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A TEST OF FLUSHING PROCEDURES TO CONTROL SALT-WATER INTRUSION AT THE W. P. FRANKLIN DAM, NEAR FT. MYERS, FLORIDA

by

Durward H. Boggess

U. S. Geological Survey

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INTRODUCTION

During low-flow periods, salty water from the tidal part of the Caloosahatchee River moves upstream during boat lockages at the W. P. Franklin Dam near Ft. Myers, Florida (Fig. 1). Each opening of the downstream sector gates, which separate tidal and fresh water, allows salty water to enter the lock chamber; when the upstream gates open, some of the salty water moves into the upper pool, probably as a density current. Repeated injections of salty water cause a progressive increase in the salinity of the upstream water. The salty water moves upstream within the deeper parts of the river channel as far as 5 or more miles above the lock. Some mixing of the high-chloride deeper water and the fresher shallow water occurs in the affected reach above the lock, probably as a result of wind and waves, and turbulence created by boat traffic.

During extended periods of low-flow, the chloride content of the shallow water increases well beyond the recommended limit of 250 mg/1 (milligrams per liter) for drinking water established by U.S. Public Health Service (1962). For example, near the end of the dry season, in May 1967, the chloride content of river water near the intake structures for the Ft. Myers and Lee County water systems, about 3/4 mile upstream from the lock, was about 500 mg/1. In early March, 1968, the chloride content of river water near the intake structures was about 250 mg/1.

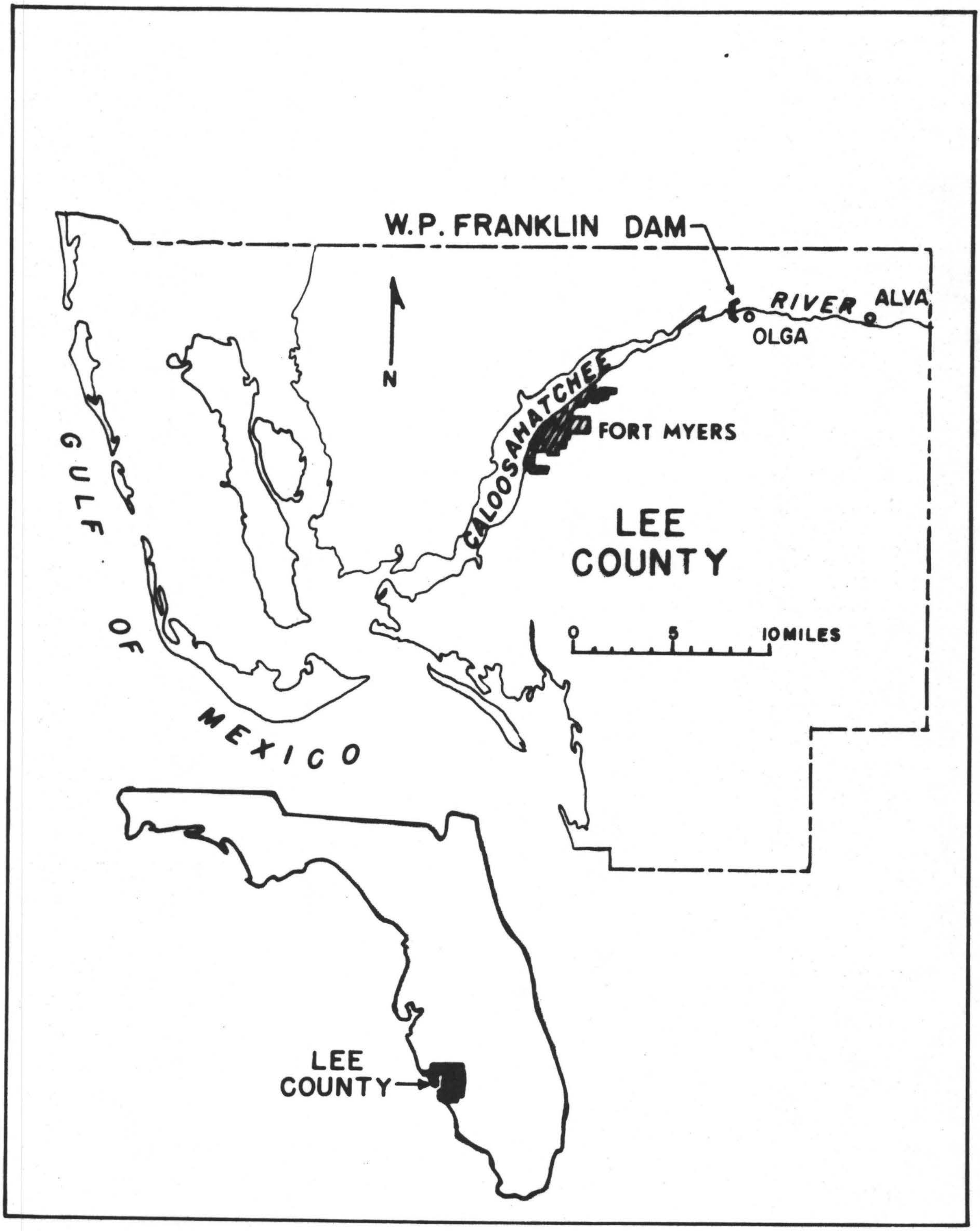

Figure 1.--Map of Lee County, Florida, showing location of W. P. Franklin Dam

The present and planned use of water from the controlled reach of the river for municipal supply purposes, has led to a coordinated effort by federal, state, and local agencies to develop an effective solution to the problem of salt-water intrusion through the lock chamber. Plans were developed for conducting several tests to determine if changes in locking procedures would effectively reduce or eliminate the problem. Testing procedures were agreed upon at a meeting attended by officials of the U.S. Corps of Engineers, the Central and Southern Florida Flood Control District, the United States Geological Survey, Lee County, City of Ft. Myers and consulting engineers for the county and the city. This report was prepared in cooperation with Lee County and the Division of Geology, Florida Board of Conservation.

PROPOSED TESTING PROCEDURES

The following three tests were proposed:

Test 1. - Flushing of salt water from the lock chamber by controlled opening of the downstream sector gates and full opening of the upstream sector gates, prior to lockages.

Test 2. - Performing lockages on a scheduled time basis for all pleasure craft, instead of on signal.

Test 3. - Flushing of salt water from the lock chamber during lockages by controlled opening of both upstream and downstream sector gates.

Because of the anticipated high manpower and equipment requirements needed for conducting test 3, it was believed that the results of test 1 would be of value in establishing these requirements, and would be helpful in determining the necessity for conducting test 3.

A detailed summary of the test conducted on March 5, 1968, is presented here, as are comments concerning proposed tests 2 and 3.

RESULTS OF TEST PROCEDURE NO. 1

Instrumentation

Three conductivity recorders were operated at locations designated as C-1, C-2, and C-3, in figure 2. The cell for each recorder was placed 1 foot above the bottom, at an altitude of 13 feet below mean sea level. In addition, a non-recording conductivity meter was operated at the fire hose station shown as CM-1 on figure 2. The cell for this meter was maintained at 13 feet below mean sea level during most of the test.

Description of the Test

Conductivity and discharge measurements were made during each of the openings of the downstream sector gates of 4, 8, and 6 feet, respectively. A repeat of the 4-foot opening was made after the 6-foot opening, to verify results obtained from the initial 4-foot test. Prior to each opening, salt water was allowed to enter the lock chamber, either as a result of normal lockages, or by opening the downstream lock gates. No attempt was made to stabilize conditions in the lock chamber, only to insure that salt water was present. The upstream lock gates were fully opened before the controlled opening of the downstream lock gates.

Data Collected

Prior to the beginning of the test, and following an overnight period of stabilization, water samples for conductance and chloride analyses were obtained at C-1, C-2, and C-3. This information is summarized in table 1.

Data obtained from C-3 during each of the downstream gate openings are presented in figure 3. Similarly, data from CM-1 are presented in figure 4. For comparison, data obtained from both stations during the 6-foot gate opening are given in figure 5.

Discharge measurements made at the center of the lock chamber during the test are summarized in table 2.

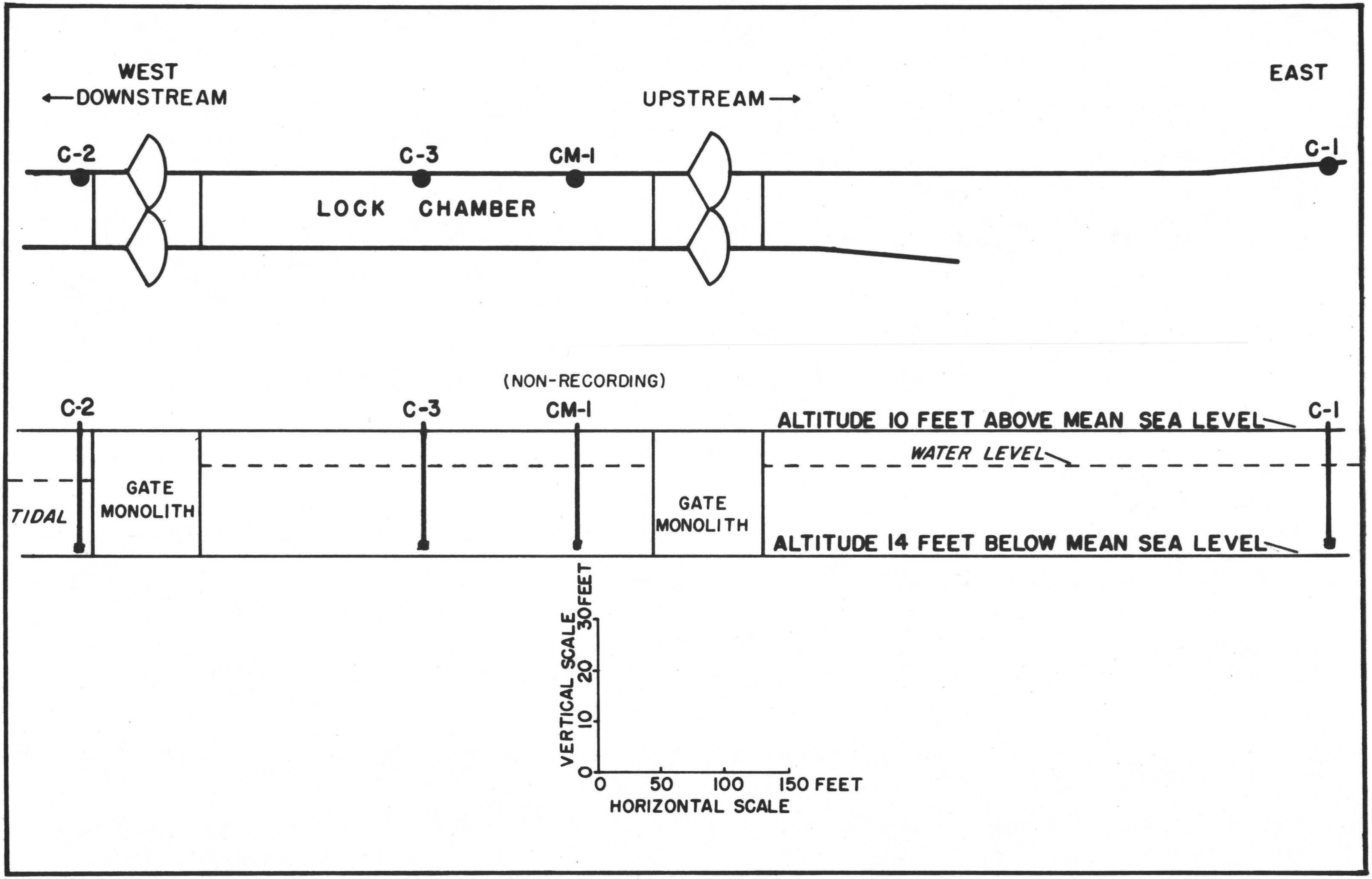

Figure 2. Plan and section views of the lock chamber at the W. P. Franklin Dam, S-79, Caloosahatchee River, showing location of recording and nonrecording instruments.

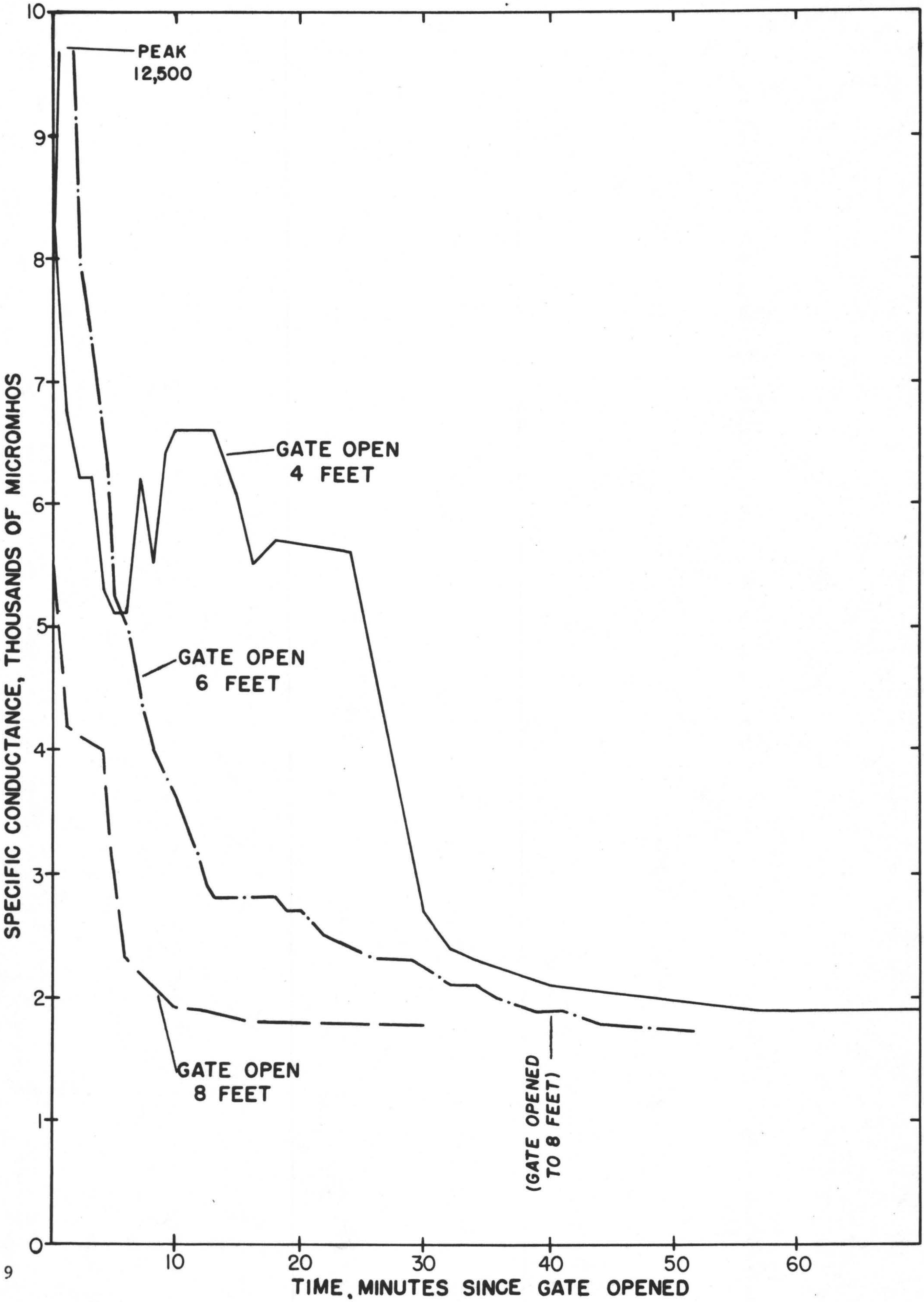

Figure 3. Graph showing variation in specific conductance at C-3 during downstream gate openings of 4, 6, and 8 feet.

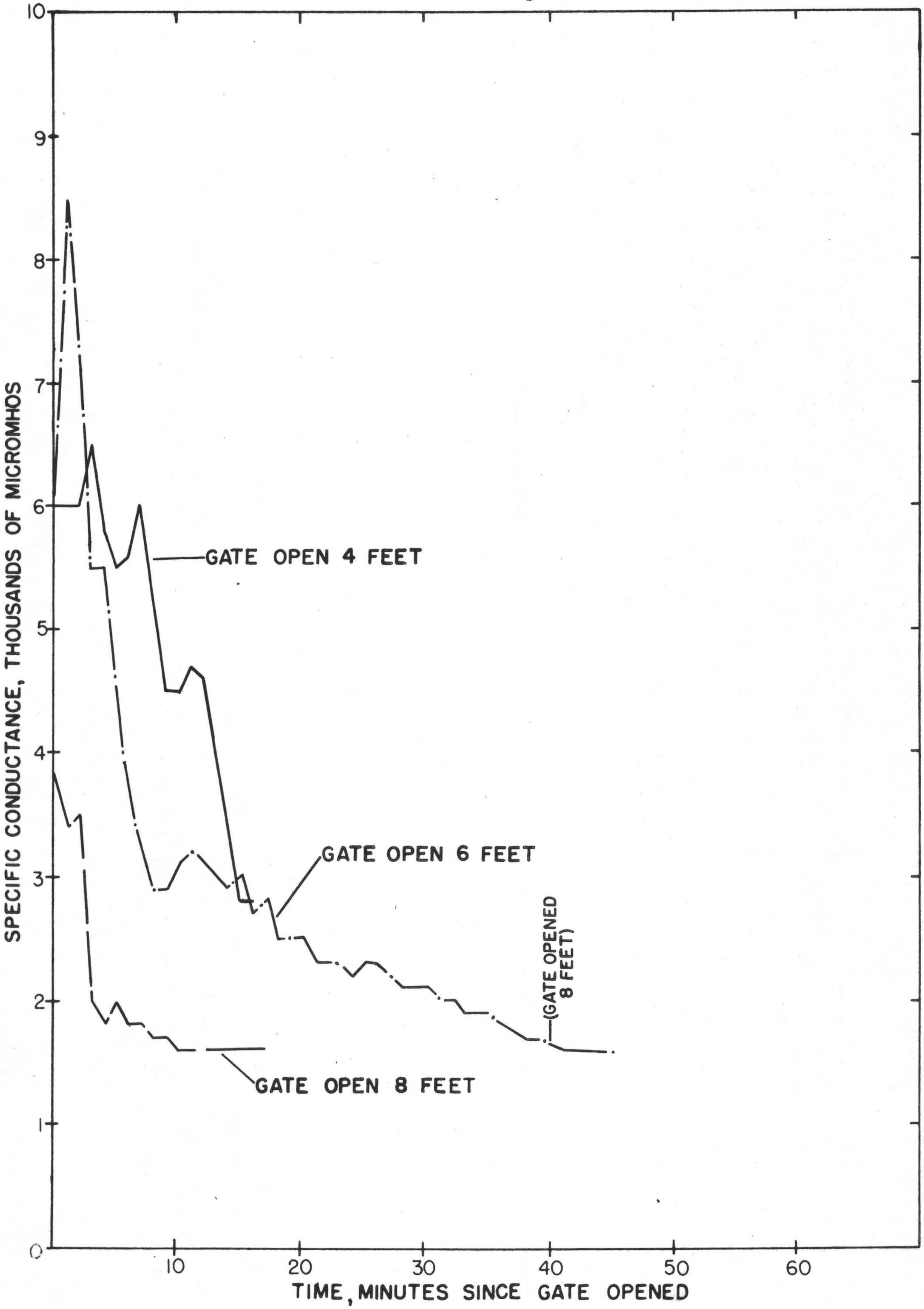

Figure 4. Graph showing variation in specific conductance at CM-1 during downstream gate openings of 4, 6, and 8 feet.

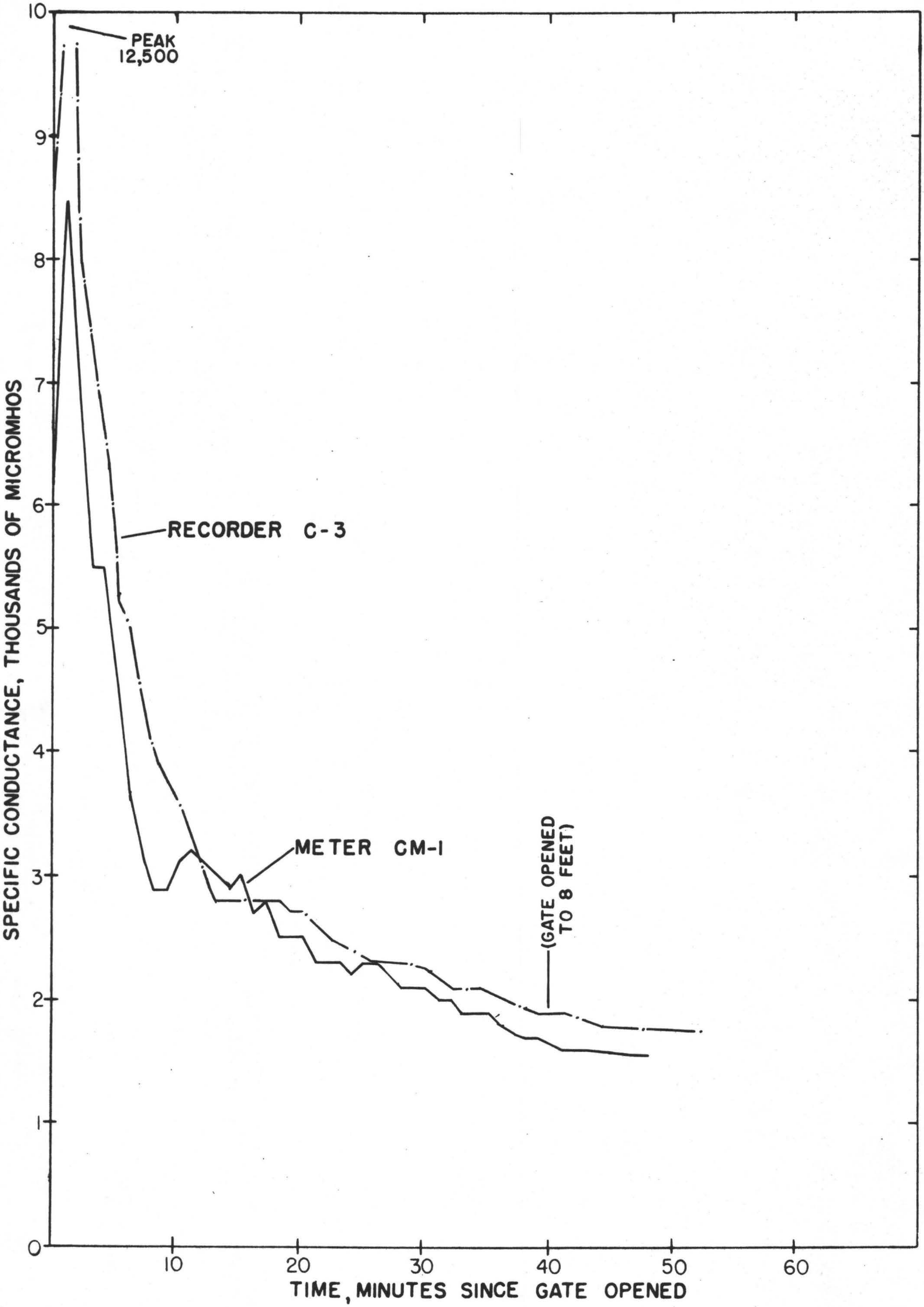

Figure 5. Graph showing variation in specific conductance at Stations C-3 and CM-1 during the 6-foot opening of the downstream gate.

Table 1.--Pre-Test Quality of Water at the W. P. Franklin Dam

Station	Sample depth	Conductance (micromhos)	Chloride mg/1
C-1	Surface	1,600	345
	Bottom	1,600	350
C-2	Surface	10,000	3,640
	Bottom	19,000	7,150
C-3	Surface	--	490
	Bottom	4,400	1,140

Table 2.--Discharges through Locks at W. P. Franklin Dam

Gate opening 1/ (feet)	Head difference (feet)	Discharge cfs	af/min
4	3.6	861	1.19
6	3.6	1,190	1.64
8	3.6	1,510	2.08

Analysis of Data Collected

It appears from figures 2 and 3, that flushing of heavy concentrations of salt water from the lock chamber can be accomplished at each of the gate openings tested. The time, and volume of flushing water required to reduce the conductivity of water at the center of the lock chamber, C-3, to 2000 micromhos (assumed to represent an acceptable value of conductivity under present conditions) is shown on table 3.

1/ Opening at the center of gates. Total opening may be one foot greater because of discharge at sides of gates.

Table 3.--Time and volume of water required to partly flush salty water from lock chamber

Gate opening (feet)	Time (minutes)	Volume[1/] (acre feet)
8	9	19
6	36	59
4	47	56

As indicated by table 3 at the 8-foot gate opening considerably less time and a smaller volume of water was required to accomplish the same flushing action as the smaller gate openings. This suggests that flushing with larger gate openings may be even more effective.

Obviously, additional time and greater volumes of water would be required to completely flush the lock chamber, because the values presented refer to conditions at the center. However, it is estimated that an additional discharge time of 6 to 8 minutes would be needed to completely flush the lock chamber at the 8-foot gate opening. Assuming that the total time would be 15 minutes, then about 31 acre feet of water would be required to flush the lock chamber. At 11 lockages per day (average for Jan.-Feb. 1968), the volume of water needed would be about 340 acre feet, which is equivalent to an average daily discharge rate of about 170 cfs.

Certain other aspects of the problem warrant consideration. Although salt water can be flushed from the lock chamber before each lockage, this does not prevent the reentry of salt water as the downstream sector gates are opened to admit eastbound boats. The reentry of salt water is clearly indicated in figure 6, which shows the sequence of events during an eastbound lockage following the flushing of the lock chamber at the 8-foot gate opening. Salt water reached the center of the lock chamber within 3 minutes of the time that the water level in the chamber reached tide level. This would indicate a rate of movement along the bottom of about 75 feet per minute. In a subsequent measurement between C-3 and CM-1, the rate of movement was about 60 feet per minute.

1/ Assuming head differences similar to those measured during the test.

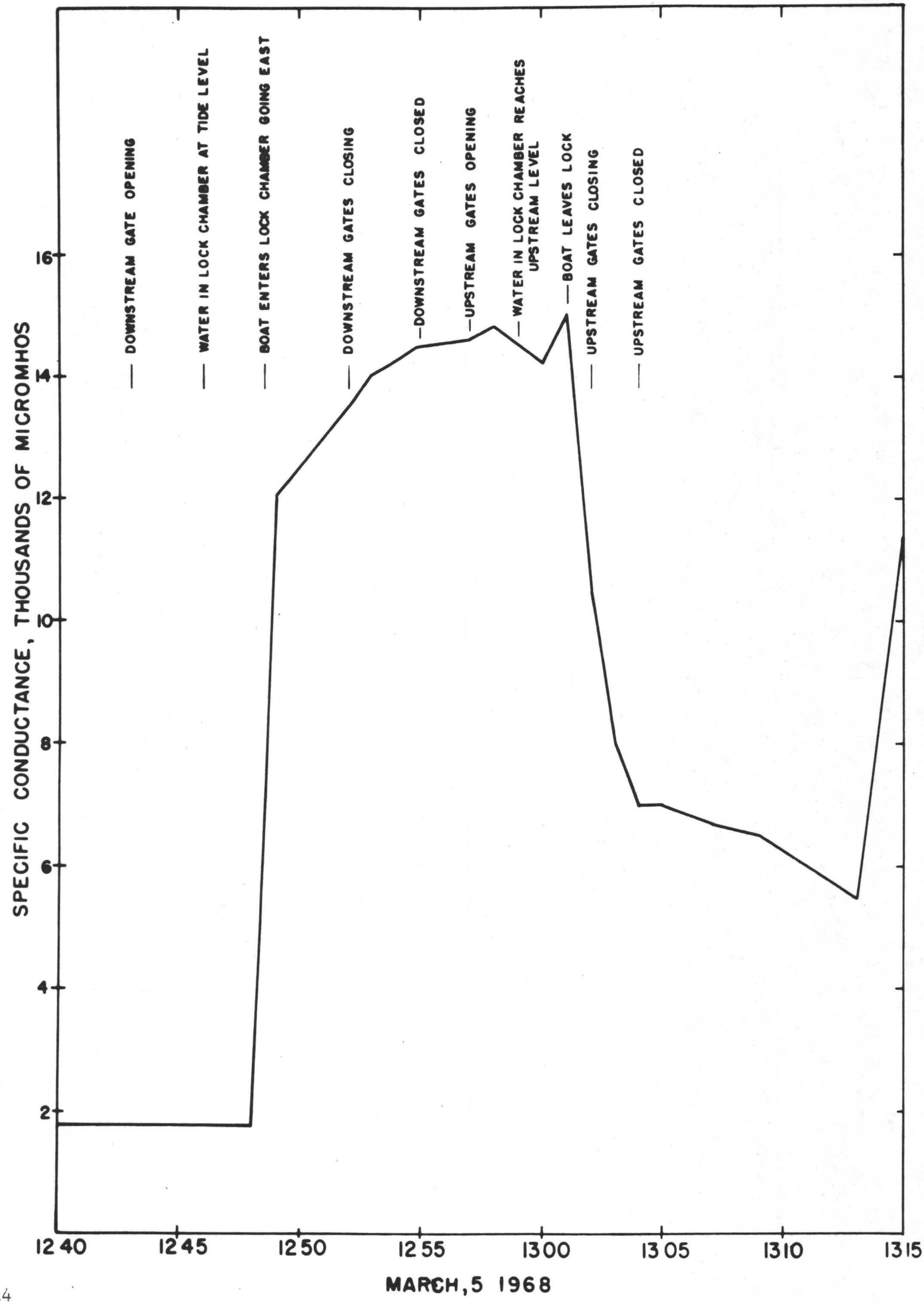

Figure 6. Graph showing the variation in specific conductance at C-3 as related to a series of events.

Opening the upstream gates normally allows salt water to move from the lock chamber into the upper pool where conductivity is recorded at station C-1, as shown in figure 7. Although a precise correlation between peak conductance values at C-1 and lockages does not exist, the general relationship is readily apparent because high values are recorded only after periods of lock operations. The rapid increase and subsequent decrease in conductance values at C-1 indicate that salty water moves to, and beyond the recorder location. The fact that all injections of salty water are not recorded, probably is related to the deeper channel (24 feet below m.s.l.) about 100 feet north of the station which allows some of the salt water to bypass the recorder. Thus, the lower conductance values shown for March, on figure 7, may not be entirely the results of the flushing tests. These conditions should be more carefully evaluated if flushing procedures are to be adopted.

A second aspect of the problem is related to the quality of water available in the upstream reach of the river. As shown in figure 8, the specific conductance of the upstream water is less than 600 micromhos (less than 70 mg/l of chloride) during periods when discharge generally exceeds 400 cfs. Conversely, during extended periods of low discharge, the repeated injections of salty water through the lock chamber causes a progressive increase in base level conductance values. The term "base level" refers to the lowest stabilized conductance values recorded following a series of peak values recorded during the period of lock operation as shown in figure 7.

Although discharge records are not yet available for the period October 1967 through March 1968, it may be inferred from figure 8 that low-flow conditions persisted for several months prior to the test of March 5, 1968.

The base level conductance at that time was 1600 micromhos (about 350 mg/l of chloride) which was considerably higher than that for a comparable period in 1967. If this trend continues over the next several months, the problem of salty water in the reach of the river from which municipal supplies are obtained, will be of greatermagnitude than that in 1967. Although the salinity generally decreases in the upstream direction, contamination was evident at Alva, about 5 miles upstream, where measurements made between February 1, 1968 and April 12, 1968 showed a progressive increase in chlorides from 170 mg/l to 585 mg/l for water in the deeper part of the river.

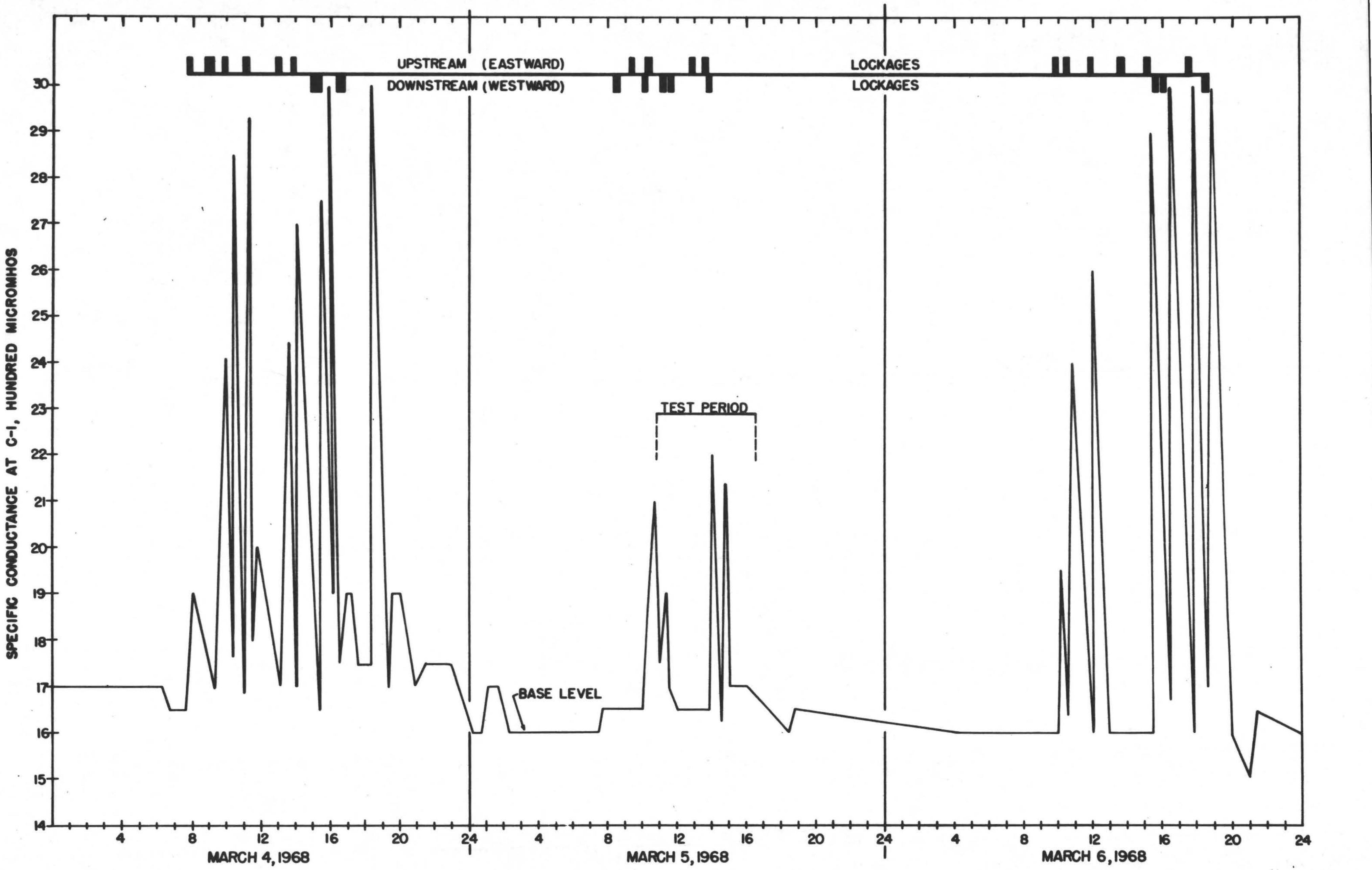

Figure 7. Graph showing the variation in specific conductance at C-1 as related to lockages during the period March 4-6, 1968.

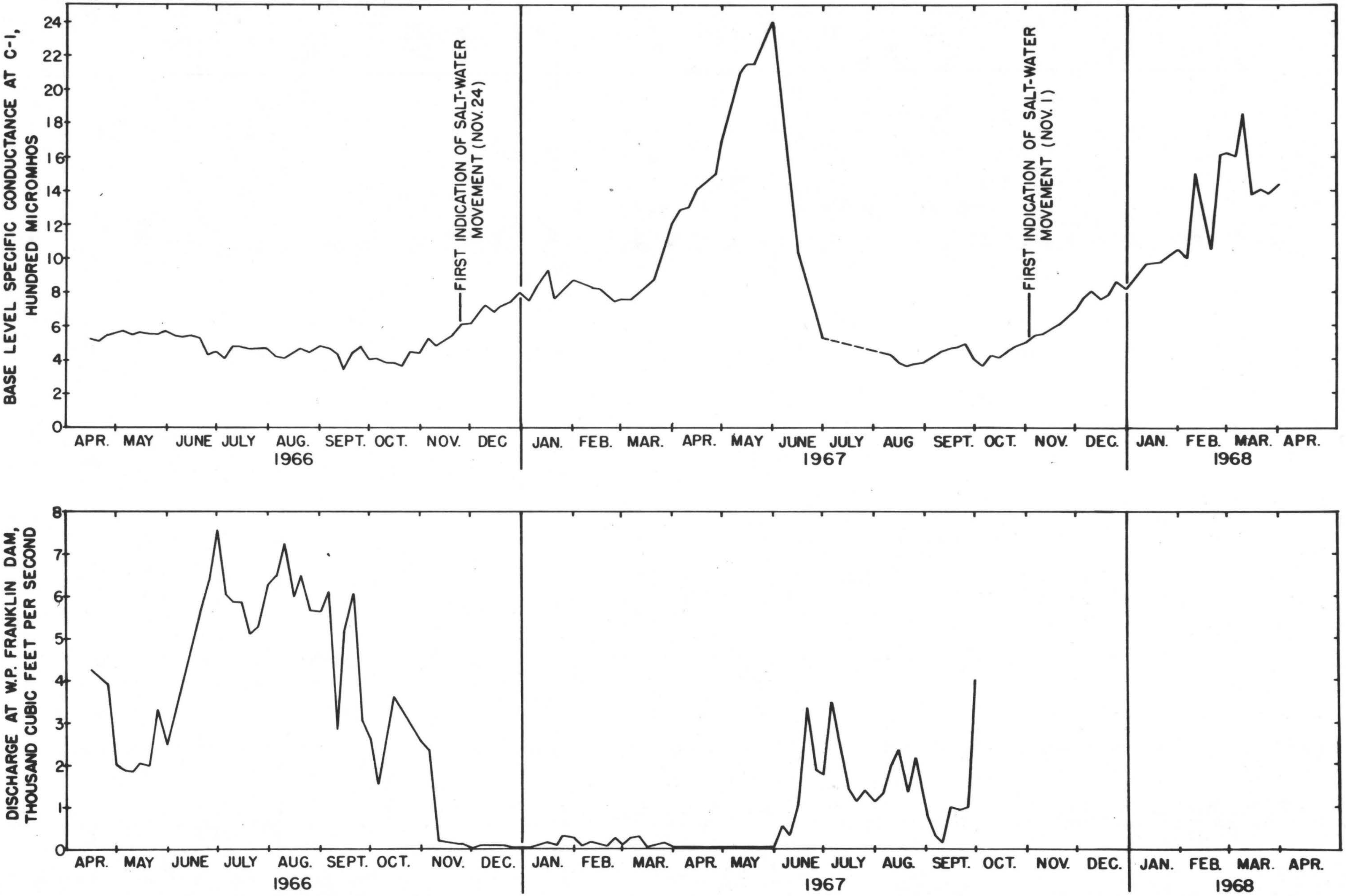

Figure 8. Graph showing variations in base level specific conductance at C-1, 1966-1968 and discharge from the W. P. Franklin Dam, 1966-1967.

The point of the preceding discussion is that the chloride content of the water in the river upstream from the lock had already (March 1968) reached an undesirable level, and that no effective reduction in these values can be expected until sufficient quantities of water are available for flushing the contaminated reach. Inasmuch as the required large quantities of water are not available, corrective action at the present time can be directed only toward preventing further encroachment of salt water.

SUMMARY AND CONCLUSIONS

It has been demonstrated from the results of test 1 that salt water can be flushed from the lock chamber prior to lockages. This can be accomplished at each of the gate openings of 4, 6, and 8 feet. An opening of 8 feet, or more, appears preferable because of the smaller volume of water required and less discharge time involved. An optimum gate opening should be developed by further testing, if this procedure is to be followed. The problem created by the re-entry of salt water into the lock chamber during eastbound lockages, also requires additional study.

Although the flushing procedures may prove effective, it is questionable whether sufficient quantities of water will be available when needed. For example, assuming that the volume of water needed is about 340 acre feet per day (170 cfs), then more than 10,000 acre feet would be required for a 30 day period. The loss of this quantity of water from river storage probably would cause an excessive lowering of the river level. Furthermore, unpublished Geological Survey discharge records from the Franklin Dam indicate a period of 68 consecutive days between March and June 1967, when no water, other than lockage and leakage, was discharged, and an extension of this period to 77 consecutive days when discharge was less than 170 cfs. This long period of low flow may represent near extreme conditions. However, shorter periods of limited discharge on an annual basis appears to be a certainty. Thus, the availability of water required for flushing should be assured if these procedures are to be adopted.

Considering present (1968) salinity conditions, and in view of the available knowledge concerning the upstream movement of salt water, it would be advisable to proceed with test No. 2 (scheduling lockages on a time basis), at the earliest convenient date. This test should be conducted over a period of several weeks, and possibly continued until the end of the dry season, if the procedure indicates significant benefit. The recording instrument at C-1, for which a large amount of background data are available, will be the principal source of information for evaluating the effects of test 2. A second conductivity recorder will be installed between the upstream lock gates and C-1 to provide supplemental information.

The principal objection to procedure in test No. 3 has been the potential danger to boats and boating personnel in moving water through the lock chamber while boats are moored. However, the procedure may have considerable merit in providing a solution to the problem of salt-water reentry during eastbound lockages, as established by test 1. It is suggested that a combination of the procedures followed in test 1, and those proposed in test 3 may be effective in reducing the movement of salty water upstream through the lock chamber.

As indicated in test 1, relatively large downstream gate openings are preferable because of the smaller volume of water and lower time requirements. The high water velocities associated with the large gate openings, would present potential danger to boat traffic if the procedures of test 3 alone were followed. However, a combination of procedures as outlined below, may provide a workable solution.

1. Lockages to the west: Flush lock chamber after each lockage using procedures developed in test 1. This would eliminate intrusion of salt water resulting from west-bound lockages.

2. Lockages to the east: Maintain some flow through lock chamber as boat enters and is secured. Continue discharge through the chamber as upstream gates are opened and boat moves upstream. Repeat flushing procedure as in 1 above.

The feasibility of using these procedures is subject to testing. Some benefit may be derived by selecting gate openings which present little additional hazard to boat traffic, considering the turbulence already created by opening the upstream sector gates while raising the water level in the lock chamber.

It is generally concluded that the quantities of salt water moving upstream can be effectively reduced by adopting changes in locking procedures. Flushing the lock chamber as described in test 1, theoretically could result in a 50 percent reduction, whereas a combination of procedures would be even more effective in controlling salt-water intrusion. Under the present circumstances, it appears unlikely that complete control and prevention of upstream salt water movement can be accomplished from a change in procedures as described; nor does it appear that complete control is entirely necessary if measures are started early in the dry season at the first indications of salt-water intrusion.

REFERENCE

U.S. Public Health Service, 1962, Drinking water standards, Public Health Service, Publication No. 956, p. 7.