SOURIS RIVER BASIN
SASKATCHEWAN, NORTH DAKOTA AND MANITOBA

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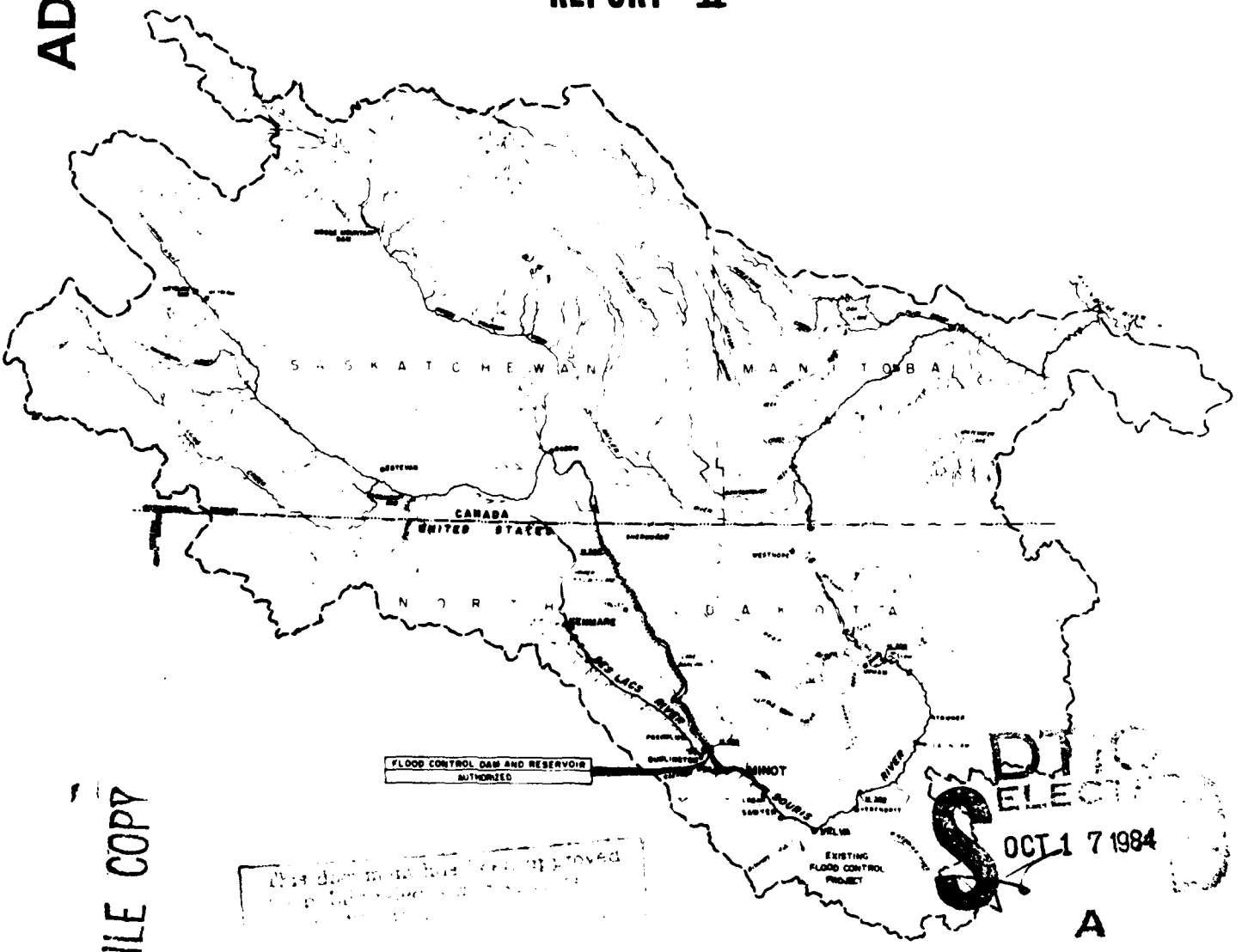
REVIEW OF THE EFFECTS ON CANADA OF IMPROVEMENTS PROPOSED FOR FLOOD CONTROL IN THE UNITED STATES

REPORT II



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TO THE
INTERNATIONAL SOURIS-RED RIVERS
ENGINEERING BOARD
BY THE
BURLINGTON DAM TASK FORCE

JUNE 1979

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To the
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Engineering Board

By the
Burlington Dam Task Force

June 1979

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INTERNATIONAL SOURIS-RED RIVERS ENGINEERING BOARD

BURLINGTON DAM TASK FORCE

29 June 1979

International Souris-Red Rivers Engineering Board
Washington, D.C., United States
Regina, Saskatchewan, Canada

Gentlemen:

The Burlington Dam Task Force, reconstituted by your Board in April 1978, has completed the studies required to respond to the Board's directive of April 5, 1978. The results of the studies are included in the attached report and its four appendices.

The Task Force regrets that this report is being transmitted approximately 3 months past the date requested by the Board. The Task Force believes, however, that the additional time required for a full review of the implications of operation of the Burlington project relative to the potential for carp infestation of the Souris River was necessary and resulted in a more definite conclusion on this complex concern.

The Task Force is prepared to respond to any questions the Board may have concerning the assignment and this report, and the Task Force awaits your further direction in this regard.

Yours sincerely,

J. R. CALTON
Chairman, United States Section

R. P. BALDWIN
Chairman, Canadian Section

W. R. SCOTT

P. N. BOOTHROYD

D. E. SIMPSON

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I INTRODUCTION

A. ASSIGNMENT

In September 1970 the International Souris-Red Rivers Engineering Board established the original Burlington Dam Task Force to provide answers to a number of technical questions resulting from the Board's review of the Corps of Engineers 1969 Review Survey on Souris River Flood Control. The Task Force presented the final report on its studies to the Board on October 31, 1977. This report, entitled "Review of the Effects on Canada of Improvements Proposed for Flood Control in the United States", contains a complete description of the original Task Force assignment and its activities.

On April 5, 1978 the International Souris-Red Rivers Engineering Board reconstituted the Burlington Dam Task Force and directed it to proceed with additional studies to supplement the original Task Force studies. The directive was formalized by a letter from the Board dated May 1, 1978 and read as follows:

> *"The International Souris-Red Rivers Engineering Board requires further information on the impact of operation of the Burlington Dam and Reservoir on Manitoba and the impact of implementation of the range of practical measures that could be undertaken to mitigate identifiable adverse impacts of the project on Manitoba. The Board requests therefore, that the Task Force undertake the studies described in the attached Plan of Study and, based on the results of these studies and the Task Force studies already completed, provide the following information to the Board in a draft report form:*
>
> 1. *The economic and environmental impact on Canada of operation of the Burlington project.*
>
> 2. *The nature, scope and cost of the range of mitigation measures identified by the Task Force.*

3. *The physical impact, if any, of the planned alterations to structures in the J. Clark Salyer Wildlife Refuge.*

4. *The environmental impacts on Canada associated with implementation of alternative mitigation measures.*

In carrying out this assignment the Task Force should assume that operation of the Burlington project will be in accordance with the operating plan described in Chapter III and Appendix C of the Task Force's October 1977 report to the Board. The Task Force should also utilize the available findings of the ongoing Canada-Manitoba-Saskatchewan Souris River Basin Study to the greatest extent possible."

The Directive to the Task Force was accompanied by a Plan of Study which is included in Appendix A. In its covering letter, the Board required that the Task Force schedule these studies to permit the Board to make a final report to the International Joint Commission at the Commission's April 1979 semiannual meeting.

This report describes the studies undertaken to provide the additional information required by the Board in its directive. The studies relied heavily on the work completed by the original Burlington Dam Task Force and the findings contained in this report are, in many cases, amplifications or clarifications of the findings in the 1977 report submitted by the original Task Force. Consequently, this report should be considered as a supplement to the 1977 report and should be read in conjunction with that report. The Task Force made no attempt to duplicate information contained in the 1977 report unless clarification was necessary or the information was required to directly support the discussion of the studies undertaken as specified in the directive. The reader is particularly referred to the earlier report for a description of the project and the Corps of Engineers operating plan for flood control.

In addition to the 1977 report, the Task Force made extensive use of the reports on the findings of two studies which were not fully available to the original Task Force. The first of these was the report of the International Garrison Diversion Study Board, which was released by the International Joint Commission in January 1977. The second was the report of the Canada-Manitoba-Saskatchewan Souris River Basin Study Board which was released in Canada in August 1978.

The Burlington Dam Task Force was appointed by the Board from those Federal, State, and Provincial agencies that had the expertise required to carry out all aspects of the Plan of Study. Membership was as follows:

Canada	United States
R. P. Baldwin (Canadian Co-chairman) Inland Waters Directorate Environment Canada	J. R. Calton (United States Co-chairman) U.S. Army Corps of Engineers
F. R. J. Martin Prairie Farm Rehabilitation Administration Department of Regional Economic Expansion	*W. R. Scott United States Geological Survey United States Department of the Interior
P. N. Boothroyd Canadian Wildlife Service Environment Canada	E. B. Soderquist United States Bureau of Reclamation United States Department of the Interior
	D. W. Houseworth (to December 1978) United States Fish and Wildlife Service United States Department of the Interior
	D. E. Simpson (from December 1978) United States Fish and Wildlife Service United States Department of the Interior

* Mr. W. R. Scott retired from active service with the United States Geological Survey in December 1978 but kindly consented to assist the Task Force with the preparation of its report after that date.

Manitoba

R. J. Bowering
Water Resources Division
Department of Mines, Natural
Resources and Environment

J. A. Bray (to March 1979)
Economics Branch
Department of Agriculture

R. B. Oetting (to November 1978)
Wildlife Branch
Department of Mines, Natural
Resources and Environment

W. N. Howard (from November 1978)
Western Region
Department of Mines, Natural
Resources and Environment

North Dakota

D. A. Sprynczynatyk
Engineering Division
North Dakota State Water
Commission

The full titles and addresses of Task Force members, as well as their designated alternates, are listed in Appendix A.

The Task Force was fortunate in that 4 of the 11 members had also served on the original Task Force, thus providing continuity from the earlier studies. These members are also identified in Appendix A.

The Task Force held its first meeting in Winnipeg, Manitoba, on April 18, 1978. Regular meetings were held on approximately a monthly basis until the conclusion of the studies. In addition to the regular meetings, the Task Force met formally with the International Souris-Red Rivers Engineering Board on three occasions to discuss study progress and review study findings. A complete meeting schedule is included in Appendix A. The Task Force concluded its work under the Directive in April 1979 with the transmittal of this report to the International Souris-Red Rivers Engineering Board.

B. REVIEW OF OCTOBER 1977 REPORT

The findings of the original Burlington Dam Task Force are summarized in Chapter IX of the 1977 report to the International Souris-Red Rivers Engineering Board as follows:

> *"In response to the Terms of Reference of February 12, 1975, as set out in Chapter I, the Task Force has reached the following conclusions:*
>
> 1. *In response to items (a) and (b) the Task Force finds that the Burlington project will affect the natural level of the water of the Souris River north of the international boundary in Saskatchewan during flood events which exceeded the 1:100 year probability. The effect will be almost totally limited to the river channel except in extremely rare floods having a recurrence probability on the average of once in 2,000 to 4,000 years. As a result economic damages can be expected to be negligible provided the operation procedure identified in this report is followed. Approval for altering the water level flow regime in the channel should be sought from Saskatchewan.*
>
> 2. *In response to item (c) the Task Force finds that the operating plan for the Burlington Dam and modified Lake Darling project as currently proposed would have a relatively minor effect on safe channel capacities throughout most of the Manitoba reach of the Souris River. For all reaches except the Westhope reach, the modified floodwaters for the nine historic floods studied would have receded below safe channel capacity within 1 week of the historic date. For the 45 flood events represented by the 9 flood studies in the 5 reaches downstream from*

the Westhope reach, the modified floods would have receded sooner than the historic floods in about 50 percent of the flood events, flood durations would have remained unchanged in 10 percent of the flood events, and the modified floods would have receded later in 40 percent of the flood events.

For the Westhope reach where the bank-full capacity is only 4.25 m^3/sec (150 cfs), reservoir drawdown would often result in late summer and fall flows which would exceed safe channel capacity. However, the resulting flooding would only extend over a relatively narrow band of bottomlands.

With Burlington Dam in operation, historic peak stages in urban centers would be changed by no more than ±0.15 meter (±0.5 foot). Of the nine floods studied the flood damage threshold elevation was exceeded at Melita eight times, at Souris six times, and at Wawanesa once. When the flood damage threshold elevation was exceeded, the Burlington project operation would have increased the flood peak elevation 5 times at Melita and three times at Souris. During the only flood occurrence at Wawanesa, the peak flow would have been reduced.

Burlington Dam operation would normally increase the areal extent of flooding in Manitoba on May 5, thereby delaying crop seeding. The maximum incremental flooding along the total Manitoba portion of the Souris River would have occurred in 1960 when Burlington Dam operation would have resulted in an additional 318 hectares (615 acres) of flooding on or after May 5. However, by June 5, flooding would normally be less under Burlington Dam operation than historically. Therefore, with Burlington Dam in operation there would be fewer occurrences of total crop loss due to flooding. The largest decrease in flooding would have occurred in 1970 when Burlington Dam operation would have resulted in a 2,416-hectare (5,970-acre) reduction in flooded area on or after June 5.

3. In response to item (d) the Task Force finds that adverse effects of the project in Saskatchewan could only occur with a very rare combination of hydrologic events warranting no further investigation. Mitigation of the adverse effects of the project in Manitoba, if required, could be achieved through a number of individual alternatives or combinations of alternatives including channelization, dyking, land purchase, flood easements, and annual compensation. Further study is required before any alternative or combination of alternatives can be recommended. Studies should include the evaluation of economic, social, and possible environmental impacts of the project operation and mitigation alternatives.

4. In response to the request that other considerations be noted, the following is provided.

   a. The project effects described in this report are based on the operating plan described in Chapter III. Any departure from this plan could alter project effects requiring modified mitigation measures. Because of the importance of compliance with the operating plan, operation of the Burlington project should be subject to review by an appropriate international body.

   b. The combined effect of the Burlington and Garrison projects depends on the amount of spring runoff in the Souris River above the Burlington project. In a given year the additional effect of the Garrison project will be insignificant during the spring breakup period from April through June. During the normal low-flow months, however, the return flows from GDU would increase the base flow in the river on which the Burlington summer releases would be superimposed, assuming the Burlington project had been operating in the spring.

c. *The Burlington project includes proposed modifications to structures operated by the U.S. Fish and Wildlife Service in the J. Clark Salyer Wildlife Refuge. Detailed designs for these modifications are currently unavailable, and hence the potential for changes in discharge-storage relationships in the refuge is unknown. Although the U.S. Fish and Wildlife Service does not anticipate changes in operating methods, and the potential effect on Manitoba of alterations in discharge-storage relationships is probably small, additional studies will be required to determine this component of project effects on Manitoba."*

Although the 1977 report responded to the Terms of Reference given to the Task Force on February 12, 1975 by the International Souris-Red Rivers Engineering Board, the utility of the information provided in the report as a guide for further discussions was adversely affected by a number of factors related to the nature of the project, the availability of information, and the scope of the studies permitted under the terms of reference. Most of these factors were noted or alluded to in the findings of the Task Force.

Operation of the Burlington project, which will be located on the Souris River approximately 410 kilometers (256 miles) upstream of the Manitoba-North Dakota boundary, will be based on operating rules related to streamflow forecasts at that location. Tributary inflow between the Burlington site and the Manitoba boundary can be substantial and highly variable. As a result, in any 2 years where the flood flow characteristics at the Burlington site were similar, the flow characteristics and hence the effect of the project could be quite different at the Manitoba boundary due to tributary inflow differences. This phenomenon made the results of any attempts to apply the effect of the project to a theoretical flood highly speculative, and therefore the studies were confined to a consideration of historic flood events.

As noted in the findings of the 1977 report, the Task Force was aware that structural alterations to the control structures in the J. Clark Salyer and Upper Souris Wildlife Refuges were being considered as Burlington project features. At the time of writing of that report, however, there was no agreement between the concerned agencies on the form that these alterations would take. As noted in the report, the studies did not, therefore, include an analysis of the potential effect of these structural alterations in the overall project effects. This exclusion had an obvious effect on the perceived reliability of the findings reported.

The terms of reference of the original Task Force did not permit the assessment of the economic, social, or environmental impacts of the project. These assessments were not required to answer the specific questions put to the Board in the September 30, 1970 letter from the I.J.C. As a result, the report did not provide sufficient detail for use as a basis for bilateral negotiations.

The terms of reference of the present Task Force require it to address the deficiencies outlined above and the following report provides the necessary detail for the preparation of a complete report by the Souris-Red Rivers Engineering Board to the International Joint Commission as well as a background document for any further discussion of the project that may be required.

II PROJECT DESCRIPTION

A. GENERAL

Since completion of the 1977 Task Force report, the Corps of Engineers has undertaken more detailed preconstruction planning which has resulted in some changes in structural design. The principal project features are shown on Plate 1 and are summarized in the following paragraphs. More detailed data are available in the report, Design Memorandum No. 2, Phase II - Project Design, August 1978, by the St. Paul District Corps of Engineers. The Burlington Project, as referred to in this report, includes the Burlington Dam, Des Lacs River Diversion, and modification to Lake Darling Dam.

B. BURLINGTON DAM

Dam and Reservoir. - Burlington Dam will be located approximately 3.2 kilometers (2 miles) upstream from Burlington, North Dakota, on the Souris River. The crest of Burlington Dam will be at elevation 496.8 meters (1630 feet); the dam will have a maximum height of 22.9 meters (75 feet) above stream bed, a crest width of 11.6 meters (38 feet) and a crest length of 1,123 meters (3,685 feet). The spillway will be located in the left abutment and be designed for a maximum discharge of 1,710 m^3/sec (60,300 cfs). The outlet works also will be located in the left abutment about 61 meters (200 feet) to the river side of the spillway. The outlet will be designed to pass 142 m^3/sec (5,000 cfs) at elevation 480.5 meters (1576.6 feet).

The dam and reservoir are designed to control Souris River flood flows up to a return period of greater than 1,000 years. At the design pool elevation of 493.8 meters (1620 feet), the Burlington Reservoir will provide 780,000 dam^3 (633,000 acre-feet) of regulated flood control storage. This capacity is equivalent to 9.14 cm (3.6 inches) of runoff from the primary contributing drainage area of 852,000 hectares (3,290 square miles). The regulated flood control storage does not include the conservation pool storage in Lake Darling of 97,000 dam^3 (79,000 acre-feet), below elevation 485.8 meters (1594 feet).

Spillway. - The spillway will be located on the left abutment. It will consist of an approach channel, a gated ogee control section, a straight constant-width chute, a horizontal stilling basin with baffle blocks and an end sill, and a discharge channel. The spillway configuration has been changed from the ungated type recommended in the Phase I, Plan Formulation studies. The change to a gated spillway was made because a more flexible operation will be possible during floods and because the maximum water surface elevation will be lower.

The ogee section will consist of five bays, each controlled by a gate 8.4 meters (27.5 feet) wide by 6.4 meters (21 feet) high. The gate height includes 0.3-meter (1.0-foot) freeboard for a wave deflector. The five bays may be reduced to three depending on the results of a cost-effectiveness study which will be done during the feature-design memorandum studies. Each bay will be designed to pass about 343 m^3/sec (12,100 cfs) at the maximum water level.

Outlet Works. - The low-level outlet works will consist of an approach channel, an intake structure with provision for multilevel releases, a three-unit rectangular conduit, a stilling basin, and a discharge channel. Each conduit unit will be 2.1 meters (6.8 feet) wide by 7.0 meters (23 feet) high. The conduit will be 82.3 meters (270 feet) long and discharge over a parabolic drop section into a stilling basin 51.2 meters (168 feet) long. The approach channel is set at elevation 474 meters (1555 feet) to permit complete evacuation of the reservoir. The design capacity of the outlet is 142 m^3/sec (5,000 cfs) with the headwater at elevation 480.5 meters (1576.6 feet). The reservoir design headwater elevation was established to prevent inundation of the upstream U.S. Fish and Wildlife Service refuge by flows up to the design discharge.

C. DES LACS RIVER DIVERSION

To provide the Minot area with a greater degree of protection from the Des Lacs River, above that which would be provided by channel and levee improvements alone, the overall plan includes diverting part of the

Des Lacs River flow through a tunnel into the proposed Burlington Reservoir. The diversion dam and tunnel intake will be located on the Des Lacs River about 12.7 valley kilometers (7.9 valley miles) above Burlington and the outlet works will be located on the Souris River about 11.3 valley kilometers (7.0 valley miles) above Burlington. The diversion facilities include a concrete-lined tunnel, an earth-fill diversion dam with outlet works, a weir and entrance channel to the tunnel portal, and a tunnel outlet to the Souris River in the Burlington Reservoir area.

Diversion into the tunnel will begin at a discharge of 39.6 m^3/sec (1,400 cfs). At the flow just before overtopping the diversion dam, 241 m^3/sec (8,500 cfs), the facilities will divert 127 m^3/sec (4,500 cfs) into the tunnel and pass 113 m^3/sec (4,000 cfs) down the river equivalent to the 142-m^3/sec (5,000-cfs) design capacity of the channel at Minot minus a 28.3-m^3/sec (1,000-cfs) allowance for inflow from the uncontrolled drainage area downstream of the diversion dam and downstream of the proposed Burlington Dam.

D. LAKE DARLING DAM MODIFICATION

Dam and Reservoir. - In 1936, the U.S. Fish and Wildlife Service completed Lake Darling Dam which is located on the Souris River at the Ward-Renville County line. The existing reservoir has a capacity of 149,000 dam^3 (121,000 acre-feet)[1] at elevation 487.1 meters (1598 feet). The reservoir is used to supply water to smaller wildlife reservoirs located farther downstream on the Souris River. The existing dam is an earth-fill structure about 9.1 meters (30 feet) high with the crest at elevation 489.5 meters (1606 feet). It includes a 97.5-meter (320-foot) long uncontrolled service spillway on the left abutment, a 76.2-meter (250-foot) long emergency spillway on the right abutment, and a 2-unit gated low-level outlet works.

Lake Darling Dam will be raised 1.2 meters (4.0 feet) as part of the flood control project. Raising Lake Darling Dam will provide additional flood storage which will reduce the frequency of Burlington Dam

(1) Based on a resurvey in 1978 by the Corps of Engineers.

operation and flooding in the wildlife pools downstream from Lake Darling. The raised dam will be subject to overtopping on an average of once in 300 years. Depending on the characteristics of the flood, the dam could overtop either from the downstream or the upstream side. The dam section design was based on a combination of maximum head differential during overtopping of 2.0 meters (6.7 feet) and maximum velocity on the downstream face of 2.8 m/sec (9.2 fps). These conditions would occur during project operation for the probable maximum flood.

The crest of the raised dam will be at elevation 490.7 meters (1610 feet); the dam will have a maximum height of about 10 meters (33 feet) above stream bed, a top width of 12.2 meters (40 feet), and a crest length of 1,128 meters (3,700 feet). The spillway will be located on the left abutment and will consist of an approach channel, a gated ogee control section, a straight, constant-width chute, and a stilling basin. The low-level outlet also is located near the left abutment. The low-level outlet will consist of a gated intake structure with provisions for multilevel release, a two-unit rectangular conduit, and a stilling basin. A common discharge channel will be provided for the outlet and the spillway.

Spillway. - The spillway will consist of an approach channel, a gated ogee control section, a straight, constant-width chute, a stilling basin, and a discharge channel to convey the water to the natural river channel. The spillway configuration has been changed from an ungated type as recommended in the Phase I, Plan Formulation studies. The gated configuration is less costly and provides for a more flexible operation during floods.

The ogee section will consist of three units, each controlled by a 7.3-meter (24-foot) wide by 6.7-meter (22-foot) high tainter gate. Each unit will be designed to pass 227 m^3/sec (8,000 cfs) with the pool at elevation 489.2 meters (1605 feet). All three gates will be lifted by individual gate hoists. The chute will be about 27.4 meters (90 feet) long and 25 meters (82 feet) wide. The stilling basin will be 43.4 meters (142.5 feet) long. A bridge will be built above the spillway.

The discharge capacity of the spillway is equal to the capacity of the existing main and emergency spillways which is 680 m^3/sec (24,000 cfs) with the headwater at elevation 489.2 meters (1605 feet). The crest of the ogee section will be at elevation 482.8 meters (1584 feet).

Outlet Works. - The low-level outlet works consist of a gate controlled multilevel intake facility, a two-unit rectangular conduit, and a stilling basin. Both the approach channel and the discharge channel are common with the spillway. Each unit will be 2.6 meters (8.5 feet) wide by 3.4 meters (11.0 feet) high. The conduit will be 63 meters (207 feet) long and will discharge into a stilling basin 16.0 meters (52.4 feet) long. The outlet will be controlled by slide gates.

The approach channel was set at elevation 480.7 meters (1577 feet) to permit complete evacuation of Lake Darling. The design capacity of the outlet is 70.8 m^3/sec (2,500 cfs) with the headwater at elevation 484.9 meters (1591 feet). The conduit will slope at 1.0 percent causing open-channel flow under design conditions. The stilling basin is designed for a tail water at elevation 482.3 meters (1582.5 feet). The low-level outlet may require operation for a wide range of headwater and tail-water conditions.

E. PROJECT OPERATION

The project operating plan, described in detail in Chapter III B of the 1977 Task Force report, was developed jointly with the U.S. Fish and Wildlife Service and has not been changed.

III PHYSICAL IMPACT OF PROJECT

A. ALTERATIONS TO J. CLARK SALYER REFUGE STRUCTURES[1]

Description of Existing Structures. - The refuge includes five principal structures identified as Dams 320, 326, 332, 341, and 357 located as shown on Figure 1. Each dam consists of a low earth dyke with top widths varying from 2.4 to 4.9 meters (8 to 16 feet) and about 1 on 3 side slopes. The dykes extend across the floodplain and include a gated outlet structure in the river channel and an uncontrolled overflow spillway section. The gated outlet structures consist of three 4.9-meter (16-foot) rectangular sections constructed of reinforced concrete. Manually operated radial gates control the discharge through the outlet structures. The uncontrolled spillways are constructed of hand-set rubble masonry with reinforced-concrete buttresses on the downstream side of the crests and at the end walls. A concrete cap beam has been placed at the downstream edge of the spillway crests of all dams except at Dam 357. A summary of the pertinent dimensions of the refuge dams is shown in Table 1.

Proposed Alterations. - Improvements to the refuge dams were planned to minimize damages to the dam structures with passage of the maximum release from the Burlington project of 142 m^3/sec (5,000 cfs) plus the 100-year local inflow below Minot (essentially equal to the local inflow during the 1976 flood). Two alternative improvements were originally considered. The first, which was eventually dropped, provided for an additional discharge unit and radial gate to be added to the outlet structures at each dam. However, because of the effect of backwater due to the flat slope and limited channel capacity, no significant increase in discharge capacity could be obtained.

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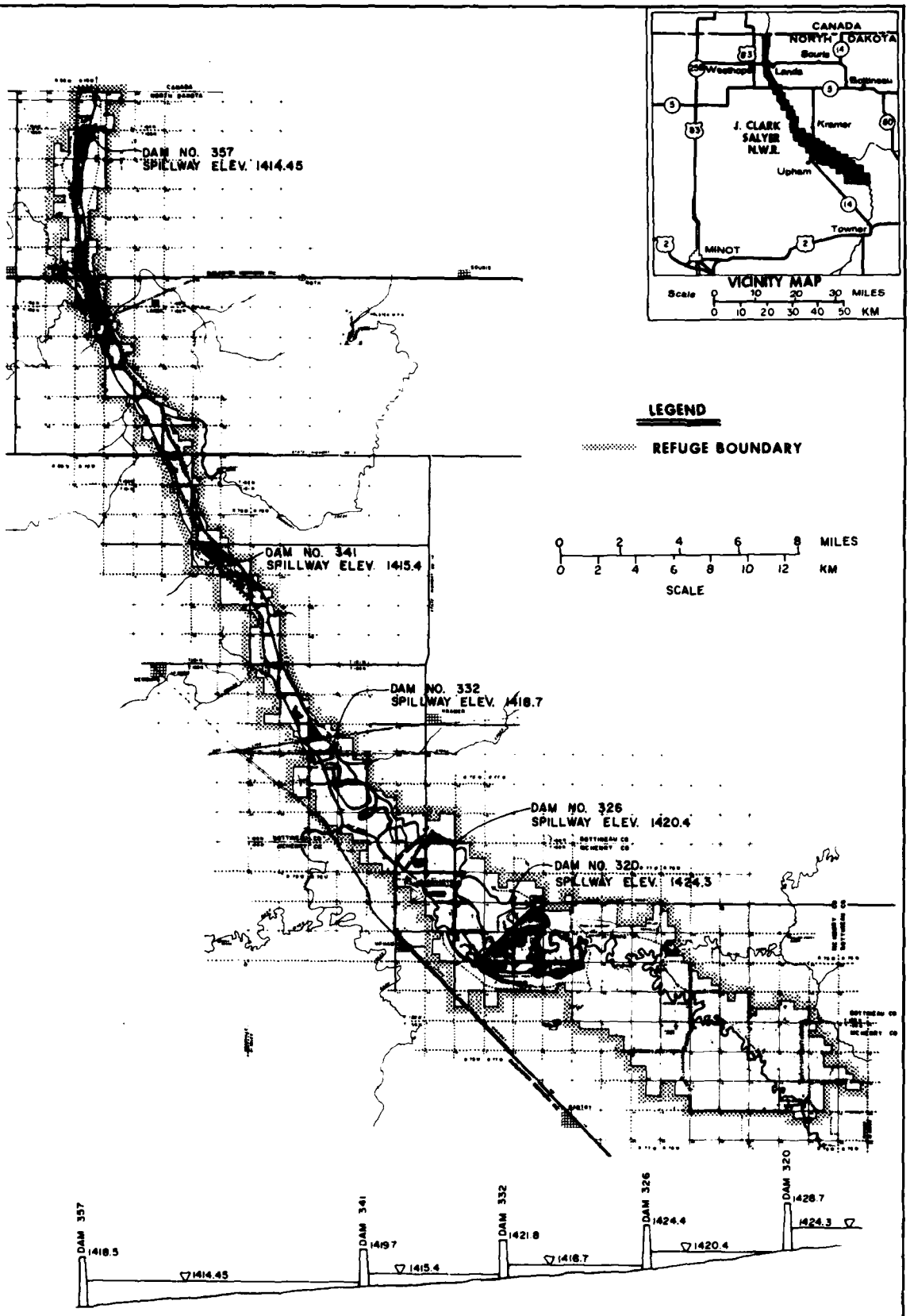
(1) Similar modifications and possible inclusion of an additional gate in the structures located in the Upper Souris River National Wildlife Refuge are proposed but would not affect flows in Manitoba.



SOURIS RIVER, NORTH DAKOTA
J. CLARK SALYER NATIONAL WILDLIFE REFUGE
GENERAL PLAN AND PROFILE

FIGURE 1

Table 1a - J. Clark Salyer National Wildlife Refuge Structure Data

Dam Number	Dam Crest Length (meters)	Dam Crest Elevation (meters, msl)	Gated Outlet Number of Gates	Gated Outlet Height (meters)	Gated Outlet Width (meters)	Gated Outlet Top Elevation (meters, msl)	Ungated Spillway Crest Elevation (meters, msl)	Ungated Spillway Crest Length (meters)
320	4,877	435.5	3[a/]	3.1	4.9	434.2	434.2	213
326	2,438	434.2	3	2.1	4.9	432.9	432.9	213
332	1,524	433.0	3	2.7	4.9	431.9	432.1	213
341	1,219	432.7	3	2.7	4.9	431.5	431.5	213
357	914	432.4	3[b/]	3.1	4.9	431.1	431.1	213

Table 1b - J. Clark Salyer National Wildlife Refuge Structure Data

Dam Number	Dam Crest Length (feet)	Dam Crest Elevation (feet, msl)	Gated Outlet Number of Gates	Gated Outlet Height (feet)	Gated Outlet Width (feet)	Gated Outlet Top Elevation (feet, msl)	Ungated Spillway Crest Elevation (feet, msl)	Ungated Spillway Crest Length (feet)
320	16,000	1428.7	3[a/]	10	16	1424.7	1424.3	700
326	8,000	1424.4	3	7	16	1420.4	1420.4	700
332	5,000	1421.8	3	9	16	1417.0	1418.7	700
341	4,000	1419.7	3	9	16	1415.7	1415.4	700
357	3,000	1418.5	3[b/]	10	16	1414.5	1414.5	700

a/ Additional outlet, 1.2-meter (4-foot) corrugated metal pipe with stop-log control, for refuge management use.

b/ Additional outlets: two 1.2-meter (4-foot) wide by 1.4-meter (4.5-foot) high stop-log sections in ungated spillway, for refuge management use; 0.9-meter (3-foot) pipe with slide-gate control, no longer operational; two 0.60 meter (2-foot) reinforced concrete pipes with slide and orifice gate control, for low-flow discharges.

The second alternative provides for raising the earth embankments, where necessary, to an elevation 0.3 meter (1 foot) above the water surface elevation obtained by routing the 1976 flood through the proposed project facilities. This alternative requires raising all dam embankments except Dam 320. The elevation criteria for the proposed raises are summarized in Table 2. The raised embankments will have side slopes of 1 on 3 and will be protected from erosion by riprap. The following additional improvements will be made:

a. Dam 320 will be stabilized, where necessary, using riprap on the embankment slopes and on the spillway. Stabilized aggregate surfacing will be required on about 50 percent of the embankment crest.

b. The entire length of the raised embankments will be surfaced with stabilized aggregate. New reinforced-concrete wing walls will be constructed at the ends of the spillways to support the raised embankments. Riprap will be placed at the downstream ends of the masonry spillway aprons.

c. New wing walls will be constructed at the upstream and downstream side of the gated outlets at Dams 320, 326, 332, and 341.

d. The piers, wing walls, walkways, and gate hoists will be raised at Dams 332, 341, and 357.

e. Approximately 366 meters (1,200 feet) of unimproved road leading to the crest of Dam 357 from the west will be raised to elevation 433.6 meters (1422.6 feet). The road will have a stabilized aggregate surface and riprap protection on the upstream slope.

f. Deteriorated concrete in the gated outlet structures and in the spillway buttresses and cap beams will be replaced. The interior piers in each of the gated outlets will be replaced.

g. The existing radial gates will be replaced. New motorized gate hoists will be installed and gate heating systems will be provided at each outlet structure.

Table 2a - Criteria for Raise of J. Clark Salyer Refuge Dams

Dam	Existing Crest Elevation (meters, msl)	Maximum Pool Elevation, 1976 Flood with Burlington (meters, msl)	Proposed Crest Elevation (meters, msl)	Proposed Increase in Crest Elevation (meters)
320	435.5	434.8	No change	None
326	434.2	433.9	434.2	0.06
332	433.4	433.7	434.0	0.61
341	432.7	433.5	433.8	1.10
357	432.4	433.3	433.6	1.25

Table 2b - Criteria for Raise of J. Clark Salyer Refuge Dams

Dam	Existing Crest Elevation (feet, msl)	Maximum Pool Elevation, 1976 Flood with Burlington (feet, msl)	Proposed Crest Elevation (feet, msl)	Proposed Increase in Crest Elevation (feet)
320	1428.7	1426.6	No change	None
326	1424.4	1423.6	1424.6	0.2
332	1421.8	1422.8	1423.8	2.0
341	1419.7	1422.3	1423.3	3.6
357	1418.5	1421.6	1422.6	4.1

Effect of Proposed Structural Modifications. - Backwater calculations for flows up to 351 m^3/sec (12,400 cfs), the maximum Souris River flood of record at Westhope, indicated only insignificant changes in velocities and head differentials at the structures due to the proposed structural alterations. In addition, none of the proposed structural modifications would permit adoption of an operation plan for the refuge dams that was not possible prior to the structural alterations.

B. FLOOD ROUTING

Rationale for Selection of Historic Events. - The development of frequency-damage curves for with- and without-Burlington conditions using peak flood discharge-frequency data was investigated, but was discarded during preliminary analysis because the frequency-damage relationship with Burlington was not well defined. As noted in the 1977 report, operation of Burlington in any given year would be based on predicted flood volumes at Sherwood. Since inflows between the Burlington project and Westhope are a major component of flow at Westhope, Burlington operation could be the same for substantially different floods entering Manitoba. As a result, no direct relationship between the incremental effects of Burlington and a historic frequency-damage curve could be determined. In the absence of this relationship, and in consideration of the findings of the Souris River Basin Study, it was felt that historic floods in the Souris River Basin would provide the most authentic and reasonable basis for determining the effects of the Burlington project on flows in Manitoba. Using historic data would also permit the accommodation of other parameters, such as duration, that are not closely related to peak flow.

The historic period 1936 to 1976 was chosen to evaluate the effect of the Burlington project for two reasons: first, this 41-year historic period was used in the Souris River Basin Study to determine average annual

damages and second, this is the maximum period for which reasonably consistent and adequate streamflow records are available on the Souris River. In addition, all flood occurrences since the mid-1930's have been modified to some extent by the operation of Lake Darling and this modification is incorporated in the streamflow records of the Souris River in North Dakota and Manitoba.

Reasons for Selection of Those Years Studied. - The streamflow records of the Souris River near Sherwood were examined to determine the years in which a maximum 30-day inflow volume exceeded 50,000 acre-feet. For years in which the maximum 30-day inflow volume was less than 50,000 acre-feet, the Burlington project would not have altered historic flows because the Burlington operating plan would not have been implemented and the operation of Lake Darling would have remained unchanged. On this basis, in only 18 of the 41 years would the Burlington project have altered historic flows in the Souris River below the project. Nine of these years (1948, 1955, 1960, 1969, 1970, 1972, 1974, 1975, and 1976) were analyzed in the studies leading to the 1977 report. To provide a complete analysis of the 41-year period, the additional nine years (1943, 1947, 1949, 1950, 1951, 1953, 1956, 1965, and 1971) were analyzed during the latest studies.

Update of Flood Routing Methods. - The additional nine floods were routed from the international streamflow station near Sherwood through the Burlington project in North Dakota to the most downstream flow measuring station on the Souris River at Wawanesa. In the United States, the Progressive-Average Lag routing method was used with variable travel times between streamflow measuring stations. Routings of the selected floods were repeated until observed flows at measuring stations were duplicated with identification of reasonable tributary inflow rates and timing. Reservoir routings were based on predetermined elevation-storage relations and the basic equation, outflow equals inflow minus change in storage. In Manitoba, the SSARR (Streamflow Synthesis and Reservoir Regulation) model was calibrated to duplicate either recorded daily flows or reconstructed daily flows provided by the Water Resources Division of the Manitoba Department of Mines, Natural Resources and Environment.

The reconstructed flows at selected locations in Manitoba were derived by the Muskingum Method during the Souris River Basin Study and were used in the absence of recorded flows to determine flood damage through urban and agricultural areas along the Souris River in Manitoba.

The hydrographs of the original nine floods as shown in the 1977 report were compared to hydrographs developed for the Souris River Basin Study. In four of the nine floods (1948, 1955, 1972, and 1975) significant differences were observed. These differences occurred primarily because average routing constants were used in the original Task Force study, whereas the floods were calibrated on an individual basis in the Souris River Basin Study. For these 4 years, the SSARR model was recalibrated for the Manitoba section of the Souris River using the hydrographs developed for the Souris River Basin Study.

Results of Flood Routing. - The flood hydrographs for the additional 9 flood years were routed through North Dakota using the same assumptions and routing procedures that were used in the 1977 report. The modified flood hydrographs for the Souris River near Westhope for these additional 9 flood years and for 4 of the original 9 flood years were routed through Manitoba to determine the effect of the Burlington project on flows in Manitoba. Table 3 provides a list of the 18 selected flood years and the recorded or reconstructed peak flows at key streamflow gauging stations on the Souris River. The existing and modified flood hydrographs for all 18 selected flood years at key locations on the Souris River are illustrated in Appendix B.

Table 3a - Peak Flow on Souris River for Existing Conditions

Year	Maximum Mean Daily Discharge in m^3/sec				
	Sherwood	Minot	Westhope	Melita	Wawanesa
1943	151	70.2	63.4	68.5 1/	57.8
1947	63.7	38.5	51.0	51.8 1/	57.2
1948	209	75.9	82.1	118 1/	117
1949	76.5	62.3	178	184 1/	234
1950	45.3	37.9	74.5	77.9 1/	107
1951	75.9	64.6	87.8	133 1/	123
1953	50.4	65.7	43.6	43.3 1/	35.7
1955	142	62.6	97.1	109 1/	116
1956	99.7	54.6	83.0	84.1 1/	205
1960	74.5	28.0	57.8	59.5 1/	229
1965	29.2	34.0	24.1	23.7	75.3
1969	311	163	176	306	323
1970	77.6	92.9	88.1	94.3	130
1971	41.9	30.9	37.9	44.7	50.7
1972	90.9	67.1	86.4	104	99.4
1974	178	99.7	158	251	345
1975	191	160	187	221 1/	259
1976	388	262	351	510	742

Table 3b - Peak Flow on Souris River for Existing Conditions

Year	Maximum Mean Daily Discharge in cfs				
	Sherwood	Minot	Westhope	Melita	Wawanesa
1943	5,320	2,480	2,240	2,420 1/	2,040
1947	2,250	1,360	1,800	1,830 1/	2,020
1948	7,380	2,680	2,900	4,180 1/	4,140
1949	2,700	2,200	6,300	6,510 1/	8,280
1950	1,600	1,340	2,630	2,750 1/	3,790
1951	2,680	2,280	3,100	4,680 1/	4,330
1953	1,780	2,320	1,540	1,530 1/	1,260
1955	5,030	2,210	3,430	3,850 1/	4,090
1956	3,520	1,930	2,930	2,970 1/	7,250
1960	2,630	990	2,040	2,100 1/	8,090
1965	1,030	1,200	850	836	2,660
1969	11,000	5,760	6,200	10,800	11,400
1970	2,740	3,280	3,110	3,330	4,590
1971	1,480	1,090	1,340	1,580	1,790
1972	3,210	2,370	3,050	3,670	3,510
1974	6,280	3,520	5,590	8,880	12,200
1975	6,750	5,660	6,600	7,810 1/	9,130
1976	13,700	9,260	12,400	18,000	26,200

1/ Computed.

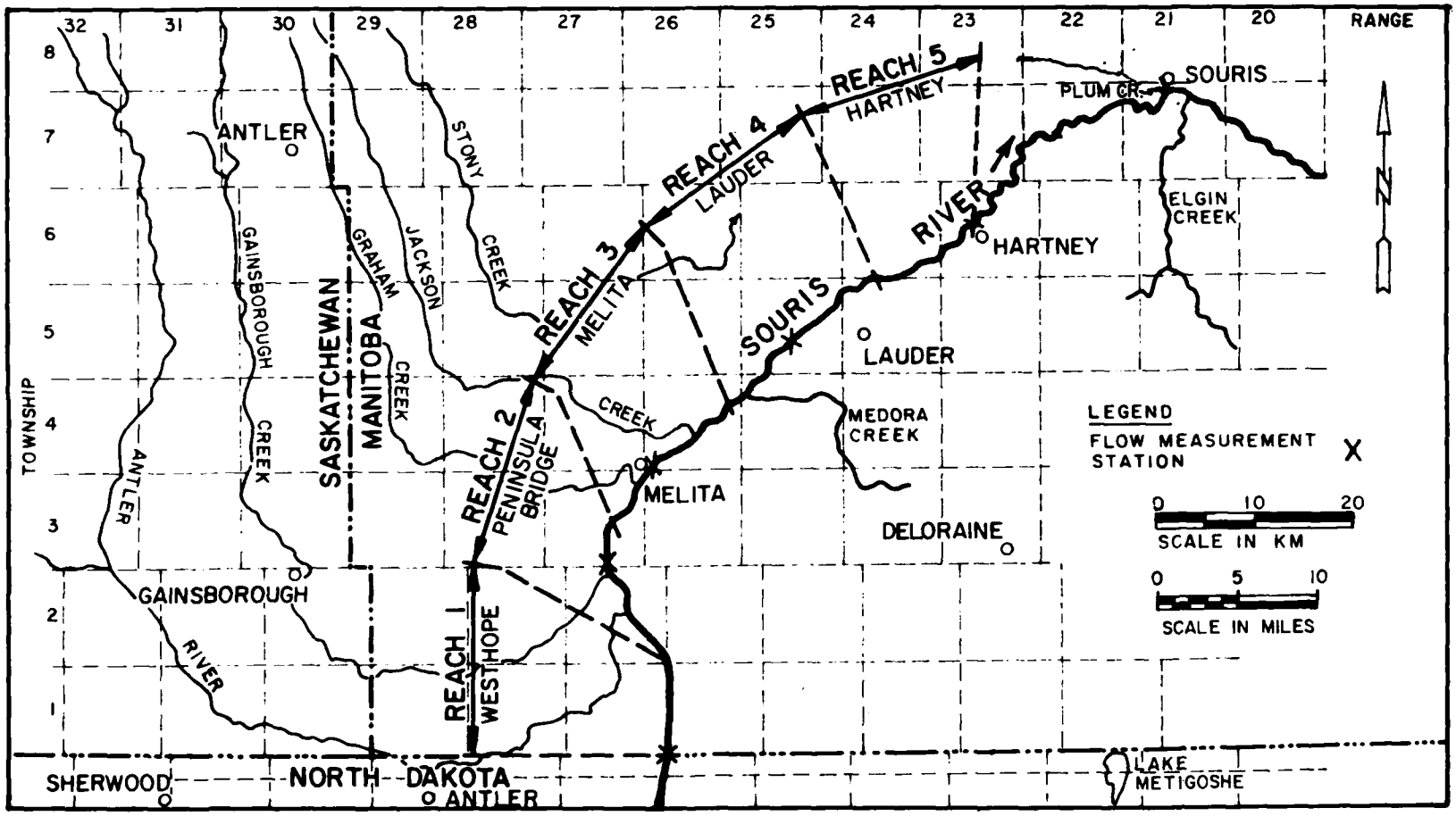
C. BENCHMARK DATA

Flows at Which Agricultural Damage Commences. - In the Manitoba portion of the Souris River Basin agricultural productivity has been periodically reduced as a result of spring and summer flooding. Agricultural flood damages occur primarily to the cultivated and pasture-lands along the valley from the international boundary to the Town of Hartney, where channel capacities range from 4.25 m^3/sec (150 cfs) to 48.1 m^3/sec (1,700 cfs).

The severity of agricultural flood damages depends on the date, extent, and duration of flooding. Normally, flooding occurs prior to crop seeding and does not cause direct damage to crops. Flooding of croplands delays planting until the water recedes and the soil moisture content is suitable for seeding. A portion of the growing season normally available for the crop to mature is lost. In 1976, the duration of flooding was such that insufficient time was available for any cereal crop production during the growing season.

Pastureland also sustains damage as a result of spring and/or summer flooding. The damage is in the form of a reduction in the number of animal grazing days available during the year. Summer flood damages are restricted mainly to low-lying pastureland. A large portion of the pastureland affected is located in the Westhope reach.

In order to assess flooding along the Souris River in Manitoba, the flood-prone portion of the river between the international boundary and the Town of Souris was divided into five reaches as shown in Figure 2. The first four of these reaches correspond to the first four of the six reaches originally developed for and used in the International Garrison Diversion Study and the Task Force studies leading to the 1977 report.



SOURIS RIVER FLOODED AREA REACHES

FIGURE 2

In the Souris River Basin Study, it was determined that agricultural losses downstream of the Town of Hartney are relatively insignificant as the valley land in the area is mostly woodland and flooding is less frequent because of increased channel capacity. Consequently, the original Hartney reach was shortened and the Souris reach was deleted for the purpose of both the Souris River Basin Study and the current Task Force studies. Each of the reaches includes a location at which elevation and discharge data have been collected. The name assigned to each reach denotes the approximate location of the data collection point.

For this study, agricultural damages were assumed to occur whenever the bank-full channel capacity of a particular reach was exceeded. Bank-full channel capacity was assumed to be the discharge above which overbank flooding begins in an agricultural reach. These bank-full channel capacities, originally obtained from Appendix B of the International Garrison Diversion Study and modified in the Souris River Basin Study, are summarized in Table 4.

Table 4 - Bank-Full Channel Capacities on the Souris River in Manitoba 1/

Agricultural Reach	m^3/sec	cfs
Westhope	4.25	150
Peninsula Bridge	41.1	1,450
Melita	36.8	1,300
Lauder	31.1	1,100
Hartney	48.1	1,700

1/ It should be noted that the channel capacities shown are for open water conditions.

Agricultural Flooding - Critical Dates for Determining Duration Impacts. The amount of annual damage that occurs to agricultural land is primarily dependent upon the timing and duration of flood occurrences. Cereal cropland flooded in the spring requires about 21 days for the land to drain and become suitable for planting. For pastureland, the area inundated requires a period of about 14 days for the land to dry prior to being available for grazing.

Based on the above criteria used in the Souris River Basin Study, the following dates are considered to be critical in determining the severity of agricultural flood damage.

April 25 - Land flooded after this date would sustain some loss in cereal crop production.

May 1 - Pastureland flooded after this date would sustain some loss in hay production and grazing potential.

May 31 - Acreages flooded after this date would be unusable for cereal production. The selection of this date was based on the Manitoba Crop Insurance Board's policy of not insuring any crop sown after June 20. Twenty days were included as an allowance for land drying and preparation.

August 15 - Pastureland flooded after this date would be unusable for hay or grazing.

Elevations at Which Urban Flooding Commences. - In addition to the five agricultural reaches, the Towns of Melita and Souris and the Village of Wawanesa were identified as flood prone communities. The flood damage threshold elevations for the three urban centers were based on the studies done for the Souris River Basin Study and the International Garrison Diversion Study and are the elevations at which damage to buildings occurs. They are summarized in Table 5.

Table 5 - Urban Flood Damage Threshold Elevations

Urban Area	Meters, msl	Feet, msl
Melita	428.6	1406
Souris	413.9	1358
Wawanesa	353.9	1161

It should be noted that the original Task Force studies based urban flood damage threshold elevations on bank-full capacity only. The elevations presented in the 1977 report represented the elevations at which

flooding of urban property commences as opposed to the point where damage to buildings commences, and therefore had values slightly different from those presented here.

D. EFFECTS ON FLOODED AREAS AND FLOOD PEAKS

In the 1977 report, results were expressed in terms of the physical changes to the flow regime in Manitoba for the nine floods considered. Due to the availability of the Souris River Basin Study economic model and the requirement for economic data in the existing terms of reference, these results were not duplicated for the second nine floods or for the four floods out of the original nine that were modified. Therefore, the physical results in the original and existing study cannot be compared directly. Tables 6 and 7 summarize the physical results in agricultural and urban areas, respectively, for all 18 floods studied and provide a link between the two reports. Table 6, however, lists total flooded agricultural acreage between the international boundary and Hartney and can only be compared approximately to Table 15 in the 1977 report which lists total flooded area between the international boundary (Westhope) and Souris after certain dates. As noted in Section D, urban threshold damage elevations have been revised and all of the Souris reach and a portion of the Hartney reach were dropped from consideration for the purposes of this report. Both tables may contain additional minor discrepancies resulting from slight changes in computational methods.

In the urban centers, for the 18 years studied, the damage threshold elevation was exceeded in 11 years at Melita and in 1 year (1976) at Souris and Wawanesa. In the case of Melita, Burlington would have caused higher stages in 6 of the years and lower stages in 5. The maximum increase would have been 0.15 meter (0.5 foot) in 1970 and 1972 and the maximum decrease would have been 0.15 meter (0.5 foot) in 1948. In Souris and Wawanesa, Burlington would have caused a decrease in the 1976 stage of 0.03 meter (0.1 foot) and 0.15 meter (0.5 foot), respectively.

In the agricultural reaches, for the 18 floods studied, there would have been less total agricultural area flooded in 9 years and more area flooded in 9 years. The maximum reduction resulting from Burlington would have been 930 hectares (2,299 acres) in 1950 and the maximum increase would have been 1,731 hectares (4,279 acres) in 1971.

Table 6 - Effect of Burlington Project on Agricultural Area Flooded Between the International Boundary and Hartney

Year	Total Agricultural Area Flooded (hectares)	Total Agricultural Area Flooded (acres)	Year	Total Agricultural Area Flooded (hectares)	Total Agricultural Area Flooded (acres)
1943			1960		
Historic	2,885	7,130	Historic	2,456	6,070
Modified	2,980	7,364	Modified	2,493	6,160
Difference	95	234	Difference	37	90
1947			1965		
Historic	1,886	4,660	Historic	255	630
Modified	1,828	4,517	Modified	155	383
Difference	-58	-143	Difference	-100	-247
1948			1969		
Historic	4,411	10,900	Historic	5,983	14,785
Modified	4,396	10,864	Modified	6,052	14,955
Difference	-15	-36	Difference	69	170
1949			1970		
Historic	5,342	13,200	Historic	3,909	9,660
Modified	5,299	13,095	Modified	4,086	10,097
Difference	-43	-105	Difference	177	437
1950			1971		
Historic	3,403	8,410	Historic	882	2,180
Modified	2,473	6,111	Modified	2,613	6,459
Difference	-930	-2,299	Difference	1,731	4,279
1951			1972		
Historic	4,524	11,180	Historic	3,962	9,790
Modified	4,758	11,757	Modified	4,268	10,547
Difference	234	577	Difference	306	757
1953			1974		
Historic	1,259	3,110	Historic	5,757	14,226
Modified	502	1,240	Modified	5,666	14,002
Difference	-757	-1,870	Difference	-91	-224
1955			1975		
Historic	4,346	10,740	Historic	5,726	14,150
Modified	4,448	10,991	Modified	5,638	13,932
Difference	102	251	Difference	-88	-218
1956			1976		
Historic	3,751	9,270	Historic	6,814	16,837
Modified	4,007	9,902	Modified	6,757	16,696
Difference	256	632	Difference	-57	-141

Table 7a - Peak Flood Elevations in Urban Centers in Meters

Year	Community: Melita	Community: Souris	Community: Wawanesa	Year	Community: Melita	Community: Souris	Community: Wawanesa
	Urban Flood Damage Threshold Elevations				Urban Flood Damage Threshold Elevations		
	428.6	413.9	353.9		428.6	413.9	353.9
1943				1960			
Historic	428.12	411.45	349.51	Historic	428.03	411.42	351.19
Modified	428.21	411.48	349.70	Modified	428.06	411.42	351.07
Difference	0.09	0.03	0.19	Difference	0.03	0.00	-0.12
1947				1965			
Historic	427.82	411.39	349.48	Historic	426.38	411.14	349.73
Modified	427.76	411.39	349.48	Modified	426.08	411.27	349.76
Difference	-0.06	0.00	0.00	Difference	-0.30	0.13	0.03
1948				1969			
Historic	428.95 1/	411.72	350.18	Historic	429.68 1/	412.82	351.83
Modified	428.79 1/	411.75	350.12	Modified	429.71 1/	412.88	351.89
Difference	-0.16	0.03	-0.06	Difference	0.03	0.06	0.06
1949				1970			
Historic	429.34 1/	412.18	350.89	Historic	428.64 1/	411.75	350.40
Modified	429.28 1/	412.15	350.82	Modified	428.79 1/	411.78	350.52
Difference	-0.06	-0.03	-0.07	Difference	0.15	0.03	0.12
1950				1971			
Historic	428.37	411.54	350.06	Historic	427.24	411.30	349.39
Modified	428.03	411.54	350.15	Modified	428.09	411.45	349.61
Difference	-0.34	0.00	0.09	Difference	0.85	0.15	0.22
1951				1972			
Historic	429.01 1/	412.03	350.22	Historic	428.67 1/	411.66	350.00
Modified	429.10 1/	412.00	350.31	Modified	428.82 1/	411.75	350.09
Difference	0.09	-0.03	0.09	Difference	0.15	0.09	0.09
1953				1974			
Historic	427.45	411.30	349.15	Historic	429.59 1/	412.67	352.04
Modified	426.99	411.21	349.06	Modified	429.55 1/	412.58	351.98
Difference	-0.46	-0.09	-0.09	Difference	-0.04	-0.09	-0.06
1955				1975			
Historic	428.85 1/	411.78	350.15	Historic	429.47 1/	412.76	351.37
Modified	428.91 1/	411.83	350.31	Modified	429.46 1/	412.76	351.40
Difference	0.06	0.05	0.16	Difference	-0.01	0.00	0.03
1956				1976			
Historic	428.58 1/	411.75	350.95	Historic	430.23 1/	415.78 1/	354.24 1/
Modified	428.67 1/	411.72	351.04	Modified	430.16 1/	415.75 1/	354.09 1/
Difference	0.09	-0.03	0.09	Difference	-0.07	-0.03	-0.15

1/ Above threshold elevation.

Table 7b - Peak Flood Elevations in Urban Centers in Feet

Year	Community: Melita Urban Flood Damage Threshold Elevations 1406	Souris 1358	Wawanesa 1161
1943			
Historic	1404.6	1349.9	1146.7
Modified	1404.9	1350.0	1147.3
Difference	0.3	0.1	0.6
1947			
Historic	1403.6	1349.7	1146.6
Modified	1403.4	1349.7	1146.6
Difference	-0.2	0.0	0.0
1948			
Historic	1407.3 1/	1350.8	1148.9
Modified	1406.8 1/	1350.9	1148.7
Difference	-0.5	0.1	-0.2
1949			
Historic	1408.6 1/	1352.3	1151.2
Modified	1408.4 1/	1352.2	1151.0
Difference	-0.2	-0.1	-0.2
1950			
Historic	1405.4	1350.2	1148.5
Modified	1404.3	1350.2	1148.8
Difference	-1.1	0.0	0.3
1951			
Historic	1407.5 1/	1351.8	1149.0
Modified	1407.8 1/	1351.7	1149.3
Difference	0.3	-0.1	0.3
1953			
Historic	1402.4	1349.4	1145.5
Modified	1400.9	1349.1	1145.2
Difference	-1.5	-0.3	-0.3
1955			
Historic	1407.0 1/	1351.0	1148.8
Modified	1407.2 1/	1351.2	1149.3
Difference	0.2	0.2	0.5
1956			
Historic	1406.1 1/	1350.9	1151.4
Modified	1406.4 1/	1350.8	1151.7
Difference	0.3	-0.1	0.3

Year	Community: Melita Urban Flood Damage Threshold Elevation 1406	Souris 1358	Wawanesa 1161
1960			
Historic	1404.3	1349.8	1152.2
Modified	1404.4	1349.8	1151.8
Difference	0.1	0.0	-0.4
1965			
Historic	1398.9	1348.9	1147.4
Modified	1397.9	1349.3	1147.5
Difference	-1.0	0.4	0.1
1969			
Historic	1409.7 1/	1354.4	1154.3
Modified	1409.8 1/	1354.6	1154.5
Difference	0.1	0.2	0.2
1970			
Historic	1406.3 1/	1350.9	1149.6
Modified	1406.8 1/	1351.0	1150.0
Difference	0.5	0.1	0.4
1971			
Historic	1401.7	1349.4	1146.3
Modified	1404.5	1349.9	1147.0
Difference	2.8	0.5	0.7
1972			
Historic	1406.4 1/	1350.6	1148.3
Modified	1406.9 1/	1350.9	1148.6
Difference	0.5	0.3	0.3
1974			
Historic	1409.4 1/	1353.9	1155.0
Modified	1409.3 1/	1353.6	1154.8
Difference	-0.1	-0.3	-0.2
1975			
Historic	1409.1 1/	1354.2	1152.8
Modified	1409.0 1/	1354.2	1152.9
Difference	-0.1	0.0	0.1
1976			
Historic	1411.5 1/	1364.1 1/	1162.2 1/
Modified	1411.3 1/	1364.0 1/	1161.7 1/
Difference	-0.2	-0.1	-0.5

1/ Above threshold elevation.

E. DETERMINATION OF PRE-BURLINGTON PROJECT FLOWS

In order that the effects in Manitoba of the Burlington project can be evaluated after the project has become operative, a procedure is necessary to determine preproject flows at the international boundary and the downstream reaches. The following method is suggested recognizing that refinements, improvements, and use of new base line data may be advisable from time to time.

Basic Data. - Provided the existing gauging stations continue to be operated in North Dakota and Manitoba, daily streamflow records would be available for the following stations on the Souris River:

Near Sherwood, North Dakota (international boundary)
Near Foxholm, North Dakota
Above Minot, North Dakota
Near Verendrye, North Dakota
Near Bantry, North Dakota
Near Westhope, North Dakota (international boundary)
Near Melita, Manitoba
At Souris, Manitoba
At Wawanesa, Manitoba

With the exception of the discharge records for the station near Sherwood, all downstream records on the Souris River would reflect flow modifications caused by operation of the Burlington project during flood years.

In addition to the records of flows on the Souris River, streamflow records would also be available for the following tributary stations:

Des Lacs River at Foxholm, North Dakota
Wintering River near Karlsruhe, North Dakota
Willow Creek near Willow City, North Dakota
Deep River below Cut Bank Creek near Upham, North Dakota

Boundary Creek near Landa, North Dakota
Antler River near Melita, Manitoba
Gainsborough Creek near Lyleton, Manitoba
Graham Creek near Melita, Manitoba
Jackson Creek near Melita, Manitoba
Medora Creek near Napinka, Manitoba
Stony Creek near Broomhill, Manitoba
Plum Creek near Souris, Manitoba
Elgin Creek near Souris, Manitoba

Records at the existing Souris River and tributary stations are necessary to the determination of pre-Burlington project flows. Other streamflow records would be available for stations located farther upstream on some of the tributaries, but these records would not normally be of value in the determination of preproject flows on the Souris River.

Determination of Tributary Inflows. - Tributary . 'ows for each reach between Souris River gauging stations can be developed using the same procedure followed for the Burlington preconstruction studies undertaken as part of the 1977 Task Force studies. After the Burlington project is completed, the available data at and below the Burlington project would be the streamflow records obtained during flood periods with flows modified by project operation. Since storage above the Burlington Dam would inundate the gauging station on the Souris River near Foxholm, the streamflow record at that station would not be available during most major flood occurrences. Thus, flows passing through Burlington Dam (based on a tail water rating curve or a gauge below the dam) would be used to determine tributary inflows. For the smaller, more frequent floods, measurements and stage records could be obtained at the present gauging station (Souris River near Foxholm) located between Lake Darling and Burlington Dam.

Records of flows passed through the Burlington Dam would be routed downstream by the Progressive-Average Lag procedure or the Streamflow Synthesis and Reservoir Regulations (SSARR) method. Tributary inflow for each reach between streamflow measuring stations would be the difference between flows at the downstream station and the flow routed to that point. The local

inflows would be checked against the flow records for tributaries discharging into the Souris River in the reach. The routing would be repeated with adjusted travel times or other variables in the program, as appropriate, to produce local inflows compatible with tributary records and to eliminate unaccountable negative inflows. Rainfall records may also be reviewed. Runoff from local storms often may account for unexplained variations in local inflows.

Preproject Operation of Lake Darling. - The current operating plan for Lake Darling is given in Table 8 and differs to some extent from procedures followed in the past, due to improvements in flood forecasting and the completion of the 142-m^3/sec (5,000-cfs) channel through Minot as well as temporary levees at other urban damage centers. The net effect of the forecasting improvements has been to permit the drawdown of the lake prior to April 1st with greater assurance that the storage could be regained from the spring runoff and the desirable summer operating level, elevation 486.5 meters (1596 feet) reached. The downstream levee and channel improvements have relieved the U.S. Fish and Wildlife Service of much of the pressures to use the limited storage to keep peak flows in the 56.6- to 85.0-m^3/sec (2,000- to 3,000-cfs) range. The operating plan does not provide for using surcharge storage above spillway crest except during the more infrequent flood occurrences when flood inflow rates exceed the maximum conduit outflow capacity and the resulting lake elevation exceeds the spillway crest elevation 487.1 meters (1598 feet).

Table 8a - Lake Darling Operation Schedule

Predicted 30-Day Flood Volume in 1,000 dam^3 From	To	Maximum Drawdown Prior to April 1st (Elevation in meters)	Available Storage to Spillway Crest Elevation 487.1 Meters (1,000 dam^3)	Maximum Anticipated Release 1/ (m^3/sec)
0	61.6	486.5 2/	28	28.3
61.6	123.3	485.8	52	42.5
123.3	185.0	485.5	63	85.0
185.0	246.7	485.2	74	113
246.7	308.3	484.6	91	142
Above 308.3		-	-	Over 142

Table 8b - Lake Darling Operation Schedule

Predicted 30-Day Flood Volume (1,000 ac-ft) From	To	Maximum Drawdown Prior to April 1st (Elevation in feet)	Available Storage to Spillway Crest Elevation 1598 Feet (1,000 ac-ft)	Maximum Anticipated Release 1/ (1,000 cfs)
0	50	1596 2/	22	1.0
50	100	1594	42	1.5
100	150	1593	51	3.0
150	200	1592	60	4.0
200	250	1590	74	5.0
Above 250		-	-	Over 5.0

1/ Based on a. existing temperatures and downstream channel conditions; b. conditions at J. Clark Salyer Refuge; c. Des Lacs River flows; and d. dam and outlet works structural safety.

2/ In a forecast drought year and depending on the water needs at J. Clark Salyer Refuge, Lake Darling might be held at a higher elevation up to spillway crest elevation.

Release from Lake Darling would normally be greater than inflows during the drawdown period, and thereafter the conduit gate would be raised to permit passage of flows up to the maximum release prescribed for the forecast flood volume. The maximum discharge capability of the conduit with the gate fully raised varies from about 73.6 m^3/sec (2,600 cfs) at pool elevation 484.3 meters (1589 feet) to 142 m^3/sec (5,000 cfs) at elevation 487.1 meters (1598 feet) as shown in Table 9.

Table 9 - Lake Darling Conduit Capacity

Pool Elevation		Discharge	
Meters	Feet	m^3/sec	Cfs
487.1	1598	142	5,000
486.5	1596	133	4,700
485.8	1594	123	4,350
485.2	1592	113	4,000
484.6	1590	99.1	3,500
484.3	1589	73.6	2,600

In most flood years, with the Burlington project in operation, storage would not be required in the Burlington pool. Thus, the Lake Darling inflow, outflow, and storage changes could be obtained from available records, and the determination of pre-Burlington Lake Darling outflows would be a relatively simple process. In the less frequent major flood years when storage would be necessary in the Burlington pool, the storage changes in the two pools and the outflow from the Burlington Dam would be available and the present operating plan for Lake Darling would be used to obtain the pre-Burlington Lake Darling outflow.

If a late spring or summer storm were to produce a significant increase in inflow to the lake, as recorded at Sherwood, outflows would be allowed to increase to the flow which would permit the summer flood to be contained without exceeding a lake elevation of 487.1 meters (1598 feet), but probably not exceeding 56.6 m^3/sec (2,000 cfs), if practical.

Inflows greater than the regulated outflow would be retained in storage. As soon as the inflow to the lake permitted, the lake level would be allowed to return to elevation 486.5 meters (1596 feet) by holding the predetermined maximum release until that elevation was approached. The outflow would then be cut back to equal inflow over a period of 5 days.

Outflows at Lake Darling Dam would be routed downstream in the same manner as the flows for conditions with the Burlington project in operation. Tributary inflows, determined as previously described, between any two main stem gauging stations would be added to the flow at the downstream gauging station and the combined flows routed to the next downstream station. In this manner the preproject flows at the international gauging station near Westhope and the key stations in each of the six reaches in Manitoba would be estimated. A comparison of the recorded hydrographs with the estimated preproject hydrographs would indicate the effect of the Burlington project on flows in Manitoba.

Base Line Flood Flows. - As described in the foregoing paragraphs the U.S. Fish and Wildlife Service will not necessarily operate Lake Darling in the future exactly as in the past in the absence of the Burlington Dam. Improved flood forecasting and completion of the 142-m^3/sec (5,000-cfs) channel through Minot have made possible the delineation of a general operating plan for Lake Darling whereas in the past the operation was on a case-by-case basis. Even with a more definite operating plan, the U.S. Fish and Wildlife Service has advised that variations could be expected based on safety considerations and other factors. Examination of the flood records has shown that rigid adherence to the current Lake Darling operating plan would result in some changes in results of routing and hence some increases in damages in certain years and decreases in other years. The net result would be little significant change in average annual damages in Canada. Also, there is considerable advantage to be found in working with actual recorded, rather than simulated, flows for pre-Burlington conditions. Accordingly, the economic analyses for this report are based on damages caused by recorded flows for comparison with damages resulting from the modified flows attributable to operation of the Burlington project.

IV ECONOMIC IMPACT OF PROJECT

A. METHODOLOGY - AGRICULTURAL DAMAGES

As requested in its directive, the Task Force made the fullest use possible of the findings and methodology used in the Souris River Basin Study. This Study was undertaken by the governments of Canada, Manitoba and Saskatchewan:

> *"to carry out an assessment of the water and related resources of the Souris River basin and of the demands being made and likely to be made of them, to set objectives relative to the management of these resources in Canada and to develop an appropriate plan to meet these objectives"*(1)

The Souris River Basin Study report included an assessment of the agricultural flood damage experienced in the Manitoba portion of the Souris River valley in the years 1936 to 1976. A full description of this assessment and its results is contained in the study report and in Volume 2 of Supplement 2 entitled "Flood Damage Reduction."

After reviewing the methods of computing flood damages used in the Souris River Basin Study, the Task Force adopted this methodology for its own economic analysis. In doing so however, the Task Force recognized that the Souris River Basin Study work involved a number of necessary approximations and assumptions that departed from conventional economic analysis. For this reason, as has been described in Chapter III C, the Task Force modified its hydraulic analysis to make the inputs to the economic analysis on the same basis as the Souris River Basin Study analysis so as to provide results that were directly comparable.

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(1) Souris River Basin Study Board, Souris River Basin Study Report, June 1978.

The Souris River Basin Study found that agricultural flood damage occurs primarily to the cultivated and pasturelands along the Souris River valley in Manitoba from the international boundary to the Town of Hartney. Damages were found to be relatively insignificant downstream of Hartney as the valley land in this area is generally woodland and flooding is less frequent because of increased channel capacity.

The method of analysis of physical damages used as a basis for economic analysis in the Souris River Basin Study was similar to the method described in the 1977 Task Force report. The valley between the international boundary and Hartney was divided into five reaches as discussed in Chapter III D. In each reach, flooded areas were determined at various flood stages by transferring the flood lines from aerial photographs for the years 1969, 1974, 1975, and 1976 to 1:50,000 scale National Topographic Series maps and planimetering the areas. The flow range covered was from 13.0 m^3/sec (460 cfs) to 566 m^3/sec (20,000 cfs). The total flooded area included all inaccessible land but excluded the surface area of the channel at bank-full capacity. The bank-full capacity was estimated from cross sections obtained in 1958 at the water level associated with the safe channel capacity flows shown in Chapter III D of this report. Land use was determined from Canada Land Inventory maps supplemented by interpretation of available recent aerial photography. Land use was classified as cultivated land, pastureland, and woodland. Discharge-flooded area curves for each reach were prepared for the cultivated land and pastureland and for the total area flooded.

For assessing damage, estimates of cropping patterns, yields, and crop production costs were obtained for the Souris River Basin Study from the Manitoba Department of Agriculture and the Faculty of Agriculture of the University of Manitoba. Crop production costs included indirect as well as direct costs. In computing damages to cultivated land, the criteria for timing and duration of inundation described in Chapter III D were applied along with the above data, and a seasonal crop damage curve was prepared.

Using this curve, damages were calculated for each flood, assuming seeding occurred in 202-hectare (500-acre) increments which corresponded to an incremental strip approximately 213 meters (700 feet) wide along each side of the river. A similar exercise was carried out for pastureland in 10-hectare (25-acre) increments. Using these general damage data, agricultural damages were computed for each flood which occurred during the period 1936-1976 inclusive. This 41-year period was assumed to be representative of the long-term future flood expectancy and, hence, average annual damages were taken as the simple average of this period. Damages were expressed in 1975 Canadian dollars.

To assess the relative effect of the Burlington project, the agricultural damage computation described above was rerun by the Task Force for the 18 years in the 41-year period in which Burlington would have been operated, using the flows modified by Burlington operation as described in Chapter III C. Damages obtained were compared directly with the historic damages that were computed in the Souris River Basin Study. The differences and comparative average annual damages were then computed.

As would be expected from the physical effects previously described (Chapter III), operation of the Burlington project could result in either damages or benefits in any given year.

In estimating damages resulting from Burlington operation, it was recognized that individual landowners might not experience the same pattern of damages and benefits experienced in the valley as a whole. Accordingly, the Task Force reviewed the land ownership patterns in the affected reaches with a view to arriving at a damage computation that would be equitable to an individual landowner. The patterns reviewed are shown in Appendix C. As a result of the review, and considering the relatively low level of incremental damages resulting from operation of Burlington, it was determined that damages computed for three elevation bands in each reach would provide a reasonable representation of the effect that could be expected by most individual landowners.

As required in the plan of study, both gross and net damage estimates were prepared. Net damages were estimated by computing the incremental damages or benefits for each elevation band in each reach, and computing a simple average annual net damage by summing the incremental damages and benefits over the 41-year period. Gross damages were determined for each elevation band in each reach in the same manner except benefits were not included.

B. METHODOLOGY - URBAN DAMAGES

Urban damages were estimated using the techniques developed in the Souris River Basin Study and direct comparisons were made between historic and with-Burlington conditions.

The Souris River Basin Study assessed flood damages over the period 1936 to 1976 inclusive for the Communities of Melita, Souris, and Wawanesa. The assessments relied heavily on data collected during the 1976 flood and reflected the flood problems experienced by each community. Where information on other historic floods was available, it was used to verify the 1976 experience and both direct and indirect economic losses were considered. A full description of the losses considered and the methodology used is contained in the Souris River Basin Study report and in Volume 2 of Supplement 2 entitled "Flood Damage Reduction."

As for agricultural damages, the Task Force noted that the assumptions made in estimating urban damages in the Souris River Basin Study required that input data be modified to correspond to that used in the study to permit a direct comparison to be made.

The Souris River Basin Study urban damage assessment was based on the analysis of flood lines plotted on 1:2,000 scale maps of the three communities with a contour interval of 0.6 meter (2 feet). The maps were prepared from aerial photography obtained in 1975 and 1976. Flood elevations for the historic period were obtained from Water Survey of Canada rating curves for gauging stations adjacent to the communities with appropriate modifications for hydraulic conditions through each community.

Urban flood damages were assessed in 1975 Canadian dollars for direct, indirect, and intangible damages. The types of damage under each classification are shown in Table 10.

Table 10 - Classification of Urban Flood Damages

Direct Damages	Indirect Damages	Intangible Damages
1. Property Damage	1. Loss of Income	1. Rerouting Traffic
a. Residential		
b. Personal		
c. Business		
d. Schools and churches		
e. Parks and recreation		
2. Damage to Public Utilities	2. Business Losses	2. Delays
3. Damage to Public Works	3. Extra Costs	3. Disruption of Utilities
a. Roads and bridges	a. Evacuation costs	
b. Flood fighting costs	b. Extra food costs	
	c. Extra labor costs	
	d. Rental value of homes	
		4. Future Loss of Business
		5. Loss of Life

SOURCE: Souris River Basin Study Board, Souris River Basin Study Report, June 1978, Supplement 2, Volume 2, "Flood Damage Reduction", page 19.

Based on the information available on historic floods in each community and information obtained from other agencies on the relationship of depth of flooding to damage, estimates of the 1976 flood and 1 in 500-year flood damages were made. A stage-damage curve for each community was then prepared using the 1976 flood and a 1 in 500-year flood damage estimates. In addition, during the Souris River Basin Study, frequency-damage curves were prepared and average annual damages were computed in the conventional fashion. Because of the indefinite relationship between the effects of the Burlington project and flood frequency, the Task Force used

the three Souris River Basin Study stage-damage curves and recomputed damages for each of the 18 years in which Burlington would have operated. These recomputed values were inserted in a tabulation of damages for the 41 years studied and a simple arithmetic average was computed. This average was assumed to be the average annual damage and was compared with a similar tabulation prepared for the period without Burlington operation. The results of this study for the period without Burlington generally agreed with Souris River Basin Study results.

C. RESULTS

The following results of the evaluation of the economic effects of the Burlington project should be read with two points in mind. First, although values are expressed to the nearest dollar, it is recognized that the assumptions in the hydrologic, hydraulic, and economic evaluation procedures inevitably result in constraints on accuracy that make such precision meaningless in a real sense. Second, although the first point is recognized by the Task Force, the values computed for years in which Burlington Dam would have been operated were computed by the methods used in the Souris River Basin Study. The Task Force is confident that they can be compared directly with the results of that study. In addition, the Souris River Basin Study represents a major effort to prepare the best estimate possible with the data available and the Task Force is satisfied that all values shown represent the best obtainable current estimates of the costs associated with flooding and the effects of the Burlington project on Manitoba.

As previously noted, agricultural damages were computed for three elevation bands in each reach. Tables 11 through 15 show damages for each band in each reach with and without Burlington Dam in operation for the 18 years in which Burlington would have operated.

In determining net damages the differences (damages and benefits) were summed and the average annual damage for the 41-year period was computed. For the 15 bands examined, 3 computations yielded a net average

annual damage due to Burlington while 12 yielded a net average annual benefit. The net average annual damages occurred in the lower band of the Westhope reach, the middle band of the Melita reach, and the upper band of the Lauder reach and were $129, $53, and $12, respectively. The net average annual benefit values ranged from $2 in the upper Hartney reach band to $1,637 in the middle Lauder reach band.

For the 18 years examined, in numerous instances no damages would have been experienced under historic conditions; and in a number of instances the incremental effect of Burlington would have been zero. Of the 15 bands examined in the 18 years (a total of 270 instances), no damage under both historic conditions and with Burlington was indicated 93 times and no incremental effects were indicated 3 times. In the remaining instances annual damages ranging from $3 to $29,203 were indicated 84 times and annual benefits ranging from $17 to $53,768 were indicated 90 times.

Net average annual urban damages with and without Burlington for the Communities of Melita, Souris, and Wawanesa are shown in Table 16. Melita would have experienced a net average damage of $152 and Souris and Wawanesa would have experienced net average annual benefits of $98 and $122, respectively, as a result of Burlington.

Gross incremental agricultural and urban damages for the period 1936 through 1976, as a result of Burlington, can be determined by extracting the incremental damages from Tables 11 through 16 and are summarized in Table 17. As shown in the table, the increase in average annual gross agricultural and urban damages resulting from Burlington operation would be $5,006 and $866, respectively.

Total average annual damages in Manitoba due to Burlington would be $346 and $5,872 for net and gross damages, respectively. Individual gross damages are shown in Table 17 and Table 18 summarizes the individual net average annual damages or benefits that were computed. From Table 18 it can been seen that, if benefits were considered, the effect would have been an average annual benefit of $5,356.

Table 11 - Agricultural Flood Damages[1/]
(1975 Canadian Dollars)

Westhope Reach

YEAR	Elevation Band: 429.2m to 429.8m (1408 ft to 1410 ft)			429.8m to 431.3m (1410 ft to 1415 ft)			431.3m to 432.8m (1415 ft to 1420 ft)		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1943	$9,787	$9,787	0	$16,555	$17,251	$-696	0	0	0
1947	9,376	6,580	$2,796	3,344	875	2,469	0	0	0
1948	10,417	9,025	1,392	21,236	19,495	1,741	$609	0	$609
1949	6,163	6,078	85	6,493	6,244	249	242	$182	60
1950	8,470	8,385	85	19,074	19,690	-616	0	31	-31
1951	7,892	7,288	604	18,848	19,939	-1,091	1,308	251	1,057
1953	11,040	11,040	0	17,472	24,868	-7,396	0	0	0
1955	10,451	9,540	911	15,036	19,277	-4,241	0	0	0
1956	9,506	8,340	1,166	13,396	16,719	-3,323	0	398	-398
1960	5,176	5,159	17	4,842	3,599	1,243	0	0	0
1965	6,560	7,666	-1,106	0	2,301	-2,301	0	0	0
1969	8,364	11,034	-2,670	20,663	20,438	225	4,879	4,726	153
1970	11,040	10,457	583	26,265	28,181	-1,916	229	1,321	-1,092
1971	7,298	7,400	-102	3,976	3,926	50	0	0	0
1972	9,272	8,958	314	9,435	8,482	953	0	0	0
1974	10,621	8,752	1,869	25,968	25,771	197	4,711	5,488	-777
1975	11,040	10,361	679	30,383	31,407	-1,024	6,778	7,507	-729
1976	9,183	10,514	-1,331	22,612	23,573	-961	5,980	5,884	102
Total Difference			$5,295			$-16,438			$-1,046
Average (41 years)			$129			$-401			$-26

1/ For years in which Burlington would have operated.
NOTE: "-" denotes benefit.

Table 12 - Agricultural Flood Damages[1/]
(1975 Canadian Dollars)

Peninsula Bridge Reach

YEAR	Elevation Band: 429.5m to 429.8m (1409 ft to 1410 ft)			429.8m to 431.3m (1410 ft to 1415 ft)			431.3m to 432.5m (1415 ft to 1419 ft)		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1943	$6,582	$7,086	$-504	$12,905	$11,557	$1,348	0	0	0
1947	1,424	0	1,424	127	0	127	0	0	0
1948	6,963	9,049	-2,086	35,795	33,070	2,725	0	$4,122	$-4,122
1949	3,109	2,999	110	16,709	16,667	42	$2,069	1,904	165
1950	8,383	8,291	92	5,907	19,583	-13,676	0	0	0
1951	6,672	8,345	-1,673	41,344	37,471	3,873	17,761	0	17,761
1953	0	1,920	-1,920	0	0	0	0	0	0
1955	8,709	9,624	-915	31,202	37,706	-6,504	0	0	0
1956	3,456	7,967	-4,511	12,849	16,814	-3,965	0	0	0
1960	2,368	1,564	804	1,478	1,014	464	0	0	0
1965	0	0	0	0	0	0	0	0	0
1969	8,377	8,258	119	47,045	47,184	-139	16,696	14,635	2,061
1970	9,004	9,913	-909	28,434	35,849	-7,415	0	0	0
1971	1,840	0	1,840	2,290	0	2,290	0	0	0
1972	3,868	3,868	0	12,414	11,792	622	0	0	0
1974	9,575	9,528	47	49,065	49,654	-589	10,816	19,972	-9,156
1975	9,730	10,675	-945	50,208	51,163	-955	23,532	41,601	-18,069
1976	8,708	8,814	-106	47,746	47,865	-119	24,048	26,876	-2,828
Total Difference			$-9,133			$-21,871			$-14,188
Average (41 years)			$-223			$-533			$-346

1/ For years in which Burlington would have operated.
NOTE: "-" denotes benefit.

Table 13 - Agricultural Flood Damages[1/]
(1975 Canadian Dollars)

Melita Reach

YEAR	Elevation Band: 427.0m to 428.2m (1401 ft to 1405 ft)			428.2m to 429.5m (1405 ft to 1409 ft)			429.5m to 430.1m (1409 ft to 1411 ft)		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1943	$18,871	$4,384	$14,487	0	0	0	0	0	0
1947	2,853	346	2,507	0	0	0	0	0	0
1948	57,793	53,979	3,814	$53,838	$30,029	$23,809	0	0	0
1949	38,927	39,215	-288	35,509	36,254	-745	0	0	0
1950	26,454	58,088	-31,634	0	25,049	-25,049	0	0	0
1951	56,010	58,359	-2,349	85,486	56,283	29,203	0	0	0
1953	0	11,812	-11,812	0	0	0	0	0	0
1955	60,499	60,556	-57	30,283	47,542	-17,259	0	0	0
1956	37,346	57,669	-20,323	100	5,611	-5,511	0	0	0
1960	11,422	8,086	3,336	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0
1969	58,088	57,935	153	118,689	112,243	6,446	0	0	0
1970	59,135	60,323	-1,188	38,991	48,969	-9,978	0	0	0
1971	10,222	643	9,579	0	0	0	0	0	0
1972	25,989	28,797	-2,808	8,723	8,494	229	0	0	0
1974	59,723	59,667	56	111,117	110,992	125	$3,198	$6,181	$-2,983
1975	59,961	61,473	-1,512	132,968	135,417	-2,449	0	926	-926
1976	58,597	58,716	-119	124,336	121,000	3,336	5,165	9,134	-3,969
Total Difference			$-38,158			$2,157			$-7,878
Average (41 years)			$-931			$ 53			$ -192

1/ For years in which Burlington would have operated.
NOTE: "-" denotes benefit.

Table 14 - Agricultural Flood Damages[1/]
(1975 Canadian Dollars)

Lauder Reach

YEAR	Elevation Band: 424.6m to 425.2m (1393 ft to 1395 ft)			425.2m to 426.7m (1395 ft to 1400 ft)			426.7m to 428.2m (1400 ft to 1405 ft)		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1943	$51,054	$51,071	$-17	$11,082	$44,453	$-33,371	0	0	0
1947	21,928	6,599	15,329	3,138	1,024	2,114	0	0	0
1948	52,298	53,861	-1,563	68,807	65,036	3,771	0	0	0
1949	45,746	45,417	329	48,727	48,288	439	0	0	0
1950	53,047	53,011	36	44,515	60,295	-15,780	0	0	0
1951	51,235	53,736	-2,501	74,849	74,008	841	0	0	0
1953	0	53,768	-53,768	0	288	-288	0	0	0
1955	57,178	56,680	498	66,622	72,301	-5,679	0	0	0
1956	44,534	52,034	-7,500	31,672	55,009	-23,337	0	0	0
1960	25,271	19,587	5,684	10,026	8,396	1,630	0	0	0
1965	0	0	0	0	0	0	0	0	0
1969	52,565	52,372	193	84,278	84,048	230	$1,851	$1,678	$173
1970	54,994	55,655	-661	68,361	70,311	-1,950	0	0	0
1971	16,708	12,767	3,941	11,816	0	11,816	0	0	0
19[illegible]2	48,767	48,649	118	38,261	38,528	-267	0	0	0
1974	54,795	54,687	108	87,216	88,597	-1,381	2,777	4,237	-1,460
1975	56,397	57,835	-1,438	90,269	92,239	-1,970	2,171	2,203	-32
1976	53,448	53,617	-169	87,524	91,452	-3,928	21,137	19,338	1,799
Total Difference			$-41,381			$-67,110			$480
Average (41 years)			$-1,009			$-1,637			$12

1/ For years in which Burlington would have operated.

NOTE: "-" denotes benefit.

Table 15 - Agricultural Flood Damages[1/]
(1975 Canadian Dollars)

Hartney Reach

YEAR	Elevation Band: 420.0m to 422.2m (1378 ft to 1385 ft)			422.2m to 423.7m (1385 ft to 1390 ft)			423.7m to 424.9m (1390 ft to 1394 ft)		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1943	$2,562	$4,948	$-2,386	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0
1948	11,829	11,296	533	0	0	0	0	0	0
1949	9,608	9,578	30	$750	$1,197	$-447	0	0	0
1950	5,559	7,890	-2,331	0	0	0	0	0	0
1951	14,671	13,968	703	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0
1955	12,304	12,901	-597	0	0	0	0	0	0
1956	5,116	6,584	-1,468	0	0	0	0	0	0
1960	1,212	884	328	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0
1969	16,744	16,741	3	5,693	5,380	313	0	0	0
1970	10,807	11,881	-1,074	0	0	0	0	0	0
1971	1,217	0	1,217	0	0	0	0	0	0
1972	7,658	7,383	275	0	0	0	0	0	0
1974	17,607	18,292	-685	6,164	6,862	-698	0	0	0
1975	19,671	20,696	-1,025	6,248	6,106	142	0	0	0
1976	17,545	17,485	60	13,106	13,451	-345	$404	$491	$-87
Total Difference			$-6,417			$-1,035			$-87
Average (41 years)			$-157			$-25			$-2

1/ For years in which Burlington would have operated.
NOTE: "-" denotes benefit.

Table 16 - Urban Flood Damages for Communities of Melita, Souris and Wawanesa

YEAR	Melita			Souris			Wawanesa		
	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference	With Burlington	Without Burlington	Difference
1936	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0
1938	0	0	0	0	0	0	0	0	0
1939	0	0	0	0	0	0	0	0	0
1940	0	0	0	0	0	0	0	0	0
1941	0	0	0	0	0	0	0	0	0
1942	0	0	0	0	0	0	0	0	0
*1943	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0
*1947	0	0	0	0	0	0	0	0	0
*1948	$10,000	$20,000	$-10,000	0	0	0	0	0	0
*1949	57,500	62,500	-5,000	0	0	0	0	0	0
*1950	0	0	0	0	0	0	0	0	0
*1951	29,250	25,000	4,250	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0
*1953	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0
*1955	18,750	13,750	5,000	0	0	0	0	0	0
*1956	2,500	0	2,500	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0
*1960	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0
*1965	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0
*1969	135,000	125,000	10,000	0	0	0	0	0	0
*1970	3,750	0	3,750	0	0	0	0	0	0
*1971	0	0	0	0	0	0	0	0	0
*1972	12,500	2,500	10,000	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0
*1974	100,000	106,000	-6,000	0	0	0	0	0	0
1975	83,750	87,500	-3,750	0	0	0	0	0	0
*1976	232,500	237,000	-4,500	$266,000	$270,000	$-4,000	$20,000	$25,000	$-5,000
Total Net Difference			$6,250			$-4,000			$-5,000
Average Net Damage			$152			$-98			$-122

*Year in which Burlington would have operated.

NOTE: "-" denotes benefit.

Table 17 - Gross Increase[1/] in Flood Damages Attributable to Burlington Project - International Boundary to Hartney

Year[2/]	Increase in Gross Damage			
		Urban		
	Agricultural	Melita	Souris	Wawanesa
1943	$15,835	0	0	0
1947	26,766	0	0	0
1948	38,394	0	0	0
1949	1,509	0	0	0
1950	213	0	0	0
1951	54,042	$4,250	0	0
1953	0	0	0	0
1955	1,409	5,000	0	0
1956	1,166	2,500	0	0
1960	13,505	0	0	0
1965	0	0	0	0
1969	10,069	10,000	0	0
1970	583	3,750	0	0
1971	30,733	0	0	0
1972	2,511	10,000	0	0
1974	2,402	0	0	0
1975	821	0	0	0
1976	5,297	0	0	0
Total	$205,255	$35,500	0	0
Average Annual Gross Increase in Damage (41 years)	$5,006	$866	0	0

Total Average Annual Gross Increase in Damage $5,872

1/ Difference between damage with Burlington and damage without Burlington except benefits are ignored.

2/ Year in which Burlington would have operated.

Table 18 - Summary of Net Average Annual Damages or Benefits Attributable to Burlington Project

Reach or Community	Elevation Band From Meters	Elevation Band From Feet	Elevation Band To Meters	Elevation Band To Feet	Net Average Annual Damages or Benefits: Damage	Net Average Annual Damages or Benefits: Benefit
Agricultural						
Westhope	429.2	1408	429.8	1410	$129	
	429.8	1410	431.3	1415		$401
	431.3	1415	432.8	1420		26
Peninsula Bridge	429.5	1409	429.8	1410		223
	429.8	1410	431.3	1415		533
	431.3	1415	432.5	1419		346
Melita	427.0	1401	428.2	1405		931
	428.2	1405	429.5	1409	53	
	429.5	1409	430.1	1411		192
Lauder	424.6	1393	425.2	1395		1,009
	425.2	1395	426.7	1400		1,637
	426.7	1400	428.2	1405	12	
Hartney	420.0	1378	422.2	1385		157
	422.2	1385	423.7	1390		25
	423.7	1390	424.9	1394		2
Total Agricultural					194	5,482
Urban						
Melita					152	
Souris						98
Wawanesa						122
Total Urban					152	220
Total damage or benefit					$346	$5,702
Total average annual effect ($5,702 - $346)						$5,356

V ENVIRONMENTAL ASSESSMENT OF PROJECT EFFECTS

A. POTENTIAL IMPACT OF CARP ON FISH AND WILDLIFE RESOURCES

A major environmental concern associated with regulation of flows by the Burlington project is the possibility that occasional prolonged releases from storage will facilitate carp movement and establishment from the Assiniboine River in Manitoba upstream into the upper Souris River in Manitoba; the J. Clark Salyer, Upper Souris, and Des Lacs National Wildlife Refuges in North Dakota; and into the Souris River headwaters in Saskatchewan. A combination of environmental events favorable to carp would allow their dispersal through much of the Souris River drainage basin with a resultant loss of fish and wildlife resources.

Historic Carp Distribution Prior to 1976. - Resident carp populations were not recorded in Manitoba until 1938 when several specimens were taken from the Red River near Lockport.[1] By 1948, carp were reported in the Assiniboine River at Virden.[2] McLeod and Moir[3] did not observe carp in their investigation in Manitoba portions of the Souris River in 1944 and 1945 but noted that the fixed crest dams at Wawanesa and Souris acted as a complete barrier at the time of the study. However, in subsequent years, infrequent sightings of carp were made upstream of these structures. The dams at Hartney, Napinka, and Melita do not impede fish passage when water levels are high or the bulk of the stop logs are removed. In most years, large carp aggregations can be observed below the Wawanesa Dam[4] but only on one occasion was a single carp recovered in Manitoba above this structure. Documentation of this occurrence was found in 1954 correspondence from G. Butler, Supervisor of Fish Culture, which stated: ". . . one (carp) was recorded during the flood period some five years or so back near Plum Creek which is a tributary of the Souris." This occurrence means that carp transcended both the Wawanesa

(1) Hinks, D. 1943. The Fishes of Manitoba. Manitoba Department Mines and Natural Resources, Province of Manitoba, 102 pp.

(2) McCrimmon, H. R. 1968. Carp in Canada. Fish. Res. Bd. Bull. 165 93 pp.

(3) McLeod, J. A. and D. R. Moir. 1944. Report on a biological investigation of the Souris River system. MS report. Manitoba Dept. Mines and Nat. Res., Fish Br., Winnipeg. 16 pp.

McLeod, J. A. and D. R. Moir. 1945. A second report on an investigation of the Souris River system. MS report. Manitoba Dept Mines and Nat. Res., Fish Br., Winnipeg, 8 pp.

(4) W. Howard, Personal Communication, 1978.

and Souris Dams around 1949. In 1949, the Wawanesa Dam was washed out by heavy floods and was not rebuilt until 1951.[1] Therefore, carp would have had unimpeded passage at the damsite during this period. Carp were observed during the 1949-1950 winter in North Dakota where Highway 5 crosses the river.[2] This location is above Dam 357 in the J. Clark Salyer National Wildlife Refuge and indicates that carp likely traveled from the Wawanesa Dam to the refuge in about 5 months.

In North Dakota, the last confirmed carp sighting was at Dam 357 in 1953 or 1954.[3] Since spring flows during the 1951-1954 period were not high enough to overtop the rebuilt dam, the carp apparently overwintered somewhere in the Manitoba portion of the Souris River. Discharge records indicate that flows were probably sufficient to permit overwintering.

Overtopping of the Wawanesa Dam occurs when flows surpass approximately 283 m^3/sec (10,000 cfs).[1] The dam was overtopped in 1969 from April 21 until April 25 and in 1974 during the period April 19-21. However, no carp were observed upstream of the dam following these flood events.

Carp have not been observed in the Saskatchewan portion of the Souris River Basin.[4]

The low number of reported carp occurrences could be due, in part, to the limited number of attempts to adequately monitor fish populations in the Souris River. No intensive coordinated studies have been conducted throughout the watershed that were specifically designed to evaluate carp presence above Wawanesa. However, a few general studies were undertaken along the river prior to 1976:

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(1) R. Bowering, Personal Communication, 1978.
(2) D. Hennegar, Personal Communication, 1978.
(3) D. Houseworth, Personal Communication, 1978.
(4) F. Atton, Personal Communication, 1978.

a. In July 1962, one gill net set was made in each of the immediate areas of the Wawanesa and Souris Dams.[1]

b. In 1975, fish collections were made under the direction of the Manitoba Museum of Man and Nature.[2]

c. In 1975, the U.S. Fish and Wildlife Service set trap and gill nets in the J. Clark Salyer National Wildlife Refuge.[3]

Carp were not reported above the Wawanesa Dam in any of the above studies.

Carp Distribution - 1976 to the Present. - In 1976, the Wawanesa Dam was again overtopped during a major flood. This time, the tail water elevation exceeded the crest elevation of the dam from April 9 until May 14. A few general fish surveys have been undertaken in the Souris River since that time:

a. In 1976, the U.S. Fish and Wildlife Service set trap and gill nets in the J. Clark Salyer National Wildlife Refuge.[3]

b. In 1976, over 700 game fish were captured north of the United States border for tagging purposes using gill, fyke, and seine nets or through angling.[4]

c. In July 1978, five locations between the Town of Souris and upstream of the Town of Hartney were test netted specifically for carp.[5]

None of these studies were successful in revealing the presence of carp upstream of the Wawanesa Dam. If carp had, in fact, traveled across the dam in the spring flood, available information indicates that they were unable to establish significant viable breeding populations.

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(1) A. Benedictson, MNRE File Information, 1962.
(2) D. McInnes, MNRE File Information, 1975.
(3) D. Houseworth, Personal Communication, 1978.
(4) Neilson, J. D. 1977. Fisheries Baseline Study. Souris River Basin Study. Supplement 5, Volume 2-K. 1978. 65 pp.
(5) W. Howard, Personal Communication, 1978.

The reasons for this are not precisely known but undoubtedly a combination of limiting factors has acted to thwart their dispersal. Some of these factors include:

a. The Wawanesa Dam, with an elevation difference between the crest and apron of approximately 3.7 meters (12 feet), acts as a physical barrier to carp during most flows. Also, the various low-level stop-log dams (Hartney, Napinka, Melita I and Melita II) and the fixed crest dam at Souris act as physical barriers during periods of very low flows.

b. Fish winterkill and summerkill are common occurrences due to the periodic low water volumes, reduced flows, organic loading, algae and macrophyte proliferation and decomposition that result in decreased water quality including critically low dissolved oxygen levels. Limiting dissolved oxygen concentration for carp has been reported to be in the 0.8 to 1.0 ppm range.[1]

c. Carp are inactive at certain temperatures. Carp become active above 4° C (38° F),[2] move toward shallow waters when the temperature exceeds 11° C (52° F), actively seek spawning areas at 15° C (59° F), and begin spawning at 17° C (62° F).[3] Short-term peak flows occurring early in the spring and submersion of the Wawanesa Dam do not necessarily coincide with water temperatures conducive to spawning carp migration. According to available Water Survey of Canada data over the 1913-1976 period, peak flows have occurred during the April-May period 85 percent of the time, the remainder occurring in the warmer May-June period.

d. Good quality carp habitat is absent in the reach of the Souris River between the communities of Wawanesa and Souris due to the elevated gradient, limited availability of backwater marsh areas, and the lack of deep water for overwintering.

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(1) Paton, D. N. 1904. Observations on the amount of dissolved oxygen in water required by young Salmonidae. Proc. Roy. Soc. Edinburgh. 24: 145-150.

Moyle, J. B., and W. D. Clothier. 1959. Effects of management and winter oxygen levels in the fish population of a prairie lake. Trans. Amer. Fish Soc. 88: 178-185.

(2) Sigler, W. F. 1958. The ecology and use of carp in Utah. Utah State Univ., Agr. Exp. Sta. No. 405. 62 pp.

(3) McCrimmon, 1968.

Consideration of these limiting factors, as well as flow, temperature, and dissolved oxygen data available for the 1976-1978 period, allows certain inferences to be made as to why carp were apparently unsuccessful in establishing viable breeding populations in the Manitoba and North Dakota portions of the Souris River following the 1976 flood. First, there were three possible outcomes of submersion of the Wawanesa Dam by high spring flows in 1976:

a. Water temperature below the Wawanesa Dam was too low to stimulate carp to move upstream over the dam; by the time the temperature had risen to the 11° C to 15° C (52° F to 59° F) range, flows were such that, once more, the dam acted as a barrier.

b. Carp moved over the Wawanesa Dam in spite of the low temperatures, continued to move upstream, and managed to reach J. Clark Salyer before low flows in mid-October[1] prevented passage through the Melita and Westhope reaches of the river.

c. Carp moved over the Wawanesa Dam when water temperature became conducive and before the dam impeded passage; due to initially low temperatures and high flows, the fish moved upstream with reduced speed and were unable to clear the Melita and Westhope reaches before low flows occurred in the fall. Subsequently, the carp were winterkilled through a combination of extreme low flows and dissolved oxygen concentration.

Water temperatures available for a number of specific dates and flow data lend some support to the first scenario. On May 5, 1976, water temperature at the Wawanesa Dam was only 7° C (45° F).[2] By May 13, it had risen to just over 13° C (56° F) while flows of 297 m^3/sec (10,500 cfs) were just sufficient to submerge the crest of the dam.[1] By May 15, flows had dropped to 279 m^3/sec (9,840 cfs) and the tail-water elevation would have dropped below the crest. It is quite possible that the carp were still

(1) Water Survey of Canada. 1977. Surface Water Data, Manitoba 1976. Supply and Services Canada, Ottawa.
(2) Neilson, J. D. and J. F. O'Connor. 1976. Management options for the Souris River sport fishery. Fisheries Study sector. Souris River Basin Study. Supplement 5. Volume 2-I. 1978. 39 pp.

in the Assiniboine River at the time temperatures started to rise above 11° C (52° F) and instigated a slow spawning migration up the Souris River. By the time they reached the Wawanesa Dam (a distance of about 22.5 kilometers (13 miles) from the Souris-Assiniboine confluence), flows could have been insufficient to permit access over the dam.

Implicit in the second scenario is that carp took full advantage of the short period of time when temperatures and flow permitted passage over the dam. Carp would still have been able to move past the dam sometime after the tail-water elevation dropped below the crest. For example, with a flow of approximately 227 m^3/sec (8,000 cfs)(occurring on May 20), there would have been an elevation difference between the crest and the tail water of only 0.6 meter (2 feet) and a depth of water flowing over the dam of 1.4 meters (4.5 feet).(1) In the Tewaukon National Wildlife Refuge in North Dakota, carp have been observed jumping over a dam when the distance from the surface of the water below the dam to the top of the structure was 1.4 meters (4.5 feet) and depth of water flowing over the dam was 0.20 to 0.25 meter (0.67 to 0.83 foot).(2) In the same refuge, they have been noted swimming with comparative ease upstream over a spillway when the flow over the stop logs was 0.3 meter (1 foot) or more in depth and the drop was as much as 1.5 meters (5 feet).(3) The swimming ability of carp has been reported on by several authors including Gray(4) and Blaxter.(5) The conclusion of these studies is that carp can attain a maximum speed of 10 body lengths per second for a limited period of time. The average size of mature carp occurring in the vicinity of the Assiniboine River is about 0.53 meter (21 inches).(6) If the relationship of velocity to body length is linear in this size range, carp could be expected to reach a maximum swimming velocity of about 5.3 m/sec (17 fps). At a discharge rate of 227 m^3/sec (8,000 cfs), the velocity of water passing over the crest of the dam would be approximately 3.1 m/sec (10 fps).(1) It is apparent, then, that carp could still have moved past the Wawanesa Dam through jumping, swimming, or a combination of the two for some time after flows had subsided below 283 m^3/sec (10,000 cfs).

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(1) R. Bowering, Personal Communication, 1978.
(2) F. Pfeifer, Personal Communication, 1978.
(3) H. Troester, Personal Communication, 1978.
(4) Gray, J. 1953. The locomotion of fishes. Chapter 1 in Essays in Marine Biology. Oliver and Boyd. Edinburgh.
(5) Blaxter, J. H. S. 1969. Swimming speeds of fish. FAO Fisheries Report No. 62, Vol. 2.
(6) MREM File Information.

The question is whether carp, having transcended the dam around mid-May, could have been able to travel the 249 kilometers (155 miles) to the J. Clark Salyer Refuge in 5 months before the arrival of extreme low flows in the fall. Certainly, carp are determined swimmers and their prolonged spawning behavior could allow a great distance to be traveled in one open-water season. While peak spawning occurs in mid-May through June, spawning has been observed through July and into early August.[1] One carp tagged in Missouri was recovered 26 months later after it had traveled 1,085 kilometers (674 miles).[2] As was indicated earlier in the chapter, in 1949, carp apparently were able to travel the distance to the J. Clark Salyer Refuge within about 5 months. Assuming they had made good headway and arrived at the refuge in only 4 months, they would have had to travel approximately 64 kilometers (40 miles) per month.

A comparison of discharge data for 1949 and 1976 indicates that, in general, average monthly flows in 1976 were approximately three to four times higher than those in 1949 (Table 19). The resultant higher water levels would have given rise to the appearance of blind channels off the main stem of the Souris River. The progress of carp up the Souris River would therefore have been reduced as a result of searching attempts for suitable spawning habitat in these new channels. Low temperatures during the early part of their migration would probably have also had the effect of suppressing their progress. In view of these factors, it is estimated that the rate of travel was reduced by one-half to 32 kilometers (20 miles) per day. At this rate, carp would not have been able to negotiate the Westhope reach before it virtually dried up on October 15.[3]

Overall, it appears that the third scenario is far more likely to have occurred. Given that carp were able to move past the Wawanesa Dam, movement of carp in the upstream reaches of the Souris River was impeded by extreme low flows in the fall. The situation was probably made worse by the fact that stop logs were replaced in the dam at Hartney on September 28.[4]

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(1) Swee, U. B. and H. L. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish Soc. 95(4): 372-380.
(2) Sigler, 1958.
(3) Water Survey of Canada, 1977.
(4) J. Moskalyk, Personal Communication, 1978.

Table 19a - Average Monthly Flows at Souris River near Wawanesa in 1949 and 1976

Year	Average Monthly Flow in m^3/sec							
	April	May	June	July	August	September	October	November
1949	116	94.0	30.2	8.23	4.02	2.35	4.84	1/
1976	487	286	107	38.2	20.1	11.1	3.71	2.40

Table 19b - Average Monthly Flows at Souris River near Wawanesa in 1949 and 1976

Year	Average Monthly Flow in cfs							
	April	May	June	July	August	September	October	November
1949	4,100	3,320	1,070	291	142	83	65	1/
1976	17,200	10,100	3,780	1,350	711	393	131	85

1/ Not measured.

Their movement prevented, carp would have had to overwinter in the Manitoba portion of the river. All potential carp overwintering areas are not known but areas near Treesbank, the "Souris River bend" (north of Margaret) and the various pools impounded by the low-level dams are likely. Oak Lake is also usually suitable for overwintering fish and has not suffered severe significant winterkill since the construction of the Oak Lake Dam in 1965. However, it may not have been possible for carp to have gained ready access to Oak Lake in 1976. Conservation officers report that high flows extending into early June blocked fish passage through the culvert where Plum Creek passes under Provincial Trunk Highway 2. Also, the entrance to Plum Creek which provides access to Oak Lake from the Souris River was blocked with debris at the Victoria Park Dam.(1) If spawning carp were able to bypass these obstacles after some delay, it is not likely that they would have passed through the prime Plum Lake spawning area into Oak Lake. During the 1976-1977 winter, Plum Lake winterkilled and any carp in the marshes would have perished.(2)

(1) Neilson and O'Connor (1976).
(2) W. Howard, Personal Communication, 1978.

Assuming that carp were able to successfully overwinter, spawning migration in the 1977 spring and summer through the upstream reaches would have been made impossible by extremely low flows. Discharge near Melita was only 0.03 m^3/sec (1.0 cfs) on April 20. The discharge remained less than this value until May 16, and did not exceed 0.57 m^3/sec (20 cfs) until June 18. At Souris River near Coulter, flows did not exceed 0.57 m^3/sec (20 cfs) until September 8 and at Souris River near Westhope, discharges were less than 0.03 m^3/sec (1.0 cfs) from April 10 until May 31 and were not recorded any higher than 0.76 m^3/sec (27 cfs) for the remainder of the year. With the existence of such an extreme drought situation, carp would not have experienced currents of sufficient velocity to stimulate them into, or permit, a spawning migration upstream.

Due to the extended period of low flows, which were not significantly improved through summer precipitation or local inflow, extreme winterkill conditions occurred during the winter of 1977-1978, judging from dissolved oxygen data available for Coulter and Westhope (Table 20). Although similar data are not available for other locations in the Manitoba portion of the Souris River, it is likely that these locations also experienced very low dissolved oxygen concentrations, considering the available flow data. Therefore, carp attempting to overwinter in the Souris River would have been completely eliminated.

Table 20 - Dissolved Oxygen Concentrations in the Souris River in 1978

Date	Dissolved Oxygen (mg/l)	
	Westhope, North Dakota 1/	Coulter, Manitoba 2/
January 5	1.3	0.8
January 18	0.0	-
February 6	-	0.55
February 10	0.0	-
February 22	0.0	-
March 6	-	0.0
March 7	0.0	-
March 24	1.5	-

1/ Data collected by USGS.
2/ Data collected by Inland Waters Directorate, Environment Canada.

The above discussion is presented to explain the reasons for the apparent absence of carp at present in the Souris River upstream from the Wawanesa Dam. This analysis is of value in determining the incremental effect of operation of the proposed Burlington project on future carp distribution in the Souris River.

Burlington Project Influence on Carp Distribution. - The relationship between flows and dissolved oxygen concentrations in the Souris River can be demonstrated from available historic data. In 1976, the recorded mean December flow at Souris River near Westhope was 1.47 m^3/sec (52 cfs)[1] and on December 7, the dissolved oxygen concentration at Souris River near Coulter was 13.7 mg/1.[2] By comparison, a similar mean flow for February 1974 of 1.63 m^3/sec (57.7 cfs) occurred but the dissolved oxygen concentration on February 25 was less than 0.1 mg/1. The explanation for the large differential in dissolved oxygen for roughly equivalent flows appears to lie in the magnitude of the flows which occurred during the year preceding each of the two winters in question. Mean annual flows at Westhope in 1973 were reported at 1.78 m^3/sec (62.9 cfs) whereas in 1976, the mean annual discharge was 45.9 m^3/sec (1,620 cfs).[1] Other data exhibit the same general trend: low volume flows of about 0.57 m^3/sec (20 cfs) in late 1974 and early 1975 at Westhope coincided with a dissolved oxygen reading of 0.0 mg/1 at Coulter on February 18, 1975.[2] However, higher flows occurring during the remainder of 1975 corresponded to a dissolved oxygen concentration of 4.2 mg/1 on February 2, 1976.[2]

The above data indicate that high flows occurring in a particular year tend to result in elevated dissolved oxygen concentrations during the following winter. The reverse situation also appears to hold true.

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(1) Water Survey of Canada. 1978. Historical Streamflow Summary. Manitoba. Supply and Services Canada, Ottawa.
(2) V. Chacko, Personal Communication, 1978.

The International Garrison Diversion Study Board noted that periods of low dissolved oxygen occur regularly on portions of the Souris River and are correlated with flows falling below 0.57 m^3/sec (20 cfs).[1] The Committee also noted that over the period 1960-1975, the median dissolved oxygen concentration under ice cover at Coulter was 1.8 mg/l and was less than 0.2 mg/l for 25 percent of the measurements taken.

The positive correlation between high prolonged flows and elevated dissolved oxygen levels could be due to a combination of various factors, including:

a. The flushing of organic materials from the system.

b. Decreased organic production due to decreased water clarity, nutrient dilution, weed bed scouring, and the flooding of lowland areas and shoreline with water of sufficient depth to limit plant growth resulting in reduced winter biochemical oxygen demand.

c. A larger water volume with a larger inherent oxygen-carrying capacity.

d. Increased aeration due to larger open water areas and turbulence at obstructions.

e. Decreased ice depths due to increased current and a resultant increase in photosynthetic oxygen production.

f. A higher water table and more active springs and tributaries.

It should be noted that there can be considerable variability over time and space in dissolved oxygen concentrations. Conditions of supersaturation can give rise to very high concentrations such as 22.5 mg/l as recorded at Souris River near Westhope on March 22, 1977. Such readings do not reflect the ability of the river to support overwintering fish. Aberrations in

(1) International Garrison Diversion Study Board, 1976. Appendix A, Water Quality Report.

dissolved oxygen readings can also occur as a result of localized photosynthetic activity, spring runoff, or concentrations of certain ions contained in municipal waste discharges into the river.

The 1976 modified discharge hydrograph (Page B-216, Appendix B), simulating Lake Darling and Burlington Dam operation, indicates that at Wawanesa, Burlington would have caused a reduction in the period of flows above 283 m^3/sec (10,000 cfs) after May 5 to 5 days from 11 days and the period of flows above 227 m^3/sec (8,000 cfs) after May 5 to 13 days from 15 days. The project would, however, have also caused a prolonged discharge of approximately 14.2 m^3/sec (500 cfs), extending into late December in the Westhope reach. The presence of elevated flows would have alleviated the extreme low-flow situation which occurred in mid-October and would have provided sufficient dissolved oxygen and flow to maintain carp migration. Extended flows or artificially induced currents at almost any time of the year are known to stimulate carp movement into the direction of flow. For example, carp have been observed to congregate at the pump discharge at Lake Audubon during pumping operations and attempt to swim up the face of the La Moure Dam on the James River in North Dakota when late summer releases are made from the Jamestown Reservoir.[1]

In 1976, therefore, although the chances for carp to negotiate the Wawanesa Dam would have been reduced, they would not have been eliminated. Once over the dam, the extended flow period may have provided the means for them to reach the J. Clark Salyer Refuge and remain there for the winter, or overwinter in the upper reaches of the Manitoba portion of the Souris River. Although winterkills have occurred within J. Clark Salyer Refuge in 7 years out of 13 years during the period 1960-1973,[2] it is unlikely that, with Burlington in operation, there would have been a winterkill over the 1976-1977 winter with the presence of the elevated flows in the fall. In the years following 1976, carp could continue to

(1) D. Hennegar, Personal Communication, 1978.
(2) International Garrison Diversion Study Board. 1976. Appendix C. Biology Report.

move upstream from the refuge and into tributaries of the Souris such as Willow Creek, Deep River, and Cut Bank Creek. During high water periods, carp would also be able to migrate to Lake Metigoshe via Willow and Oak Creeks. Lake Metigoshe has not experienced a complete winterkill in the last 30 years[1] and would, therefore, be capable of supporting resident carp populations which could sustain and replenish populations throughout the Souris River system. Another possible carp breeding reservoir exists in Buffalo Lodge Lake which could be reached by Cut Bank Creek. Historic information indicates that winterkill of fish could be expected in the lake every 3 to 5 years depending on water levels.[1]

Habitat conditions in the Souris loop are not limiting to carp and, according to available dissolved oxygen data (Appendix D), overwintering is likely possible in most years in many reaches of the river. Barring drought conditions, carp would probably reach the Lake Darling Dam within 2 or 3 years following their appearance in the J. Clark Salyer Refuge. Apparently carp did not reach the Lake Darling Dam in the years following 1954 when one was recorded at Dam 357. Burlington Dam would not pose any barrier to carp movement in years in which it was not operated and the small earth fill dam proposed for the Des Lacs River would not prevent carp from moving into the Des Lacs National Wildlife Refuge. Good quality carp breeding habitat exists below the Lake Darling Dam and, according to available dissolved oxygen data for the Souris River near Foxholm (Appendix D), carp would experience winterkill infrequently. In years when overwintering was possible, carp would be present just below the Lake Darling Dam, waiting for suitable conditions of flow and temperature which would allow them to negotiate the dam.

An examination of the hydraulic characteristics of the existing Lake Darling Dam indicates that it would form an effective barrier to carp. The combination of water level differential and velocities over the spillway and through the conduit should prove impossible for carp to negotiate at all reasonably conceivable flows and water levels. With Burlington Dam in place, however, the flooding out of the Lake Darling structure in rare flood years could provide the means for carp to move over the dam and into Lake Darling.

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(1) D. Hennegar, Personal Communication, 1978.

Once over the Lake Darling Dam, carp would be able to establish a large resident population in Lake Darling and continue moving upstream into the upper reaches of the Souris River in Saskatchewan. The existence of resident breeding populations, especially in Lakes Darling and Metigoshe, would ensure maintenance of carp populations throughout the Souris River system in years in which local populations were eradicated by winterkill or other controls.

In summary, it is evident that carp have been on the verge of establishing themselves in the Souris River above the Wawanesa Dam for many years. From the information available it appears that this has been prevented by the absence of the right combination of flows, temperatures, and dissolved oxygen at critical times. It also appears that enhancement of any of these characteristics could result in the successful establishment of carp in the Souris River above the Wawanesa Dam and below Lake Darling. Although this enhancement could result from a number of activities, including improved sewage treatment in urban centers discharging into the Souris River, changes in management techniques in the Souris Wildlife Refuges, and diversions for water supply such as have been proposed in Canada and the United States, it has been demonstrated that operation of Burlington could have provided this enhancement in 1976 and could be expected to do so at some time in the future. Operation of Burlington would, however, be the only one of the potential changes identified that could provide the means for carp to enter Lake Darling. Carp entry could occur in the rare instance when the Lake Darling Dam spillway is drowned out by the Burlington pool, approximately a 1-percent chance in any given year.

Potential Impact on the International Waterfowl Resource - North Dakota. - The effect of carp introduction in the Souris River was treated by the Biology Committee of the International Joint Commission's Garrison Diversion Unit (GDU) Study Board:

"Scott and Crossman (1973) noted that carp '. . . adversely affect duck populations by the destruction of rooted aquatic plants in marshes.' Proliferation of carp in North Dakota wildlife refuges along the Souris River will result in damage to waterfowl-producing marshes and exacerbate other waterfowl losses resulting from GDU."[1]

It has been found that carp reduced submergent aquatic vegetation by up to 75 percent.[2] Certain submergent aquatic species, such as pondweeds, are important foods for waterfowl. Many authors have noted the preference for pondweeds by canvasbacks.[3] Sugden found that slender pondweeds were the most important food items for young flightless widgeon and gadwall in Alberta.[4] Napier related population fluctuations of waterfowl, particularly canvasbacks, to fluctuations in sago pondweed production resulting from carp infestation at the Malheur National Wildlife Refuge in Oregon.[5]

Detailed quantitative accounts of waterfowl production losses resulting from habitat destruction by carp are not numerous in the literature. Studies conducted by Marshall and Napier indicate that waterfowl production in the Malheur National Wildlife Refuge was reduced by as much as

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(1) International Garrison Diversion Study Board, 1976.

(2) King, D. R. and G. S. Hunt. 1967. Effect of carp on vegetation in a Lake Erie marsh. J. Wildl. Manage. 31(1): 181-188.

(3) Cottam, C. 1939. Food habits of North American diving ducks. U.S. Dep. Agric. Tech. Bull. 643. 140 pp.

Rawls, C. J. Jr. 1954. Reelfort Lake waterfowl research. Tenn. Game and Fish Comm. 80 pp.

Yocom, C. F. and M. Keller. 1961. Correlation of food habits and abundance of waterfowl, Humboldt Bay, California. Calif. Fish and Game 47: 41-53.

Bartonek, J. C. and J. J. Hickey. 1969. Selective feeding by juvenile diving ducks in summer. Auk 86: 443-457.

(4) Sugden, L. G. 1973. Feeding ecology of Pintail, Gadwall, American Widgeon and Lesser Scaup ducklings. Cdn. Wild. Serv. Rept. Ser. No. 24. 45 pp.

(5) Napier, L. D. 1977. Carp in Malheur Lake marsh. U.S. Fish and Wild. Serv. unpubl. rept. 36 pp.

80 percent due to carp irruption.[1] Experiences at other refuges further indicate the influence of carp in suppressing waterfowl production. At the Crescent Lake National Wildlife Refuge in Nebraska, carp eradication in Roundup Lake and Hackberry Lake resulted in an overall increase in duck production of 100 percent in each lake.[2] At the Sand Lake National Wildlife Refuge on the James River in South Dakota, duck production averaged about 4,000 from 1963 through 1968. During this period, large carp were abundant in the marshes of the refuge. Intentional winterkill of carp in the fall of 1968 is considered to be a major factor influencing record duck production of 15,000 the following summer.[3] Winterkill of carp at the Arrowwood National Wildlife Refuge in North Dakota contributed to a 100-percent increase in duck production.[3]

It is difficult to determine to what extent carp would reduce waterfowl production following irruption in the J. Clark Salyer, Des Lacs, and Upper Souris National Wildlife Refuges. However, there is no reason to expect that the magnitude of production loss experienced at Malheur (80 percent) could not also occur as a worst case at the refuges along the Souris River especially considering the high quality of waterfowl habitat present in the refuges. Periodic winterkill would, however, tend to reduce the average annual production loss to an unknown extent.

The procedure used to calculate waterfowl losses to Canada resulting from reduction of waterfowl production in North Dakota due to carp essentially follows the methods developed by the International Garrison Diversion Study Board for estimating waterfowl losses resulting from the Garrison Diversion project.[4] The reader should refer to the Biology Appendix of the Board's report for a full explanation of this procedure and relevant biological concepts.

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(1) Marshall. 1957. Carp control program at Malheur Lake, Oregon. Unpubl. rept. Napier, 1977.
(2) A. Zeillemaker, Personal Communication, 1978.
(3) D. E. Simpson, Personal Communication.
(4) International Garrison Diversion Study Board, 1976.

Production loss was estimated separately for the three refuges, for portions of the Des Lacs and Souris Rivers not included in the refuges, and for sections of tributaries entering J. Clark Salyer which are accessible to carp during periods of high water levels. Waterfowl in these areas represent an international resource and Canada shares the impact of carp on production through loss of birds in the breeding reservoir and fall shuffle.[1] It was estimated in the Garrison Diversion Study that Manitoba would share 20 percent of the waterfowl loss attributable to the Garrison Diversion Unit. This percentage was based on a breeding reservoir concept of large geographic size (all of North Dakota and Manitoba). In the case of the Burlington project, the breeding reservoir is much smaller, consisting of the southwest corner of Manitoba, southeast corner of Saskatchewan, and the northwest corner of North Dakota. This area contains prime waterfowl habitat which is considered to be some of the best in the world. Obviously, in such a small area, much interchange of waterfowl occurs in the breeding reservoir and the fall shuffle. Therefore, Manitoba and Saskatchewan would share a larger portion of production loss than was estimated for GDU. It is impossible, however, to state what Canada's share of the production loss would be under these circumstances. Therefore, the 20 percent figure is used in this study and estimates of waterfowl losses resulting from Burlington project operation are probably low due to the smaller breeding reservoir.

Waterfowl loss for the refuges was calculated using annual production data collected by the U.S. Fish and Wildlife Service over the period 1959-1978. Waterfowl production for the remainder of the Des Lacs and Souris Rivers within North Dakota was estimated by assuming a density of five breeding pairs per river kilometer (eight per mile) and a production success of 1.08 fledged young per adult.[1] Production estimates for the Souris River tributaries entering the J. Clark Salyer Refuge were derived from breeding pair surveys conducted on Cut Bank Creek, Spring Coulee, and South Egg Creek in 1976 and 1978[2] (Table 21). The average number of breeding pairs per unit distance was calculated from these data and the value of 1.08 fledged young per adult was used to arrive at production.

(1) International Garrison Diversion Study Board, 1976.
(2) D. E. Hubbard, Personal Communication, 1979.

Breeding pairs per unit distance for Little Deep Creek were estimated through comparison of brood data collected for this creek and brood data for the three tributaries for which breeding pair data had been collected.[1] Deep River and Willow, Wolf, Ox, Mud, and Oak Creeks were not surveyed, but breeding pair density for these tributaries was assumed to be approximated by the pair density for Cut Bank Creek.

Table 21 - Average Annual Duck Production Estimates for the Des Lacs River, Souris River, and Major Souris River Tributaries in North Dakota

Streamcourse	Length of streamcourse (kilometers)	Length of streamcourse (miles)	Estimated breeding pairs (per kilometer)	Estimated breeding pairs (per mile)	Estimated breeding pairs	Average annual production
Des Lacs River	59.5	37.0	5.0	8.0	296	640
Souris River	361.1	224.4	5.0	8.0	1,795	3,880
Tributaries:						
Cut Bank Creek	30.7	19.1	13.6	21.8	416	900
Spring Coulee	21.9	13.6	9.9	15.9	216	465
South Egg Creek	8.7	5.4	9.9	16.0	86	185
Little Deep Creek	48.9	30.4	18.4	29.6	900	1,945
Deep River	51.8	32.2	13.6	21.8	702	1,515
Willow Creek drainage (Willow, Wolf, Ox, Mud, and Oak Creeks)	214.8	133.5	13.6	21.8	2,910	6,285
Totals	797.6	495.6	-	-	7,321	15,815

Combined production for the three National Wildlife Refuges is estimated at an average of about 28,000 birds annually (Table 22). Average annual production from the Des Lacs and Souris Rivers (not including the refuges) is estimated at 640 and 3,880, respectively, and combined annual production of the tributaries is about 11,300 for a total of about 15,800 (Table 21). Total annual waterfowl production from wetlands in the Souris River drainage accessible to carp is therefore approximately 43,700. Based on an 80-percent reduction in production and a 20-percent contribution to Canada through the fall shuffle and breeding reservoir, Canada

(1) D. E. Hubbard, Personal Communication, 1979.

could lose up to 7,000 birds annually through carp infestation of wetlands in North Dakota. This estimate does not take into consideration any efforts to eradicate carp to reduce waterfowl losses. In addition, as was stated earlier, Canada's share of the production loss is probably higher than 20 percent.

Table 22 - Average Duck Production Estimates for Three North Dakota National Wildlife Refuges, 1959-1978[1/]

Species	J. Clark Salyer	Upper Souris	Des Lacs	Total
Mallard	4,780	1,000	960	6,740
Gadwall	2,835	800	1,245	4,880
Pintail	2,800	150	475	3,425
Green-winged teal	55	100	-	155
Blue-winged teal	2,850	1,750	405	5,005
American widgeon	1,340	450	590	2,380
Northern shoveler	570	250	25	845
Wood duck	230	50	-	280
Redhead	1,250	150	10	1,410
Canvasback	1,250	150	120	1,520
Lesser scaup	55	50	690	795
Ruddy duck	295	100	-	395
Hooded merganser	90	-	-	90
Totals	18,400	5,000	4,520	27,920

1/ U.S. Fish and Wildlife Service, 1959-1978.

Potential Impact on the International Waterfowl Resource - Manitoba. - There are no wetland areas along the Souris River itself, upstream of the Wawanesa Dam within Manitoba, which contribute significantly to the waterfowl production of the southwest corner of the Province. Waterfowl capability of these areas is classified as either Class 3 or Class 4 under the Canada Land Inventory system. The main factors limiting waterfowl production are water level fluctuation and high seasonal flows.[(1)]

(1) Adams, G. D. and R. C. Hutchison. 1968. Land capability for Wildlife - Waterfowl. Queen's Printer, Ottawa.

As was described in a preceding section of this chapter, carp appear to be presently capable of crossing the Wawanesa Dam under certain environmental conditions. If this happened without the Burlington project, waterfowl habitat along the Manitoba portion of the Souris and in the Oak-Plum Lakes complex could be affected by carp until subsequent summerkill or winterkill of the population occurred. With Burlington, summerkill or winterkill would probably not occur in some years due to the presence of increased fall flows and therefore the impact of carp in Manitoba could be prolonged. It is impossible to accurately determine how much waterfowl production loss due to carp could be attributed to the Burlington project and how much to naturally occurring conditions. Because of this uncertainty and the naturally low waterfowl capability of the Souris River in Manitoba compared to other reaches of the river, waterfowl production loss in Manitoba due to Burlington was assumed to be negligible.

Potential Impact on the International Waterfowl Resource - Saskatchewan.- As previously noted, waterfowl production losses in Saskatchewan could be attributed directly to the Burlington project if carp became established in the Souris River below Lake Darling. Unlike the Souris Loop in North Dakota, there are no wildlife refuges or management areas along the Souris River or its tributaries in Saskatchewan for which adequate waterfowl production data are available. Therefore, waterfowl losses resulting from habitat destruction by carp in Saskatchewan were calculated in the same way as for the non-refuge portions of the Des Lacs and Souris Rivers in North Dakota. Production was estimated assuming five breeding pairs per kilometer (eight per mile) and a production success of 1.08 fledged young per adult. It was assumed that carp would not be able to negotiate the dams situated at the downstream ends of the Boundary Reservoir on Long Creek, Moose Mountain Lake on Moose Mountain Creek, and the Weyburn Reservoir on the Souris River.(1) Therefore, only habitat existing in reaches downstream of these structures was considered.

(1) R. P. Johnson, Personal Communication, 1978.

Annual waterfowl production is estimated to average about 3,000 birds (Table 23). Assuming 80-percent reduction in waterfowl production, due to carp, waterfowl losses to Saskatchewan could in some years amount to about 2,400 birds.

Table 23 - Annual Duck Production Estimates for Selected Reaches of the Souris River and Moose Mountain Creek in Saskatchewan 1/

Reach	Length of reach (kilometers)	Length of reach (miles)	Breeding pairs (per kilometer)	Breeding pairs (per mile)	Estimated breeding pairs	Estimated annual production
Dead Lake to point south of Glen Ewen	152.9	95	5	8	760	1,640
Moose Mountain Creek:						
Moose Mountain Lake to Souris River	130.4	81	5	8	648	1,400
Total	283.3	176			1,408	3,040

1/ Class 2 waterfowl habitat (Canada land inventory).

Potential Impact on the Fish Resource - Manitoba. - Carp are considered detrimental to native fish populations because they increase the turbidity of the water as they search for food and uproot and destroy submerged aquatic vegetation that is essential for the survival of native species.(1) Such vegetative growth provides cover and food for all species of fish and may be used as spawning sites by certain species such as northern pike, perch, and minnows.(1) These species are known to occur in the Manitoba portion of the Souris River.(2) If spring environmental conditions are not conducive to early primary production, food competition among all species could be severe. Carp control programs in some lakes have led to improvement in game fish habitat and angling success.(3)

(1) Scott, W. and E. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can., Bull. 184. 966 pp.
(2) International Garrison Diversion Study Board, 1976.
(3) Peterson, L. I. 1956. Carp control on Lake Koshkonong. Wisconsin Conserv. Bull. 21(5). 4 pp.
Rose, E. T. and T. Moen. 1953. The increase in game fish populations in East Okoboji Lake, Iowa, following intensive removal of rough fish. Trans. Amer. Fish Soc., 82: 104-114.

Cahn described how the fine sport fishery of Neosha Lake in Wisconsin was destroyed by carp introduction. When Neosha Lake was drained, 98 percent of the fish present in the lake were found to be carp.[1] While it is difficult to quantitatively assess the effect of carp on the riverine fish resource in Manitoba, introduction of the species would result in some reduction of native sport fish populations. The extent of this reduction would depend on the size of the carp population. Carp, in moderate numbers, will have little detrimental effect on the size of a game fish population.[2] A 1976 creel census of the Souris River sport fishery in Manitoba estimated angling pressure at 16,900 angler hours.[3] Walleye, pike, and perch were the main species being caught. Although this angler use does not indicate an extensive fishery, any reduction in numbers of these species would be viewed as a significant loss by the local fishermen who derive recreational benefit from the Souris River.

Potential Impact on the Fish Resource - Saskatchewan. - The Souris River sport fishery in Saskatchewan was described in the Souris River Basin Study Report.[4] Although detailed information for items such as population sizes and recreational value is not available on the sport fishery of the Saskatchewan portion of the Souris River, the fishery is more substantial than that of the Manitoba portion. However, a large percentage of the angling and resulting catch is derived from several reservoirs located on the Souris River or its tributaries, including the Boundary, Larsen, and Weyburn Reservoirs.[5] These three reservoirs have been stocked with walleye in past years for recreational purposes.[5] When the effect of carp on waterfowl in Saskatchewan was considered earlier, an assumption was made that carp would not be able to negotiate the dams located at the downstream ends of the Boundary and Weyburn Reservoirs and Moose Mountain Lake. Some reduction in sport fish populations downstream of these dams would result from carp introduction with resulting loss of recreational benefits to local fishermen.

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(1) Cahn, A. R. 1929. The effect of carp on a small lake: the carp as a dominant. Ecology, 10(3): 271-275.

(2) Miller, N. J. 1952. Carp control and utilization. Wisconsin Conserv. Bull. 5:3-7.

(3) Neilson, J. D. 1977. The present use of the Souris River sport-fish resource. Souris River Basin Study. Supplement 5. Volume 2-0. 1978. 69 pp.

(4) Blood, D. A. 1977. Related resource study - Saskatchewan - Present use study. Souris River Basin Study. Supplement 5. Volume 1 - E. 1978. 60 pp.

Pierce, G. W. and D. A. Blood. 1977. Water Related Resource Study - Saskatchewan - Fisheries Base Study. Souris River Basin Study. Supplement 5, Volume 1-C. 79 pp.

(5) R. P. Johnson, Personal Communication, 1978.

B. POTENTIAL IMPACT OF ALTERED FLOW REGIME ON FISH AND WILDLIFE RESOURCES

Potential Impact on the Wildlife Resource - Manitoba. - Inspection of the hydrographs constructed through routing of historic floods (Appendix B) reveals that the range of peak flows resulting from operation of the Burlington project would essentially be the same as those experienced under existing conditions. However, with Burlington, the channel capacity of the Westhope reach of 4.25 m^3/sec (150 cfs) would be exceeded during the fall months in some years, causing flooding of bottomlands on both sides of the channel. The hydrograph for 1976 (Page B-210, Appendix B) shows this flooding would persist until January of the following year. Flows in the other reaches of the Souris River remained within the channel capacities of these reaches and therefore Burlington would not have caused any flooding in the fall.

The environmental impact of fall flooding on upland habitat in the Westhope reach can be assessed by considering the nature and extent of present wildlife use of this habitat. Goodwin and Koonz noted that the capacity of this reach to support beaver, muskrat, or mink populations is minimal due to the absence of suitable quality habitat.(1) Therefore, flooding is unlikely to have any significant effect on these furbearers. White-tailed deer use of the area affected by fall flooding is also minimal and is probably related to the acute shortage of herbaceous or wooded cover.(2) In addition, the fall months mark the onset of the rut when male deer, at least, range more widely than in the summer months.(3) Impact of flooding on deer, therefore, would likely be insignificant. Use of the bottomlands in the Westhope reach by sharp-tailed grouse is probably minimal due to the lack of adequate herbaceous vegetation or ungrazed grass-shrub and hayland. Such habitat components are required for sharp-tail populations to be maintained at viable levels.(4) The availability

(1) Goodwin, G. M. and W. H. Koonz. 1977. Wildlife populations and habitat in the Souris River Basin - Manitoba. Wildlife Sector. Souris River Basin Study. Supplement 5, Volume 2-J. 1978. 74 pp.
(2) I. Milliken, Personal Communication, 1978.
(3) Taylor, W. P. 1956. The deer of North America. Stackpole Company, Harrisburg, Pa. 668 pp.
(4) Pepper, G. W. 1972. The ecology of Sharp-tailed Grouse during spring and summer in the aspen parklands of Saskatchewan. Sask. Dep. Nat. Res. Wildl. Rept. No. 1.

of herbaceous or woodland cover is especially important for their survival in the winter months.[1] Sharp-tailed grouse are therefore not expected to be significantly affected by operation of the Burlington project.

In general, occasional fall flooding of the Westhope reach, resulting from Burlington project operation, would not significantly affect wildlife populations in Manitoba due to the poor quality of available upland habitat and the time of year that flooding would occur.

Potential Impact on the Wildlife Resource - Saskatchewan. - As noted in the 1977 Task Force report, backwater effects on Souris River flood levels in Saskatchewan resulting from operation of the Burlington project would not be great enough to cause any significant impact on the farmland in the valley flats. Except for extremely rare flood events (events occurring once in several thousand years), backwater effects would be limited to the river channel. Therefore, unlike the Westhope reach in Manitoba, flows would not be high enough to exceed the channel and cause flooding of upland habitat in the valley flats. Consequently the effect of Burlington project operation on upland wildlife populations in Saskatchewan would be insignificant.

Potential Impact on the Fish Resource - Manitoba. - Limited flow, high summer water temperature, low dissolved oxygen levels and nutrient concentrations are presently some of the factors limiting fish production in Manitoba portions of the Souris River.[2] Increased and prolonged flows produced by Burlington in some years would have a periodic positive influence on Manitoba fish stock maintenance and production.

Winter water quality in the Souris River would likely be improved by a high discharge rate extending into the winter. For major floods when the Burlington project would be in operation, downstream winter dissolved oxygen levels could be improved and the likelihood of fish winterkill could be reduced. Overwintering fish stocks, especially of the more sensitive species such as perch and walleye, could be maintained

(1) Bent, A. C. 1932. Life histories of North American gallinaceous birds. U.S. Government Printing Office. Bulletin 162.
(2) Neilson and O'Connor, 1976.

if their presence were coincident with high water occurrence. Angling success would be expected to improve due to the availability of sport species throughout the winter and an increased population resulting from spawning the following spring. Even with low flow returning the year following the flood event, one successful spawning could result in temporarily improved angling for more than one year since some of the fish could redistribute themselves to areas less prone to subsequent winterkill and therefore survive to maintain populations.

A negative influence could develop from the prolonged summer flows followed by a quick drop from approximately 14.2 m^3/sec (500 cfs) to normal low fall or winter flows at Westhope. Normal reduced flows in late summer and fall result in fish movement downstream to deeper holding areas as the water levels decline. High constant flows could result in fish holding their position for a longer period of time and then being suddenly exposed to drastically reduced flows. Many fish could be caught in shallow pools without adequate water depth to allow movement to more favorable areas. Reduced flow allows greater ice development and possible freezing to the bottom. Fish trapped in these shallow pools could, therefore, be winterkilled.

In summary, prolonged high winter flows produced by Burlington operation in some years would have a periodic positive influence on Manitoba fish stock maintenance and production. However, as indicated in Section A, repeated annual carp introductions from established populations in Lake Darling and Oak Lake, plus overwintering populations of carp in various parts of the drainage basin, would have a long-term negative impact on present sport species populations, primarily due to the low frequency of enhancement by prolonged Burlington flows.

Potential Impact on the Fish Resource - Saskatchewan. - Except for very rare flood events, the direct backwater effects in Saskatchewan resulting from Burlington operation will be negligible. With the modifications to the Lake Darling Dam, greater storage potential exists which could provide a slight positive spawning benefit to Lake Darling fish stocks that seasonally range into Saskatchewan. The introduction of carp into Lake Darling would, in all likelihood, cancel this benefit and, as discussed in Section A, the sport fishery could decline as the direct result of competition from carp moving into the river in Saskatchewan.

C. POTENTIAL IMPACT OF THE PROJECT ON RARE AND ENDANGERED SPECIES

Manitoba. - Nero and Wrigley identified several wildlife species considered to be rare or endangered which are known to inhabit various areas of the Province.[1] The Souris River valley contains no habitats unique to any rare or endangered species. Therefore, such species in Manitoba should not be adversely affected by Burlington project operation.

Saskatchewan. - The Province of Saskatchewan uses the species identified by the Convention on International Trade in Endangered Species of Wild Flora and Fauna in assigning a status to species found in Saskatchewan. As in Manitoba the habitat in the Souris River valley in Saskatchewan is not unique to any rare or endangered species and no adverse effect from Burlington operation should occur.[2]

D. POTENTIAL IMPACT OF THE PROJECT ON WATER QUALITY

Operation of Burlington Dam will have no effect on water quality in the Souris River in Manitoba during most years. Unusual floods of sufficient peak discharge and volume, ranging in frequency of occurrence at Minot from once in 80 years to once in 200 years, may cause releases to be sustained much longer than can be expected on the average. In these rare instances, the flows would produce quantifiable effects on water quality in the Manitoba portion of the river. The effects would be better chemical water quality, with total dissolved solids and other chemical constituents at lower level than normally experienced, during the drier portions of the year. Water temperatures would be lower and the dissolved oxygen content would be higher than under natural conditions. This improved biological water quality condition could be offset to some degree by an increase in the sediment load of the stream. This load, consisting of suspended and non-suspended particles, would be larger than that normally carried by the river; however, it is unlikely that its concentration and hence the impact on water quality would be great.

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(1) Nero, R. W. and R. E. Wrigley. 1977. Rare, endangered, and extinct wildlife in Manitoba. Manitoba Nature 18(2): 4-37.
(2) G. F. Couldwell, Personal Communication, 1978.

The above impacts, both beneficial and adverse, would be insignificant when the natural condition of the river and the infrequency of occurrence are considered.

Activities associated with construction of the Burlington Dam can be expected to increase the sediment load of the Souris River downstream of the damsite. Further sediments may be added through erosion of the reservoir banks by wave action and wind setup until the banks become stabilized by vegetation. Conversely the reservoir as well as the Des Lacs weir would serve as additional sediment traps on these streams and create some potential for increased erosion below the structures. The resulting unbalanced situation is likely to exist for several years following completion of the dam. The sediment load increase resulting from dam construction would probably be minor. The quality of aquatic habitat downstream of the damsite would deteriorate somewhat during and following construction of the dam. This impact would probably be felt only in North Dakota, although there may be a small increase in sediment load occurring in Manitoba at the time of peak flows during the construction period.

Erosion of the banks of the Souris River downstream of the dam is not likely to increase except as noted above. Therefore, a few years after completion of the dam, sediment levels would probably return to conditions existing prior to construction.

E. ENVIRONMENTAL STATEMENT

Environmental impacts of the Burlington project have been identified as unique and nonunique. The unique impacts are those that can be attributed to Burlington project operation alone, such as the impact of changes in the flow regime on Manitoba fisheries and upland wildlife populations. Nonunique impacts are those that could be attributed to a number of causes including Burlington project operation. The invasion of carp into the Souris River above the Wawanesa Dam and the consequent impact on waterfowl is the primary example of this latter type of impact.

The unique environmental impacts of the Burlington project on Canada are not expected to be great, primarily because of the infrequent use of the project. Impacts on wildlife (other than waterfowl), rare and endangered species, and water quality are expected to be negligible. The sport fishery in Saskatchewan may be slightly enhanced by improvements in fish habitat in Lake Darling and subsequent increased migration. The sport fishery in Manitoba should be enhanced in those infrequent years in which Burlington provides a sustained flow during the summer and fall in the Souris River in Manitoba, although a sudden reduction to normal low fall and winter flows at Westhope could cause entrapment and subsequent kills of sport fish.

The primary nonunique environmental impact of the Burlington project is its potential to encourage carp migration from the Assiniboine River in Manitoba to the Souris River. A successful invasion of the Souris River by carp is probably imminent and could result from minor improvements in flow characteristics, temperature, or dissolved oxygen in the Souris River. In some years, Burlington could provide an improvement in flow or dissolved oxygen that would permit carp to migrate and overwinter and ultimately populate the river as far upstream as Lake Darling Dam, which is currently an effective barrier to carp movement. At this point, Burlington could provide the unique means for carp to negotiate the dam in those rare years when the lower Burlington pool submerged the Lake Darling spillway crest. Once in Lake Darling, carp would move up the Souris River to Saskatchewan, although Boundary Dam and Moose Mountain Dam should bar them from Long Creek and the upper reaches of Moose Mountain Creek.

The successful introduction of carp to the Souris River would negate the benefits to the Canadian sport fishery attributable to the Burlington project and could have a serious effect on the international waterfowl resource. Habitat destruction in the river and the U.S. Fish and Wildlife Service National Wildlife Refuges could result in the indirect loss of 7,000 birds to Canada in some years and the direct loss to Saskatchewan of

about 2,400 birds annually. Direct losses to Manitoba due to the Burlington project would be negligible due to the poor quality of existing habitat along the Souris River in that Province.

During the course of its studies the Task Force determined that the U.S. Fish and Wildlife Service and the Corps of Engineers are actively studying the potential carp problem as a domestic United States concern.

VI MITIGATION

A. ECONOMIC IMPACTS

General. - Mitigation is normally defined as an action to offset or to make milder the effects of another action. Compensation is defined as something given as an equivalent to make amends for damages. In the instance of the Burlington project, both mitigation measures and compensation measures have been reviewed in order to consider as many alternative actions as possible to alleviate the impacts of the project in Manitoba. For purposes of this chapter the term "mitigation" will be used interchangeably for compensation in describing these alternative measures.

Mitigation in Manitoba for damages caused by the Burlington project could be structural (physical), nonstructural (economic), or a combination of both. Structural measures could include levees or dykes along the channel in the low channel-capacity areas, stream channelization in these same areas, a floodway around these areas, or the reflooding of natural storage areas adjacent to the present channel to be managed as wildlife areas. Nonstructural mitigation measures could include purchase of flooded areas, replacement of flooded acreages with nonflooded acreages, purchase of flood easements, or payment to landowners of flooded acreages. Table 24 at the end of this section summarizes the mitigation measures discussed.

Structural Measures. -

a. Dykes. - Dykes could be constructed along the existing channel of the Westhope reach to handle flows up to 17.0 m^3/sec (600 cfs) allowing for 0.6 meter (2 feet) of freeboard. The dykes would handle flood flows during the late summer extended drawdown periods. The cost of this alternative is estimated to be $675,000 plus maintenance and would reduce net and gross average annual agricultural flood damages due to Burlington by somewhat less than $129 and $256, respectively.

Larger dykes could be constructed along the Westhope reach to handle flows up to 130 m^3/sec (4,600 cfs) or approximately the 12-percent flood peak. Costs would total about $4.2 million. If the dykes were constructed large enough to handle 363 m^3/sec (12,800 cfs), the 2-percent flood peak, costs would be about $10 million. This alternative would provide protection in the Westhope reach to the 1976 flood elevation and would reduce net and gross average annual agricultural damages by $129 and $478, respectively.

Urban damages due to Burlington at the Town of Melita could be reduced by dyking. Dykes constructed to protect to the 1976 flood elevation would cost about $200,000 and would reduce the gross average annual urban damages due to Burlington by $866.

b. Channelization. - In the Westhope reach it would be possible to widen and deepen the river channel in order to increase its capacity to a minimum of 17.0 m^3/sec (600 cfs). This alternative essentially entails a dredging operation, with disposal of the dredged material possibly being a problem. The mitigation effect of this alternative would be the same as for dykes. The cost estimate for improvement of the first 17.6 kilometers (11 miles) of channel in Canada is $2.5 million. Channelization to provide greater protection would be less cost effective relative to damages resulting from the Burlington Project when compared to dyking because of the large cost.

c. Floodway. - An alternative similar to channelization but one that would leave the existing channel intact would be a floodway approximately 17.6 kilometers (11 miles) in length around the flooded area. The floodway could be designed to have a capacity of 17.0 m^3/sec (600 cfs) or even greater if desired. The cost of this alternative for 17.0 m^3/sec (600 cfs) would be considerably more than for dyking or channelization, and thus relative to damages resulting from the Burlington project would not be as cost effective as dyking.

d. Wildlife Impoundment. - Natural storage areas in the Souris River floodplain could be reflooded. These areas are usually abandoned oxbows adjacent to the existing channels. However, it is unlikely that these impoundments would have sufficient capacity to reduce flood damages during major flood events. It would also be possible to dam off portions of the Souris Valley in Manitoba to create pools for the retention of floodwater and provide impoundments for the establishment of wildlife refuges. These refuges would be similar to the existing J. Clark Salyer National Wildlife Refuge in North Dakota. The cost for development of a refuge pond near Coulter with storage of water to elevation 430.7 meters (1413 feet) and provision of additional land up to elevation 431.3 meters (1415 feet) for waterfowl nesting cover is approximately $2 million. This alternative would provide mitigation in the Westhope reach through land use change and would provide for a reduction in net and gross average annual agricultural damages due to Burlington of $129 and $256, respectively, in the lower band, to elevation 429.8 meters (1410 feet).

A shallow reservoir of this size (810 hectares (2,000 acres)) would have large evaporation losses, and would have reduced the average flow from 0.43 m^3/sec (15 cfs) to 0.34 m^3/sec (12 cfs) at Coulter for the critical period, June to October from 1930 to 1941. The reservoir would extend south of the international boundary to Dam 357 in the J. Clark Salyer National Wildlife Refuge. Problems could arise because the structure would cause flooding in the short reach of the river from Dam 357 to the boundary and would limit the drawdown capabilities of the reservoir behind Dam 357.

Nonstructural Measures. -

a. Land Purchase. - The area flooded in the Westhope reach at a flow of 17.0 m^3/sec (600 cfs) is 140 hectares (350 acres). In order to prevent damages to private landowners, these lands could be purchased and turned over to the Manitoba government for subsequent management.

Management options could include leasing the land back to the original landowner, developing the areas into park and recreation areas, or developing the areas for fish and wildlife purposes. The purchase cost of this land, which would provide mitigation only during late summer project releases, would be about $54,000. Costs of acquiring the land could be partially recoverable if a lease back arrangement were selected.

Within the Westhope reach, approximately 1,025 hectares (2,530 acres) of flood prone land exists below elevation 432.8 meters (1420 feet). The purchase of these lands would cost approximately $393,400 and would provide full mitigation of the net and gross average annual agricultural damages of $129 and $478, respectively, in the Westhope reach.

If consideration were given to purchase of the entire flood prone area within the 1976 flood elevation from the international boundary to Hartney, the cost would be approximately $4.3 million. This alternative would involve the purchase of 7,800 hectares (19,500 acres) and eliminate all flood damage to the elevation of the 1976 flood, including the net and gross average annual agricultural damages of $194 and $5,006, respectively.

b. Flood Easements. - Easements could be purchased from landowners to compensate for damages. These easements would allow the landowner to retain control over the management of his land, recognizing the fact he would be flooded in certain years. A problem with this alternative is the difficulty in determining and showing those flood damages or areas affected by the Burlington project.

In the Westhope reach, easements could be purchased on the 140 hectares (350 acres) needed to handle a flow of 17.0 m^3/sec (600 cfs). The cost would be about $21,200. To obtain easements to elevation 432.8 meters (1420 feet) to compensate for all agricultural damages in the Westhope reach, 1,025 hectares (2,530 acres) would be included at a cost of about $154,600. If easements were obtained for all areas up to the 1976 flood elevation from the boundary to Hartney, the cost would approximate $1.7 million.

c. Acreage Replacement. - Those acres that would be adversely affected by the project could be replaced with nonflooded acres of equal value and equal agricultural production. This alternative would require the purchase of lands outside the area of the floodplain which would be turned over to the affected landowners. Those additional lands purchased would have to be purchased from a willing seller. The ownership of flooded lands would then revert to the Manitoba government and be treated in the same manner as the outright purchase of land alternative discussed above. Mitigation again would be comparable to that for land purchase, although the social impact of an unwilling seller losing his land and possibly his livelihood would be reduced but the area of impact would be increased. Acreage replacement of the 140 hectares (350 acres) in the Westhope reach would cost approximately $81,000. Replacement of the 1,025 hectares (2,530 acres) up to elevation 432.8 meters (1420 feet) in the Westhope reach would cost about $590,000. Acreage replacement of the 7,800 hectares (19,500 acres) from the boundary to Hartney would cost about $6.5 million.

d. Sinking Fund (Monetary Payment). - The United States Government could make a lump sum payment to the Canadian Government, based either on gross or net average annual damages or on claims for damages occurring in any given flood year. Net average annual agricultural damages, in those elevation bands in which they occur, plus net average annual urban damages would be $346. The estimate of gross average annual agricultural and urban damages is $5,872. Gross average annual damages do not take into account any benefits that may accrue to landowners because of reduced flood flows in some years.

It may also be possible for the United States Government to purchase an insurance policy to cover damages, thus having a private insurance company pay damage claims periodically as damages occur.

A one-time payment to compensate for gross damages would be about $82,000, assuming a 10-percent firm interest yield. As an indication of the inflation of damages over time an interest rate of 5 percent would require about $164,000. This alternative would include the cost of administering

the funds (20 percent of the initial investment) as well as a contingency fund (20 percent of the average annual damages) to offset the potential loss of a large portion of the funds in early years due to a series of high flood damage conditions.

If net damages in various elevation bands were considered, recognizing benefits accruing from the project due to reduced flows, the one-time payment would be about $4,800 at a 10-percent interest rate and about $9,600 at a 5-percent interest rate. This method considers only the net damages in common elevation bands, for example from elevation 429.8 meters (1410 feet) to elevation 432.8 meters (1420 feet) in the Westhope reach.

e. Nonmitigation. - If no mitigation actions were taken, the net average annual urban and agricultural loss in those elevation bands in which a net damage occurs to Canada would be $346. Considering gross average annual damages, not recognizing benefits, the loss would be $5,872 annually. Considering overall benefits and damages to Canada without reference to impact on individuals, the average annual impact would be a benefit of $5,356 annually.

B. ENVIRONMENTAL IMPACTS

The Burlington project could be one of the factors that would permit carp to invade the Souris River below Lake Darling Dam. As such an invasion cannot be considered to be a unique impact of Burlington project operation, no environmental mitigation measures specific to carp were identified. Because of the existing threat to the international waterfowl

resource by carp invasion, however, the Task Force notes that continuous monitoring of the Souris River above Wawanesa Dam could provide early detection of carp movement. Early detection would result in a better opportunity to apply control measures and to determine what factors induced the carp invasion. Further, if carp were detected above Wawanesa Dam in the early stages of an invasion there would be an opportunity to implement control measures and monitoring at Lake Darling Dam.

The Task Force notes that the U.S. Fish and Wildlife Service and the Corps of Engineers are currently making efforts to develop control measures to prevent carp from invading the National Wildlife Refuges in the United States. These efforts would be complementary to the measures described above.

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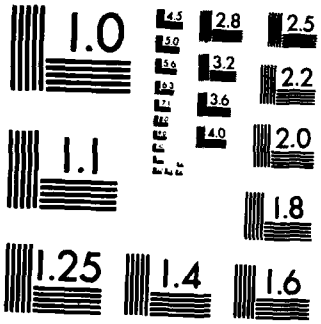
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Table 24 - Summary of Mitigation Measures

Type	Description	Damage Reduction(1)	Approximate Cost
Structural			
Dykes	A. Westhope reach, 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases	$675,000
	B. Westhope reach, 130-m^3/sec (4,600-cfs) capacity	Protect against 12-percent flood peak	4.2 million
	C. Westhope reach, in combination with channel improvement, 363-m^3/sec (12,800-cfs) capacity (1976 flood level)	Protect against 2-percent flood peak (full mitigation in Westhope reach)	10 million
	D. Dyke at Melita to 1976 flood level	Prevention of urban damage to 1976 flood level	200,000
Channelization	Westhope reach, 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases	2.5 million
Floodway	Westhope reach, 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases	Greater than channelization cost of $2.5 million
Wildlife Impoundment	Westhope reach to elevation 431.3 meters (1415 feet)	Elimination of most damages in Westhope reach	2.0 million
Nonstructural			
Land Purchase	A. 140 hectares (350 acres) in Westhope reach up to 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases	54,000
	B. 1,025 hectares (2,530 acres) in Westhope reach up to elevation 432.8 meters (1420 feet)	All damages in Westhope reach	393,400
	C. 7,800 hectares (19,500 acres) from boundary to Hartney up to elevation of 1976 flood	Full mitigation of agricultural damages	4.3 million
Flood Easements	A. 140 hectares (350 acres) in Westhope reach up to 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases	21,200
	B. 1,025 hectares (2,530 acres) in Westhope reach up to elevation 432.8 meters (1420 feet)	All damages in Westhope reach	154,600
	C. 7,800 hectares (19,500 acres) from boundary to Hartney up to elevation of 1976 flood	Full mitigation of agricultural damages	1.7 million
Acreage Replacement	A. Replacement of 140 hectares (350 acres) in Westhope reach up to 17.0-m^3/sec (600-cfs) capacity	Prevent late summer agricultural damages from project releases, plus reduced social impact	81,000
	B. Replacement of 1,025 hectares (2,530 acres) in Westhope reach up to elevation 432.8 meters (1420 feet)	All damages in Westhope reach plus reduced social impact	590,000
	C. Replacement of 7,800 hectares (19,500 acres) from boundary to Hartney, up to elevation of 1976 flood	Full mitigation	6.5 million
Sinking Fund	A. Based on net average annual damages in all reaches of $346	Net mitigation in elevation bands only, without regard to land ownership	$4,800 at 10 percent $9,600 at 5 percent
	B. Based on gross average annual damages in all reaches of $5,872	Full mitigation	$82,000 at 10 percent $164,000 at 5 percent
Nonmitigation	No action, net annual loss to Canada of $346, considering overall benefits and damages; net effect to Canada is an annual benefit - $5,356	None	-

(1) Does not include secondary economic and environmental impacts. See Chapter VII for discussion of environmental impacts.

VII ENVIRONMENTAL ASSESSMENT OF ECONOMIC MITIGATION ALTERNATIVES

A. INTRODUCTION

The environmental implications of structural mitigation alternatives identified in Chapter VI are discussed in general terms in this chapter. The alternatives are: dykes, channelization, a floodway, and a wildlife impoundment. The first alternative includes dyking at Melita and in the Westhope reach. The wildlife impoundment option also involves the Westhope reach, while channelization and construction of a floodway would involve the first 17.6 kilometers (11 miles) of the Souris River in Manitoba. To avoid duplication, the environmental implications of combined structural alternatives have not been discussed separately.

B. DYKES

Westhope Reach. - Dykes would be constructed along the existing channel to handle flows up to 17.0, 130, or 363 m^3/sec (600, 4,600, or 12,800 cfs). During dyke construction, there would likely be some addition of soil material into the Souris River through disturbance of the existing soil base and placement of new fill. This alternative would cause an increase in the sediment load of the river during the construction period.

Following construction, erosion of the newly constructed dykes by Souris River flows would occur until the dykes had become stabilized by vegetation. Addition of sediments to the river would be most significant during high spring flows.

The extent of increased sediment loading due to dyke construction would depend on the construction methods employed. However, it would probably be relatively minor and the effects on migrating or spawning fish would probably be insignificant.

Due to the absence of suitable bankside waterfowl habitat in the Westhope reach at the present time, construction of dykes would not have a significant impact on waterfowl populations in the immediate area. Some short-term impact on furbearer populations inhabiting the banks of the river

may occur through disturbance during construction. However, this impact would probably not be significant. Other wildlife species, such as deer and upland game birds, may also experience disturbance during the dyke construction period. Due to the low use of the Westhope reach by these species, the effect of this disturbance would be insignificant.

In general, the environmental implications of dyke construction in the Westhope reach are likely to be minor and short-term.

Melita. - Since dyking would take place in the Town of Melita itself, the effects of its construction on various aspects of the environment would be insignificant.

C. CHANNELIZATION

The first 17.6 kilometers (11 miles) of the Souris River would be widened and deepened to increase channel capacity to a minimum of 17.0 m^3/sec (600 cfs). Since the existing channel in the Westhope reach has already been channelized to some degree it is therefore relatively straight; consequently the first 9.6 kilometers (6 miles) of the channel would not be realigned. However, the remaining 8.0 kilometers (5 miles) would likely include some straightening.

The most significant effect of channelization would be the addition of large amounts of silt to the sediment load of the Souris River. The effects of sediment loading on aquatic life were described by the U.S. Fish and Wildlife Service in its evaluation of the potential impacts of the Garrison Diversion Unit[1] and by the International Roseau River Engineering Board which identified potential impacts of proposed flood control works on the Roseau River.[2] Increased sedimentation and turbidity would reduce the availability of suitable spawning habitat in the downstream reaches of the river and reduce species diversity of macroinvertebrate fauna, thereby causing a reduction in preferred food types available to game fish species. These effects would lead to diminished fish populations in the areas affected.

(1) United States Fish and Wildlife Service. 1976. An evaluation of the impacts caused by the Garrison Diversion Unit on national wildlife refuges in North Dakota. Unpubl. rept. 113 pp.

(2) International Roseau River Engineering Board. 1975. Joint studies for coordinated water use and control in the Roseau River Basin. Main Report and Appendices.

Breeding and juvenile ducks are heavily dependent on invertebrates as a source of protein.[1] Availability of such invertebrates is improved in slower moving, more protected areas of the river where there is also more extensive development of aquatic emergent vegetation. Silt and other materials transported by the river would tend to be deposited in these areas resulting in detrimental effects to invertebrate populations and aquatic vegetation. Such effects would be reflected in reduction in the use of these areas by waterfowl.

Another environmental problem associated with channelization is disposal of the dredged material. Since the locations for disposal are not known, the effect of disposal activity on the environment cannot be determined. Upland habitat on the bottomlands of the Westhope reach is of poor quality and deposition of dredged material would probably not significantly affect wildlife populations; however, to be effective, channelization would have to be continued well into the Peninsula Bridge reach where habitat is of higher quality. Fish and wildlife could be significantly affected in this reach. As with dyking, noise disturbance associated with the dredging activity would cause some wildlife to vacate the area until the operation had been completed. This impact would be a short-term and relatively minor impact.

Widening of the river channel necessitates removal of existing riverbanks and any vegetation that has developed there. Present riverbank vegetation in the Westhope reach is poorly developed due to frequent submersion of the bottomlands. Removal of bank material is therefore unlikely to significantly affect wildlife in this reach. Wildlife would be more seriously affected by removal of riverbank vegetation in the Peninsula Bridge reach.

Following channelization, erosion of the new banks would occur, resulting in further additions of sediment to the Souris River as was described in the dyking mitigation alternative. Such sediment loading would continue for several years until bank stabilization occurred.

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(1) Swanson, G. A., M. I. Meyer and J. R. Serie. 1974. Feeding ecology of breeding blue-winged teals. J. Wildl. Manage. 38(3): 396-407.
Krapu, G. L. and G. A. Swanson. 1975. Some nutritional aspects of reproduction in prairie nesting pintails. J. Wildl. Manage. 39(1): 156-162.

Use of the reach by certain bank dwelling furbearers, such as muskrat and beaver, may increase following channelization. This would depend on the nature of the new bank material and water level fluctuations. Because of the increased potential for downstream sedimentation and the extension of channelization into the Peninsula Bridge reach, impact of the channelization alternative would be greater than that of the dyking alternative. The impact of channelization is however considered to be relatively low.

D. FLOODWAY

The floodway alternative would presumably involve new bottomlands within the heights of land fringing the Westhope reach. From an environmental standpoint, this alternative is essentially a combination of channelization and dyking: large amounts of material would have to be removed and disposed of and flows would be directed along a channel of newly prepared material. Increased sediment loading of the river would occur, following completion of the floodway, from erosion of unstabilized material. The environmental effects of increased sediment loading have already been described. The impact would be similar to the dyking alternative but would extend over a wider area and would include more productive habitat.

E. WILDLIFE IMPOUNDMENT

A dam could be built at the downstream end of the Westhope reach to create a pool similar in nature to those in the J. Clark Salyer National Wildlife Refuge. This mitigation alternative is distinct from the preceding ones since it alleviates the costs arising from flooding by transferring land use from agriculture to wildlife. Therefore, there are definite wildlife benefits to be gained from this alternative.

Assuming that water levels in the impoundment could be controlled and suitable upland and aquatic vegetation could be developed, several hundred ducks could be produced annually from the pool. Construction of nesting islands and other habitat improvement measures would significantly increase the waterfowl production of the impoundment.

Furbearers populations in the reach would experience a significant increase. Muskrats would probably benefit the most since many waterfowl habitat management techniques are also conducive to muskrats. Other furbearers such as mink, fox, and raccoon may also increase in relation to the presence of waterfowl and muskrats. Ungulate use of the area would probably remain largely unaffected.

The presence of an impoundment in the Westhope reach may adversely affect the operation of Dam 357 in the J. Clark Salyer National Wildlife Refuge. In periods of high flows, the reservoir resulting from impoundment would extend south of the international boundary to Dam 357 and could seriously limit its drawdown capabilities. This alternative could hinder management practices and reduce the potential of the refuge to produce the desired number of ducks.

F. ENVIRONMENTAL STATEMENT

The environmental impact of the structural mitigation measures can generally be considered to be low but will be greater than the direct environmental impact of the project itself. Because the cost of these measures prohibited their serious consideration by the Task Force, measures for mitigating their environmental effects were not considered. The impoundment alternative would result in some environmental enhancement.

VIII DISCUSSION AND CONCLUSIONS

A. DISCUSSION

In carrying out the studies outlined in the Plan of Study which accompanied the Board's Directive of April 5, 1978, the Task Force made extensive use of its 1977 report to the Board and the study reports of the Souris River Basin Study. In a number of instances, new information or different techniques emerged from the Souris River Basin Study which updated or modified the results of the studies leading to the 1977 Task Force report. Where the discrepancies between the two would cause problems with the use of the results of the Souris River Basin Study, the Task Force modified its previous results as required. In the case of minor discrepancies which would not affect this use, the discrepancies were simply noted.

In addition to the requirements of the Board's Plan of Study, the Task Force found it necessary to review the project details and update the project description contained in the 1977 Task Force report. A revised project description is provided in Chapter II of this report.

With reference to the above, and recognizing that project details will continue to be discussed by the Corps of Engineers and the U.S. Fish and Wildlife Service, the Task Force reiterates that this study of the impacts of the Burlington project is based on adherence to the operating plan described in the 1977 report to the Board.

With respect to the Board's Plan of Study, the following points must be kept in mind during any review of the results of this study.

Flood Damage Relationships. - As described in Chapters III and IV, the Task Force made full use of the flood damage relationships derived in the Souris River Basin Study. In so doing, the Task Force recognized that some of the assumptions required to develop a workable economic

model for the Souris River Basin Study departed from conventional economic evaluation practice. In addition, the increases or decreases in flood damages computed for specific floods imply a degree of certainty which exceeds the reliability of the available data, both hydrologic and economic, and is not obtainable in flood routing through a distance of several hundred kilometers (miles). However, the results of the estimates of flood damages with and without the Burlington project are considered to define within reasonable limits the economic effects in Canada of the project.

As noted in Chapter III, the Souris River Basin Study used a different method of routing flows in Manitoba than that originally used by the Task Force. In order to enter the economic model on the same basis as the Souris River Basin Study, the Task Force reviewed the hydraulic analysis of the nine floods evaluated in the 1977 report and subsequently rerouted four of them. This rerouting resulted in some changes in stage and duration data from the 1977 report.

Damage data and flood damage relationships in the Souris River Basin Study were used without modification. All dollar values are expressed in terms of 1975 Canadian dollars.

Land Ownership Identification. - The land ownership maps contained in Appendix C were prepared from material supplied by the Province of Manitoba. During preparation of the maps it became apparent that the impact of floods on most landowners could be reasonably approximated by bands between selected elevations in each of the five reaches studied. This approximation was used to compute representative impacts for individual landowners in the study area.

Statistical Base Studies. - A further review of Burlington Dam operation relative to theoretical and historic floods failed to reveal any statistical relationship between flood peak frequency in Manitoba and Burlington operation. As discussed in Chapter III, this result is to be expected because peak flows and flood volumes at Sherwood are significantly modified

by runoff between Sherwood and Westhope so that a theoretical 100-year or 500-year event at Sherwood might result in an entirely different frequency event at Westhope. Consequently, theoretical floods were not used in the current economic studies.

In order to provide for the consideration of flood duration along with peak stage and frequency, the Souris River Basin Study analyzed the period of record from 1936 to 1976 and found that it was a reasonable representation of the long-term flows that could be anticipated on the Souris River. As a result, this 41-year period of record was used as the statistical base for the Souris River Basin Study. The Task Force agreed that the assumptions made were reasonable. For this reason and to maintain a basis for comparison with the Souris River Basin Study results, the 41-year historic base was adopted by the Task Force. Based on the operating plan, the Task Force determined that the Burlington project would have been used in 18 of the 41 years. As the effects of the project on flows for 9 of these years had already been studied by the Task Force, the remaining 9 years were evaluated to determine the incremental effects of Burlington over the entire 41-year period.

To provide a means of determining preproject flows in years in which Burlington would operate, the Task Force developed the procedure described in Chapter III A. It is noted that, insofar as is practical, the U.S. Fish and Wildlife Service has declared its intention to take advantage of the increased capacity provided by the recently completed channel improvement through Minot so that Lake Darling would be used less in the future for flood control should the Burlington project not proceed. The U.S. Fish and Wildlife Service has provided the Task Force with a description of these management criteria. Thus, the future results of operation of Lake Darling in the absence of the Burlington project could differ somewhat from the operation which produced the historic record.

Economic Impact of Burlington Operation. - The economic effects due to Burlington operation were taken as the difference between the average of damages sustained over the 41-year period under historic

conditions and the average of damages sustained over the 41-year period with Burlington operating in 18 of the years. As required in the Plan of Study, both gross (increases in damages only) and net (increases and decreases in damages) average annual damages were computed. Separate values were developed for three elevation bands in the five agricultural reaches studied and for the urban centers of Melita, Souris, and Wawanesa.

The results of the economic studies reinforce the findings of the original Task Force study. The increase in average annual damages attributable to operation of the Burlington project would be very low in comparison to average annual damage from historic flooding over the same period. The net average annual damage for all agricultural reaches and urban centers, in all reaches where net damage would occur, would be $346. The gross average annual damage (benefits ignored) for the same area would be $5,872. Combining all estimated damages and benefits for the entire study area would result in a net benefit to Manitoba of $5,356.

Economic Mitigation Measures. - The Task Force identified a number of structural and nonstructural mitigation measures. Evaluation of the costs of implementing the structural measures indicated that costs would be far in excess of benefits. Costs of the nonstructural measures are also high relative to their benefits. Flood easement and a sinking fund arrangement for damage payments appear to have some advantages relative to their cost. The nonmitigation alternative also warrants consideration.

Evaluation of the Physical Impact on Manitoba of Alterations to the Structures in the J. Clark Salyer Wildlife Refuge. - Two alternatives for alteration of the J. Clark Salyer Refuge structures were considered by the Corps of Engineers and the U.S. Fish and Wildlife Service. The alternative selected involves no increase in size of structure openings and the Task Force has determined that the effect on Manitoba would be minimal.

Environmental Impact. - As noted in Chapter IV, the Task Force has determined that the unique environmental impact of operation of the Burlington project would be minor. Further, the project might provide some minor enhancement of sport fisheries in Manitoba and Saskatchewan. In some years, however, the project could prove to be the factor which would provide the necessary combination of elements to allow carp to migrate from the Assiniboine River to the Souris River below Lake Darling and establish resident populations. It should be noted that other activities such as improved sewage treatment, changes in refuge management practices, and future diversions in Canada or the United States could produce the same effects, resulting in a similar migration. The ultimate effect of such a migration could be an annual loss to Canada of 7,000 birds in some years from the international waterfowl resource, primarily from the Souris National Wildlife Refuges.

If carp, for one reason or another, did gain access to the Souris River, operation of Burlington Dam in those relatively rare years (once in about 100 years) in which the Lake Darling spillway would be drowned out would permit carp to negotiate the dam and pass into Lake Darling and the Upper Souris River. The direct loss to Saskatchewan from such an event could be about 2,400 waterfowl annually. In addition to the impact on waterfowl, carp migration could negate the project benefits to the sport fisheries in Saskatchewan and Manitoba.

Environmental Mitigation Measures. - No mitigating measures were identified for the potential invasion of carp into the Souris River above Wawanesa Dam because this impact is not unique to the Burlington project. Since the invasion of carp would be the primary environmental impact associated with the project, possible measures were discussed. The discussion described monitoring measures that could be undertaken and also noted current efforts by the U.S. Fish and Wildlife Service and Corps of Engineers to develop control measures.

As noted above, after reviewing the range of possible structural and nonstructural mitigation measures, the Task Force determined that the cost of the structural alternatives prohibited their serious consideration. A preliminary evaluation of the environmental impact of these alternatives did, however, indicate that they would generally have a greater adverse direct environmental impact than the project itself.

B. CONCLUSIONS

In response to the Board's directive the Task Force has reached the following conclusions. As with the findings of the 1977 Task Force report, these conclusions are based on the assumption that the Burlington project operating plan described in Chapter III of the 1977 report will be followed in years in which the Burlington project is operated.

1. Relative to the historic agricultural and urban flood damages determined by the Canada-Manitoba-Saskatchewan Souris River Basin Study for the 41-year period from 1936-1976, operation of the Burlington project would result in net average annual damages in all elevation bands where net damage would occur by $346 and gross average annual damage (benefits ignored) by $5,872 in Manitoba. Combining all estimated damages and benefits for the study area in Manitoba would result in a net benefit to Manitoba of $5,356 annually.

2. The unique environmental impact of operation of the Burlington project on Manitoba and Saskatchewan would be minimal, and could result in some slight enhancement of sport fisheries in the two Provinces. The project has the potential, as could other activities, however, to be the cause of carp migration from the Assiniboine River to the Souris River Basin below Lake Darling. In turn, carp infestation of the river could result in the loss to Canada of 7,000 birds from the international waterfowl resource in some years and could negate the project benefit to the Manitoba sport fishery.

3. If, for any reason, carp become established in the Souris River below Lake Darling, operation of the Burlington project could, in some years, permit carp to negotiate the Lake Darling Dam through submergence of the spillway crest. Carp infestation of Lake Darling and the upper Souris River could result in the annual loss of about 2,400 waterfowl to Saskatchewan and negate the project benefit to Canada in Saskatchewan sport fishery.

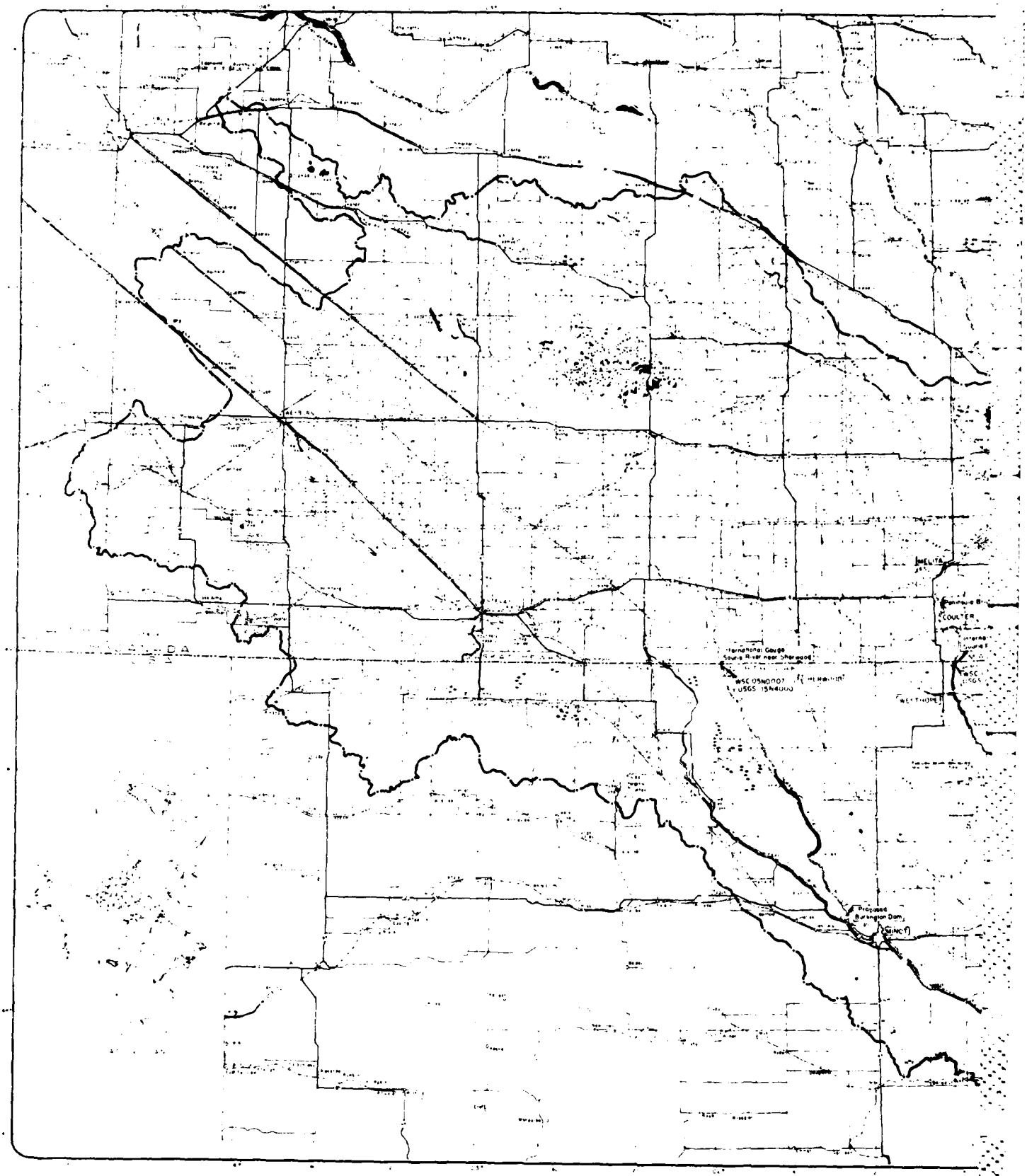
4. Although structural mitigation measures to mitigate flooding impacts in Manitoba were identified, their costs would, under normal conditions, render them unfeasible. A combination of nonstructural alternatives, particularly flood easements and a sinking fund for damage compensation, warrants consideration. Costs would range from $4.3 million for purchase of all flood prone lands up to the elevation of the 1976 flood to $4,800 for a sinking fund to compensate for the net average annual damage, assuming a firm interest rate of 10 percent.

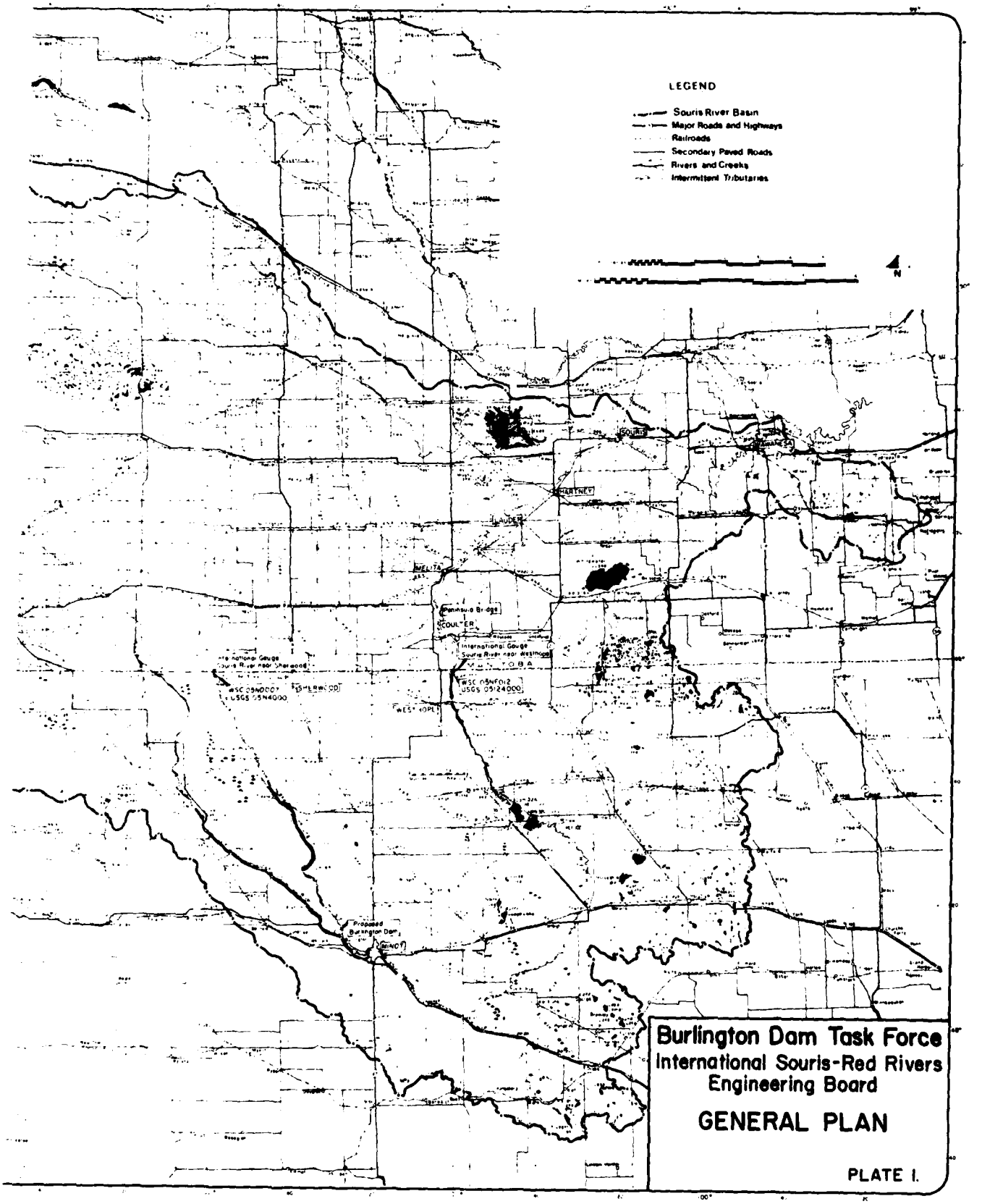
The nonmitigation alternative also warrants consideration.

5. No environmental impact is expected to result from the nonstructural mitigation measures.

6. The structural alterations in the J. Clark Salyer Wildlife Refuge that have been agreed to by the U.S. Fish and Wildlife Service and the Corps of Engineers, if implemented, should result in minimal physical impact on flows in the Souris River entering Manitoba.

7. The problem of carp migration into the Souris River above Wawanesa Dam, although not unique to the Burlington project, is serious enough to warrant consideration of possible control measures.


International Gauge
Souris River near Sherwood
WSC 05NO007
USGS 15N40W
Proposed
Burlington Dam
(Saint)
COULTER
WESTHOPE



Burlington Dam Task Force
International Souris-Red Rivers Engineering Board

GENERAL PLAN

PLATE I.

U.S.GPO:1979-665-055/84 Region No. 6

2

APPENDIX A

TASK FORCE BACKGROUND

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B.	TASK FORCE MEMBERSHIP	A-4
C.	MEETING SCHEDULE	A-7

APPENDIX A

TASK FORCE BACKGROUND

A. PLAN OF STUDY

The Plan of Study to be followed by the Burlington Dam Task Force in complying with the Board's Directive of April 5, 1978 should consist of the following.

1. Flood Damage Relationships

The relationships between flooding and damage in the agricultural and urban areas along the Souris River in Manitoba derived in the Souris River Basin Study should be reviewed and adapted as necessary for the use of the Task Force.

2. Land Ownership Identification

Due to the potential for beneficial as well as adverse economic effects, the ownership of lands along the main stem of the Souris River that would be affected by floods up to and including the 1976 flood should be determined and the various parcels identified on the available contour maps of the area.

3. Statistical Base Studies

The Task Force should carry out studies to determine a reasonable method of relating the effects of the operation of the Burlington Dam project to a common statistical base with existing flow, stage, and damage information. These studies may involve the evaluation of additional flood events. The studies should also include the assembly of pre-project baseline data for determination of the natural runoff which would occur downstream between Burlington Dam and the international boundary.

4. Economic Impact of Burlington Operation

Based on discharge-flood damage relationships for the flood events evaluated by the Task Force, gross damages in Manitoba, with and without Burlington project operation should be computed for each damaged reach and affected urban area. Impacts of the Burlington project operation on individual Manitoba landowners should be evaluated whenever a probability exists that uncompensated adverse effects may occur.

The results of these studies should show the estimated benefits and damages that could be sustained in Manitoba due to operation of the Burlington project in any one of the selected flood years. These damages should include the economic impact of physical damages to land, crops and structures and should also include, to the extent possible with available information, estimates of indirect damages such as flood fighting costs, reduced property values, lost income and employment, to the Manitoba economy. In addition, if a satisfactory statistical relationship is derived from the statistical base studies, the average annual damages that could be expected with and without the Burlington project operation should be determined.

5. Mitigating Measures

The nature, scope, and cost of implementing measures identified by the Task Force to mitigate both the total effects and the uncompensated adverse effects of the Burlington project should be determined. Where mitigation measures involve annual expenditures, these should be brought to present value to achieve a first cost for each measure. Mitigation programs should use information available from all sources, including the Souris River Basin Study to the greatest extent possible.

6. Evaluation of the Physical Impact on Manitoba of Alterations to the Structures in the J. Clark Salyer Wildlife Refuge

Detailed plans for alterations to the structures in the J. Clark Salyer Wildlife Refuge are not available. This study will evaluate the impact on flows and levels in the Souris River in Manitoba of the range of

changes in the wildlife pool stage-discharge relationships that could occur within the limitations of the capacity of the channels connecting the pools. The elevation should consider the historical range of low, normal, and high flow years and should be based on typical annual objectives for operation of the Refuge obtained from the United States Fish and Wildlife Service. A comparison with the actual operation of the Refuge in the years selected should be provided. Any significant changes in flows in Manitoba resulting from changes in refuge operation attributable to the structure alterations should be applied to the flood events evaluated by the Task Force in its October, 1977 report and to any additional flood events evaluated in the present study.

7. Environmental Impact

The environmental impact on Manitoba of the operation of the Burlington project will be assessed along with the environmental impact of each mitigation measure that is seriously considered by the Task Force together with identification of any measures required to offset adverse environmental effects. In addition, the environmental impact, if any, of the project on Saskatchewan should be evaluated. The study results should consist of environmental statement on the project effect and on each mitigation alternative. The environmental study should result in an analysis equivalent to a preliminary environmental assessment and should allow the identification of significant problems that may require further detailed investigations. The study should use the available results from the Souris River Basin Study to the greatest extent possible.

B. TASK FORCE MEMBERSHIP

Chairman - United States Section

April 1978 to Date	J. R. CALTON,* Chief, Planning Branch U.S. Army, Corps of Engineers, 1135 U.S. Post Office and Customs House St. Paul, Minnesota 55101

Members - United States Section

April 1978 to December 1978	D.W. HOUSEWORTH Assistant Area Manager Hatcheries/Fishery Resources U.S. Fish and Wildlife Service P.O. Box 1897 Bismarck, North Dakota 58501
April 1978 to Date	W.R. SCOTT + District Chief U.S. Geological Survey, WRD 821 East Interstate Avenue Bismarck, North Dakota 58501
December 1978 to Date	D.E. SIMPSON Staff Biologist U.S. Fish and Wildlife Service P.O. Box 1897 Bismarck, North Dakota 58501
April 1978 to Date	E. B. SODERQUIST Reports Coordinator Planning Division Bureau of Reclamation P.O. Box 1017 Bismarck, North Dakota 58502
April 1978 to Date	D.A. SPRYNCZYNATYK* Director, Engineering Division North Dakota State Water Commission State Office Building 900 East Boulevard Bismarck, North Dakota 58505

Chairman - Canadian Section

April 1978 to Date	R.P. BALDWIN* Chief, Water Planning & Management Branch Inland Waters Directorate Western and Northern Region Environment Canada First Floor, Motherwell Building 1901 Victoria Avenue Regina, Saskatchewan S4P 3R4

Members - Canadian Section

April 1978 to Date	P. N. BOOTHROYD Habitat Assessment Biologist Canadian Wildlife Service Western and Northern Region Environment Canada Freshwater Institute 501 University Crescent Winnipeg, Manitoba R3T 2N6
April 1978 to Date	R.J. BOWERING Assistant Head, Water Planning Section Water Resources Division Manitoba Department of Mines, Natural Resources and Environment 1577 Dublin Avenue Winnipeg, Manitoba R3E 3J5
April 1978 to March 1979	J.A. BRAY Resource Analyst Economics Branch Manitoba Department of Agriculture 903 - 401 York Avenue Winnipeg, Manitoba R3C OP8
April 1978 to Date	F.R.J. MARTIN Hydrologic Engineer, Hydrology Division Prairie Farm Rehabilitation Administration 7th Floor, Motherwell Building 1901 Victoria Avenue Regina, Saskatchewan S4P OR5

April 1978 to November 1978	DR. R.B. OETTING Wildlife Specialist Wildlife Section, Operations Division Manitoba Department of Renewable Resources & Transportation Services 1495 St. James Street Winnipeg, Manitoba R3H OW9
November 1978 to Date	W.N. HOWARD Fisheries Biologist Western Region Manitoba Department of Mines, Natural Resources and Environment 1129 Queens Avenue Brandon, Manitoba R7A 1L9

Alternates

L. Bidlake	for	R.B. Oetting (June 20, 1978)
R. Harrison	for	R.J. Bowering (September 7, 1978)
E. Wesolowski	for	E. B. Soderquist (November 21, 1978)
T. Crooks	for	E. B. Soderquist (December 12, 1978)

* Members of Initial Task Force

+ W.R. Scott retired from active service with the United States Geological Survey in December, 1978 but kindly consented to assist the Task Force with the preparation of its report after that date.

C. MEETING SCHEDULE

Date	Location	Remarks
1978		
April 18	Winnipeg; Manitoba	H. Nelson, U.S. Army Corps of Engineers, United States Observer
May 16	Bismarck, North Dakota	J. Malcolm, U.S. Fish and Wildlife Service, United States Observer R. Wright, U.S. Fish and Wildlife Service, United States Observer
June 20	Winnipeg, Manitoba	
August 3	Bismarck, North Dakota	W. Dybvig, Saskatchewan Department of the Environment Canadian Observer D. Henegar, North Dakota State Game and Fish Service United States Observer D. Simpson, U.S. Fish and Wildlife Service, United States Observer D. Stewart, U.S. Fish and Wildlife Service United States Observer S. Zschomler, U.S. Fish and Wildlife Service United States Observer
September 6	St. Paul, Minnesota	Meeting with International Souris-Red Rivers Engineering Board
September 7	St. Paul, Minnesota	
September 27	Regina, Saskatchewan	R. Pentland, Saskatchewan Department of the Environment Canadian Observer
October 24	Winnipeg, Manitoba	
November 21	Bismarck, North Dakota	J. Malcolm, U.S. Fish and Wildlife Service United States Observer
December 12	Winnipeg, Manitoba	D. E. Simpson, U.S. Fish and Wildlife Service United States Observer

Date	Location	Remarks
1978		
		V. Chacko, Environment Canada Canadian Observer
1979		
January 18	Winnipeg, Manitoba	Included meeting with International Souris-Red Rivers Engineering Board
February 22	Bismarck, North Dakota	J. Malcolm, U.S. Fish and Wildlife Service United States Observer
		R. Wright, U.S. Fish and Wildlife Service United States Observer
		F. Pfeifer, U.S. Fish and Wildlife Service United States Observer
March 22	Winnipeg, Manitoba	
May 24	St. Paul, Minnesota	Meeting with International Souris-Red Rivers Engineering Board to review draft of report

APPENDIX B

FLOOD HYDROGRAPHS

APPENDIX B

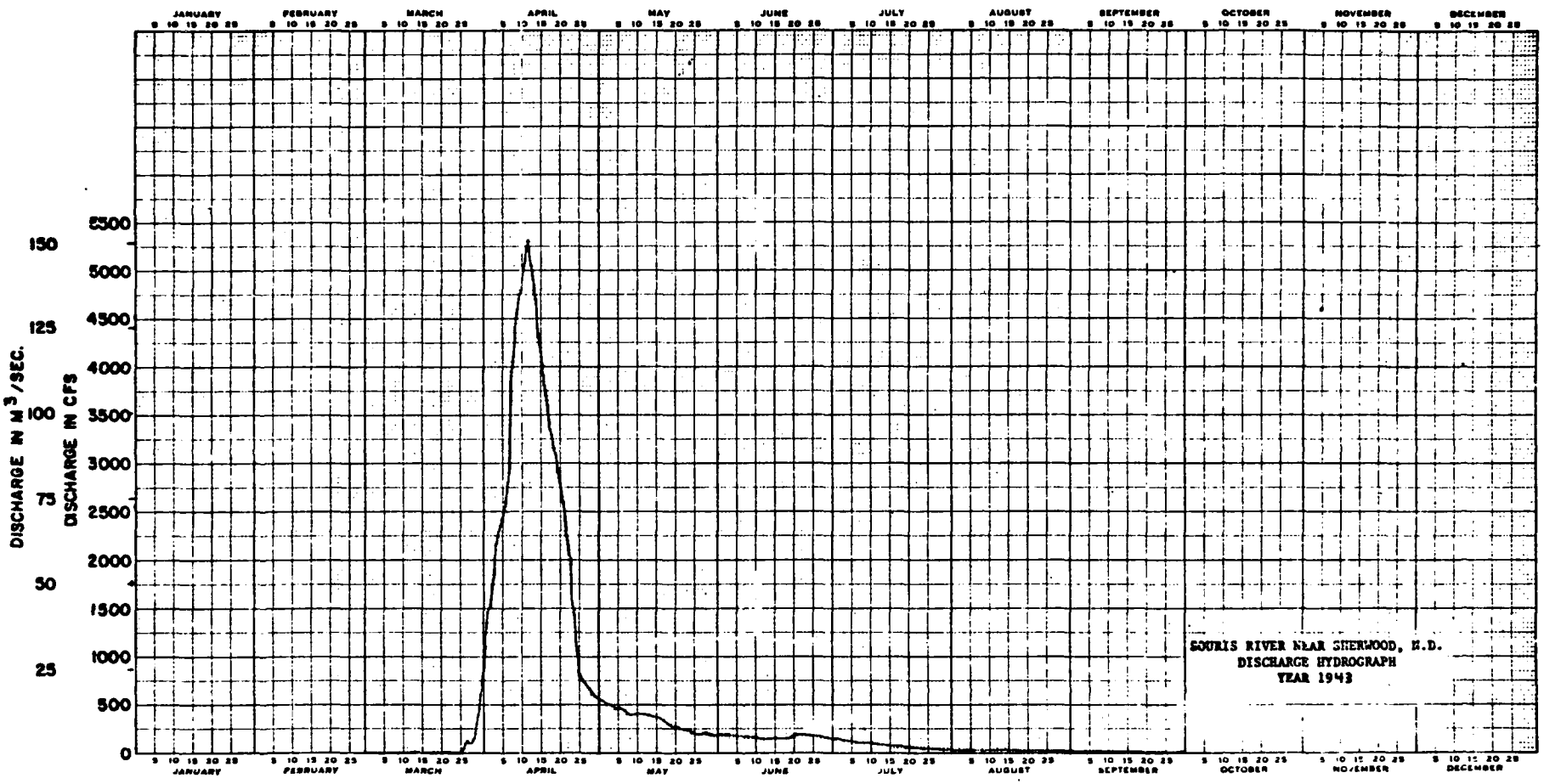
TABLE OF CONTENTS

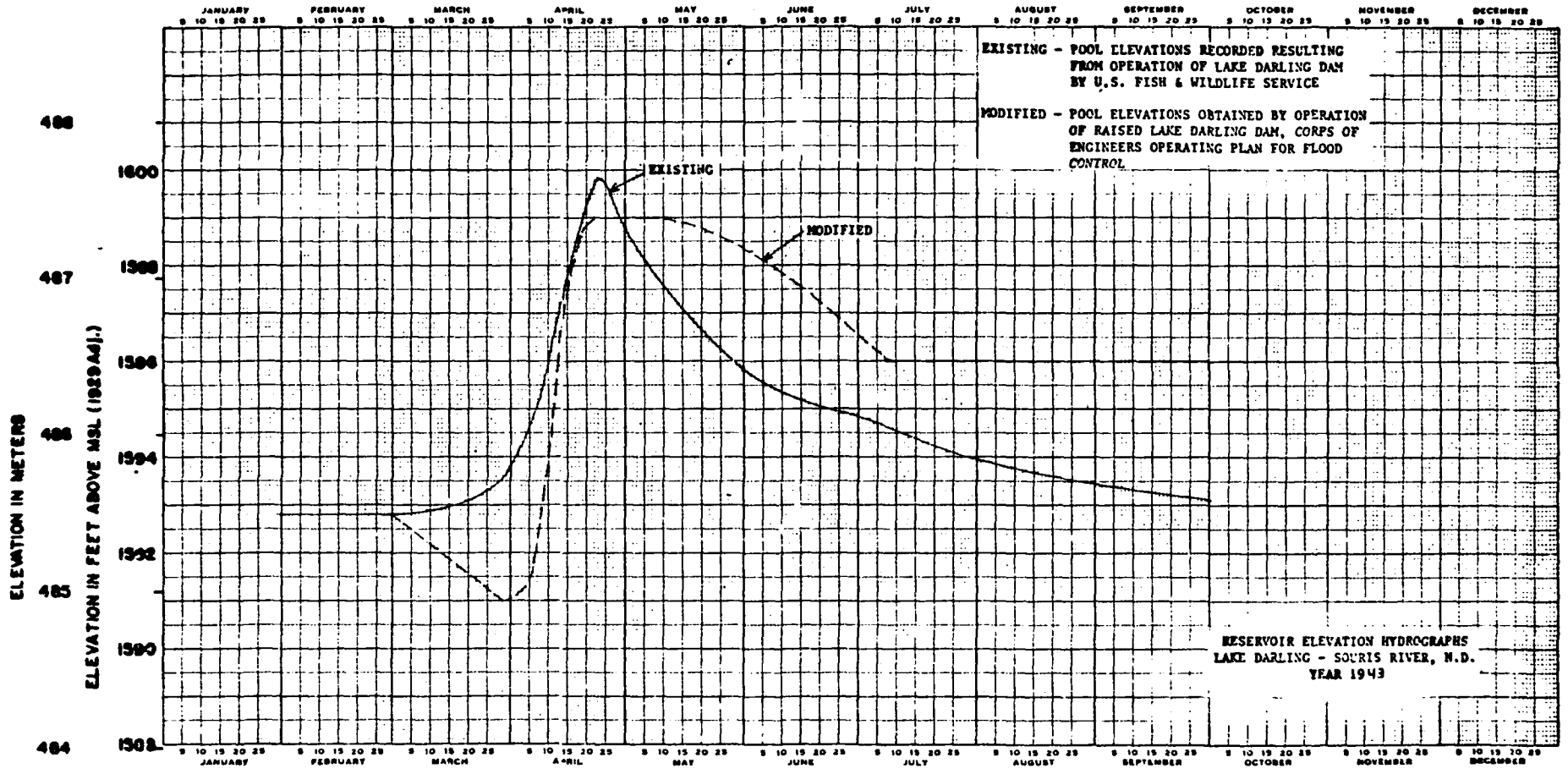
NOTE: The hydrographs in this appendix are grouped sequentially by year. Each group contains hydrographs for the existing and modified flows at the following points:

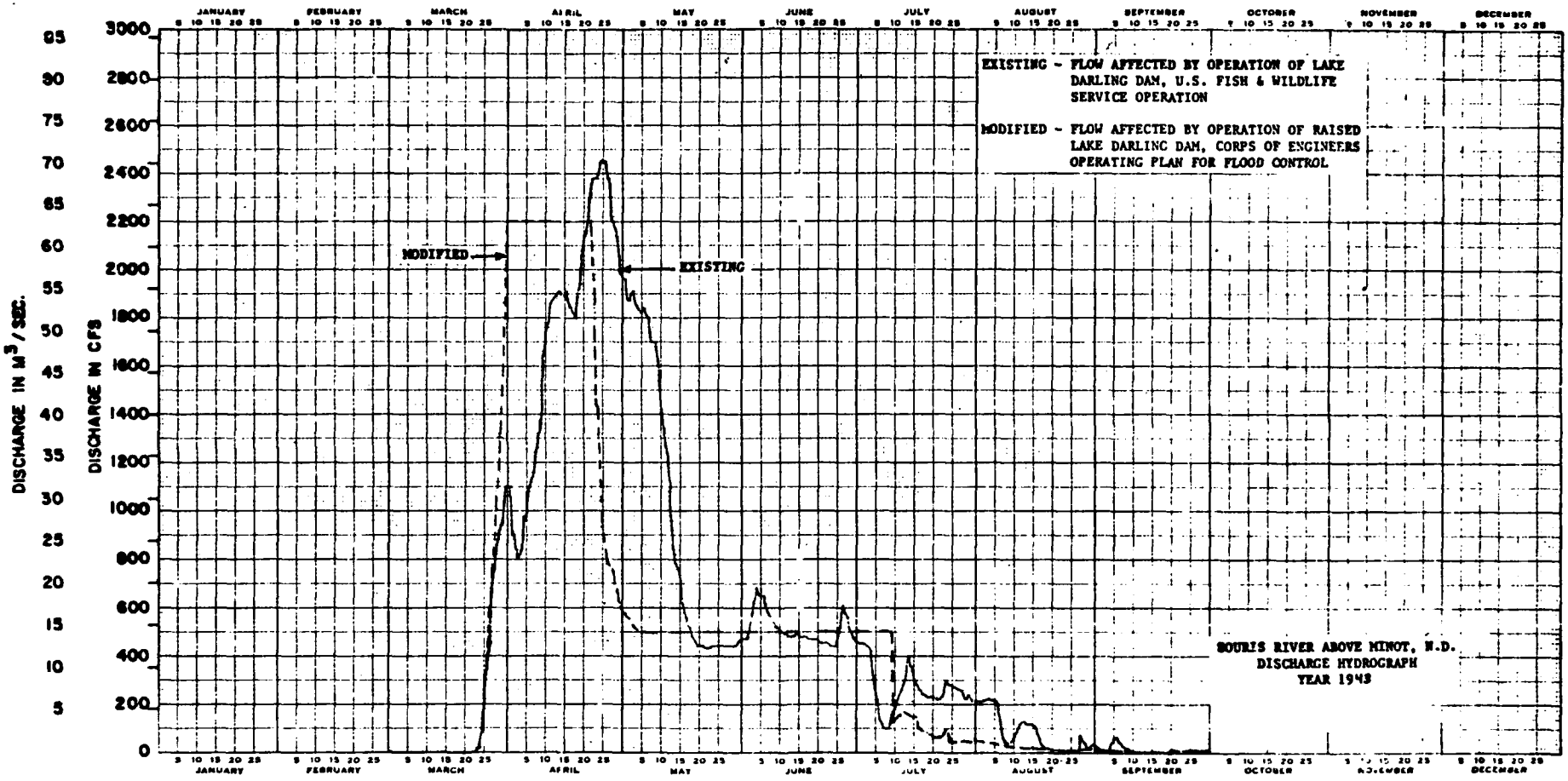
Sherwood
Lake Darling - Burlington
Minot
Westhope
Peninsula Bridge
Highway No. 3 Bridge
Lauder Bridge
Hartney Bridge
Souris
Wawanesa

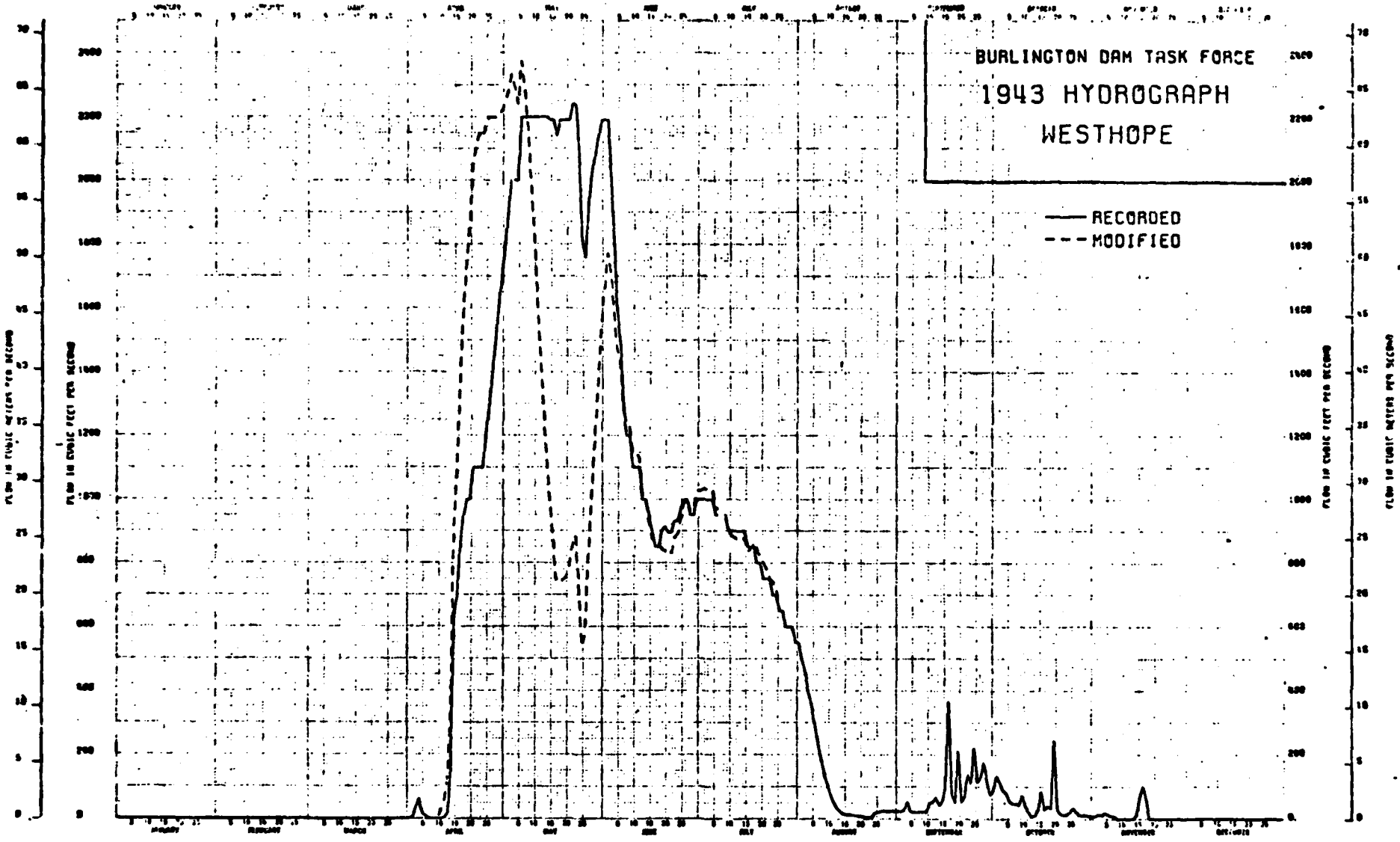
Year	Page
1943	B-1
1947	B-13
1948	B-25
1949	B-37
1950	B-49
1951	B-61
1953	B-73
1955	B-85
1956	B-97
1960	B-109
1965	B-121
1969	B-133
1970	B-145
1971	B-157
1972	B-169
1974	B-181
1975	B-193
1976	B-205

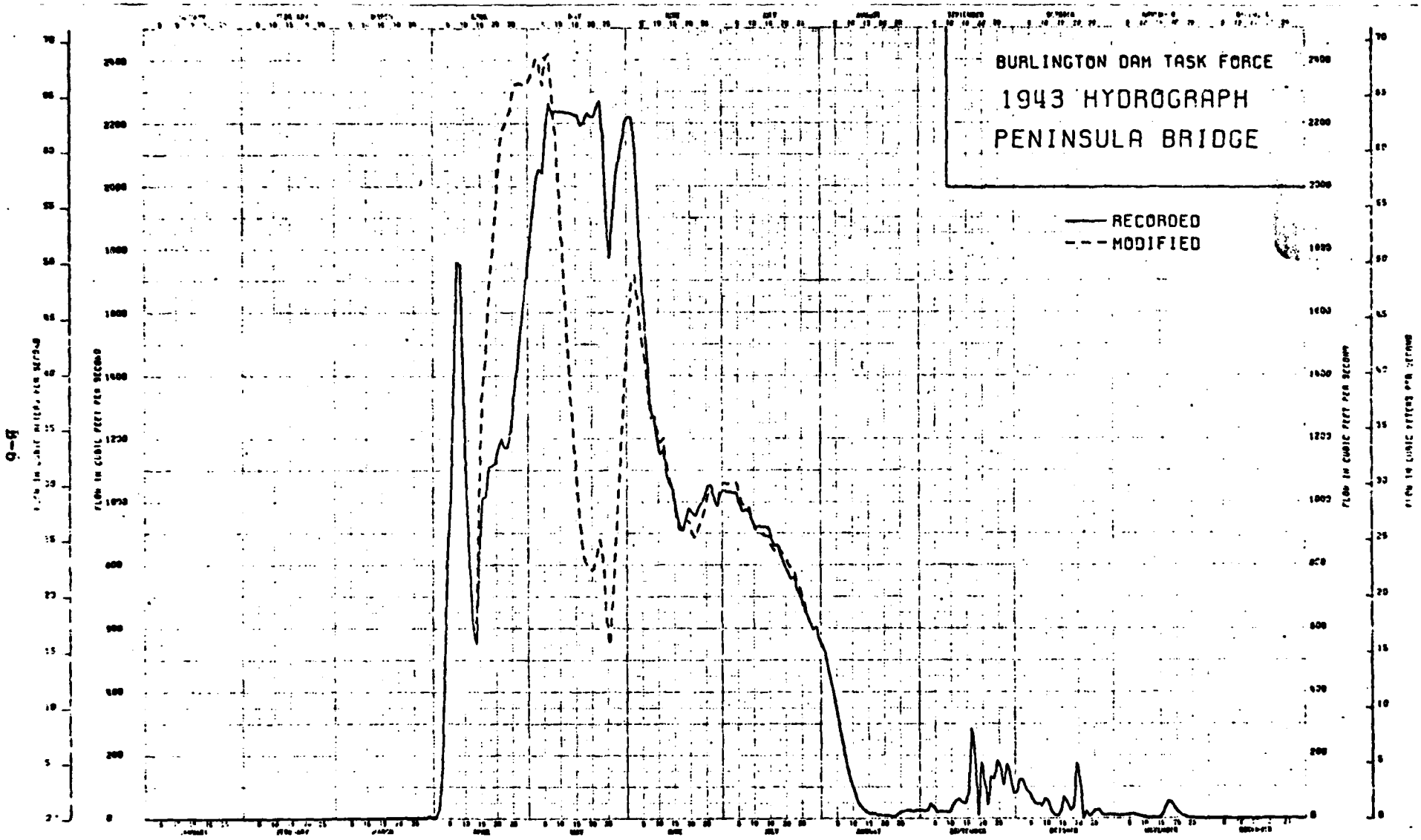
1943

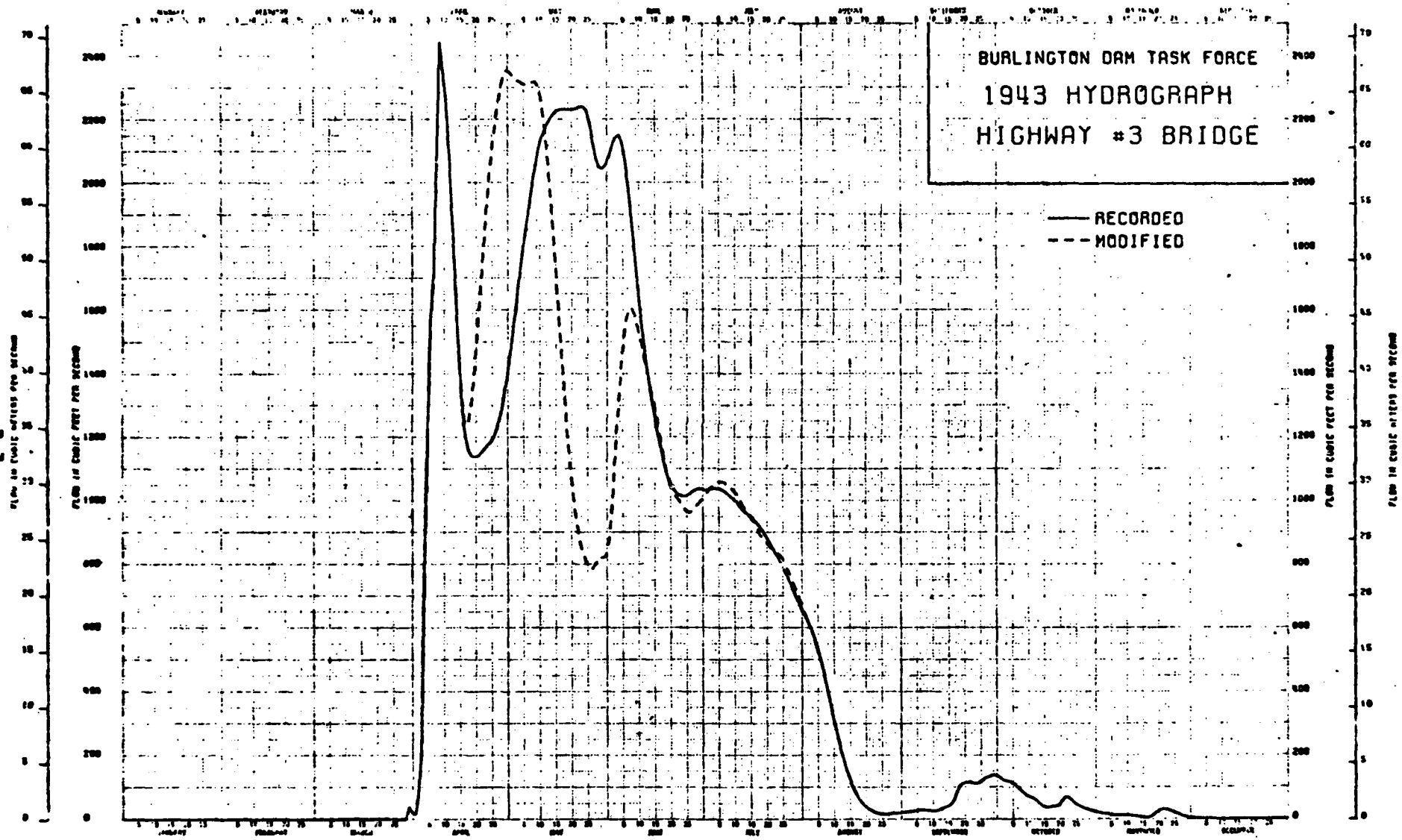

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
150
125
100
75
50
25
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1943

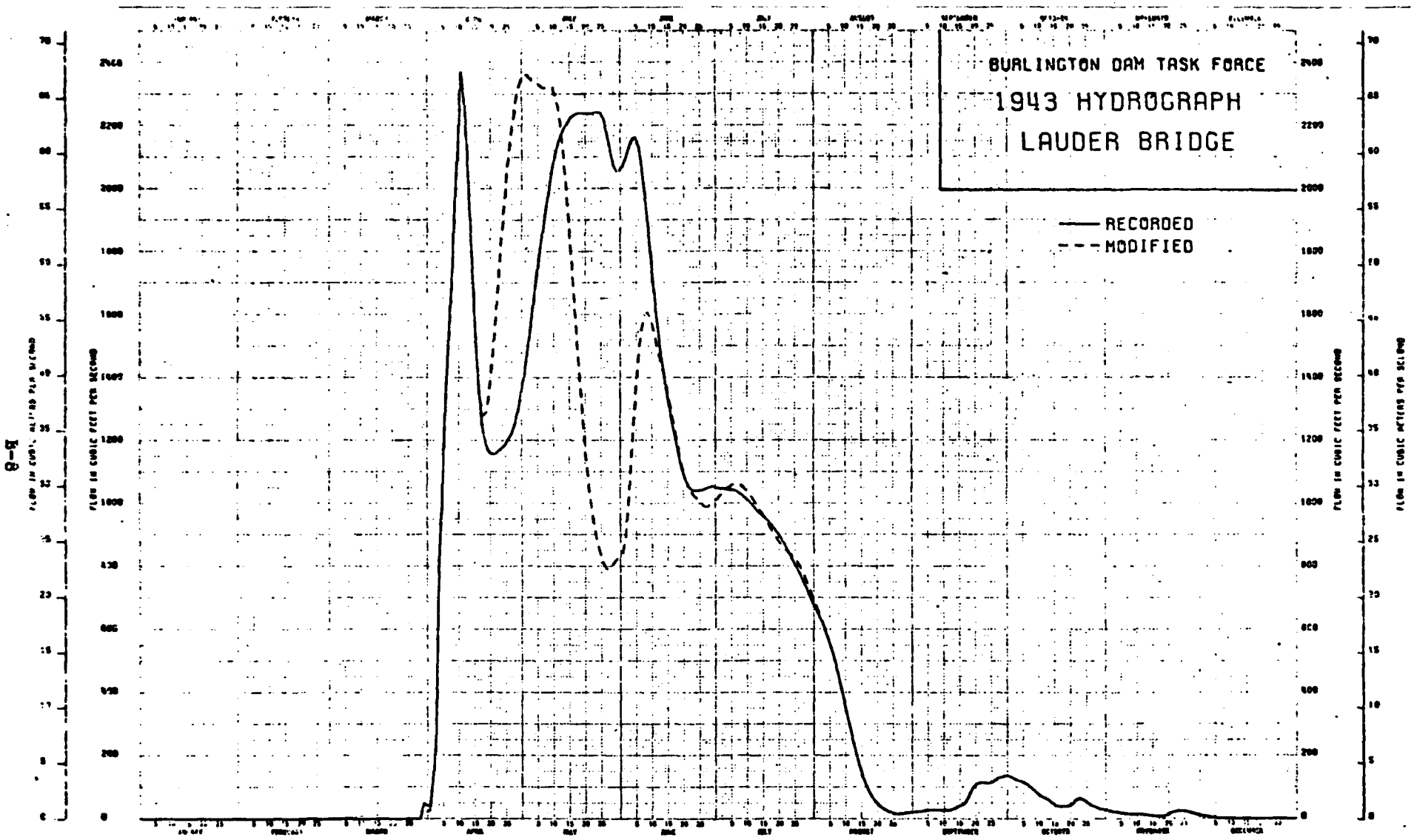

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1943
ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
488
487
486
485
484
1600
1598
1596
1594
1592
1590
1588
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

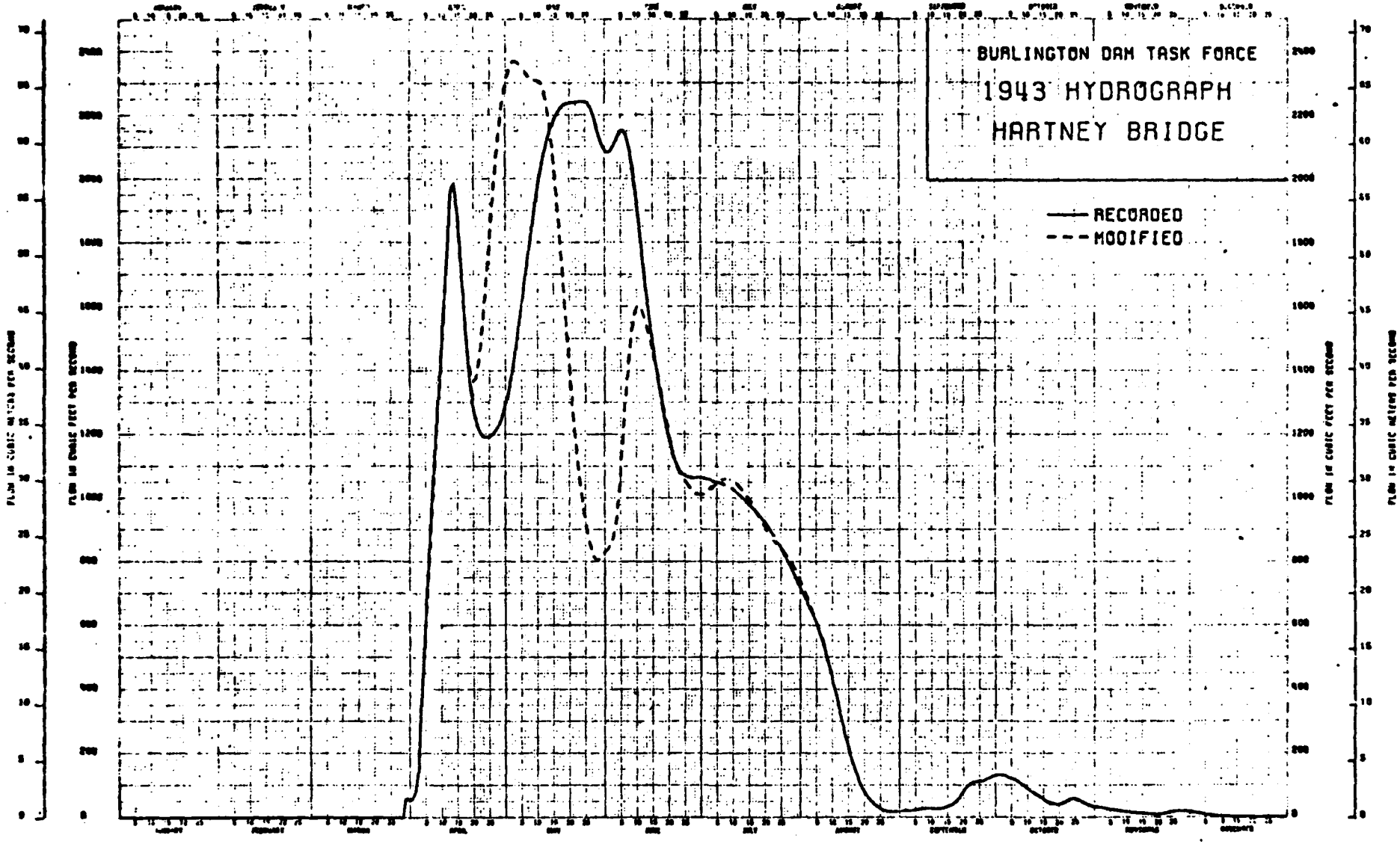

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1943
DISCHARGE IN CFS
DISCHARGE IN M³/SEC.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

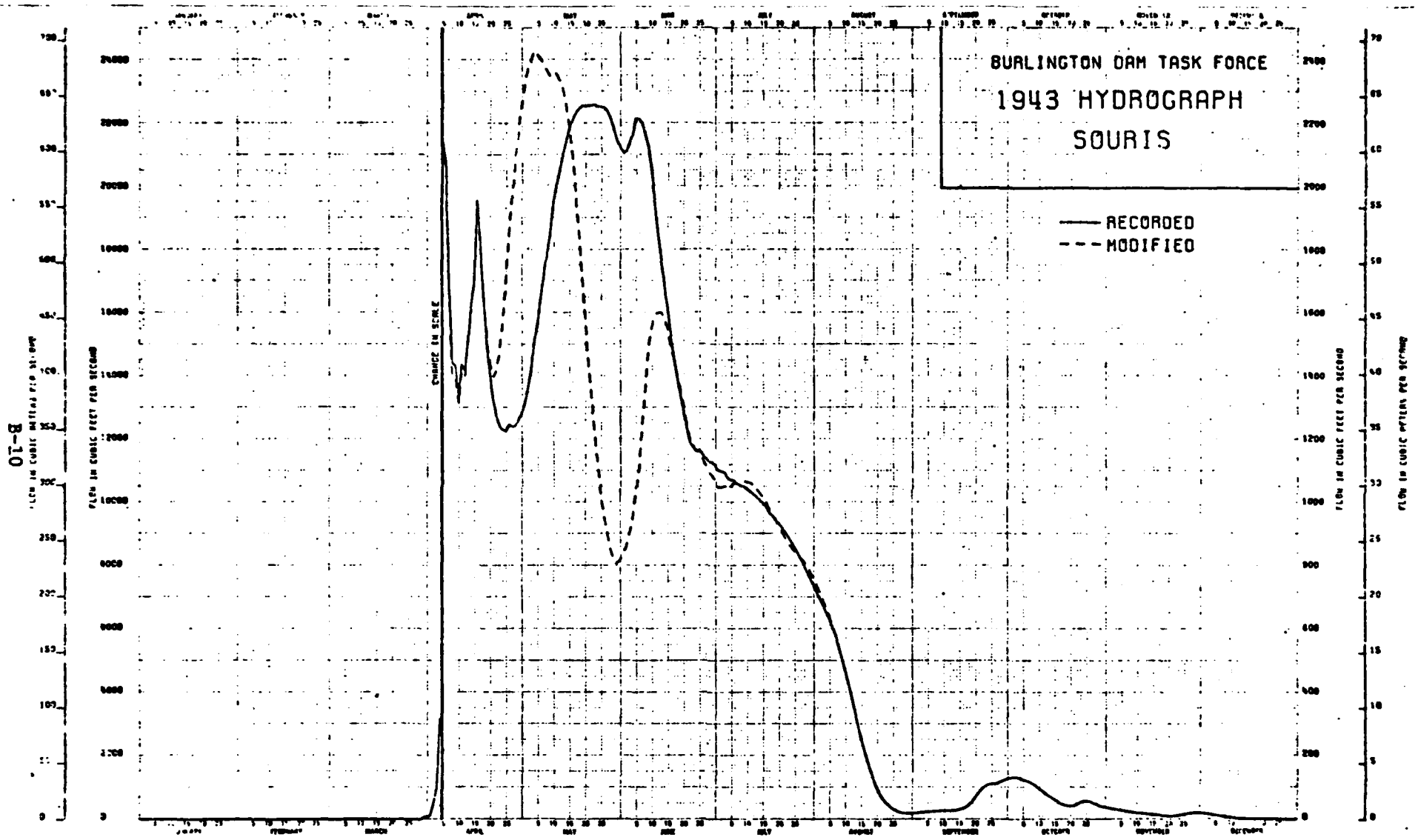

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

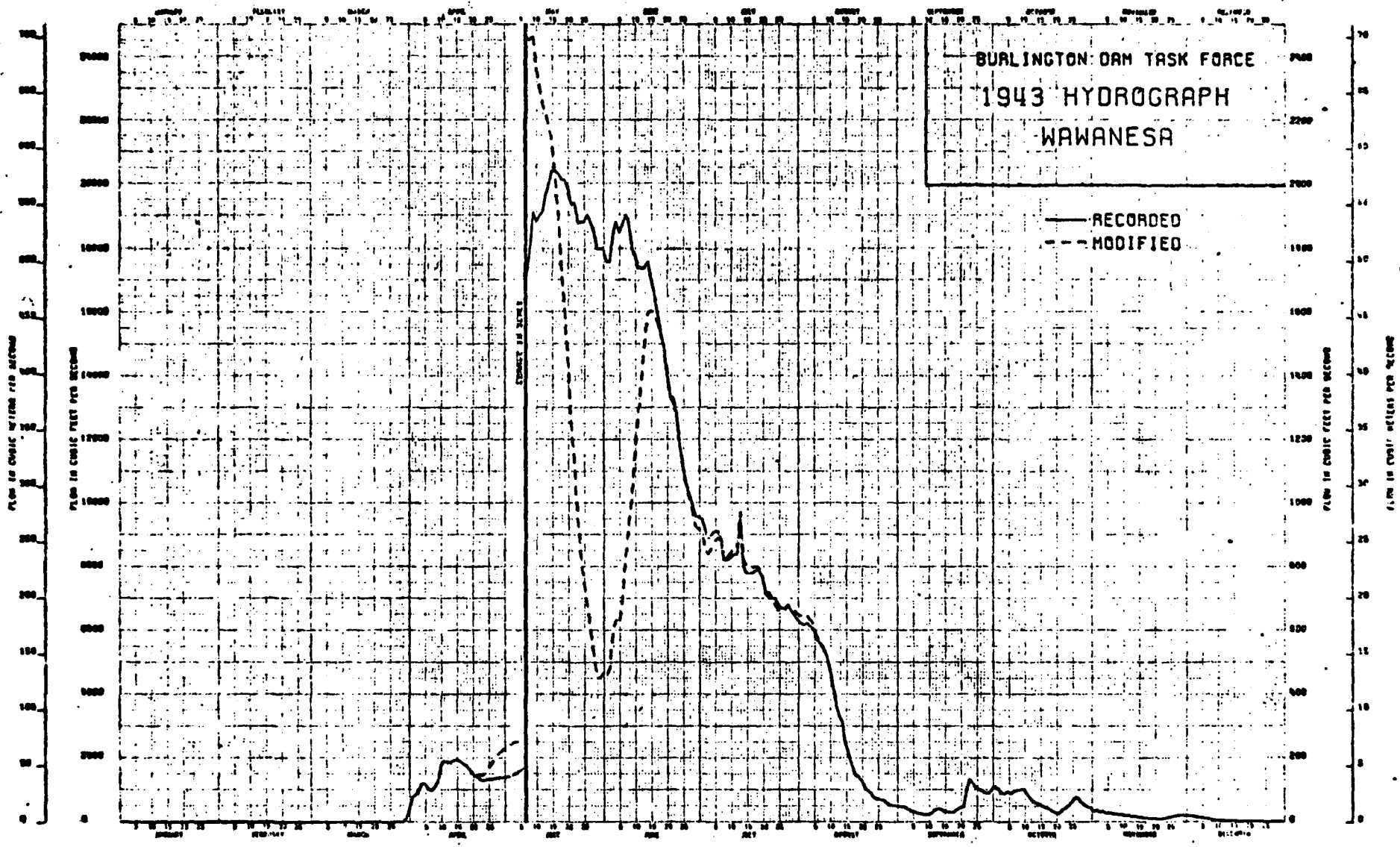

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED

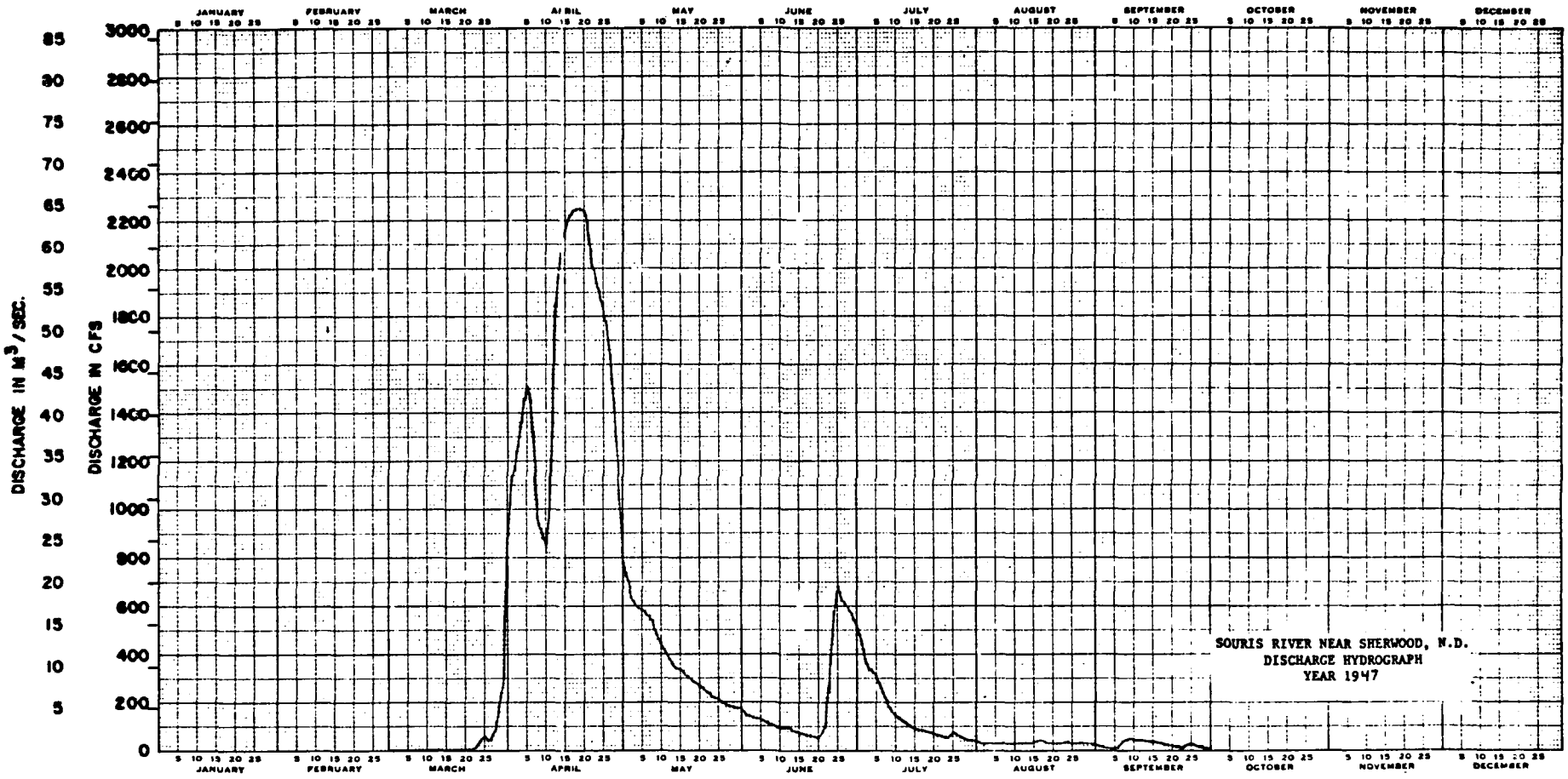

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

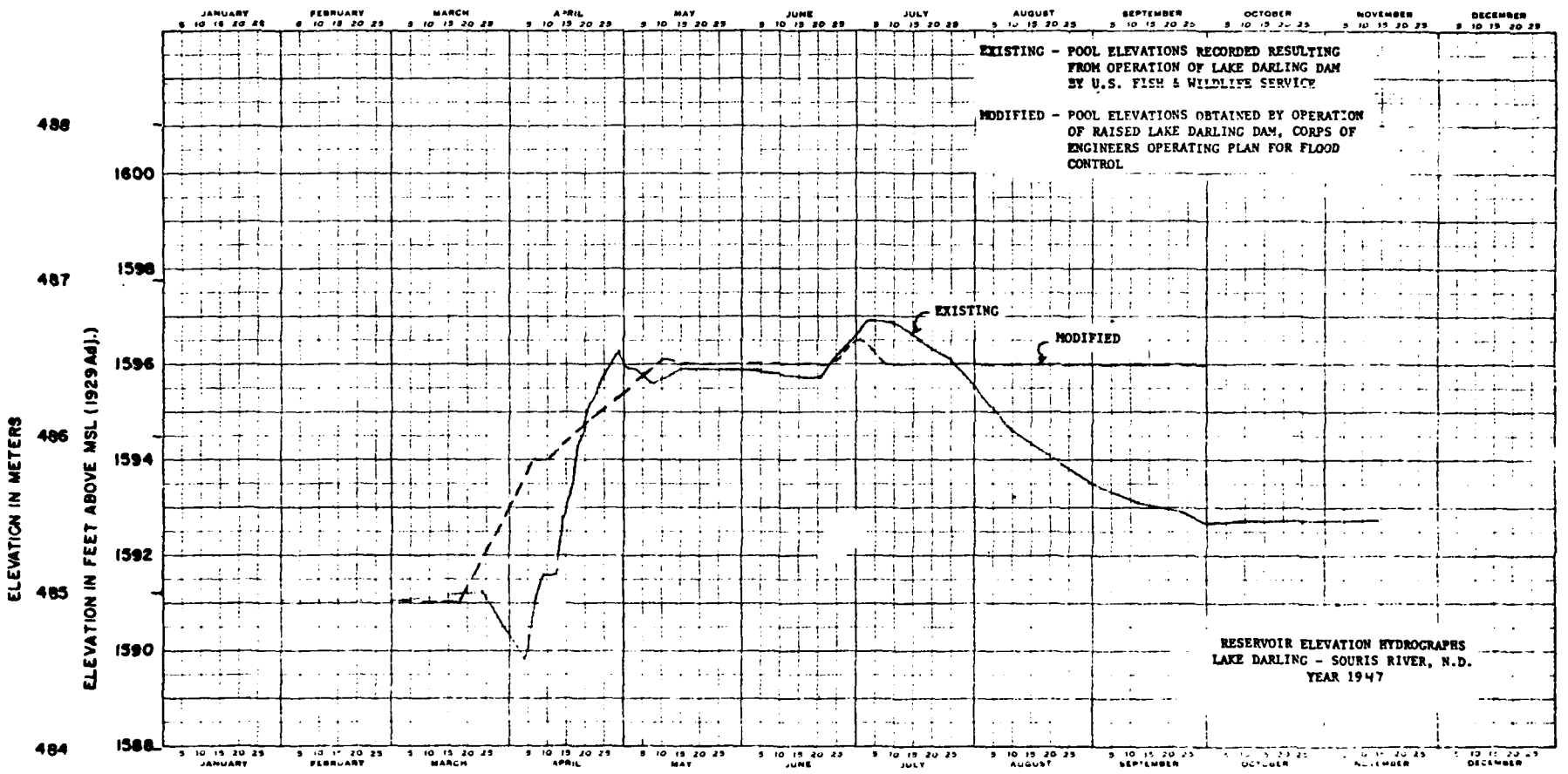

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED

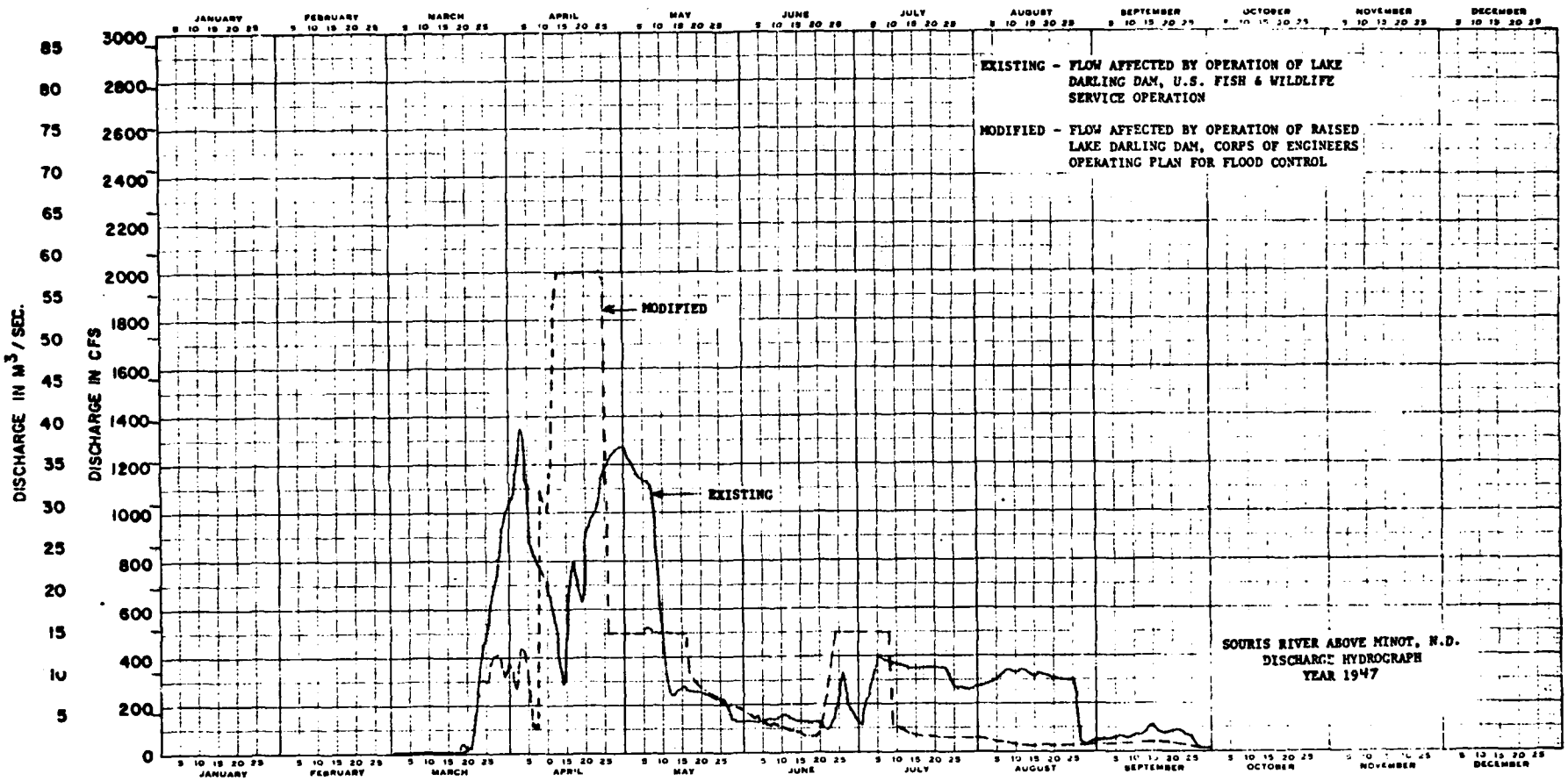

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

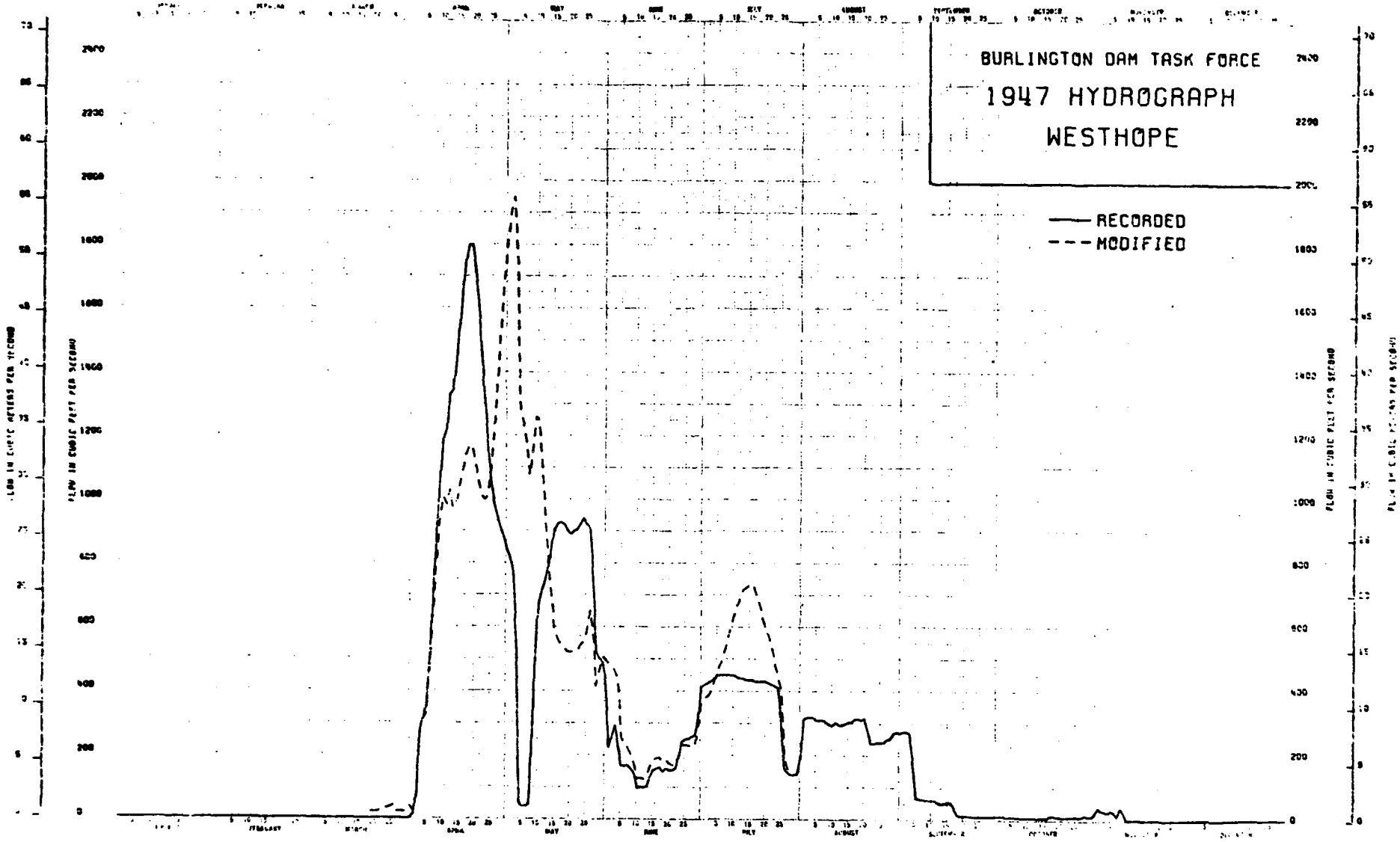

BURLINGTON DAM TASK FORCE
1943 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED

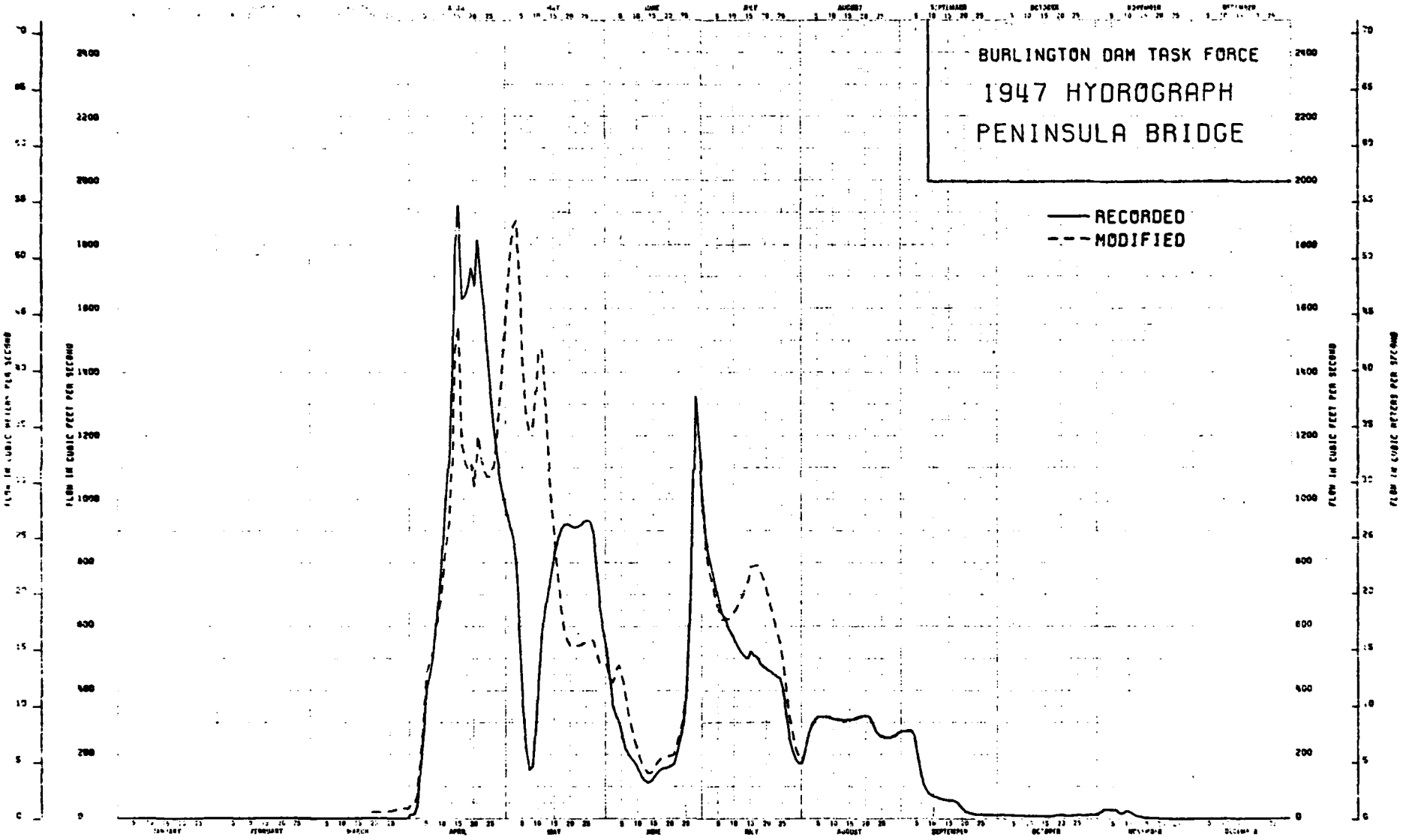
1947

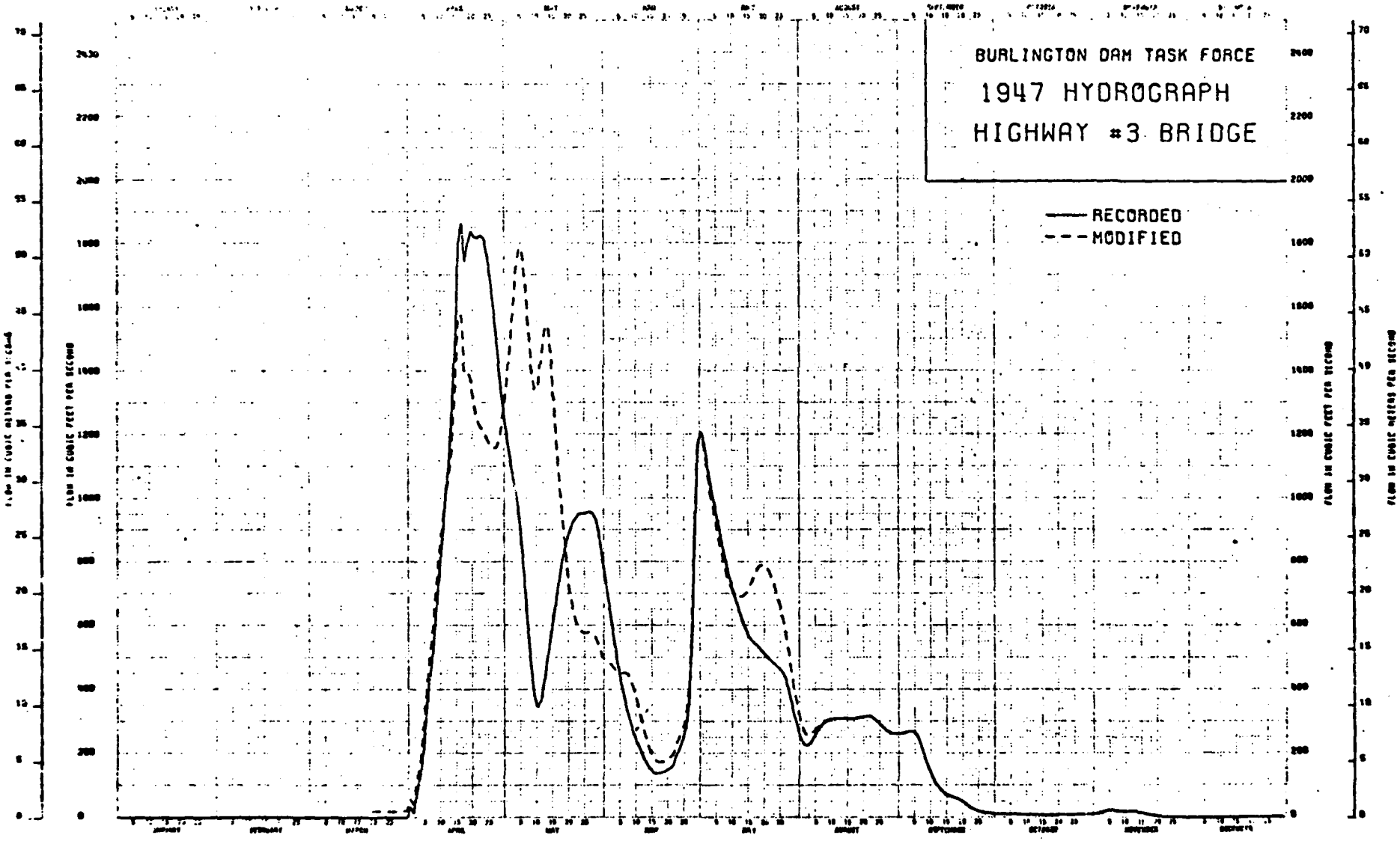

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN M³/SEC.
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
DISCHARGE IN CFS
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1947

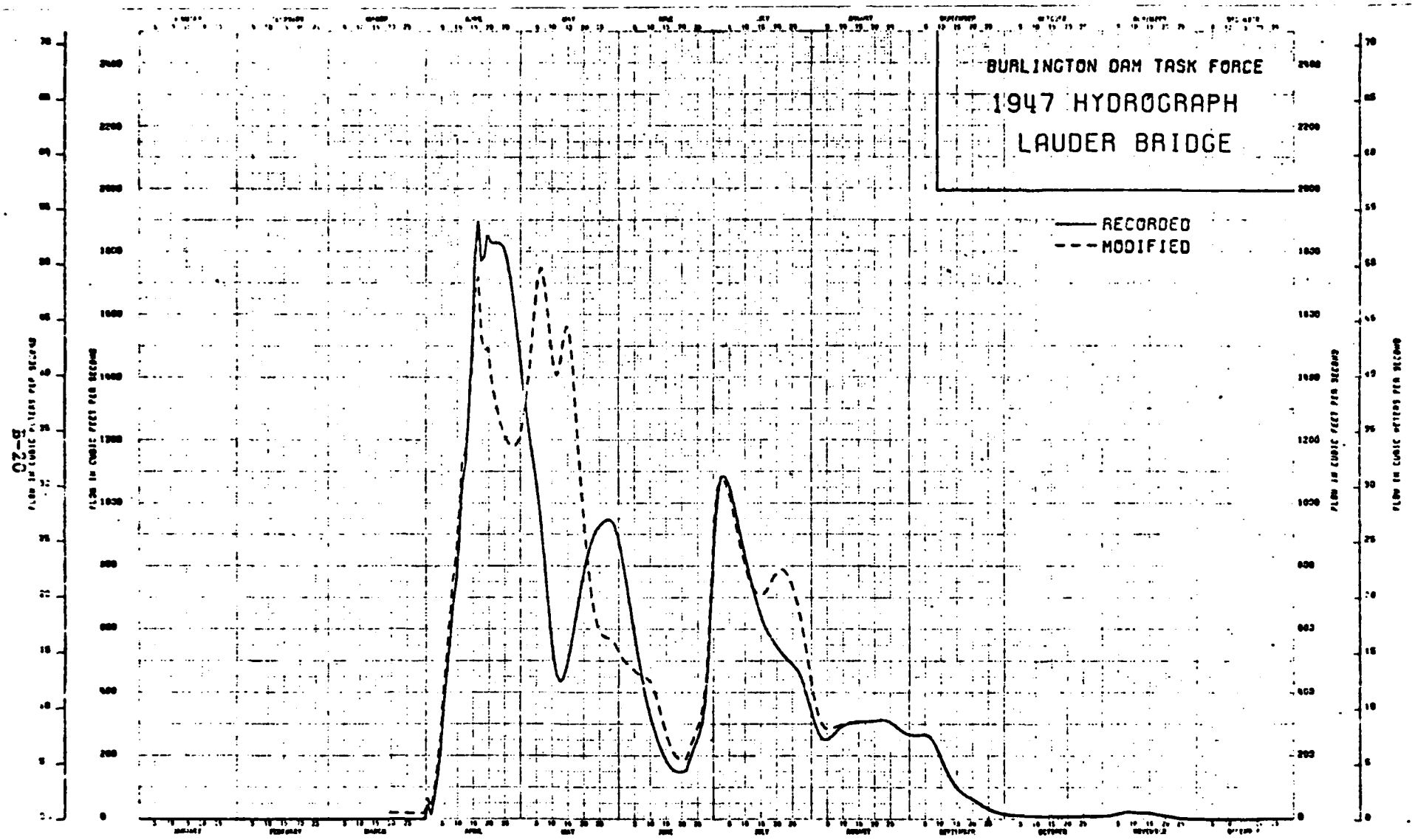

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1947
ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
488
487
486
485
484
1600
1598
1596
1594
1592
1590
1588
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

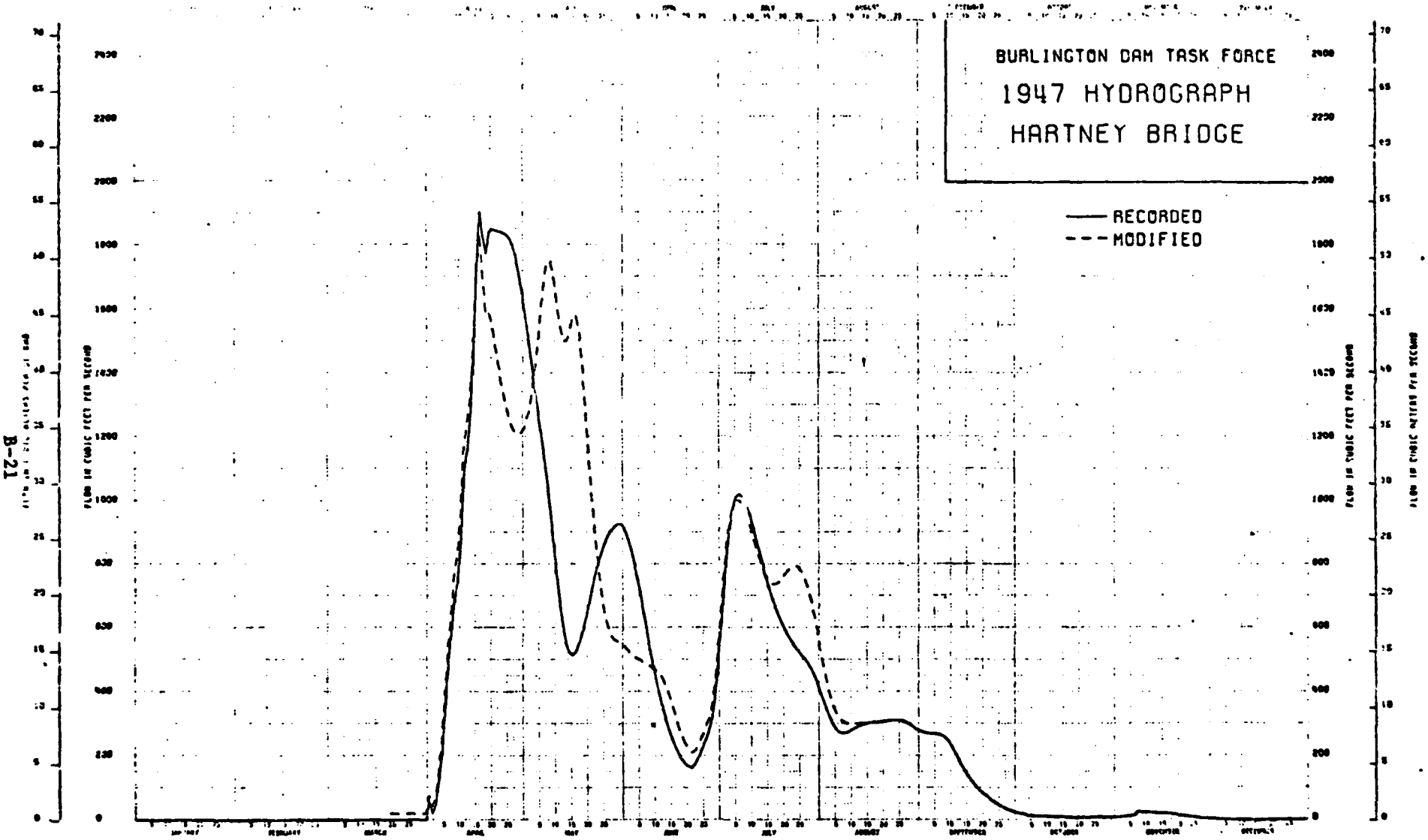

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1947
DISCHARGE IN CFS
DISCHARGE IN M³/SEC.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

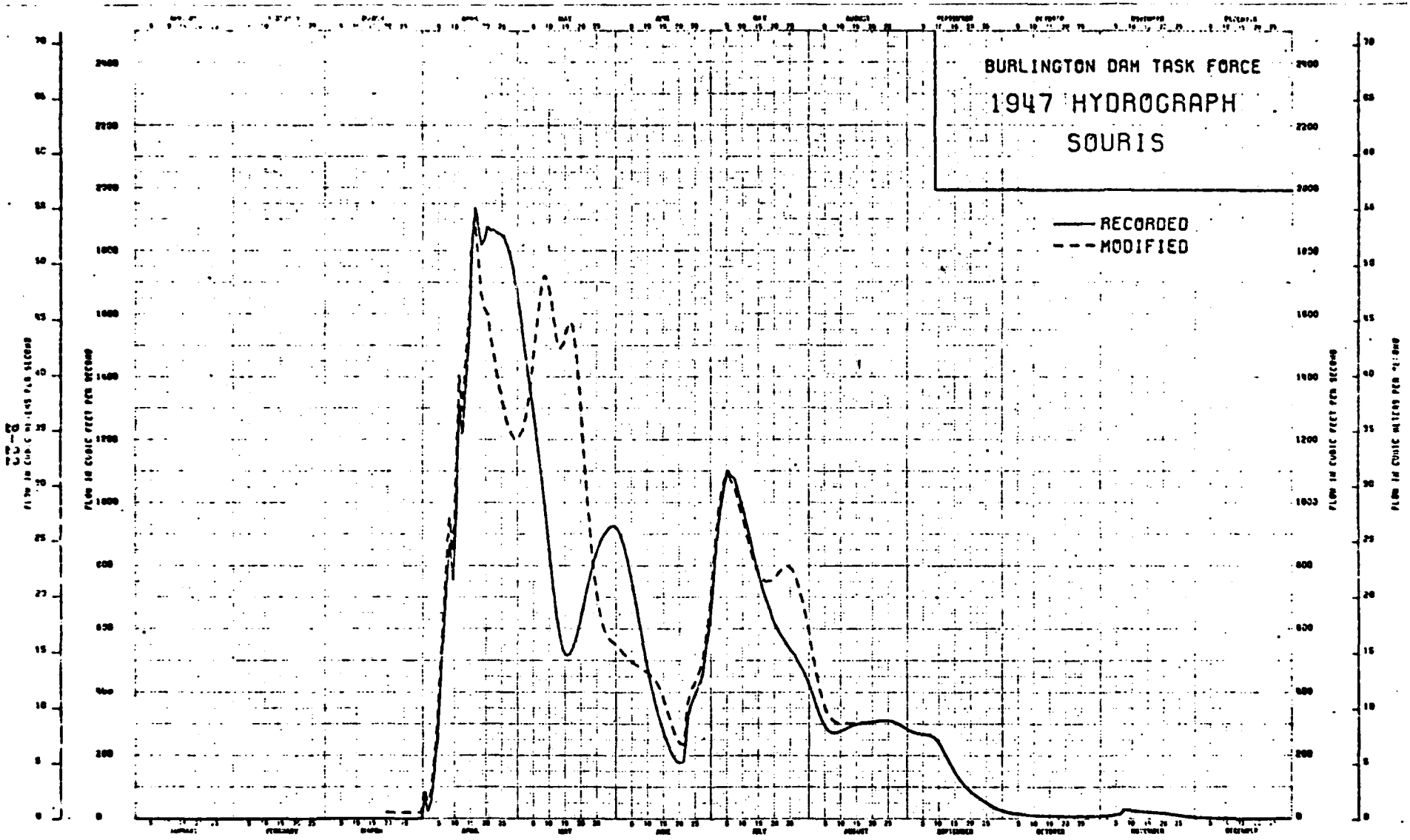

BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

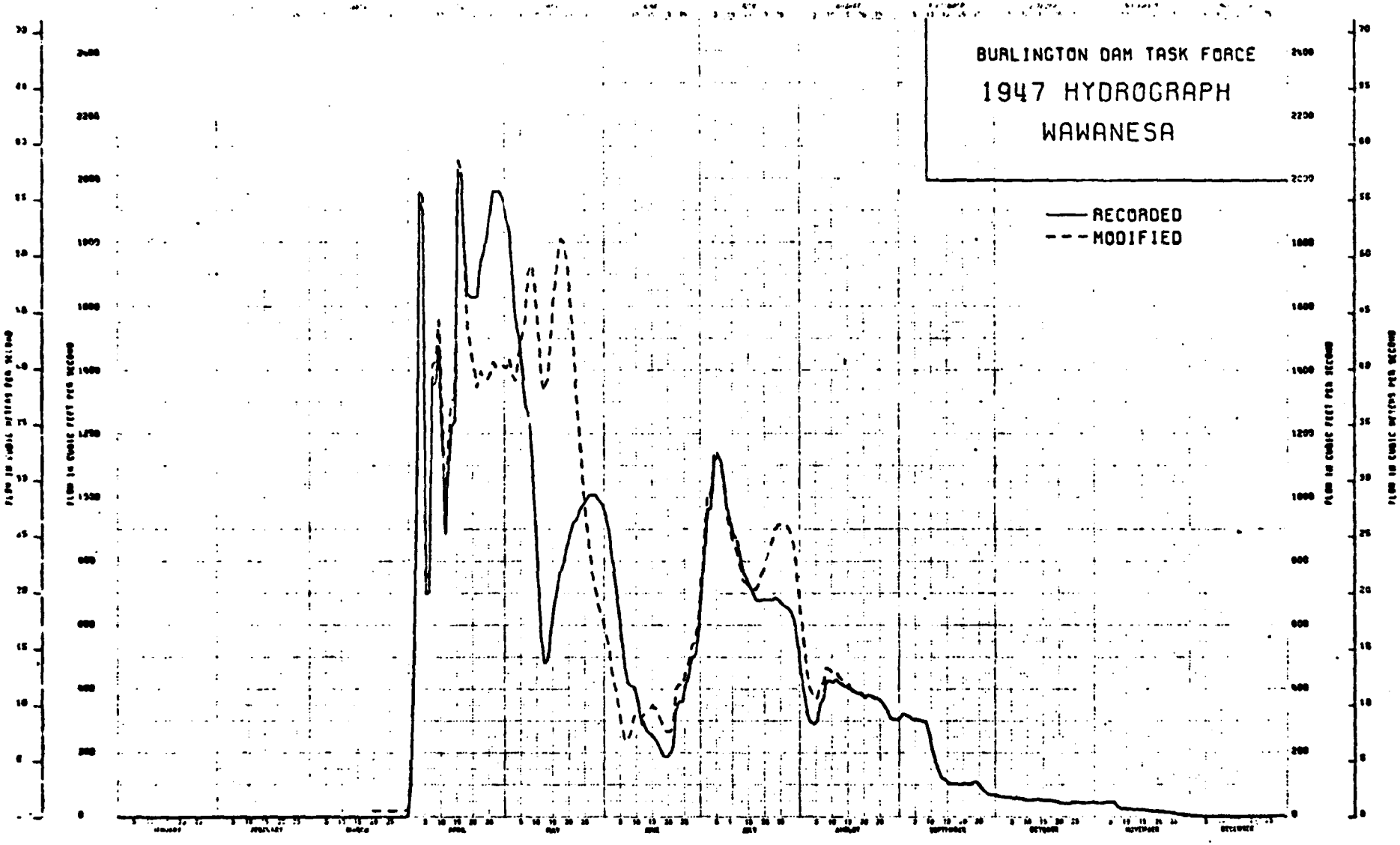

BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED

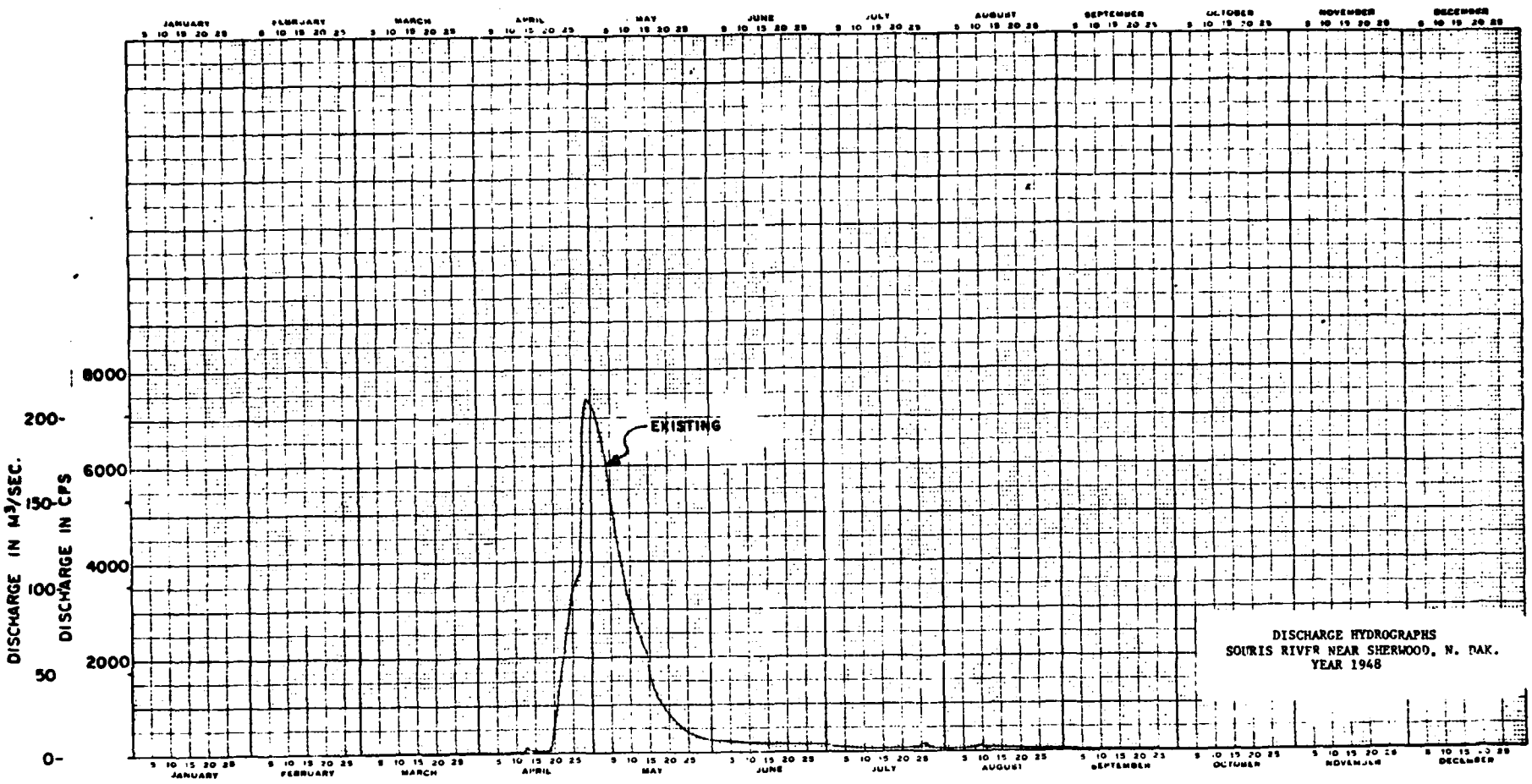

BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED

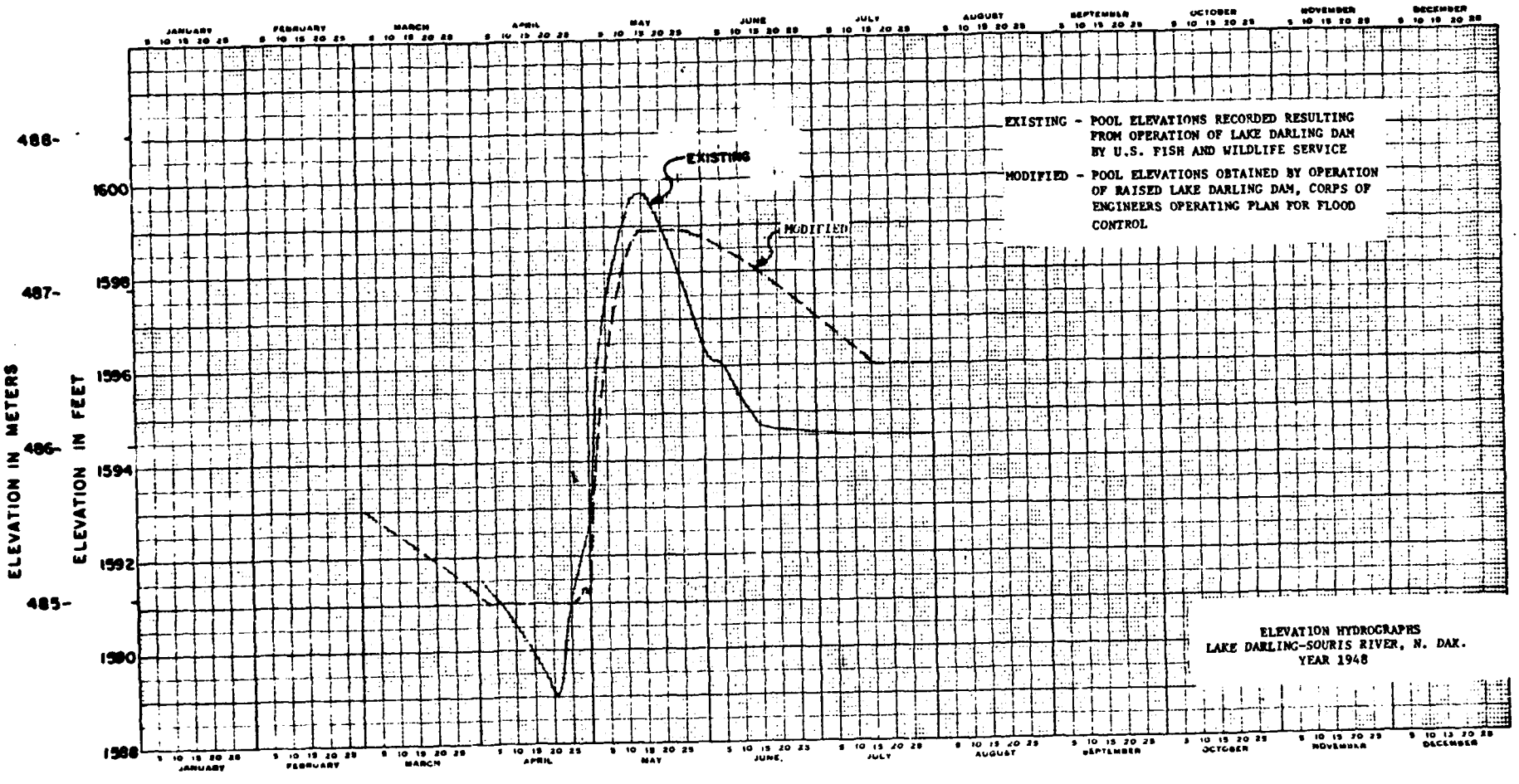

BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
SOURIS
RECORDED
MODIFIED

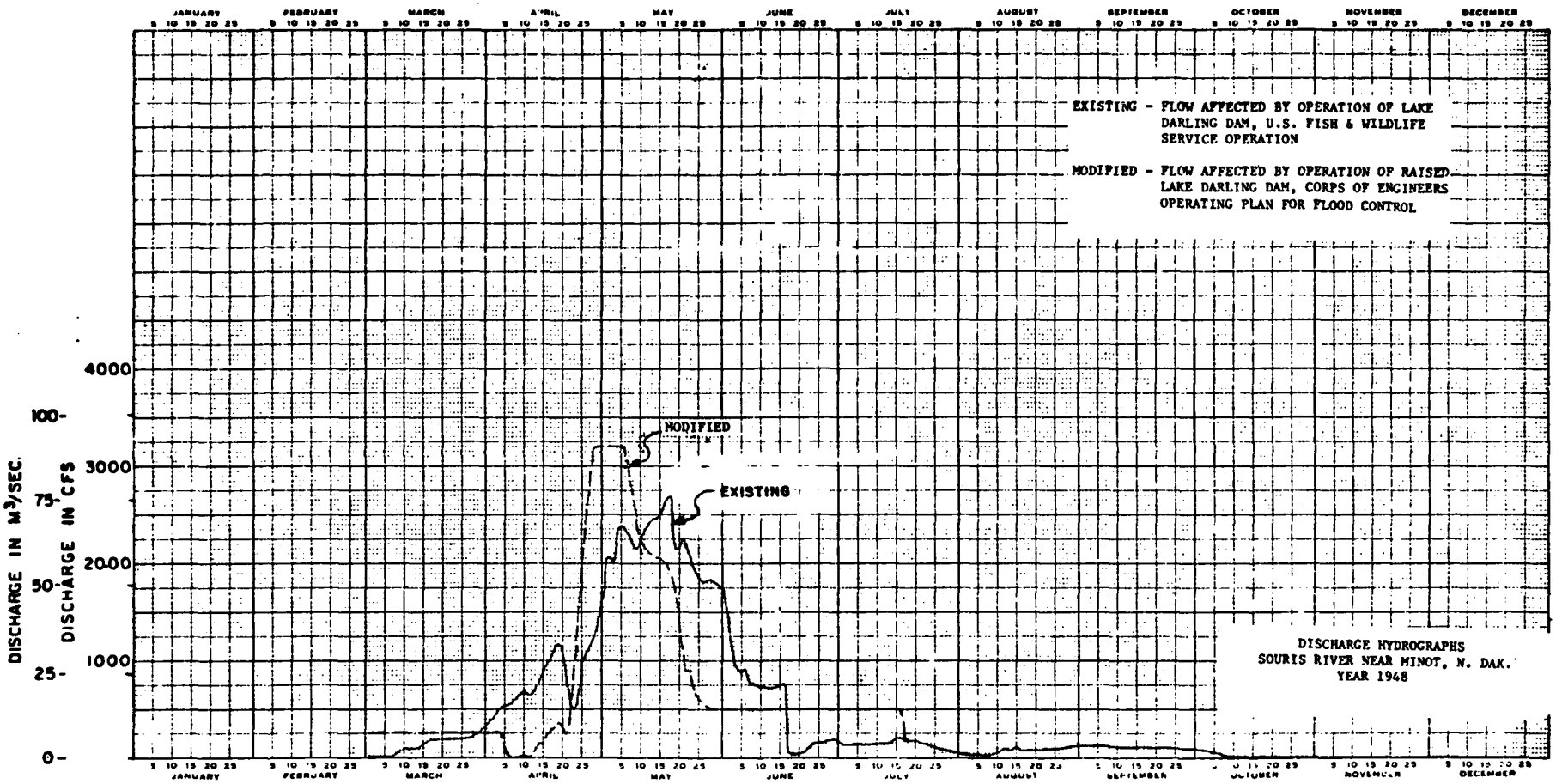

BURLINGTON DAM TASK FORCE
1947 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED

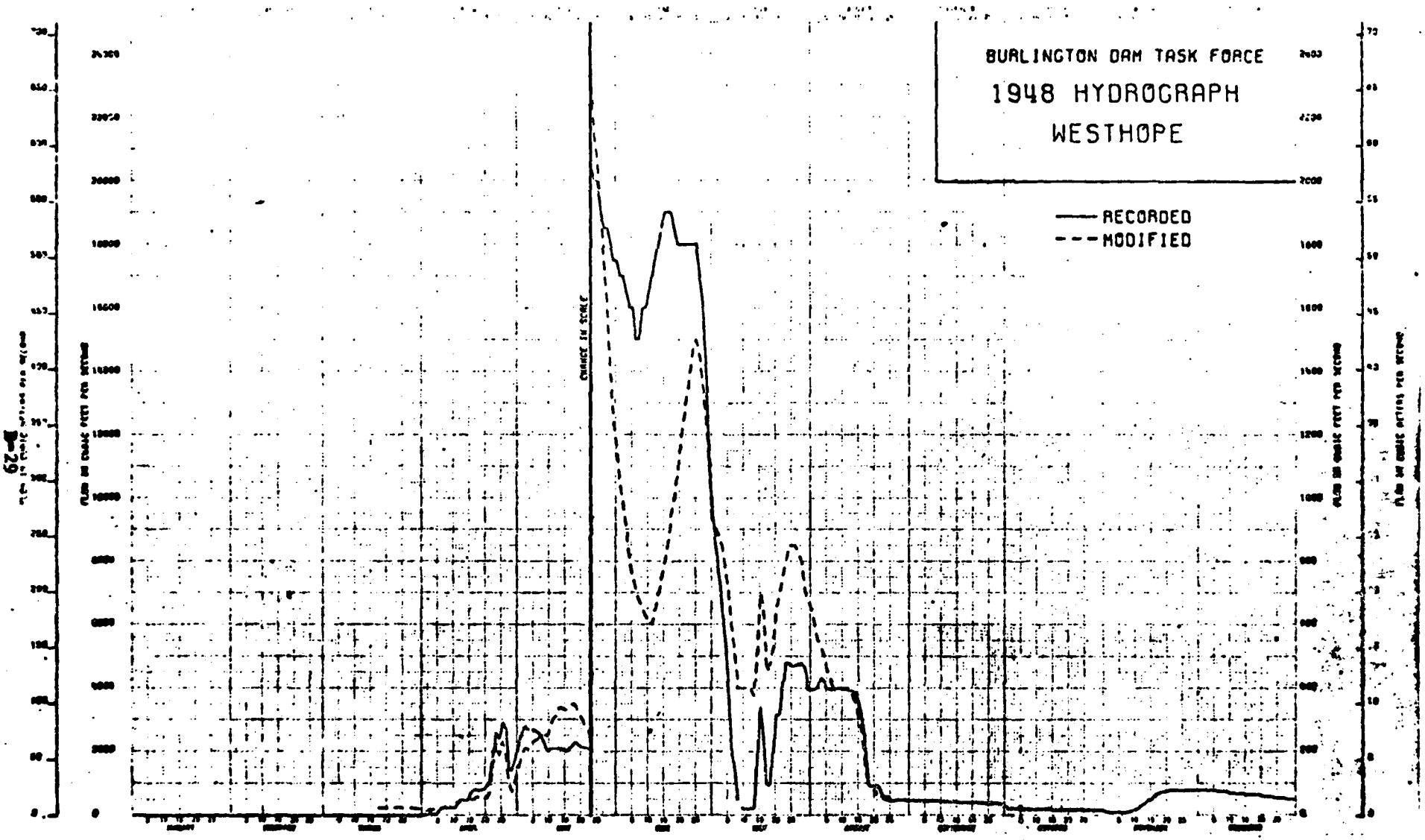
1948

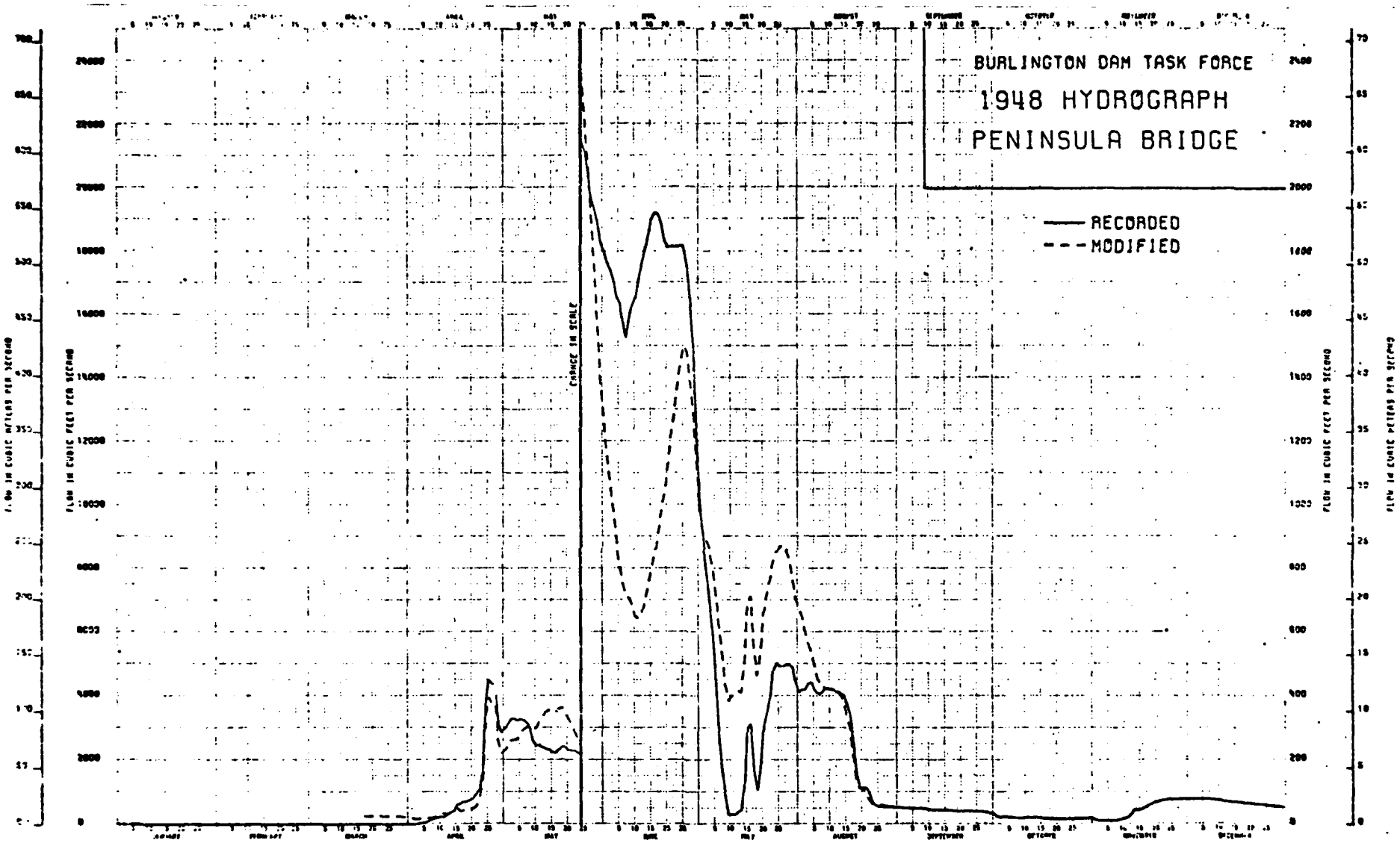

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
200
150
100
50
0
8000
6000
4000
2000
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1948

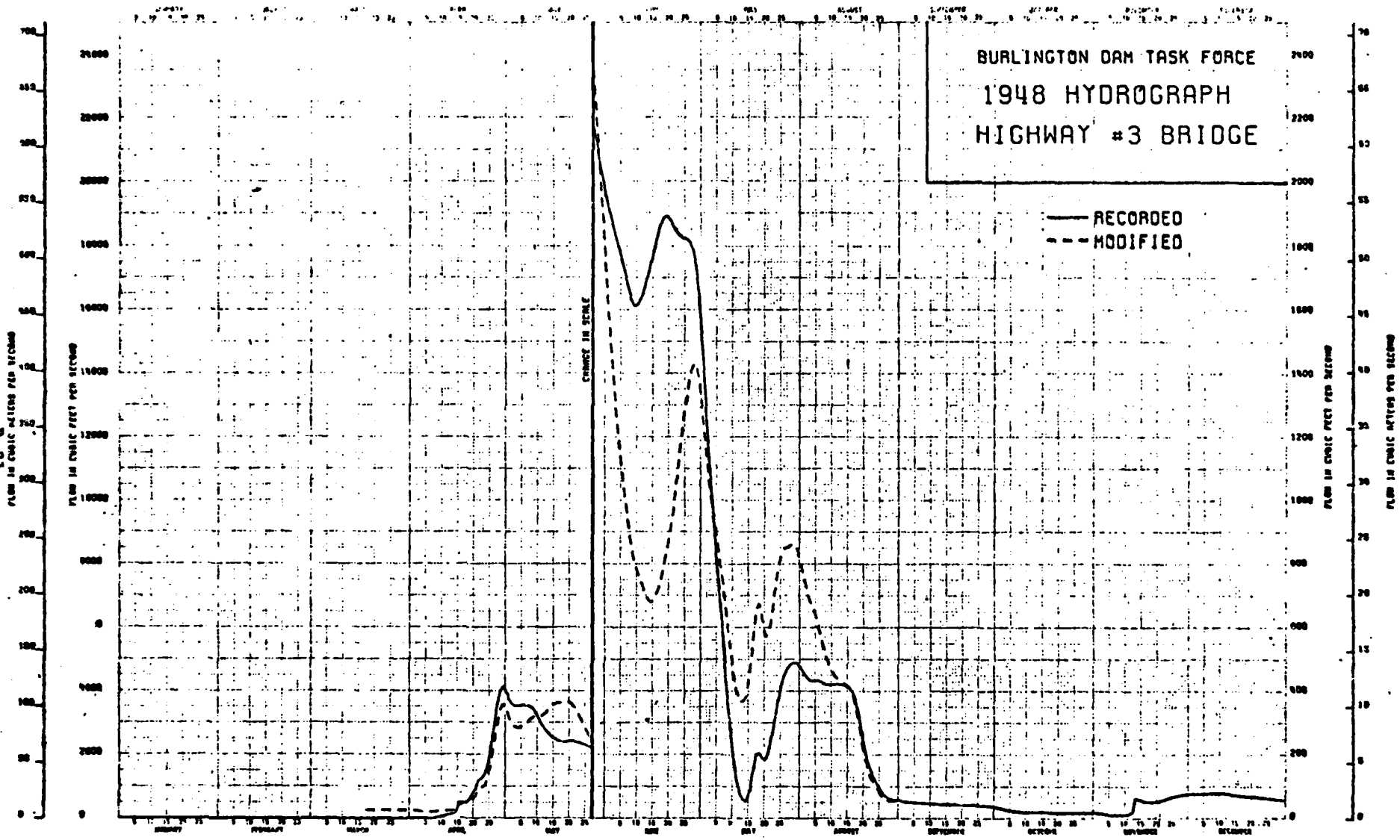


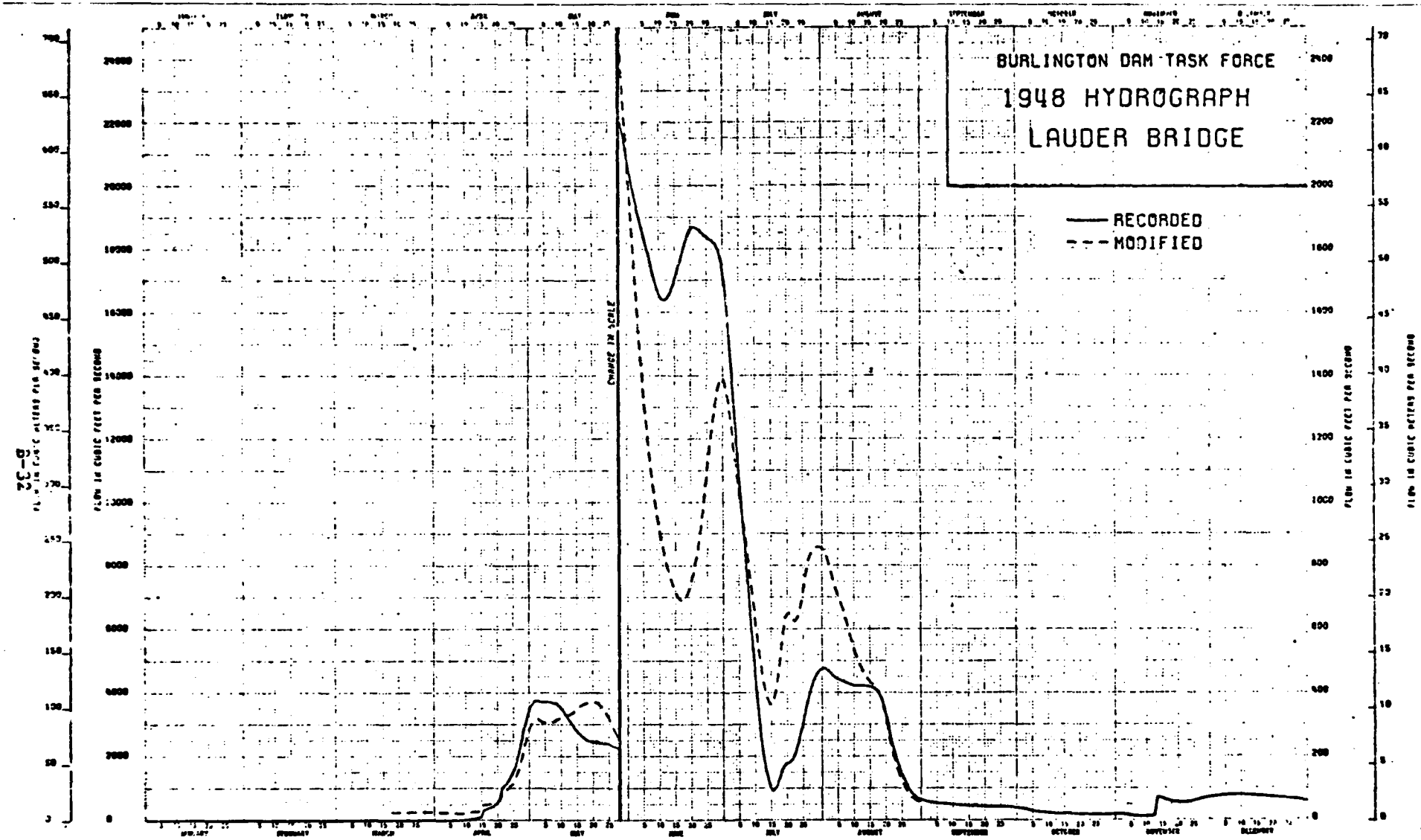
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1948

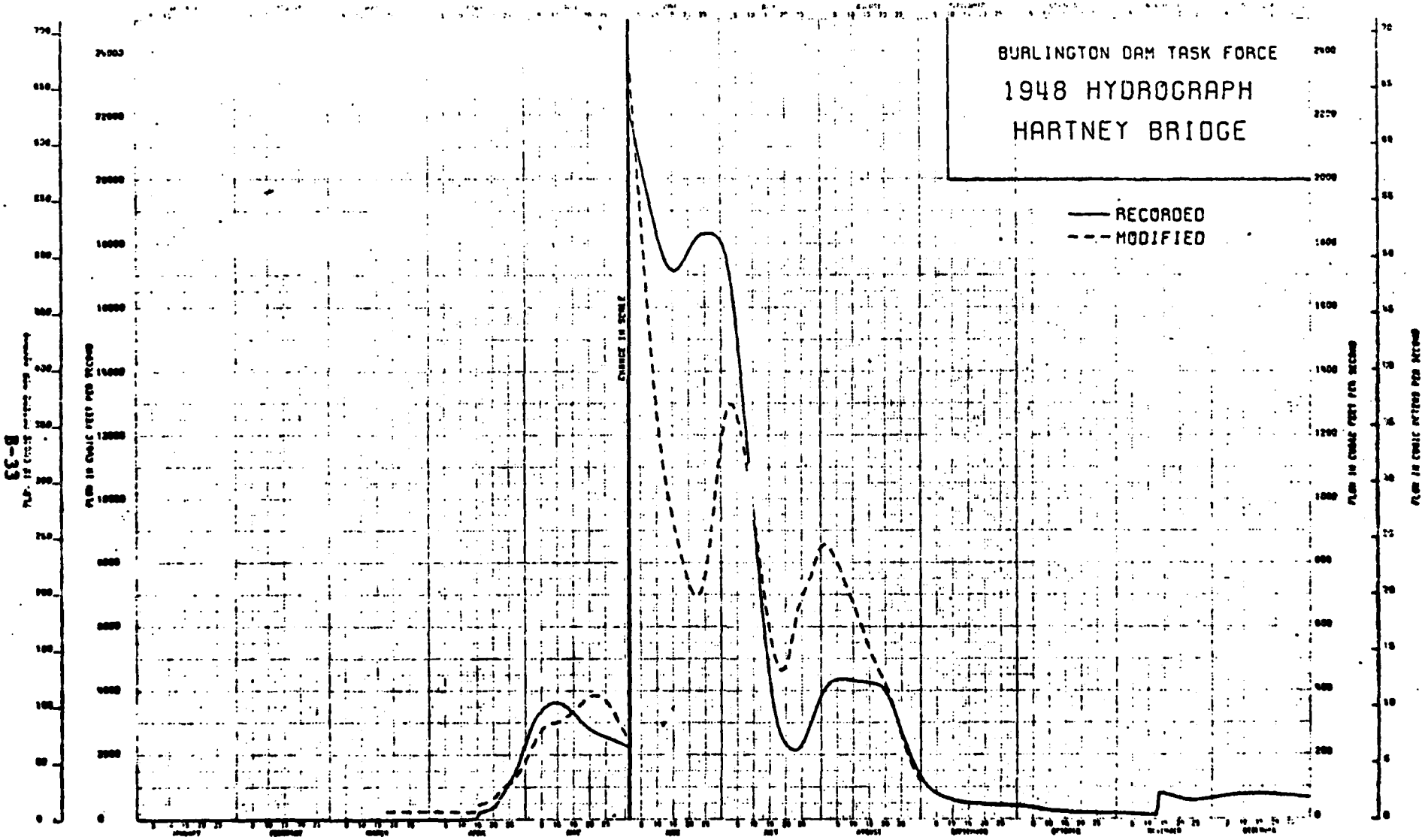

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
100
75
50
25
0
4000
3000
2000
1000
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1948

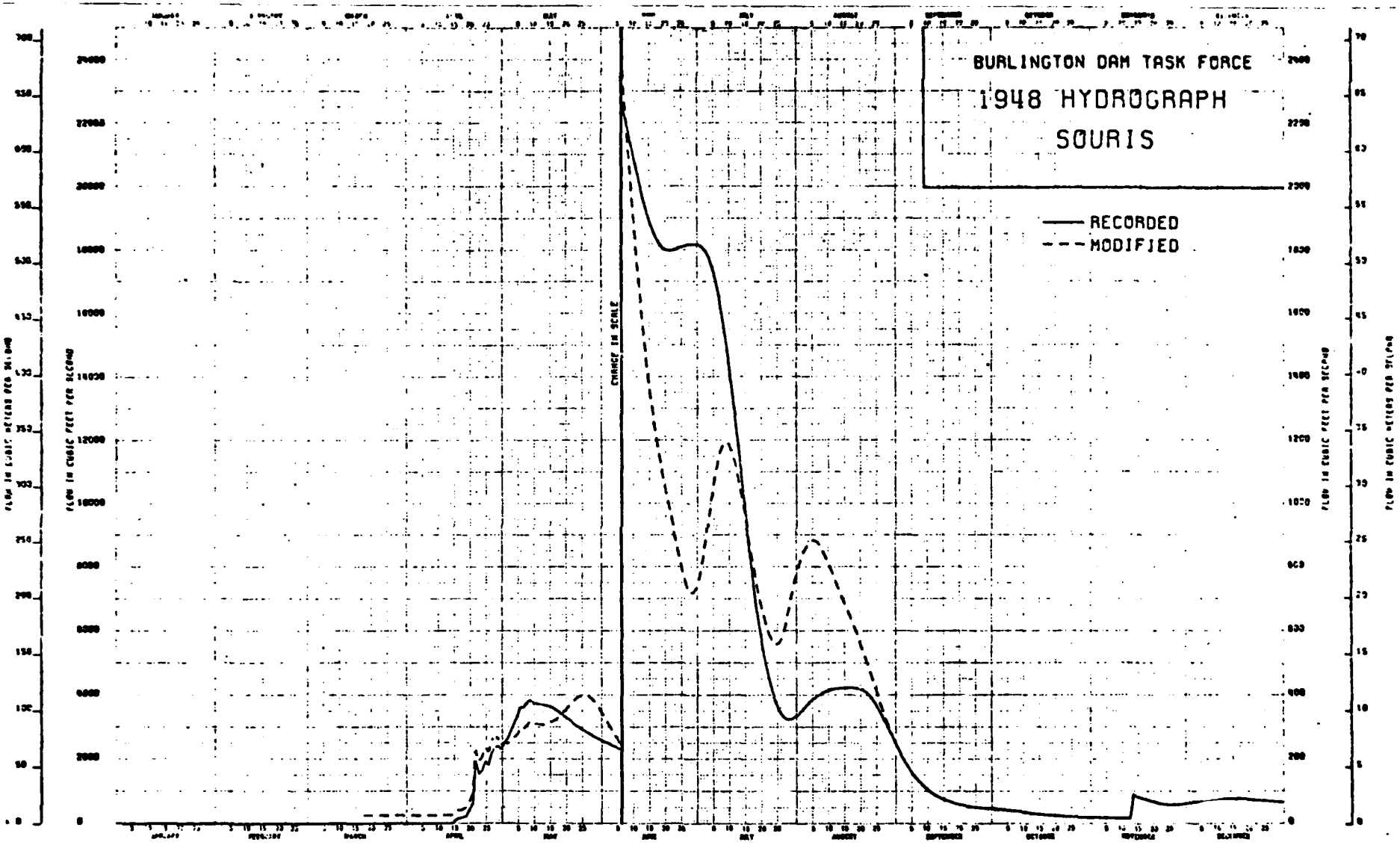

BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

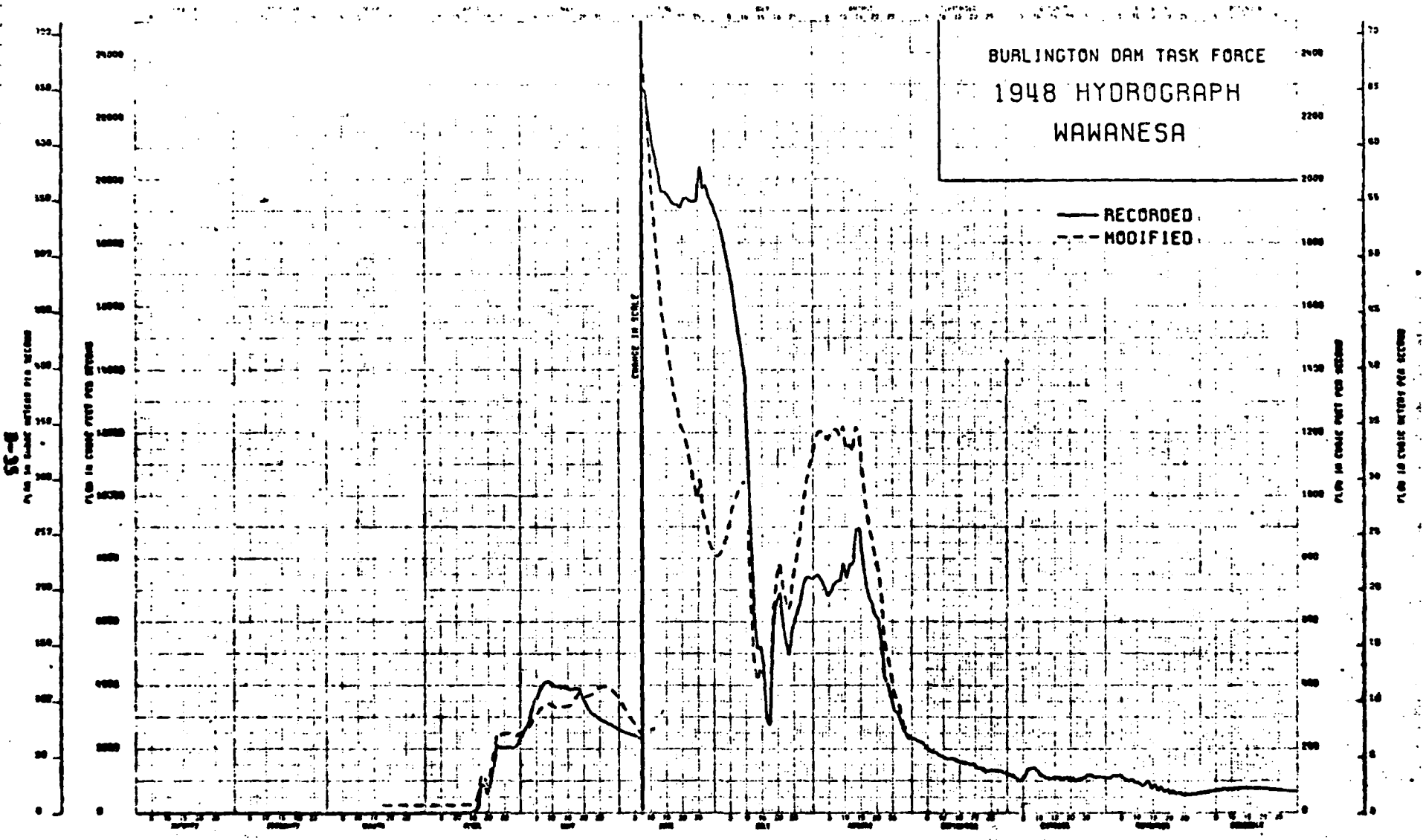

BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

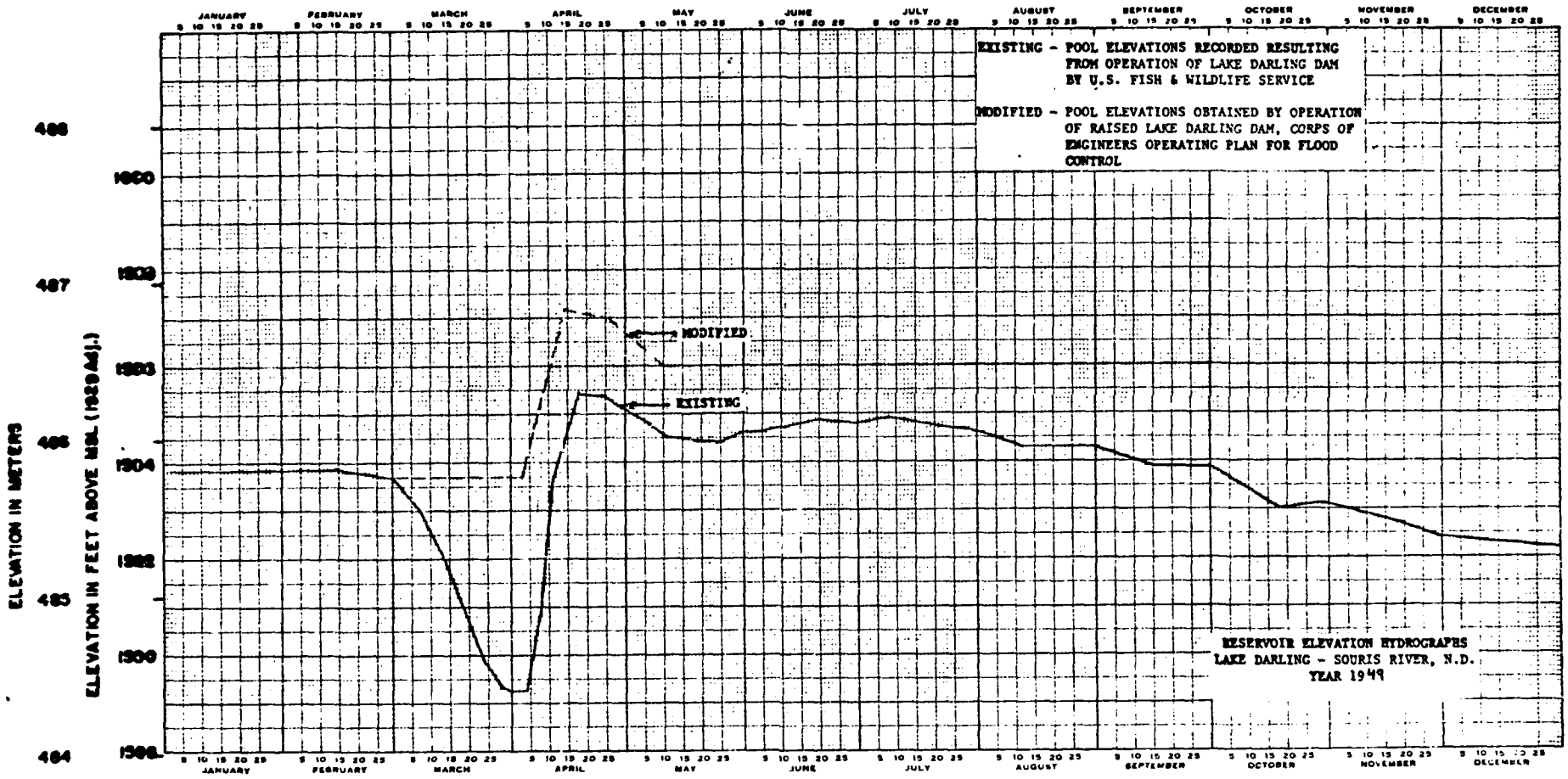

BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED

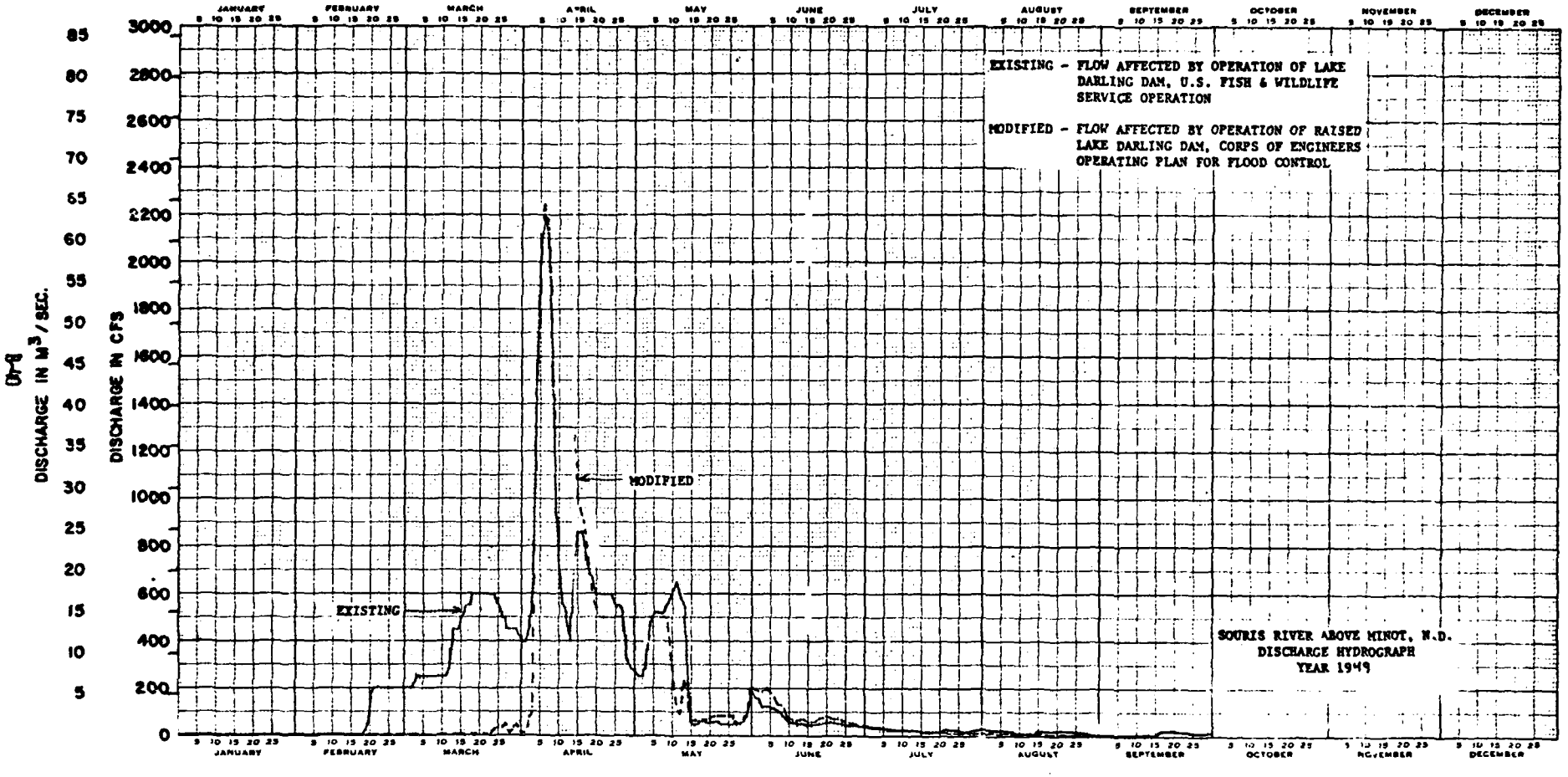

BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

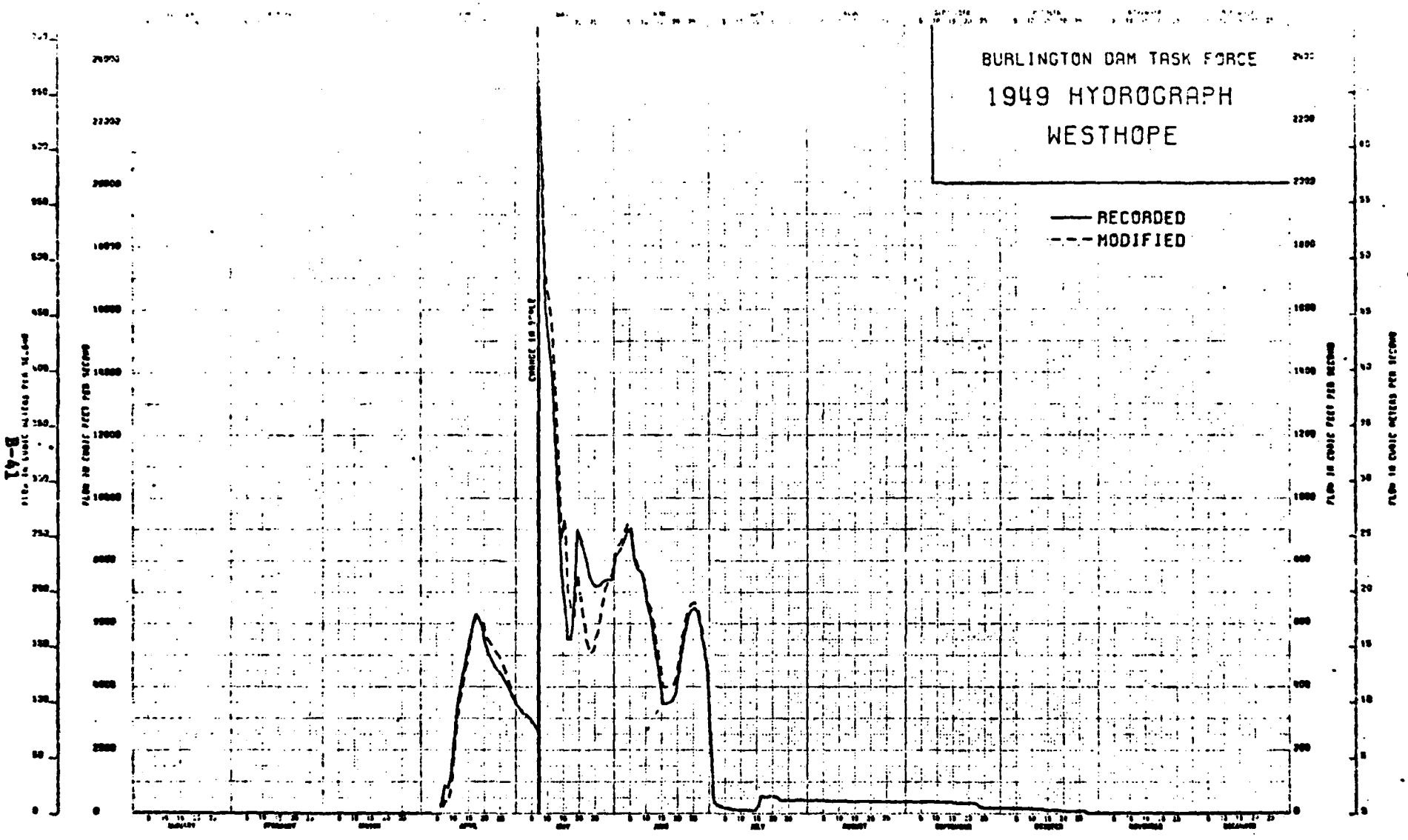

BURLINGTON DAM TASK FORCE
1948 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE

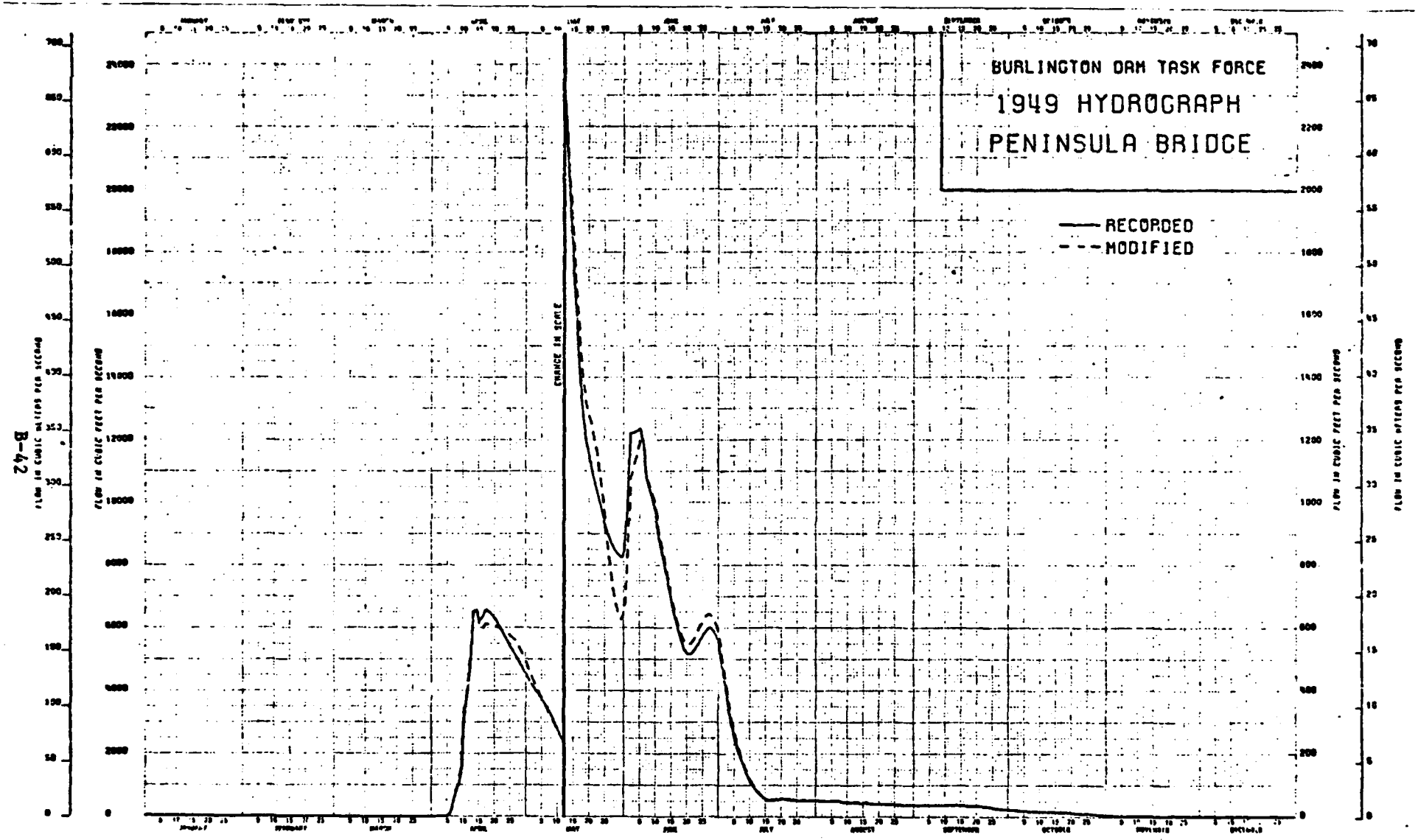
1949

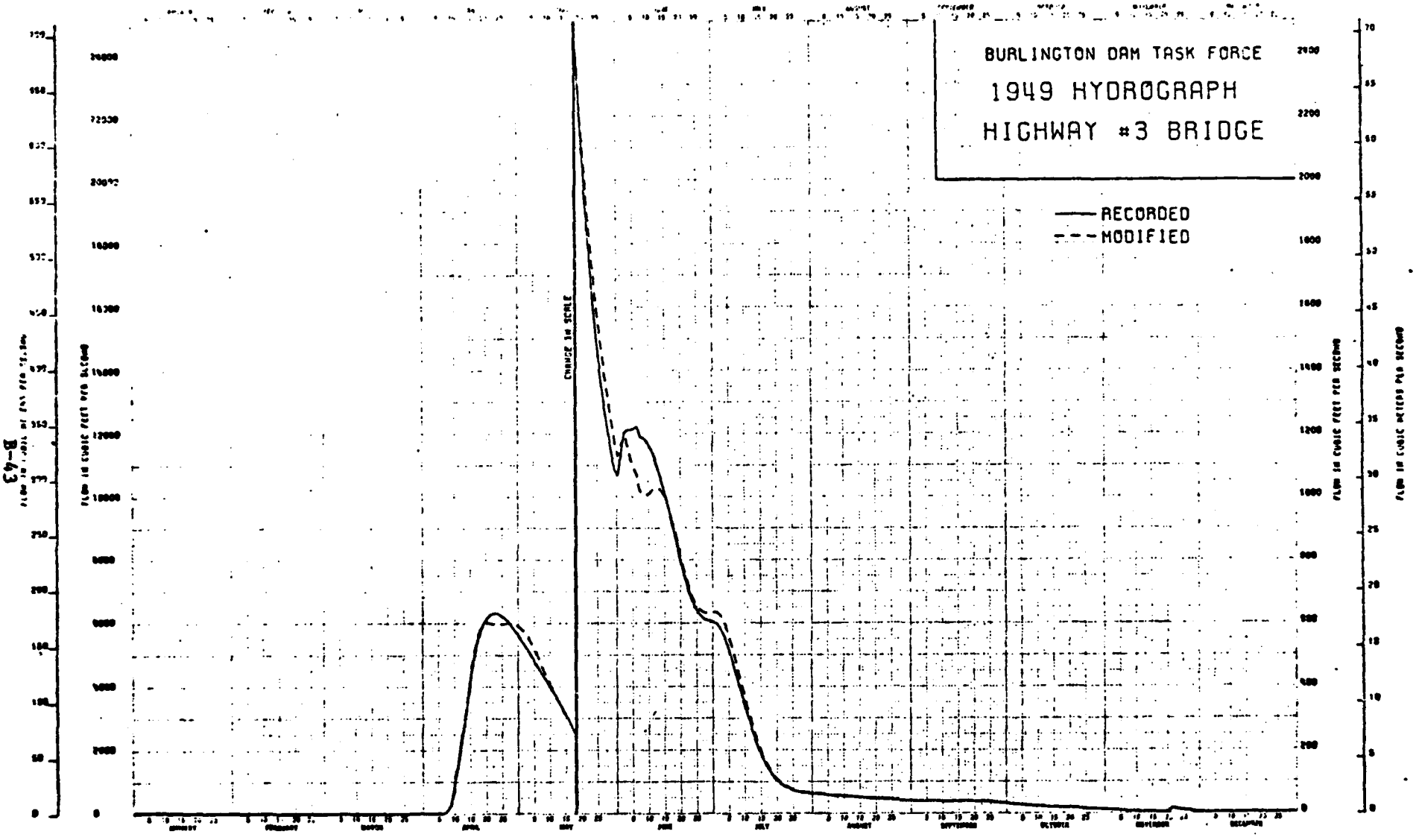
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN CFS
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
DISCHARGE IN M³/SEC.
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1949

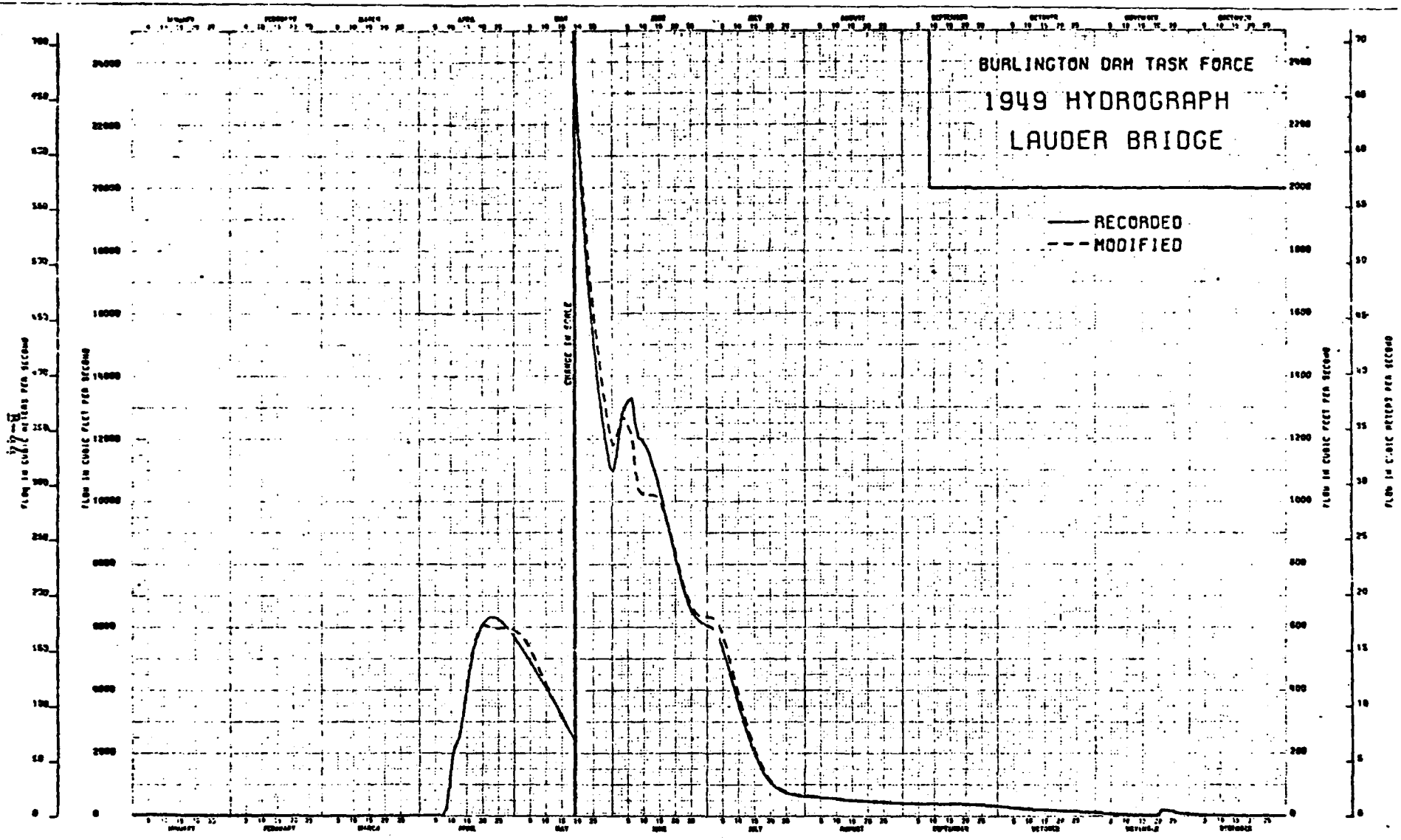

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1949
ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

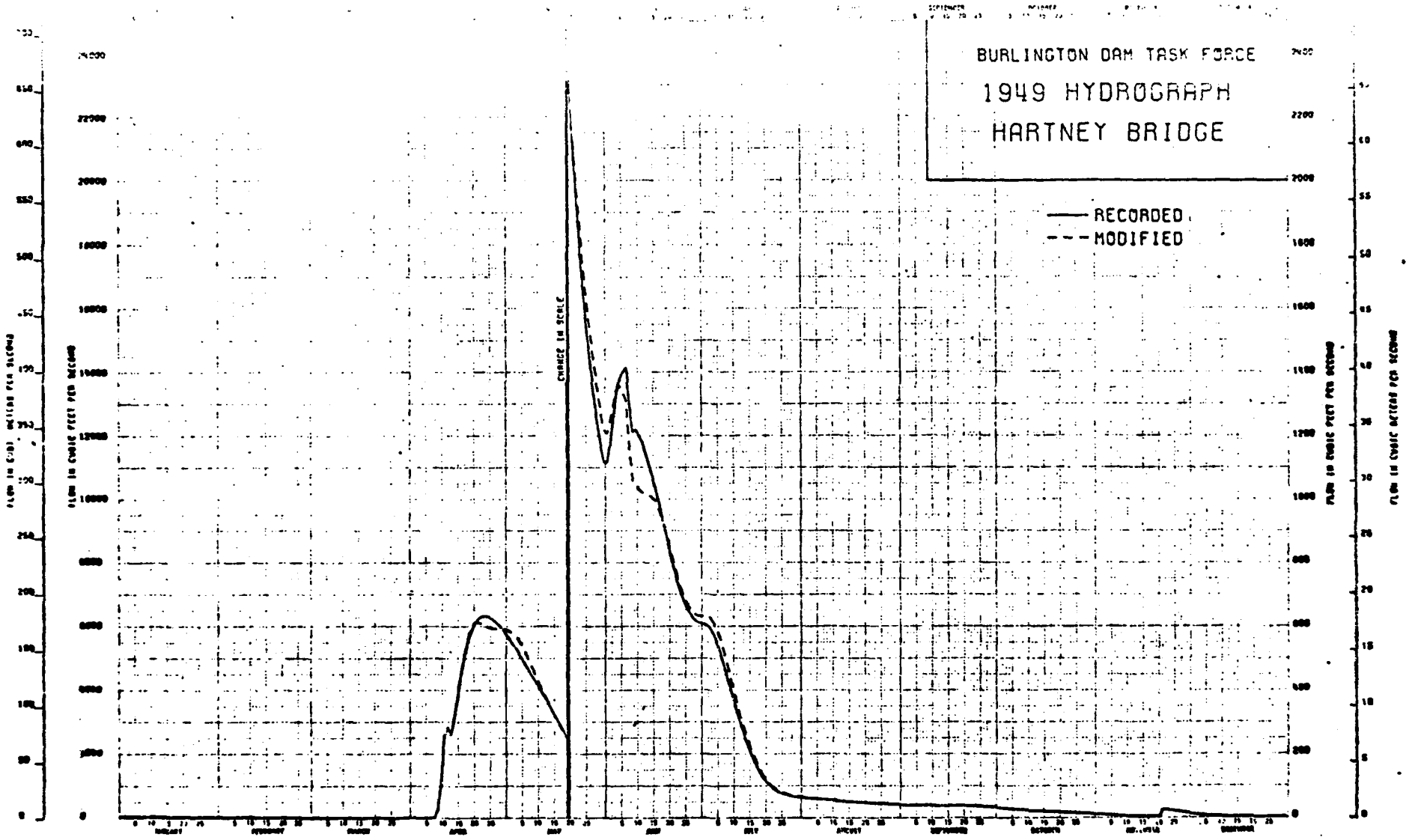

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1949
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
EXISTING
MODIFIED
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

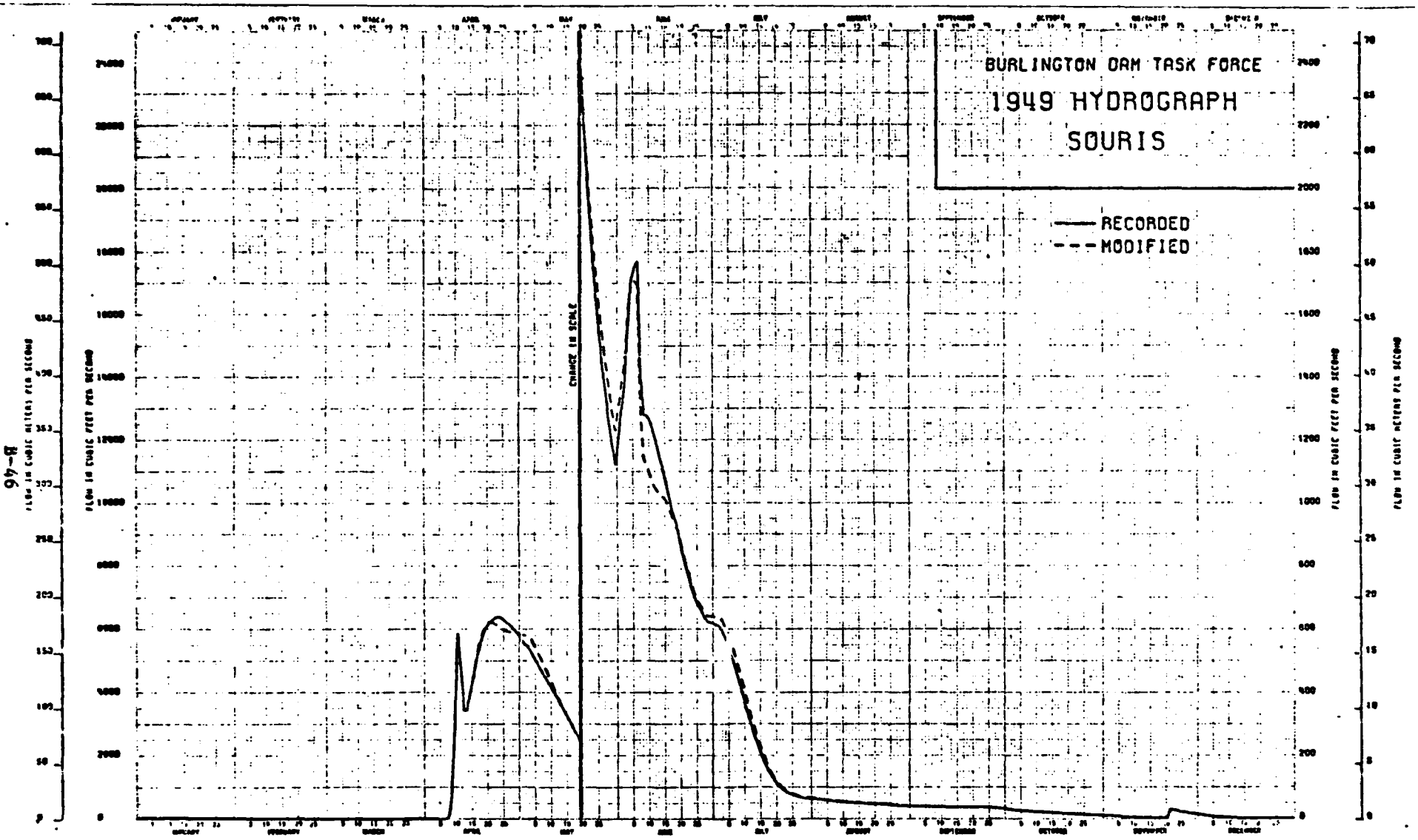

BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

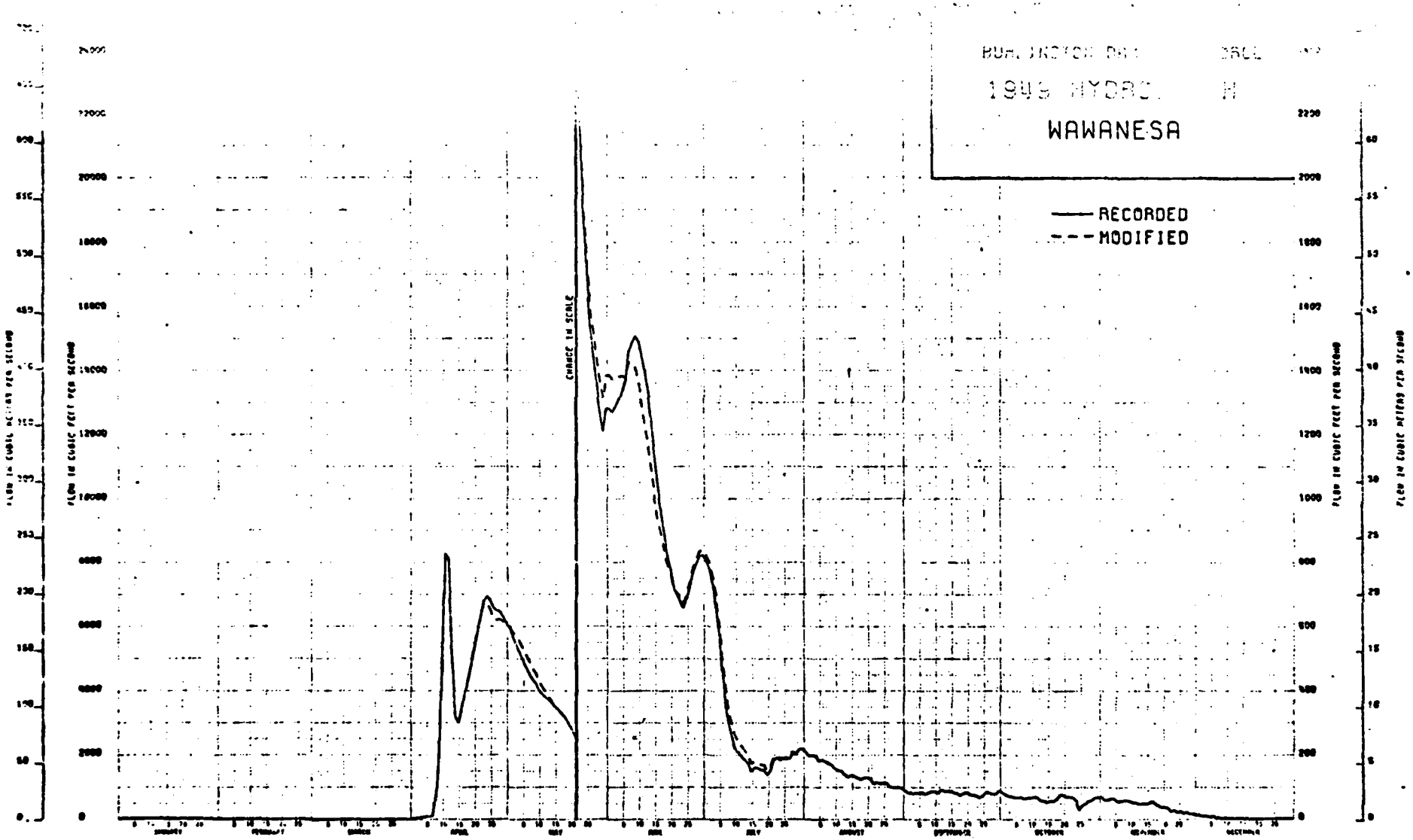

BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

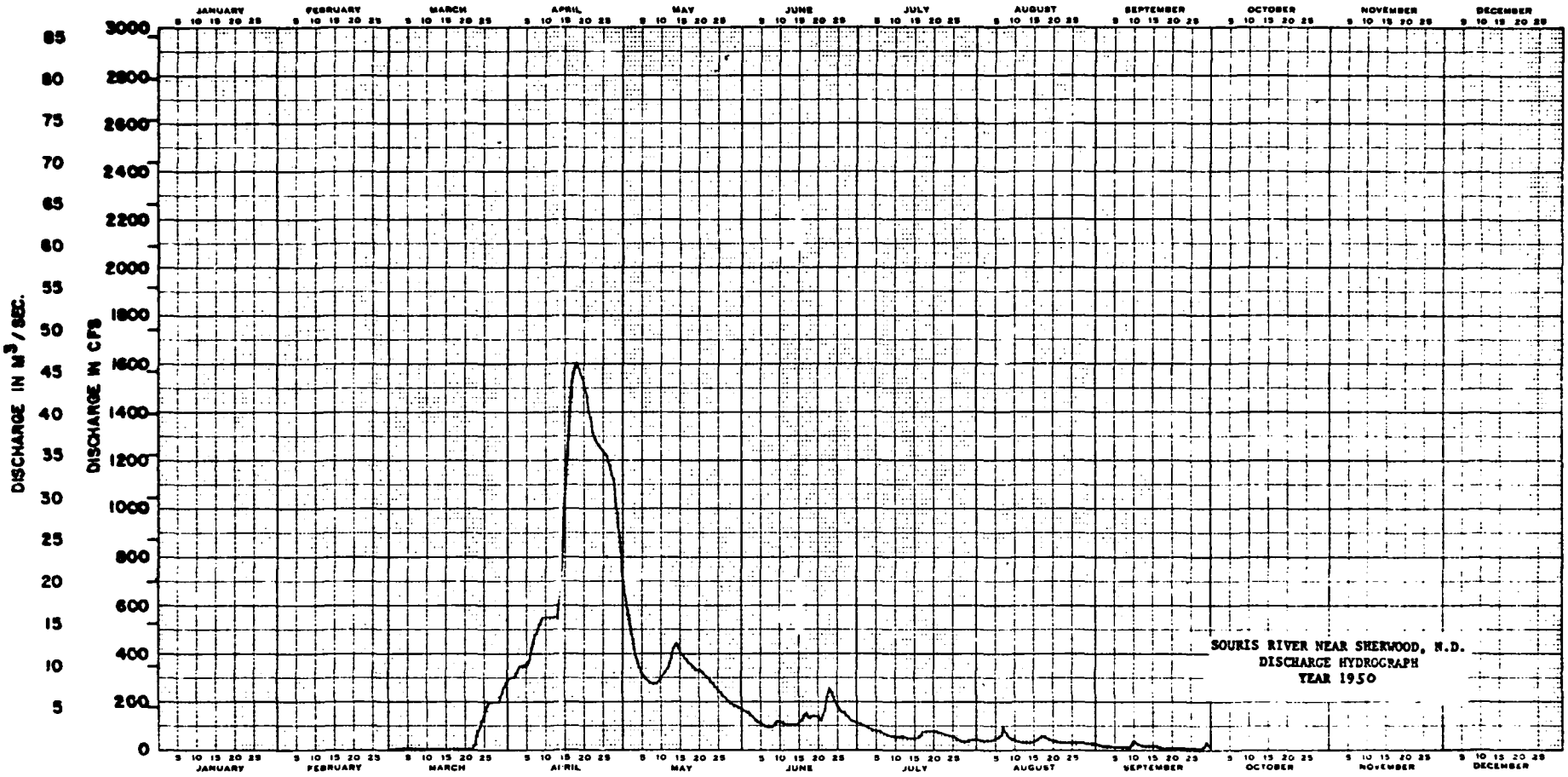

BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

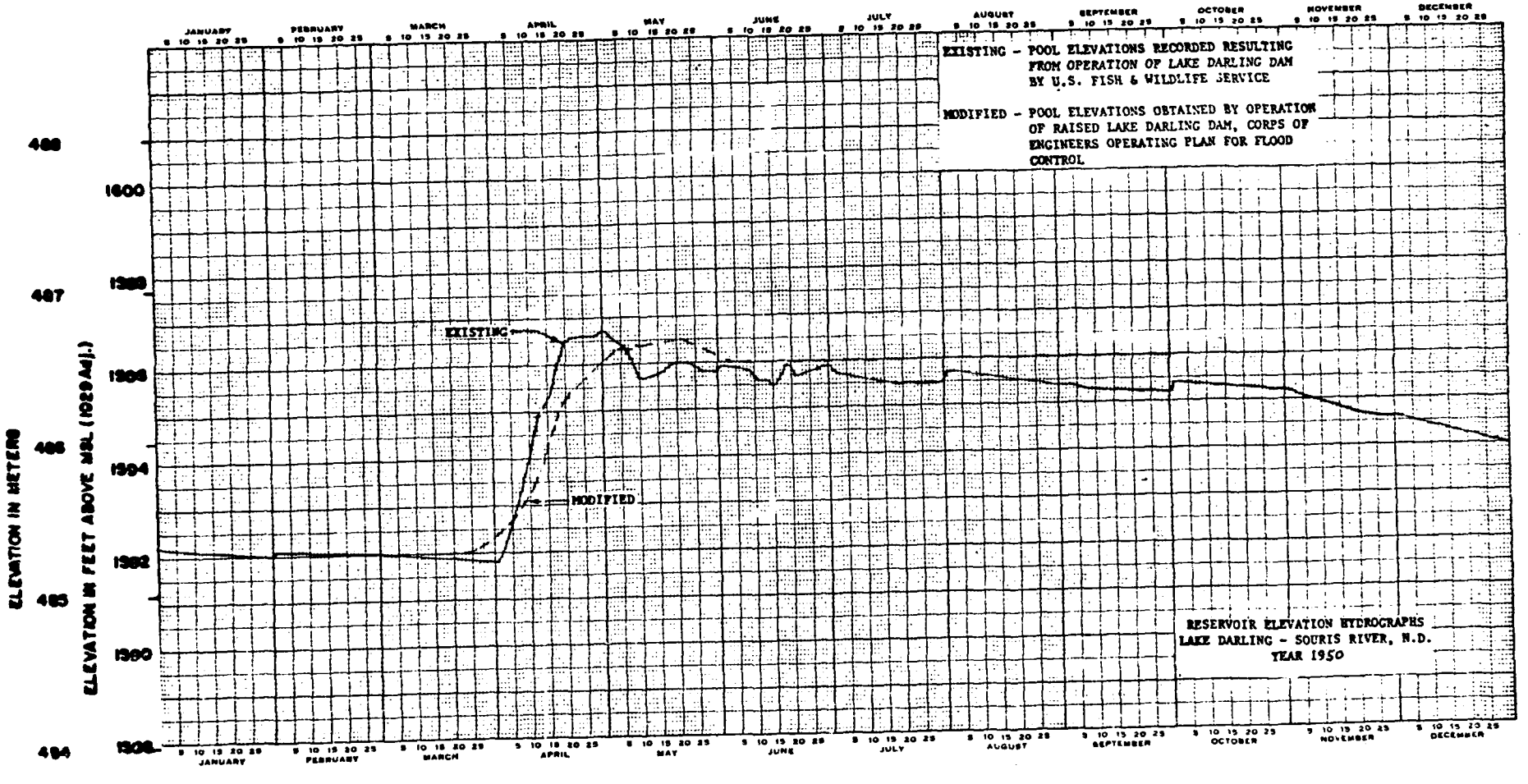

BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

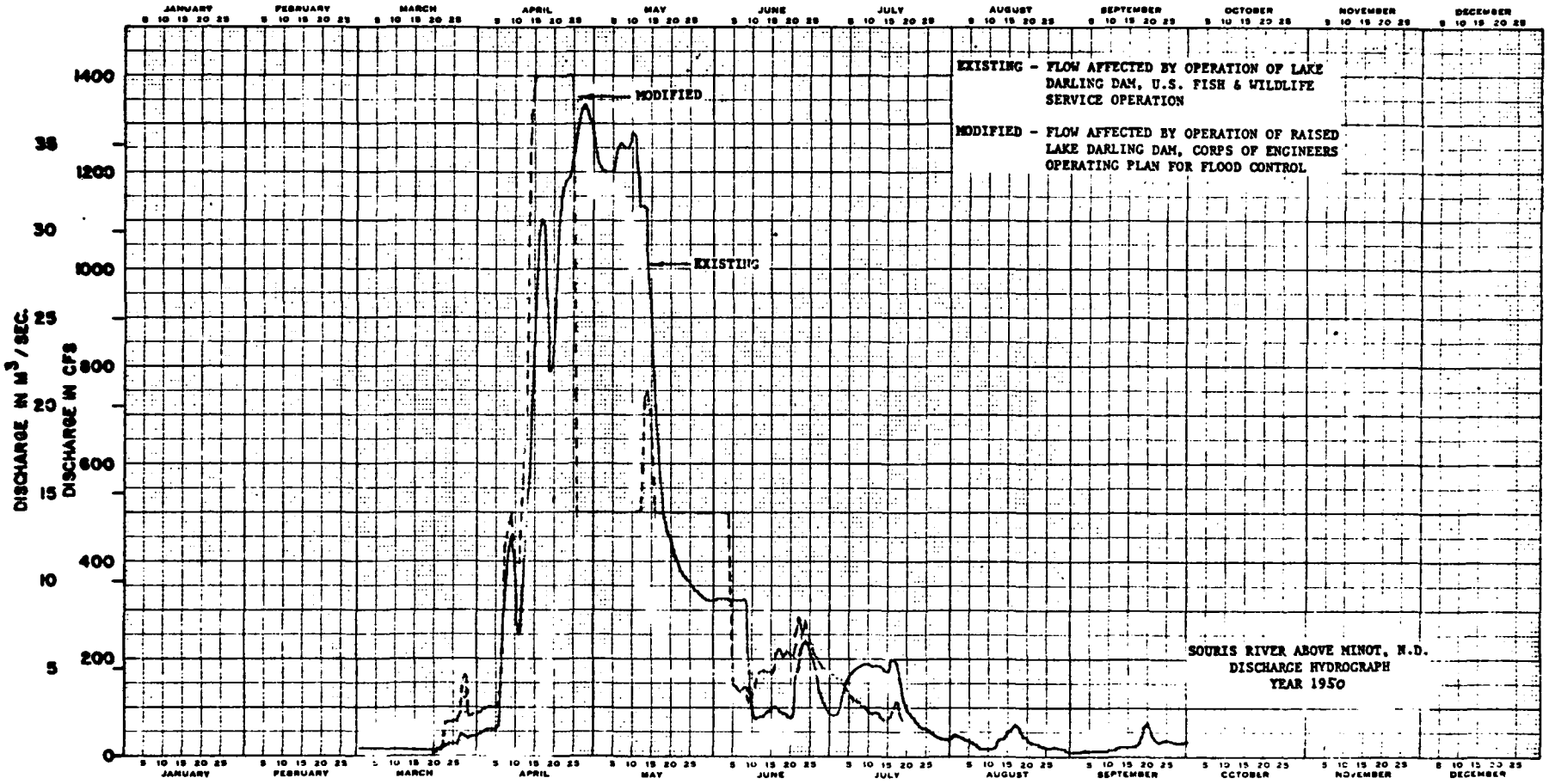

BURLINGTON DAM TASK FORCE
1949 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

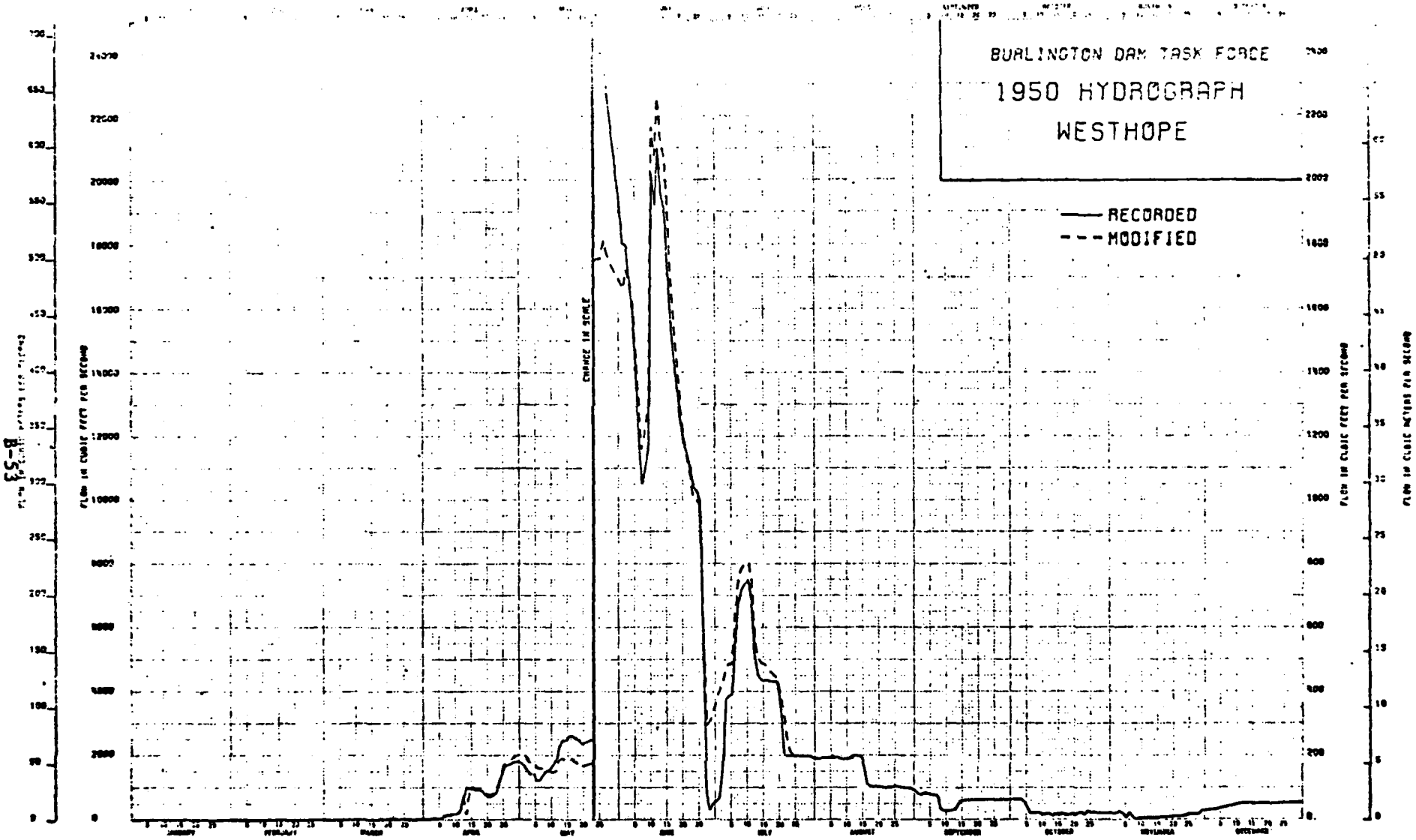

1945 HYDRO. H
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

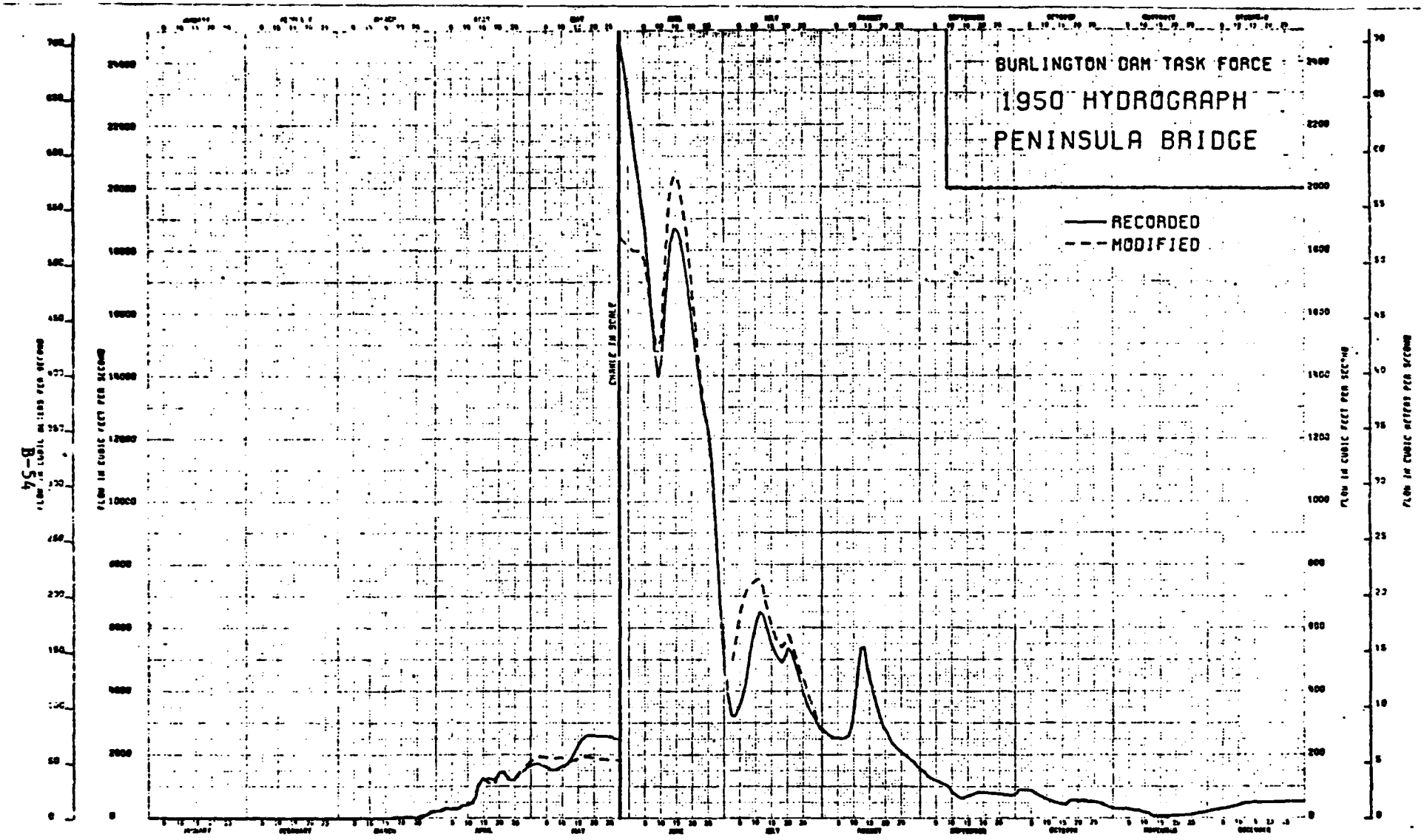
1950

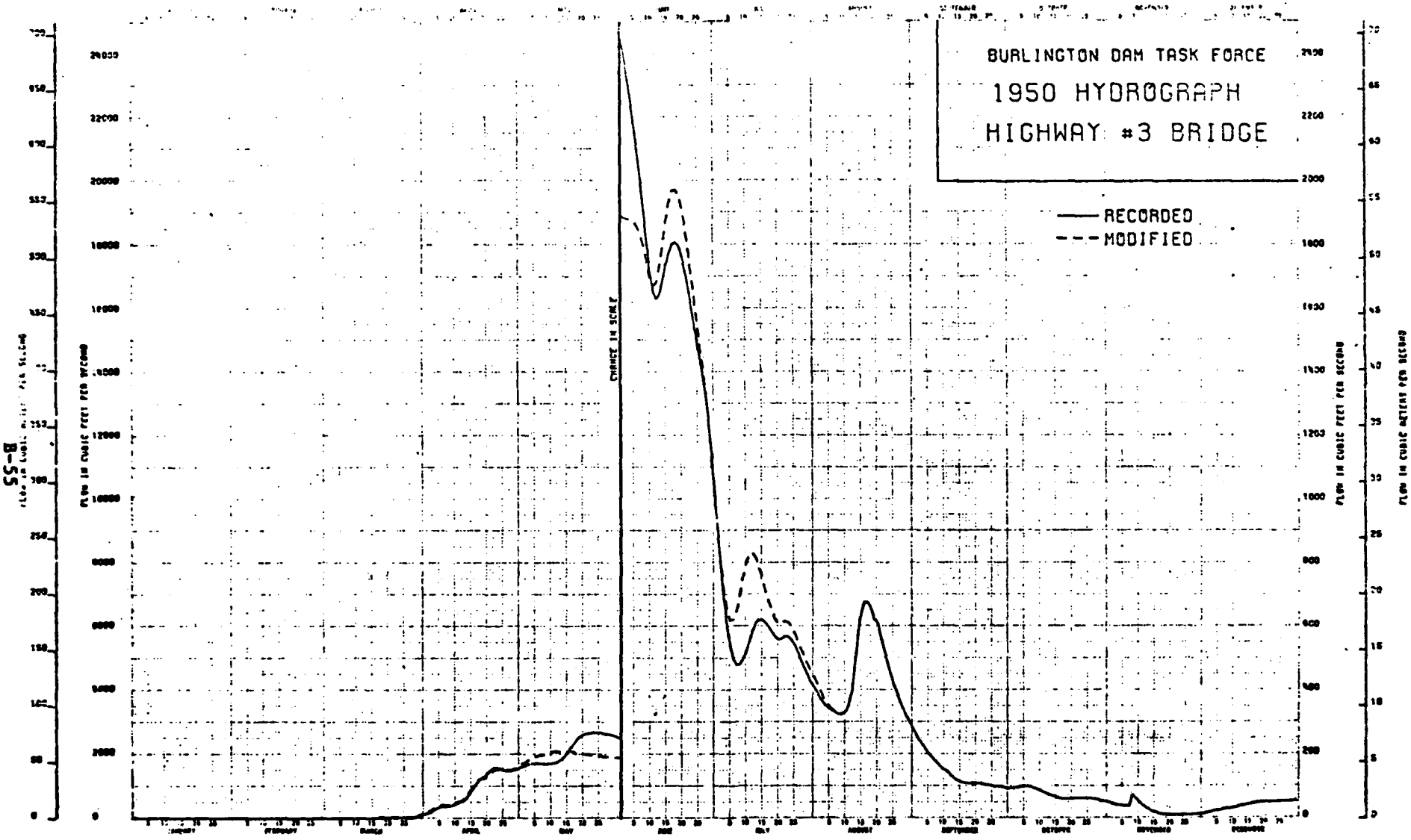

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN M³/SEC.
85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5
DISCHARGE IN CFS
3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400 200 0
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1950

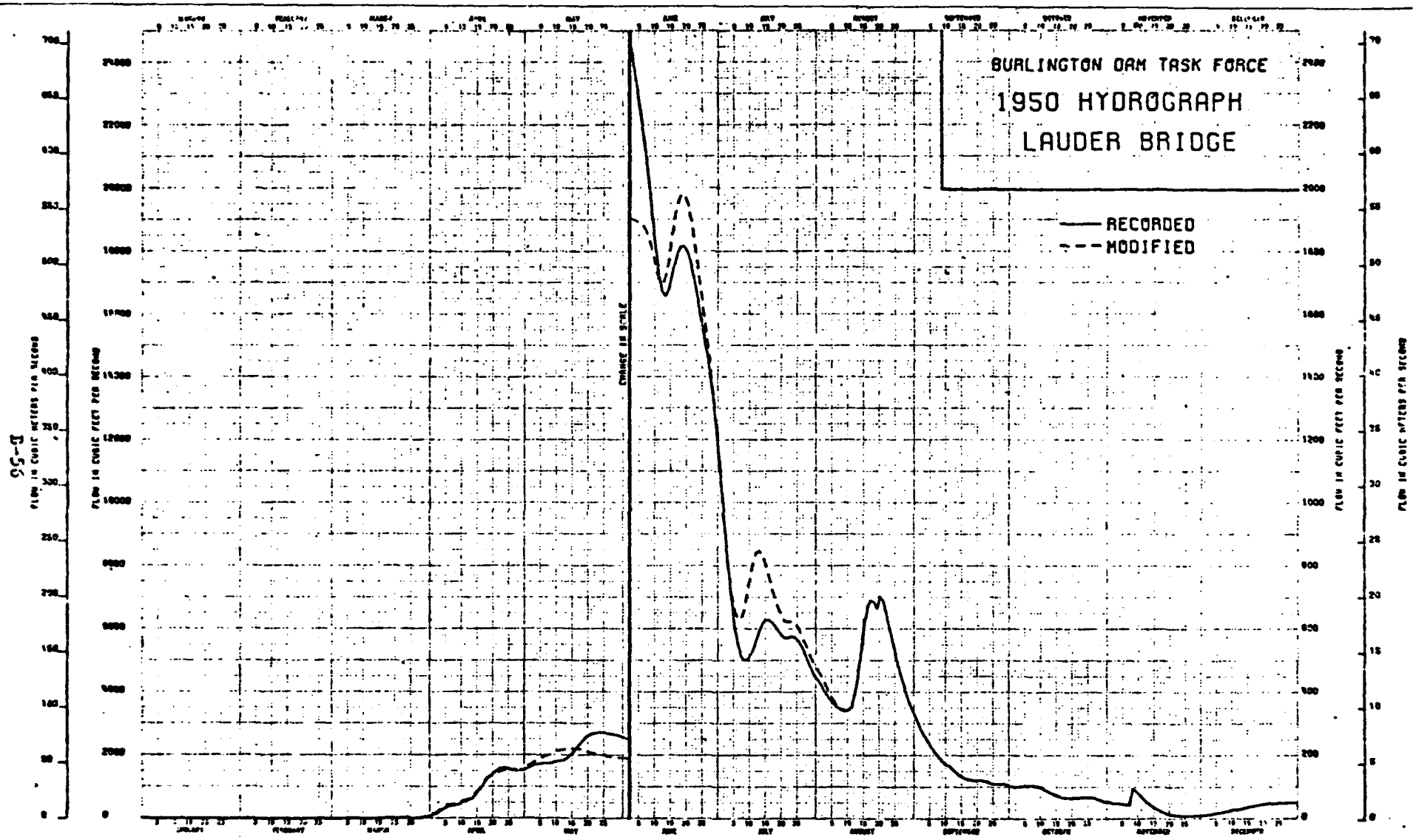

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1950
EXISTING
MODIFIED
ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
488
487
486
485
484
1600
1598
1596
1594
1592
1590
1588
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

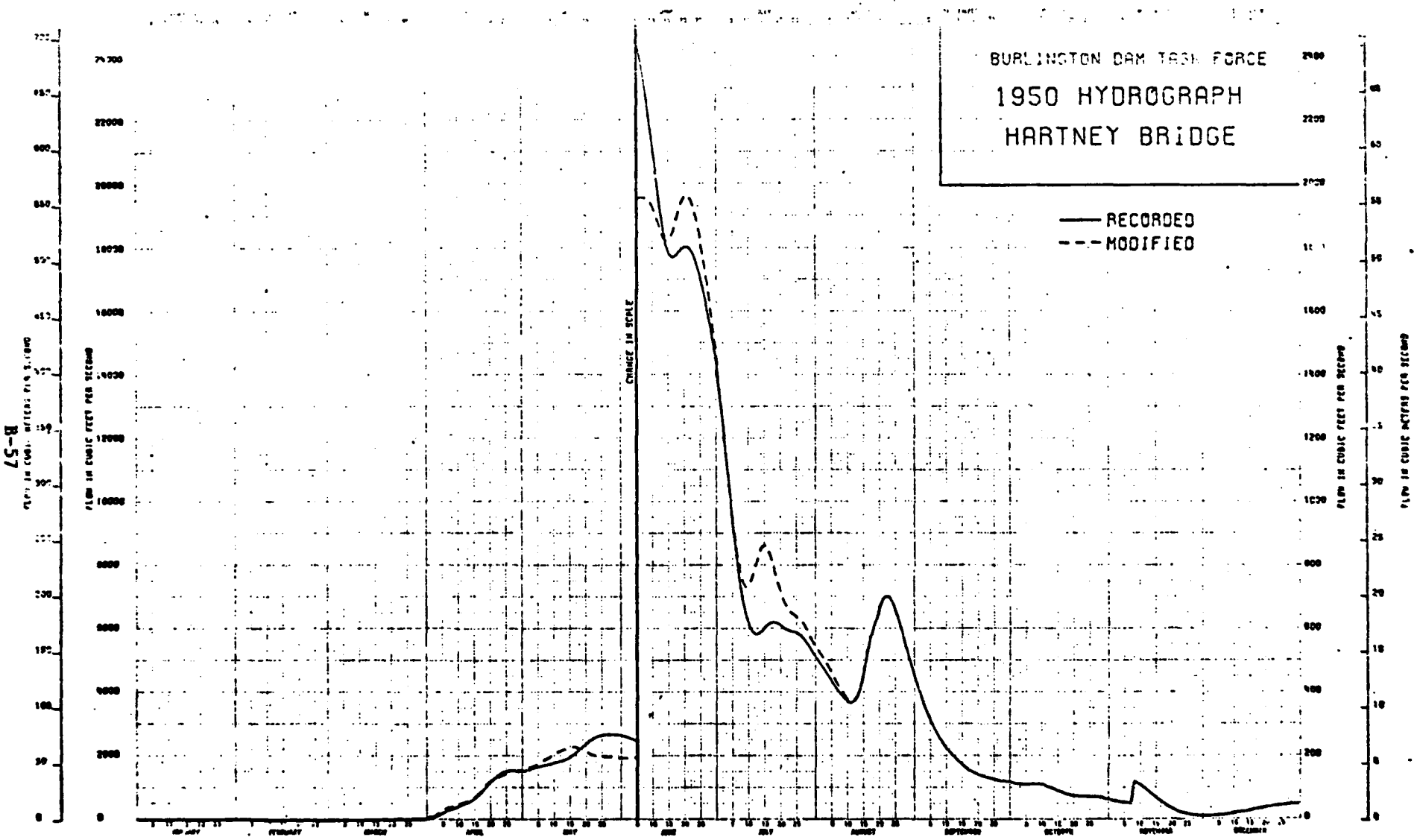

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
0
5
10
15
20
25
30
35
200
400
600
800
1000
1200
1400
MODIFIED
EXISTING
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1950

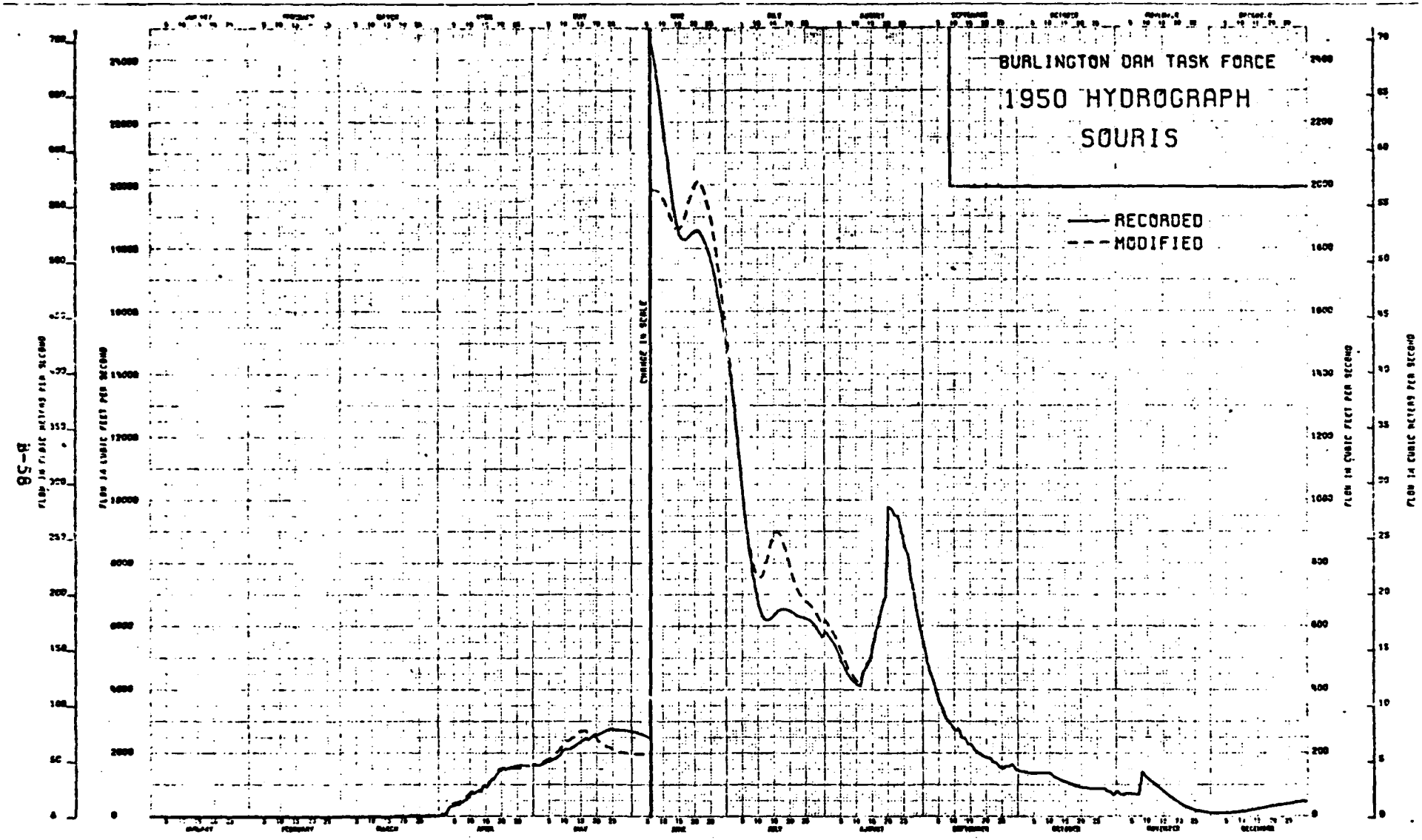

BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE

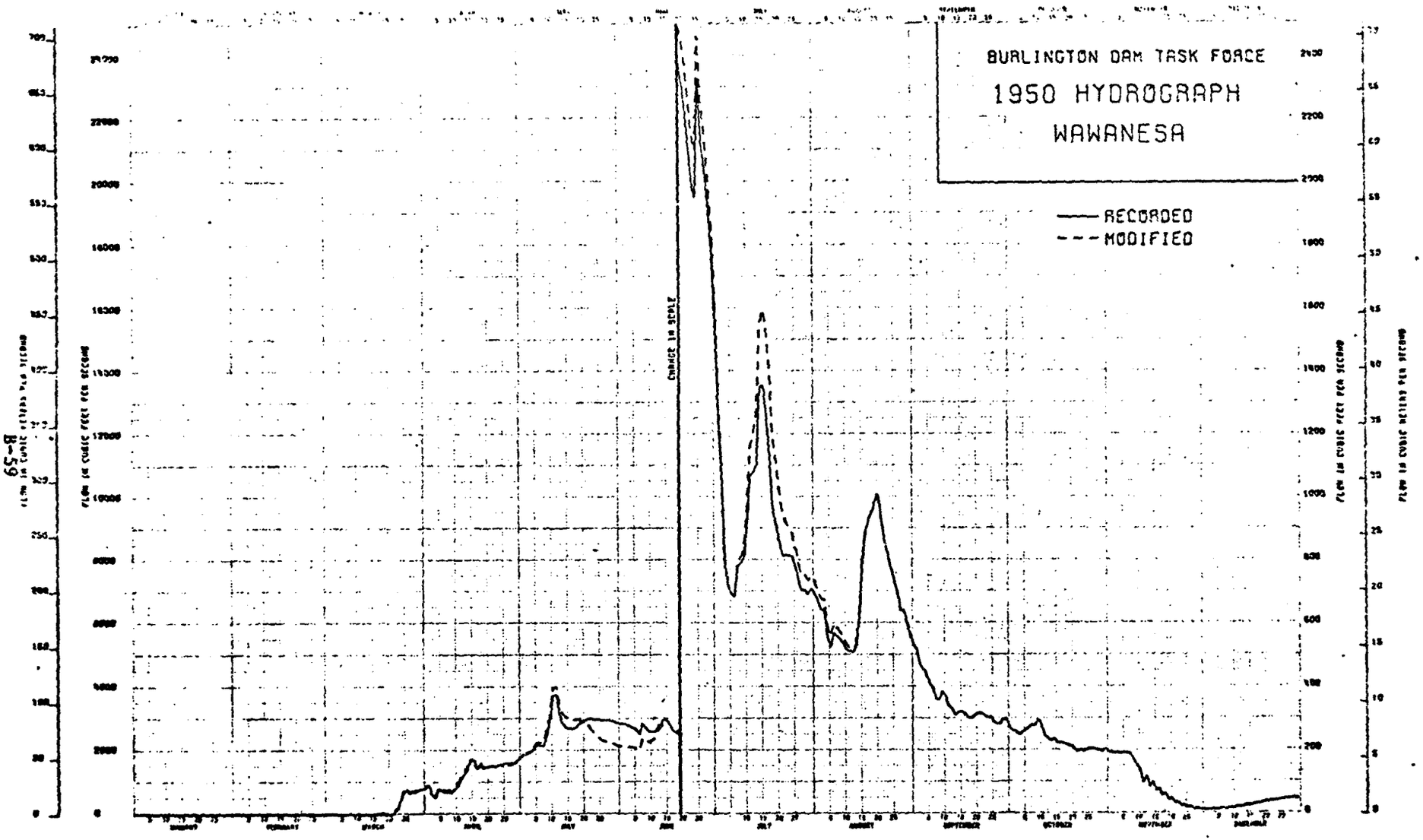

BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

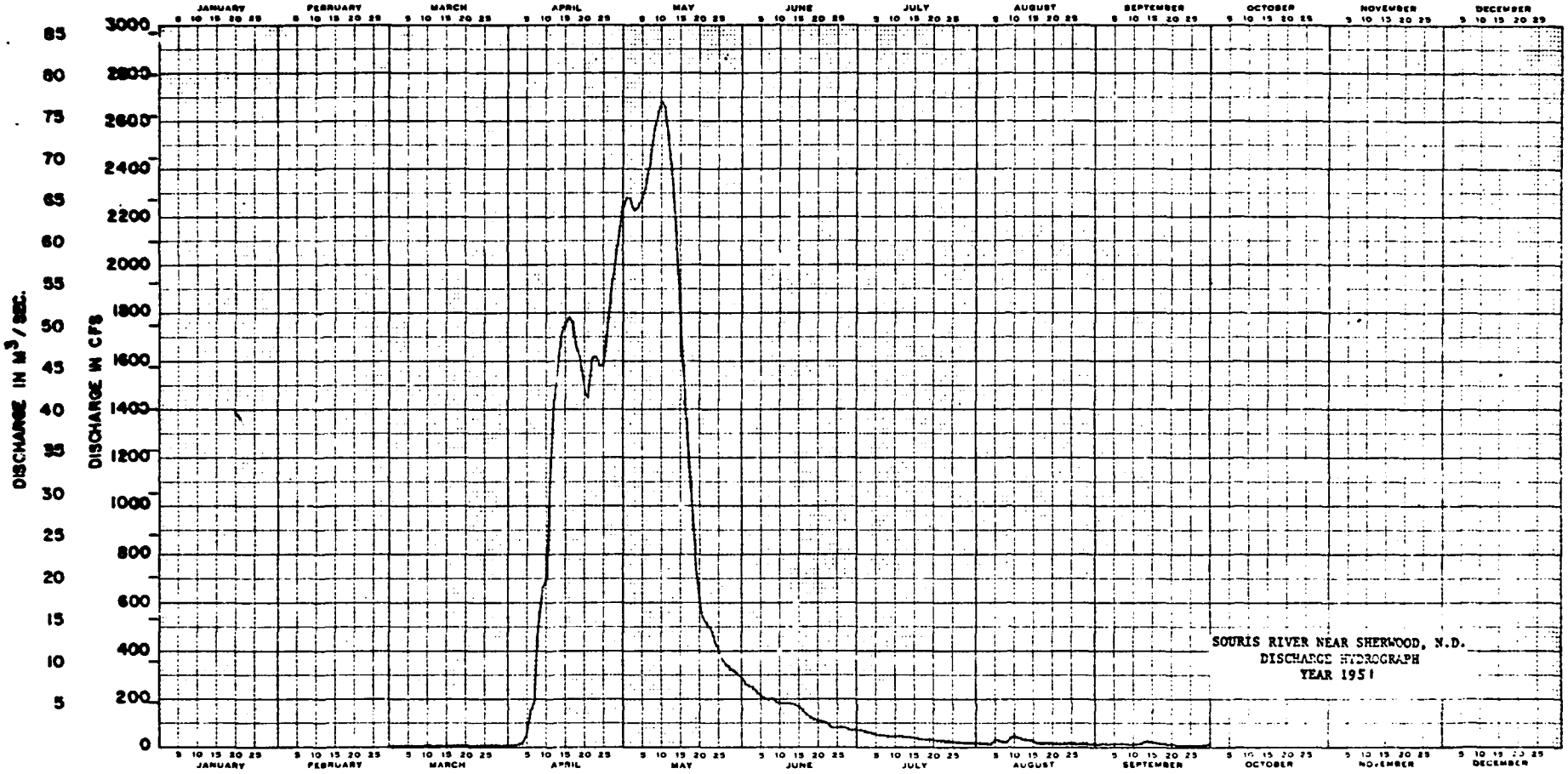

BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

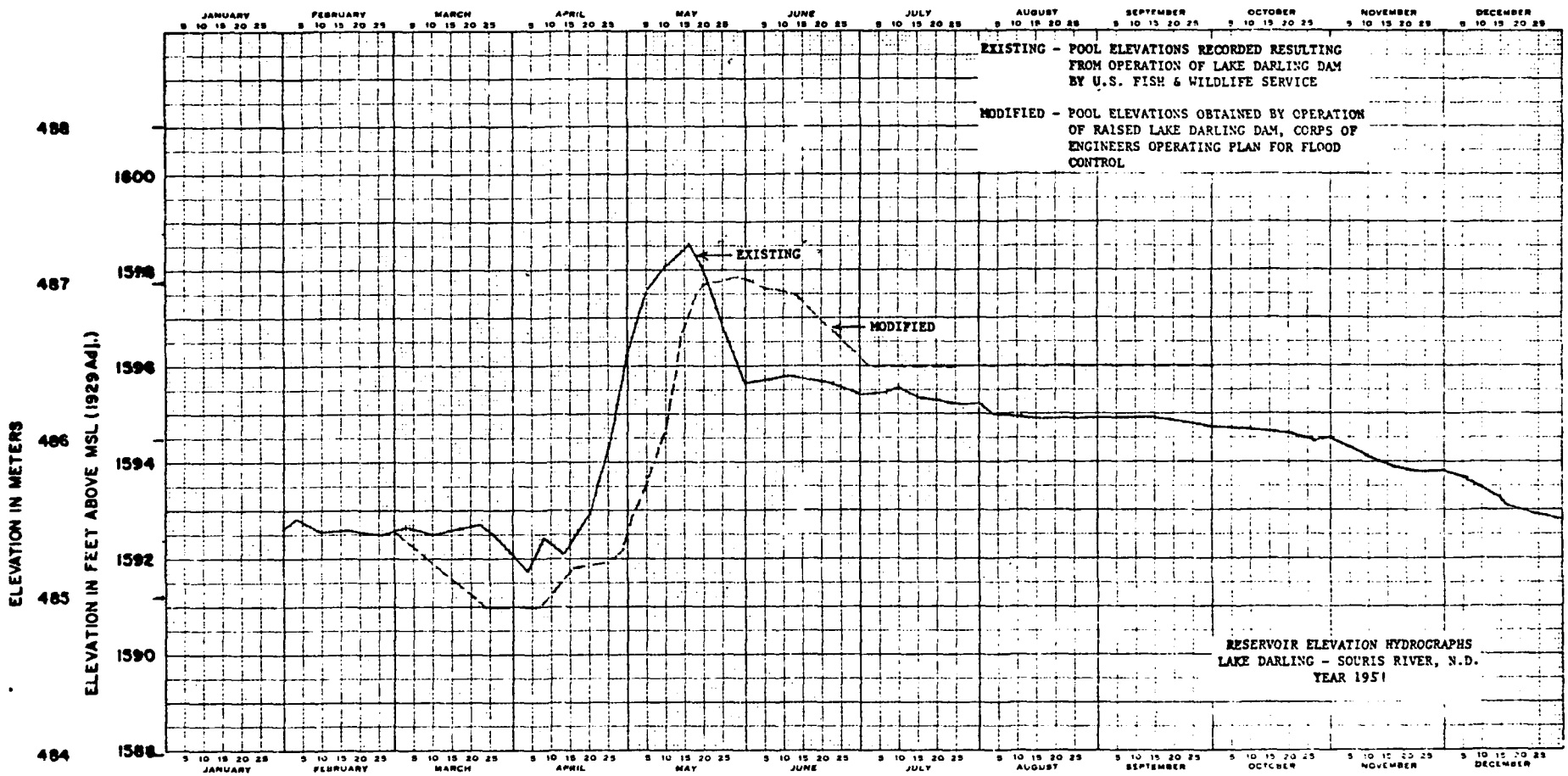

BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

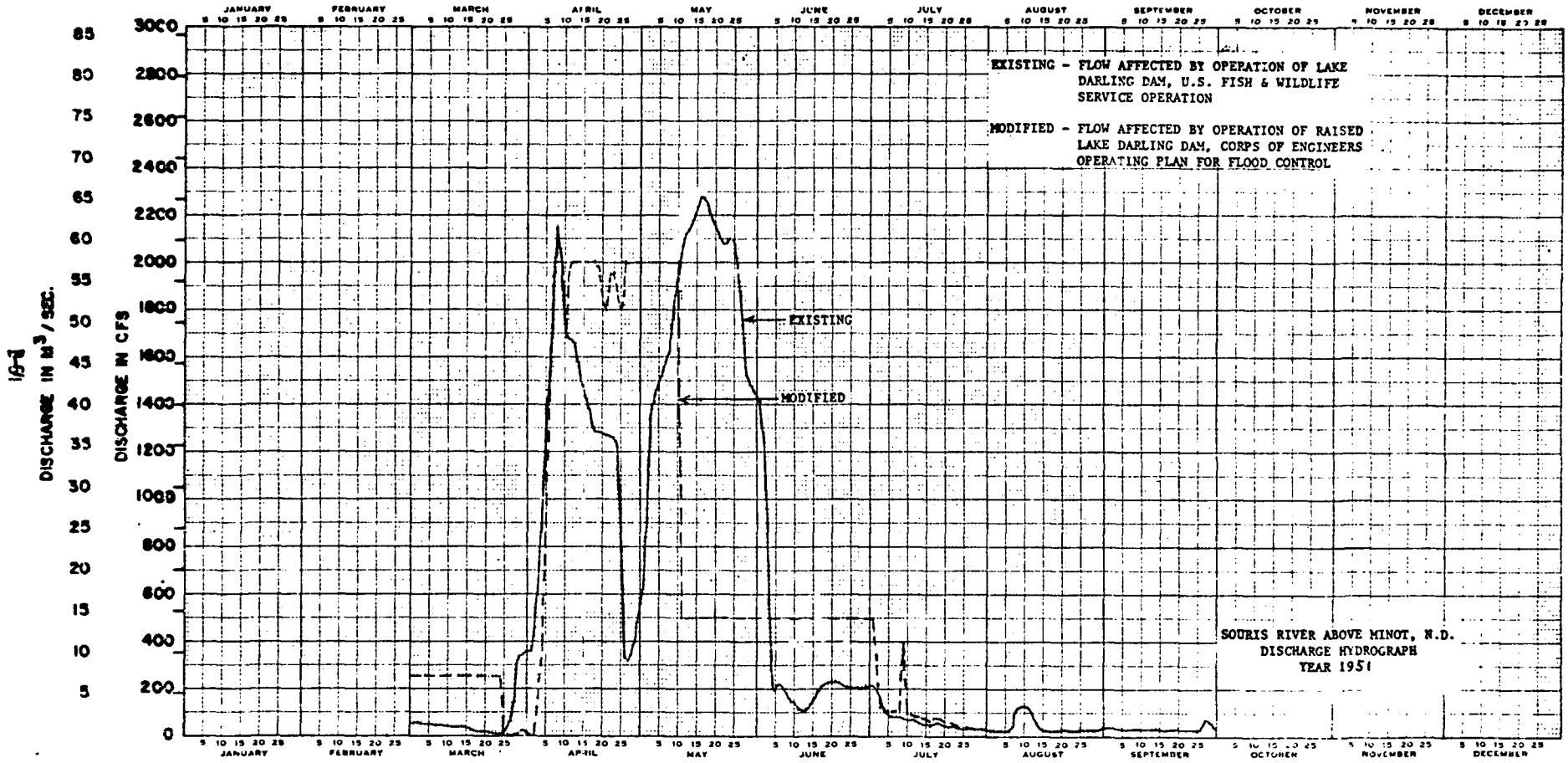

BURLINGTON DAM TASK FORCE
1950 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE

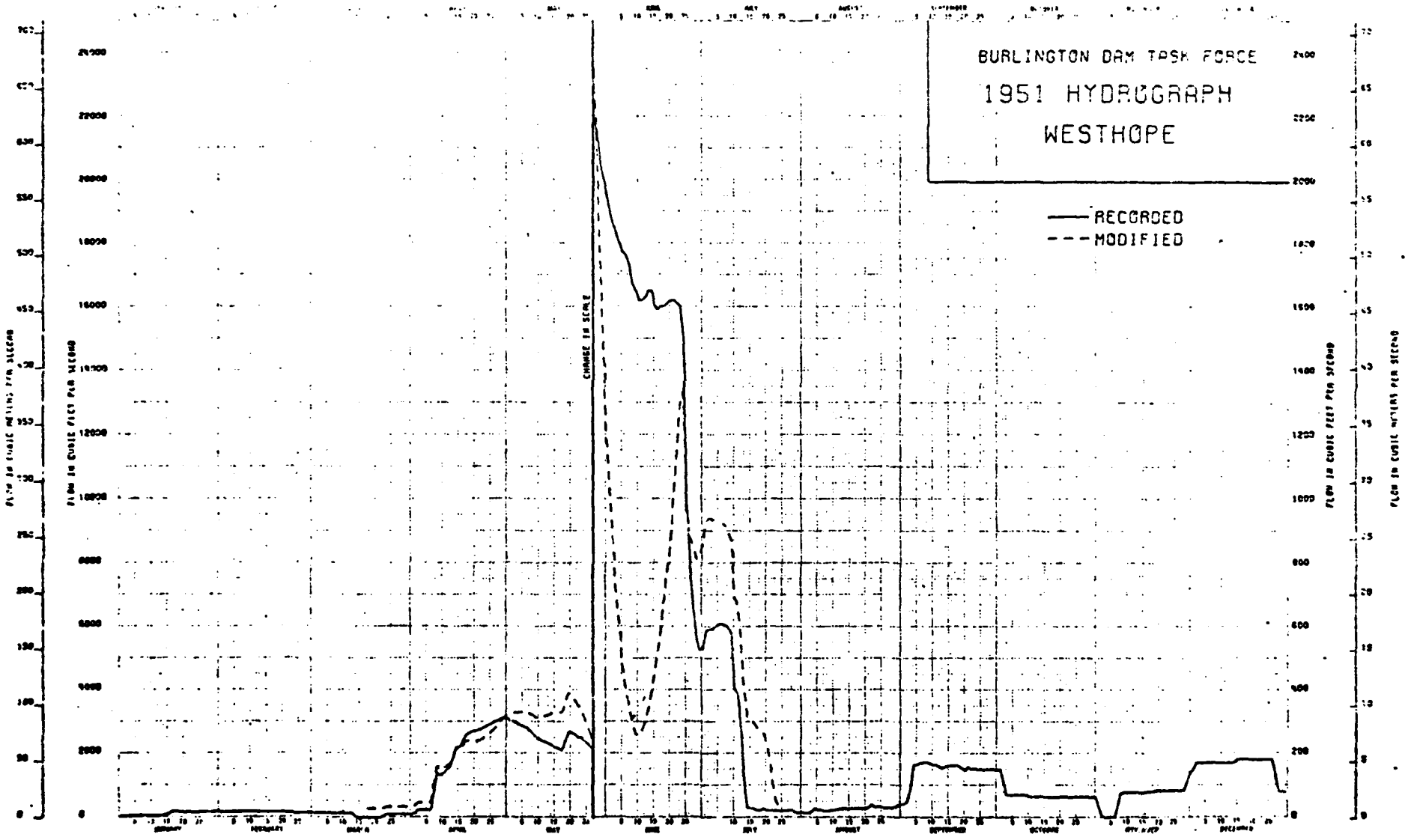
1951

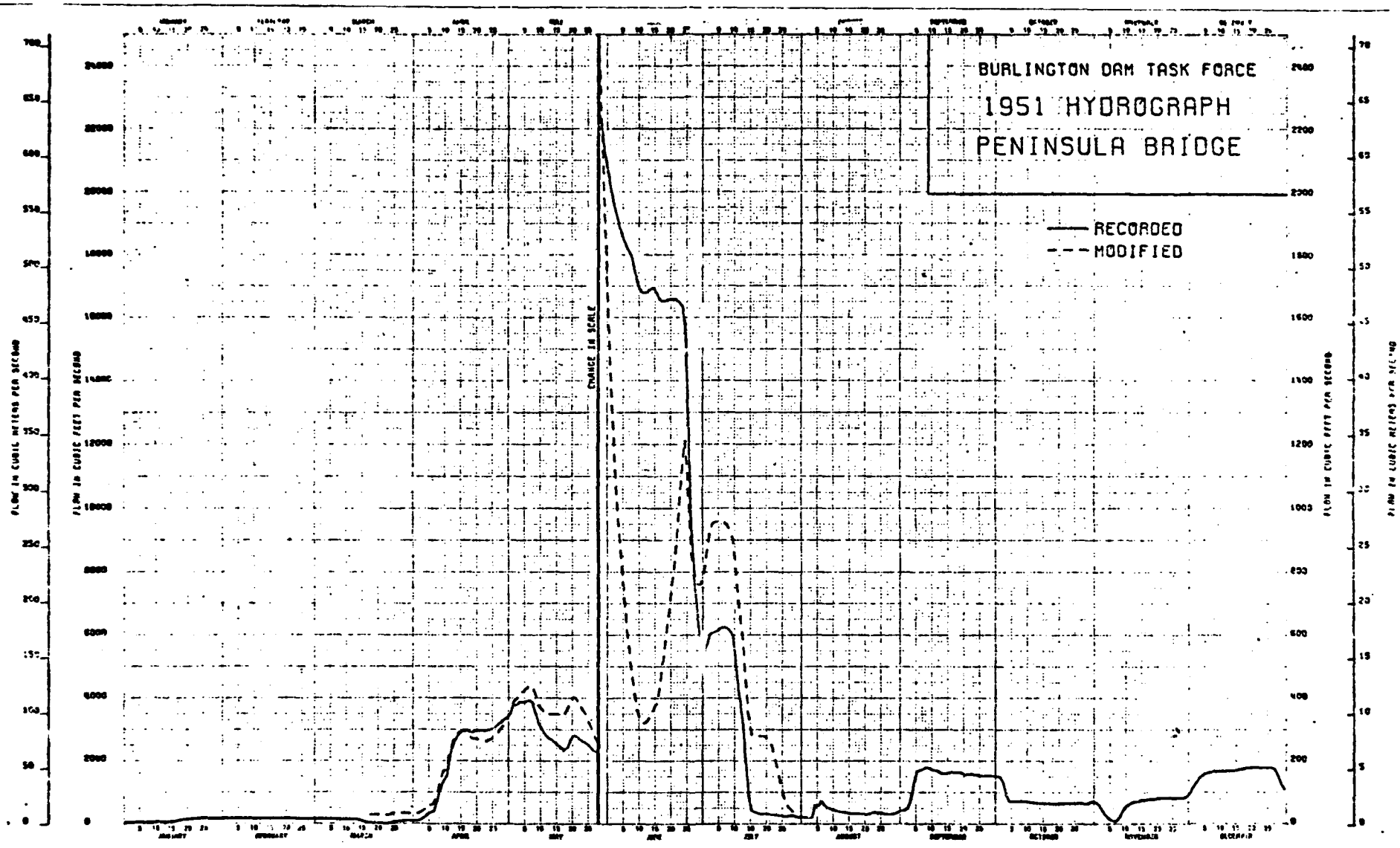

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN CFS
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
DISCHARGE IN M³/SEC.
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1951

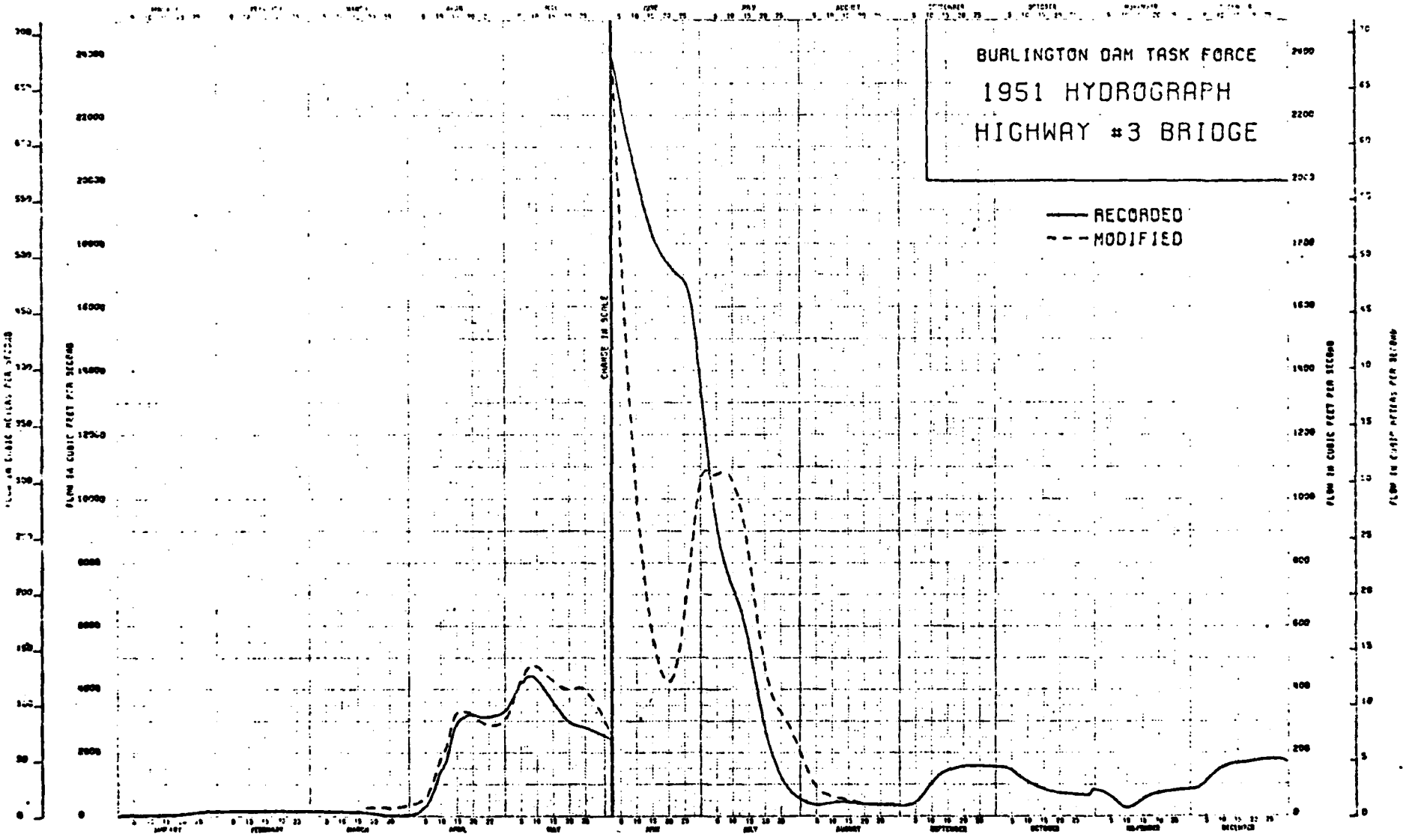


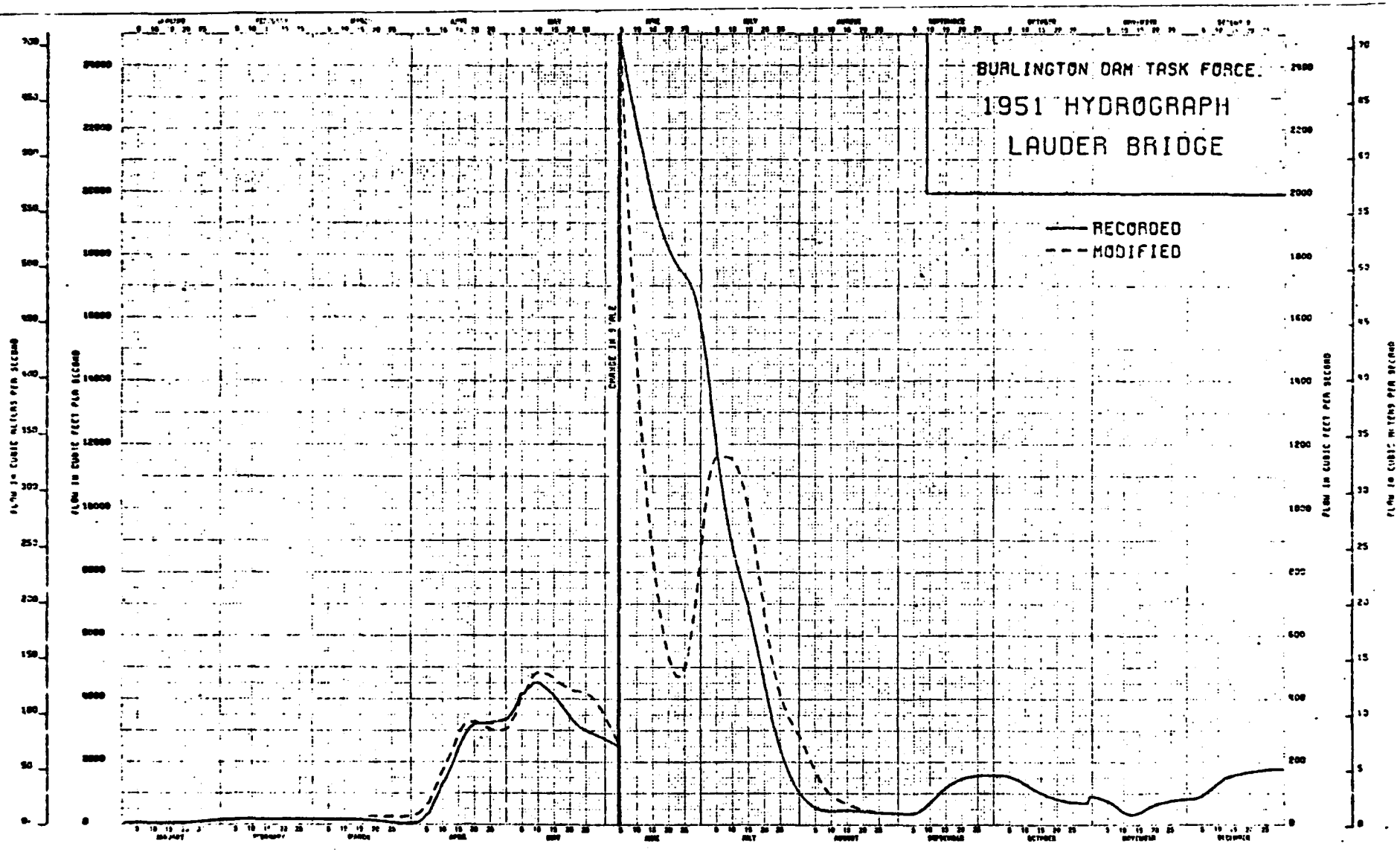
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1951

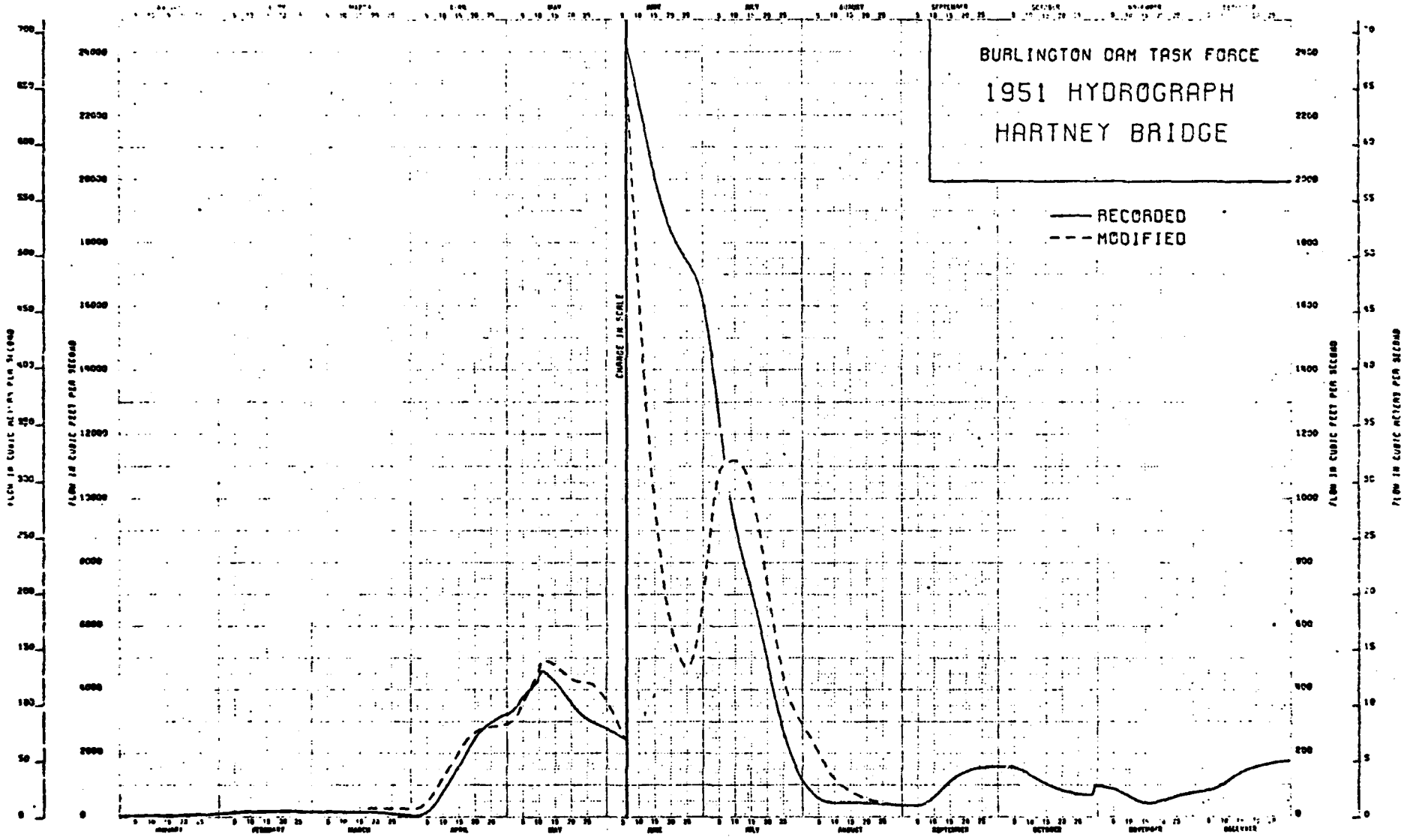

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1951
DISCHARGE IN CFS
DISCHARGE IN M³/SEC.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

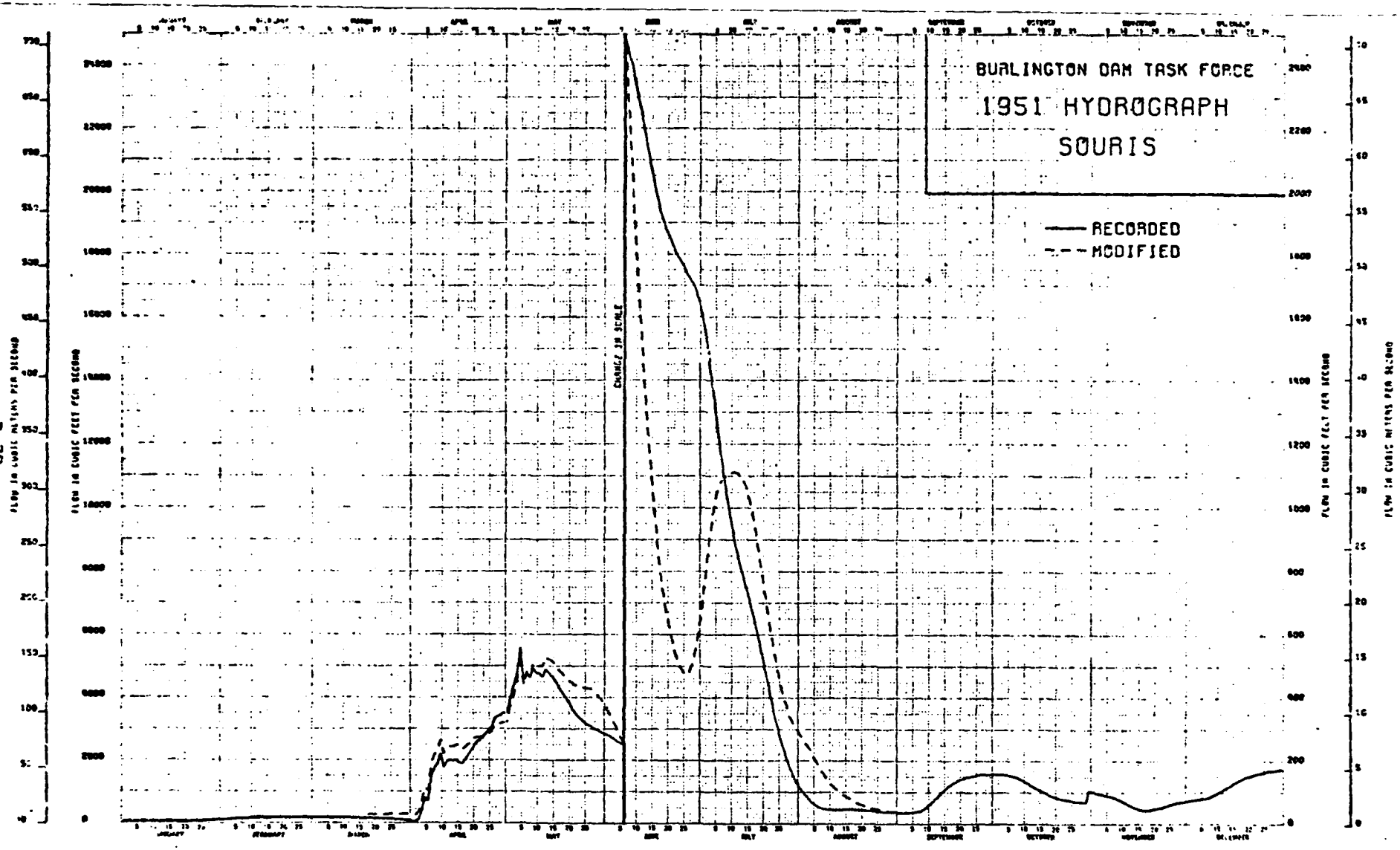

BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE

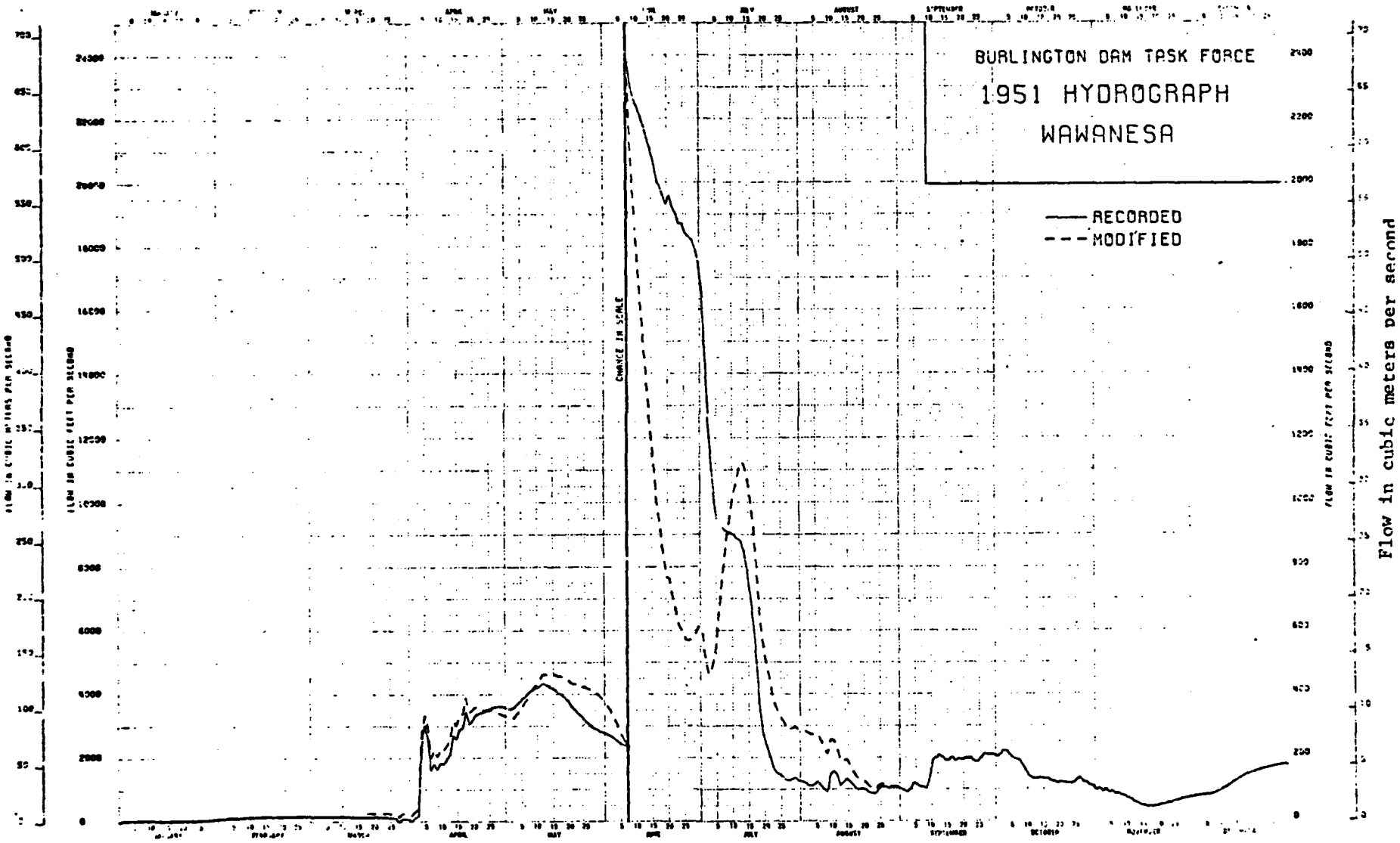

BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

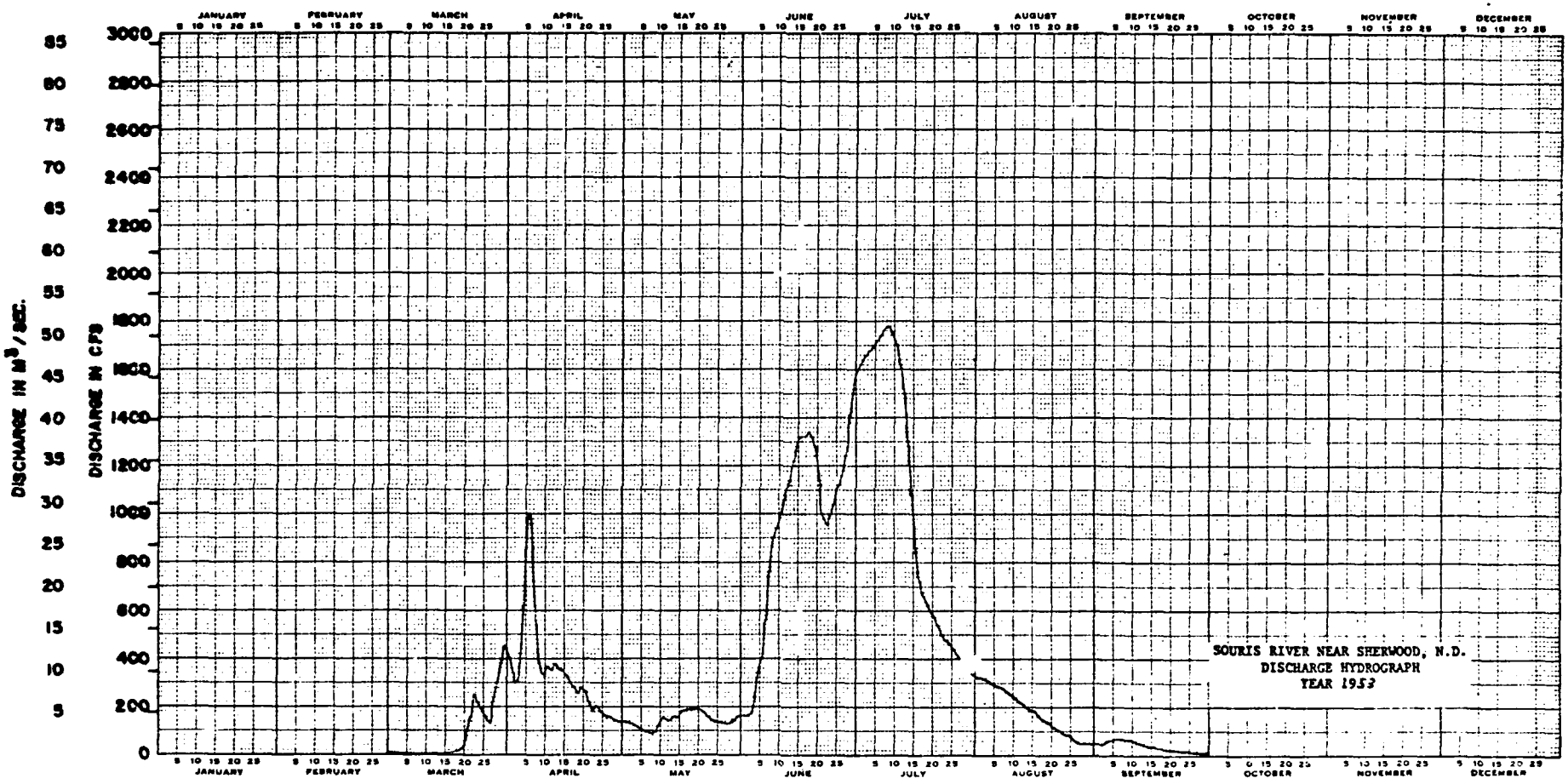

BURLINGTON DAM TASK FORCE.
1951 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN 9 MILE


BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1951 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
Flow in cubic meters per second

1953


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN M³/SEC.
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
DISCHARGE IN CFS
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
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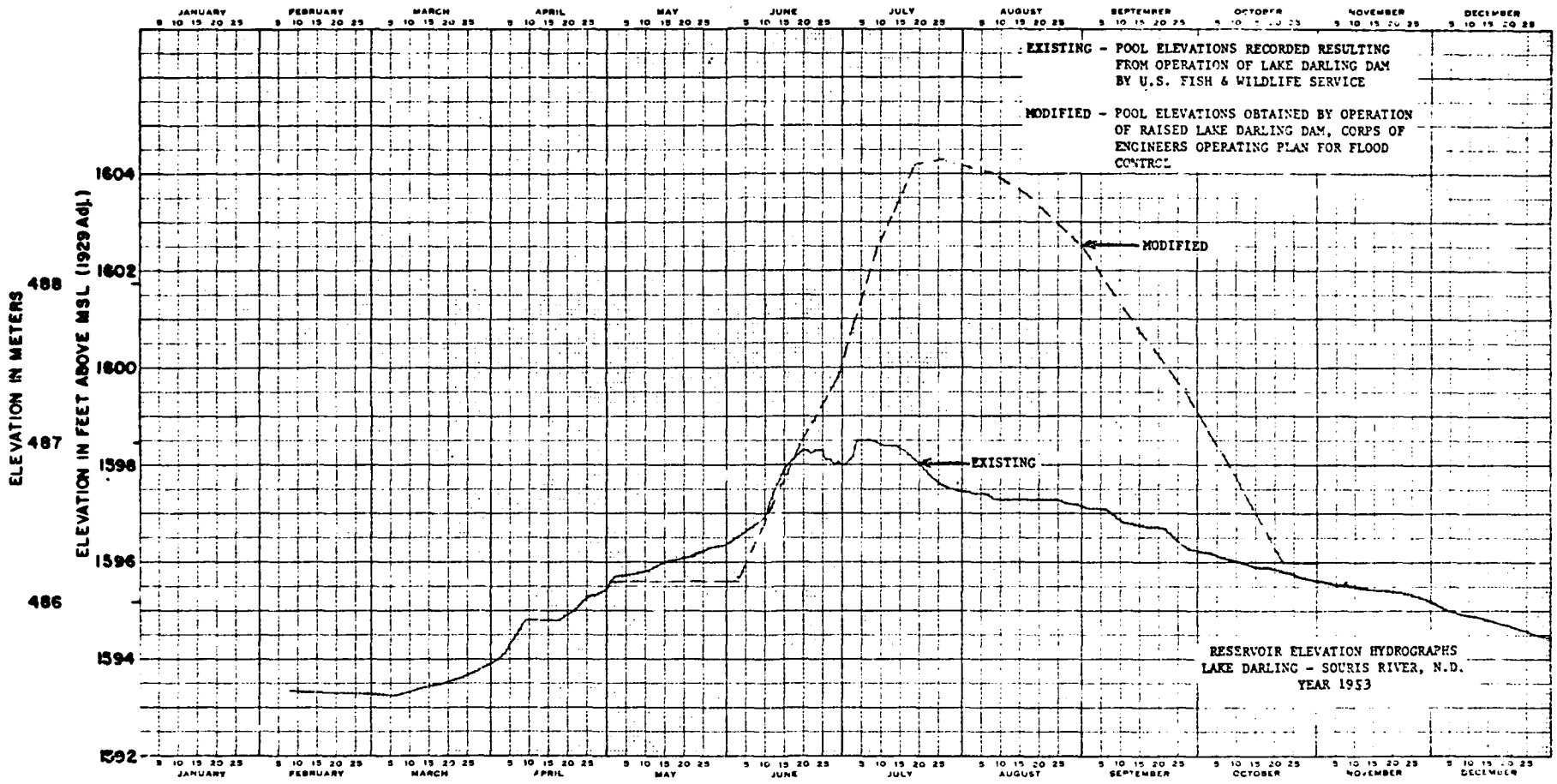
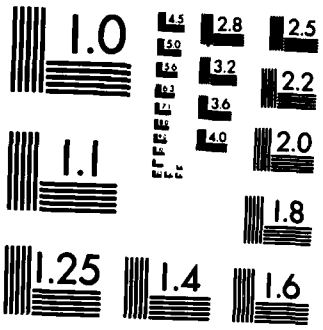
200
0
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1953

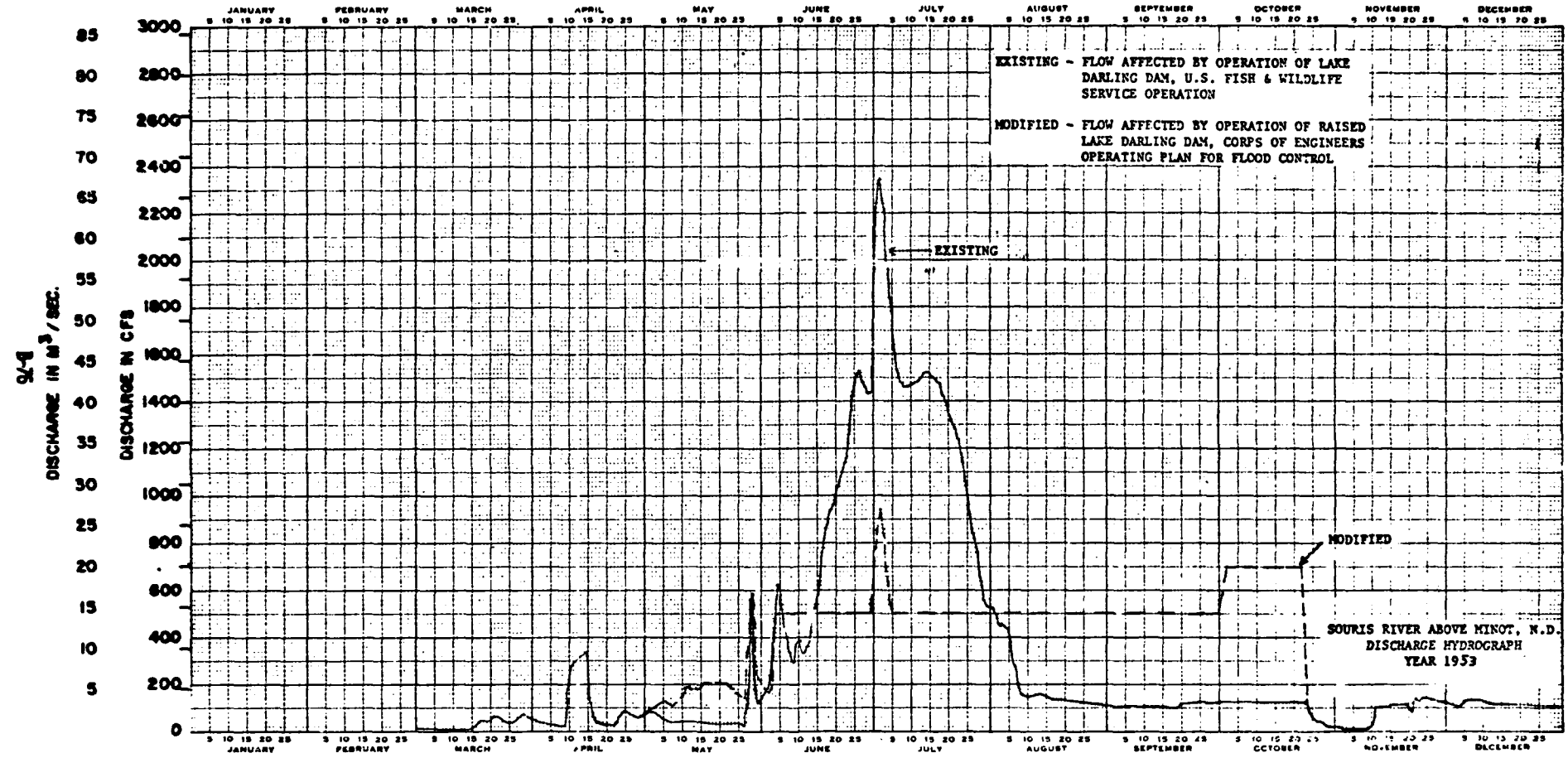


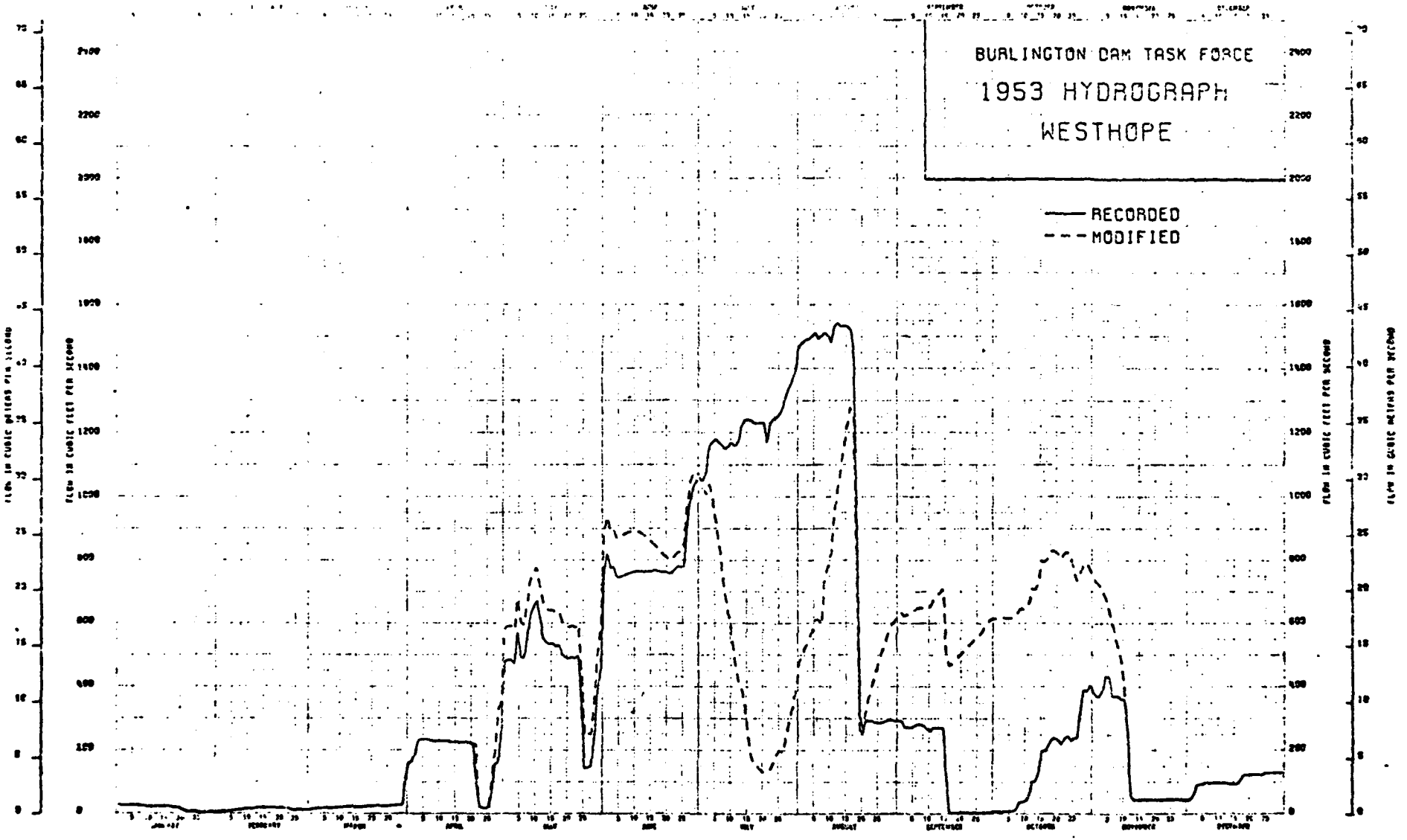
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1953

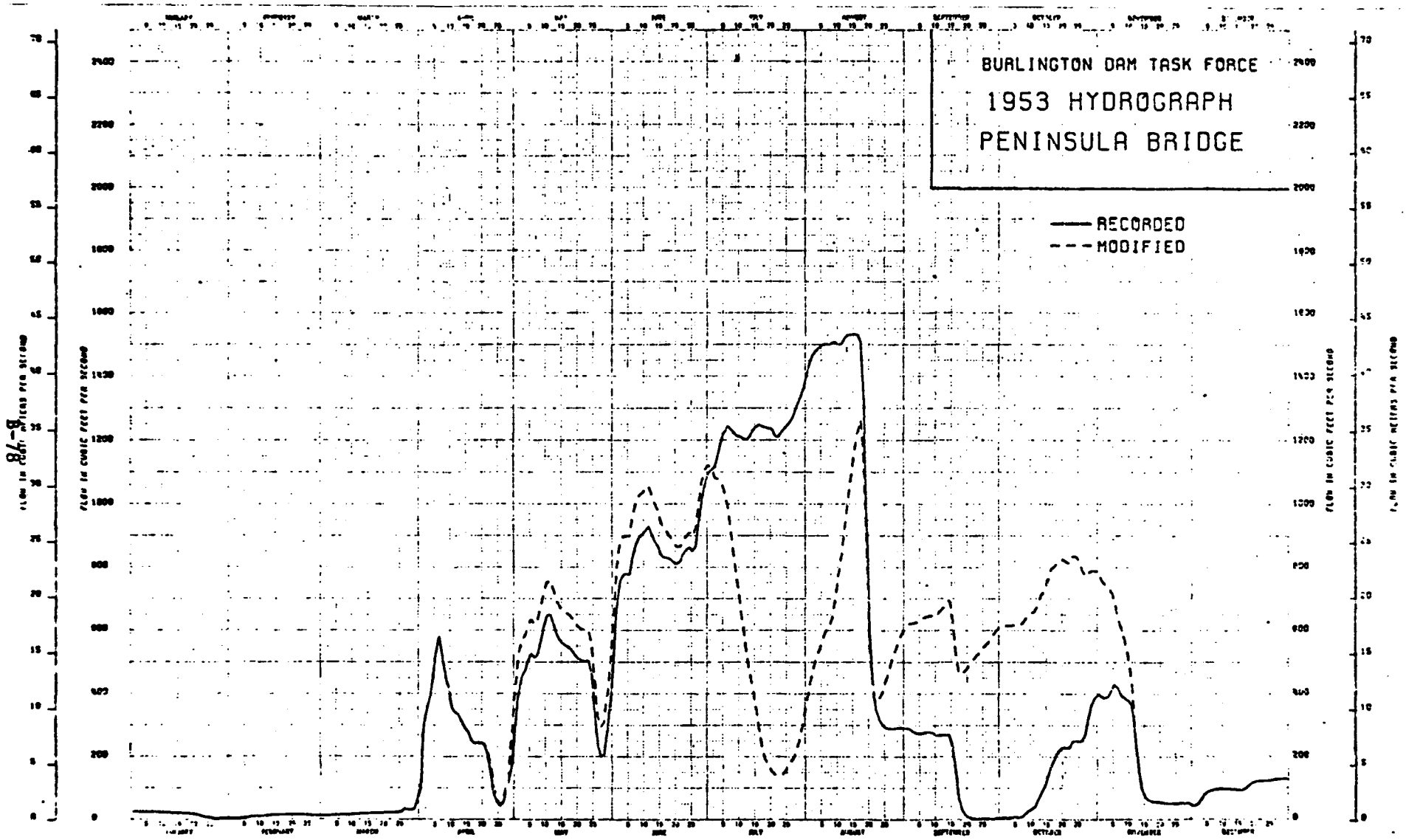
AD-A146 947 SOURIS RIVER BASIN SASKATCHEWAN NORTH DAKOTA AND MANITOBA REVIEW OF THE E..(U) BURLINGTON DAM TASK FORCE JUN 79 3/4

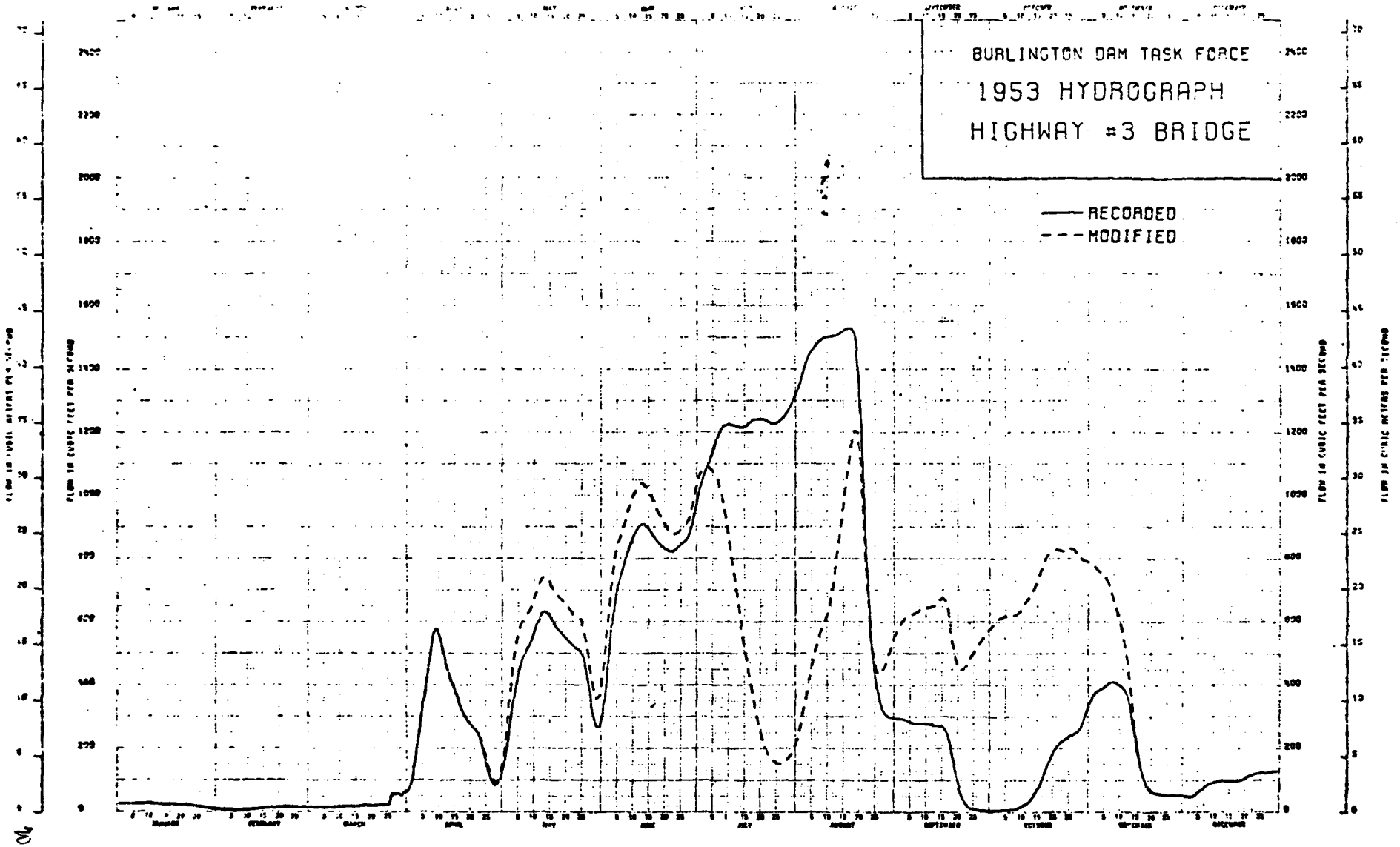
UNCLASSIFIED F/G 13/2 NL

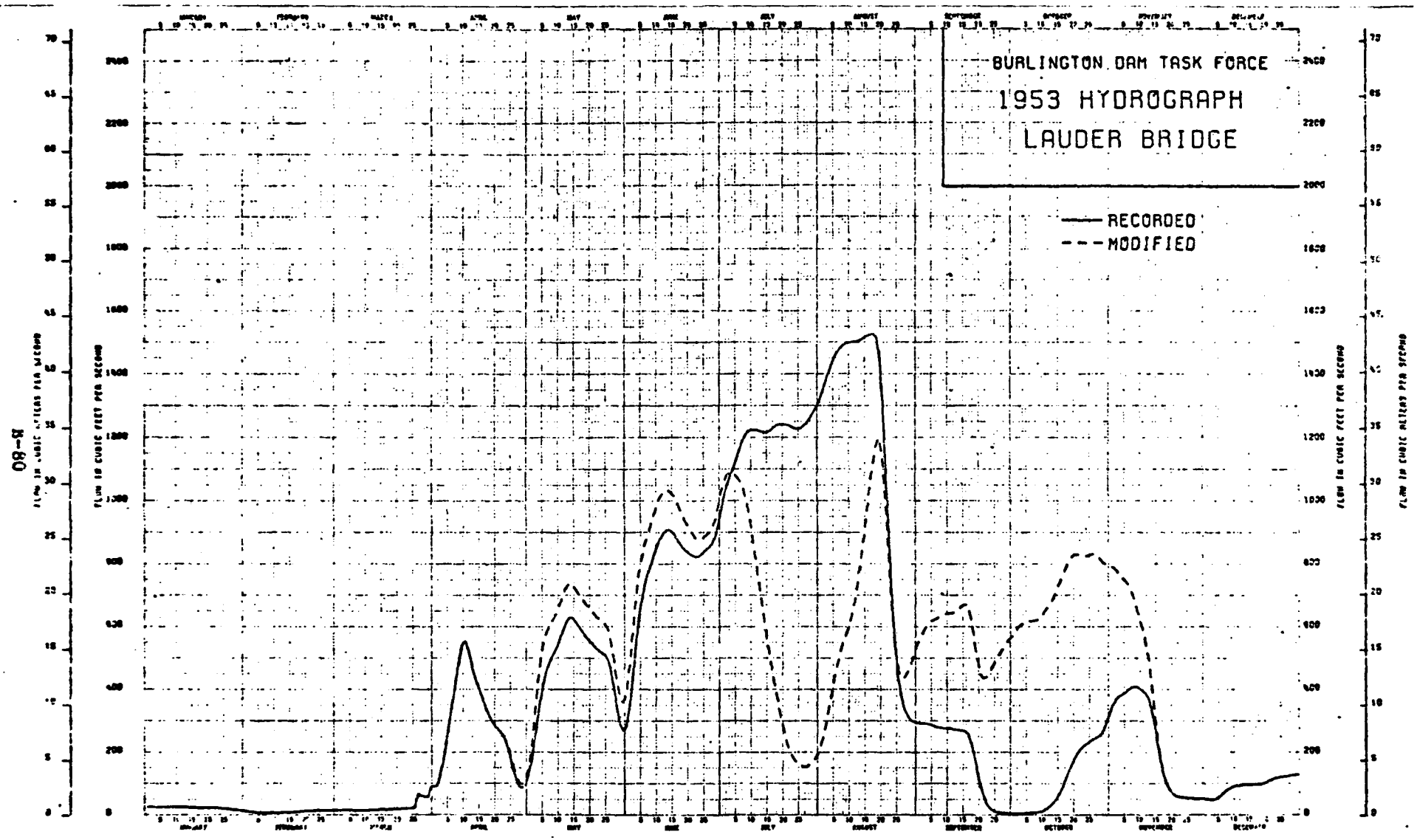

1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

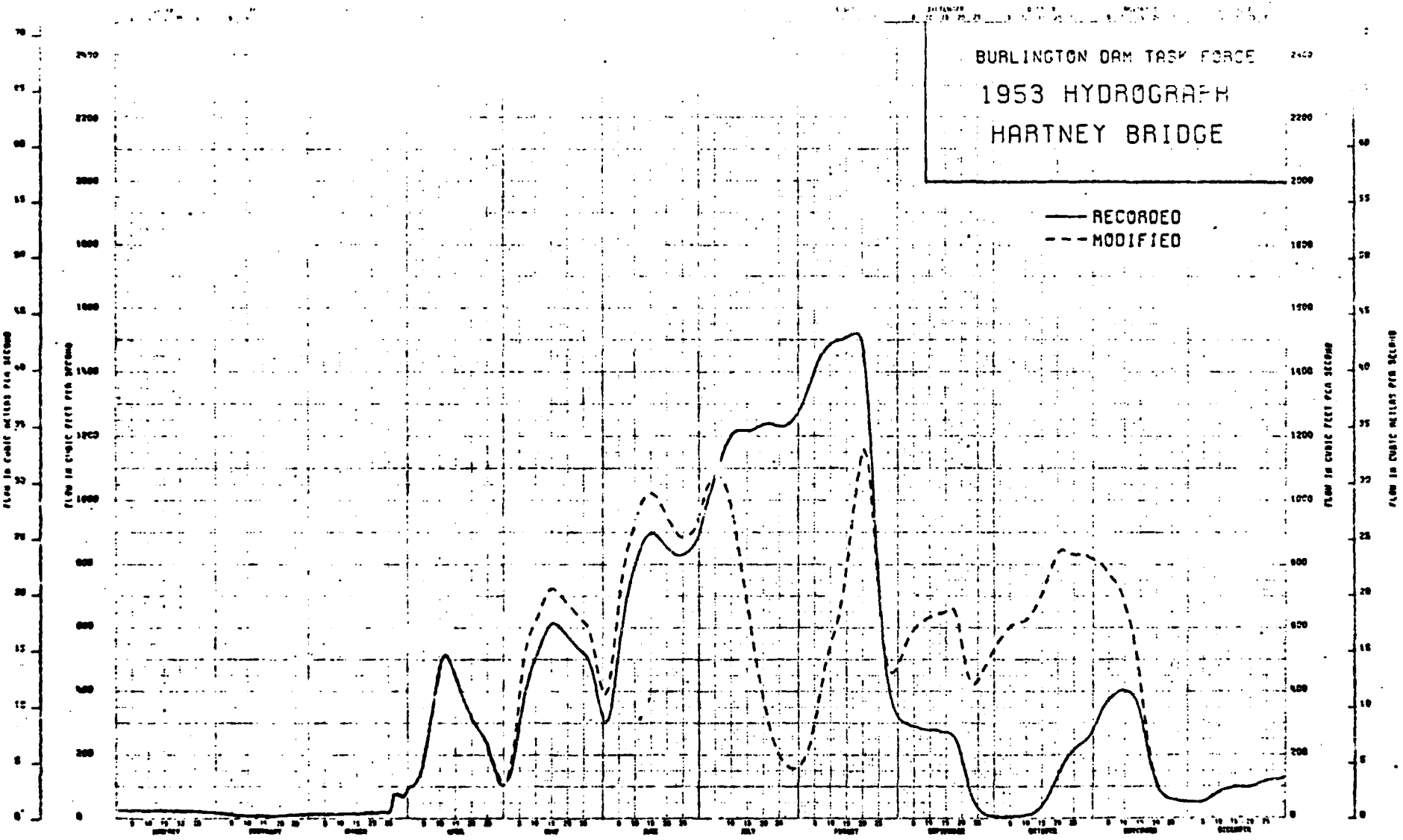

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1953
DISCHARGE IN CFS
DISCHARGE IN M³/SEC.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

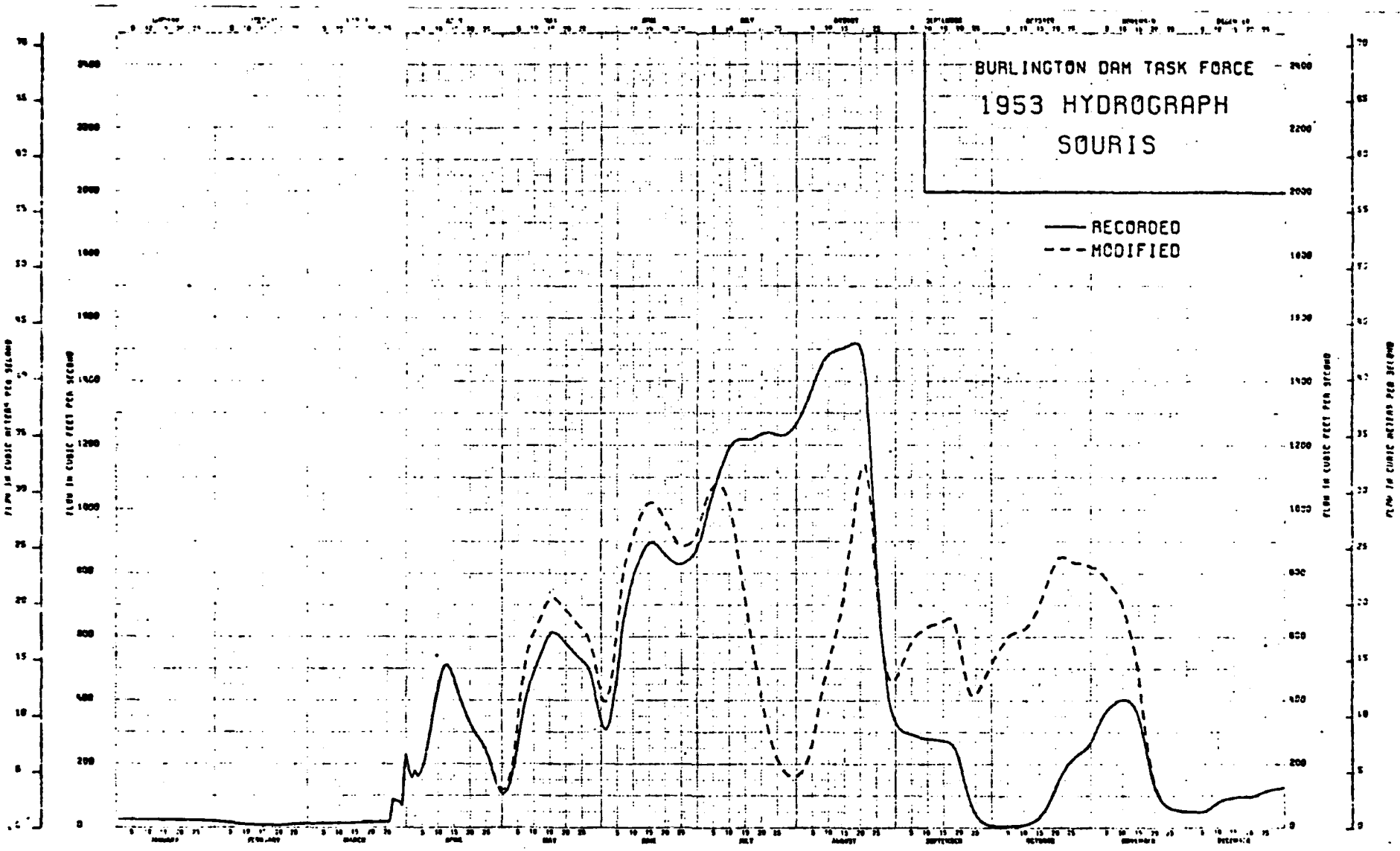

BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

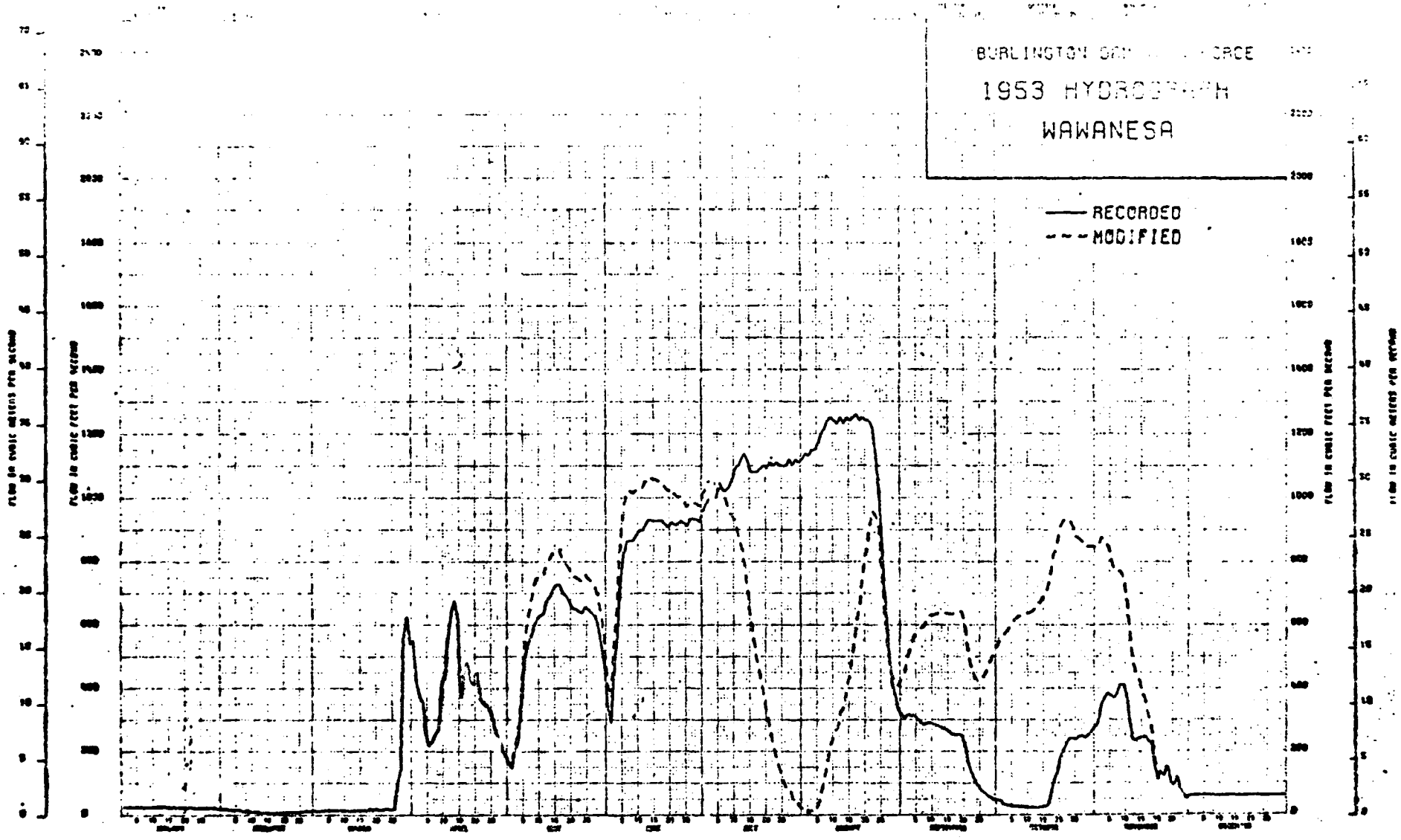

BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED

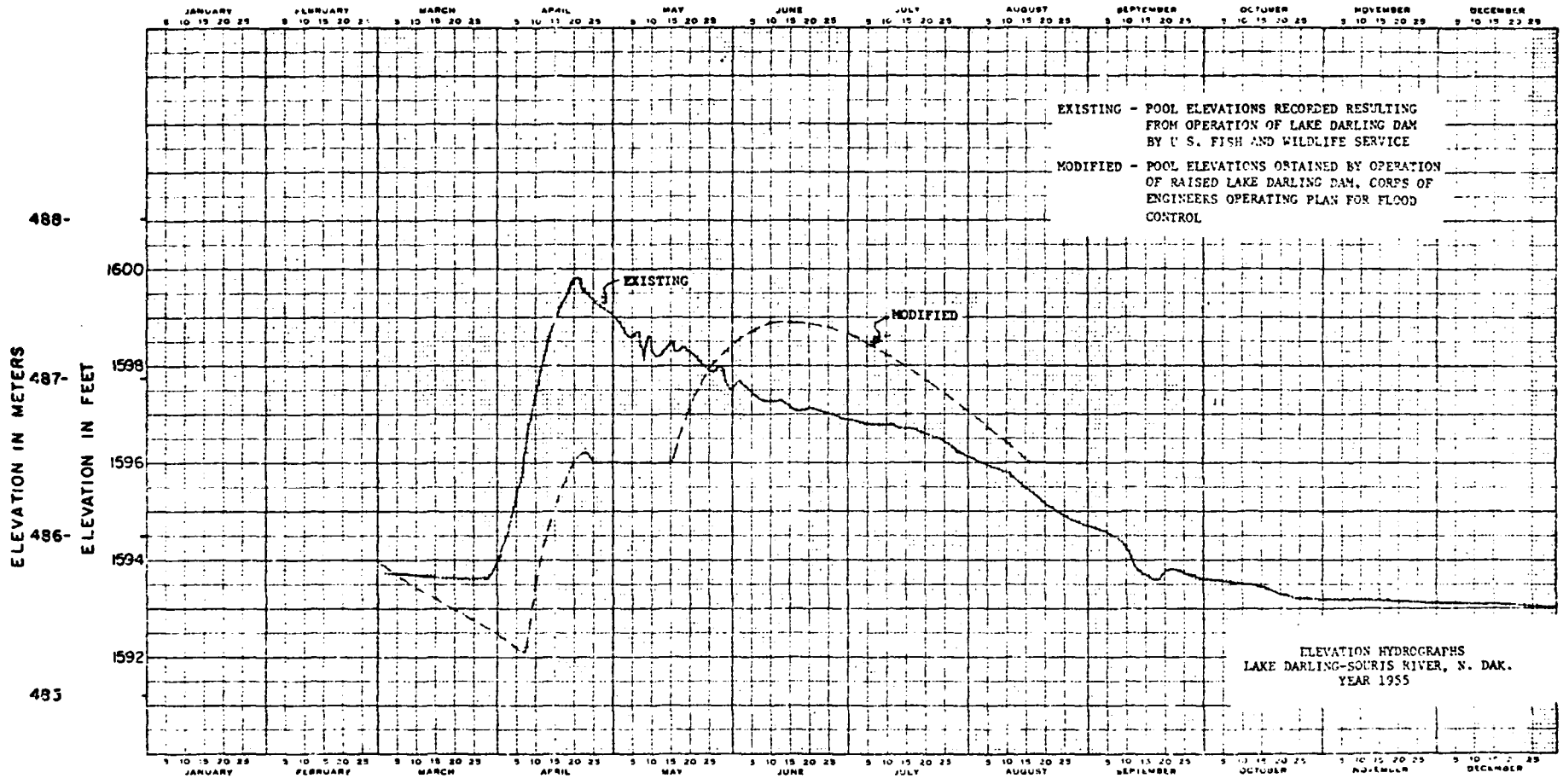

BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1953 HYDROGRAPH
SOURIS
RECORDED
MODIFIED

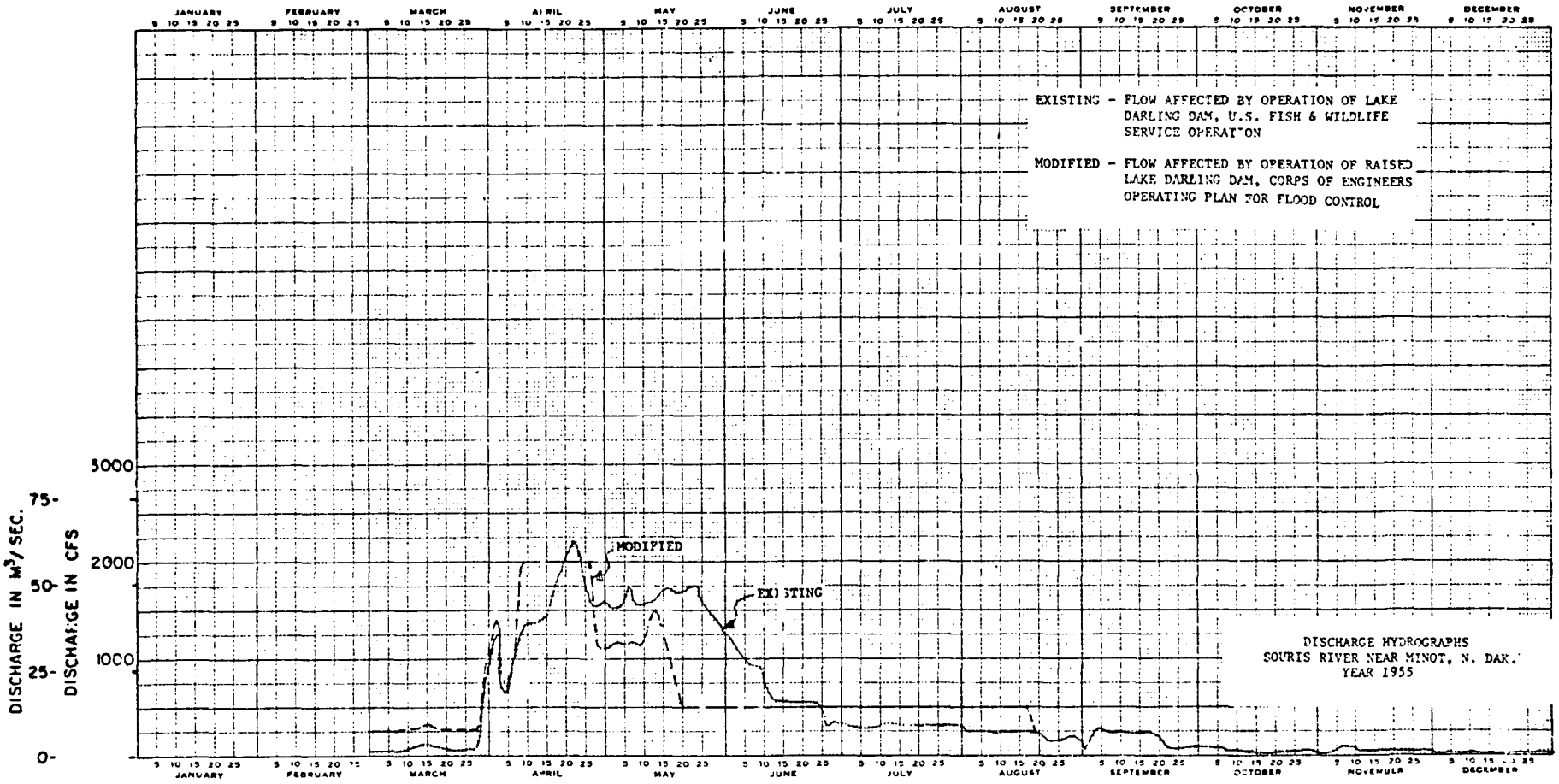

BURLINGTON
1953 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED

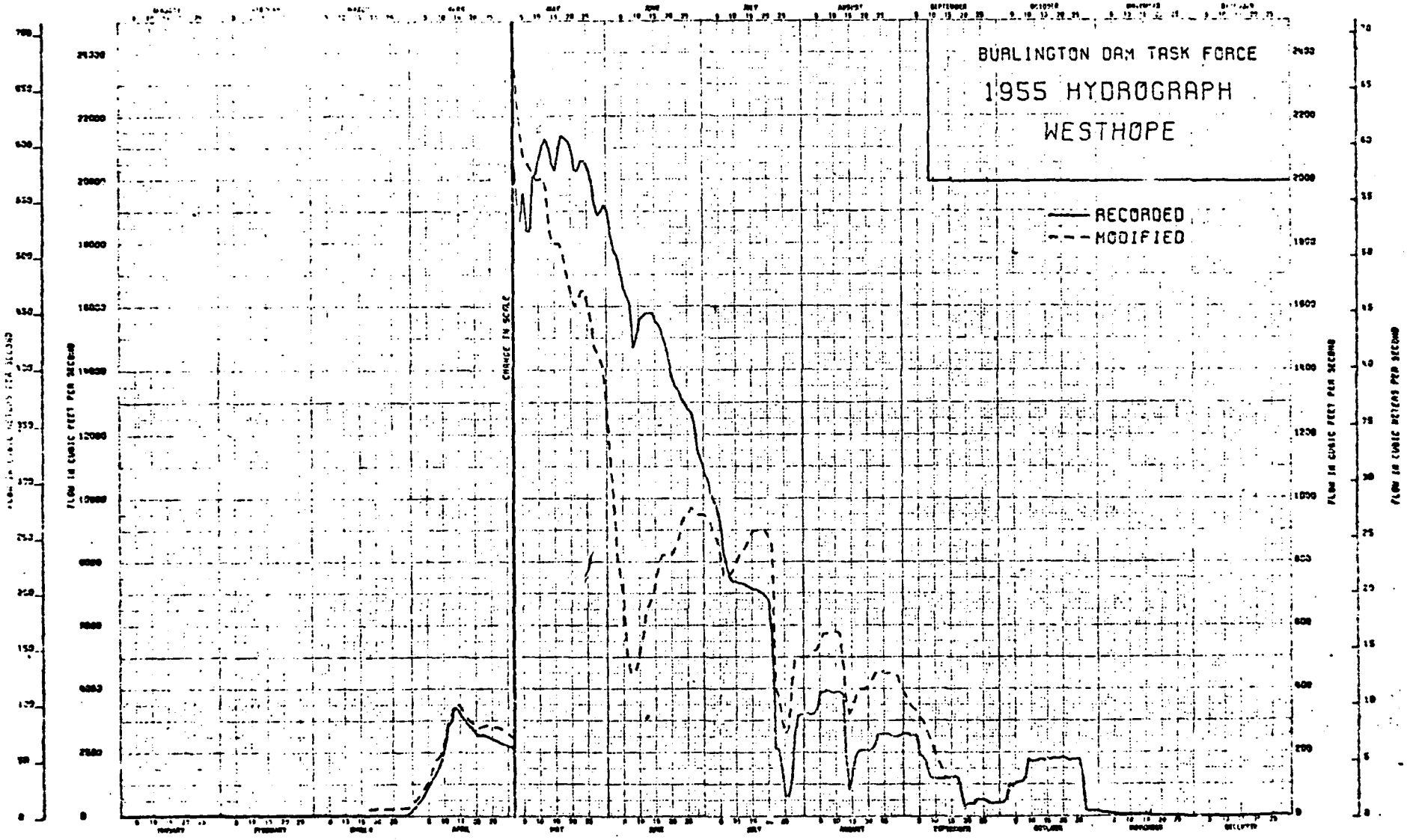
1955

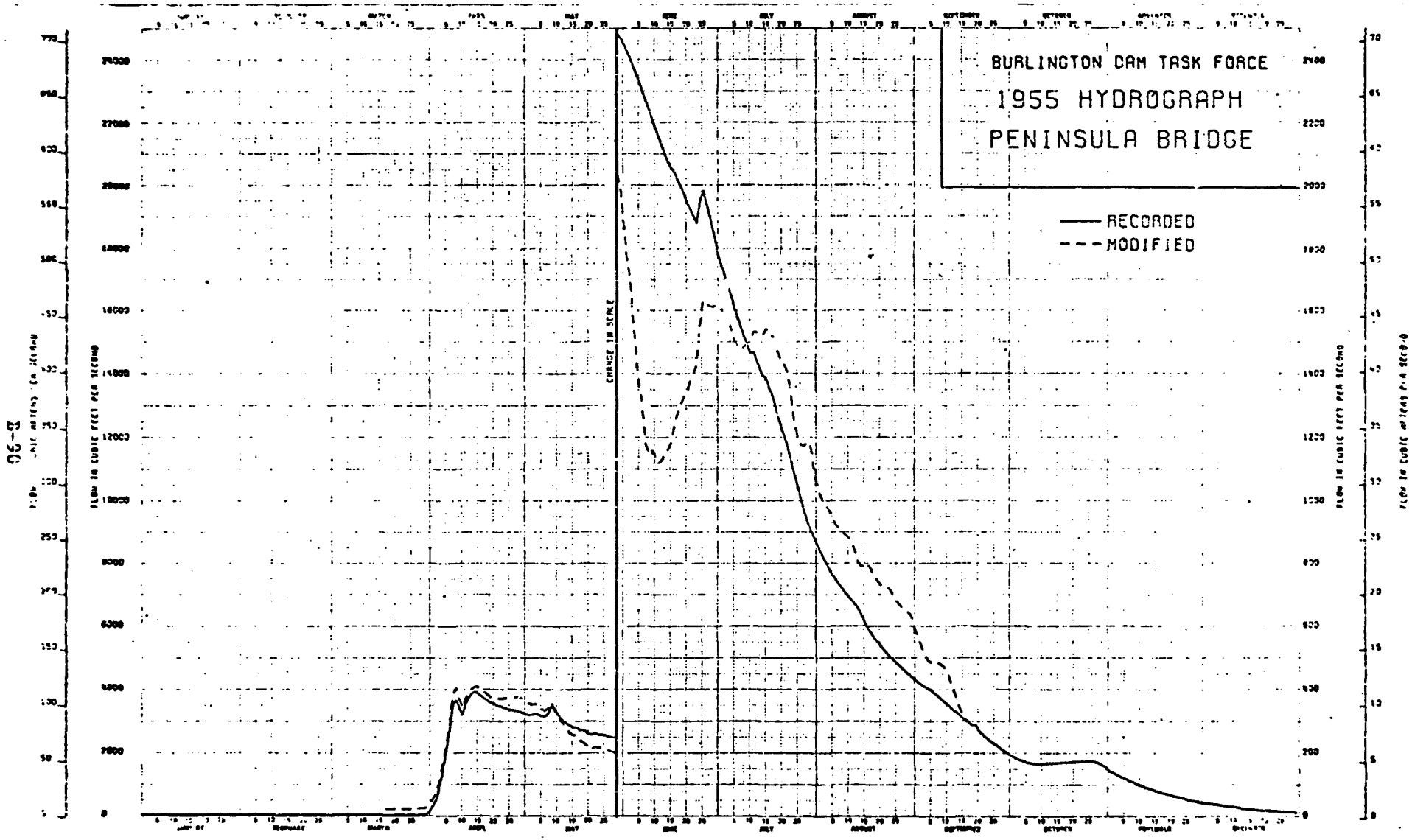
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1955

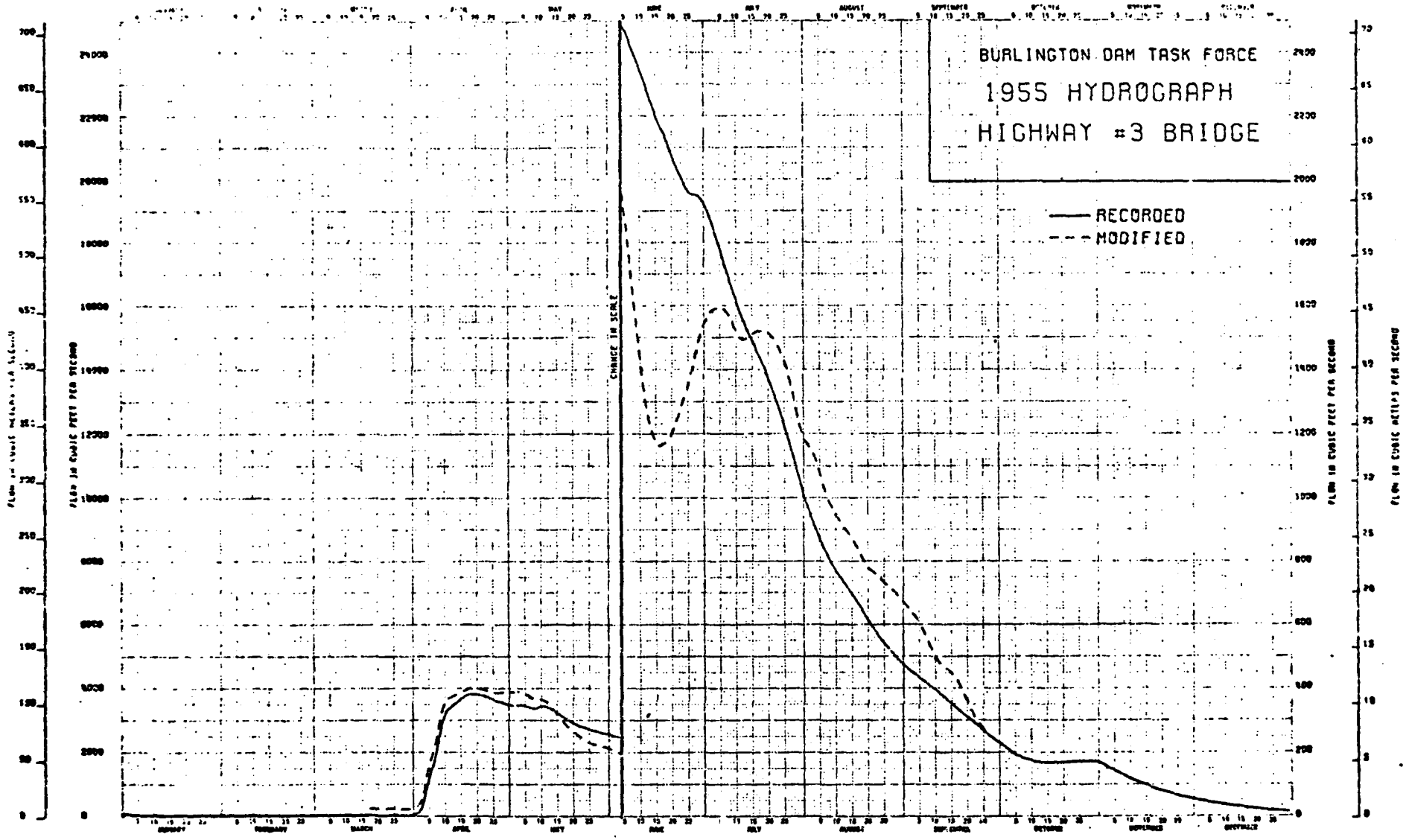


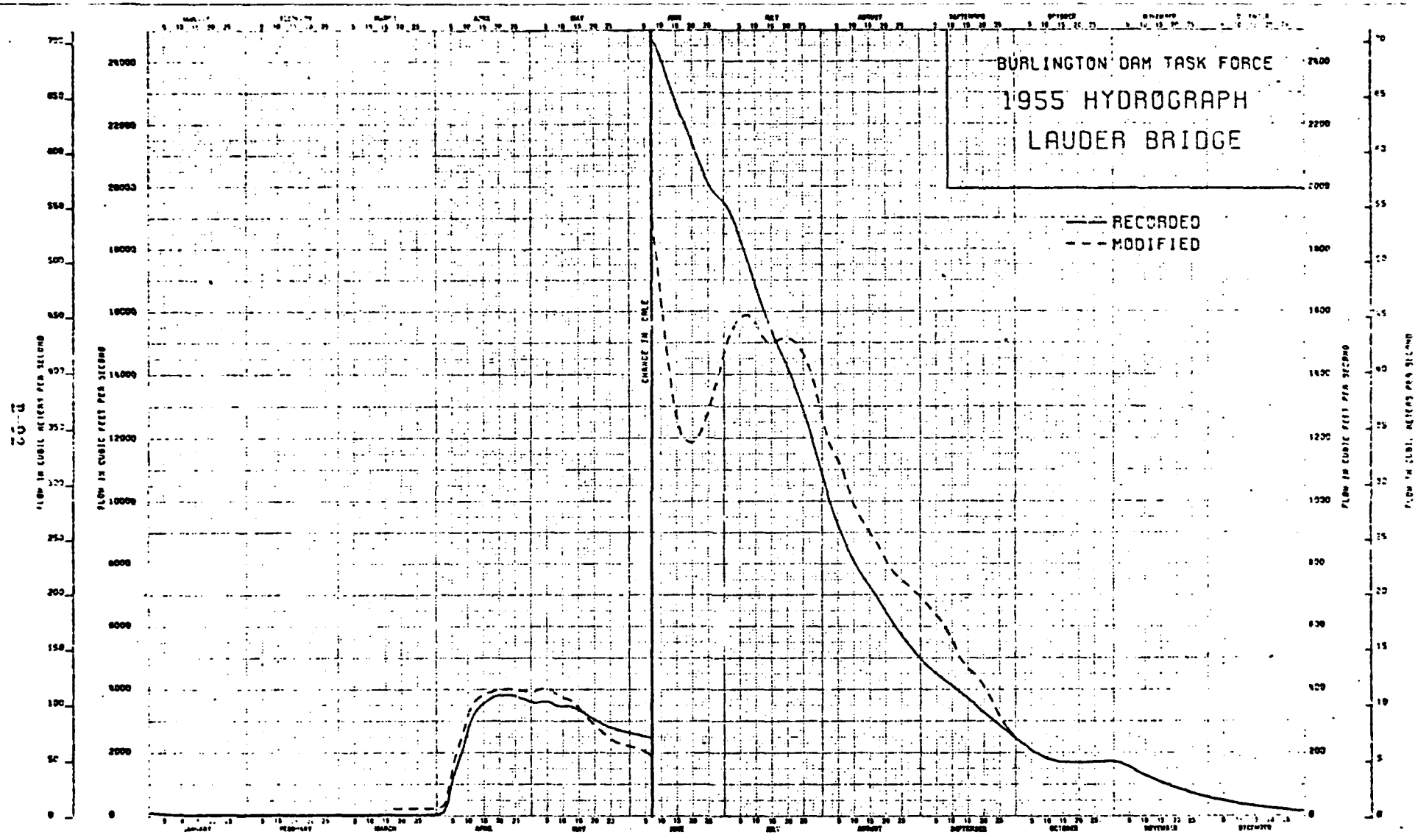
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1955

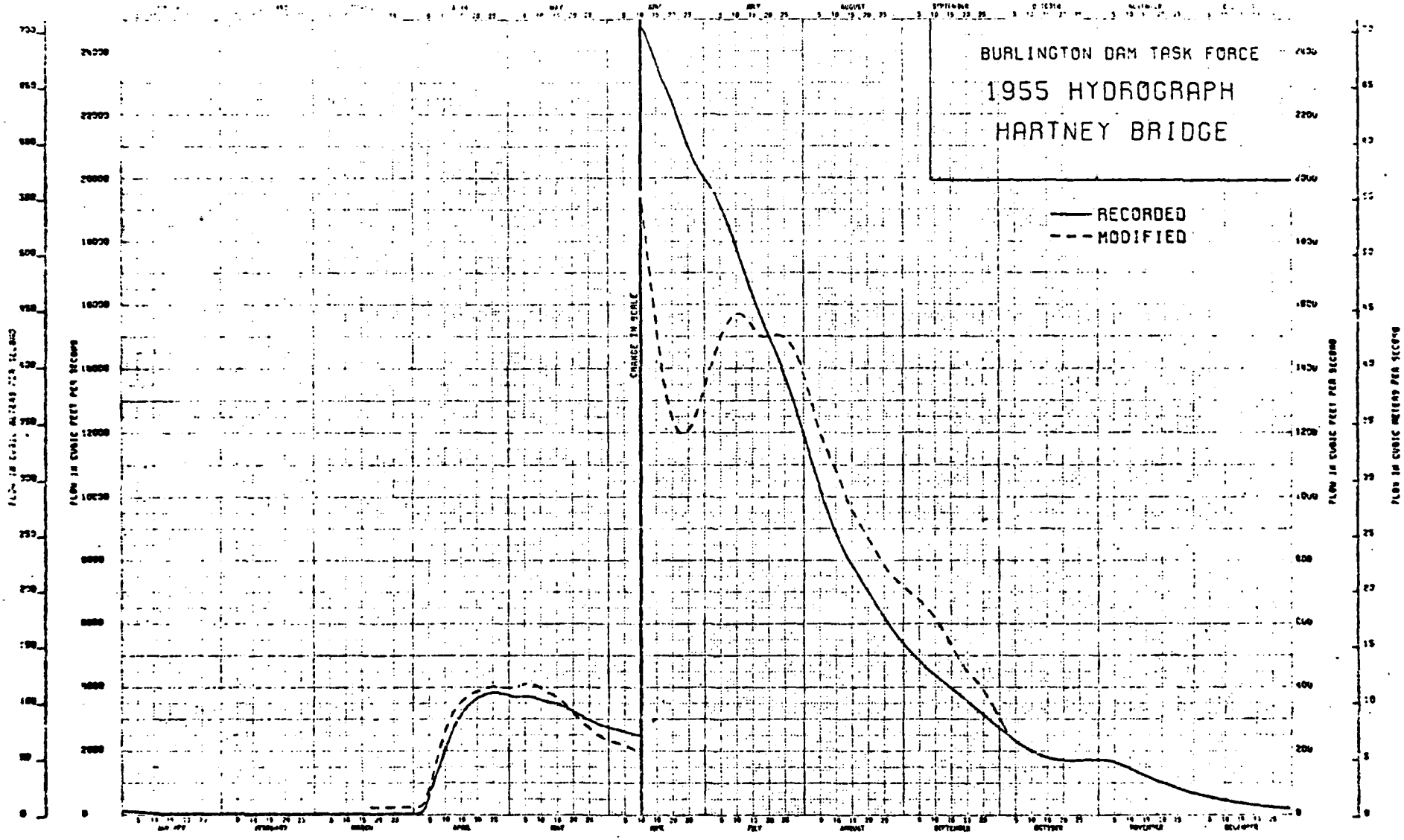

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1955
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
75
50
25
0
3000
2000
1000

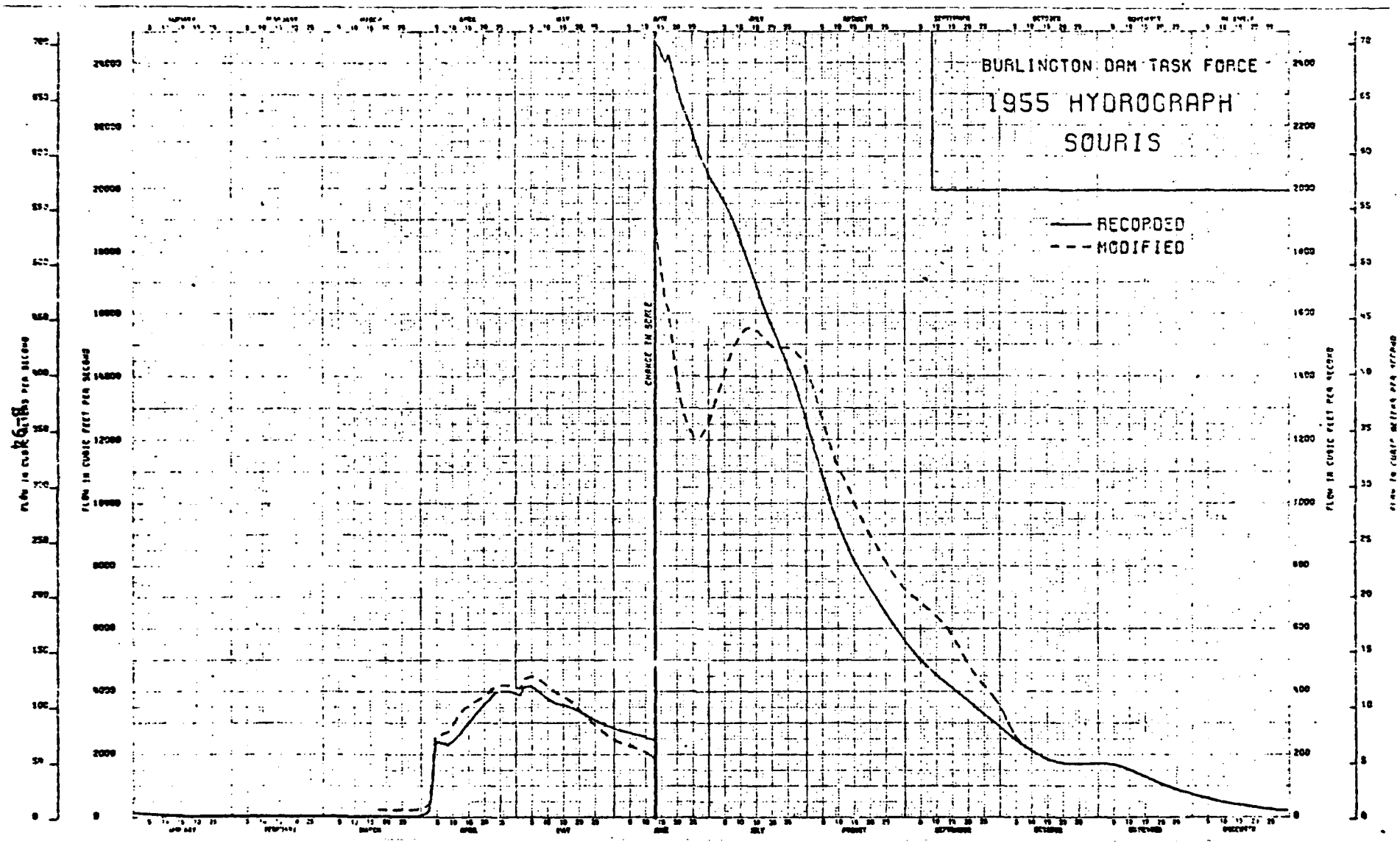

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

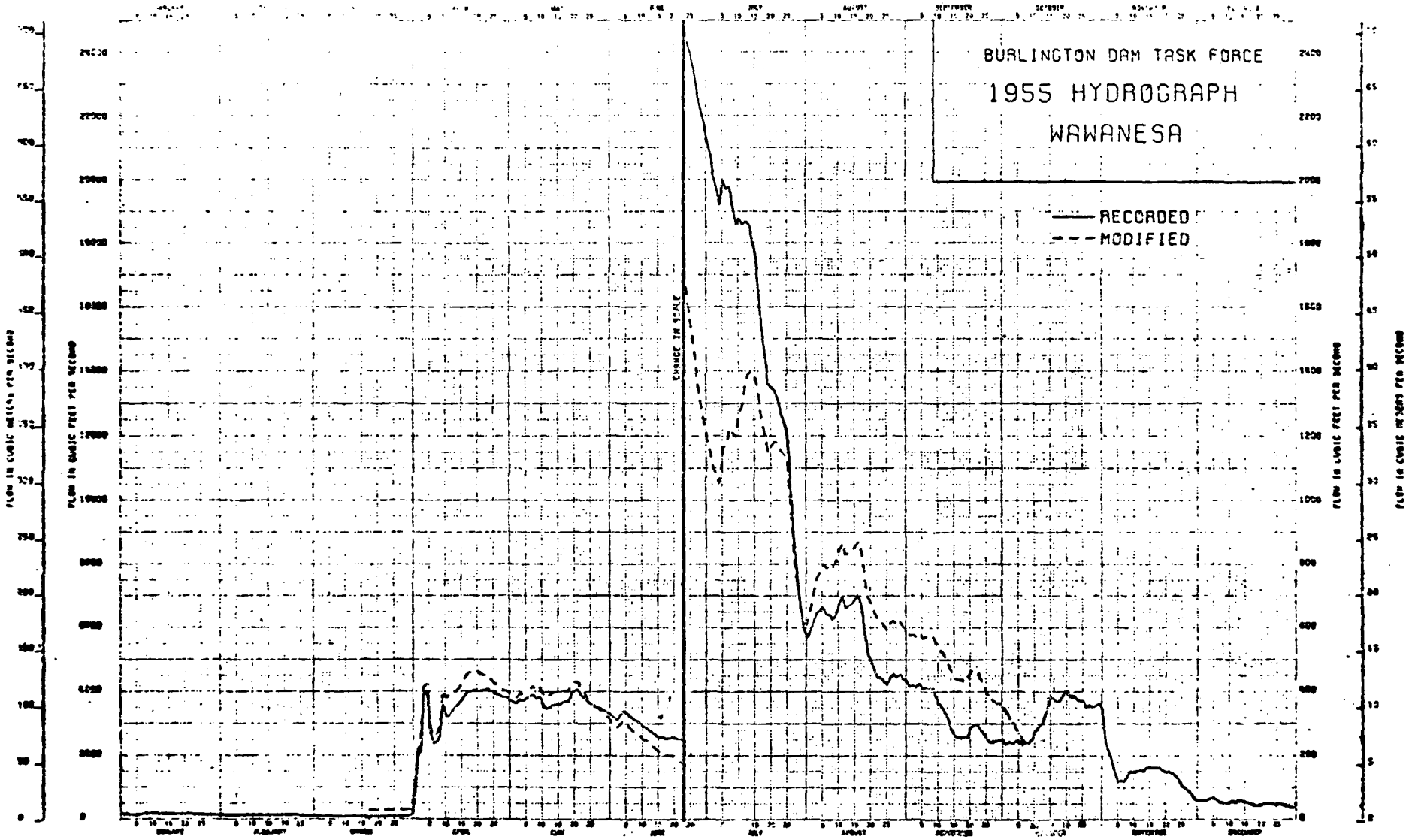

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

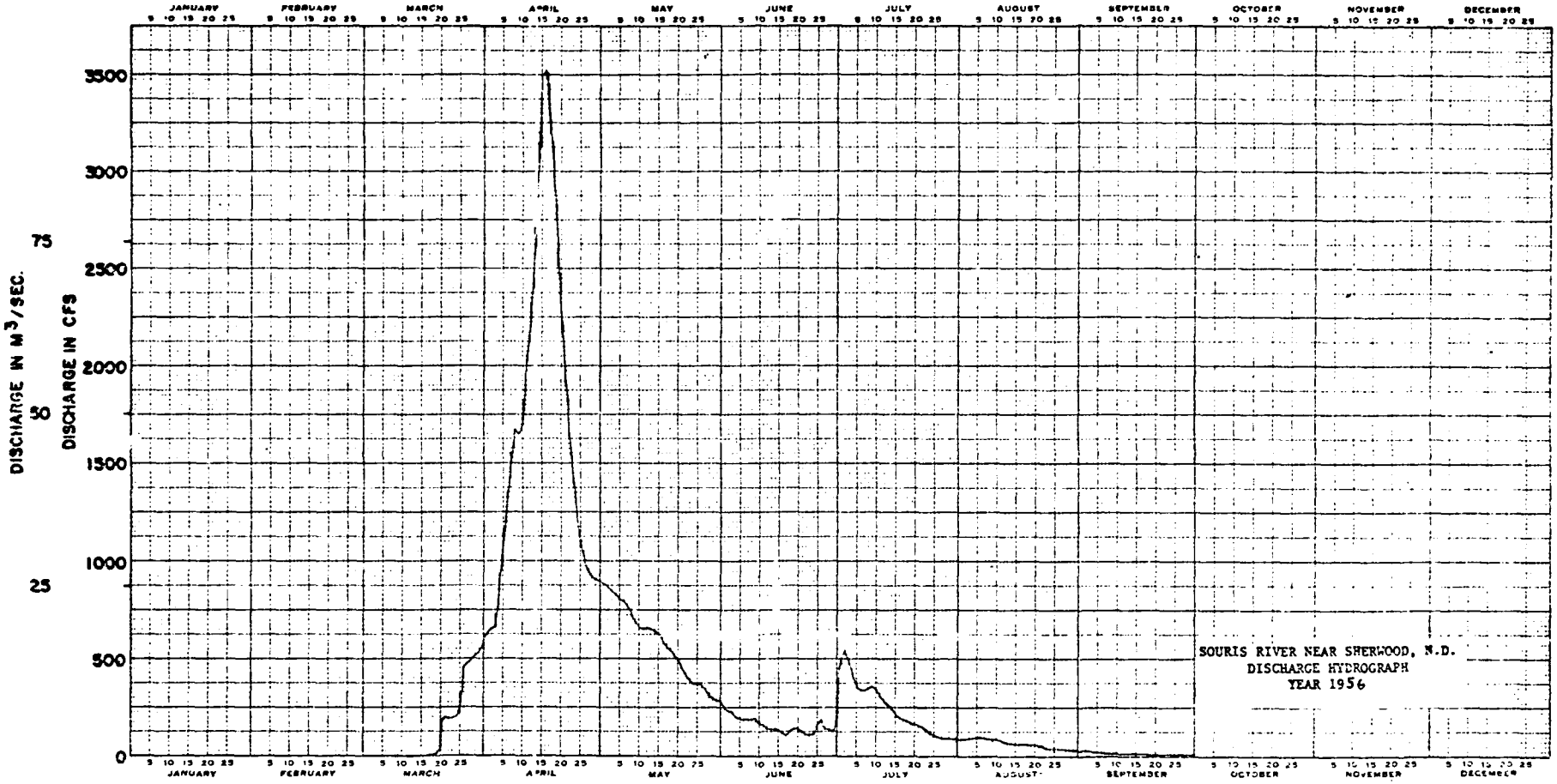

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

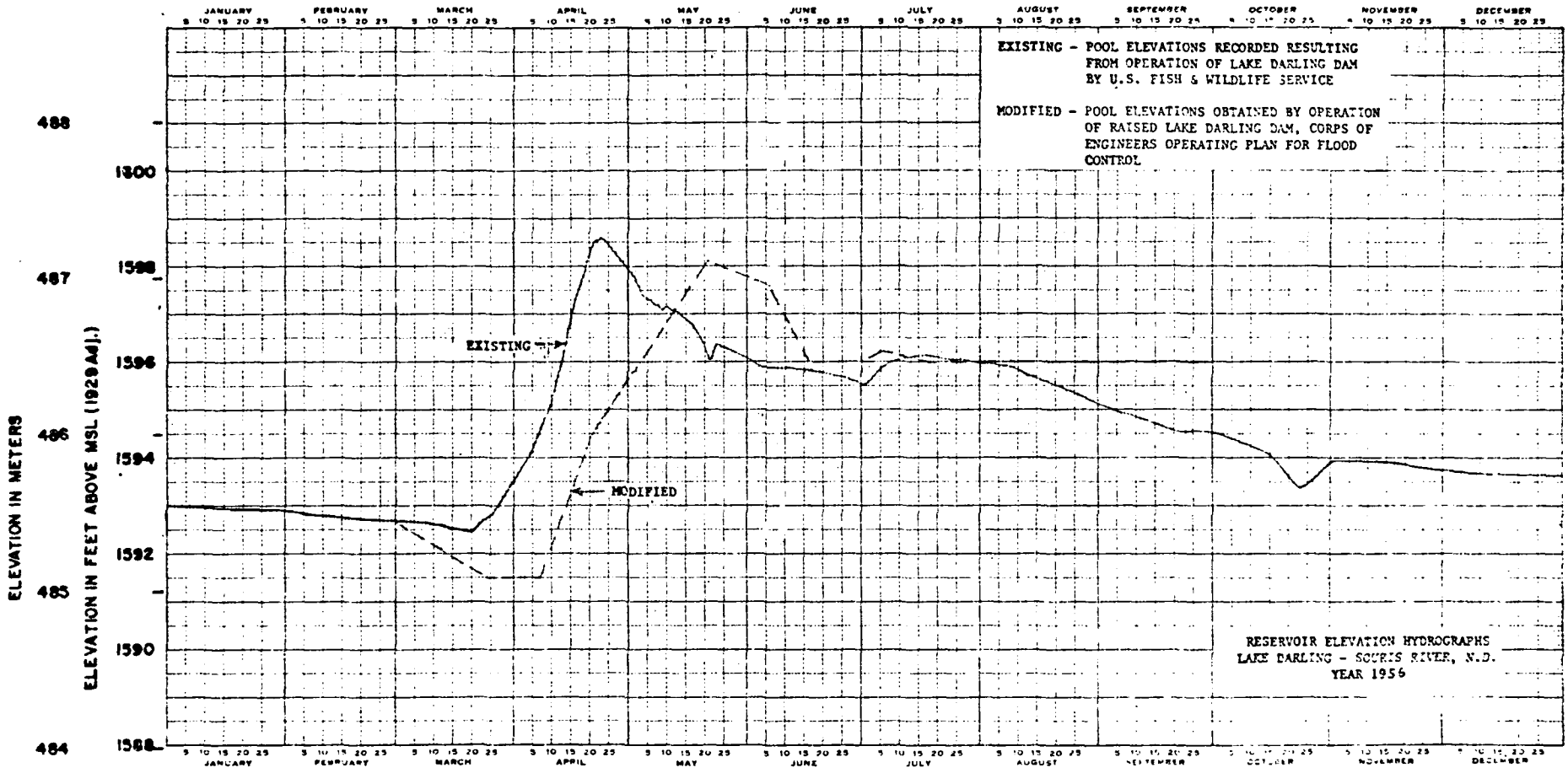

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

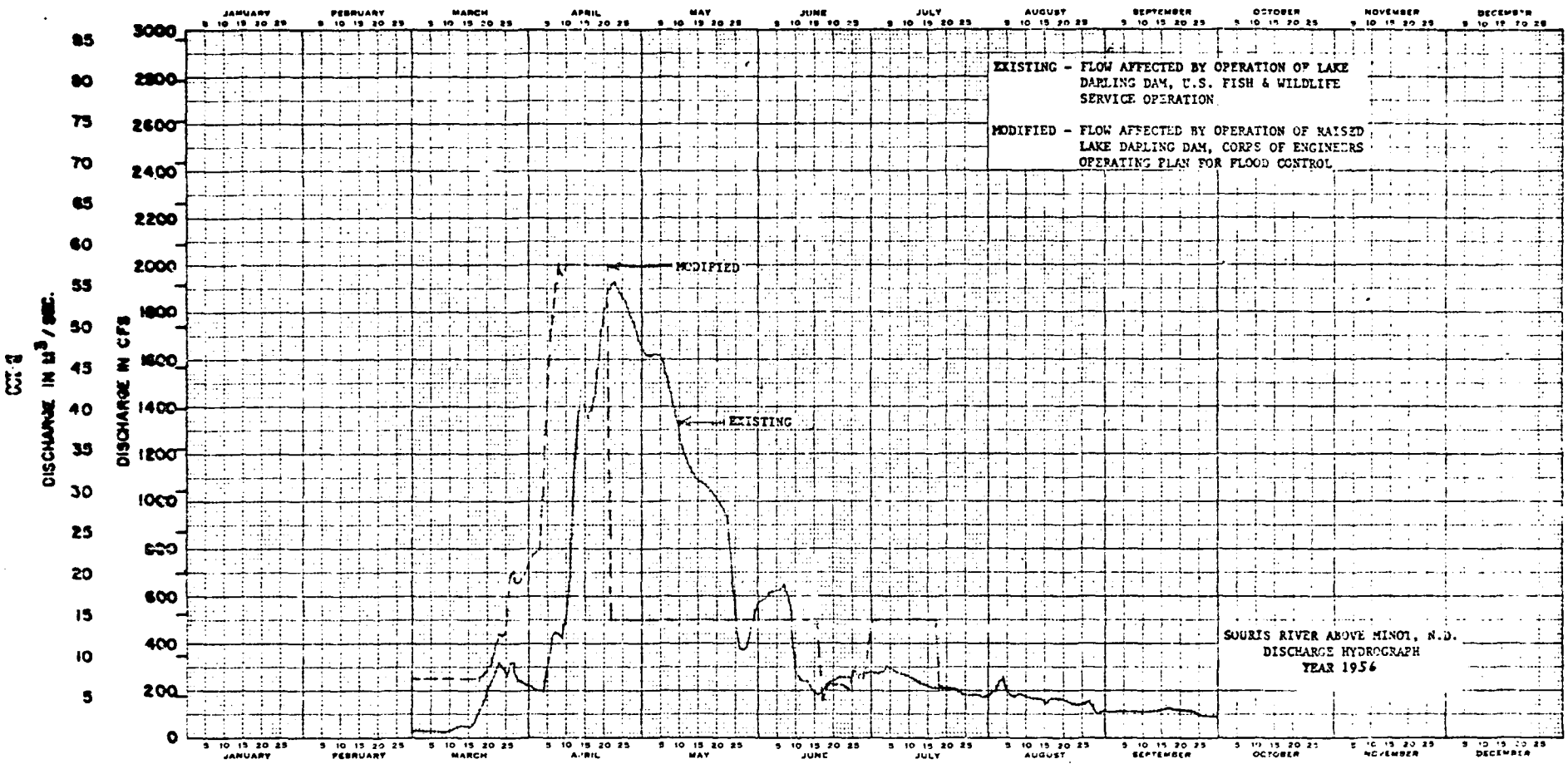

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

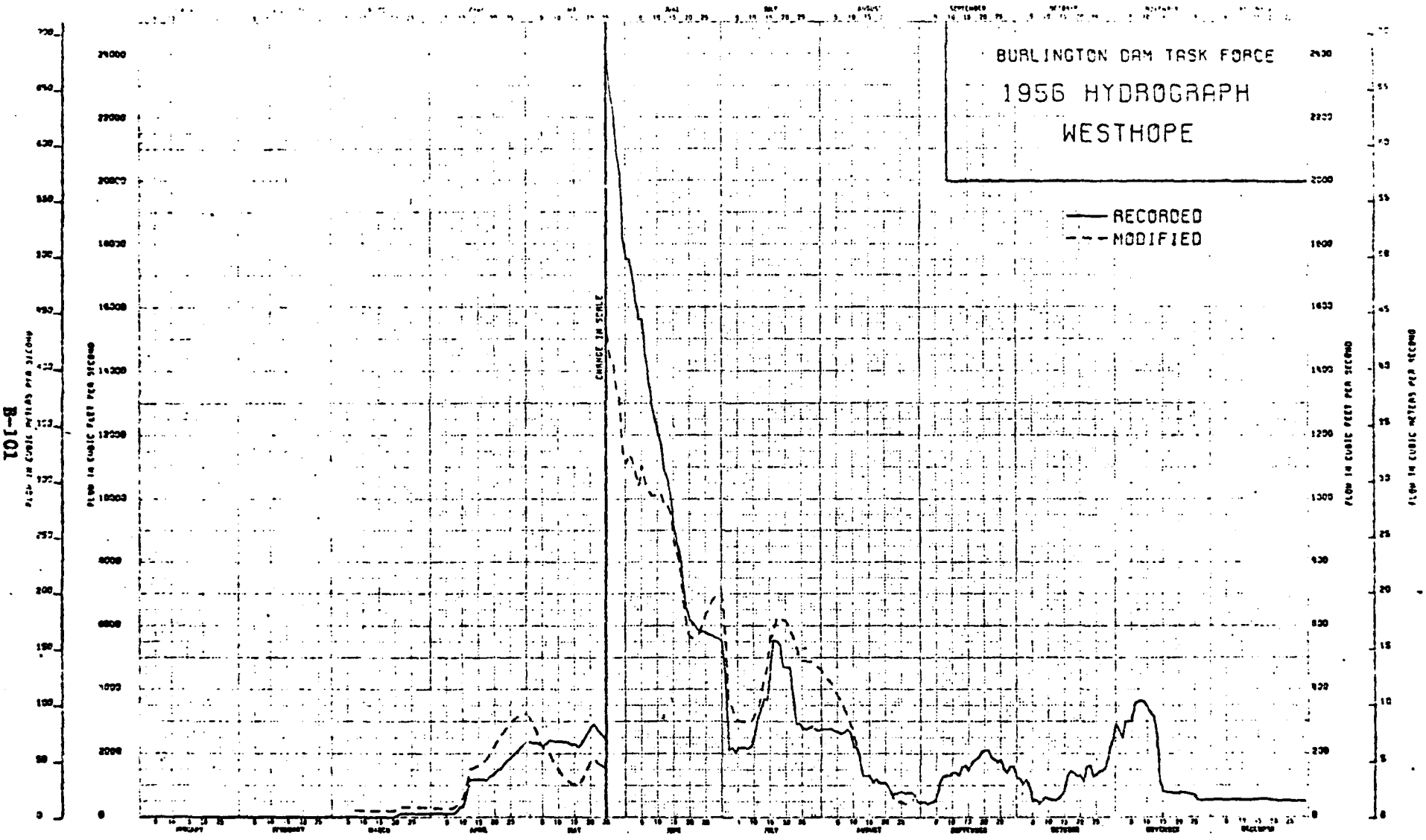

BURLINGTON DAM TASK FORCE
1955 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE

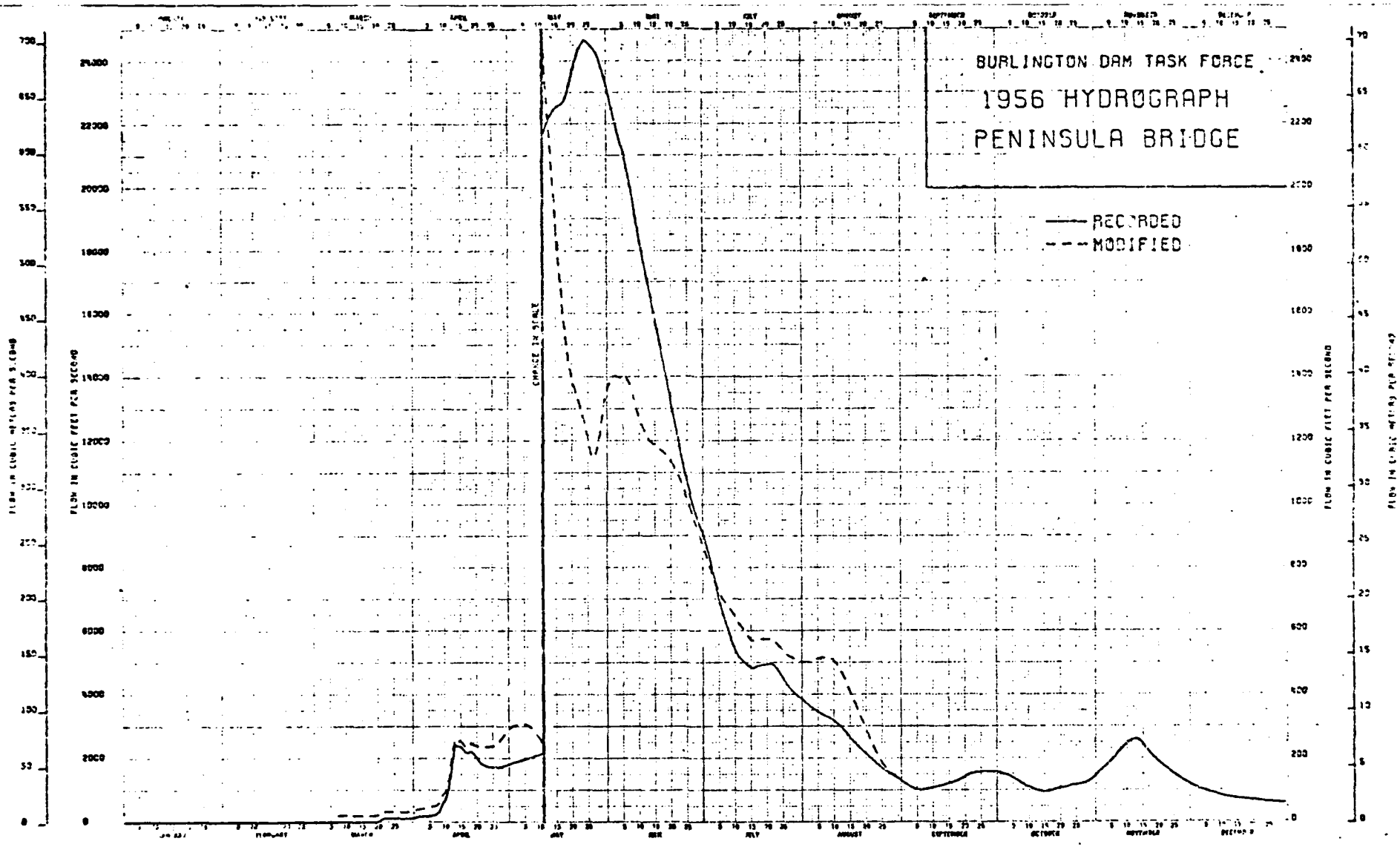
1956

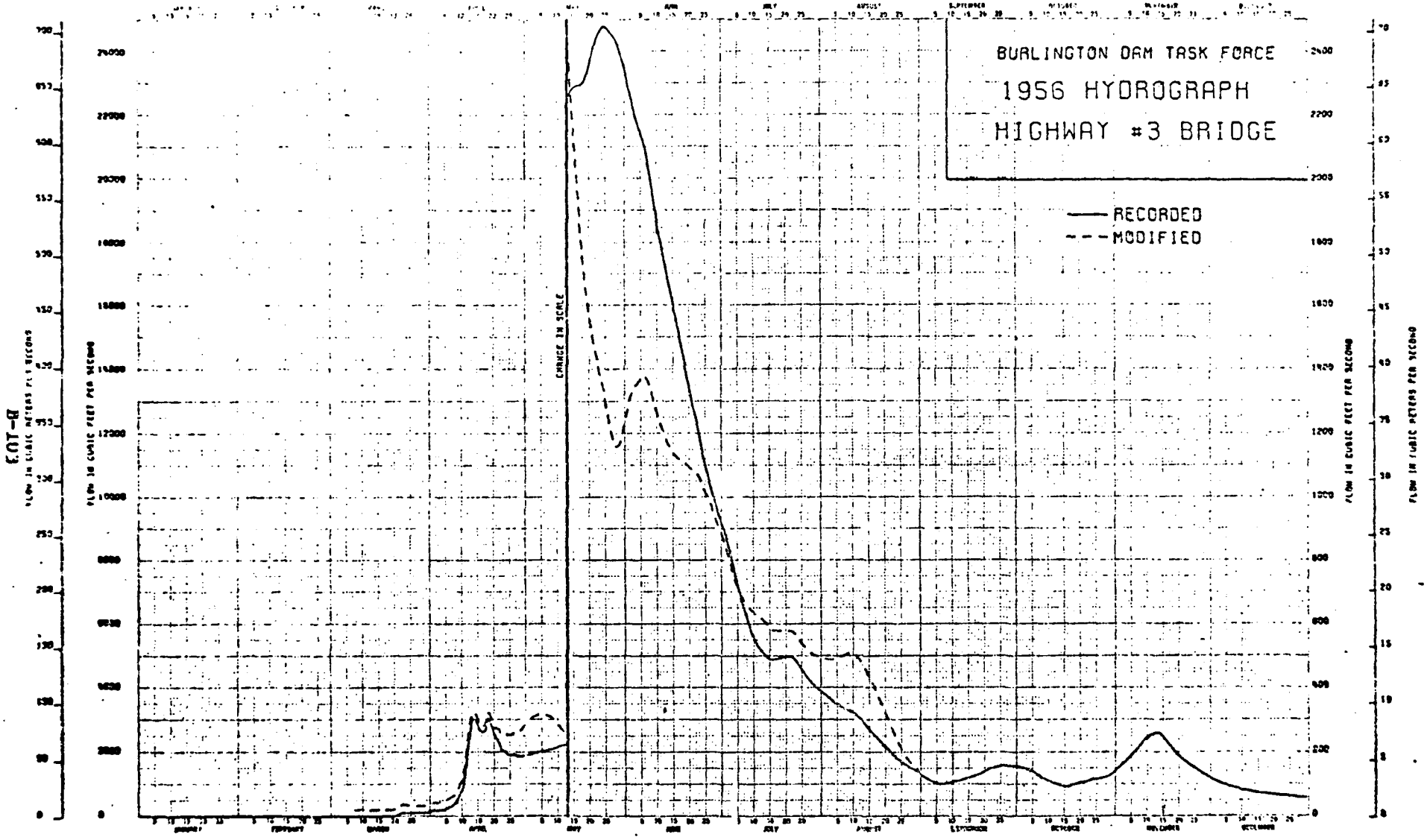

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
75
50
25
3500
3000
2500
2000
1500
1000
500
0
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1956

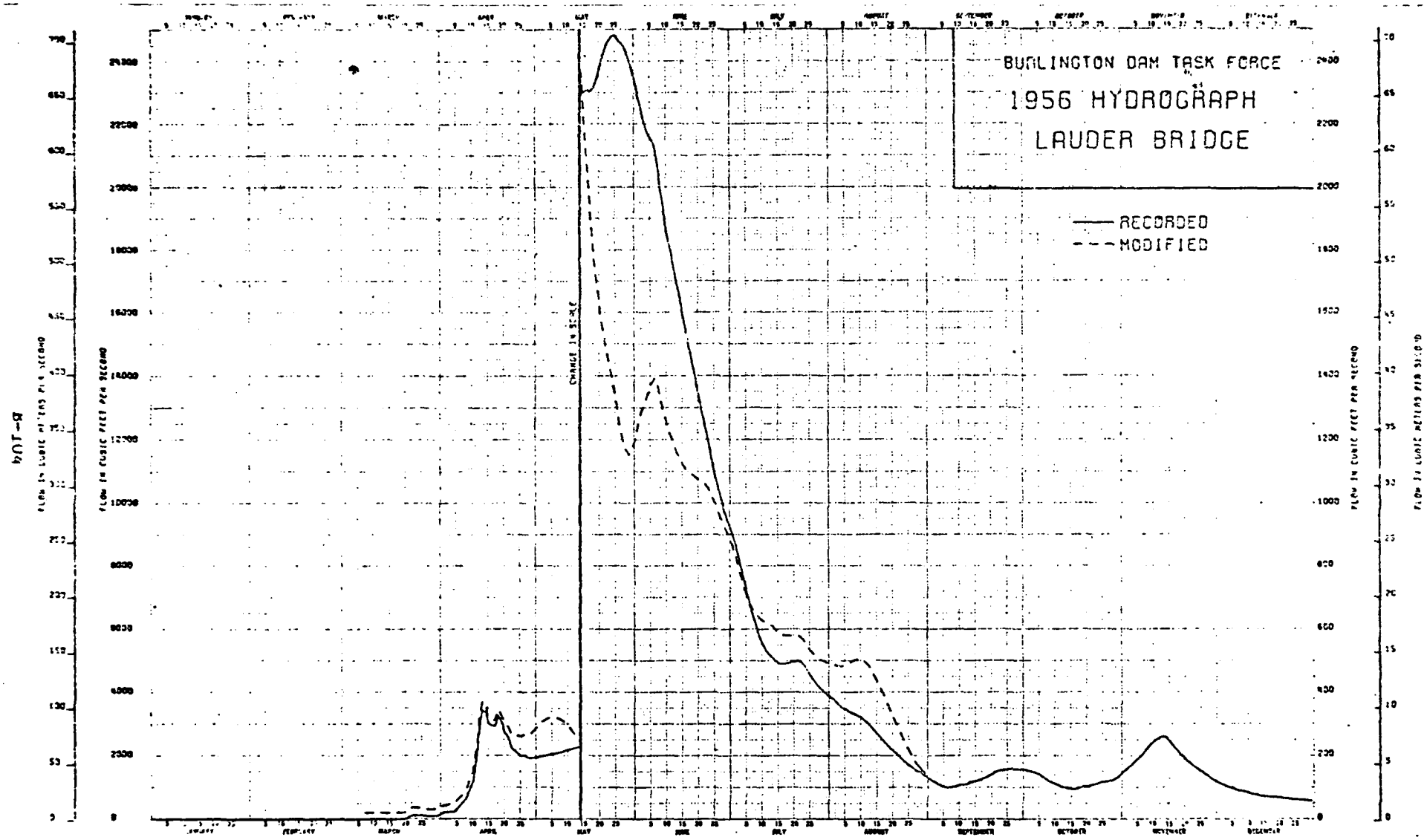

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1956
EXISTING
MODIFIED
ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
488
487
486
485
484
1600
1598
1596
1594
1592
1590
1588
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

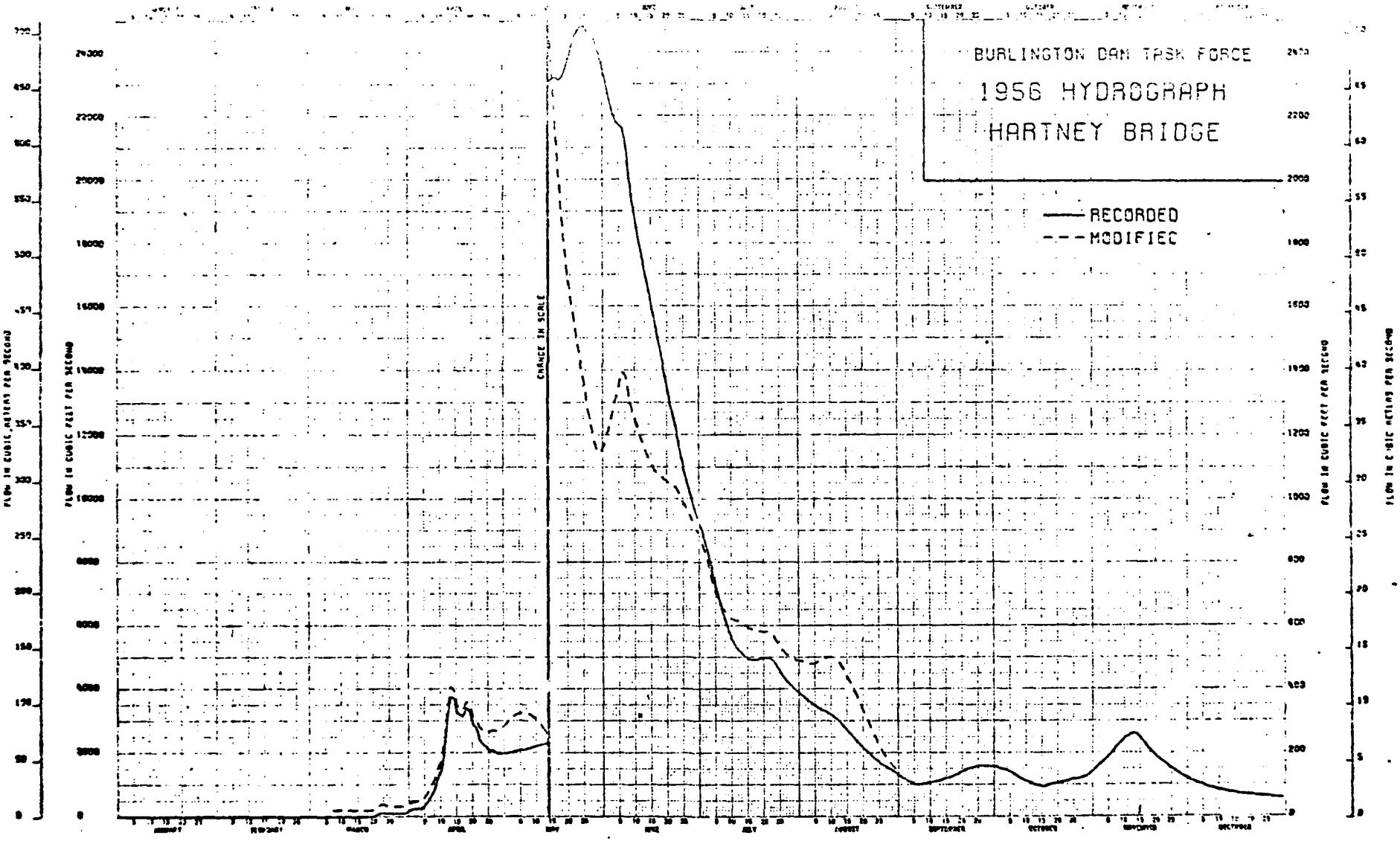

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1956
DISCHARGE IN CFS
DISCHARGE IN m³/sec.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

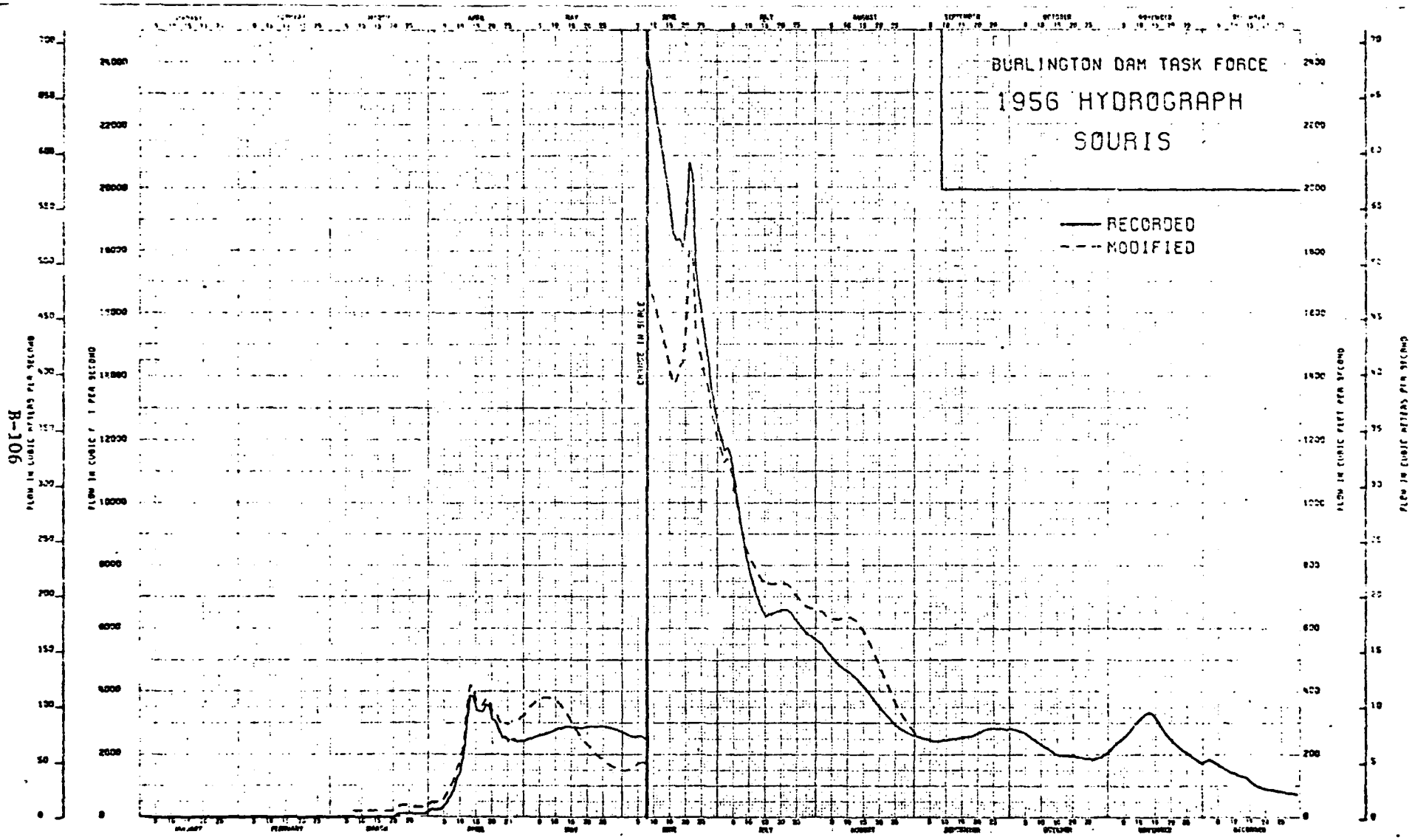

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

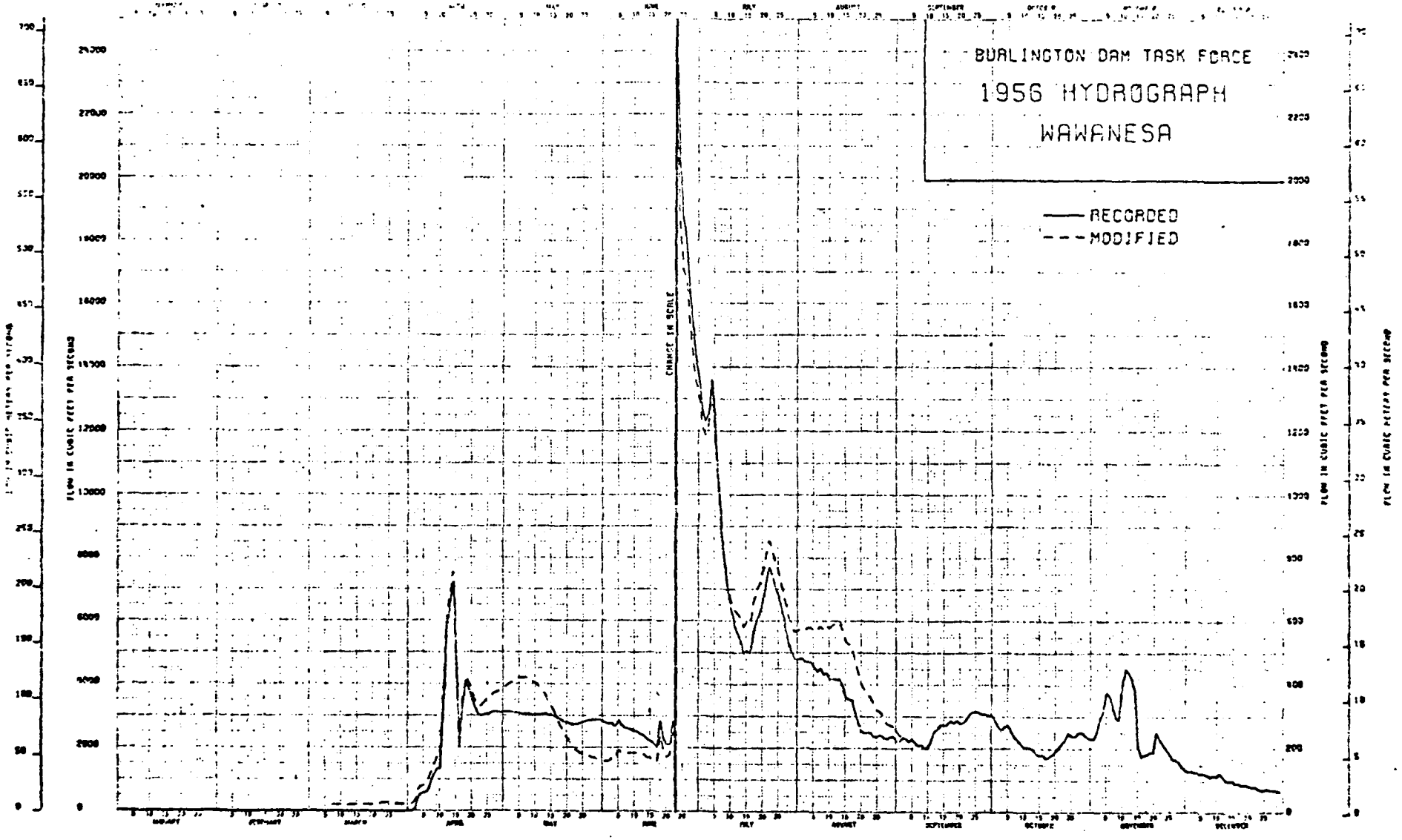

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

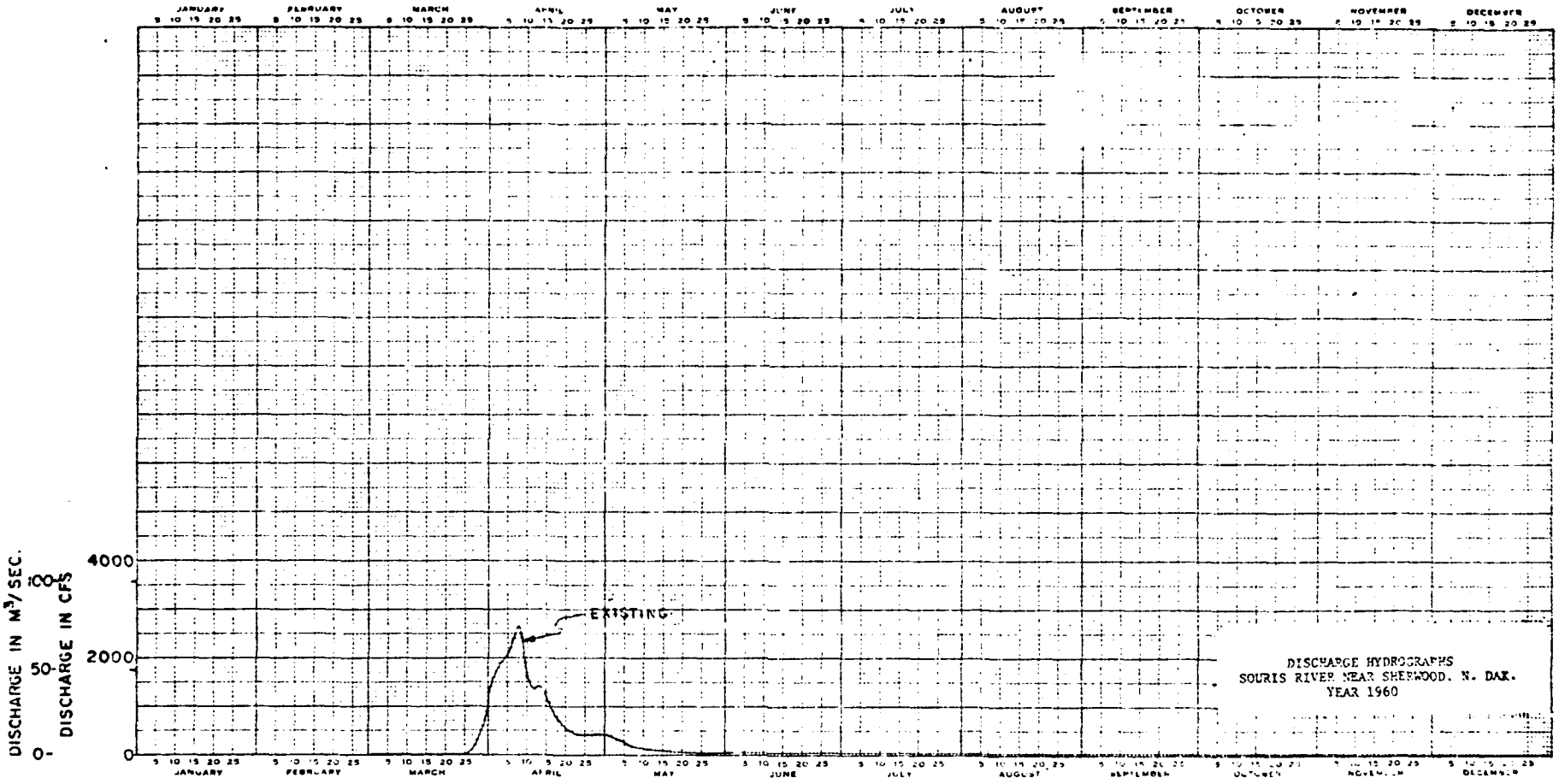

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

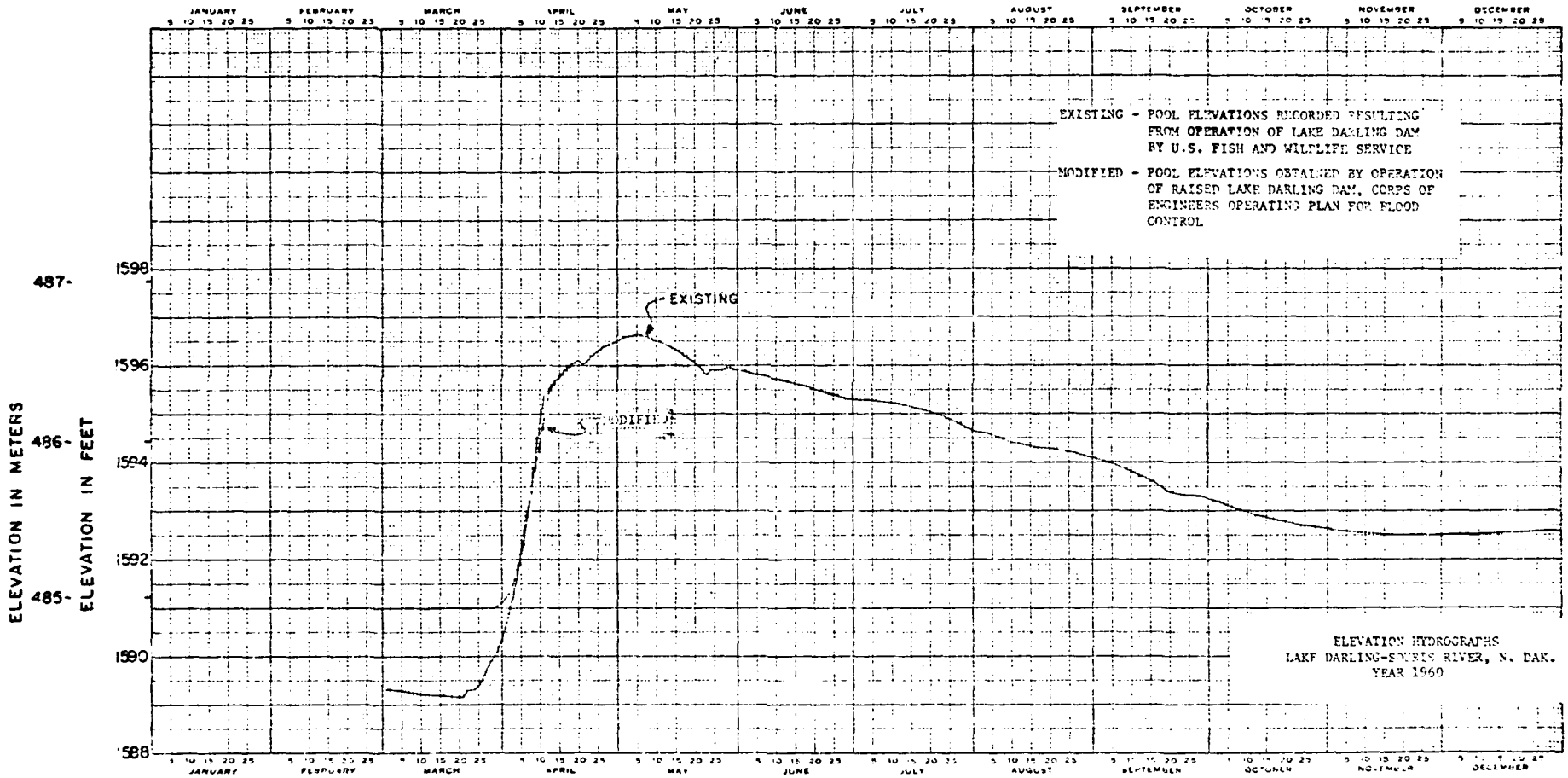

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

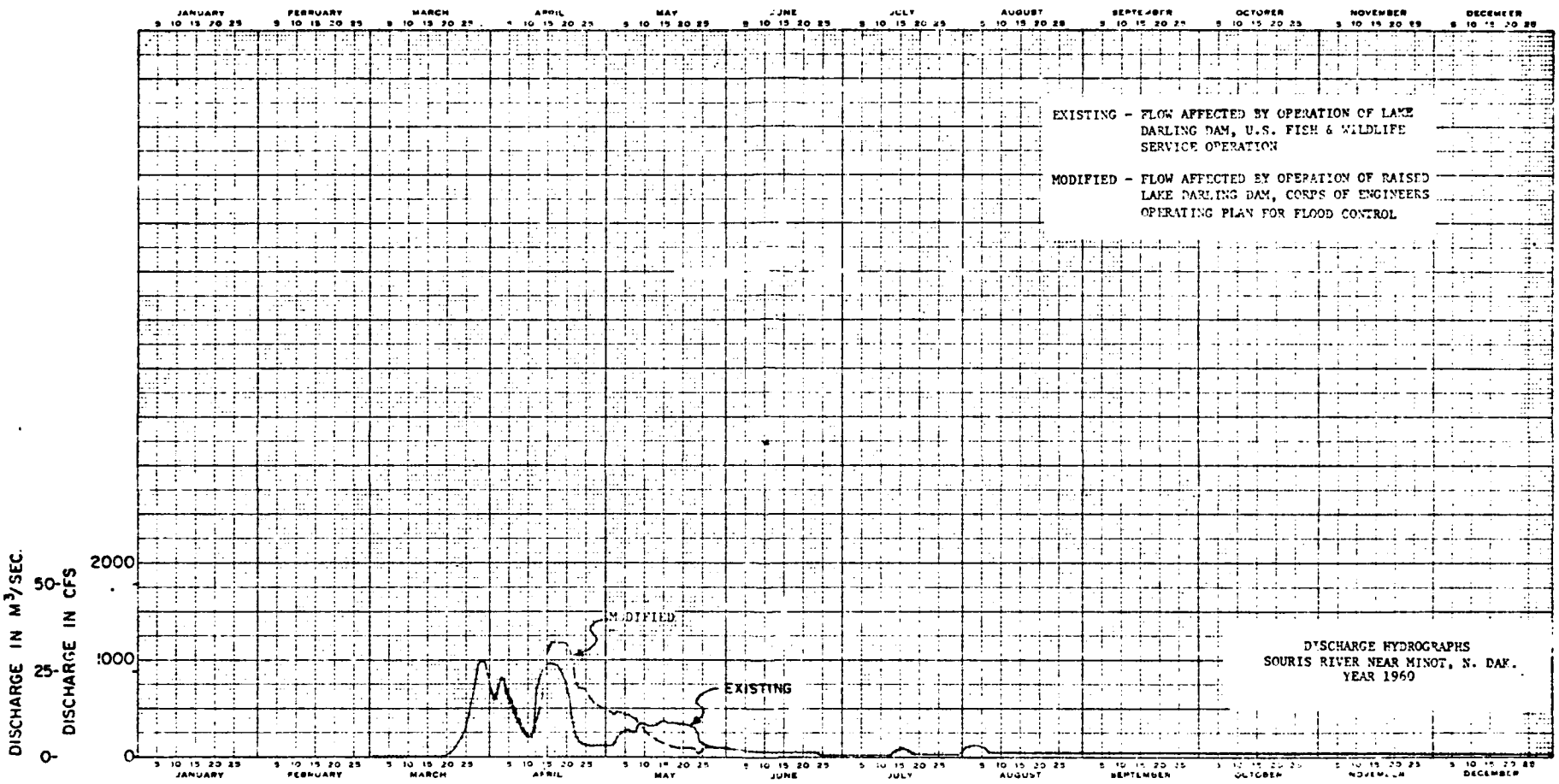

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
SOURIS
RECORDED
MODIFIED

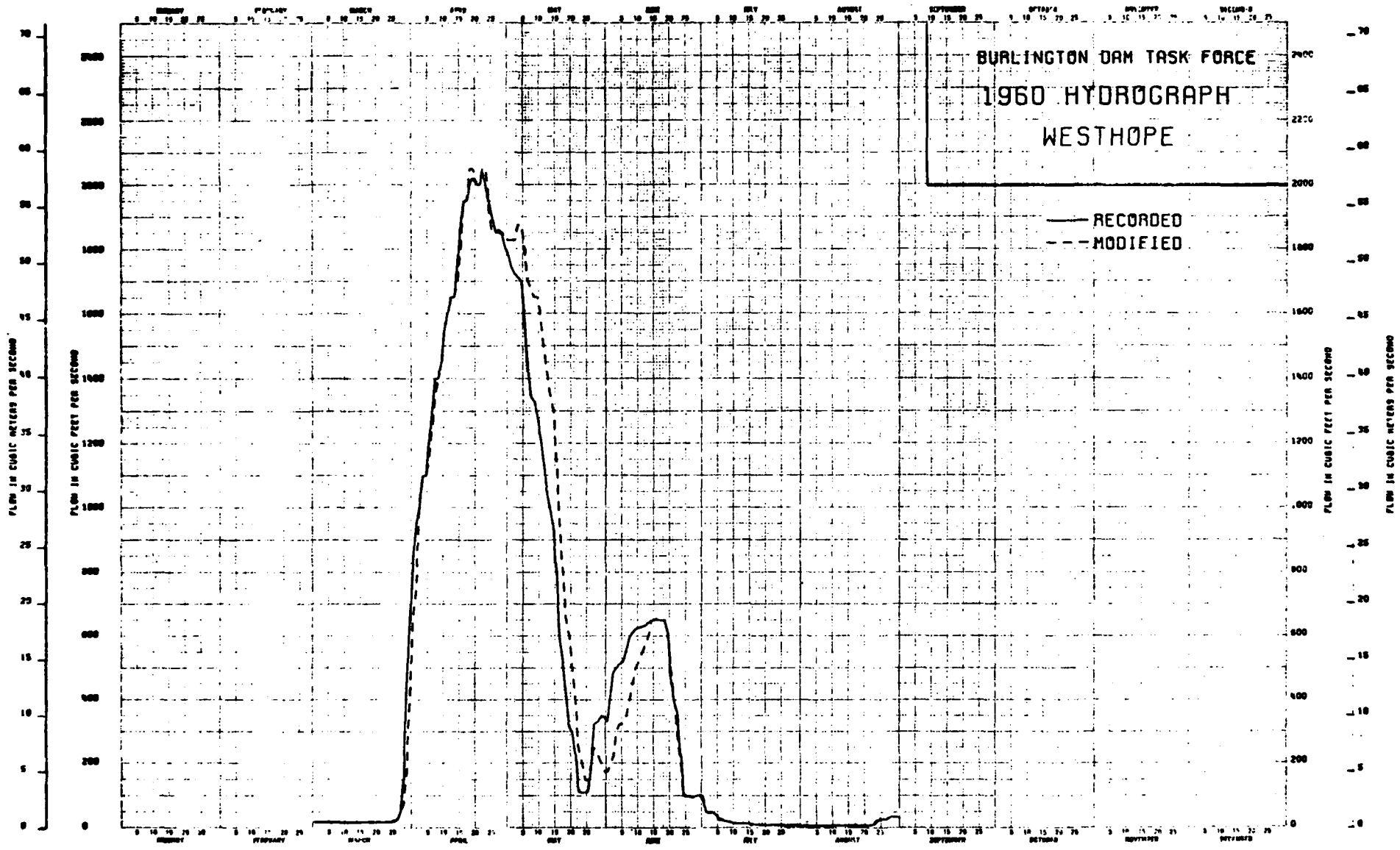

BURLINGTON DAM TASK FORCE
1956 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

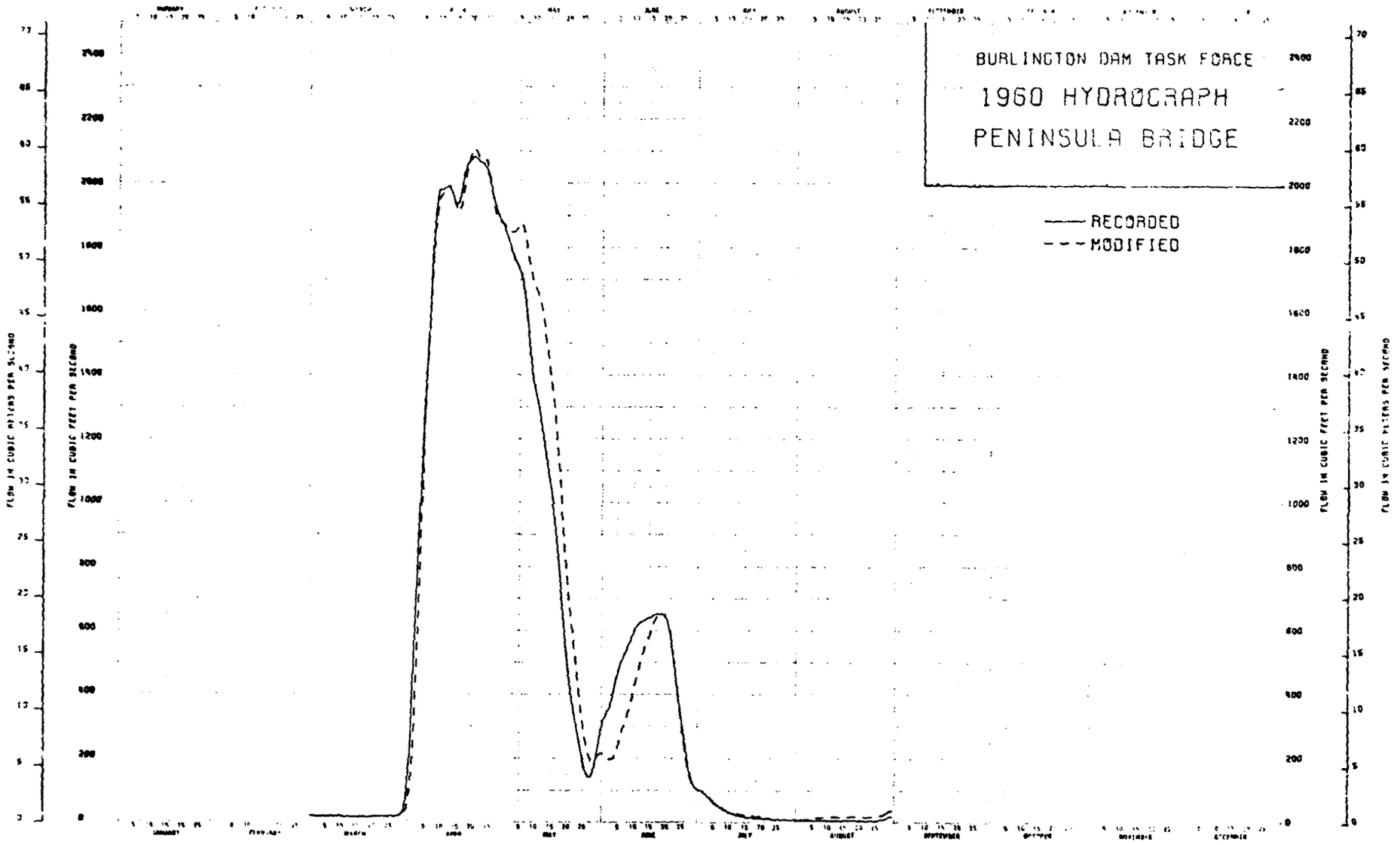
1960

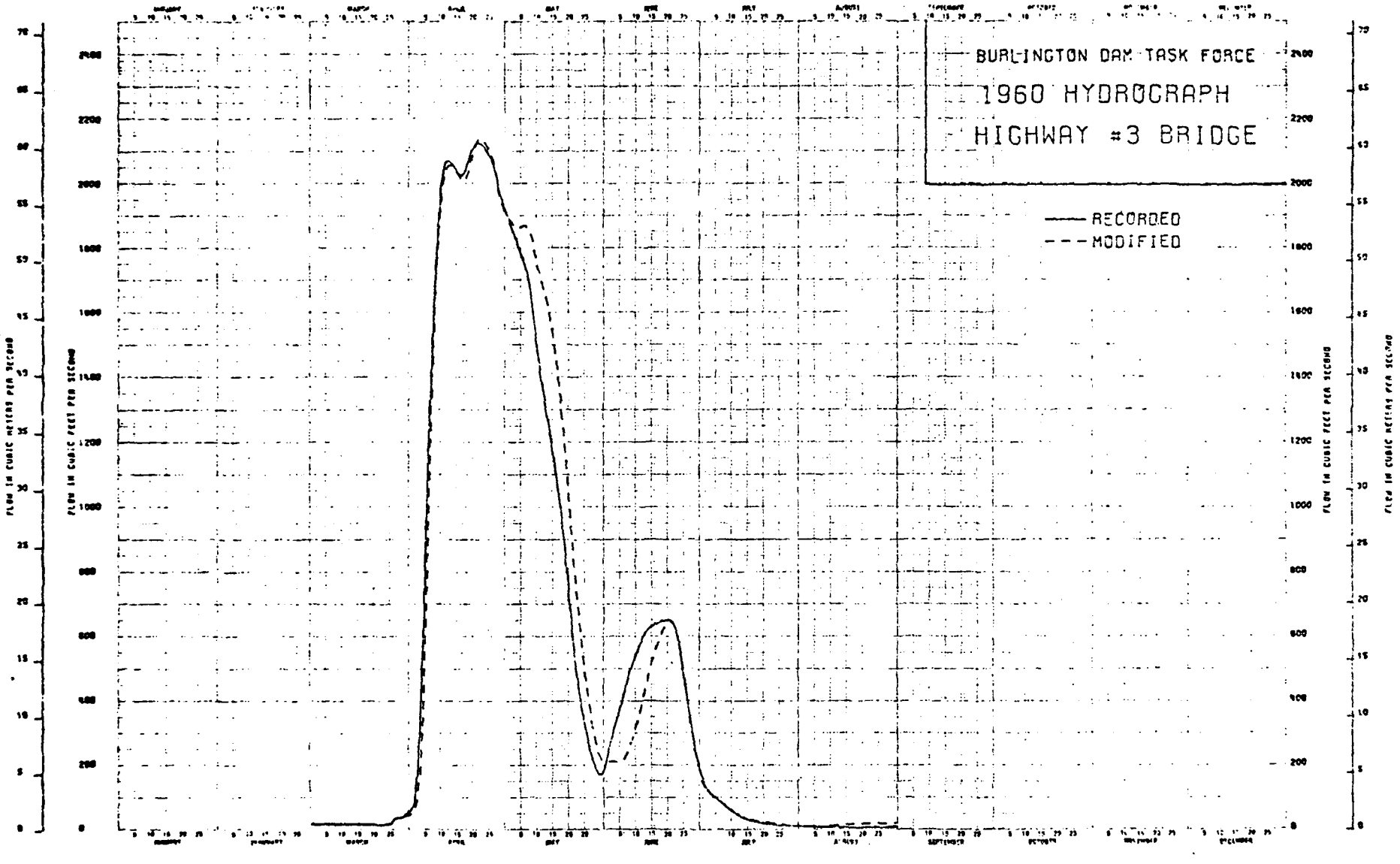

DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1960
EXISTING
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
4000
2000
0
100
50
0
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

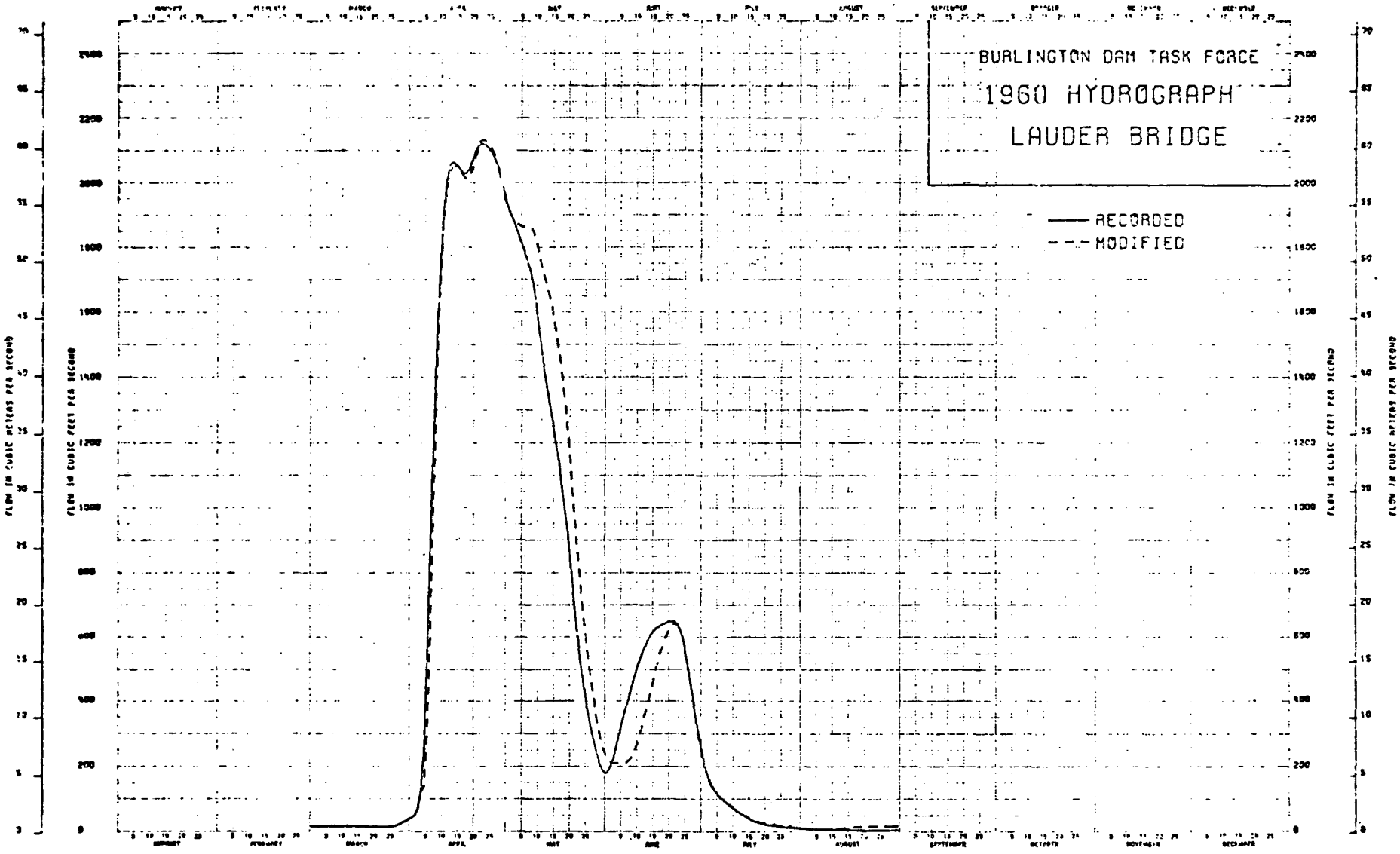

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
ELEVATION IN METERS
ELEVATION IN FEET
487
486
485
1598
1596
1594
1592
1590
1588
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1960

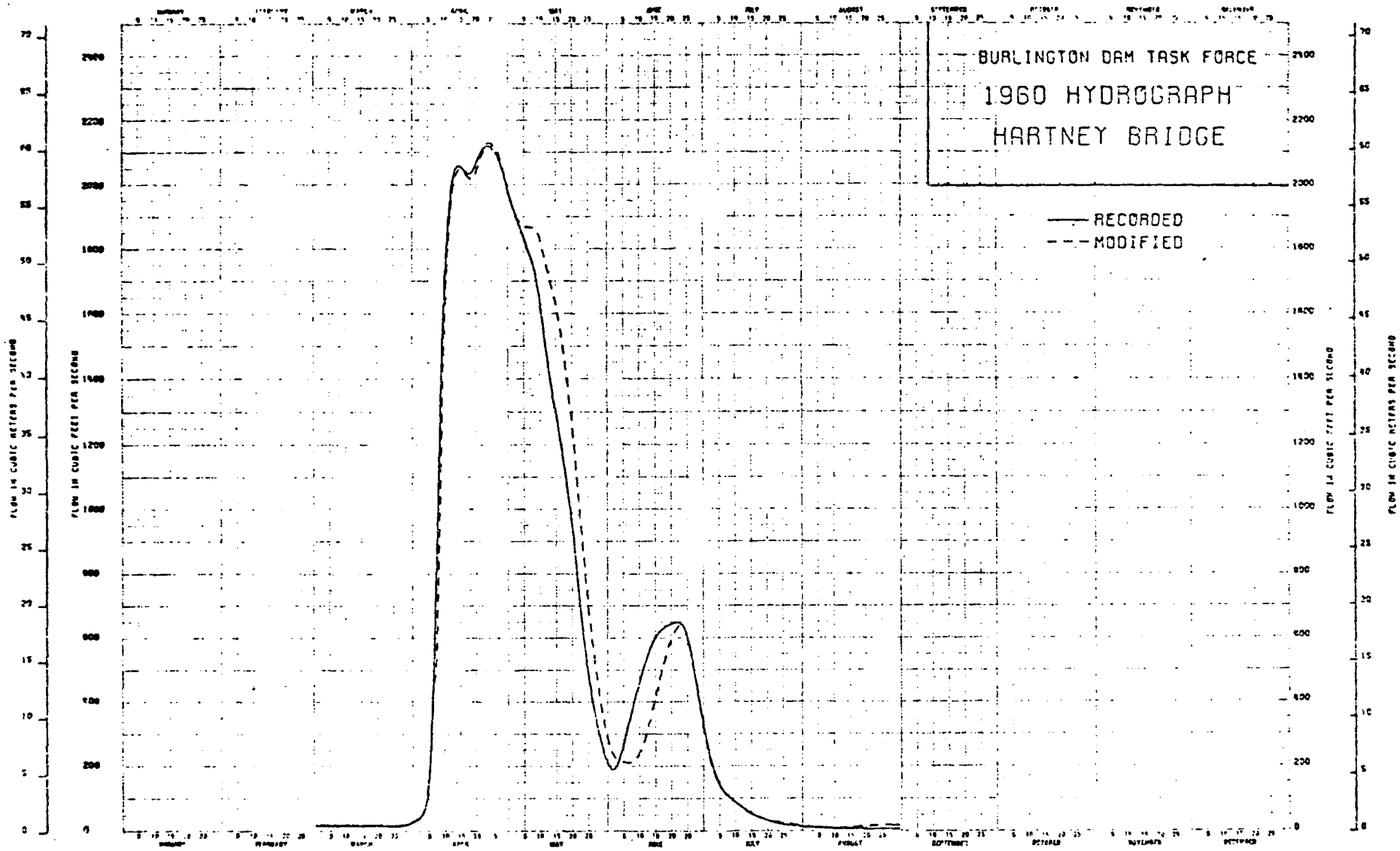

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1969
DISCHARGE IN M³/SEC
DISCHARGE IN CFS
50
25
0
2000
1000
0

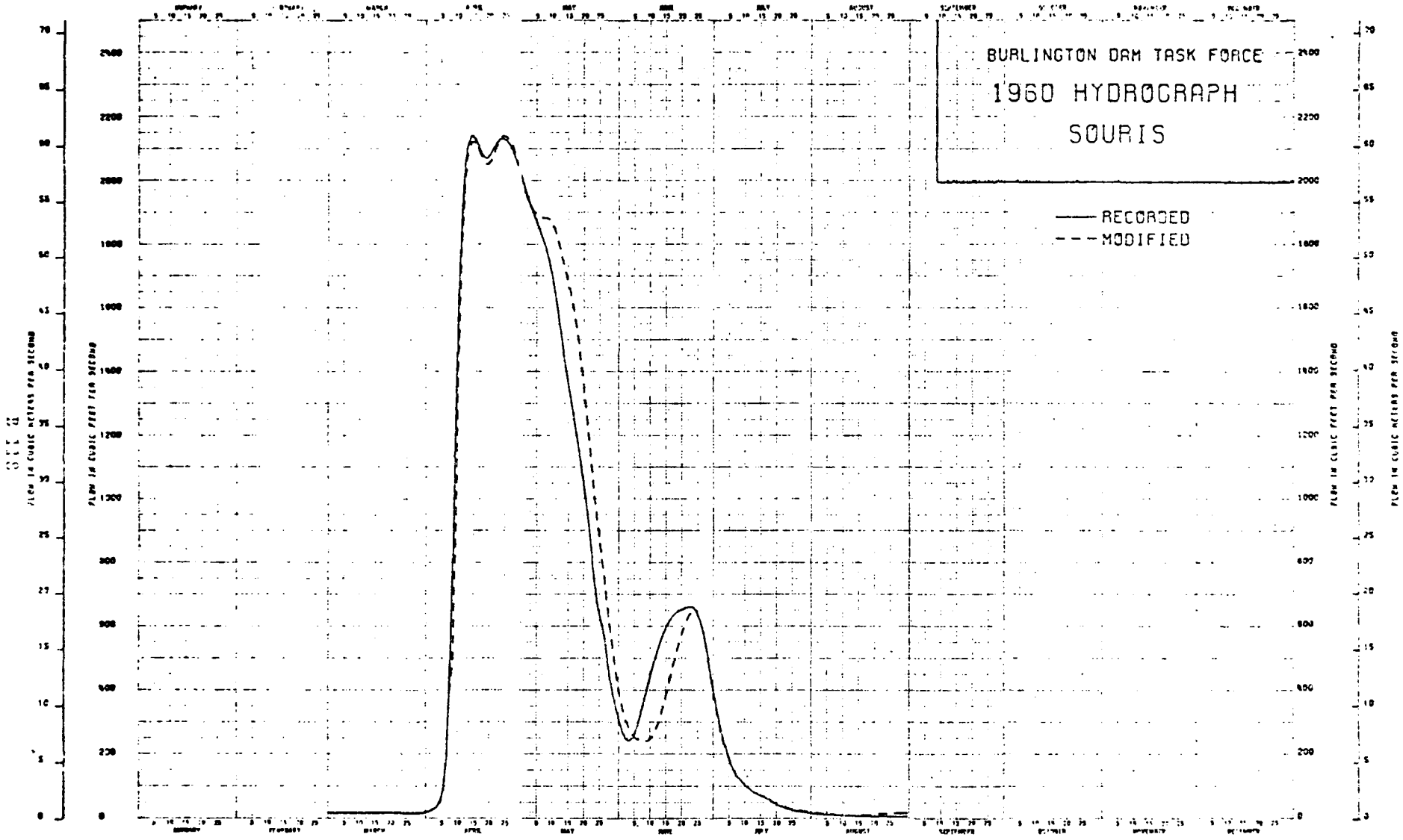

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

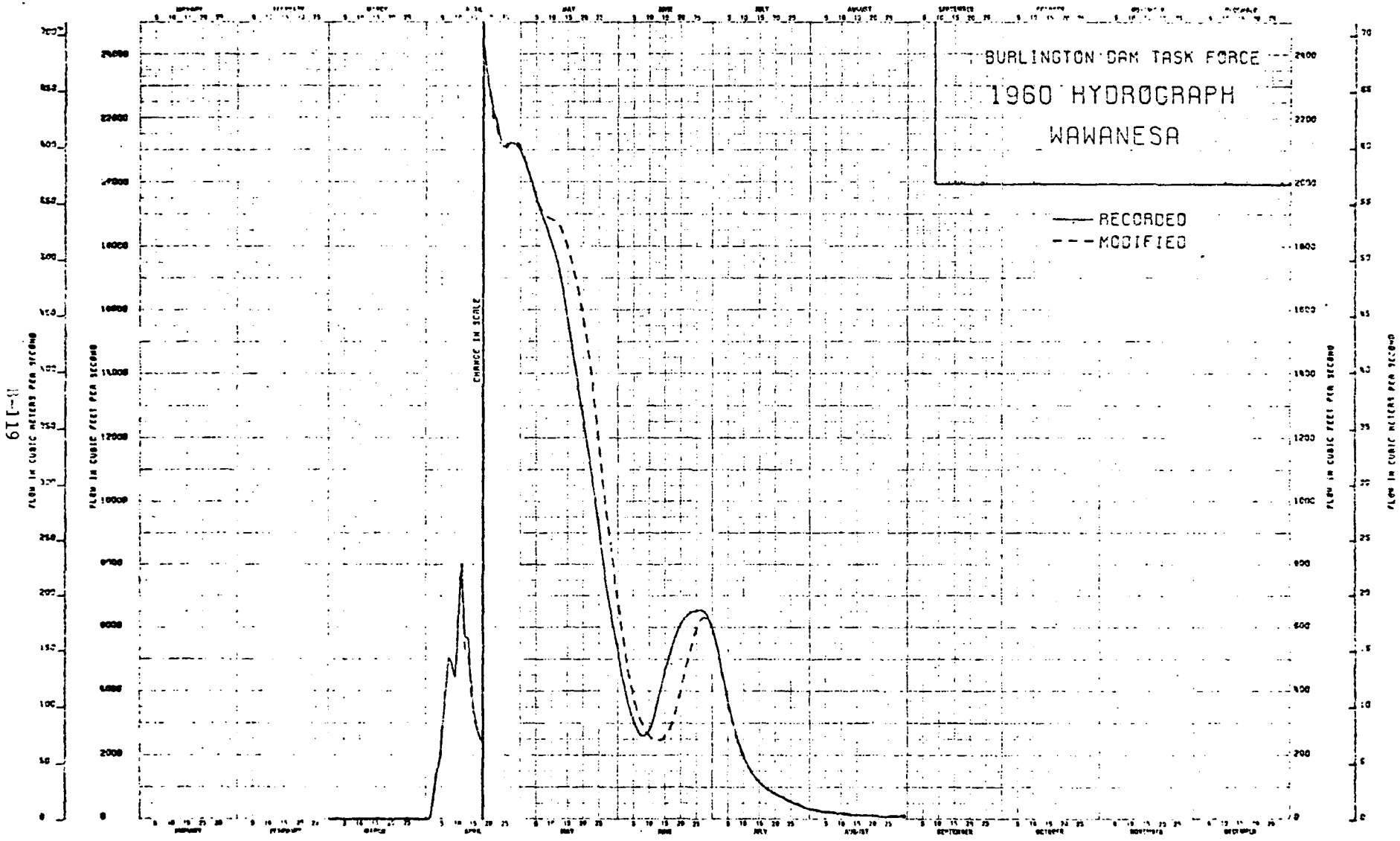

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

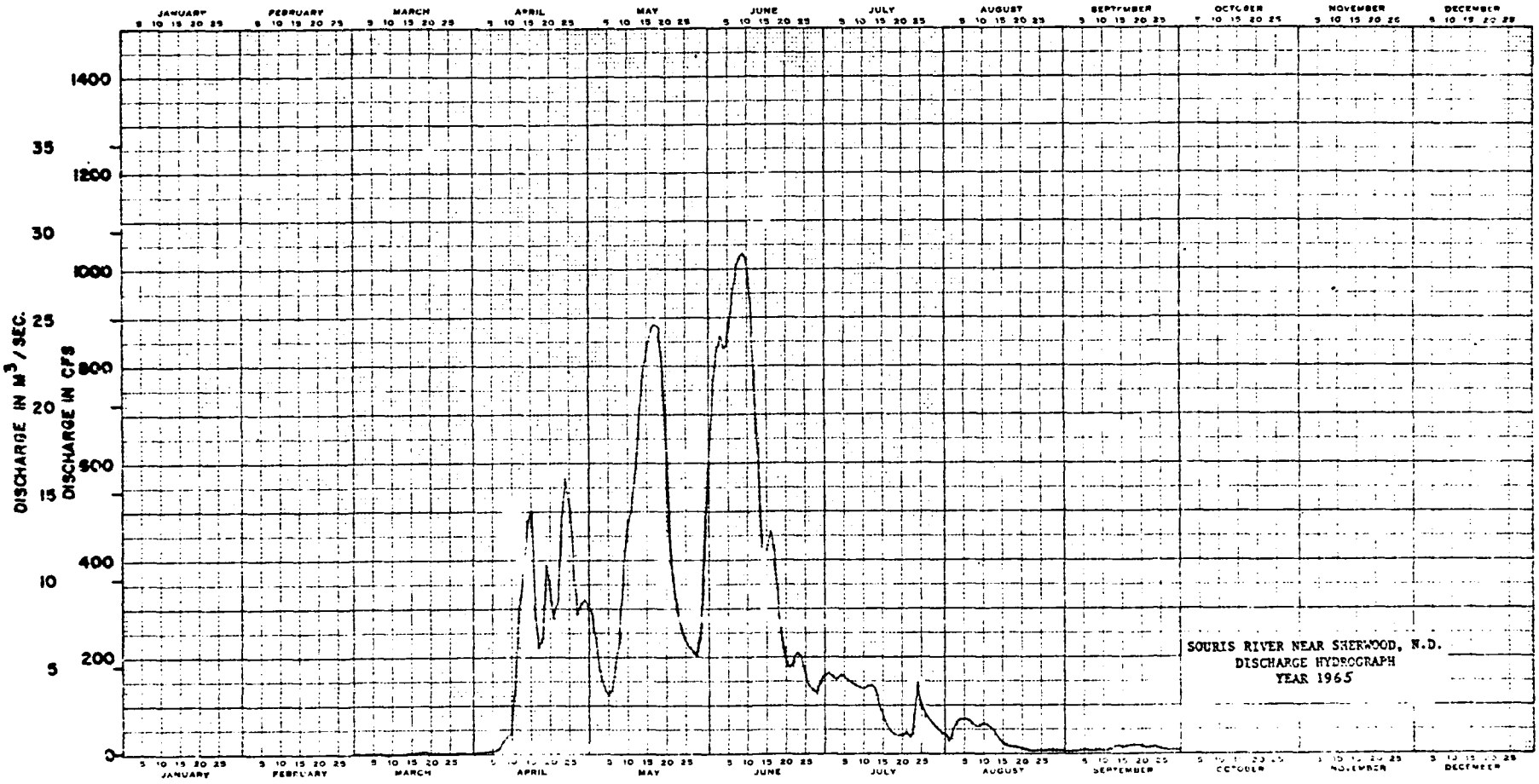

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

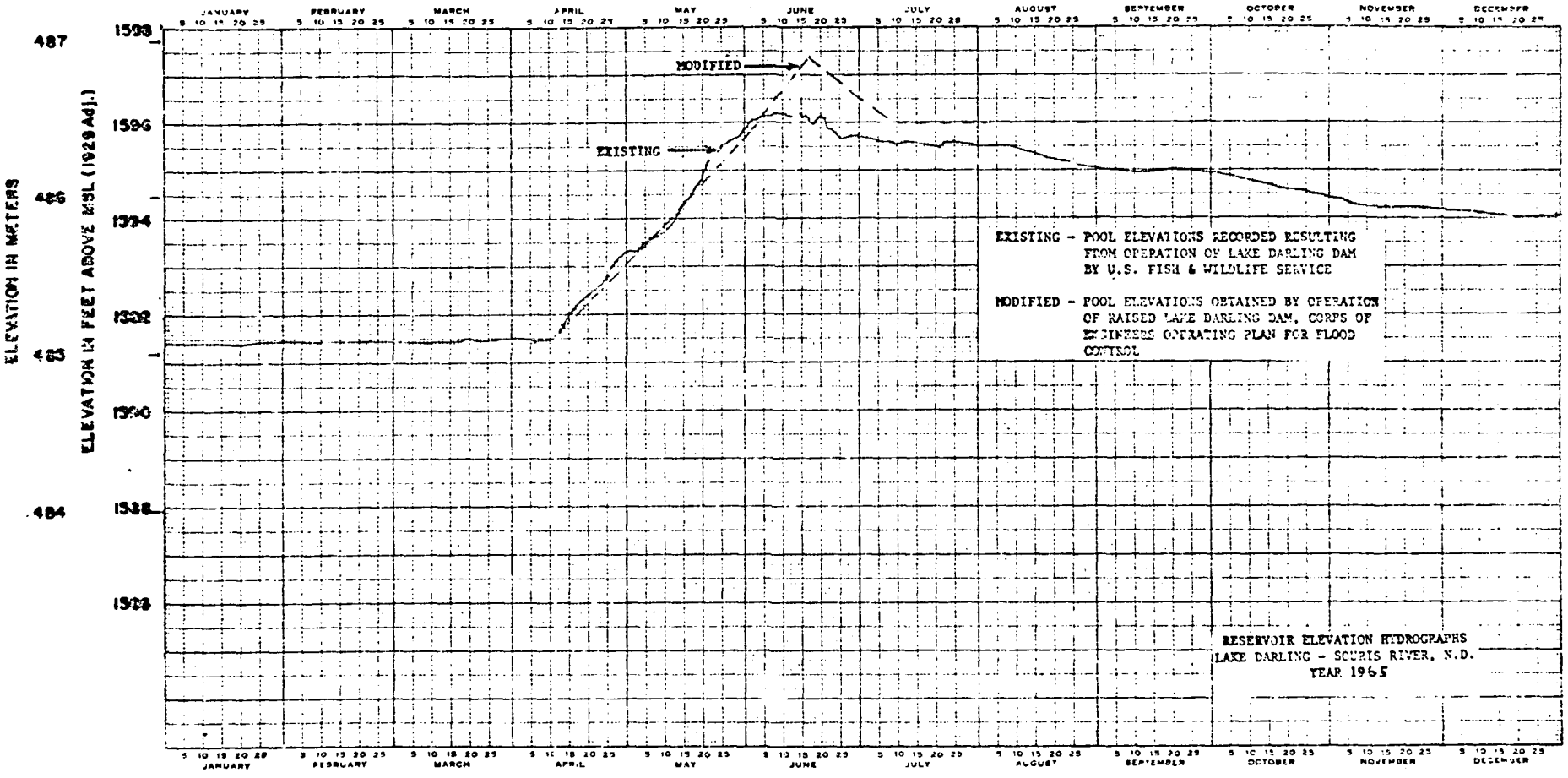

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

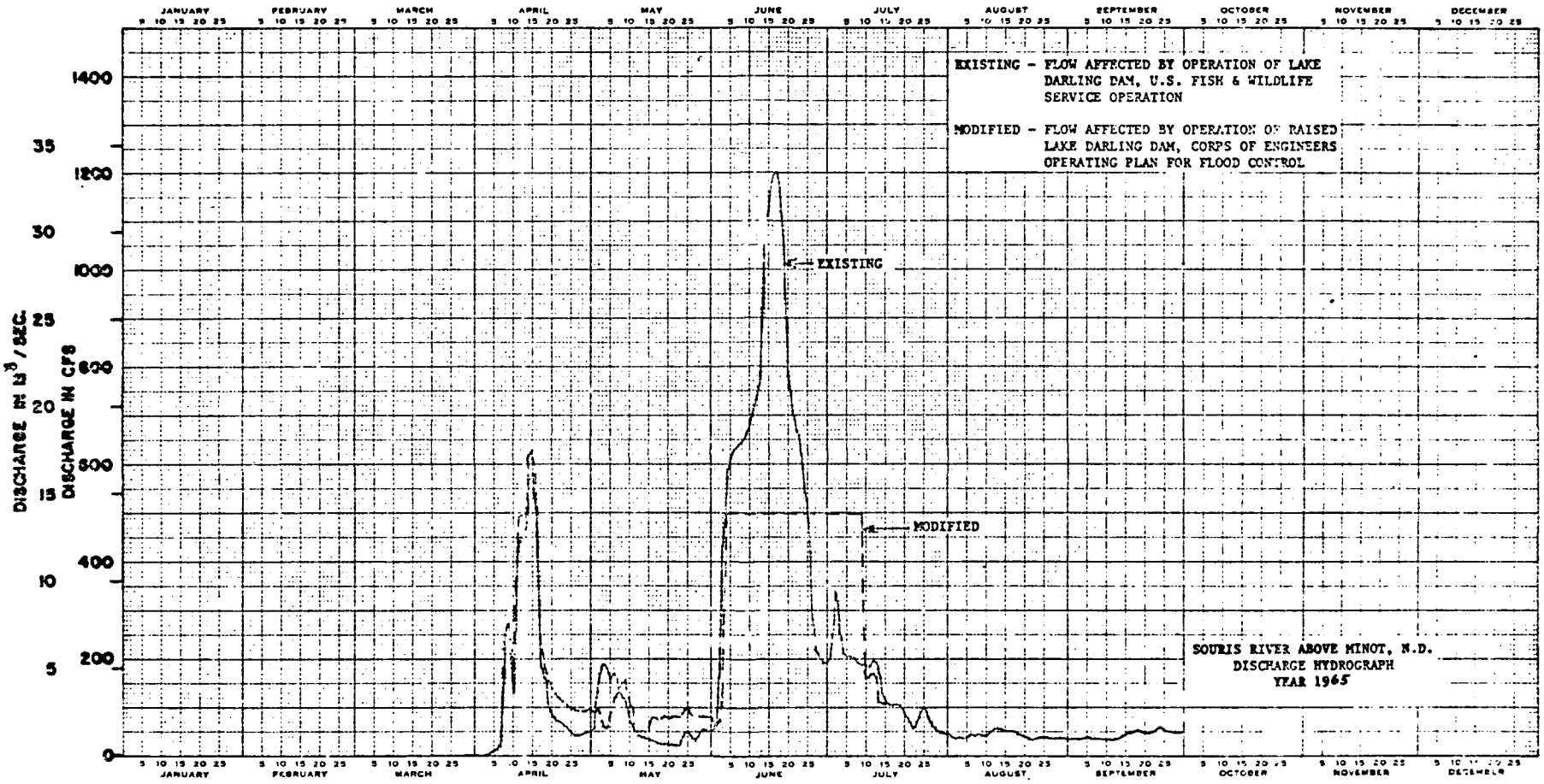

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
SOURIS
RECORDED
MODIFIED

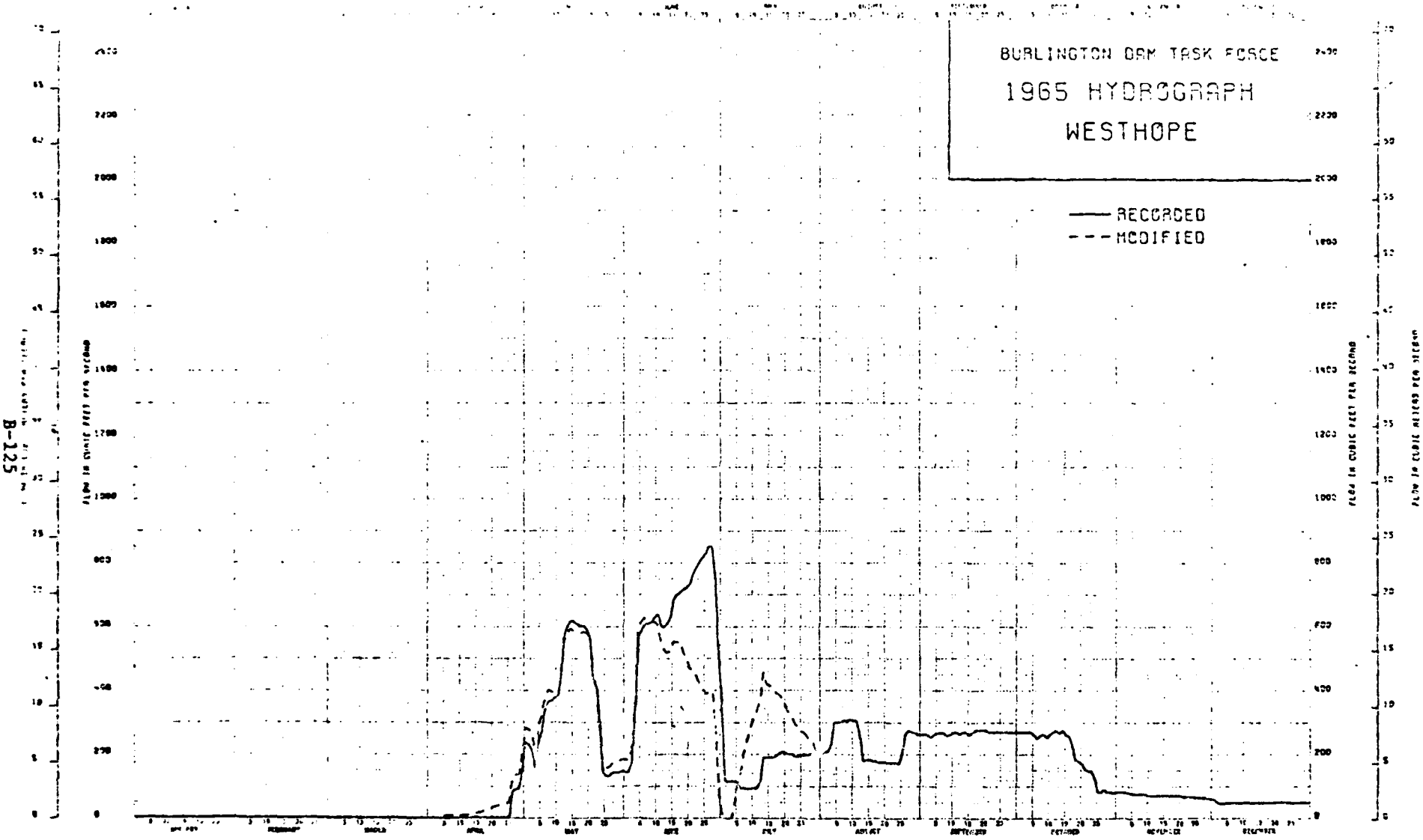

BURLINGTON DAM TASK FORCE
1960 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

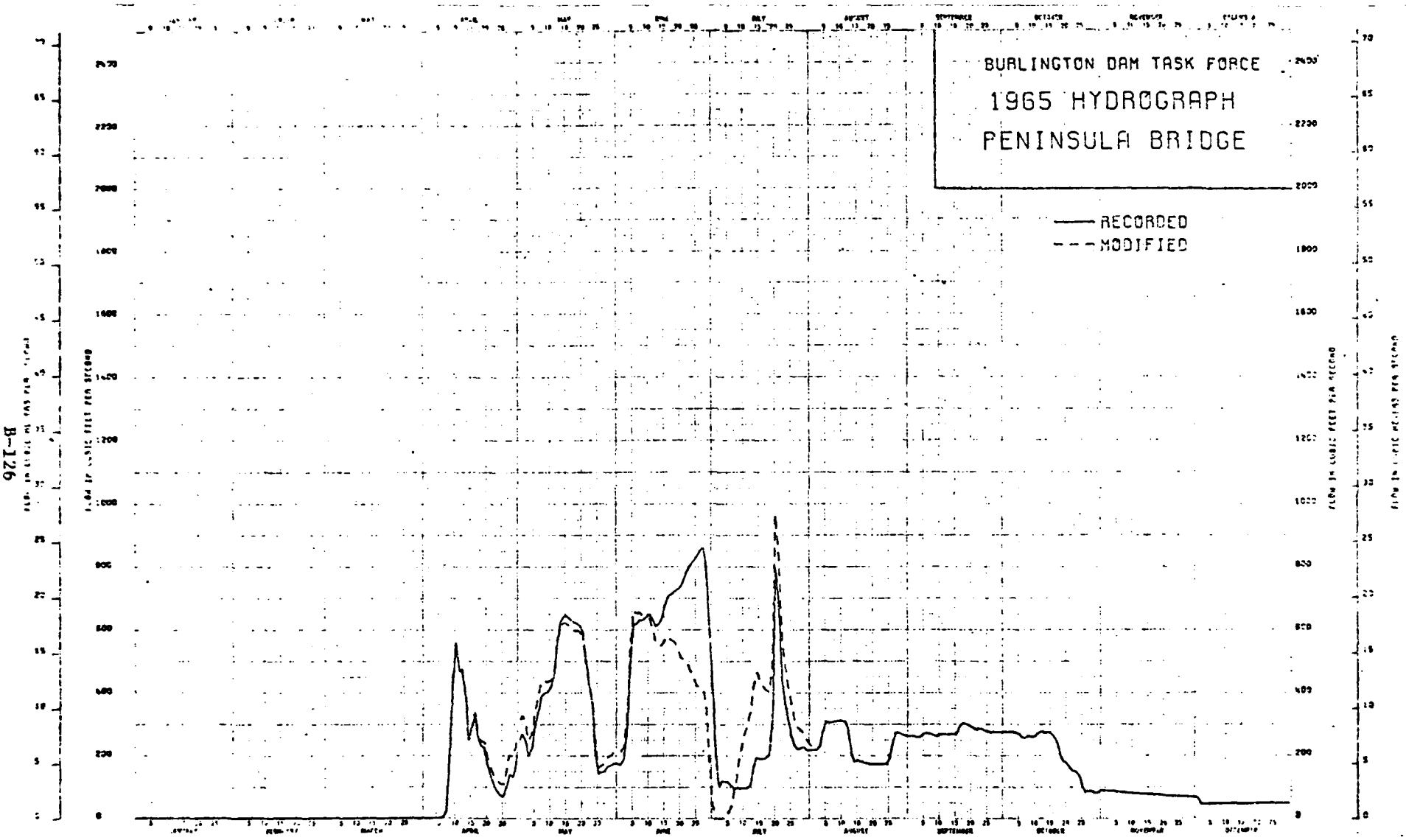
1965

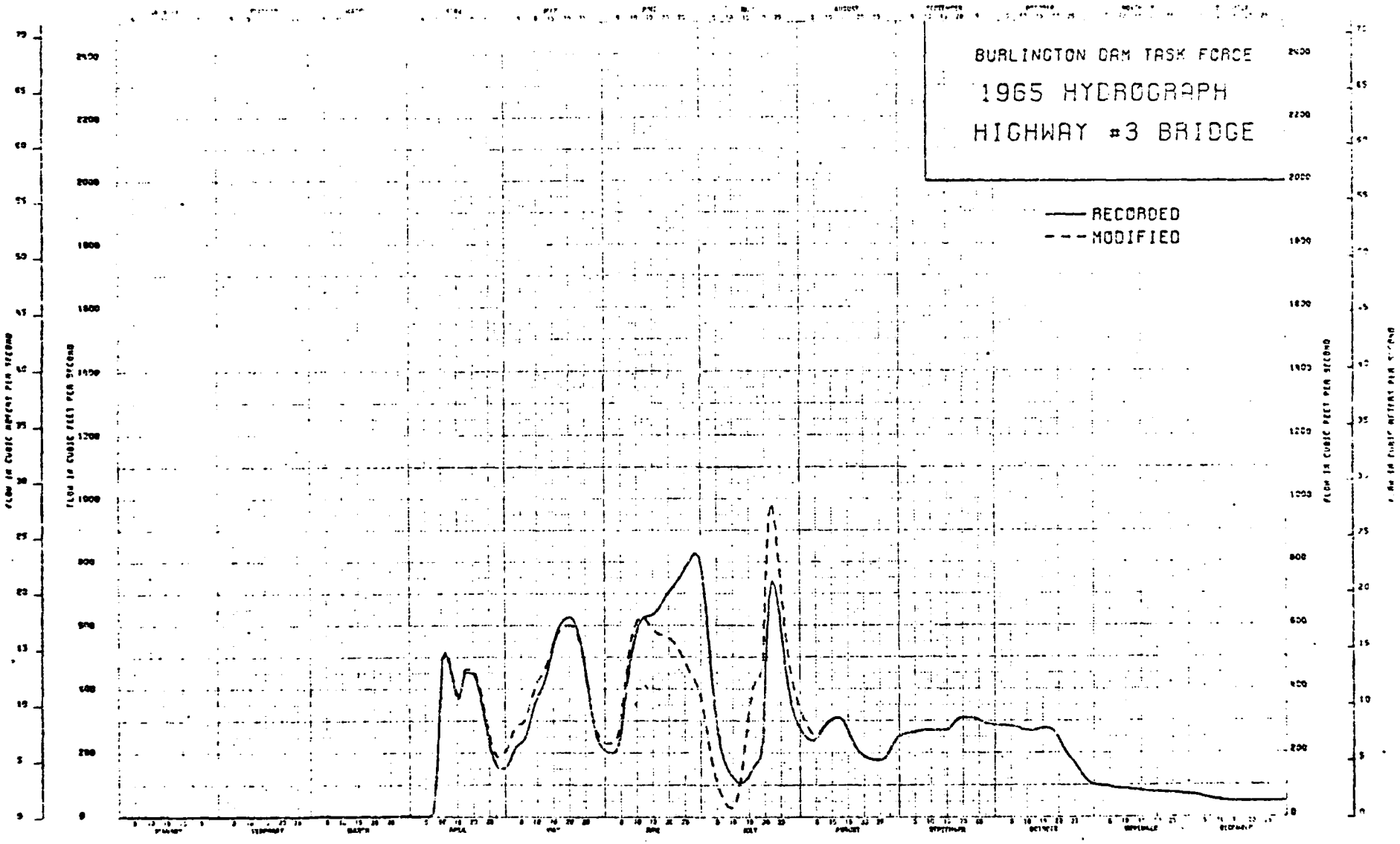

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
35
30
25
20
15
10
5
0
1400
1200
1000
800
600
400
200
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1965

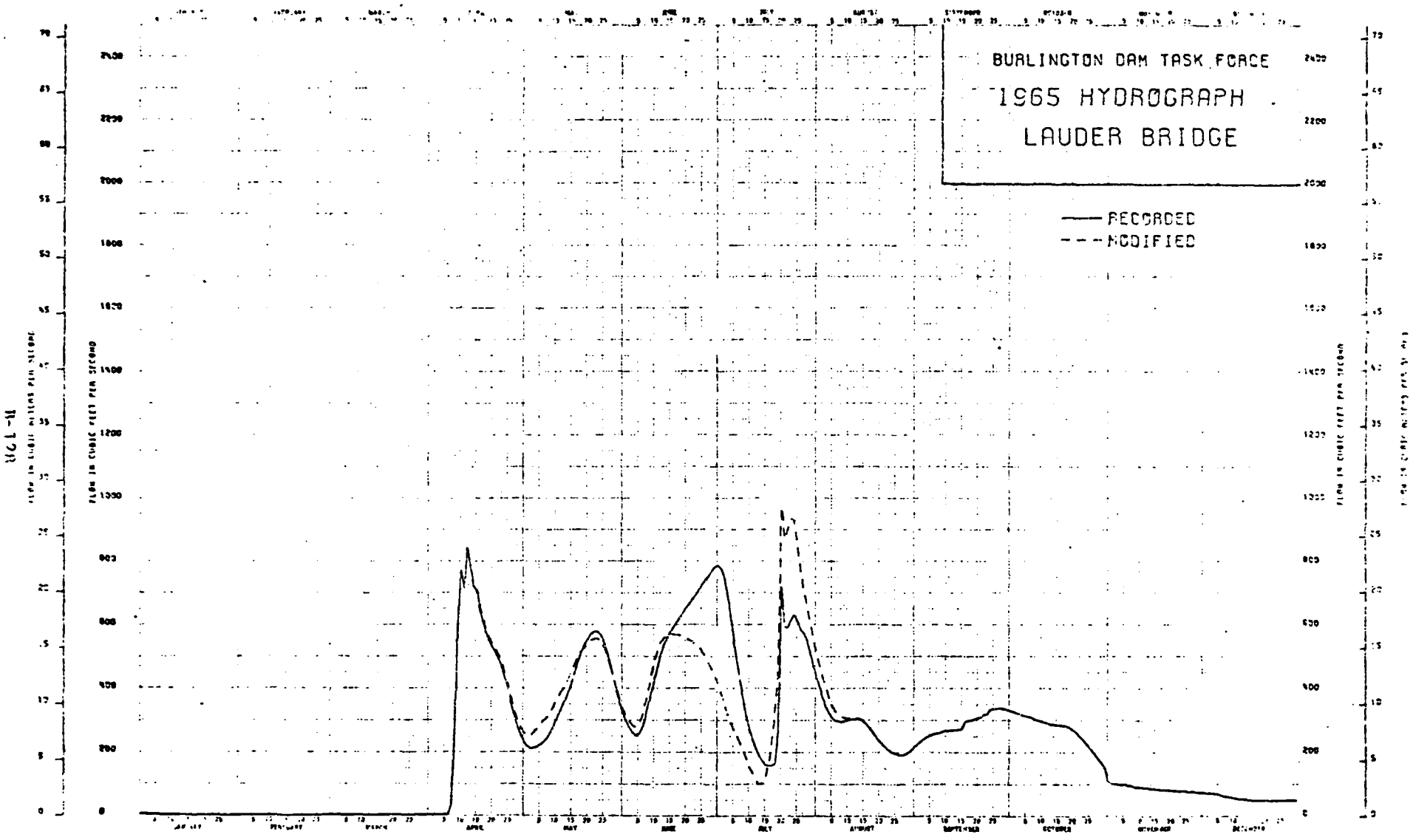

ELEVATION IN METERS
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
487
486
485
484
1598
1596
1594
1592
1590
1588
1586
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
MODIFIED
EXISTING
EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1965

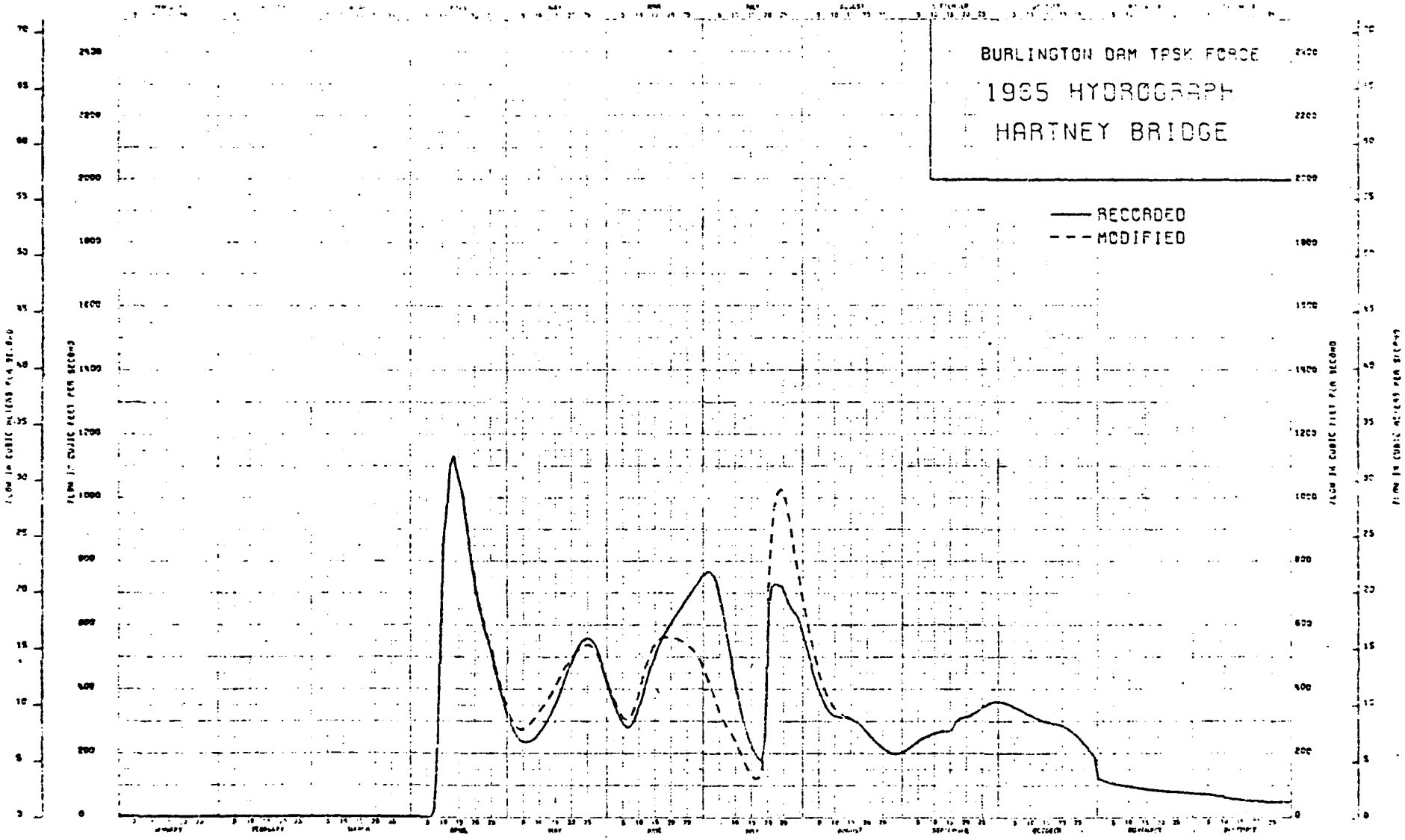

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1965
DISCHARGE IN CFS
DISCHARGE IN M³/SEC.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

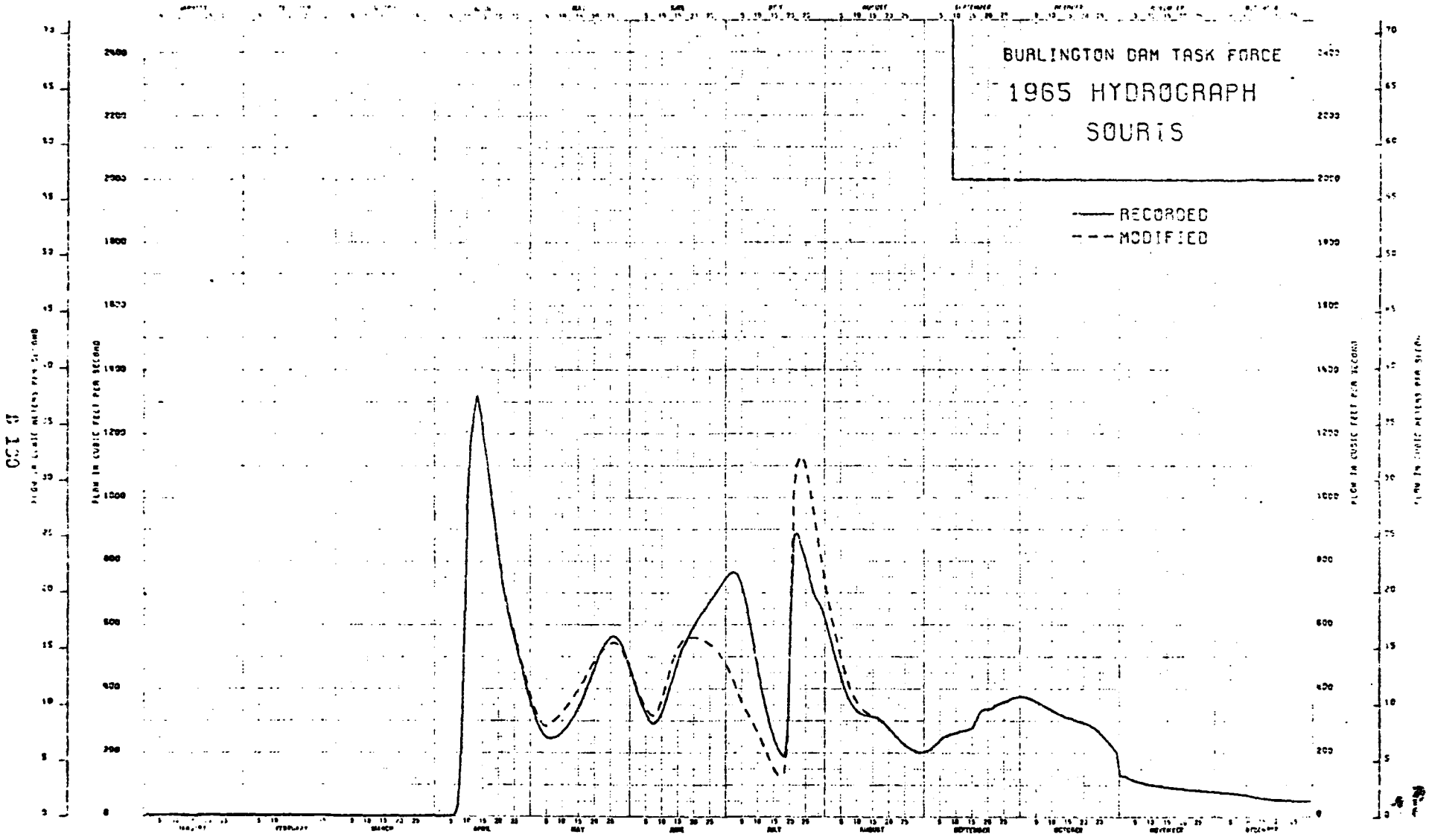

BURLINGTON DAM TASK FORCE
1965 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

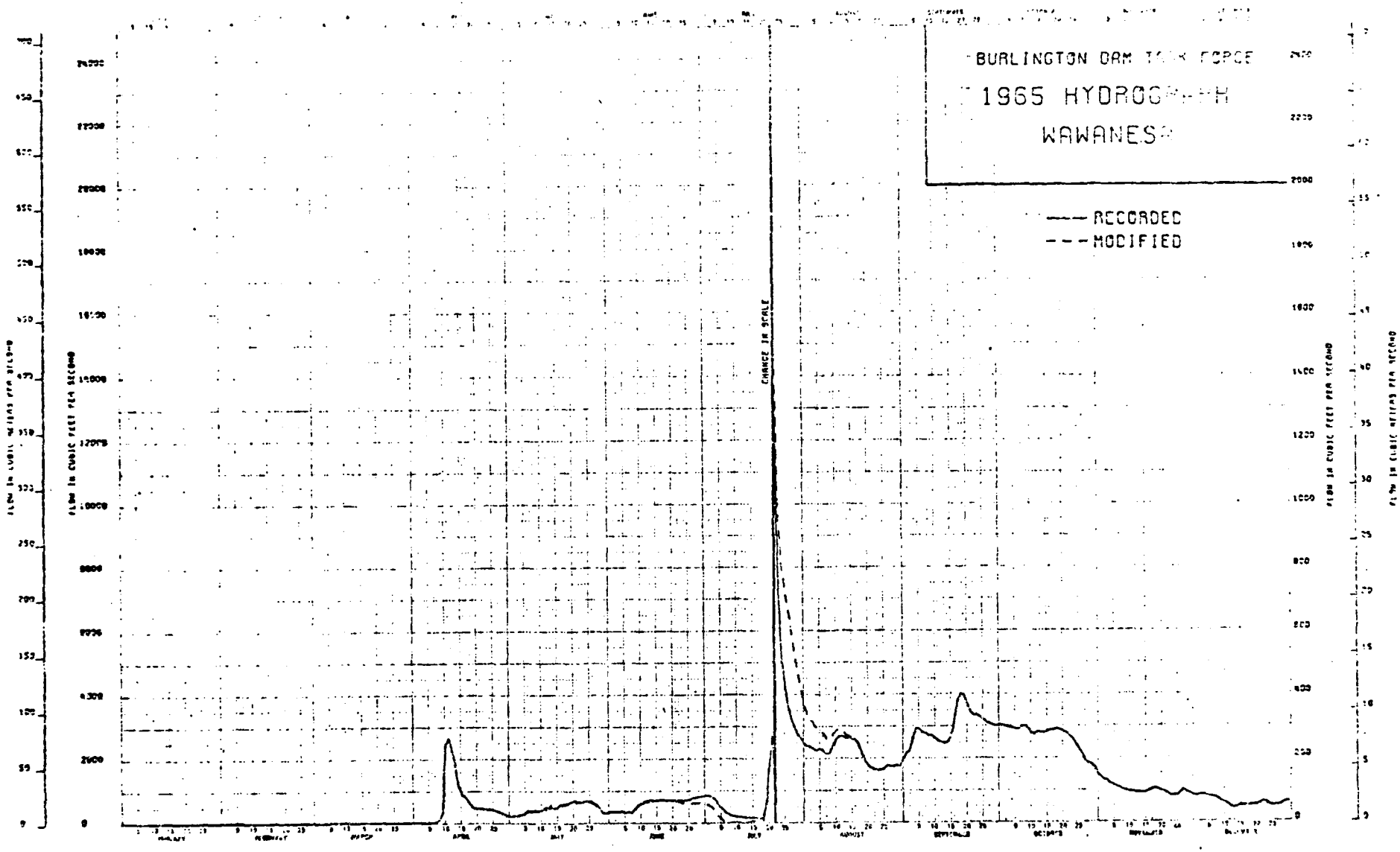

BURLINGTON DAM TASK FORCE
1965 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1965 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED

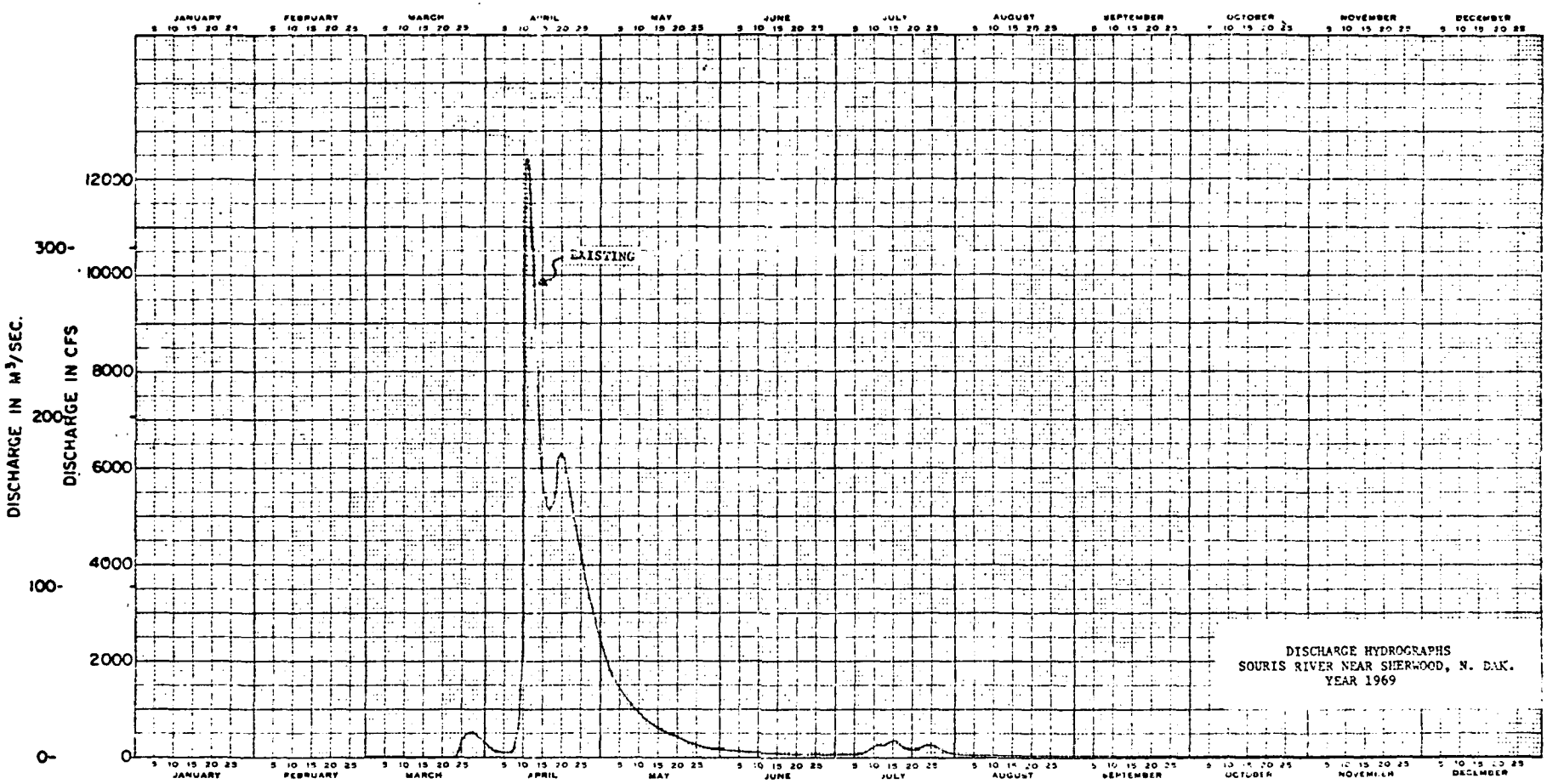

BURLINGTON DAM TASK FORCE
1965 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

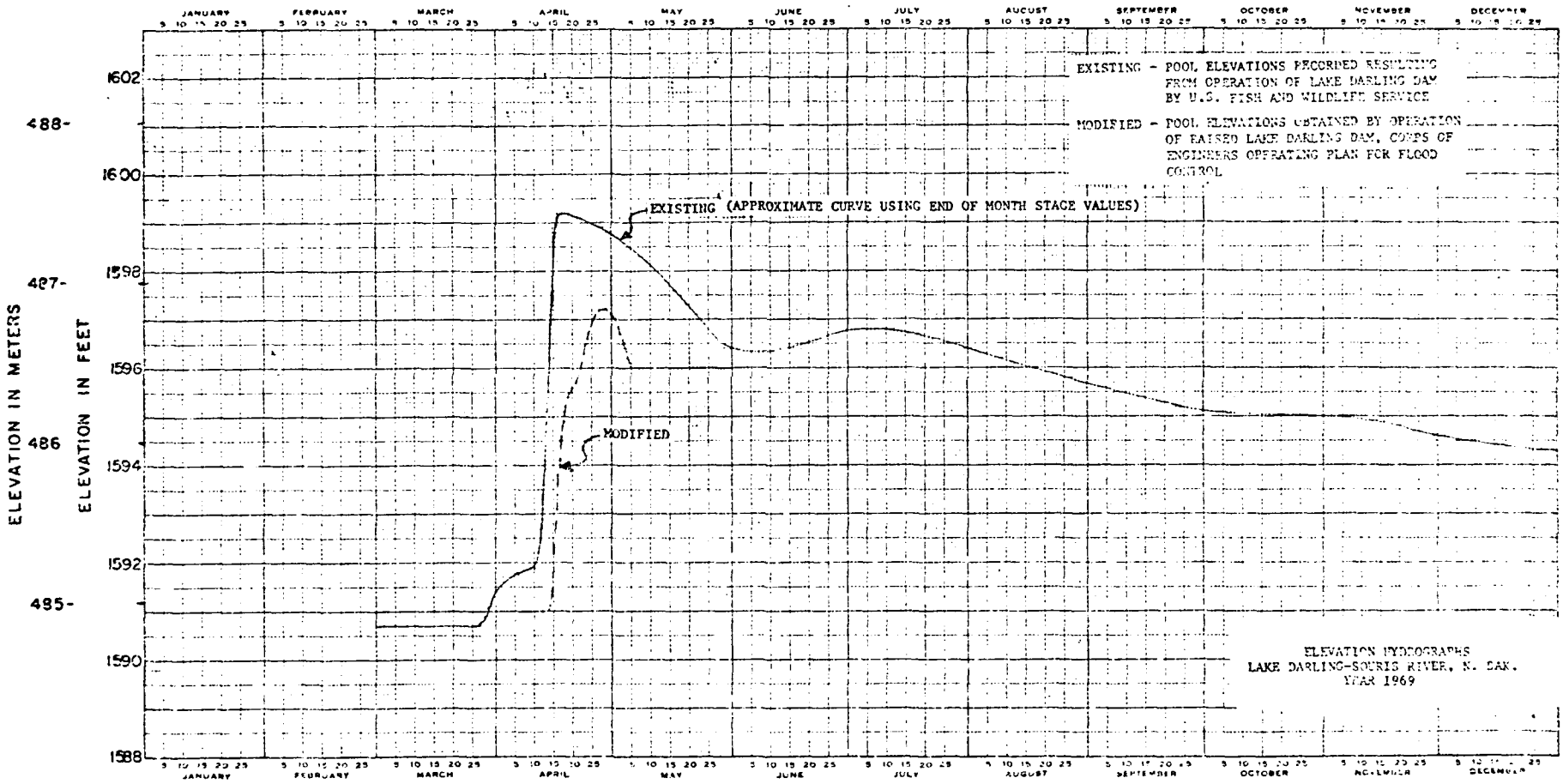

BURLINGTON DAM TASK FORCE
1985 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1965 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

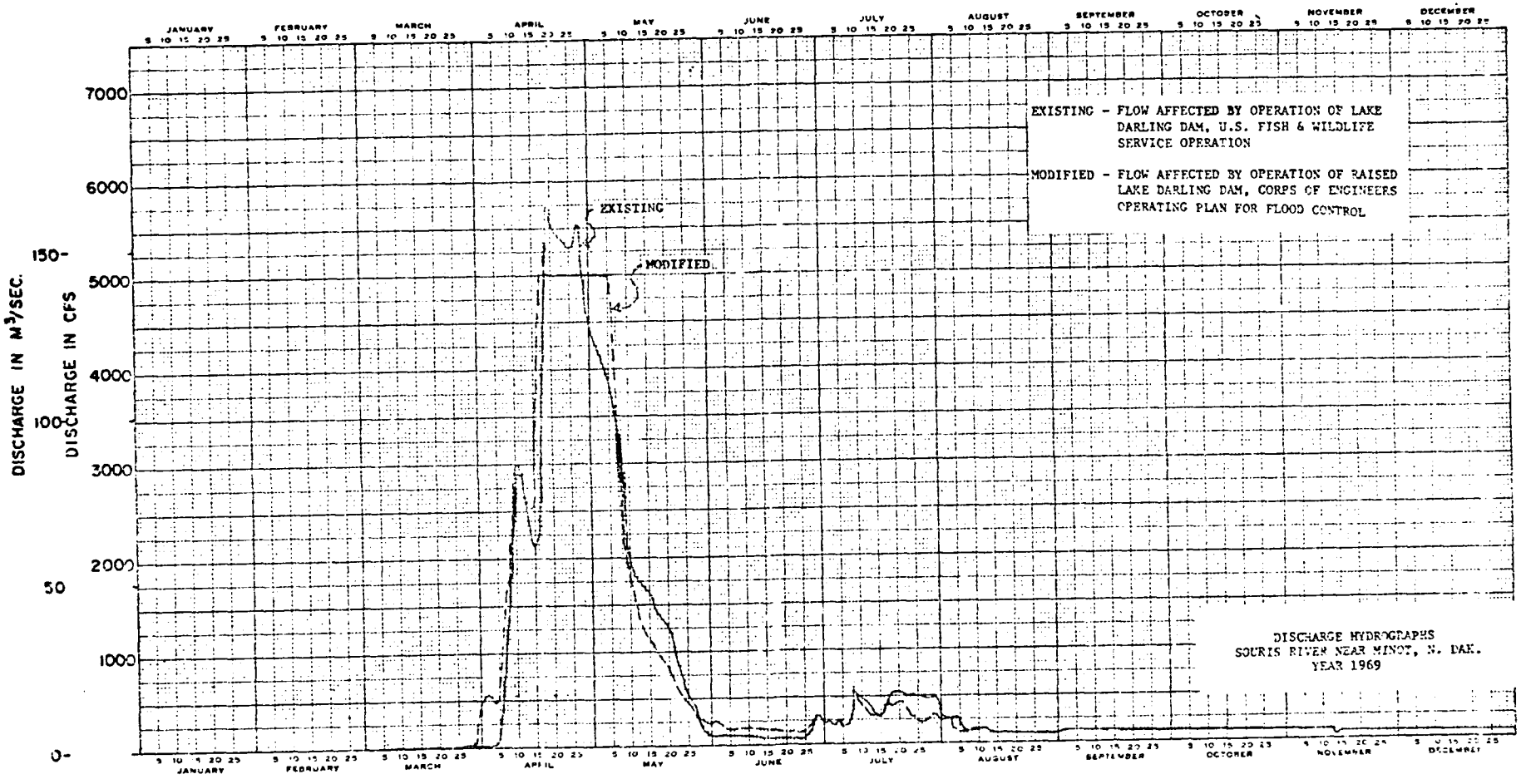

BURLINGTON DAM
1965 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE

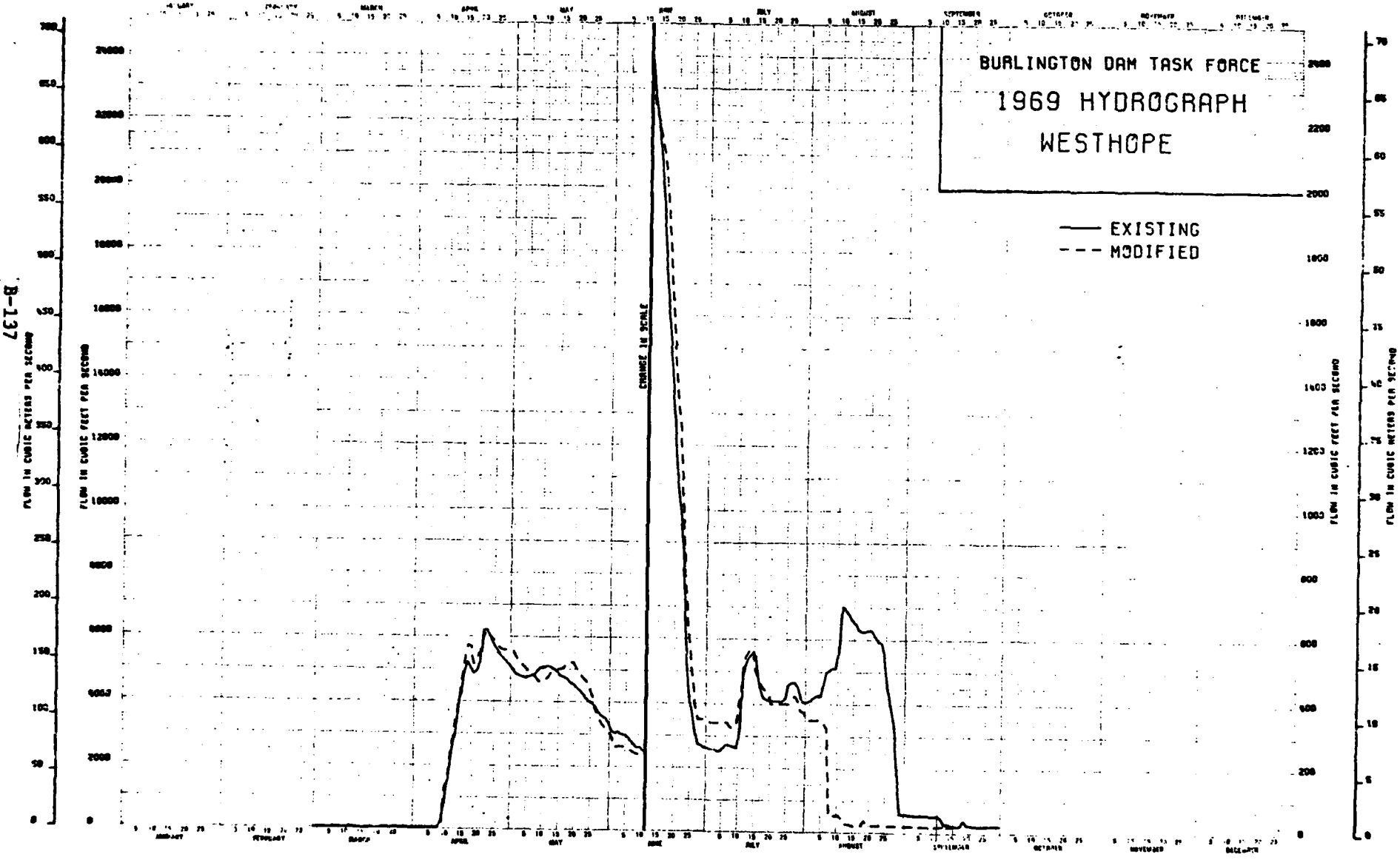
1969

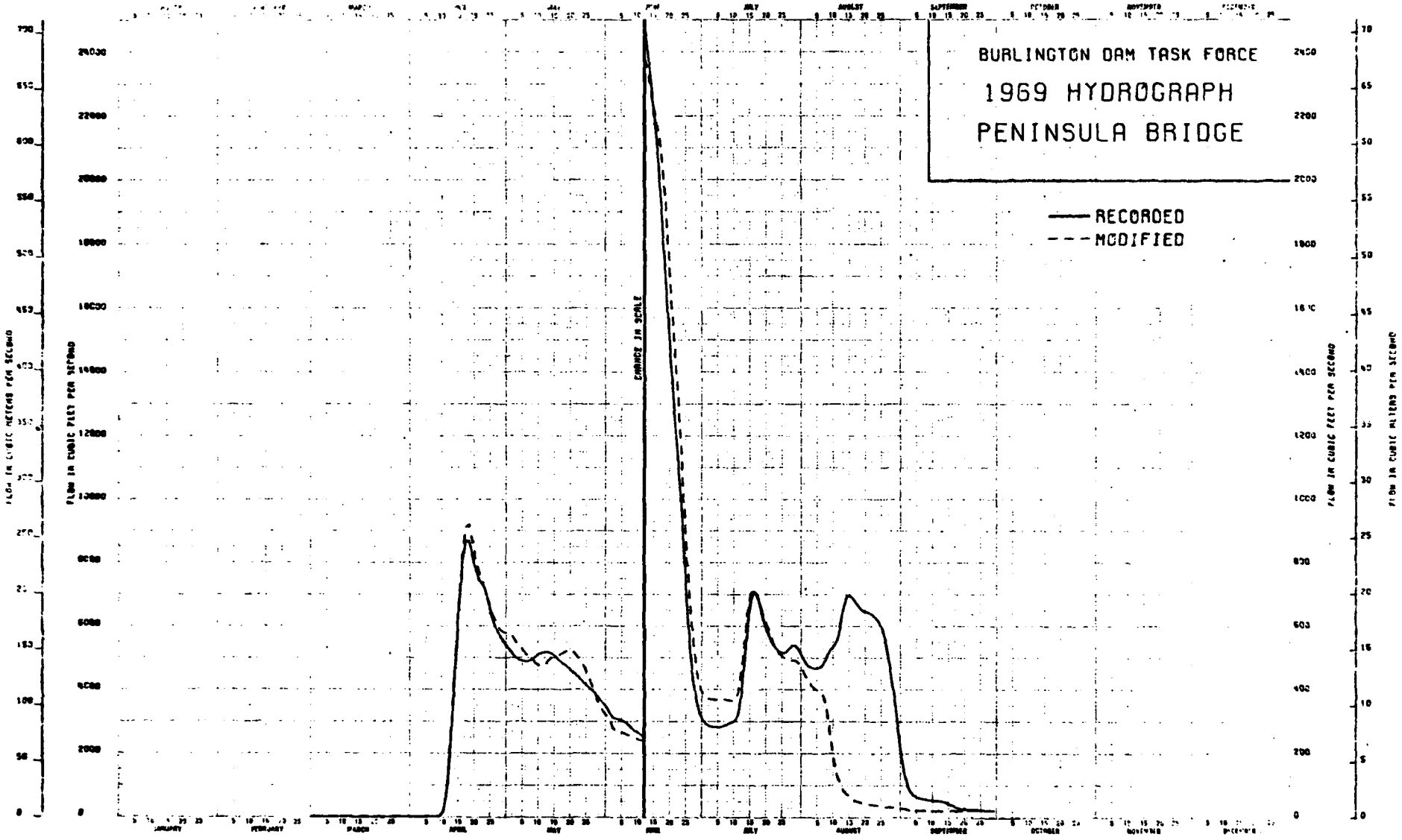

DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
300-
200
100-
0-
12000
10000
8000
6000
4000
2000
0
EXISTING
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1969

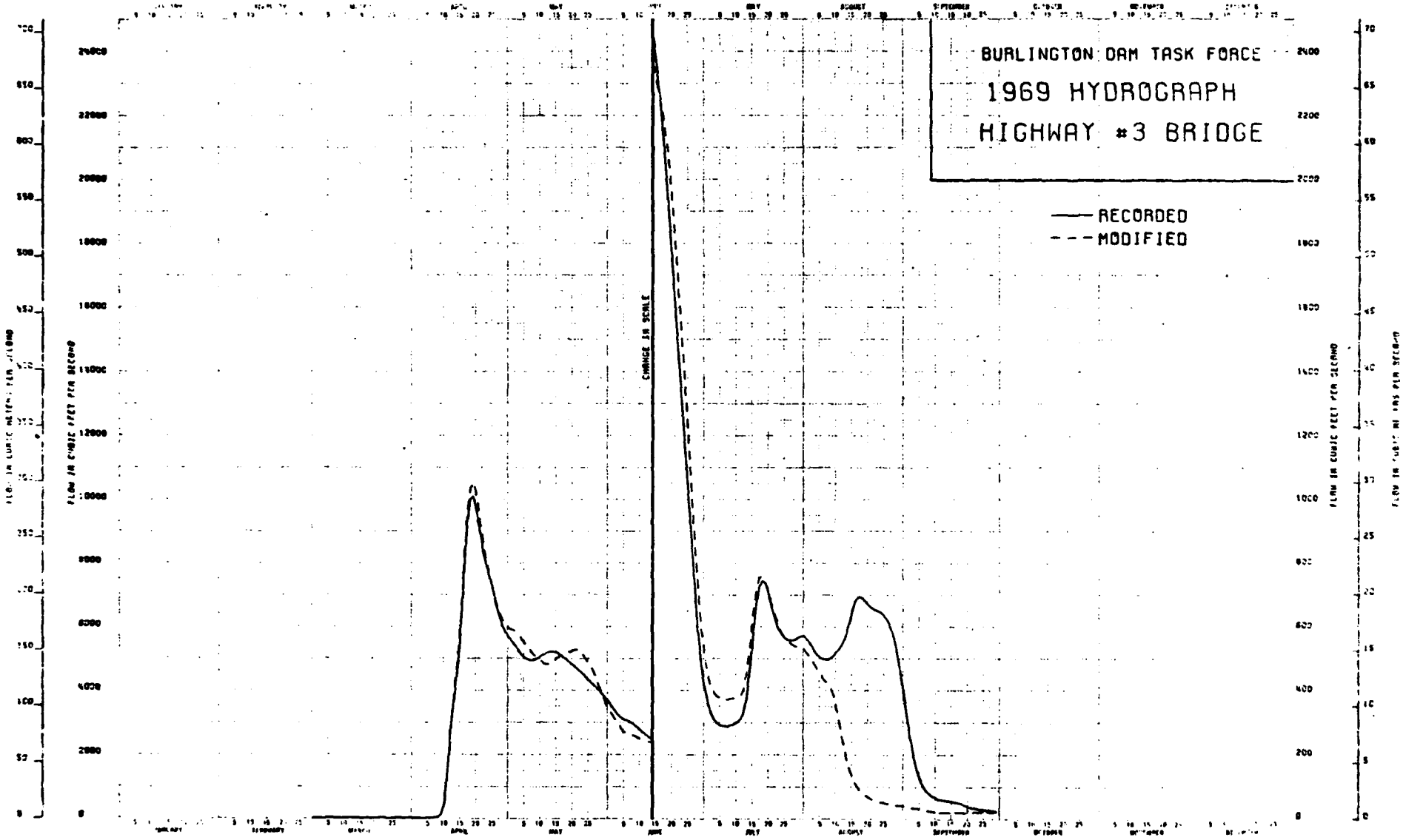


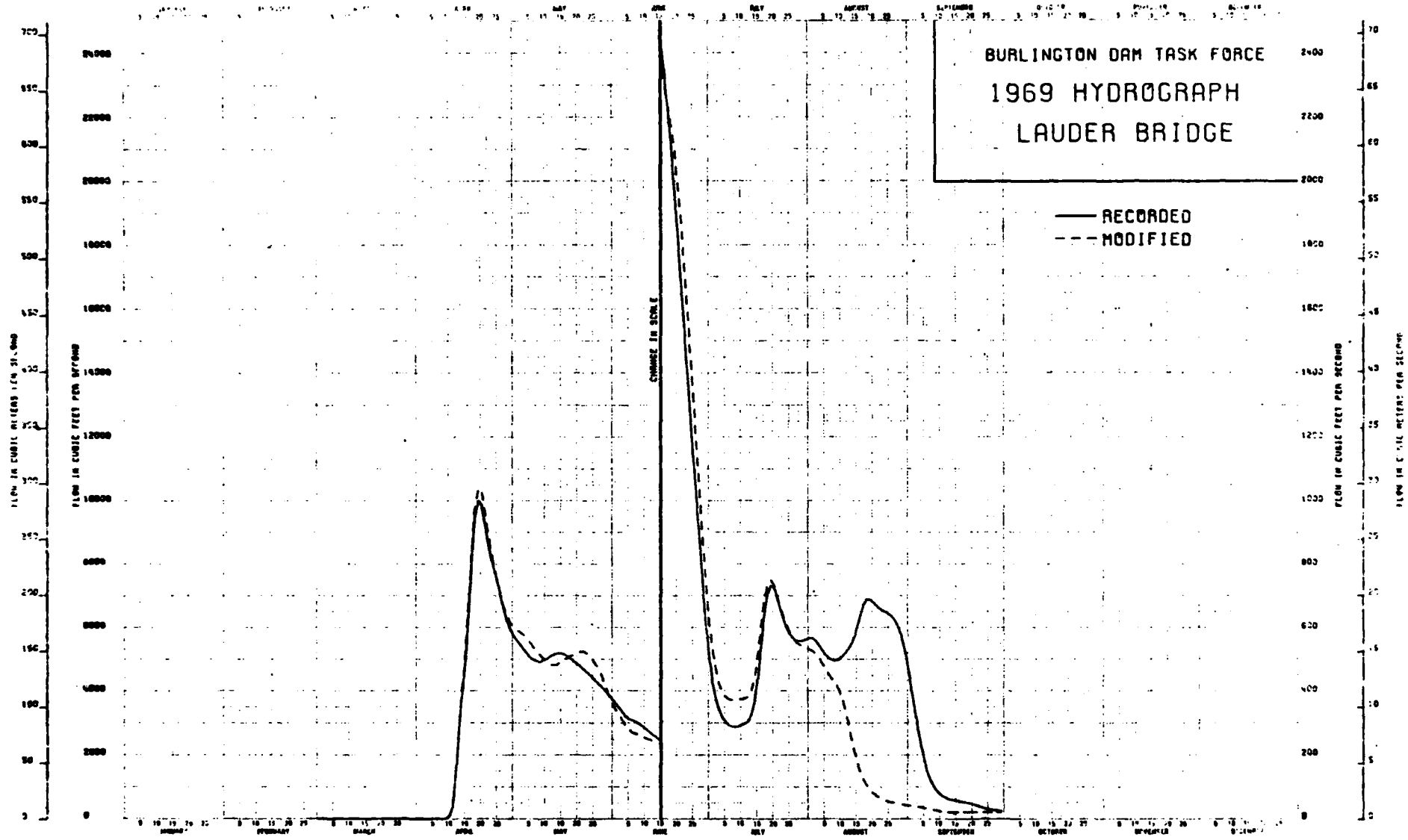
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1969

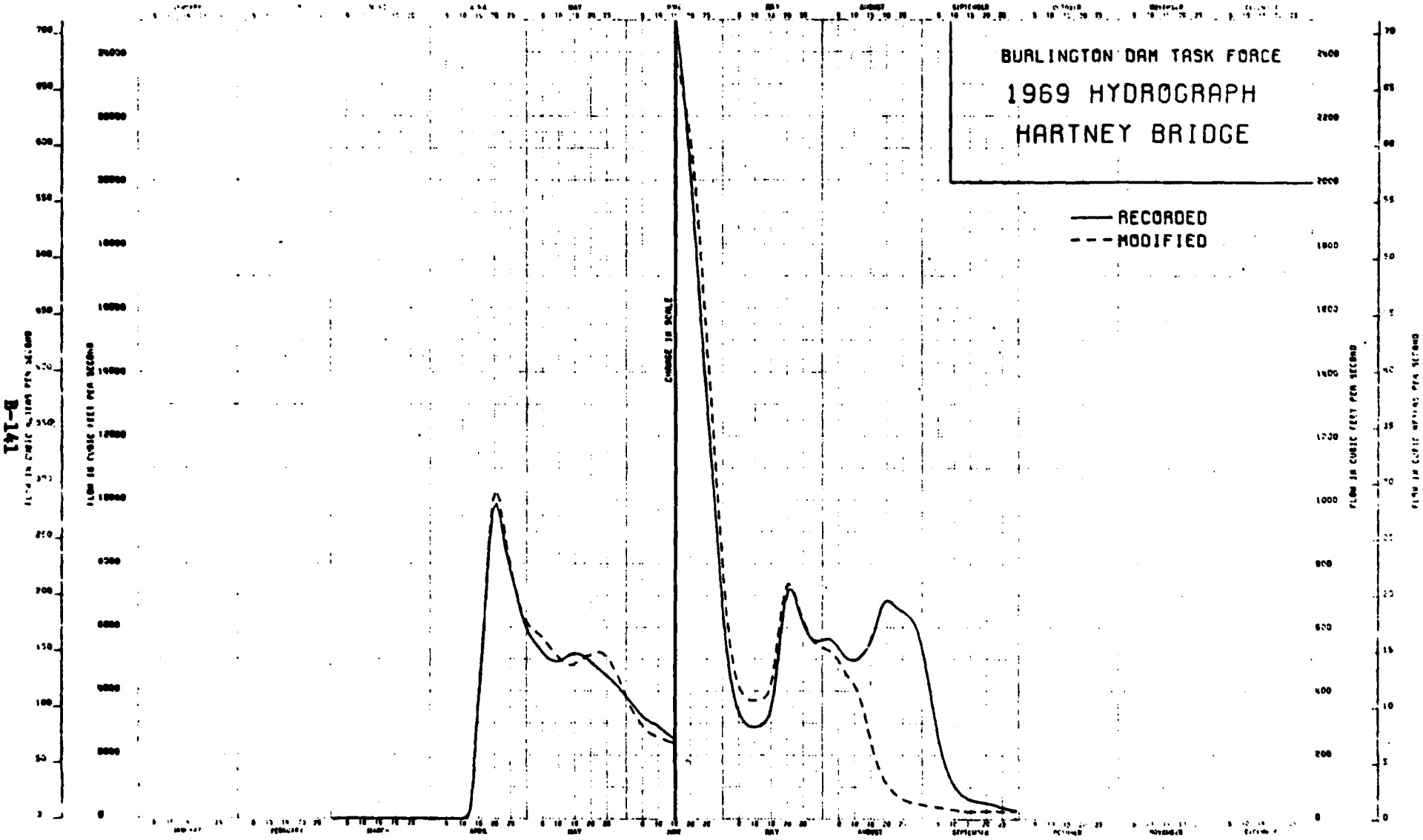

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1969
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
EXISTING
MODIFIED
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
7000
6000
5000
4000
3000
2000
1000
0
150
100
50

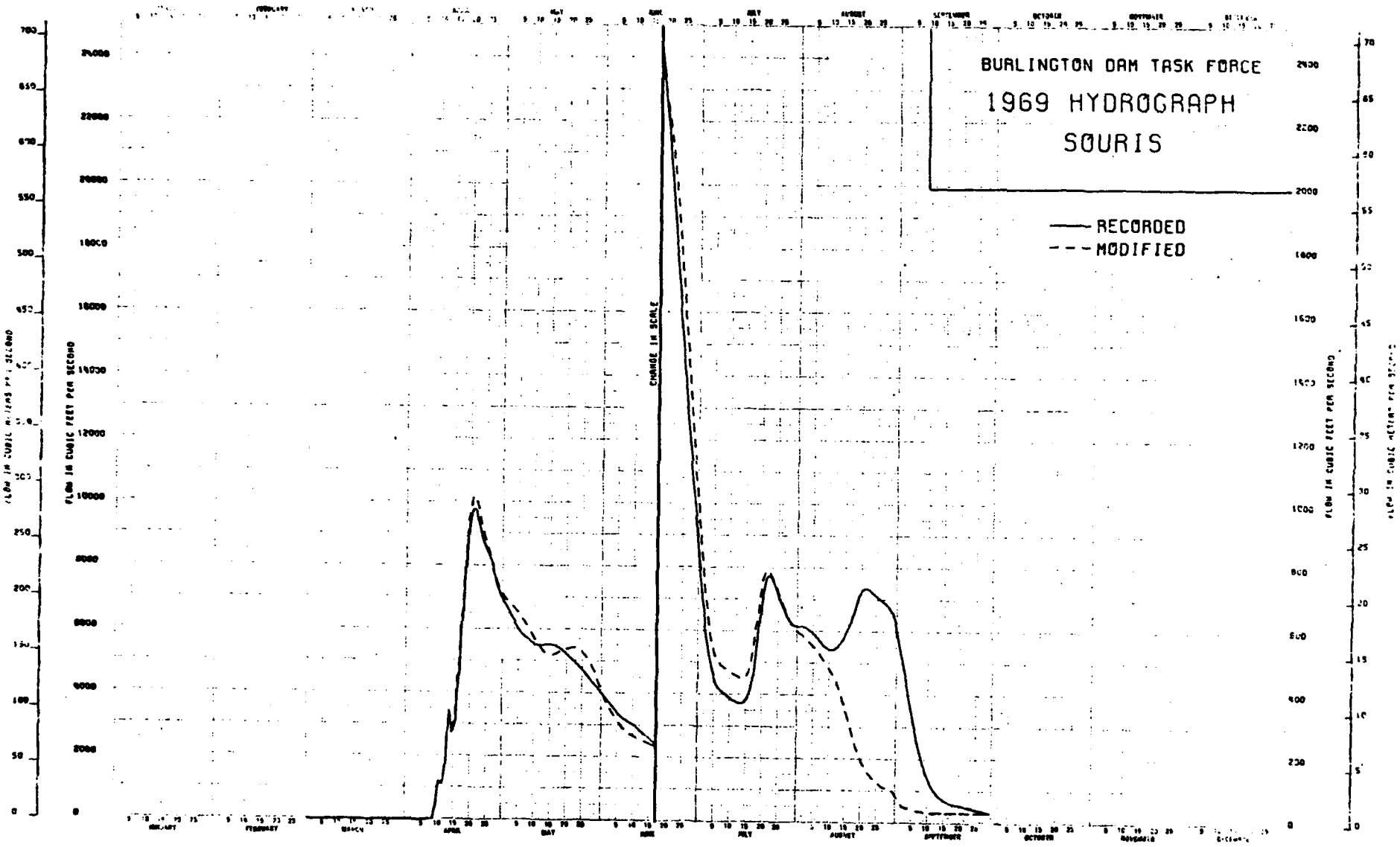

BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
WESTHOPE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

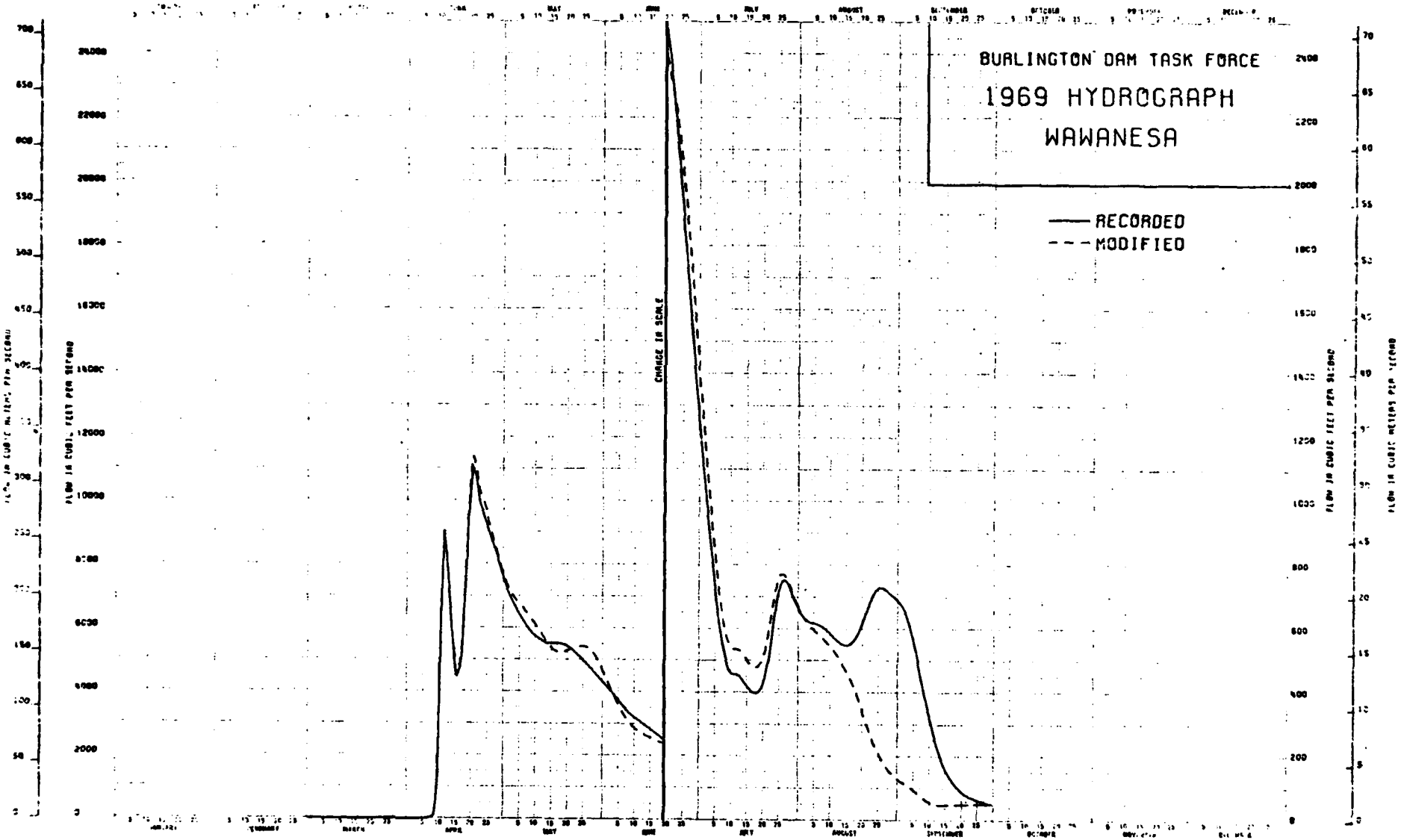

BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER


BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

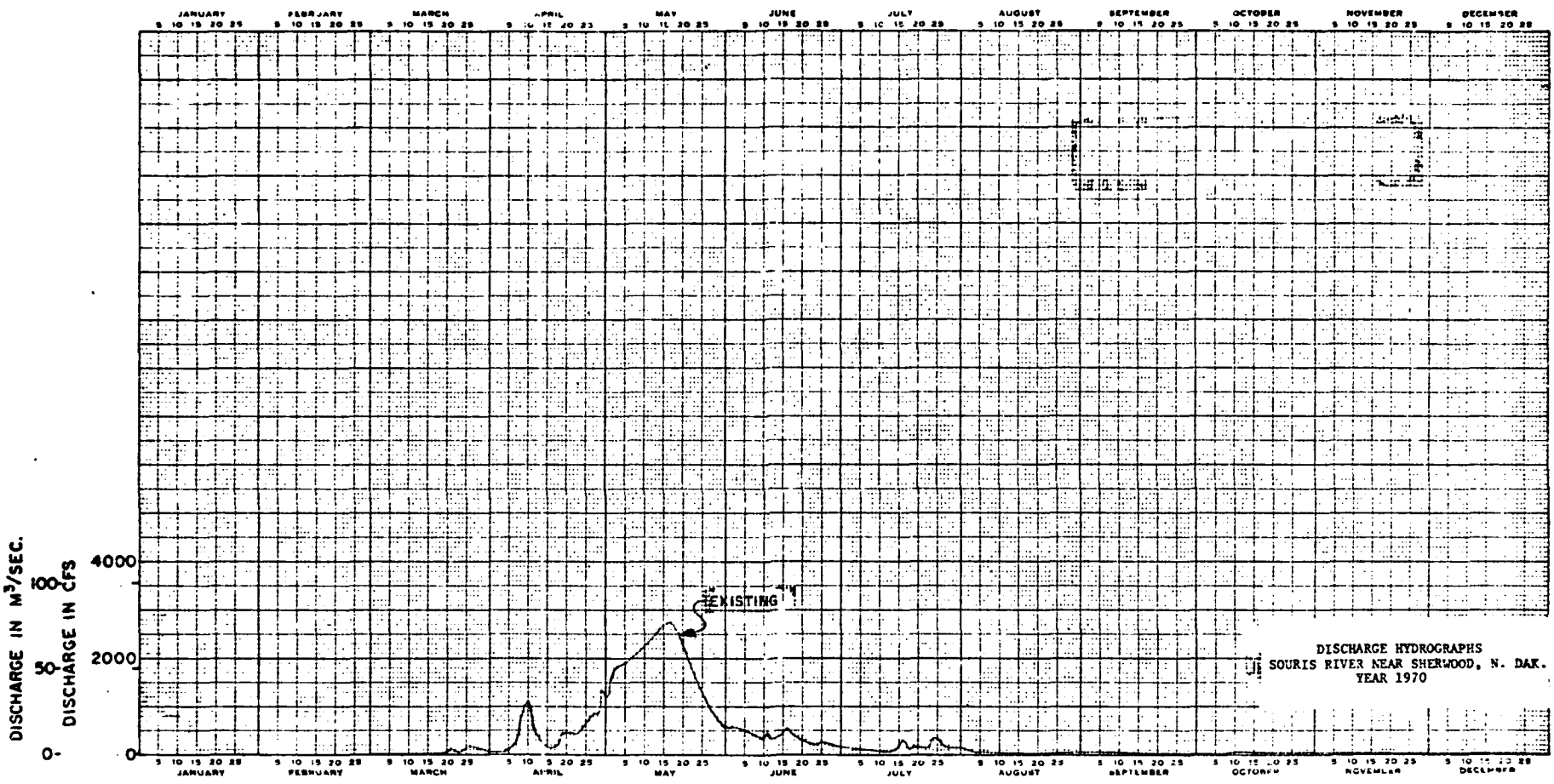

BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

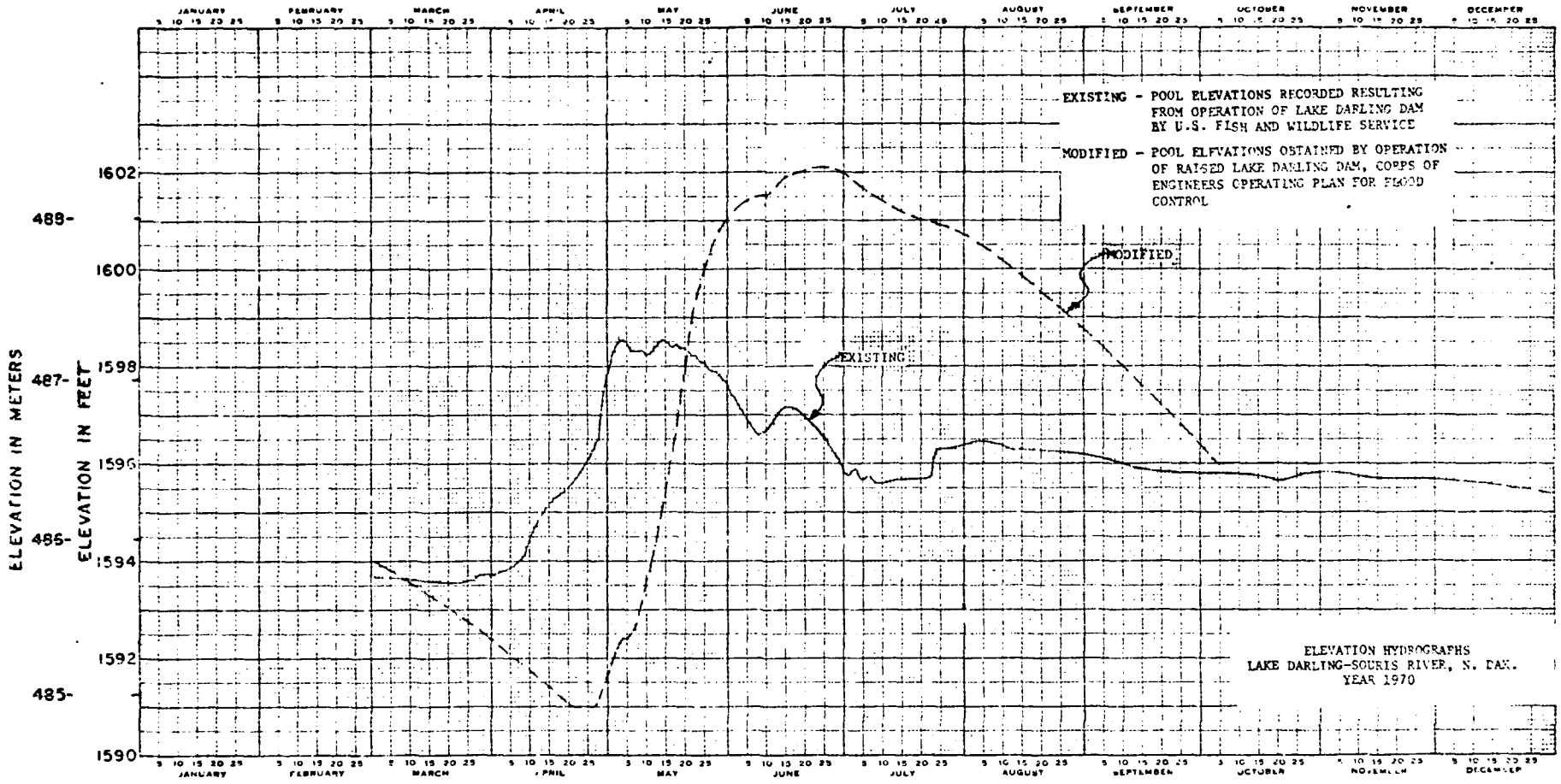

BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER

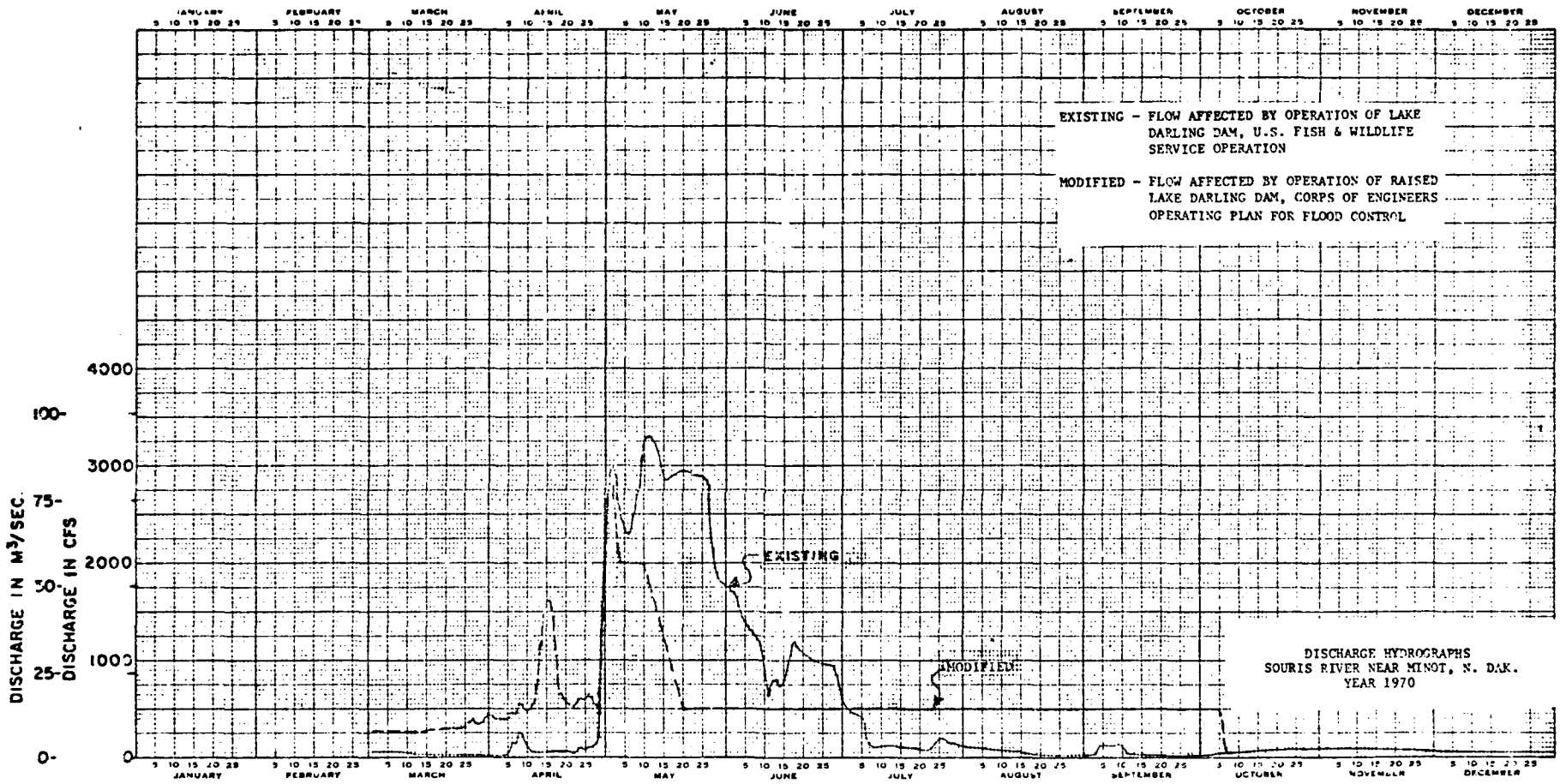

BURLINGTON DAM TASK FORCE
1969 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

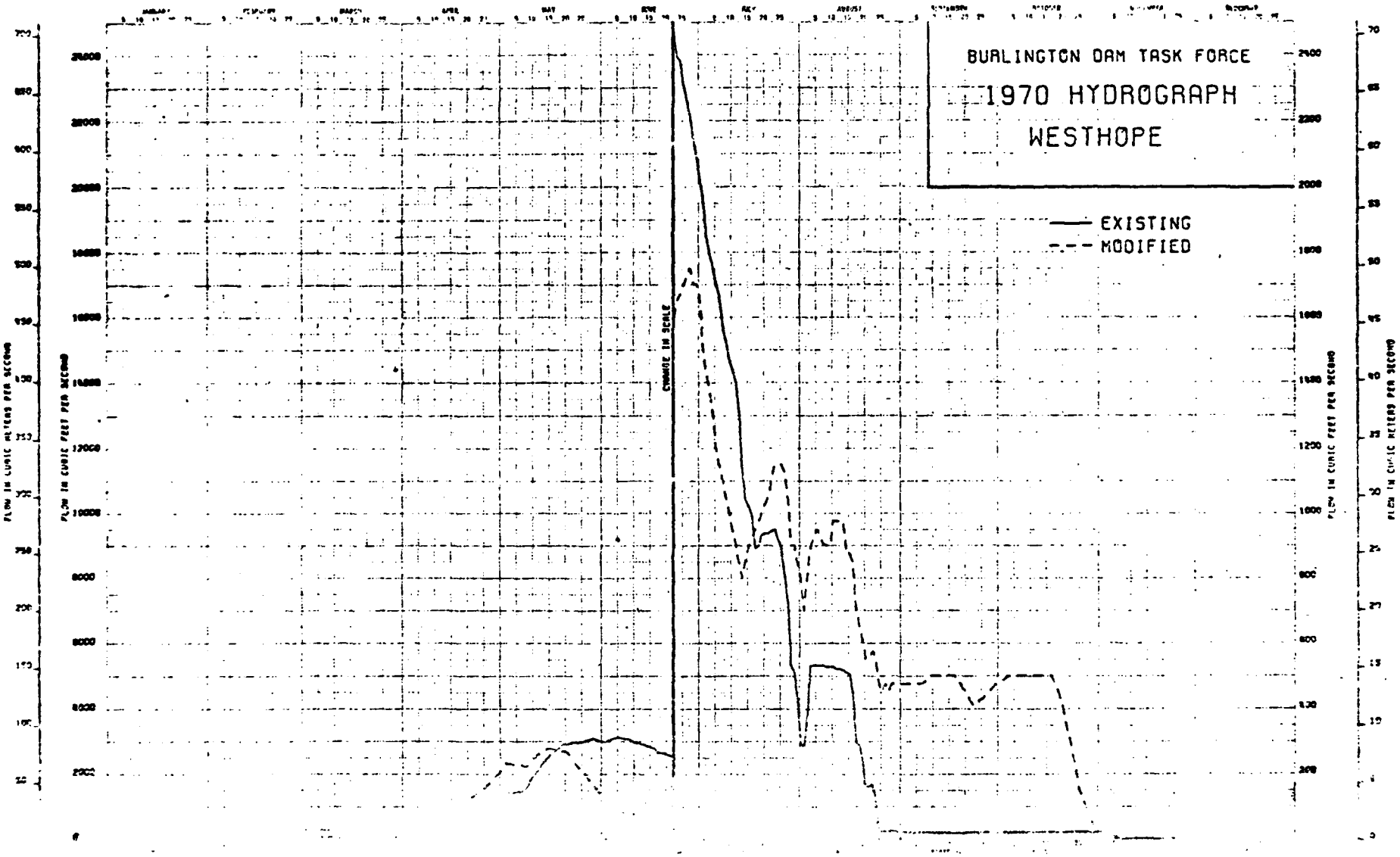
1970

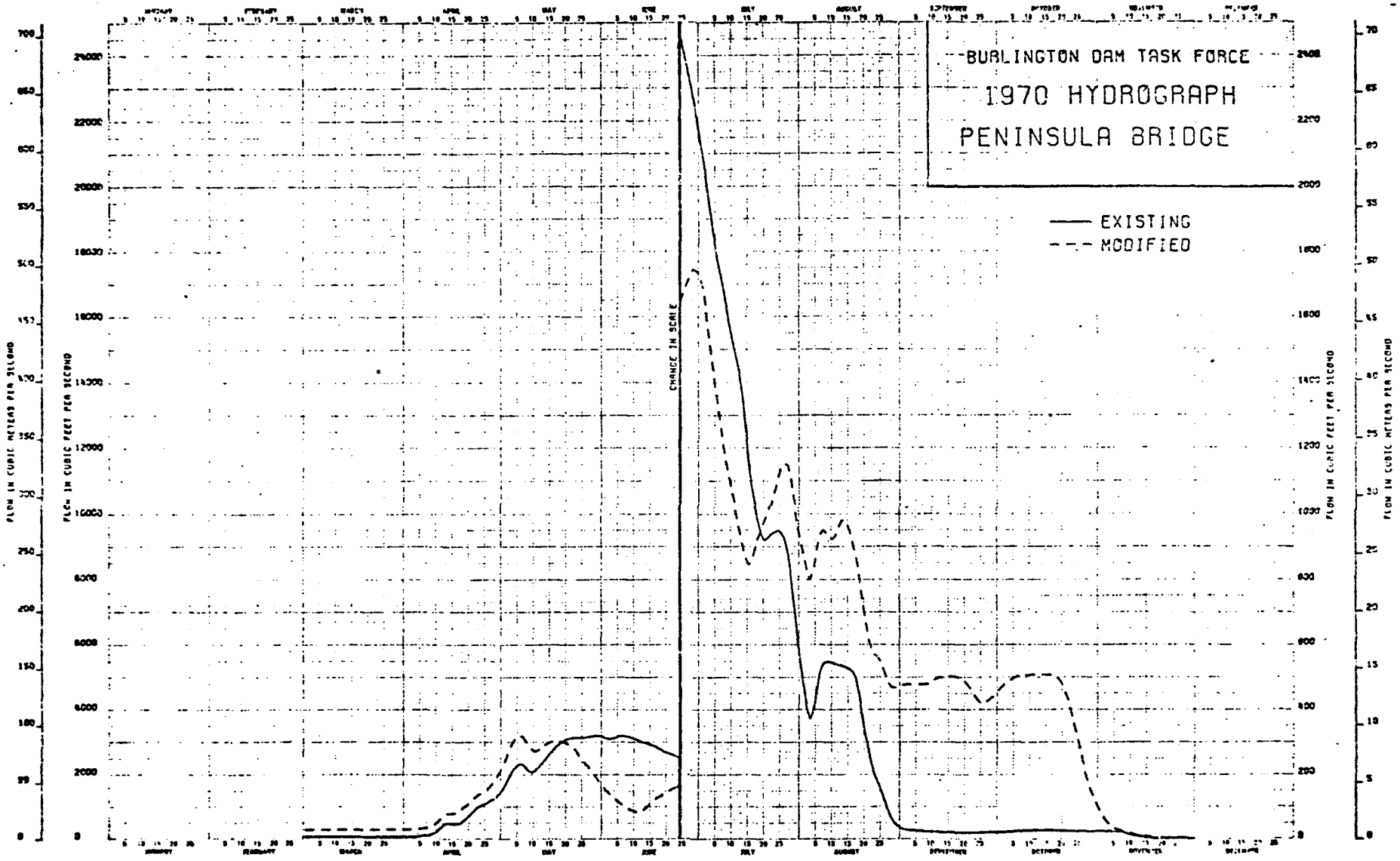


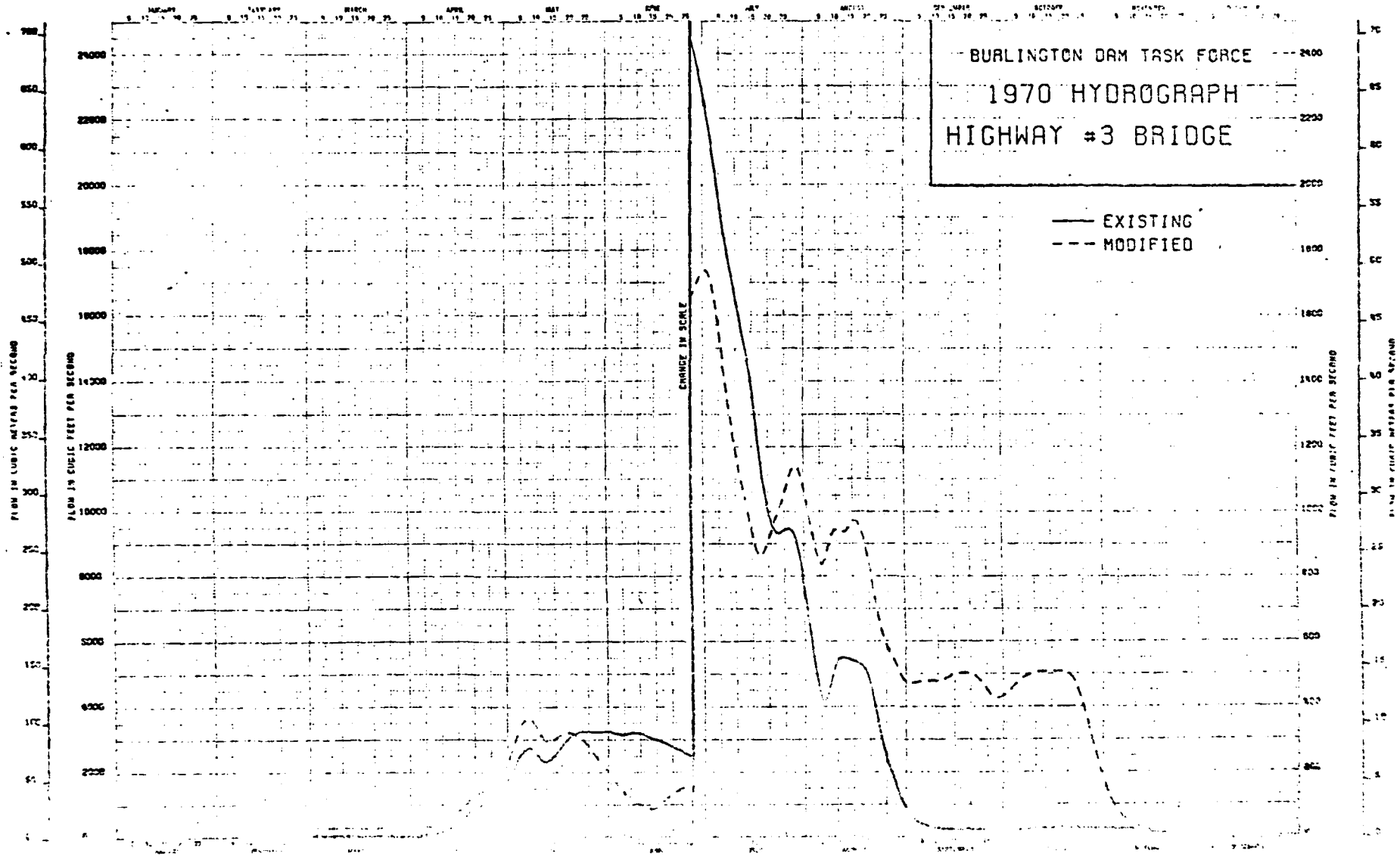
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1970

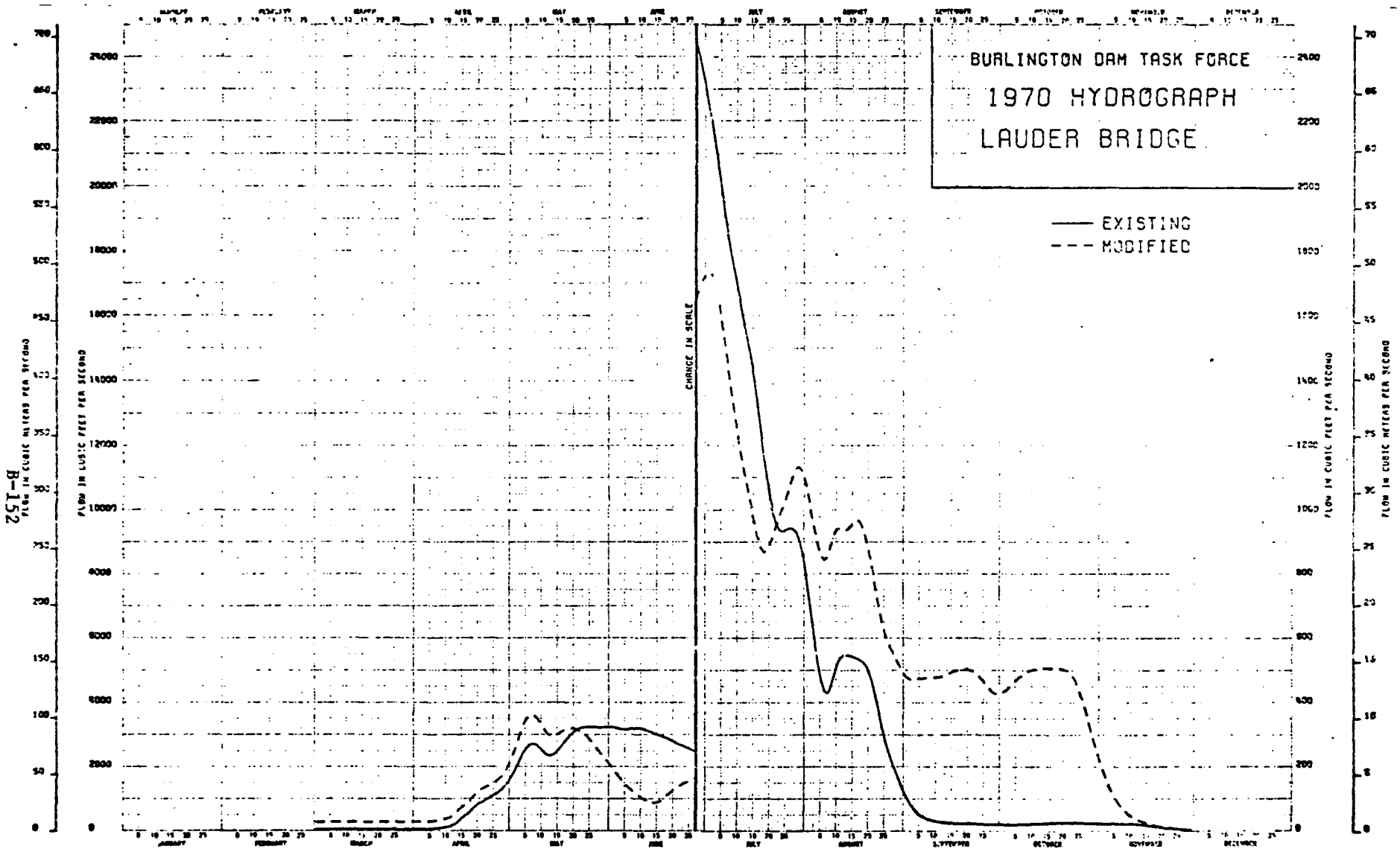

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
ELEVATION IN METERS
ELEVATION IN FEET
488-
487-
486-
485-
1602
1600
1598
1596
1594
1592
1590
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1970

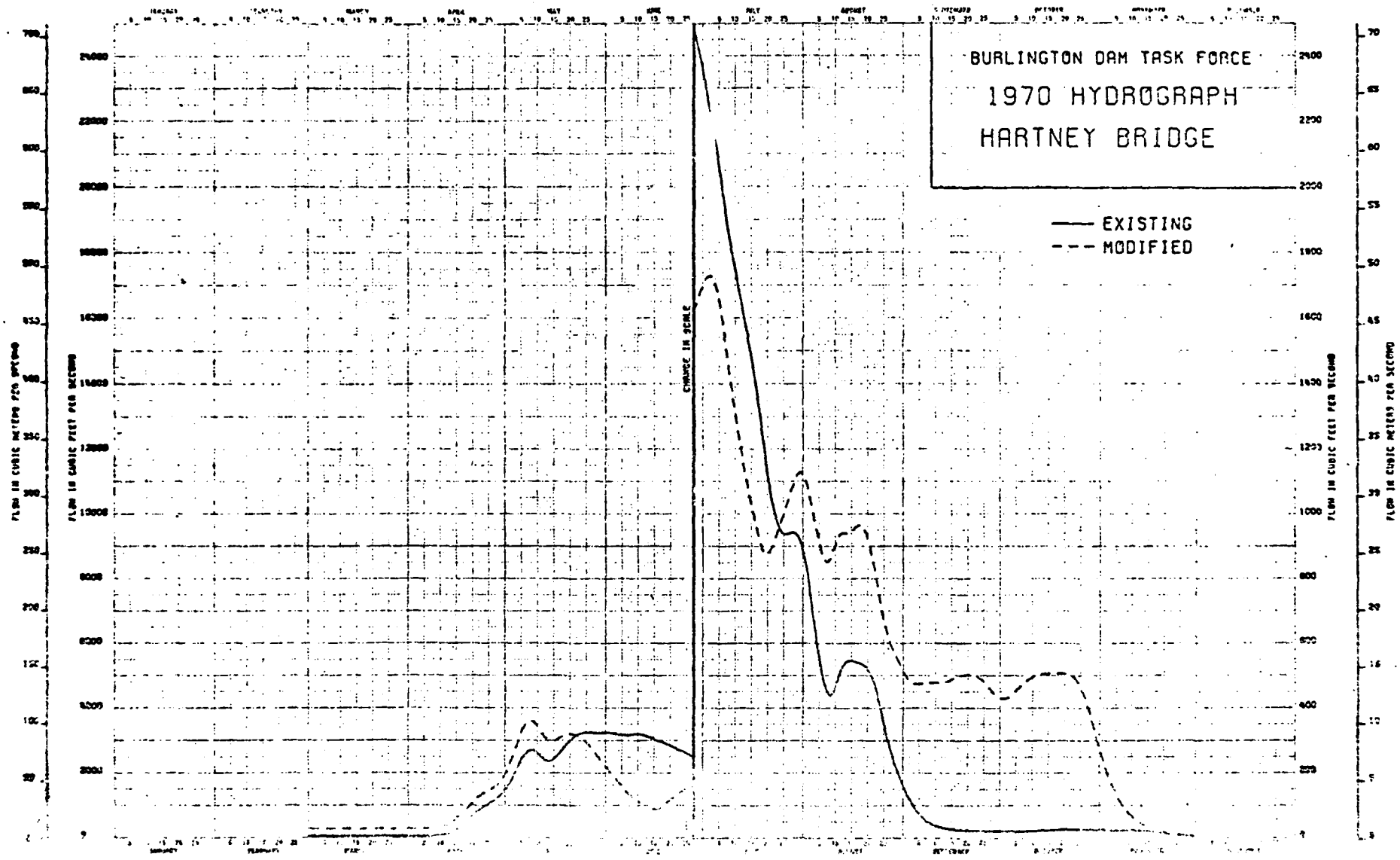

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1970
EXISTING
MODIFIED
DISCHARGE IN M³/SEC
DISCHARGE IN CFS
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

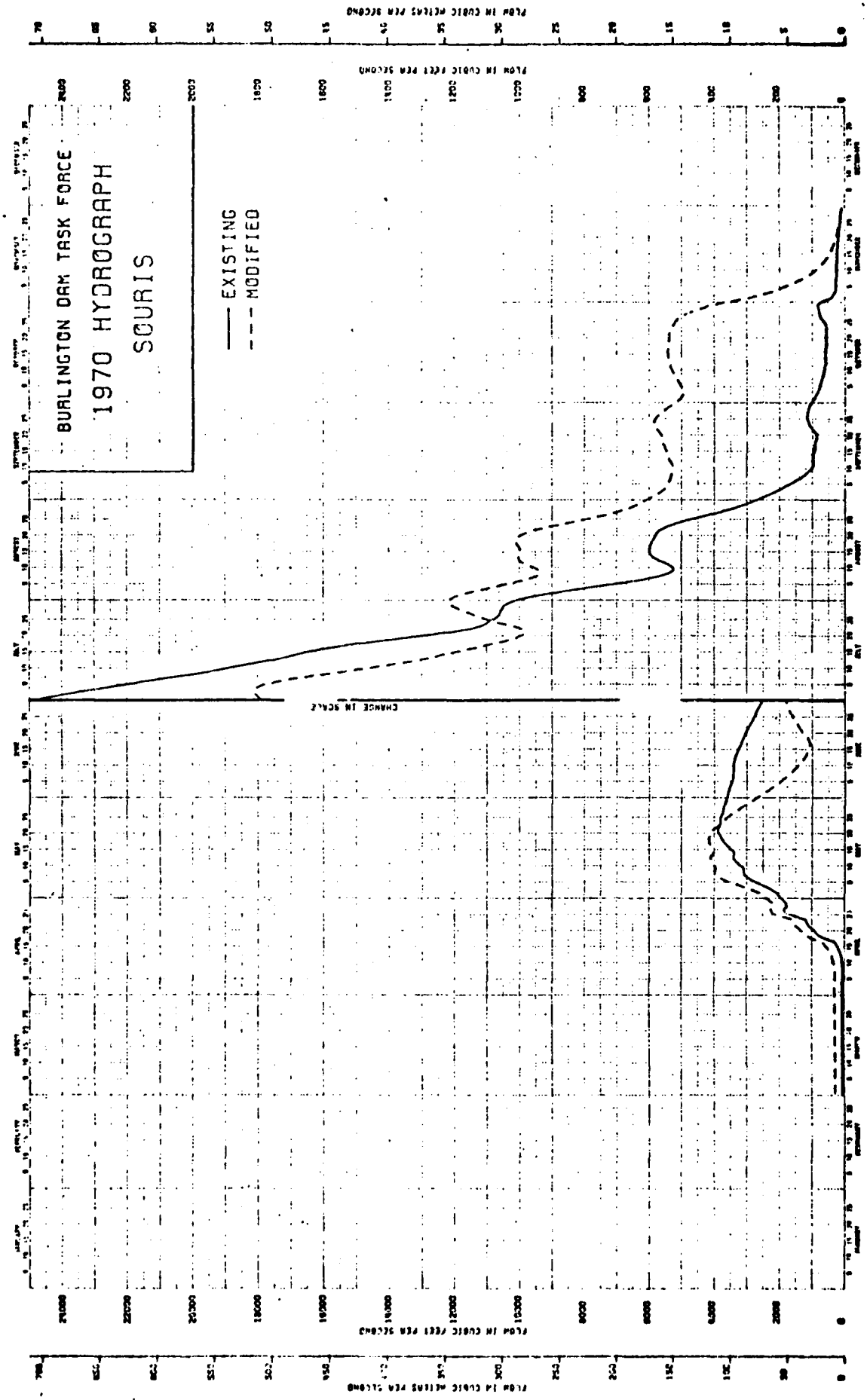

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
WESTHOPE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

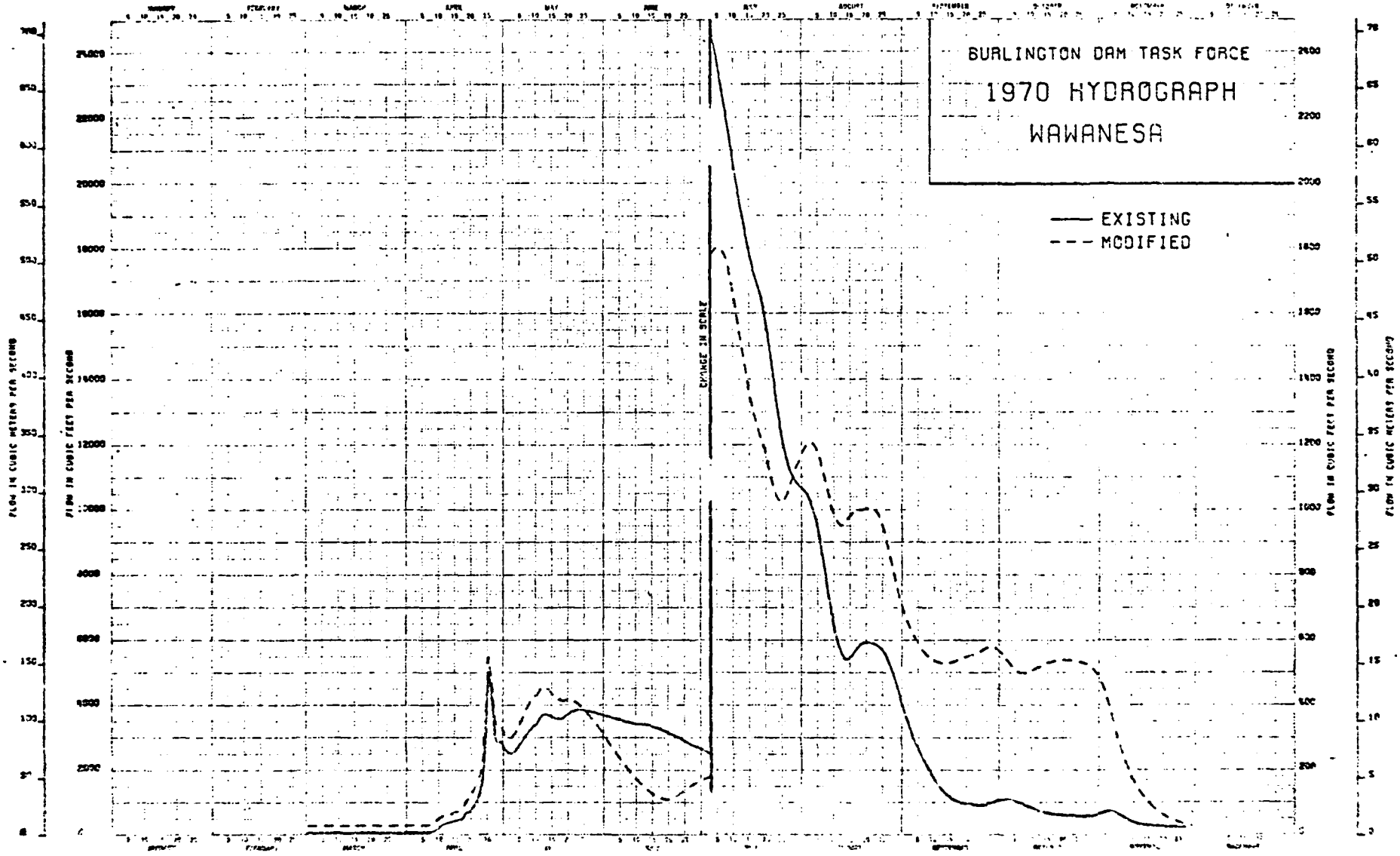

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
PENINSULA BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
HIGHWAY #3 BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

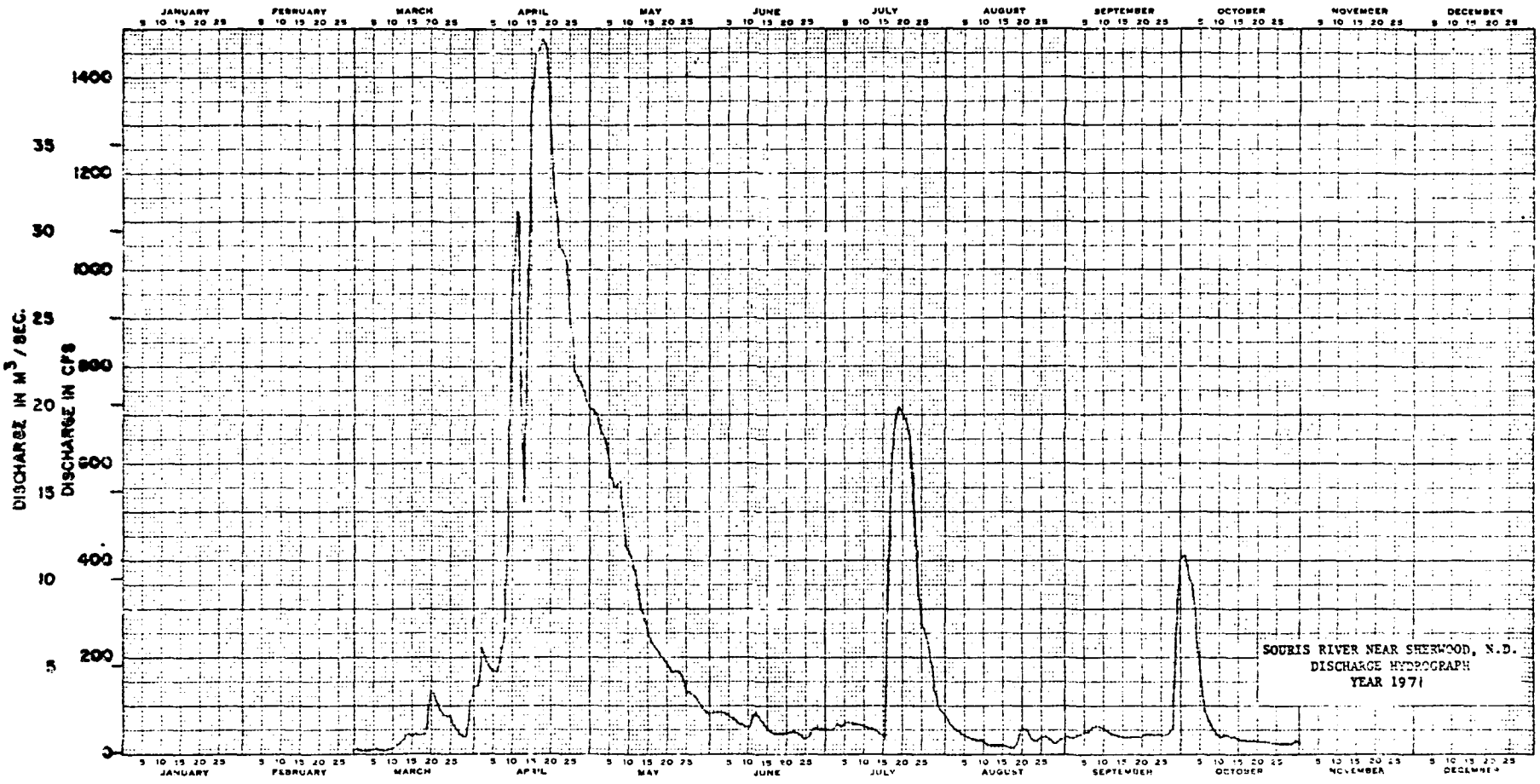

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
LAUDER BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

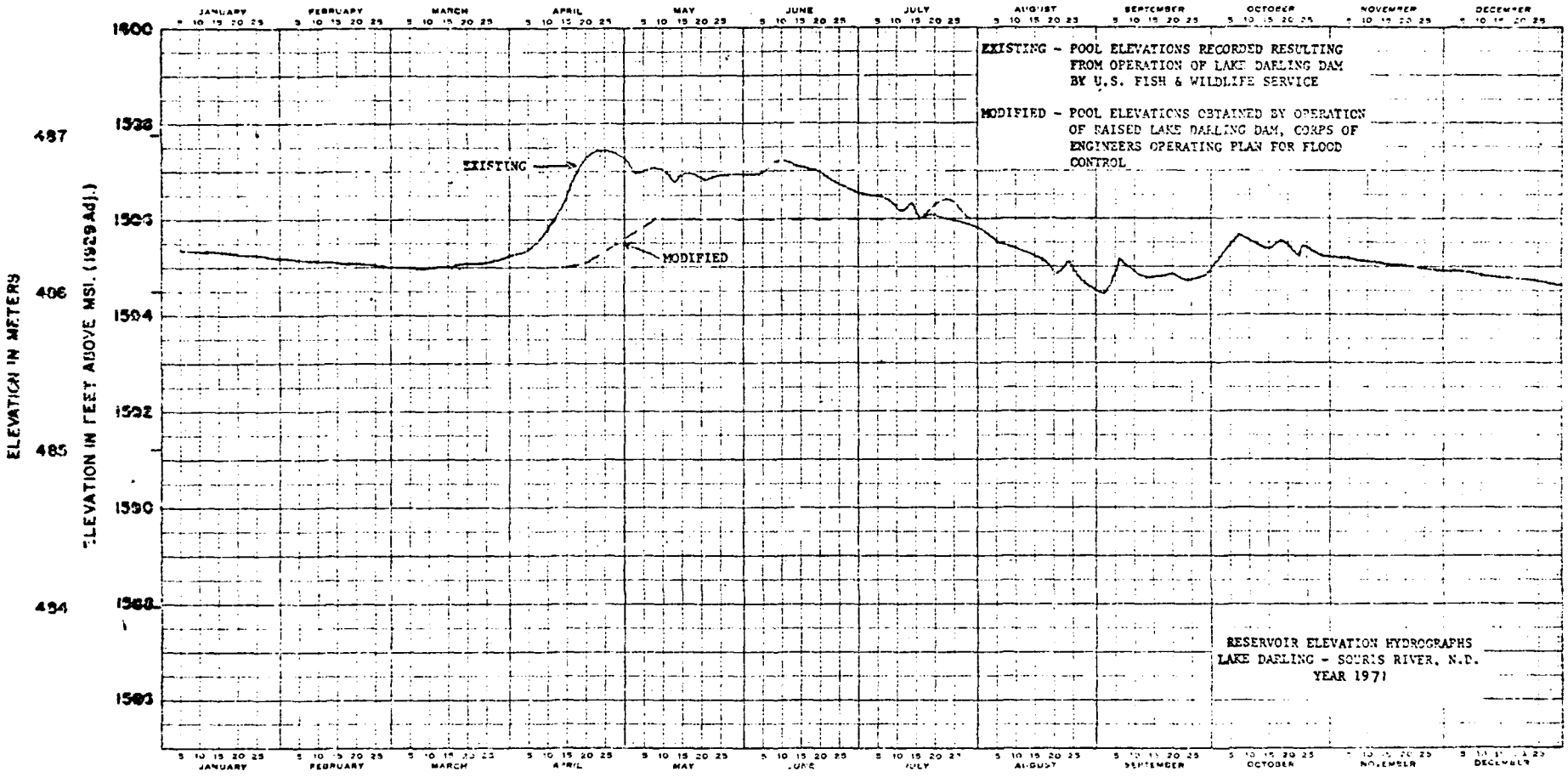

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
HARTNEY BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

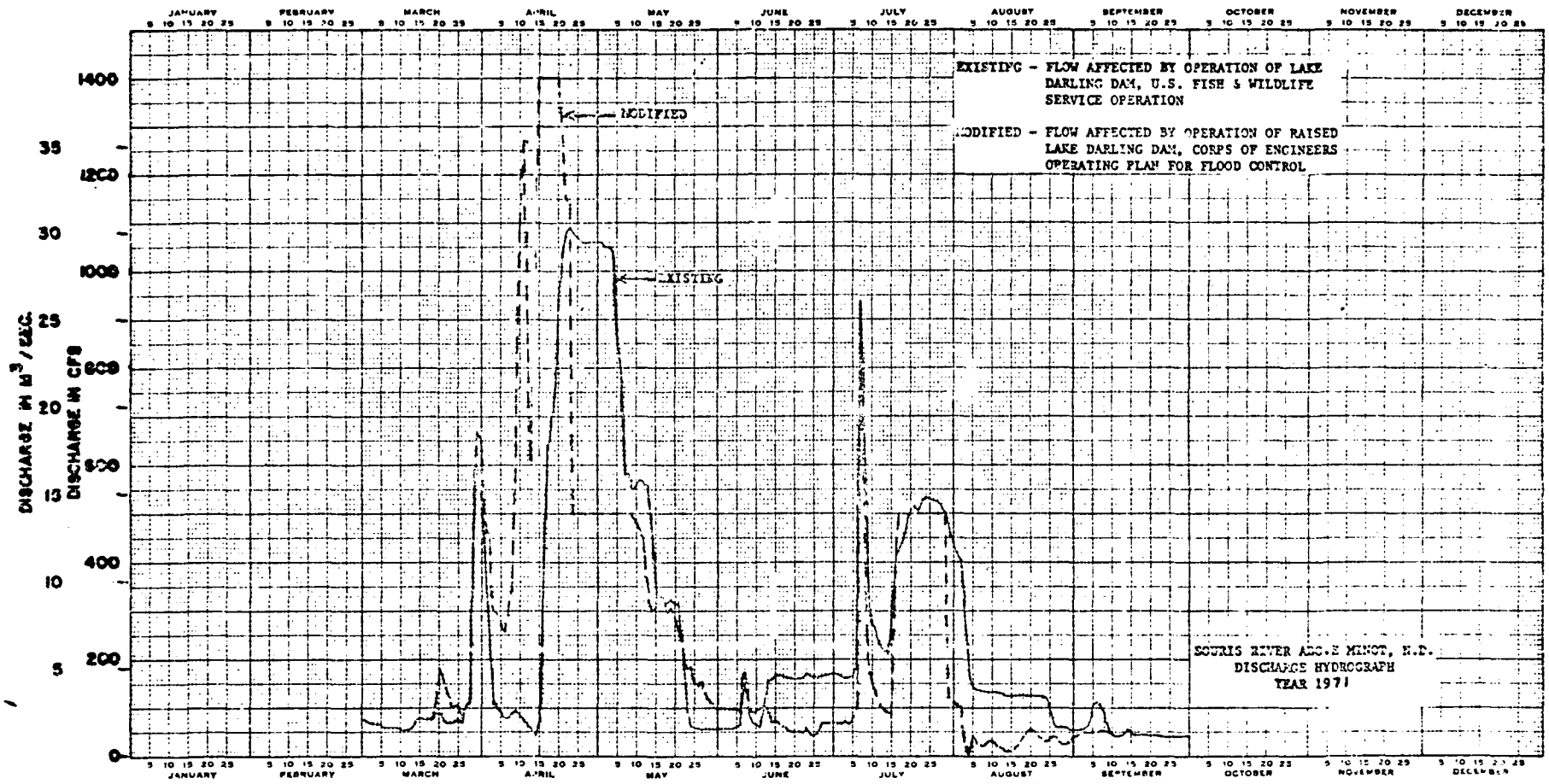

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
SOURIS
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

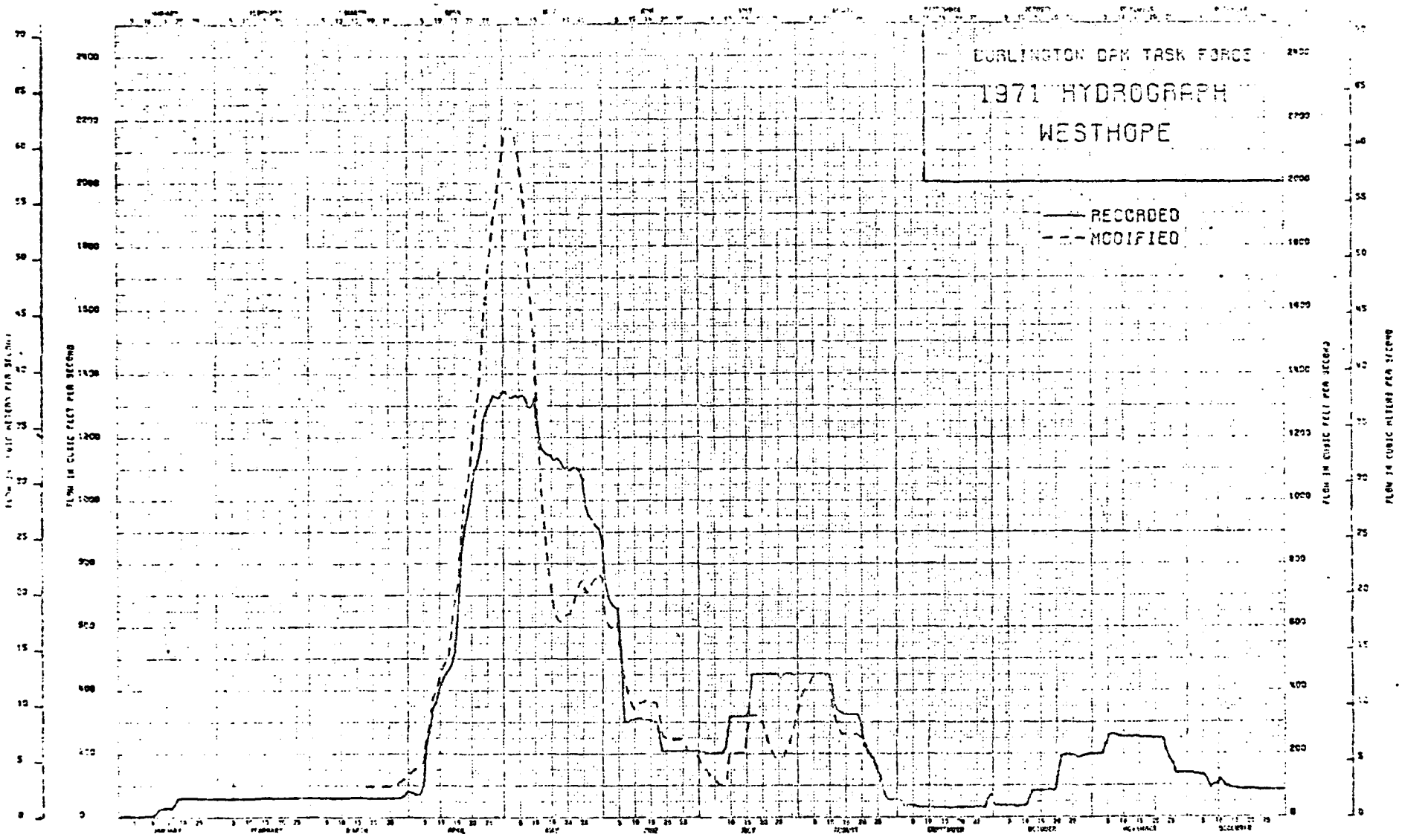

BURLINGTON DAM TASK FORCE
1970 HYDROGRAPH
WAWANESA
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

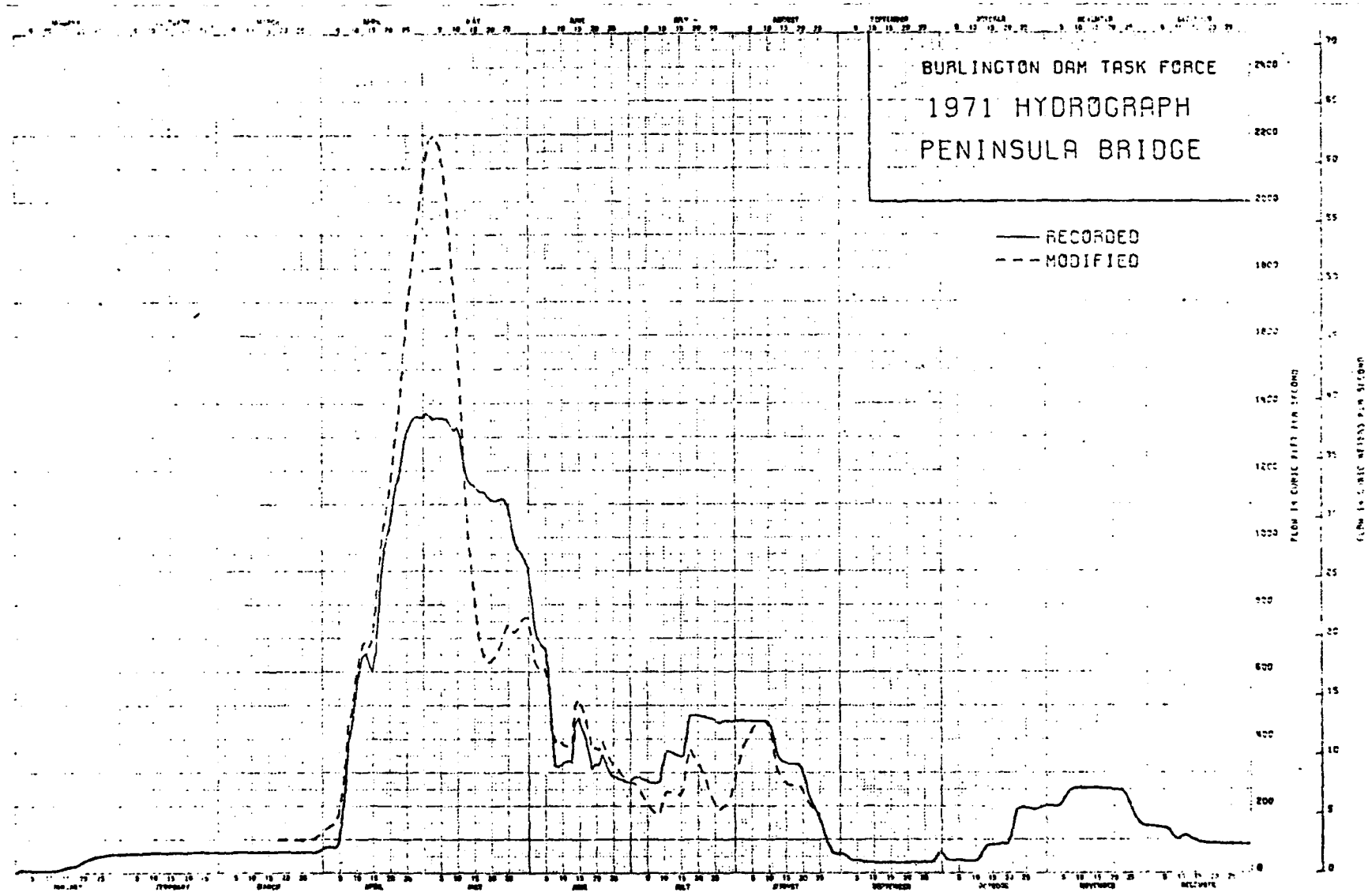
1971

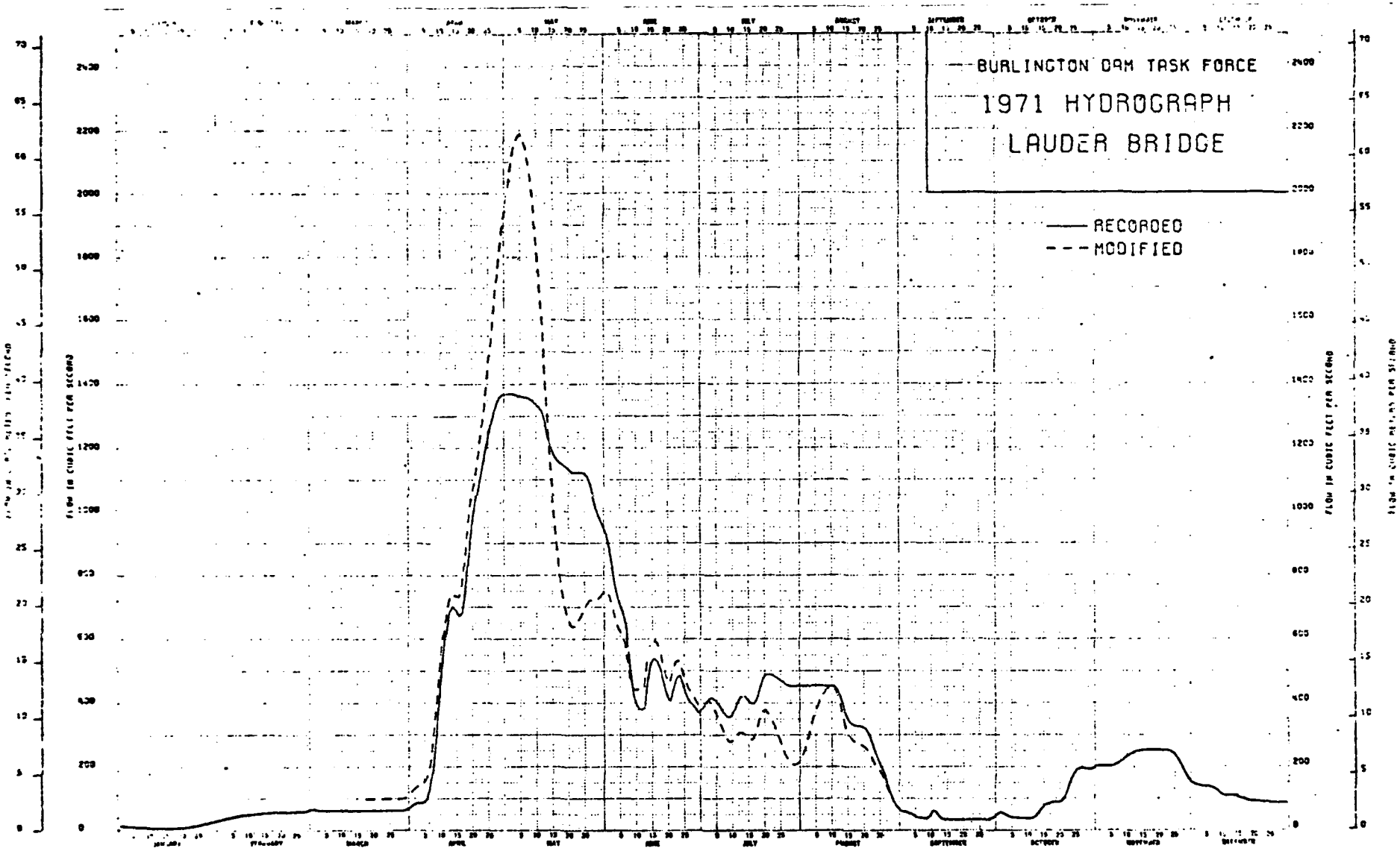

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
0
5
10
15
20
25
30
35
200
400
600
800
1000
1200
1400
SOURIS RIVER NEAR SHERWOOD, N.D.
DISCHARGE HYDROGRAPH
YEAR 1971

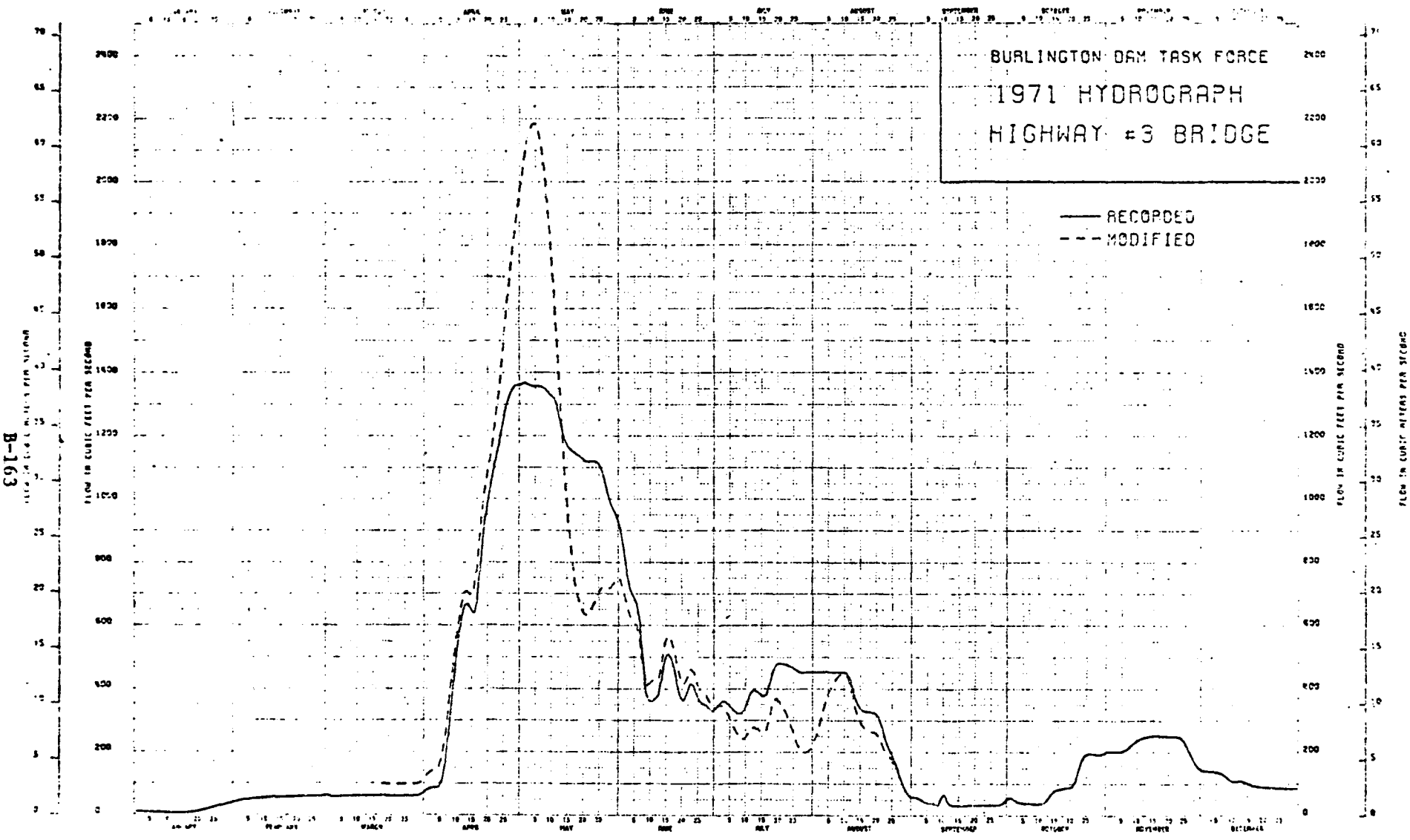

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH & WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
ELEVATION IN FEET ABOVE MSL (1929 Adj.)
ELEVATION IN METERS
1600
1598
1596
1594
1592
1590
1588
1586
487
486
485
484
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
RESERVOIR ELEVATION HYDROGRAPHS
LAKE DARLING - SOURIS RIVER, N.D.
YEAR 1971

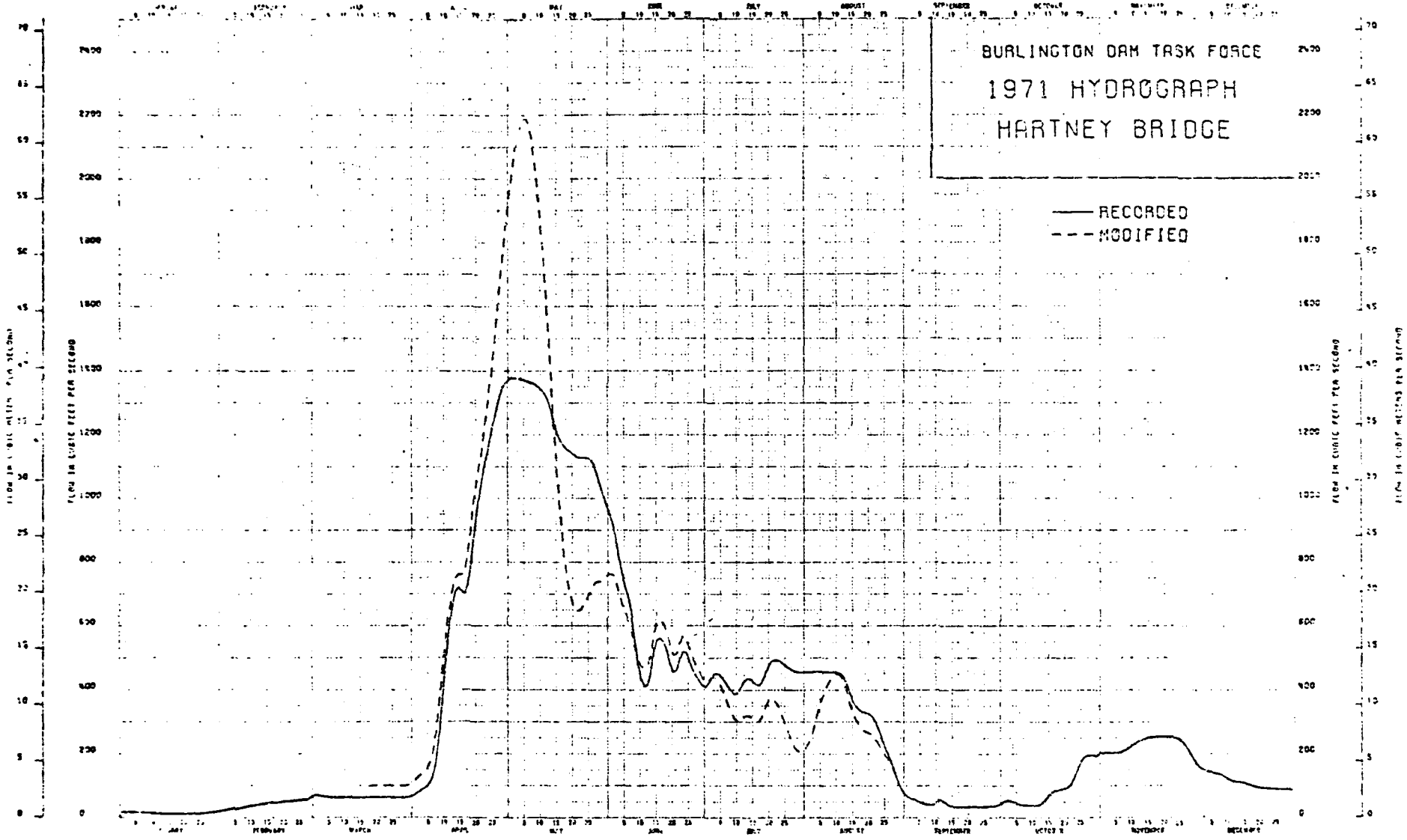

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
0
5
10
15
20
25
30
35
200
400
600
800
1000
1200
1400
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
SOURIS RIVER ABOVE MINOT, N.D.
DISCHARGE HYDROGRAPH
YEAR 1971

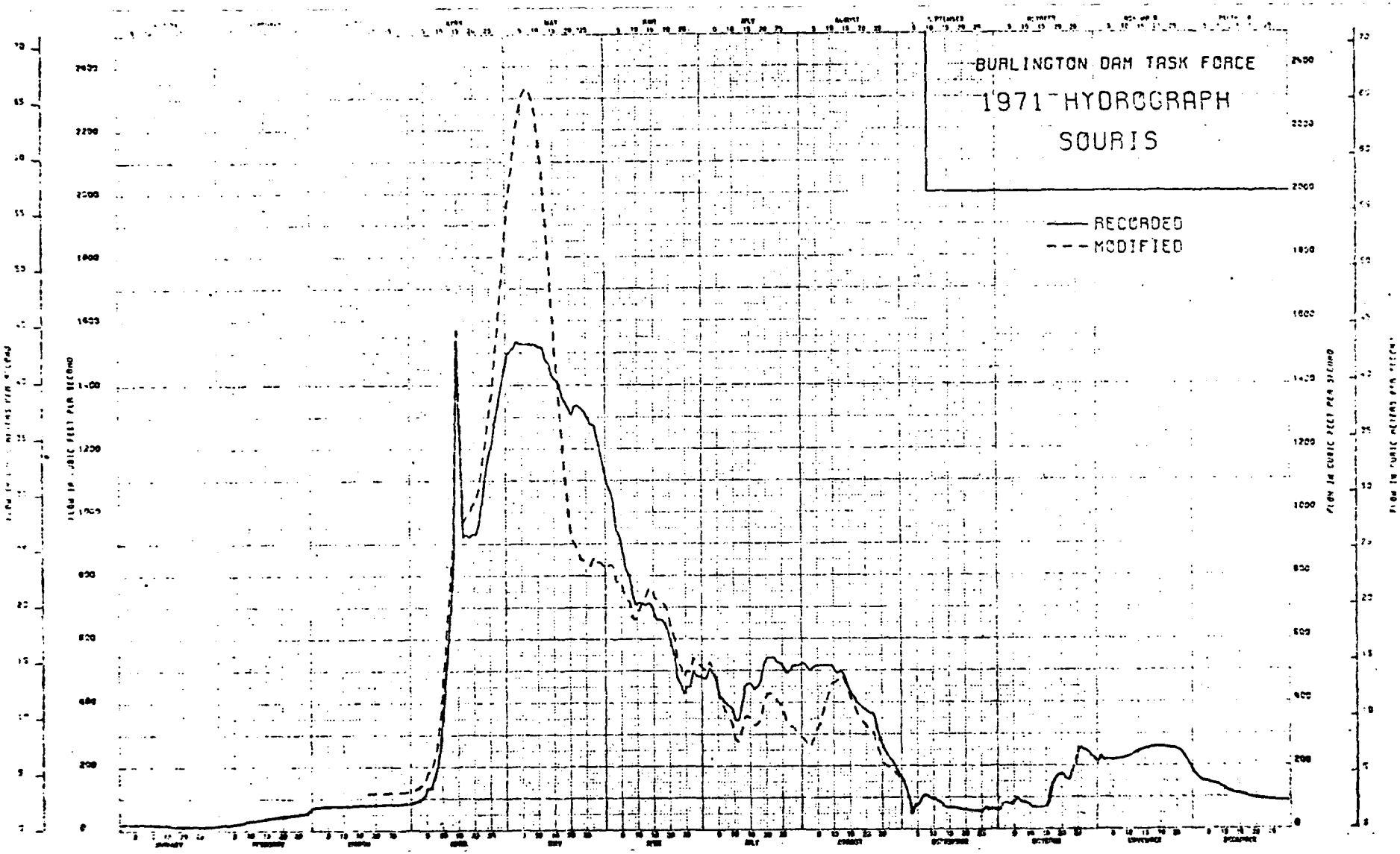

BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED

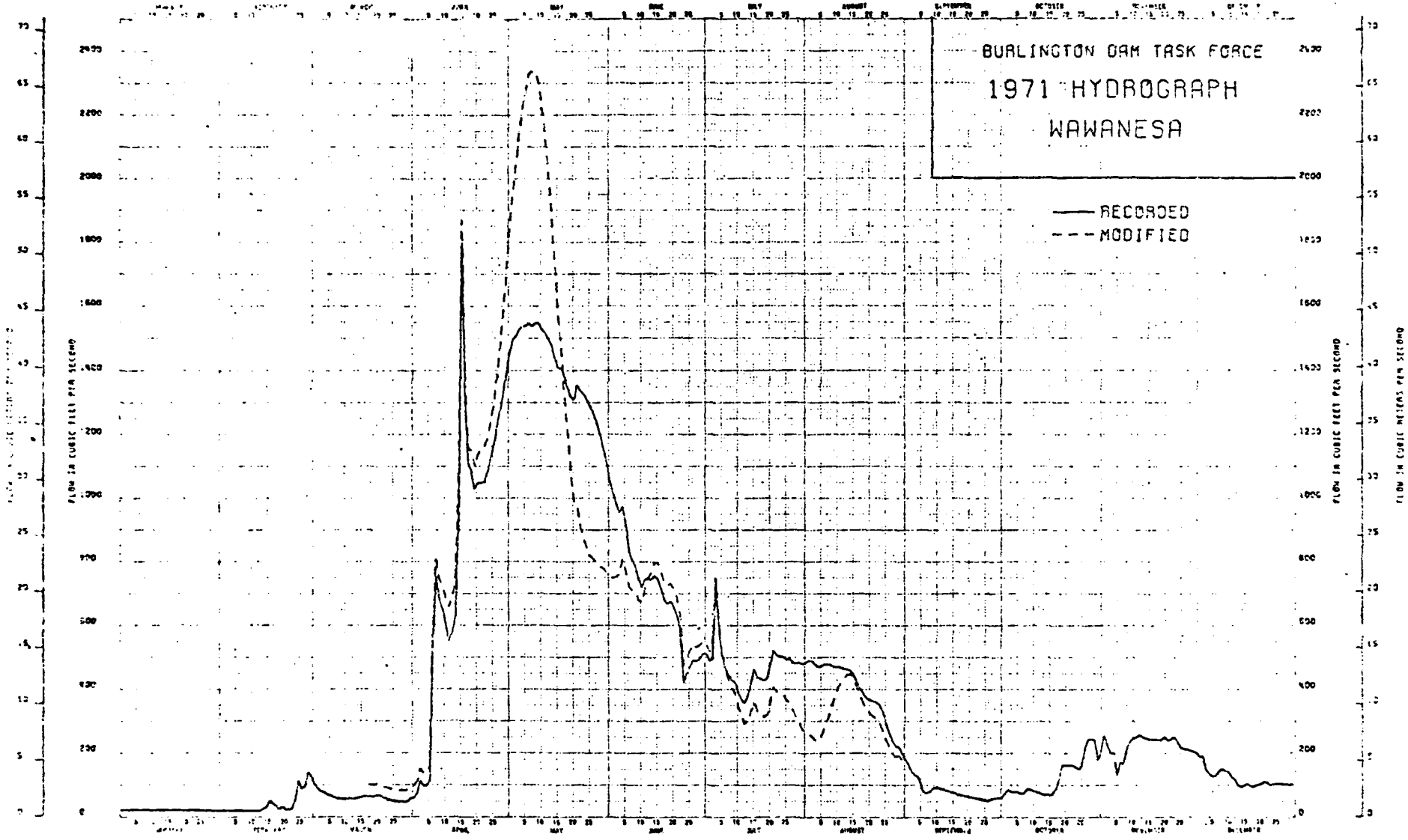

BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED

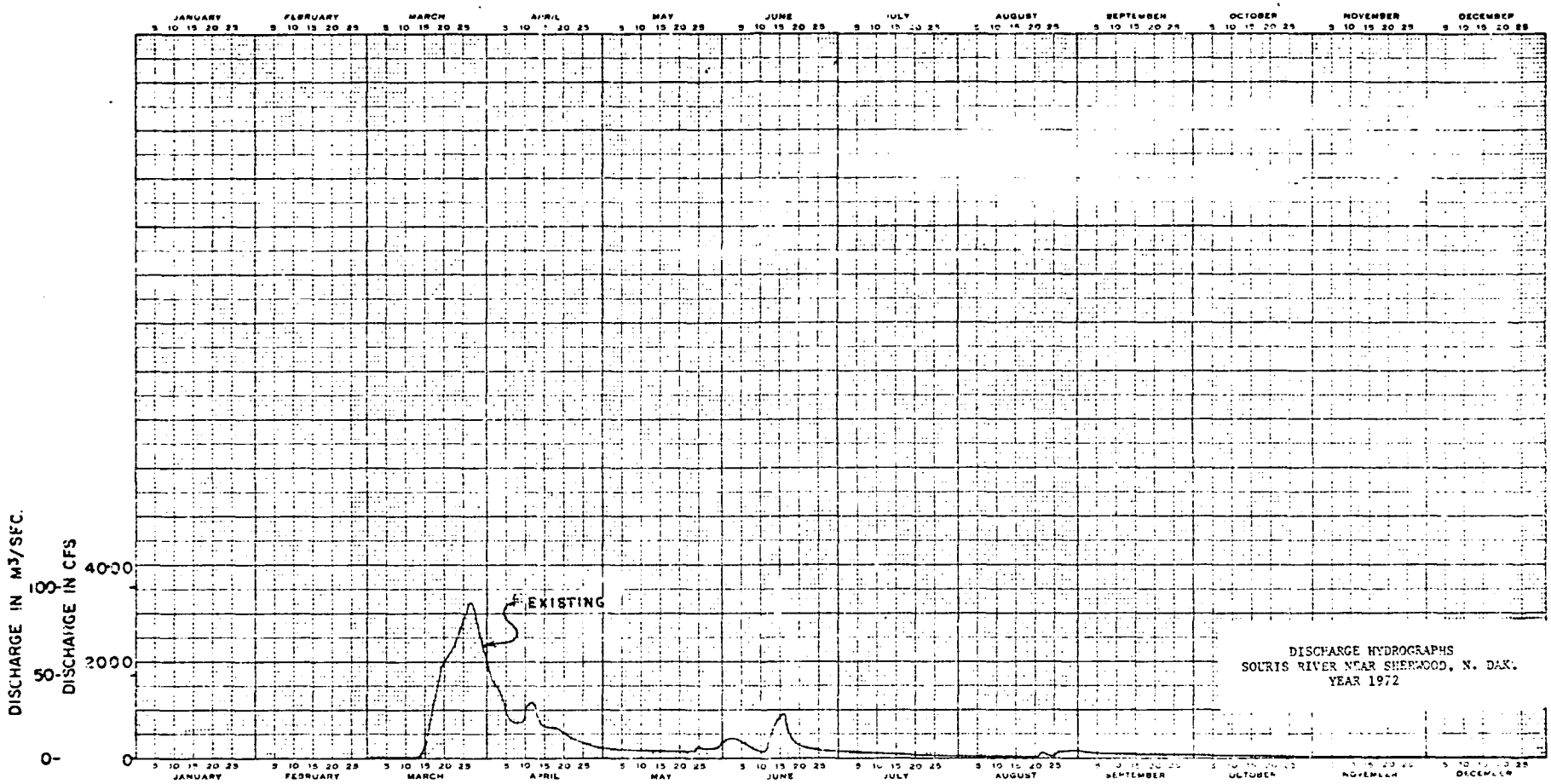

BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED

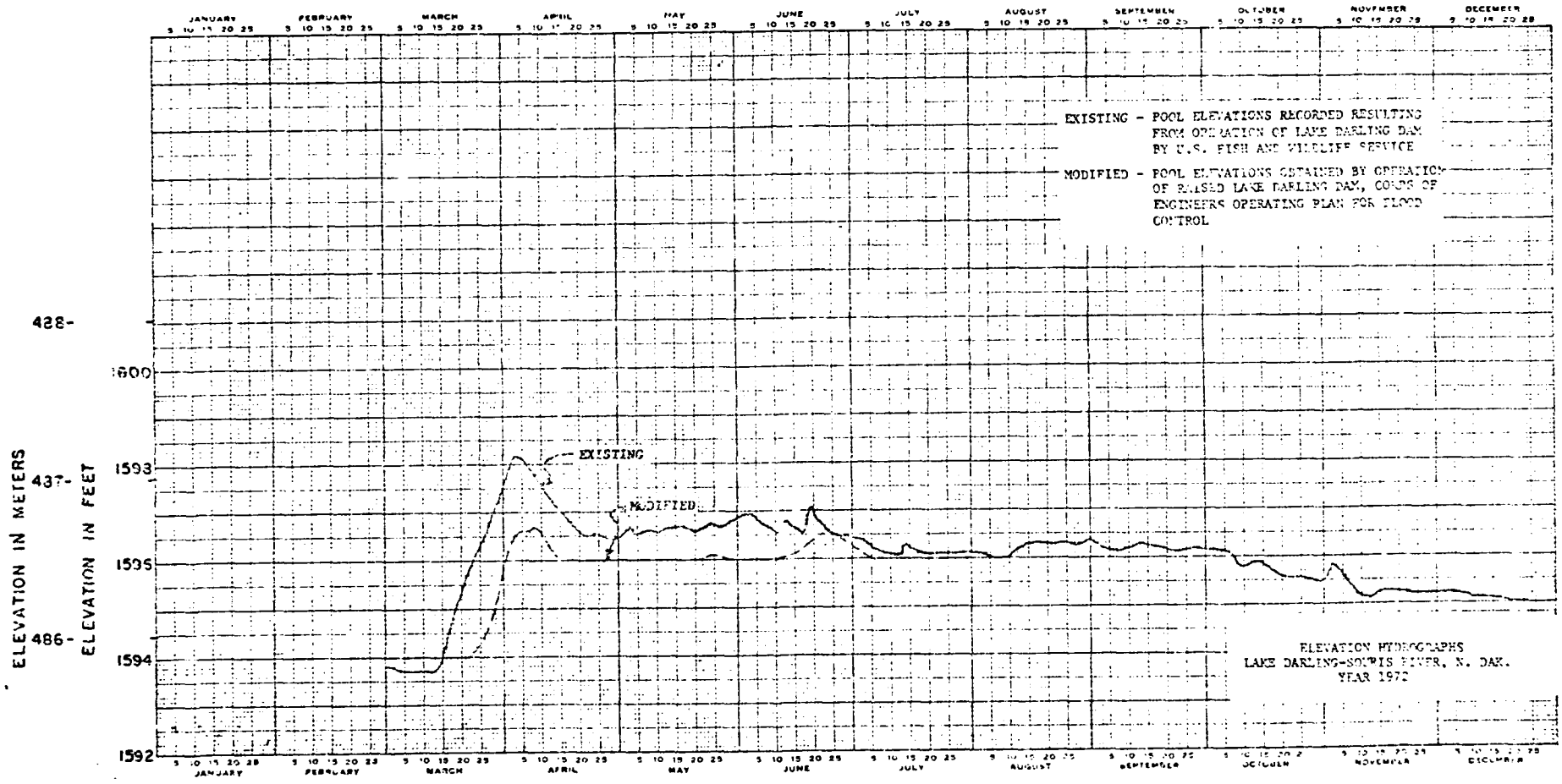

BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED


BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
SOURIS
RECORDED
MODIFIED

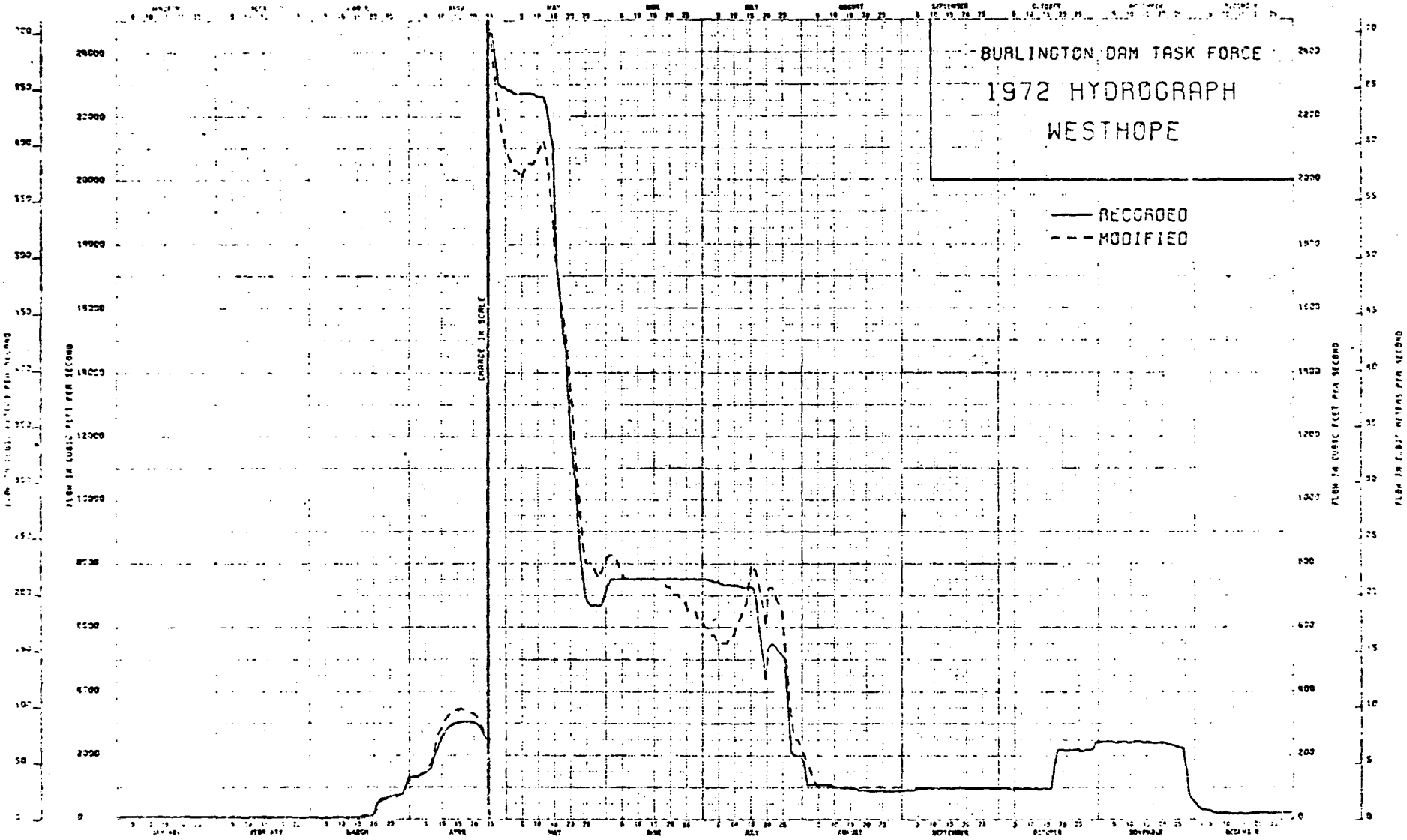

BURLINGTON DAM TASK FORCE
1971 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

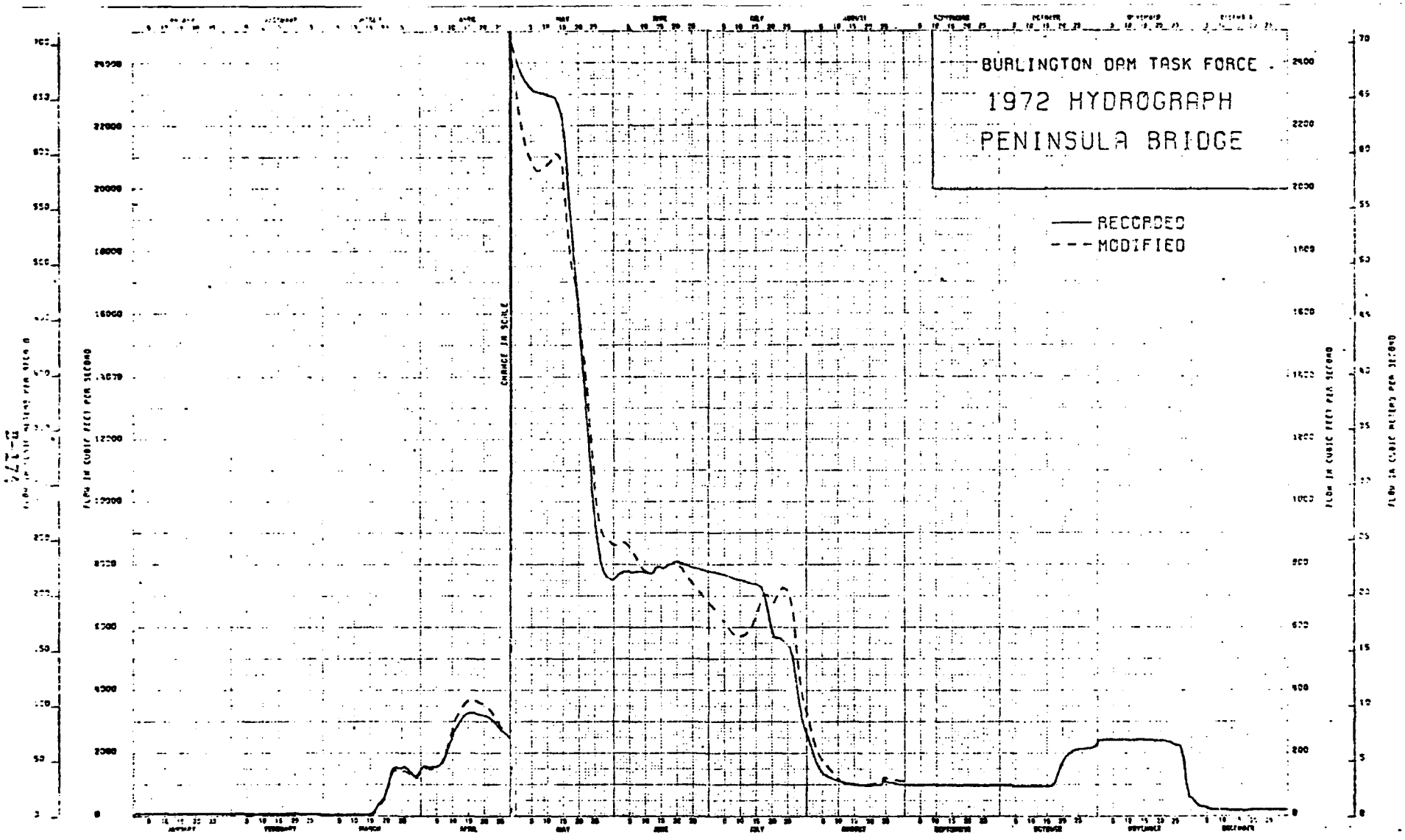
1972

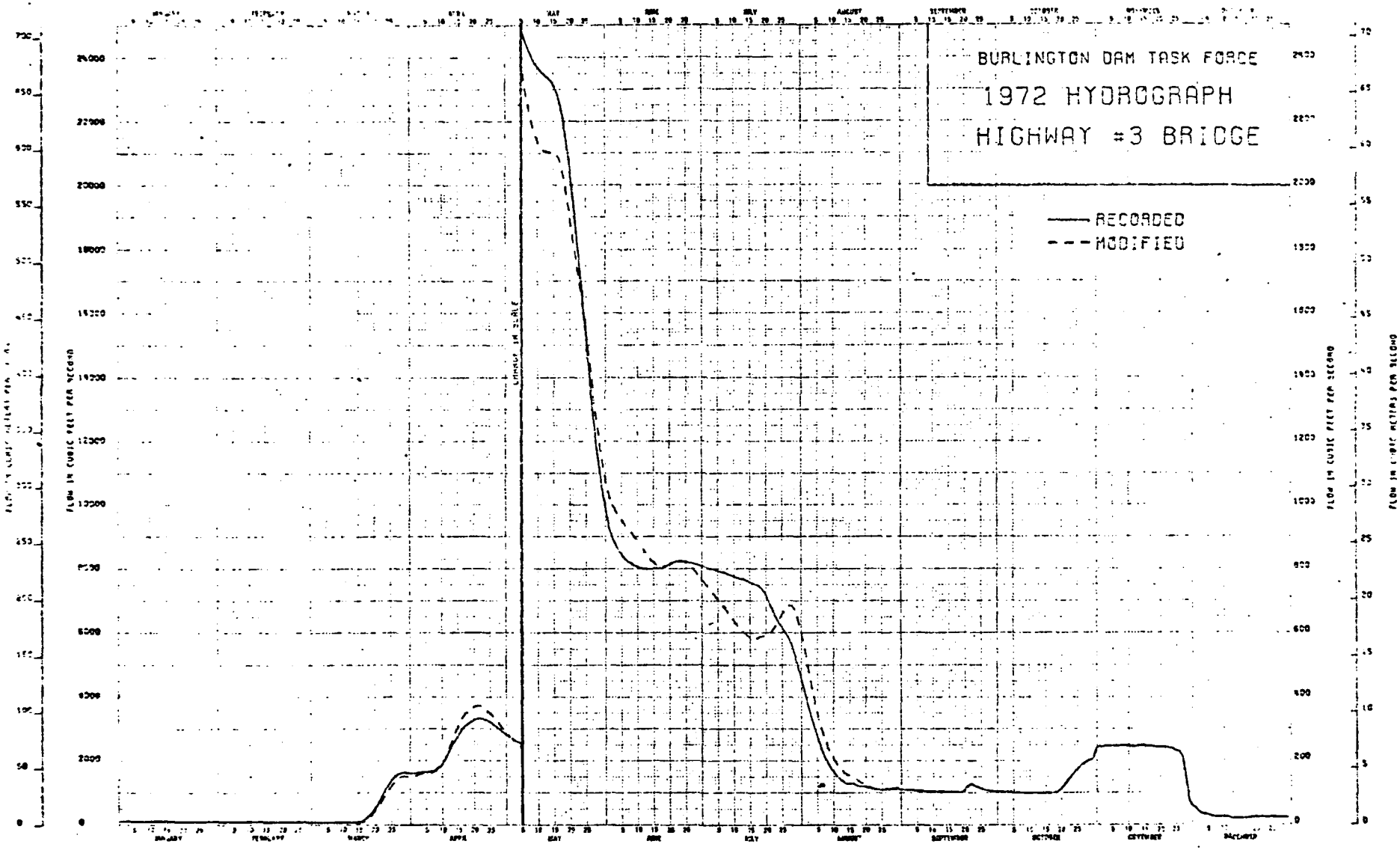

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M3/SEC.
DISCHARGE IN CFS
100
50
0
4000
2000
0
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1972

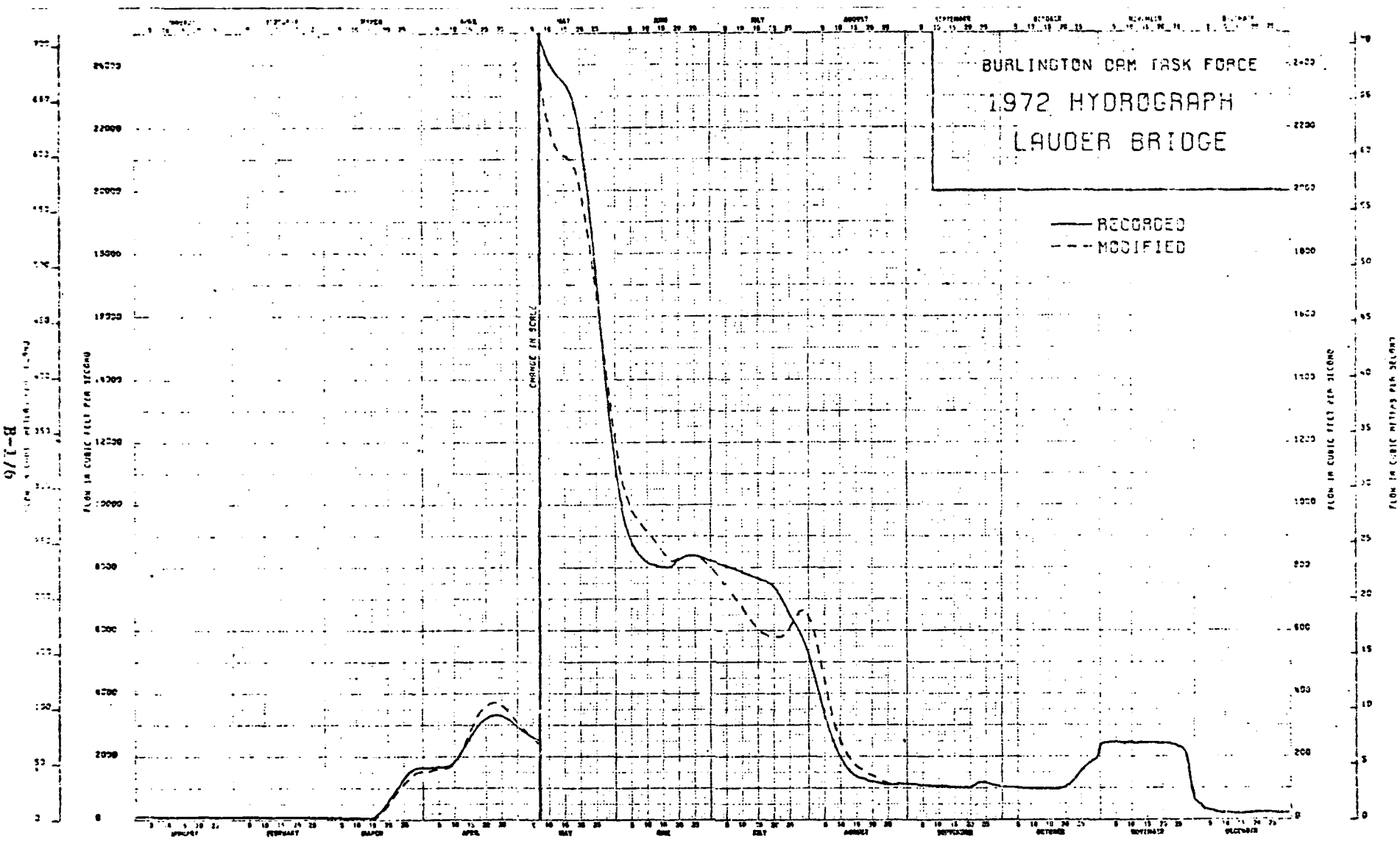

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1972
ELEVATION IN METERS
ELEVATION IN FEET
428
437
486
1600
1593
1595
1594
1592
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

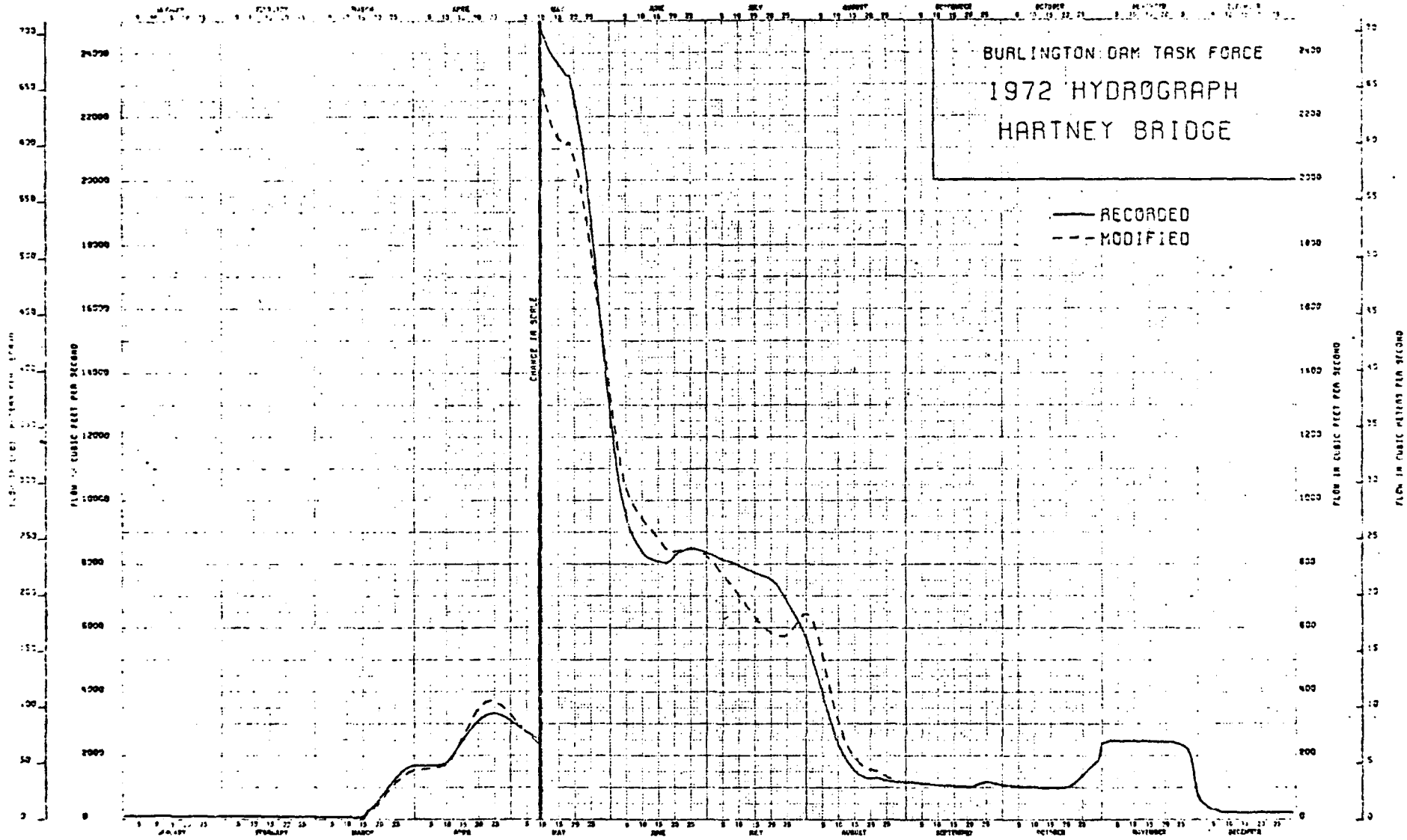
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1972
MODIFIED
EXISTING
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
75
50
25
0
3000
2000
1000
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

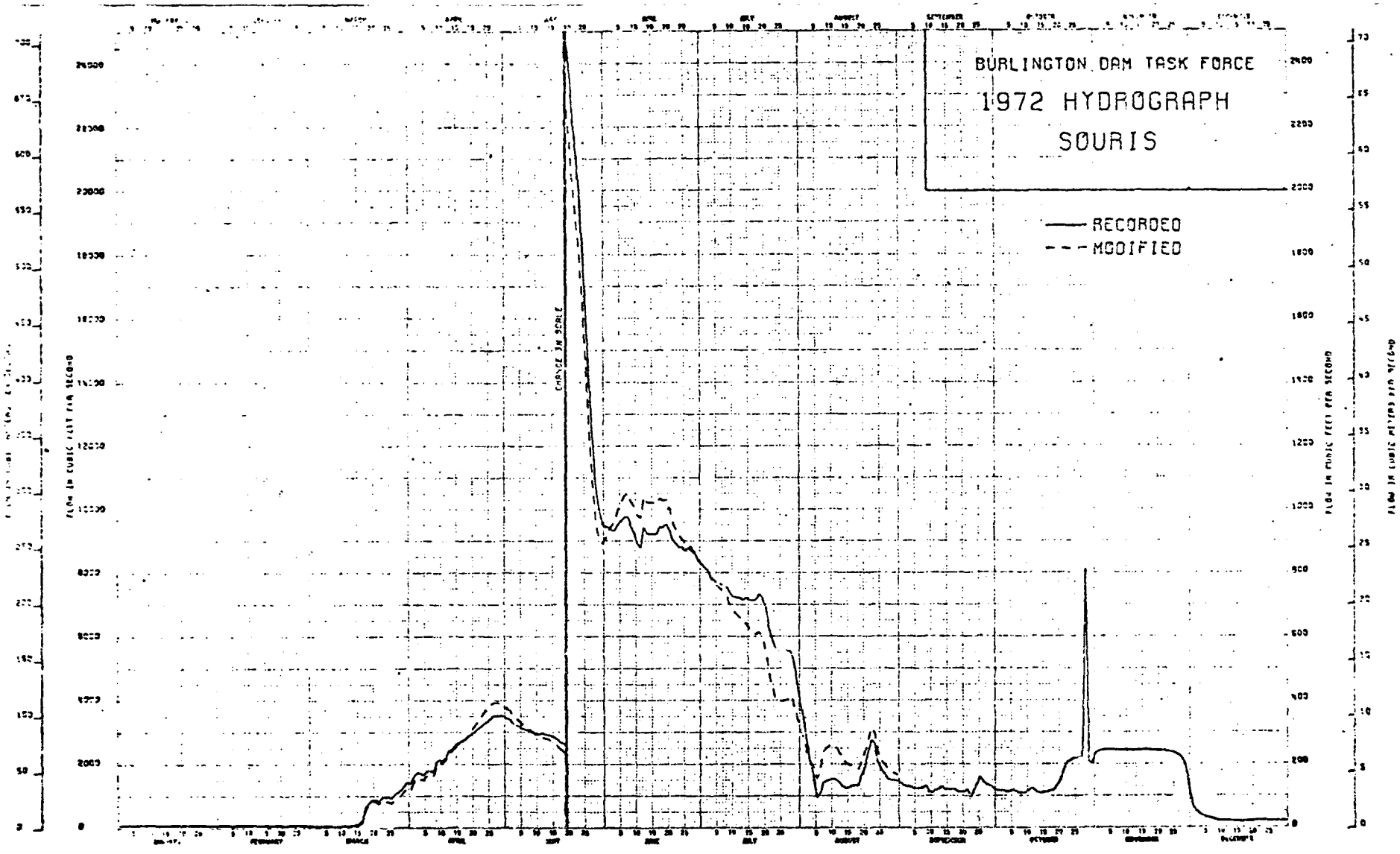

BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE

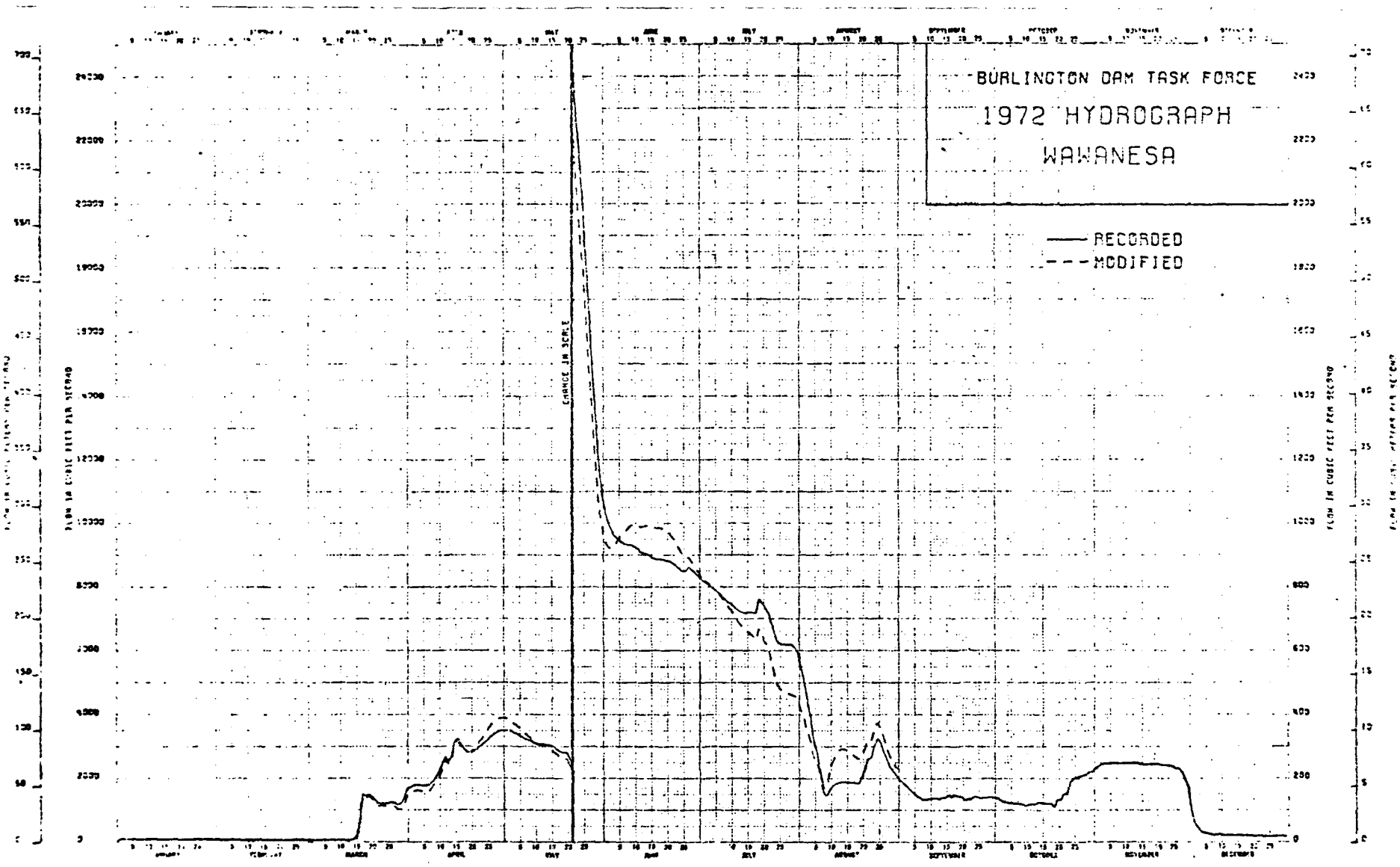

BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND


BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

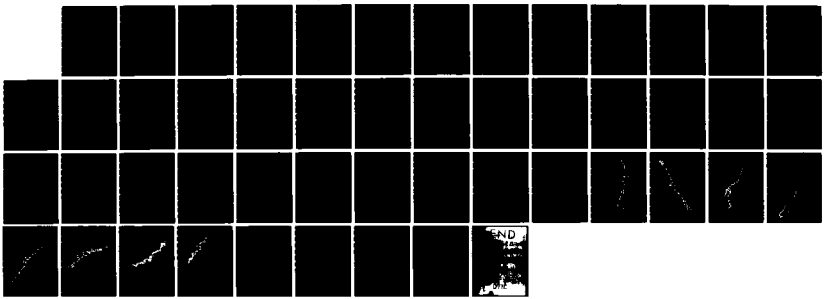

BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

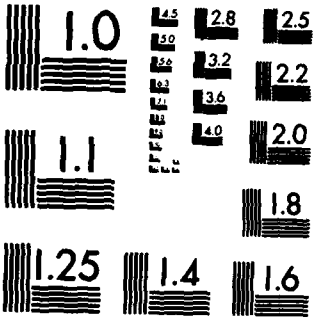

BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1972 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE

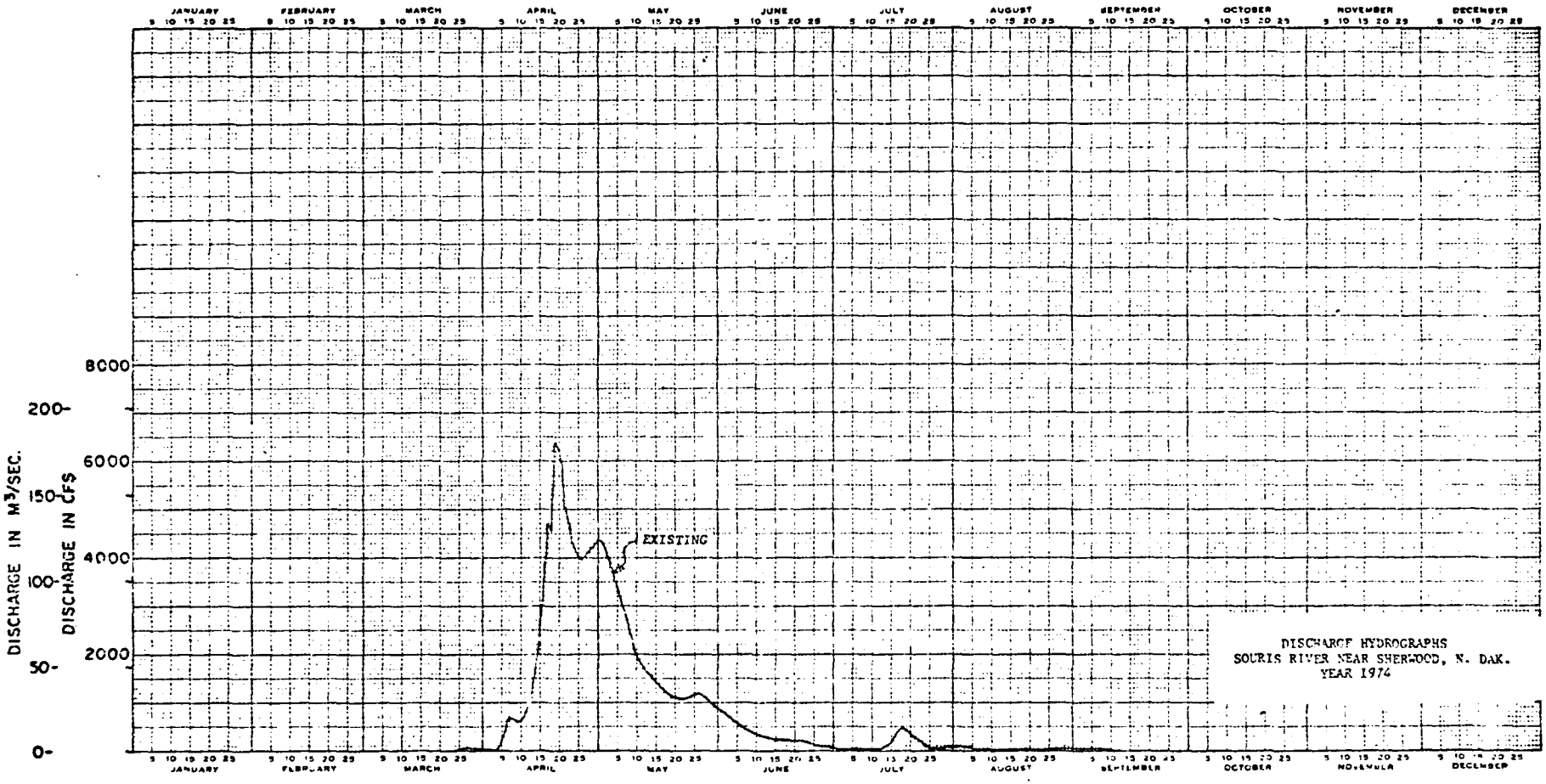
AD-A146 947 SOURIS RIVER BASIN SASKATCHEWAN NORTH DAKOTA AND MANITOBA REVIEW OF THE E..(U) BURLINGTON DAM TASK FORCE JUN 79 4/4

UNCLASSIFIED F/G 13/2 NL

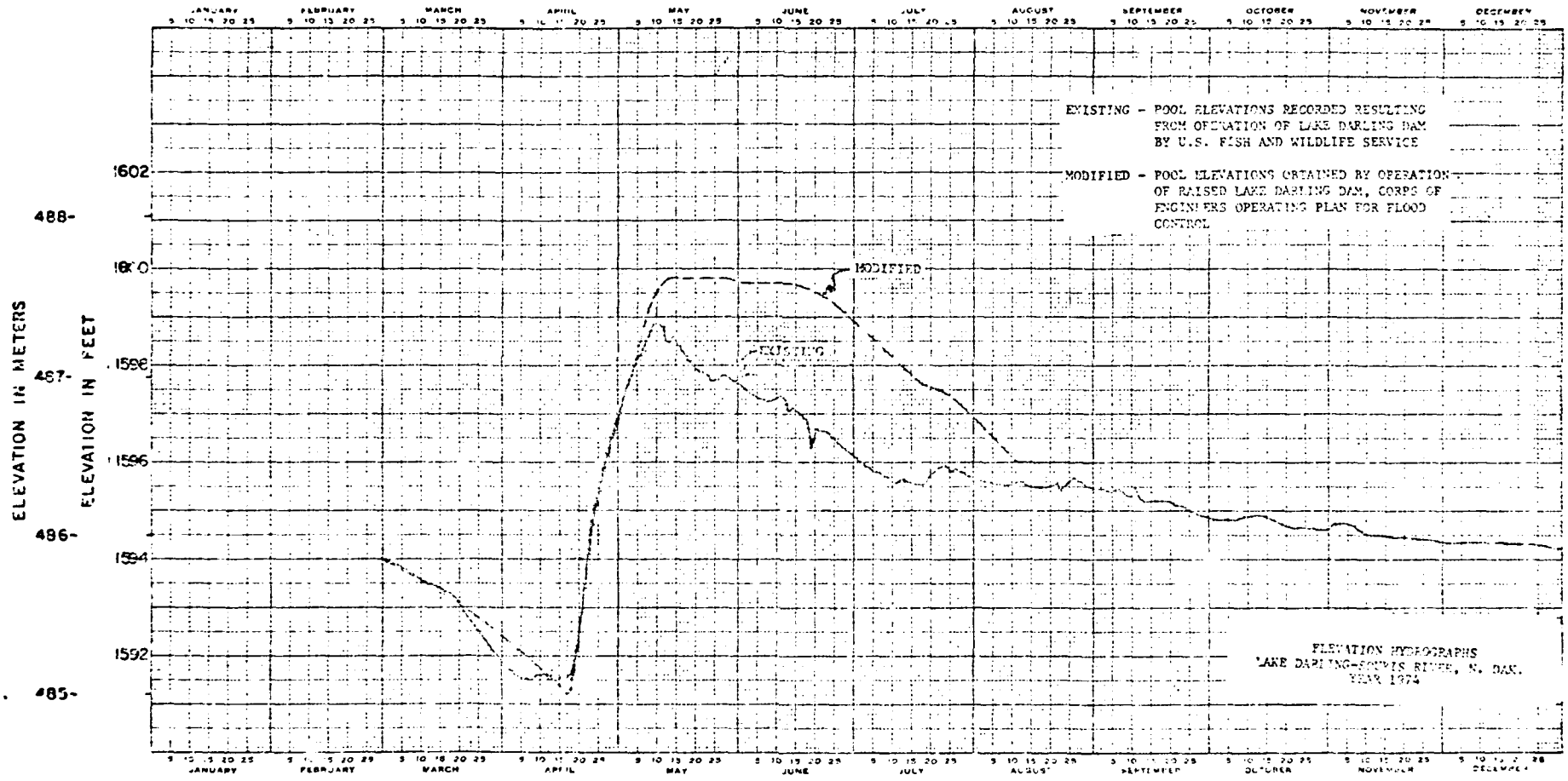


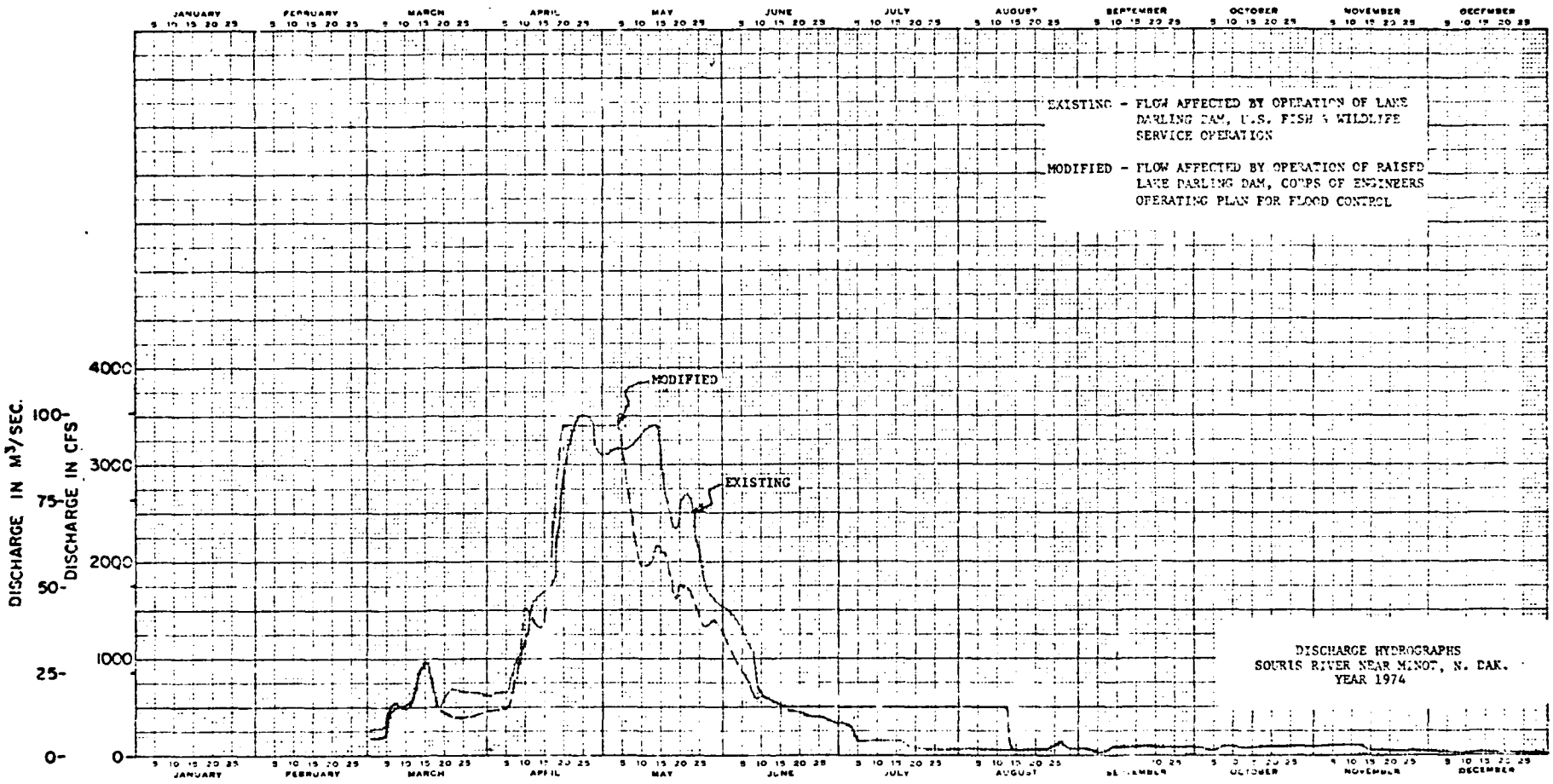

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

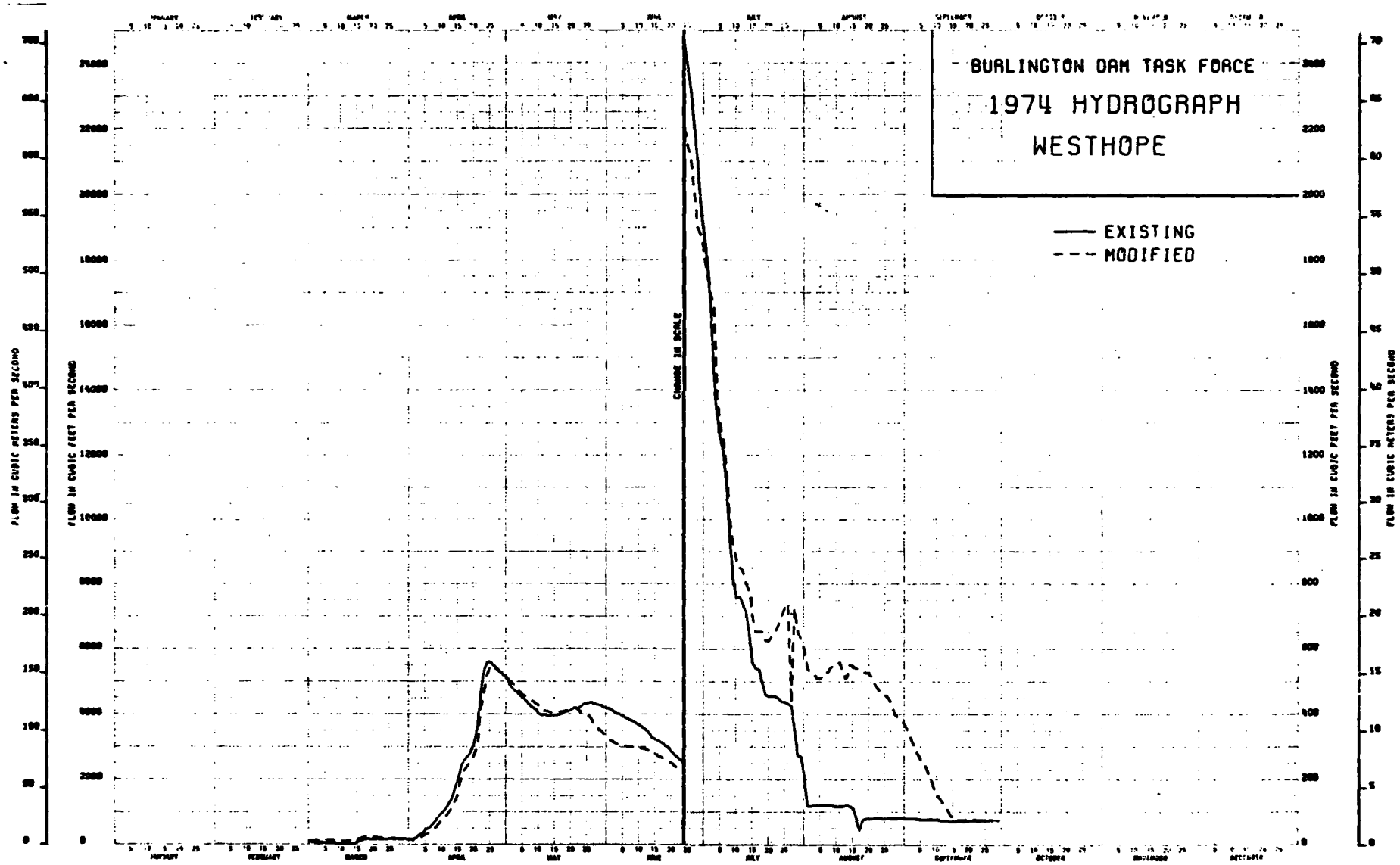
1974

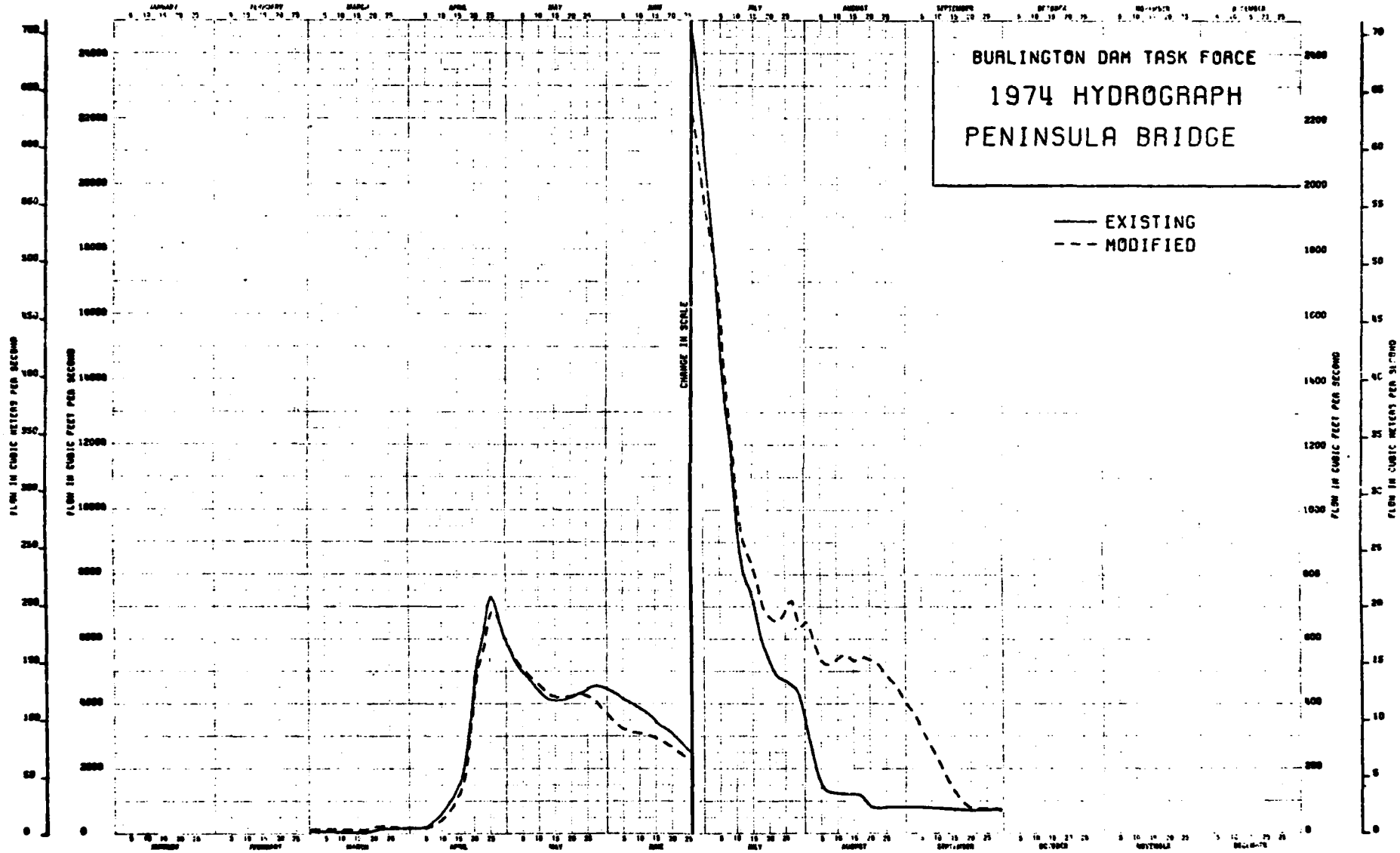


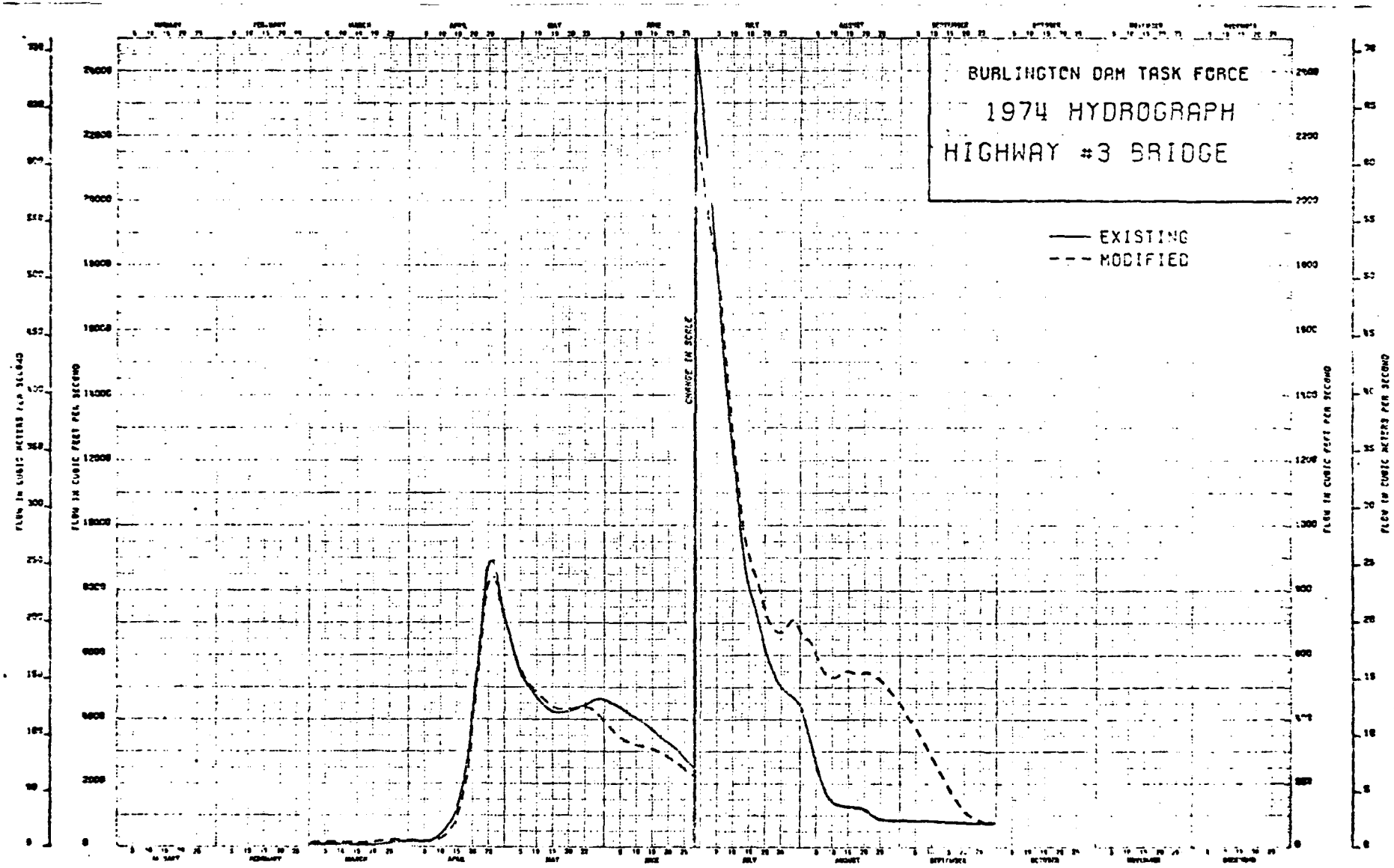
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1974

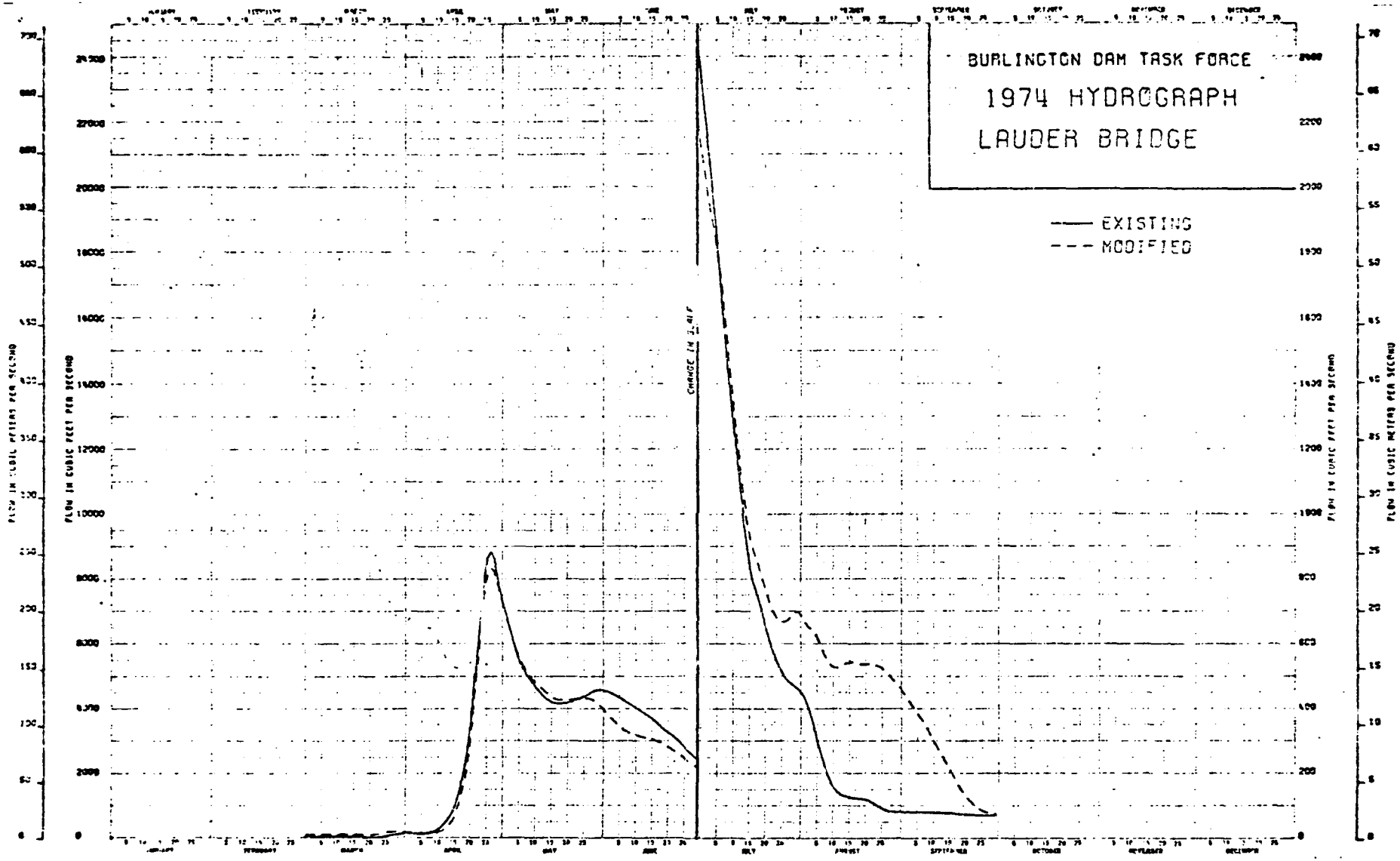

EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
ELEVATION IN METERS
ELEVATION IN FEET
488-
487-
486-
485-
1602
1600
1598
1596
1594
1592
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1974

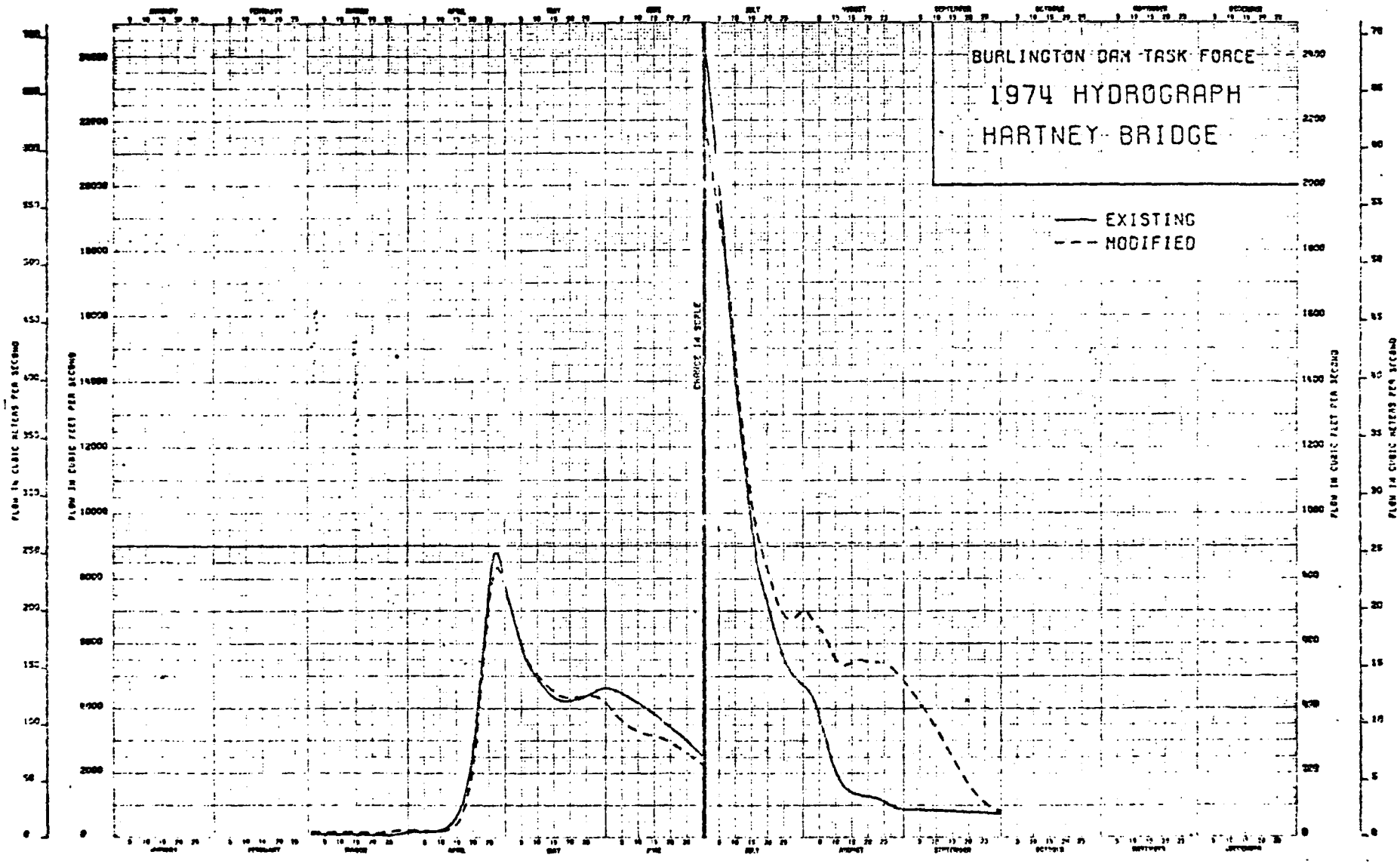

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
4000
3000
2000
1000
0
100
75
50
25
0
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1974

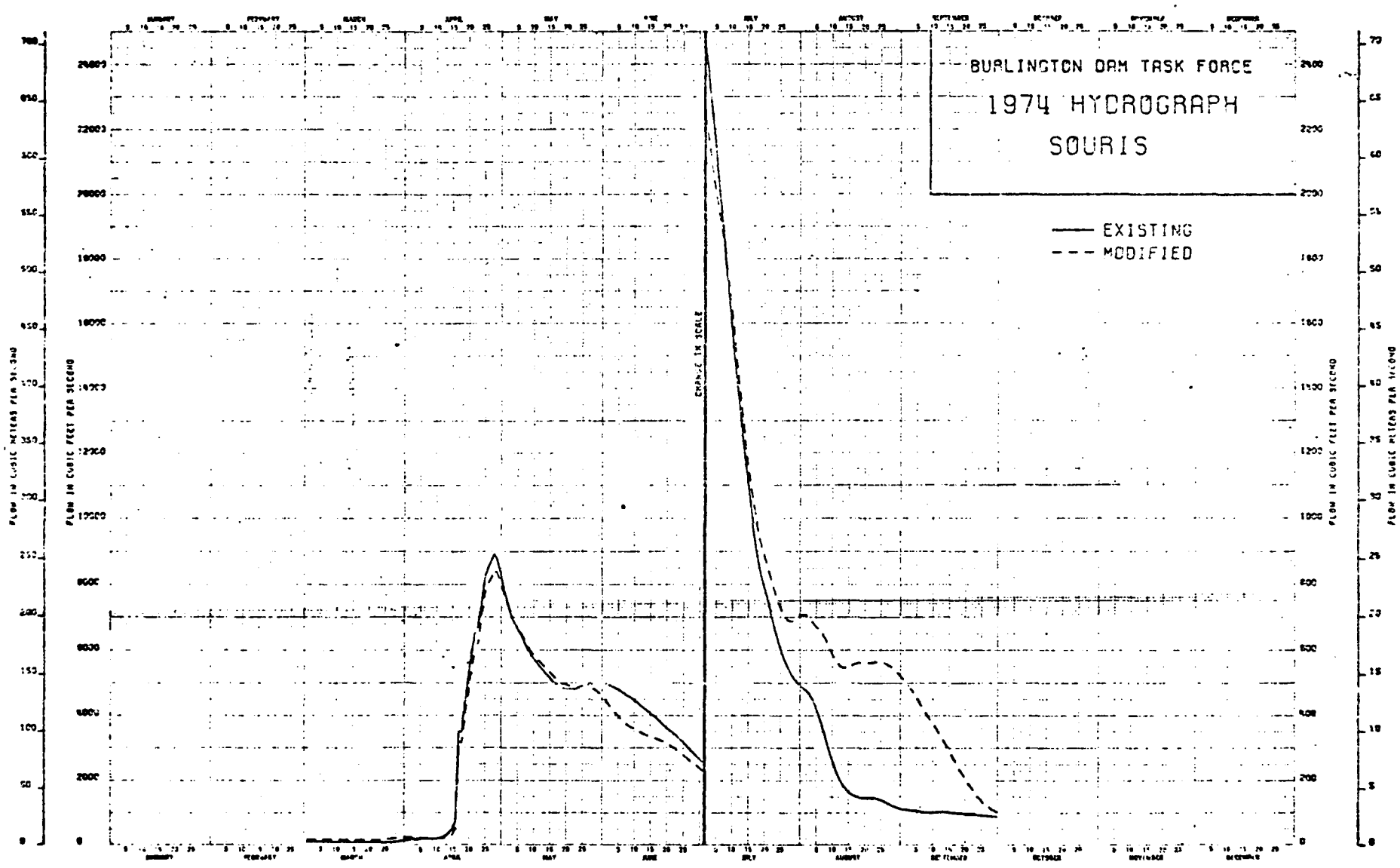

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
WESTHOPE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

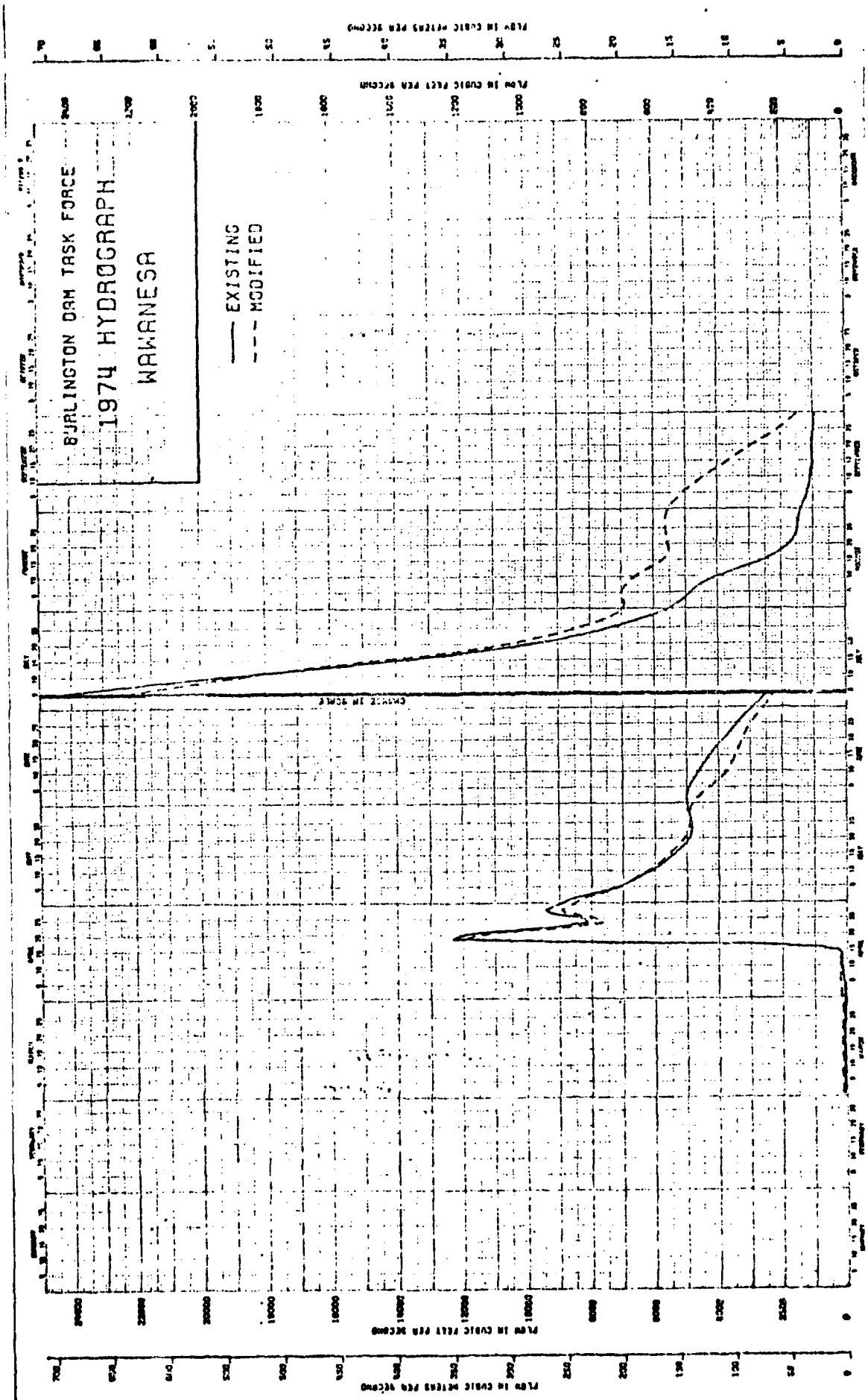

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
PENINSULA BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
HIGHWAY #3 BRIDGE
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

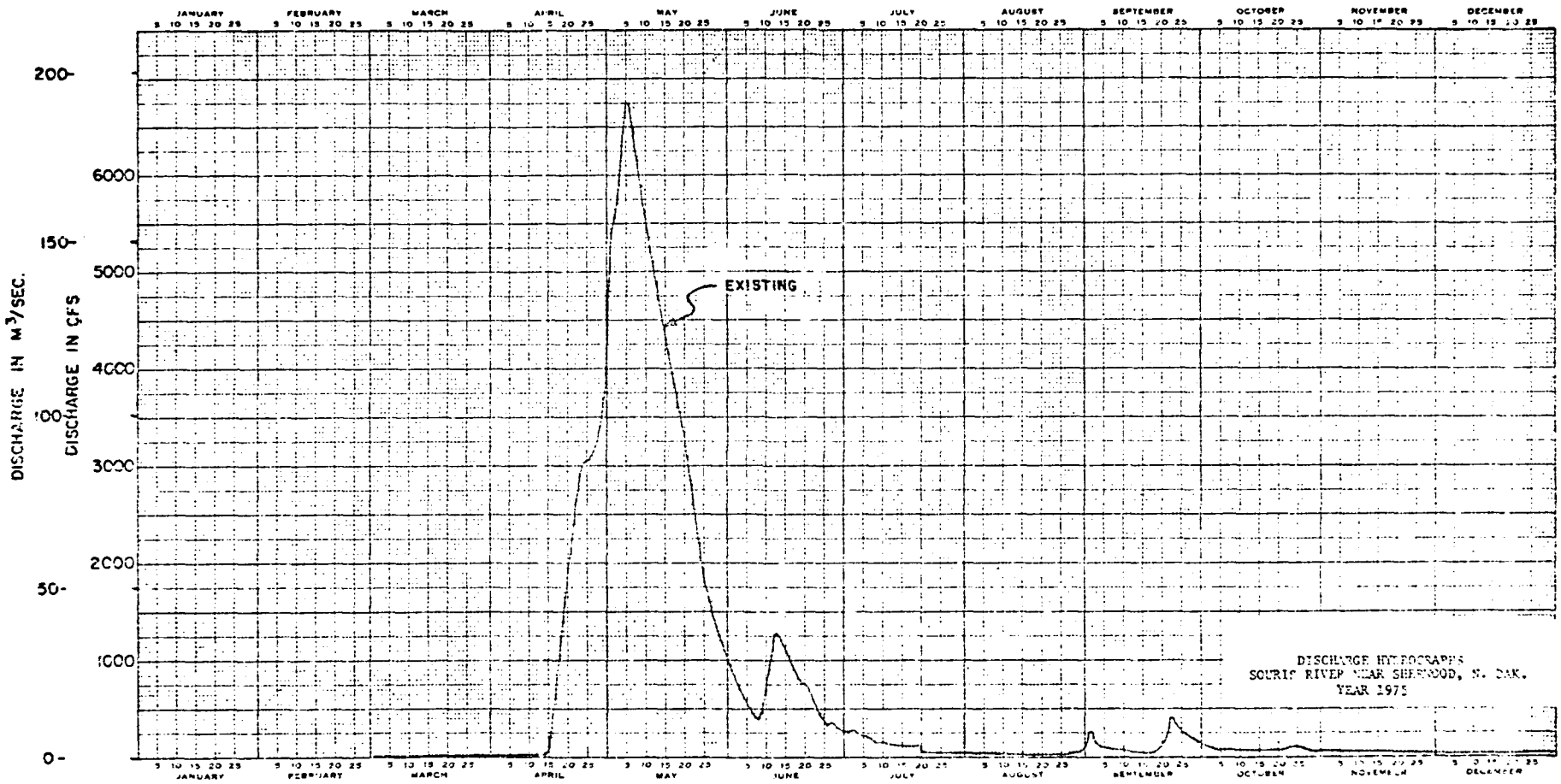

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
LAUDER BRIDGE
EXISTING
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
CHANGE IN 3.41 F

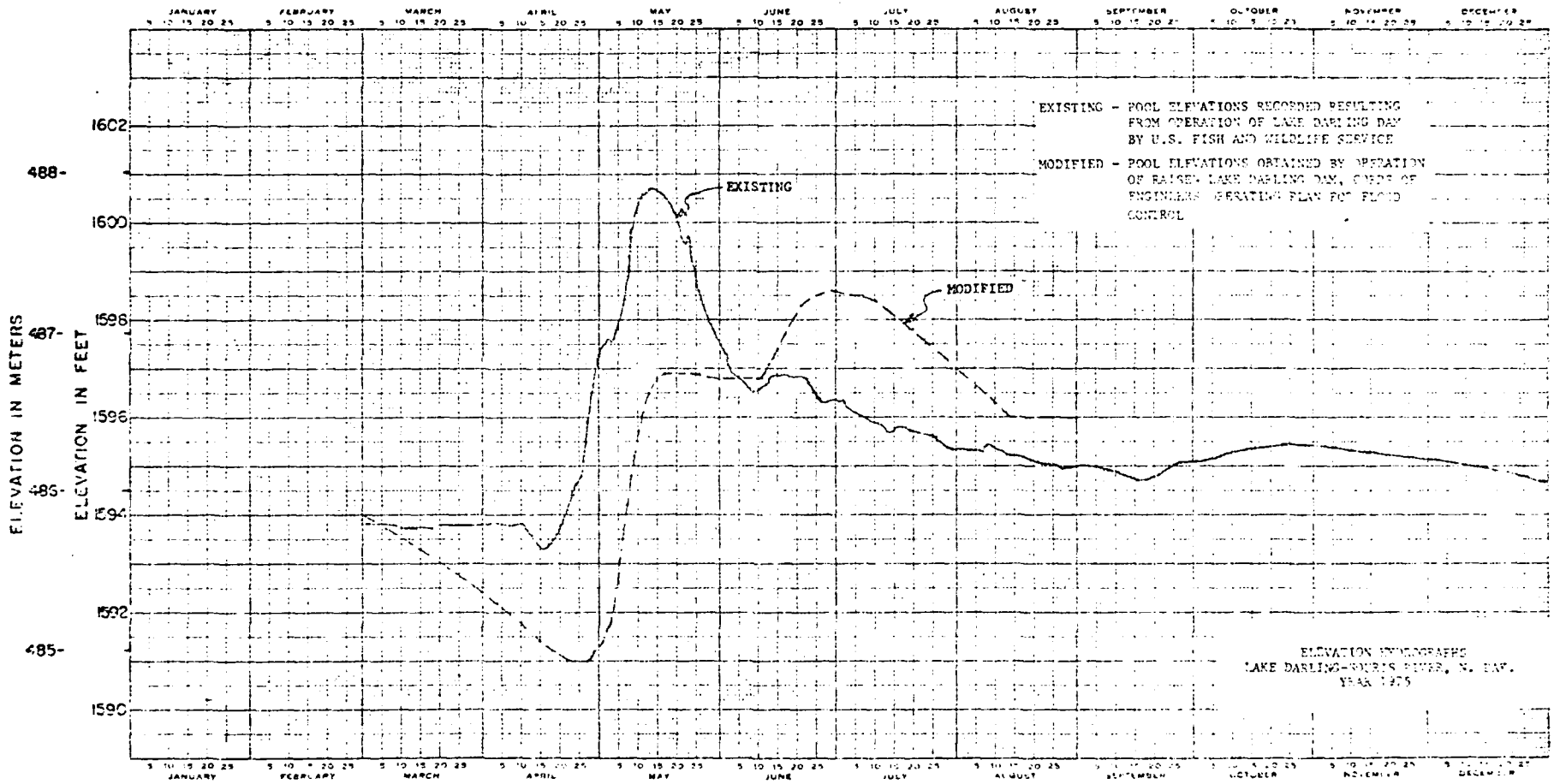

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
HARTNEY BRIDGE
EXISTING
MODIFIED

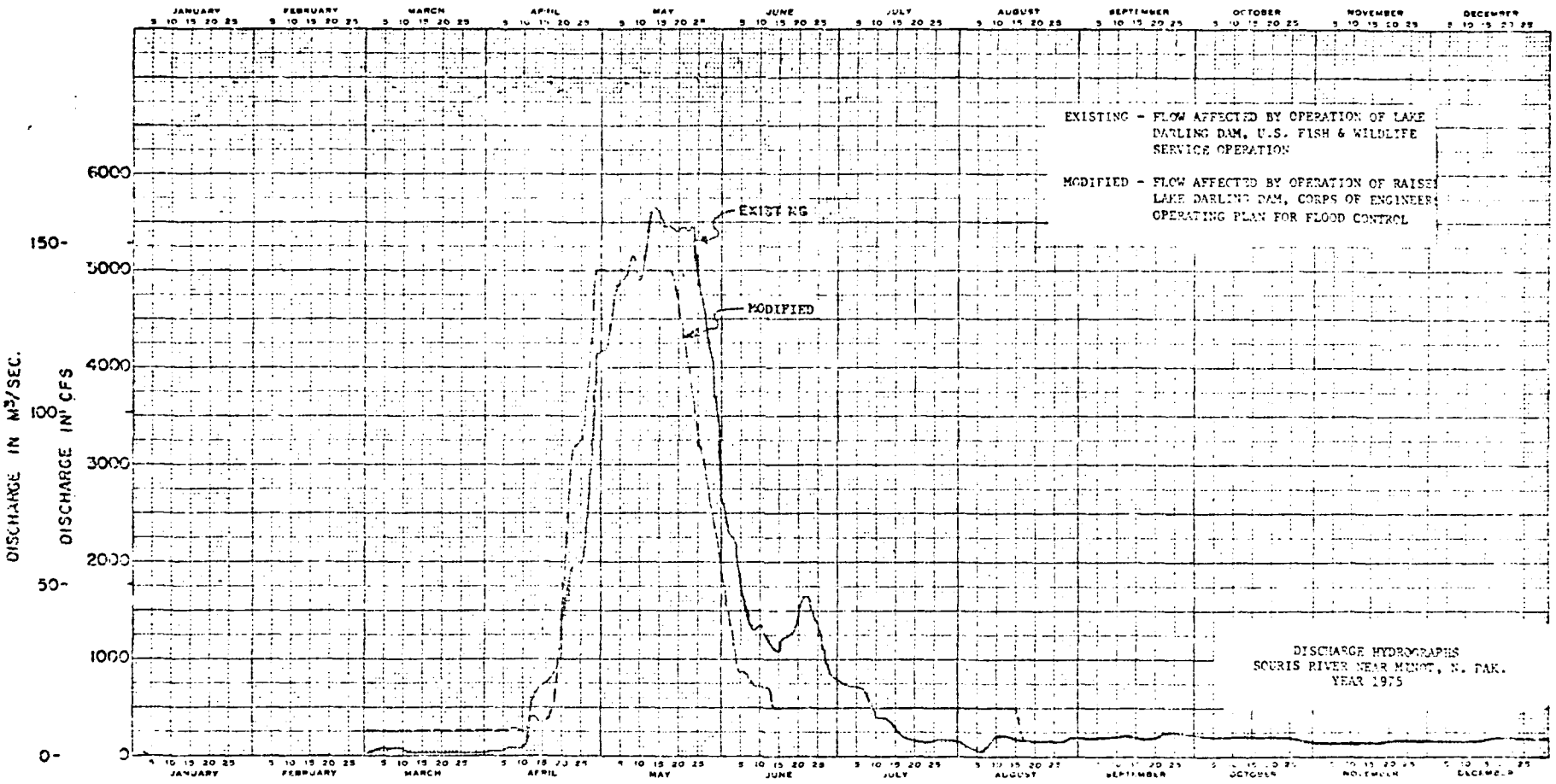

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
SOURIS
EXISTING
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

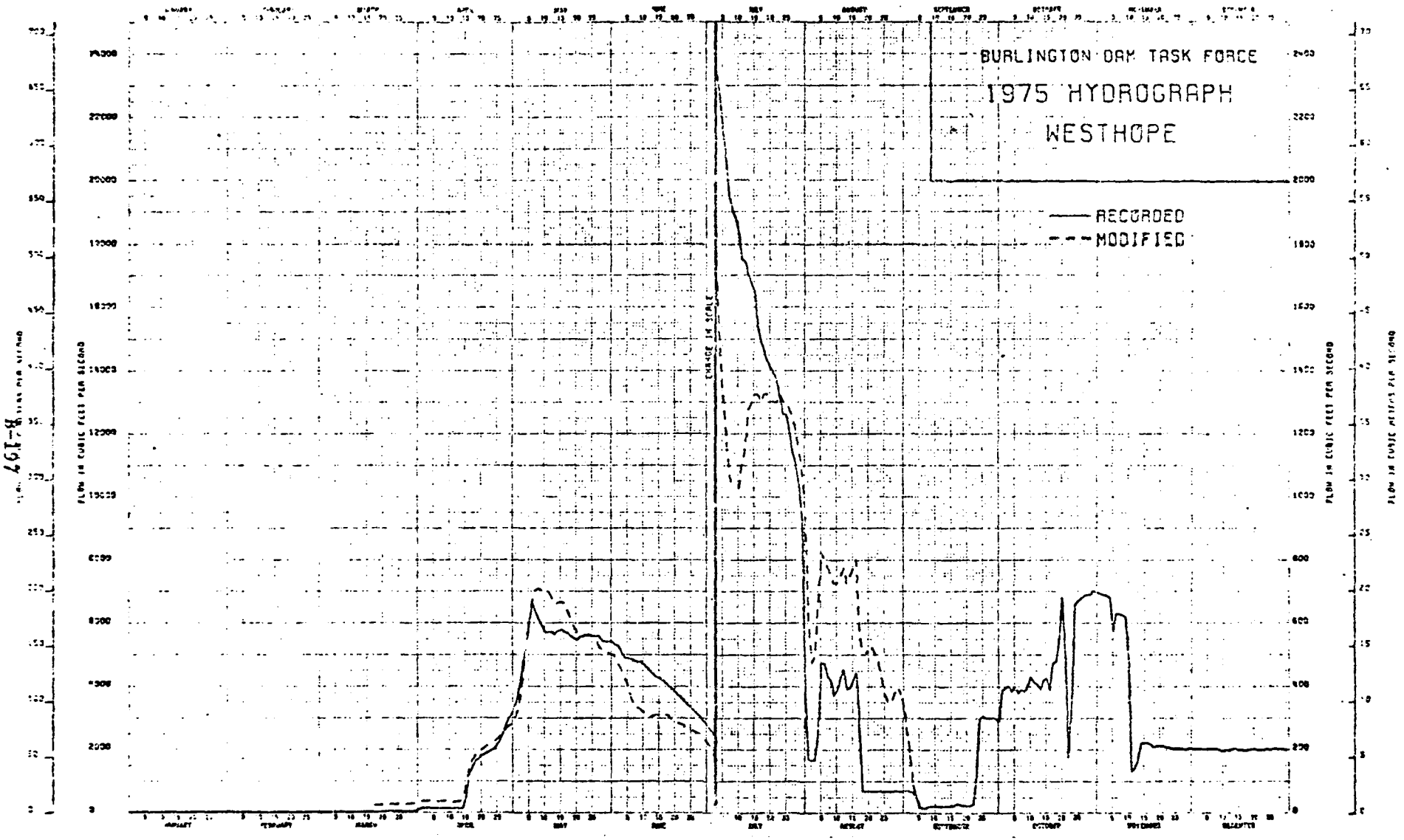

BURLINGTON DAM TASK FORCE
1974 HYDROGRAPH
WAWANESA
EXISTING
MODIFIED
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND
CHANGE IN SCALE

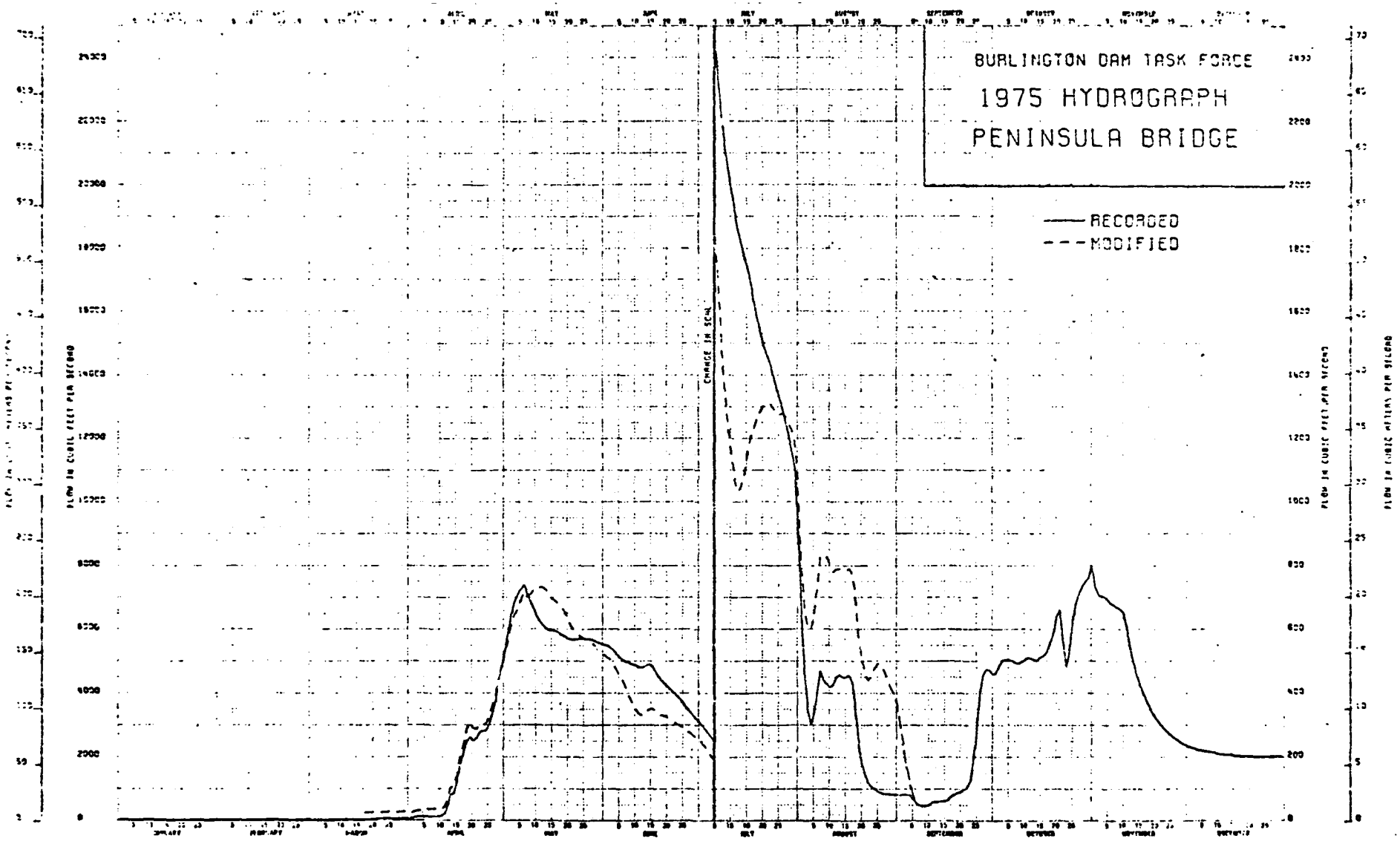
1975

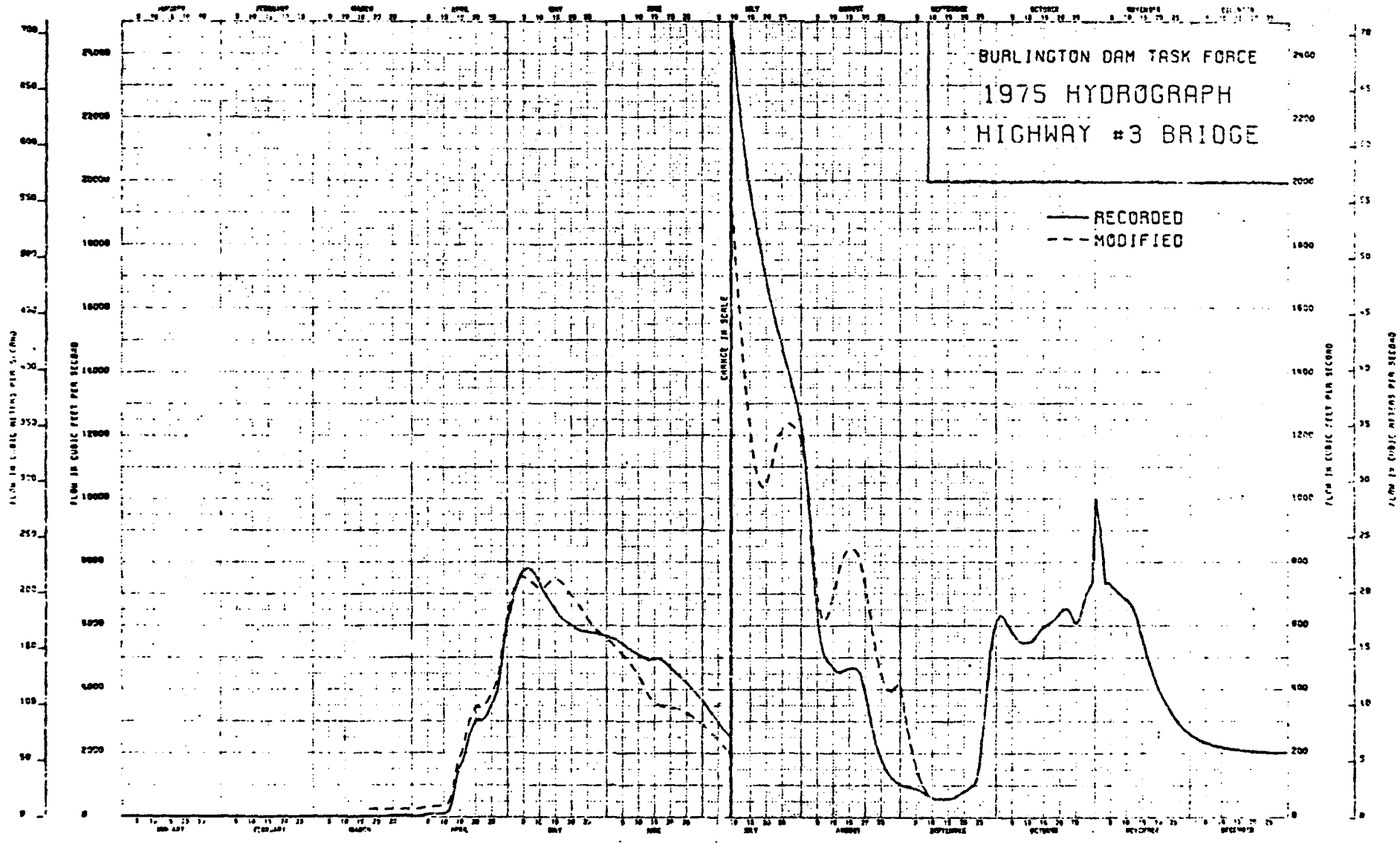

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M3/SEC.
DISCHARGE IN CFS
200
150
100
50
0
6000
5000
4000
3000
2000
1000
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1975

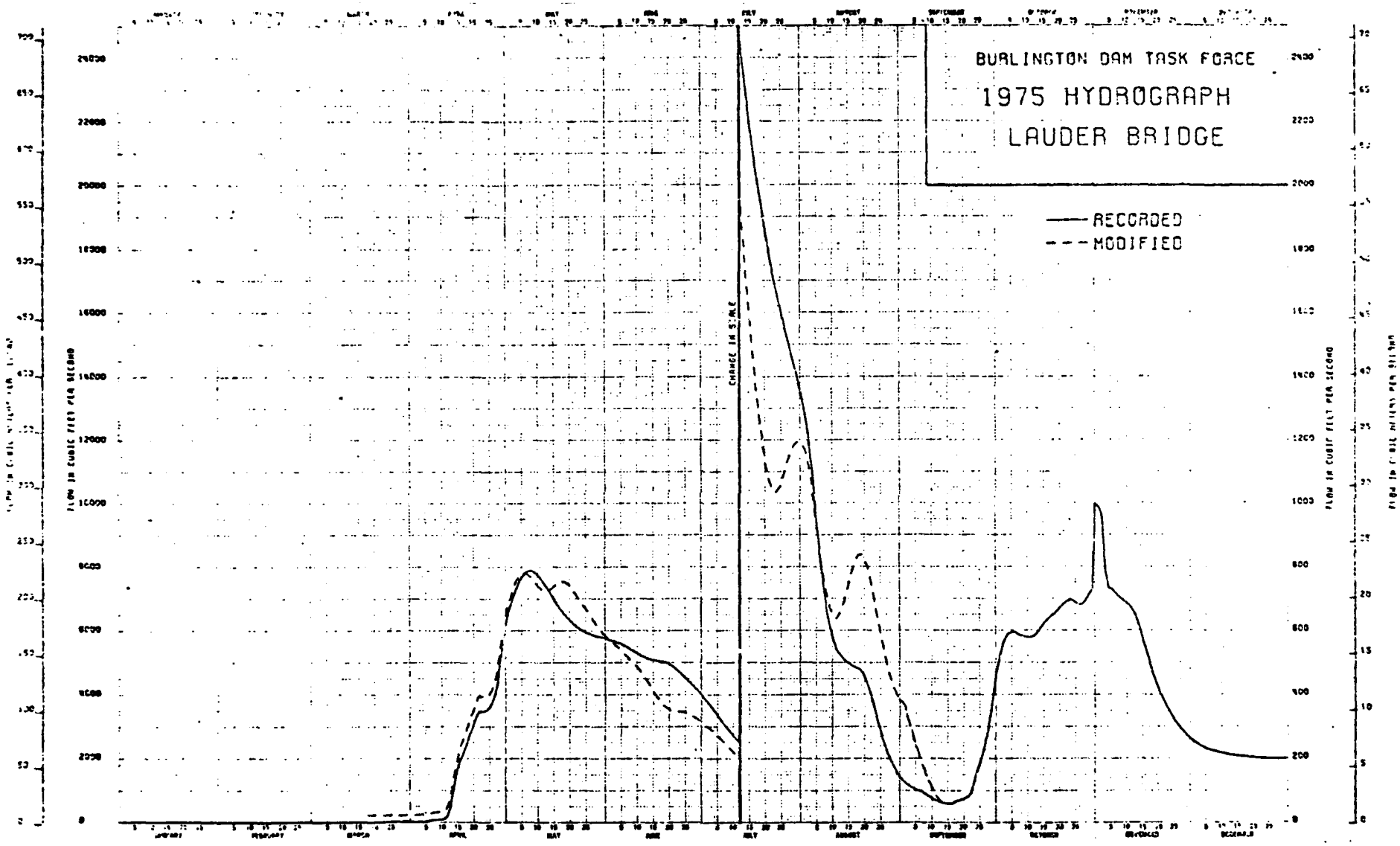

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
ELEVATION IN METERS
ELEVATION IN FEET
488-
487-
486-
485-
1602
1600
1598
1596
1594
1592
1590
EXISTING
MODIFIED
EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
ELEVATION HYDROGRAPHS
LAKE DARLING-BOWBIS RIVER, N. DAK.
YEAR 1975

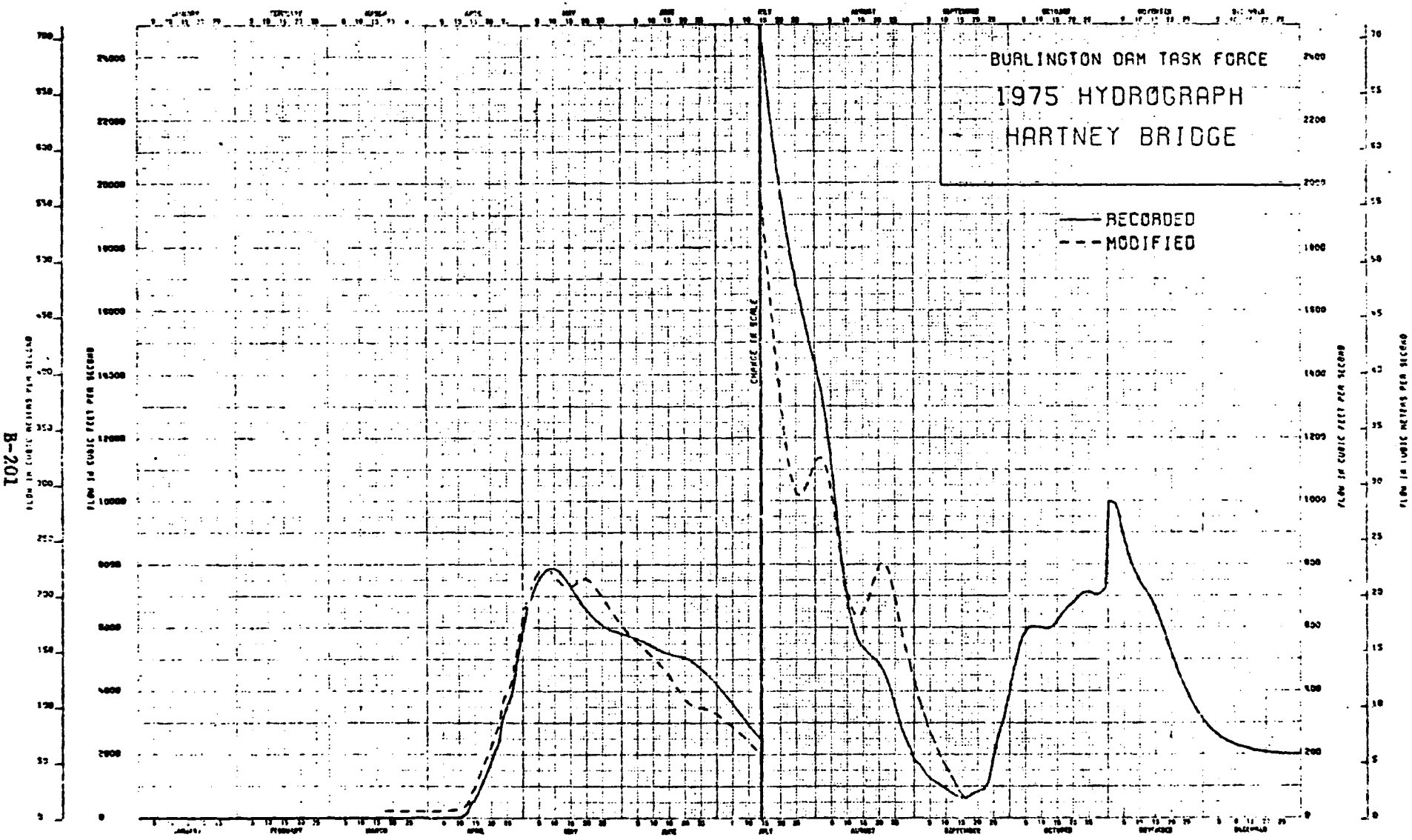

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
EXISTING
MODIFIED
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
150
100
50
0
6000
5000
4000
3000
2000
1000
0
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
YEAR 1975

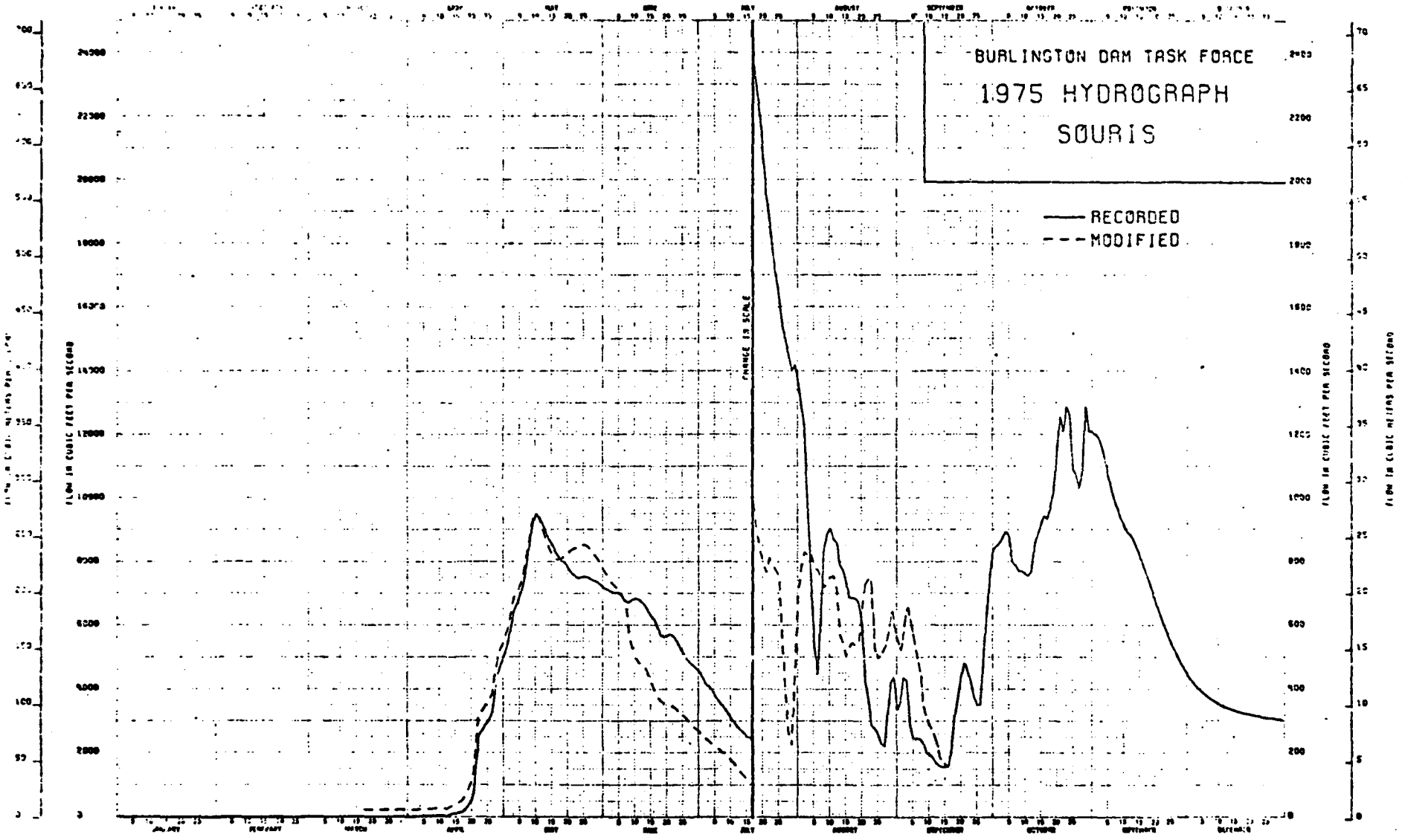

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND

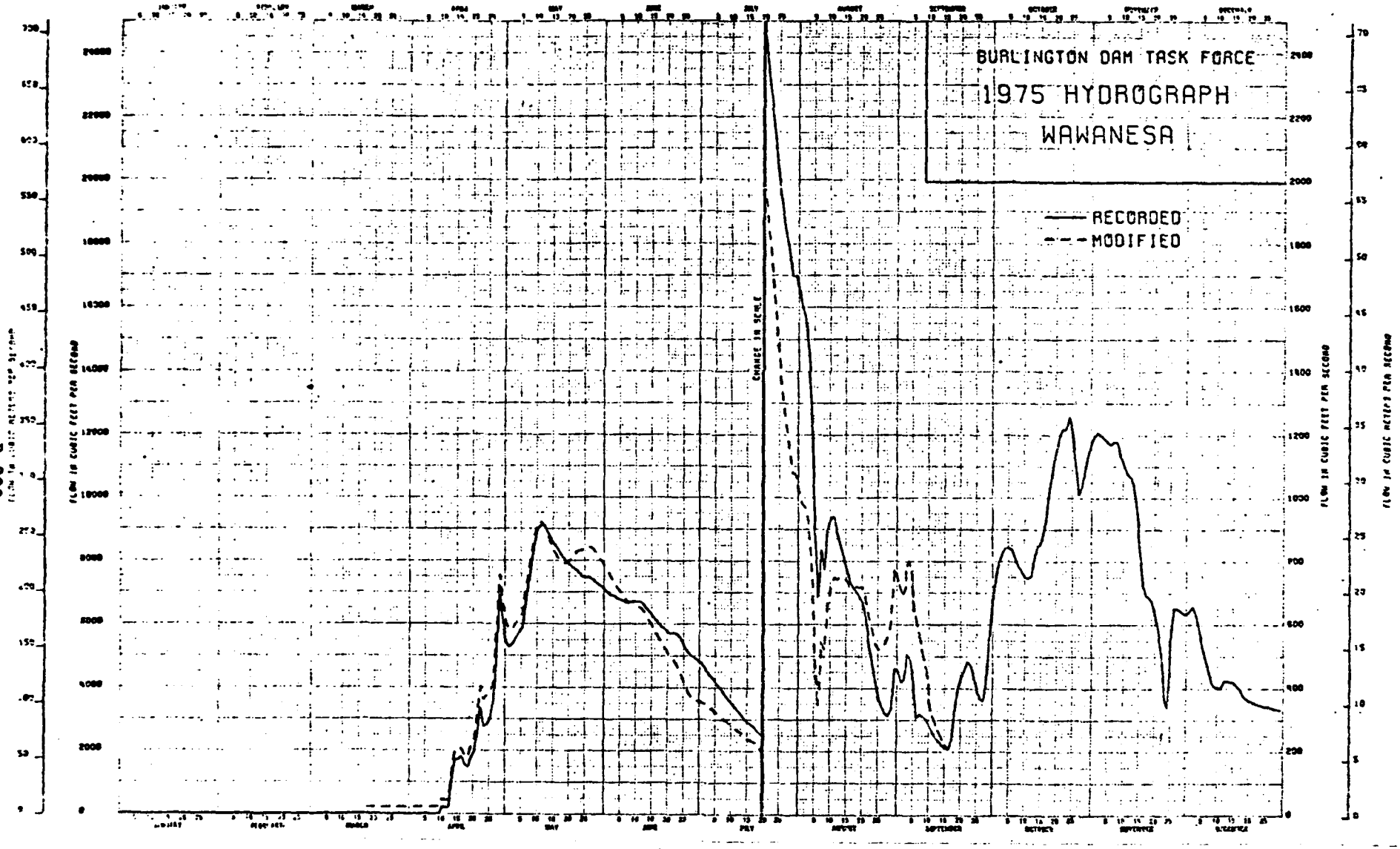

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCAL


BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE

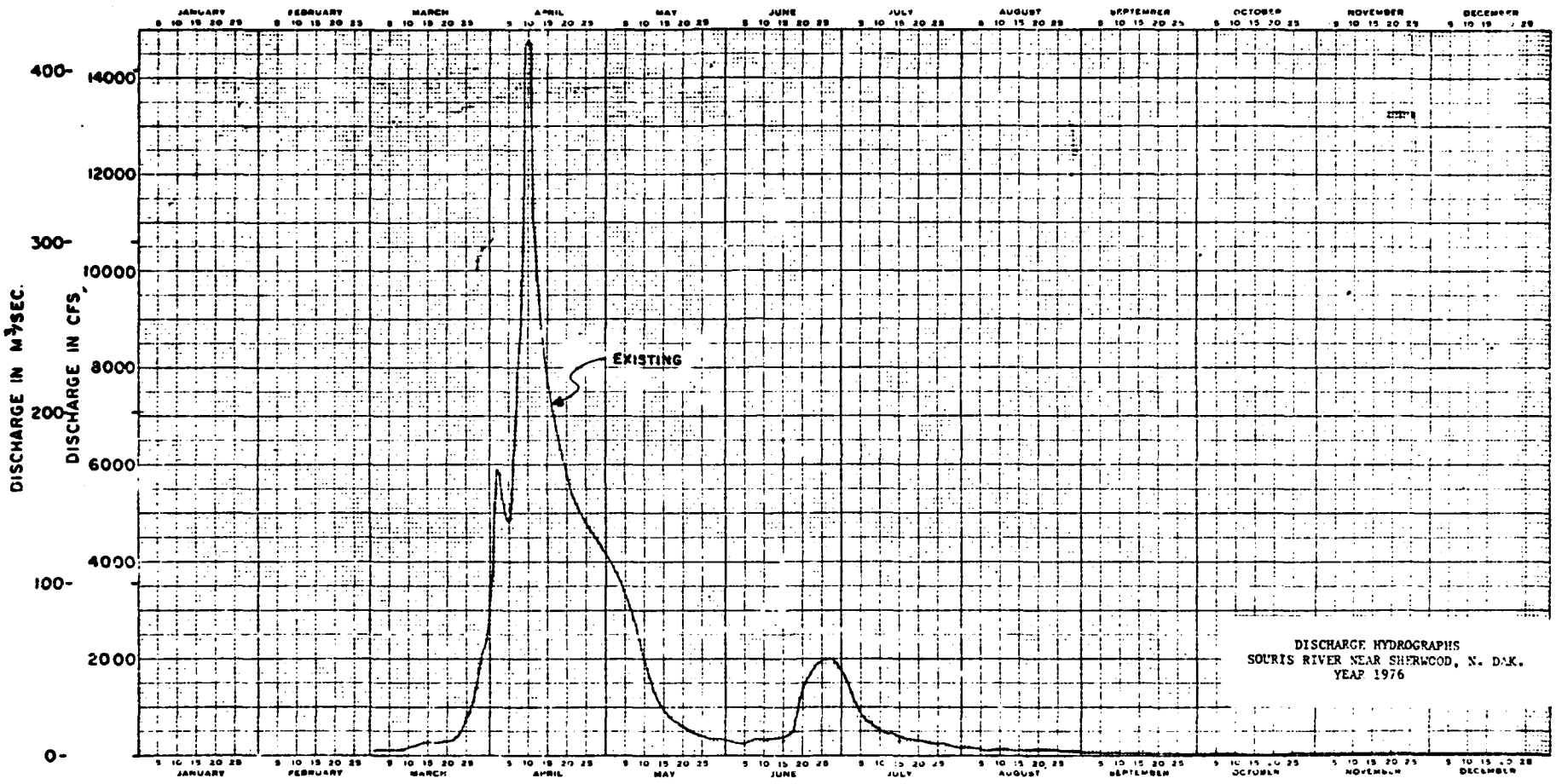

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN S.M.E.
FLOW IN CUBIC FEET PER SECOND

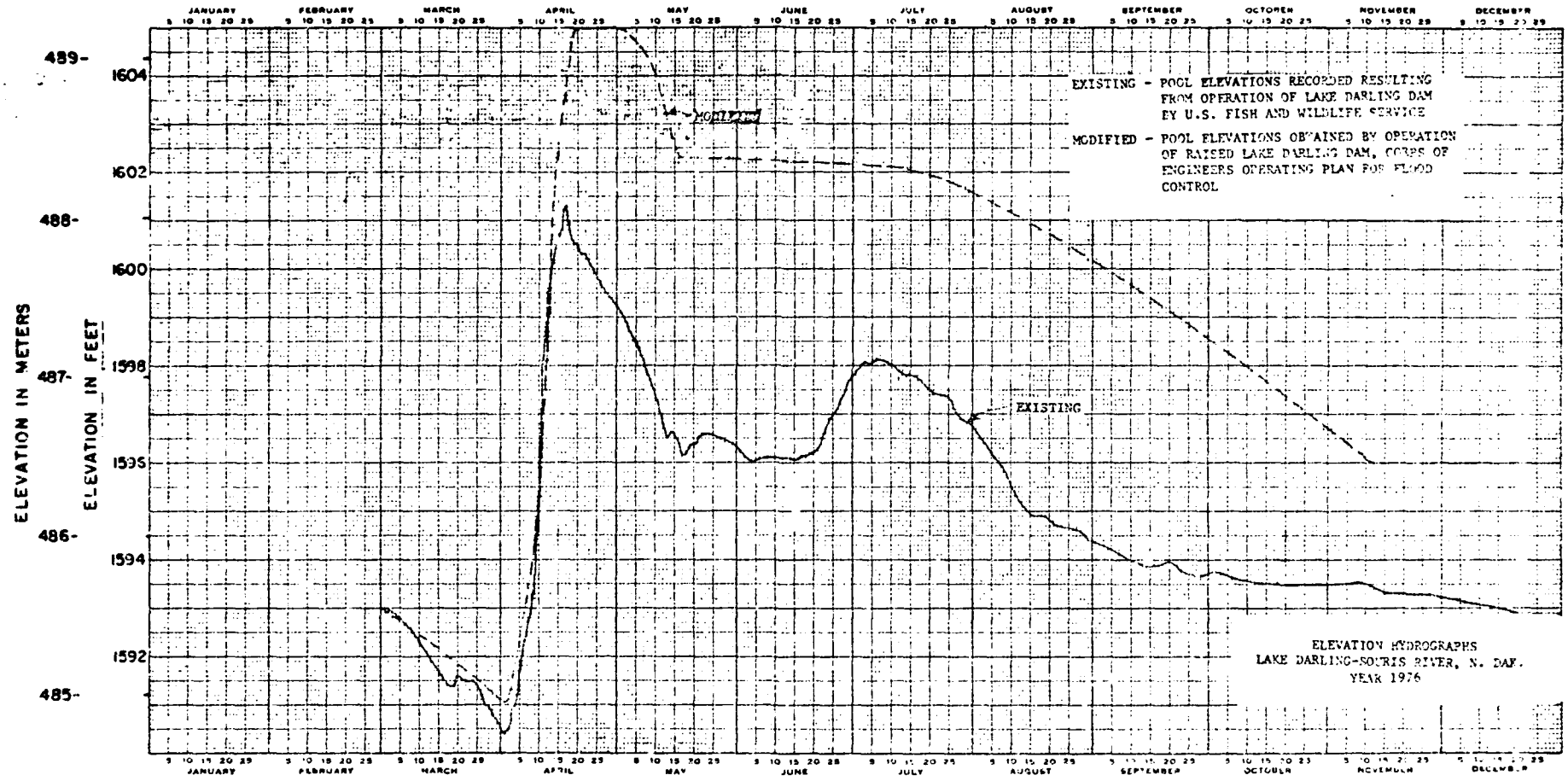

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

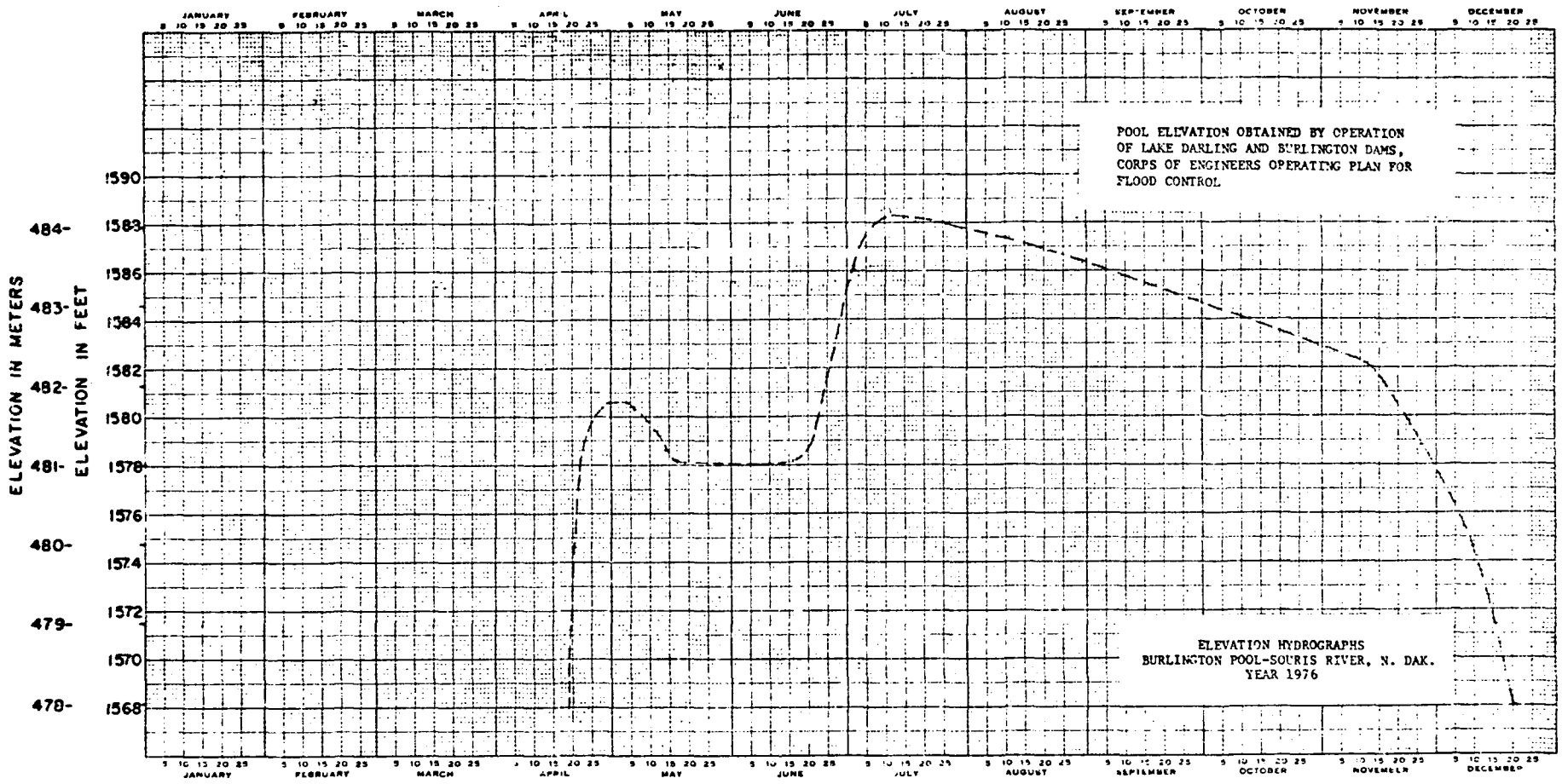

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

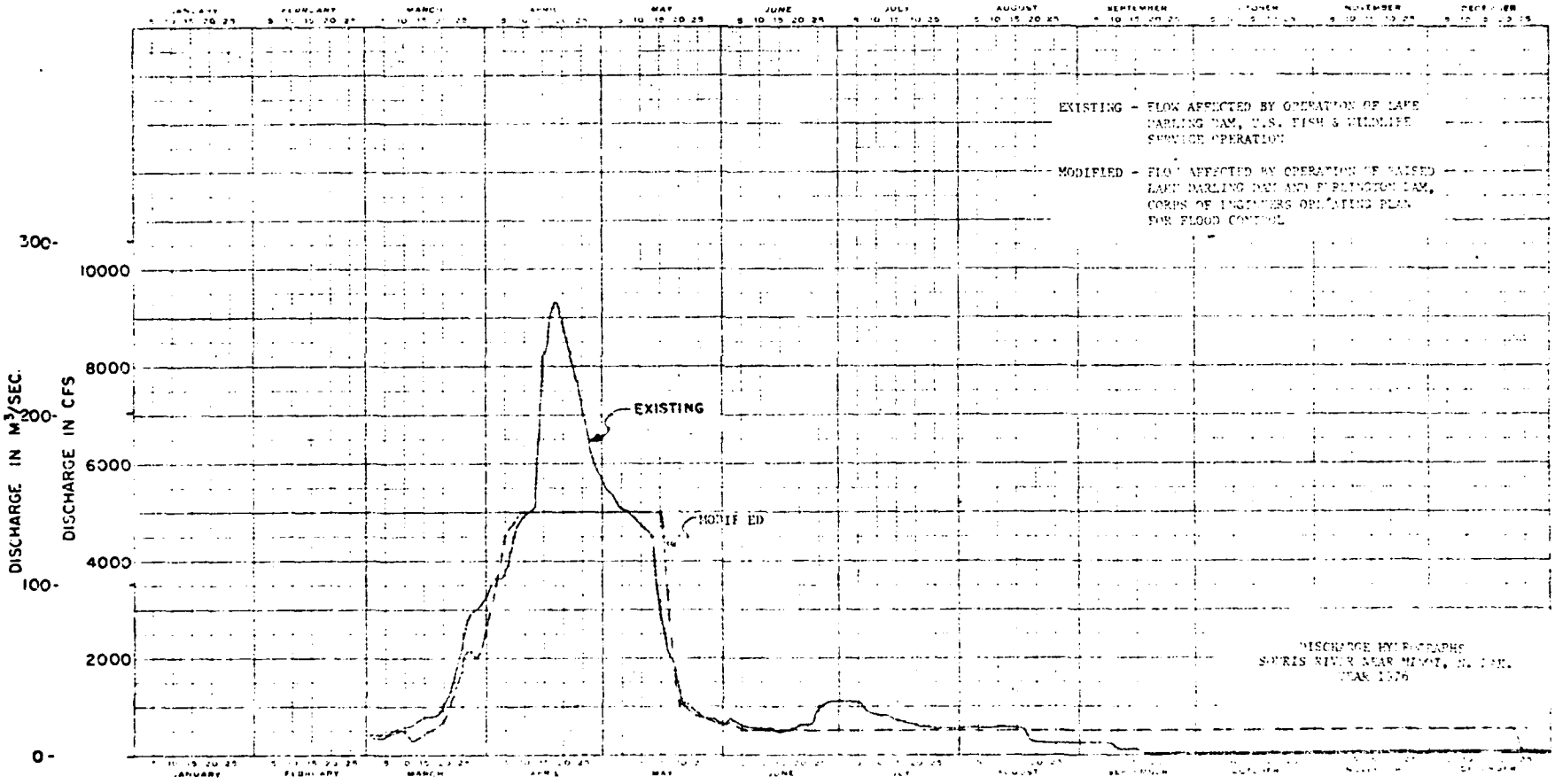

BURLINGTON DAM TASK FORCE
1975 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC FEET PER SECOND
FLOW IN CUBIC METERS PER SECOND

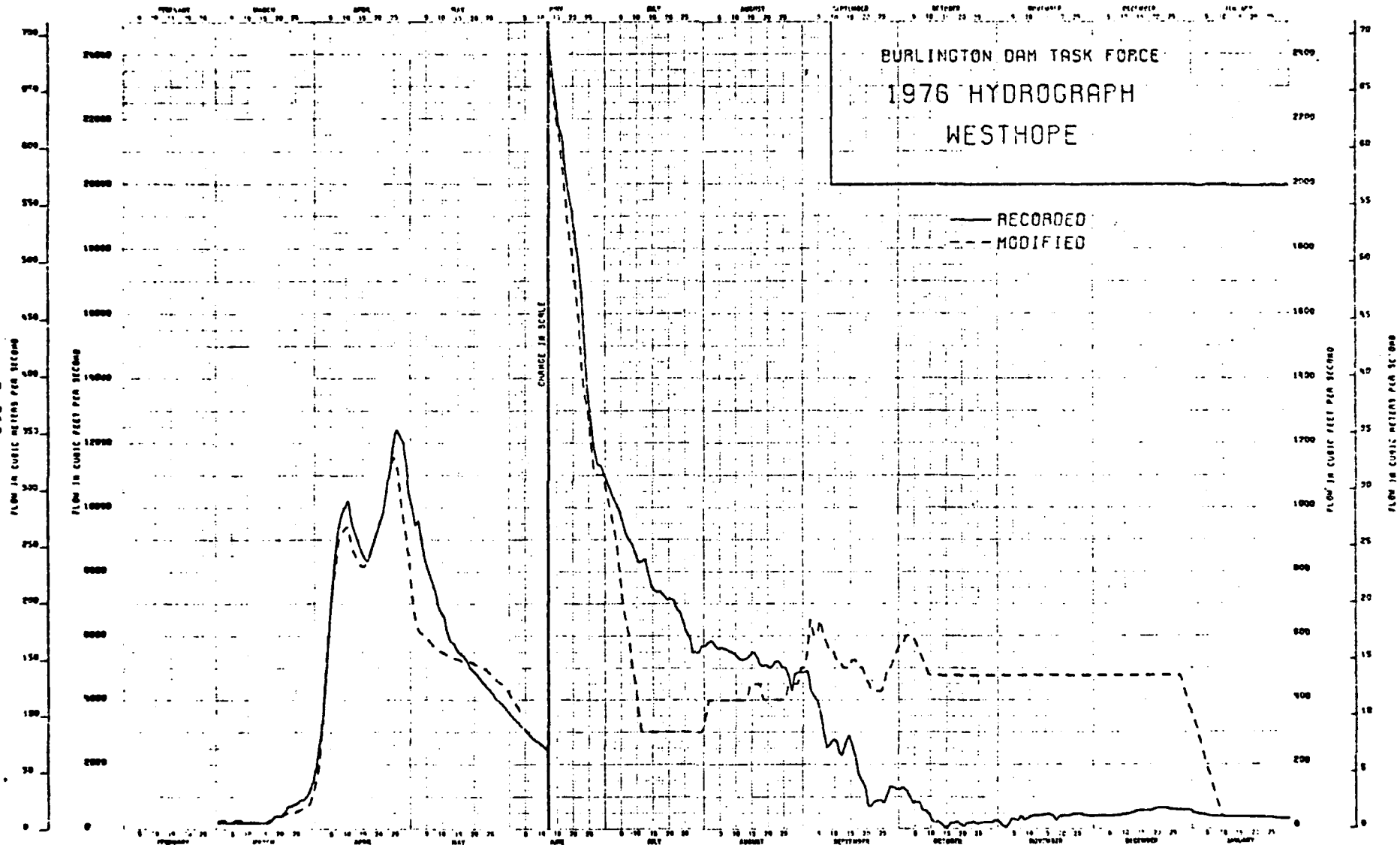
1976

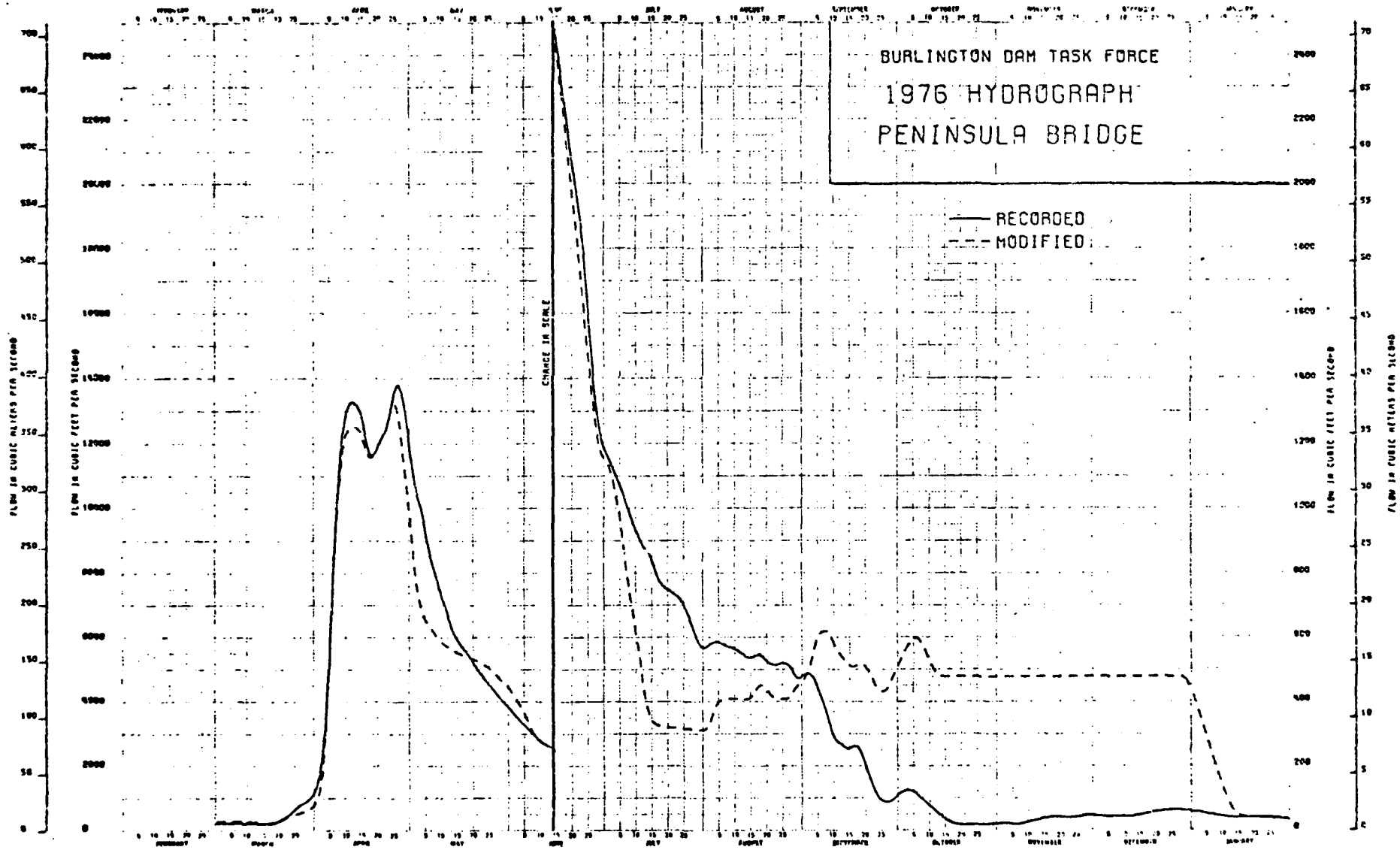

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS.
400-
300-
200-
100-
0-
14000
12000
10000
8000
6000
4000
2000
EXISTING
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR SHERWOOD, N. DAK.
YEAR 1976

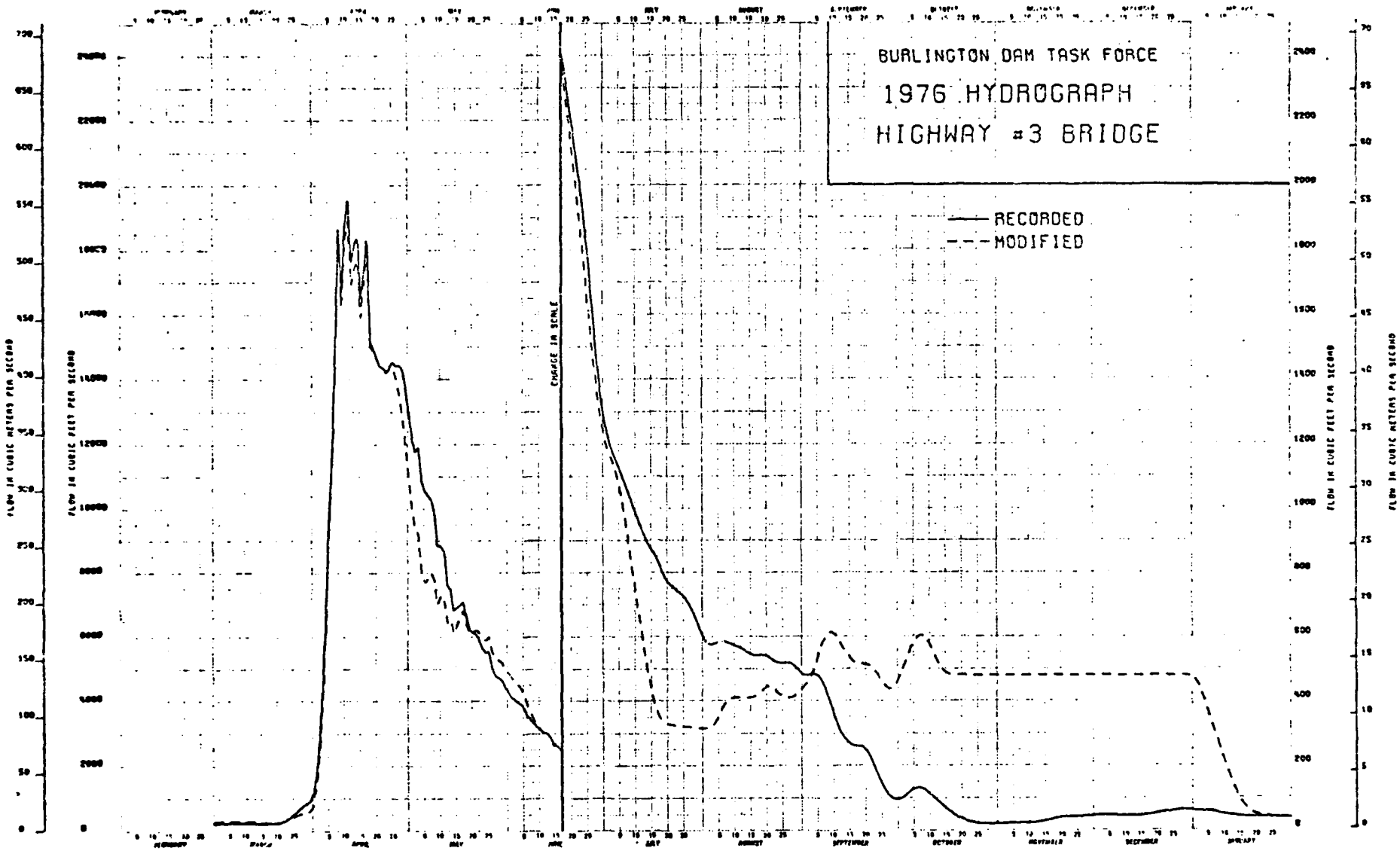

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
ELEVATION IN METERS
ELEVATION IN FEET
489-
488-
487-
486-
485-
1604
1602
1600
1598
1596
1594
1592
EXISTING - POOL ELEVATIONS RECORDED RESULTING FROM OPERATION OF LAKE DARLING DAM BY U.S. FISH AND WILDLIFE SERVICE
MODIFIED - POOL ELEVATIONS OBTAINED BY OPERATION OF RAISED LAKE DARLING DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
MODIFIED
EXISTING
ELEVATION HYDROGRAPHS
LAKE DARLING-SOURIS RIVER, N. DAK.
YEAR 1976

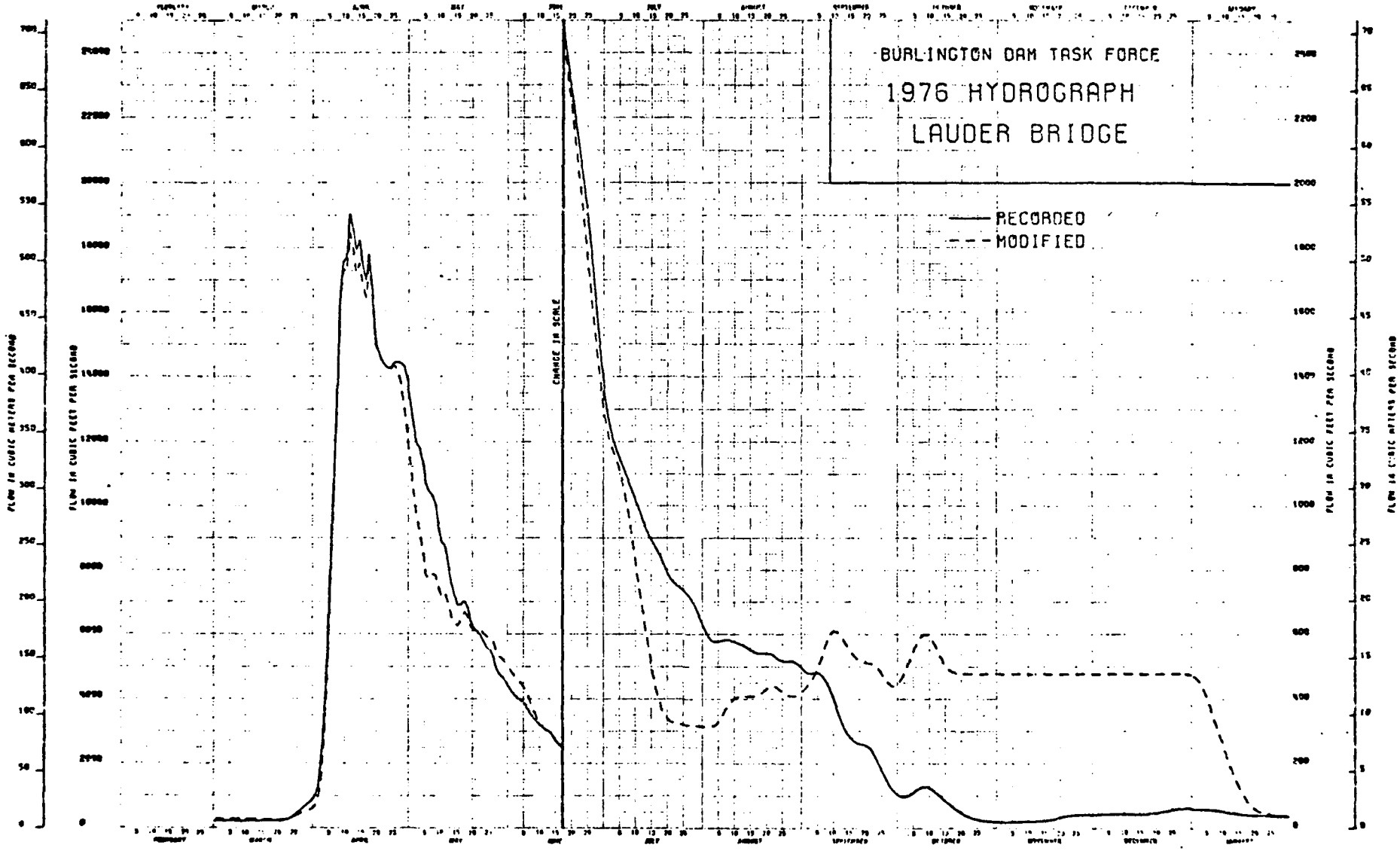

POOL ELEVATION OBTAINED BY OPERATION OF LAKE DARLING AND BURLINGTON DAMS, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
ELEVATION HYDROGRAPHS
BURLINGTON POOL-SOURIS RIVER, N. DAK.
YEAR 1976
ELEVATION IN METERS
ELEVATION IN FEET
484-
483-
482-
481-
480-
479-
478-
1590
1588
1586
1584
1582
1580
1578
1576
1574
1572
1570
1568
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

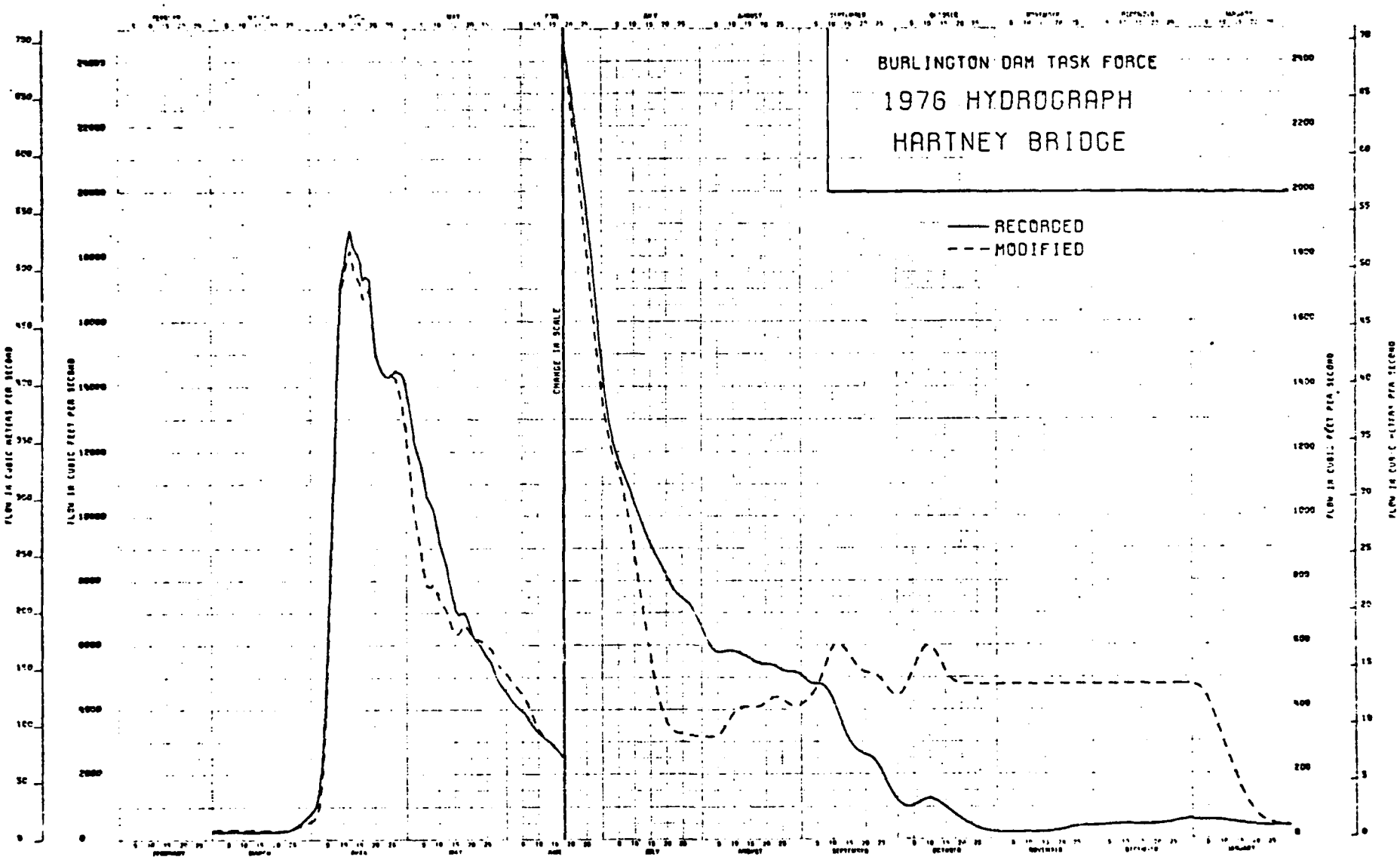

EXISTING - FLOW AFFECTED BY OPERATION OF LAKE DARLING DAM, U.S. FISH & WILDLIFE SERVICE OPERATION
MODIFIED - FLOW AFFECTED BY OPERATION OF RAISED LAKE DARLING DAM AND FORKSTON DAM, CORPS OF ENGINEERS OPERATING PLAN FOR FLOOD CONTROL
DISCHARGE HYDROGRAPHS
SOURIS RIVER NEAR MINOT, N. DAK.
MAR 1976
DISCHARGE IN M³/SEC.
DISCHARGE IN CFS
300
200
100
0
10000
8000
6000
4000
2000
EXISTING
MODIFIED
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

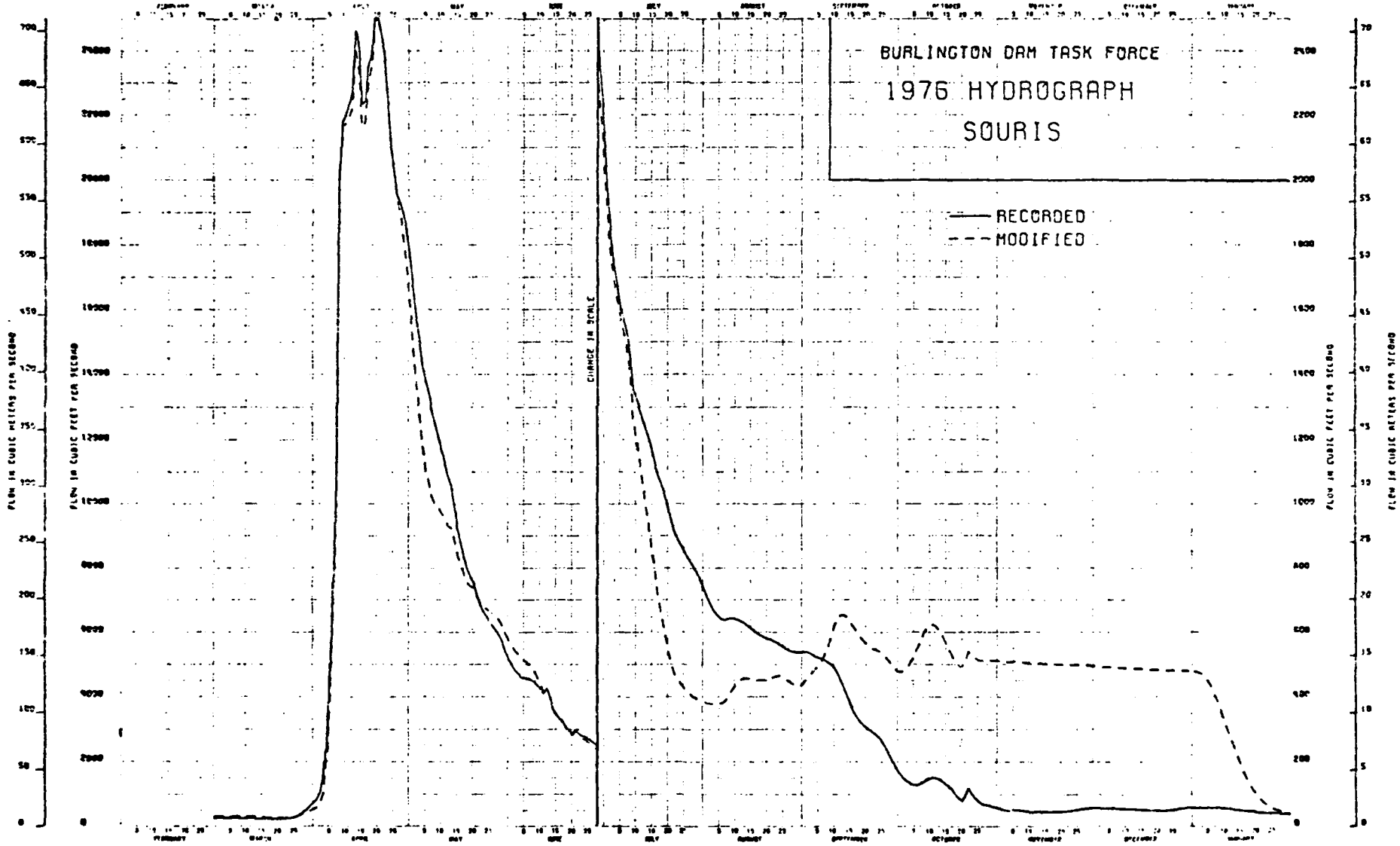

BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
WESTHOPE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

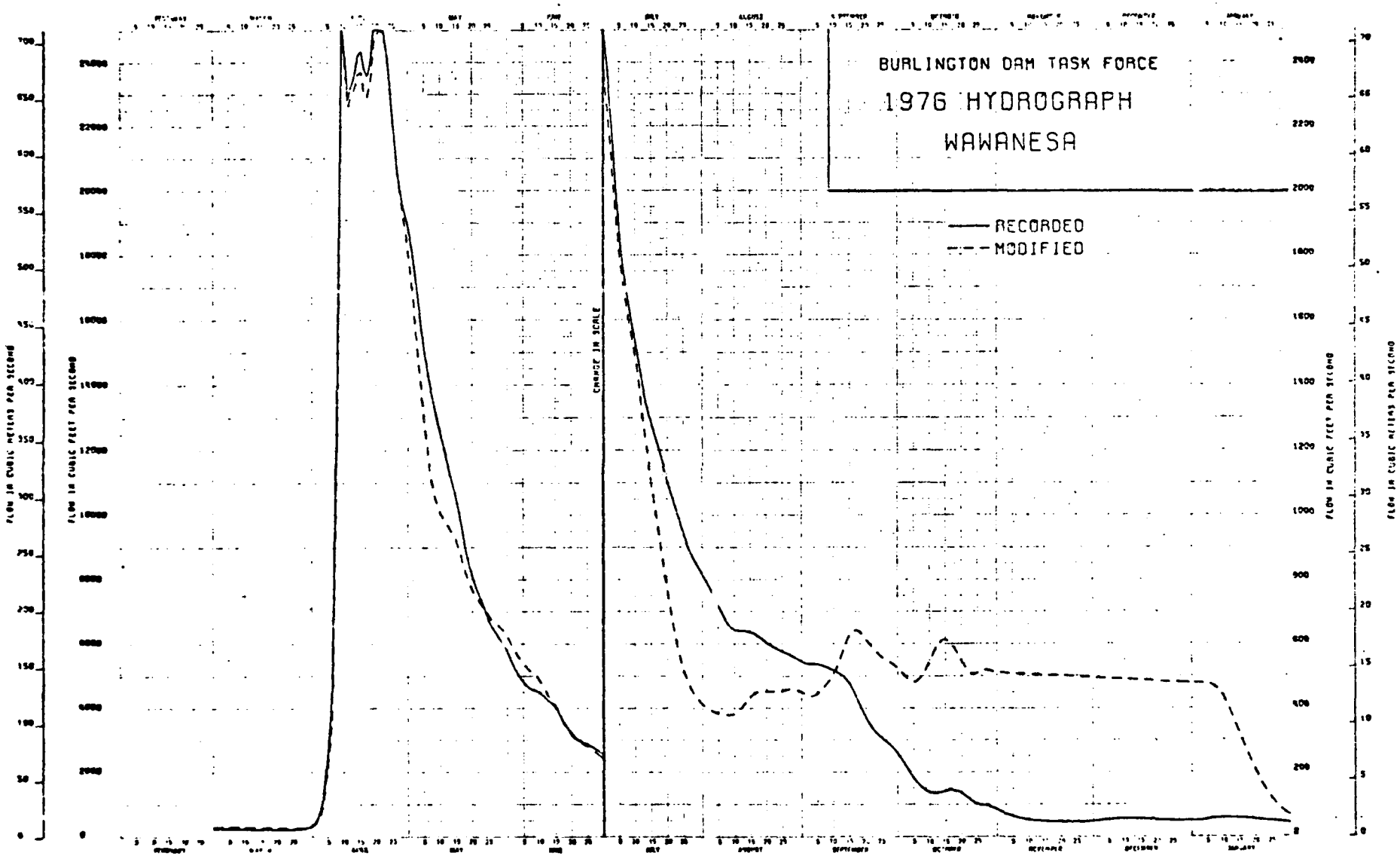

BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
PENINSULA BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
HIGHWAY #3 BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
LAUDER BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
HARTNEY BRIDGE
RECORDED
MODIFIED
CHANGE IN SCALE


BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
SOURIS
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND


BURLINGTON DAM TASK FORCE
1976 HYDROGRAPH
WAWANESA
RECORDED
MODIFIED
CHANGE IN SCALE
FLOW IN CUBIC METERS PER SECOND
FLOW IN CUBIC FEET PER SECOND

APPENDIX C

LAND OWNERSHIP PATTERNS

APPENDIX C

LAND OWNERSHIP PATTERNS

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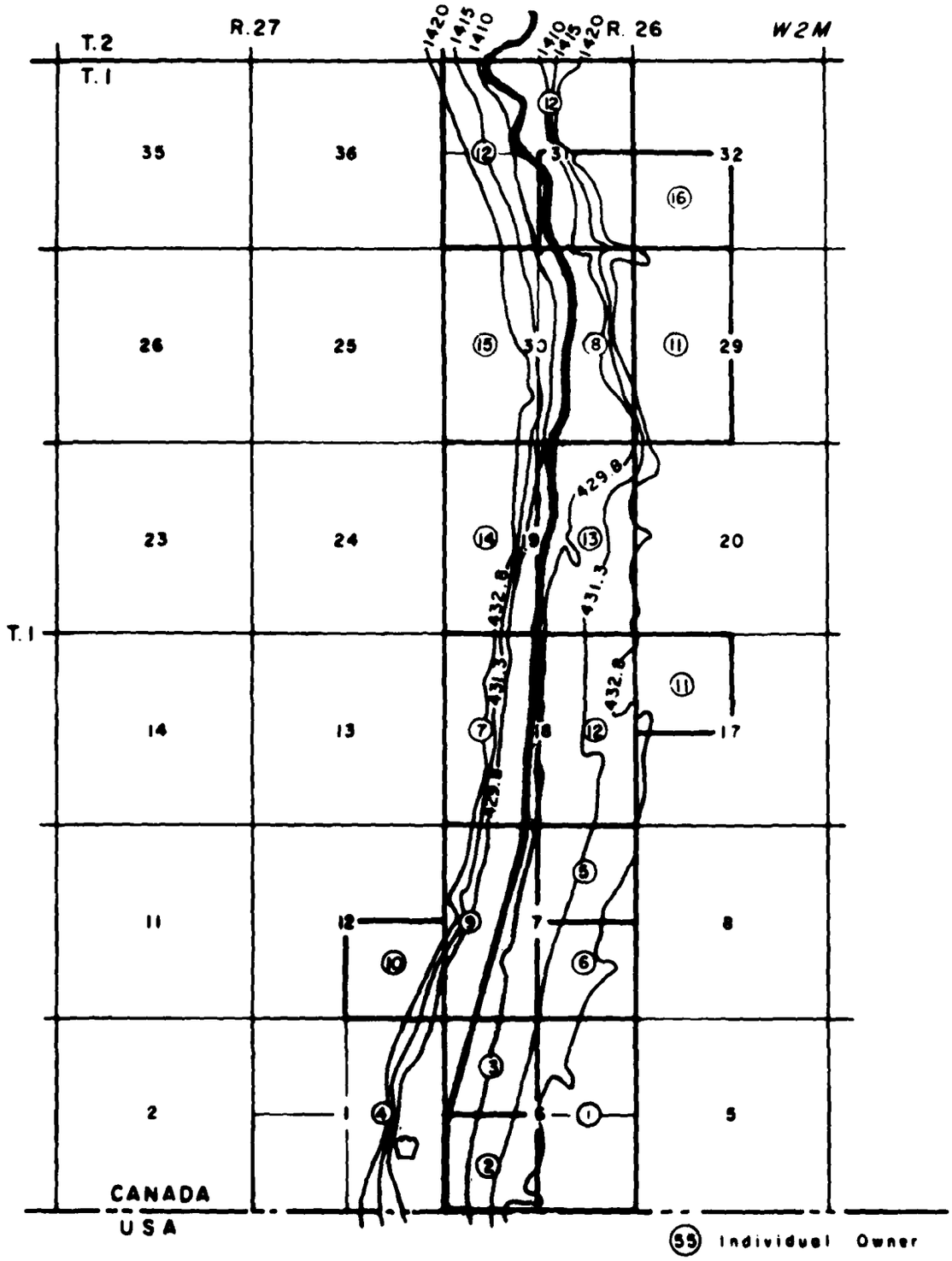

FIGURE C-1 : LAND OWNERSHIP PATTERNS - WESTHOPE REACH

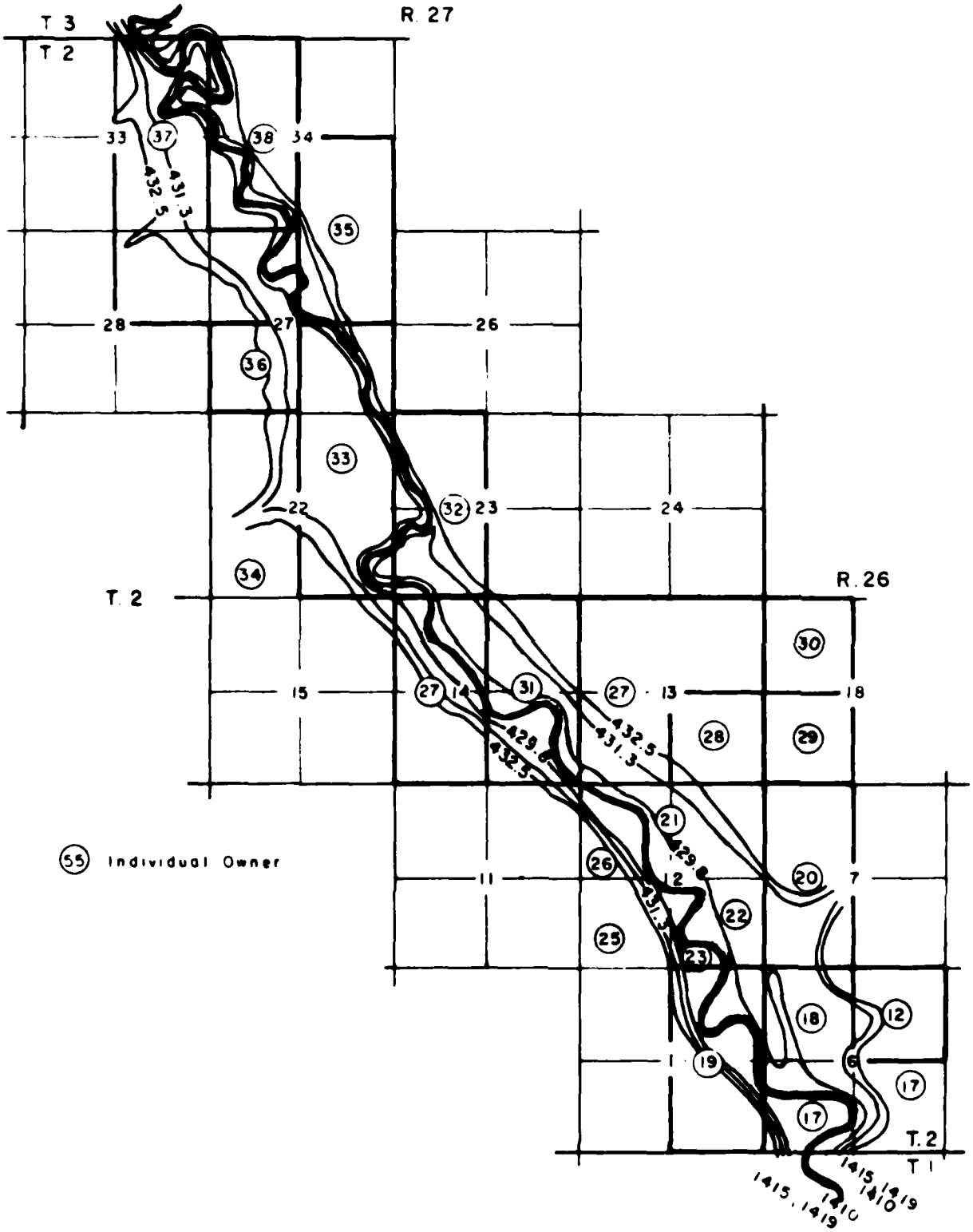

FIGURE C-2 LAND OWNERSHIP PATTERNS - PENINSULA BRIDGE REACH

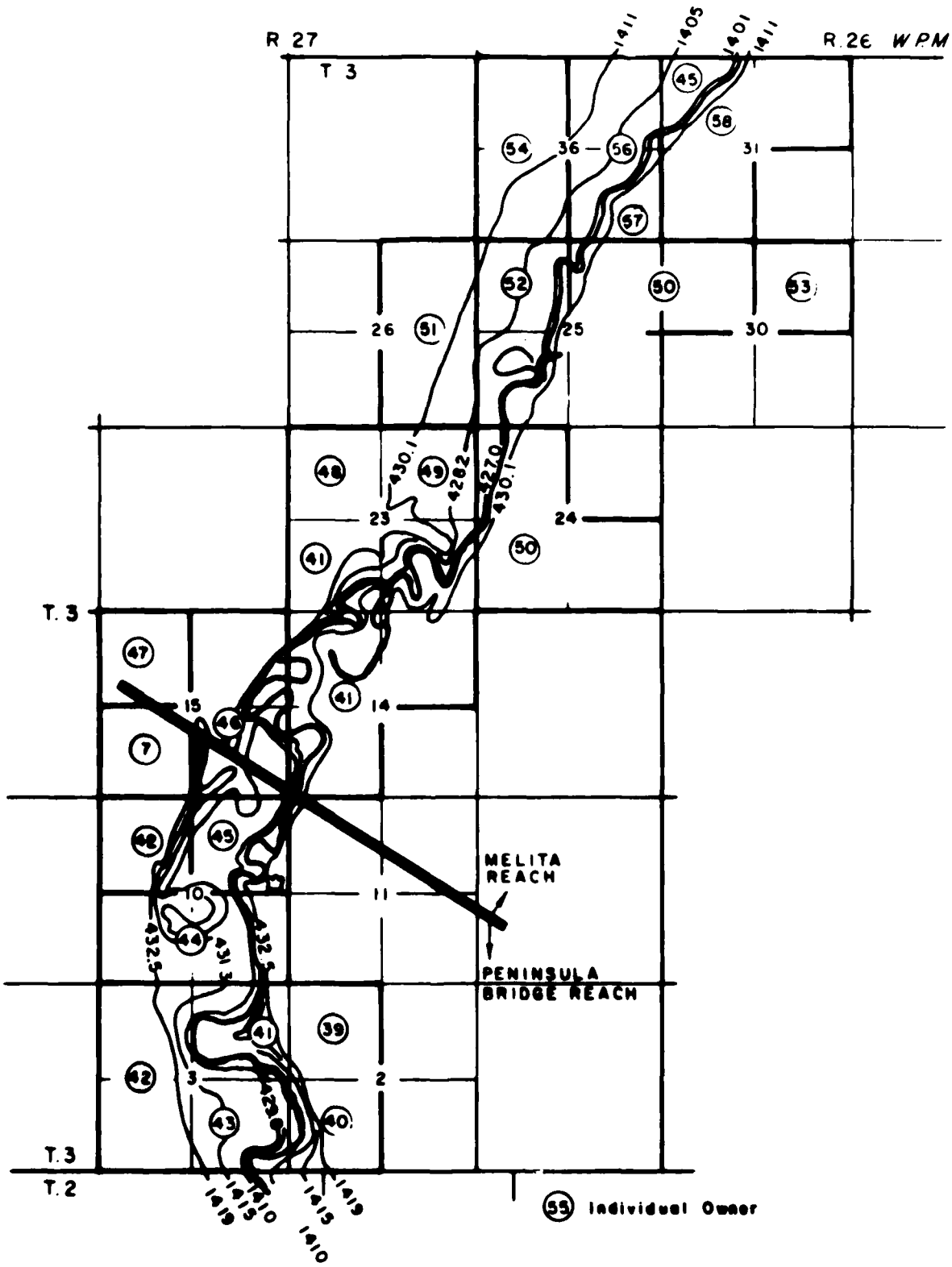

FIGURE C-3: LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY-
PENINSULA BRIDGE - MELITA REACHES

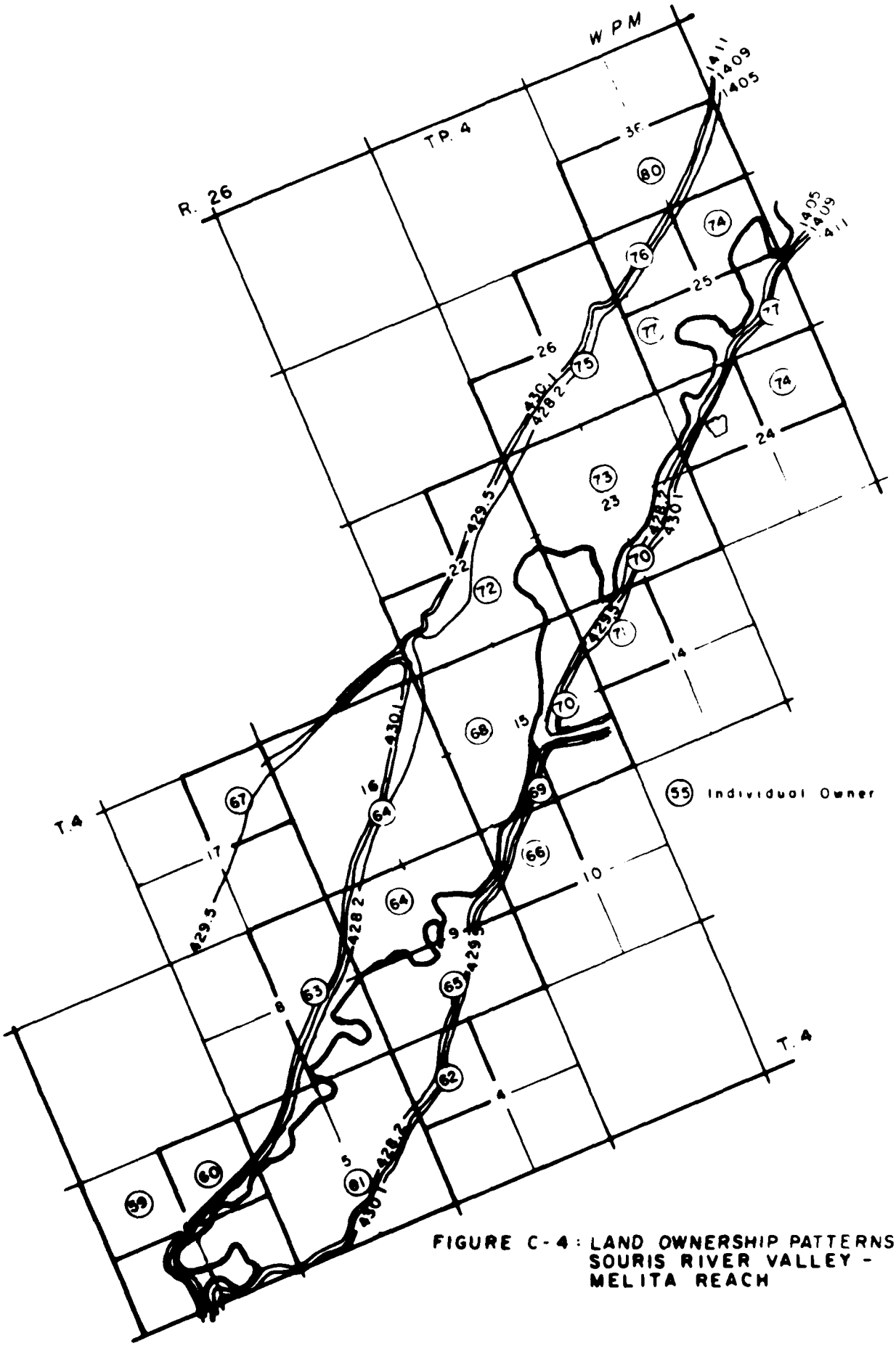

FIGURE C-4: LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY -
MELITA REACH

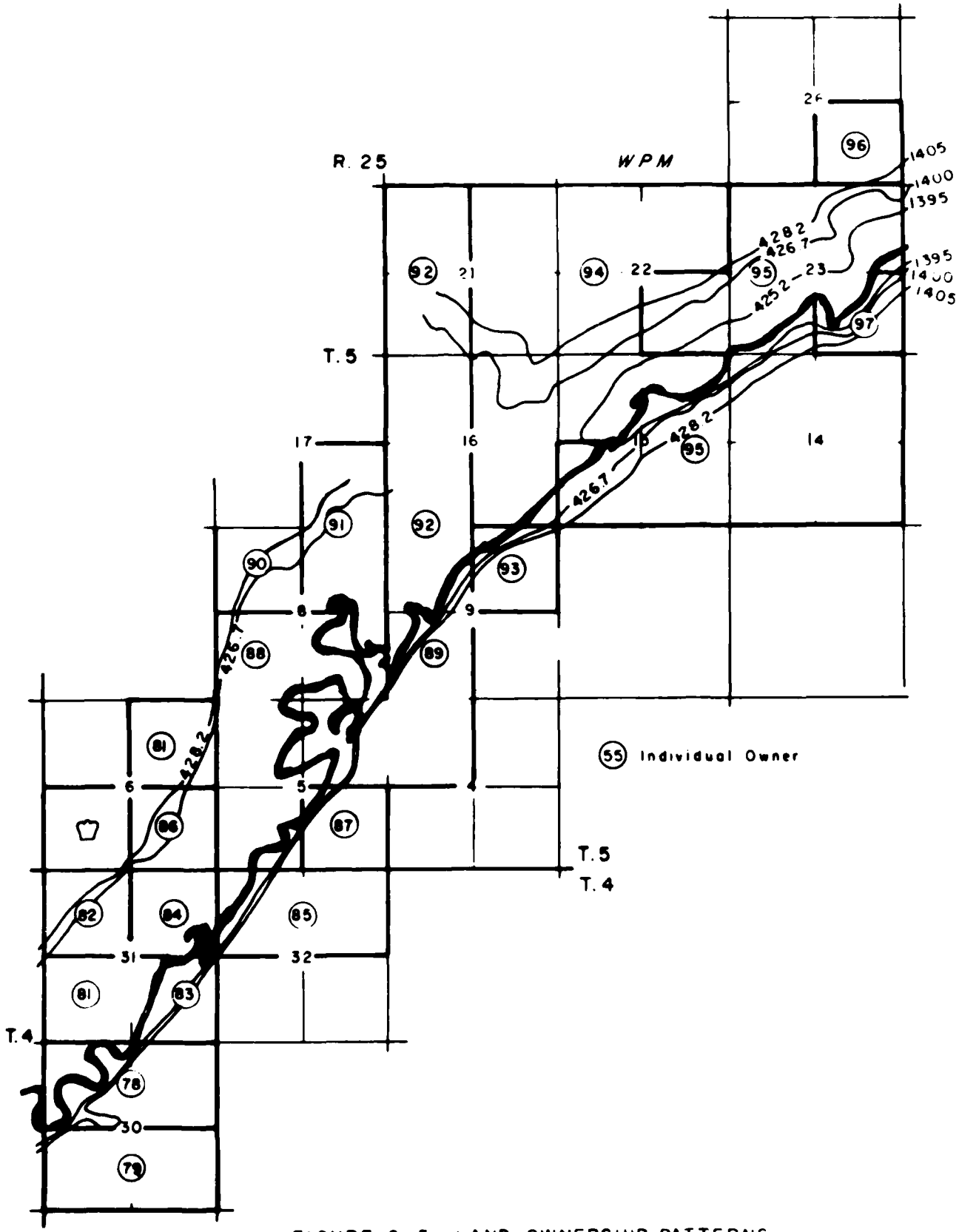

FIGURE C-5 · LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY -
LAUDER REACH

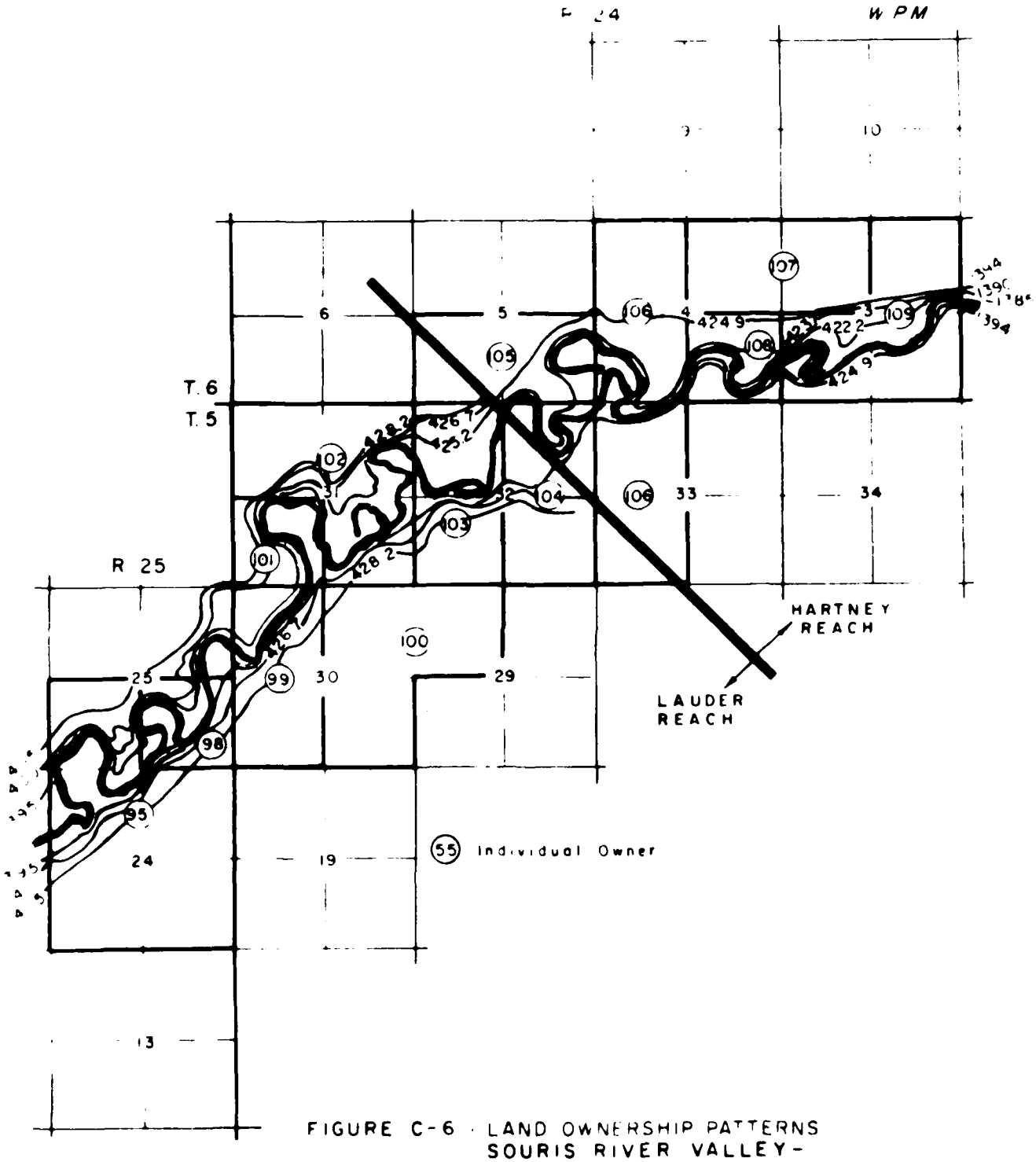

FIGURE C-6 · LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY-
LAUDER - HARTNEY REACHES

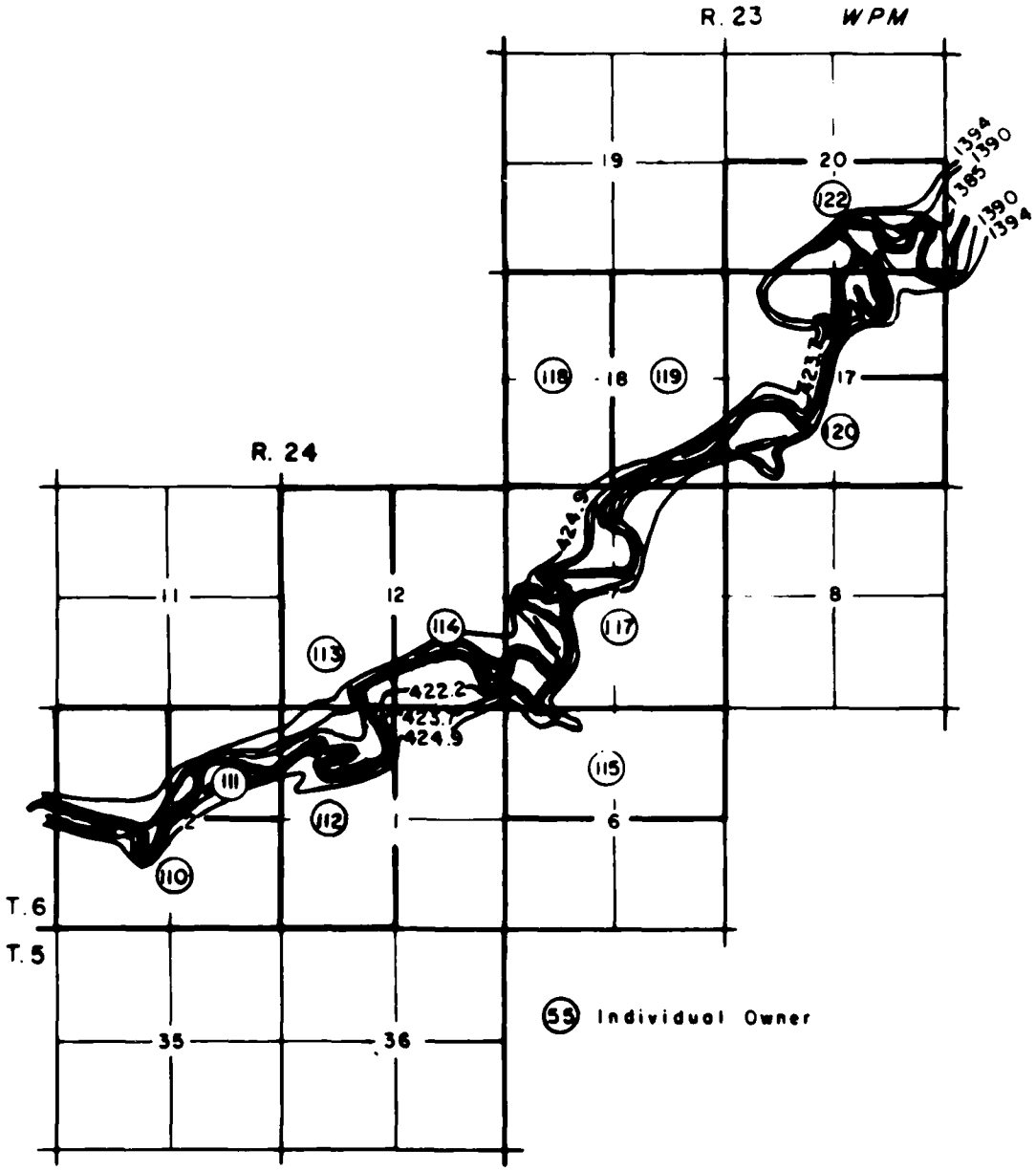

FIGURE C - 7 : LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY-
HARTNEY REACH

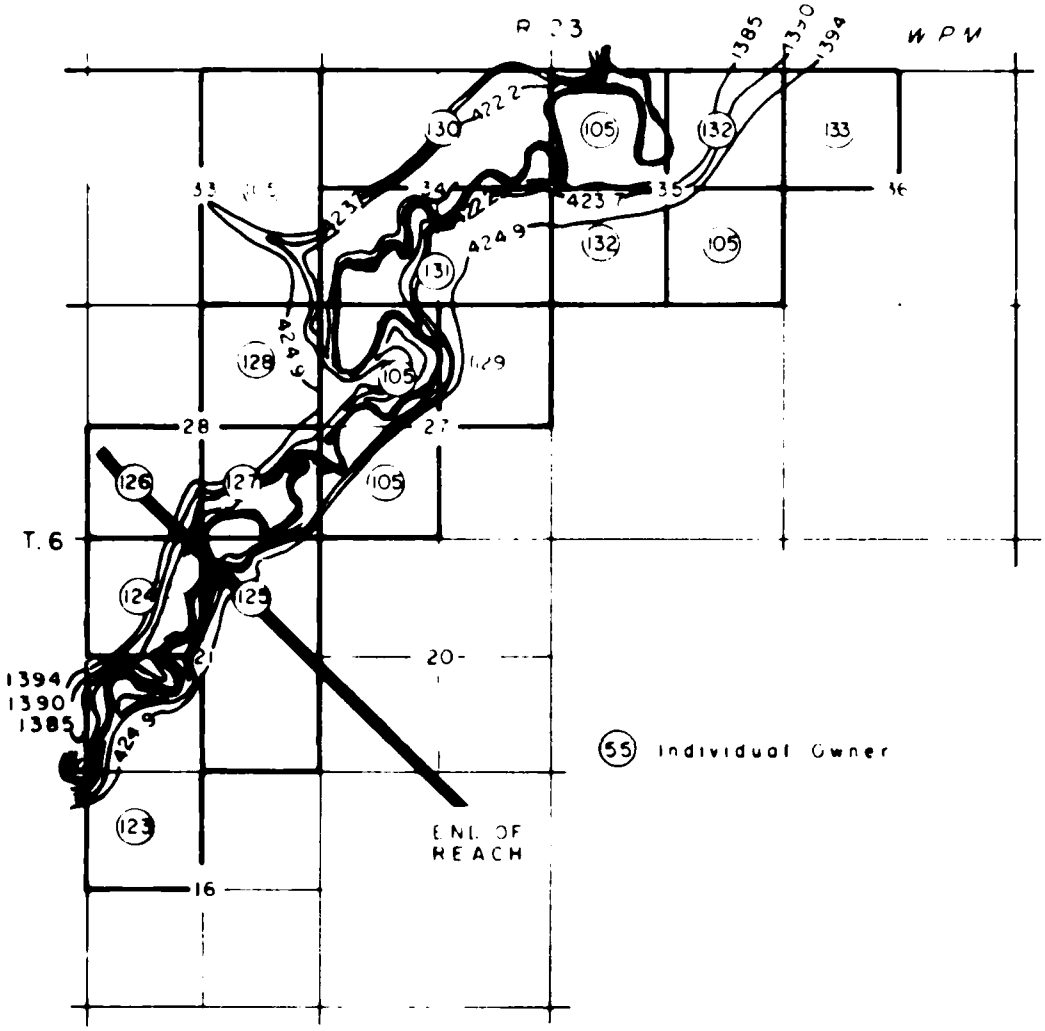

FIGURE C-8 : LAND OWNERSHIP PATTERNS
SOURIS RIVER VALLEY -
HARTNEY REACH

APPENDIX D

DISSOLVED OXYGEN CONCENTRATIONS IN THE NORTH DAKOTA PORTION OF THE SOURIS RIVER 1969-1978

APPENDIX D

DISSOLVED OXYGEN CONCENTRATIONS IN THE NORTH DAKOTA PORTION OF THE SOURIS RIVER 1969-1978

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TABLE D-1 Dissolved Oxygen Concentrations in the North Dakota Portion of the Souris River (1969-1978) D-1

Table D-1 Dissolved Oxygen Concentrations in the North Dakota Portion of the Souris River (1969-1[illegible])

DISSOLVED OXYGEN (mg/l) - SOURIS LOOP

DATE	STATION							
	Near Sherwood	Near Foxholm	W. of Mohall	At Minot	N. of Sawyer	Near Verendrye	At Towner	Near Westhope
69/02/06	-	-	-	-	-	-	-	0.0*
69/03/12	-	-	-	-	-	-	-	7.9*
69/03/27	-	-	-	-	-	-	-	8.5*
70/01/13	-	-	-	-	-	3.0	-	-
70/01/14	-	-	-	-	-	-	-	2.0
70/01/15	-	-	-	8.1	-	-	-	10.6*
70/02/04	-	-	-	7.4	-	-	-	4.1*
70/02/10	-	-	-	-	-	-	-	1.8
70/02/11	-	-	-	-	-	2.4	-	-
70/03/10	-	-	-	-	-	-	-	11.6
70/03/11	-	-	-	-	-	3.6	-	-
70/03/26	-	-	-	10.6	-	-	-	9.8*
71/01/07	-	-	-	14.1	-	2.3	9.3	12.7* 3.6
71/02/04	-	-	-	-	-	2.0	-	-
71/02/05	-	-	-	-	-	-	-	0.8
71/02/24	-	-	-	10.1	-	-	-	9.8*
71/03/09	-	-	-	-	-	5.0	-	-
71/03/11	-	-	-	-	-	-	-	12.0
71/03/26	-	-	-	10.8	-	-	-	14.5*
72/01/06	-	-	-	-	-	-	9.8	11.8*
72/01/07	-	-	-	10.7	-	-	-	-
72/02/03	-	-	-	-	-	5.0	-	-
72/02/04	-	-	-	-	-	-	-	-
72/02/25	-	-	-	6.4	-	-	4.8	7.6*
72/02/28	-	-	-	-	-	4.6	-	-
72/02/29	-	-	-	-	-	-	-	7.2
72/03/16	-	-	-	-	-	-	7.4	6.4*
72/03/17	-	-	-	7.6	-	-	-	-
72/03/30	-	-	-	-	-	9.9	-	-
72/03/31	-	-	-	-	-	-	-	12.0
73/01/09	-	8.4	-	-	-	-	12.2	10.8*
73/01/10	-	-	-	11.2	-	-	-	-
73/01/11	-	-	-	-	-	0.3	-	-
73/01/12	-	-	-	-	-	-	-	5.8
73/02/08	-	-	-	-	-	-	1.9	12.7*
73/02/09	-	-	-	11.2	-	-	-	-
73/02/28	-	14.3	-	-	-	4.5	-	-
73/03/01	-	-	-	-	-	-	-	15.8
73/03/15	-	-	-	-	-	-	9.6	10.4*
73/03/16	-	-	-	8.4	-	-	-	-
74/01/02	-	-	-	-	-	1.6	-	-
74/01/03	-	0.2	-	-	-	-	-	-
74/01/08	-	-	-	-	-	-	-	0.2
74/01/10	-	-	1.5	-	1.0	-	1.9	0.0*
74/01/30	-	-	-	-	-	1.6	-	-
74/02/01	-	0.2	-	-	-	-	-	-
74/02/05	-	-	-	-	-	-	-	-
74/02/08	-	-	-	-	7.1	-	-	-
74/02/27	-	8.6	-	-	-	-	-	-
74/02/28	-	-	-	-	-	-	-	-
74/03/05	2.6	-	-	-	-	-	-	-
74/03/11	-	-	-	-	-	-	-	0.0*
74/03/12	-	-	-	-	9.2	-	-	-
74/03/19	-	-	-	-	-	-	-	-
74/04/20	0.9	-	-	-	-	-	-	-
75/01/07	3.5	-	-	-	-	-	-	-
75/01/08	-	-	-	-	-	-	-	-
75/01/21	2.3	-	-	-	-	-	-	-
75/01/22	-		-	-	-	-	-	-
75/01/23		8.8	-	-	-	-	-	-
75/02/04	1.8	-	-	-	-	-	-	-
75/02/06	-	-	-	-	-	-	6.5	-
75/02/19	-	8.0	-	-	-	-	-	-
75/02/20	1.0	-	-	-	-	-	-	-
75/03/04	-	-	-	-	0.0	-	0.0	-
75/03/05	1.8	-	-	-	-	-	-	-
75/03/19	-	-	-	-	-	-	-	-
75/03/20	1.8	-	-	-	-	-	-	-
75/03/21	-	12.2	-	-	-	-	-	-

Table D-1 - Dissolved Oxygen Concentrations in the North Dakota Portion of the Souris River (1969-1978) (cont)

DATE	STATION							
	Near Sherwood	Near Foxholm	W. of Mohall	At Minot	N. of Sawyer	Near Verendrye	At Towner	Near Westhope
76/01/07	6.6	-	-	-	-	-	-	-
76/01/09	-	-	-	-	-	-	-	3.5
76/01/12	-	-	-	-	11.0	-	9.8	-
76/01/20	-	10.1	-	-	-	-	-	-
76/01/21	6.4	-	-	-	-	-	-	-
76/01/22	-	-	-	-	-	-	-	3.4
76/02/03	7.0	-	-	-	-	-	-	-
76/02/04	-	-	-	-	-	-	-	3.6
76/02/09	-	-	-	-	11.2	-	9.6	-
76/02/18	-	-	-	-	-	-	-	3.4
76/02/19	7.0	-	-	-	-	-	-	-
76/02/20	-	12.2	-	-	-	-	-	-
76/03/03	-	-	-	-	-	-	-	3.5
76/03/04	10.0	-	-	-	-	-	-	-
76/03/08	-	-	-	-	2.3	-	2.0	-
76/03/17	-	-	-	-	-	-	-	2.5
76/03/18	11.4	-	-	-	-	-	-	-
76/03/26	-	11.7	-	-	-	-	-	-
76/03/30	11.1	-	-	-	-	-	-	-
76/03/31	-	-	-	-	-	-	-	6.5
77/01/04	0.2	-	-	-	-	-	-	9.6
77/01/13	-	-	-	-	6.9	-	-	-
77/01/18	0.4	-	-	-	-	-	-	-
77/01/19	-	-	-	-	-	-	-	9.3
77/01/20	-	10.4	-	-	-	-	-	-
77/02/01	0.0	-	-	-	-	-	-	11.0
77/02/03	-	-	-	-	7.9	-	-	-
77/02/15	-	-	-	-	-	-	-	19.3
77/02/16	0.0	-	-	-	-	-	-	-
77/02/17	-	10.6	-	-	-	-	-	-
77/03/01	1.3	-	-	-	-	-	-	15.0
77/03/03	-	-	-	-	6.4	-	-	-
77/03/22	-	-	-	-	-	-	-	22.5
77/03/23	13.0	-	-	-	-	-	-	-
77/03/25	-	16.0	-	-	-	-	-	-
78/01/05	-	-	-	-	-	-	-	1.3
78/01/06	4.4	-	-	-	-	-	-	-
78/01/17	4.3	-	-	-	-	-	-	-
78/01/18	-	-	-	-	-	-	-	0.0
78/01/19	-	2.0	-	-	-	-	-	-
78/02/08	-	-	-	-	-	-	0.0	-
78/02/10	2.1	-	-	-	-	-	-	0.0
78/02/21	-	0.2	-	-	-	-	-	-
78/02/22	-	-	-	-	-	-	-	0.0
78/02/23	2.4	-	-	-	-	-	-	-
78/03/07	-	-	-	-	-	-	-	0.0
78/03/10	2.2	-	-	-	-	-	-	-
78/03/15	-	-	-	-	-	-	0.0	-
78/03/23	6.8	8.8	-	-	-	-	-	-
78/03/24	-	-	-	-	-	-	-	1.5

* data collected by North Dakota Health Department

All other data collected by USGS

END

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