SOME ASPECTS OF THE HYDROLOGY OF CONSERVATION AREA NO. 3

INTRODUCTION

DRE-10
Resource Planning Department, 1971

SOME ASPECTS OF THE HYDROLOGY OF CONSERVATION AREA NO. 3

INTRODUCTION

In December, 1970, the decision was made to undertake an independent preliminary investigation of the hydrology of the Conservation Areas. This was in response to one of the major recommendations of the "Loveless Report" of August, 1970. Drs. Pyatt, Heaney and Huber of the Department of Environmental Engineering, University of Florida, were selected in February, 1971, to perform this investigation.

A staff study of Conservation Area No. 3 was initiated at about this same time. The staff study was not intended to either supplant or serve as an alternative to the independent study. At most it might be used to supplement, clarify or confirm the findings of that study. Additionally it might provide the staff with some insights regarding the hydrology of Conservation Area No. 3 which could assist in developing an understanding of the probably more sophisticated evaluation being made by the consultants.

No detailed and comprehensive evaluation of the overall operational hydrology of the conservation areas has ever been made by the FCD, nor is the present study of such nature. With the Corps having the responsibility for flood control operations, such overall operational analysis of the conservation areas as was believed to be necessary was left to the Corps. Any analysis which the District has done has been in relation to specific problems; i.e., regulation schedules for Area No. 1, proper use of gages for regulation Area No. 1, etc. The present study is more or less of this same type.

This study was unsophisticated in nature and consisted primarily of an examination of the stage records at various locations in Conservation Area No. 3 for selected periods. Rainfall and controlled inflows for the same periods were related to the stage hydrographs. The purpose of the study was to see if, on a qualitative basis, there were any recurring relationships between stages, inflow, controlled discharge and rainfall which could be noted. If so, this could afford some insight as to the relative weight of these factors in influencing the hydrology of the area.

STUDY PLAN

Water level gages 3-2 and 3-3 (see Figure 1) were selected for analysis. Gage 3-2 is the "deer gage", and is located in the northwest quadrant of Conservation Area No. 3. Gage 3-3 is located in the northeast quadrant. These locations were selected because the possibility of man-induced changes in the hydrology of the area being more readily apparent here than in the lower portion of the pool. This is not to say that the hydrology of the lower pool has not been modified, because observation indicates it has. However, greater public concern has been expressed over management of water levels north of Alligator Alley because of the alleged effects of S-8, S-140, the Alley and C-123 in particular connection with the deer herd in the northwest quadrant. This indicated the selection of the area north of the Alley for this particular study.

DESCRIPTION

Conservation Area No. 3A, the most southerly of three water retention areas which lie within the Everglades area of the Central and Southern Florida Flood Control District, has an area of 734 square miles. The underlying limestone is overlain by 2 to 4 feet of muck. The vegetation is primarily sawgrass, interspersed with shallow sloughs of wet prairie plants such as beakrush, maidencane, and lilies. These sloughs run generally south-southeasterly, and in general lie at elevations less than one foot lower than the surrounding terrain. Elongated tree islands a few acres in size in the northerly portion, but increasing in area toward the south, consist chiefly of low growths of wax myrtle, willow and elderberry. However, larger hardwoods are also usually present. These "islands" lie at elevations 1 to 2 feet above the general adjacent terrain.

The muck surface slopes from an elevation of approximately 13.0 ft. msl. in the northwest portion to 7.0 ft. and 8.0 ft. to the south. (Figure 2). The vegetation, both in the sloughs and on the higher ground, is sufficient to retard water movement to the near imperceptible. See Figure 3 for the general vegetative characteristics of the area.

Historically, water levels varied with rainfall, both seasonally and yearly. Under the Central and Southern Florida Flood Control Project the approved regulation schedule calls for a seasonal fluctuation of stages between 9.5 ft. and 10.5 ft. to generally follow the "natural" seasonal variation. The stage used for regulation is the average of the stages recorded at Sites 3-3, 3-4 and 3-28 (Figure 1). This regulation usually results in one-half to one foot of water over the northern portion of the area and three to three and one-half feet over the southerly portion. Ground levels at the gage sites are indicated in Figure 1.

Figure 4 provides an approximate relationship between the various gages when Conservation Area No. 3 is at regulation stage and under conditions of no localized rainfall. This set of graphs was constructed by plotting the stage at each gage at selected times when: (a) the conservation area was at regulation stage as computed from the three-gage average indicated above, (b) there was no localized rainfall over the area, and (c) the inflow-outflow relationship, when existing, was considered to be "normal." The points plotted for the ten selected dates used were then connected to obtain the graphs for each gage. Also plotted on this figure is the regulation schedule. The graphs on this figure will be discussed further in a following section of this report.

Channelization in the area consists of inside rim canals extending continuously along the entire lengths of the east, southeast and south sides, and Canals 123 and 60.

INFLOW LOCATIONS

Location	Capacity
Pumping Station 140	1300 cfs
L-4 borrow canal	varies
Pumping Station 8	4160 cfs
Structure 150	1000 cfs
Structures 11A, B, C	17200 cfs
Pumping Station 9	2880 cfs
7-Mile opening in L-28	indeterminate
L-28 Interceptor Canal	2960 cfs

OUTFLOW LOCATIONS

Structure 151	700 cfs
Structures 12A, B, C, D	32000 cfs

AVAILABLE DATA

Continuous stage data is available from gage sites 3-2, 3-3, 3-4 and 3-28 in the interior of Conservation Area No. 3. Data for the years 1963 through 1970 were considered indicative of the general stage trend and are those used for this study.

Stage records at all points of controlled inflow and outflow are available; these permit the computation of discharges into and out of the area at these locations.

Once-monthly stage data along Alligator Alley has been procured since December, 1967. Periodic discharge measurements have been made at the Alligator Alley bridge openings.

Periodic stage and discharge measurements have been made at the northwest corner of Conservation Area No. 3.

Continuous rainfall data is available from eight recording rainfall gages on the perimeter and in the interior of Conservation Area No. 3 (see Figure 5).

Evapotranspiration and out-seepage were not generally considered in this study. Since the study did not include development of a water budget these two factors, plus changes in storage, were not considered particularly pertinent. Both evapotranspiration and seepage are "discharges." Their effects, although always present, are perhaps most important on the recession side of the stage hydrograph; at least they are more readily discernible and isolated, qualitatively, during stage recession. The approach used in this study in regard to recessions, which involved a simple comparison of stage recessions for various periods, did not require identification of the relative contributions of evapotranspiration and seepage to the "natural" recession.

RAINFALL EFFECT

Four isolated rainfall periods were selected for examination as to effects on stages. They are those of February 12, 1963; September 8, 1965; October 17, 1968; and April 28, 1969. Rainfall patterns are shown on Figures

5 through 8. The eight recording rain gages used are shown on these figures. These periods were selected because of the concentrated nature of the rainfall, the fact that rainfall effects could probably be isolated from inflow, and the condition that stages at the start were above ground level.

Examination of these data, shown on Figures 9 through 12, indicates that the rise in stage at the individual stations approximately equalled the rainfall. There are inconsistencies difficult to explain, such as a rise of 7 inches for a 3.75 inch rain at gage 3-3 for the February 12, 1963 rainfall. It is understandable that rainfall in the deeper pool at the south end of Conservation Area No. 3 would tend to equalize any local rain throughout the pool, but this would not be expected to be true at gage 3-3. Nevertheless, it is obvious from this examination that when pool stages are above ground surface there is an immediate response to rainfall which is approximately equivalent to the rainfall depth.

As stated earlier, evapotranspiration and seepage were not considered. In this particular examination, involving at most a three-day period, these factors can be neglected.

To obtain an indication of what the relative effect of rainfall and pumping at S-8 might be on stages at gage 3-2, two periods of extended rainfall and moderate continuous pumping at S-8 were examined. The data from these two periods, June-July 1966 and October-November 1969, are shown on Figures 13 and 14. For this particular study evapotranspiration losses were estimated, as shown on the respective figures. No attempt was made to estimate overland movement of water into and out of the area whose water levels are reflected by stages at gage 3-2. It is probably safe to assume that this inflow-outflow roughly balanced for these periods.

These data indicate that under conditions of sustained pumping at S-8 at about one-quarter the design capacity (1000 cfs) or less, the initial stage response at gage 3-2 is largely attributable to uncontrollable factors; i.e., rainfall and evapotranspiration. Further discussion of these data in terms of stage recession will be presented in the section on effects of S-8 pumping.

EFFECT OF S-11 DISCHARGES

The S-11 structure consists of three spillway units, S-11A, S-11B, and S-11C, immediately north of Andytown, through U. S. Highway 27. The structures are approximately two miles apart and have a combined design capacity of 17,200 cfs. They serve to regulate water elevations in Conservation Area No. 2. The maximum recorded discharge to date is approximately 6200 cfs which occurred on March 28, 1970. Structure 150, with a design capacity of 1000 cfs, is located west of S-7 and discharges into Conservation Area No. 3 by way of the L-38W borrow canal.

Gage 3-3

Stage and discharge graphs for the early portion of the wet years of 1966, 1969 and 1970 are given in Figures 15, 16 and 17. Discharge approximating 1000 cfs through S-11 and the 500 cfs through S-150 has no significant effect on stages at gage 3-3, the interior gage closest to S-11 and the northeast rim canal. This rim canal was designed to accommodate a discharge of 1000 cfs and was completed in September 1968. An S-11 discharge of approximately 3000 cfs raised the gage 3-3 stage approximately 0.4 ft. in 10 days (Figure 16) in 1969, while a discharge of 5000 cfs raised the stage about 0.5 in 10 days (Figure 17) in 1970. Both these values have been adjusted for the estimated effect of rainfall; 2.0" in two days in the first case and 4.1" in two days in the second case. These are specific cases which should hold true for general application, but the stage-discharge relationship will probably vary somewhat depending on the starting stage at gage 3-3.

Examination of the hydrograph recessions (August-December 1968 on Figure 18 and August-December 1966 on Figure 19) shows that the stage recession rates at gage 3-3 and immediately downstream of S-11 (S-11 T.W.) are approximately the same. This is the "natural" recession and shows the takeover of the evapotranspiration effect. These two hydrographs also show consistently lower stages at S-11 T.W. than at gage 3-3. This shows the effect of the rim canal as compared with the natural impedance to water movement created by the vegetation in the interior.

A comparison of the gage 3-3 hydrograph for April-May 1966 (Figure 15) with that for May 1970 (Figure 17) seems to indicate some retarding effect on interior stage recession resulting from sustained discharges of 2000 cfs at S-11. The recession rate was more rapid in 1970 than in 1966, with no S-11 discharge in May 1970. However, the more rapid recession in 1970 could also be accounted for by:

1. The improved rim canal conveyance system, completed in September 1968, and
2. Discharges at S-12 on the order of 2500 to 3000 cfs in the 1970 period compared with 1000 cfs in the 1966 period.

Concerning the effect of the improved rim canal conveyance system on stages at gage 3-3 the available data is quite limited due to the short period of observations. A comparison of the gage 3-3 hydrographs for late 1966 and late 1970 shows a somewhat more rapid recession (1.4 feet in two months) in 1970 than in 1966 (1.1 feet in two months). In 1970 the November-December discharges at S-12 averaged 750 to 1000 cfs; in 1966 there were no November-December discharges at S-12. The tentative conclusion could be drawn that S-12 discharges together with the improved rim canal conveyance system do have a slight noticeable effect on stages in the interior of the northeast quadrant of Conservation Area No. 3. However, additional observations and analysis are required.

In general, that data indicate the following:

1. Discharges at S-11 and S-150, separately or combined, in the range of 1500-2000 cfs will have a minimal effect on producing a rise in stage at gage 3-3.
2. Discharges above these values will create a rise in water elevations in the interior. A considerable amount of data would have to be analyzed to determine the nature of the stage-discharge relationship in relation to "starting" water elevations in the interior.
3. With such discharges the response at gage 3-3 is comparatively rapid; a matter of a few days.
4. No definite conclusions can be drawn regarding the effect of sustained discharges of 1000 to 2000 cfs at S-11 on retarding the recession of stages in the interior of the northeast quadrant.
5. No definite conclusions can be drawn concerning the effect of S-12 discharges (and the rim canal conveyance system) on reducing high stages in the interior of the northeast quadrant. Preliminary indications are that there is a positive effect, however.

Gage 3-2

No direct effect of S-11 discharge on stages at gage 3-2 could be noted. (Figures 18 through 20). The inconsistent stage relation between gage 3-3 and gage 3-2 also tends to verify this conclusion. It is apparent, however, that when water elevations in the northern quadrants of Conservation Area No. 3 reach values of 11.5 to 12.0 on the rising side of the hydrograph, stages at gages 3-2 and 3-3 will be approximately the same. It can also be noted that stages at gage 3-2 recede more slowly from these peaks than do stages at gage 3-3. The slower rate of recession at gage 3-2 is again indicative of the impedance to water movement created by the natural vegetation.

EFFECT OF S-8 DISCHARGES

Pumping Station 8 is located in the Miami Canal on the northerly boundary of Conservation Area No. 3. It has a design capacity of 4160 cfs and removes excess surface water from the Everglades Agricultural Area. The maximum recorded discharge to date of 4240 cfs occurred on October 22, 1969. A spillway in the station permits gravity drainage capability approximating 500 cfs.

The pump discharge channel extended only four miles below the station into Conservation Area No. 3 until December 1969 when C-123 was completed with a design capacity of 1000 cfs. The original Miami Canal across Conservation Area No. 3 consists of a channel only a few feet deep excavated to the muck. It was relatively ineffective as a discharge channel.

No period is available for analysis to definitely indicate the effect of S-8 pumping on stages at gage 3-2. This is primarily due to the fact that pumping at S-8 cannot clearly be isolated from rainfall occurring during the same period in a sufficient number of instances to establish a supportable relationship.

The period March 5-20, 1966 (Figure 21) indicates a rise in stage of 0.4 ft. at gage 3-2 during a non-rainy period. This could have been caused by pumping at S-8, which was started some ten days earlier. This is a fairly long lag time. However, no other reason for the stage rise is apparent since rainfall was minimal, unless we assume it was caused by S-11 discharge. This is considered highly unlikely since stage at gage 3-3 remained 0.6 ft. lower than that at gage 3-2.

No reason other than S-8 pumping can be found for the rise at gage 3-2 the last of March 1969. This record shows an apparent 15 day lag time between S-8 pumping and gage 3-2 stage rise. (Figures 22 and 23).

The March 7 and 8, 1970 incidence (Figure 23), unlike the previous two, involved a heavy rainfall of 3.4 inches in two days. The total rise in stage at gage 3-2 was 0.6 feet. Deducting for rainfall, the remaining 0.3 ft. of stage rise can be attributed to pumping at S-8. This discharge at a rate of nearly 1500 cfs occurred on the same days as the rainfall and on the same days in which the stage at gage 3-2 rose. If the assumption that a rise of 0.3 ft. was attributable to S-8 discharge, then in this case there was no more than a day or two of lag time.

The variations in lag times are not readily explainable and obviously additional analysis is required. In these three cases the starting stages at gage 3-2 were 10.7 ft. in 1969, 11.2 ft. in 1966 and 11.5 ft. in 1970 (after adding the 3.4 inches of rainfall). Apparent lag times were ± 15 days, ± 10 days, and ± 2 days respectively. It is possible that the greater apparent lag times which seem to be associated with the lower starting stages is explainable by the early portion of S-8 discharges going to fill up storage in the lower sloughs. When storage is satisfied, subsequent discharges are translated into a more general movement of water overland. At higher starting stages, less water is required to satisfy storage and overland movement takes place earlier. See the discussion in the section on C-123 for another possible explanation.

In regard to recession of stages at gage 3-2, Figures 13 and 14 indicate that sustained pumping at S-8 in the range of 500 to 1000 cfs retard stage recession in the interior of the southern portion of northwest quadrant when stages are 11.5 and above. Analysis of a number of recession hydrographs shows that the "natural" recession rate in this area is about 0.5 ft. per month. The hydrographs on these two figures indicate practically no recession, once the effects of rainfall and evapotranspiration are taken out.

In summary, there is insufficient data to conclusively indicate the relationship between stage rise at gage 3-2 and S-8 pumping. It is certainly probable, however, that sustained pumping at S-8 does affect stages at gage 3-2 both in terms of raising stages and in retarding recession. It also appears that the contribution of S-8 pumping to stage rise may well be dependent on general water levels in the area when pumping starts.

EFFECT OF L-4 BORROW CANAL

L-4 borrow canal enters the conservation area in the extreme northwest corner. It drains approximately 261 square miles in Hendry County consisting primarily of pasture land. Capacity of the canal is roughly 1400 cfs.

The northwest quadrant of Conservation Area No. 3 (gage 3-2) is the only portion of the area which is felt to be directly affected by discharge from this source. The only high runoff recorded since periodic measurements were started in April 1970 is the 1170 cfs measured on April 2, 1970, the day following the peak discharge. See Table 1. The quantitative effect of this discharge on gage 3-2, however, cannot be determined from the data since S-8 was also pumping large quantities of water the last week of March 1970. The stage at gage 3-2 did rise slightly during this period with no apparent rainfall (Figure 23), but the cause of this rise cannot be clearly identified.

This canal will be enlarged under the L-100 Project which will result in increased peak runoff rates into this sector of the conservation area.

EFFECT OF PUMPING STATION 140 AND C-60

Pumping Station 140 is located on the west side of Conservation Area No. 3, approximately eleven miles south of the northwest corner. It has a design capacity of 1300 cfs and is designed to remove 7/16 inch per day from 110 square miles west of L-28. The installation includes a spillway with a gravity discharge capacity of 300 cfs. Discharge is into Canal 60, which extends 4.3 miles eastward through the conservation area to Alligator Alley Bridge No. 11. See Figure 24 for location.

This pumping station was activated in April 1970 and the stage record was started on April 17, 1970. The record being short, little can be firmly established as to the effect of the pump discharges on stages in the vicinity of gage 3-2. A five-day, 8-hour, pumping schedule using two of three pumps was in effect during the period June-October 1970 (Figure 25). The data indicates that pumping on this schedule can raise stages at gage 3-2 from 0.1 to 0.2 ft. over the 5-day period, when Conservation Area No. 3 is on or above schedule. It is estimated three pumps operating continuously would hold the stage 0.2 to 0.3 ft. higher at gage 3-2. The record for this extended period of pumping five days on and two days off at very modest rates (200-400 cfs) indicates that higher rates of pumping at S-140 could have a noticeable effect on stages in the vicinity of gage 3-2. Additional data needs to be collected and analyzed for any quantitative approximation of this effect to be made.

No effect of S-140 pumping on gages other than gage 3-2 is evidenced from the short record of this station. Indications are that this will remain true as more data is obtained.

EFFECT OF PUMPING STATION 9

Pumping Station 9 is located on the east side of Conservation Area No. 3, south of Alligator Alley, on the South New River Canal and pumps a 71 square mile area to the east. It contains three pumping units having a total design capacity of 2870 cfs. A portion of this capacity is for the control of seepage. During the wet season, pumping is generally necessary a portion of each day for maintenance of adequate levels in the South New River Canal east of the levee.

This pump discharge does raise the conservation area stage to the south, depending on the number of units pumping and the duration of pumping. This effect was not examined in the present study.

From the meager data available which was suitable for attempting to isolate S-9 pumping effects from other factors, it appears that moderate S-9 discharges have no observable effect on stages at gage 3-3. Figure 26 shows conditions for a portion of the September-October 1969 period. This was a period of sustained moderate pumping at S-9 and no inflow from S-11. The very slight rise in stage at gage 3-3 is attributable to the almost daily rainfall which occurred during this period, and not to S-9 pumping.

It is possible that pumping at design rates at S-9 for comparatively long durations could create a backwater effect, or else usurp the rim canal capacity to the south, which would result in maintaining higher stages for longer periods north of Alligator Alley. Without the use of sophisticated techniques (a routing model) this possible effect cannot be quantitiatively evaluated. In any event, it would be a comparatively rare occurrence.

EFFECT OF ALLIGATOR ALLEY

Alligator Alley (State Road No. 84) is a highway extending west through Conservation Area No. 3 from Andytown. It contains eleven bridges (Figure 24) designed to hold the design flow through the width of the bridges to a 0.1 ft. head loss.

Canal borrows on the north and south sides of the highway direct water to the bridges and disperse it downstream. The majority of the flow is through the seven bridges east of Miami Canal, in the area of lower ground elevations. Periodic discharge measurements through the highway are available for the period starting January 6, 1970. See Table 2.

Three sets of staff gages were installed halfway between the bridges north and south of the highway in December 1967, for the purpose of determining the effect of the highway on stages in the native undisturbed vegetation. See Figure 24 for location of gages. Observations made approximately once monthly indicate little or no head loss through the reach of highway east of Miami Canal. See Table 3. Measured head losses at the middle and westerly staff gages vary from 0.0 to 1.36 ft. The higher loss values can be attributed to vegetative impedance as the water flows parallel to the highway to reach the bridge openings. It is believed this head loss can be materially lowered by extending collector channels on the north side of the highway. The effect of vegetative impedance is particularly apparent in the Bridge 10 reach where flow is usually zero (Table 2). Westward expansion of the north side collector channel to this bridge would probably assist in maintaining lower high water stages at gage 3-2, which is about four miles north of the highway.

Pumping at S-140 will result in larger flows reaching Bridge 11 (Figure 24), which is connected with S-140 by Canal 60. A significant portion of this discharge would flow east to Bridge 10 if the aforementioned north collector for Bridge 10 was extended to Bridge 11.

In summary, the bridges east of Miami Canal function in accordance with the design parameters initially established for these structures. There has been no observable effect of Alligator Alley in this reach on stages in the northeast quadrant of Conservation Area No. 3 either in terms of creating a backwater condition during high water periods or of hastening recessions after high water peaks have passed. However, the record indicates that west of Miami Canal the highway does create a backwater condition under certain circumstances. This can be further aggravated by moderate to high rates of pumping at S-140. A means for correcting this condition has been suggested above.

EFFECT OF C-123

The original Miami Canal in Conservation Area No. 3 north of the South New River Canal is a shallow canal in which only the muck overburden had been removed. Aquatic growth completely chokes this section except for a narrow boat channel in the middle. It therefore has little water carrying capacity. South of the South New River Canal it was dug into rock, has a section approximating 800 square feet, and has always conveyed a substantial amount of water. The portion of South New River Canal in Conservation Area No. 3 likewise was not dug to sufficient depth to move water to any appreciable degree. It also is almost completely filled with aquatic growth.

C-123 was constructed west of and adjacent to the original Miami Canal to assist in conveying water to Everglades National Park and the lower east coast during periods of low stages in the conservation area system. The canal improvement extends from the S-8 discharge channel to the confluence of the Miami and South New River Canals. It has a design capacity of 1000 cfs and was completed in December 1969.

The available short record since completion of C-123 indicates that it has had no effect on reducing stages at either gage 3-2 or gage 3-3. Comparing the gage 3-2 stage hydrographs for April-May 1970 with those for April-May 1966 it can be seen that the recession rates are approximately the same once allowance has been made for the early May rainfall in 1966. Again, the November-December recession rates at gage 3-3 for 1966, 1969 and 1970 are all approximately the same, as are those for gage 3-2. In fact, for 1970 the gage 3-2 rate is somewhat flatter than that in either 1966 and 1969.

The rapid stage reduction at gage 3-3 in May 1970 is unusual but is more likely attributable to the influence of the L-68 and L-67 borrow canals, rather than C-123, together with the curtailment of discharge at S-11, (see earlier discussion herein in section on S-11 discharges).

More record is needed to substantiate or alter these preliminary conclusions.

Discharge at S-8 following completion of C-123 has been largely limited to values less than the design capacity of 1000 cfs of C-123. It appears logical to assume that the improved conveyance (maximum recorded C-123 discharge being 848 cfs on April 15, 1970) will result in some reduction in stage under high water conditions in the upper portion of the northwest quadrant. Such effect, however, might not necessarily be felt, or might not be as noticeable, at gage 3-2 which is some 6 miles west of C-123 and 12 miles south of S-8. This possible effect can be better evaluated once our additional gage is placed in the northwest quadrant and data collection there begins.

In the section of this report dealing with the effects of S-8 discharges the lag time between initiation of S-8 pumping and apparent stage response at gage 3-2 was discussed. Three incidents, in 1969, 1966 and 1970, were examined. The last of these occurred after completion of C-123; this incident also had the shortest apparent lag time. This effect is possibly attributable to the functioning of C-123. It may be that the improved conveyance southward in C-123 has shortened the time of travel between the discharge side of S-8 and the vicinity of gage 3-2 by reducing the flow path through the vegetative cover approximately 50%. Again, additional data for analysis is required.

EFFECT OF S-12 DISCHARGES

This effect was not examined in great detail for this study. In the earlier section on the effects of S-11 discharges it was stated that a tentative conclusion could be drawn that the improved rim canal conveyance on the east side has some effect on stage recession at gage 3-3 when S-12 is discharging.

Examination of the fall recession hydrographs for gage 3-3 on Figures 18 through 20 indicate that first, at some point any effect of the east rim canal and S-12 discharge is largely negated by inflows into the northeast quadrant on the rising side of the stage hydrograph. Second, it indicates that once inflows are reduced, or cease, the effects of the improved conveyance on the east side are noticeable at gage 3-3.

Figure 27, showing conditions for the fall of 1966, give a clearer picture of the probable relationship between S-12 discharges and stages at gage 3-2. Stage recession started at the end of September and was continuous until the end of the year. S-12 discharges were continuous from the end of September until November 10; subsequently there was no discharge at S-12. The recession rate at gage 3-2, however, was uniform throughout the entire period, indicating no effect of S-12 discharge on stages at gage 3-2.

The same figure shows a slightly steeper recession rate at gage 3-3 and an apparent slight flattening of the recession in late November. These effects are small, but tend to confirm that there is some effect on stages at gage 3-3.

Figure 4, referred to earlier herein, has plotted on it the criteria furnished by the Game Commission for maximum tolerance stages at the "deer gage", gage 3-2. It will be noted that during the apparently critical spring period there is no "freeboard" between the maximum tolerable stage and what might be considered the normal stage for this area. Therefore, there is no storage cushion available to accommodate above normal spring rainfalls. This, combined with the fact noted above concerning the effect of S-12 discharges on stages at gage 3-2 would tend to indicate that there are constraints on regulating water elevations in conformity with single species requirements on a regular basis in this area. Further analysis of stages in this area is required, however.

SUMMARY

The examination of eight years (1963-1970) of stage, rainfall and discharge record pertinent to Conservation Area No. 3 produced very few instances wherein the individual factors influencing stage response could be clearly isolated. This was as expected, since events which produce surplus water conditions in the Conservation Area are normally fairly wide-spread

in nature.

Another complicating factor is the fact that much of the available data was from the period prior to completion of conveyance facilities (C-123 and the east rim canal system) in the area. Therefore, there is only one to two years of data in hand for the area as it now exists.

Nevertheless, sufficient data was available for purposes of the simple analysis undertaken in this study to arrive at certain conclusions regarding the effect of certain factors on water elevations north of Alligator Alley.

1. When water levels are above ground surface, rainfall, as could be expected, creates stage increases at the rainfall-stage stations which generally approximate the rainfall amount. The stage response from this factor is immediate. Any localized rainfall equalizes more slowly over the vegetated area in the upper three-quarters of the area than in the lower end which assumes a flat pool configuration due to greater depths of water.

2. S-11 discharges at downstream stages beginning at 9.5 to 10.0 ft. cause stages at gage 3-3 to rise. The effect is minimal at discharges up to about 2000 cfs. Above this value significant stage increases in the interior can be expected. After stages have peaked, continued, but reduced, discharges at S-11 may have some effect on retarding the "natural" recession in the northeast quadrant. The breakpoint is probably within the range of 1000 to 2000 cfs, but insufficient data is available to permit a determination to be made.

S-11 discharges have no effect on stages in the vicinity of gage 3-2.

3. Insufficient data is available to definitely assess the effect of S-8 pumping on stages at gage 3-2. The data tend to indicate that any immediate stage rise response at gage 3-2 is due to rainfall rather than pumping at S-8, and that there is usually a considerable lag time between initiation of pumping and an observable stage effect at gage 3-2. The data also appear to indicate that continued pumping, after the peaks have been reached, may retard the "natural" stage recession. Further evaluation of the effect of C-123 in distributing pump discharges is required.

4. The effect on stages at gage 3-2 of the one period of high discharge from L-4 was largely indeterminate. However, since the ground slope is in that direction it can be reasonably assumed that some effect does exist. The situation at the northwest corner of Conservation Area No. 3 will be changed substantially when the L-100 project is completed. There is no need, therefore, to study existing conditions in any further detail except as they will provide insight for evaluation of L-100 impact.

5. The short record at S-140 indicates a rise in stage at gage 3-2 of 0.1 to 0.2 ft. with two pumps in operation when Conservation Area No. 3 is at, or above, regulation. Indications are that stages would increase an additional 0.2 to 0.3 ft. with the full capacity of S-140 being used. In short, there will be a marked effect on stages at gage 3-2 with S-140 pumping at or near design capacity.

6. Data at Alligator Alley indicates it has created heads as high as 1.36 ft. west of C-123 due to the necessity of the flow to travel through the vegetation parallel to the highway to reach bridge openings. This head can be reduced by extending the collector borrow canals on

the north side of the highway. Additional bridge openings west of Miami Canal will be required when the L-100 project goes in.

7. Pumping at S-9 has no observable effect on stages at gage 3-3, the interior gage closest to the station. It also has no effect on stages at gage 3-2.

8. The short record available on C-123 indicates its construction produces no short range effect on stages at gages 3-2 and 3-3. Additional data must be obtained for analysis in order to arrive at definite conclusions.

9. The effect of S-12 discharges on stages north of Alligator Alley was not examined in detail for this study. There is some indication that the improved conveyance along the east rim, together with S-12 discharges, may have a slight effect on increasing the rate of stage recession in the northeast quadrant of Conservation Area No. 3.

S-12 discharges have no observable effect on stage recession in the northwest quadrant of Conservation Area No. 3.

10. The findings noted in items 2, 8 and 9, above, taken together indicate that internal control operations within Conservation Area No. 3 (operations at S-11 and S-12) have no meaningful effect on stages at gage 3-2.

CONCLUSIONS

There is a limited understanding in this office and elsewhere of the manner in which water movement takes place in Conservation Area No. 3 and the interaction of the several factors which influence that movement. Up to this point individual experience, personal observations, and periodic examination of selected data have enabled certain opinions to be expressed concerning this matter with some degree of confidence. However, the data base which is required to assist in achieving a better understanding of the mechanism of the system, thus permitting statements to be made with a higher degree of confidence, is not available.

The present staff study has been helpful in improving our understanding of some of these factors on a qualitative basis. This type of study can, of course, be extended. It is our intent to do so and, in addition, to continuously analyze current stage, discharge and rainfall data pertinent to the conservation area on a routine basis. Even for this type of analysis, however, additional data collection points are required. The four additional stage and rainfall gages now being installed in Conservation Area No. 3 (three FCD, one Corps) is a step in this direction. Also, more frequent and extended periodic discharge measurements in the interior canal system, including Alligator Alley, will be made as a part of the program of operations analysis.

This type of analysis, though of value, is limited in what it can provide in the way of knowledge of quantitiative relationships. An extended computational analysis is required, leading to development of a mathematical model of the system.

This leads to some questions concerning the value of detailed computational analysis and a system model as it might be used as an operational decision-making tool. If nothing else, our present study has indicated that Project works have tended to keep the major portion of Conservation Area No. 3 wetter rather than drier. Despite the well-publicized but unscientific "yo-yo principle", operations during wet periods are considerably more critical in the minds of conservationists, ecologists, hunters and the public in general than operations at other times. Conflicts between differing concepts of how the conservation area should be used are all tied in to high water conditions. These are the times, then, when the decision-maker would like to have available to him some operational choices. These would be the times, if operational choices were available, that a system model giving quantitative responses to given inputs would be of inestimable value. With the present system configuration and its operational imperatives, however, these are just the times when no operational choices are available.

One example may suffice to indicate the scope of this particular problem. With Conservation Area No. 3 at schedule an extended period of general, area-wide rainfall occurs. Pumping at S-8 is required to conform with Project requirements for flood protection in the Ag Area. Choices are available ranging from no pumping to pumping at the maximum capacity needed to prevent flood damage in the Ag Area. Delayed, or reduced, pumping results in Ag Area flooding, which is not acceptable as is, of course, no pumping. "No pumping" may help the situation at the "deer gage"; reduced or delayed pumping would simply defer any adverse effects at the "deer gage". In any event, with an area-wide rainfall, the incremental effect of pumping above and beyond the effect of the rainfall would undoubtedly be minimal, with no incremental damage occuring above that occasioned by uncontrollable factors. It is clear, then, that any rational decision-maker would make the choice to pump at the required rate. What, then, is the need for a model to make this type of decision?

There is, however, another application of a detailed computational analysis and system model which justifies taking this approach. It could be useful in evaluating various possible regulation schedules to determine if a more suitable configuration, or set of configurations, can be developed.

We conclude, therefore, that:

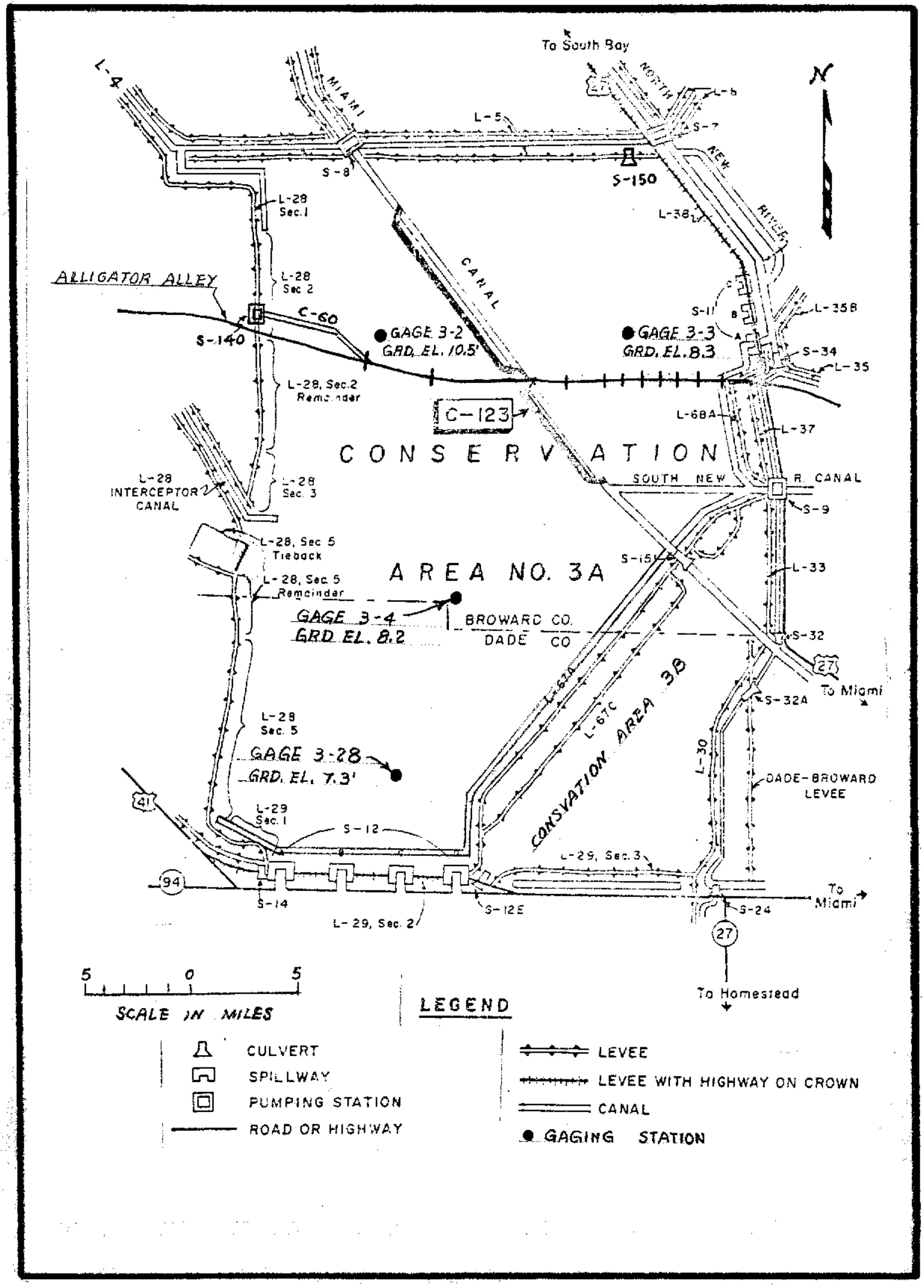
1. A system model of the conservation areas should be developed for the purpose of establishing, if possible, a means for a more flexible general operational strategy.

2. The District should institute a program of routine review and analysis of current hydrologic and meteorologic data pertinent to the conservation areas.

3. The District and/or the Corps of Engineers should implement a program of expanded data collection as necessary to meet the requirements of 1 and 2.

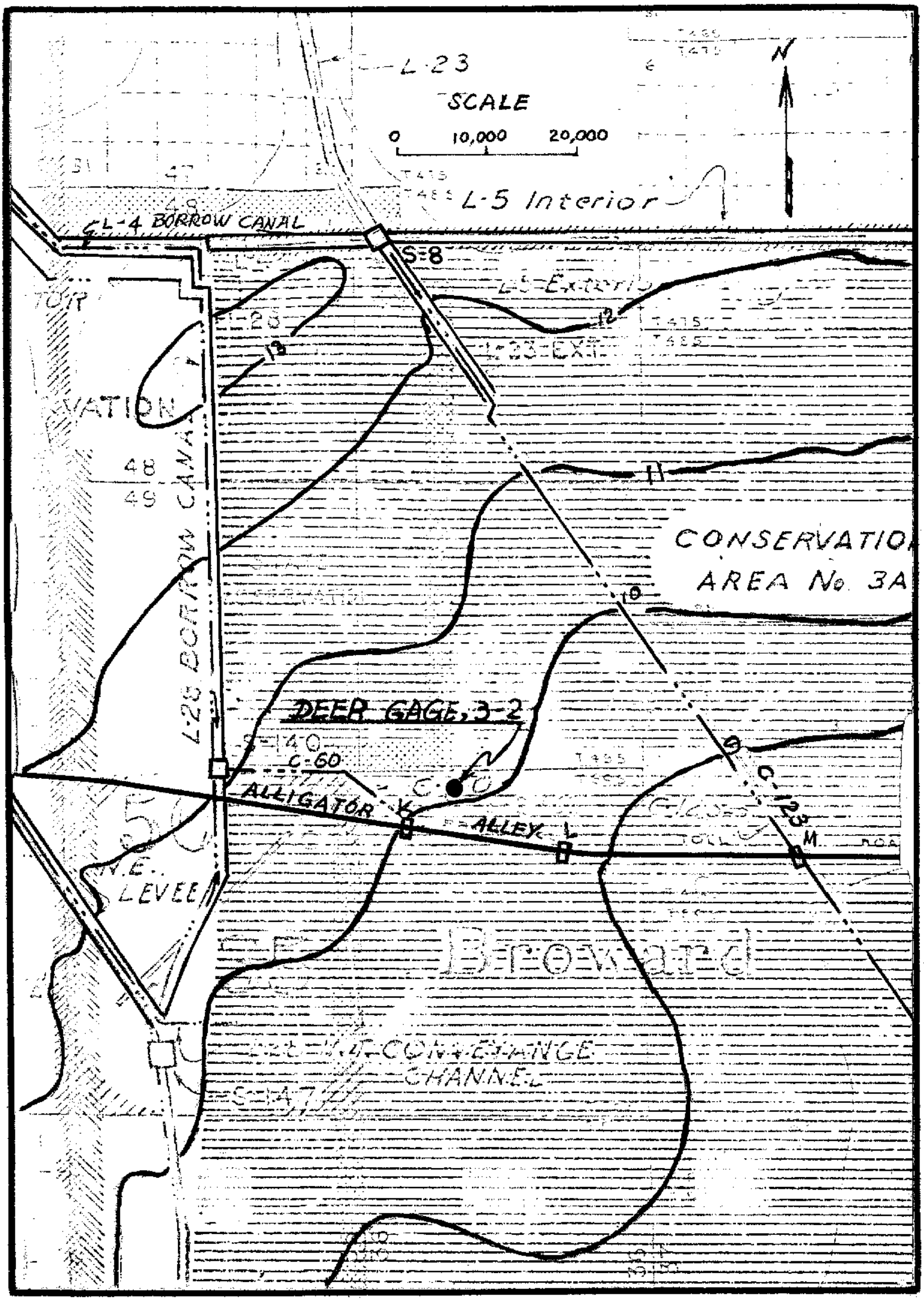
SOME ASPECTS OF THE HYDROLOGY OF CONSERVATION AREA NO. 3

FIGURES AND TABLES



EXISTING FLOOD CONTROL FACILITIES IN CONSERVATION AREA 3-A

FIGURE. 1



TOPOGRAPHIC MAP AND FACILITIES GOVERNING THE STAGE OF DEER GAGE 3-2

FIGURE 2

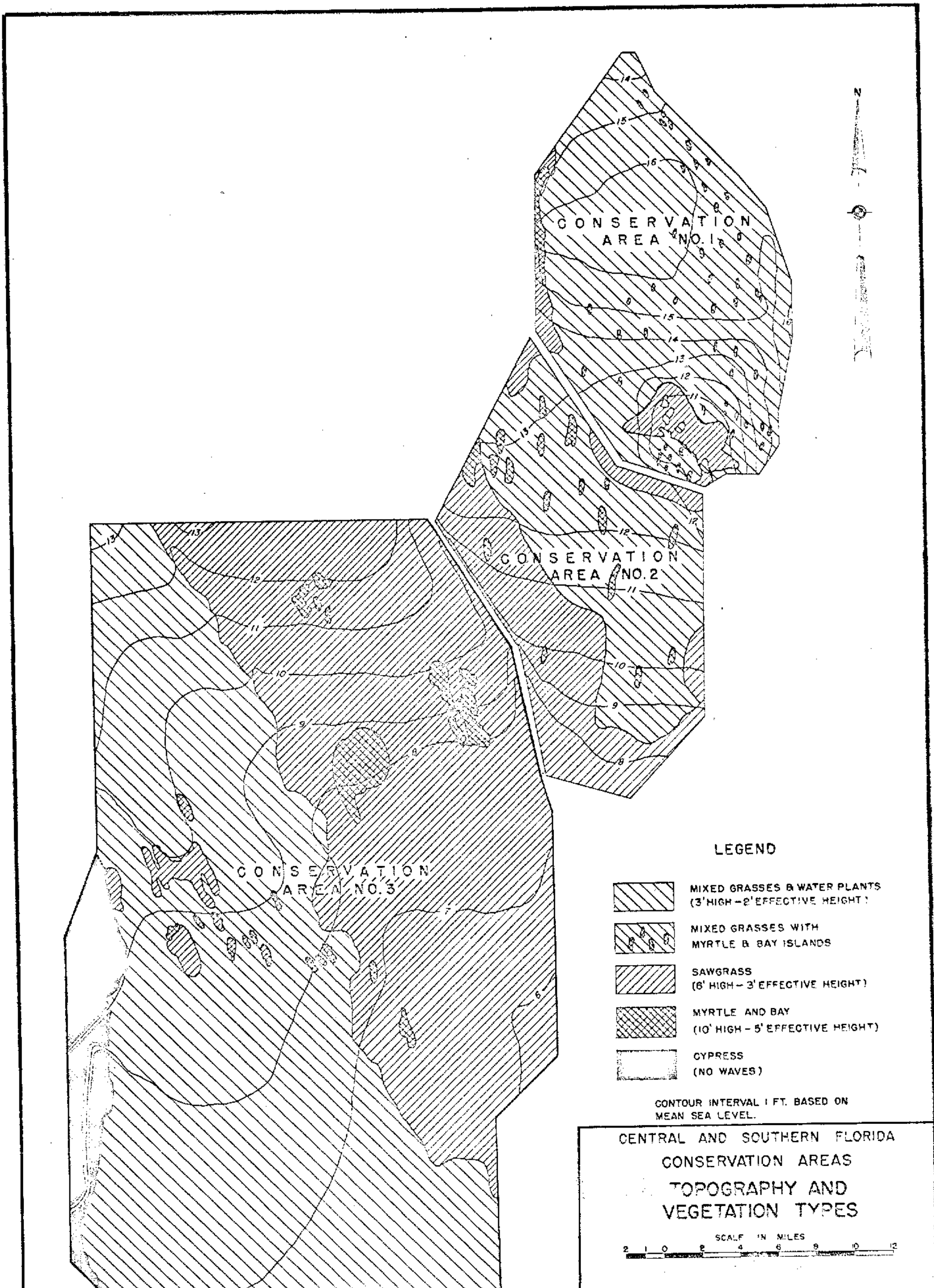
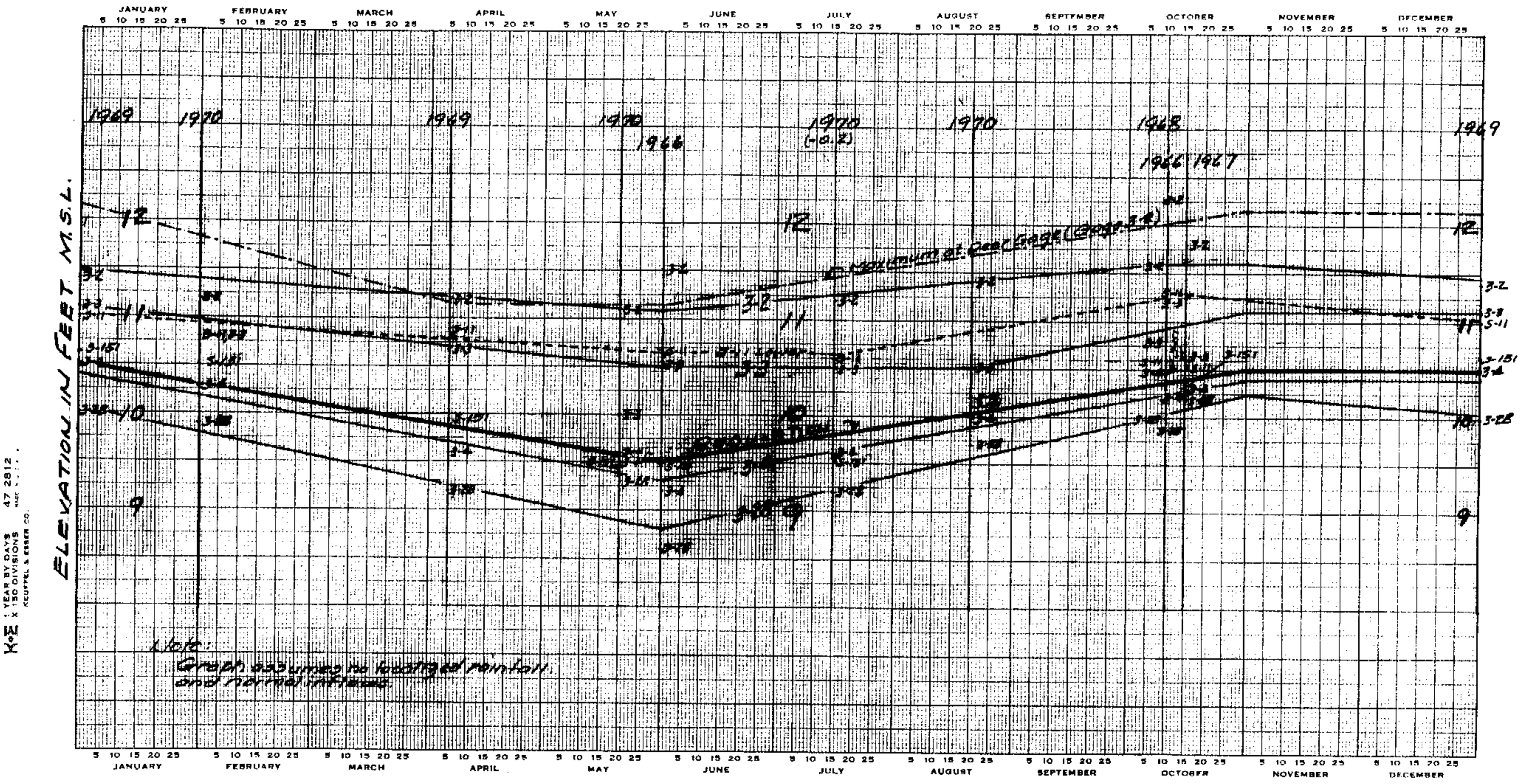
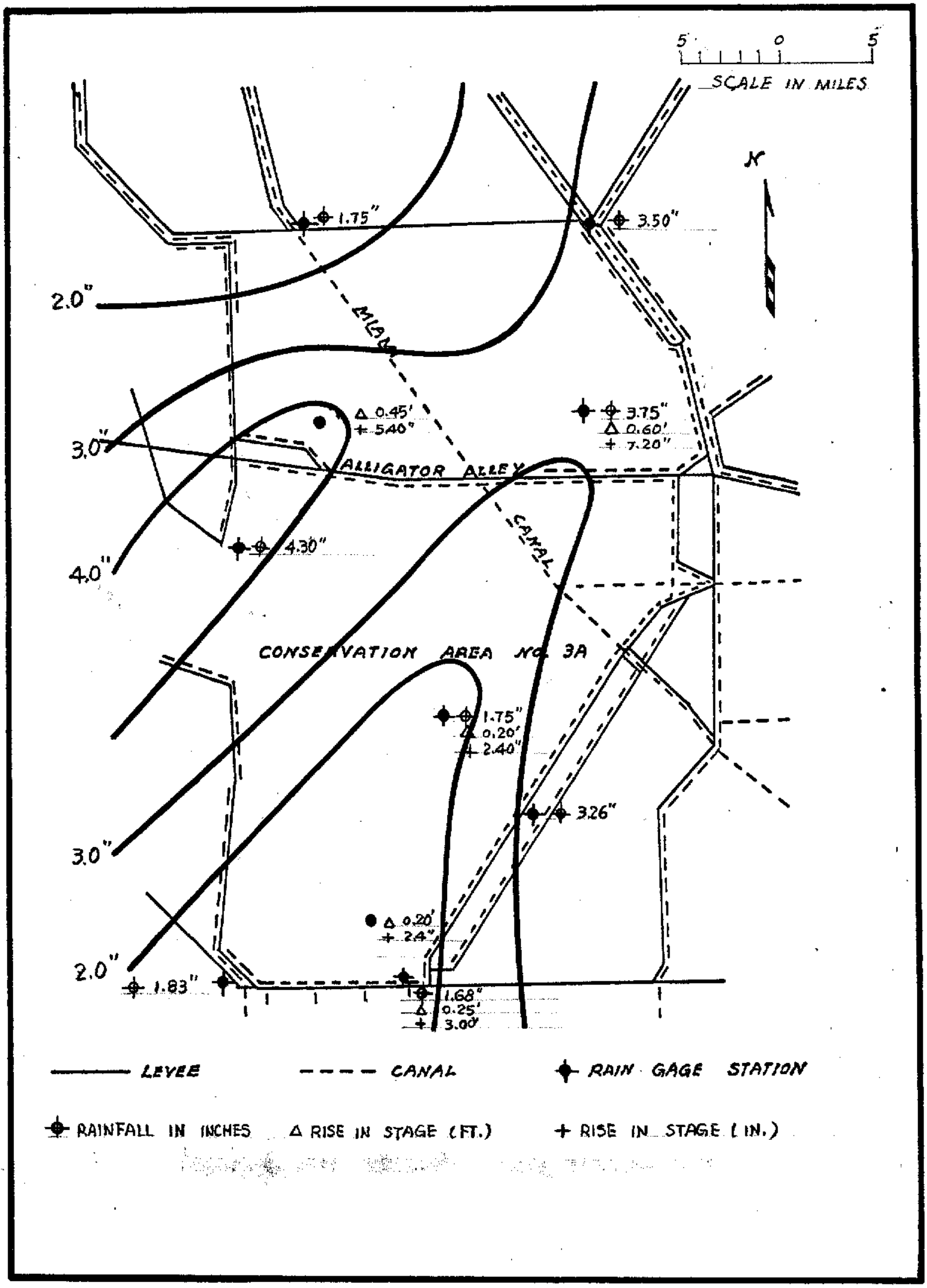

CONSERVATION AREA NO. 1
CONSERVATION AREA NO. 2
CONSERVATION AREA NO. 3
N
LEGEND
MIXED GRASSES & WATER PLANTS (3' HIGH – 2' EFFECTIVE HEIGHT)
MIXED GRASSES WITH MYRTLE & BAY ISLANDS
SAWGRASS (6' HIGH – 3' EFFECTIVE HEIGHT)
MYRTLE AND BAY (10' HIGH – 5' EFFECTIVE HEIGHT)
CYPRESS (NO WAVES)
CONTOUR INTERVAL 1 FT. BASED ON MEAN SEA LEVEL.
CENTRAL AND SOUTHERN FLORIDA
CONSERVATION AREAS
TOPOGRAPHY AND VEGETATION TYPES
SCALE IN MILES

FIGURE 3



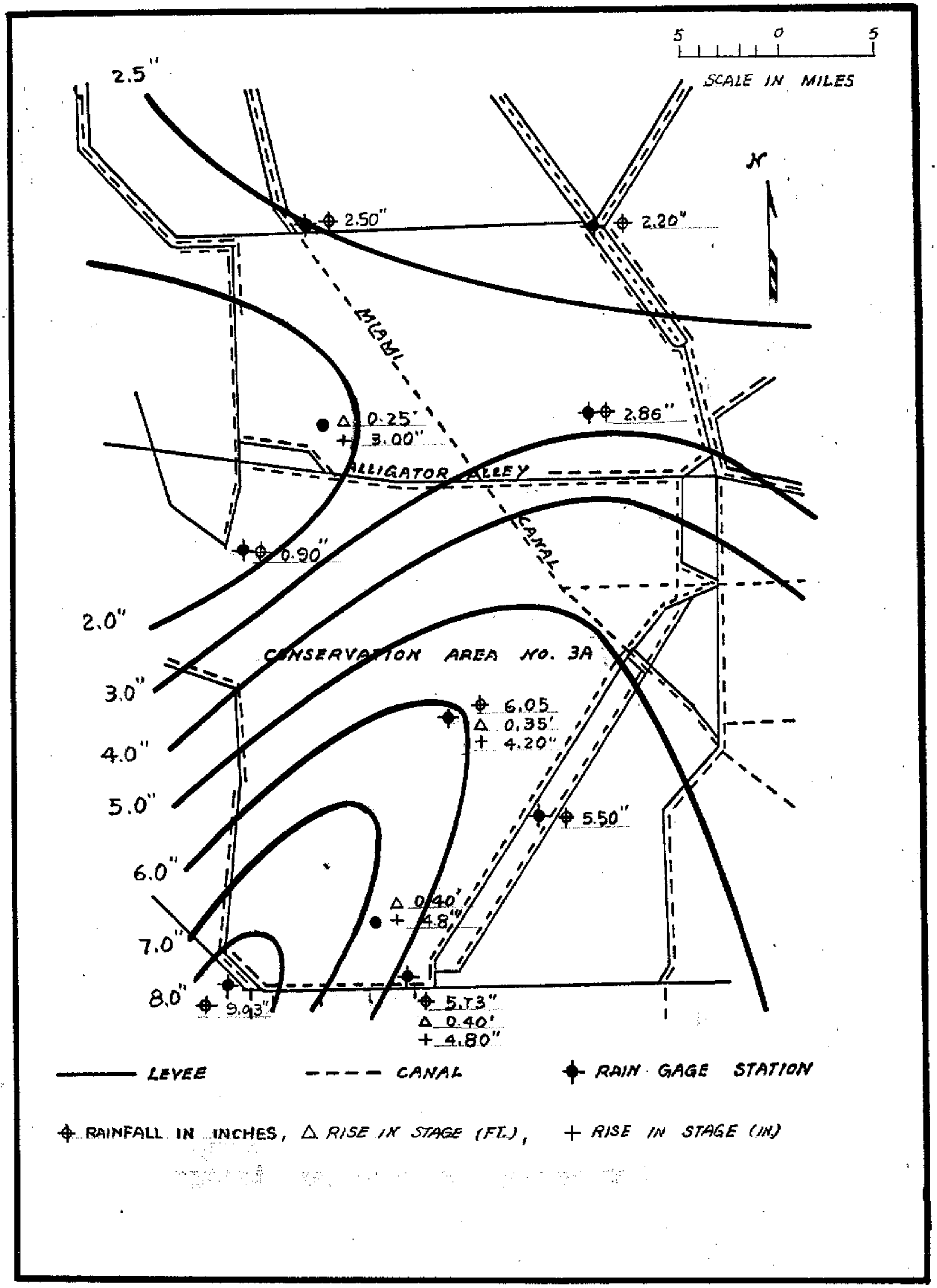
GRAPH OF FIELD ELEVATIONS WHEN AVERAGE STAGE AT REGULATION IN CONSERVATION AREA NO. 3A

FIGURE 4



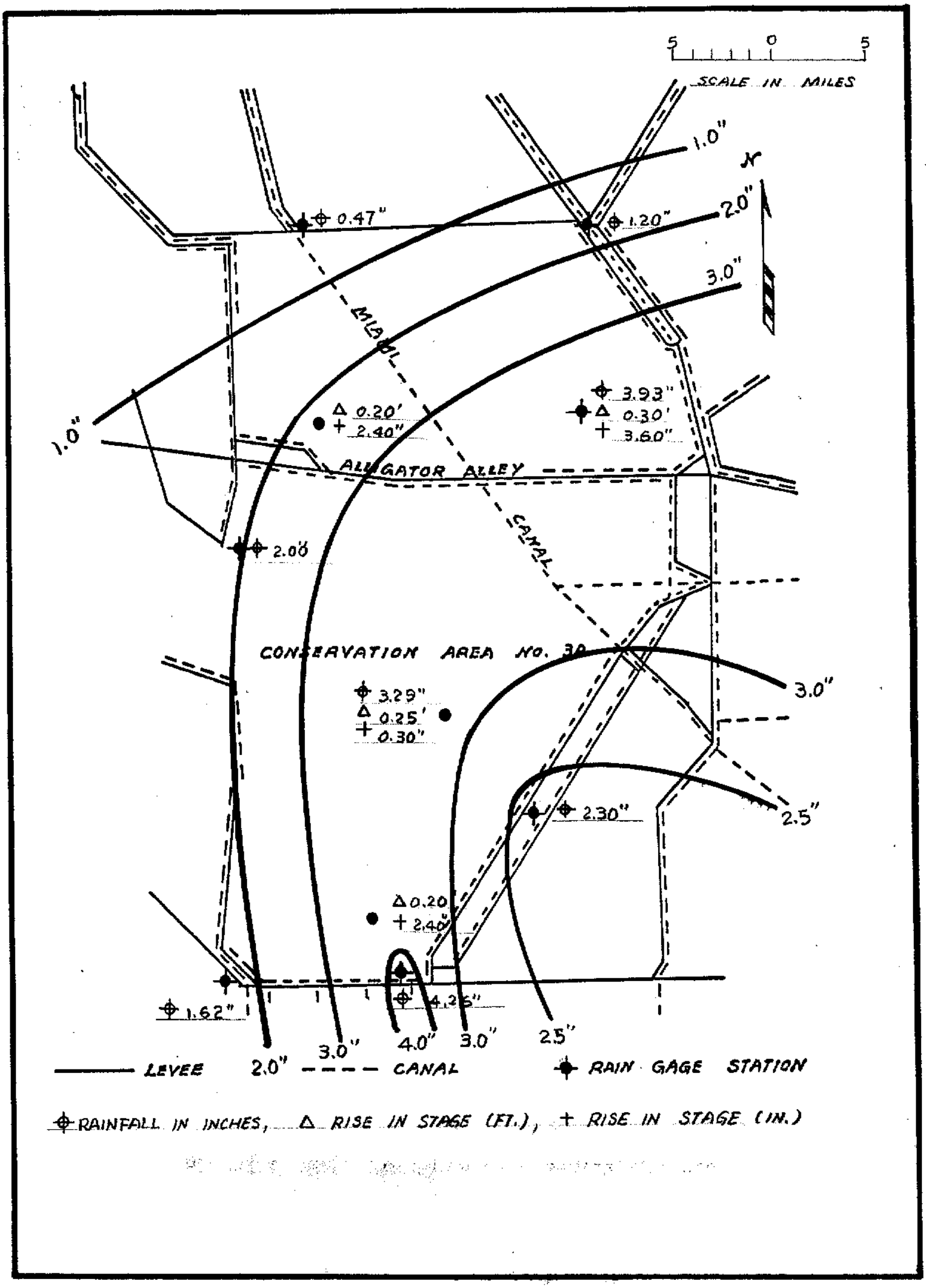
ISOHYETAL MAP OF RAINFALL 2-12-63

FIGURE 5



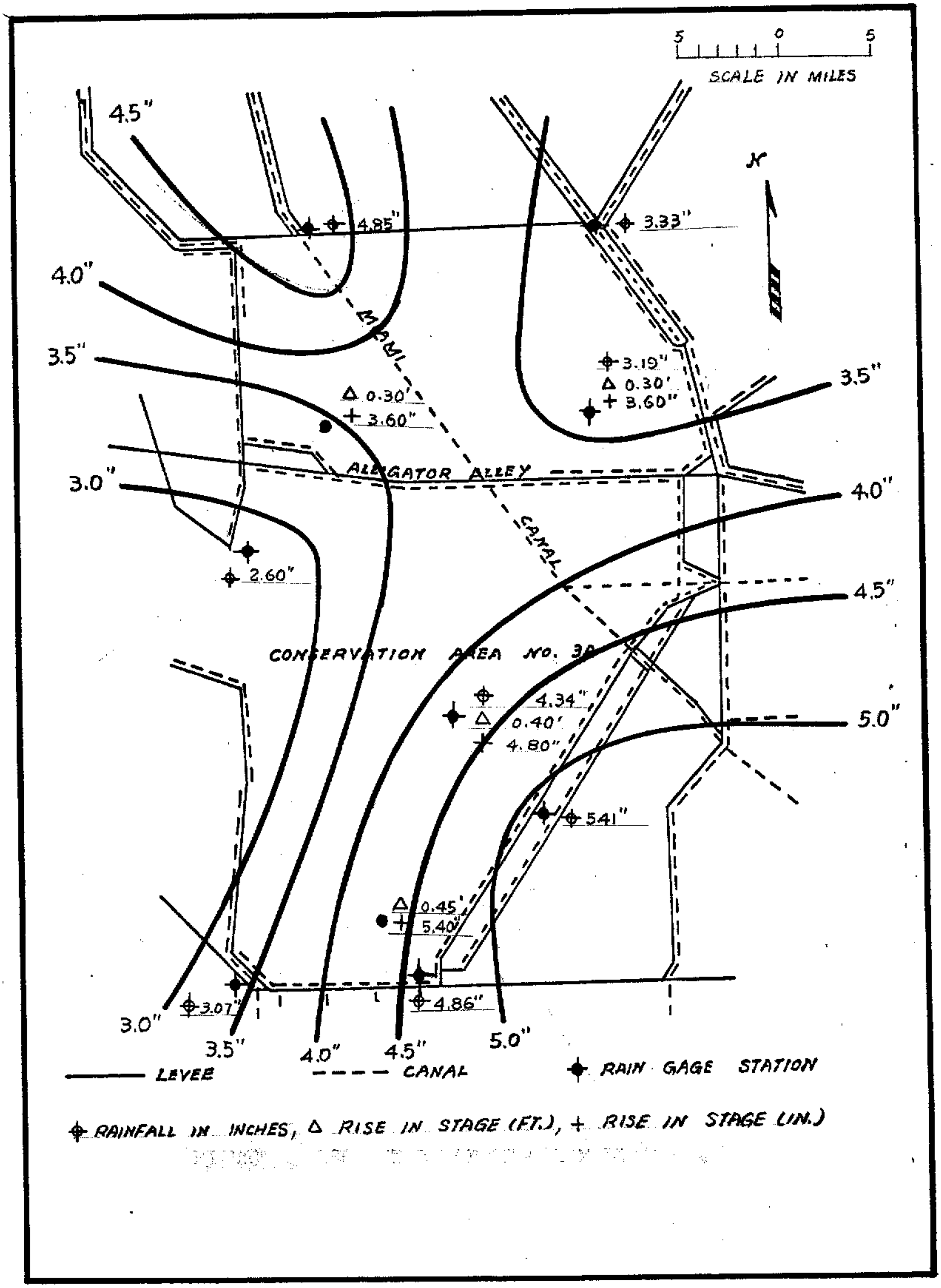
ISOHYETAL MAP OF RAINFALL 9-8-65

FIGURE 6



ISOHYETAL MAP OF RAINFALL 4-28-69

FIGURE 7



ISOHYETAL MAP OF RAINFALL 10-17-68

FIGURE 8

OPERATIONAL HYDROGRAPHS OF RAINFALL ON 2-12-63

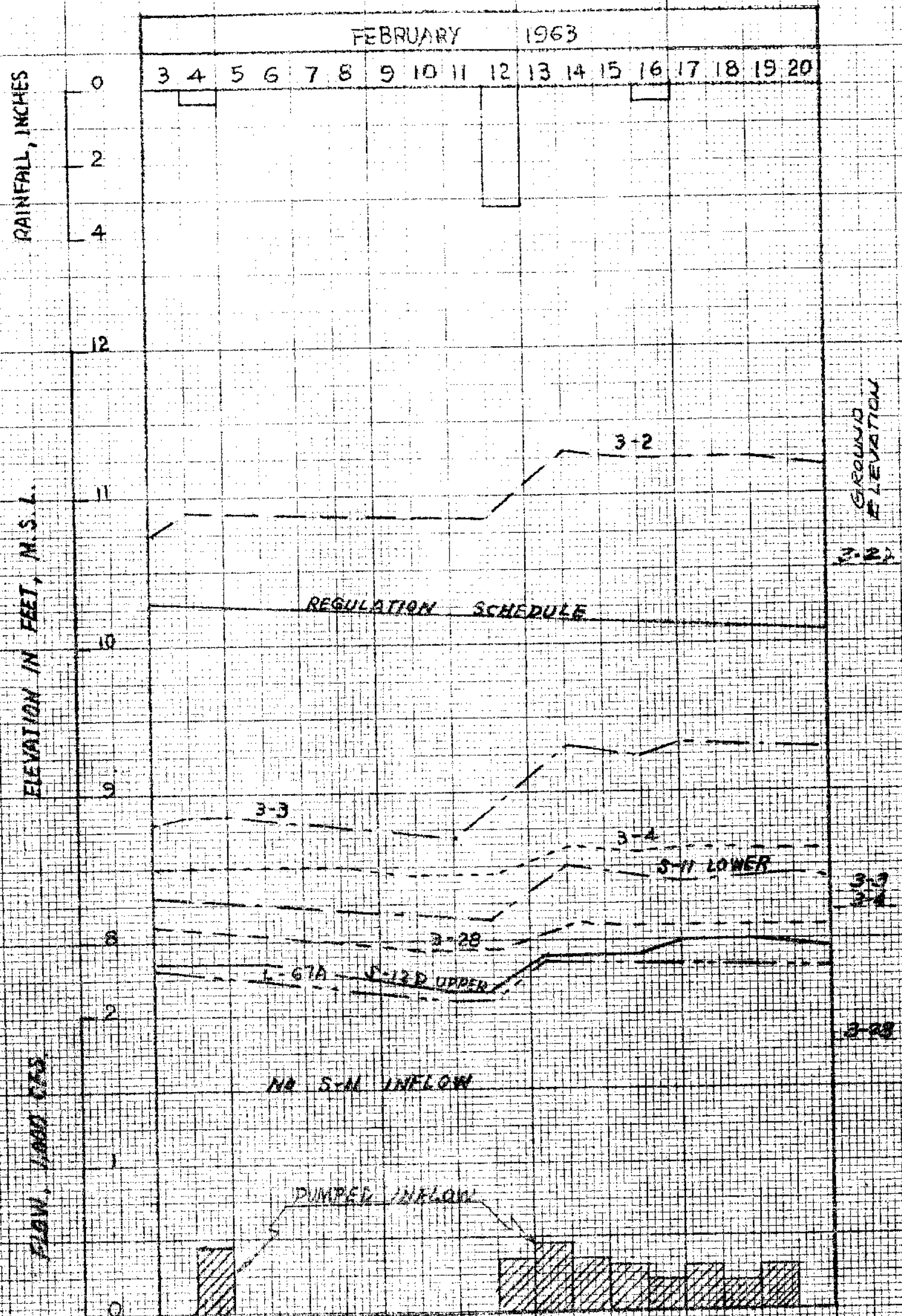


FIGURE 9

OPERATIONAL HYDROGRAPHS OF RAINFALL ON 9-8-65

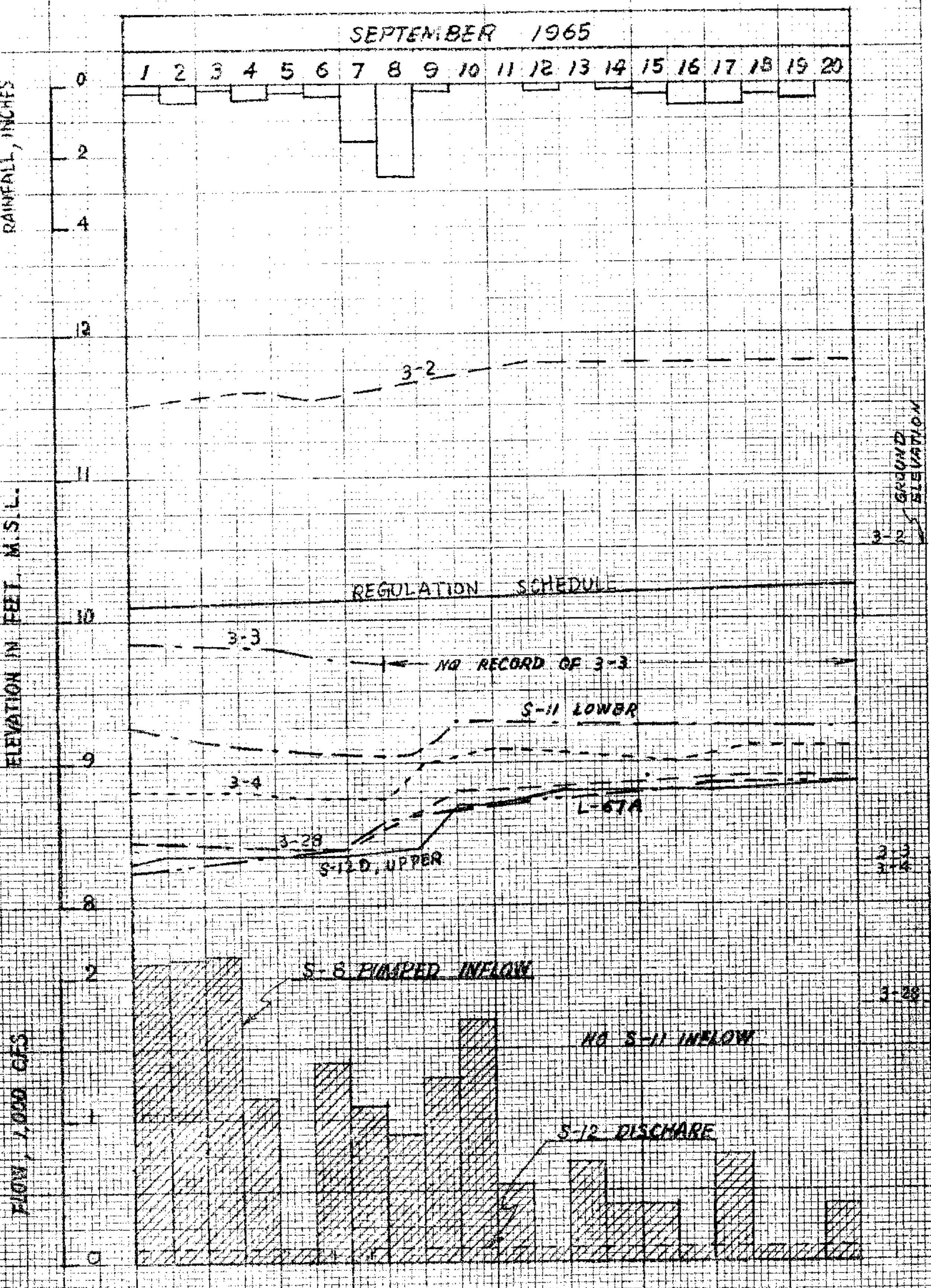


FIGURE 10

OPERATIONAL HYDROGRAPHS OF RAINFALL ON 10-17-68

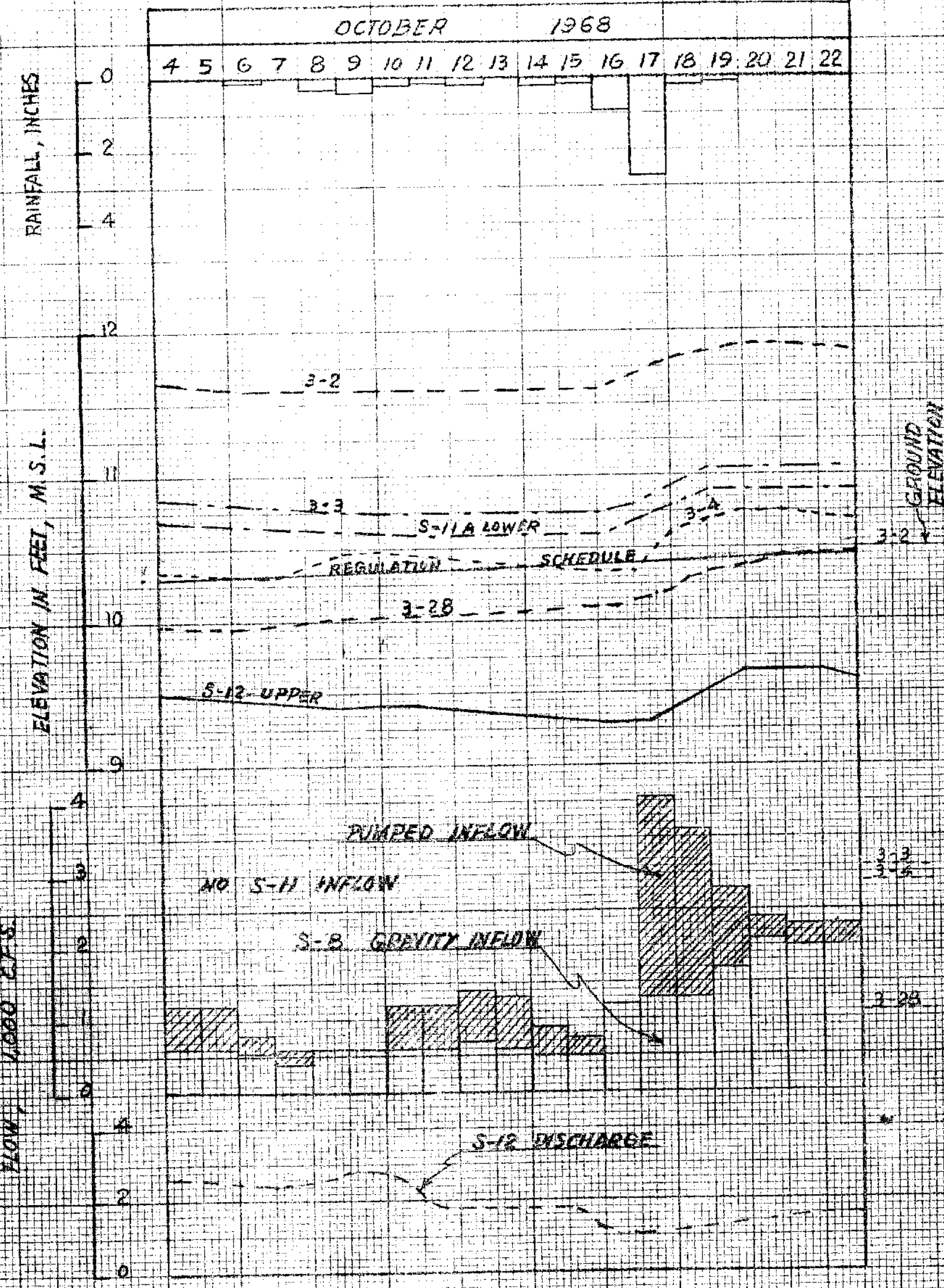


FIGURE 11

OPERATIONAL HYDROGRAPHS OF RAINFALL ON 4-28-69

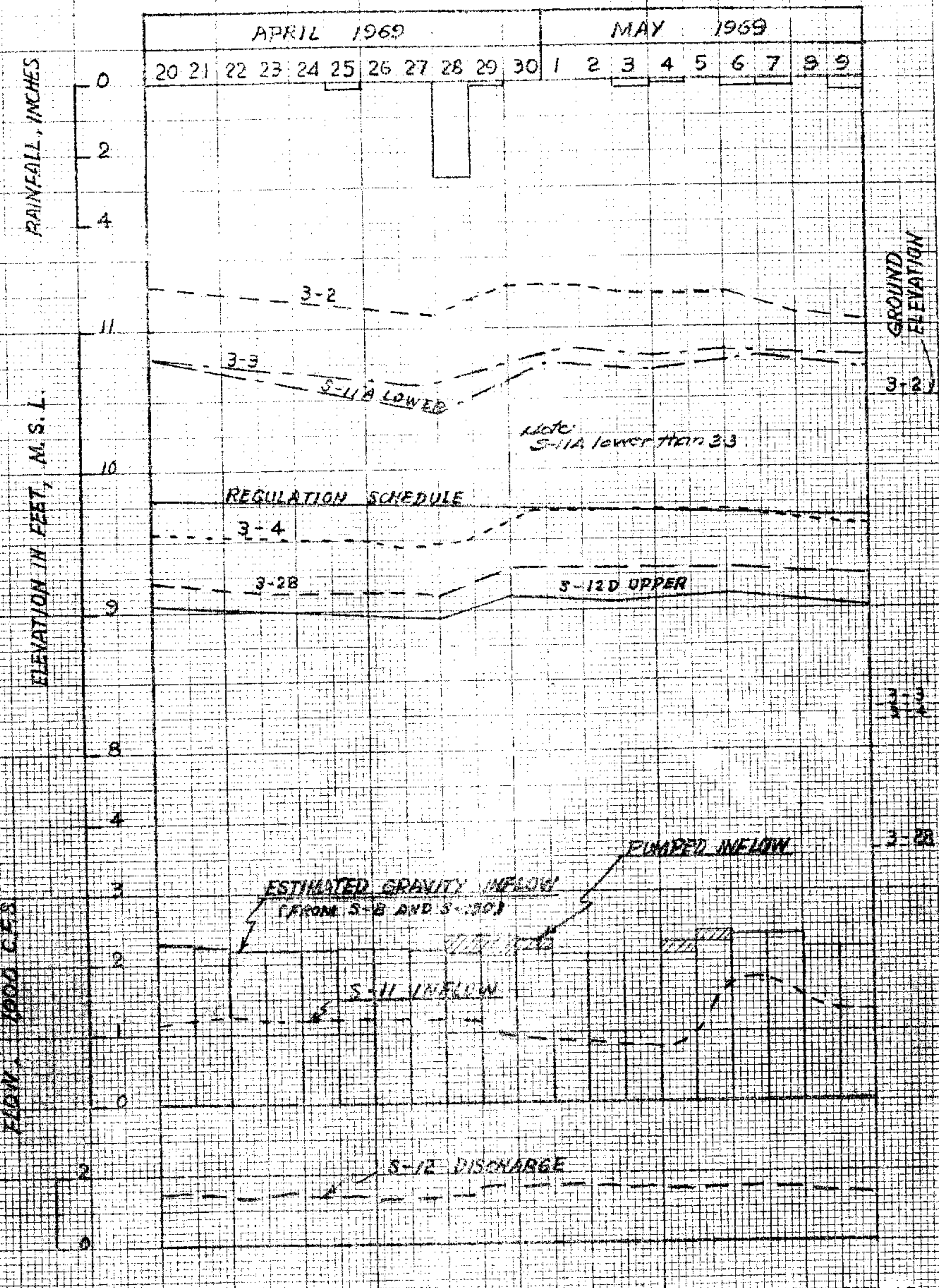


FIGURE 12

EFFECT OF LOCAL RAINFALL ON GAGE 3-2

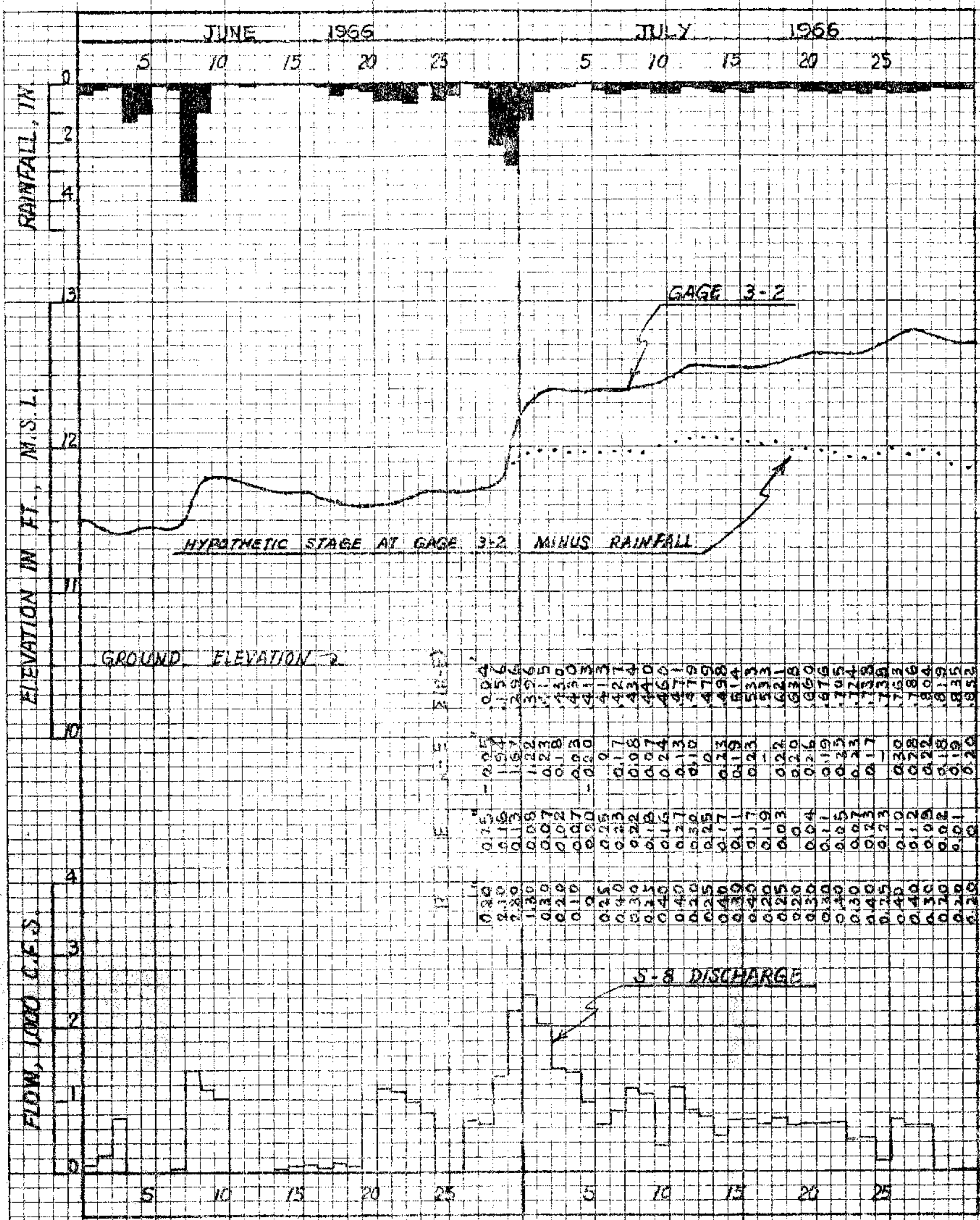


FIGURE 13

EFFECT OF LOCAL RAINFALL ON GAGE 3-2

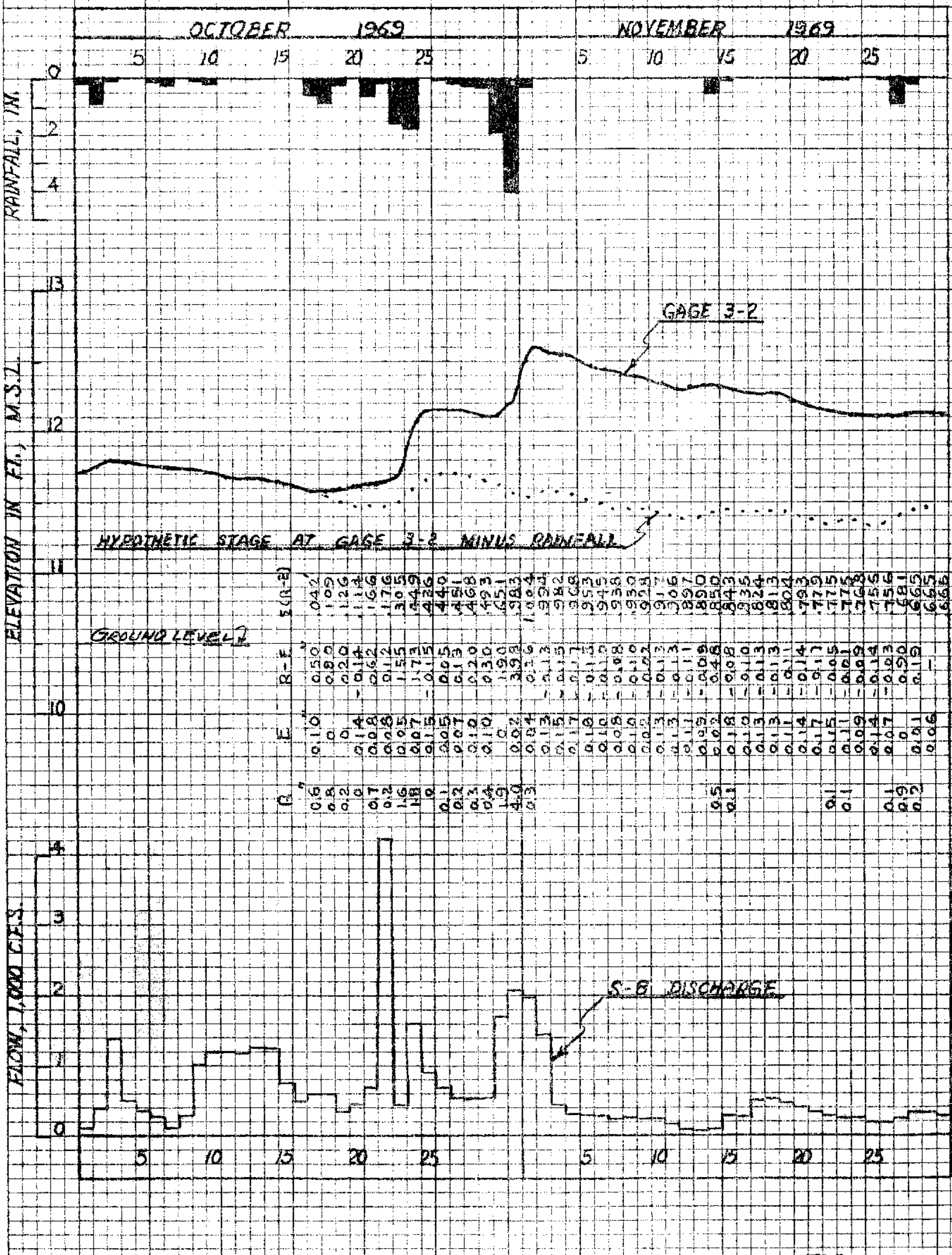


FIGURE 14

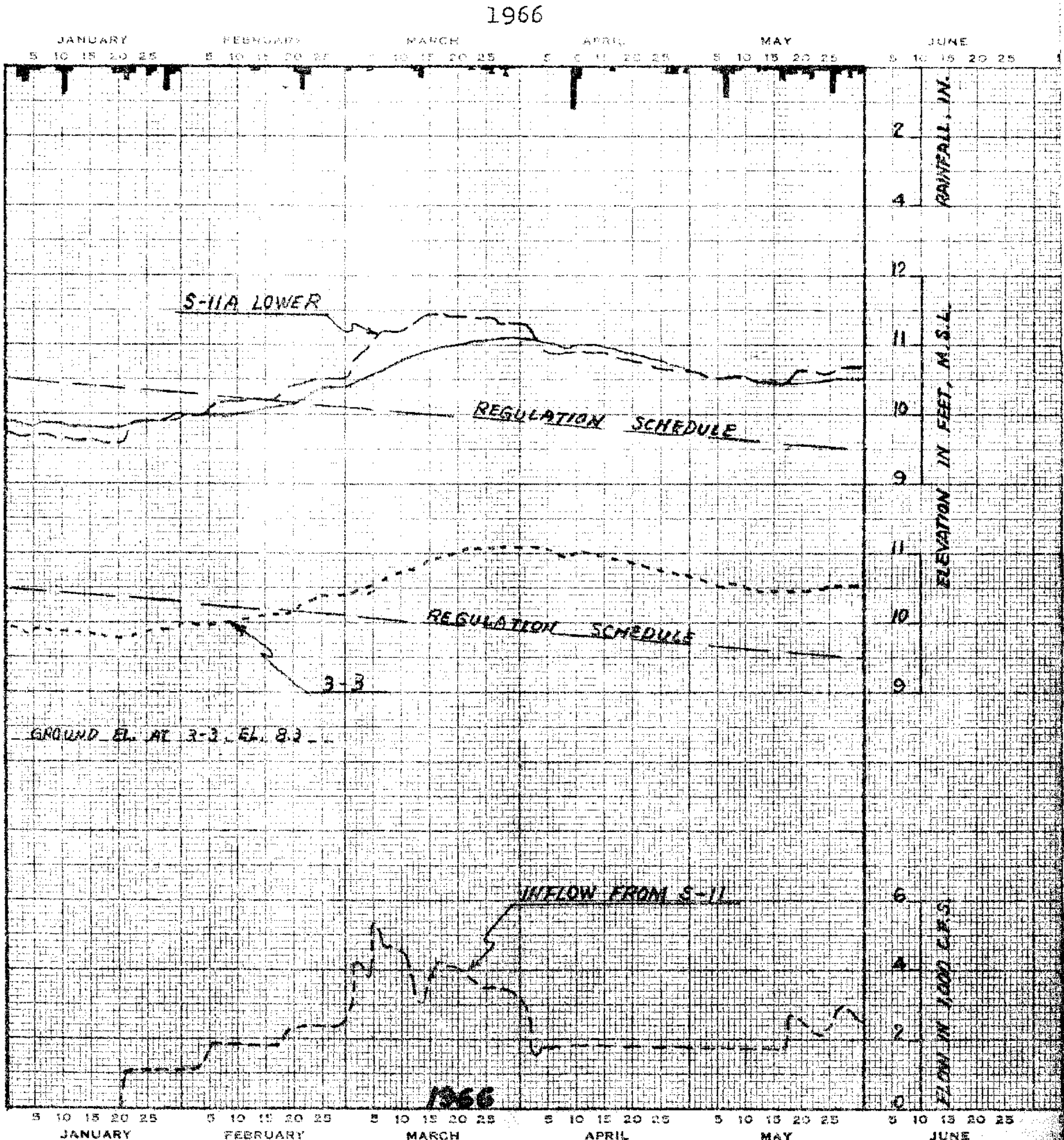


FIG. 15 STAGE AND DISCHARGE HYDROGRAPHS FOR GAGE 3-3 EVALUATION

FIGURE 15

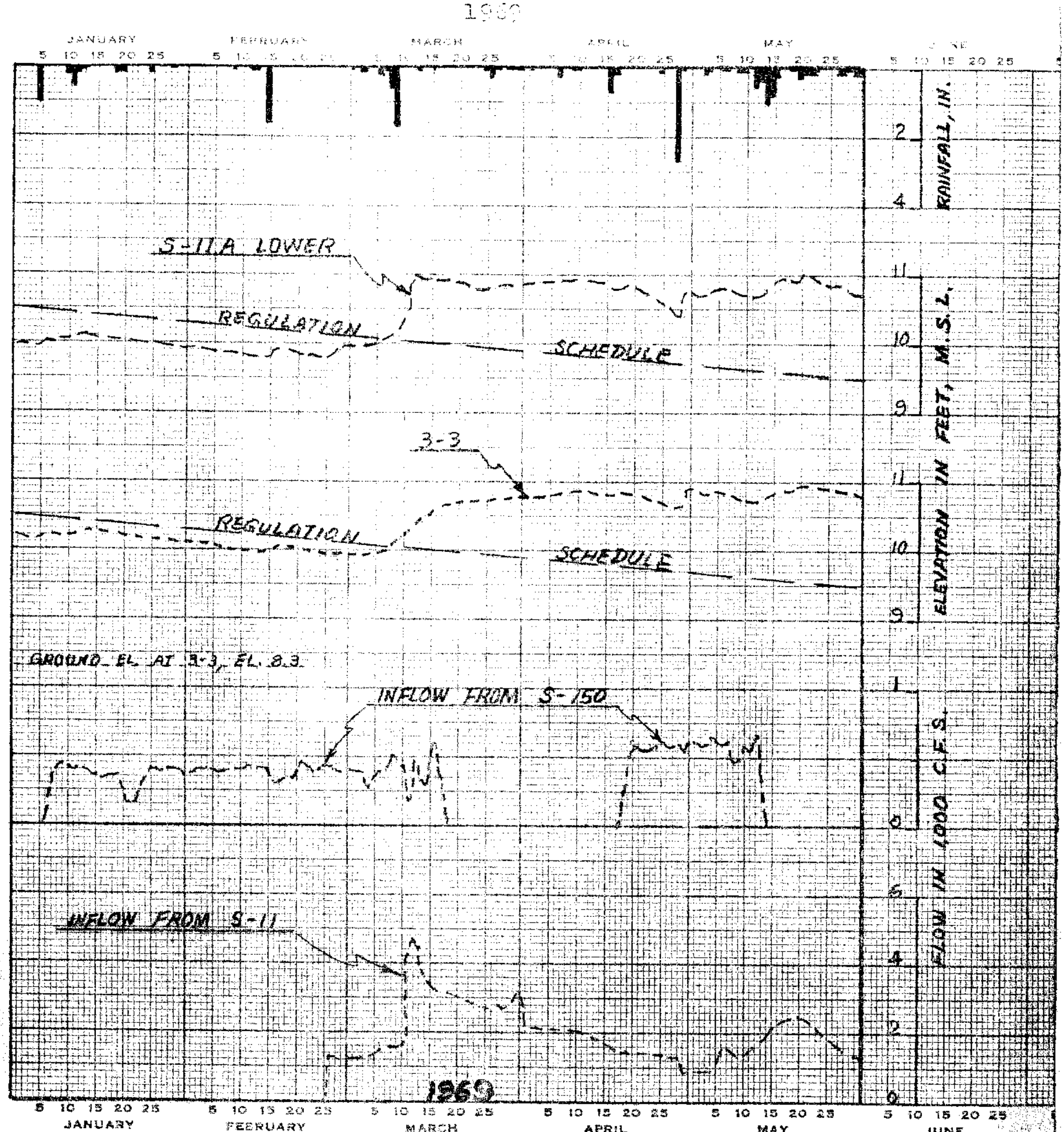


FIG. 16 STAGE AND DISCHARGE HYDROGRAPHS FOR GAGE 3-3 EVALUATION

FIGURE 16

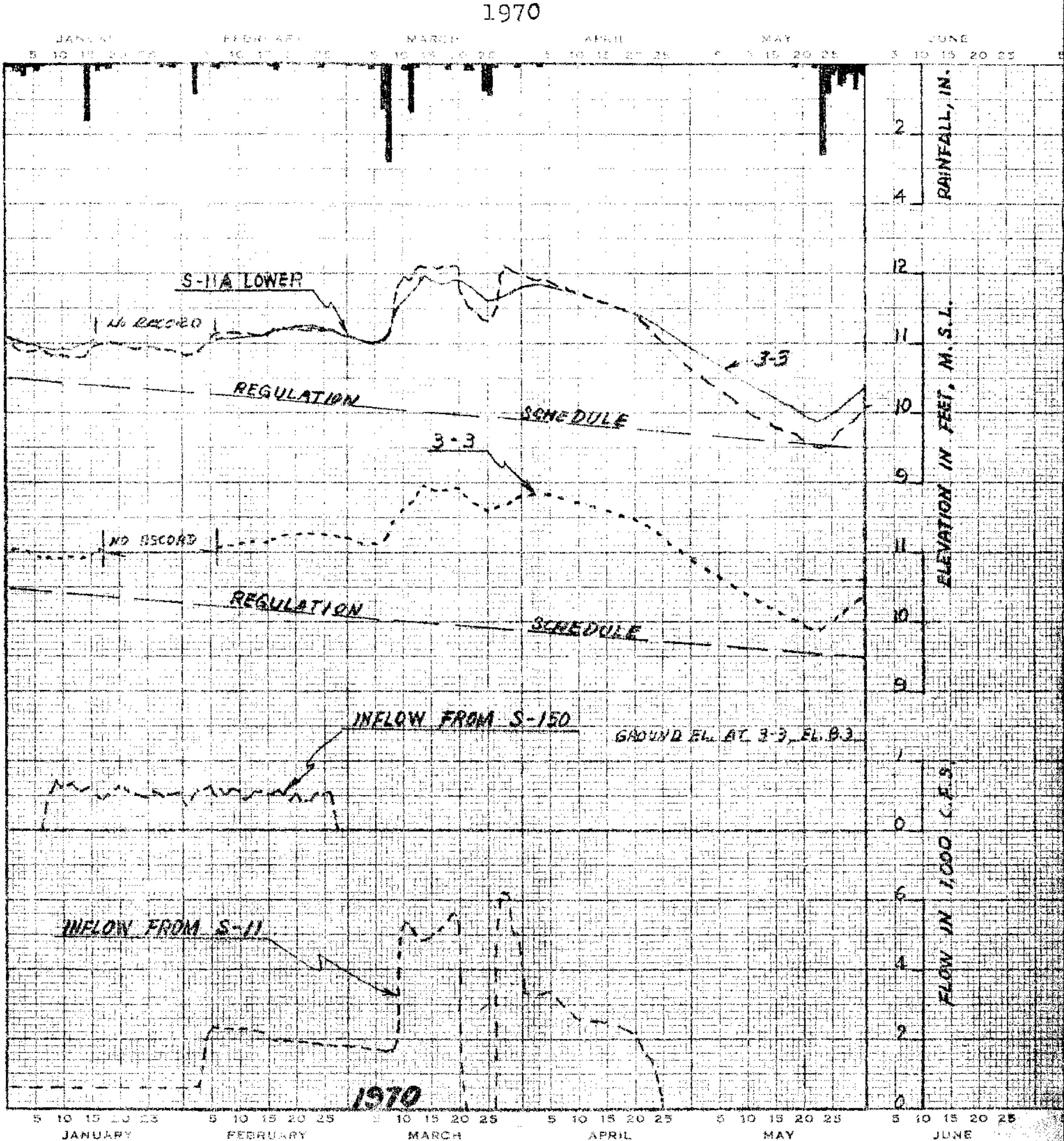


FIG. 17 STAGE AND DISCHARGE HYDROGRAPHS FOR GAGE 3-3 EVALUATION

FIGURE 17

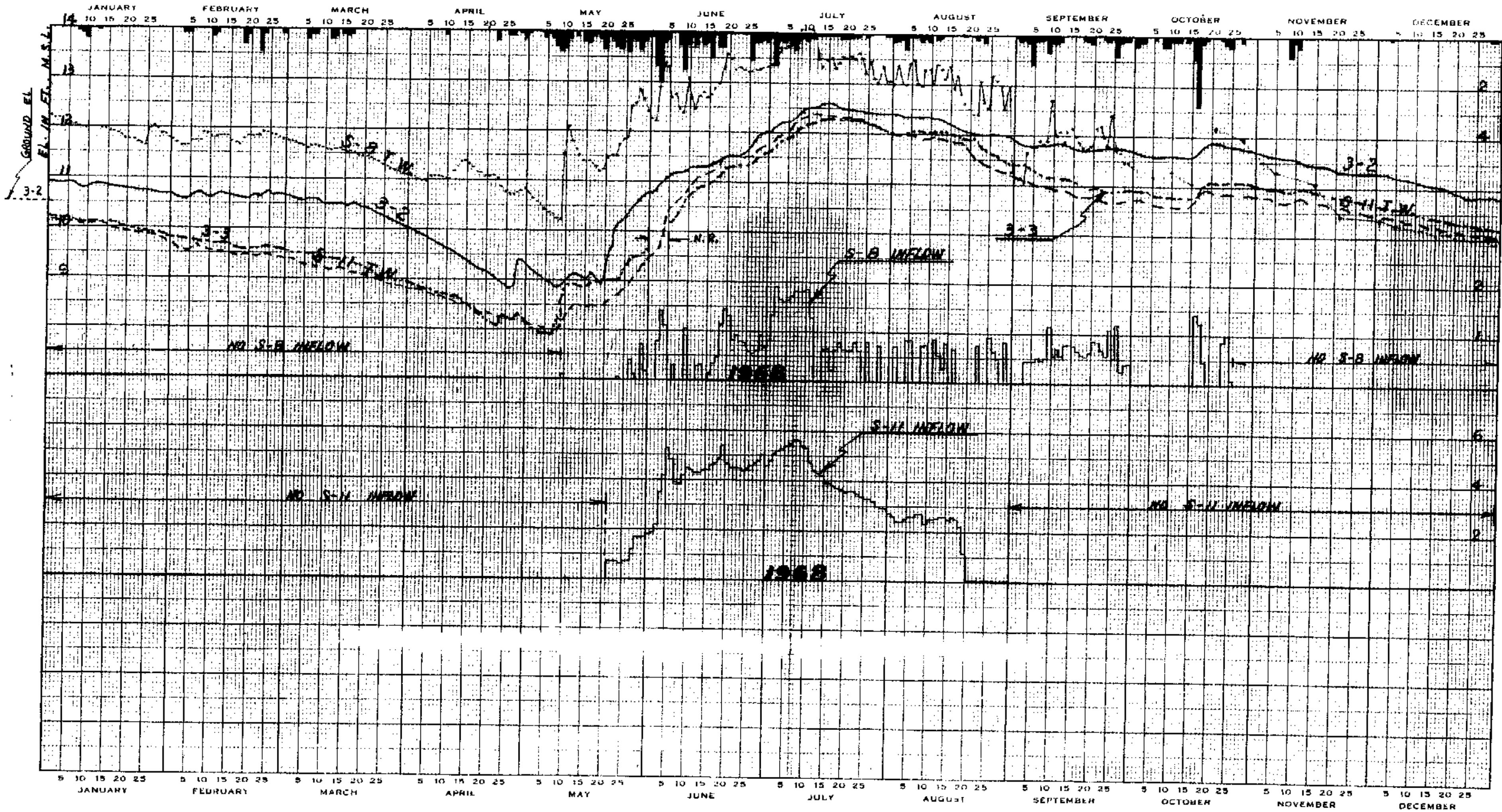


FIG. 18 HYDROGRAPHS OF STAGE AT GAGE 3-2, 3-3 AND DISCHARGE AT S-11 AND S-8

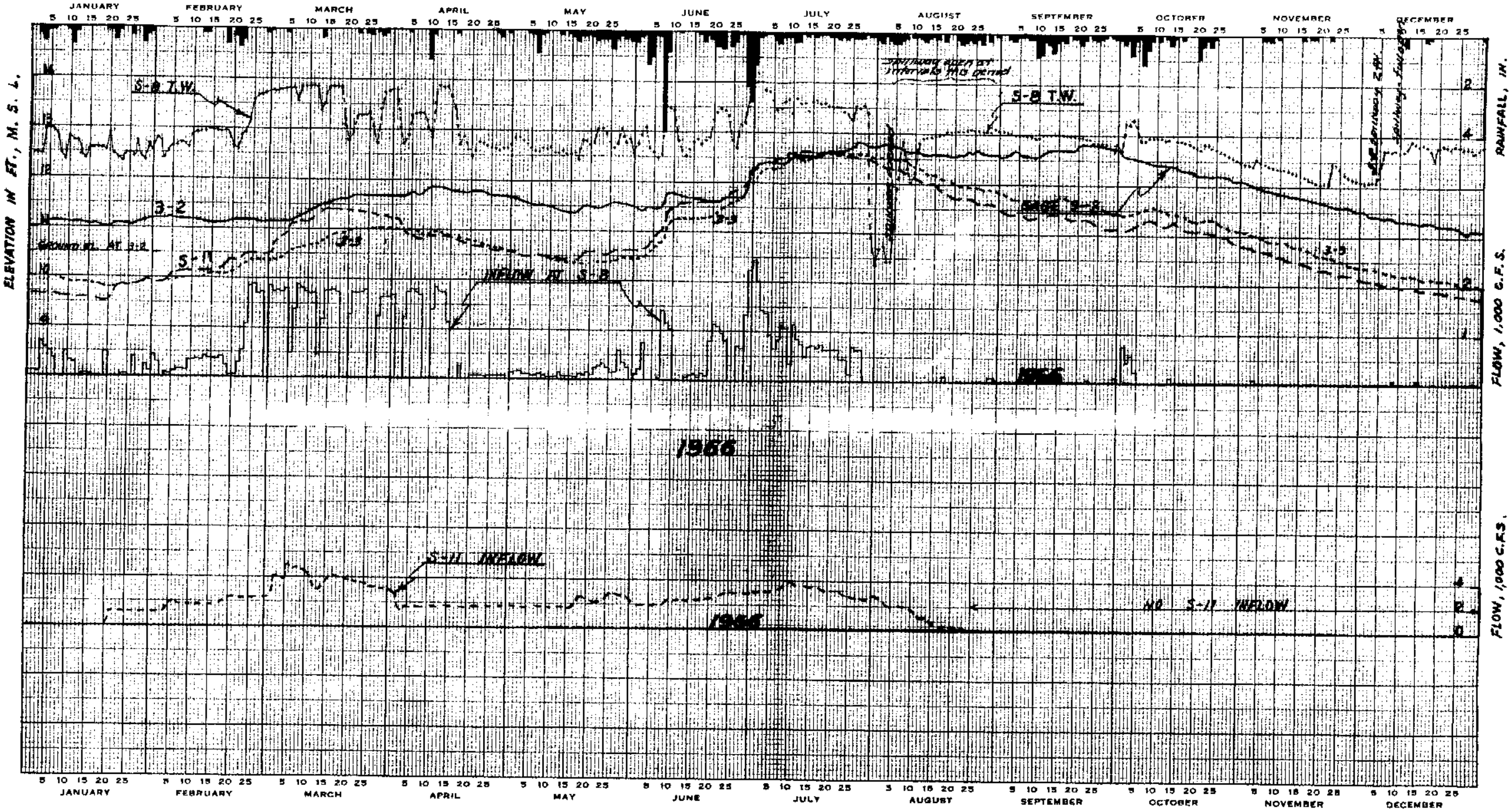


FIG. 19 HYDROGRAPHS OF STAGE AT GAGE 3-2, S-8 TAILWATER AND DISCHARGE AT S-8

FIGURE 19

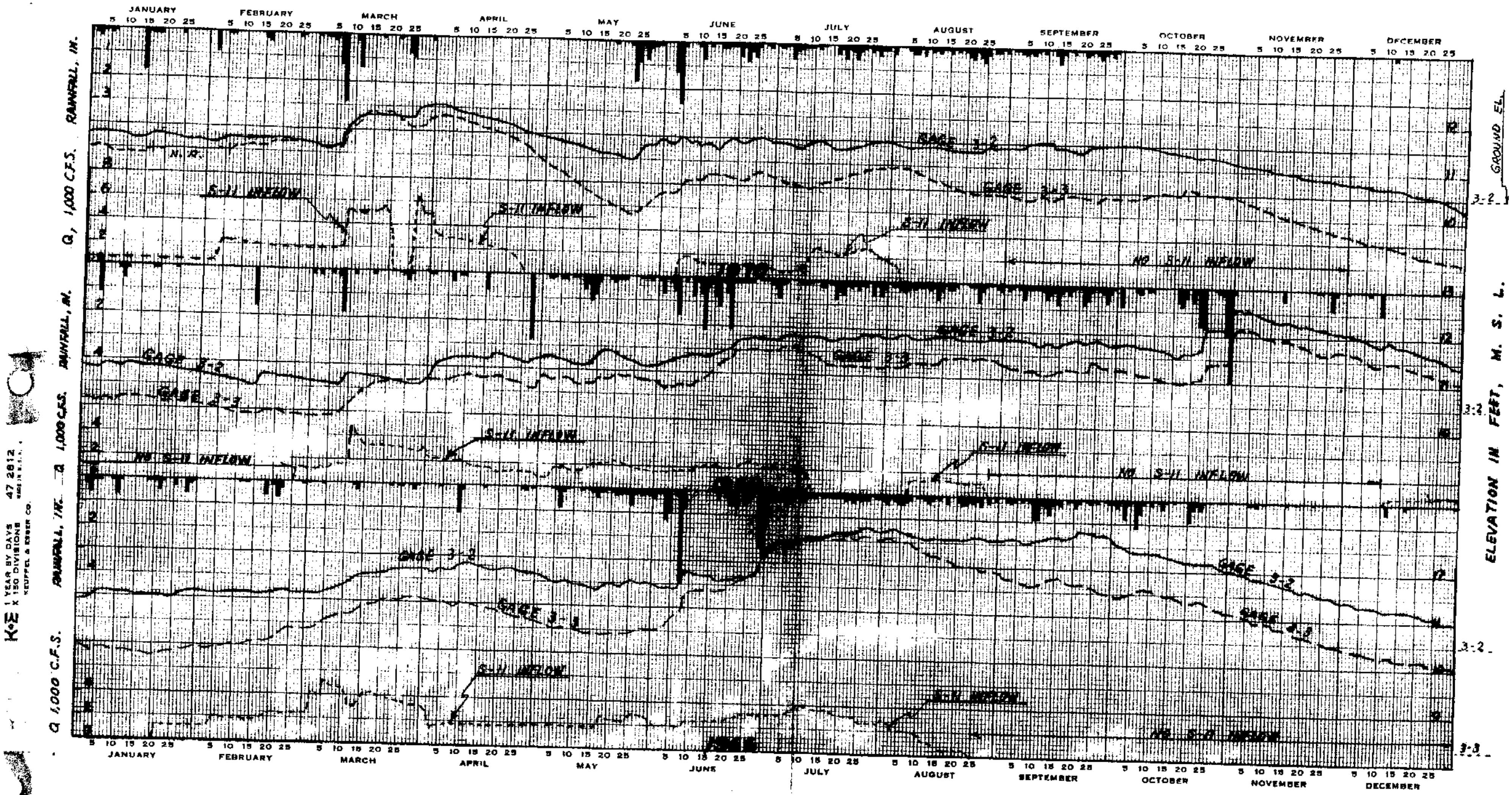


FIG. 20 HYDROGRAPHS OF STAGE AT GAGE 3-2, 3-3 AND DISCHARGE AT S-11

FIGURE 20

FIG. 21 EFFECT OF S-8 PUMPING ON GAGE 3-2

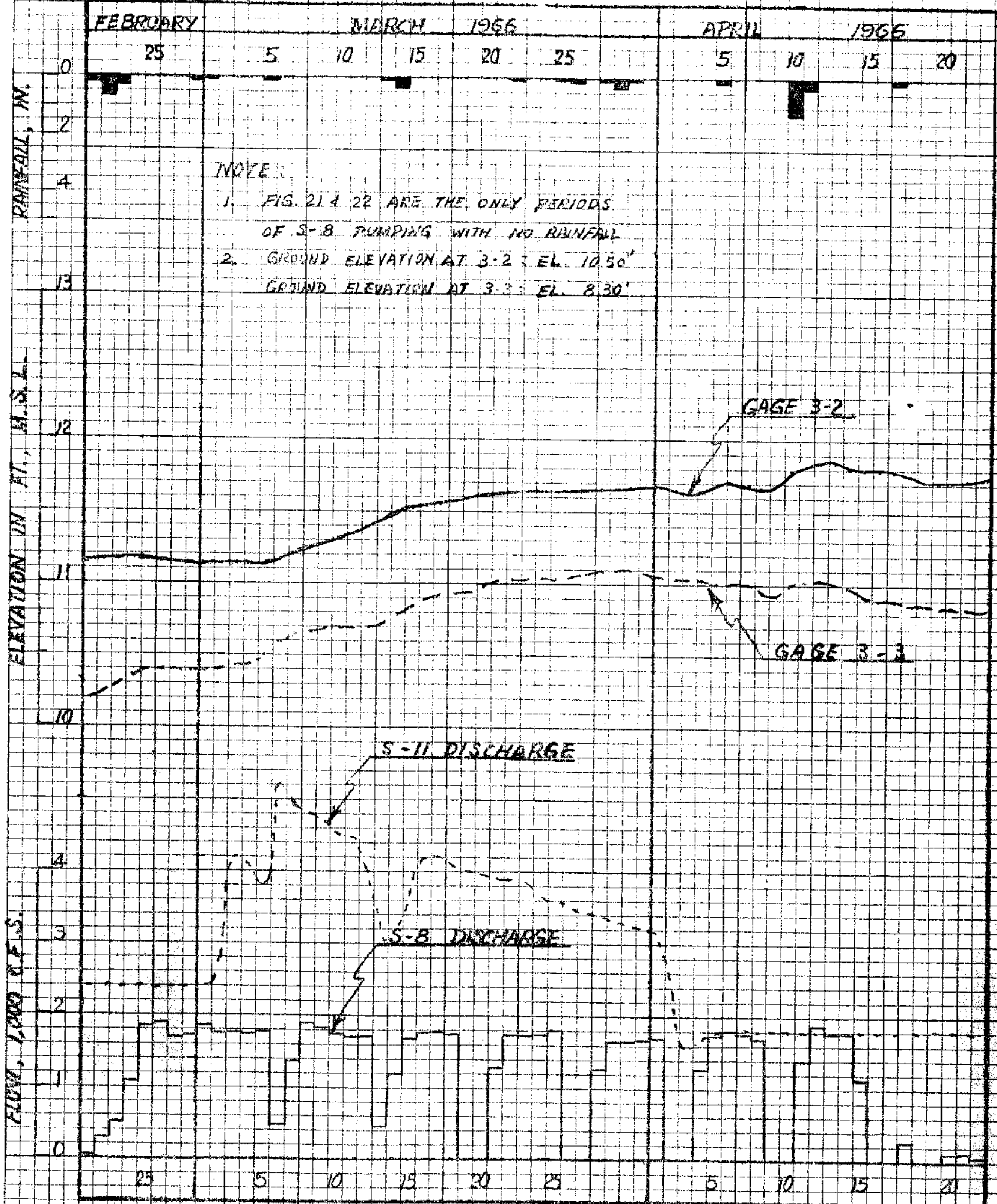


FIGURE 21

FIG. 22 EFFECT OF S-8 PUMPING ON GAGE 3-2

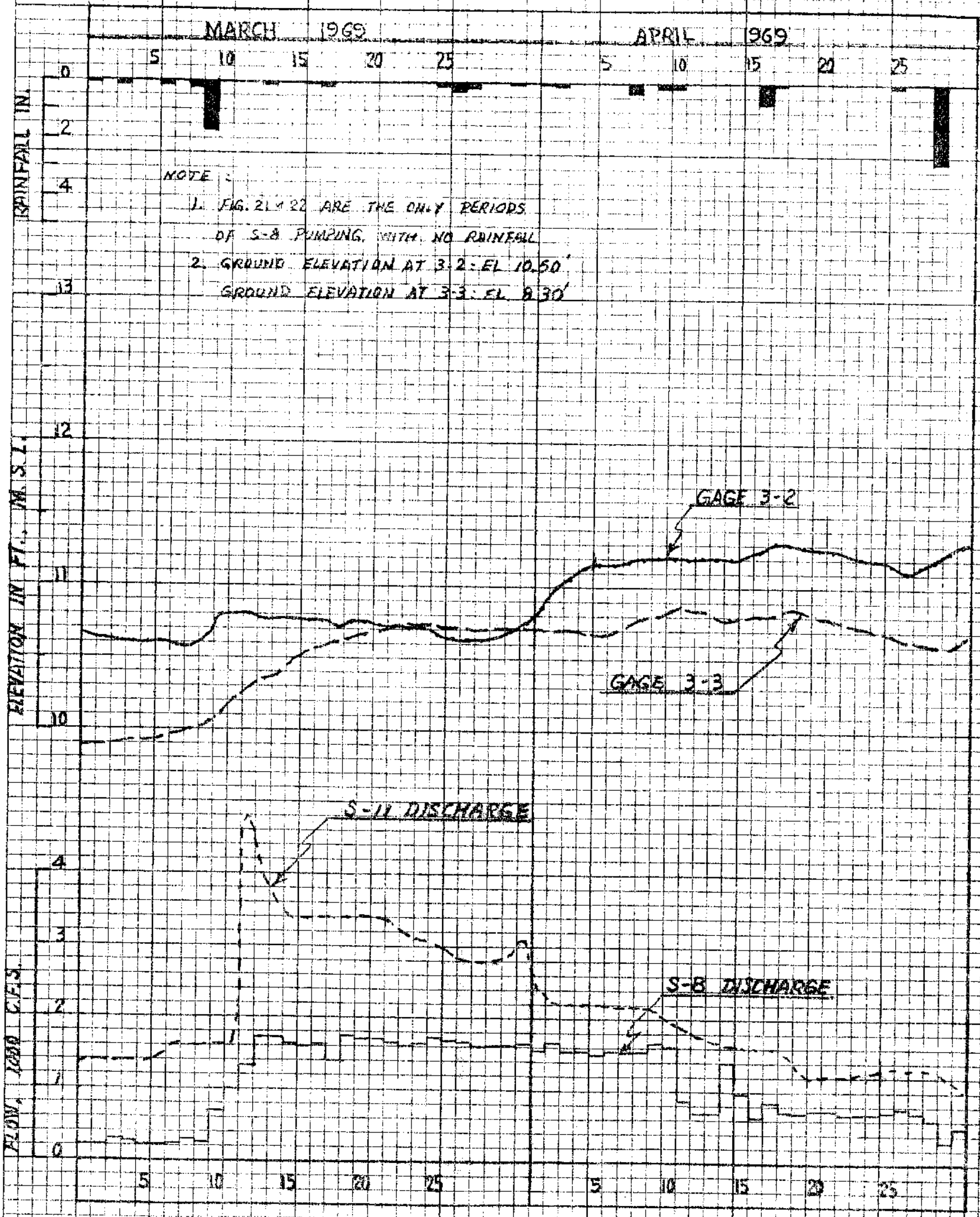


FIGURE 22

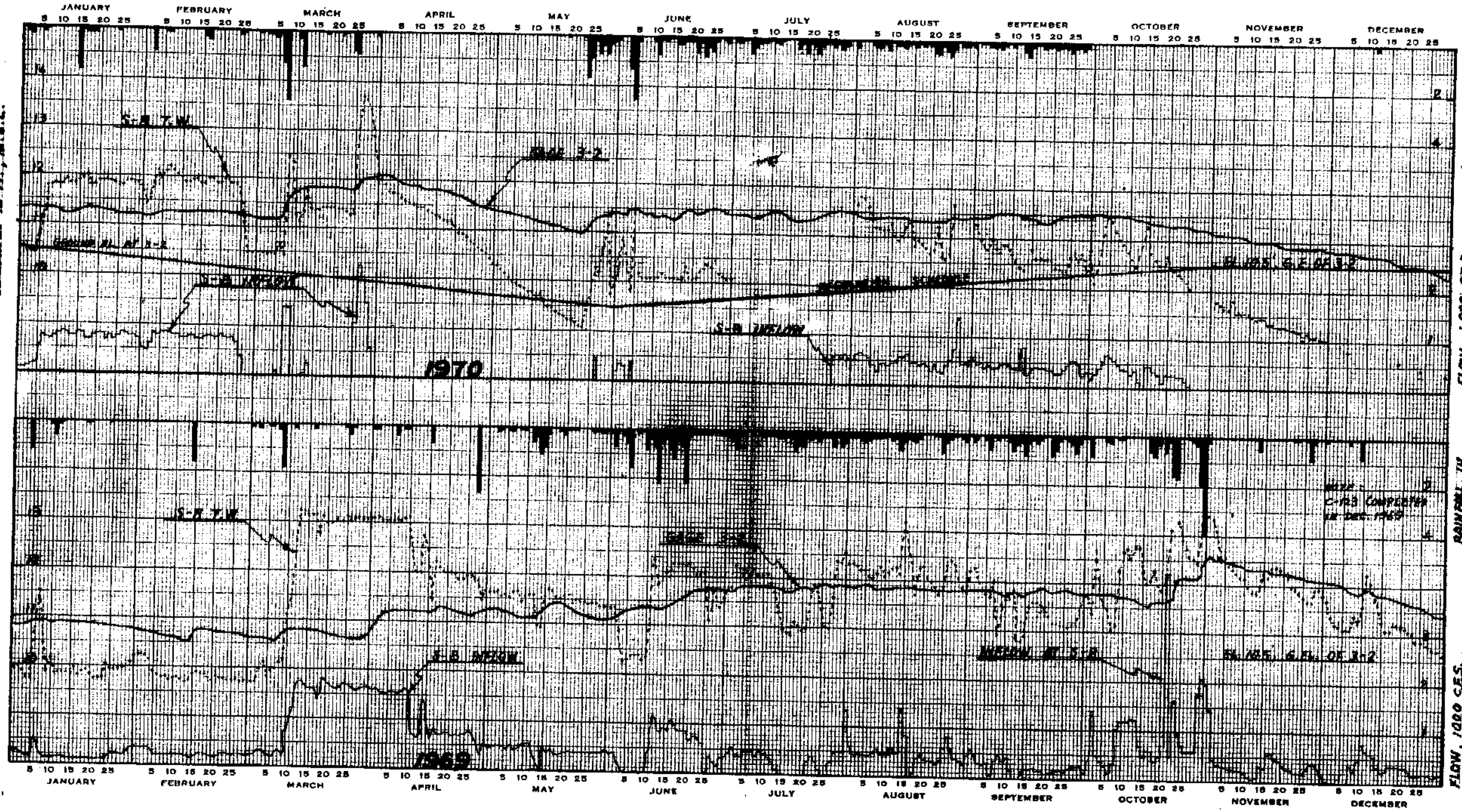


FIG. 23 HYDROGRAPHS OF STAGE AT GAGE 3-2, S-8 TAILWATER AND DISCHARGE AT S-8

FIGURE 23

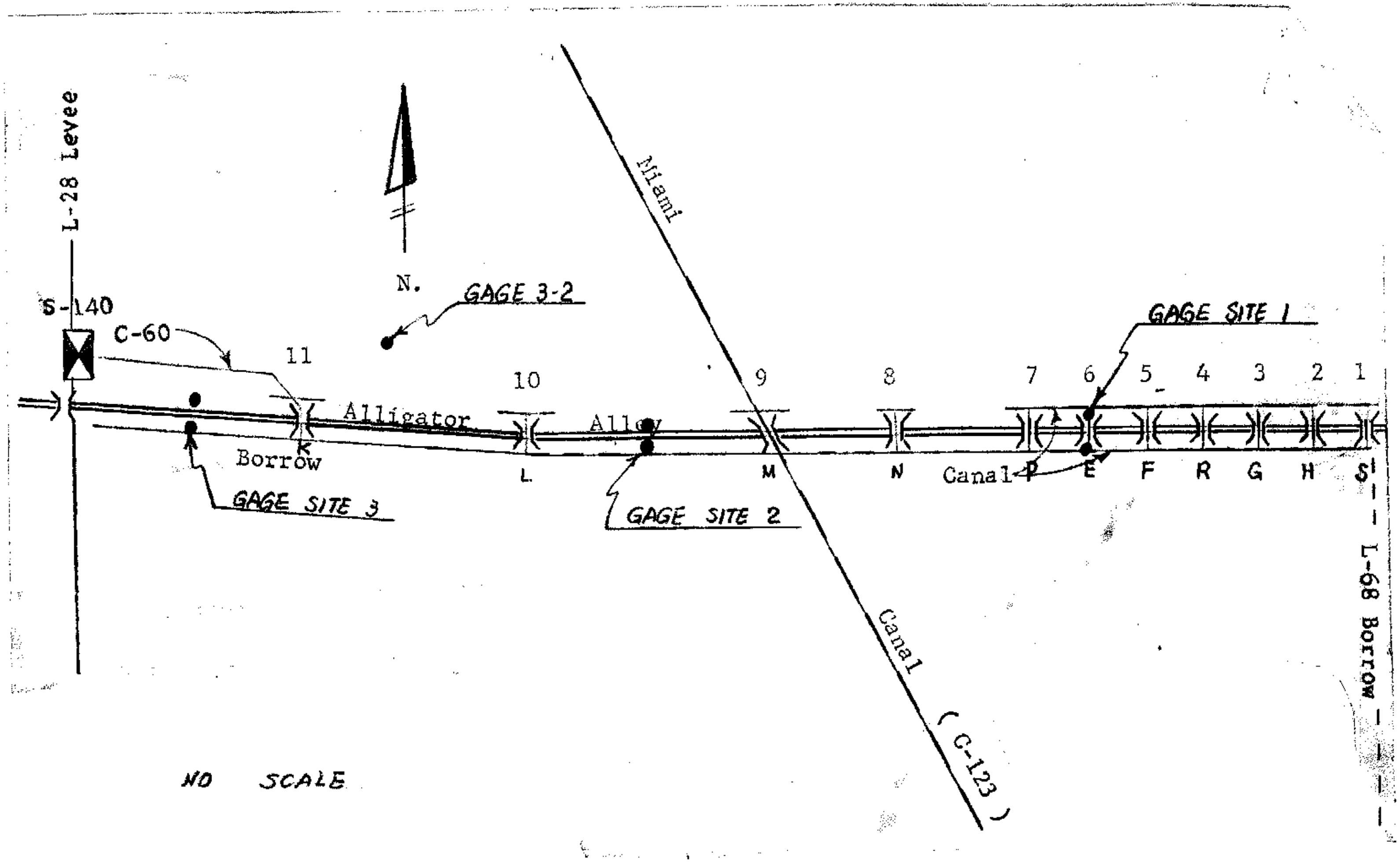


FIG 24 SKETCH OF LOCATION FOR BRIDGES ALONG ALLIGATOR ALLEY

FIGURE 24

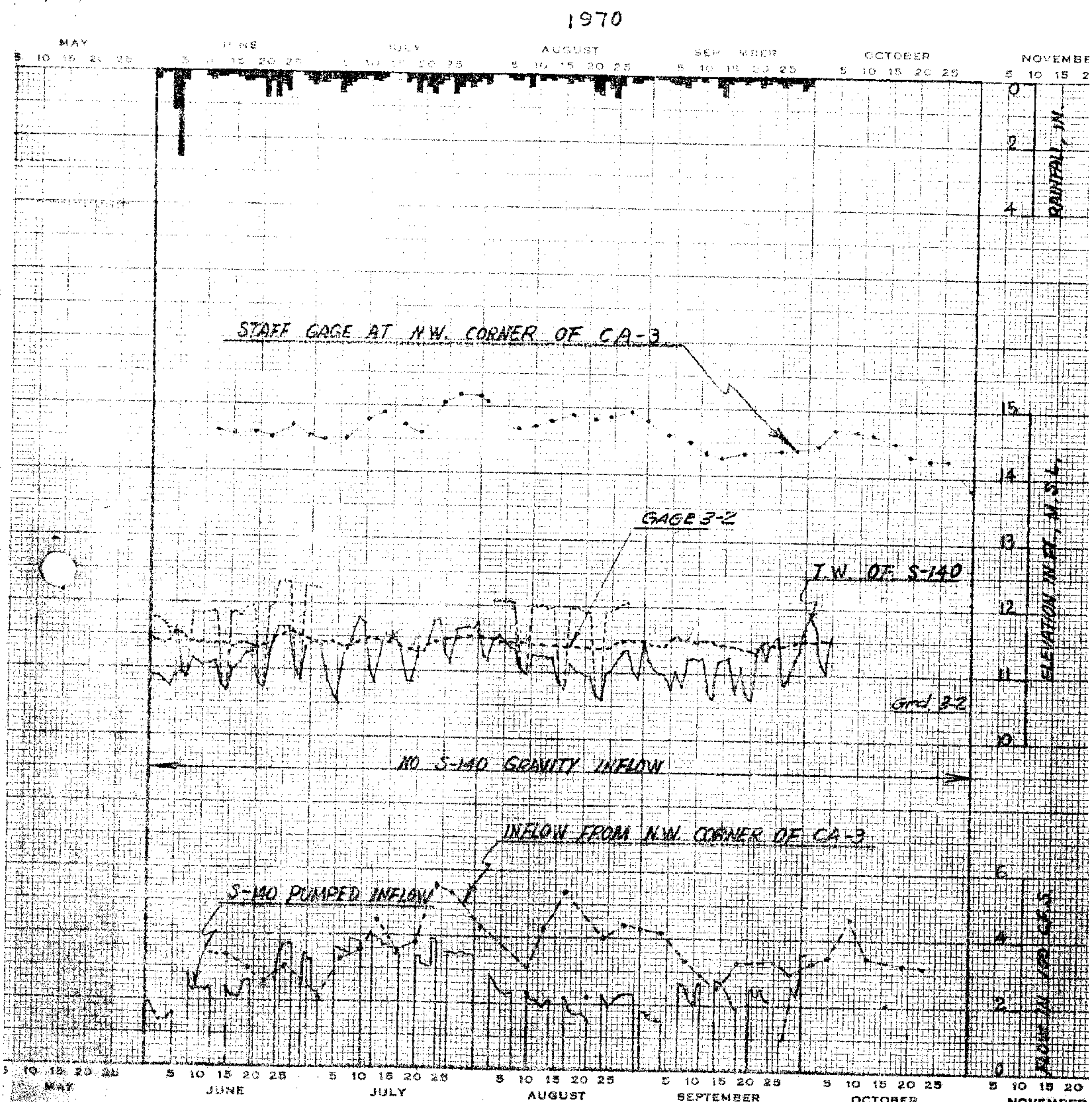


FIG. 25 STAGE AND DISCHARGE HYDROGRAPHS AT S-140 & NW CORNER OF CONSERVATION AREA 3 FOR GAGE 3-2 EVALUATION

FIGURE 25

FIG. 26 STAGE AND DISCHARGE HYDROGRAPHS OF S-9

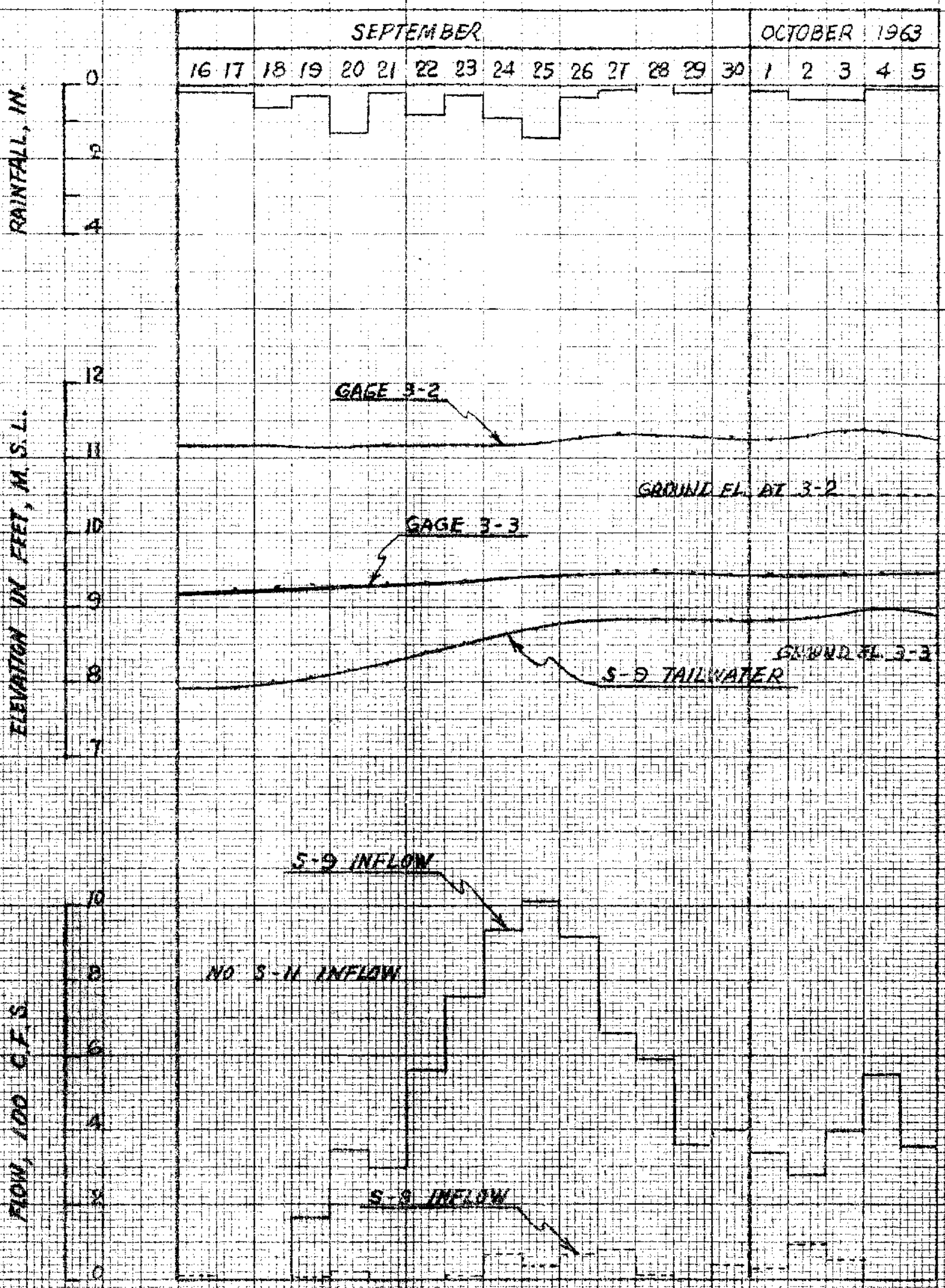


FIGURE 26

FIG. 27 STAGE AND DISCHARGE HYDROGRAPHS OF S-12

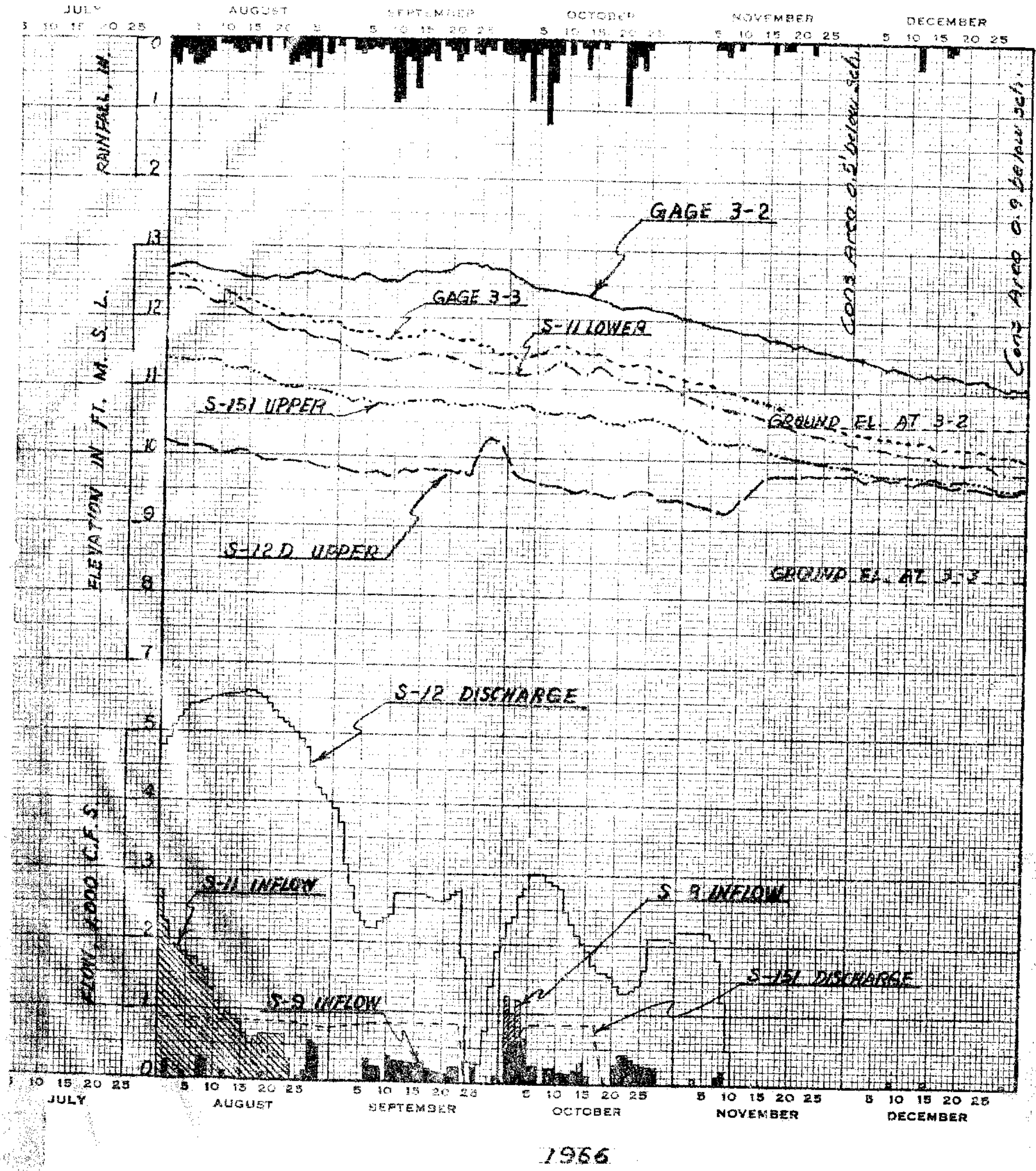


FIGURE 27

TABLE I. DISCHARGE ESTIMATION AT N.W. CORNER OF CA-3A

DATE	OIL WELL BRIDGE (FT. M.S.L.)	N.W. CORN. CA-3A (FT. M.S.L.)	A (FT^2)	P (FT)	R (FT)	$R^{2/3}$	n	S 10^{-6}	$S^{1/2}$	Q (C.F.S.)
4-2-70	16.40	16.00 *	1120	118.0	9.49	4.48	0.032	25.0	.0050	1166
6-12-70	16.65	14.60	976	113.2	8.64	4.21		3.1	.0018	343
6-15-70	14.60	14.55	970	113.1	8.60	4.20		3.1	.0018	341
6-19-70	14.63	14.59	976	113.2	8.64	4.21		2.5	.0016	301
6-22-70	14.53	14.50	965	113.0	8.52	4.17		1.9	.0014	261
6-26-70	14.72	14.68	987	113.4	8.70	4.23		2.5	.0016	309
6-29-70	14.58	14.55	970	113.1	8.60	4.20		1.9	.0014	265
7-2-70	14.50	14.48	964	113.0	8.51	4.17		1.3	.0011	205
7-6-70	14.55	14.50	965	113.0	8.52	4.17		3.1	.0018	336
7-10-70	14.85	14.80	995	113.6	8.83	4.27		3.1	.0018	356
7-13-70	14.98	14.90	1009	113.8	9.00	4.33		5.0	.0022	451
7-17-70	14.77	14.72	988	113.5	8.72	4.24		3.1	.0018	350
7-20-70	14.66	14.60	976	113.2	8.64	4.21		3.8	.0020	382
7-24-70	15.18	15.06	1027	114.1	9.03	4.34		7.5	.0027	560
7-27-70	15.28	15.18	1040	114.4	9.12	4.37		6.3	.0025	528
7-31-70	15.24	15.16	1038	114.3	9.05	4.34		5.0	.0022	458
8-1-70	15.00	15.07	1028	114.0	9.03	4.34		4.4	.0021	435
8-7-70	14.68	14.67	987	113.4	8.70	4.23		0.6	.0008	154
8-10-70	14.74	14.70	988	113.4	8.71	4.23		2.5	.0016	310
8-13-70	14.88	14.80	995	113.6	8.83	4.27		5.0	.0022	430
8-17-70	15.02	14.90	1009	113.8	9.00	4.33		7.5	.0027	542
8-21-70	14.82	14.80	995	113.6	8.83	4.27		1.3	.0011	218
8-24-70	14.92	14.86	1006	113.7	8.85	4.28		3.8	.0020	397
8-28-70	15.02	14.94	1013	113.9	8.90	4.30		5.0	.0022	445
8-31-70	14.88	14.80	995	113.6	8.83	4.27		5.0	.0022	435
9-4-70	14.68	14.60	976	113.2	8.64	4.21		5.0	.0022	420
9-8-70	14.55	14.50	965	113.0	8.52	4.17		3.1	.0018	336
9-11-70	14.39	14.35	948	112.7	8.40	4.13		2.5	.0016	290
9-14-70	14.30	14.27	940	112.5	8.35	4.12		1.9	.0014	252
9-18-70	14.40	14.35	948	112.7	8.40	4.13		3.1	.0018	327
9-25-70	14.41	14.36	948	112.7	8.40	4.13		3.1	.0018	329
9-28-70	14.42	14.38	953	112.8	8.66	4.21		2.5	.0016	299
10-2-70	14.50	14.45	960	112.9	8.50	4.17		3.1	.0018	335
10-5-70	14.74	14.69	988	113.4	8.71	4.23		3.1	.0018	350
10-9-70	14.74	14.65	985	113.3	8.70	4.23		5.6	.0024	465
10-12-70	14.67	14.62	976	113.2	8.64	4.21		3.1	.0018	343
10-16-70	14.52	14.50	965	113.0	8.52	4.17		1.3	.0011	205
10-19-70	14.35	14.30	942	112.6	8.36	4.12	0.032	3.1	.0018	324

* REFER TO DEER FENCE STAGE RECORD, THE PEAK OF THE FLOOD OCCURED ON 4-2-70.