwater table.

Three recording groundwater table gauges in wells #1, #2 and #5 were analyzed. An attempt was made to use an average change in depth of the water table using weighted areas for the three recording gauges (Table 3). However, a quick analysis did not indicate good results.

When graphs of the depth to water table in wells #1, #2, and #5, similar to Figure 8 were plotted, it was noticed that the levels in well #5 were much quicker in responding to rainfall, exhibiting sharp rises and showing smooth gradual recessions following rainfall. Although data from all three wells was studied, it became apparent that well #5 was the most sensitive to precipitation in the basin. There is a large contrast between changes in water table in wells #5 and #2.

Well #2, located in a valley bottom near the stream, is affected by lateral flow and does not exhibit large fluctuations in the water table levels. In the thesis by Cox (1968), the Wilson Creek was divided into four distinct physiographic units:

a. Western Uplands
b. Upper Escarpment
c. Lower Escarpment
d. Manitoba Lowlands

Well #2 is located in the Manitoba lowlands described as an "area of deposition, in the form of an alluvial fan. The ground surface elevation at well #2 is 1256.85 feet, G.S. of C. Well #5, however, is located in the Upper Escarpment." The ground surface elevation at well #5 is 1912.85 feet, G.S. of C. A shallow excavation very near well #5 indicates that the well is placed in a weathered, highly fractured cretaceous shale.

The continuous plot of soil moisture deficit (Figure 11) was based on variations in rainfall, Depth to Groundwater table in well #5 and the antecedent precipitation index. It is noted that soil moisture deficit appears to be a more sensitive indicator of the soil wetness in the watershed than the depth to groundwater table since the groundwater table is not too sensitive to small amounts of rainfall which may get stored in the upper layers of soil. The depth to groundwater table is a continuous recorded value, however, while the soil moisture deficit is an estimate with individual daily values which may have large errors.

5.4 Stream Hydrograph Separations

To enable the use of storm rainfall-storm runoff correlation, the plotted streamflow hydrographs were subdivided into base flow and direct runoff. Three methods of base flow separations were investigated.

5.4.1 Arbitrary Separation

The base flow separation was started at beginning of hydrograph rise and a straight line was extended to a point on the recession line which was estimated to be the end of direct runoff (Appendices B and C). The selection of this end point of direct runoff was based partially on observation of the streamflow hydrograph and partially on a composite recession curve (Figure 3). Although consideration was also given to use a constant number of days or hours from peak to end of direct runoff, some of the smaller hydrographs did not seem to permit such a constant use of time period obtained by multiplying the drainage area to the 0.2 power as suggested by Linsley, Kohler, and Paulhus (1958).

5.4.2 Barnes Method

This method of base flow separation is discussed in Section 4.1.2. Although Barnes (1942) states in his method that stream hydrograph recessions, when plotted on semi-log paper, give the same recession constant, it was not the case in this study. Three examples of base flow separation using Barnes Method are shown in Figure 4. A complete listing of recession constants obtained from analysis of the available hydrographs is presented in Table 4. There is a fairly large range in this recession constant. Further analysis of the recession constant, (Tables 5 and 6), indicates a relationship between the size of the hydrograph peak and the recession constant but no apparent relationship between seasonal change and the recession constant as suggested by Riggs (1963), and Bruce and Clark (1966).

5.4.3 Chemical Method

In this method, the base flow component of the stream discharge is computed using the dilution of $SO_4^=$ concentration during the storm period (Newbury, Cherry, and Cox, 1969). The method of obtaining the chemical data is well described by the authors. The relationship used to compute the base flow component is presented below.

$$Qg,t = \frac{Cs,t \times Qs,t}{Cg,t}$$

where

Qg,t = discharge from long term groundwater storage

Cs,t = the concentration of the characteristic ion in the streamflow (in this case $SO_4^=$)

Qs,t = the total stream discharge

Cg,t = the concentration of the characteristic ion in the groundwater derived from the concentration before and after the storm runoff period

Examples of the chemical method of hydrograph separation on Wilson Creek Watershed in 1968 may be observed in Figure 5. Only a limited amount of data from chemical base flow separation (Table 1) was available however for this study, to use in a rainfall-runoff relationship. A comparison between direct runoff obtained by the chemical base flow separations and that obtained by the arbitrary base flow separation procedure is made in Figure 6. This method appears to cut off too much direct runoff due to fairly high base flow peaks.

Upon observation, the maximum groundwater peak of 200 cfs (preliminary data by Dr. J. Cherry, 1970) for the 1969 June Streamflow hydrograph, appears to be rather high for a total streamflow peak of 700 cfs. To check on the possibility of obtaining such a large groundwater flow, a relationship was determined between groundwater level at well #5 and streamflow during periods of zero rainfall. Since the relationship was curvilinear (Figure 9) and was based on low flows, it was difficult to make an estimate of maximum groundwater flow. A plot of depth to water table in well #5 against base flow on log-log paper appears to provide a straight line relationship (Figure 10) and does substantiate the possibility of high groundwater flows.

If this relationship in Figure 10 was used to estimate base flow, one other concept appears to be worth mentioning. The time of the occurrence of the groundwater peak under the streamflow hydrograph could possibly be obtained from the groundwater recorder chart in well #5. It would at least provide a better basis for selection of that time, than just using an arbitrary point, such as the time of the stream flow peak, the inflection point, or the change in recession. For example, using storm hydrograph 65-9-1 and the depth to groundwater relationship versus streamflow in Figure 10, the base flow peak of 14.5 cfs occurs at 4:00 A.M. September 6, which appears to be a reasonable location under the hydrograph (Appendix C). Using Barnes method, the discharge at that point in time is 13.1 cfs. For storm 65-9-2, the base flow peak of 22.2 cfs would occur at 4:00 A.M. on September 18 (Appendix C). Using Barnes method, the base flow at that time would be 19.2 cfs. As may be noted, this method should be further investigated since it may provide the complete baseflow discharge hydrograph or a comparison for the chemical method of base flow separation.

5.4.4 Direct Runoff

As may be seen in Table 1, the amount of direct runoff from a storm depends on the technique of base flow separation. Observation of any one technique shows variations in the amount of direct-runoff for similar amounts of rainfall. The following section on correlations will point out that the major factor causing this variation is the antecedent basin moisture prior to each storm.

5.5 Storm Rainfall-Storm Runoff Correlation Analysis

Due to the quick response of the basin to sharp intense storm rainfall of small duration, as may be observed in Appendices B and C, it appeared that a good storm rainfall - storm runoff relationship may be achieved at Wilson Creek Watershed.

When actual storm rainfall - storm runoff data was graphically plotted, as shown in Figure 7, a fairly large scatter of points was observed. The best fit line was obtained from a least squares, log-log correlation analysis.

The large scatter of points indicates the effect that other hydrologic factors have on this relationship. The intent of this study was to pinpoint one of the major hydrologic factors or parameters affecting this relationship. To determine which base flow separation provides the best direct runoff data for use in storm rainfall - storm runoff relations, correlation coefficients for the relation were determined for Arbitrary Base Flow Separation Method #1, Barnes Method, and Arbitrary Base Flow Separation Method #2 (Table 1). Lack of data prevented use of the Chemical Method of Base Flow Separation to obtain a correlation coefficient. Data from the Chemical Method was plotted with data from the Arbitrary Separation #1 for comparison purposes (Figure 6). As may be observed, there is no trend of higher or lower values.

In Arbitrary Method #2, small values of rainfall at the beginning of each rainstorm, and which probably did not contribute to direct runoff, were eliminated. Furthermore, two fairly distinct successive hydrographs resulting from closely spaced rainfall were separated as shown in Appendix C, storms 69-6-1 and 69-6-2.

The best correlation coefficient of 0.7122 was obtained from the storm runoff data obtained by Arbitrary Separation #1. All correlation coefficients are shown at the bottom of Table 1. It is interesting to note that the correlation coefficient was the lowest for data from Arbitrary Separation #2 which excluded some of the non runoff producing rainfall and split up complex hydrographs.

The correlation coefficient by Barnes Method was fairly close to the Arbitrary Separation #1 correlation coefficient. The separation by Barnes method appears to cut off too much direct runoff. This may be due to placing the peak of the base flow under the peak of the hydrograph. It should probably be placed a certain time period past the peak of the hydrograph.

Since the best correlation was obtained from data by the Arbitrary Separation #1, it was decided to use this data in further analysis. Several parameters were considered in the investigation. These were season of the year, intensity and duration of rainfall, areal distribution of rainfall, and the basin moisture prior to each rainstorm.

The effect of change in season, which takes into account vegetation and temperature changes, on the rainfall-runoff relation was studied. It was noted that the runoff in May and June is generally larger than for July, August, and September. However, some inconsistencies imply that other factors must affect the rainfall-runoff relationship.

Intensity, duration and areal extent of rainfall were observed separately on the rainfall-runoff relationship but did not show any consistent trend. It is quite possible that if these parameters were considered in connection with other parameters in multiple or coaxial correlation, they would be an aid in obtaining a better estimate of runoff.

The next parameter considered was the basin moisture prior to each rainstorm. After due consideration, it was decided to three separate indices for the basin moisture. These three indices consisted of an average basin soil moisture deficit, a groundwater index and an antecedent precipitation index.

The soil moisture content estimates have been made on Wilson Creek Watershed since 1963. In the July, 1970 Report on Activities in the Wilson Creek Watershed, Thomlinson states, "Although the method does not provide accurate values of the soil moisture content, it has given reliable estimates in the last six seasons and has helped to explain why some heavy rainstorms have produced very little runoff." An example is also provided to indicate the effect of different soil moisture content on basin runoff .....,"the 40-hour storm of August 5 to 7, 1966 produced 4.6 inches of rainfall, a maximum hourly intensity of 1.4 inches and a peak flow of 120 cubic feet per second at the Wilson Creek weir. The 48-hour storm of June 25 to 27, 1969 produced 4.9 inches of rainfall, a maximum hourly intensity of 0.7 inches and a peak flow of 700 cubic feet per second. Although the two rainstorms were similar there was a great difference in the runoff because of the moisture content of the soil before the storms. Soil moisture tests before the storms indicated that the soil could absorb more than two inches in the 1966 storm and only 0.75 of an inch in the 1969 storm."

Using weekly estimates however does not provide an accurate value of soil moisture content just prior to the storm. In this thesis it was decided to estimate a continuous soil moisture deficit, that is what the soil could absorb, using weekly soil moisture content estimate and a continuous rainfall hydrograph of rain gauge no. 10. Using this method, the soil moisture deficit prior to the August 1966 was 2.00 and prior to June, 1969 storm was 0.73. The computed storm runoffs using Arbitrary Base flow Separation #1 were .554 inches and 1.690 inches respectively.

Possibly a better estimate of the continuous soil moisture deficit prior to each storm may have been obtained if the rainfall at gauge no. 10 was adjusted to the basin average.

When storm runoff was plotted against storm rainfall and the estimated values of soil moisture deficit were marked beside each point, (Figure 13), the effect of this parameter on the rainfall-runoff relationship was readily noticed.

Since these values of soil moisture deficit were only estimates it was decided to try other indices of soil moisture in the basin.

A plot of the rainfall-runoff relationship along with the computed antecedent precipitation values is shown in Figure 12.

The rainfall-runoff relationship with the appropriate value of depth to groundwater table index is shown in Figure 14.

Both the soil moisture and the depth to groundwater table parameters appeared to indicate a possibility of establishing a family of curves on the rainfall-runoff relationship. However, since the soil moisture deficit values were estimated with a possibility of large errors in any one individual value while the values of depth to groundwater table were actual precise observations obtained from a continuous groundwater recorder trace, it was decided to use the groundwater table parameter for further investigations.

After numerous trial and error graphical plots on arithmetic, semi-log and log-log paper, the best possible graphical plot by eye judgment of rainfall-runoff with the depth to groundwater table parameter family of curves is shown in Figure 15.

As may be observed from this graph, the family of curves are straight lines on log-log paper which means they may be interpreted by mathematical means. Each straight line may be interpreted by the power formula;

$$y = aX^b$$

where "y" is the dependent variable storm runoff, "x" is the independent variable storm rainfall and "a" and "b" are constants.

Procedure for deriving the mathematical formulas to represent the family of curves are described in most mathematical texts including Brink (1954). The major steps along with the values of constants "a" and "b" for each foot of the depth to groundwater table parameter are shown in Table 7.

To enable the use of this power formula with any value of depth to groundwater table, it was decided to relate the constants "a" and "b" to this parameter. The relationship curves are drawn on arithmetic and log-log plots shown in Figure 16. It was hoped that a straight line relationship may result on log-log plot thus enabling a mathematical relationship. This relationship turned out to be curvilinear and thus either the graphical plot on log-log or the one on arithmetic paper may be used.

Using this graphical plot and the power formula computations were performed to establish a final family of curves relationship showing a curve for each foot of depth of groundwater table. The computed data is shown in Table 8 while the graphical representation may be observed on log-log paper in Figure 17 and on arithmetic paper in Figure 18.

Computed data of storm runoff for each individual storm using the derived power formula relationship are presented in Table 9 and thus may be compared to the observed storm runoff on the same table. Figure 19 shows the relationship between computed and observed values of storm runoff. Although there is scatter in this relationship, and this is a result of not only possible errors in the observed runoff but also the effect of other hydrologic parameters, it does indicate a reasonable correlation and points out the tremendous effect that the depth to groundwater table parameter, as an index of basin moisture, has on the rainfall-runoff relationship of the Wilson Creek Watershed.

5.6 Unit Hydrograph Analysis

Having a relationship between storm runoff and storm rainfall only provides a value of the volume of storm runoff. To enable the forecast of the peak and time distribution of this storm runoff an attempt was made to derive a unit hydrograph for Wilson Creek Watershed.

In the selection of storms to be used in the unit hydrograph study, the rainfall hydrographs were analyzed for ease in selecting the hourly time unit corresponding to excess rainfall, which is the runoff producing rainfall.

All individual computed unit hydrographs were transformed to a common time unit of 4 hours for the derivation of a standard unit hydrograph for the whole basin. The data for all 4-hour unit hydrographs is presented in Appendix E.

Due to the large variability in these 4-hour unit hydrographs and especially the number of lines crossing each other in the rising and falling limbs, only the peaks are presented in Figure 20. This graph shows a large variability in time to peaks and also in the size of the peaks. A summary of the individual storm 4-hour unit hydrograph characteristics is presented in Table 10.

The highest peaks appear to come from unit hydrographs with very low storm runoff. Most hydrology texts suggest the computation of unit hydrographs for 1 inch of storm runoff or higher. If an error is present in the determination of storm runoff, this error is highly magnified when a unit hydrograph is computed. This appears to be the case in our study. The graph does show a tendency for a unit hydrograph from low storm runoff to exhibit high peaks, as the top 5 peaks are from unit hydrographs of low runoff. Storm intensity and storm duration were observed but could not provide any better explanation when considering all these unit hydrographs.

Since there are not too many storms on Wilson Creek Watershed with 1 inch of runoff or higher it was decided to use the unit hydrographs with at least 0.10 inches of runoff.

Only 6 unit hydrographs comply to this limitation. A graph of these unit hydrograph is presented in Figure 21, while the data pertaining to these hydrographs is presented in Table 11.

In attempting to achieve a unit hydrograph from these 6 storms, several points were noticed. Although the peaks of the individual hydrographs ranged between 185 and 230 cfs, the largest difference appears to be in the time from start of direct storm runoff to the peak. The times ranged from 10 hours for storm 62-5-1 to 26 hours for 68-6-2. By observation of such parameters as rainfall intensity, soil moisture deficit prior to storm, depth to groundwater table and location of storm centre it is apparent that no single parameter explains the differences in times to peak. There appears to be a split into 2 groups - storms 62-5-1, 62-5-2 and 66-8-1 in group 1 and storms 65-9-1, 68-6-2 and 68-9-1 in group 2 .The two four-hour unit hydrographs based on the two groups are shown in Figure 22. The apparent difference may be due to change in season and to maximum rainfall intensity.

Storm hydrographs 62-5-1 and 62-5-2 rise very fast to their peaks. This may be due to partially frozen ground at that time causing a quick runoff. The reverse is true to storms 65-9-1, 68-6-2 and 68-9-1. The ground may be drier, there is a lot more vegetation to slow down the runoff thus increasing the times to peak. For storm 66-8-1 the high maximum intensity of 0.84 inches/hour breaks down the seasonal slow down of vegetation and causes a fast rising limb of its storm hydrograph.

Another observation can be made when comparing time to peak and the peaks of U.H.'s. With the exception of 65-9-1, all other 4-hour unit hydrographs exhibited a higher peak discharge when the time to peak was greater.

A relationship was drawn between maximum rainfall intensity and the time to the 4-hour unit hydrograph peak and may be observed in Figure 23. A trend is shown but there appears to be some large scatter.

Average intensities were also observed for each storm and the ratio of maximum intensity to average intensity, but these parameters could not explain the differences in the unit hydrographs.

Further study is required into the unit hydrograph of the Wilson Creek Watershed to determine the factors which affect it.

5.7 Summary of Results

Observation of storm rainfall data on Wilson Creek Watershed indicates that rainfall values are not uniform over the watershed, with the higher rates and amounts generally occurring at the higher elevations in the headwaters. These variations may affect both the storm runoff volume and its time distribution.

In the analysis of runoff, some inconsistencies were observed in the streamflow hydrograph recessions at low flows. These may be caused by changes in control, as a result of sediment deposits upstream or on top of the weir, and inaccuracies in recording of stage.

Three methods of base flow separation were tested for deriving direct storm runoff. The choice of method does not seem to be of prime importance as there is no consistent indication of higher or lower values by any one method. The plot of direct runoff from arbitrary base flow separation and total rainfall provided the best correlation coefficient in the simple rainfall-runoff relationship. It is of interest to note that although the sharp, intense rainfall results in a quick response of runoff, there is still a very large scatter of points on the simple graphical correlation plot of rainfall-runoff (Figure 7). Using direct storm-runoff from Barnes technique of base flow separation, the rainfall-runoff correlation coefficient was just slightly lower than that using the arbitrary base flow relationship. The worst correlation coefficient was obtained from data where small amounts of rainfall was deleted before and after each storm and where several complex stream hydrographs were subdivided.

The large scatter of points on the simple rainfall-runoff relationship (Figure 7) indicated the interrelationship of other parameters in this process.

The effect of several parameters on this storm rainfall-runoff relationship was investigated. These parameters were seasonal changes throughout the year, intensity, duration, and areal distribution of rainfall and basin moisture prior to each storm. With the exception of the basin moisture parameter, all other parameters showed some inconsistencies when plotted individually on the rainfall-runoff relationship.

Three indicators of basin moisture prior to rainstorms were investigated -- an average basin moisture deficit, an antecedent precipitation index and a depth to groundwater table index. The groundwater table in Well #5 was found to be the best indicator of basin moisture. The soil moisture deficit obtained from actual moisture measurements might have been a better parameter if it was recorded on a continuous basis since it appears to be more sensitive to rainfall.

An interesting aspect of the investigation of the basin moisture using the depth to groundwater table in Well #5 parameter was the achievement of a relationship between this parameter and dry weather flow (Figure 10). As a result of this relationship, it appears that a complete base flow hydrograph may be derived under the total streamflow hydrograph since the groundwater well is equipped with a contiuous recorder chart. The discussion in the latter part of Section 5.4.3 indicates that this relationship will provide a time location for the base flow peak that can be based on actual field data instead of just using an arbitrary choice.

Having computed the values of depth to groundwater table in Well #5, these values were plotted on the rainfall-runoff relationship and a family of curves was derived and is shown in Figure 18 on page 56 of this chapter. The graph in Figure 19, showing the comparison of observed runoff versus runoff computed from the relationship in

Figure 18, indicates the tremendously large effect of antecedent basin moisture on the storm rainfall-runoff of Wilson Creek Watershed.
In order to achieve a time distribution of storm runoff and prediction of peak flows an attempt was made to derive a unit hydrograph for the basin. The analysis of the derived 4-hour unit hydrographs (Figure 22) indicates a variation in both the time distribution of runoff and the size of unit hydrograph peaks. Lack of data from storms with values of 1 inch of runoff or higher makes the results inconclusive and further investigation is required into this aspect. The preliminary results indicate a trend, however, in the relationship between maximum rainfall intensity and the time to the derived 4-hour unit hydrograph peaks. Other parameters which should be looked into are change in season, soil moisture deficit prior to each storm, and areal distribution of rainfall.

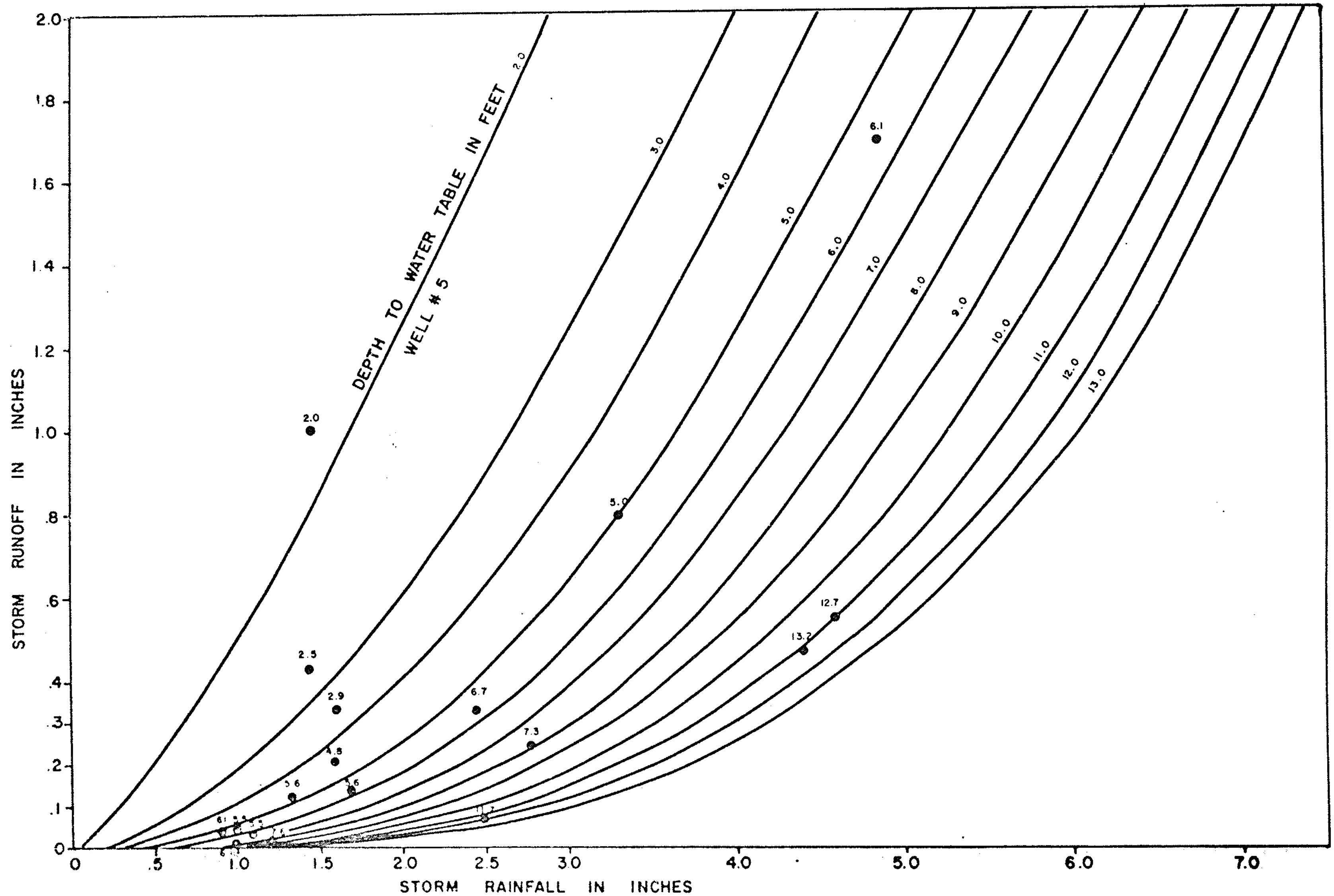


Figure 18. Final graphical plot of lines of depth to groundwater table in well #5 as derived from storm equation $Y=aX^b$ on arithmetic scale.

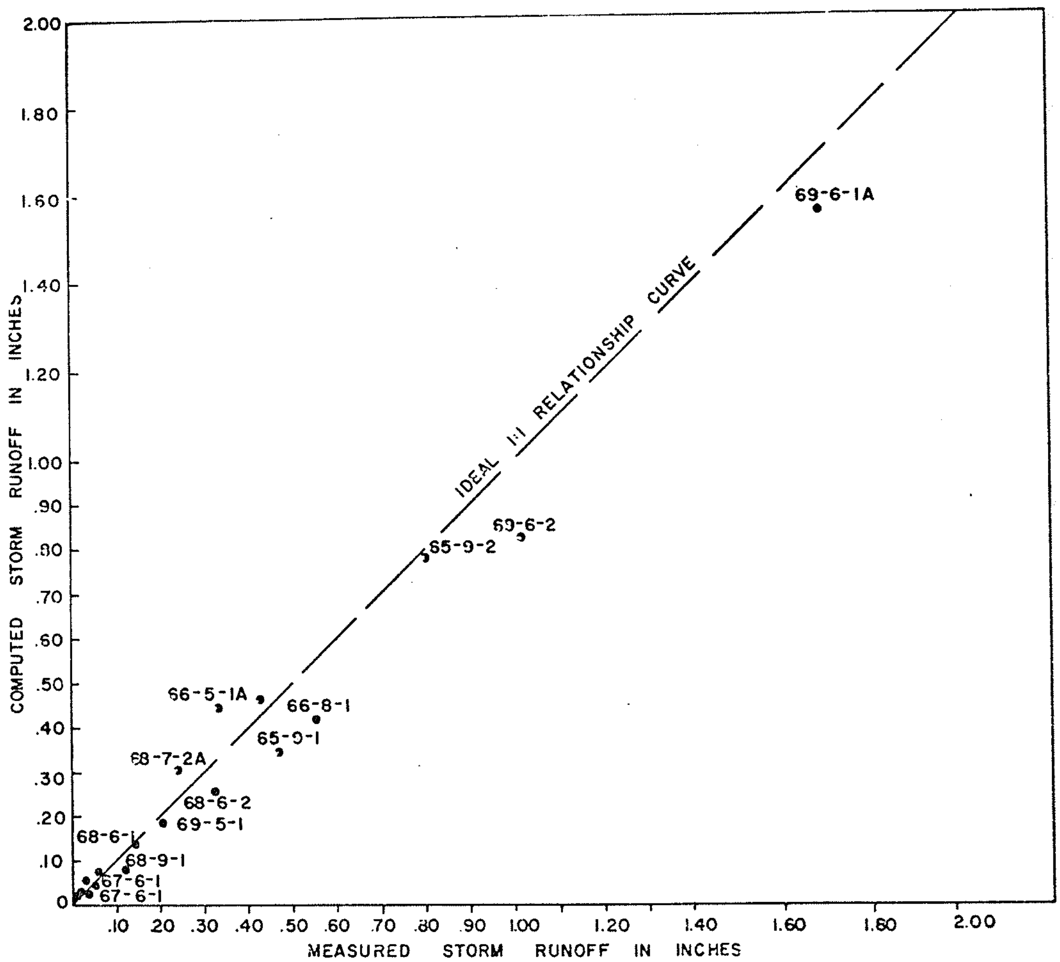


Figure 19. Comparison of computed versus measured storm runoff.

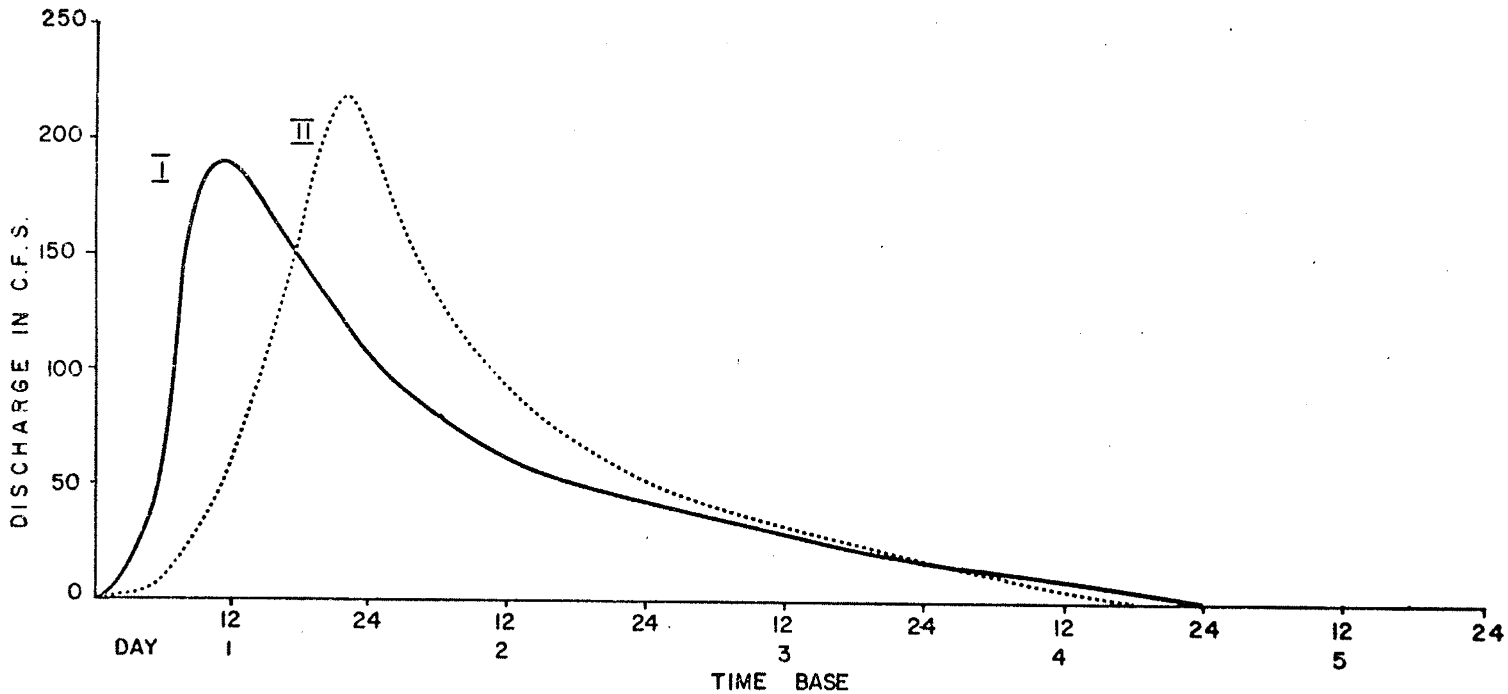


Figure 22. Composite four-hour unit hydrographs.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 The antecedent basin moisture condition just prior to storm rainfall appears to be the major parameter affecting the rainfall runoff process on the Wilson Creek Watershed.

6.1.2 The depth to the groundwater table in well #5 was found to be a more accurate indicator of the basin moisture just prior to storm rainfall than the average soil moisture deficit as computed from field moisture estimates.

6.1.3 The choice of technique of base flow separation does not seem to be significant for computing storm runoff volumes. The storm runoff data from the arbitrary base flow separation technique was used in the final rainfall-runoff relationship.

6.1.4 An improvement in the base flow separation technique may be made by using a derived relationship between the continuous recording charts of groundwater levels in well #5 and dry weather flow as it provides the base flow peak discharge and its time location under the streamflow hydrograph.

6.1.5 The preliminary attempt to derive a unit hydrograph for the basin indicates that the peak discharge and its time distribution is variable. Further investigations into this process is included in the recommendations.

6.2 Recommendations

6.2.1 To check on applicability of the rainfall-runoff relation to other watersheds on the Manitoba Escarpment, it is recommended that groundwater wells be located in the headwaters of 2 or 3 other watersheds, to be used as indices of the basin moisture prior to each storm rainfall.

6.2.2 Since groundwater levels at Well #5 appear to correlate fairly reasonable with base flow, analysis should be carried out to determine whether the peak of the base flow would plot under a storm hydrograph. This may provide a quantitative method of locating the peak of base flow on a consistent basis in each hydrograph analysis instead of an arbitrary choice.

6.2.3 The continuous recording chart of groundwater level in Well #5 and the relationship curve between depth to groundwater level versus base flow should be investigated further to determine if it could provide a continuous base flow hydrograph.

6.2.4 Compare base flow peak location derived from the relationship of base flow with groundwater level in Well #5 with those determined by chemical methods, Barnes method and arbitrary methods.

6.2.5 Methods of measuring and computing soil moisture on a continuous basis should be improved since soil moisture is more sensitive to rainfall than the groundwater table and if accurately determined, could provide better data for rainfall-runoff relations.

6.2.6 Consideration should be given to using Thiessen polygon method to basin soil moisture computations since it gives weight to the areas covered by each point moisture observation than using an arithmetic average.

6.2.7 Studies should be made to analyze effects of extremely uneven areal distribution of rainfall on the storm-runoff hydrograph.

6.2.8 Effects of maximum 5, 10, 15, and 30 minute rainfall intensities on the rainfall runoff and the unit hydrograph should be investigated to determine effects on runoff volumes and peaks.

6.2.9 Brief analysis of rainfall-runoff should possibly be made using Wilson Creek tributaries and their applicable areas to reduce the effect of rainfall variability.

6.2.10 Further studies are required to determine factors affecting the unit hydrograph peak flow and its time distribution.

6.2.11 Strong efforts should be made to measure flow on Wilson Creek during storms of high runoff volumes. This is extremely important for the derivation of an accurate unit hydrograph for the basin.

6.2.12 Interflow separations were not included in this thesis. It may be interesting in future studies to compare interflow from Barnes separation and by the Chemical Method presently used on Wilson Creek.

6.2.13 New data from research watersheds should be analyzed after 2 or 3 years of operation to check on adequacy of data and determine where improvements in data collection could be made.

6.2.14 The performance of the Wilson Creek weir, especially at low flows, should be analyzed. The stage-discharge relationship and the setting of the recorder chart by summer students should also be checked. Possibly a recommendation should be made that Water Survey of Canada carry out these investigations and that their personnel visit this site on a monthly basis.

REFERENCES

1. BARNES, B. S., 1942, Discussion on Rainfall-Runoff Prediction by Linsley and Ackerman, ASCE Transactions, pp. 836-841.

2. BEARD, L. R., 1962, Statistical Methods in Hydrology, U. S. Army Engineer District, Corps of Engineers, Sacramento, California, U.S.A.

3. BETSON, R. P., TUCKER, R. L., and HALLER, F. M., 1969, Using Analytical Methods to Develop a Surface-Runoff Model, Water Resources Research, Vol. 5, No. 1, pp. 103-111.

4. BRATER, E. F., 1940, The Unit Hydrograph Principle Applied to Small Watersheds, A.S.C.E. Trans. Vol. 105 pp. 1154-1178.

5. BRINK, R. W., 1954, A First Year of College Mathematics, Appleton-Century-Cropts Inc., New York.

6. BRUCE, J. P., and CLARK, R. H., 1966, Introduction to Hydrometeorology, Pergamon Press Ltd.

7. CHERNAYA, T. M., 1964, Comparative Evaluation of Graphical Methods of Separation of Groundwater Components of Streamflow Hydrographs, Soviet Hydrology 5, pp. 454-465.

8. CHOW, V. T., 1956, Hydrologic Studies of Floods in the United States, International Association of Scientific Hydrology Publication 42, pp. 134-170.

9. CHOW, V. T., 1964, Handbook of Applied Hydrology, McGraw-Hill Book Company, New York.

10. COX, R. A., 1968, An Investigation into the Streamflow and Groundwater Hydrology of Wilson Creek, A Small Manitoba Watershed, M. A. Thesis, the University of Manitoba.

11. DURUM, W. H., 1953, Relationship of the Mineral Constituents in Solution to Streamflow, Trans. American Geophysical Union #34.

12. EZEKIEL, M., 1941, Methods of Correlation Analysis, 2nd Edition, Wiley, New York.

13. HALL, F. R., 1968, Base Flow Recessions - A Review, Water Resources Research, Vol. 4, No. 5.

14. HEM, J. D., 1959, Study and Interpretation of the Chemical Characteristics of Natural Water, U. S. Geol. Survey, Water Supply Paper 1473.

15. HENDRICKSON, G. E., and KRIEGER, R. A., 1960, Relationship of Chemical Quality of Water to Stream Discharge in Kentucky, International Geol. Cong. 21st, Copenhagen, Rept., pt. 1, Geochemical cycles, pp. 66-75.

16. JONES, J. F., 1967, Groundwater-Streamflow Interactions, Proceedings of Workshop Seminar on Groundwater-Streamflow Systems, sponsored by the Canadian National Committee of the IHD, Laval University.

17. KNISEL et al, 1969, Runoff Volume Prediction from Daily Climatic Data, Water Resources Research, Vol. 5 No. 1, pp. 84-94.

18. KOHLER, M. A., 1964, Rainfall-Runoff Models, IASH Publication No. 63, pp. 479-491.

19. KULANDAISWAMY, V. C., and SEETHARAMAN, S., 1969, A Note on Barnes Method of Hydrograph Separation, Journal of Hydrology pp. 222-229, North Holland Co. Amsterdam.

20. KUNKLE, G. R., 1965, Computations of Ground-Water Discharge to Streams During Floods or to Individual Reaches During Base Flow, By Use of Specific Conductance, U. S. Geol. Survey Prof. Paper 525-D, pp. D207 - D210.

21. LINSLEY, R. K., and ACKERMAN, W. C., 1942, Method of Predicting the Runoff from Rainfall, Trans. A.S.C.E., Paper No. 2147, pp. 825-835.

22. LINSLEY, R. K., KOHLER, M. A., and PAULHUS, J. L. H., 1949, Applied Hydrology, McGraw-Hill Book Company, New York.

23. LINSLEY, R. K., KOHLER, M. A., and PAULHUS, J. L. H., 1958, Hydrology for Engineers, McGraw-Hill Book Company, New York.

24. MACKAY, G. H., and STANTON, C. R., 1964, Wilson Creek Study, Erosion and Sedimentation Control, Proceedings of Hydrology Symposium No. 4, Research Watersheds, National Research Council of Canada.

25. MILLER, J. F., and PAULHUS, J. L. H., 1957, Rainfall-Runoff Relation for Small Basins, Trans. Am. Geophys. Union, Vol. 38, pp. 216-218.

26. MINSHALL, N. E., 1960, Predicting Storm Runoff on Small Experimental Watersheds, Journal of the Hydraulics Division, Proc. of the A.S.C.E.

27. NEWBURY, R. W., CHERRY, J. A., and COX, R. A., 1969, Groundwater Streamflow Systems in Wilson Creek Watershed, Manitoba, Canadian Journal of Earth Sciences, Vol. 6, No. 4.

28. OSBORN, H. B. and LANE, L., 1969, Precipitation-Runoff Relations for Very Small Semiarid Rangeland Watersheds, Water Resources Research, Vol. 5, No. 2.

29. PINDER, G. F., and JONES, J. R., 1969, Determination of the Groundwater Component of Peak Discharge from the Chemistry of Total Runoff, Water Resources Research, Vol. 5 No. 2.

30. RASSMUSSEN, W. C., and ANDREASEN, G. E., 1959, Hydrologic Budget of the Beaverdam Creek Basin, Maryland, U. S. Geol. Survey Water Supply Paper 1472, 106 p.

31. RICHARDS, M. M., 1964, Prediction of Runoff Volume from Storm Rainfall, Trans. of the Inter-Regional Seminar on Methods of Hydrological Forecasting for the Utilization of Water Resources, Bangkok, Thailand, United Nations Water Resources Series No. 27.

32. RIGGS, H. C., 1963, The Base-Flow Recession Curve As An Indicator of Ground Water, International Association of Scientific Hydrology, Berkeley, U. S. A.

33. SCHICHT, R. J., and WALTON, W. C., 1961, Hydrologic Budgets for Three Small Watersheds in Illinois, Illinois State Water Survey, Rept. of Investigation 40, 40 p.

34. SCULLY, D. R., and BENDER, D. L., 1969, Separation of Rainfall Excess from Total Rainfall, Water Resources Research, Vol. 5, No. 4.

35. SHERMAN, L., 1942, Discussion on Method of Predicting the Runoff from Rainfall by Linsley et Ackermann, Trans. A.S.C.E., Paper No. 2147.

36. SINGH, K. P., 1968, Some Factors Affecting Baseflow, Water Resources Research, Vol. 4 No. 5.

37. SYDOR, M., 1970, Computer Simulation Model of Wilson Creek Watershed, M. Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

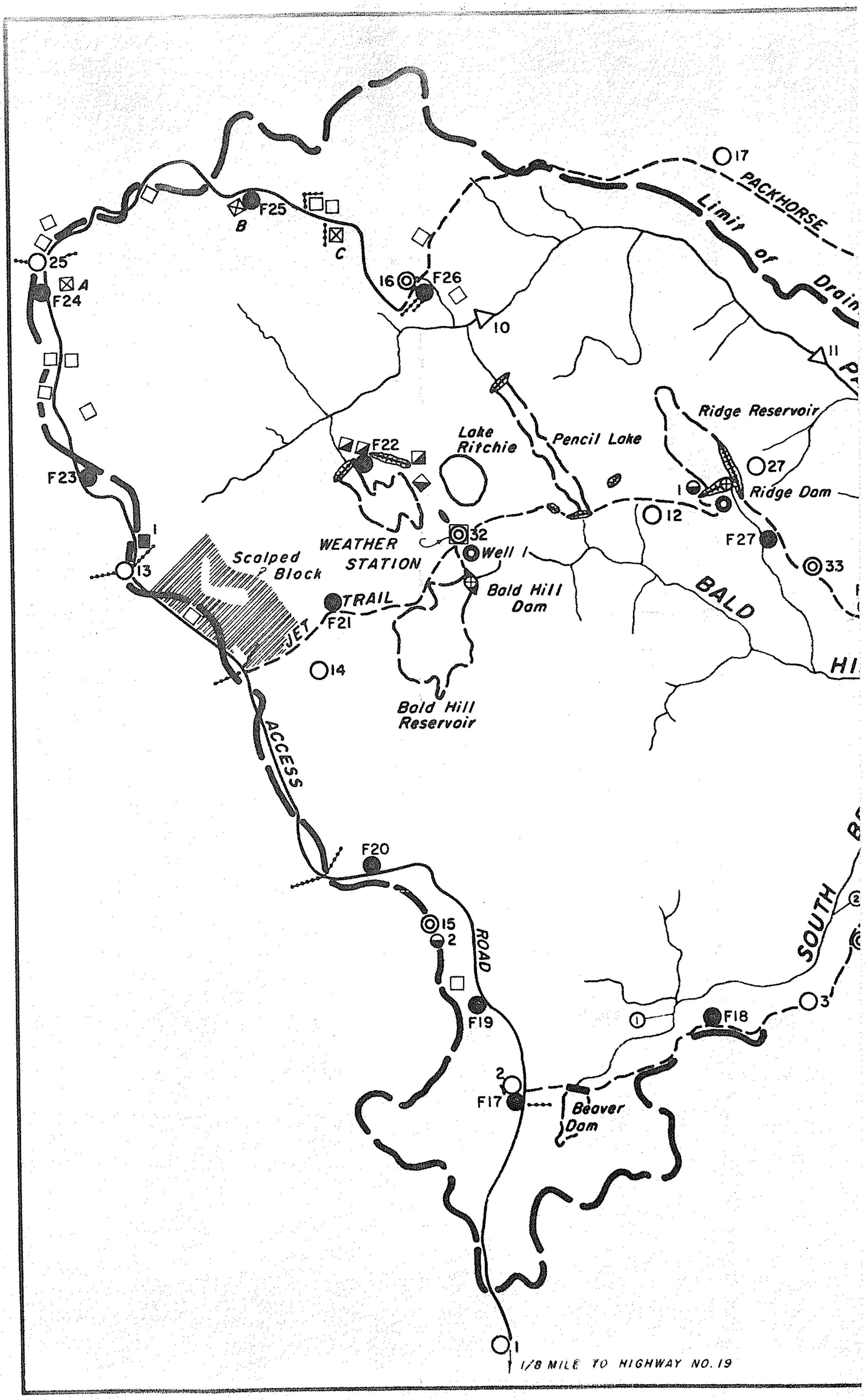
38. THOMLINSON, J. E., Annual Reports on Activities in Wilson Creek Watersheds.

A. 1969
B. 1970

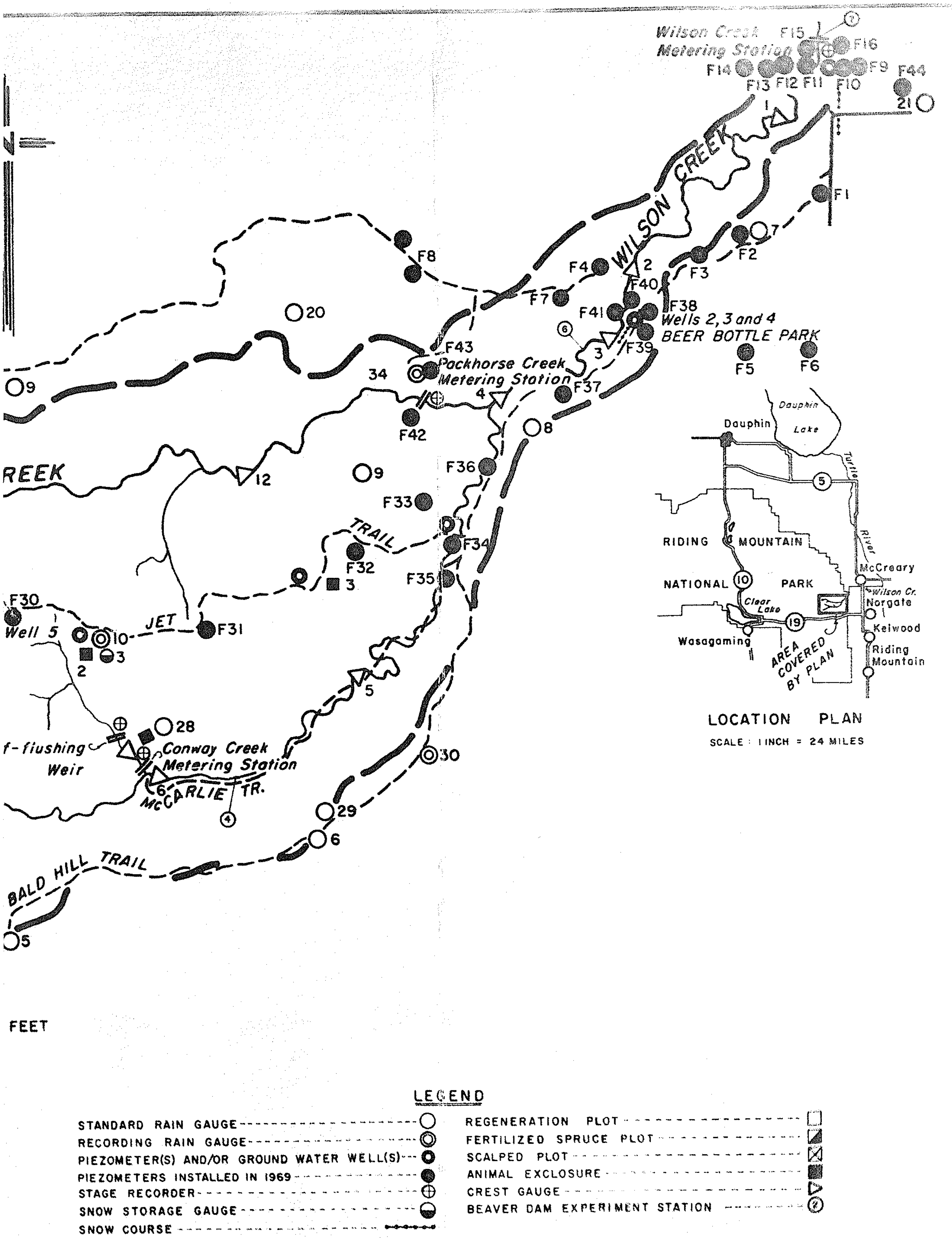
39. TOLER, L. G., 1965, Relation Between Chemical Quality and Water Discharge in Spring Creek, South Western Georgia, U. S. Geol. Survey Prof. Paper 525-C, pp. C209 - C213.

40. WARD, R. C., 1967, Principles of Hydrology, McGraw-Hill Publishing Co. Ltd., London.

41. WITHERSPOON, D. F., 1963, Runoff from Rainfall on Small Rural Watersheds, EIC Transactions, Vol. 6, No. 10-A, 7 pp.



17
PACKHORSE
Limit of Drain
F25
B
C
25
A
F24
16
F26
10
11
Ridge Reservoir
Lake Ritchie
Pencil Lake
F22
27
Ridge Dam
F23
1
12
32
WEATHER STATION
Well 1
F27
33
Scalped ? Block
13
TRAIL
JET
F21
Bald Hill Dam
BALD
HI
14
Bald Hill Reservoir
ACCESS
ROAD
F20
15
2
SOUTH
F19
3
F18
F17
Beaver Dam
1
1/8 MILE TO HIGHWAY NO. 19



INSTALLATIONS IN WILSON CREEK EXPERIMENTAL WATERSHED

MARCH 1970

70612

FIG. 1

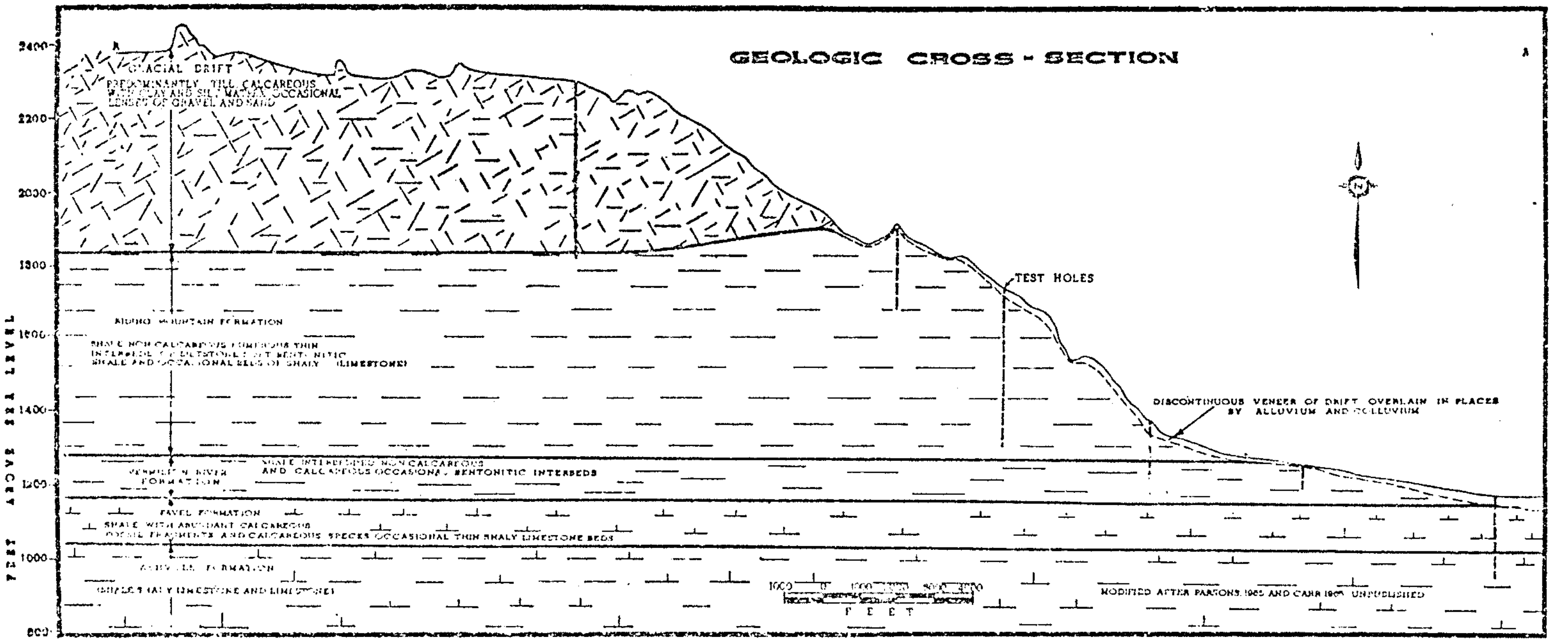


Figure 2. Geological cross-section, Wilson Creek Watershed
(after Newbury et al., 1969)

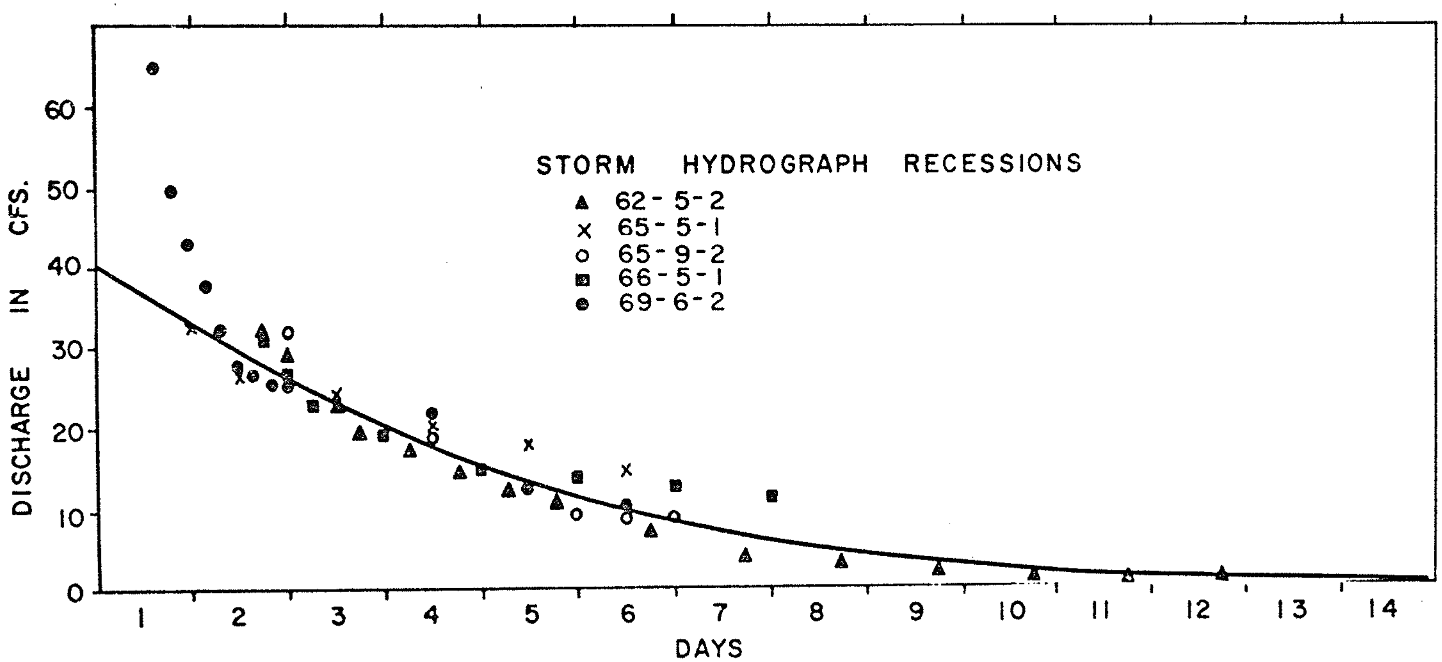


Figure 3. Composite base flow recession curve

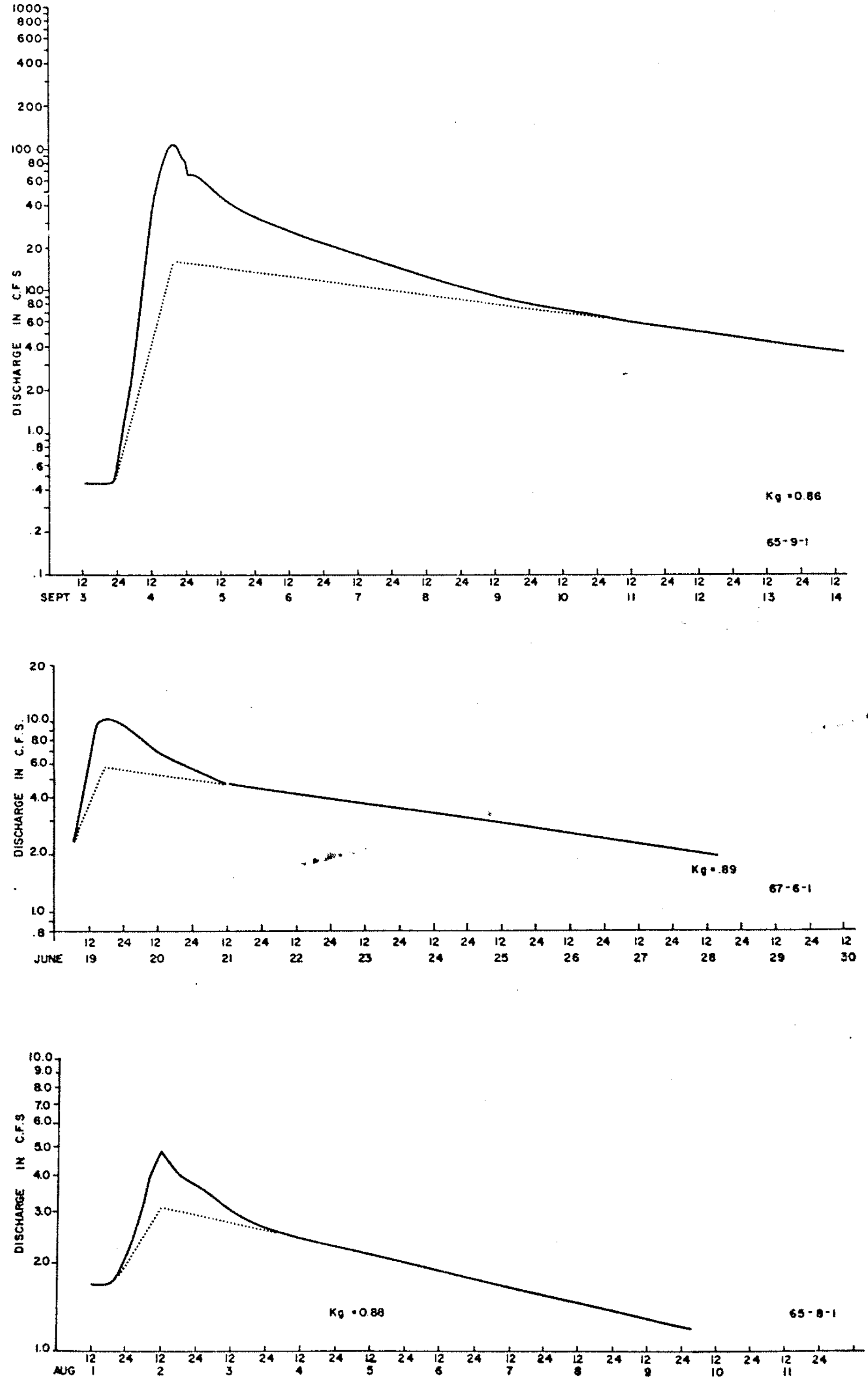


Figure 4. Examples of Barnes' method of base flow separation.

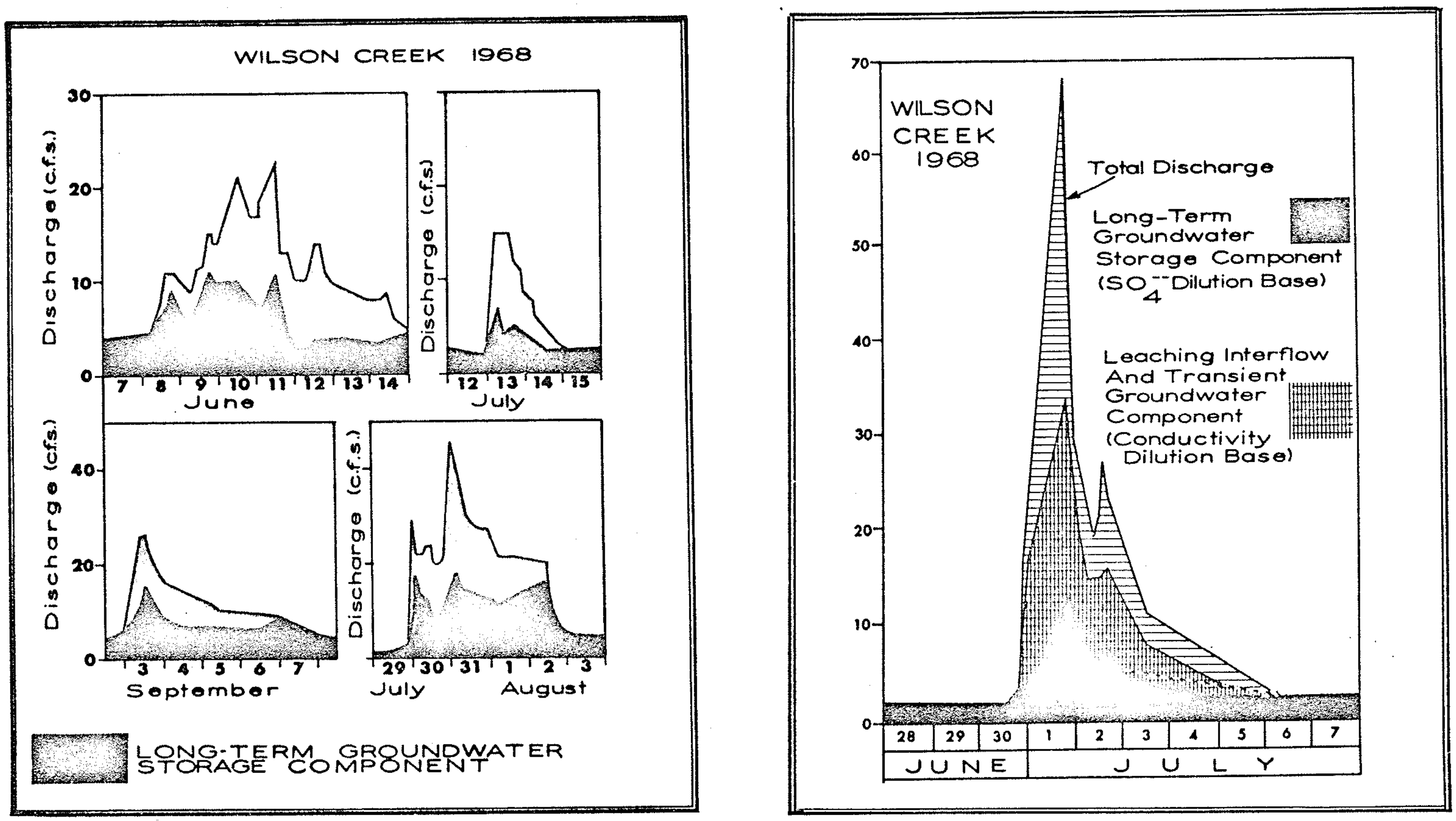


Figure 5. Examples of the Chemical Method of Baseflow Separation (After Newbury, Cherry, and Cox, 1969).

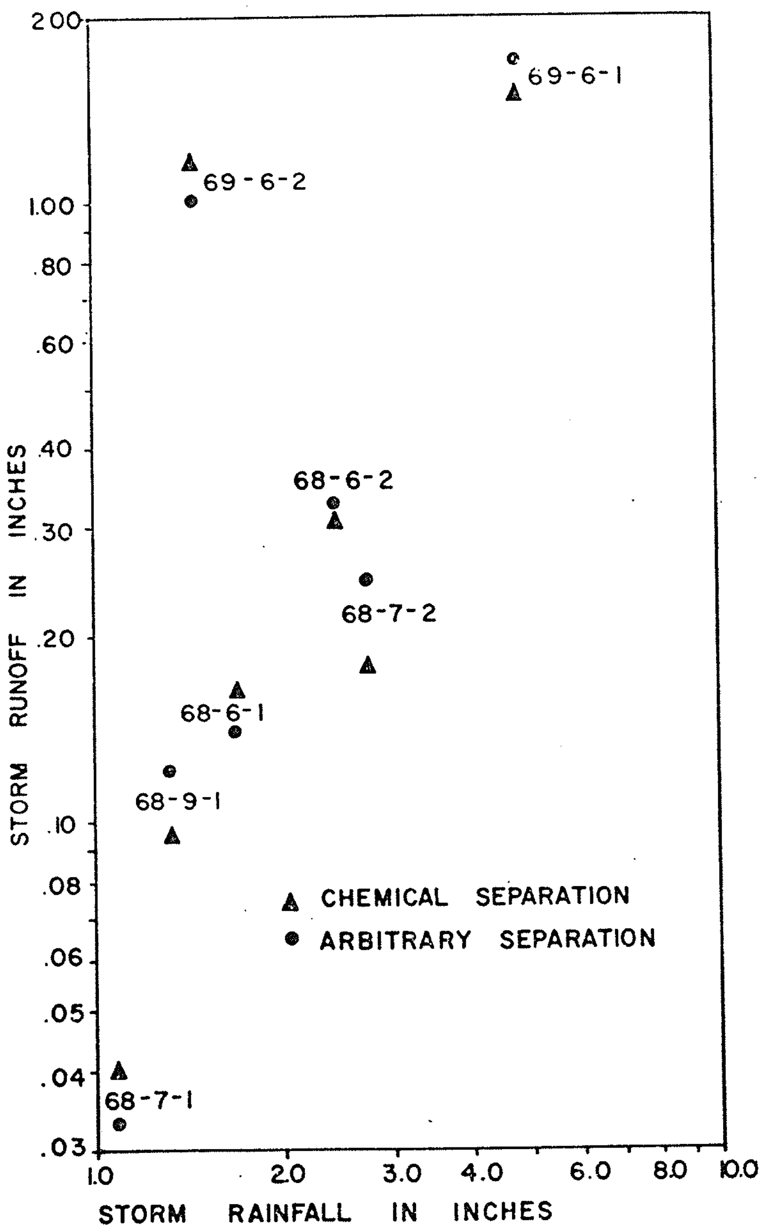


Figure 6. Comparison of storm runoff from chemical base flow separation with the arbitrary base flow separation #1.

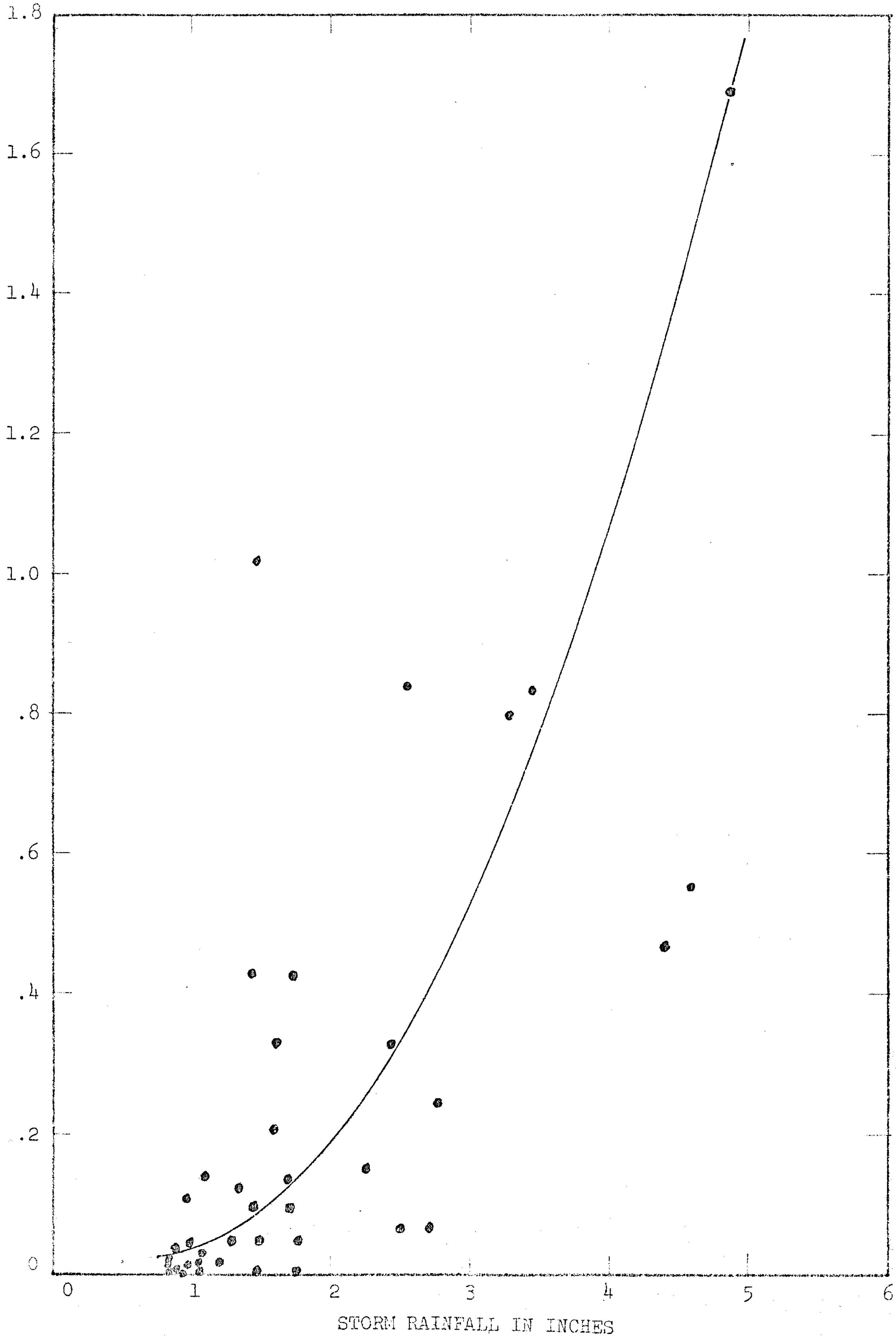


Figure 7. Wilson Creek rainfall - runoff relation

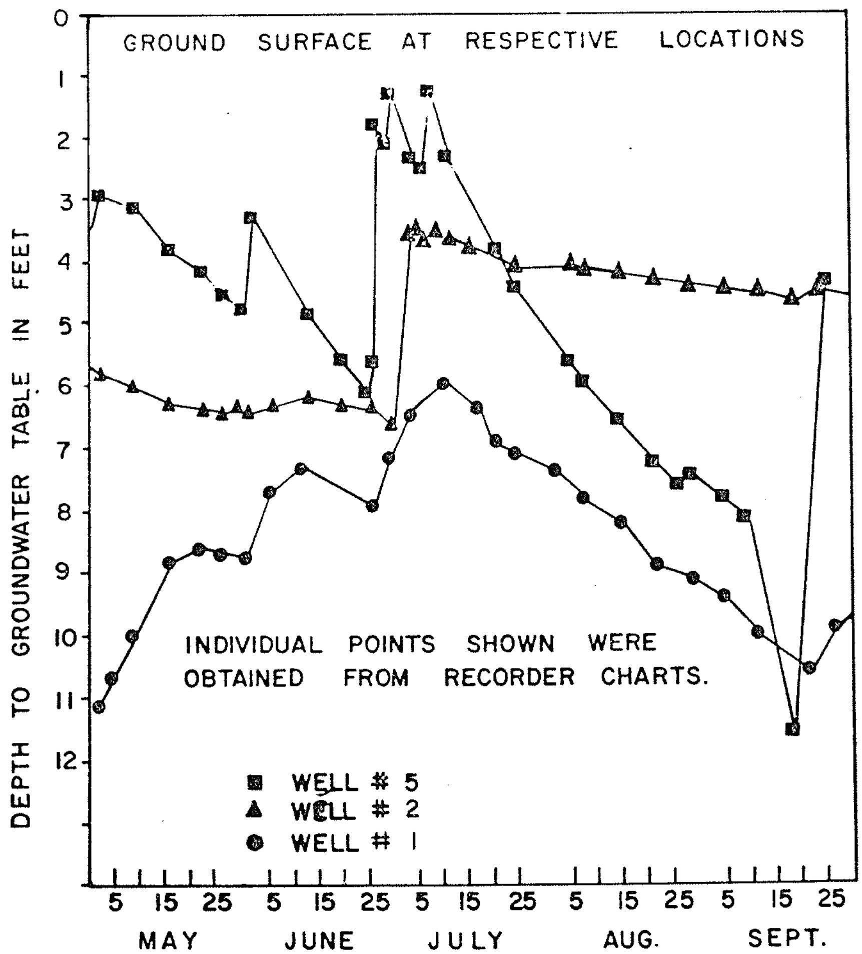


Figure 8. Groundwater table fluctuations in Wells #1, #2 and #5 in 1969.

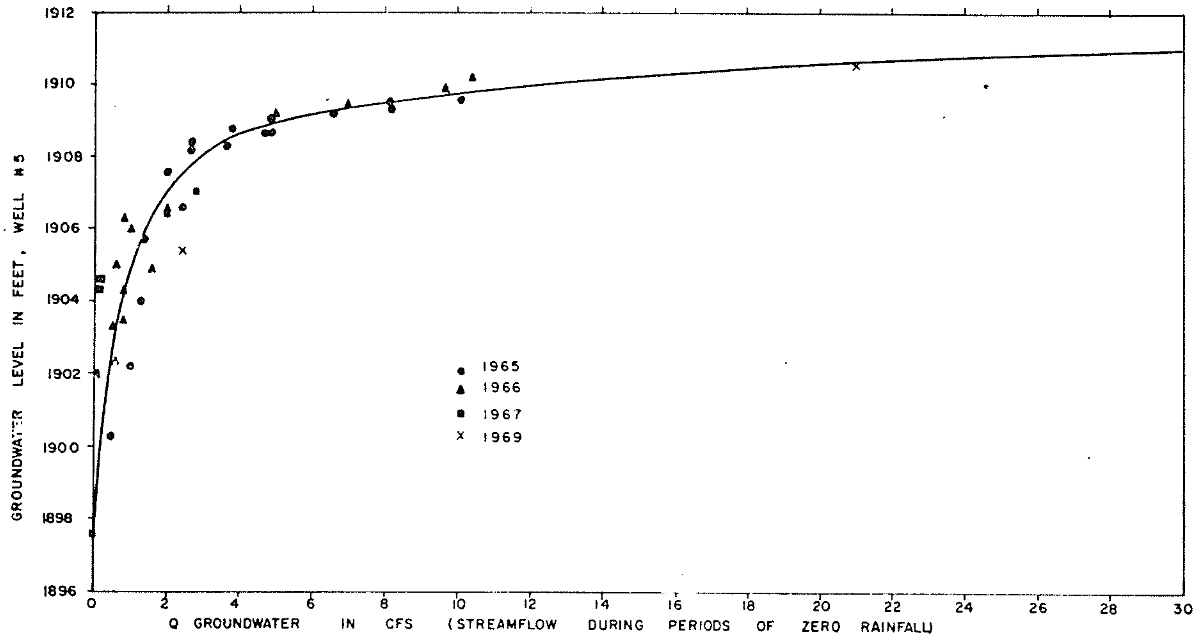


Figure 9. Groundwater table levels in well #5 versus streamflow at Wilson Creek weir during periods of zero rainfall.

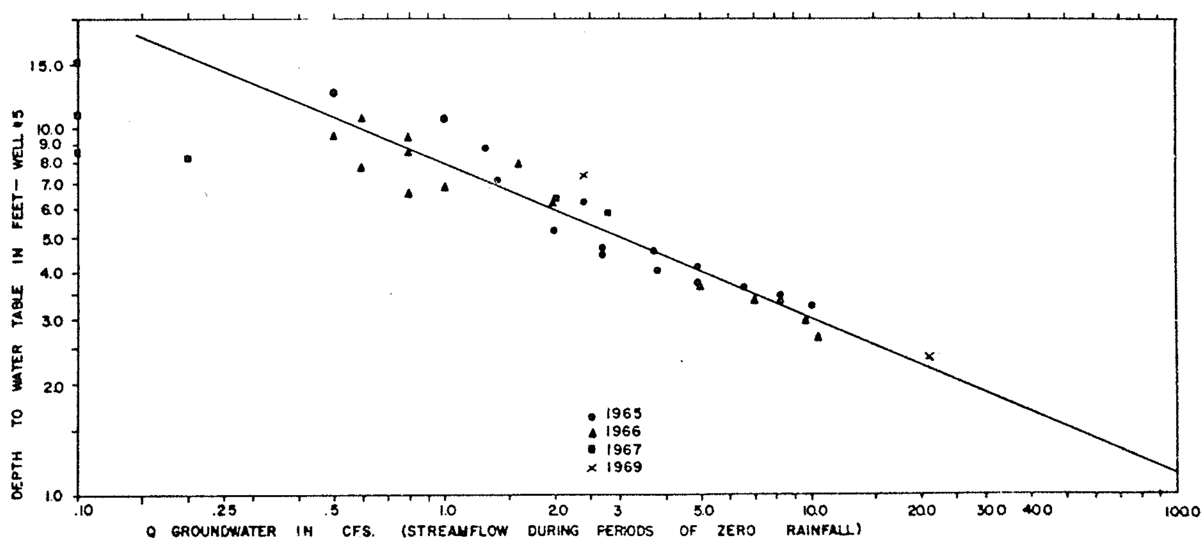


Figure 10. Depth to groundwater table in well #5 versus streamflow during periods of zero rainfall plotted on log-log scale.

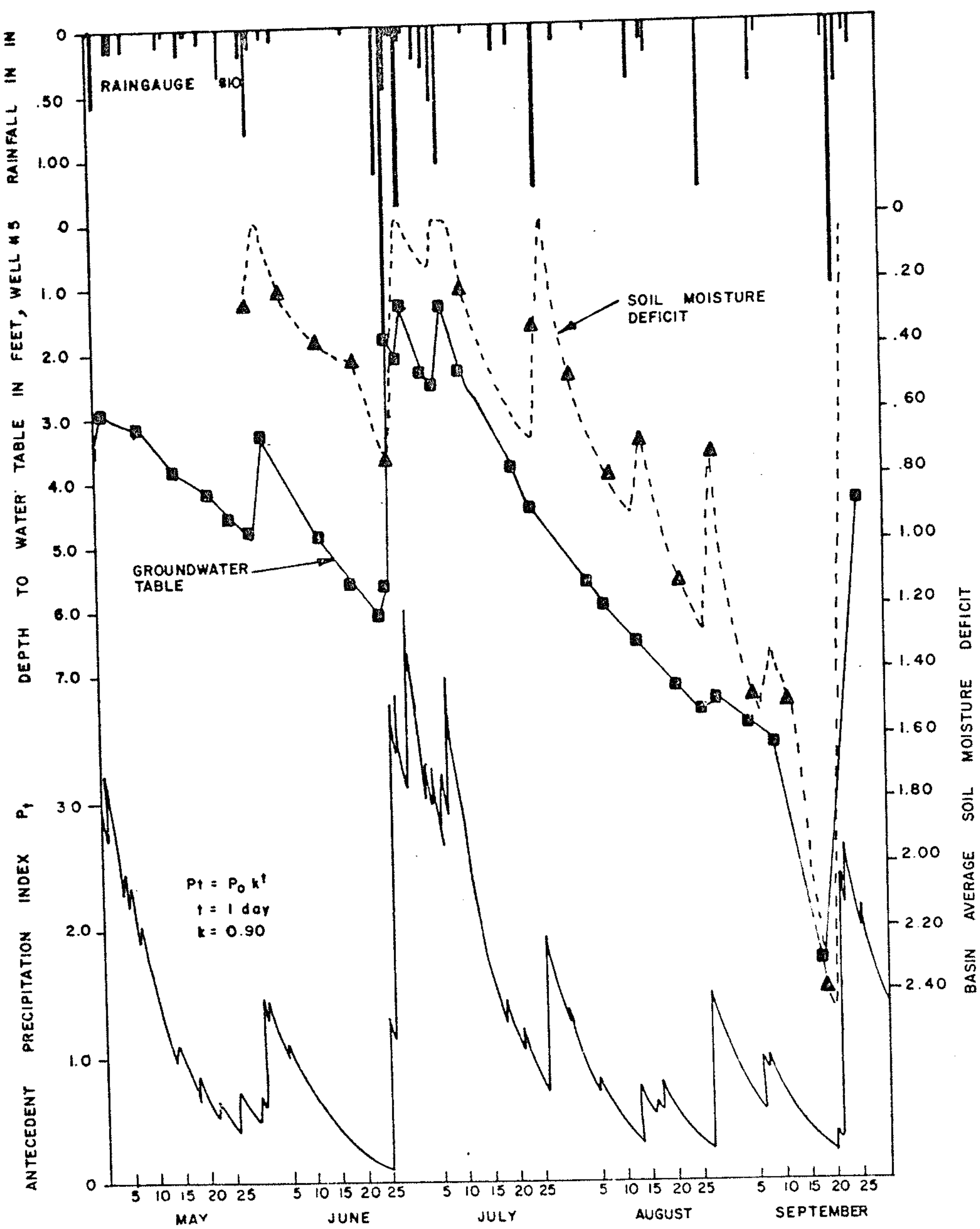


Figure 11. Effects of rainfall on basin soil moisture deficit, depth to groundwater table in well #5 and on the antecedent precipitation index in 1969.

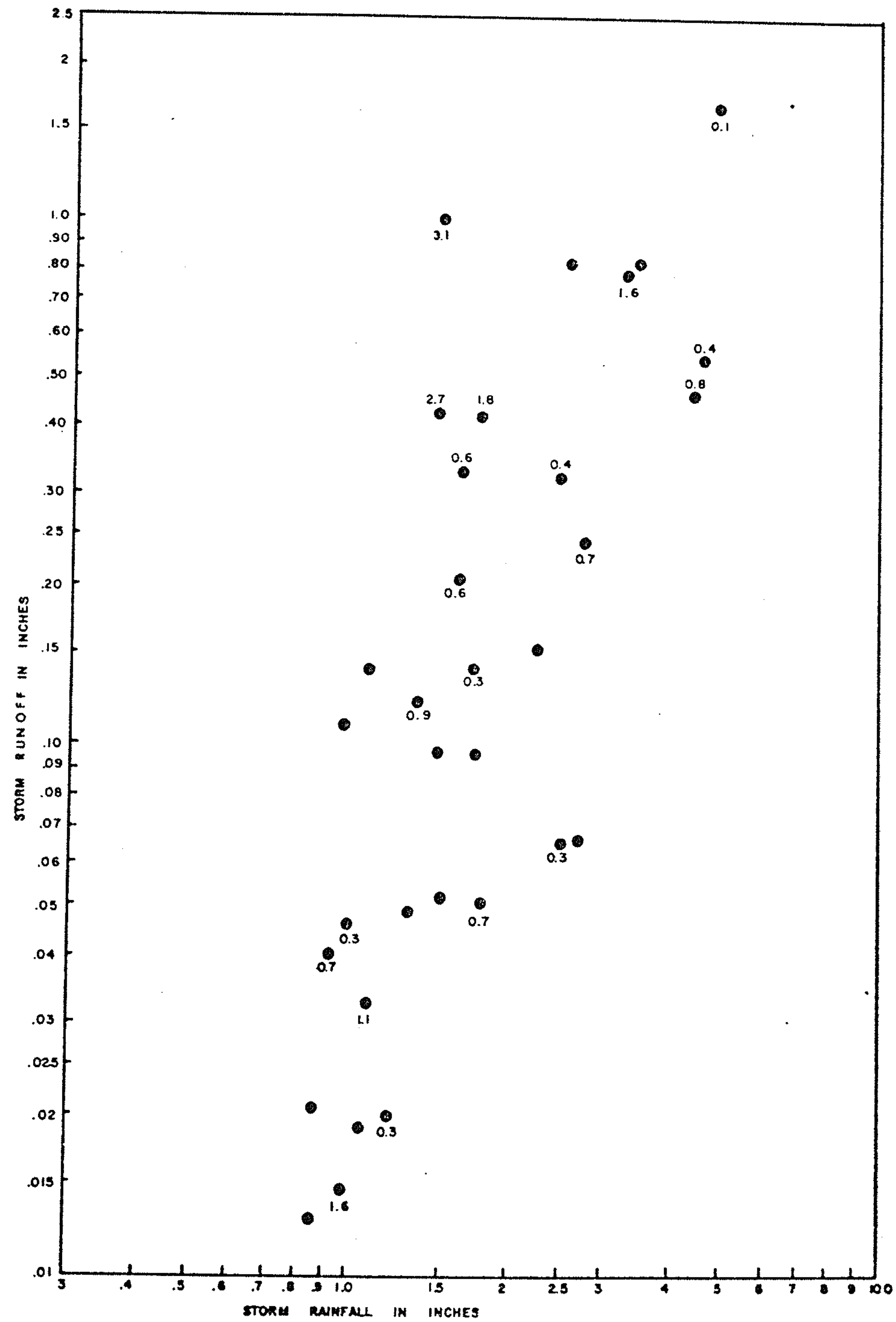


Figure 12. Storm runoff by arbitrary base flow separation #1 versus storm rainfall on log-log scale with the antecedent precipitation index parameter.

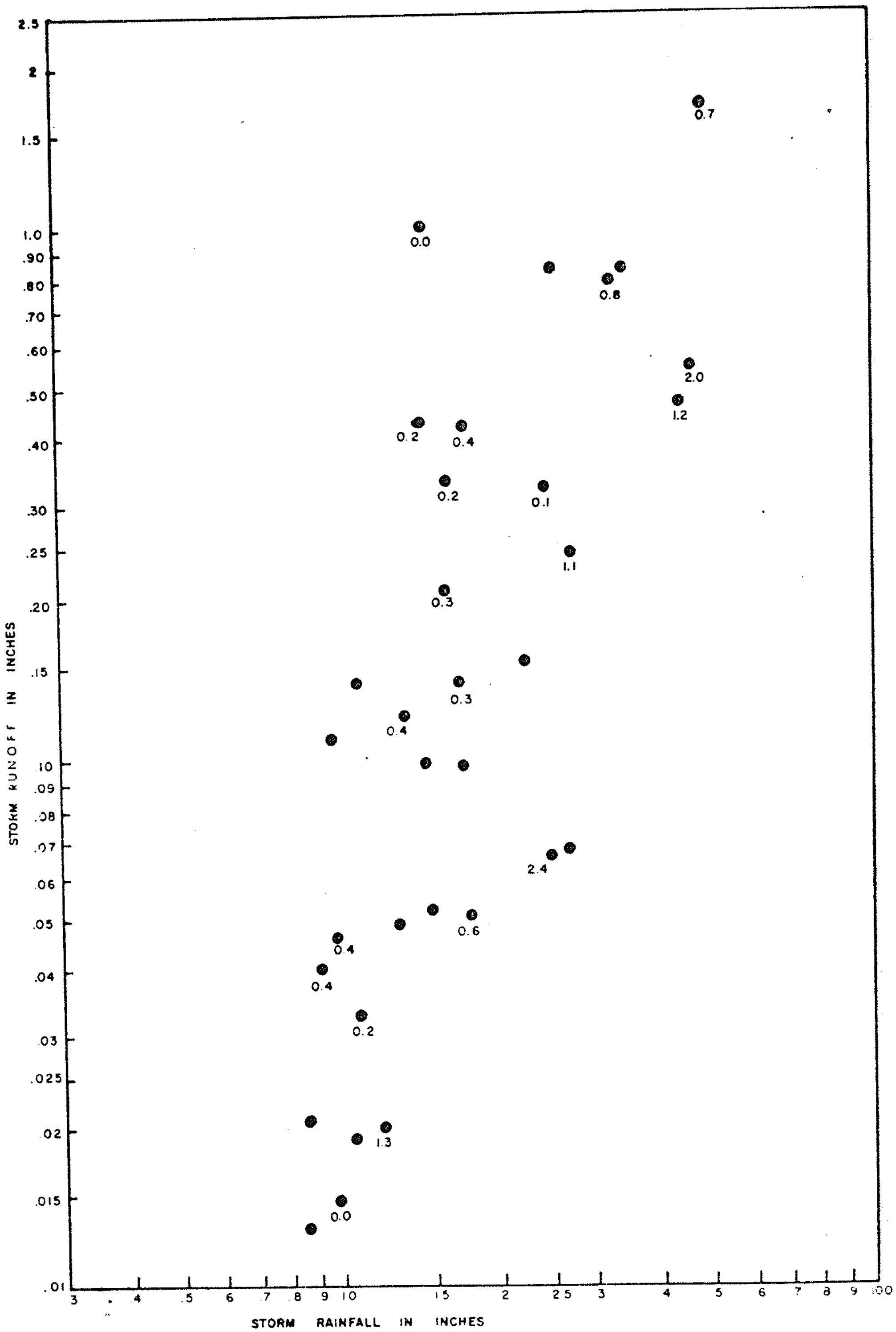


Figure 13. Storm runoff by arbitrary base flow separation #1 versus storm rainfall on log-log scale with the soil moisture deficit parameter.

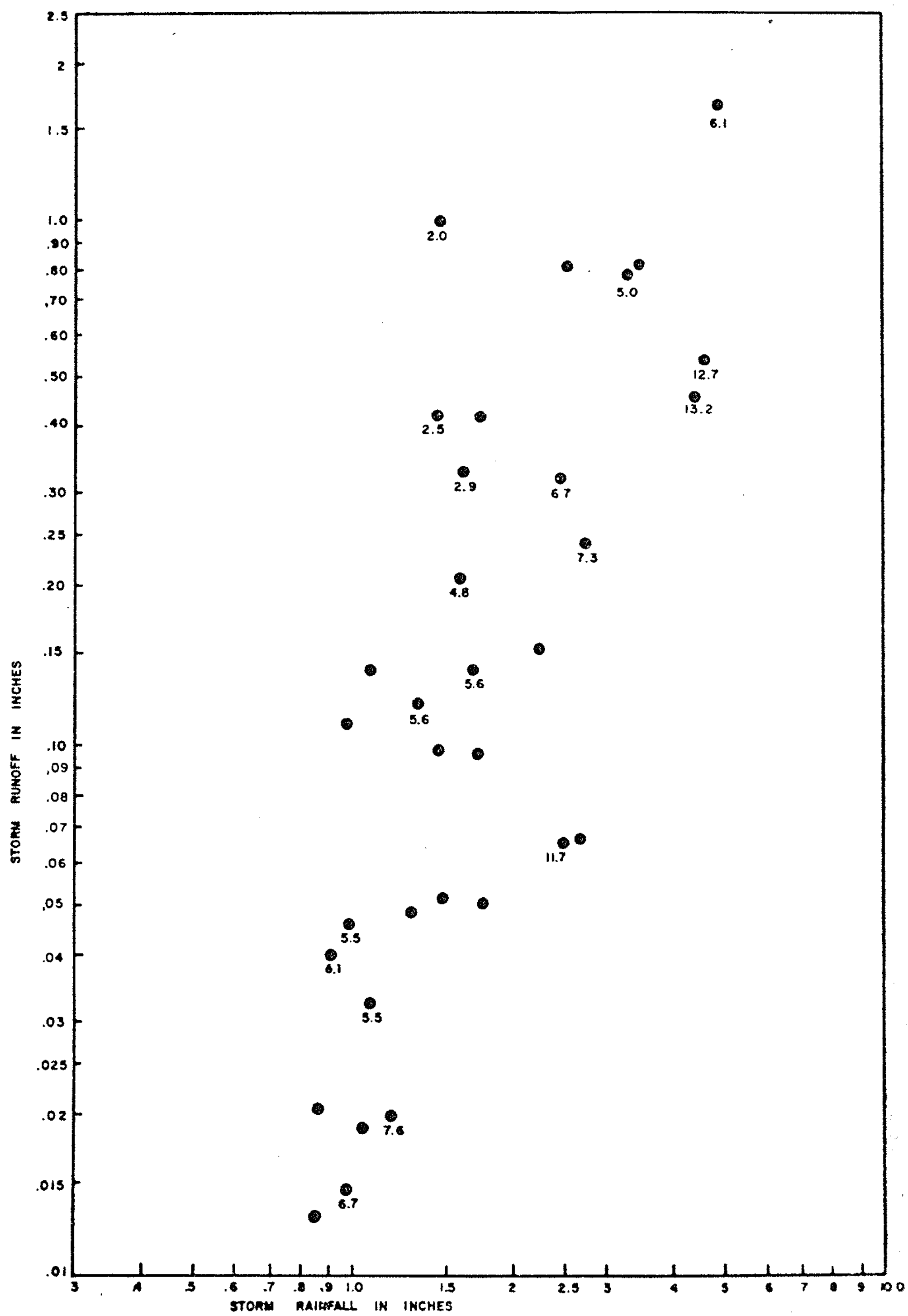


Figure 14. Storm runoff by arbitrary base flow separation #1 versus storm rainfall on log-log scale with the depth to groundwater table in well #5 parameter.

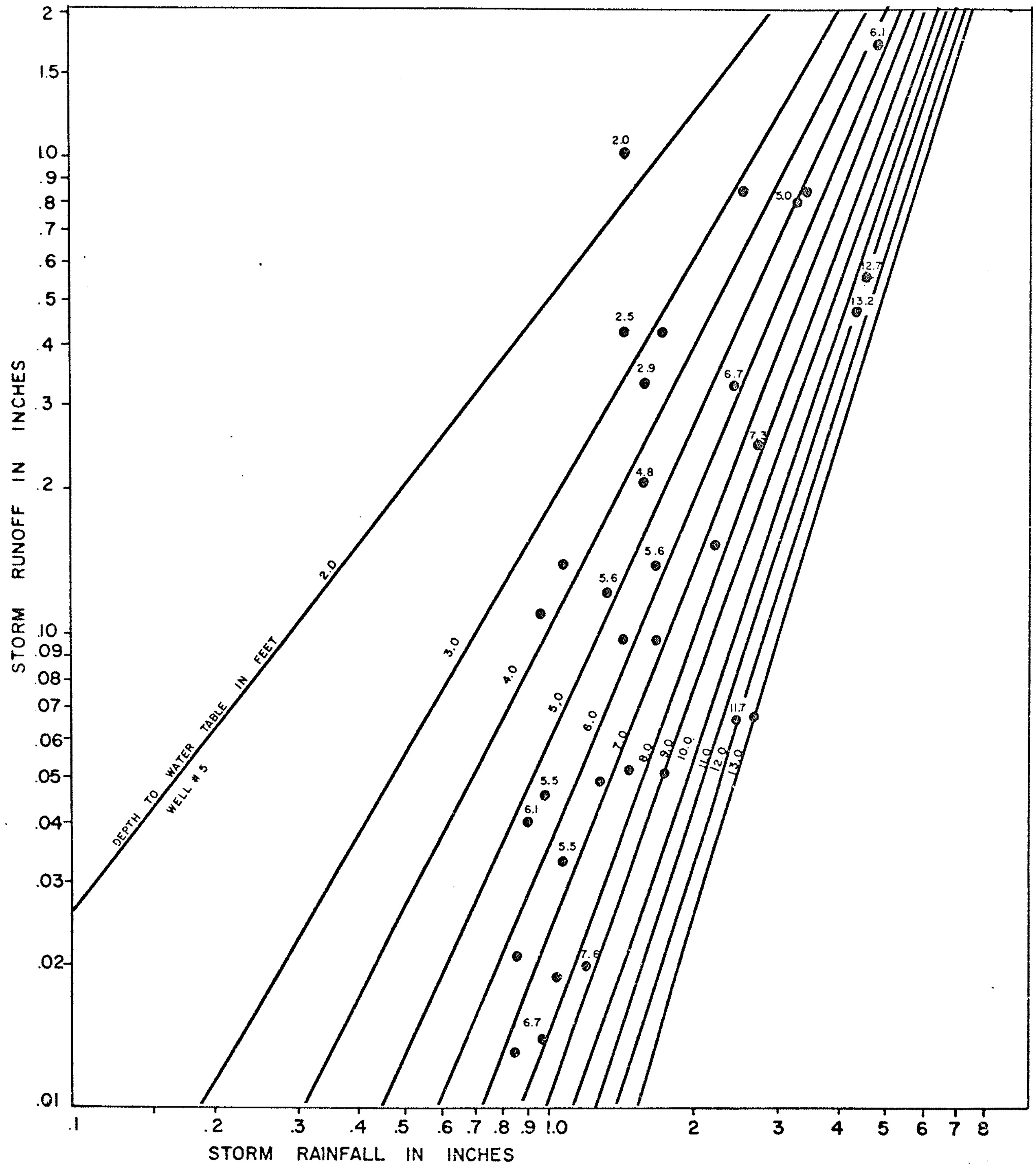


Figure 15. Storm runoff by arbitrary base flow separation #1 versus storm rainfall on log-log scale with a plot of depth to groundwater table in well #5 parameter.

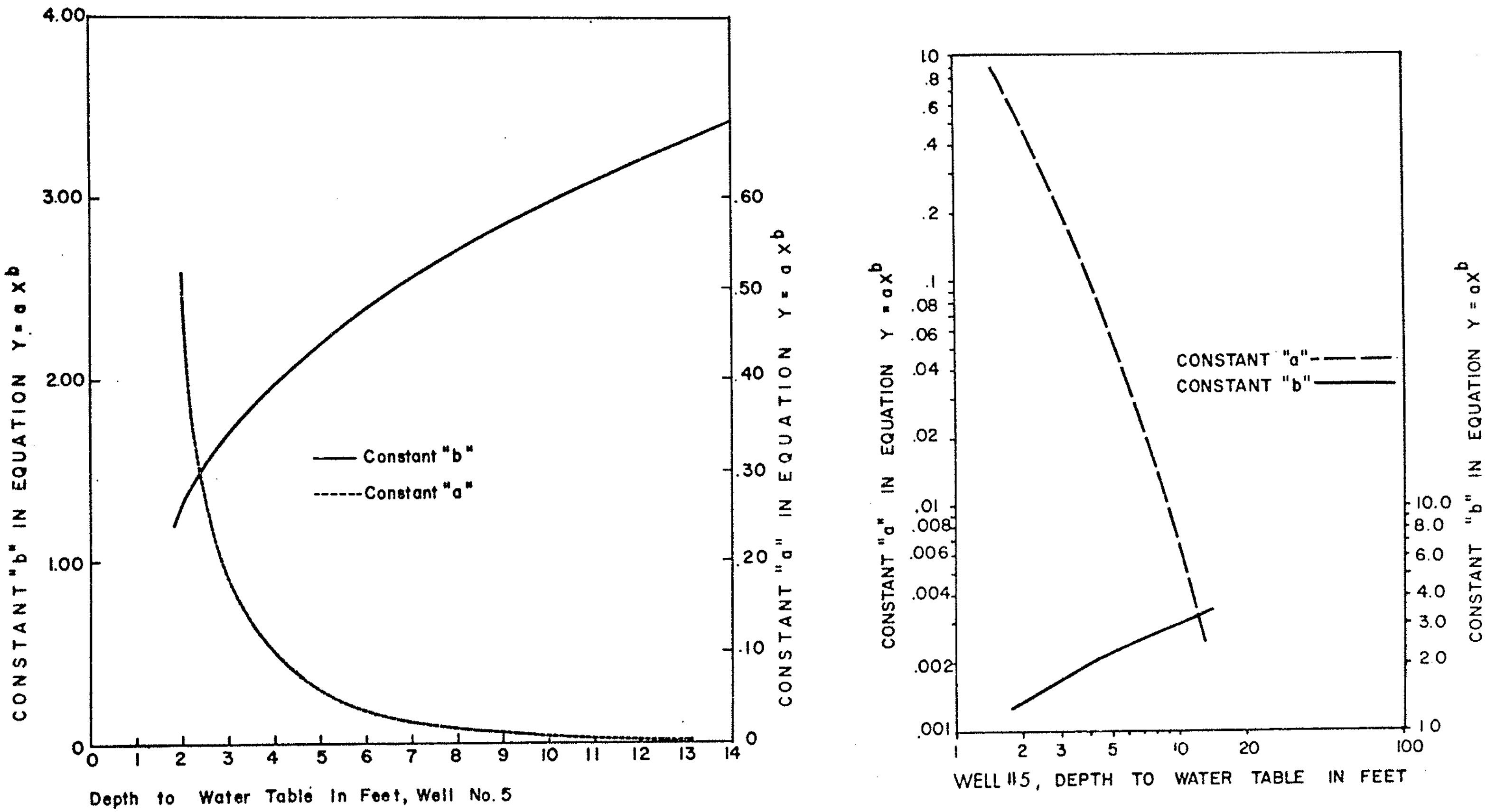


Figure 16. Depth to groundwater table in well #5 versus constants "a" and "b" in storm runoff equation $Y=aX^b$ on arithmetic scale and log-log scale.

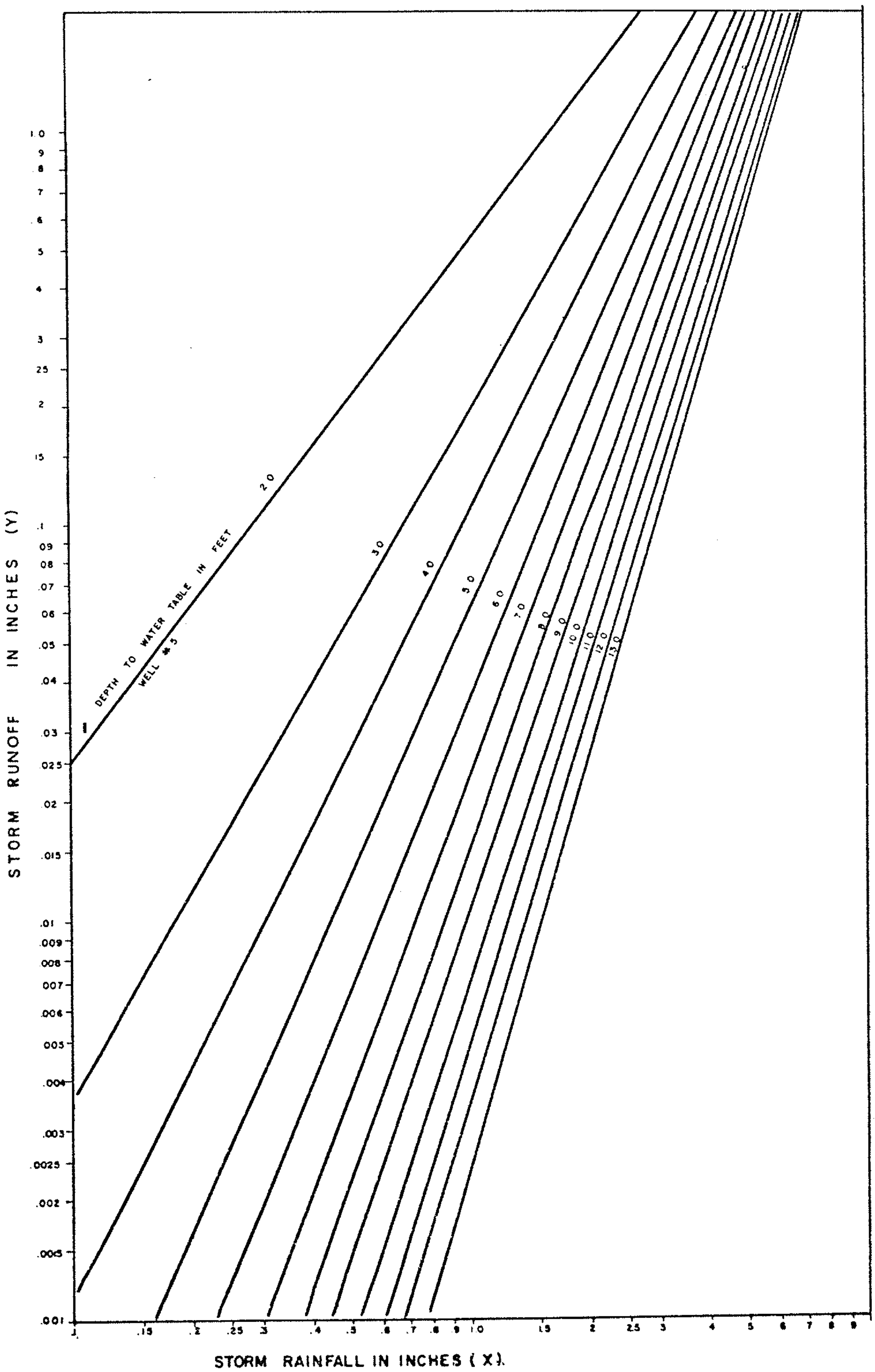


Figure 17. Final graphical plot of lines of depth to groundwater table in well #5 as derived from storm equation $Y=aX^b$ on log-log scale.

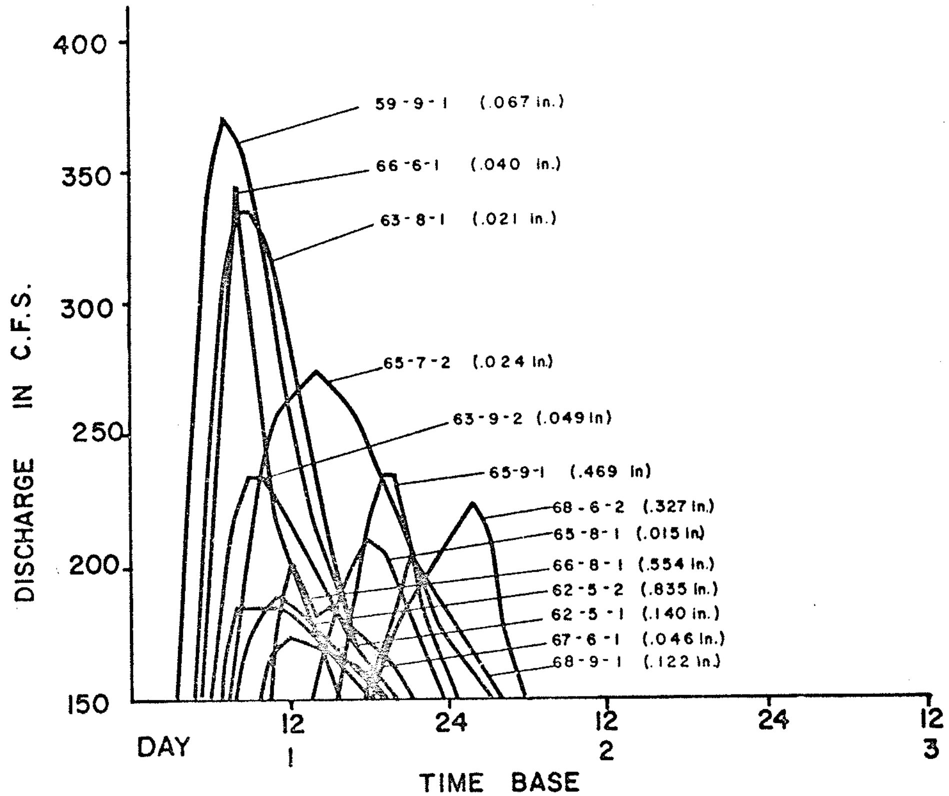


Figure 20. Four-hour unit hydrographs using storms of varying size, including those of very minor runoff.

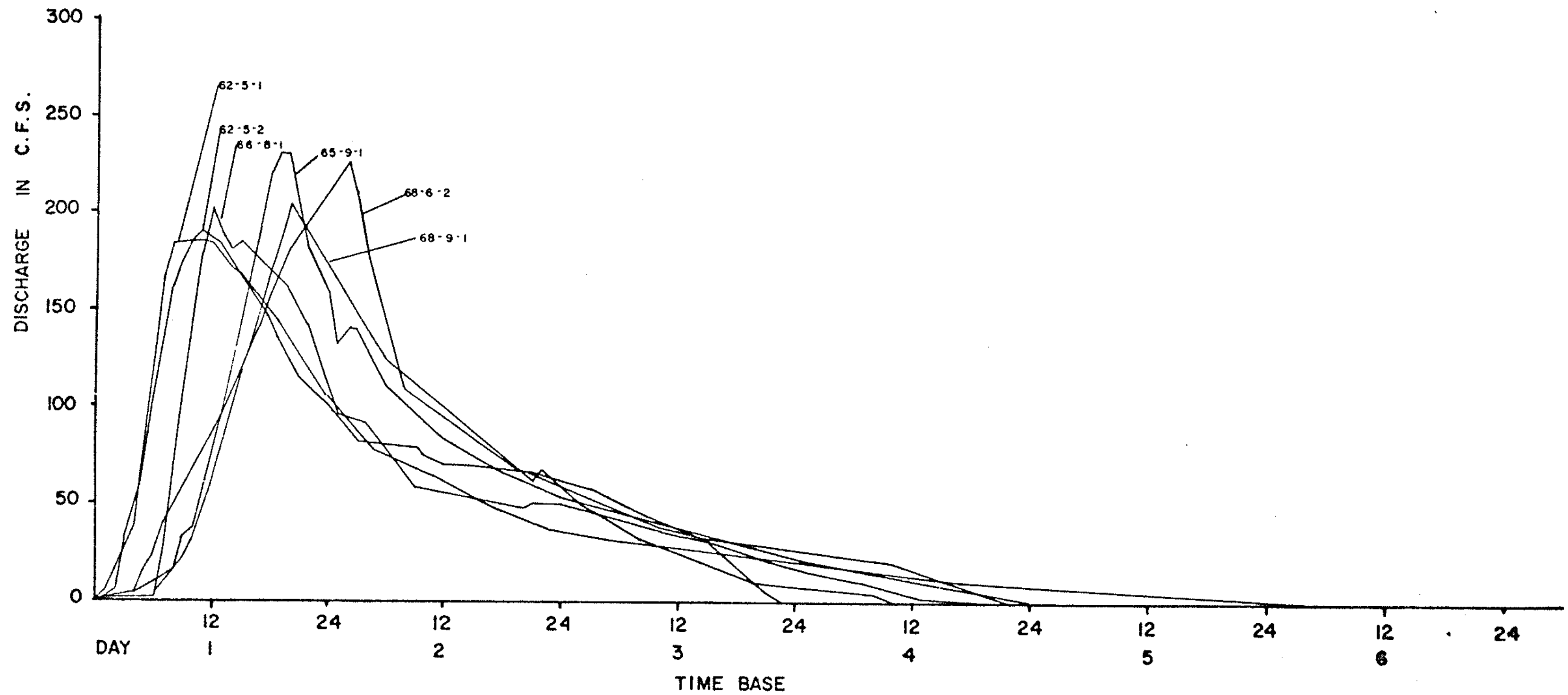


Figure 21. Four-hour unit hydrographs using storms exceeding 0.10 inches of runoff.

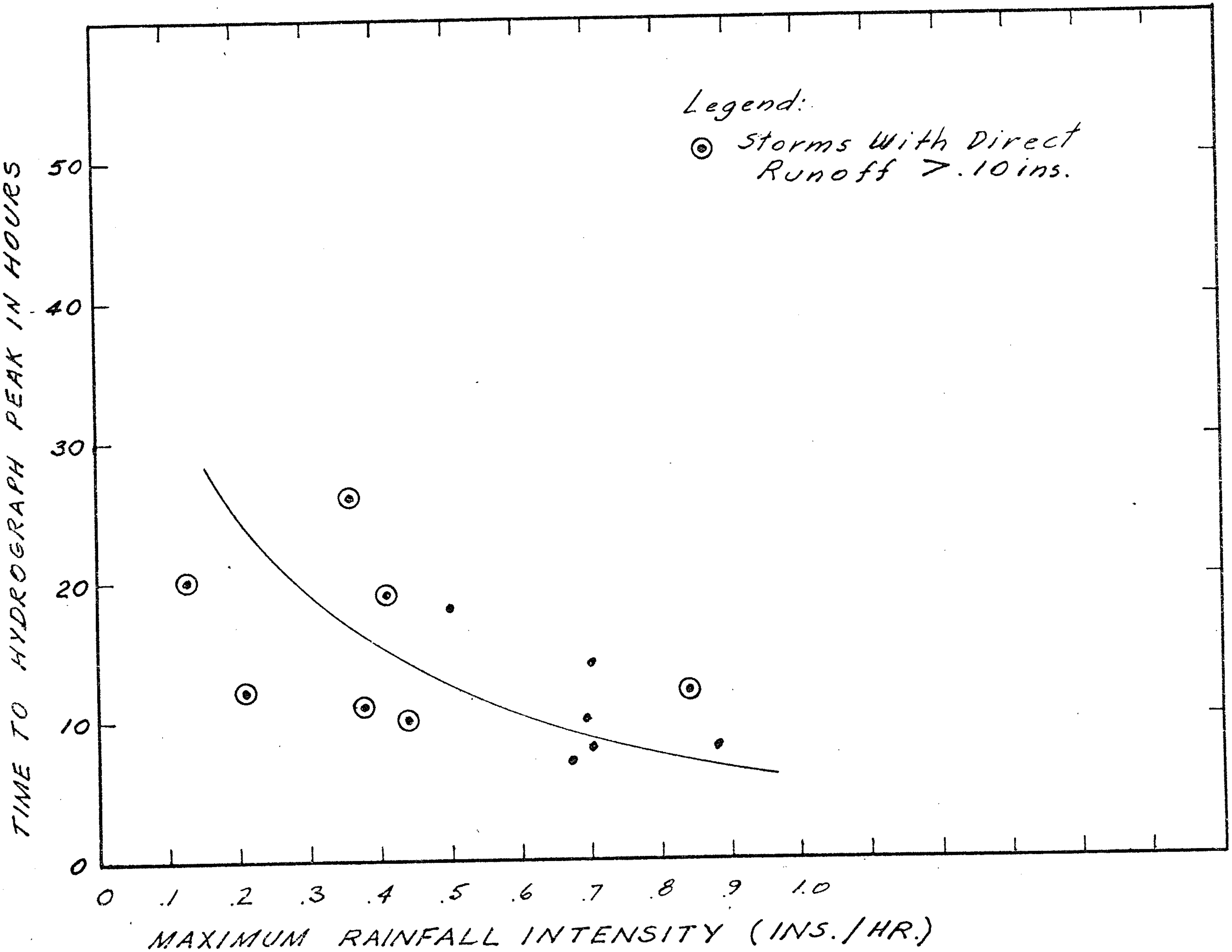
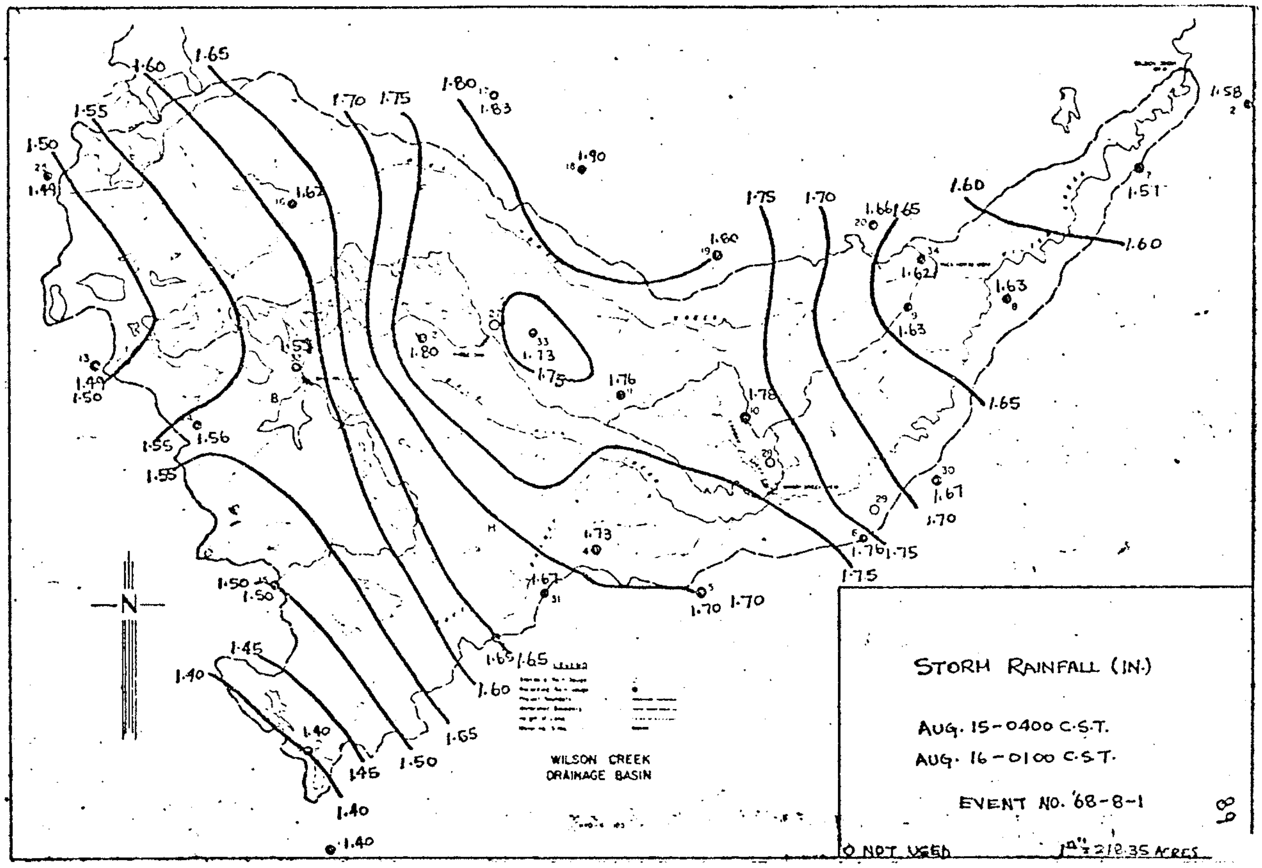


FIGURE 23. Effect of Storm Maximum Rainfall Intensity on Time to Hydrograph Peak



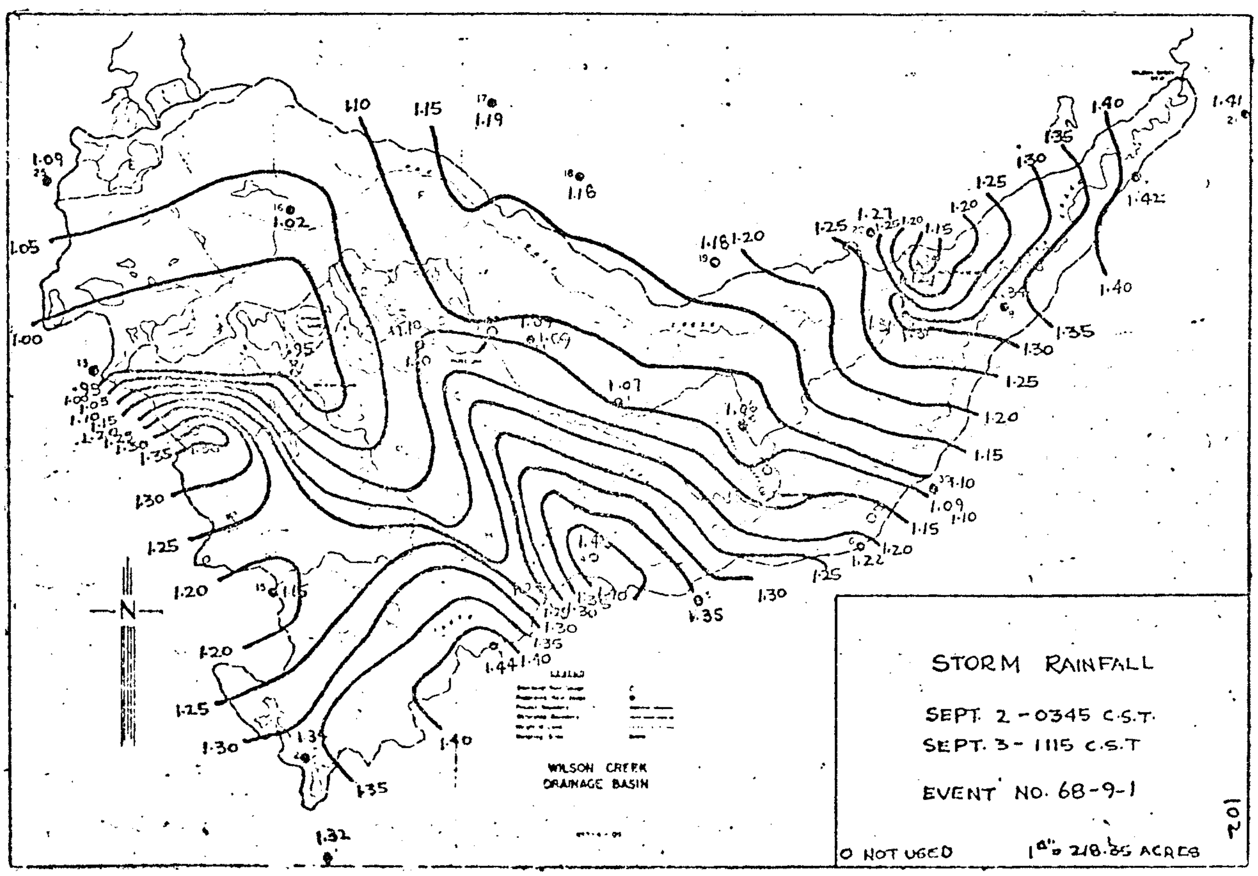


Figure 24. Isohyetal lines of rainfall on Wilson Creek Experimental Watershed for rainstorms 68-8-1 and 68-9-1.

TABLE I

STORM RAINFALL-STORM RUNOFF DATA, WILSON CREEK STORMS

STORM EVENT	STORM RAIN-FALL	STORM RUNOFF BY ARBITRARY BASE FLOW SEPARA TION #1	STORM RUNOFF BY BARNES METHOD OF BASE FLOW SEPARATION	STORM RUN-OFF BY THE CHEMICAL METHOD OF BASE FLOW SEPARATION	FILTERED STORM RAINFALL	STORM RUNOFF BY ARBITRARY BASE FLOW SEPARA-TION #2
59-6-1A	1.46	.098	.090		0.70	.009
59-6-1B					0.76	.089
59-9-1	2.70	.067	.064		1.63	.067
59-9-2	2.25	.153	.154		1.98	.153
60-8-2	1.76	.004	.002		1.76	.004
61-7-2	1.48	.006	.006		1.48	.006
62-5-1	1.08	.140	.123		1.08	.140
62-5-2	3.45	.835	.937		3.21	.835
62-8-1	1.49	.052	.051		1.49	.052
63-6-1	0.97	.111	.092		0.91	.111
63-6-2	2.55	.840	.548		2.55	.840
63-7-1	0.85	.013	.012		0.76	.013
63-8-1	0.86	.021	.017		0.86	.021
63-9-1	0.89	.007	.004		0.89	.007
63-9-2	1.29	.049	.032		1.22	.049
64-6-1	1.05	.019	.017		0.97	.019
64-6-2A	1.71	.097			0.81	.009
64-6-2B					0.90	.088
64-9-1	1.07	.004	.004		0.96	.004
64-9-2	0.94	.001	.001		0.94	.001
65-5-1	1.73	.425	.599		1.73	.425
65-6-1	0.87	.008			0.87	.008
65-7-2&3	1.77	.051	.038			
65-7-2					1.01	.024
65-7-3					0.76	.027
65-7-4	0.87	.007	.004		0.87	.007
65-8-1	0.98	.014	.006		0.98	.014
65-9-1	4.41	.469	.440		4.41	.469
65-9-2	3.29	.799	.691		2.84	.799
66-5-1A	1.61	.332	.236		1.17	.224
66-5-1B					0.44	.108
66-6-1	0.91	.040	.033		0.91	.040
66-8-1	4.60	.554	.519		4.27	.554
67-6-1	0.99	.046	.020		0.99	.046
68-6-1	1.69	.139		.162		
68-6-2	2.45	.327	.293	.305	2.45	.327
68-7-1	1.08	.033	.027	.040	1.08	.033
68-7-2A	2.77	.245	.243	.177	1.71	.061
68-7-2B					0.98	.184
68-9-1	1.33	.122	.082	.095	1.00	.103
69-5-1	1.59	.207			1.59	.207
69-6-1A	4.87	1.690	1.487	1.479	1.72	.158
69-6-1B					2.86	1.532
69-6-2	1.47	1.020	.914	1.162	1.47	1.020
69-7-1	1.44	.428	.428		1.44	.428
69-8-1	1.21	.020	.013		1.21	.020
69-9-1	2.49	.066	.034		1.91	.066

On arithmetic plot

r = .7122 r = .7109 r = .6507

On log plot r = .6810

TABLE 2

SUMMARY DATA OF
COMPUTED BASIN MOISTURE INDICATORS
PRIOR TO EACH STORM ON WILSON CREEK WATERSHED
1965 - 1969

STORM EVENT	STORM RAIN-FALL	STORM RUNOFF BY ARBITRARY BASE FLOW SEPARATION #1	ANTECEDENT PRECIPITA-TION INDEX	BASIN SOIL MPISTURE DEFICIT	DEPTH TO GROUND WATER TABLE WELL #5
65-5-1	1.73	.425	1.85	0.40	
65-6-1	0.87	.008	0.20	0.80	
65-7-2&3	1.77	.051	0.72	0.65	
65-7-4	0.87	.007	0.90	0.48	
65-8-1	0.98	.014	1.60	0	6.70
65-9-1	4.41	.469	0.77	1.20	13.20
65-9-2	3.29	.799	1.58	0.75	5.00
66-5-1A	1.61	.332	0.60	0.20	2.90
66-6-1	0.91	.040	0.65	0.42	6.10
66-8-1	4.60	.554	0.35	2.00	12.65
67-6-1	0.99	.046	0.25	0.40	5.50
68-6-1	1.69	.139	0.30	0.34	5.60
68-6-2	2.45	.327	0.43	0.10	6.70
68-7-1	1.08	.033	1.11	0.20	5.45
68-7-2A	2.77	.245	0.65	1.05	7.25
68-9-1	1.33	.122	0.87	0.35	5.65
69-5-1	1.59	.207	0.62	0.25	4.75
69-6-1A	4.87	1.690	0.13	0.73	6.10
69-6-2	1.47	1.020	3.10	0	2.00
69-7-1	1.44	.428	2.65	0.15	2.50
69-8-1	1.21	.020	0.28	1.27	7.60
69-9-1	2.49	.066	0.25	2.40	11.70

CHANGES IN DEPTH TO WATER TABLE IN THREE WELLS

RESULTING FROM EACH RAIN STORM

	DEPTH TO WATER TABLE BEFORE STORM			MINIMUM DEPTH TO WATER TABLE REACHED DUE TO STORM					
EVENT	WELL #1	WELL #2	WELL #5	WELL #1	WELL #2	WELL #5	RISE #1	RISE #2	RISE #5
65-8-1	3.45	5.60	6.70	0.55	5.50	6.25	2.90	0.10	0.45
65-9-1	9.38	6.00	13.20	6.30	5.05	2.50	3.08	0.95	10.70
65-9-2	6.30	5.40	5.00	4.66	4.60	1.35	1.64	0.80	3.65
66-5-1	5.60	4.95	2.95	5.15	4.80	1.95	0.45	0.15	1.00
66-6-1	7.45	5.50	6.10	7.43	5.50	6.05	0.02	0.00	0.05
66-8-1	9.30	6.35	12.65	8.20	5.70	2.70	1.10	0.65	9.95
67-6-1	7.55	6.20	5.50	7.50	6.20	5.40	0.05	0.00	0.10
68-6-1	6.30	6.05	5.60	6.00	5.85	4.10	0.30	0.20	1.50
68-6-2	7.60	6.40	6.80	6.80	6.15	3.30	0.80	0.25	3.50
68-7-1	7.00	6.30	5.45	5.80	6.30	5.20	1.20	0.00	0.25
68-7-2	7.15	6.50	7.25	6.30	6.35	4.10	0.85	0.15	3.15
68-9-1	5.85	7.10	5.65	5.55	6.90	4.30	0.30	0.20	1.35
69-5-1	8.75	6.40	4.75	7.30	6.30	3.25	1.45	0.10	1.50
69-6-1	7.90	6.35	6.10	7.20	3.55	1.80	0.70	3.00	4.30
69-6-2	7.20	3.65	2.00	6.50	3.52	1.25	0.70	0.13	0.75
69-7-1	6.50	3.65	2.95	6.00	3.55	1.25	0.50	0.10	1.70
69-8-1	9.05	4.40	7.60	9.05	4.40	7.40	0.00	0.00	0.20
69-9-1	10.60	4.65	11.60	9.35	4.45	4.35	1.25	0.20	7.25

TABLE 4

GROUNDWATER RECESSION CONSTANTS FROM BARNES METHOD OF BASEFLOW SEPARATION

STORM EVENT		GROUNDWATER RECESSION CONSTANT
59-6-1		.77
59-9-1		.80
59-9-2		.90
60-8-1		.96
60-8-2		.95
62-5-1		.96
62-5-2		.85
63-6-1		.89
63-6-2		.84
63-7-1		.94
63-9-1		.89
63-9-2		.91
64-6-1		.87
65-5-1		.87
65-7-2&3		.86
65-7-4		.97
65-8-1		.88
65-9-1		.86
65-9-2		.86
66-5-1		.91
66-6-1		.89
66-8-1		.88
67-6-1		.89
68-6-2		.78
68-7-1		.90
68-7-2		.89
68-9-1		.90
69-6-1		.88
	TOTAL	25.68
	AVG. Kg	.89

TABLE 5

EFFECT OF SIZE OF STREAMFLOW HYDROGRAPH PEAKS ON THE GROUNDWATER RECESSION CONSTANTS FROM BARNES METHOD OF BASEFLOW SEPARATION

	RANGE IN SIZE OF PEAK IN CUBIC FEET PER SECOND				
	0-5	5-10	10-20	20-50	Above 100
GROUNDWATER RECESSION CONSTANTS (Kg)	.96	.94	.77	.80	.85
	.95	.89	.91	.90	.84
	.89	.91	.89	.96	.87
	.88	.86	.89	.89	.86
		.97	.90	.91	.86
				.89	.88
				.90	
				.88	
TOTALS	3.68	4.57	4.36	7.13	5.16
Kg AVERAGE	.92	.91	.87*	.89	.86

* without .77 event Kg Avg. = .89

TABLE 6

EFFECT OF CHANGE IN SEASONS
ON GROUNDWATER RECESSION CONSTANTS
FROM BARNES METHOD OF BASEFLOW SEPARATION

	MONTHS OF THE YEAR				
	MAY	JUNE	JULY	AUG.	SEPT.
Groundwater Recession Constants Kg	.96	.91	.94	.96	.89
	.91	.89	.86	.95	.91
	.85	.89	.97	.88	.80
	.87	.89	.77	.89	.90
		.84	.90	.88	.90
		.78	.89		.86
		.88	.88		.86
TOTALS	3.59	6.08	6.21	4.56	6.12
Kg AVERAGE	.90	.87	.89*	.91	.88

* Without .77 event Kg Average = .91.

TABLE

COMPUTATION OF CONSTANTS "A" AND "B" FOR STORM RUNOFF EQUATION $Y = AX^{B}$ (INITIAL DATA TAKEN FROM FIGURE 15)

STEP 1 Obtaining 2 pts. from each succeeding foot line of depth to water table parameter on log-log plot.

x	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11	y12	y13
1.10	.574	.215	.124	.0705	.0445	.0289	.0190	.0137	.0092	.0066	.0048	.0034
2.50	1.665	.885	.618	.430	.320	.239	.178	.140	.1065	.084	.066	.0525

STEP 2 Taking logs of each of the above 2 points

.041	$\bar{1}.759$	$\bar{1}.332$	$\bar{1}.093$	$\bar{2}.848$	$\bar{2}.648$	$\bar{2}.461$	$\bar{2}.279$	$\bar{2}.137$	$\bar{3}.964$	$\bar{3}.820$	$\bar{3}.681$	$\bar{3}.532$
.398	.221	$\bar{1}.947$	$\bar{1}.791$	$\bar{1}.634$	$\bar{1}.505$	$\bar{1}.378$	$\bar{1}.250$	$\bar{1}.146$	$\bar{1}.027$	$\bar{2}.924$	$\bar{2}.820$	$\bar{2}.720$

STEP 3 To determine constant "b" from slope of line on log-log plot "b" = $\frac{Y2(2) - Y2(1)}{X2 - X1}$

b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13
1.296	1.723	1.960	2.200	2.400	2.570	2.720	2.830	2.980	2.100	3.195	3.335

STEP 4 To determine "A" in equation y = bX + A where Y = log y; X = log x; A = log a

A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
$\bar{1}.704$	$\bar{1}.261$	$\bar{1}.011$	$\bar{2}.759$	$\bar{2}.550$	$\bar{2}.355$	$\bar{2}.168$	$\bar{2}.021$	$\bar{3}.842$	$\bar{3}.692$	$\bar{3}.549$	$\bar{3}.393$

STEP 5 To determine "a" take antilogs of A

a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	a13
.5058	.1824	.1026	.0574	.0355	.0227	.0147	.0105	.00695	.0049	.0035	.0025

TABLE 8

COMPUTATIONS PERFORMED TO SET UP FINAL FAMILY OF CURVES OF DEPTH TO WATER TABLE PARAMETER

STEP 1 Obtain corrected "b" from "b" versus depth to water table parameter relation.

b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13
1.296	1.720	1.970	2.200	2.400	2.570	2.720	2.850	2.980	3.100	3.215	3.325

STEP 2 Obtain corrected "a" from "a" versus depth to water table parameter relation.

a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	a13
.5000	.1850	.1026	.0570	.0350	.0227	.0147	.0105	.00695	.0049	.0035	.0025

STEP 3 Multiply each x by appropriate power b.

x	x^{b2}	x^{b3}	x^{b4}	x^{b5}	x^{b6}	x^{b7}	x^{b8}	x^{b9}	x^{b10}	x^{b11}	x^{b12}	x^{b13}
1.10	1.132	1.178	1.206	1.233	1.257	1.278	1.296	1.312	1.328	1.344	1.359	1.373
2.50	3.280	4.840	6.090	7.510	9.000	10.530	12.100	13.600	15.350	17.150	19.000	21.000

STEP 4 Multiply x^b by appropriate constant "a" to obtain "y" for final graphical plot.

x	y2	y3	y4	y5	y6	y7	y8	y9	y10	y11	y12	y13
1.10	.567	.218	.124	.0704	.0440	.0290	.0191	.0138	.0092	.0066	.0048	.0034
2.50	1.640	.897	.624	.428	.3160	.239	.178	.143	.1070	.0839	.0665	.0525

TABLE 9

COMPUTED STORM RUNOFF FROM DEPTH TO WATER TABLE
IN WELL #5 PARAMETER AND THE EQUATION $Y = aX^b$

EVENT	DEPTH TO WATER TABLE WELL #5	CONSTANT "b"	RAIN STORM x	x^b	CONSTANT "a"	COMPUTED STORM RUNOFF $y = ax^b$	OBSERVED RUNOFF
65-8-1	6.70	2.52	0.98	0.950	.027	.026	.014
65-9-1	13.20	3.34	4.41	138.0	.0025	.346	.469
65-9-2	5.00	2.20	3.29	13.7	.057	.781	.799
66-5-1A	2.90	1.675	1.61	2.24	.198	.444	.332
66-6-1	6.10	2.42	0.91	0.797	.034	.027	.040
66-8-1	12.65	3.28	4.60	150.0	.0028	.420	.554
67-6-1	5.50	2.31	0.99	0.977	.0450	.044	.046
68-6-1	5.60	2.32	1.69	3.38	.0420	.142	.139
68-6-2	6.70	2.52	2.45	9.55	.027	.258	.327
68-7-1	5.45	2.29	1.08	1.193	.0470	.056	.033
68-7-2A	7.25	2.60	2.77	14.16	.0215	.305	.245
68-9-1	5.65	2.33	1.33	1.94	.0415	.081	.122
69-5-1	4.75	2.15	1.59	2.71	.069	.187	.207
69-6-1A	6.10	2.42	4.87	46.0	.034	1.562	1.690
69-6-2	2.00	1.30	1.47	1.651	.500	.826	1.020
69-7-1	2.50	1.55	1.44	1.760	.262	.460	.428
69-8-1	7.60	2.66	1.21	1.660	.0185	.033	.020
69-9-1	11.70	3.18	2.49	18.20	.0040	.073	.066

$r = .9882$

TABLE 10

SUMMARY OF

INDIVIDUAL 4 HR. U.H. CHARACTERISTICS

M	STORM RUNOFF (in.)	TIME BASE (hrs.)	TIME TO PEAK (hrs.)	4 HOUR U.H. PEAK (cfs)	MAX. R.F. INT. (in/hr)
-1	.0670	45	7	372	.67
-1	.1398	71	10	185	.44
-2	.8350	125	11	189	.38
-1	.0206	60	8	335	.70
-2	.0488	67	10	235	.69
-2	.0241	56	14	274	.70
-1	.0145	79	18	209	.50
-1	.4685	96	19	230	.41
-1	.0404	61	8	346	.88
-1	.5536	94	12	202	.84
-1	.0462	92	12	173	.21
-2	.3265	82	26	225	.36
-1	.1223	91	10	203	.13

4 HOUR UNIT HYDROGRAPH CHARACTERISTICS FROM

STORMS HAVING DIRECT RUNOFF OVER 0.10 INCHES

STORM	STORM RUNOFF (in.)	TIME BASE (hrs.)	TIME TO PEAK (hrs.)	4 HR. U.H. PEAK (cfs)	MAX. R.F. INT. (in/hr)	20% OF PEAK ON RISING LIMB (cfs)	TIME - .2 PEAK Q TO PEAK (hrs.)	TIME FROM PEAK TO .2 PEAK Q ON FALLING LIMB (hrs.)
62-5-1	.1398	71	10	185	.44	37	6	50
62-5-2	.8350	125	11	189	.38	38	8	36
65-9-1	.4685	96	19	230	.41	46	8	35
66-8-1	.5536	94	12	202	.84	40	5	43
68-6-2	.3265	82	26	225	.36	45	18	26
68-9-1	.1223	91	20	203	.13	41	9	36
							Avg.= $\frac{54}{6}$ = 9 hrs.	Avg.= $\frac{226}{6}$ = 38 hours

Avg. peak = $\frac{1234}{6}$ = 206 cfs

Avg. base = $\frac{559}{6}$ = 93 hours

Avg. time to peak = $\frac{98}{6}$ = 16 hours

APPENDIX A

HOURLY STORM RAINFALL AND STREAMFLOW DATA
WILSON CREEK WATERSHED

1959-1969

EVENT	DATE	TIME (HRS.)	R.F. (in.)	Q (cfs.)
59-6-1	June 26	24		.41
	June 27	1		.41
		2	.01	.41
		3	.05	.49
		4	.36	.83
		5	.23	1.10
		6	.03	1.27
		7	.02	1.39
		8	.00	1.59
		9		1.80
		10		6.7
		11		7.5
		12		6.7
		13		6.4
		14		1.80
		15		1.73
		16		1.66
		17		1.59
		18		1.53
		19		1.46
		20		1.39
		21		1.33
		22	.00	1.33
		23	.01	1.33
		24	.03	1.33
	June 28	1	.00	1.33
		2	.00	1.27
		3	.01	1.27
		4	.06	1.27
		5	.19	1.46
		6	.07	1.73
		7	.08	1.80
		8	.02	6.4
		9	.03	7.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
59-6-1 (cont'd)	June 28	10	.02	8.7
		11	.01	9.5
		12	.01	10.5
		13	.04	11.5
		14	.04	13.0
		15	.03	13.0
		16	.03	15.0
		17	.02	17.0
		18	.03	17.0
		19	.03	19.2
		20	1.46	19.2
		21		19.2
		22		19.2
		23		17.0
		24		17.0
	June 29	6		13.0
		12		10.5
		18		8.5
		24		6.1
	June 30	12		1.39
		24		1.22
	July 1	12		1.04
		24		.93
	July 2	12		.83
59-9-1	Sept.1	9	.03	.06
		10	.10	.08
		11	.05	.08
		12	.28	.13
		13	.17	.13
		14	.04	.11
		15	.00	.08
		16	.02	.07
		17	.00	.07
		18	.01	.07
		19	.00	.07

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
59-9-1 (cont'd)	Sept.1	20		.20
		21		.20
		22		.18
		23		.15
		24		.11
	Sept.2	1	.00	"
		2	.08	"
		3	.10	"
		4	.11	"
		5	.06	"
		6	.02	.11
		7	.00	.13
		8		.15
		9		.20
		10		.26
		11		.37
		12		.37
		13		.33
		14		.26
		15		.20
		16	.00	.18
		17	.03	.15
		18	.67	.63
		19	.03	1.46
		20	.17	8.7
		21	.23	18.5
		22	.07	25.5
		23	.03	25.5
		24	.09	25.5
	Sept.3	1	.07	25.5
		2	.03	23.8
		3	.04	
		4	.02	
		5	.04	
		6	.04	15.8

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
59-9-1 (cont'd)	Sept.3	7	.02	
		8	.02	
		9	.02	
		10	.00	
			2.70	
		12		11.0
		18		6.6
		24		3.1
	Sept.4	12		1.22
		24		1.04
	Sept.5	12		.93
		24		.83
	Sept.6	12		.68
59-9-2	Sept.25	17	.05	.06
		18	.21	.06
		19	.27	.08
		20	.18	.08
		21	.12	.08
		22	.16	.83
		23	.10	1.33
		24	.08	7.5
	Sept.26	1	.07	22.1
		2	.12	29.1
		3	.15	29.1
		4	.04	27.3
		5	.02	27.3
		6	.04	27.3
		7	.01	29.1
		8	.05	27.3
		9	.03	27.3
		10	.04	27.3
		11	.06	25.5
		12	.04	25.5
		13	.07	25.5
		14	.06	25.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
59-9-2 (cont'd)	Sept.26	15	.01	27.3
		16	.00	"
		17		"
		18		"
		19	.00	"
		20	.01	27.3
		21	.00	25.5
		22		23.8
		23		22.1
		24		20.3
	Sept.27	3	.00	
		4	.02	
		5	.00	
		6	.00	
		7	.03	
		8	.00	
		12		10.5
		15	.00	
		16	.01	
		17	.00	
		18	.01	
		19	.00	
		20	.00	
		22	.01	
		23	.00	
		24		1.80
	Sept.28	4	.00	
		5	.04	
		6	.01	
		7	.00	
		12	.00	1.66
		13	.00	
		14	.03	
		15	.02	
		16	.01	
		17	.01	
		18	.03	

Event	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
59-9-2 (Cont'd)	Sept.28	19	.02	
		20	.01	
		21	.00	
			2.25	
		24		1.73
	Sept.29	12		1.66
		24		1.46
	Sept.30	12		1.33
60-7-1	July 14	21	.00	2.7
		22	.23	"
		23	.38	"
		24	.00	"
	July 15	1	.00	"
		2	.00	"
		3	.00	2.7
		4	.11	2.8
		5	.01	2.9
		6	.01	2.9
		7	.04	3.0
			.78	
		8		3.0
		9		"
		12		"
		18		"
		24		3.0
	July 16	12		2.9
		24		2.9
	July 17	12		2.9
		24		2.9
	July 18	12		2.8
		21		2.8
		24		2.8
	July 19	6		2.9
		24		2.9

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
60-8-1	Aug.7	8		2.6
		9	.07	2.7
		10	.20	2.9
		11	.08	3.2
		12	.06	3.3
		13	.13	3.4
		14	.12	3.5
		15	.10	3.5
		16	.10	3.5
		17	.11	3.5
		18	.14	3.6
		19	.19	3.7
		20	.31	3.8
		21	.14	3.8
		22	.03	3.9
			1.78	
		24		3.9
	Aug.8	1		3.9
		7		3.9
		8		3.8
		9		3.8
		10		3.7
		11		3.7
		12		3.7
		13		3.7
		14		3.6
		15		3.5
		21		3.5
		22		3.4
		24		3.4
	Aug.9	12		3.3
		24		3.1
	Aug.10	12		3.0
		24		3.0
	Aug.11	12		2.9
		24		2.8

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
60-8-2	Aug.16	10	.15	
		11	.59	
		12	.76	
		13	.18	
		14	.08	
		15	.00	
			1.76	
		21		2.8
		22		2.8
		23		2.9
		24		2.9
	Aug.17	1		3.1
		2		3.2
		3		3.4
		4		3.7
		5		3.8
		11		3.8
		12		3.7
		13		3.7
		14		3.7
		15		3.7
		16		3.6
		17		3.6
		18		3.6
		24		3.5
	Aug.18	12		3.4
		24		3.2
	Aug.19	12		3.2
		24		3.1
	Aug.20	12		3.0
60-8-3	Aug.25	13	.08	2.7
		14	.16	2.7
		15	.17	2.7
		16	.19	2.7
		17	.22	2.7

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
60-8-3 (cont'd)	Aug.25	18	.10	2.9
		19	.07	2.9
		20	.02	2.9
		21	.00	3.0
			1.01	
		24		3.0
	Aug.26	24		3.0
	Aug.27	6		2.9
		18		2.9
	Aug.28	12		2.9
		24		2.8
	Aug.29	12		2.7
		24		2.1
	Aug.30	12		1.9
61-7-2	July 17	19	.77	.1
		20	.53	1.1
		21	.17	.3
		22	.01	.2
			1.48	
		23		.2
		24		6.3
	July 18	1		6.3
		2		5.5
		3		4.0
		4		3.0
		5		2.3
		6		2.0
		7		1.4
		8		1.1
		9		1.0
		10		.8
		11		.7
		12		.5
		13		.3

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
61-7-2 (cont'd)	July 18	14		.2
		15		.2
		16		.2
		17		.1
		24		.1
	July 19	24		.1
62-5-1	May 17	8	.03	1.2
		9	.05	1.2
		10	.40	2.5
		11	.44	4.0
		12	.05	6.3
		13	.08	7.5
		14	.02	16.5
		15	.01	22.0
		16	.00	27.0
			1.08	
		17		27.5
		21		27.5
		22		26.0
		23		26.0
		24		25.0
	May 18	1		23.5
		2		23.0
		3		22.0
		4		20.0
		5		19.0
		6		18.0
		7		17.0
		8		17.0
		9		16.5
		10		15.5
		11		14.5
		12		14.0
		18		14.0
		19		13.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
62-5-1 (cont'd)	May 18	20		13.0
		21		13.0
		22		13.0
		23		12.9
		24		12.9
	May 19	6		12.7
		12		11.8
		18		9.8
		24		8.5
	May 20	6		4.5
	May 21	12		4.5
		18		4.3
	May 22	6		4.3
		12		6.2
62-5-2	May 28	12		.8
		16	.00	.8
		17	.05	"
		18	.03	"
		19	.00	"
		22	.04	"
		23	.01	"
		24	.01	"
	May 29	1	.04	"
		9	.02	"
		10	.07	"
		11	.02	"
		12	.01	"
		13	.03	"
		14	.02	"
		15	.18	"
		16	.16	.8
		17	.25	.9
		18	.13	.9
		19	.37	1.0
		20	.37	2.2

EVENT	DATE	TIME (hrs.)	R.F (in.)	Q (cfs.)
62-5-2 (cont'd)	May 29	21	.38	6.0
		22	.27	27.8
		23	.25	40.6
		24	.16	63.5
	May 30	1	.05	89.0
		2	.08	109.0
		3	.06	135.3
		4	.05	147.2
		5	.03	155.0
		6	.06	159.8
		7	.03	157.6
		8	.04	155.0
		9	.02	147.2
		10	.03	142.5
		11	.01	137.6
		12	.02	130.7
		13	.02	126.0
		14	.00	121.5
		15		115.2
		16		109.0
		17		103.2
		18		97.3
		19		90.5
		20		85.6
		21	.02	80.7
		22		76.5
		23		70.3
		24		67.8
	May 31	6		57.3
		9	.01	
		10	.01	
		11	.01	
		12	.01	43.9
		14	.01	
		17	.01	
			3.45	
		18		35.7

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
62-5-2	May 31	24		32.1
(cont'd)	June 1	6		29.4
		12		27.0
		18		23.0
		24		19.4
	June 2	12		17.4
		24		14.6
	June 3	12		12.2
		24		10.7
	June 4	12		8.2
		24		6.8
	June 5	12		5.2
		24		3.8
	June 6	12		3.0
		24		2.7
	June 7	12		2.2
		24		1.8
	June 8	12		1.6
		24		1.2
	June 9	24		1.0
	June 10	24		0.9
	June 11	24		0.9
62-8-1	Aug.22	23	.28	1.2
		24	.14	1.2
	Aug.23	1	.01	"
		2	.01	"
		3	.09	1.2
		4	.30	2.1
		5	.21	4.3
		6	.13	6.3
		7	.07	6.3
		8	.06	11.8
		9	.01	12.7
		10	.05	13.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
62-8-1 (cont'd)	Aug.23	11	.09	13.5
		12	.04	13.5
			1.49	
		13		12.7
		14		12.2
		19		12.2
		20		11.8
		22		11.8
		23		9.8
		24		9.8
	Aug.24	6		5.5
		12		3.6
		18		2.4
		24		2.4
	Aug.25	12		1.6
		24		1.2
	Aug.26	12		1.2
63-6-1	June 3	10	.01	7.6
		12	.01	"
		13	.04	"
		21	.07	"
		22	.06	"
		23	.01	"
		24	.01	7.6
	June 4	1	.10	10.0
		2	.16	"
		3	.19	10.0
		4	.07	12.6
		5	.13	12.6
		6	.09	15.6
			.97	
		9		18.9
		12		22.5
		13		26.4
		14		26.4

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
63-6-1 (cont'd)	June 4	15		30.7
		16		26.4
		18		26.4
		24		22.5
	June 5	6		18.9
		12		15.6
		18		15.6
		24		12.6
	June 6	24		12.6
	June 7	6		12.6
		12		10.0
		18		10.0
		24		7.6
	June 8	12		7.6
63-6-2	June 9	15	.00	5.7
		16	.01	5.7
		17	.34	7.6
		18	.33	7.6
		19	.28	10.0
		20	.14	12.6
		21	.12	18.9
		22	.09	26.4
		23	.14	40.0
		24	.08	55.5
	June 10	1	.20	74.5
		2	.28	96.8
		3	.17	121.4
		4	.11	147.5
		5	.07	187.0
		6	.05	218.0
		7	.04	"
		8	.02	"
		9	.02	"
		10	.02	"
		11	.02	218.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
63-6-2 (cont'd)	June 10	12	.01	202.4
		13		202.4
		14		187.0
		15		173.0
		16		173.0
		17		158.0
		18	.01	148.2
			2.55	
		21		139.0
		24		121.4
	June 11	3		89.0
		6		61.5
		7		50.0
		12		50.0
		24		44.9
	June 12	12		40.0
		13		40.0
63-7-1	July 6	10	.03	4.3
		11	.03	5.7
		12	.03	"
		18	.02	"
		19	.01	"
		20	.03	"
		21	.02	"
		22	.17	"
		23	.24	"
		24	.22	5.7
	July 7	1	.03	7.6
		2	.02	7.6
			.85	
		3		7.6
		4		10.0
		5		10.0
		6		10.0
		7		10.0
		12		7.6

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
63-8-1	Aug.8	0		.7
		1	.70	.9
		2	.04	1.3
		3	.03	3.0
		4	.03	5.7
		5		7.6
		6		7.6
		7	.02	7.6
		8	.02	7.6
		9	.02	7.6
			.86	
		12		5.7
		15		4.3
		18		4.3
		21		3.0
		24		3.0
	Aug.9	12		1.5
		24		1.3
	Aug.10	12		1.1
		24		1.1
63-9-1	Sept.11	3	.03	.7
		4	.06	.9
		5	.06	.9
		6	.04	.9
		7	.05	1.1
		8	.20	1.1
		9	.15	1.3
		10	.13	1.5
		11	.12	2.3
		12	.04	2.3
		13	.01	3.0
			.89	
		17		3.0
		18		2.3
		24		1.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
63-9-1 (cont'd)	Sept.12	6		1.3
		12		1.1
		18		1.1
		24		1.1
	Sept.13	12		.9
		24		.9
63-9-2	Sept.16	16	.05	.9
		17	.00	.9
		18	.01	.9
		19	.00	.9
		20	.01	.9
		21	.69	1.3
		22	.28	2.3
		23	.00	4.3
		24	.12	7.6
	Sept.17	1	.11	10.0
		2	.02	12.6
		3	.00	12.6
			1.29	
		6		12.6
		9		10.0
		12		10.0
		18		7.6
		24		5.7
	Sept.18	12		4.3
		24		4.3
	Sept.19	12		3.0
		24		3.0
	Sept.20	12		3.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-5-1	May 1	13	.00	11.0
		14	"	"
		15	"	"
		16	"	"
		17	"	"
		18	.01	"
		19	"	"
		20	.00	"
		21	.01	"
		22	.00	"
		23	"	"
		24	"	"
	May 2	1	"	"
		2	"	"
		3	"	"
		4	"	"
		5	"	"
		6	"	"
		7	"	"
		8	"	"
		9	.01	"
		10	.00	"
		11	.02	"
		12	.02	"
		13	.00	"
		14	"	"
		15	"	"
		16	"	"
		17	"	"
		18	"	"
		19	"	"
		20	"	"
		21	"	11.0
		22	"	15.5
		23	"	"
		24	"	"
	May 3	1	"	"
		2	"	"

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-5-1 (cont'd)	May 3	3	.00	15.5
		4	.01	"
		5	.07	"
		6	.04	20.0
		7	.00	"
		8	.01	"
		9	.12	"
		10	.19	"
		11	.09	"
		12	.04	"
		13	.04	26.0
		14	.00	"
		15	.00	"
		16	.00	"
		17	.00	"
		18	.00	32.0
		19	.05	"
		20	.18	"
		21	.16	"
		22	.12	"
		23	.00	39.5
			1.20	
		24		47.0
	May 4	2		64.0
		4		64.0
		6		73.0
		12		64.0
		18		55.0
		24		"
	May 5	6		"
		12		"
		18		"
		24		"
	May 6	6		64.0
		12		64.0
		18		64.0
		24		64.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-6-1	June 11	24	.01	0.6
	June 12	1	.02	0.6
		2	.11	0.6
		3	.19	0.6
		4	.26	1.2
		5	.14	1.2
		6	.15	2.0
		7	.08	3.0
		8	.01	3.0
		9	.00	6.0
		10	.00	6.0
		11	.00	6.0
		12	.08	6.0
			1.05	
		15		4.4
		18		3.0
		21		3.0
		24		2.0
	June 13	12		2.0
		24		1.2
	June 14	12		1.2
		24		0.6
	June 15	12		0.6
64-6-2	June 16	17	.00	0.6
		18	.00	
		19	.01	
		20	.02	
		21	.00	
		22	.01	
		23	.00	
		24	.00	0.6
	June 17	1	.00	
		2	.08	
		3	.09	
		4	.01	
		5	.07	0.6
		6	.07	1.2

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (Cfs.)
64-6-2 (cont'd)	June 17	7	.02	1.2
		8	.08	"
		9	.06	"
		10	.02	"
		11	.01	"
		12	.00	2.0
		13	.00	"
		14	.01	"
		15	.01	"
		16	.00	"
		17	.00	"
		18	.00	"
		19	.01	"
		20	.00	"
		21	.02	"
		22	.03	"
		23	.03	"
		24	.00	2.0
	June 18	1	.00	"
		2	.00	"
		3	.01	"
		4	.05	"
		5	.02	"
		6	.04	"
		7	.03	"
		8	.00	"
		9	"	"
		10	"	"
		11	"	"
		12	"	2.0
		13	"	"
		14	"	"
		15	"	"
		16	"	"
		17	.00	"
		18	.01	2.0
		19	.03	"
		20	.06	"

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-6-2 (cont'd)	June 18	21	.01	3.0
		22	.05	"
		23	.02	"
		24	.03	"
	June 19	1	.11	"
		2	.12	3.0
		3	.17	
		4	.17	4.4
		5	.08	"
		6	.03	6.0
		7	.01	8.4
			1.71	
		11		11.4
		14		11.4
		24		11.4
	June 20	6		8.4
		12		8.4
		18		6.0
		24		6.0
	June 21	12		4.4
		24		4.4
	June 22	12		3.0
64-9-1	Sept.1	2	.00	.15
		3	.00	
		4	.00	
		5	.00	
		6	.01	
		7	.00	
		8	.00	
		9	.01	
		10	.02	
		11	.00	
		12	"	.15
		13	"	
		14	"	
		15	"	

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-9-1 (cont'd)	Sept.1	16	.00	
		17	.00	
		18	.00	
		19	.00	
		20	.02	
		21	.01	
		22	.00	
		23	.01	
		24	.00	.15
	Sept.2	1	.00	
		2	.00	
		3	.00	
		4	.00	
		5	.01	
		6	.02	.15
		7	.00	
		8	.00	
		9	.00	
		10	.00	
		11	.00	
		12	.00	.15
		13	.88	
		14	.08	
			1.07	
		15		.15
		16		.50
		17		1.60
		18		8.75
		19		1.60
		20		1.25
		21		1.00
		22		.70
		23		.50
		24		.30
	Sept.3	12		.30
		24		.15

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
64-9-2	Sept.22	16		.15
		17	.00	
		18	.14	.15
		19	.12	
		20	.19	
		21	.22	
		22	.16	
		23	.08	
		24	.03	.15
	Sept.23	1	.00	
			.94	
		6		.30
		12		.15
		24		.15
		16		41.45
65-5-1	May 5	17	.07	38.40
		18	.08	33.90
		19	.15	32.45
		20	.17	32.45
		21	.07	36.80
		22	.02	39.95
		23	.01	46.20
		24	.03	46.20
	May 6	1	.04	47.75
		2	.06	54.25
		3	.20	57.50
		4	.14	62.70
		5	.07	71.75
		6	.06	92.90
		7	.12	105.75
		8	.04	113.00
		9	.05	116.85
		10	.01	122.80
		11	.00	126.50
		12	.01	116.85
		13	.00	111.10
		14	.10	105.75
		15	.06	98.35

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-5-1 (cont'd)	May 6	16	.04	98.35
		17	.07	105.75
		18	.02	107.50
		19	.01	107.50
		20	.00	104.00
		21	.00	98.35
		22	.01	96.60
		23	.00	92.90
		24	.00	87.45
	May 7	1	.00	80.50
		2	.02	78.50
		3	.00	
		4		71.75
		5		
		6		67.95
		7		
		8		66.20
		9		
		10		55.80
		11		
		12		52.50
		13		
		14		
		15	.00	
			1.73	
		24		39.95
	May 8	12		32.45
		24		26.95
	May 9	24		24.30
	May 10	24		20.40
	May 11	24		18.00
	May 12	24		14.50

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-6-1	June 26	16	.02	1.05
		17	.03	1.10
		18	.03	1.10
		19	.00	1.20
		20	.02	1.20
		21	.00	1.30
		22	.00	1.30
		23	.06	1.30
		24	.02	1.35
	June 27	1	.01	1.35
		2	.02	1.35
		3	.00	1.35
		4	.00	1.40
		5	.00	1.40
		6	.01	1.40
		7	.00	1.40
		8		1.40
		9		1.50
		10		1.50
		11		1.50
		12		1.50
		13		1.50
		14		1.40
		15		1.35
		16		1.35
		17		1.35
		18		1.35
		19		1.35
		20	.00	"
		21	.01	"
		22	.00	"
		23	.02	"
		24	.00	"
	June 28	1	.08	1.35
		2	.24	1.50
		3	.05	1.60
		4	.00	1.60
		5	.01	1.60

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-6-1 (cont'd)	June 28	6	.02	1.60
		7	.01	1.60
		8	.02	1.60
		9	.02	1.60
		10	.03	1.70
		11	.02	1.70
		12	.03	1.75
		13	.04	1.75
		14	.06	1.75
		15	.00	1.75
		16	.00	1.75
			.87	
		18		1.80
		24		1.80
	June 29	6		1.75
		12		1.35
		24		1.35
	June 30	12		1.00
65-7-1	July 1	5		1.05
		6	.12	1.10
		7	.09	1.20
		8	.25	1.30
		9	.16	1.40
		10	.20	1.60
		11	.07	1.75
		12	.01	1.80
		13	.03	2.00
		14	.04	2.10
		15	.06	2.20
		16	.03	2.30
		17	.00	2.30
		18	.00	2.50
		19	.00	2.50
		20	.01	2.70
		21	.07	2.70
		22	.01	2.70
			1.15	
		23		2.70

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-7-1 (cont'd)	July 1	24		2.70
	July 2	6		2.70
		8		2.50
	July 3	8		2.20
	July 4	8		1.75
65-7-2	July 19	6		1.60
		7	.21	1.60
		8	.70	1.70
		9	.10	2.30
			1.01	
		10		3.00
		11		3.70
		12		4.40
		13		5.40
		14		6.60
		15		7.40
		16		7.40
		17		8.20
		18		8.20
		21		8.20
		24		7.40
	July 20	6		5.40
		12		3.70
		18		2.2
65-7-3		19	.30	2.1
		20	.08	2.1
		21	.13	2.2
		22	.00	2.3
		23	.00	2.5
		24	.16	2.7
	July 21	1	.08	3.3
		2	.01	3.7
		5	.76	4.4
		6		4.9
		12		6.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-7-3 (cont'd)	July 21	14		6.0
		24		4.9
	July 22	8		4.15
	July 23	8		2.35
	July 24	8		1.92
65-7-4	July 29	22		
		23	.01	
		24	.02	
	July 30	1	.12	
		2	.10	
		3	.03	
		4	.27	
		5	.19	
		6	.01	2.00
		7	.06	2.30
		8	.04	2.70
		9	.00	3.00
		10	.00	3.00
		11	.00	3.30
		12	.02	3.30
		24	.87	
65-8-1	Aug.1	18		1.7
		19	.34	1.7
		20	.50	1.7
		21	.14	1.8
		22	.98	1.9
		23		2.0
		24		2.1
	Aug.2	1		2.3
		2		2.4
		3		2.6
		4		2.8
		5		3.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-8-1 (cont'd)	Aug.2	6		3.3
		7		3.7
		8		4.0
		9		4.2
		10		4.4
		11		4.7
		12		4.9
		13		4.9
		14		4.8
		15		4.6
		16		4.4
		17		4.2
		18		4.0
		19		3.9
		20		3.9
		21		3.8
		22		3.8
		23		3.7
		24		3.7
	Aug.3	3		3.5
		6		3.3
		9		3.1
		12		3.0
		24		2.6
	Aug.4	12		2.4
		24		2.3
	Aug.5	24		1.50
	Aug.6	24		1.30
	Aug.7	24		.60
65-9-1	Sept.3	21		.45
		22	.06	.45
		23	.02	.45
		24	.09	.60
	Sept.4	1	.11	.85
		2	.13	1.10

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-9-1 (cont'd)	Sept.4	3	.13	1.50
		4	.23	1.80
		5	.26	2.30
		6	.31	3.70
		7	.20	6.00
		8	.20	9.10
		9	.23	13.40
		10	.32	19.20
		11	.30	26.95
		12	.41	36.80
		13	.24	46.20
		14	.19	57.50
		15	.13	69.85
		16	.11	82.00
		17	.12	92.90
		18	.12	105.75
		19	.11	111.10
		20	.07	111.10
		21	.07	100.10
		22	.10	89.40
		23	.04	84.00
		24	.06	78.50
	Sept.5	1	.04	66.20
		2	.01	69.85
		3	.00	69.85
		4	.00	
		5	.00	
			4.41	
		6		57
		12		45
		18		38
		24		33
	Sept.6	24		21.5
	Sept.7	24		15
	Sept.8	24		10.7

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-9-2	Sept.15	18		3.0
		19	.02	3.0
		20	.10	3.0
		21	.10	3.3
		22	.04	3.7
		23	.10	4.0
		24	.04	4.4
	Sept.16	1	.04	5.4
		2	.01	6.0
		3	.02	6.0
		4	.02	6.0
		5	.02	4.4
		6	.01	4.0
		7	.07	4.0
		8	.02	4.0
		9	.04	4.0
		10	.04	4.4
		11	.06	4.9
		12	.05	5.4
		13	.09	6.0
		14	.06	7.4
		15	.07	8.2
		16	.08	10.1
		17	.13	11.2
		18	.09	12.3
		19	.09	14.5
		20	.12	18.0
		21	.14	19.2
		22	.12	23.0
		23	.16	26.95
		24	.13	28.3
	Sept.17	1	.14	35.4
		2	.08	41.45
		3	.07	49.35
		4	.06	57.5
		5	.10	66.2

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
65-9-2 (cont'd)	Sept.17	6	.09	75.0
		7	.08	84.0
		8	.05	91.15
		9	.07	100.1
		10	.02	113.0
		11	.02	126.5
		12	.04	140.2
		13	.02	150.0
		14	.04	150.0
		15	.00	148.0
		16	.06	146.1
		17	.01	144.1
		18	.03	140.2
		19	.02	136.2
		20	.01	130.3
		21	.00	126.5
		22	.01	124.6
		23	.00	118.8
		24	.03	114.9
	Sept.18	1	.00	107.5
		2	.02	104.0
		3	.00	98.35
		4	.04	92.9
		5	.07	87.45
		6	.03	82.0
		7	.00	76.75
			3.29	
		12		57.5
66-5-1	May 15	5		11.2
		6	.00	11.2
		7	.10	11.2
		8	.20	12.0
		9	.08	12.9
		10	.09	13.8
		11	.10	15.8
		12	.12	18.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-5-1 (cont'd)	May 15	13	.11	24.3
		14	.05	30.0
		15	.04	30.0
		16	.05	30.0
		17	.01	31.4
		18	.02	33.0
		19	.02	34.5
		20	.00	37.5
		21	.01	42.4
		22	.00	42.4
		23	.00	39.0
		24	.01	39.0
	May 16	1	.00	39.0
		2		39.0
		3		39.0
		4		37.5
		5		36.0
		6		36.0
		7		36.0
		8		36.0
		9		34.5
		10		33.0
		11		33.0
		12		31.4
		13		31.4
		14		31.4
		15		31.4
		16		31.4
		17		31.4
		18		31.4
		19	.00	31.4
		20	.03	30.0
		21	.00	30.0
		22		30.0
		23		30.0
		24		28.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-5-1 (cont'd)	May 17	1	.00	27.0
		2	.01	27.0
		3	.00	27.0
		4	.01	27.0
		5	.00	25.7
		6		25.7
		7		25.7
		8		24.3
		9		24.3
		10		24.3
		11	.00	24.3
		12	.01	24.3
		13	.02	24.3
		14	.00	24.3
		15	.01	24.3
		16	.00	24.3
		17	.01	24.3
		18	.01	24.3
		19	.00	24.3
		20		24.3
		21		24.3
		22		24.3
		23		22.9
		24		21.6
	May 18	1	.00	21.6
		2	.01	20.3
		3	.00	20.3
		4	.00	20.3
		5	.01	19.0
		6	.01	19.0
		7	.00	18.0
		8	.00	18.0
		9	.01	16.8
		10	.00	16.8

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-5-1	May 18	11	.01	16.8
(cont'd)		12	.00	16.8
		13		16.8
		14		16.8
		15		16.8
		16		16.8
		17	.00	16.8
		18	.01	16.8
		19	.02	16.8
		20	.03	16.8
		21	.00	16.8
		22	.07	18.0
		23	.04	18.0
		24	.02	19.0
	May 19	1	.06	19.0
		2	.06	19.0
		3	.05	20.3
		4	.00	22.9
		5	.02	24.3
		6	.03	25.7
		7	.00	25.7
		8	.02	27.0
		9	.01	28.5
		10	.00	30.0
			1.61	31.4
		11		31.4
		12		31.4
		14		31.4
		16		31.4
		18		31.4
		24		27.0
	May 20	6		22.9
		24		19.0
	May 21	24		14.8

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-5-1 (cont'd)	May 22	24		13.8
	May 23	24		12.9
	May 24	24		11.2
66-6-1	June 30	2		2.30
		3	.00	4.0
		4	.88	4.7
		5	.00	4.7
		6	.02	4.7
		7	.01	18.0
			.91	
		8		18.0
		9		15.8
		10		12.9
		11		11.2
		12		10.4
		13		10.4
		24		6.5
	July 1	24		4.0
	July 2	12		3.2
		24		2.6
	July 3	9		2.2
	July 4	9		2.2

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-8-1	Aug.5	13	.03	1.35
		14	.08	1.35
		15	.00	1.30
		16		"
		17		"
		18		"
		19		"
		20		"
		21		"
		22		1.30
		23		1.20
	Aug.6	1		"
		2		"
		3		"
		4	.00	"
		5	.02	"
		6	.03	"
		7	.05	1.20
		8	.03	1.30
		9	.04	1.35
		10	.05	1.60
		11	.02	1.80
		12	.01	1.85
		13	.00	1.96
		14	.03	1.95
		15	.12	2.20
		16	.11	2.30
		17	.16	2.45
		18	.35	2.80
		19	.72	3.0
		20	.84	3.7
		21	.60	15.8
		22	.57	37.5
		23	.34	70.3
		24	.29	70.3

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
66-8-1	Aug.7	1	.12	100.4
(cont'd)		2	.01	114.1
		3	.01	106.4
		4	.01	102.4
		5	.00	104.4
			4.60	
		10		92.4
		12		80.8
		14		56.4
		17		54.4
		24		36.0
	Aug.8	10		31.4
		11		33.0
		15		33.0
		24		25.7
	Aug.9	24		19.0
	Aug.10	24		9.7
	Aug.11	24		5.5
	Aug.12	24		7.0
	Aug.13	24		6.5
	Aug.14	24		5.5
	Aug.15	24		3.2
67-6-1	June 19	6		2.3
		7	.06	2.3
		8	.21	2.6
		9	.15	3.2
		10	.20	4.3
		11	.20	5.05
		12	.03	6.0
		13	.14	6.50
			0.99	
		14		8.25
		15		9.7
		16		10.45
		17		10.45

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
67-6-1 (cont'd)	June 19	18		10.45
		24		9.7
	June 20	12		7.0
		24		5.5
	June 21	12		4.7
	June 21	24		4.3
	June 22	24		3.7
	June 23	24		3.2
	June 24	24		2.45
68-6-1	June 7	15		3.7
		16	.00	"
		17	.00	"
		18	.00	"
		19	.02	"
		20	.01	"
		21	.02	"
		22	.00	"
		23		3.7
		24		3.9
	June 8	1	.00	3.9
		2	.01	3.9
		3	.03	4.1
		4	.07	"
		5	.10	"
		6	.08	"
		7	.01	4.1
		8	.14	4.3
		9	.16	4.6
		10	.01	5.3
		11	.02	6.1
		12	.00	6.9
		13	.04	8.6
		14	.00	8.6
		15	.00	7.9
		16		7.4
		17		"

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-6-1 (cont'd)	June 8	18	.00	7.4
		19	.01	"
		20	.02	"
		21	.02	"
		22	.02	"
		23	.02	7.4
		24	.02	"
	June 9	1	.04	"
		2	.02	"
		3	.02	"
		4	.03	"
		5	.03	"
		6	.01	7.4
		7	.05	7.9
		8	.03	"
		9	.01	"
		10	.01	"
		11	.00	7.9
		12	.01	8.6
		13	.00	8.6
		14	.01	8.6
		15	.00	10.2
		16	.00	10.2
		17	.00	8.6
		18	.01	"
		19	.03	"
		20	.01	"
		21	.01	"
		22	.03	"
		23	.03	8.6
		24	.03	9.4

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-6-1 (cont'd)	June 10	1	.01	10.2
		2	.02	11.1
		3	.02	12.0
		4	.01	12.0
		5	.02	13.0
		6	.00	13.0
		7	.02	14.1
		8	.00	
		9		
		10		
		11		
		12		16.5
		13	.00	17.8
		14	.00	
		15	.00	
		16	.01	
		17	.00	14.1
		18		13.0
		19		
		20	.00	
		21	.01	13.0
		22	.00	13.0
		23	.06	13.0
		24	.01	14.1
	June 11	1	.02	15.2
		2	.02	15.2
		3	.00	16.5
		4	.00	17.8
		5	.00	17.8
		6	.01	17.8
		7	.05	17.8
		8	.01	19.1
		9	.04	19.1
		10	.00	

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-6-1 (cont'd)	June 11	11		19.1
		12		9.4
		18		9.4
		19		8.6
		23		8.6
		24		7.9
	June 12	1		7.4
		10		7.4
		13		10.2
		18	.00	8.6
		19	.01	8.6
		20	.10	8.6
		21	.01	8.6
			1.69	
68-6-1	June 12	24		7.4
	June 13	24		6.1
	June 14	9		6.1
		12		5.3
		24		4.8
	June 15	12		4.8
		24		5.1
	June 16	24		5.1
	June 17	24		4.8

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-6-2	June 30	11		
		12	.01	2.4
		13	.05	"
		14	.02	"
		15	.10	"
		16	.36	2.4
		17	.19	3.1
		18	.24	3.4
		19	.21	3.7
		20	.23	4.1
		21	.12	12.0
		22	.04	16.5
		23	.05	19.1
		24	.13	20.6
	July 1	1	.07	25.8
		2	.09	27.7
		3	.12	29.6
		4	.06	35.4
		5	.13	39.3
		6	.11	43.0
		7	.10	46.8
		8	.12	50.6
		9	.00	52.5
			2.45	
		12		65.9
		18		80.1
		19		69.7
		20		44.9
		24		37.4
	July 2	11		22.2
		12		27.7
		13		29.6
		14		27.7
		18		20.6
		24		16.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-6-2 (cont'd)	July 3	12		9.4
		24		8.6
	July 4	12		6.1
		24		5.3
	July 5	8		4.8
		12		4.1
		24		3.2

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-7-1	July 12	20		2.7
		21	.07	2.7
		22	.26	2.7
		23	.26	2.7
		24	.31	2.7
	July 13	1	.10	3.4
		2	.05	4.6
		3	.03	5.3
			1.08	
		4		7.4
		5		11.1
		6		11.1
		12		11.1
		15		11.1
		18		7.9
		24		6.1
	July 14	12		4.1
		18		3.6
		24		3.4
	July 15	12		3.1
		24		2.9

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-7-2	July 29	2		.8
		3	.01	.8
		4	.04	.8
		5	.03	.9
		6	.00	1.0
		7		
		8		1.0
		9		
		10		
		11		
		12		1.3
		13		1.3
		14		1.3
		15	.00	1.3
		16	.05	1.4
		17	.12	1.7
		18	.05	2.0
		19	.09	2.2
		20	.39	2.4
		21	.69	3.9
		22	.15	5.1
		23	.16	7.9
		24	.01	25.8
	July 30	1	.00	20.6
		2	.00	17.8
		3		
		4		
		5		
		6		19.1
		7		
		8		
		9		
		10		
		11		
		12		20.6
		13	.00	20.6

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-7-2 (cont'd)	July 30	14	.04	15.2
		15	.23	15.2
		16	.24	16.5
		17	.30	17.8
		18	.10	19.1
		19	.06	19.1
		20	.01	20.6
			2.77	
		21		22.2
		24		29.6
	July 31	6		46.8
		7		37.4
		12		33.5
		18		23.8
		24		13.0
	Aug.1	12		12.0
		24		11.1
	Aug.2	12		11.1
		13		11.1
		14		11.1
		15		6.9
		16		6.1
		24		5.3
	Aug.3	12		4.3
		24		4.3
	Aug.4	24		4.3

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-9-1	Sept.2	3		3.6
		4	.00	"
		5	.02	"
		6	.01	"
		7	.04	"
		8	.02	"
		9	.02	"
		10	.00	"
		11	.00	"
		12	.00	3.6
		13	.00	3.6
		14	.00	3.6
		15	.10	3.7
		16	.10	3.7
		17	.11	3.7
		18	.10	3.9
		19	.04	3.9
		20	.04	4.1
		21	.04	4.2
		22	.03	4.6
		23	.06	5.1
		24	.01	5.3
	Sept.3	1	.07	5.7
		2	.07	6.4
		3	.05	7.4
		4	.05	9.4
		5	.04	11.1
		6	.05	13.0
		7	.01	15.2
		8	.05	16.5
		9	.03	19.1
		10	.00	20.6
		11	.00	22.2
		12	.01	23.8
		13		26.7
		14		29.6
		24		15.2

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
68-9-1	Sept.4	11	.03	
(cont'd)		12	.01	11.1
		13	.00	11.1
		14		11.1
		15		
		16		
		17		
		18		
		19		
		20		
		21		
		22		
		23		
		24		8.6
	Sept.5	1		8.5
		2		8.3
		3		8.2
		4		8.1
		5		
		6		
		7		
		8		
		9		
		10		
		11		
		12		6.9
		13		
		14		
		15	.00	
		16	.13	6.9
		17	.05	6.9
		18	.04	6.9
		20	1.33	
		24		7.4
	Sept.6	12		7.4
		24		6.4
	Sept.7	24		

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-5-1	May 30	16		5.0
		17	.00	5.0
		18	.05	5.0
		19	.03	5.0
		20	.03	5.0
		21	.01	5.2
		22	.01	5.7
		23	.03	5.7
		24	.01	5.7
	May 31	1	.00	5.7
		2	.01	6.0
		3	.03	6.0
		4	.01	6.0
		5	.00	6.0
		6	.05	6.2
		7	.01	6.2
		8	.01	6.5
		9	.02	6.5
		10	.01	6.7
		11	.03	6.7
		12	.03	7.0
		13	.07	7.0
		14	.06	7.7
		15	.04	8.0
		16	.15	8.0
		17	.10	8.5
		18	.09	9.7
		19	.07	11.8
		20	.03	14.2
		21	.08	16.0
		22	.06	21.7
		23	.07	25.7
		24	.08	28.5

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-5-1 (cont'd)	June 1	1	.04	30.0
		2	.07	33.3
		3	.06	35.0
		4	.05	37.0
			1.59	
		6		37.0
		10		28.5
		12		28.5
		15		28.5
		18		39.0
		24		37.0
	June 2	12		30.0
		24		20.5
	June 3	12		17.0
		24		16.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-7-1	July 6	14	.00	8.5
		15	.01	8.5
		16	.09	8.5
		17	.13	8.5
		18	.16	8.5
		19	.12	9.0
		20	.02	9.7
		21	.01	9.7
		22	.00	10.3
	July 7	1		11.8
		4		14.2
		7		18.2
		11		24.3
		12	.00	25.7
		13	.04	27.0
		14	.02	27.0
		15	.02	27.0
		16	.04	28.5
		17	.06	30.0
		18	.05	33.3
		19	.09	37.0
		20	.08	40.7
		21	.08	44
		22	.12	53.0
		23	.23	60.3
		24	.07	65.0
	July 8	6		97.0
		12	1.44	97.0
		18		76.0
		24		7.3
	July 9	12		1.2
		24		.5

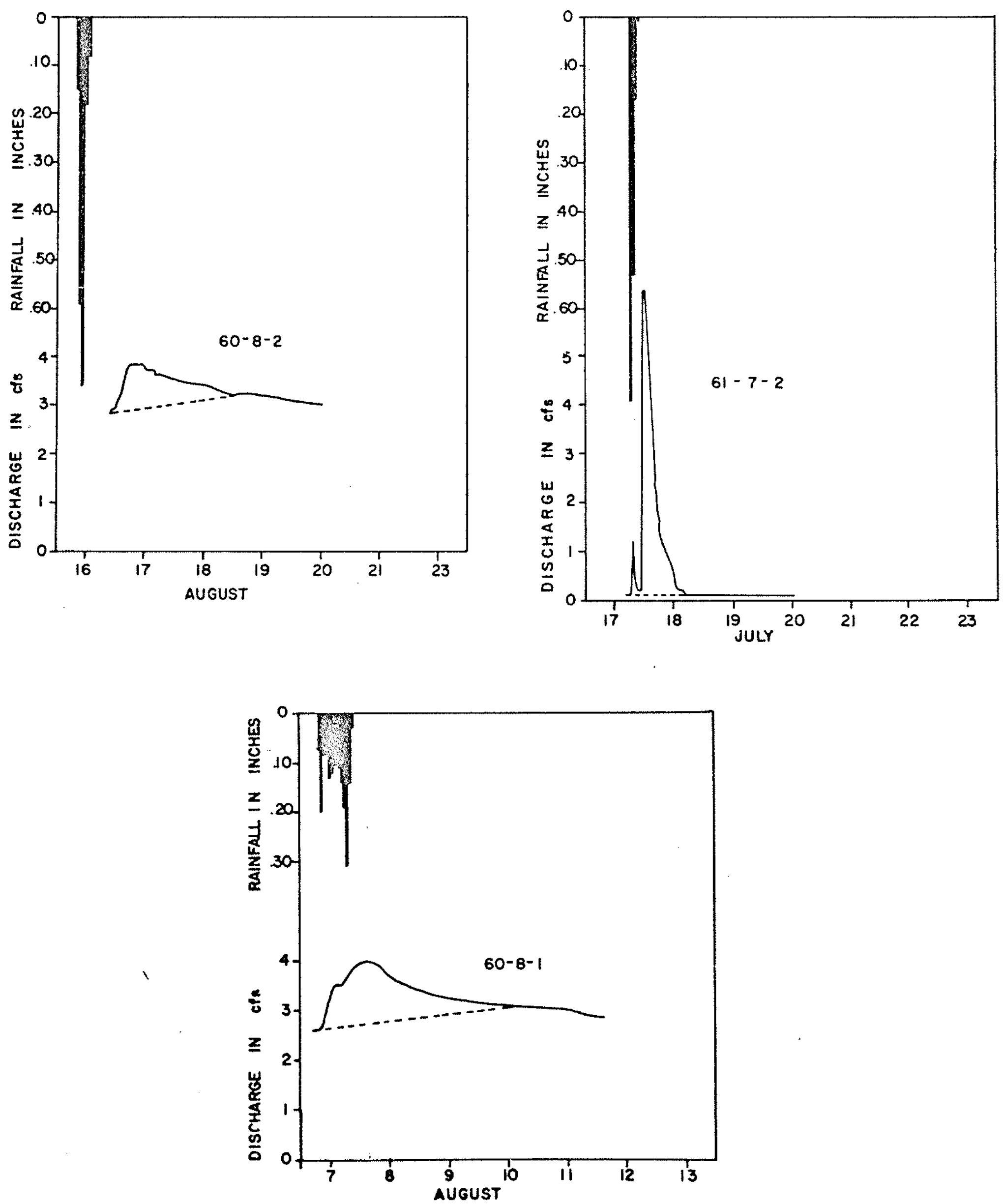
EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-7-2	July 26	1		17.0
		2	.01	17.0
		3	.08	18.2
		4	.03	18.2
		5	.04	18.2
		6	.02	18.2
		7	.04	18.2
		8	.00	18.2
		9	.00	18.2
		10	.03	18.2
		11	.00	18.2
		12	.00	18.2
		13	.03	18.2
		14	.04	18.2
		15	.08	18.2
		16	.14	18.2
		17	.13	18.2
		18	.15	19.3
		19	.18	21.7
		20	.04	23.0
		21	.06	23.0
		22	.05	23.0
		23	.04	23.0
		24	.01	23.0
	July 27	12	1.29	19.3
		24		17.0
	July 28	12		9.7
		24		7.7

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-8-1	Aug.27	6		0.8
		7	.74	2.0
		8	.20	4.3
		9	.09	7.3
		10	.12	10.3
		11	.06	17.0
		12	1.21	16.0
		15		4.2
		18		3.3
		24		3.1
	Aug.28	12		3.3
		24		3.0
	Aug.29	12		2.4

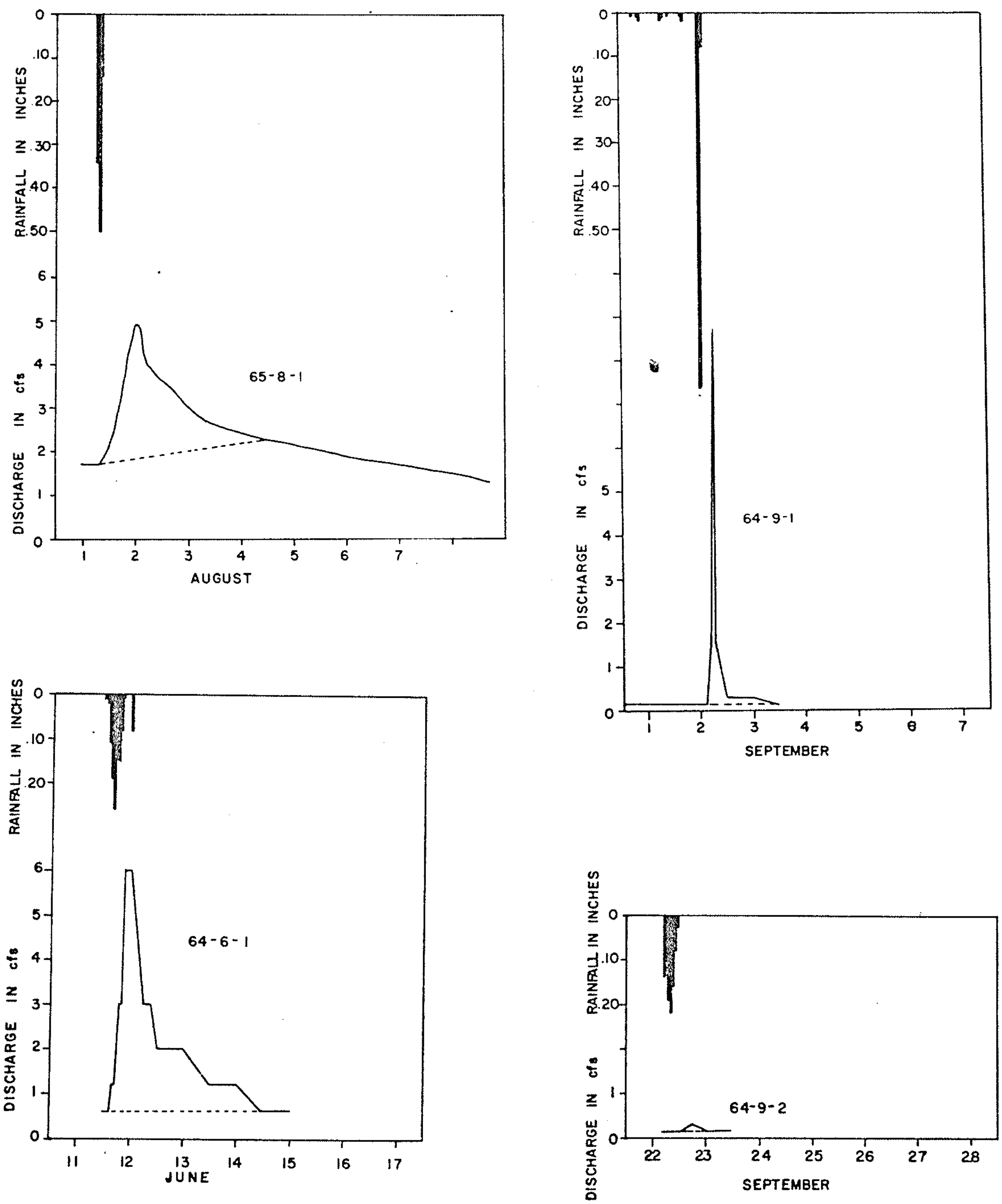
EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-9-1	Sept.20	19		
		20	.00	0.4
		21	.03	0.4
		22	.07	0.4
		23	.01	0.4
		24	.00	0.4
	Sept.21	1	.01	0.4
		2	.02	0.4
		3	.01	0.5
		4	.03	
		5	.16	1.6
		6	.41	3.0
		7	.16	3.9
		8	.01	5.7
		9	.00	6.5
		10	.00	8.0
		11	.03	
		12	.03	9.0
		13	.00	10.3
		14	.12	11.0
		15	.11	11.8
		16	.48	12.5
		17	.08	14.2
		18	.03	15.0
		19	.02	16.0
		20	.02	17.0
		21	.00	17.0
		22	.01	17.0
		23	.01	16.0
		24	.01	16.0

EVENT	DATE	TIME (hrs.)	R.F. (in.)	Q (cfs.)
69-9-1	Sept.22	1	.03	16.0
(cont'd)		2	.00	15.0
		3	.03	15.0
		4	.00	14.2
		5	.00	
		6	.02	
		7	.01	
		8	.03	
		9	.04	
		10	.07	
		11	.05	
		12	.02	10.3
		13	.03	
		14	.06	
		15	.05	
		16	.08	
		17	.03	
		18	.02	
		19	.01	
		20	.02	
		21	.01	
		22	.00	
		23	.00	
		24	2.49	
	Sept.23	12		8.5
	Sept.24	12		7.7
	Sept.25	12		7.3

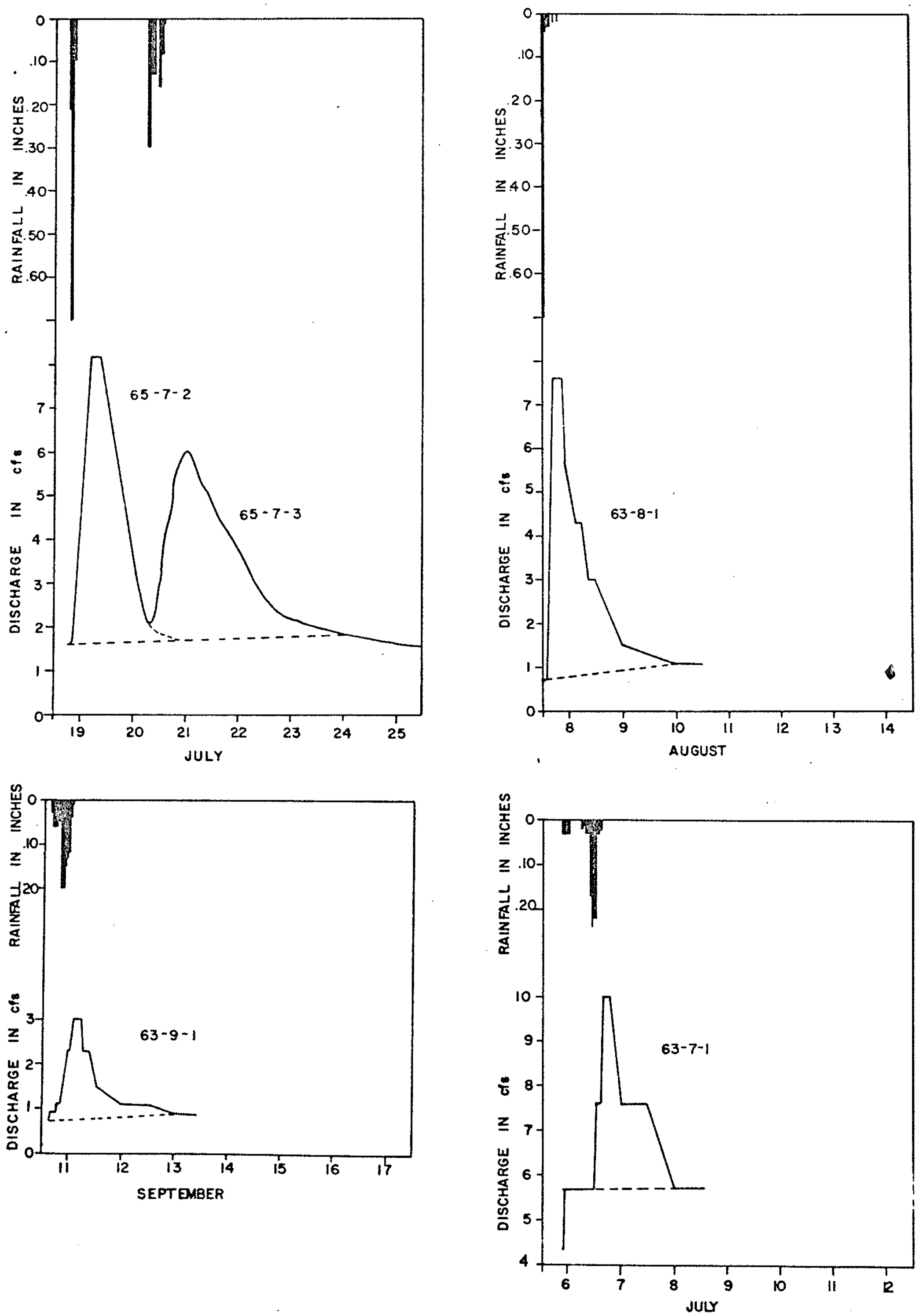
APPENDIX B



Hourly precipitation and storm runoff hydrographs
showing different base flow separations.
(For peaks between 0 and 10 cfs).

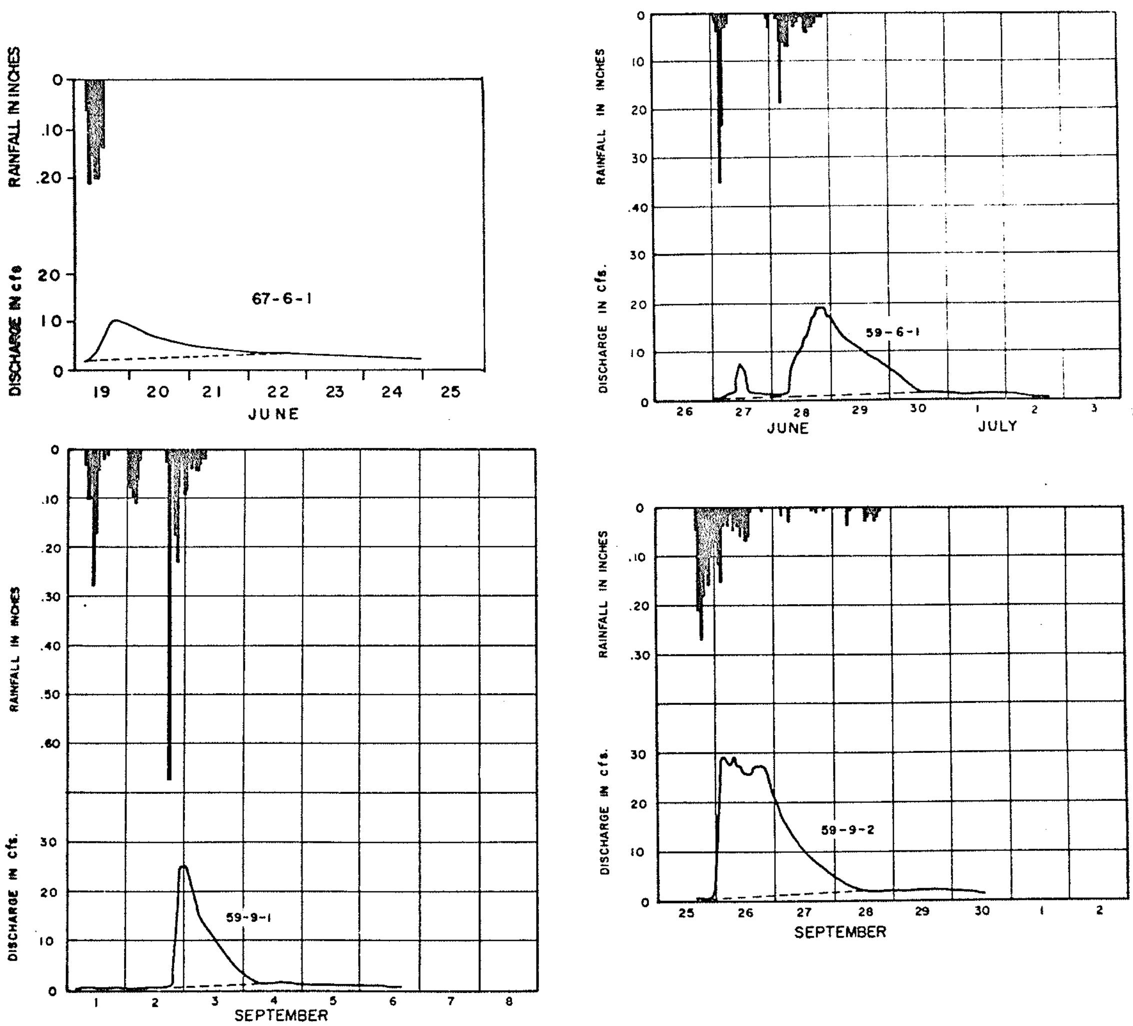


Hourly precipitation and storm runoff hydrographs showing different base flow separations. (For peaks between 0 and 10 cfs).

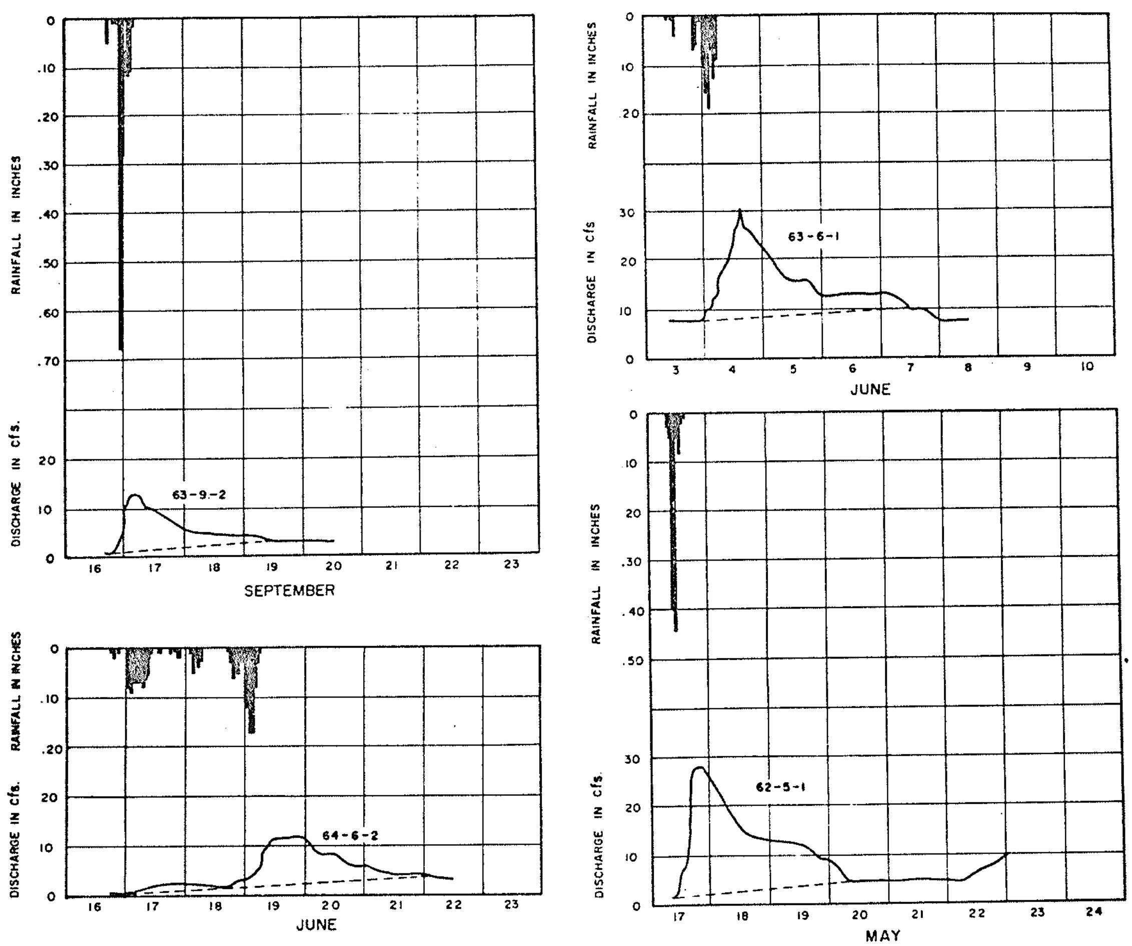


Hourly precipitation and storm runoff hydrographs
showing different base flow separations.
(For peaks between 0 and 10 cfs).

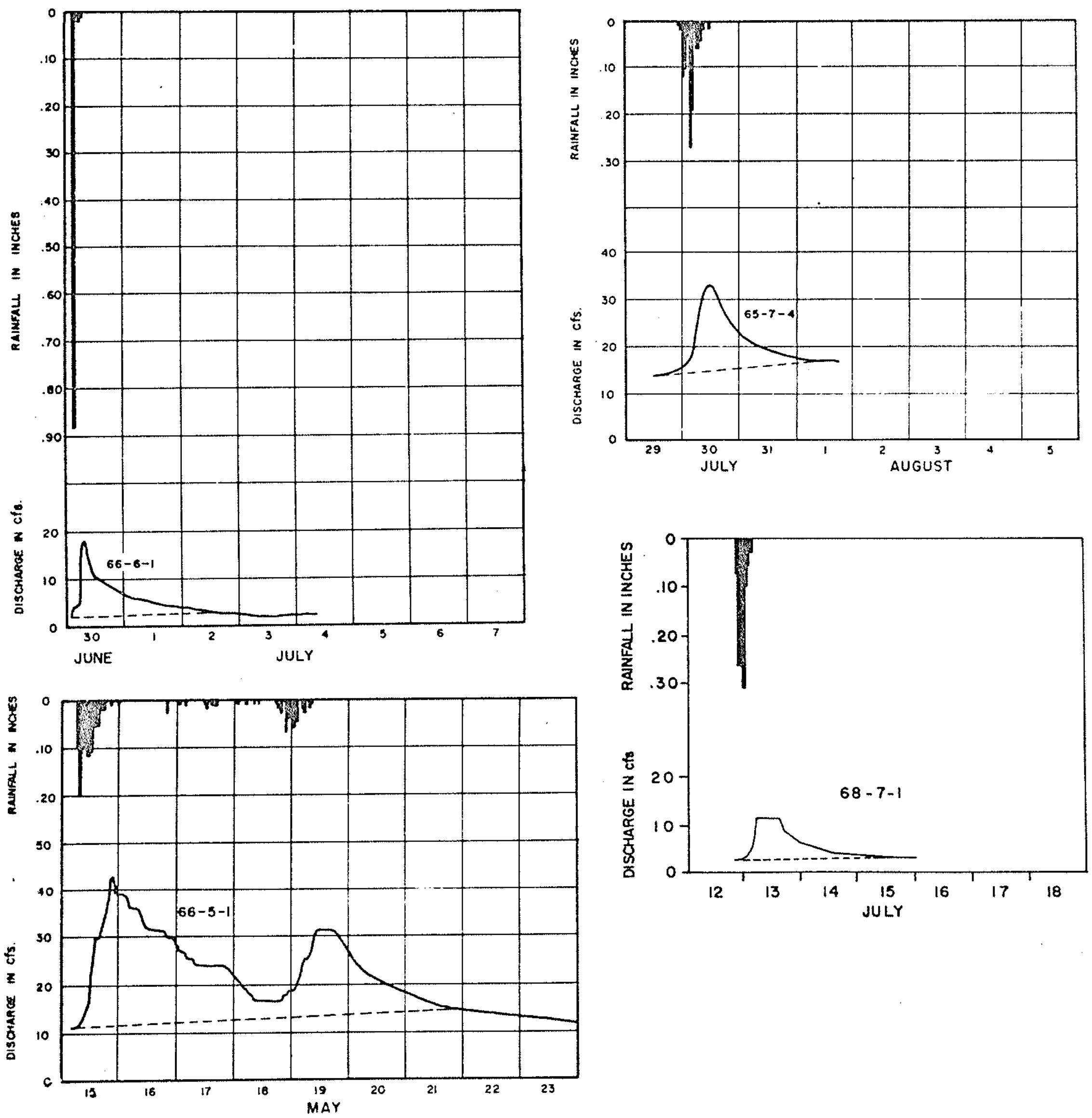
APPENDIX C



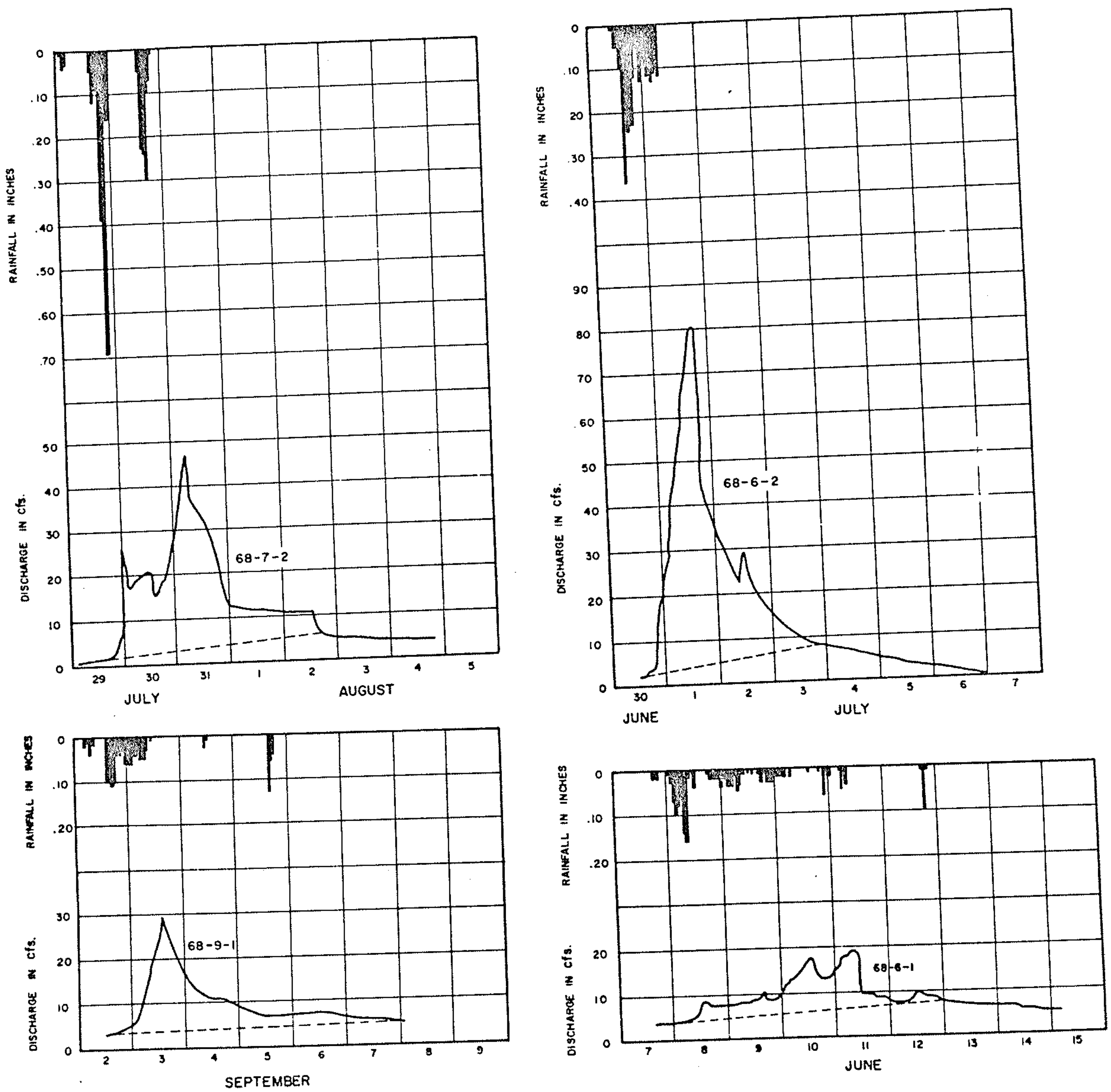
Hourly precipitation and storm runoff hydrographs showing different base flow separation. (For peaks above 10 cfs).



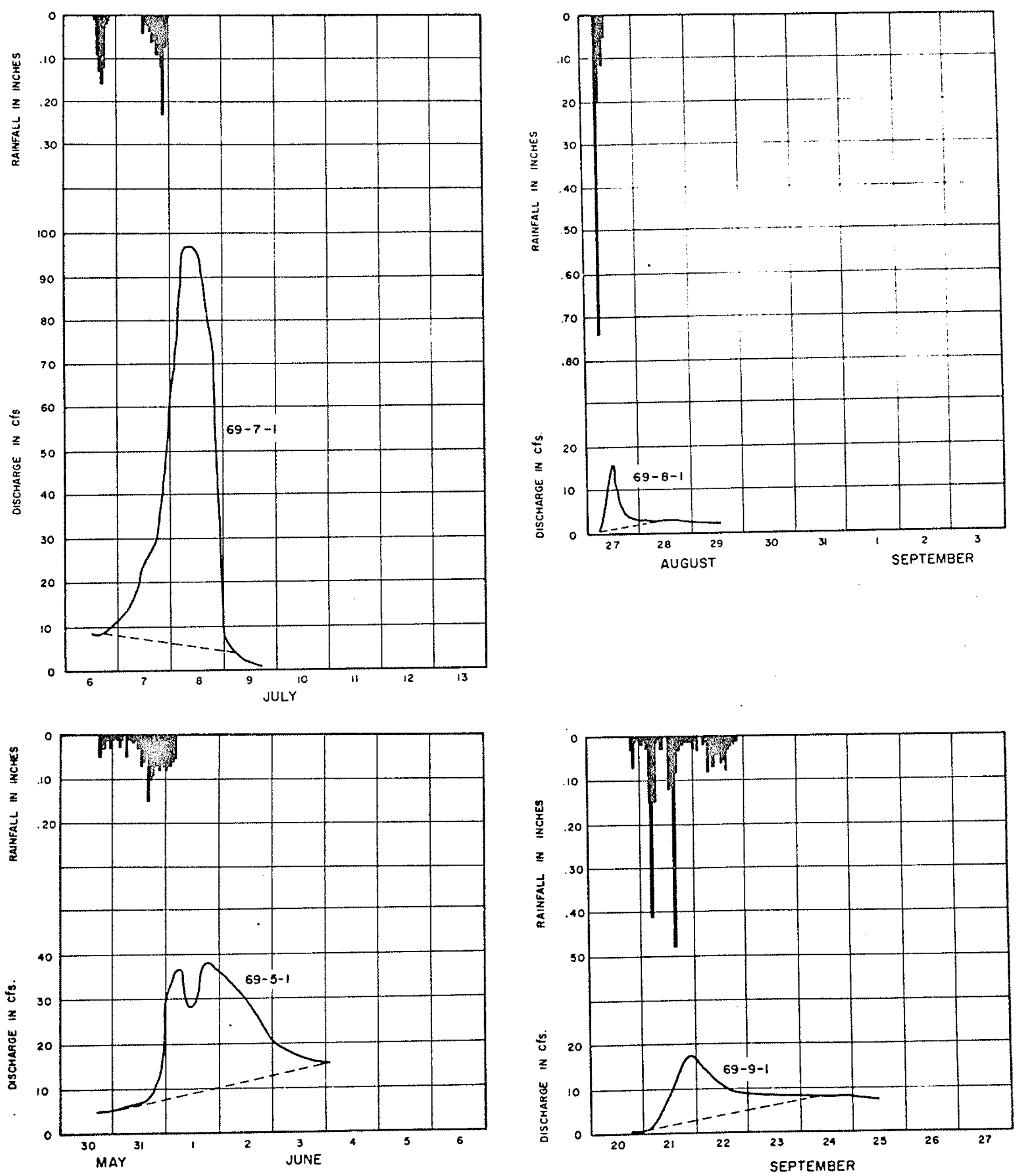
Hourly precipitation and storm runoff hydrographs
showing different base flow separation.
(For peaks above 10 cfs).



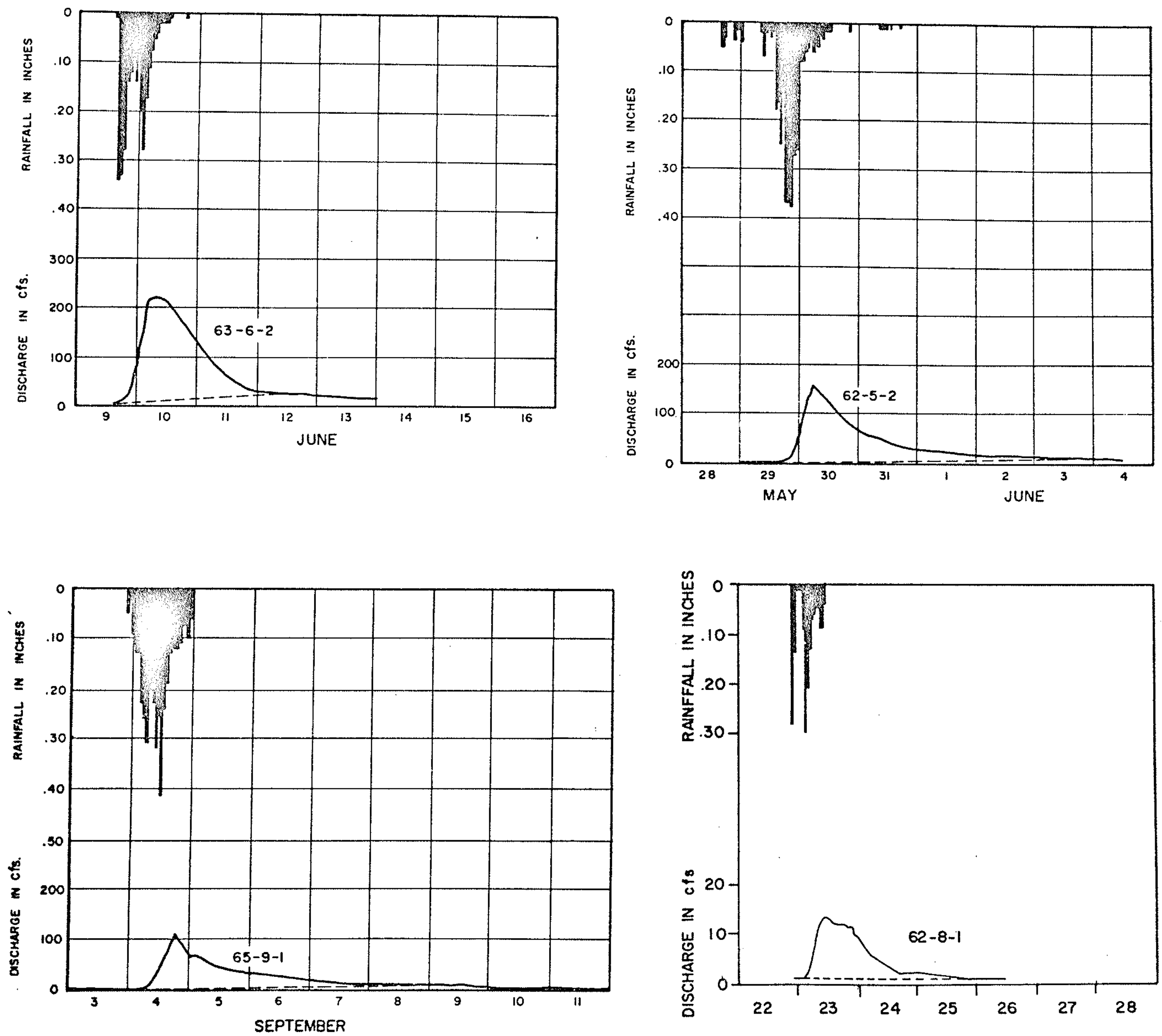
Hourly precipitation and storm runoff hydrographs
showing different base flow separation.
(For peaks above 10 cfs).



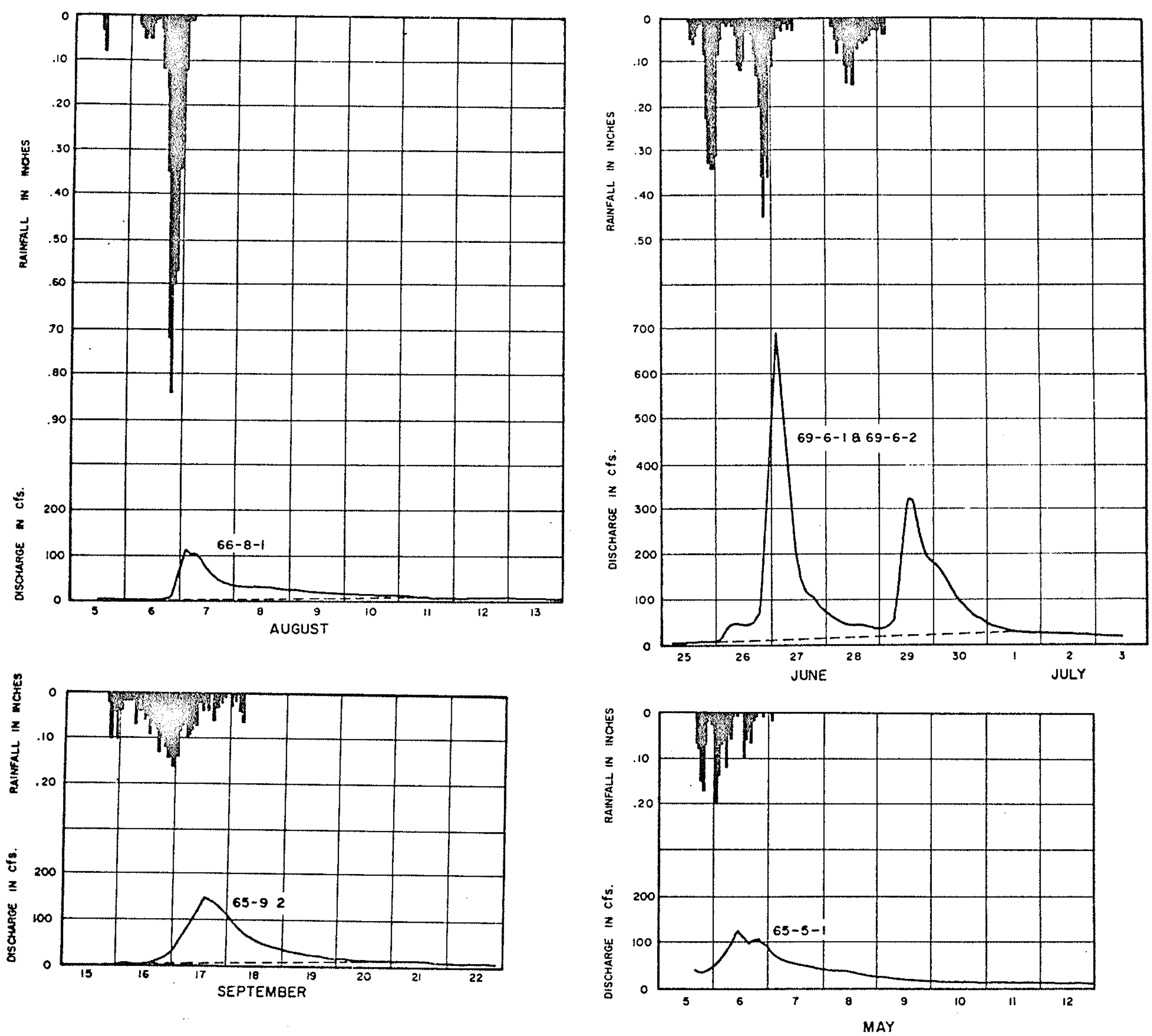
Hourly precipitation and storm runoff hydrographs
showing different base flow separation.
(For peaks above 10 cfs).



Hourly precipitation and storm runoff hydrographs showing different base flow separation. (For peaks above 10 cfs).



Hourly precipitation and storm runoff hydrographs
showing different base flow separation.
(For peaks above 10 cfs).



Hourly precipitation and storm runoff hydrographs
showing different base flow separation.
(For peaks above 10 cfs).

APPENDIX D

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85)

YEAR	DATE	TIME	G.W.L.	DEPTH TO WATER TABLE
1965	July 12	16	1906.30	6.55
	13	16	1906.08	6.77
	15	16	1906.00	6.85
	19	0	1905.65	7.20
		8	1905.58	7.27
		16	1905.65	7.20
		24	1905.85	7.00
	20	20	1906.20	6.65
	22	4	1907.45	5.40
	23	20	1906.95	5.90
	30	12	1906.13	6.72
	31	12	1906.25	6.60
	Break in chart with peak at		1906.60	6.25
	Aug. 6	13	1906.30	6.55
	12	0	1905.22	7.63
	17	24	1903.05	9.80
	20	12	1902.15	10.70
	28	16	1900.35	12.50
	Sept. 2	8	1900.00	12.85
	4	12	1899.70	13.15
	5	24	1910.35	2.50
	10	9	1909.05	3.80
	16	12	1907.83	5.02
		24	1908.45	4.40
	17	16	1911.35	1.50
	18	8	1911.45	1.40
	20	24	1910.57	2.28
	22	24	1910.08	2.77
	24	15	1909.90	2.95
	25	24	1909.60	3.25
	Oct. 1	16	1908.85	4.00
	2	10	1908.55	4.30
	4	15	1908.30	4.55
	8	10	1907.80	5.05
	15	10	1907.15	5.75
	22	10	1906.55	6.30

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85)

YEAR	DATE		TIME	G.W.L.	DEPTH TO WATER TABLE
1966	May	2	15	1908.80	4.05
		3	12	1908.77	4.08
		4	12	1911.10	1.75
		6	10	1910.85	2.00
		11	8	1910.15	2.70
		15	8	1909.95	2.90
			24	1910.75	2.10
		16	12	1910.75	2.10
		18	20	1910.47	2.38
		19	12	1911.00	1.85
		27	10	1909.75	3.10
		31	10	1909.20	3.65
	June	3	10	1908.80	4.05
		10	10	1908.20	4.65
		17	10	1907.85	5.00
		24	10	1907.15	5.70
		30	10	1906.75	6.10
	July	5	12	1906.65	6.20
		8	10	1906.40	6.45
		15	10	1904.85	8.00
		22	10	1904.15	8.70
		30	10	1902.30	10.55
	Aug.	3	8	1901.00	11.85
		6	24	1900.25	12.60
		7	24	1910.00	2.85
		8	12	1910.17	2.68
		12	10	1909.05	3.80
		16	8	1908.00	4.85
		19	10	1907.35	5.50
		27	24	1906.40	6.45
	Sept.	2	10	1906.35	6.50
		13	16	1904.77	8.08
		19	0	1904.37	8.48
		23	11	1903.60	9.25
	Oct.	3	11	1900.55	12.30
		11	10	1898.95	13.90
		14	24	1898.35	14.50
		17	16	1899.20	13.65

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85)

YEAR	DATE	TIME	G.W.L.	DEPTH TO WATER TABLE
1967	Apr. 28	14	1910.25	2.60
	30	8	1910.10	2.75
	May 1	4	1910.28	2.57
		24	1910.00	2.85
	4	12	1909.55	3.30
	7	8	1910.90	1.95
	10	24	1910.78	2.07
	11	12	1910.50	2.35
	17	24	1910.50	2.35
	19	10	1910.35	2.50
	22	8	1910.18	2.67
	23	8	1909.82	3.03
	June 1	12	1909.10	3.75
	3	12	1909.00	3.85
	4	12	1908.37	4.48
	5	12	1908.52	4.33
	9	10	1908.10	4.75
	11	8	1908.08	4.77
	18	24	1907.40	5.45
	20	12	1907.48	5.37
	30	10	1906.70	6.15
	July 9	16	1906.10	6.75
	15	24	1905.05	7.80
	18	12	1904.82	8.03
	28	10	1904.45	8.40
	Aug. 4	10	1904.30	8.55
	6	12	1904.30	8.55
	11	10	1904.40	8.45
	18	10	1904.20	8.65
	19	16	1904.20	8.65
	25	10	1903.65	9.20
	Sept. 1	10	1902.45	10.40
	8	10	1901.60	11.25
	15	10	1898.60	14.25
	22	10	1897.20	15.65
	Oct. 1	9	1895.80	17.05
	6	9	1895.15	17.70
	7	24	1895.00	17.85
	14	12	1906.78	6.07

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85)

YEAR	DATE	TIME	G.W.L.	DEPTH TO WATER TABLE
1968	Apr. 5	10	1905.50	7.35
	11	12	1908.20	4.65
	19	12	1907.90	4.95
		24	1907.85	5.00
	21	8	1909.28	3.57
	May 3	10	1908.15	4.70
	6	12	1908.00	4.85
	Time uncertain 8	12	1910.25	2.60
	17	12	1909.15	3.70
	19	12	1908.90	3.95
	20	24	1909.55	3.30
	24	10	1908.90	3.95
		20	1909.10	4.75
	31	10	1908.07	4.78
Missing records here				
	June 7	10	1907.25	5.60
	12	Chart risen to	1908.75	4.10
	21	12	1907.20	5.65
		24	1906.90	5.95
Chart rise - elevation not too certain				
	28	12	1906.60	6.25
	30	12	1906.15	6.70
	July 2	12	1909.55	3.30
	3	10	1909.30	3.55
	5	10	1908.80	4.05
	11	10	1907.40	5.45
	12	8	1907.35	5.50
		16	1907.65	5.20
	19	11	1906.55	6.30
	26	12	1906.00	6.85
	29	16	1905.65	7.20
	31	8	1908.77	4.08

NOTE: Elevation on July 31 at 8:00 a.m. uncertain. It could have been higher.

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85)

YEAR	DATE	TIME	G.W.L.	DEPTH TO WATER TABLE
1968	Aug. 2	12	1908.60	4.25
	3	10	1908.25	4.60
	9	12	1907.00	5.85
	16	20	1906.40	6.45
	17	16	1908.50	4.35
	19	16	1908.33	4.52
	20	16	1909.55	3.30
	27	10	1908.80	4.05
	30	12	1907.60	5.25
	Sept. 2	16	1907.25	5.60
	3	24	1908.55	4.30
	6	11	1908.15	4.70
	13	10	1907.00	5.85
	20	10	1906.05	6.80
	27	10	1904.95	7.90
	Oct. 1	9	1904.50	8.35
	18	9	1900.40	12.45
1969	Apr. 11	12	1896.00	18.85
	18	10	1910.15	2.70
	25	10	1909.65	3.20
	30	16	1909.35	3.50
	May 2	24	1909.90	2.95
	9	10	1909.05	3.80
	23	10	1908.69	4.16
	27	10	1908.30	4.55
	31	16	1908.07	4.78

DEPTH TO GROUNDWATER TABLE IN WELL #5

(DATA OBTAINED FROM
CONTINUOUS GROUNDWATER CHART.
GROUND SURFACE ELEVATION 1912.85).

YEAR	DATE	TIME	G.W.L.	DEPTH TO WATER TABLE
1969	June 2	4	1909.60	3.25
	13	10	1908.00	4.85
	20	10	1907.25	5.60
	25	20	1906.75	6.10
	26	24	1907.25	5.60
	27	20	1911.03	1.82
	29	4	1910.75	2.10
	30	10	1911.55	1.30
	July 4	10	1910.50	2.35
	6	16	1910.35	2.50
	8	8	1911.55	1.30
	11	11	1910.55	2.30
	21	16	1909.05	3.80
	25		1908.40	4.45
	Aug. 5	9	1907.25	5.60
	8	10	1906.90	5.95
	15	14	1906.30	6.55
	22	10	1905.65	7.20
	27	12	1905.25	7.60
	29	14	1905.40	7.45
	Sept. 5	10	1905.05	7.80
	10	8	1904.75	8.10
	19	9	1901.30	11.55
Large rise takes place up to Sept. 26.				
	Sept.26	12	1908.50	4.35
	Oct. 3	9	1908.45	4.40
	6	14	1905.75	7.10

NOTE: Records may not be dependable after Sept. 19.

APPENDIX E

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE-FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
59-9-1	Sept. 2	18	.63	.63	0	0				0	0
		19	1.46	.64	.8	12	0			12	3
		20	8.7	.66	8.0	120	12	0		132	33
		21	18.5	.67	17.8	267	120	12	0	399	100
		22	22.5	.69	24.8	372	267	120	12	771	193
		23	25.5	.70	24.8	372	372	267	120	1131	283
		24	25.5	.72	24.8	372	372	372	267	1383	346
	Sept. 3	1	25.5	.73	24.8	372	372	372	372	1488	372
		2	23.8	.76	23.0	335	372	372	372	1451	363
		3				303	335	372	372	1382	346
		4			18.1	271	303	335	372	1281	320
		5				248	271	303	335	1157	289
		6	15.8	.84	15.0	225	248	271	303	1047	262
		7					225		271		
		8			13.3	200		225			212
		9							225		
		10			11.5	172		200			186
		11									
		12	11.0	.92	10.1	152		172			162
		13									
		14									
		15									
		16									
		17									
		18	6.6	1.00	5.6	8.4					
		19									
		20			4.4	6.6		8.4			7.5
		21									
		22									
		23									
		24	3.1	1.07	2.0	3.0		4.0			3.5

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE-FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
59-9-1 (cont'd)	Sept. 4	~~2~~									
		4			0.9	1.5		2.3			1.9
		~~6~~									
		~~8~~									
		~~10~~									
		12	1.22	1.22	0	0					
		13					0				
		14					~~0~~	0			
		15						~~0~~	0	0	0
						2 HR.					
62-5-1	May 17	7	1.2	1.2							
		8	1.2	1.2							
		9	1.2	1.2	0	0				0	0
		10	2.5	1.3	1.2	9	0			9	5
		11	4.0	1.3	2.7	19	9			28	14
		12	6.3	1.4	4.9	35	19			54	27
		13	7.5	1.4	6.1	44	35			79	40
		14	16.5	1.5	15.0	107	44			151	75
		15	22.0	1.5	20.5	147	107			254	127
		16	27.0	1.6	25.4	182	147			329	165
		17	27.5	1.6	25.9	185	182			367	184
		18	27.5	1.7	25.8	185	185			370	185
		19	27.5	1.7	25.8	185	185			370	185
		20	27.5	1.8	25.7	184	185			369	185
		21	27.5	1.8	25.7	184	184			368	184
		22	26.0	1.9	24.1	173	184			357	178
		23	26.0	2.0	24.0	172	173			345	172
		24	25.0	2.0	23.0	165	172			337	168

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	2 HR. U.H.				SUM.	4 HR. U.H.
62-5-1 (cont'd)	May 18	1	23.5	2.1	21.4	153	165			318	159
		2	23.0	2.1	20.9	150	153			303	152
		3	22.0	2.2	19.8	142	150			292	146
		4	20.0	2.2	17.8	128	142			270	135
		5	19.0	2.3	16.7	120	128			248	124
		6	18.0	2.3	15.7	112	120			232	116
		7	17.0	2.4	14.6	105	112			217	109
		8	17.0	2.4	14.6	105	105			210	105
		9	16.5	2.5	14.0	100	105			205	102
		10	15.5	2.5	13.0	93	100			193	96
		11	14.5	2.6	11.9	85	93			178	89
		12	14.0	2.6	11.4	81	85			166	83
		13	14.0	2.7	11.3	81	81			162	81
		14	14.0	2.7	11.3	81	81			162	81
		15	14.0	2.8	11.2	80	81			161	81
		16	14.0	2.8	11.2	80	80			160	80
		17	14.0	2.9	11.1	79	80			1 9	80
		18	14.0	2.9	11.1	79	79			158	79
		19	13.0	2.9	10.1	72	79			151	76
		20	13.0	3.0	10.0	71	72			143	72
		21	13.0	3.0	10.0	71	71			142	71
		22	13.0	3.1	10.0	71	71			142	71
		23	12.9	3.1	9.8	70	71			141	70
		24	12.9	3.2	9.7	69	70			139	70
	May 19	2		3.3			69				
		6	12.7	3.5	9.2	66	67			133	67
		8		3.6			66				
		12	11.8	3.8	8.0	57	60			117	58
		14		3.9							
		18	9.8	4.1	5.7	41	45			86	43
		24	8.5	4.3	4.2	30	33			63	31
	May 20	6	4.5	4.5	0	0	10			10	5
		8					0			0	0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.					SUM.	4 HR. U.H.
62-5-2	May 29	19	1.0	1.0	0						0
		20	2.2	1.0	1.2						1.4
		21	6.0	1.1	4.9						5.9
		22	27.8	1.1	26.7						32
		23	40.6	1.2	39.4						47
		24	63.5	1.3	62.2						74
	May 30	1	89.0	1.4	87.6						105
		2	109.0	1.4	107.6						129
		3	135.3	1.5	133.8						160
		4	147.2	1.6	145.6						174
		5	155.0	1.7	153.3						184
		6	159.8	1.8	158.0						189
		7	157.6	1.9	155.7						187
		8	155.0	2.0	153.0						183
		9	147.2	2.0	145.2						174
		10	142.5	2.1	140.4						168
		11	137.6	2.2	135.4						162
		12	130.7	2.2	128.5						154
		13	126.0	2.3	123.7						148
		14	121.5	2.4	119.1						143
		15	115.2	2.5	112.7						135
		16	109.0	2.6	106.4						128
		17	103.2	2.7	100.5						120
		18	97.3	2.8	94.5						113
		19	90.5	2.8	87.7						105
		20	85.6	2.9	82.7						99
		24	67.8	3.2	64.6						77

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.					SUM.	4 HR. U.H.
62-5-2 (cont'd)	May 31	6	57.3	3.2	64.6						64
		12	43.9	4.2	39.7						48
		18	35.7	4.7	31.0						37
		24	32.1	5.1	27.0						32
	June 1	12	27.0	6.0	21.0						25
		24	19.4	6.9	12.5						15
	June 2	12	17.4	7.8	9.6						11
		24	14.6	8.8	5.8						6.9
	June 3	12	12.2	9.7	2.5						3.0
		24	10.7	10.7	0	1HR.UH					0
63-8-1	Aug. 8	0	0.7	0.7	0	0				0	0
		1	0.9	0.7	0.2	10	0			10	3
		2	1.3	0.7	.6	29	10	0		39	10
		3	3.0	0.7	2.3	112	29	10	0	151	37
		4	5.7	0.7	5.0	243	112	29	10	394	98
		5	7.6	0.7	6.9	335	243	112	29	719	180
		6	7.6	0.7	6.9	335	335	243	112	1025	256
		7	7.6	0.7	6.9	335	335	335	243	1248	312
		8	7.6	0.7	6.9	335	335	335	335	1340	335
		9	7.6	0.8	6.8	330	335	335	335	1335	334
		10				300	330	335	335	1300	325
		11				270	300	330	335	1235	309

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
63-8-1											
(cont'd)	Aug. 8	12	5.7	0.8	4.9	238	270	300	330	1138	285
		13					238				
		14						238			
		15	4.3	0.8	3.5	170			238		204
		16					170				
		17						170			
		18	4.3	0.8	3.5	170			170		170
		19					170				
		20						170			
		21	3.0	0.8	2.2	107			170		138
		22					107				
		23						107			
		24	3.0	0.8	2.2	107	107	107	107		107
	Aug. 9	1					107				
		2						107			
		3							107		
		4									
		12	1.5	0.9	0.6	29	40	50	60	179	45
		24	1.3	1.0	0.3	15	15	20	20	70	18
	Aug. 10	12	1.1	1.1	0	0			0	0	0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
63-9-2	Sept. 16	20	0.9	0.9	0	0				0	0
		21	1.3	0.9	.4	8	0			8	2
		22	2.3	0.9	1.4	29	8	0		37	9
		23	4.3	1.0	3.3	68	29	8	0	105	21
		24	7.6	1.0	6.6	135	68	29	8	240	60
	Sept. 17	1	10.0	1.0	9.0	184	135	68	29	416	104
		2	12.6	1.1	11.5	235	184	135	68	622	156
		3	12.6	1.1	11.5	235	235	184	135	789	197
		4				235	235	235	184	889	222
		5				235	235	235	235	940	235
		6	12.6	1.2	11.4	234	235	235	235	940	235
		9	10.0	1.3	8.7	178	197	217	234	827	206
		12	10.0	1.4	8.6	176	177	177	178		177
		18	7.6	1.6	6.0	123			150		136
		24	5.7	1.8	3.9	80			105		92
	Sept. 18	12	4.3	2.2	2.1	43					
		24	4.3	2.6	1.7	35					38
	Sept. 19	12	3.0	3.0	0	0					
		13					0				
		14						0			
		15							0	0	0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR U.H.				SUM.	4 HR. U.H.
65-7-2	July 19	7	1.6	1.6	0	0				0	0
		8	1.7	1.6	0.1	4	0			4	1
		9	2.3	1.6	0.7	29	4	0		33	8
		10	3.0	1.6	1.4	58	29	4	0	91	23
		11	3.7	1.6	2.1	87	58	29	4	178	44
		12	4.4	1.6	2.8	116	87	58	29	290	72
		13	5.4	1.6	3.8	158	116	87	58	419	105
		14	6.6	1.6	5.0	207	158	116	87	568	142
		15	7.4	1.6	5.8	240	207	158	116	721	180
		16	7.4	1.6	5.8	240	240	207	158	845	211
		17	8.2	1.6	6.6	274	240	240	207	961	240
		18	8.2	1.6	6.6	274	274	240	240	1028	257
		21	8.2	1.6	6.6	274			274		274
		24	7.4	1.6	5.8	240			274		257
	July 20	6	5.4	1.6	3.8	158			200		179
		12	3.7	1.6	3.1	129			144		137
		18	2.2	1.7	0.5	21			50		36
		24			0.3	12			17		15
	July 21	6									
		12	1.7	1.7	0	0					
		13									
		14									
		15									0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
65-8-1	Aug. 1	18	1.7	1.7	0						
		19	1.7	1.7	0						
		20	1.7	1.7	0	0				0	0
		21	1.8	1.7	0.1	7	0			7	2
		22	1.9	1.7	0.2	14	7	0		21	5
		23	2.0	1.7	0.3	21	14	7	0	42	10
		24	2.1	1.7	0.4	28	21	14	7	70	18
	Aug. 2	1	2.3	1.7	0.6	41	28	21	14	104	26
		2	2.4	1.8	0.6	41	41	28	21	131	33
		3	2.6	1.8	0.8	55	41	41	28	165	41
		4	2.8	1.8	1.0	69	55	41	41	206	51
		5	3.0	1.8	1.2	83	69	55	41	248	62
		6	3.3	1.8	1.5	103	83	69	55	310	78
		7	3.7	1.8	1.9	131	103	83	69	386	97
		8	4.0	1.8	2.2	152	131	103	83	469	117
		9	4.2	1.8	2.4	166	152	131	103	552	138
		10	4.4	1.8	2.6	180	166	152	131	629	157
		11	4.7	1.8	2.9	200	180	166	152	698	174
		12	4.9	1.8	3.1	214	200	180	166	760	190
		13	4.9	1.8	3.1	214	214	200	180	808	202
		14	4.8	1.8	3.0	207	214	214	200	835	209
		15	4.6	1.8	2.8	194	207	214	214	829	207
		16	4.4	1.9	2.5	173	194	207	214	788	197
		17	4.2	1.9	2.3	158	173	194	207	732	183
		18	4.0	1.9	2.1	145	158	173	194	670	168
		19	3.9	1.9	2.0	138	145	158	173	614	154
		20	3.9	1.9	2.0	138	138	145	158	579	145
		21	3.8	1.9	1.9	131	138	138	145	552	138
		22	3.8	1.9	1.9	131	131	138	138	538	135
		23	3.7	1.9	1.8	125	131	131	138	525	131
		24	3.7	1.9	1.8	125	125	131	131	512	128

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
65-8-1 (cont'd)	Aug. 3	3	3.5	1.9	1.6	110			125		117
		6	3.3	2.0	1.3	90			110		100
		9	3.1	2.0	1.1	76			90		83
		12	3.0	2.0	1.0	59			76		72
		24	2.6	2.1	.5	35			52		43
	Aug. 4	12	2.4	2.2	.2	14			25		20
		24	2.3	2.3	0	0			7		4
	Aug. 5	3							0		0
65-9-1	Sept. 3	23	.45								
		24	.60	.60	0						0
	4	1	.85	.70	.15						.3
		2	1.10	.90	.20						.4
		3	1.50	1.10	.40						.9
		4	1.80	1.20	.60						1.3
		5	2.30	1.40	.90						1.9
		6	3.7	1.60	2.1						4.5
		7	6.0	1.70	4.3						9.2
		8	9.1	1.80	7.3						15.6
		9	13.4	1.90	11.5						32.0
		10	19.2	2.10	17.1						36.6

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
65-9-1 (cont'd)	Sept. 4	11	26.95	2.2	24.75						52.8
		12	36.8	2.4	34.4						73.5
		13	46.2	2.6	43.6						93.0
		14	57.5	2.7	55.8						119
		15	69.85	2.9	66.95						143
		16	82.0	3.1	78.9						168
		17	92.9	3.2	89.7						191
		18	105.8	3.4	102.4						219
		19	111.1	3.6	107.5						230
		20	111.1	3.7	107.4						229
		21	100.1	3.9	96.2						206
		22	89.4	4.0	85.4						182
		23	84.0	4.1	79.9						171
		24	78.5	4.2	74.3						159
	Sept. 5	1	66.2	4.4	61.8						132
		2	69.85	4.5	65.35						140
		3	69.85	4.7	65.15						139
		4									
		5									
		6	57	5.1	51.9						111
		12	45	6.0	39.0						83.3
		18	38	6.9	31.1						66.5
		24	33	7.8	25.2						53.7
	Sept. 6	24	21.5	11.3	10.2						21.8
	Sept. 7	24	15.0	15.0	0						0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
66-6-1	June 30	2	2.3	2.3	0	0				0	0
		3	4.0	2.3	1.7	42	0			42	10
		4	4.7	2.3	2.4	59	42	0		101	25
		5	4.7	2.3	2.4	59	59	42	0	160	40
		6	4.7	2.3	2.4	59	59	59	42	219	55
		7	18.0	2.4	15.6	396	59	59	59	573	143
		8	18.0	2.4	15.6	396	396	59	59	910	227
		9	15.8	2.4	13.4	332	396	396	59	1183	295
		10	12.9	2.4	10.5	260	332	396	396	1384	346
		11	11.2	2.4	8.8	218	260	332	396	1206	301
		12	10.4	2.4	8.0	198	218	260	332	1008	252
		13	10.4	2.4	8.0	198	198	218	260	874	218
		14				188	198	198	218	802	200
		15						198	198		
		24	6.5	2.5	4.0	99			126		56
	July 1	24	4.0	3.0	1.0	25	30	35	40		32
	2	12	3.2	3.2	0	0					
		13									
		14									
		15							0	0	0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
66-8-1	Aug. 6	14	1.95	1.95	0						0
		18	2.8	2.0	0.8						1.6
		19	3.0	2.1	0.9						1.8
		20	3.7	2.2	1.5						2.7
		21	15.8	2.3	13.5						25
		22	37.5	2.3	35.2						64
		23	70.3	2.4	67.9						104
		24		2.5							143
	Aug. 7	1	100.4	2.6	97.8						178
		2	114.1	2.7	111.4						202
		3	106.1	2.7	103.7						188
		4	102.4	2.8	99.6						181
		5	104.4	2.9	101.5						185
		10	92.4	3.2	89.2						162
		12	80.8	3.4	77.4						141
		14	56.4	3.5	52.9						96
		17	54.4	3.8	50.6						92
		24	36.0	4.1	31.9						58
	Aug. 8	10	31.4	5.0	26.4						48
		11	33.0	5.1	27.9						51
		15	33.0	5.4	27.6						50
		24	25.7	6.0	19.7						36
	Aug. 9	24	19.0	7.9	11.1						20
	Aug. 10	12	10.0	10.0	0						0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
67-6-1	June 19	6	2.3	2.3	0	0					
		7	2.3	2.3	0	0				0	0
		8	2.6	2.3	.3	6	0			6	2
		9	3.2	2.3	.9	19	6	0		25	6
		10	4.3	2.4	1.9	41	19	6	0	66	16
		11	5.1	2.4	2.7	58	41	19	6	124	31
		12	6.0	2.4	3.6	78	58	41	19	196	49
		13	6.5	2.4	4.1	89	78	58	41	266	66
		14	8.3	2.4	5.9	128	89	78	58	353	88
		15	9.7	2.4	7.3	158	128	89	78	453	113
		16	10.4	2.4	8.0	173	158	128	89	548	137
		17	10.5	2.5	8.0	173	173	158	128	632	158
		18	10.5	2.5	8.0	173	173	173	158	677	169
		19	10.4	2.5	7.9	171	173	173	173	690	173
		20	10.4	2.5	7.9	171	171	173	173	688	172
		21	10.3	2.5	7.8	169	171	171	173	684	171
		22	10.1	2.6	7.5	162	169	171	171	673	168
		23	9.9	2.6	7.3	158	162	169	171	660	165
		24	9.7	2.6	7.1	154	158	162	169	643	161
	June 20	1	9.5	2.6	6.9	149	154	158	162		
		2	9.3	2.6	6.7	145	149	154	158		
		3	9.0	2.6	6.4	139	145	149	154	587	147
		4	8.8	2.6	6.2	134	139	145	149		
		5	8.6	2.7	5.9	128	134	139	145		
		6	8.4	2.7	5.7	123	128	134	139	524	131
		7	8.1	2.7	5.4	117	123	128	134		
		8	7.9	2.7	5.2	113	117	123	128		

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
67-6-1 (cont'd)	June 20	9	7.6	2.7	4.9	106	113	117	123	459	115
		10	7.4	2.8	4.6	100	106	113	117		
		11	7.2	2.8	4.4	95	100	106	113		
		12	7.0	2.8	4.2	91	95	100	106	392	98
		15	6.5	2.8	3.7	80			91		85
		18	6.1	2.9	3.2	69			80		75
		21	5.8	2.9	2.9	63			69		66
		24	5.5	3.0	2.5	54			63		59
	June 21	12	4.7	3.2	1.5	32					35
		24	4.3	3.4	0.9	19					
	June 22	24	3.8	3.8	0	0					
	June 23	3									0
						2 HR U.H.					
68-6-2	June 30	16	2.4	2.4	0	0				0	0
		17	3.1	2.4	0.7	2				2	1
		18	3.4	2.5	0.9	3	0			3	2
		19	3.7	2.6	1.1	3	2			5	3
		20	4.1	2.7	1.4	4	3			7	4
		21	12.0	2.7	9.3	28	3			31	16
		22	16.5	2.8	13.7	42	4			46	23
		23	19.1	2.9	16.2	50	28			78	39
		24	20.6	2.9	17.7	54	42			96	48

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM FLOW Q	BASE FLOW	D.R.O.	2 HR. U.H.				SUM.	4 HR. U.H.
68-6-2 (cont'd)	July 1	1	25.8	3.0	22.8	70	50			120	60
		2	27.7	3.1	24.6	75	54			129	65
		3	29.6	3.1	26.5	81	70			151	75
		4	35.4	3.2	32.2	98	75			173	87
		5	39.3	3.3	36.0	110	81			191	96
		6	43.0	3.4	39.6	122	98			220	110
		7	46.8	3.5	43.3	132	110			242	121
		8	50.6	3.5	47.1	144	122			266	133
		9	52.5	3.6	48.9	150	132			282	141
		10				170	144			314	157
		12	65.9	3.9	62.0	190	170			360	180
		18	80.1	4.2	75.9	232	218			450	225
		19	69.7	4.3	63.4	194	225			419	210
		20	44.9	4.4	40.5	124	232			356	178
		24	37.4	4.8	32.6	100	112			212	106
	July 2	11	22.2	5.6	16.6	51					
		12	27.7	5.7	22.0	67					
		13	29.6	5.8	23.8	73	51			124	62
		14	27.7	5.9	21.8	67	67			134	67
		18	20.6	6.2	14.4	44	55			99	50
		24	16.5	6.7	9.8	30	35			65	32
	July 3	12	9.4	7.6	1.8	6	10			16	8
		24	8.6	8.6	0	0					4
	July 4	2					0			0	0

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
68-9-1	Sept. 2	17	3.7	3.7	0	0				0	0
		18	3.9	3.7	.2	2	0			2	0
		19	3.9	3.7	.2	2	2	0		4	1
		20	4.1	3.7	.4	4	2	2	0	8	2
		21	4.2	3.8	.4	4	4	2	2	12	3
		22	4.6	3.8	.8	8	4	4	2	20	5
		23	5.1	3.8	1.3	12	8	4	4	28	7
		24	5.3	3.8	1.5	14	12	8	4	38	9
	Sept. 3	1	5.7	3.8	1.9	18	14	12	8	52	13
		2	6.4	3.8	2.6	24	18	14	12	68	17
		3	7.4	3.8	3.6	34	24	18	14	90	22
		4	9.4	3.8	5.5	52	34	24	18	128	32
		5	11.1	3.9	7.2	68	52	34	24	178	45
		6	13.0	3.9	9.1	85	68	52	34	239	60
		7	15.2	3.9	11.3	106	85	68	52	311	78
		8	16.5	3.9	12.6	118	106	85	68	377	94
		9	19.1	3.9	15.2	143	118	106	85	452	113
		10	20.6	3.9	16.7	157	143	118	106	524	131
		11	22.2	3.9	18.3	172	157	143	118	590	148
		12	23.8	3.9	19.9	187	172	157	143	659	165
		13	26.7			214	187	172	157	730	182
		14	29.6	4.0	25.6	240	214	187	172	813	203
		24	15.2	4.0	11.2	105	118	132	145	500	125

INDIVIDUAL STORM 4 HOUR UNIT HYDROGRAPHS

EVENT	DATE	TIME	STREAM-FLOW Q	BASE FLOW	D.R.O.	1 HR. U.H.				SUM.	4 HR. U.H.
68-9-1 (cont'd)	Sept. 4	12	11.1	4.2	6.9	65					
		13	11.1	4.2	6.9	65	65				
		14	11.1	4.2	6.9	65	65	65	70	265	66
	Sept. 5	1	8.5	4.2	4.3	40					
		2	8.3	4.3	4.0	38	40				
		3	8.2	4.3	3.9	37	38	40			
		4	8.1	4.3	3.8	36	37	38	40	151	38
		12	6.9	4.5	2.4	23					
		13	6.8	4.5	2.3	22	23				
		14	6.7	4.6	2.1	20	22	23			
		15	6.6	4.6	2.0	19	20	22	23	84	21
		18	6.3	4.8	1.5	14			19		16
		24	5.8	4.8	1.0	9			12		10
	Sept. 6	6				1					2
		8	5.0	5.0	0	0					
		12							0	0	0

APPENDIX F

BASIN SOIL MOISTURE OBSERVATIONS

	Date	Soil Moisture Deficit without site #6	Soil Moisture Deficit with site #6	Soil Moisture Deficit at site #5 only*
1962	Sept 14		1.03	.81
	21		.74	.46
1963	June 5		.10	0
	14		.03	0
	21	old system ends here		
	21	New values - didn't work for June 21		
	29		3.93	.96
	July 5		3.64	2.27
	26		3.41	1.62
	Aug 2		4.16	3.11
	9		3.64	3.21
	16			
	19		4.38	3.61
	23		4.42	3.53
	30		2.40	2.23
	Sept 6		3.80	3.92
	13		3.12	3.19
	20		1.83	2.21
	27		2.34	2.06
1964	May 29		1.58	1.52
	June 5		1.24	.92
	26		.58	.20
	July 3		.73	.35
	10	.37	.81	.20
	17		1.02	.32
	24	1.45	2.03	.76
	Aug 7	1.86	2.44	2.78
	14	1.19	1.76	1.76
	21	1.40	1.93	1.46
	28	1.78	2.26	1.46

* Site #5 located in vicinity of rain gauge #10 and groundwater well #5.

	Date	Soil Moisture Deficit without site #6	Soil Moisture Deficit with site #6	Soil Moisture Deficit at site #5 only
1965	June 18	.57	.83	.25
	25	.78	1.11	.50
	July 15	.58		.10
	19	.53	.79	.05
	23	.31	.30	.05
	Aug 6	.32	.93	.12
	13	.76	1.07	.27
	20	1.04	1.55	.20
	Sept 3	.71		.15
1966	July 15	.72		.20
	22	1.55		1.29
	29	1.85		0.54
	Aug 12	Ground Saturated		
	19	.50		.15
	26	.49		.27
	Sept 2	0.83		.34
	23	1.98		2.64
1967	June 2	.45		.25
	May 5	Snow on Ground		
	12	"		
	19	Frost in Ground		
	26	"		
	June 9	.47		.25
	16	.30		.27
	30	.72		.25
	July 14	1.70		1.52
	21	2.02		1.29
	28	2.60		2.79
	Aug 4	2.08		1.60
	11	.93		.15
	18	1.92		2.34
	25	2.51		3.01
	Sept 2	3.37		3.76
	8	3.76		3.76
	22	3.97		4.20
	29	3.87		4.29

	Date		Soil Moisture Deficit without site #6	Soil Moisture Deficit with site #6	Soil Moisture Deficit at site #5 only
1968	May	3	.16		.05
		10	.04		.05
		17	.14		.15
		24	.23		.15
		31	.15		.05
	June	7	.33		.20
		14	Saturated		
		24	.20		.15
		28	All Saturated		
	July	5	.22		.15
		15	.40		.15
		19	.37		.15
		26	.65		.20
	Aug	2	.21		.15
		23	.13		.15
		30	.25		.15
	Sept	6	.20		.15
		13	.52		.40
		20	.63		.32
		27	.87		.40
1969	May	30	.25		
	June	6	.22		
		13	.37		
		20	.42		
		27	Saturated (June 25 prior to storm est @0.75")		
	Jul	4	Watershed saturated		
		11	.21		
		25	.32		
	Aug	1	.48		
		8	.79		
		15	.69		
		22	1.13		
		29	.73		
	Sept	5	1.49		
		12	1.50		
		19	2.41		