Contract Report 533

Effect of Stratton Dam Operation on Flood Control Along the Fox River and Fox Chain of Lakes

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Prepared for the
Illinois Department of Transportation, Division of Water Resources

July 1992

Illinois State Water Survey
Hydrology Division
Champaign, Illinois

A Division of the Illinois Department of Energy and Natural Resources

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Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820-7495

July 1992

ISSN 0733-3927

The body of this report was printed on recycled and recyclable paper

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1. INTRODUCTION

Stratton Dam, formerly McHenry Dam, is the outlet control for the Fox Chain of Lakes, a series of interconnected glacial lakes located along the Fox River in northeastern Illinois. The location of the dam and the Chain of Lakes is shown in figure 1. Stratton Dam is operated by the Illinois Department of Transportation, Division of Water Resources (IDOT-DWR), to both maintain the recreational pool in the Fox Chain of Lakes and provide flood control. Flood damages to the extensive residential and commercial development along both the lakes and the Fox River have created greater interest in improving the effectiveness of the dam operation for providing flood control. Because of the development alongside the Chain of Lakes, the acceptable range of pool levels is small; therefore, the dam's potential to store flood waters is limited. Thus the dam must be operated efficiently for it to minimize flood damage both upstream and downstream.

Over the last 30 years, both IDOT-DWR and the U.S. Army Corps of Engineers, Chicago District have examined alternatives for improving the flood control operation at Stratton Dam. In their 1984 study (USACOE; 1984), the Corps of Engineers advised that additional capacity for controlling flow releases could be created by installing an additional flood gate (called a Foster gate) to the existing outlet facilities at Stratton Dam. The Corps of Engineers also recommended that a second Foster gate be installed downstream at Algonquin Dam.

The two major benefits of the proposed Foster gates, as indicated by the Corps of Engineers, are: 1) modification of the discharge-stage ratings at the dams to reduce the flood stage for a given discharge, and 2) lowering of the stage in the lakes prior to the arrival of a flood to increase the volume that would be available for flood storage. Operation of the gates to achieve these purposes would require a flood forecast system that provides lead-time and sufficiently estimates the magnitude of an approaching flood.

Following the Corps of Engineers recommendation, IDOT-DWR has conducted and sponsored research to more closely examine the flood control benefits provided by the proposed Foster gates. This research has resulted in the development of two models: 1) the Fox River hydrologic model (Knapp et al., 1991), which simulates the rainfall-runoff process in the Fox River watershed; and 2) the Fox River FEQ model (IDOT-DWR, 1991a), an unsteady flow routing model that simulates the flow hydraulics of Stratton Dam, the Fox Chain of Lakes, and the Fox River. The Fox River hydrologic model was also designed to work as the flow forecast model needed for implementation of the early release of storage in the lakes, as recommended by the Corps of Engineers.

The purpose of this study was to use both models to simulate the effect of the Stratton Dam operation, and possible structural modifications such as the addition of Foster gates, on flood stages and discharges in the Fox River and the Fox Chain of Lakes. The hydraulics and hydrology of Stratton Dam, the Fox River, and the Chain of Lakes were simulated for a wide range of historical flooding conditions and potential operation schemes. Responses for many different major flood conditions were analyzed, but two particular aspects of flood control were given special attention: 1) increasing outflow from the lakes in anticipation of a major flood, and 2) facilitating the flow release of the lakes by adding Foster gates at Stratton Dam and downstream at Algonquin Dam. This information will provide the IDOT-DWR with information for implementing possible modifications to the Stratton Dam operation during flood conditions.

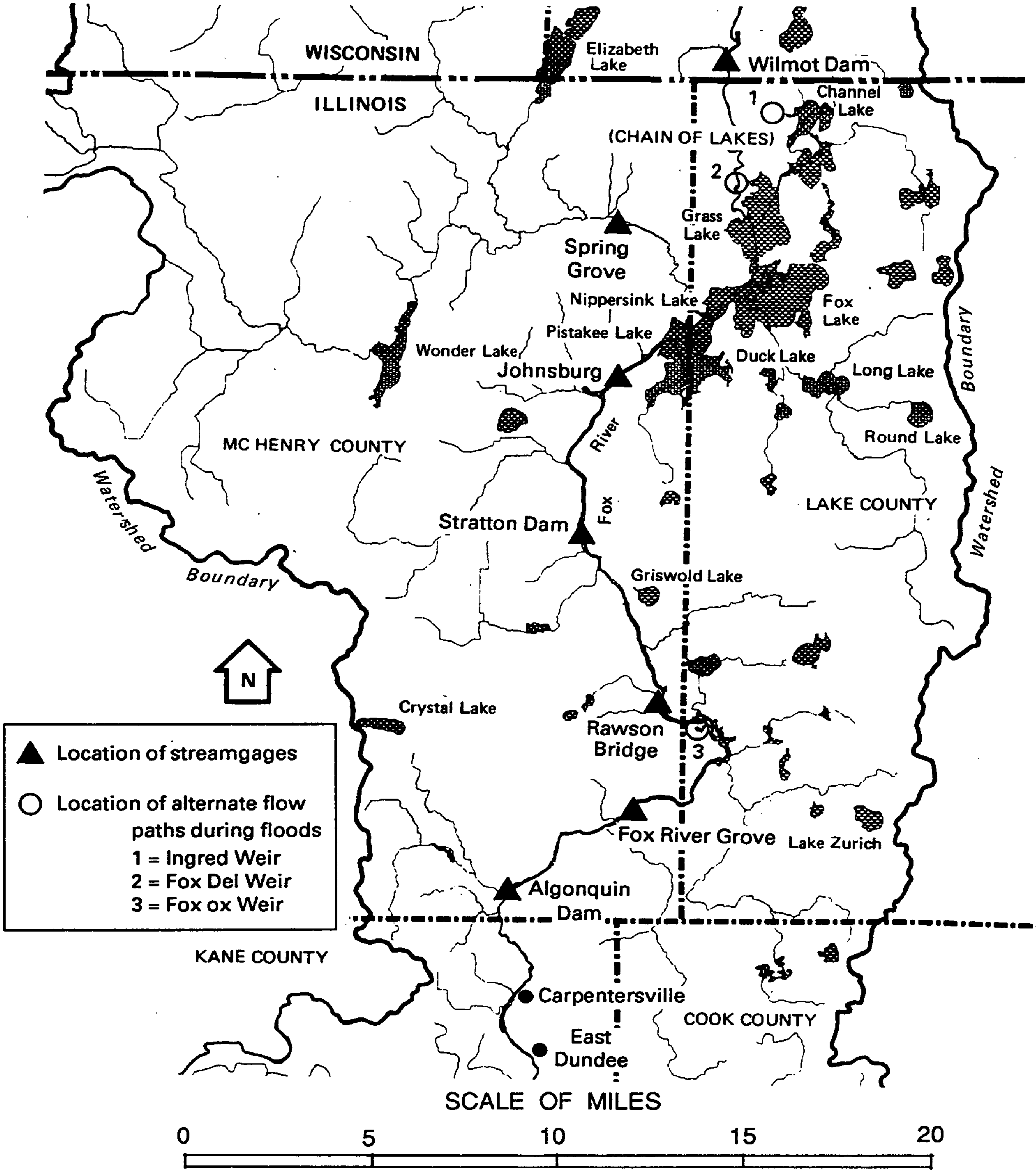

Figure 1. Location of the Fox Chain of Lakes, Stratton Dam, and other sites of interest within the study area

2. DAM OPERATION ALTERNATIVES FOR FLOOD MANAGEMENT

List of Operation Alternatives

The following is a list of the dam operation alternatives that were evaluated in this study for possible use in flood management. The rationale for using these different alternatives is discussed after the list.

Nonstructural Measures

0) Continue to operate the gates in a manner similar to the historical gate operations.
1) Follow the historical operation, but open gates wider during intra-storm periods whenever stages in the Chain of Lakes exceed the normal pool level by over 0.5 foot. [The normal pool level is approximately 737.00 feet except in winter, when it is lowered approximately 1.5 feet.] Differences in the historical operation of the selected floods are discussed in the following section.
2) Follow the historical operation, but instead of limiting the maximum gate setting to 4 feet, open the gates wide to provide maximum available outflow.
3) Open the existing gates <u>prior</u> <u>to</u> the flood, using the flow forecast model to estimate inflow (maximum gate opening of 4 feet).
4) Open the existing gates wide <u>prior</u> <u>to</u> the flood to provide maximum outflow, using the flow forecast model to estimate inflow.
5) Follow alternative 4 <u>and</u> raise the winter pool to the level of the recreational pool.

Structural Measures

6) Add a Foster gate at Algonquin Dam. Operate the gate conjunctively with alternative 4, opening the Foster gate when sluice gates are fully opened.
7) Add a Foster gate at Stratton Dam. Operate the gate conjunctively with alternative 4, opening the Foster gate when sluice gates are fully opened.
8) Add Foster gates at both Stratton and Algonquin Dams. Operate the gates conjunctively with alternative 4, opening the Foster gates when sluice gates are fully opened.
9) Add Foster gates at both Stratton and Algonquin Dams, following alternative 8, <u>and</u> raise the winter pool to the level of the recreational pool.
10) Modify the opening of the railroad bridge that crosses the Chain of Lakes adjacent to U.S. Highway 12, and operate using alternative #4.

In addition to these eleven operation alternatives, simulations were also conducted for two scenarios:

Scenario **ND** (No Dam), representing the hypothetical flow conditions that would occur if Stratton Dam were removed.

Scenario **NG** (No Gates), representing the flow conditions if the Stratton Dam sluice gates were fully closed and the only outflow was the uncontrolled flow that occurred over the existing spillway.

Rationale for Selecting Operation Alternatives

One of the major purposes in conducting this study was to further analyze the hydrology and hydraulics of the recommended plan given in the Corps of Engineers study (1984). This recommendation called, in part, for the installation of Foster gates in the existing spillways of Stratton and Algonquin Dams. The recommended project assumed that the Foster gates were to be fully opened during the storm event, and that the existing sluice gates were kept opened to their maximum. Alternative 8 simulates the gate operations associated with this plan. Other plans examined by the Corps of Engineers include the installation of a Foster gate solely at McHenry (Alternative 7) and solely at Algonquin (Alternative 6). The alternative 6 plan, as evaluated by the Corps of Engineers, did not produce an acceptable benefit-to-cost ratio but was included in the present study to help understand the individual effects of each Foster gate.

Two major purposes of the proposed Foster gates are the modification of the rating curve at Stratton Dam, and lowering of the stage in the lakes prior to the arrival of a flood. Alternatives 1,2,3, and 4 examine to what extent the existing sluice gates may be used to achieve these purposes. The strategies employed in these alternatives include opening the gates earlier, opening the gates wider, or a combination thereof. Flow forecasting plays an integral role in alternatives 3 and 4, as it also does with alternatives 6, 7, and 8.

The operating policy for Stratton Dam includes a seasonal change in the pool level between winter and summer. The winter pool level is typically 1.5 feet below the normal recreational pool level. The practice of lowering the lake level during winter has been questioned because the decreased water level may adversely effect the aquatic life in the lakes (NIPC, 1992). A potential change in policy could result in maintaining the normal recreational pool level year-round. Alternatives 5 and 9 were included to simulate flood control conditions associated with such a policy change.

Simulations from the FEQ unsteady flow model indicate a noticeable drop in flood stage in the Chain of Lakes between Nippersink Lake and Pistakee Lake. It was observed that the existing Chicago Milwaukee & St. Paul Railroad bridge constricts the flow between these lakes. Alternative 10 simulates the flood control impacts of modifying the bridge opening to reduce the constriction. There is no examination of the economic viability of alternative 10.

Scenarios ND and NG are not considered as feasible alternatives for dam operation, but were evaluated because their simulations present the absolute minimum and maximum flood stages that could occur at Stratton Dam without considerable modification of the river/lake system.

3. FLOOD EVENTS SELECTED FOR THE SIMULATION ANALYSIS

Eight historical floods occurring on the Chain of Lakes and Fox River were chosen for simulation with the FEQ model. The selected floods were the annual maximum floods for 1960, 1972, 1973, 1974, 1978, 1979, 1982, and 1986. Criteria used to select the floods were: 1) the magnitude of the flooding [most of the selected events are major floods but two minor floods, 1978 and 1982, were also included]; 2) the character of the flood in terms of seasonal effects, meteorologic factors, and antecedent conditions; and 3) the availability of precipitation and streamgage information for replicating the storm events.

Magnitude of Flooding

Table 1 lists the ten most severe floods that have occurred on the Chain of Lakes since Stratton Dam (formerly McHenry Dam) was reconstructed in 1939. The ranking of floods is based primarily on the peak stage recorded on the Chain of Lakes. The peak stage at Channel Lake is used in table 1 as an indicator of the relative stages on the other lakes. The 1979 flood is ranked higher than the 1986 flood, even though its peak stage was not quite as high, because the antecedent storage in the lakes was considerably lower and the resulting downstream discharges were higher. The recurrence interval is estimated from the rank of the flood (m) divided by the number of years of record (N) as follows:

$$\text{Recurrence Interval} = m / (N + 1)$$

Six of the ten most severe floods (those indicated by an asterisk in table 1) were chosen for use in the simulation analysis. The recurrence intervals of these six floods ranges from 5 years to over 50 years. Also selected for simulation were two floods, 1978 and 1982, that represent “average” conditions. The recurrence interval of these two floods is estimated to be 1.7 and 2.3 years, respectively.

Table 1. Ranking of the Major Floods on the Fox Chain of Lakes

Year	*Rank*	*Peak stage at Channel Lake (ft)*	*Peak discharge at Algonquin (cfs)*	*Recurrence interval (years)*
1960*	#1	741.32	6610	52.0
1979*	#2	740.69	6610	26.0
1986*	#3	740.70	6170	17.3
1973*	#4	740.55	5750	13.0
1948	#5	740.44	4680	10.4
1962	#6	740.37	4870	8.7
1974*	#7	740.05	5310	7.4
1983	#8	739.89	5160	6.5
1952	#9	739.94	4400	5.8
1972*	#10	739.79	4700	5.2
1982*		738.91	4040	2.3
1978*		738.44	3210	1.7

Note: * Floods chosen for the simulation analysis

Antecedent Conditions and Seasonal/Meteorologic Factors Leading to Flooding

Most flooding events on the Chain of Lakes occur in spring (March and April) as the result of spring thaw, snowmelt, a series of spring rainfalls, or a combination thereof. A much smaller group of major flood events have occurred in summer (June through September), and are generally caused by the composite effect of several intense storms. The set of flood events used for the simulation analysis was chosen to include floods having a variety of different causes. The following paragraphs briefly describe the conditions leading to each of the floods being evaluated.

Summer Floods (1972, 1978, and 1986)

The 1972, 1978, and 1986 floods occurred in mid- to late summer. Both the 1972 and 1986 floods were caused by a series of large rainfall events occurring over a span of 5 to 10 days. The total 5-day rainfall over the watershed in 1986 exceeded 5 inches, and the total 10-day rainfall in 1972 exceeded 7 inches. Major flooding on the Chain of Lakes is not usually caused by single-storm events. In 1978 the annual peak flood was caused by a single storm having an average watershed rainfall in excess of 3 inches. However, this storm produced only minor flooding having a recurrence interval of less than 2 years.

Spring Floods Caused by a Series of Moderate Rainfall Events (1973)

Because the drainage in the Fox River watershed and out of the Chain of Lakes is relatively slow, a period of above-normal rainfall can result in high antecedent streamflow and lake stage. At this point, any moderately sized storm can produce a major flood. Throughout the early part of April 1973, light periodic rainfall kept inflows to the Chain of Lakes continually high and levels in the Chain of Lakes rose to over 738.00 feet -- even though the gates at Stratton Dam were kept at a fairly wide opening (3.0 feet) to allow high outflow. A 2-inch rainfall during the three-day period, April 20-22, produced the major flooding.

Floods Caused by the Spring Thaw (1974)

Above-normal temperatures in early spring, which result in thawing of frozen ground, lakes, and streams, can often by themselves cause significant flooding along the Fox River. The flood of 1974 is an extreme example of the effect of the spring thaw. In the first two months of 1974, above-normal precipitation produced high antecedent soil moisture and surface storage in the watershed, though there was little accumulation of snow. Then, for a six-day period in early March, temperatures were much above normal, averaging over 50ºF, and having a peak temperature of 72°F. The precipitation total for this period was about 1 inch, but the amount for any one day never exceeded 0.4 inches.

Floods Caused by a Combination of Snowmelt, Spring Thaw, and Rain (1960, 1979, and 1982)

The 1960 and 1979 floods are the two largest floods on record along the Fox River. Both floods are similar in that the primary source of flooding was snowmelt and the spring thaw. In addition, this flooding was augmented by a l-inch rainfall. In March 1960, the average snow depth over the watershed was 12 inches when above-freezing temperatures occurred. The snowmelt and ground thaw alone would have produced a major flood, but an additional 1.3 inches of rain occurred as streamflows were reaching flood stage. In 1979, the peak flood stage resulting from snowmelt and minor rainfall had just been exceeded when an additional l-inch rainfall occurred over the watershed. This rainfall produced a second peak, of similar magnitude, five days after the first peak.

Precipitation and Streamflow Gage Records

Precipitation Records -- Input for the Fox River Hydrologic Model

The Fox River hydrologic model (FRH model) was developed in a previous study (Knapp et al., 1991) and was used for two aspects of the present study. First, the model estimated flow hydrographs for each of the ungaged tributaries of the Fox River upstream of South Elgin; these hydrographs were used as input into the FEQ model for simulating-the flood. For its second use, the FRH model was modified into a *flow forecast model* to produce flow forecasts using near real-time data and, as an option, to employ precipitation prognoses. The flow forecast model was then used to estimate a "pseudo-forecast" for each historical flood being analyzed, i.e., the forecast that would have been available on a near real-time basis for these historical floods. The pseudo-forecast was used to aid decisions on how the existing and proposed gates would have been operated for each alternative.

There are 16 precipitation gages in and near the Fox River watershed. However, presently only six of these gages (Antioch, Burlington, Germantown, Lake Geneva, Marengo, and Waukesha) report on a near real-time basis, which is needed for use in applying the flow forecast model. These six gages were used in developing the pseudo-forecasts so that the gate openings used to develop the simulated conditions most closely match the present operating conditions.

Increasing the number of gages that provide near real-time information will likely result in a more accurate forecast of the Fox River flows. It is recommended that this potential forecast improvement be evaluated and, if warranted, additional raingages in the Fox watershed be installed or modified to provide near real-time information. A reduction in the forecast accuracy, caused by using a limited number of precipitation gages, could affect gate operation and would increase the likelihood that an undesirable gate operation will be employed. Undesirable gate operations are further examined in Section 4: Use of the Flow Forecast Model in Gate Operation.

Input for FEQ

Inflow conditions for these floods were replicated using both streamgage records and the simulated flows from the FRH model. The two streamgages that provided data for flows entering the Fox Chain of Lakes are located on the Fox River at Wilmot and Nippersink Creek near Spring Grove. The periods of record at these two gages are 1939-1990 and 1966-1990, respectively. The inflow for Nippersink Creek during the 1960 flood (the only selected flood not recorded at this station) was simulated using the FRH model. Inflows from all other tributaries along the Fox River down to South Elgin were also simulated using the FRH model. The input hydrographs for the FEQ model are discussed further in Section 5: Calibration and Validation of the FEQ Unsteady Flow Model.

Differences in Historical Gate Operation Practices

Over the last 30 years, the decisions for operating Stratton Dam during flood conditions have varied. The change in operation practices that has resulted in the largest difference in flood stages and discharges is the maximum opening to which the sluice gates are raised. During most of the selected floods, the sluice gates at Stratton Dam were raised to provide a maximum opening of 4 feet (see table 2). However, the maximum gate openings for the 1960 and 1972 floods were 2.4 feet and 3.0 feet, respectively. These smaller gate openings caused the upstream lake levels during these floods to be relatively greater in comparison to the other historical floods. The impact of the different gate openings on flood stage and discharge is presented in Section 6: Model Results.

There are also differences between historical floods in how soon the gates were raised in response to advancing flood conditions. For a number of earlier floods (1960, 1972, 1978, and 1979), the gates were not raised significantly until after high stages had developed at Stratton Dam. In more recent years, however, the gate operation has attempted to anticipate the rising floodwaters. For example, the discharge record for Nippersink Creek near Spring Grove is presently used as an indicator of the likely inflow conditions for the Fox River. Because the Nippersink Creek hydrologic response precedes the Fox River response, action can be taken before a significant portion of the floodwaters arrive. A description of the historical gate operation for each flood is given in table 2.

The differences in the characteristics of each of the floods and their antecedent conditions make it virtually impossible to develop an “historical operation scenario” that is completely consistent between floods. For the selected floods, there is generally a one or two day difference in the timing for opening the gates to their maximum height [such as between 1) opening when Nippersink Creek displays high flow and 2) opening after the stage in the lakes has risen]. But the timing differences between the historical floods do not have a significant impact on the resulting peak stages and discharges. A simulation analysis of both the 1960 and 1986 floods, conducted using the FEQ model (and presented in Section 6: Model Results), indicates that a two-day difference in the response time for these floods would have created no more than a 0.06 foot change in the peak stage at any point on the Chain of Lakes or Fox River. These changes in stage are generally small compared to the differences created by the various operation alternatives examined in this study.

Table 2. Maximum Gate Opening and General Description of Historical Gate Operation during Selected Flood Events

Year	*Maximum gate opening (feet)*	*Description of operation*
1960	2.4	gates open to maximum after stage has risen
1972	3.0	gates open to maximum after stage has risen
1973	4.0	gates already open to 3.0 feet, opened to maximum after heavy rain
1974	4.0	gates already opened to maximum prior to flood
1978	3.5	gates open to maximum after stage has risen
1979	4.0	gates open as the stage rises
1982	4.2	gates open to maximum as stage rises
1986	4.0	gates open to maximum when Nippersink Creek displays high flow

4. Use of the Flow Forecast Model for Gate Operation

To simulate the effects that various operation alternatives would have had on historical floods, it was necessary to replicate the real-time decisions that would have been made for dam operation during those floods. To make an operating decision for any day during these historical floods this it is necessary to have : 1) knowledge of the antecedent streamflow and lake conditions occurring that day, 2) an estimate of the flow forecast that would have been available on that day, and 3) a recommended policy for operating the dams for each alternative, which is based on the antecedent conditions and forecast data.

Development of a recommended policy for alternatives 0, 1, and 2 was not necessary since they basically follow historical gate operation practices, with minor variations.

Deciding When and How Much to Open the Sluice Gates and Foster Gates

Operation alternatives 3-10 must employ a flow forecast so that the gates at Stratton Dam (and possibly Algonquin Dam) can be opened prior to the arrival of most of the floodwaters. For this, it is necessary to have a policy to decide under what conditions the gates will be opened. The ability of the floodgate operation to lower the stages in the Chain of Lakes depend upon how soon ahead of the flood the gates are opened, and how wide the gates are opened.

Timing of Response

The following list provides several possible scenarios of the timing for opening up the gates.

a) Open gates based on the flow forecasts using the 48-hour quantitative precipitation forecast (QPF) and the 5-day temperature prognoses.

b) Open gates based on the flow forecast using real-time (or near real-time) rainfall amounts from the existing or improved raingage network.

c) Open gates when flows observed at the Nippersink Creek streamgage indicate flooding. This is the method presently used for Stratton Dam operation during floods.

d) Opening of gates when the stage at McHenry Dam rises. This information provides the most certain knowledge of flooding, yet provides no time to use flood storage.

In the first two scenarios, flow forecasting plays and integral role in dam operation. As the scenarios progress, the operators have increasingly more accurate knowledge of the volume and peak of oncoming flood flows, yet the available time with which to respond to the flow event decreases. Since the reduction the pool level in the Chain of Lakes takes time, the earlier responses will have the greatest flood-control benefit.

The 48-hour QPFs could be used to provide a one-day advance prediction of potential flow conditions. But, though the QPFs provide valuable information on precipitation potential, they are generally poor in forecasting the actual amount of areal rainfall. Thus the flow forecasts based on the QPFs would likely have considerable uncertainty. There is a concern that operation problems would occur if the predicted rainfall did not arrive. Simulations indicate that there is only a moderate flood benefit in having this one-day advance warning (see Section 6: Model Results). For this reason, scenario b was used in developing the operation policy for the simulation analysis. In addition, the 5-day temperature prognoses are extremely important for anticipating snowmelt events, and were used for that purpose.

Flow Releases

In the simulation studies, the pool level is reduced by opening the gates to one of two target discharge levels: 1) 1800 cfs, which the maximum discharge for which no-wake conditions can be maintained, and 2) up to 3000 cfs which is the maximum discharge without overbank flooding. At the recreational pool level (737.00 feet), the 1800 cfs discharge is achieved by opening the sluice gates to a setting of 2.5 feet. When the stage at Stratton Dam is over one foot below the recreational pool level, and gate opening of 3.0 feet may be required. The second discharge level (3000 cfs) is achieved at normal pool level when all gates (including the potential Foster gate) are opened wide.

The criteria for opening the gates to release 3000 cfs, described below, requires relatively certain knowledge that severe (overbank) flooding is approaching the Chain of Lakes. Releases from Stratton Dam are allowed to exceed the target discharges when high stages in the lakes cause increasing amounts of uncontrolled flow over the Stratton Dam spillway.

Flood Control Policy Used for Simulations

The following policy was chosen after analyzing: 1) the simulated impacts of using various operation alternatives, 2) expected relationships between the flow forecasts and associated observed flows, and 3) the frequency at which the policy will be employed.

This flood control policy is designed so that the operation of the Stratton Dam gates does not directly induce flooding downstream except when the flow forecast model indicates the approach of extremely high flows (in which case the occurrence of downstream flooding is almost certain). For lesser events, the policy keeps Stratton Dam gate openings at a level (2.5 feet) that will allow no-wake flow conditions to continue, until that time when increasing stages at Stratton Dam create sufficient uncontrolled flow over the spillway, thereby causing the total release exceed the maximum no-wake flow.

During high flows and flood events it is not always possible to maintain the normal pool level both on the Chain of Lakes and at Stratton Dam. For these times, the operating criteria are based on stages observed on the Chain of Lakes, not at Stratton Dam. The decision to shift the stage control upstream to the lakes is consistent with a recommendation given in the Corps of Engineers study (USACOE, 1984).

Criteria for Opening the Sluice Gates and Foster Gates, Used for Simulation of Operation Alternatives

1. With the stage in the upper Chain of Lakes[a] at or near its normal pool level[b] (be it the winter or summer level), use the following response:

Inflow Forecast[c]	Response
< 1800 cfs	Continue normal gate operation to maintain lake levels.
> 1800 cfs	Adjust sluice gates in response to increases in the stage at Stratton Dam. Gate openings should not exceed 2.5 feet (3.0 feet during winter pool conditions).

> 3000 cfs	Immediately open sluice gates to 2.5 feet (if not already open this far). This opening should provide the maximum flow which does not exceed no wake conditions (1800 cfs). If the headwater stage at Stratton Dam falls, or at times of winter pool, the gates may be opened further to 3.0 feet to maintain this 1800 cfs discharge. If stages continue to rise, do not open gates further until either criterion 3 or 4 is met.
> 6000 cfs	Immediately open sluice gates to the maximum setting and open Foster gates. Maximum setting for the sluice gates is restricted only in alternative 3. Foster gates are fully open whenever in use.

2. Under normal operating conditions, when the stage in the upper Chain of Lakes[a] exceeds 0.5 foot above the normal pool level[b], open the sluice gates sufficiently to reduce the pool level (up to an opening of 2.5 feet).

3. For every 0.5-foot increment that the stage in the upper Chain of Lakes[a] exceeds the normal pool level[b], reduce the forecast flow quantity needed to fully open the sluice gates and Foster gates by 500 cfs.

4. If the stage in the upper Chain of Lakes[a] exceeds 738.50 feet and the forecasted flow exceeds 3000 cfs, fully open the sluice gates and Foster gates. [This elevation was selected because, at this stage, the outflow from Stratton Dam will already be causing overbank flooding on the Fox River.]

5. Following a flood event during which the sluice gates have been fully opened, the stages in the Chain of Lakes should be returned to the normal pool as soon as possible. It is recommended that the sluice gate setting be lowered to 2.5 feet (and Foster gates closed) only when the stage in the upper Chain of Lakes[a] falls to within 0.5 foot of the normal pool level[b]. Following that gate closure, continue to lower the stage in the upper Chain of Lakes to normal pool, if possible. This prompt return of lake levels to normal pool is consistent with a recommendation given in the Corps of Engineers study (USACOE, 1984).

Notes:

[a] Includes Nippersink Lake and all lakes further upstream. The stages of the “upper lakes” are similar for most conditions. The stage at Channel Lake is used as a representative value.

[b] The recreational pool (summer pool) is normally 2 or 3 inches above the crest of the Stratton Dam spillway. For the simulation analysis, an elevation of 737.00 feet was used for the recreational pool of the upper lakes. During the winter period, the pool level of the upper lakes is normally kept near 735.50 feet.

[c] The inflow forecast for the Fox Chain of Lakes is computed by adding all of the inflow hydrographs for streams entering the Chain of Lakes and Fox River upstream of Stratton Dam with the net lake precipitation. The maximum daily discharge of the forecasted inflow hydrograph is used for decision making.

Frequency at Which Gates Would Be Opened

Table 3 lists all of the major and minor flood events in the Chain of Lakes over the period 1972-1990. For each flood, column 4 indicates if the gates would be opened to their maximum setting (and the Foster gates utilized) following the policy described above. Under this policy, the gates would be opened to their maximum setting 16 times in the 19-year period, or less than once per year. Of these 16 openings, 14 occur as early releases prior to the arrival of floodwaters, and 2 occur for other floods when the Channel Lake stage exceeds 738.50 feet. Eight of the 16 openings occur during winter pool conditions (November to mid-March).

Probability of Opening Gates at Undesirable Times

The flow forecast model provides only an estimate of oncoming flow conditions based on the available near real-time precipitation and air temperature measurements. Limited precipitation data and errors in the forecast model may result in an underestimation or overestimation of the actual flow that will occur.

Underestimation of Floods

In a case where a major flood is underestimated, the gates will not be opened prior to the flood. A full opening of the gates would be delayed until the flood stage reached a critical level (738.50 feet in the recommended flood control policy), and any advantages of opening the gates early could not be realized. Examples of underestimated floods, given in table 3, are the February 1985 and March 1986 events. The peak stage in Channel Lake for these two floods was 739.01 and 738.84 feet, respectively.

Overestimation of Floods

In a case where a flood is overestimated, opening the gates early may produce a higher flow downstream than would otherwise have occurred if no early response had been taken. Two floods given in table 3 are sufficiently overestimated to cause such an opening of the gates: April 26, 1976 and July 1, 1978. The frequency of this type of occurrence is estimated as the number of undesirable openings divided by the total number of years analyzed:

Frequency of severe overestimation = 2 occurrences/19 years = 0.105

For both the 1976 and 1978 events, the gates would have been opened for flood events that did not reach a stage of 738.5 feet at Stratton Dam. These floods would not have produced overbank flooding downstream of the dam. The impact of opening the gates early in the July 1978 event is examined in Section 6: Model Results.

The tendency of the flow forecast model to overestimate inflow is greatest for storms in which the quantity of rainfall has a large spatial variance. This more commonly happens with summer storms. [For example, in the July 1978 storm, the rainfall measured at the Marengo precipitation gage was 4.9 inches while that measured at most of the other raingages in the watershed was approximately 2.5 inches.] Thus it is advised that the rainfall input into the flow forecast model for spatially variable storms be based on as many near real-time measurements as possible and, as best as possible, represent the average watershed rainfall.

Table 3. Recommended Operation for Opening Foster Gates and Sluice Gates for Historical Floods at Stratton Dam, 1972 - 1990

Date of forecast	*Forecasted flow (cfs)*	*Antecedent stage (ft)*	*Decision to fully open gates (Y/N)*	*Historical peak stage (ft)*
Sept.17,1972	6120 (7300)*	738.15	Y	739.47
Mar.11,1973	4760	737.12	N	738.49
Apr.22,1973	5318 (6187)*	738.30	Y	740.55
Dec.7,1973	4400	737.18	N	737.47
Jan.26,1974	4740	737.18	Y	738.87
Mar.5,1974	4700	738.80	Y (already open)	740.04
May17,1974	5700	738.52	Y	739.46
Mar.22, 1975	4840	737.60	N	738.56
Mar.5,1976	11360	738.17	Y	739.48
Apr.26,1976	6900	737.95	Y	738.39
Mar.31,1977	4070	736.38	N	737.38
Jul.1,1978	6500	737.53	Y	738.35
Jul. 21,1978	5400	737.45	N	738.08
Aug.18,1978	5600	737.44	N	738.44
Mar.14, 1979	6000 (7900)*	736.82	Y	740.60
Apr.26,1979	6800	738.12	Y	739.54
Dec.8,1980	4900	736.55	N	737.35
Apr.13, 1981	4500	737.40	N	738.00
Mar.17,1982	5200	738.00	Y	738.91
Apr.6,1982	6900	738.34	Y (already open)	738.87
Jul. 21,1982	5600	737.35	N	737.87
Dec.6,1982	8400	738.81	Y	739.42
Apr. 4, 1983	6500	738.35	Y	739.89
Feb.15,1984	4900	736.79	N	737.84
Feb.26,1985	4500	737.19	N~	739.01
Nov.3,1985	4600	737.38	N	737.74
Nov.18,1985	4500	737.53	N	737.97
Mar.12,1986	4400	736.49	N~	738.84
Sep.23,1986	6050 (10100)*	737.46	Y	740.70
Apr.16,1987	4600	736.95	N	737.90
Mar.14,1990	6700	738.08	Y	738.75

Notes:

* eventual forecast peak

~ gates are eventually opened because of high flood stages

Effect of Changing the Policy for Early Releases of Flow

The probability of underestimating or overestimating a flow will change if: 1) a greater or lesser number of precipitation gages are used to develop the flow forecast, and 2) if the gate operation policy, presented earlier, is modified. Increasing the number of gages used for the forecast would result in a lower probability of underestimation or overestimation. Adopting a more conservative operation policy (i.e., one that requires a larger forecasted flow to open the gates, such as 7000 cfs) reduces the chance of overestimation, but also decreases the number of major floods for which an early response is possible. A more aggressive policy (requiring a smaller forecasted flow to open the gates) could increase the probability that the gates are always opened early for major floods, but would result in the opening of the gates during a greater number of minor events that otherwise would not reach flood stage. Table 4 lists the number of gate openings that would be expected for the period 1972-1990 using more conservative and more aggressive policies.

Table 4. Number of Floods for Which the Gates Would Be Opened to Their Maximum Setting Using the Flow Forecast Model

	Flow forecast at which the gates open early		
Number of times:	*5000 cfs*	*6000 cfs*	*7000 cfs*
Gates would be opened early, prior to the arrival of flood waters	18	14	12
Minor flood would be overestimated; the early release producing undesirable high flows	6	2	1
Flood would be underestimated; the opening of gates being delayed until the high flood stages occur	1	2	5

5. CALIBRATION AND VALIDATION OF THE FEQ UNSTEADY FLOW MODEL

FEQ Data Compilation

Data compilation involved two data types, physical data and temporal data. Physical data consists of the channel and lake cross-sections, bridge data, dam data, and overflow weir data. Temporal data consists of inflow hydrographs, Stratton Dam gate operations, and initial water levels. Much of the physical data presented below was developed by the Illinois Division of Water Resources (IDOT-DWR, 1991a).

Physical Data

Cross-sectional Data

Cross-sectional data for the main stem Fox River, tributaries, and Chain of Lakes were compiled from previous surveys, studies, and maps. Cross-sectional tables in the FEQ format were generated using the FEQ utility program, FEQUTL. The stationing index, data, and data source are contained in IDOT-DWR (1991a).

Bridge Data

Table 5 lists the 21 bridges used in the model. Bridge losses were computed using the BRIDGE routine in FEQUTL version 3.66. BRIDGE is an implementation of the Hydraulics of Bridge Waterways procedure (U.S. Department of Transportation, 1986).

Table 5. FEQ Fox River Bridges

No.	*Bridge description*	*FEQ table no.*	*Distance above mouth (miles)*
1	Illinois Route 173 West	401-402	113.6
2	Illinois Route 173 East	403-404	
3	Grass Lake Road West	405406	108.5
4	Grass Lake Road East	407-408	
5*	Chicago Milwaukee & St. Paul R.R. Illinois Route 12	409-410	106.4 106.4
6	Johnsburg Road	411-412	103.0
7	Pearl Street	413-414	100.6
8	Illinois Route 120	415-416	100.4
9	Bull Valley Road	417-418	98.0
10	Illinois Route 176 Burtons Bridge	419-420	95.2
11	Rawson Bridge	421-422	92.4
12*	US Highway 14 Chicago & Northwestern R.R. Illinois Route 62	423-424	86.0 86.0 81.6
13	Chicago & Northwestern R.R.	425-426	81.2
14	Chicago & Northwestern R.R.	427-428	76.9
15*	Huntley Road Foot Bridge	429-430	76.7 76.1
16	Illinois Route 63	43I-432	75.7
17	Abandoned Piers	433-434	74.0
18*	Interstate 90 Kimball Street	435-436	73.2 71.0
19*	Highland Avenue Illinois Route 19	437-438	70.7 70.7
20	Walnut Avenue	439-440	70.1
21*	US Highway 20 Chicago Milwaukee & St. Paul R.R. Chicago & Northwestern R.R.	441-442	69.4 69.4 69.3

* multiple bridges combined into one table

Dam and Weir Data

Table 6 lists the structures used in the model. FEQUTL was used to create rating tables for all of the structures except Stratton Dam. The Stratton Dam rating is coded internally in FEQ and uses the rating given in *Discharge Ratings for Control Structures at McHenry Dam on the Fox River, Illinois* (Fisk, 1988).

Table 6. FEQ Fox River Structures

Structure	*FEQ table no.*	*Crest stage (ft NGVD)*[a]	*Crest length (ft.)*
Wilmot Dam spillway	262	740.26	138.
Wilmot Dam sluice gates	258	736.85	18.
Wilmot Dam abutment	260	741.00	30.
Ingred Weir	200	740.50	1050.
Fox Del Weir	208	738.50	1000.
Duck Lake fake dam	263	737.00	30.
Long Lake fake dam	264	739.00	50.
Stratton Dam spillway	[b]	736.68	288.
Stratton Dam sluice gates	[b]	731.15	68.75
Stratton Dam Foster gate	320	730.68	50.
Griswold Lake Dam	228	733.23	36.11
Fox Ox Weir	234	732.70	1000.
Algonquin Dam	274	730.30	300.
Algonquin Foster gate	321	724.30	50.
Carpentersville Dam	242	720.70	378.
Elgin Dam	252	708.36	325.
South Elgin Dam	302	700.00	357.

Notes:

[a] NGVD = National Geodetic Vertical Datum

[b] coded into the FEQ model

The navigation lock at Stratton dam and its approach channel were not modeled. During flooding conditions, the navigation lock would be closed and hence not contribute to the dam's total discharge. In studies involving low flow conditions, however, the discharge due to navigational locking may be significant.

Three overflow weirs were modeled: Ingred Weir, Fox Del Weir, and Fox Ox Weir. These weirs represent hypothetical structures at locations where divided flow can occur. Ingred Weir represents a roadway, located in a low area north of Illinois Route 173 and east of Lake Ingred, between the Fox River and Channel Lake. During flood conditions, a portion of the flow in the Fox River will take this flow path through the low area. Another alternate flow path for flood conditions is represented by the Fox Del Weir, which models the low area along the Fox River where it parallels Grass Lake, approximately one mile north of its normal inflow location. Fox Ox Weir is located along the Fox River downstream of Rawson Bridge, where floods overflow into an oxbow lake which at one time was part of the Fox River channel. The general location of these overflow flow paths is shown in figure 1.

Proposed Stratton Dam and Algonquin Foster Gates
The Foster gates proposed for Stratton Dam and Algonquin are 50 feet wide and have a crest elevation 6 feet below the existing dam's spillway, as recommended by the U.S. Army Corps of Engineers (1984). Coding of the Foster gates into the FEQ format was performed by the IDOT-DWR and is documented in *Fox River Project: Foster Gates at McHenry and Algonquin* (IDOT-DWR, 1991b). Three possible scenarios were studied for placement of the Foster gates: 1) Foster gates at both Stratton Dam and Algonquin Dam, 2) a Foster gate solely at Stratton Dam, and 3) a Foster gate solely at Algonquin Dam. The U.S. Army Corps of Engineers (1984) recommended Foster gates at both locations.

Temporal Data

Inflow Hydrographs
Table 7 lists the 24 inflows used in the model and their respective drainage areas. The hydrographs for these inflow points were developed using a combination of historical and simulated discharge data. Two streamgages were used for the historic flow data: the Fox River at Wilmot (USGS gage 05546500) and Nippersink Creek at Spring Grove (USGS gage 05546500). Data from these two gages comprise the major portions of the Fox River and Nippersink Creek inflow hydrographs. These two gages have a combined drainage area of

Table 7. FEQ Fox River Point Inflows

Point inflows	*FEQ table no.*	*Distance above mouth (miles)*	*Model drainage area (sq mi)*
Fox River at Wilmot	1	116.6	882.2
Trevor Creek	3	113.6	17.7
Sequoit Creek	5	109.5	13.7
Grass Lake	7	108.5	5.2
Long Lake	9	107.5	36.6
Duck Lake	11	107.5	9.9
Brandenberg Lake	13	106.4	3.5
Nippersink Creek	15	106.3	209.7
Lily Lake Drain	17	103.0	9.0
Dutch Creek	19	102.5	15.8
Boone Creek	21	100.3	25.9
Marina Inlet	23	99.7	6.3
Sleepy Hollow Creek	25	96.9	20.0
Griswold Lake	27	95.6	7.7
Cotton Creek	29	94.3	17.3
Silver Lake and drains	31	92.6	8.7
Slocum Lake	33	90.8	11.5
Flint Creek	35	89.4	43.6
Spring Creek	37	85.3	35.0
Crystal Creek	39	81.6	34.4
Unnamed tributaries	41	78.0	14.9
Jelkes Creek	43	74.6	16.3
Tyler Creek	45	72.2	45.6
Poplar Creek	47	68.8	51.0

1060 square miles, accounting for approximately 68 percent of the total watershed above South Elgin and 85 percent of the watershed above Stratton Dam. Simulated data were used for the 1960 flood on Nippersink Creek because the streamgage did not exist then.

The remaining inflow hydrographs were developed using simulated data from the FRH model. For modeling convenience, discharge records from two available streamgages, Boone Creek near McHenry (USGS gage 05549000) and Poplar Creek at Elgin (USGS gage 05549500), were not used in estimating the inflow hydrographs for their respective watersheds. The Poplar Creek inflow is located downstream of the study area and does not affect discharges and stages for the portion of the river evaluated in this study. The Boone Creek gage has a watershed area of 15 square miles, only 1% of the study area. Its record was not used because of the effort needed to estimate the flow contribution from the ungaged portions of that stream. The error between the historical and simulated discharges for the Boone Creek and Poplar Creek gages is given in Knapp et al. (1991), and is relatively small compared to other modeling errors.

The daily hydrographs, both simulated and historical, were differentiated into instantaneous discharge rates using a parsing routine developed for the FRH model (Knapp et al., 1991). Parsing of the daily data was necessary because the daily time step was too large for this application of FEQ. In brief, the routine parses the daily data into four instantaneous rates for 12 a.m., 6 a.m., 12 p.m., and 6 p.m. each day.

Accounting for Rainfall and Evaporation

Rainfall and evaporation from the surface of the Chain of Lakes were modeled as inflow hydrographs. Kothandaraman et al. (1977) list the Chain of Lakes surface area as 6844 acres (10.7 square miles) at an elevation of 735.5 feet. The daily amounts of rainfall and evaporation occurring over the lakes were computed using the FRH model.

Lake evaporation will sometimes produce negative flows in the lake-surface hydrographs. Having these negative flows can make it difficult for the FEQ model to reach a solution. For this reason, the lake-surface hydrographs were apportioned and added to the inflow hydrographs of the various tributaries that drain into the Chain of Lakes. Generally, a higher percentage of the lake-surface hydrographs were assigned to the inflows having larger drainage areas, so that none of the inflow hydrographs was dominated by the added lake-surface portion of flow. In this manner, negative flows rarely occurred in the compound inflow hydrographs. Table 8 lists the distribution of the lake-surface hydrographs to the point inflow hydrographs.

Table 8. Distribution of Lake-Surface Hydrographs to Tributary Inflows

Tributary inflow	*Lake area (sq mi)*	*Percentage*
Fox River at Wilmot	3.4	32
Long Lake	1.9	18
Nippersink Creek	1.7	16
Lily Lake drain	1.3	12
Trevor Creek	1.1	10
Duck Lake	0.7	6
Grass Lake	0.6	6

Stratton Dam Sluice Gate Operation

Gate operations at Stratton Dam were obtained from IDOT-DWR records. These records provide the exact time of all changes in gate settings for the 1982 and 1986 floods. For the earlier flood events, the available record lists the gate setting only at specific times each day (8 a.m. and 4 p.m.), but not the exact time that the gate setting was changed. For these floods, it was assumed that any recorded changes in the gate setting occurred at the 8 a.m. or 4 p.m. reading when the new gate setting was first recorded. It is possible that the gate setting may have been changed several hours prior to the time of the recording. It may be more reasonable to assume the gate changes occurred midway between readings. However, short differences in the timing of the gate openings have little effect on the simulated peak (as shown in Section 6: Model Results). All gate changes were assumed to be completed in 0.1 hours (6 minutes).

FEQ Calibration

The FEQ Fox River model (FEQ version 7.0) was calibrated for the reach of the Fox River from Wilmot, WI to Algonquin, IL. Model calibration from Algonquin downstream to South Elgin was subsequently performed by the IDOT-DWR, but is not described.

Table 9 lists the stage records used for calibration and validation. The U.S Geological Survey (USGS) gages, listed in this table, provide continuous records of mean daily stage values. The IDOT records are instantaneous stage readings. Data for the Stratton Dam tailwater were recorded twice daily, usually at 8 a.m. and 4 p.m. The data for Rawson Bridge, Fox River Grove, and Algonquin were usually recorded weekly, and were not available for all of the floods being simulated. The IDOT record at Algonquin was taken from a USGS-operated gage. Additional 15-minute stage data were available in computerized format for the 1986 event for all USGS gages, as well as for the Stratton Dam tailwater and Algonquin gages.

Table 9. Stage Records Used in Model Calibration

Agency	*Station no.*	*Station name or description*
USGS	05547000	Channel Lake near Antioch
USGS	05547500	Fox Lake near Lake Villa
USGS	05548000	Nippersink Lake at Fox Lake
USGS	05548500	Fox River at Johnsburg
USGS	05549500	Fox River near McHenry
IDOT		Stratton Dam tailwater
IDOT		Fox River at Rawson Bridge
IDOT		Fox River at Fox River Grove
IDOT		Fox River at Algonquin

The FEQ model was calibrated to two flood events: 1973 and 1986. The 1986 event was selected because of the availability of 15-minute stage data. The 1973 event was selected because daily stage data were available for Rawson Bridge. Table 10 lists the range of low and high daily discharges that occurred during the calibration period for each flood. In the calibration procedure, greater emphasis was on matching the stages during high flows.

Table 10. Range of Daily Flows Used in Calibration

Flood event and location	*Low (cfs)*	*High (cfs)*
1986 event (September 1 - October 30)		
Fox River at Wilmot	210	3780
Nippersink Creek at Spring Grove	43	1750
Fox River at McHenry	290	5980
Fox River at Algonquin	347	6050
1973 event (April 1 - June 10)		
Fox River at Wilmot	1040	6430
Nippersink Creek at Spring Grove	227	1460
Fox River at McHenry	1497	5234
Fox River at Algonquin	1850	5710

Channel and floodplain losses were calibrated using a combination of visual and numerical calibration criteria since FEQ does not contain an automatic calibration procedure. Peak stage, peak timing, and the stage hydrograph shape were compared for the stations listed in table 9. Discharge data at Stratton Dam were also used to judge the simulation.

Calibration involved adjustment of the roughness coefficients such that the simulated results satisfied the calibration criteria. Two types of adjustments were necessary; these were, in order of preference: 1) to increase or decrease the numerical roughness value, and 2) to increase the number of roughness subsections. All calibration changes were applied to both floods so that a consistent set of parameters was maintained.

Comparison of Historical and Simulated Stages

The simulated stage hydrographs for the 1973 flood are compared to historical (observed) stages in figures 2-5. Similar comparisons for the 1986 flood are shown in figures 6-10. Generally, the stage hydrographs are well simulated for both events.

Table 11 compares the simulated peak stages (following calibration) to the historical maximum daily stages for the 1973 and 1986 floods. Also shown are the instantaneous peak stages for the historical record. Historical maximum daily stages are more appropriate than instantaneous peaks for model comparison because the latter values are more influenced by temporary factors such as wind set-up and waves. Maximum daily and peak stages for the simulated record differ by 0.01 foot or less.

The simulated peak stages for the 1973 event closely match the historical maximum daily stages for Channel, Fox, and Nippersink Lakes. For the 1986 flood, peak stages on these lakes are overpredicted by 0.2 foot. The model has a tendency to overpredict the peak stages at Stratton Dam. This suggests that the rating data used in the FEQ model may be underpredicting the discharge from the dam for high stages. Peak timing errors for both storms were usually one day or less.

Table 11. Calibrated Maximum Daily Stages

Flood event and location	Historical Max. daily stage (ft)	Historical Date	Historical Peak stage	Simulated Max. daily stage (ft)	Simulated Date	Difference Max. daily stage (ft)
1973 event						
Channel Lake near Antioch	740.55	May 2	740.62	740.54	May 4	-0.01
Fox Lake Near Lake Villa	740.44	May 3,4	740.47	740.49	May 4	+0.05
Nippersink Lake at Fox Lake	740.40	May 4	740.42	740.48	May 4	+0.08
Fox River at Johnsburg	739.84	May 4	739.89	740.01	May 4	+0.17
Fox River near McHenry	738.73	May 4	738.74	738.99	May 4	+0.26
1986 event						
Channel Lake near Antioch	740.70	Oct 3	740.72	740.94	Oct 2	+0.24
Fox Lake Near Lake Villa	740.65	Oct 3	740.65	740.85	Oct 2	+0.20
Nippersink Lake at Fox Lake	740.60	Oct 3	740.62	740.84	Oct 2	+0.24
Fox River at Johnsburg	740.06	Oct 3	740.06	740.37	Oct 2	+0.31
Fox River near McHenry	739.03	Oct 3	739.04	739.30	Oct 2	+0.27

Comparison of Historical and Simulated Discharges

Figures 11 and 12 show the simulated and observed Stratton Dam discharge for 1973 and 1986, respectively. Table 12 lists the relative error statistics for these events by discharge range. The relative error for the flow at any one time is defined as:

Relative Error = (Simulated Flow - Historical Flow) / Historical Flow

The mean relative error was 1.0 percent for the 1973 event and 0.6 percent for the 1986 event. The standard deviations of the relative errors were 4.5 percent for the 1973 event and 9.5 percent for the 1986 event, indicating relatively good agreement for both events. The positive relative error in the 1973 event for flows greater than 4000 cfs was expected since the peak stage was overpredicted. The standard deviations for the high flows (greater than 4000 cfs) are similar for both storms; the amounts of the deviation are comparable to average stage differences of approximately 0.2 foot.

Table 12. Calibrated Stratton Discharge Relative Error (%)

Relative error	Discharge Range <3000 cfs	3000-4000 cfs	4000-5000 cfs	>5000 cfs	Composite
1973 event					
Mean	0.5	0.04	2.3	2.9	1.0
S.D.	3.1	9.0	6.5	3.7	4.5
1986 event					
Mean	1.2	-1.8	-0.5	1.0	0.6
S.D.	11.5	6.2	6.3	2.8	9.5

FEQ Validation

The model was validated using storm events occurring in 1960, 1972, 1974, 1978, 1979, and 1982. Table 13 lists the low and high mean daily discharges that occurred during the validation periods.

Comparison of Historical and Simulated Stages

The simulated and historical maximum daily stages and the historical peak stages are compared in table 14. Selected stage hydrographs for the 1960, 1972, 1974, 1978, 1979, and 1982 floods are presented in figures 13-21. In some cases the floods had multiple peaks, each of which were simulated. The 1978 simulation was unique in that it spanned three distinct storms, each with a recurrence interval of less than two years.

Table 13. Range of Daily Flows Used in Model Validation

Flood event and location	*Low (cfs)*	*High (cfs)*
1960 event (March 15 - April 30)		
Fox River at Wilmot	398	7100
Fox River at McHenry	637	6467
Fox River at Algonquin	708	6480
1972 event (September 1 - October 10)		
Fox River at Wilmot	590	3250
Nippersink Creek at Spring Grove	163	1300
Fox River at McHenry	949	4112
Fox River at Algonquin	1140	4690
1974 event (February 25 - April 20)		
Fox River at Wilmot	1290	3880
Nippersink Creek at Spring Grove	272	1610
Fox River at McHenry	2069	4917
Fox River at Algonquin	2310	5290
1978 event (June 1 - September 15)		
Fox River at Wilmot	209	2270
Nippersink Creek at Spring Grove	42	946
Fox River at McHenry	168	2715
Fox River at Algonquin	214	3180
1979 event (March 1 - May 31)		
Fox River at Wilmot	402	4880
Nippersink Creek at Spring Grove	70	1740
Fox River at McHenry	621	5710
Fox River at Algonquin	750	6560
1982 event (March 1 - April 30)		
Fox River at Wilmot	451	3000
Nippersink Creek at Spring Grove	103	1390
Fox River at McHenry	506	3670
Fox River at Algonquin	736	3990

Table 14. Comparison of Simulated and Historical Maximum Daily Stages

Flood event and location	Historical Max. daily stage (ft)	Historical Date	Historical Peak stage (ft)	Simulated Max. daily stage (ft)	Simulated Date	Difference Max. daily stage (ft)
1960 event						
Channel Lake near Antioch	741.27	Apr 5	741.34	741.70	Apr 5	+0.43
Fox Lake near Lake Villa	741.11	Apr 5	741.13	741.53	Apr 5	+0.42
Nippersink Lake at Fox Lake	741.04	Apr 5	741.05	741.52	Apr 5	+0.48
Fox River at Johnsburg	740.53	Apr 6	740.59	740.98	Apr 5	+0.45
Fox River near McHenry	739.34	Apr 5,6	739.44	739.96	Apr 5	+0.62
1972 event						
Channel Lake near Antioch	739.79	Sep 25	739.82	739.79	Sep 24	0.00
Fox Lake near Lake Villa	739.70	Sep 26	739.72	739.75	Sep 24	+0.05
Nippersink Lake at Fox Lake	739.59	Sep 26	739.60	739.75	Sep 24	+0.16
Fox River at Johnsburg	739.13	Sep 26	739.14	739.37	Sep 24	+0.24
Fox River near McHenry	738.33	Sep 26	738.34	738.59	Sep 24	+0.26
1974 Event						
Channel Lake near Antioch	740.05	Mar 11	740.06	739.70	Mar 12	-0.35
Fox Lake near Lake Villa	739.98	Mar 11	739.99	739.66	Mar 12	-0.32
Nippersink Lake at Fox Lake	739.96	Mar 11,12	739.97	739.66	Mar 12	-0.30
Fox River at Johnsburg	739.46	Mar 12	739.48	739.20	Mar 12	-0.26
Fox River near McHenry	738.50	Mar 12	738.53	738.25	Mar 12	-0.25
1978 event						
Channel Lake near Antioch	738.43	Jul 6	---	738.49	Jul 5	+0.06
Fox Lake near Lake Villa	738.35	Jul 6	---	738.46	Jul 5	+0.11
Nippersink Lake at Fox Lake	738.29	Jul 6	---	738.46	Jul 5	+0.17
Fox River at Johnsburg	737.98	Jul 5	738.03	738.22	Jul 5	+0.24
Fox River near McHenry	737.49	Jul 5	---	737.71	Jul 5	+0.22
Channel Lake near Antioch	738.44	Aug 22	738.49	738.49	Aug 22	+0.05
Fox Lake near Lake Villa	738.36	Aug 22	738.44	738.46	Aug 22	+0.10
Nippersink Lake at Fox Lake	738.31	Aug 22	738.34	738.46	Aug 22	+0.15
Fox River at Johnsburg	737.98	Aug 21,22	---	738.17	Aug 22	+0.19
Fox River near McHenry	737.55	Aug 19	737.80	737.75	Aug 21	+0.20
1979 event						
Channel Lake near Antioch	740.69	Apr 2	740.70	741.06	Apr 2	+0.35
Fox Lake near Lake Villa	740.64	Apr 2	740.64	740.94	Apr 2	+0.30
Nippersink Lake at Fox Lake	740.57	Apr 2	740.58	740.93	Apr 2	+0.26
Fox River at Johnsburg	740.04	Apr 2	740.07	740.42	Apr 2	+0.38
Fox River near McHenry	738.93	Apr 2	738.95	739.37	Apr 2	+0.44
1982 event						
Channel Lake near Antioch	738.91	Mar 25	738.92	738.77	Mar 26	-0.14
Fox Lake near Lake Villa	738.84	Mar 26	738.84	738.72	Mar 26	-0.12
Nippersink Lake at Fox Lake	738.79	Mar 26	738.80	738.72	Mar 26	-0.07
Fox River at Johnsburg	738.33	Mar 25,26	---	738.32	Mar 25	-0.01
Fox River near McHenry	737.57	Mar 26	---	737.44	Mar 25	-0.13
Channel Lake near Antioch	738.87	Apr 7	---	738.87	Apr 7	0.00
Fox Lake near Lake Villa	738.81	Apr 7,8	---	738.83	Apr 7	+0.02
Nippersink Lake at Fox Lake	738.74	Apr 7	---	738.82	Apr 7	+0.08
Fox River at Johnsburg	738.32	Apr 8	738.38	738.42	Apr 7	+0.10
Fox River near McHenry	737.53	Apr 8	737.65	737.52	Apr 6,7	-0.01

The simulated stages are overestimated by over 0.3 foot for both the 1960 and 1979 events, the two largest floods on record. As suggested earlier, the rating data used in the FEQ model may be underpredicting the discharge from the dam for very high stages. The 1960 event has the greatest error at peak conditions, the mean error (for the five stations listed) being 0.44 foot for the maximum daily stage. Although the error at peak conditions is high for both these events, the stage hydrographs are generally well simulated (figures 13-18).

The peak timing of the historical and simulated hydrographs for all the floods generally agree. However, the 1972 event displayed a two-day difference in the date of the peak stage (figure 19). The 1974 simulation also shows a slight difference in the timing of the peak (figure 20). The 1982 event was a double-peaked event in which the historical maximum occurred during the first peak, while the simulated maximum occurred during the second (figure 21).

Comparison of Historical and Simulated Discharges

Table 15 lists the statistics of the relative error computed between the simulated and observed discharges at Stratton Dam for the 1960, 1972, 1974, 1978, 1979, and 1982 floods. Mean discharge was slightly underestimated during four events, as indicated by the negative relative error, and overestimated for two events. Generally, the mean relative error was below 5 percent with a standard deviation below 10 percent, which compares favorably with the statistics for the calibrated events. The relative error in discharge is also comparable to the errors in peak stage given in table 14.

The relative error statistics for the 1978 event are greater than those for the other floods used for model validation. Although the relative error for discharge appears to be somewhat high, the stage hydrographs are generally well simulated (figure 22), as are the discharges at Stratton Dam (figure 23). An examination of figure 23 reveals that discharges above 500 cfs are reasonably simulated, and that most of the error occurs at low discharges. In this case, the mean relative error statistic is greatly influenced by the low flows and is not indicative of how the FEQ model simulates the high flow conditions. The error for the low flows in the 1978 event could have resulted either because FEQ was not calibrated to discharges this low, or because of differences between simulated and observed low flows.

Continuous Simulation of Stage and Discharge

As a final validation aid, and to determine if an error trend would exist over a longer simulation interval, a validation run was made covering a 17-month period. The starting date was January 1, 1973, and the ending date was May 15, 1974. Stage hydrographs for Fox Lake and Stratton Dam are shown in figures 24 and 25, respectively. The simulated stages agreed well with those recorded. The slight stage overprediction starting on approximately July 1, 1973, and running through November 15, 1973, may be due to an overprediction of the inflow hydrographs. After November 15, 1973, the stage errors appear random, showing no tendency towards overprediction or underprediction.

Table 15. Relative Error of the Stratton Dam Discharge (%)

	1960	*1972*	*1974*	*1978*	*1979*	*1982*
Mean	-3.7	-2.0	-4.8	10.4	5.6	-2.3
Standard Deviation	7.3	8.3	6.1	24.2	7.7	5.2

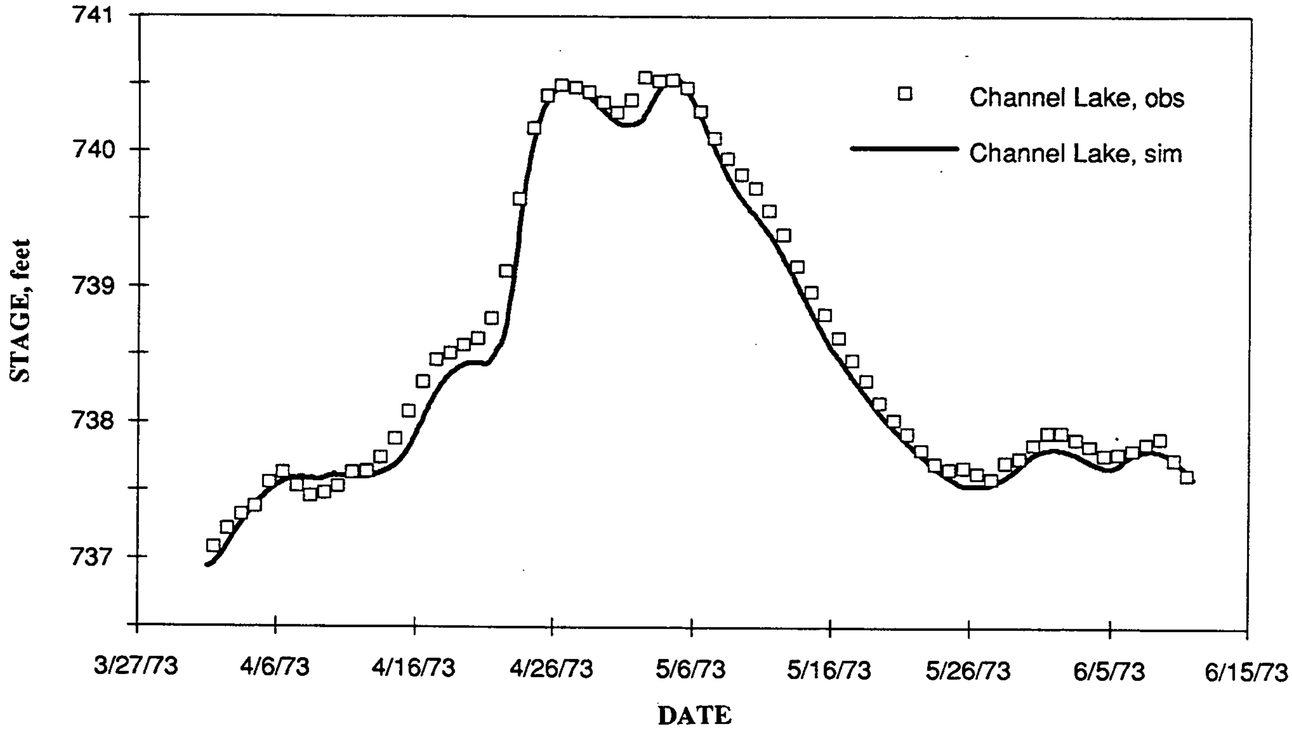

Figure 2. Simulated and observed stages; 1973 flood at Channel Lake

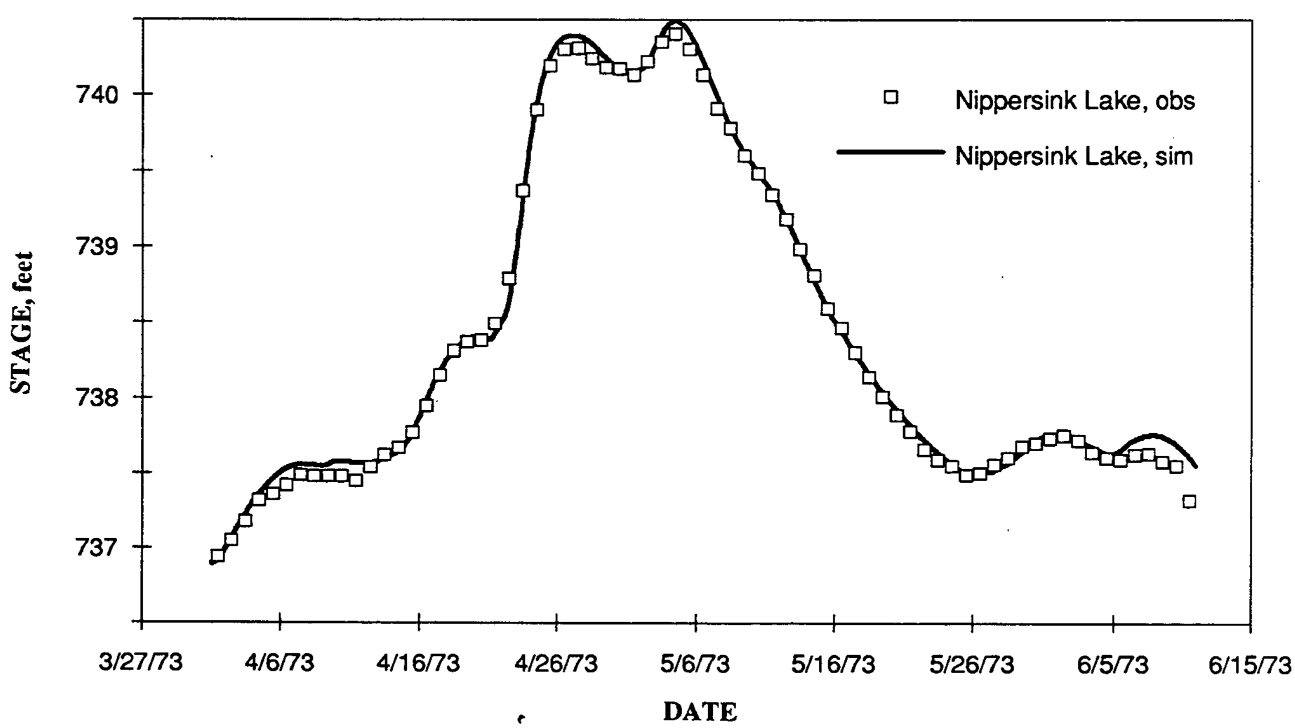

Figure 3. Simulated and observed stages; 1973 flood at Nippersink Lake

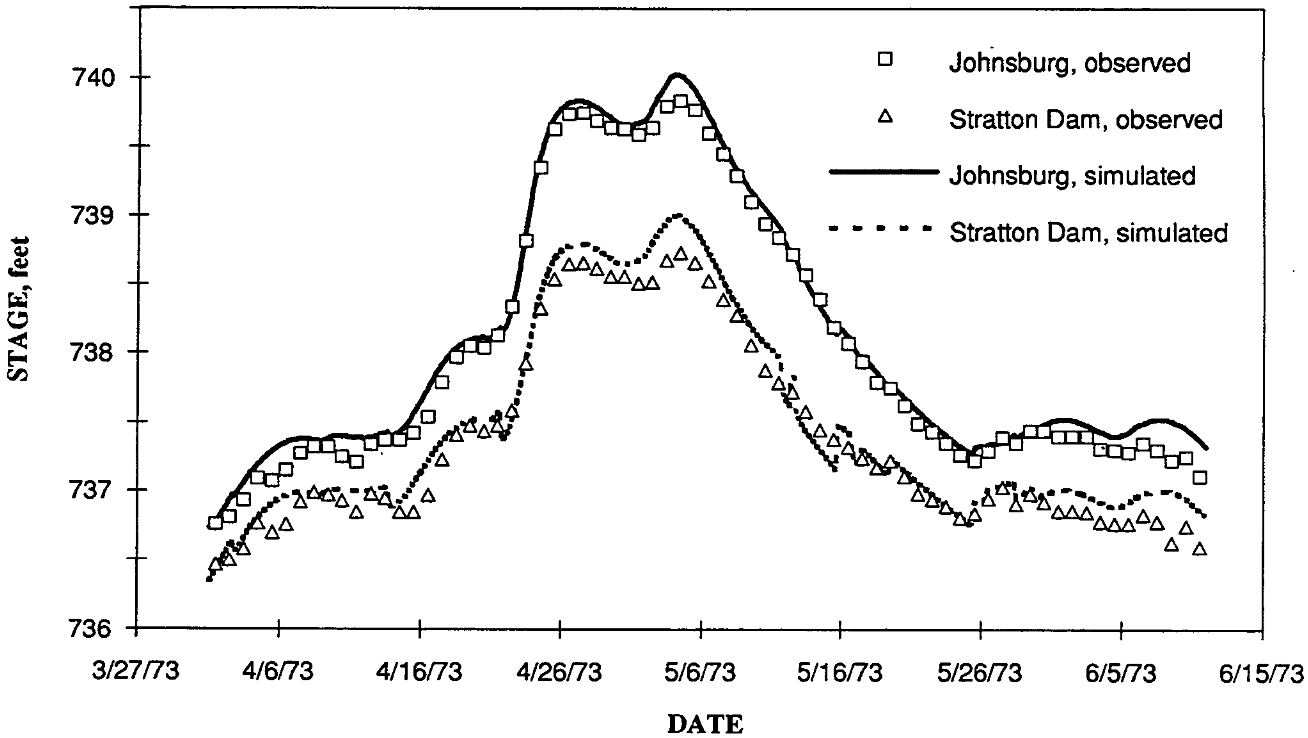

Figure 4. Simulated and observed stages; 1973 flood at Johnsburg and Stratton Dam

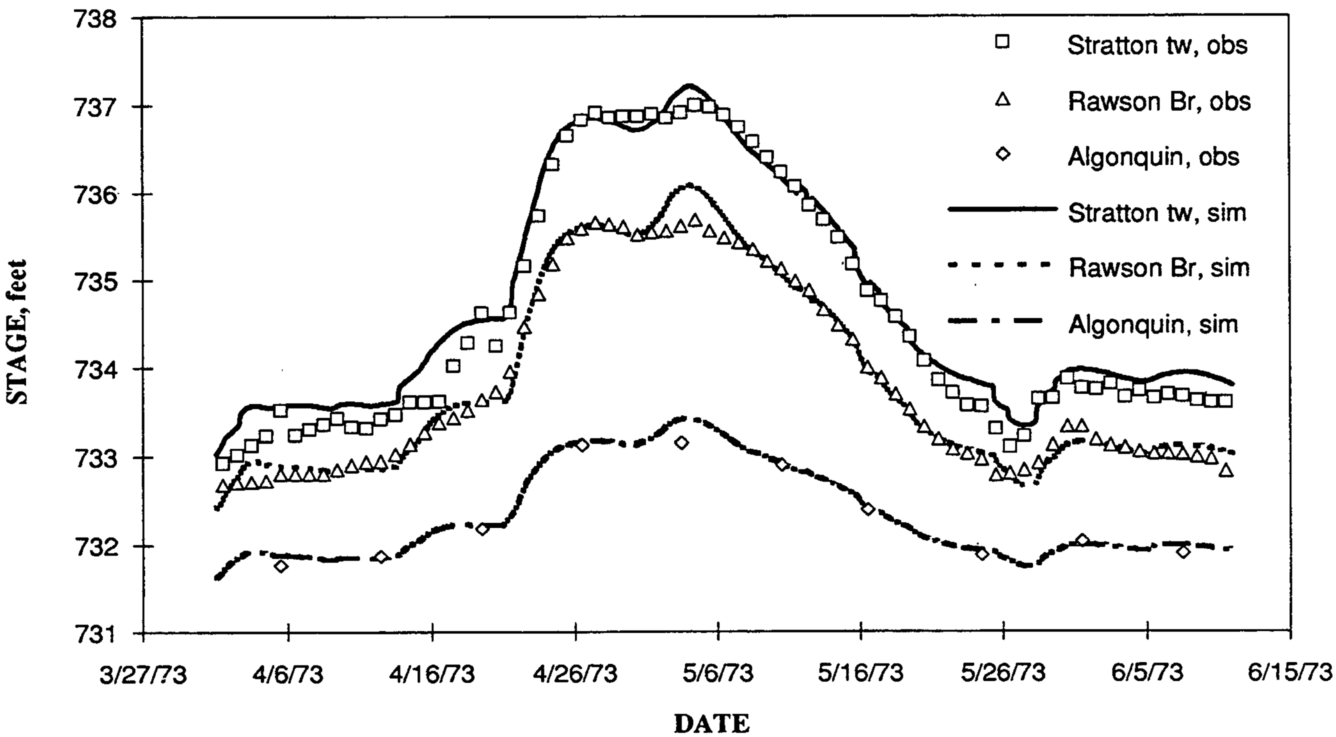

Figure 5. Simulated and observed stages; 1973 flood at the Stratton Dam tailwater, Rawson Bridge, and Algonquin Dam

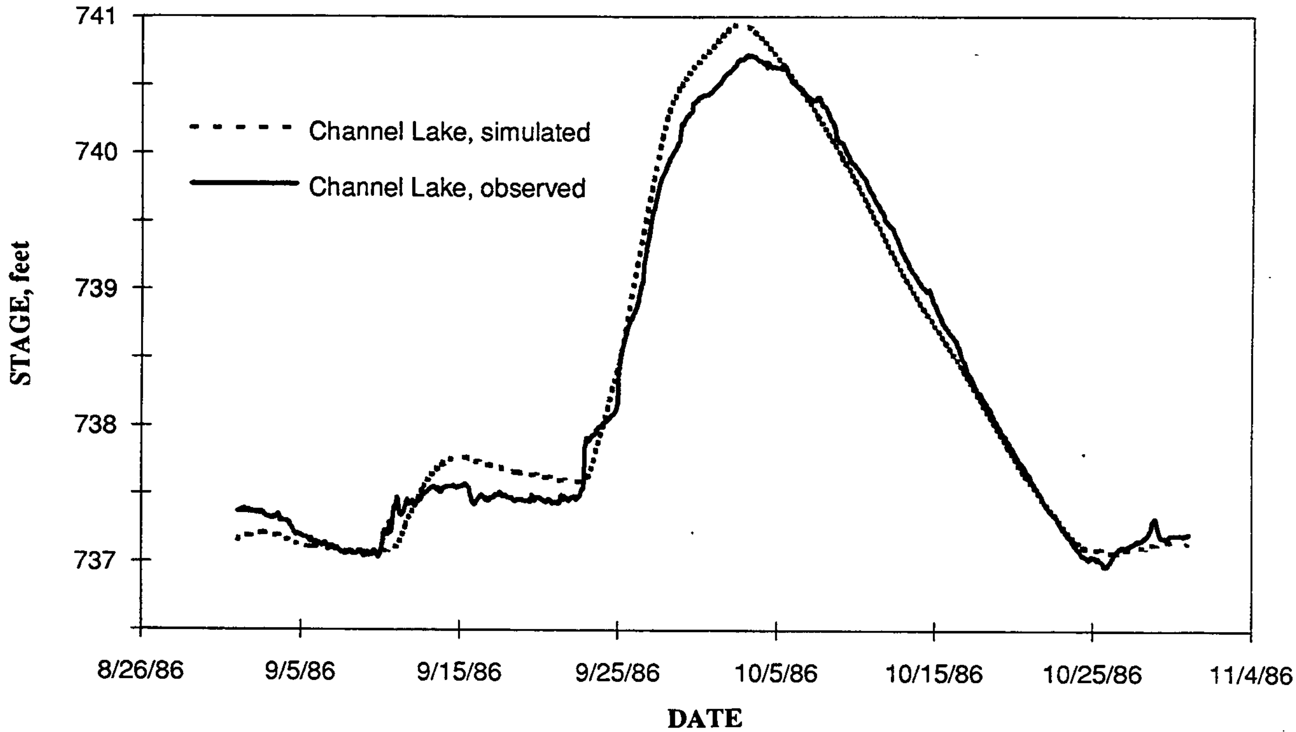

Figure 6. Simulated and observed stages; 1986 flood at Channel Lake

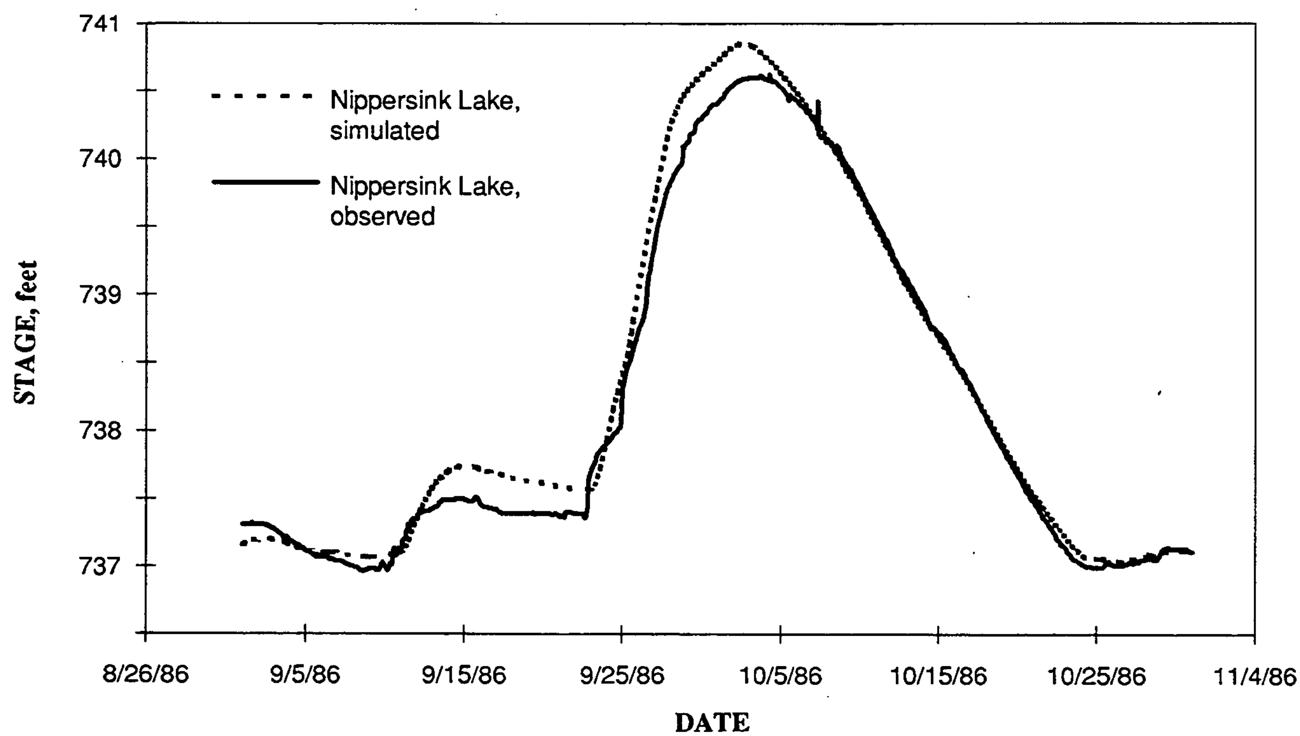

Figure 7. Simulated and observed stages; 1986 flood at Nippersink Lake

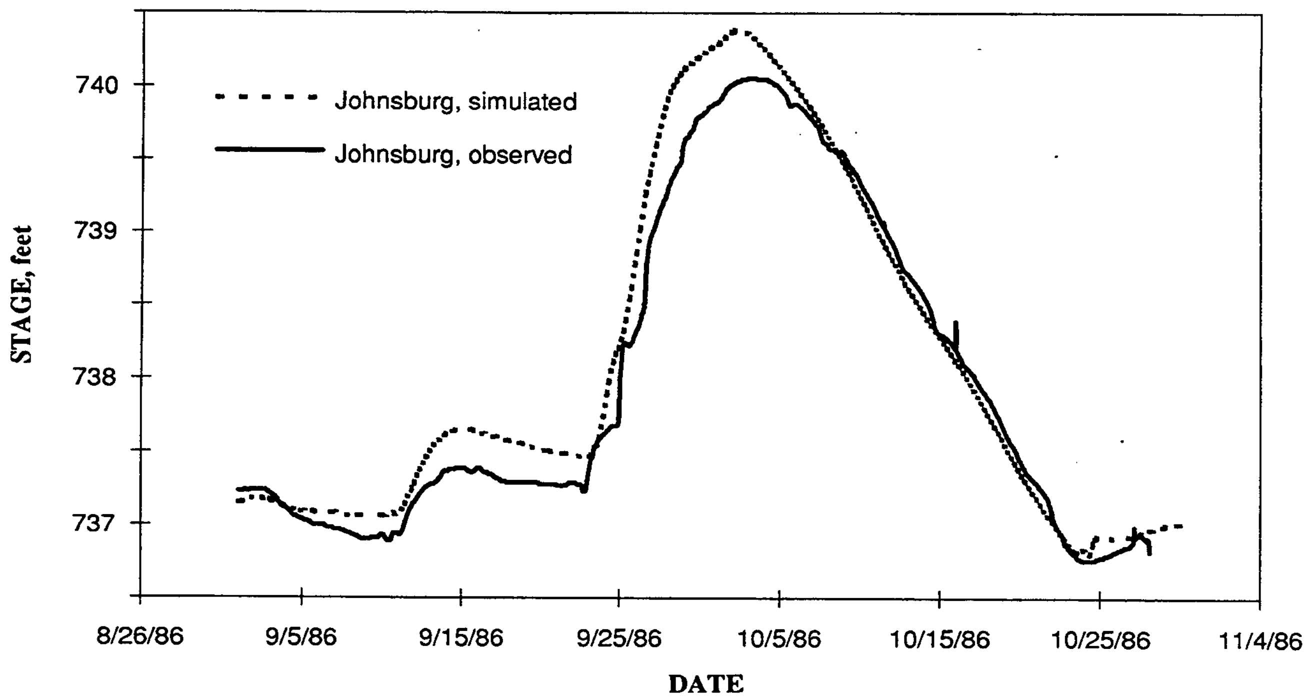

Figure 8. Simulated and observed stages; 1986 flood at Johnsburg

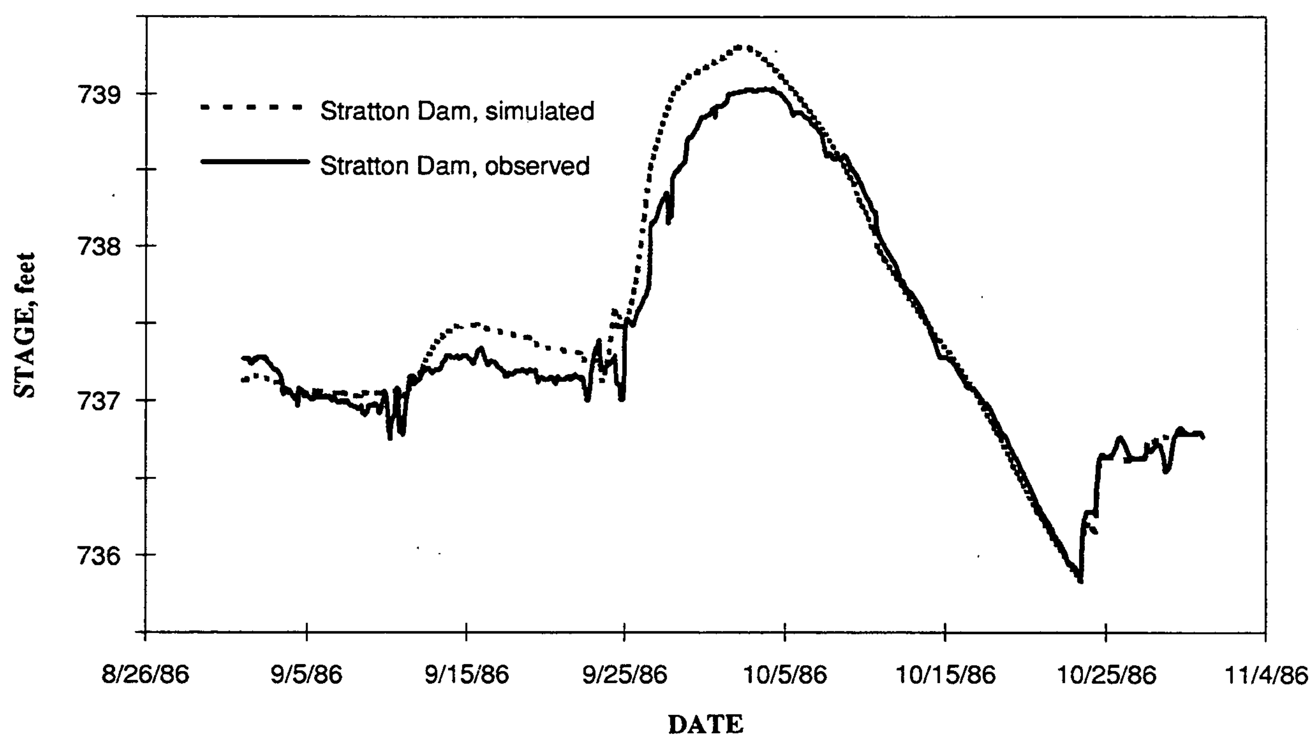

Figure 9. Simulated and observed stages; 1986 flood at Stratton Dam

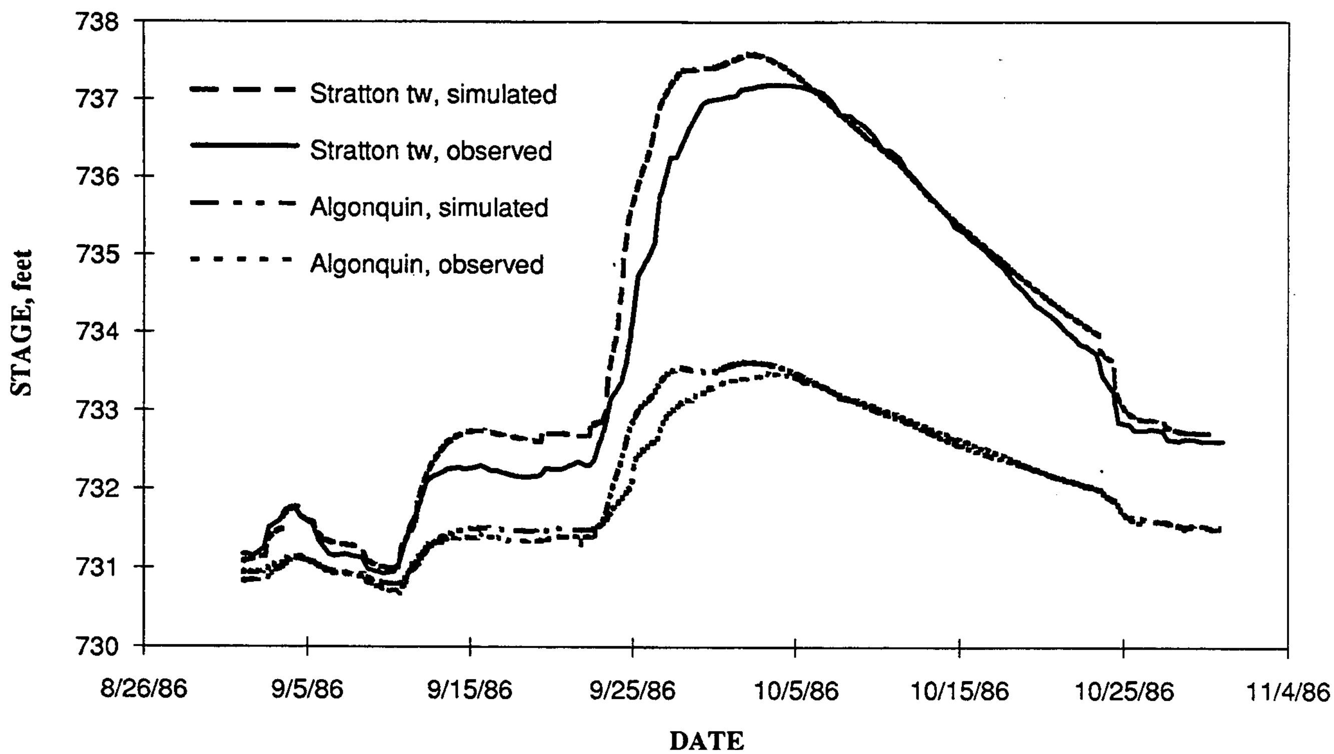

Figure 10. Simulated and observed stages; 1986 flood at the Stratton Dam tailwater and Algonquin Dam

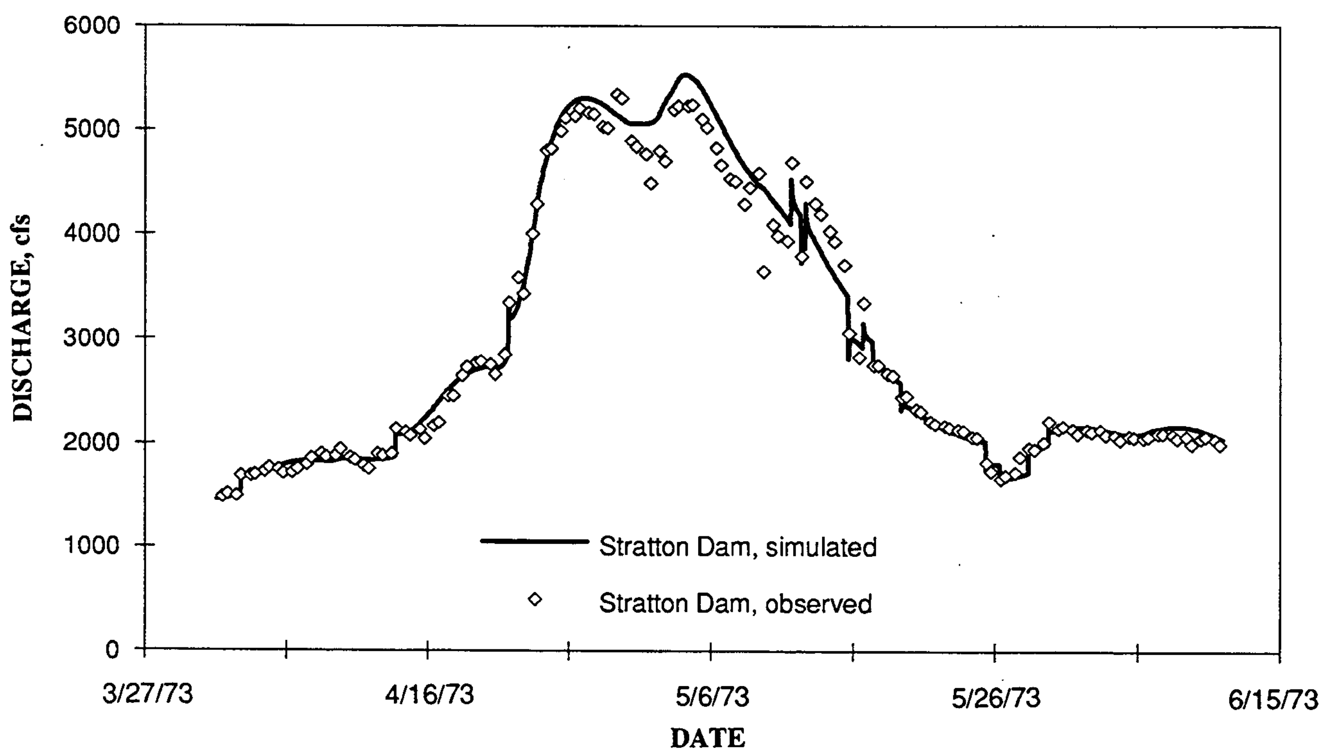

Figure 11. Simulated and observed discharges; 1973 flood at Stratton Dam

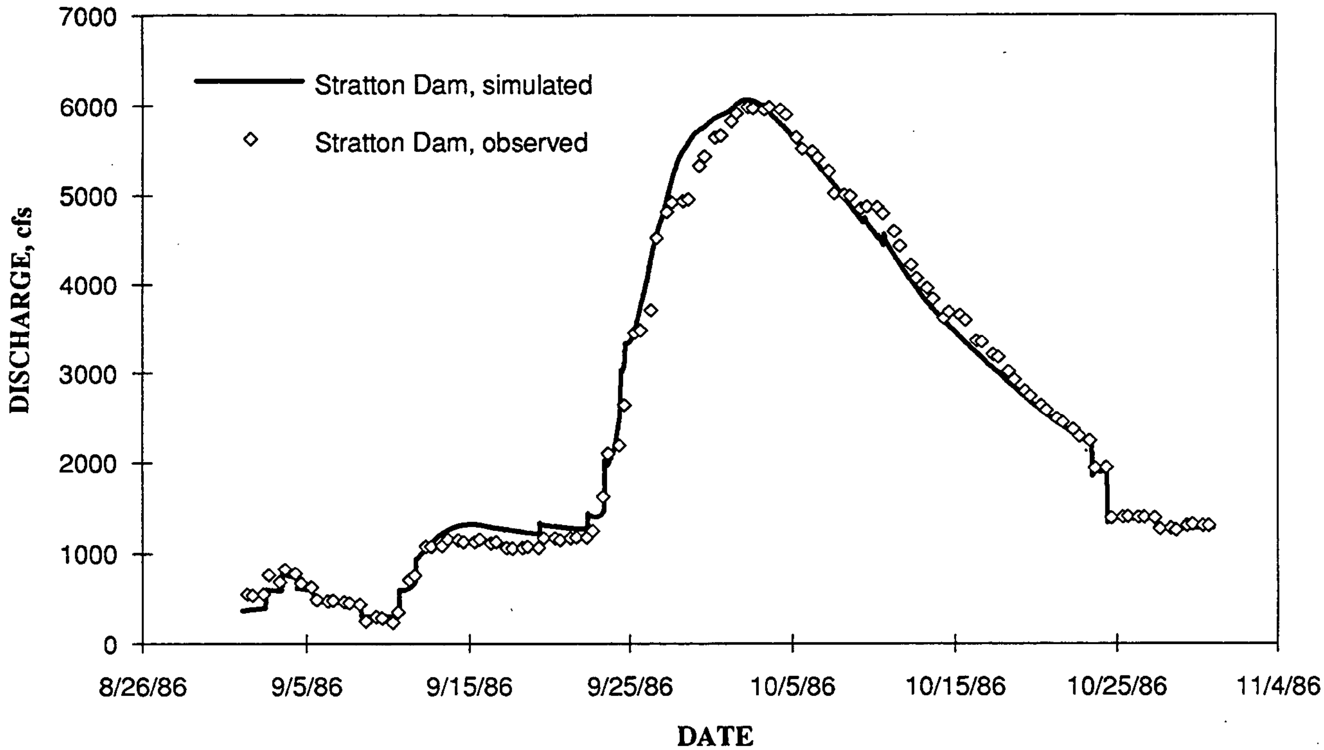

Figure 12. Simulated and observed discharges; 1986 flood at Stratton Dam

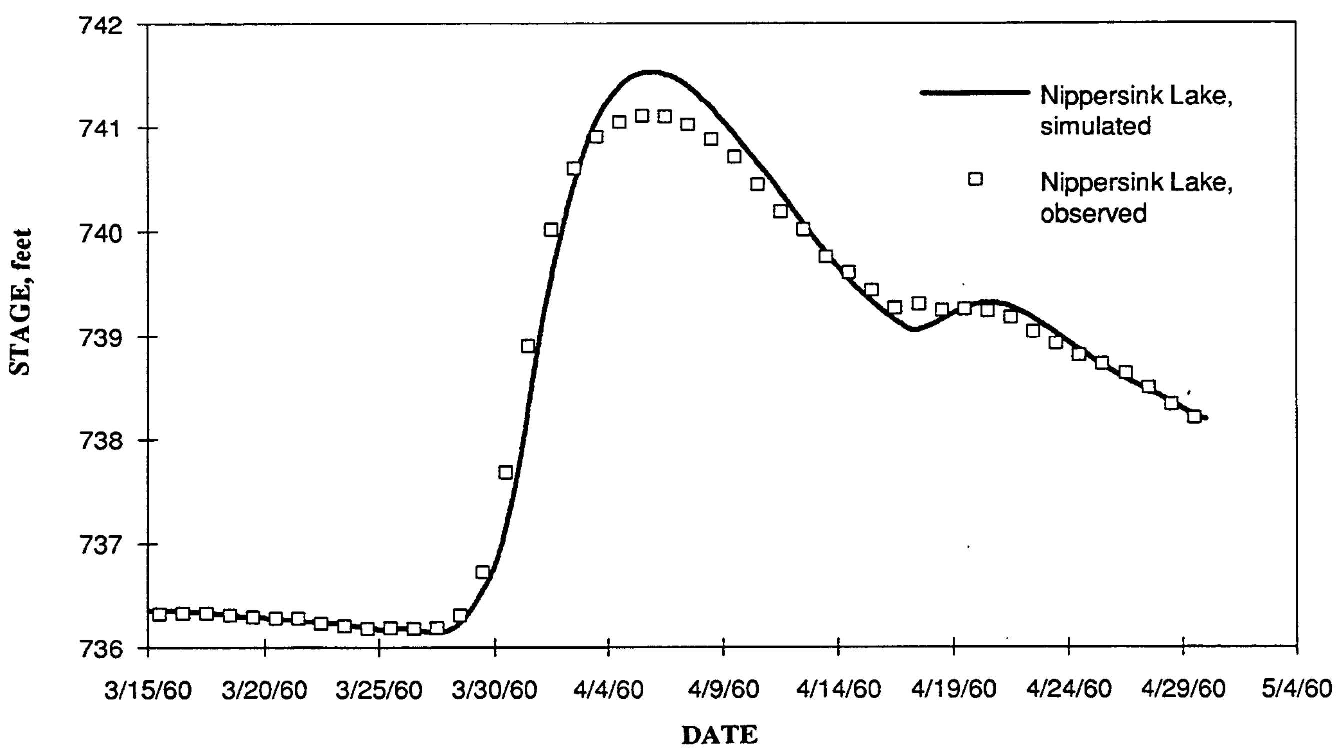

Figure 13. Simulated and observed stages; 1960 flood at Nippersink Lake

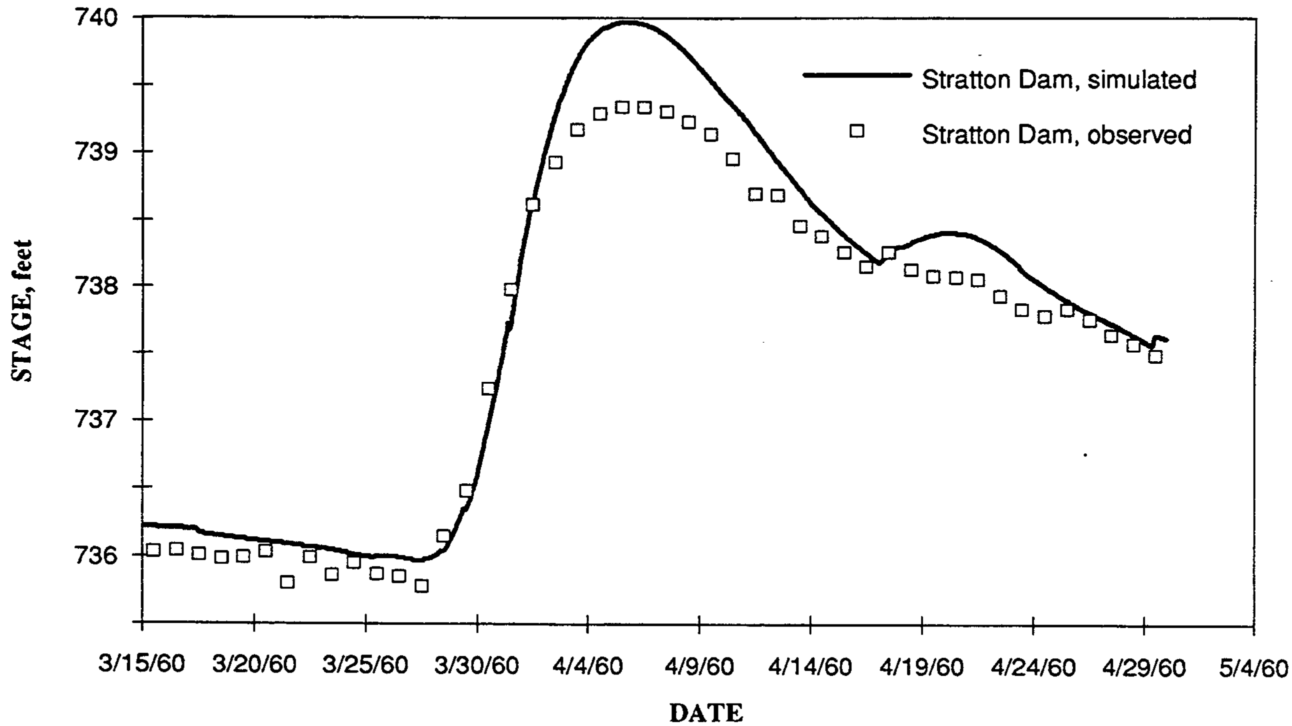

Figure 14. Simulated and observed stages; 1960 flood at Stratton Dam

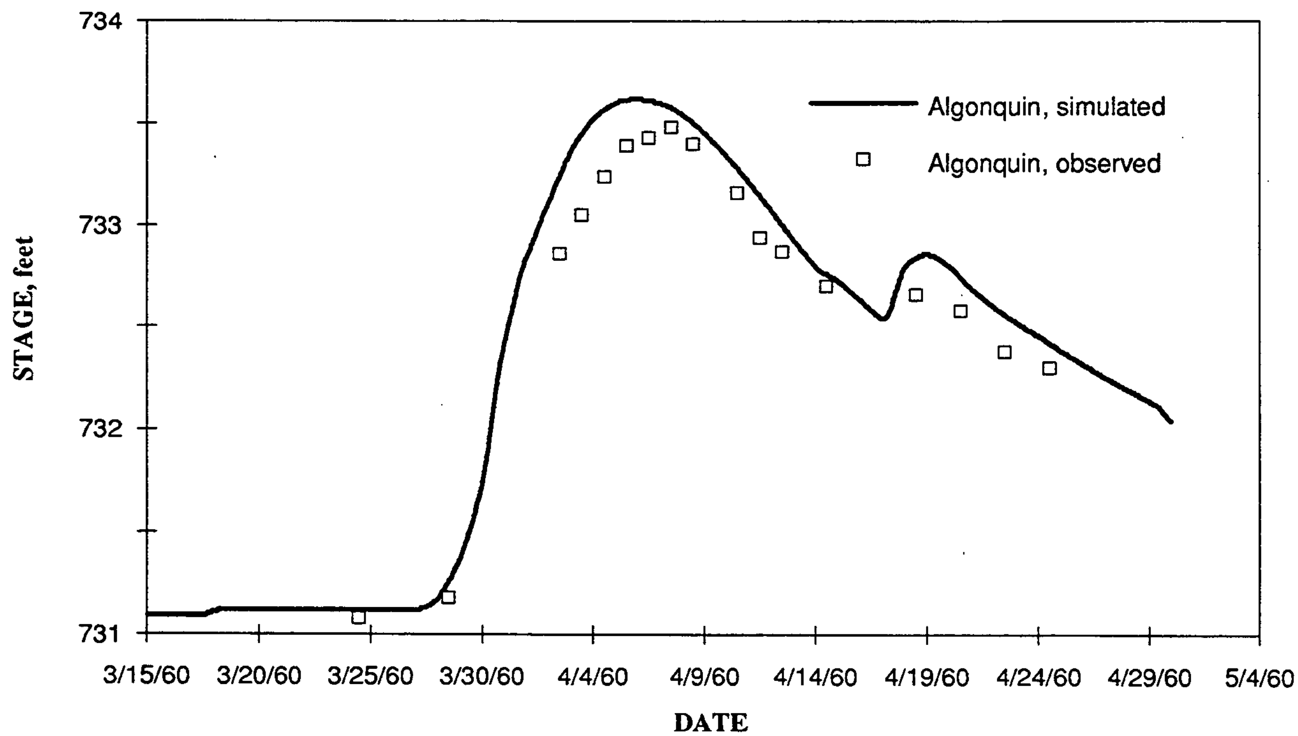

Figure 15. Simulated and observed stages; 1960 flood at Algonquin Dam

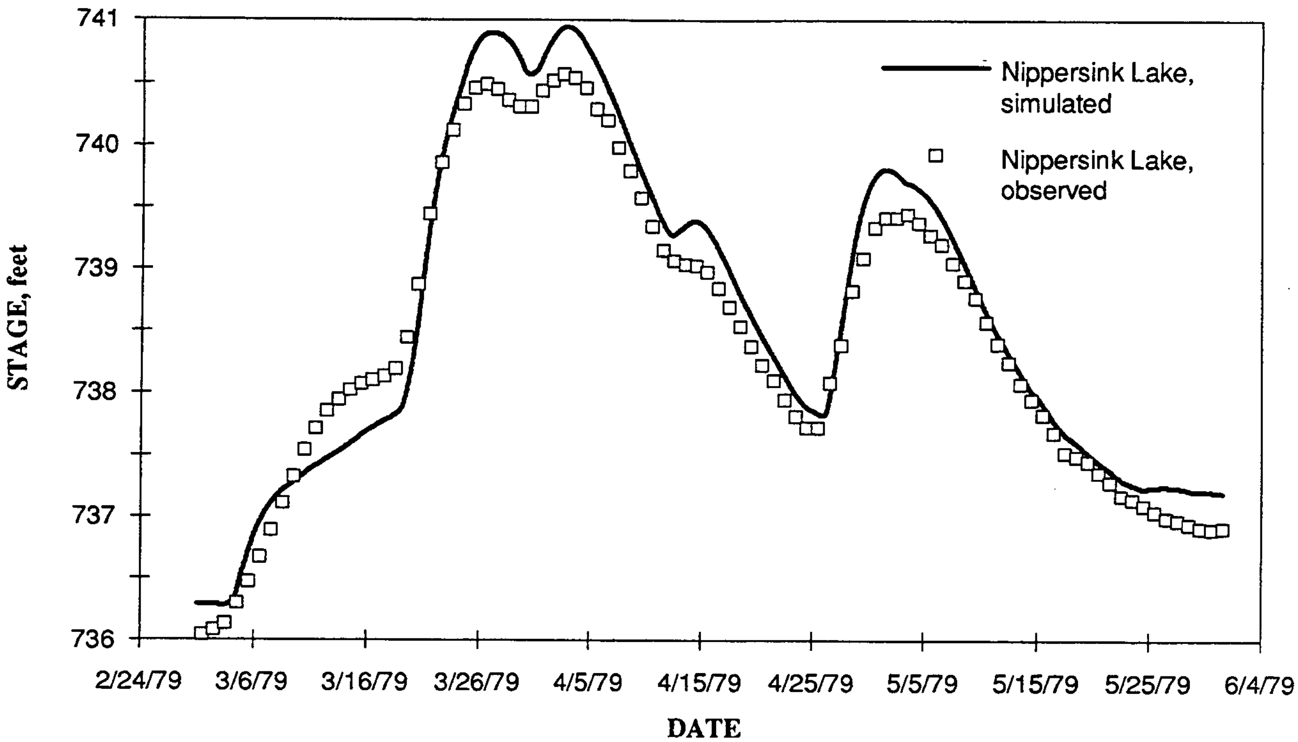

Figure 16. Simulated and observed stages; 1979 flood at Nippersink Lake

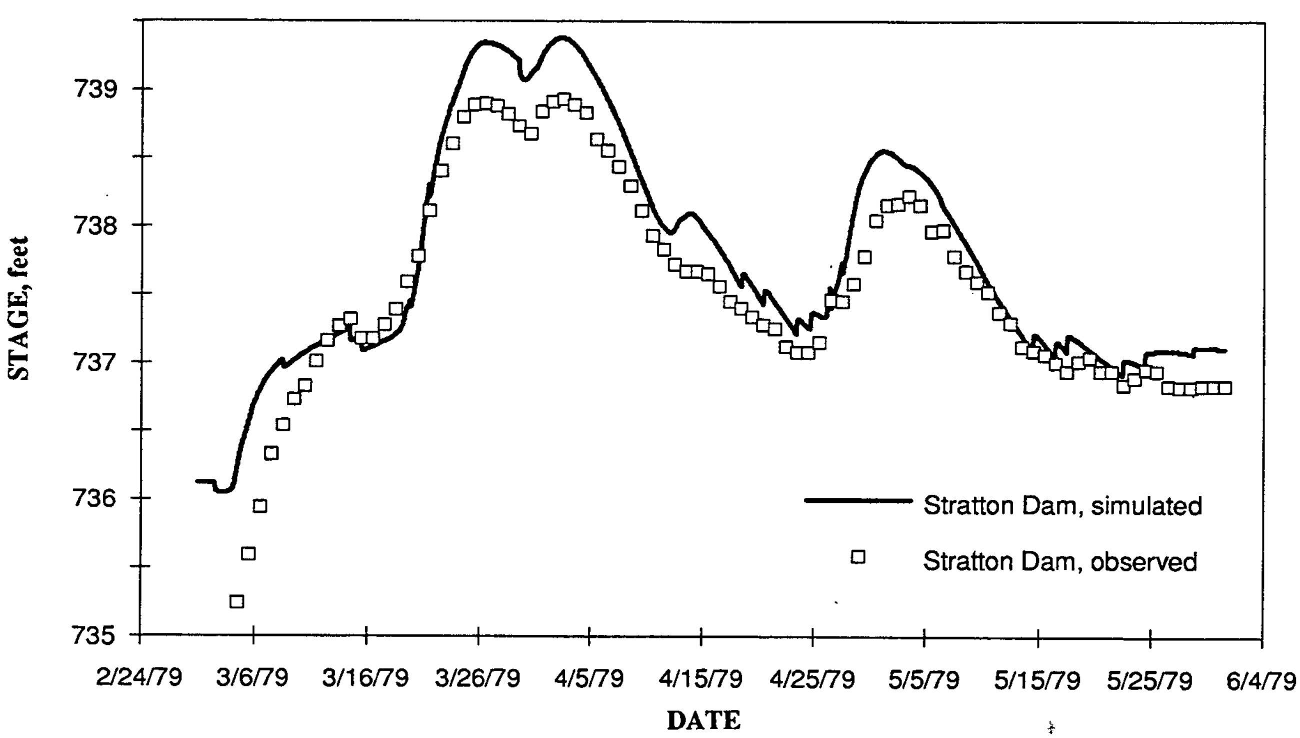

Figure 17. Simulated and observed stages; 1979 flood at Stratton Dam

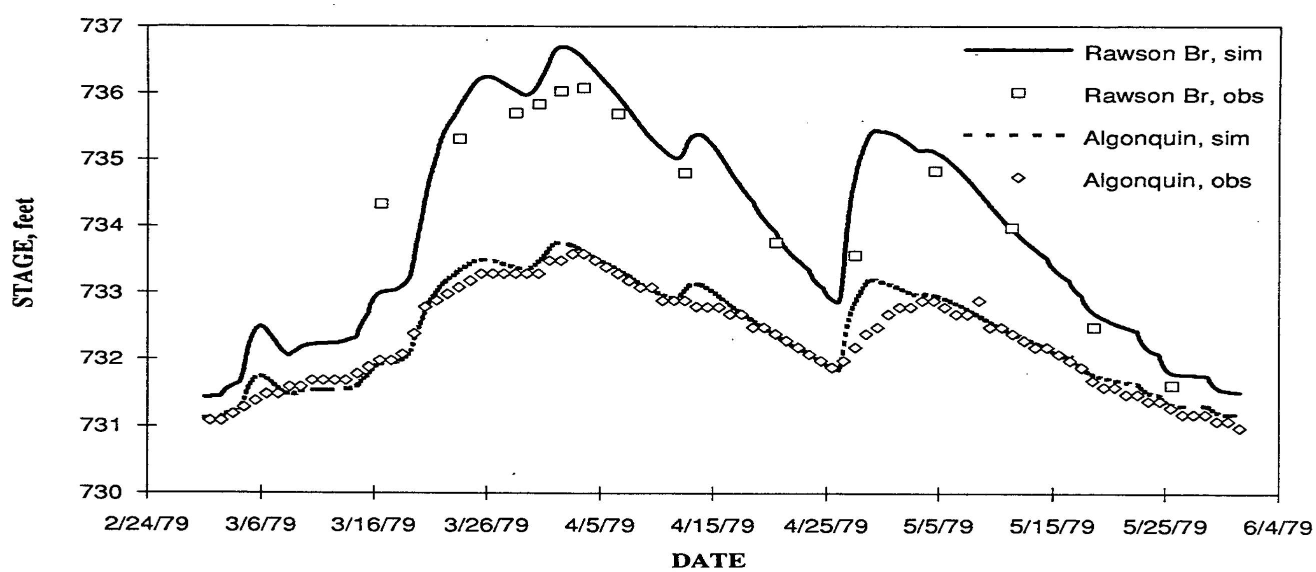

Figure 18. Simulated and observed stages; 1979 flood at Rawson Bridge and Algonquin Dam

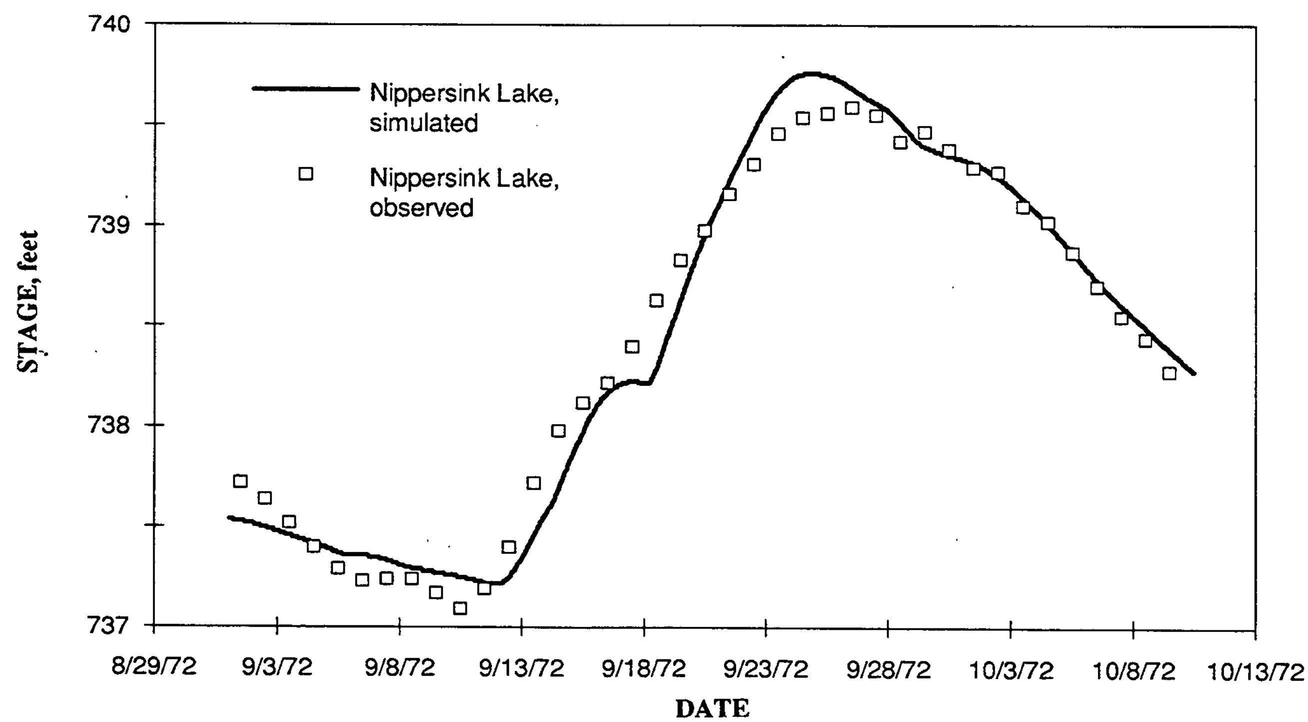

Figure 19. Simulated and observed stages; 1972 flood at Nippersink Lake

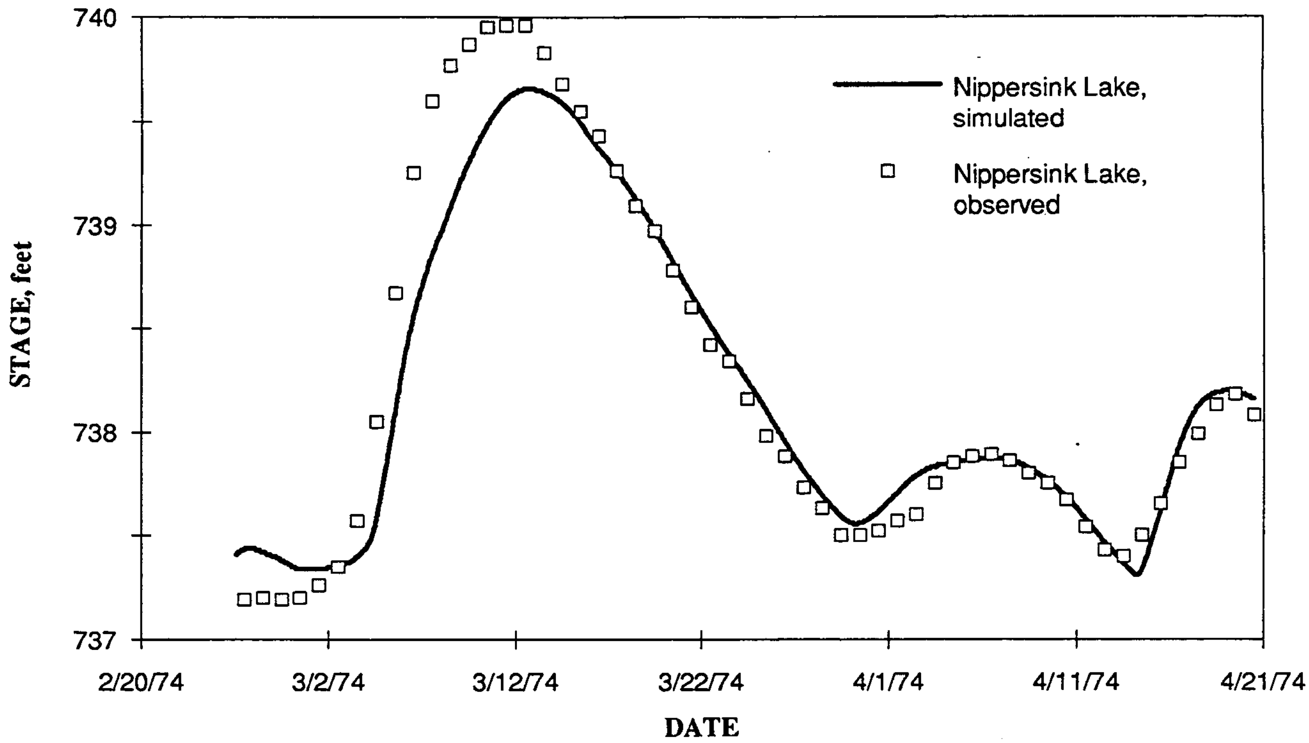

Figure 20. Simulated and observed stages; 1974 flood at Nippersink Lake

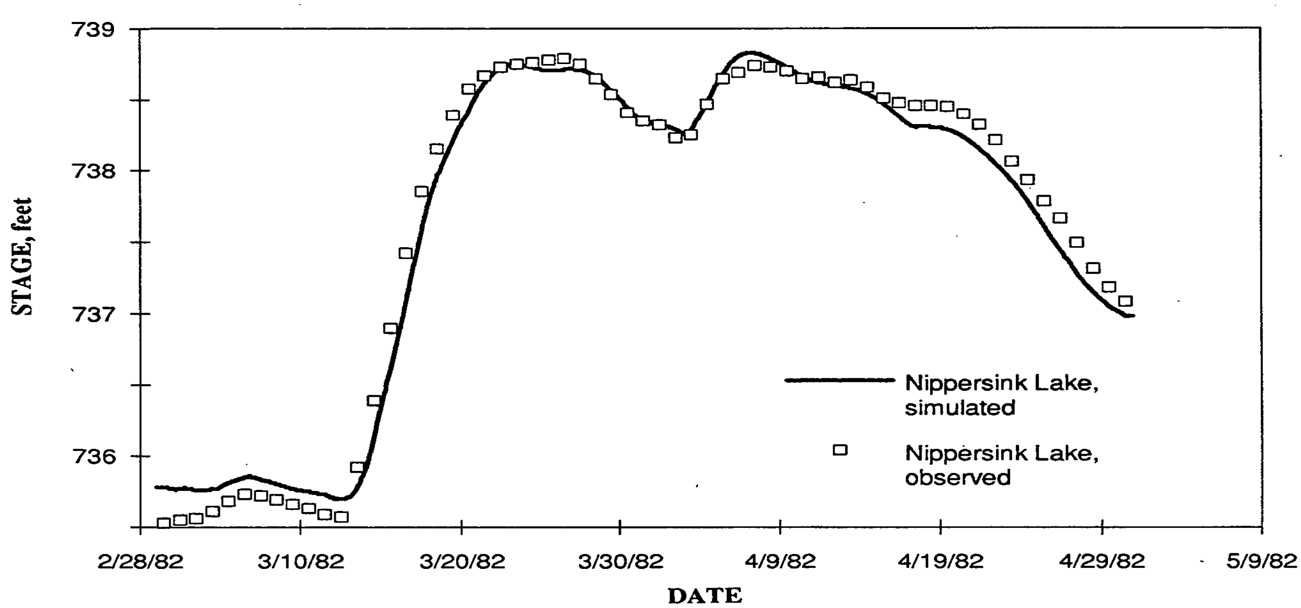

Figure 21. Simulated and observed stages; 1982 flood at Nippersink Lake

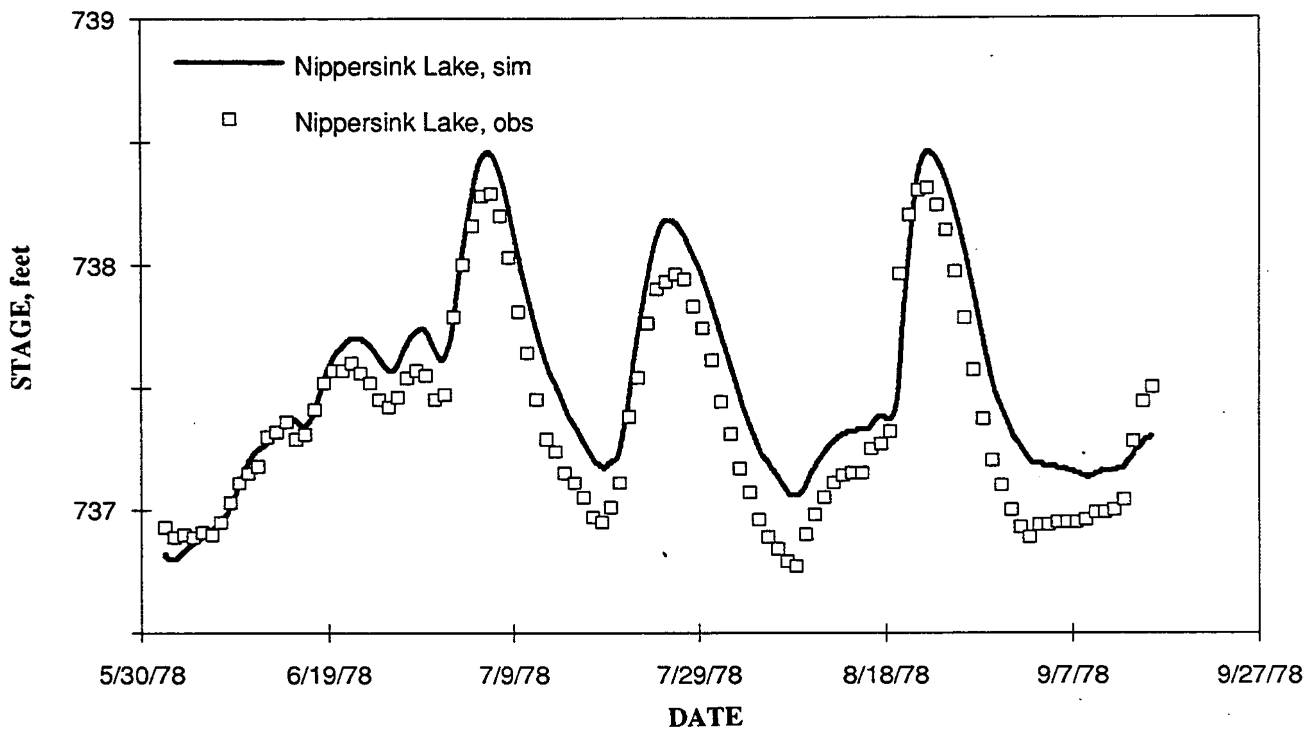

Figure 22. Simulated and observed stages; 1978 flood at Nippersink Lake

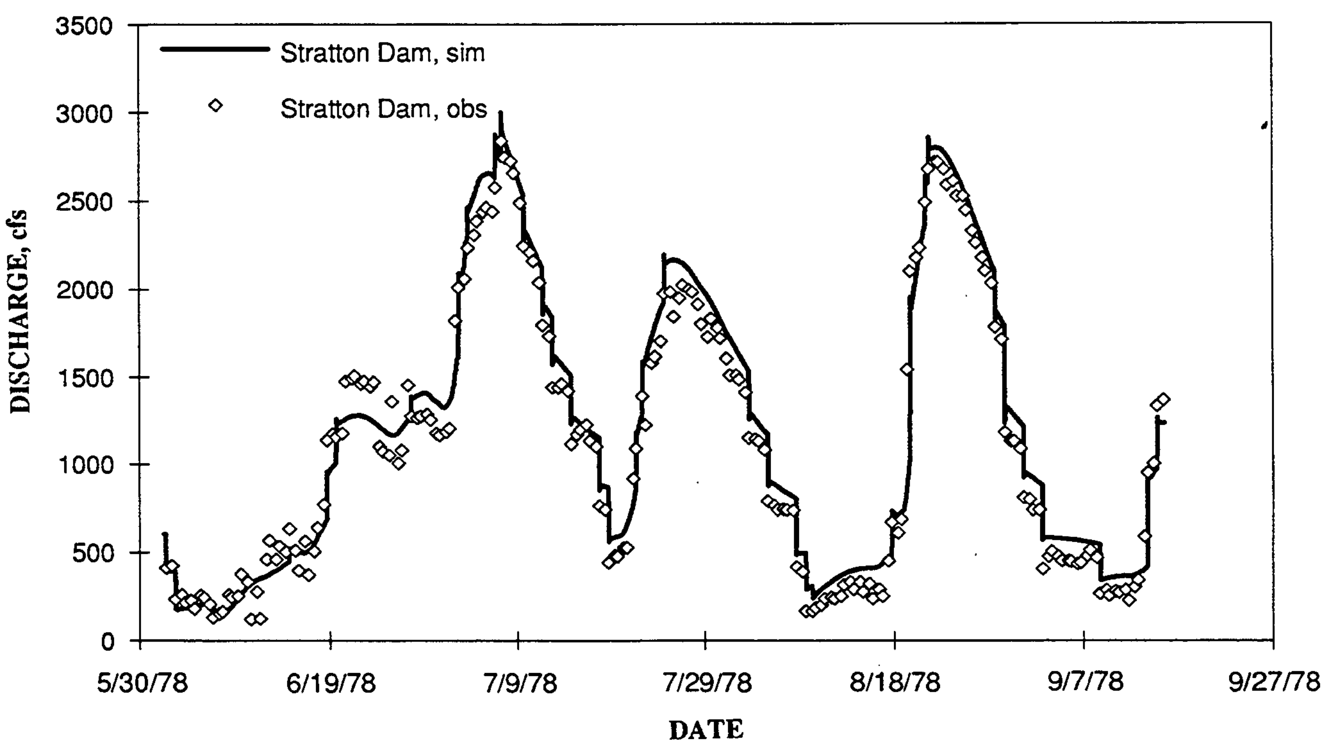

Figure 23. Simulated and observed discharges; 1978 flood at Stratton Dam

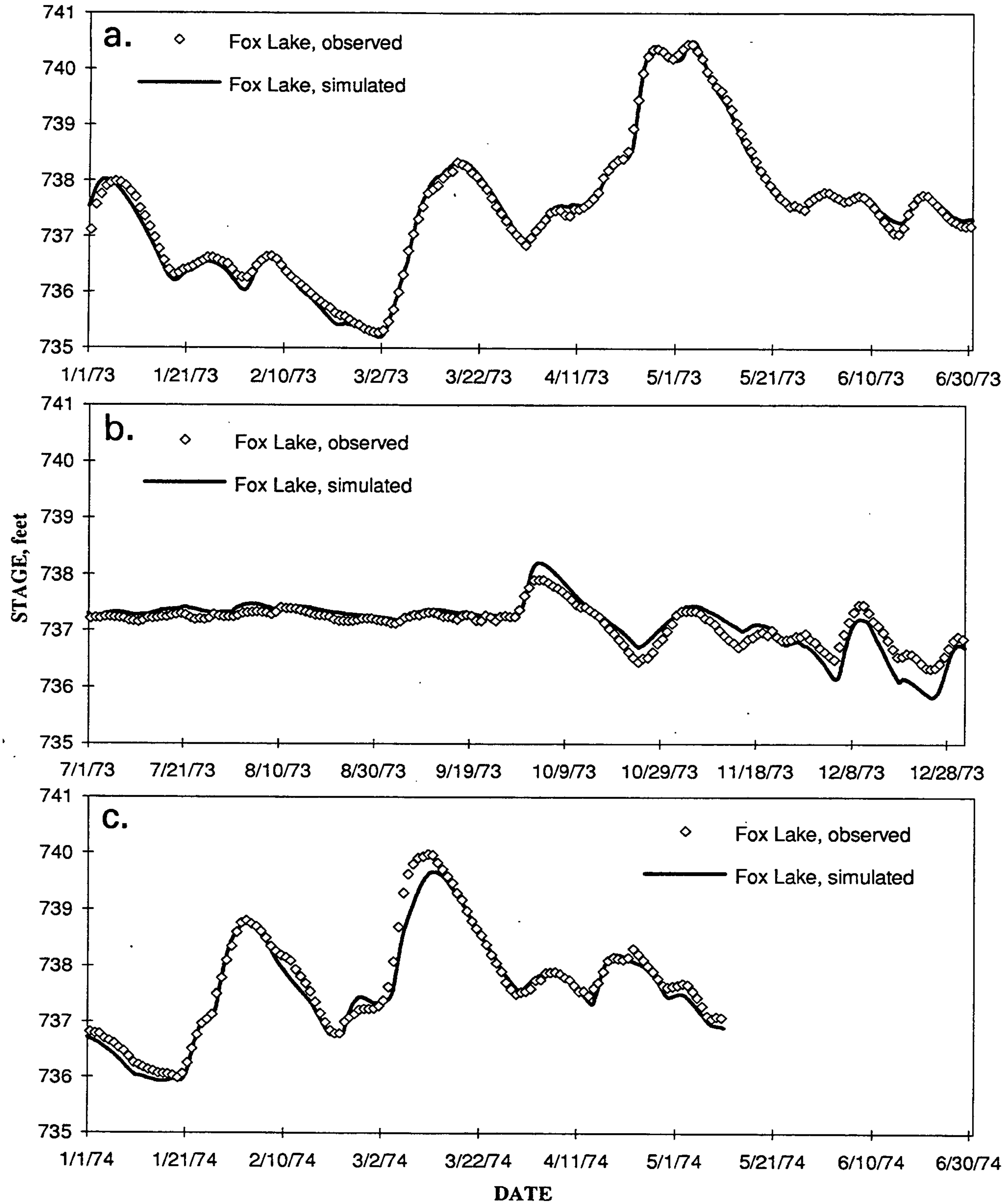

Figure 24. Simulated and observed stages; January 1, 1973 through May 15, 1974 at Fox Lake

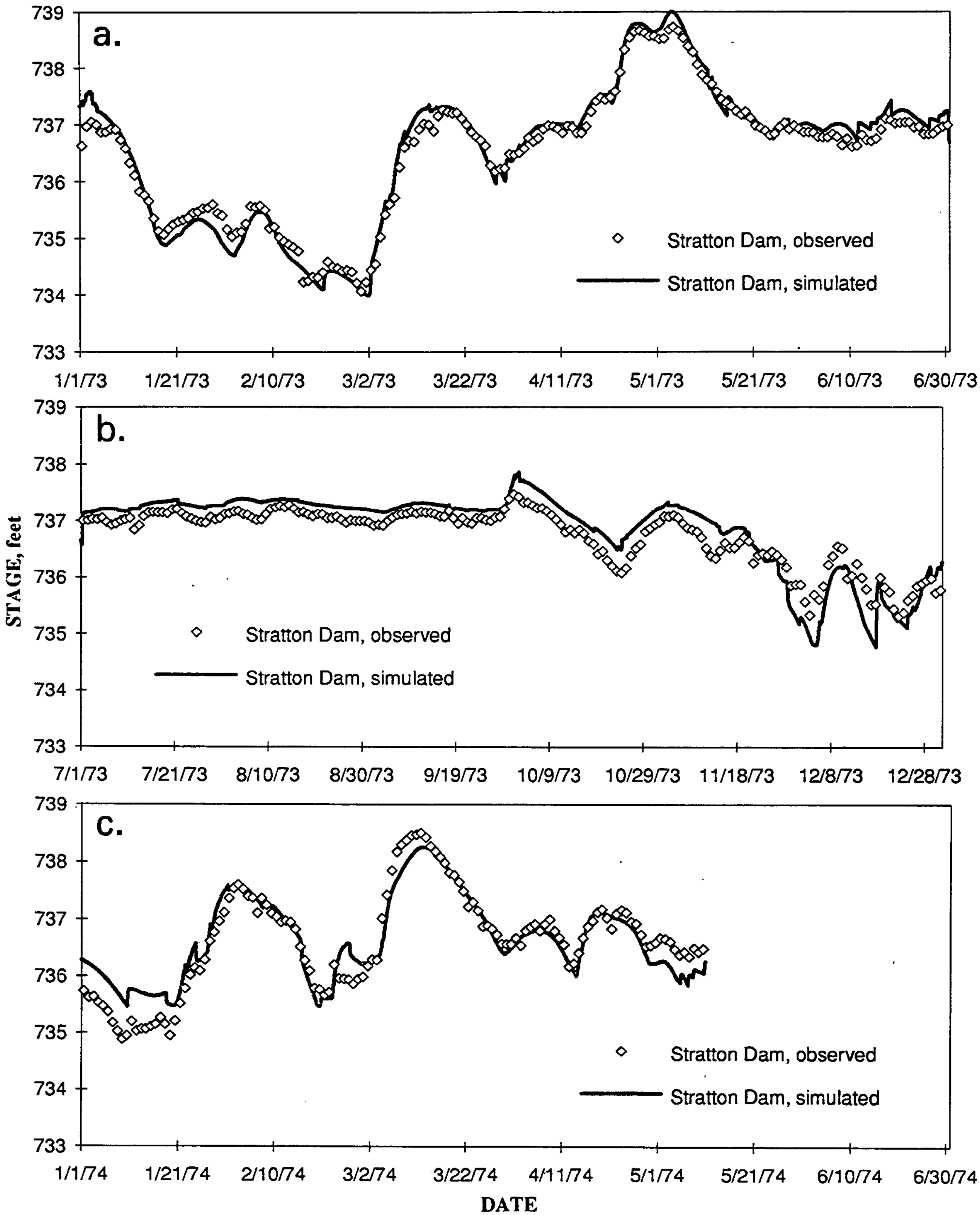

Figure 25. Simulated and observed stages; January 1, 1973 through May 15, 1974 at Stratton Dam

6. MODEL RESULTS

Description of Stage and Discharge Impacts for Selected Scenarios

The flow forecast model estimates the amount of water that will be flowing into the Chain. of Lakes system up to five days in advance. For many floods, lowering the lake levels prior to the arrival of a flood may be useful in reducing flood stages both in the lakes and downstream. Alternatives 3-10 (described earlier in Section 2: Dam Operation Alternatives for Flood Management) employ this early release of floodwaters for lowering the lake. Of these, alternatives 4 and 8 were selected for the following descriptions on the impacts of the early release on flood control.

Discharges from Stratton Dam

Figures 26-33 illustrate the impacts of gate operation on releases from the Stratton Dam, using historical operation practices (alternative 0), alternatives 4 and 8, and scenario ND. For most of the floods, the discharge hydrographs for the various alternatives and the ND scenario are very similar. The only apparent differences in the discharges for many of these floods occur for alternatives 4 and 8 during those days when the gates would be opened prior to the arrival of the flood inflows. For some floods, differences in historical gate operation practices and in alternatives 4 and 8 may occur as much as several weeks ahead of the flood peak -- not because of any prior knowledge of oncoming flood conditions, but as a response to either increases in the flow entering the Chain of Lakes or abnormally high stages in the lakes.

Between the alternatives, the relative differences in discharge are usually greater for smaller floods, and become less for larger floods. For the 1978 event (a small flood), large differences in the discharges occur because the early release of floodwaters creates a discharge in excess of that which otherwise would have occurred (based on historical operation practices). However the amount released does not appear to be sufficient to cause overbank flooding.

Cumulative Amount of Water Released Prior to the Arrival of the Flood (Alternatives 4 and 8)

Alternatives 4 and 8 involve the release of water from Stratton Dam ahead of the arrival of flood inflows into the lakes. The cumulative amount of water discharged from the lakes using alternative 8 (pictured in figures 26-33) ranges from less than 2000 acre-feet for the 1978 and 1986 floods to nearly 8000 acre-feet for the 1960 and 1979 floods. The cumulative quantity of water that can be released ahead of any given flood is mostly a function of 1) antecedent lake stage and 2) how long the release continues before floodwaters arrive. The greatest cumulative release occurs with floods caused by snowmelt and spring thaw, because the forecast model can provide a longer warning period of oncoming flow conditions. The smallest amount of early release occurs with floods that are caused by intense summer rainfall, for which there may be uncertain quantitative information of the expected rainfall.

Stage Hydrographs at Stratton Dam

Figures 34-37 illustrate the impacts of gate operation (using alternatives 0, 4, and 8, and scenarios ND and NG) on the upstream stage at Stratton Dam for the 1960, 1978, 1979, and 1986 floods. For alternatives 4 and 8, an initial reduction in stage may occur up to ten days prior to the flood, as the gates are opened in response to either high inflows or abnormally high stages in the Chain of Lakes. But the major gate opening for these alternatives usually occurs immediately prior to the major flooding. Significant drops in the upstream stage at Stratton

Dam will occur as the sluice gates and Foster gates are dropped to their maximum opening (as simulated by the FEQ model).

Releasing water ahead of the flood significantly lowers the antecedent stage at Stratton Dam. The reduction in antecedent stage is greatest for alternative 8, which employs the Foster gates. The historical flood that displays the greatest reduction in the simulated antecedent stage at Stratton Dam is the 1979 flood (figure 33), which has a reduction of 2.5 feet.

Stage Hydrographs Upstream of Stratton Dam

Figures 38-41 present the impacts of the various alternatives on the simulated stages at Johnsburg for the 1960, 1978, 1979, and 1982 floods. Figures 42-45 provide the stage hydrographs at Channel Lake for those same floods. The simulated stages at Fox Lake and Nippersink Lake are virtually identical to those of Channel Lake.

Figures 38-45 illustrate that the use of either alternative 4 or alternative 8 causes a reduction in the antecedent stage, when compared to alternative 0 (the historical operation). Much of this reduction in stage is maintained during the entire flood period, such that there are noticeable reductions in the flood peaks both for alternatives 4 and 8. In many cases, the flood peaks associated with alternative 8 are only slightly greater than those associated with the "no dam" scenario.

Table 16 compares the difference in the antecedent stages at Stratton Dam, Johnsburg, and Channel Lake between alternatives 0 and 8. An examination of this table indicates that the difference in stage is smaller at Johnsburg than at Stratton Dam, and is smaller at Channel Lake than at Johnsburg. For example, the reduction in the 1960 antecedent stage for alternative 8 is 2.4, 0.8, and 0.5 feet at Stratton Dam, Johnsburg, and Channel Lake, respectively. [The reduction in the flood peak at these three locations is 1.2, 0.6, and 0.5 feet, respectively.]

Table 16. Change in Antecedent Stage (feet) between Alternative 0 (Historical Gate Operation) and Alternative 8

Year of Flood	*Stratton Dam*	*Johnsburg*	*Channel Lake*
1960	2.4	0.8	0.5
1972	1.6	0.5	0.3
1973	1.4	0.7	0.5
1974	1.4	0.5	0.3
1978	1.8	0.8	0.6
1979	2.5	1.3	1.0
1982	1.4	0.4	0.3
1986	2.0	0.7	0.5

Water Surface Gradient along the Johnsburg Chute

The data in table 16 indicate that, as the stage at Stratton Dam is drawn down prior to the flood event, an increase in the gradient of the water surface occurs between the dam and the Chain of Lakes. With the increase in the gradient, larger discharges can be maintained at a lower stage -- a condition that can last through the duration of the flood. Figures 46 and 47 present profiles of the simulated peak stages along the Johnsburg Chute (Stratton Dam to Nippersink Lake) for the 1960 and 1982 floods, respectively. These profiles indicate that the increased gradient, established prior to the flood, is maintained through the flood peak for both alternatives 4 and 8.

Johnsburg Stage-Discharge Rating

As noted earlier in figures 26-33, the various alternatives do not cause much of a change in the overall discharge from Stratton Dam, even though the stage levels upstream are reduced. The alternative schemes produce a change in the stage-discharge relationship (rating curve) at Stratton Dam and along the Johnsburg Chute. The change in the rating curve at Johnsburg is illustrated in figure 48 for the 1979 flood for alternatives 0, 4, and 8. The loops in the rating curve, seen in figure 48, appear to be caused primarily by the influx of tributary flows downstream of Johnsburg (Dutch Creek and Boone Creek) and, at times, by the opening and closing of gates at Stratton Dam. For a given operation alternative, the rating curve appears to remain fairly consistent between floods. This is illustrated in figure 49, in which the rating curves at Johnsburg for the 1960, 1979, and 1986 floods using alternative 4 are plotted.

Stage Hydrographs Downstream of Stratton Dam

Figures 50-53 illustrate the impacts of gate operation (using alternatives 0, 4, and 8, and scenario ND) on the stage at Algonquin Dam for the 1960, 1978, 1979, and 1986 floods. These figures indicate that the installation and use of a Foster gate at the Algonquin Dam (alternative 8) would consistently lower flood stages at the Algonquin dam by over 0.7 foot. The reduction in stage caused by the Foster dam at Algonquin decreases upstream -- as shown in figure 54 for the 1960 flood – to a point where the impact on the tailwater at the Stratton Dam is negligible.

For alternatives 0 and 4 and scenario ND, the flood stages between Stratton Dam and Algonquin Dam are affected only to a small degree. This is to be expected, since the differences in the discharge from Stratton Dam are relatively small. Only for the 1978 event is there a relatively large difference in the discharge from Stratton Dam. For this event, the use of alternative 4 increases the peak stage over the historical peak by approximately 0.2 foot (see figure 51). However, the maximum stage for the 1978 event is low and, even with the stage increase, the flood stage at Algonquin is not reached.

Downstream of Algonquin Dam there is generally little difference in the stage hydrographs for any of the alternatives, with the exception of the 1978 event. As shown in figure 55, the early release during the 1978 event would have caused as much as a 0.3 foot increase in the peak stage at East Dundee. However, the peak elevations associated with the 1978 event do not appear to reach flood stage.

Effects of the Winter Pool Level on Flood Stage and Discharge

From early spring to late fall, Stratton Dam is operated to maintain the recreational pool close to or slightly above the elevation of its spillway crest (736.68 feet). During the winter months (early November through mid-March) the pool is lowered approximately 1.5 feet to reduce the flooding potential in the lakes and reduce damages to boating facilities caused by ice. However, this policy has recently been questioned concerning potential adverse impacts to the aquatic life in the lakes.

Simulation analysis was conducted in order to quantify the potential flood control benefit provided with the lowered winter pool. Four of the floods were examined: 1960, 1974, 1979, and 1982; these floods occurred when the lakes were at their winter pool level. Simulations were conducted on these floods, using operation alternative 8, to analyze the effect of antecedent stage on flooding conditions.

Figures 56-59 illustrate the effect that the winter pool elevation has on the stage hydrographs at Nippersink Lake. These figures indicate that the differences in stage that exist at the beginning of the flood are gradually diminished as the flood stage increases. When the antecedent pool is raised over one foot to the normal recreational pool, the flood peak on Nippersink Lake is generally increased by only 0.15 foot.

The flood peaks downstream of Stratton Dam are also affected by the change in the winter pool level. This happens because a greater amount of water must be released from Stratton Dam during the flood event. Figures 60 and 61 illustrate the change in flood stage that would occur at East Dundee for the 1960 and 1974 floods.

The simulation analysis described above addresses just the flood control impacts of changing the winter pool level. There is no attempt to examine any other issues that may be affected by the change in winter pool. It is thus recommended that these other impacts, including effects on aquatic life, ice damage, water quality, and recreation, be fully studied to determine the overall, most-beneficial pool level for winter operation.

Summary

As described above, there appear to be two advantages of opening the gates prior to the arrival of floodwaters: 1) antecedent storage in the lakes is reduced, thereby becoming available for use in storing floodwaters, and 2) the reduced stage at Stratton Dam sets up a better slope through the Johnsburg Chute, creating more efficient outflow from the lakes. It appears that the second of these two impacts is more critical for reducing overall flood stage in the Chain of Lakes.

Raising the winter pool level to the normal, recreational pool level appears to cause an approximate 0.15-foot increase in flood stage on the Chain of Lakes. A similar increase in flood stage occurs along the Fox River downstream to Elgin.

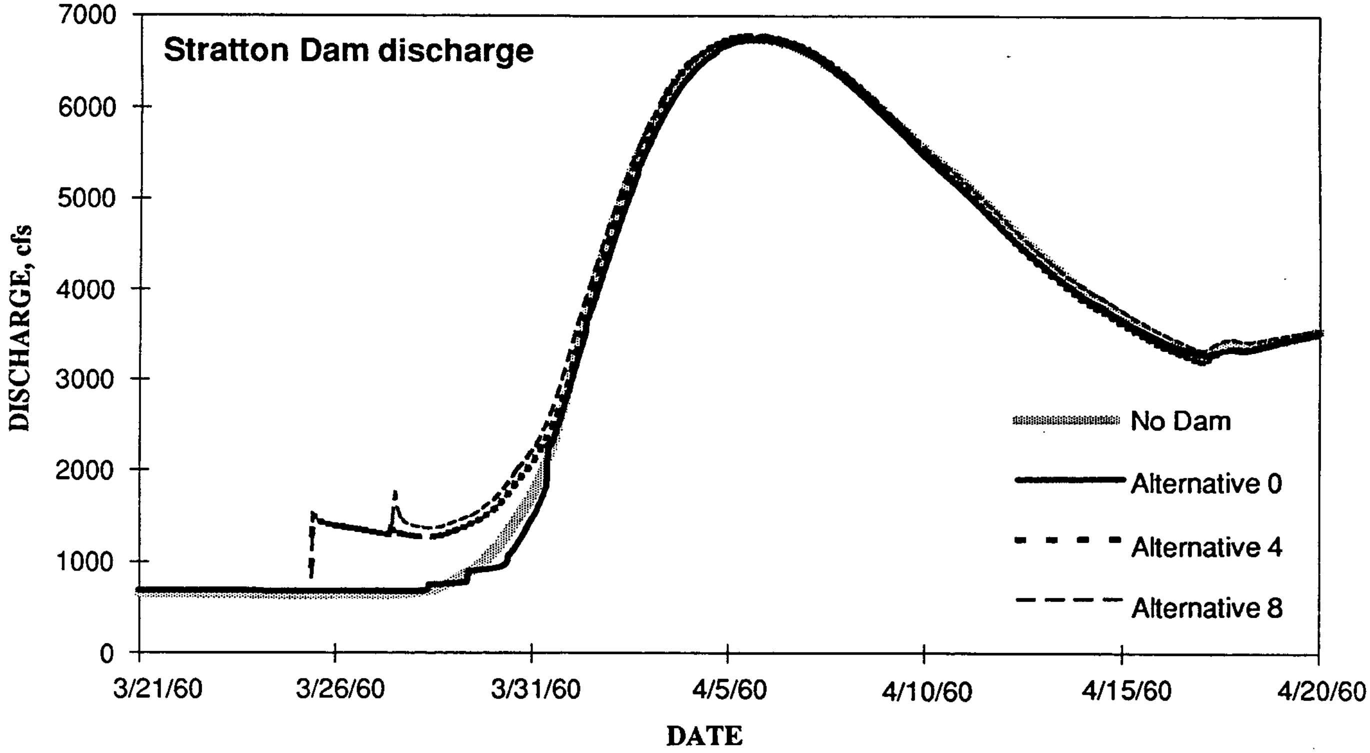

Figure 26. Effect of gate operations on simulated discharges; 1960 flood at Stratton Dam

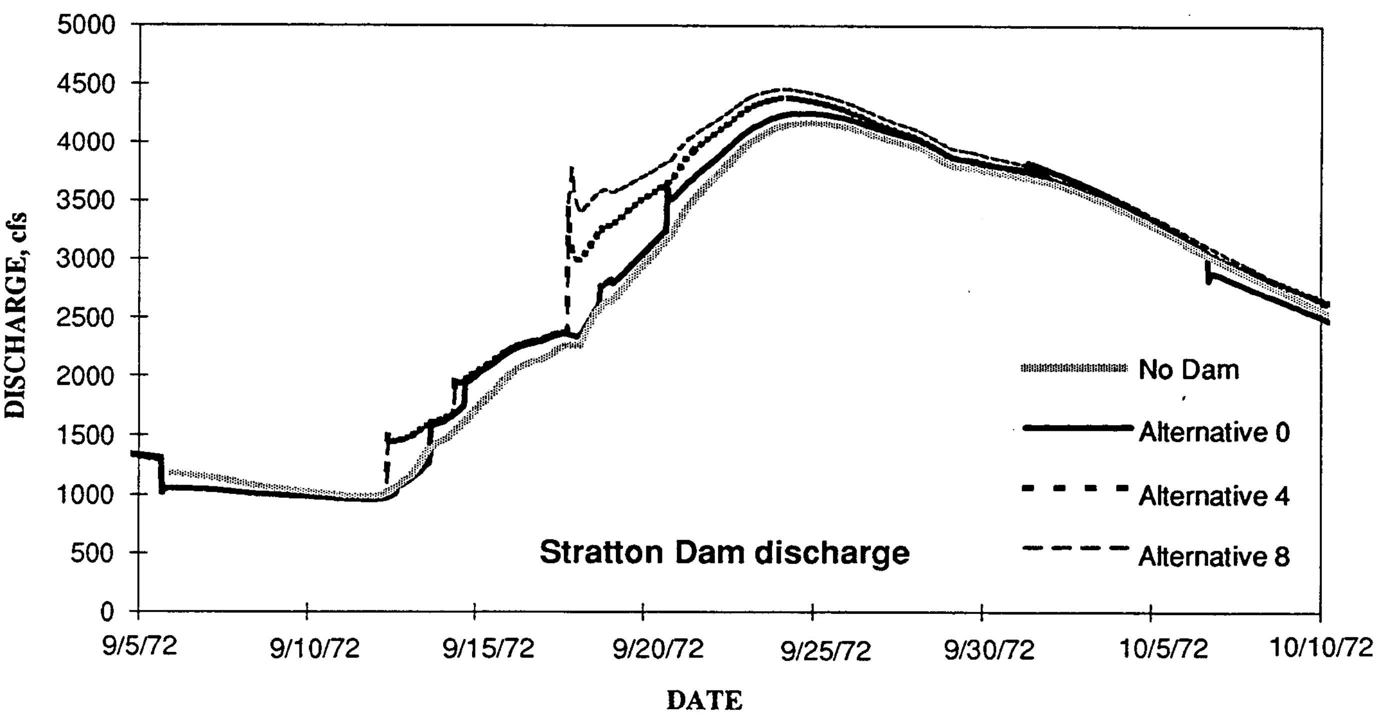

Figure 27. Effect of gate operations on simulated discharges; 1972 flood at Stratton Dam

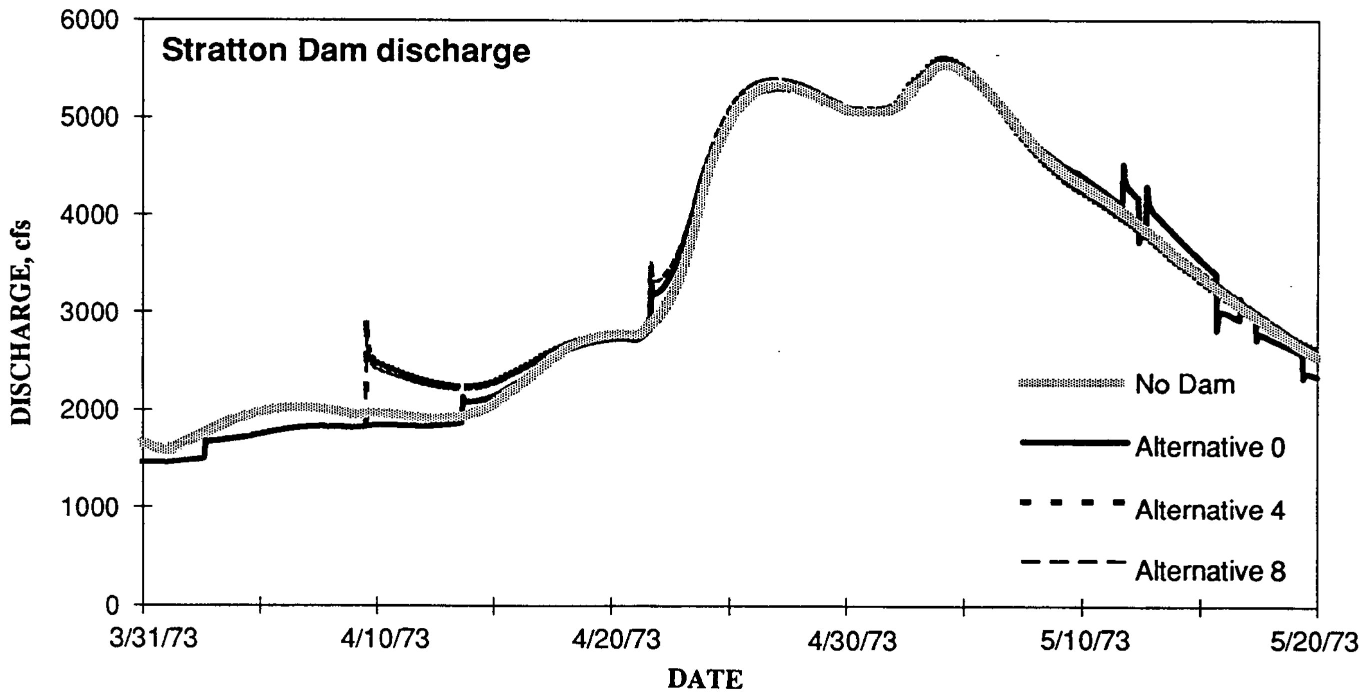

Figure 28. Effect of gate operations on simulated discharges; 1973 flood at Stratton Dam

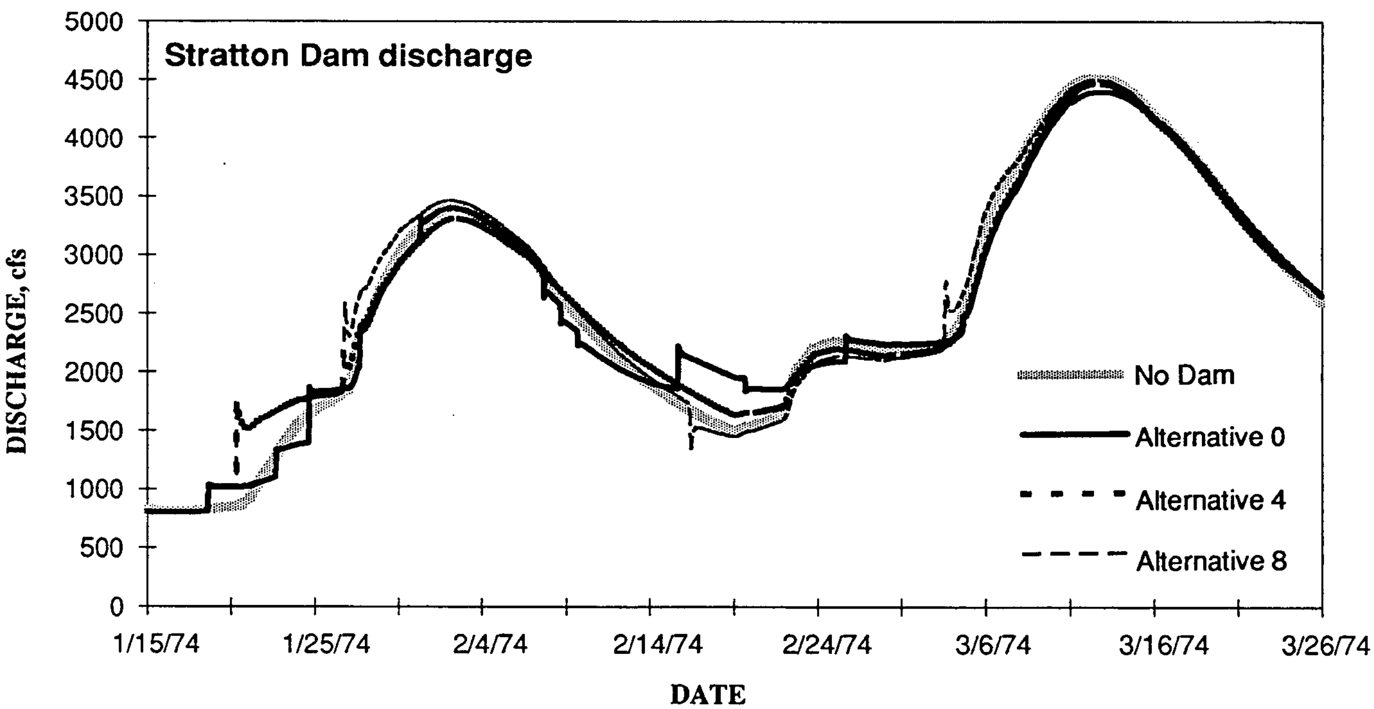

Figure 29. Effect of gate operations on simulated discharges; 1974 flood at Stratton Dam

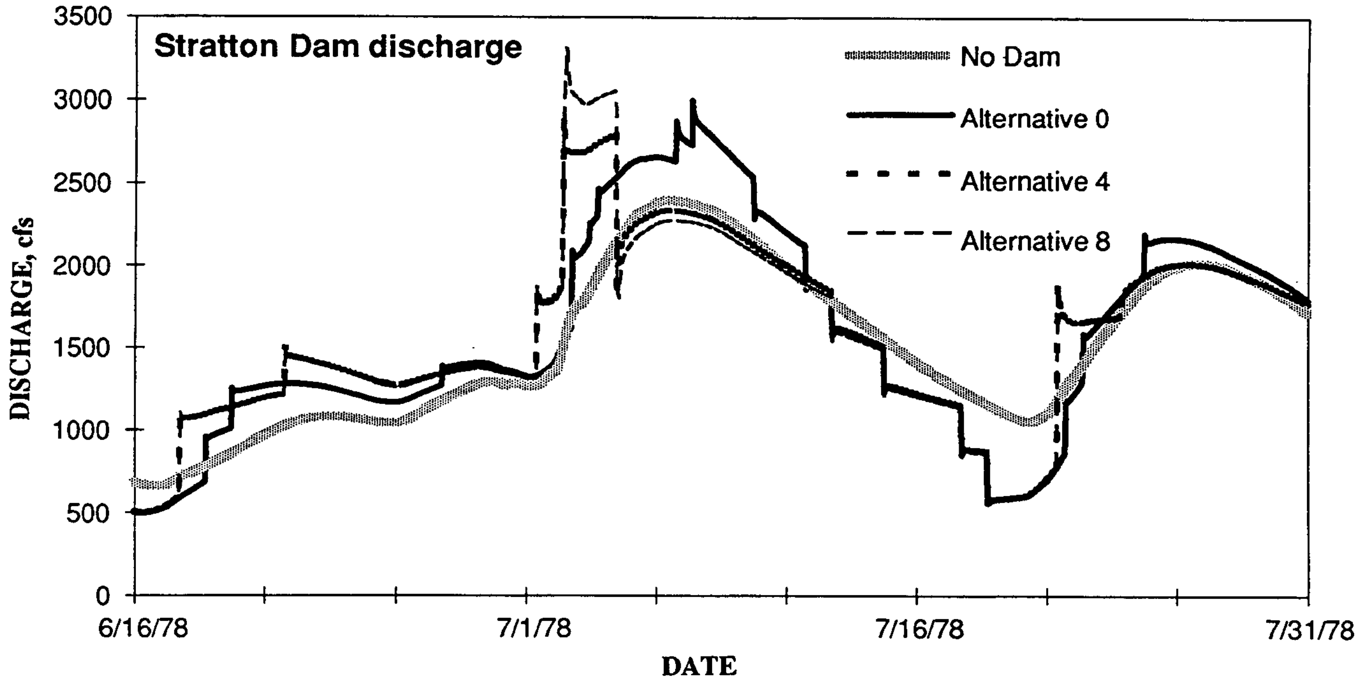

Figure 30. Effect of gate operations on simulated discharges; 1978 flood at Stratton Dam

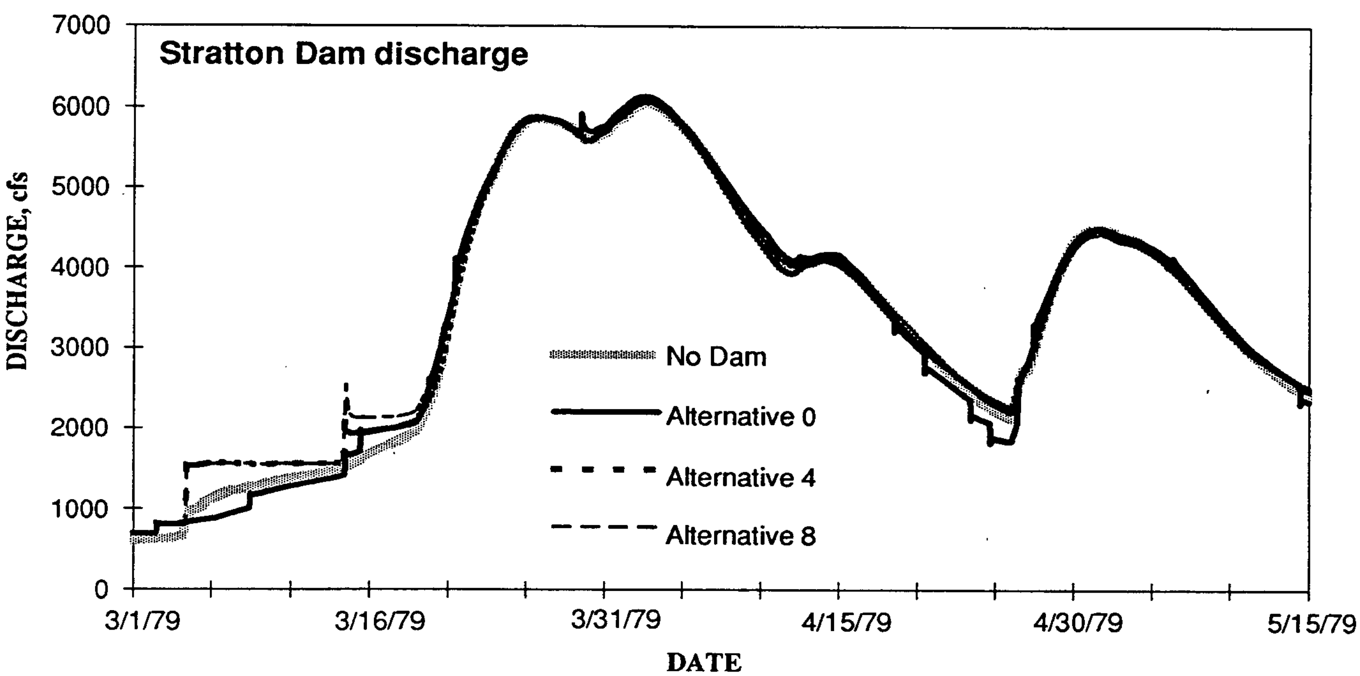

Figure 31. Effect of gate operations on simulated discharges; 1979 flood at Stratton Dam

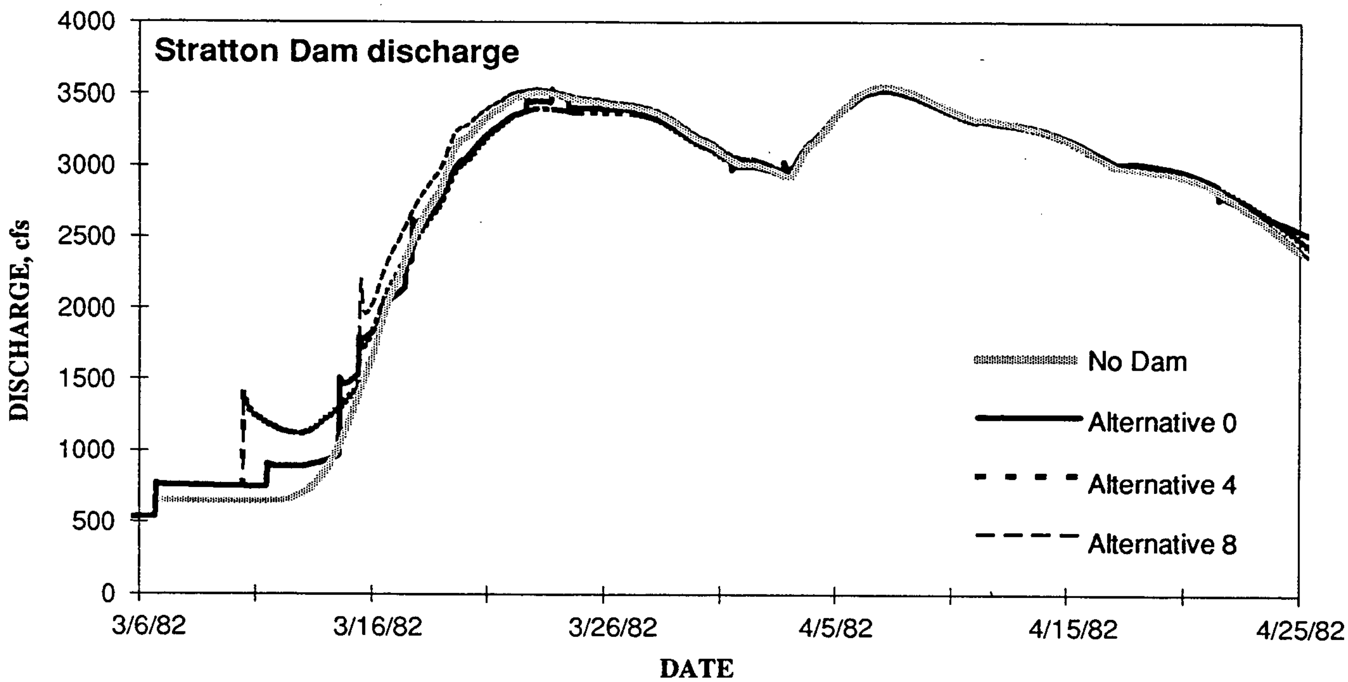

Figure 32. Effect of gate operations on simulated discharges; 1982 flood at Stratton Dam

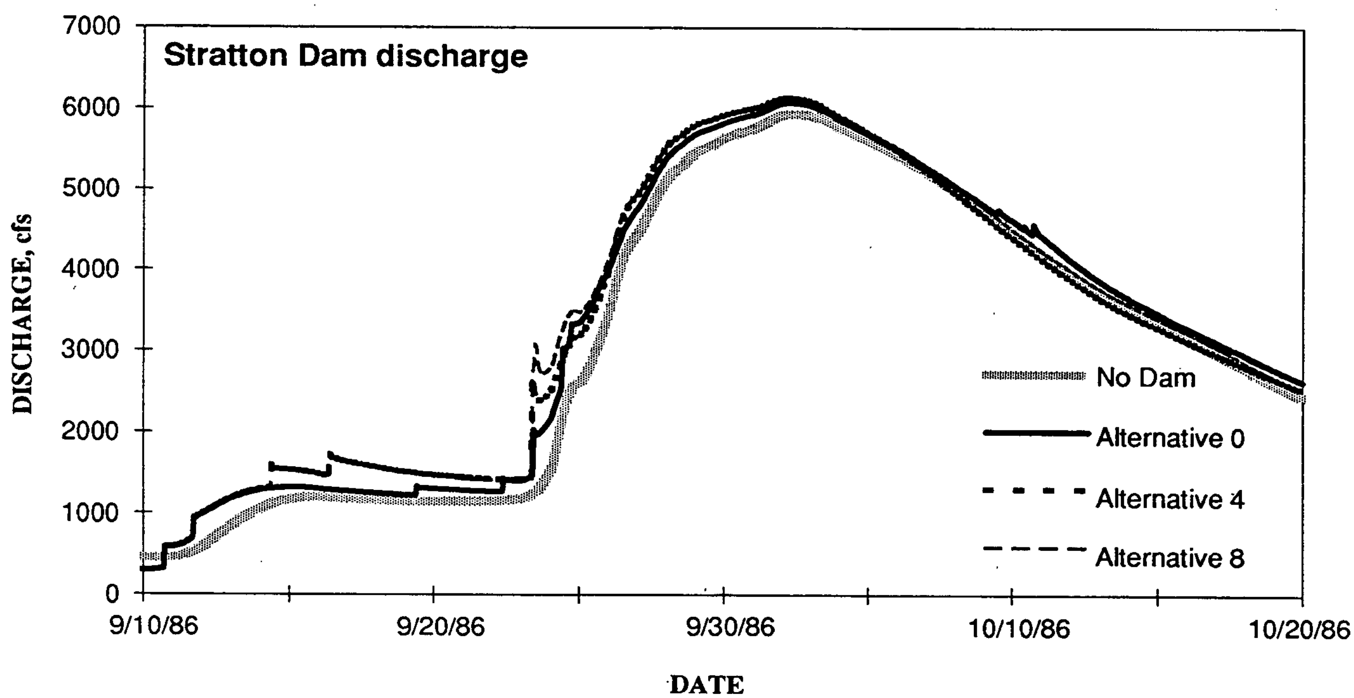

Figure 33. Effect of gate operations on simulated discharges; 1986 flood at Stratton Dam

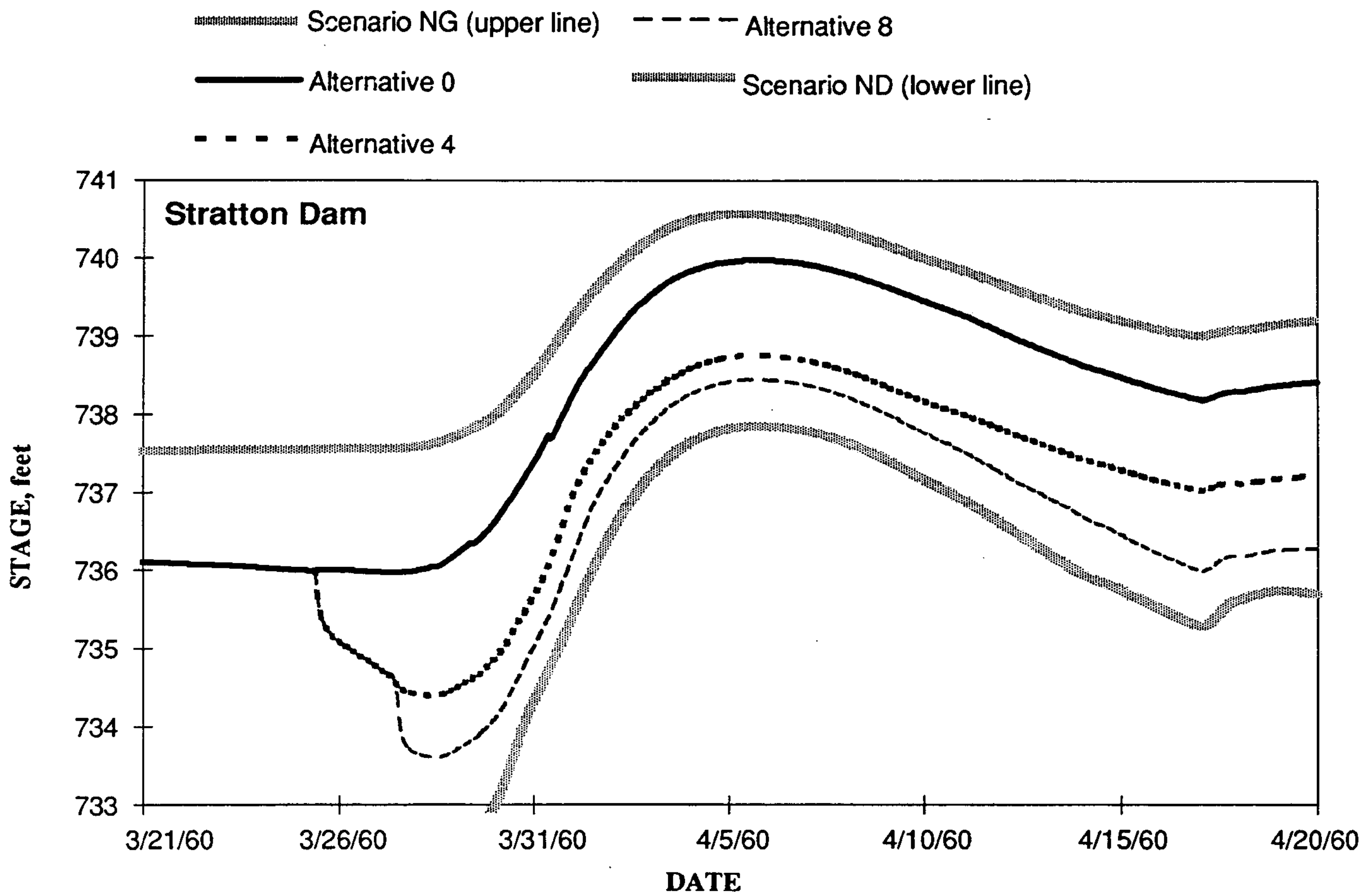

Figure 34. Effect of gate operations on simulated stages; 1960 flood at Stratton Dam

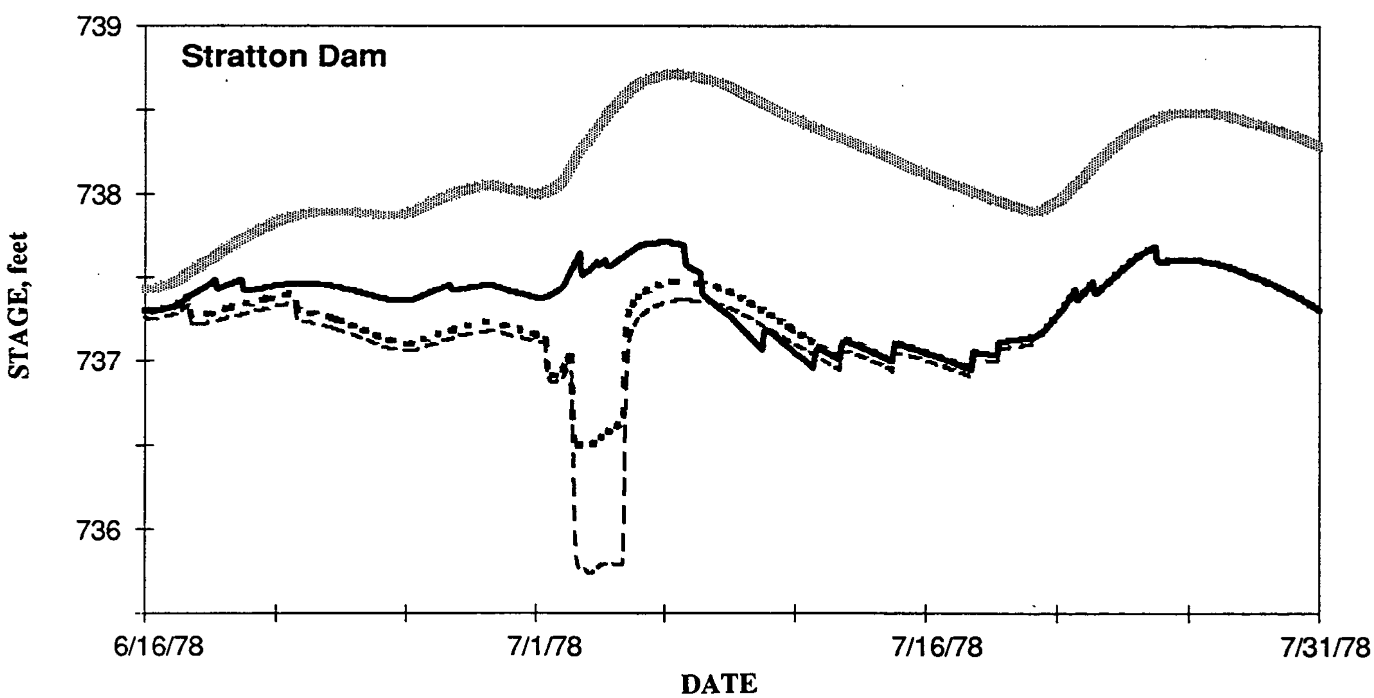

Figure 35. Effect of gate operations on simulated stages; 1978 flood at Stratton Dam

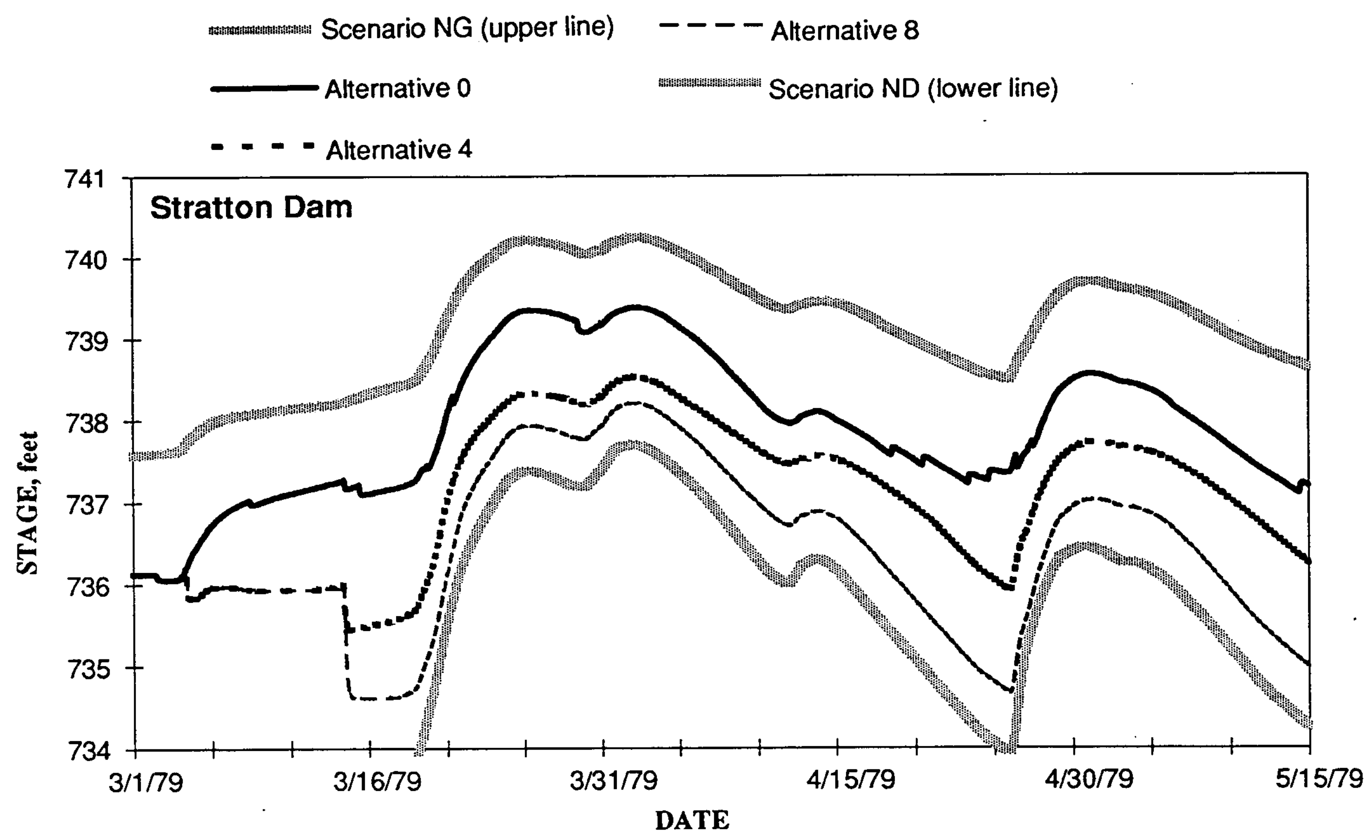

Figure 36. Effect of gate operations on simulated stages; 1979 flood at Stratton Dam

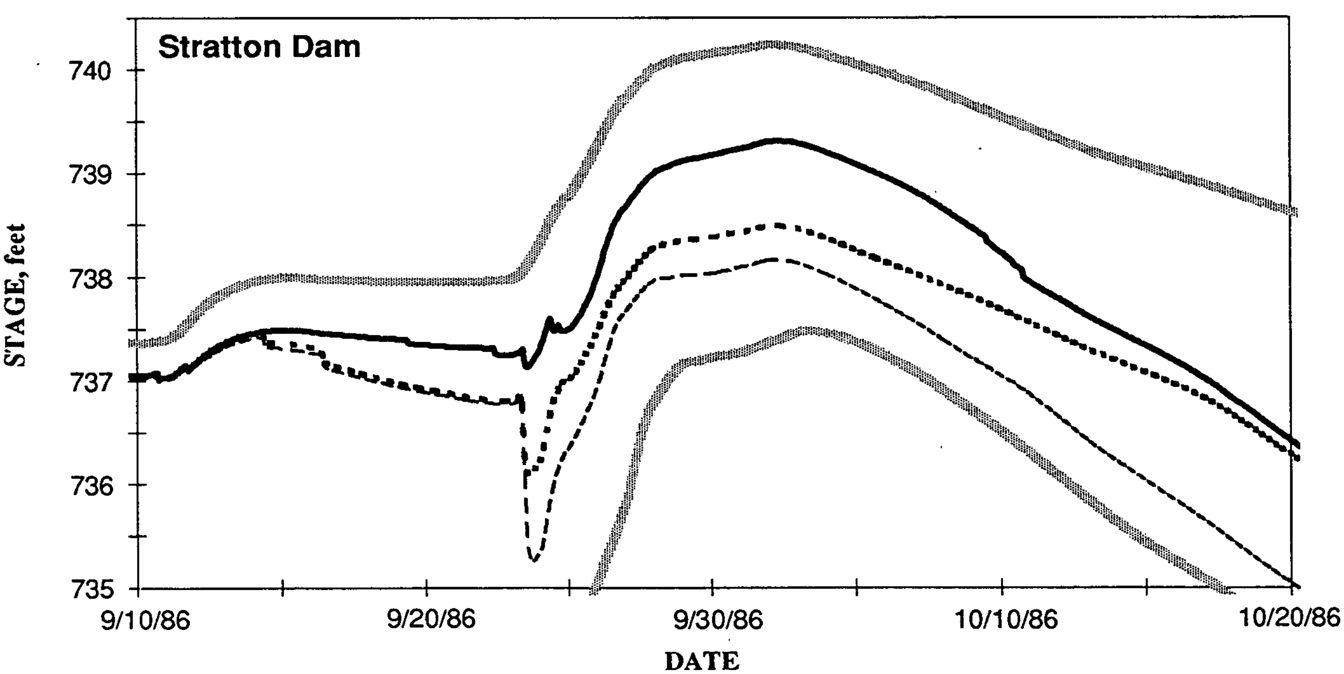

Figure 37. Effect of gate operations on simulated stages; 1986 flood at Stratton Dam

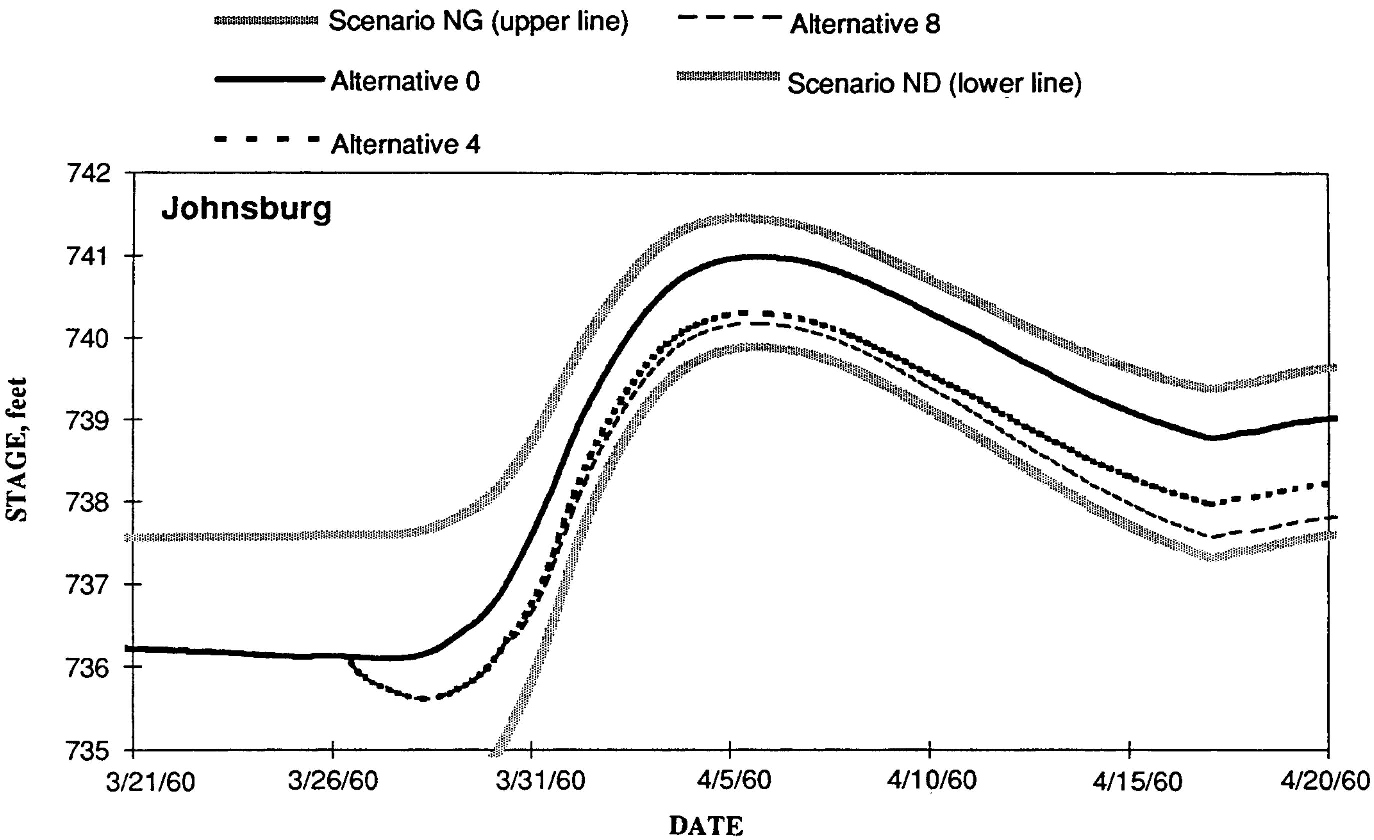

Figure 38. Effect of gate operations on simulated stages; 1960 flood at Johnsburg

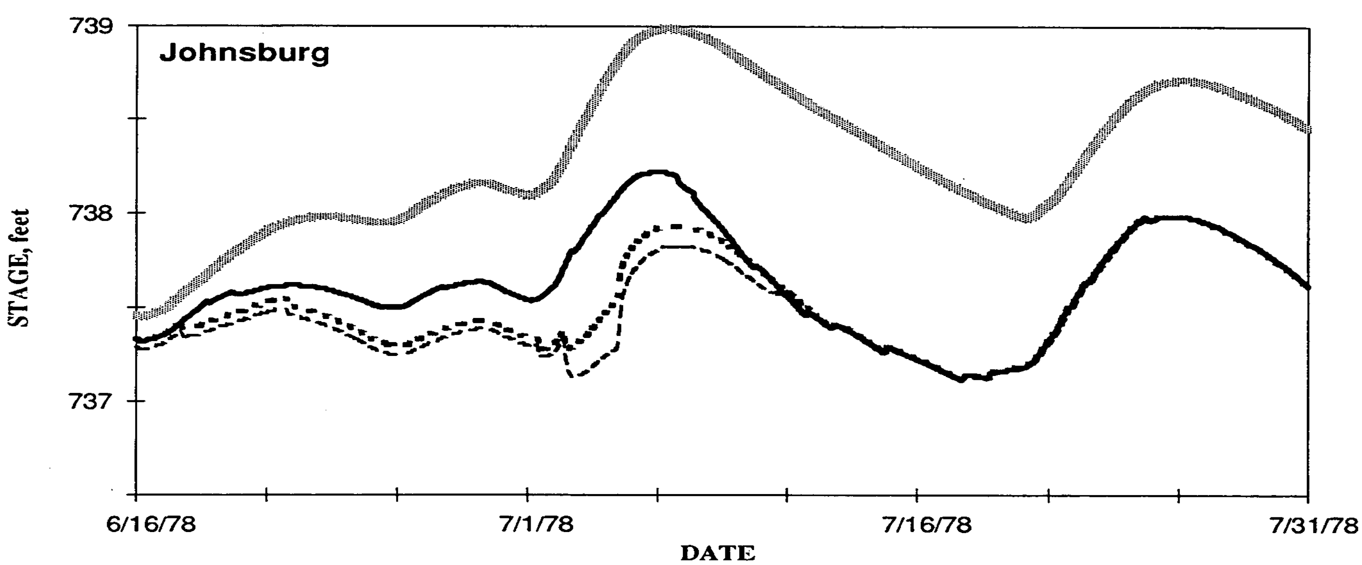

Figure 39. Effect of gate operations on simulated stages; 1978 flood at Johnsburg

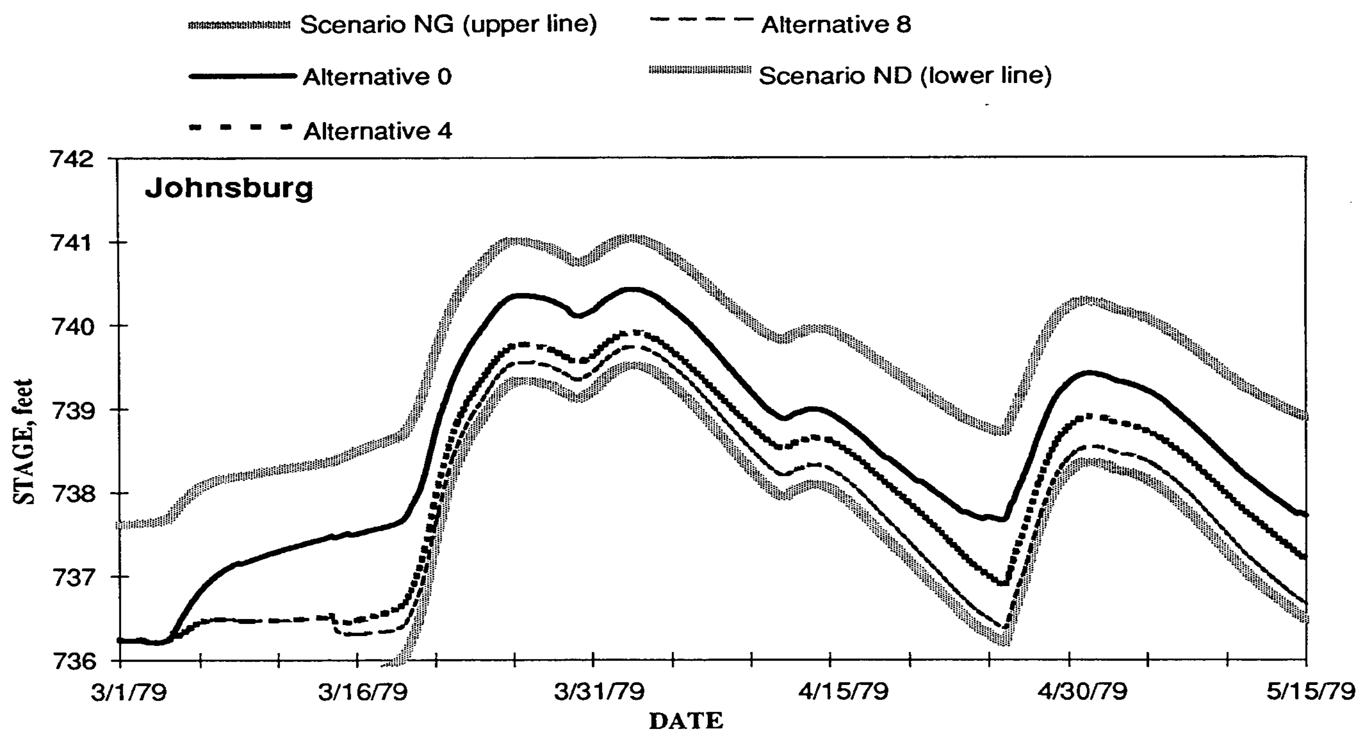

Figure 40. Effect of gate operations on simulated stages; 1979 flood at Johnsburg

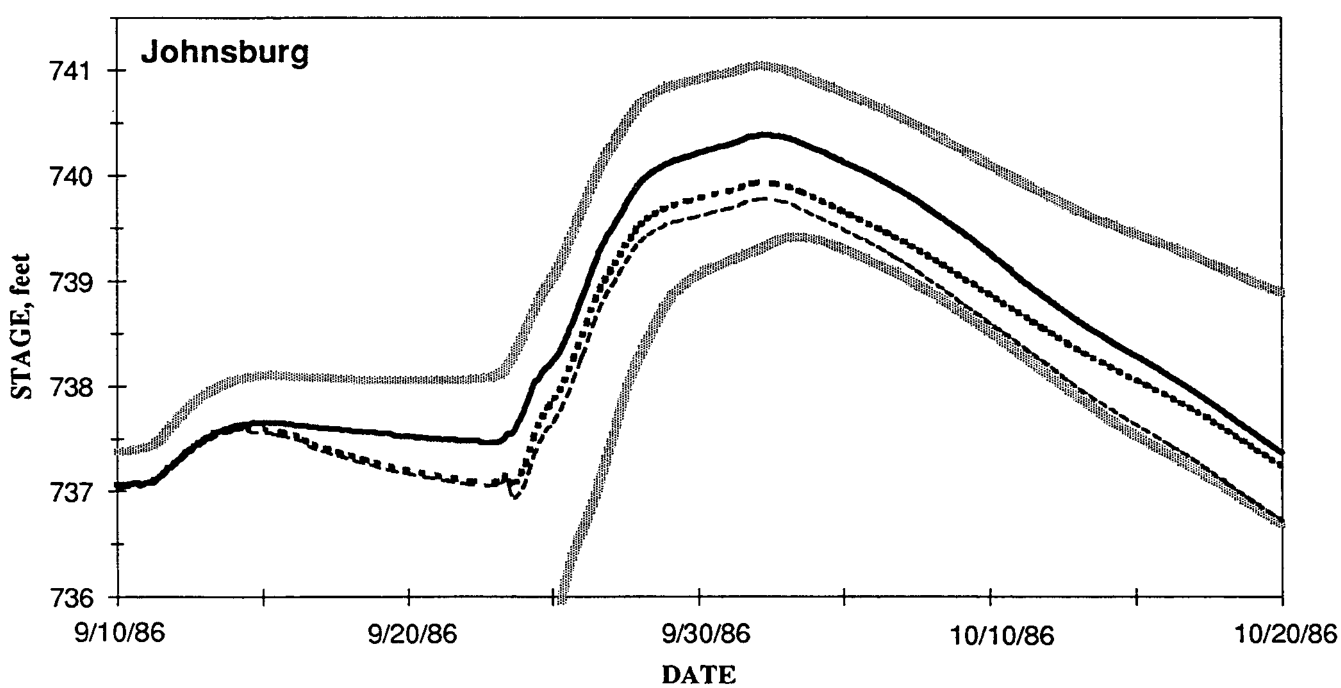

Figure 41. Effect of gate operations on simulated stages; 1986 flood at Johnsburg

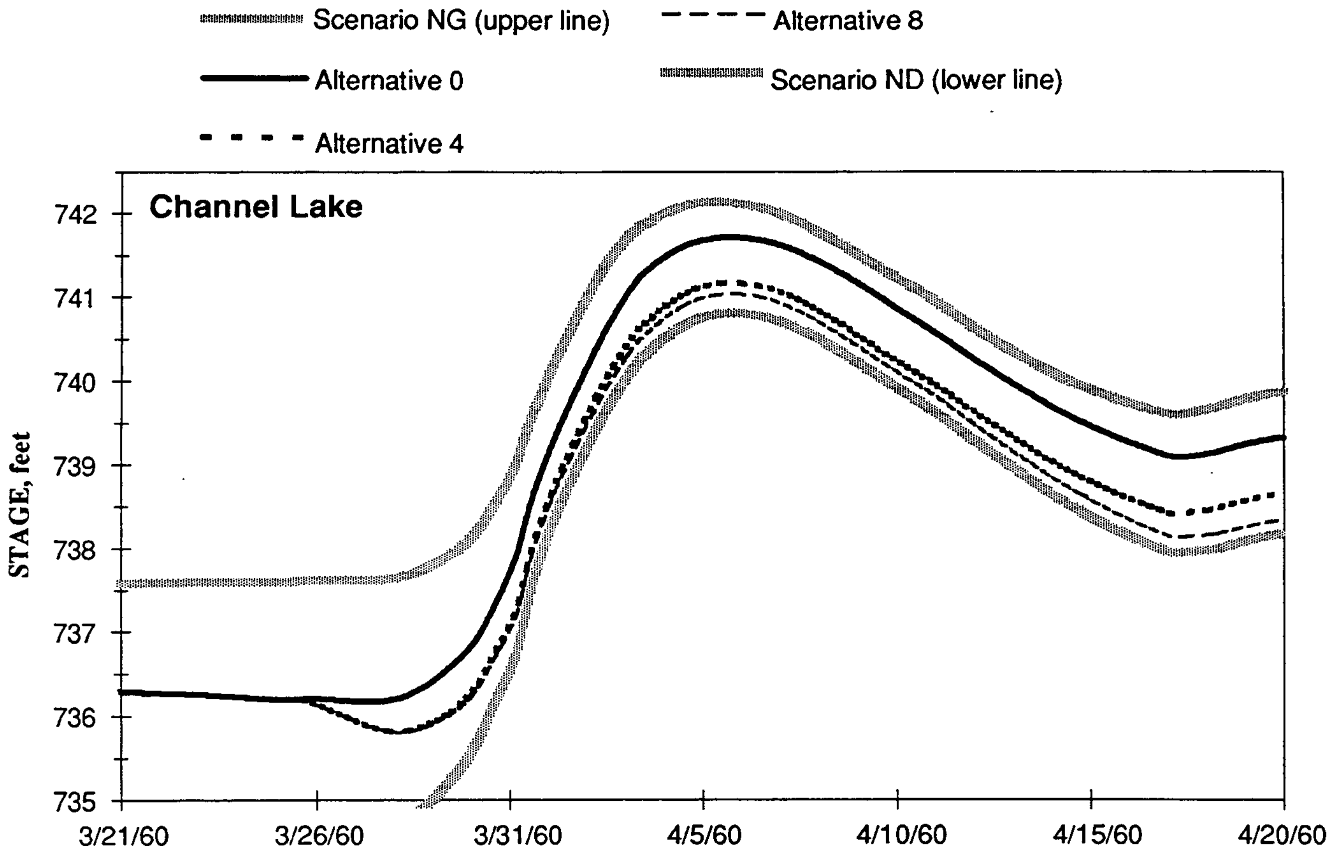

Figure 42. Effect of gate operations on simulated stages; 1960 flood at Channel Lake

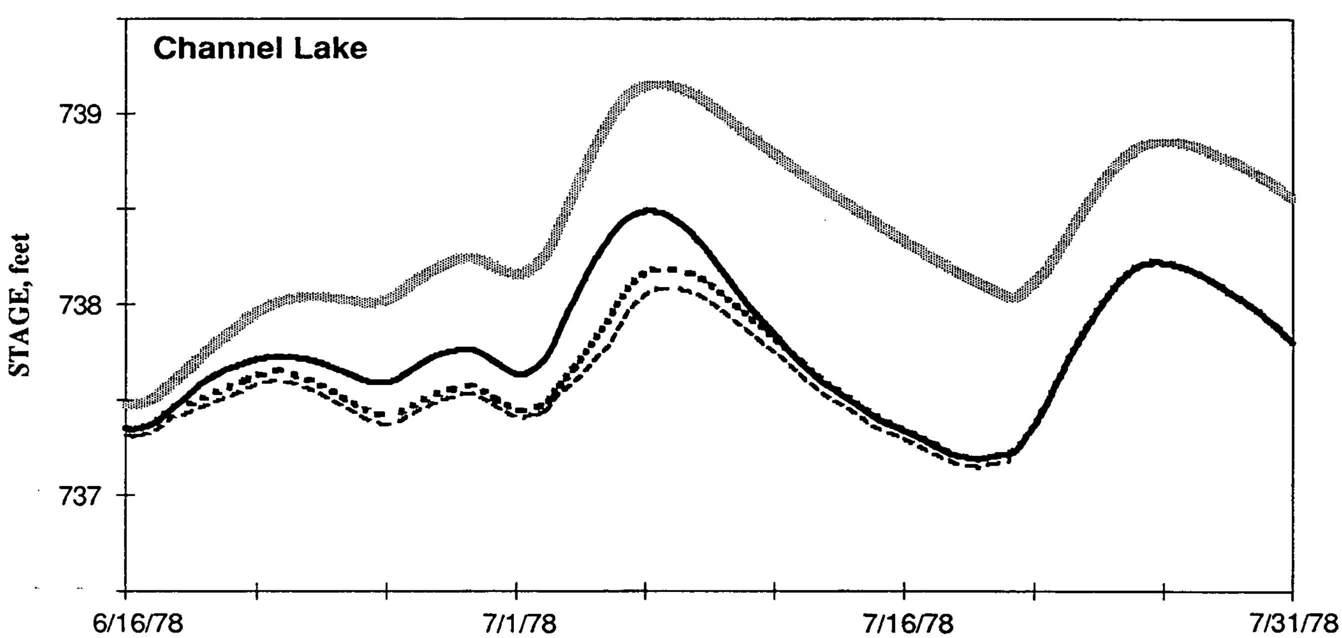

Figure 43. Effect of gate operations on simulated stages; 1978 flood at Channel Lake

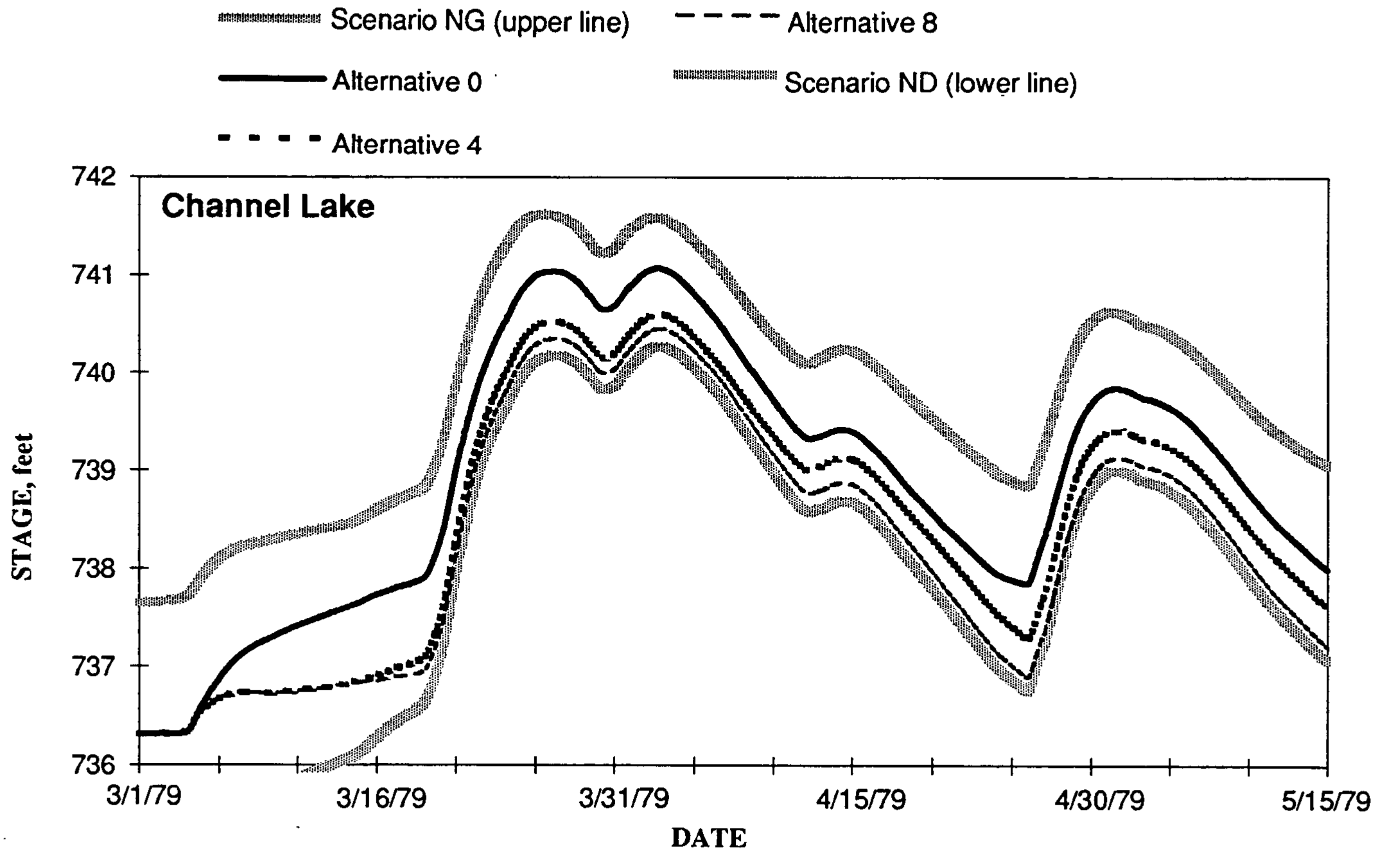

Figure 44. Effect of gate operations on simulated stages; 1979 flood at Channel Lake

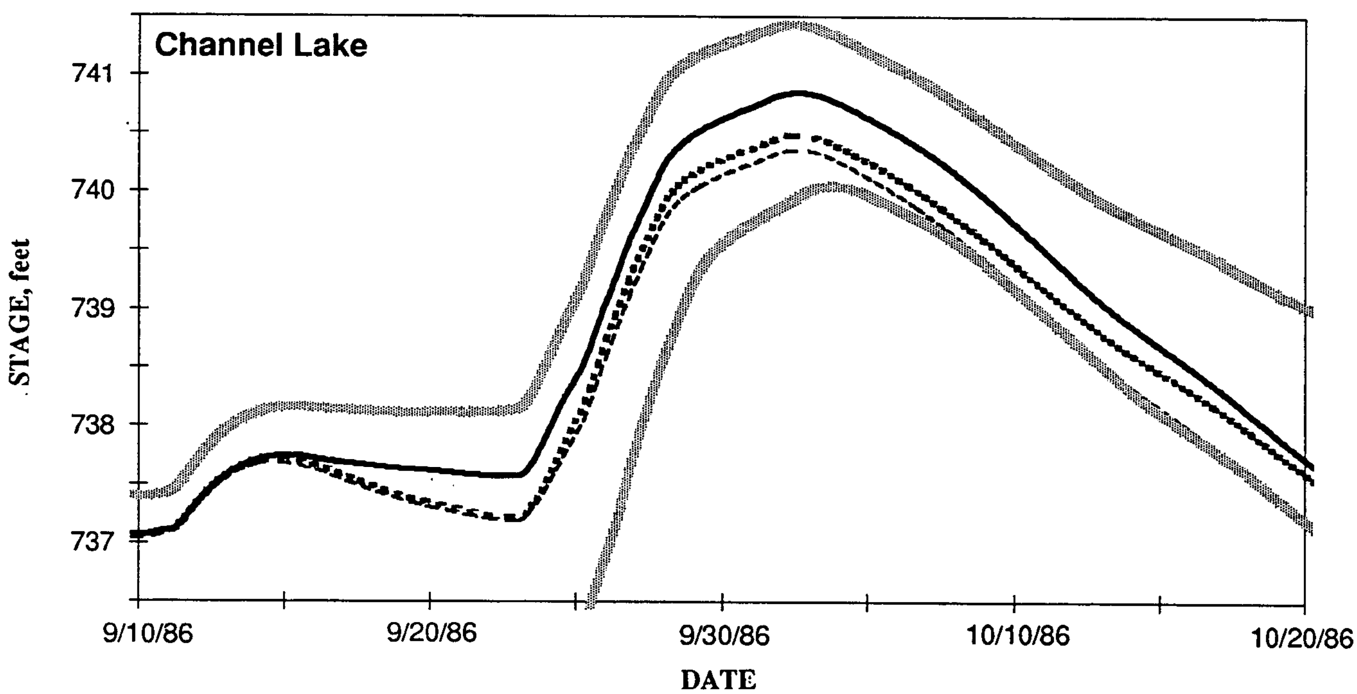

Figure 45. Effect of gate operations on simulated stages; 1986 flood at Channel Lake

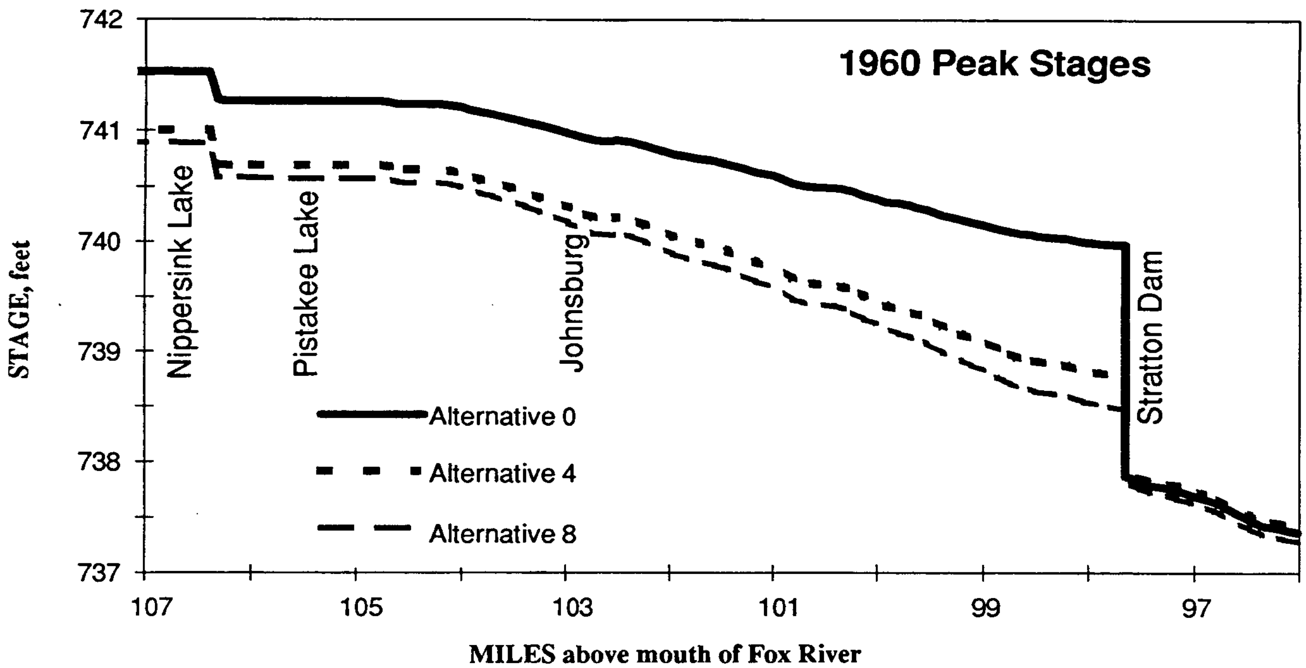

Figure 46. Effect of gate operations on simulated peak stages; 1960 flood from Stratton Dam to Nippersink Lake

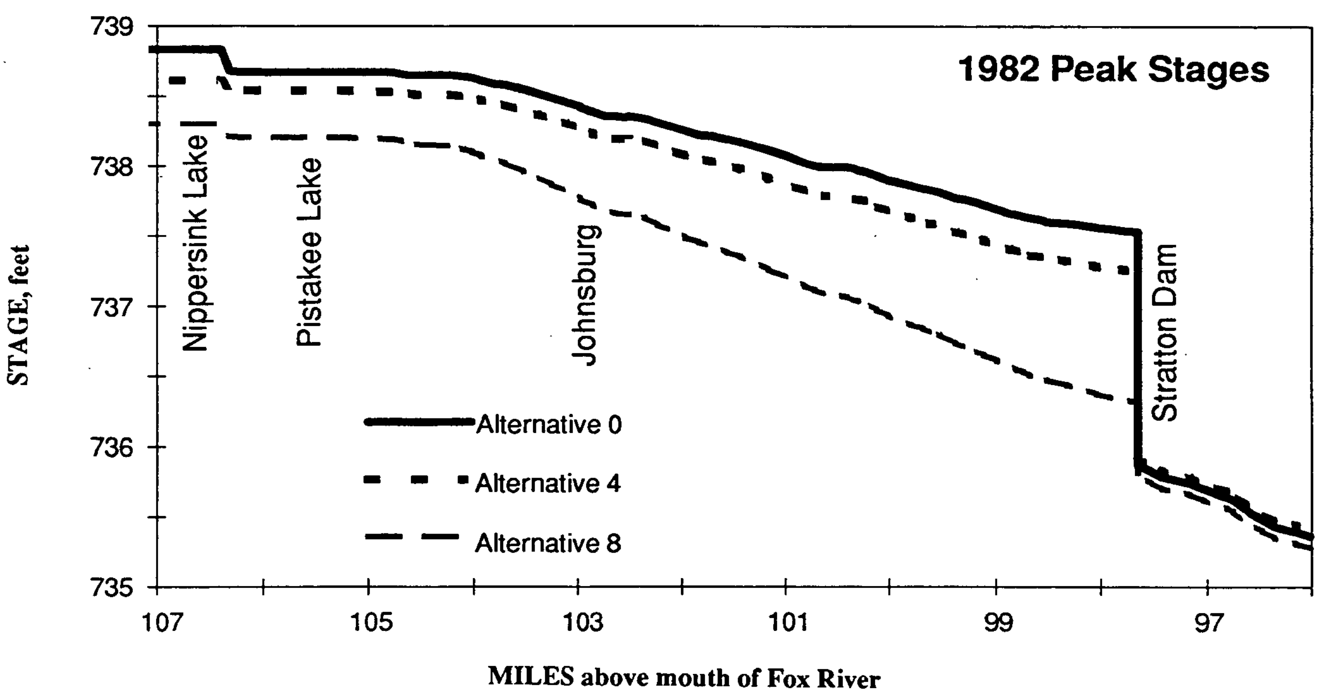

Figure 47. Effect of gate operations on simulated peak stages; 1982 flood from Stratton Dam to Nippersink Lake

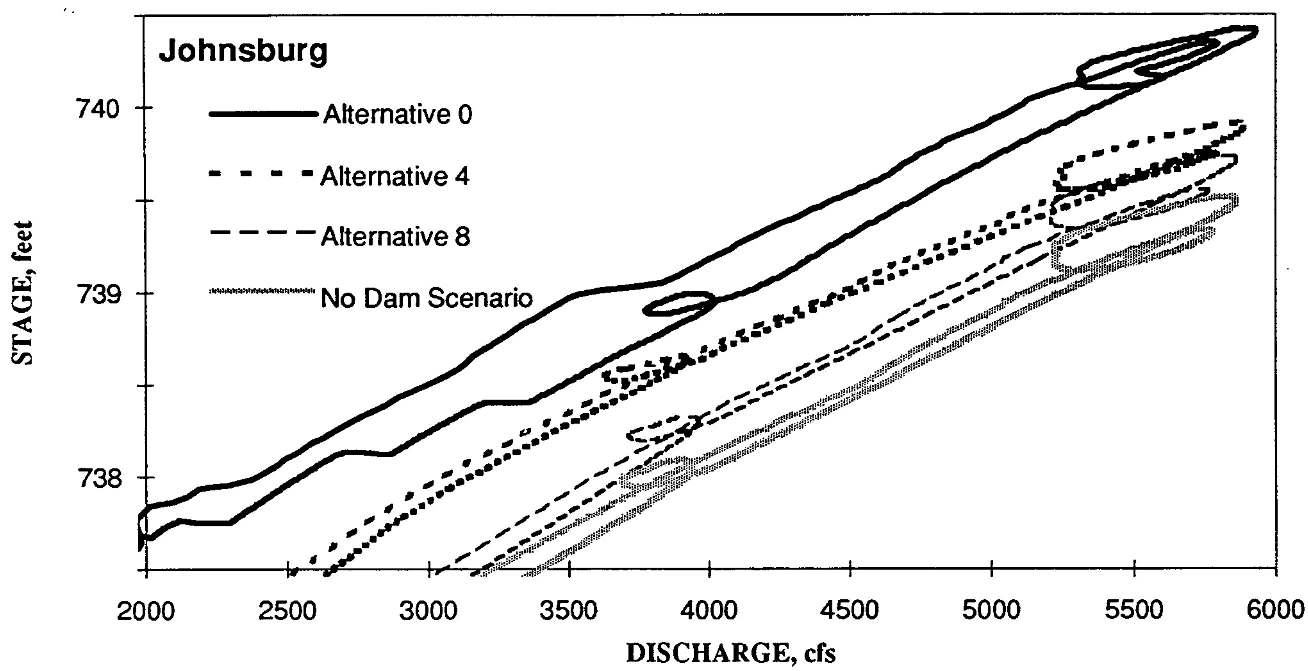

Figure 48. Effect of gate operations on the simulated stage-discharge relationship at Johnsburg; 1979 flood

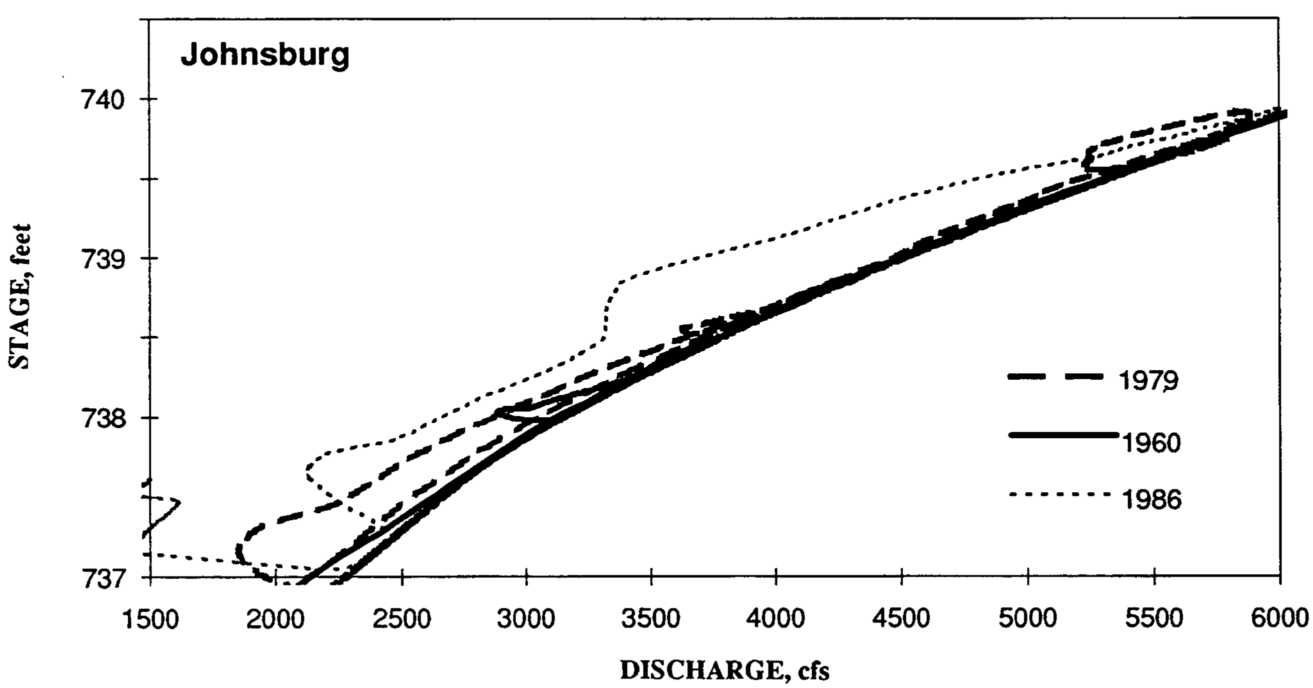

Figure 49. Variation in the simulated stages-discharge relationship at Johnsburg; 1960, 1979, and 1986 floods

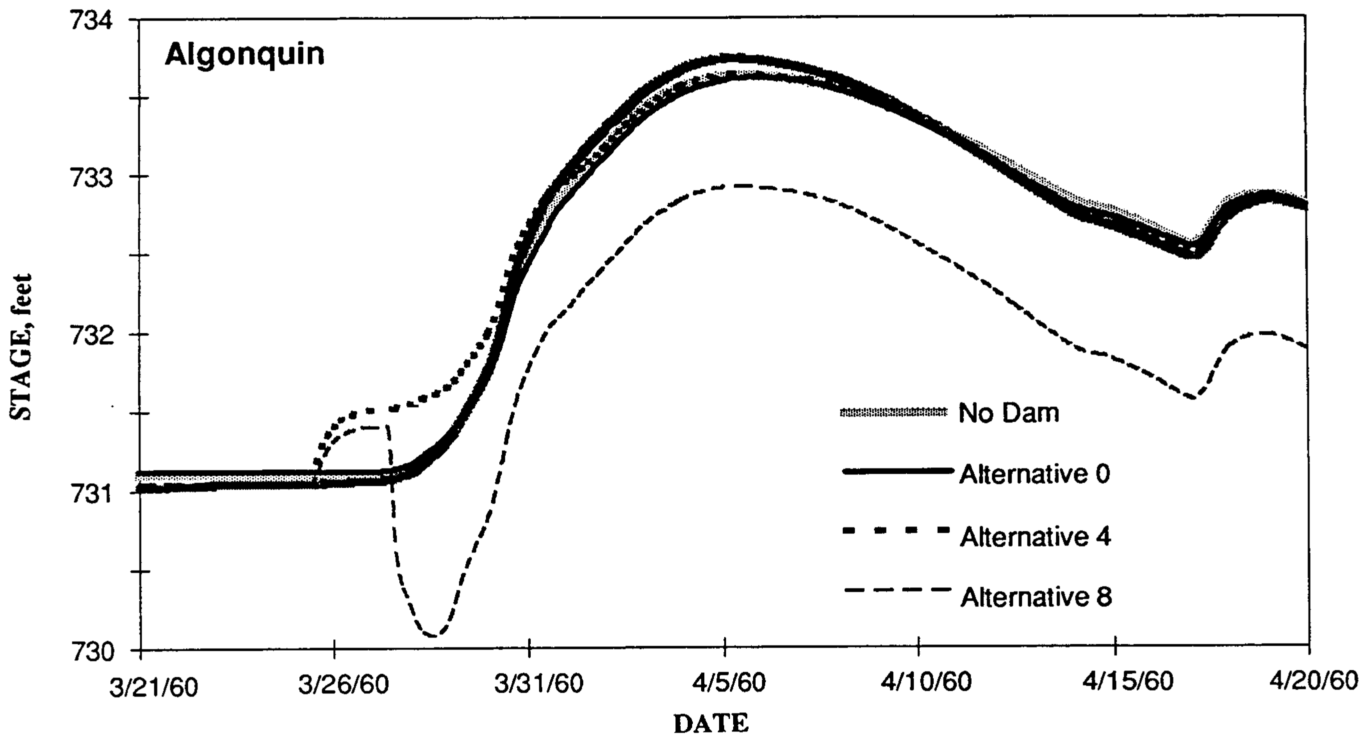

Figure 50. Effect of gate operations on simulated stages; 1960 flood at Algonquin Dam

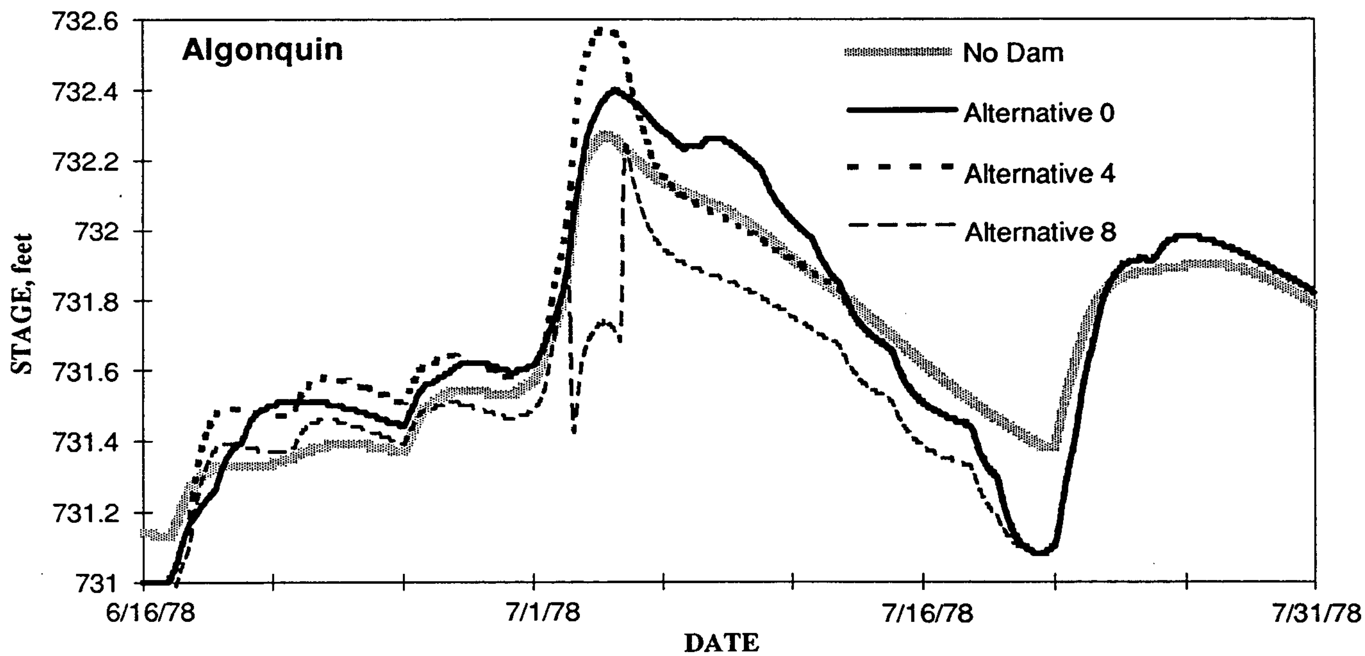

Figure 51. Effect of gate operations on simulated stages; 1978 flood at Algonquin Dam

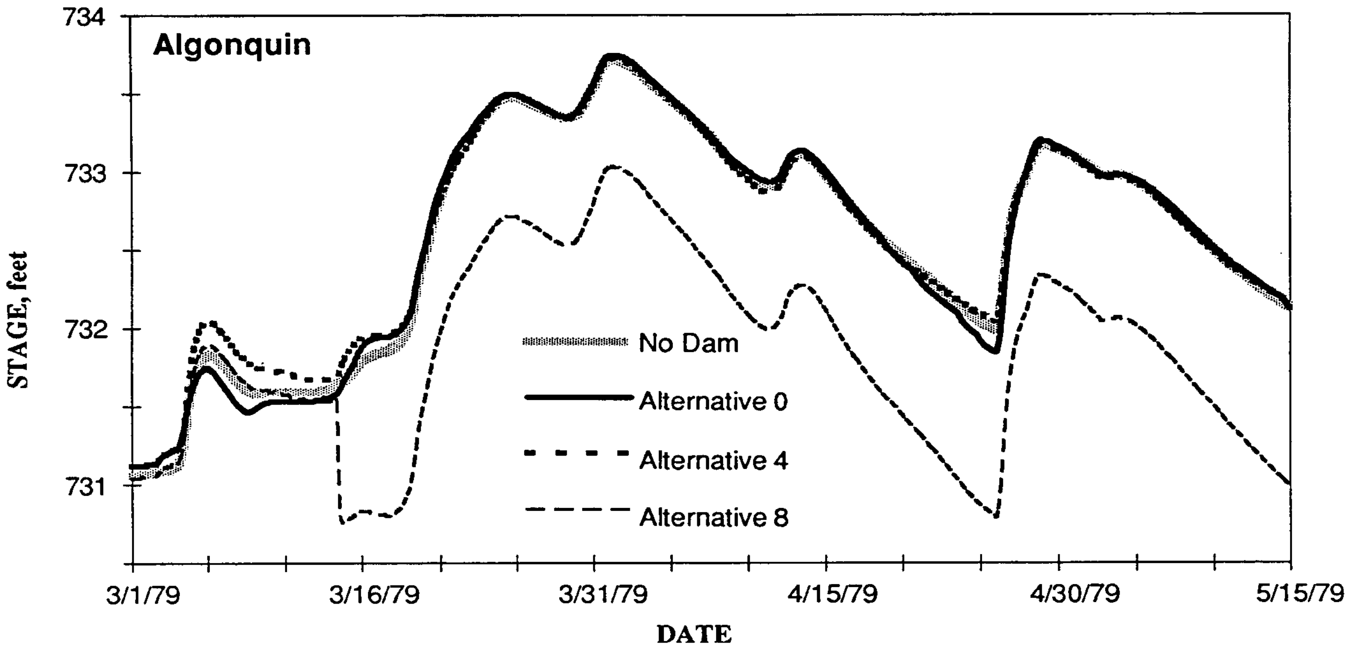

Figure 52. Effect of gate operations on simulated stages; 1979 flood at Algonquin Dam

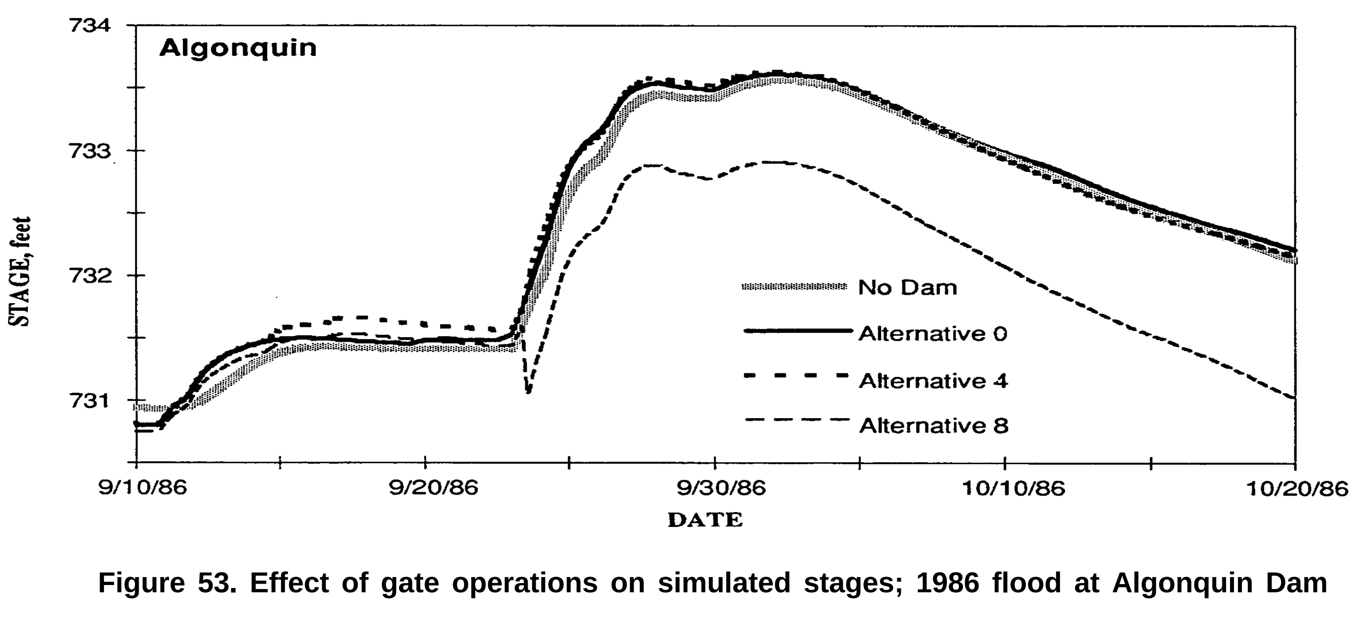

Figure 53. Effect of gate operations on simulated stages; 1986 flood at Algonquin Dam

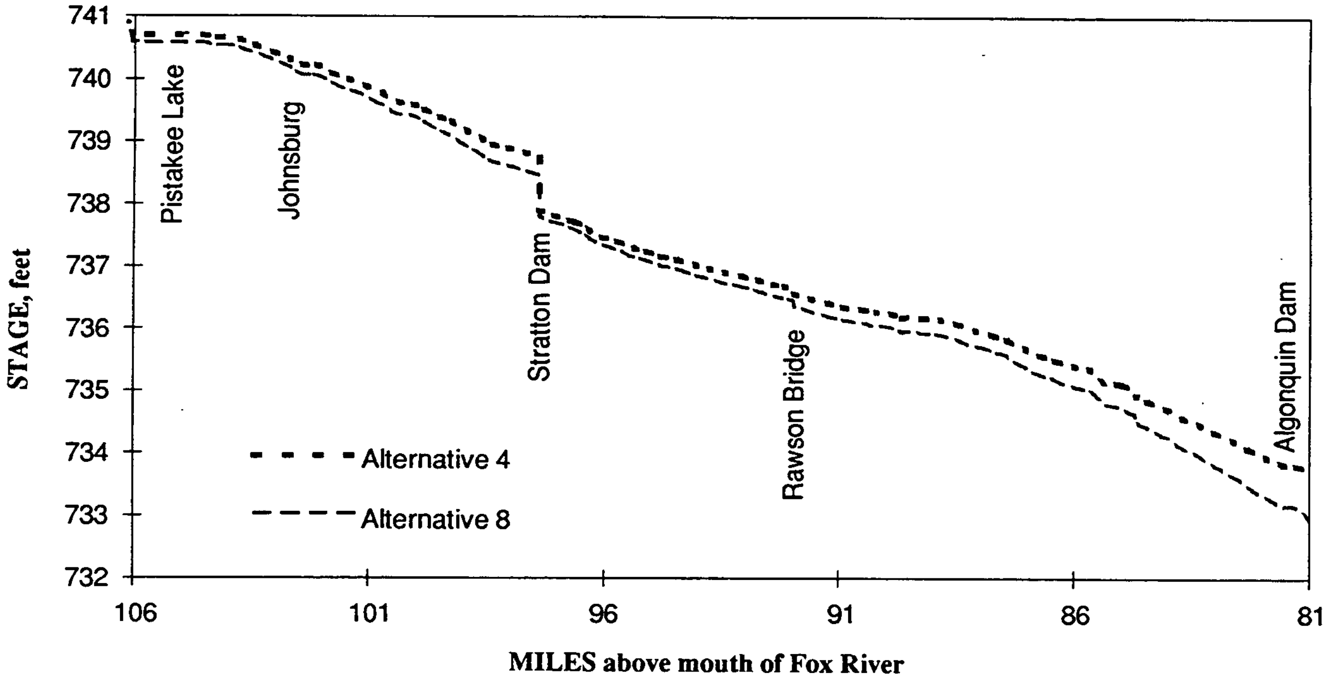

Figure 54. Reduction in simulated peak stages caused by the Foster gates at Stratton Dam and Algonquin Dam; 1960 flood

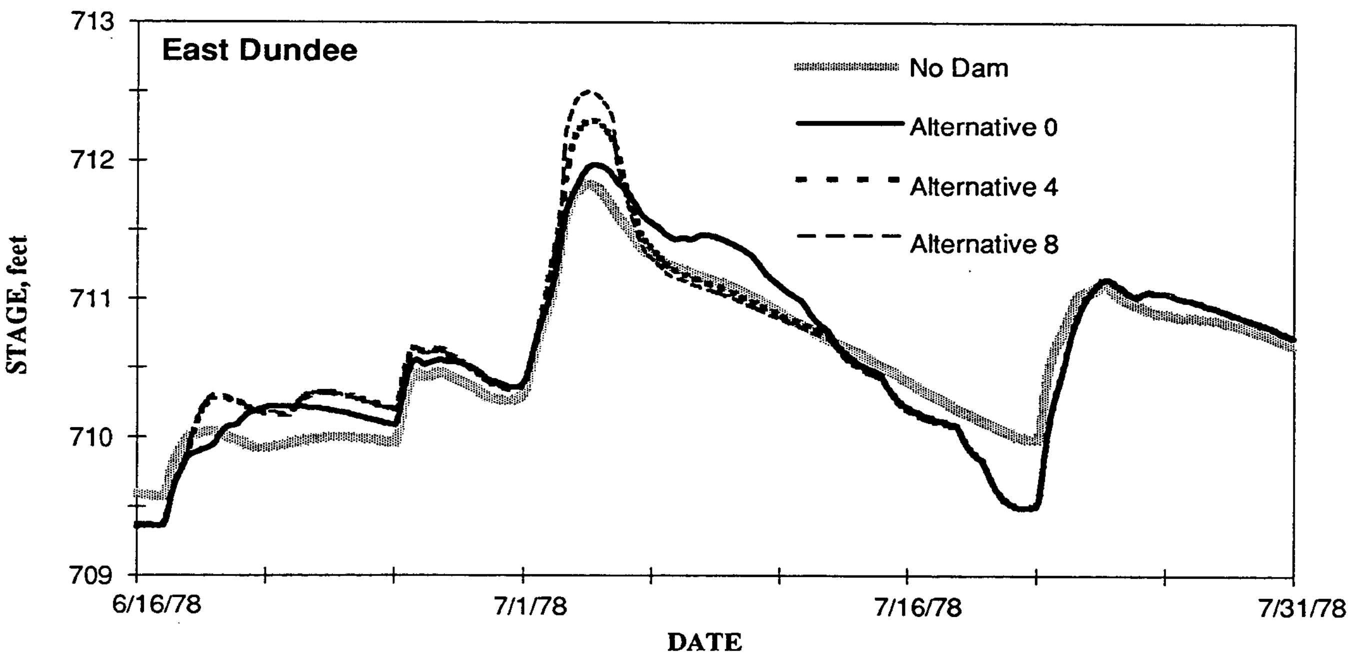

Figure 55. Effect of gate operations on simulated stages; 1978 flood at East Dundee

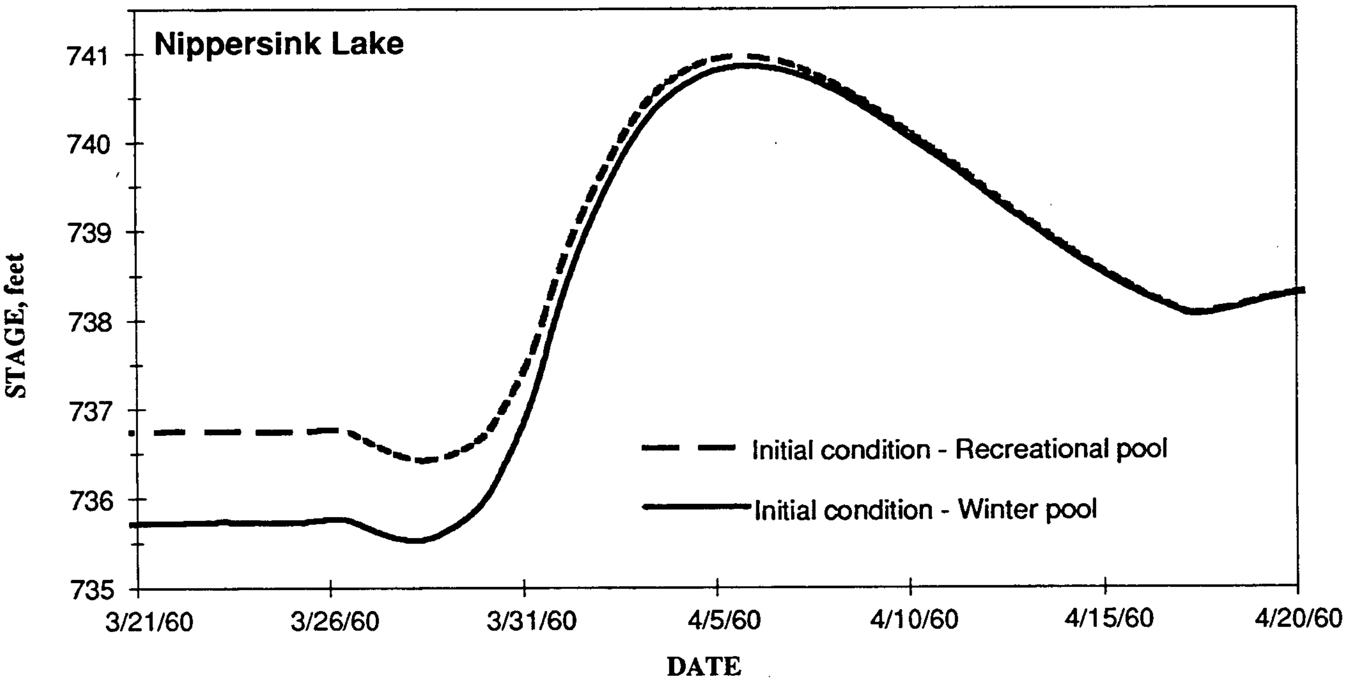

Figure 56. Effect of initial pool elevation on simulated stages; 1960 flood at Nippersink Lake

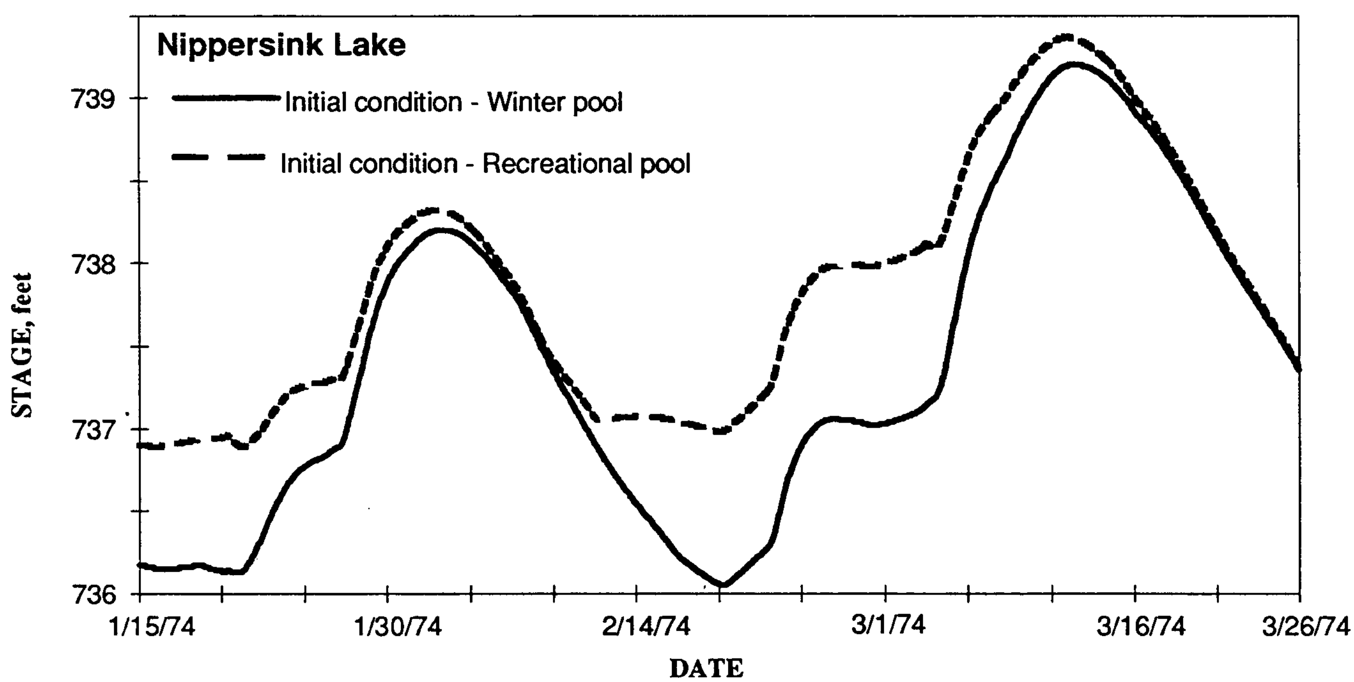

Figure 57. Effect of initial pool elevation on simulated stages; 1974 flood at Nippersink Lake

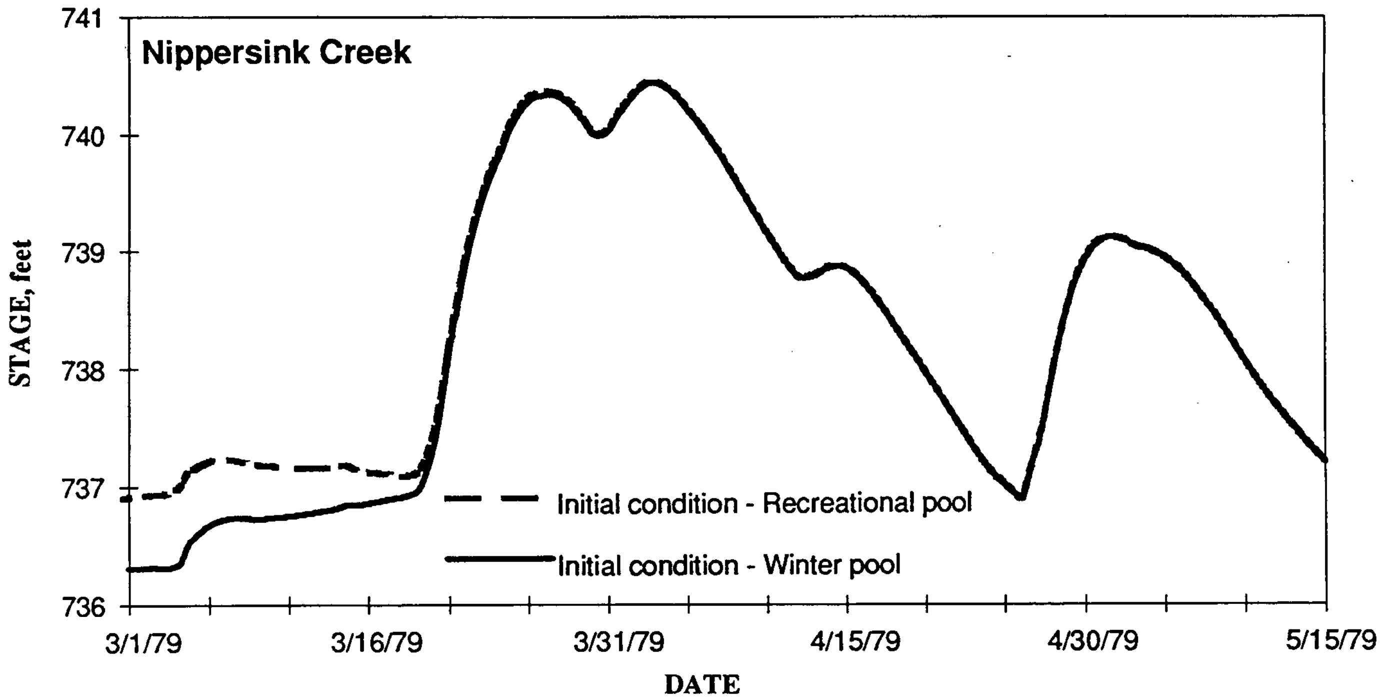

Figure 58. Effect of initial pool elevation on simulated stages; 1979 flood at Nippersink Lake

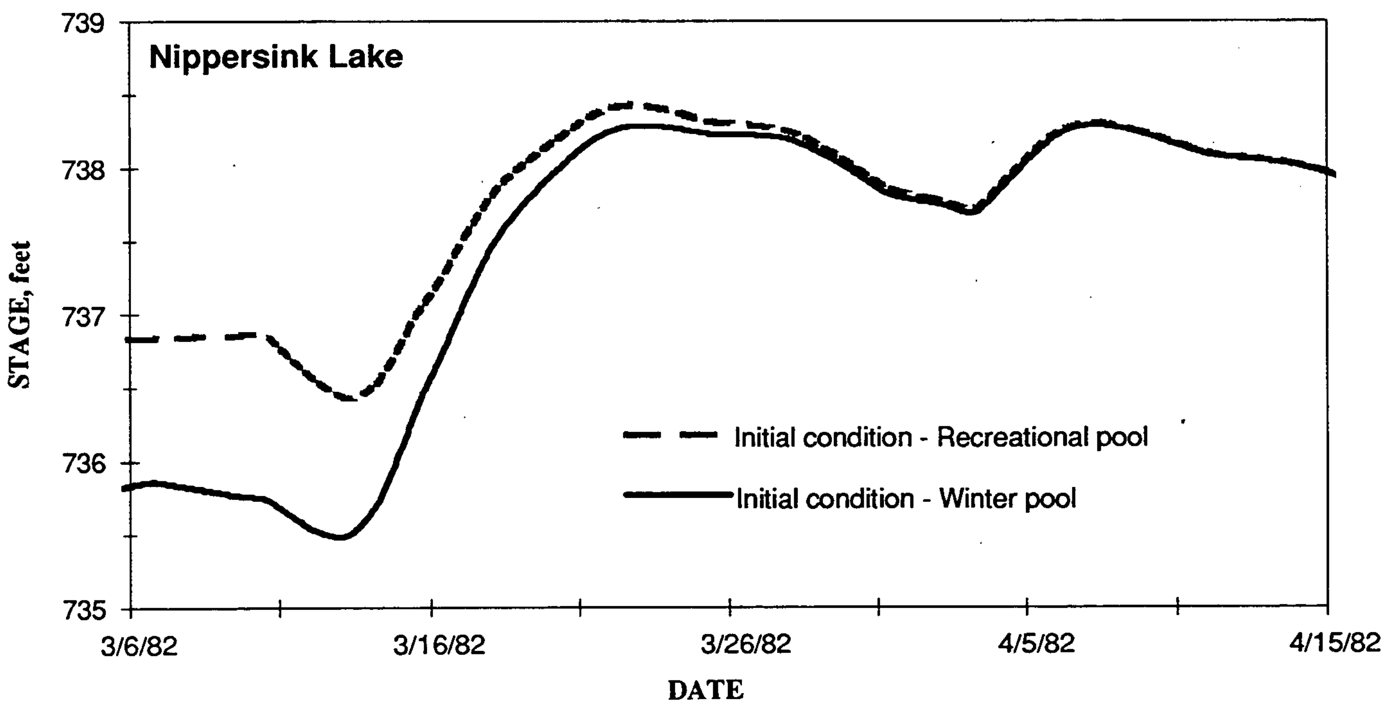

Figure 59. Effect of initial pool elevation on simulated stages; 1982 flood at Nippersink Lake

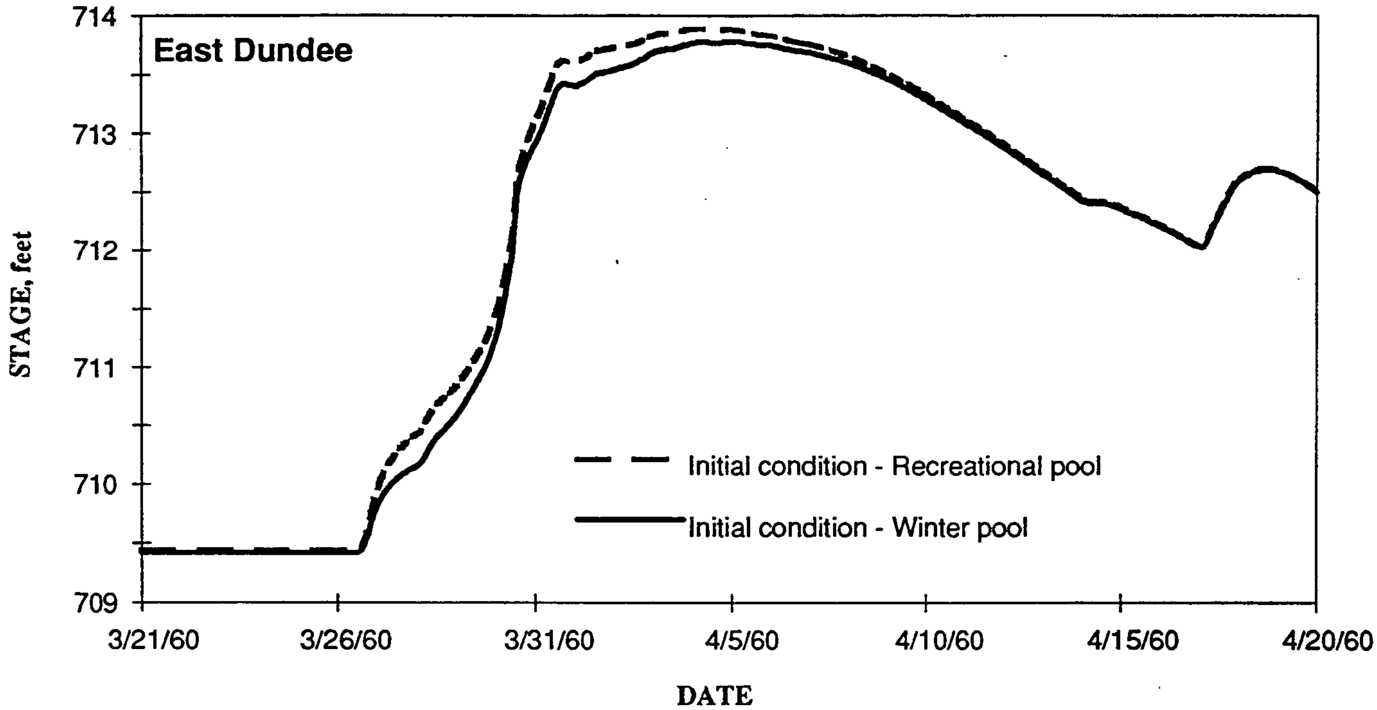

Figure 60. Effect of initial pool elevation on simulated stages; 1960 flood at East Dundee

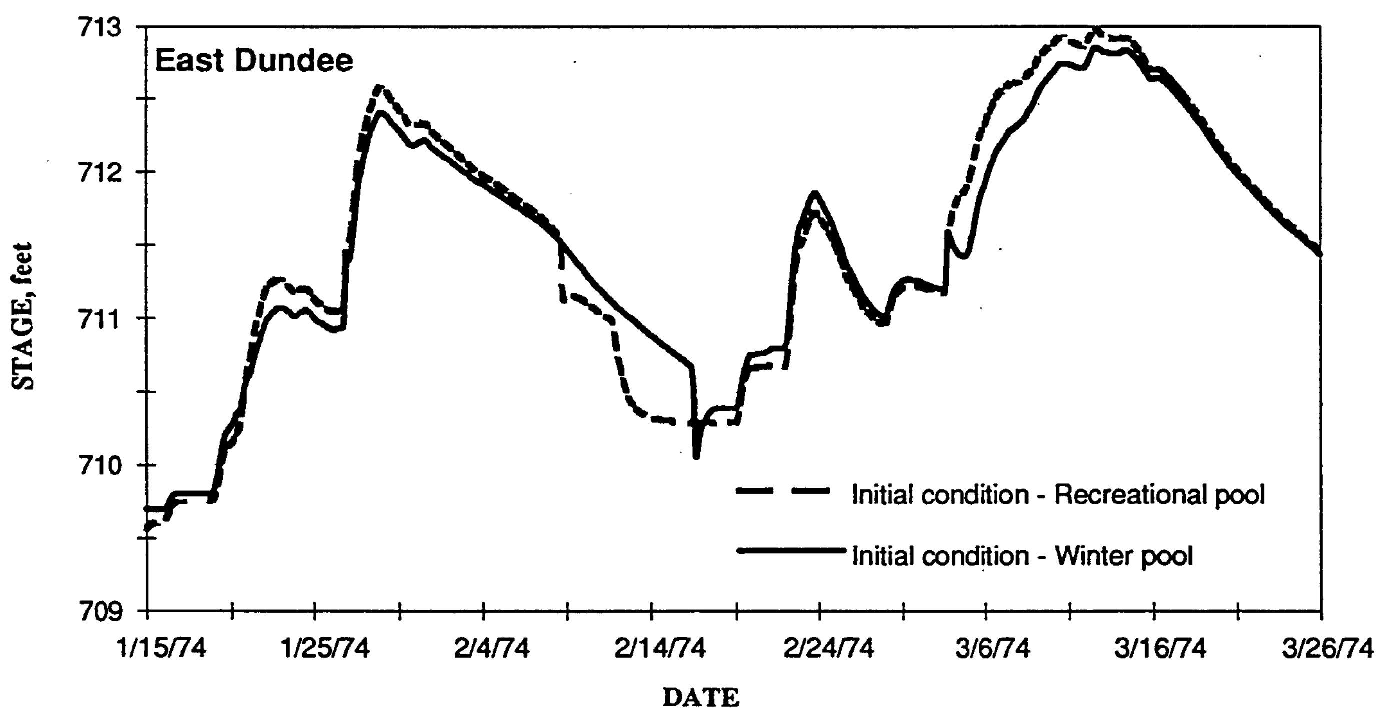

Figure 61. Effect of initial pool elevation on simulated stages; 1974 flood at East Dundee

Effect of Operation Alternatives on Peak Stages

The following pages contain tables, each of which provide the relative reduction in flood stages offered by each of the eleven operating alternatives that were evaluated in this study and listed below:

Alternative

0) Continue to operate the gates similar to historical gate operations
1) Open gates during intra-storm periods to reduce high pool levels
2) Open gates wider during major flood conditions
3) Open gates several days before flood inflows arrive (maximum opening = 4 feet)
4) Open gates wider and before flood inflows arrive
5) Open the existing gates early (alternative 4) and raise winter pool to the level of the recreational pool
6) Add a Foster gate solely at Algonquin Dam
7) Add a Foster gate solely at Stratton Dam
8) Add Foster gates at Stratton and Algonquin Dams
9) Add Foster gates at Stratton and Algonquin Dams and raise winter pool level
10) Modify opening of the railroad bridge across the Chain of Lakes adjacent to U.S. Highway 12

The peak flood stages are compared for nine locations. These locations, and the three-letter abbreviation used in the tables to identify each location are as follows:

Location	Abbreviation
Channel Lake	CHA
Fox Lake	FOX
Nippersink Lake	NIP
Fox River at Johnsburg	JOH
Stratton Dam headwater	STR
Fox River at Rawson Bridge	RAW
Algonquin Dam headwater	ALG
Carpentersville Dam headwater	CAR
Fox River at East Dundee	EDU

As noted earlier, both the 1979 and 1982 floods have double peaks, where the second peak generally produces the maximum stage. For most of the alternatives, the impact of that alternative on both peaks is presented. For some alternatives, there is little impact on the second peak, then only the results from the first peak are provided.

Alternative #O. Continue to operate the gates similar to historical gate operations

The simulations using historical gate operation practices were used as the base conditions to which alternatives l-4 are compared. For the 1960 and 1972 events, the base conditions used the simulation where the maximum gate setting was increased to 4 feet, instead of using historical operations, to maintain a uniform comparison between this and other alternatives.

Historical Operation Practices: Effect of Maximum Gate Opening on Peak Stages

During most major floods in the last 25 years, the sluice gates at Stratton Dam have been operated to provide a maximum opening of approximately 4 feet. Prior to 1965, the maximum gate opening during floods was usually considerably less; for example, during the flood of 1960 the maximum opening was 2.4 feet. Table 17 provides the comparison of simulated flood stages for the 1960 event between historical gate operation practices and gate operation that provides a 4-foot opening. The FEQ model estimates that the flood stages in the Fox Chain of Lakes during the 1960 event would have been reduced by approximately 0.2 foot if the gates had been opened to the 4-foot setting;, however, stages on the Fox River downstream of Stratton Dam would have been increased by as much as 0.1 foot.

In 1972 the maximum gate setting during the flood was 3 feet. This smaller gate opening was apparently used to avoid creating excessive discharge from the dam. The change in stage that would have been caused by raising the gates from 3 feet to 4 feet is presented in table 17. The smaller gate opening resulted in a minor reduction of the peak stages downstream of the dam, but also caused higher flood stages in the Chain of Lakes.

Table 17. Differences in Peak Stages (feet) Using a Maximum Gate Opening of 4 Feet: 1960 and 1972 Floods

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*R A W*	*A L G*	*CAR*	*EDU*
1960									
2.4 ft opening	741.71	741.54	741.53	740.98	739.97	736.58	733.62	723.88	713.73
4.0 ft opening	741.55	741.36	741.36	740.77	739.62	736.62	733.63	723.90	713.77
Difference	-0.16	-0.18	-0.17	-0.21	-0.35	+0.04	+0.01	+0.02	+0.04
1972									
3.0 ft opening	739.80	739.76	739.76	739.38	738.59	735.15	732.99	723.33	721.90
4.0 ft opening	739.59	739.55	739.54	739.10	738.13	735.27	733.06	723.40	713.03
Difference	-0.21	-0.21	-0.22	-0.28	-0.46	+0.12	+0.07	+0.07	+0.13

Historical Operation Practices: Effect of Timing on Peak Stages

The timing response at Stratton Dam to flood conditions is slightly different for each of the selected historical floods (see table 2). The differences in timing for opening the sluice gates has generally been only 1 day, for some cases 2 days. The effect of these timing differences on the peak flood stage for two selected floods, 1960 and 1986, was simulated using the FEQ model by delaying all changes in the historical gate openings by one and two days. The results of this modeling a presented in table 18. Timing differences of 1 day cause no more than a 0.03 foot change in the eventual flood peak. The impact of a 2-day timing difference is generally less than 0.06 foot.

Table 18. Effects of the Time of Gate Opening on Peak Stage (feet); Historical Operation of the 1960 and 1986 Floods

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
No delay	741.55	741.36	741.36	740.77	739.62	736.62	733.63	723.90	713.77
1 day delay	741.58	741.39	741.39	740.79	739.64	736.64	733.65	723.92	713.79
2 day delay	741.61	741.42	741.42	740.83	739.67	736.66	733.67	723.94	713.81
1986									
No delay	740.94	740.85	740.85	740.38	739.31	736.44	733.61	723.92	713.90
1 day delay	740.96	740.87	740.87	740.39	739.32		733.62		
2 day delay	740.99	740.89	740.89	740.41	739.34		733.63		

Alternative #1. Open gates during intra-storm periods to reduce high pool levels

For half the floods (1972, 1978, 1979, and 1986) the antecedent stage in the Chain of Lakes was observed to be higher than the normal target pool level. In most cases these higher stages had lingered following previous high flow events. Simulations were conducted to determine if these high antecedent stages affect the peak stages of the floods. In these simulations, the gates at Stratton Dam were opened to a higher setting to reduce the lake stage whenever the stages in the upper lakes exceeded an elevation of 737.50 feet. The typical reduction in the antecedent stage using this alternative was 0.4 foot.

Table 19 compares the simulated peak stages using alternative 1 and historical gate operation practices. There is a consistent reduction of the peak stages, however, the average reduction is only 0.07 foot. The reduction in peak stage is fairly consistent along the entire length of the Fox River, but is slightly greater in the Chain of Lakes than downstream of Algonquin Dam.

Table 19. Differences in Peak Stages (feet): Alternative 1

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1972									
Historical	739.59	739.55	739.54	739.10	738.13	735.27	733.06	723.40	713.03
Alternative 1	739.53	739.49	739.48	739.04	738.08	735.19	733.03	723.36	712.97
Difference	-0.06	-0.06	-0.06	-0.06	-0.05	-0.08	-0.03	-0.04	-0.06
1978									
Historical	738.49	738.46	738.46	738.22	737.71	733.86	732.40	722.75	711.97
Alternative 1	738.33	738.30	738.29	738.07	737.58	733.67	732.31	722.67	711.87
Difference	-0.16	-0.16	-0.17	-0.15	-0.13	-0.19	-0.09	-0.08	-0.10
1979 (1st peak)									
Historical	741.04	740.90	740.89	740.35	739.35	736.25	733.49	723.80	713.62
Alternative 1	741.01	740.87	740.86	740.32	739.33	736.21	733.48	723.78	713.59
Difference	-0.03	-0.03	-0.03	-0.03	-0.02	-0.04	-0.01	-0.02	-0.03
1986									
Historical	740.94	740.85	740.85	740.38	739.31	736.44	733.61	723.92	713.90
Alternative 1	740.89	740.81	740.80	740.33	739.26	736.39	733.58	723.90	713.85
Difference	-0.05	-0.04	-0.05	-0.05	-0.05	-0.05	-0.03	-0.02	-0.05

Alternative #2. Open gates wider during major flood conditions

Table 20 compares the simulated stages resulting from historical gate operation and alternative 2. In the alternative 2 scenario, the gates are opened wide during major floods -- those flood conditions where the gates would otherwise be opened to 4 feet -- so as not to restrict flow from the dam.

During major flood events the 4-foot maximum gate opening limits the total outflow from the dam. The reduced outflow reduces flood stages downstream, but causes higher flood stages in the lakes. Conversely, having a wider maximum opening for the Stratton Dam gates results in lower stages upstream of the dam, but higher stages downstream. However, the upstream stages are affected to a greater degree than those downstream. The average reduction in the peak stage of the Chain of Lakes is approximately 0.3 foot, with a maximum reduction of 0.42 foot in Channel Lake for the second peak of the 1979 flood. The average increase in peak stage downstream of Stratton Dam is approximately 0.1 foot, with a maximum increase of 0.23 foot at Rawson Bridge for the first peak of the 1979 flood.

The differences in peak stage shown in table 20 are greater for the larger flood events compared to the smaller flood events. For the 1982 flood, the stage at Stratton Dam is never sufficiently high to cause much of a difference in discharge from the dam. Therefore the differences in flood stage are not great. The use of alternative 2 for the 1978 flood was not simulated because that flood was not a major flood event.

Alternative #3. Open gates several days before flood inflows arrive (max. opening = 4 feet)

Alternative 3 involves the use of the existing gates at Stratton Dam for water release as soon as flood conditions are forecast. The flow forecast provides the information for judging if the potential inflow is sufficiently large to justify opening the sluice gates to lower lake levels. The forecast conditions at which the gates are opened are described in Section 4: Use of the Flow Forecast Model for Gate Operation.

Table 21 lists the simulated change in peak stages that would be incurred if the sluice gates at Stratton Dam were opened in advance of the major floods. The maximum simulated gate opening is 4.0 feet, the same as the maximum opening for most of the historical gate simulations. For almost all the storms, opening the gates early results in a decrease in the peak stages both upstream and downstream of the dam (when compared to the historical operation). The magnitude of the decrease is approximately 0.15 feet upstream of the dam, and 0.10 feet downstream of the dam.

The only simulated storm for which there is an increase in the peak stage downstream is the 1978 storm, in which the forecasted inflow is much greater than the observed inflow. For this case, the outflow from the dam produces a flow similar to the 2-year flood event (as compared to the 1.5-year flood that otherwise would have occurred). The downstream stage, though increased, reaches only the bankfull stage at Algonquin and is 0.5 feet below the level of a “minor” flood (733.00 feet at Algonquin, as defined in U.S. Army Corps of Engineers, 1984). Increases in the stage of small floods, similar to those presented for the 1978 flood, will occur approximately once in ten years (as estimated earlier in this report).

Table 20. Differences in Peak Stages (feet): Alternative 2

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*A L G*	*CAR*	*EDU*
1960									
Historical	741.55	741.36	741.36	740.77	739.62	736.62	733.63	723.90	713.77
Alternative 2	741.34	741.14	741.13	740.45	738.89	736.81	733.74	724.00	713.95
Difference	-0.21	-0.22	-0.23	-0.32	-0.73	+0.19	+0.11	+0.10	+0.18
1972									
Historical	739.59	739.55	739.54	739.10	738.13	735.27	733.06	723.40	713.03
Alternative 2	739.54	739.50	739.49	739.00	738.20	735.50	733.16	723.49	713.14
Difference	-0.05	-0.05	-0.05	-0.10	+0.07	+0.23	+0.10	+0.09	+0.11
1973									
Historical	740.55	740.55	740.49	740.03	739.00	736.08	733.42	723.72	713.51
Alternative 2	740.33	740.24	740.23	739.63	738.24	736.17	733.46	723.77	713.57
Difference	-0.22	-0.31	-0.26	-0.40	-0.76	+0.09	+0.04	+0.05	+0.06
1974									
Historical	739.70	739.66	739.66	739.20	738.25	735.13	732.97	723.28	712.80
Alternative 2	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Difference	-0.20	-0.21	-0.22	-0.28	-0.53	+0.04	+0.02	+0.01	+0.03
1978									
Not simulated									
1979 (1st peak)									
Historical	741.04	740.90	740.89	740.35	739.35	736.25	733.49	723.80	713.62
Alternative 2	740.71	740.61	740.60	739.94	738.50	736.48	733.60	723.91	713.82
Difference	-0.33	-0.29	-0.29	-0.41	-0.85	+0.23	+0.11	+0.11	+0.20
1979 (2nd peak)									
Historical	741.07	740.95	740.94	740.42	739.38	736.69	733.74	724.08	714.15
Alternative 2	740.65	740.56	740.56	739.95	738.57	736.71	733.75	723.09	714.17
Difference	-0.42	-0.39	-0.38	-0.47	-0.81	+0.02	+0.01	+0.01	+0.02
1982 (1st peak)									
Historical	738.79	738.75	738.75	738.36	737.52	734.42	732.65	722.98	712.30
Alternative 2	738.69	738.65	738.64	738.22	737.21	734.51	732.70	723.02	712.37
Difference	-0.10	-0.10	-0.11	-0.14	-0.31	+0.09	+0.05	+0.04	+0.07
1982 (2nd peak)									
Historical	738.87	738.83	738.83	738.43	737.53	734.57	732.73	723.07	712.44
Alternative 2	738.74	738.70	738.69	738.26	737.24	734.57	732.73	723.06	712.44
Difference	-0.13	-0.13	-0.14	-0.17	-0.29	0.00	0.00	-0.01	0.00
1986									
Historical	740.94	740.85	740.85	740.38	739.31	736.44	733.61	723.92	713.90
Alternative 2	740.62	740.55	740.55	739.99	738.55	736.56	733.67	724.01	714.00
Difference	-0.32	-0.30	-0.30	-0.39	-0.76	+0.12	+0.06	+0.09	+0.10

Table 21. Differences in Peak Stages (feet): Alternative 3

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Historical	741.55	741.36	741.36	740.77	739.62	736.62	733.63	723.90	713.77
Alternative 3	741.41	741.22	741.22	740.63	739.50	736.46	733.56	723.82	713.63
Difference	-0.14	-0.14	-0.14	-0.14	-0.12	-0.16	-0.07	-0.08	-0.14
1972									
Historical	739.59	739.55	739.54	739.10	738.13	735.27	733.06	723.40	713.03
Alternative 3	739.53	739.49	739.49	739.05	738.07	735.21	733.03	723.37	712.97
Difference	-0.06	-0.06	-0.05	-0.05	-0.06	-0.06	-0.03	-0.03	-0.06
1973									
Historical	740.55	740.55	740.49	740.03	739.00	736.08	733.42	723.72	713.51
Alternative 3	740.51	740.46	740.45	739.99	738.97	736.04	733.40	723.71	713.47
Difference	-0.04	-0.09	-0.04	-0.04	-0.03	-0.04	-0.02	-0.01	-0.04
1974									
Historical	739.70	739.66	739.66	739.20	738.25	735.13	732.97	723.28	712.80
Alternative 3	739.63	739.59	739.58	739.11	738.12	735.12	732.97	723.27	712.78
Difference	-0.07	-0.07	-0.08	-0.09	-0.13	-0.01	0.00	-0.01	-0.02
1978									
Historical	738.49	738.46	738.46	738.22	737.71	733.86	732.40	722.75	711.97
Alternative 3	738.21	738.19	738.18	737.96	737.50	734.13	732.54	722.90	712.25
Difference	-0.28	-0.27	-0.28	-0.26	-0.21	+0.27	+0.14	+0.15	+0.28
1979 (1st peak)									
Historical	741.04	740.90	740.89	740.35	739.35	736.25	733.49	723.80	713.62
Alternative 3	740.76	740.65	740.65	740.09	739.04	736.05	733.40	723.74	713.52
Difference	-0.28	-0.25	-0.24	-0.26	-0.31	-0.20	-0.09	-0.06	-0.10
1979 (2nd peak)									
Historical	741.07	740.95	740.94	740.42	739.38	736.69	733.74	724.08	714.15
Alternative 3	740.97	740.86	740.86	740.34	739.30	736.58	733.68	724.03	714.06
Difference	-0.10	-0.09	-0.08	-0.08	-0.08	-0.11	-0.06	-0.05	-0.09
1982 (1st peak)									
Historical	738.79	738.75	738.75	738.36	737.52	734.42	732.65	722.98	712.30
Alternative 3	738.72	738.67	738.67	738.27	737.43	734.30	732.60	722.92	712.21
Difference	-0.07	-0.08	-0.08	-0.09	-0.09	-0.12	-0.05	-0.06	-0.09
1982 (2nd peak)									
Historical	738.87	738.83	738.83	738.43	737.53	734.57	732.73	723.07	712.44
Alternative 3	738.87	738.83	738.82	738.42	737.52	734.56	732.73	723.06	712.44
Difference	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	-0.01	0.00
1986									
Historical	740.94	740.85	740.85	740.38	739.31	736.44	733.61	723.92	713.90
Alternative 3	740.87	740.79	740.78	740.31	739.25	736.27	733.57	723.88	713.84
Difference	-0.07	-0.06	-0.07	-0.07	-0.06	-0.17	-0.04	-0.04	-0.06

Alternative #4. Open gates wider and before flood inflows arrive

Alternative 4 combines the effects of alternatives 2 (opening the gates wider) and 3 (opening the gates early). The forecast conditions used to decide when the gates would be opened wide are the same used in alternative 3, and described earlier in the report. The peak stages simulated using the historical operation and alternative 4 are compared in table 22.

The reduction in flood stage upstream of Stratton Dam is greater for Alternative 4 than any of the other nonstructural alternatives. For the set of simulated storms, alternative 4 (when compared to the historical operation) reduces flood stages in the Chain of Lakes from 0.13 foot to 0.53 foot, with an average reduction of approximately 0.3 foot. The overall impact of alternative 4 is roughly the same as the combined effects of alternatives 1 and 2.

The impact of alternative 4 on flood stages downstream of Stratton Dam is less than 0.04 foot for all events but the 1978 flood. Given the accuracy level of the FEQ model, this is considered a negligible increase. For this reason it is concluded that alternative 4 has no negative impacts downstream except for those events when the flow forecast model significantly overestimates the flood flow.

The impact on the 1978 storm is very similar to that discussed under alternative 3. Overbank flow will likely occur at several locations downstream, but still be below the minor flood stage. Increases in the stage of small floods, similar to those presented for the 1978 flood, will occur approximately once in ten years (as estimated earlier in this report).

Alternative #5. Open the existing gates early (alternative 4) and raise winter pool to the level of the recreational pool

The effect of raising the winter pool level to the normal recreational pool while operating under alternative 4 was simulated for the 1960, 1974, 1979, and 1982 floods. The remaining floods were not evaluated because they occurred in late spring or summer when the antecedent lake level was at the normal summer (recreational) pool elevation. Under alternative 5, the peak stages for these other floods would be exactly the same as under alternative 4. Winter-pool conditions were simulated for the 1960 and 1979 floods because, with historical operation, the antecedent lake levels for these two floods were not as low as the winter pool level.

Table 23 compares the flood stages for alternative 5 to alternative 4, which uses the same operation policy but a different initial stage. The impact of raising the winter pool on the Chain of Lakes flood stage ranges from +0.05 foot (1979 flood) to +0.15 foot (1974 flood). The impact on the flood stage downstream of Stratton Dam ranges from +0.02 foot (1979 flood) to +0.17 foot (1982 flood at Rawson Bridge). The average increase in the simulated downstream stages for these four floods (above their historical stages) is 0.11 foot.

Table 22. Differences in Peak Stages (feet): Alternative 4

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Historical	741.55	741.36	741.36	740.77	739.62	736.62	733.63	723.90	713.77
Alternative 4	741.19	741.00	741.00	740.31	738.77	736.65	733.65	723.92	713.80
Difference	-0.36	-0.36	-0.36	-0.46	-0.85	+0.03	+0.02	+0.02	+0.03
1972									
Historical	739.59	739.55	739.54	739.10	738.13	735.27	733.06	723.40	713.03
Alternative 4	739.39	739.35	739.34	738.86	737.68	735.30	733.07	723.41	713.04
Difference	-0.20	-0.20	-0.20	-0.24	-0.45	+0.03	+0.01	+0.01	+0.01
1973									
Historical	740.55	740.55	740.49	740.03	739.00	736.08	733.42	723.72	713.51
Alternative 4	740.20	740.16	740.15	739.60	738.21	736.13	733.44	723.75	713.54
Difference	-0.35	-0.39	-0.34	-0.43	-0.79	+0.05	+0.02	+0.03	+0.03
1974									
Historical	739.70	739.66	739.66	739.20	738.25	735.13	732.97	723.28	712.80
Alternative 4	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Difference	-0.20	-0.21	-0.22	-0.28	-0.53	+0.04	+0.02	+0.01	+0.03
1978									
Historical	738.49	738.46	738.46	738.22	737.71	733.86	732.40	722.75	711.97
Alternative 4	738.19	738.16	738.15	737.93	737.47	734.21	732.57	722.93	712.30
Difference	-0.30	-0.30	-0.31	-0.29	-0.24	+0.36	+0.17	+0.18	+0.33
1979 (1st peak)									
Historical	741.04	740.90	740.89	740.35	739.35	736.25	733.49	723.80	713.62
Alternative 4	740.51	740.42	740.41	739.76	738.33	736.24	733.48	723.79	713.60
Difference	-0.53	-0.48	-0.48	-0.59	-1.02	-0.01	-0.01	-0.01	-0.02
1979 (2nd peak)									
Historical	741.07	740.95	740.94	740.42	739.38	736.69	733.74	724.08	714.15
Alternative 4	740.59	740.52	740.51	739.91	738.53	736.65	733.72	724.06	714.11
Difference	-0.48	-0.43	-0.43	-0.51	-0.85	-0.04	-0.02	-0.02	-0.04
1982 (1st peak)									
Historical	738.79	738.75	738.75	738.36	737.52	734.42	732.65	722.98	712.30
Alternative 4	738.62	738.57	738.57	738.15	737.15	734.41	732.64	722.97	712.28
Difference	-0.17	-0.18	-0.18	-0.21	-0.37	-0.01	-0.01	-0.01	-0.02
1982 (2nd peak)									
Historical	738.87	738.83	738.83	738.43	737.53	734.57	732.73	723.07	712.44
Alternative 4	738.74	738.70	738.69	738.26	737.24	734.56	732.73	723.06	712.43
Difference	-0.13	-0.13	-0.14	-0.17	-0.29	-0.01	0.00	-0.01	-0.01
1986									
Historical	740.94	740.85	740.85	740.38	739.31	736.44	733.61	723.92	713.90
Alternative 4	740.55	740.49	740.48	739.93	738.49	736.49	733.63	723.94	713.94
Difference	-0.39	-0.36	-0.37	-0.45	-0.82	+0.05	+0.02	+0.02	+0.04

Table 23. Differences in Peak Stages (feet): Alternative 5 (Raising the Winter Pool)

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Alternative 4	741.19	741.00	741.00	740.31	738.77	736.65	733.65	723.92	713.80
Winter Pool*	741.15	740.97	740.96	740.28	738.74	736.61	733.63	723.90	713.77
Alternative 5	741.27	741.07	741.06	740.38	738.83	736.73	733.69	723.96	713.87
Difference	+0.12	+0.10	+0.10	+0.07	+0.09	+0.12	+0.06	+0.06	+0.10
1974									
Alternative 4	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Alternative 5	739.65	739.60	739.59	739.05	737.82	735.33	733.07	723.37	712.96
Difference	+0.15	+0.15	+0.15	+0.13	+0.10	+0.16	+0.08	+0.08	+0.13
1979 (1st peak)									
Alternative 4	740.51	740.42	740.41	739.76	738.33	736.24	733.48	723.79	713.60
Winter Pool*	740.48	740.39	740.38	739.73	738.31	736.20	733.47	723.77	713.57
Alternative 5	740.54	740.44	740.43	739.78	738.35	736.27	733.50	723.80	713.63
Difference	+0.06	+0.05	+0.05	+0.05	+0.04	+0.07	+0.03	+0.03	+0.06
1982 (1st peak)									
Alternative 4	738.62	738.57	738.57	738.15	737.15	734.41	732.64	722.97	712.28
Alternative 5	738.74	738.70	738.69	738.27	737.25	734.58	732.73	723.05	712.42
Difference	+0.12	+0.13	+0.12	+0.12	+0.10	+0.17	+0.09	+0.08	+0.14

Note: * Winter pool conditions were simulated when the historical antecedent stages were higher than the normal winter pool.

- *Alternatives 6-8.* Alternatives 6-8 simulate the use of Foster gates at Algonquin and Stratton Dams. The operation of these alternatives is exactly the same as for alternative 4, except that the Foster gates are also fully opened at the same time that the sluice gates are opened to their maximum setting. Partial opening of the Foster gates was not considered. Flood stages for alternatives 6-8 are compared to alternative 4, specifically addressing the maximum flood control benefit of adding the Foster gates.

Alternative #6. Add a Foster Gate solely at Algonquin Dam

Alternative 6 assumes that a Foster gate is constructed only at Algonquin. Table 24 compares the simulated peak stages using this alternative and alternative 4. The addition of the Algonquin gate has a significant impact on the peak stages in the Algonquin pool, but has almost no impact on either the Chain of Lakes or on the Fox River downstream of Algonquin. The flood stage level at the Algonquin Dam is most greatly reduced, with an average drop in flood stage of over 0.75 foot (ranging from 0.43 to 0.95 foot). The reduction in peak stage caused by the Foster gate attenuates upstream, as shown earlier in figure 57. At Rawson Bridge the average drop in peak stage is 0.30 foot (ranging from 0.19 to 0.49 foot). Figure 57 shows that the peak stage of the tailwater at Stratton Dam is only slightly affected. The impact of the Foster gate on the peak flood stages downstream of Algonquin is negligible.

Table 24. Differences in Peak Stages (feet): Alternative 6

	CHA	FOX	NIP	JOH	STR	RAW	ALG	CAR	EDU
1960									
Alternative 4	741.19	741 .00	741 .00	740.31	738.77	736.65	733.65	723.92	713.80
Alternative 6	741.18	741 .00	740.99	740.30	738.73	736.46	732.94	723.93	713.81
Difference	-0.01	0.00	-0.01	-0.01	-0.04	-0.19	-0.71	+0.01	+0.01
1972									
Alternative 4	739.39	739.35	739.34	738.86	737.68	735.30	733.07	723.41	713.04
Alternative 6	739.39	739.35	739.34	738.86	737.68	735.01	732.22	723.41	713.04
Difference	0.00	0.00	0.00	0.00	0.00	-0.29	-0.85	0.00	0.00
1973									
Alternative 4	740.20	740.16	740.15	739.60	738.21	736.13	733.44	723.75	713.54
Alternative 6	740.20	740.16	740.15	739.60	738.21	735.90	732.67	723.75	713.54
Difference	0.00	0.00	0.00	0.00	0.00	-0.23	-0.77	0.00	0.00
1974									
Alternative 4	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Alternative 6	739.50	739.45	739.44	738.92	737.72	734.87	732.15	723.30	712.83
Difference	0.00	0.00	0.00	0.00	0.00	-0.30	-0.84	+0.01	0.00
1978									
Alternative 4	738.19	738.16	738.15	737.93	737.47	734.21	732.57	722.93	712.30
Alternative 6	738.19	738.16	738.15	737.93	737.47	733.87	732.14	722.96	712.37
Difference	0.00	0.00	0.00	0.00	0.00	-0.34	-0.43	+0.03	+0.07
1979 (1st peak)									
Alternative 4	740.51	740.42	740.41	739.76	738.33	736.24	733.48	723.79	713.60
Alternative 6	740.51	740.42	740.41	739.75	738.31	736.02	732.73	723.79	713.60
Difference	0.00	0.00	0.00	-0.01	-0.02	-0.22	-0.75	0.00	0.00
1979 (2nd peak)									
Alternative 4	740.59	740.52	740.51	739.91	738.53	736.65	733.72	724.06	714.11
Alternative 6	740.58	740.50	740.50	739.89	738.47	736.46	733.05	724.07	714.12
Difference	-0.01	-0.02	-0.01	-0.02	-0.06	-0.19	-0.67	+0.01	+0.01
1982 (1st peak)									
Alternative 4	738.62	738.57	738.57	738.15	737.15	734.41	732.64	722.97	712.28
Alternative 6	738.62	738.57	738.57	738.15	737.15	733.92	731.78	722.92	712.20
Difference	0.00	0.00	0.00	0.00	0.00	-0.49	-0.86	-0.05	-0.08
1982 (2nd peak)									
Alternative 4	738.74	738.70	738.69	738.26	737.24	734.56	732.73	723.06	712.43
Alternative 6	738.74	738.70	738.69	738.26	737.24	734.20	731.78	723.06	712.43
Difference	0.00	0.00	0.00	0.00	0.00	-0.36	-0.95	0.00	0.00
1986									
Alternative 4	740.55	740.49	740.48	739.93	738.49	736.49	733.63	723.94	713.94
Alternative 6	740.53	740.47	740.47	739.91	738.44	736.28	732.92	723.95	713.95
Difference	-0.02	-0.02	-0.01	-0.02	-0.05	-0.21	-0.71	+0.01	+0.01

Alternative #7. Add a Foster Gate solely at Stratton Dam

Alternative 7 represents the condition where a Foster gate is added only at Stratton Dam. Table 25 compares the peak flood stages between alternatives 4 and 7. The addition of the gate at Stratton Dam helps further lower the pool level in the Chain of Lakes beyond that associated with simply lowering the existing sluice gates. The average reduction in the peak stage of the Chain of Lakes is 0.17 foot. For the largest storms (1960, 1973, 1979, and 1986), the Foster gate lowers the peak stage in the Chain of Lakes from 0.10 foot to 0.15 foot. Peak stage downstream of Stratton Dam is virtually unaffected for these larger storms. For less severe floods (1972, 1974, and 1982), the Foster gate lowers the peak stage in the Chain of Lakes a greater amount, ranging from 0.18 foot to 0.37 foot. However, both the 1972 and 1982 floods also cause a small increase in the downstream peak stage. The greatest increase in downstream stages occurs with the 1978 flood.

Alternative #8. Add Foster Gates at Stratton and Algonquin Dams

Table 26 compares the peak flood stages for alternatives 4 and 8. The flood control benefit associated with the addition of Foster gates at both Stratton and Algonquin Dams (alternative 8) is essentially the combined effect of alternatives 6 and 7. This suggests that the impacts of the Foster gates at Algonquin and Stratton Dams are virtually independent. As with alternative 7, the Foster gates lower the peak stage in the Chain of Lakes from 0.10 foot to 0.15 foot for the largest storms (1960, 1973, 1979, and 1986). The greatest reductions in flood stage occur at both Algonquin and Stratton Dams; the reduction in stage attenuates upstream from both of the dams. Downstream stages are slightly increased for the 1972, 1978, and 1982 floods.

Effect of Varying the Response Time for Opening the Foster Gates

In simulating the effects of the Foster gates, the opening of the Foster gates was based on the flow forecast using near real-time precipitation data. In their 1984 study, the Corps of Engineers recommended that the gate openings be based on a one-day advance rainfall prognosis. Simulation results, shown below, indicate that this difference in response time has relatively little effect on the resulting peak stages of the floods.

Effect of Response Time on Peak Stages (feet) using Alternative 8; 1986 flood

Open gates using:	*CHA*	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
2-day prognosis	740.36	740.31	740.31	739.72	738.12	736.22	732.88	723.92	713.90
1-day prognosis	740.39	740.34	740.33	739.74	738.14	736.24	732.90	723.93	713.92
Near real-time	740.41	740.36	740.35	739.77	738.16	736.27	732.91	723.95	713.94
1 day late	740.44	740.39	740.38	739.80	738.19	736.30	732.93	723.98	713.97
2 days late	740.48	740.42	740.42	739.83	738.23	736.34	732.96	724.01	714.00

Table 25. Differences in Peak Stages (feet): Alternative 7

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Alternative 4	741.19	741.00	741.00	740.31	738.77	736.65	733.65	723.92	713.80
Alternative 7	741.10	740.92	740.91	740.20	738.55	736.65	733.65	723.92	713.81
Difference	-0.09	-0.08	-0.09	-0.11	-0.22	0.00	0.00	0.00	+0.01
1972									
Alternative 4	739.39	739.35	739.34	738.86	737.68	735.30	733.07	723.41	713.04
Alternative 7	739.21	739.16	739.15	738.60	737.43	735.37	733.11	723.45	713.11
Difference	-0.18	-0.19	-0.19	-0.26	-0.25	+0.07	+0.04	+0.04	+0.07
1973									
Alternative 4	740.20	740.16	740.15	739.60	738.21	736.13	733.44	723.75	713.54
Alternative 7	740.05	740.01	740.00	739.42	737.89	736.10	733.43	723.74	713.52
Difference	-0.15	-0.15	-0.15	-0.22	-0.32	-0.03	-0.01	-0.01	-0.02
1974									
Alternative 4	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Alternative 7	739.28	739.22	739.21	738.62	737.10	735.20	733.00	723.30	712.85
Difference	-0.22	-0.23	-0.23	-0.30	-0.62	+0.03	+0.01	+0.01	+0.02
1978									
Alternative 4	738.19	738.16	738.15	737.93	737.47	734.21	732.57	722.93	712.30
Alternative 7	738.09	738.06	738.05	737.83	737.36	734.40	732.66	723.01	712.43
Difference	-0.10	-0.10	-0.10	-0.10	-0.11	+0.19	+0.09	+0.08	+0.13
1979 (1st peak)									
Alternative 4	740.51	740.42	740.41	739.76	738.33	736.24	733.48	723.79	713.60
Alternative 7	740.37	740.28	740.27	739.59	738.02	736.20	733.47	723.77	713.58
Difference	-0.14	-0.14	-0.14	-0.17	-0.31	-0.04	-0.01	-0.02	-0.02
1979 (2nd peak)									
Alternative 4	740.59	740.52	740.51	739.91	738.53	736.65	733.72	724.06	714.11
Alternative 7	740.48	740.41	740.40	739.78	738.29	736.62	733.71	724.05	714.10
Difference	-0.11	-0.11	-0.11	-0.13	-0.24	-0.03	-0.01	-0.01	-0.01
1982 (1st peak)									
Alternative 4	738.62	738.57	738.57	738.15	737.15	734.41	732.64	722.97	712.28
Alternative 7	738.37	738.32	738.32	738.79	736.26	734.55	732.72	723.04	712.41
Difference	-0.25	-0.25	-0.25	-0.36	-0.89	+0.14	+0.12	+0.07	+0.13
1982 (2nd peak)									
Alternative 4	738.74	738.70	738.69	738.26	737.24	734.56	732.73	723.06	712.43
Alternative 7	738.38	738.33	738.32	737.79	736.26	734.57	732.73	723.06	712.44
Difference	-0.36	-0.37	-0.37	-0.47	-0.98	+0.01	0.00	0.00	+0.01
1986									
Alternative 4	740.55	740.49	740.48	739.93	738.49	736.49	733.63	723.94	713.94
Alternative 7	740.44	740.39	740.38	739.80	738.25	736.48	733.63	723.95	713.93
Difference	-0.11	-0.10	-0.10	-0.13	-0.24	-0.01	0.00	+0.01	-0.01

Table 26. Differences in Peak Stages (feet): Alternative 8

	CHA	FOX	NIP	JOH	STR	RAW	ALG	CAR	EDU
1960									
Alternative 4	741.19	741.00	741.00	740.31	738.77	736.65	733.65	723.92	713.80
Alternative 8	741.07	740.90	740.89	740.17	738.47	736.46	732.95	723.93	713.82
Difference	-0.12	-0.10	-0.11	-0.14	-0.30	-0.19	-0.70	+0.01	+0.02
1972									
Alternative 4	739.39	739.35	739.34	738.86	737.68	735.30	733.07	723.41	713.04
Alternative 8	739.18	739.14	739.13	738.57	737.43	735.10	732.28	723.46	713.13
Difference	-0.21	-0.21	-0.21	-0.29	-0.25	-0.20	-0.79	+0.05	+0.09
1973									
Alternative 4	740.20	740.16	740.15	739.60	738.21	736.13	733.44	723.75	713.54
Alternative 8	740.02	739.98	739.97	739.39	737.80	735.87	732.66	723.74	713.53
Difference	-0.18	-0.18	-0.18	-0.21	-0.41	-0.26	-0.78	-0.01	-0.01
1974									
Alternative 4	739.50	739.45	739.44	738.92	737.72	735.17	732.99	723.29	712.83
Alternative 8	739.26	739.21	739.20	738.60	737.05	734.90	732.12	723.30	712.85
Difference	-0.24	-0.24	-0.24	-0.32	-0.67	-0.27	-0.87	+0.01	+0.02
1978									
Alternative 4	738.19	738.16	738.15	737.93	737.47	734.21	732.57	722.93	712.30
Alternative 8	738.08	738.05	738.05	737.82	737.36	734.10	732.24	723.04	712.50
Difference	-0.11	-0.11	-0.10	-0.11	-0.11	-0.11	-0.29	+0.11	+0.20
1979 (1st peak)									
Alternative 4	740.51	740.42	740.41	739.76	738.33	736.24	733.48	723.79	713.60
Alternative 8	740.34	740.26	740.25	739.55	737.94	735.98	732.71	723.78	713.59
Difference	-0.17	-0.16	-0.16	-0.21	-0.39	-0.26	-0.77	-0.01	-0.01
1979 (2nd peak)									
Alternative 4	740.59	740.52	740.51	739.91	738.53	736.65	733.72	724.06	714.11
Alternative 8	740.44	740.37	740.37	739.73	738.20	736.42	733.03	724.06	714.10
Difference	-0.15	-0.15	-0.14	-0.18	-0.33	-0.23	-0.69	0.00	-0.01
1982 (1st peak)									
Alternative 4	738.62	738.57	738.57	738.15	737.15	734.41	732.64	722.97	712.28
Alternative 8	738.36	738.30	738.29	737.77	736.19	734.21	731.78	723.04	712.41
Difference	-0.26	-0.27	-0.28	-0.38	-0.96	-0.20	-0.86	+0.07	+0.13
1982 (2nd peak)									
Alternative 4	738.74	738.70	738.69	738.26	737.24	734.56	732.73	723.06	712.43
Alternative 8	738.37	738.31	738.30	737.77	736.19	734.21	731.79	723.06	712.44
Difference	-0.37	-0.39	-0.39	-0.49	-1.05	-0.35	-0.94	0.00	+0.01
1986									
Alternative 4	740.55	740.49	740.48	739.93	738.49	736.49	733.63	723.94	713.94
Alternative 8	740.41	740.36	740.35	739.77	738.16	736.27	732.91	723.95	713.94
Difference	-0.14	-0.13	-0.13	-0.16	-0.33	-0.22	-0.72	+0.01	0.00

Alternative #9. Add Foster Gates at Stratton and Algonquin Dams and Raise Winter Pool Level

Alternative 9 represents the condition in which Foster gates are added at both Stratton and Algonquin Dams, and the winter pool level is raised to the recreational pool. Table 27 compares the peaks stages for alternative 9 with alternative 8 for the 1960, 1974, 1979, and 1982 floods. The peak stages for the 1972, 1973, 1978, and 1986 floods would be exactly the same as under alternative 8.

As with alternative 5, raising the winter pool causes higher flood stages on the Chain of Lakes for each flood, ranging from +0.05 foot (1979 flood) to +0.18 foot (1974 flood at Channel Lake). But, when compared to historical operations, alternative 9 provides significant overall reduction in the peak stages upstream of Algonquin Dam.

The impact on the flood stage downstream of Algonquin Dam ranges from +0.03 foot (1979 flood) to +0.13 foot (1974 flood), when compared to alternative 8. Table 28 compares the alternative 9 peak stages with historical operations (alternative 0) for all eight floods at Carpentersville and East Dundee. The increase in the average peak stages at Carpentersville and East Dundee, for all floods except the 1978 flood, is 0.07 and 0.10 feet, respectively.

Table 27. Differences in Peak Stages (feet): Raising the Winter Pool with Foster Gates

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Alternative 8	741.07	740.90	740.89	740.17	738.47	736.46	732.95	723.93	713.82
Winter Pool*	741.03	740.86	740.85	740.14	738.44	736.42	732.92	723.91	713.78
Alternative 9	741.16	740.97	740.96	740.24	738.54	736.54	733.00	723.97	713.89
Difference	+0.13	+0.11	+0.11	+0.10	+0.10	+0.12	+0.08	+0.06	+0.11
1974									
Alternative 8	739.26	739.21	739.20	738.60	737.05	734.90	732.12	723.30	712.85
Alternative 9	739.43	739.37	739.37	738.75	737.53	735.08	732.22	723.38	712.98
Difference	+0.18	+0.16	+0.17	+0.15	+0.48	+0.18	+0.10	+0.08	+0.13
1979 (1st peak)									
Alternative 8	740.34	740.26	740.25	739.55	737.94	735.98	732.71	723.78	713.59
Winter Pool	740.31	740.23	740.22	739.53	737.92	735.94	732.70	723.76	713.56
Alternative 9	740.37	740.28	740.27	739.58	737.96	736.01	732.73	723.79	713.62
Difference	+0.06	+0.05	+0.05	+0.05	+0.04	+0.07	+0.03	+0.03	+0.06
1982 (1st peak)									
Alternative 8	738.36	738.30	738.29	737.77	736.19	734.21	731.78	723.04	712.41
Alternative 9	738.49	738.43	738.43	737.90	736.77	734.36	731.88	723.12	712.53
Difference	+0.13	+0.13	+0.14	+0.13	+0.58	+0.15	+0.10	+0.08	+0.12

Note: * Winter pool conditions were simulated when the historical antecedent stages were higher than the normal winter pool.

Table 28. Differences in Peak Stages at Carpentersville and East Dundee: Alternatives 0 and 9

	1960	1972	1973	1974	1978	1979	1982	1986
Carpentersville								
Historical	723.90	723.40	723.72	723.28	722.75	723.80	722.98	723.92
Alternative 9	723.97	723.46	723.73	723.38	723.04	723.79	723.12	723.95
Difference	+0.07	+0.06	+0.01	+0.10	+0.29	-0.01	+0.14	+0.03
East Dundee								
Historical	713.77	713.03	713.51	712.80	711.97	713.62	712.30	713.90
Alternative 9	713.89	713.13	713.53	712.98	712.50	713.62	712.53	713.94
Difference	+0.12	+0.10	+0.02	+0.18	+0.53	0.00	+0.23	+0.04

Alternative #10. Modify opening of the railroad bridge across the Chain of Lakes adjacent to U.S. Highway 12

The Chicago Milwaukee & St. Paul Railroad Bridge, located adjacent to the U.S. Highway 12 crossing between Nippersink Lake and Pistakee Lake, constricts the flow between those two lakes. The effect of modifying this bridge, so that it provides an opening similar to that of Highway 12, was simulated by modifying the cross-sections in the FEQ input files. A limited number of simulations was performed to estimate the effect of such a modification. Table 29 compares the peak stages determined by using the historical gate operations with and without modification of the railroad bridge.

Table 29. Differences in Peak Stages (feet): Modifications to Railroad Bridge

	CHA	*FOX*	*NIP*	*JOH*	*STR*	*RAW*	*ALG*	*CAR*	*EDU*
1960									
Historical*	741.71	741.54	741.53	740.98	739.97	736.58	733.62	723.88	713.73
Alternative 10	741.64	741.46	741.45	741.04	740.01	736.65	733.64	723.91	713.77
Difference	-0.07	-0.08	-0.08	+0.06	+0.04	+0.07	+0.02	+0.03	+0.04
1973									
Historical	740.55	740.55	740.49	740.03	739.00	736.08	733.42	723.72	713.51
Alternative 10	740.44	740.39	740.38	740.02	738.99	736.07	733.41	723.72	713.50
Difference	-0.11	-0.16	-0.11	-0.01	-0.01	-0.01	-0.01	0.00	-0.01
1982 (2nd peak)									
Historical	738.87	738.83	738.83	738.43	737.53	734.57	732.73	723.07	712.44
Alternative 10	738.81	738.76	738.76	738.44	737.54	734.58	731.73	723.07	712.44
Difference	-0.06	-0.07	-0.07	+0.01	+0.01	+0.01	0.00	0.00	0.00

* 1960 historical operation with maximum 2.4-foot opening

Effect of Dam Operation on Peak Discharge

Table 30 compares the peak discharges for each of the ten alternatives and the historical operation (alternative 0) at Stratton Dam (STR), Rawson Bridge (RAW), Algonquin Dam (ALG), and both Carpentersville and East Dundee (CAR/EDU). In general, the relative decrease and increase in the peak discharges for any one alternative are consistent for all locations.

Only alternatives 1 and 3 provide a consistent reduction in the peak discharges along the Fox River, compared to the historical operation. In general, alternatives 0, 4, 6, 7, 8, and 10 result in similar discharges. Alternatives 2, 5, and 9 produce an overall increase in discharges along the Fox River.

Summary of Model Results

All the alternatives examined provide an overall reduction in flood stages upstream of Stratton Dam, regardless of changes in discharge. This reduction in peak stage in the Chain of Lakes is greatest for the alternatives that involve the use of the flow forecast model to open the available gates early and to a wide setting. By adding a Foster gate at Stratton Dam, flood stages can be reduced, on average, an additional 0.17 foot. The benefit to the larger floods is slightly less than to the more frequent flood event. Cost-benefit considerations for building this gate should be evaluated.

Significant reductions in the peak stages in the Algonquin pool, from the Algonquin Dam upstream to Stratton Dam, are provided only by a Foster gate at Algonquin Dam (alternatives 6 and 8). The average reductions in peak stage at the Algonquin Dam using a Foster gate are 0.75 foot. Reductions in stage are less upstream. Cost-benefit considerations for building this gate should also be evaluated. Minor reductions in the peak stage in the Algonquin pool are provided by alternatives 1 and 3. The peak stage in the pool is unaffected by alternatives 4, 7, and 10. Small increases in the peak stage are associated with alternatives 2, 5, and 9.

The relationship between the changes in peak discharge and peak stage is most consistent for the locations downstream of Algonquin Dam, i.e. Carpentersville and East Dundee. Alternatives 1 and 3 provide a small reduction in the peak stages downstream of Algonquin. Alternatives 0, 4, 6, 7, 8, and 10 result in little or no changes in the peak stages, and alternatives 2, 5, and 9 produce a small increase in the peak stages.

Floods that are significantly overestimated by the flow forecast model, such as the 1978 flood, can result in sizable increases in peak stage downstream of Stratton Dam. However, these floods are necessarily small, and the increased levels in the 1978 flood did not result in stages considered to be as high as a “minor flood.” Operating conditions similar to those simulated for the 1978 flood are expected to occur approximately once every ten years.

The alternative to raise the winter pool to the recreational pool level, while still operating under the historical gate operations, was not simulated because raising the pool level would necessarily require a change in the gate operation. It can be deduced, however, that this alternative would result in increases in the peak flood stages similar to those shown in table 23 (for alternative 5).

Table 30. Differences in Peak Discharges (cfs): All Alternatives

	Alternative										
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1960											
STR	6763	----	7037	6539	6815	6923	6738	6804	6831	6938	6842
RAW	6834	----	7125	6596	6890	7004	6910	6889	6910	7023	6898
ALG	6997	----	7334	6726	7060	7194	7074	7061	7090	7223	7037
CAR/EDU	7094	----	7447	6799	7158	7300	7175	7158	7193	7333	7109
1972											
STR	4376	4186	4706	4291	4384	----	4384	4461	4460	----	----
RAW	4558	4342	4864	4488	4603	----	4602	4680	4694	----	----
ALG	5100	4788	5406	4997	5134	----	5133	5240	5265	----	----
CAR/EDU	5393	5052	5668	5278	5420	----	5417	5547	5593	----	----
1973											
STR	5529	----	5661	na	5617	5616	5621	5559	5571	na	5521
RAW	5766	----	5901	na	5853	5852	5856	5797	5810	na	5753
ALG	6238	----	6380	na	6323	6322	6322	6272	6286	na	6220
CAR/EDU	6451	----	6591	na	6529	6528	6526	6486	6498	na	6436
1974											
STR	4400	----	4472	4388	4471	4678	4471	4497	4503	4710	----
RAW	4517	----	4585	4501	4584	4804	4584	4612	4616	4843	----
ALG	4826	----	4886	4812	4886	5119	4889	4920	4924	5158	----
CAR/EDU	4993	----	5053	4979	5052	5279	5055	5078	5085	5318	----
1978											
STR	3001	2832	----	2672	2899	----	2898	3306	3309	----	----
RAW	2891	2748	----	3163	3263	----	3305	3497	3589	----	----
ALG	3257	3042	----	3631	3720	----	3796	3948	4034	----	----
CAR/EDU	3466	3260	----	3892	3975	----	4079	4201	4302	----	----
1979 (1st peak)											
STR	5879	na	6167	5643	5873	5915	5880	5827	5837	5870	na
RAW	6084	na	6409	5798	6073	6121	6084	6015	6030	6070	na
ALG	6491	na	6881	6158	6470	6528	6476	6412	6429	6476	na
CAR/EDU	6697	na	7113	6340	6663	6727	6663	6614	6630	6682	na
1979 (2nd peak)											
STR	6126	na	6140	6000	6077	6084	6095	6042	6046	6056	na
RAW	6523	na	6541	6366	6460	6472	6487	6418	6425	6436	na
ALG	7332	na	7366	7145	7264	7278	7290	7219	7229	7242	na
CAR/EDU	7758	na	7798	7566	7690	7706	7714	7648	7656	7671	na
1982 (1st peak)											
STR	3533	----	3490	3439	3399	3547	3439	3530	3535	3694	----
RAW	3551	----	3589	3453	3483	3663	3454	3630	3639	3822	----
ALG	3929	----	4049	3781	3909	4139	3774	4112	4116	4312	----
CAR/EDU	4116	----	4238	3962	4092	4332	3959	4307	4309	4515	----
1982 (2nd peak)											
STR	3526	----	3538	3516	3532	3542	3516	3529	3528	3538	----
RAW	3649	----	3660	3638	3652	3665	3634	3644	3640	3653	----
ALG	4144	----	4140	4130	4130	4147	4121	4137	4133	4150	----
CAR/EDU	4374	----	4368	4359	4357	4375	4347	4368	4361	4379	----
1986											
STR	6065	5991	6223	na	6128	----	6142	6113	6123	----	----
RAW	6220	6139	6477	na	6289	----	6304	6274	6286	----	----
ALG	6906	6815	7105	na	6983	----	7000	6968	6983	----	----
CAR/EDU	7165	7066	7497	na	7246	----	7266	7252	7284	----	----

Notes: ---- simulation not performed   na = data not available

7. Summary and Recommendations

Summary

Discharges and stages for simulated flood conditions along the Fox River and Chain of Lakes were estimated using the FEQ unsteady flow routing model. Various alternatives for the operation of Stratton Dam were simulated, resulting in an estimation of their effects on upstream and downstream flood levels. Nonstructural alternatives that were simulated include modifying the lake level for non-flood periods, changing the maximum gate opening during floods, and using the flow forecast model to provide for a release of water from the Chain of Lakes immediately prior to the arrival of floods. The structural alternatives that were simulated include the use of Foster gates to facilitate outflow from the Stratton and Algonquin Dams, and the modification of the railroad bridge structure between Nippersink Lake and Pistakee Lake.

The simulation analyses indicate the following:

1) Flooding stages upstream of Stratton Dam can most effectively be reduced by increasing that dam's discharge-versus-stage capacity during flood conditions. This increase in capacity can be accomplished through using larger gate openings for the existing sluice gates or, for an even greater capacity, by adding a Foster gate at Stratton Dam.

2) Potential increases in downstream flooding -- that could result from a greater discharge capacity at Stratton Dam -- can generally be offset by the early release of water from the dam prior to the arrival of the flood. The early release allows more water to be passed in the initial stages of the storm, so that high lake levels (which contribute to large discharges from the dam) are reduced. Implementation of the early release of water requires the use of a flow forecast model.

3) The installation and operation of a Foster gate at Algonquin Dam will reduce the flood stages in the Algonquin pool, but will have little effect on peak flood stages downstream or on discharges from Stratton Dam.

4) A decision to open the gates prior to a major flood should be based on the present pool level in the lakes and the magnitude of that flood, as estimated by the flow forecast model. When following the forecast guidelines presented in this report, the decision for an early release would occur less than once a year.

5) A flow forecast model can overestimate the severity of the flood, and in some of these cases an early release of water may increase peak stages downstream of Stratton Dam above that which would otherwise occur. Generally, in those situations, the increased stage will likely result in little or no overbank flooding downstream. When following the forecast guidelines presented in this report, this type of operating condition would be expected to occur infrequently, approximately once every ten years. The probability of this condition will be influenced by the accuracy of the flow forecast model, which is affected in part by the number of precipitation gages used to develop the flow forecast.

6) Although a few of the alternatives examined provide for a small reduction in peak stage down-stream of Algonquin, no alternative produces significant downstream flood control benefits.

7) Raising the winter pool 1.5 feet, to the present recreational pool level, will result in a relatively small increase in flood stage both in the Chain of Lakes and along the Fox River downstream of Stratton Dam.

Recommendations

Using the Early Flood Release / Increasing the Raingage Network Used for Flow Forecasts

The analysis indicates that significiant flood contol benefits can result from an early release combined with either opening the existing sluice gates wider or adding a Foster gate at Stratton Dam. It is recommended that a floodgate operation policy using the existing sluice gates be adopted, and the benefit-to-cost of adding the Foster gate be analyzed. The adoption of the early release operating policy should acknowledge the possible impacts of incorrectly forecasting the magnitude of the approaching flood. Analysis presented in this report indicates that adverse impacts of incorrect forecasting will be infrequent and not result in significant additional flood damage.

The success of an early release approach lies in the ability of the flow forecast model to accurately estimate approaching flood conditions, and its accuracy is dependent on the quantity and quality of near real-time precipitation data. In this study, the amount of precipitation data used to develop forecasts was limited to a level similar to that which would be available for current applications of the model. It is recommended that the improvements of additional raingages be evaluated and, if warranted, the number of raingages that provide near real-time data be increased above the present level. Using a larger raingage network should improve normal flow forecasts, reduce possible adverse impacts when any existing gages fail to report, and reduce the chance that an improper operation decision will be chosen.

Determining Changes in Flood Frequency

This study analyzed the effects of various operation alternatives on selected historical floods. Potential changes in the frequency distributions of peak discharge and stage have not been evaluated. This frequency analysis will be needed to better assess the economic aspects of flood damages.

Economic Analysis of the Flood Control Benefits of the Foster Gates

The simulation analysis indicates that the addition of Foster gates to both the Stratton and Algonquin Dams would further lower the peak flood stages in each dam's respective pool. Economic analysis is needed to determine if the long-term reduction in flood damage, provided by the Foster gate at either of these dams, surpasses the amortized cost of building the gate.

Need for Assessing the Impact of the Winter Pool on Aquatic Life and Other Issues

The analysis on raising the winter pool level, conducted in this study, only addresses the flood control impacts of changes in the pool level. An objective evaluation of other effects, including impacts on aquatic life, recreation, and ice damage, etc., should be conducted to assess the benefits and possible costs of changing the winter pool level.

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Acknowledgments

This study was supported by the Illinois Department of Transportation, Division of Water Resources (IDOT-DWR), with William W. Rice as project coordinator. The investigation was prepared under the general supervision of Mark E. Peden, Acting Chief of the Illinois State Water Survey; John M. Shafer, Hydrology Division Head; and Krishan P. Singh, Director of the Office of Surface Water Resources and Systems Analysis. Linda J. Hascall and David Cox assisted with the illustrations, and the report was edited by Eva C. Kingston.

The FEQ model used in this study was primarily developed by IDOT-DWR. William Rice, Joe Maynerich, and Rita Marion of the DWR provided the investigators with valuable information concerning the FEQ model development, Stratton Dam operating procedures, and operation records.