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DETAILED PROJECT REPORT ON FLOOD CONTROL

FOR

BLACK RIVER
CHEBOYGAN COUNTY,
MICHIGAN

U. S. ARMY ENGINEER DISTRICT, DETROIT
CORPS OF ENGINEERS
DETROIT, MICHIGAN

1965

DETAILED PROJECT REPORT ON FLOOD CONTROL
FOR
BLACK RIVER, CHEBOYGAN COUNTY

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U. S. ARMY ENGINEER DISTRICT, DETROIT
CORPS OF ENGINEERS
150 MICHIGAN AVENUE
DETROIT, MICHIGAN

NCEED-B

SUBJECT: Detailed Project Report on Flood Control for Black River, Cheboygan County, Michigan

TO: Division Engineer
U. S. Army Engineer Division, North Central

INVESTIGATION AUTHORITY AND SCOPE

1. This Detailed Project Report for Black River was authorized by second indorsement of OCE, dated 25 January 1963, pursuant to Section 205 of the 1948 Flood Control Act as amended (Public Law 685, 84th Congress). The problem was brought to the District Engineer's attention jointly by Senator Hart and the Michigan Water Resources Commission. Formal request for a flood control study was also contained in letters from Presque Isle and Cheboygan County Boards of Supervisors.

2. This report is of design memorandum scope. All known flood problems occurring in the Black Lake area were considered during studies made for this report. Local, state, and interested Federal agencies hav been consulted during these studies to insure proper consideration had been given of their views. Coordination with these agencies is discussed further in subsequent paragraphs.

PRIOR REPORTS

3. No previous flood control or navigation projects have been considered at Black Lake or Black River under Public Law 685 or any other Federal authority.

4. A report on the flood problem at Black Lake was published in 1947 by the Michigan Department of Conservation which recommended improving about one mile of channel in the Black River between the Alverno Dam a Black Lake. However, as yet, local interests have not constructed the Department's recommended improvements and no definite plans are known for constructing them.

5. Two separate reports on Black Lake were made by United Associates, Inc. of Cheboygan, Michigan and by Professor C. O. Wisler of the University of Michigan. Both reports dealt with the possible effect that the operation of the Kleber Dam had upon the fluctuation of the level of Black Lake during the 1960 period of high water. The Kleber Dam is located on the Black River upstream from Black Lake.

6. DESCRIPTION OF THE AREA

The Black River drainage basin lies in the extreme northern part of the lower peninsula of Michigan. Black Lake occupies a midpoint position in the pattern of Black River and its tributaries and acts as a natural stabilizing influence on downstream discharges. Black Lake is oriented in a northwest-southeast direction with a length slightly greater than six miles and a maximum width of 3-3/4 miles. Black Lake has a total water surface area of approximately 15-1/2 square miles. The lake is fed by Rainy and Black Rivers and by several small creeks which rise within a mile or two of its shores. The total drainage area of Black Lake at its outlet is 597 square miles. The outlet of Black Lake is Black River which flows in a northwesterly direction for a distance of about ten miles to join the Cheboygan River. Water levels in the upstream portion of this stretch including Black Lake are controlled by Alverno Dam, located about 5-1/2 miles downstream from the lake, and by "Smith's Rapids", located about midway between the dam and the lake. The present owner of Alverno Dam, Consumers Power Company, is negotiating with Cheboygan County on the Company's proposed transfer of the dam and associated facilities to the County. A condition of the transfer proposal would preclude further electrical generation at the site.

7. Upstream from the confluence with the Cheboygan River for 2-1/2 miles, the river is wide and deep, gradually shoaling. Above this point, aquatic plants make it difficult for even shallow draft boats to traverse the remaining 2-3/4 miles to Alverno Dam. A marine railway at Alverno Dam is maintained by the Consumers Power Company which provides access to the pool above the dam. The waters above the pool, including the river and Black Lake, are uncharted but can be navigated with caution.

8. ECONOMIC DEVELOPMENT

The Black Lake shore line varies from low ground on the west side to high banks on the east side of the lake. The market value of shore line property varies from about $35 to $75 per foot of frontage. Filling of the lowland is usually required before it can be developed. Most of the beaches are sandy although some stony areas are located on the southeast side of the lake. A total of about 340 cottages and homes along the lake shore were shown on U. S. Geological Survey maps dated 1957. The damage studies conducted in 1963 listed 497 structures within the same area. Most of these were summer cottages although some all-year homes were present and more all-year homes are being built each year. The completion of new state and interstate highways have and will continue to increase the rate of growth around this and other lake areas in the northern part of Michigan. There appears to be a very definite trend towards the more expensive year-around home. The Black Lake State Forest surrounds the lake, except for the northwestern and southernmost tips. Onaway State Park is located on the southern tip of the lake and offers camping, picnicking, swimming, and boat launching facilities.

9. CLIMATOLOGY

The climate of the area is influenced mainly by the latitude and by the Great Lakes. The lakes have a stabilizing effect on temperature which produce cooler springs, longer autumns, and more evenly distributed precipitation throughout the year in comparison to other areas of equal latitude. See appendix A for climatological records.

10. STREAM FLOW DATA

Presently, the U. S. Geological Survey operates three stream gaging stations in the Black River basin. One station located on the lower Black River serves the dual purpose of both a lake stage recorder for Black Lake and a river discharge recorder. The other two stations are located on the upper Black River and the Rainy River. These three gages along with most of the other stream gages in the Cheboygan River basin were installed in the fall of 1942.

11. The average annual outflow for Black Lake has been 421 cfs for the period of record. The recorded high was 2,500 cfs on 20 April 1960 and the low was 11 cfs on 14 August 1949.

12. FLOODS OF RECORD

In the period since 1942, the most significant periods of high lake stage have occurred in 1943, 1951, 1952, and 1960. There is no record of any flood prior to this date, but it appears that this is due to lack of development on the lake and, consequently, lack of interest in lake levels, and not an absence of flood stages. Pertinent data regarding the available stream flow records are summarized in table A-1.

13. FLOOD FREQUENCIES

A stage-frequency relationship based on lake inflows and calculated lake stages was adopted for Black Lake. All attempts to assign frequencies to observed lake stages were of no avail due to the varying effects of lake regulation over the years and to a lesser extent the natural variations between floods. The Alverno Dam was operated primarily for power production and only in recent years has the operation been modified to consider lake level regulation. Also, it is not known to what degree lake level regulation is practiced in the present dam operation. Details of the frequency studies are in appendix A.

14. STANDARD PROJECT FLOOD

An estimate of the standard project flood was made for the drainage area contributing to Black Lake in accordance with instructions contained in Civil Engineer Bulletin No. 52-8 titled "Standard Project Flood Determinations." This estimate was obtained by applying standard project rainfall values to an inflow unit hydrograph developed for Black Lake. The estimate peak inflows to the lake resulting from the standard project flood was about 22,500 cfs and would have a recurrence frequency of approximately once in 850 years. Details of this estimate are in appendix A.

15. PROJECT DESIGN FLOOD

Lake levels and stream discharge records have been maintained on Black Lake and River since 1942. Legal summer and winter lake elevations of 612.2 and 610.5 respectively have been established by a State court decree. The existing channel has an approximate discharge capacity of 800 cfs at lake elevation 612.2 and the considered improved channel has a discharge capacity of 1,650 cfs at the same lake elevation. The recorded high discharge is 2,500 cfs which occurred on 20 April 1960 and it resulted from a high lake stage elevation of 615.0. Under the considered improved channel conditions, the 2,500 cfs discharge would occur at a lake stage elevation of 614. Information on other stage and discharge records are available in appendix A.

16. FLOOD LOSSES

Flood damages around Black Lake are due to high lake stages, winds and/or wind blown ice. Some beach erosion and tree damage can occur at lake levels below the legal summer stage of 612.2. While the lake stages are between elevations of 612.2 and 613.5, beach erosion and tree damages may occur if waves are present. Cottage damage due to the high lake stages only begin at elevation 613.5. The damage estimate for the recurrence of the 1960 high water elevation of 615 was $70,500. It was also estimated that $420,000 of damages would be sustained should the lake reach elevation 617. During the 1960 high water period, several houses beside the lake were damaged by ice that was piled up on the beach by wind. This condition caused approximately $18,000 in building damages which was not included in the $70,500 damage estimate because of the unpredictable nature of wind blown ice. Additional losses have been sustained by property owners who were not on hand immediately after a high water period to salvage and cleanup their property.

17. EXISTING FLOOD CONTROL PROJECTS

No Federal projects exist on Black River or Black Lake.

18. IMPROVEMENTS DESIRED

The improvements desired were set forth in the form of recommendations made in a report by the Michigan Department of Conservation, dated 5 September 1947. This report recommended some channel improvement and that the Alverno Dam be operated as a lake level control structure. The lake would be maintained at a lower level throughout the winter months to help handle the large volume of spring runoff at a lower lake stage. Local interests also desired an improved river channel through a constriction in the river called "Smith's Rapids." Channel improvement would improve the dam's regulatory ability, especially during low lake levels. The channel bottom width recommended by the Conservation Department was 70 feet. Recently the Consumers Power Company who now operate the dam decided to dispose of the dam because it is not needed for electric power production. Therefore, lake level regulation would be the only consideration in further usage of the dam.

19. SOLUTIONS CONSIDERED

The general methods considered either singly or in combination for reducing the flood problems at Black Lake included impounding flows in upstream reservoirs, regulation of Alverno Dam, levees, evacuation of damage areas, diversion, and channel improvement. Detailed information on the consideration given to the above methods are given in appendix A.

20. DESIGN CONSIDERATIONS

a. Soil Conditions.- Investigations indicated that the soils in the considered channel excavation zone will require special treatment. The present channel is analogous to a riprapped channel in that once the surface layer is removed, the channel would be subject to scour and erosion during periods of high flows. Sufficient channel erosion could shift the high flow control from the channel to Alverno Dam. Detailed soil information is presented in appendix B.

b. Hydraulic Design.- Presently, the Alverno Dam controls the Black Lake's stages and discharges in the lower flow range. In the higher flow ranges of 1,500 cfs and upward, the constrictive channel conditions between the dam and the lake restrict the lake outflow which causes the higher lake stages. It was considered desirable to increase the channel discharge capacity for lower lake stages and to retain the channel control during the higher flow ranges. The detailed hydraulic information is presented in appendix A.

21. PLAN OF IMPROVEMENT

The plan of improvement considered to be most feasible for Black River consists of channel improvement through Smith's Rapids. The 1.2 miles of improved channel would have a design bottom slope of 0.0004, a bottom width of 100 feet, sideslopes of two horizontal to one vertical and two stone sills to control channel bottom erosion. Local interests would be required to operate the Alverno Dam as a lake level control structure in accordance with the established legal lake levels. The change in channel and lake conditions would be as shown in table 1.

Table 1

LAKE STAGE AND FREQUENCY RELATIONSHIPS

	Black Lake stage	Exceedence interval (yrs)	
		Existing conditions	Improved conditions
(Legal summer level)	612.2	1.2	3
(Start of major damage)	613.5	3	12
(1960 high water stage)	615.0	18	50

22. SOURCES OF CONSTRUCTION MATERIALS

Since the quantity of construction materials is small, no investigation has been conducted. However, steel sheet piling is known to be available in the Detroit area and stone is available from stone quarries at Bayport or Alpena, Michigan.

23. REAL ESTATE REQUIREMENTS

Minor amounts of land will be necessary for the construction of the improved channel through Smith's Rapids. Local interests have indicated their ability to furnish all lands, easements and rights-of-way necessary for the construction of the project and for operation and maintenance of the project after completion. The proposed taking lines for permanent rights-of-way are shown on plates 2 thru 5. The temporary spoil disposal easement areas are shown on plate 1. The estimated cost thereof is included in the detailed cost estimate contained in appendix D.

24. MULTIPLE-PURPOSE FEATURES

The flood control plan of improvement on the Black River as described herein has the single purpose of flood control and has no other water use features which could be effectively developed.

RECREATIONAL DEVELOPMENT

25. There would be no Federal recreational development associated with the considered plan of improvement on the Black River.

ESTIMATE OF FIRST COST

26. The estimate of first cost for the considered plan of improvement on the Black River is summarized in table 2. The estimates are based on 1965 price levels and include 15% contingency allowances for construction items, 10% contingency allowances for land purchases and 12% contingency allowances for dredging. Additional details, including an itemized cost breakdown are included in appendix D.

Table 2

ESTIMATE OF FIRST COST

FEDERAL COST		
Channels		
Clearing, 5 acres @ $400/acre	$ 2,000	
Excavation, earth 59,500 cu. yds. @ $2.40/cu. yd.	142,800	
Contingencies	17,400	
Structures		
Sills	57,400	
Contingencies	8,600	
Contract cost		$231,200
Engineering and design		
Surveys	5,000	
Subsurface investigations	9,000	
Preparation of Detailed Project Report	38,500	
Real Estate investigations of local assurances	3,500	
Preparation of plans and specifications	11,500	
Subtotal, engineering and design		67,000
Supervision and inspection	23,800	
Subtotal, supervision and inspection		23,800
Total Federal first cost		$322,000
NON-FEDERAL COST		
Lands		
Right-of-way - easements	38,200	
Contingencies	3,800	
Total lands		42,000
TOTAL FEDERAL AND NON-FEDERAL FIRST COSTS		$364,000

ESTIMATES OF ANNUAL CHARGES

27. Annual charges for the proposed plan of improvement are computed on the basis of an interest rate of 3-1/8 percent on Federal and 3-1/8 percent on non-Federal costs, with a 50-year life for amortization. Interest charges for the construction period are not included since construction time is expected to be less than two years. An annual maintenance charge, consisting primarily of cost related to anticipated routine cleanouts of the improved channel, is included. The annual charges are presented in table 3, and additional details are given in appendix D.

Table 3

AVERAGE ANNUAL CHARGES

Item	Federal	Non-Federal	Total
Investment costs(1)	$322,000	$42,000	$364,000
Annual charges			
Interest	10,060	1,310	11,370
Amortization	2,750	360	3,110
Maintenance		500	500
Total annual charges	$ 12,810	$ 2,170	$ 14,980

(1) Detailed project study cost of $38,500 is included.

ESTIMATES OF BENEFITS

28. There were about 340 structures located near the lake in 1957. Most of these were summer cottages although some all-year homes were present and more all-year homes are being built each year, that would be protected by the proposed improvement works. All-year residences in this area consist of moderately priced dwellings.

29. Flood control benefits resulting from the considered plan of improvement are estimated as the difference between the spring time losses that would occur under existing conditions and the spring time losses that would occur after construction of the project. These benefits were adjusted to include the growth in damages that is expected in the area exposed to flooding. This growth will occur primarily in residential developments on the presently vacant lands which will result in higher damage potential. It is estimated that during the assumed project life of 50 years this development, even without the construction of the proposed improvements, will add 44 percent more damages to those existing.

The growth benefits were discounted at an interest rate of 3 percent and were based on an estimated growth pattern for the 50-year period. The estimated benefits are presented in table 4 and the details pertaining to their derivation are presented in appendix C.

Table 4

AVERAGE ANNUAL BENEFITS

Price and physical development levels of January 1965

Average annual damage	Residual damage	Average annual benefits	Adjusted average annual benefits
$38,300	$13,300	$25,000	$31,900

30. These benefits result from the reduction of damages caused by direct inundation and beach erosion occurring during spring high lake levels. However, the summer and fall flood damages were not used in this study since it would be very difficult to estimate the frequency of these event: and the unrelated operation of Alverno Dam. Damages caused by high lake levels at peak inflows would be reduced but not eliminated because modification of the dam to increase its present capacity was not economically feasible at this time.

31. INTANGIBLE BENEFITS

Lowering the lake stages during the period of the spring breakup when ice is still present in the lake will reduce the possibility of ice being pushed up the beach by wave and wind action. Ice damage to houses beside Black Lake in 1960 amounted to about $18,000.

32. Additional intangible benefits would occur by eliminating the need t evacuate homes during most flood periods. Damp living quarters, contaminated wells, and flooded septic tanks which add to the health hazards would be reduced. There would be fewer instances of inconvenience which result when high water obstructs a flooded area. It is not possible to assign a monetary value to these intangible benefits. However, the cite benefits are important to the health and welfare of local residents.

33. OTHER BENEFITS CONSIDERED

An investigation was made to determine if the considered channel improvement works would result in additional benefits such as land enhancement, increased navigation, and related items. After careful analysis of the problem area, it was concluded that there would be no additional benefits.

PROJECT FORMULATION AND ECONOMIC JUSTIFICATION

34. Project formulation studies were made to determine the method and degree of protection which would provide the most effective and economical means of providing flood protection in the Black River area. After consideration of the alternative methods of protecting the principal damage area (reservoir storage and modification of the Alverno Dam), it appeared that the most feasible plan would be to increase the capacity of the channel through the Smith's Rapids section of the Black River to provide for more positive control of the lake.

35. Project formulation studies were carried out to determine the optimum project. Further description and data on these studies are presented in appendix C. The channel design was selected based on careful consideration of the flow, the degree of protection afforded, and the cost of project compared with the corresponding benefits. Since the considered project would increase the exceedence interval of the 1960 flood of record from 18 years to 50 years, the degree of protection selected represents a sound basis of design for this area. The benefit-cost ratio for the selected degree of protection would be 2.1 to 1.

ALLOCATION OF COSTS AMONG PURPOSES

36. The proposed Black River channel improvement has the singular function of alleviating flood damages in the problem areas around Black Lake. Consequently, all project costs would be allocated to flood prevention.

APPORTIONMENT OF COSTS AMONG INTERESTS

37. The initial cost of improving the Black River between Black Lake and Alverno Dam has been apportioned between Federal and non-Federal interests in accordance with existing legislation. Federal costs for this flood protection project would include the expense for channel excavation and the cost of construction of sills in the Black River. Non-Federal interests would bear the cost of lands, easements, and rights-of-way and of utility relocations required for the construction of the considered project. Maintenance of the improvement would be the responsibility of local interests. Apportionment of the considered improvement costs is summarized in table 5 and additional details are presented in appendix D.

Table 5

APPORTIONMENT OF PROJECT COSTS

	First costs	Annual maintenance
Federal (including detailed study costs)	$279,500	
Non-Federal	42,500	$500
Total	$322,000	$500

SCHEDULE FOR DESIGN AND CONSTRUCTION

38. DESIGN

Pending approval of the considered project, the design, plans and specifications could be accomplished during the third and fourth quarters of FY 1966.

39. CONSTRUCTION

If construction funds are received for Black River for FY 1967, construction would be initiated in mid-summer of 1966 and completed in the fall of 1966. All flood control works at Black River will be accomplished by contract.

40. FUNDS

Funds available and currently recommended for the project are as follows:

Allotment to date	$ 38,500
Funds required in FY 66	28,500
Funds required in FY 67	255,000

Funds allotted to date include construction general funds in the amount of $38,500, all of which has been expended for this detailed project report. The funds recommended for FY 1966 and 1967 in the amount of $283,500 are considered sufficient to complete the project at Black Rive The above funding schedule does include funds for the remaining detaile preconstruction planning.

OPERATION AND MAINTENANCE

41. GENERAL

The local cooperating agency for the Black River flood control project will be responsible for the operation and maintenance of flood control features of the project. The Corps of Engineers will prepare and issue an Operation and Maintenance Manual for the project area when construction thereof is completed and the project is turned over to the local responsible agency. The maintanance requirements for the project in general are briefly described in paragraph 42.

42. MAINTENANCE

The estimated costs for operation and maintenance of project is given in table 5. The project is to be maintained to the design condition to insure operation as intended. The maintenance will consist primarily of removing any shoaling or other obstructions in the excavated channel to insure proper operation at all times.

43. OPERATION

Operation of the project for flood control will be accomplished by local interests in accordance with the Operation and Maintenance Manual referred to in paragraph 41 above.

COORDINATION WITH OTHER AGENCIES

44. Representatives of the District Engineer examined the study area and conferred with local officials before and after improvement plans were developed. The Michigan Water Resources Commission which serves as the Governor's representative on matters that are related to flood control was kept informed throughout the course of the study. However, the Commission is not empowered with the authority to guarantee assurances required from local interests under existing state legislation. Consequently, in Michigan, it is necessary to obtain assurances from the local government unit which has jurisdiction over the area which would directly benefit from a project.

45. A public meeting was held on 7 June 1965 to outline the results of the detailed project study to all interested parties. Persons attending the meeting represented the Cheboygan and Presque Isle County Boardsof Supervisors, Michigan Water Resources Commission, Michigan Conservation Department, Consumers Power Company (owner of Alverno Dam), Black Lake Association, the Cheboygan and Presque Isle County Prosecutors, and others. No objections to the proposed plan of improvement were voiced during this meeting. Letters have been received from the local cooperating counties stating that the proposed proposed project is generally

acceptable, and that the "Counties have the ability to cooperate with the Federal government and would be willing to do so." The complete letters are included in appendix E to this report.

46. Comments concerning the considered plan of improvement were solicited from other interested Federal and state agencies including the U. S. Fish and Wildlife Service, U. S. Geological Survey, U. S. Public Health Service and Michigan Water Resources Commission. No adverse comments have been received and the replies are presented in appendix E. The U. S. Fish and Wildlife Service

Suggestions and opinions of others were considered and incorporated into the improvement plan whenever this was possible. The considered plan of improvement is similar to one proposed by the Michigan Department of Conservation in their 1947 report. The U. S. Department of Agriculture is aware of the plan in conjunction with the Soil Conservation Service watershed development projects.

DISCUSSION

47. High lake stages, winds, and/or ice have caused severe flood damage around Black Lake. Damages have been sustained by buildings, trees, and beaches in this area. Due to the unpredictable nature of the ice damage to the buildings around the lake, no benefits were credited to the considered project for the reduction of this type of damage. Beach erosion damages occur when high lake stages are accompanied by high winds. The problem in the Black Lake area appears to be due mainly to inadequate lake outlet capability for controlling the lake level. Although the Alverno Dam provides some control, inadequate channel capacity through the Smith's Rapids area which is upstream from the dam prevents the lake from being drawn down during periods of high inflow into the lake.

48. Consideration was given to improvement plans which would utilize reservoirs and lake regulation. Consideration was also given to providing an improved channel through the Smith's Rapids area and to increasing the spillway capacity of the Alverno Dam. The cost of dam modifications and channel improvement could not be economically justified. Therefore, it was determined that the most suitable improvement plan would consist of improving about 1.2 miles of river channel through the rapids area.

49. Several schemes of channel improvement were investigated and it was determined that the 100-foot bottom width channel would afford the maximum degree of protection. The considered plan of protection would eliminate about 65 percent of the flood and beach erosion damages in the Black Lake area. The average recurrence interval above legal lake elevation would be increased from 1.2 years to 3 years. Also, the recurrence interval of building damages and of the maximum lake stage of record would be increased from 3 years to 12 years and from 18 years to 50 years, respectively. These conditions served as a basis for estimating the annual damages and benefits. In recognition of the residual threat, local interests should recognize the possibility of high lake stages on Black Lake after construction of the improvements.

50. The total first cost of the improvement plan is estimated to be $364,000 (inclusive of $38,500 detailed project report costs), of which $322,000 would be a Federal cost. In return for the benefits they would receive from the project, local interests would be required to furnish any lands and rights-of-way and to maintain the project. It is estimated that the non-Federal first cost would amount to $42,000 and that the project maintenance costs would average $500 per annum.

CONCLUSIONS

51. The plan of improvement considered the most suitable consists of improving the Black River through the rapids area. This plan would eliminate substantial damages in the Black Lake area caused by high stages on Black Lake. Since the estimated annual benefits would exceed annual charges by about 110 percent, the proposed plan of improvement is economically justified. It is recognized that the proposed improvements will only reduce the recurrence intervals of the high lake stages and serious damage can occur even with the proposed improvements.

RECOMMENDATIONS

52. It is recommended that a Federal project be authorized for flood protection along Black Lake which consists of widening and deepening about 1.2 miles of channel through the Smith's Rapids section of the Black River and the installation of two channel erosion control sills as described in this report, at an estimated Federal first cost of $322,000. The recommendation for construction of this project is contingent upon the provision that no funds be expended by the United States until local interests have given assurances satisfactory to the Secretary of the Army that they will without cost to the United States:

a. Provide all lands, easements, and rights-of-way required to complete the project.

b. Hold and save the United States free from damages incidental to construction of the project.

c. Maintain and operate the Alverno Dam and the project after completion in accordance with regulations prescribed by the Secretary of the Army.

d. Modify or relocate water lines, sewers, utilities, and other facilities where necessary for the construction of the project.

e. Prevent any encroachments on the project flood channel which would decrease the effectiveness of the flood control improvements. If the capacity is impaired, promptly substitute capacities necessary to restore the effectiveness of the flood control project.

EDWARD C. BRUCE
Colonel, Corps of Engineers
District Engineer

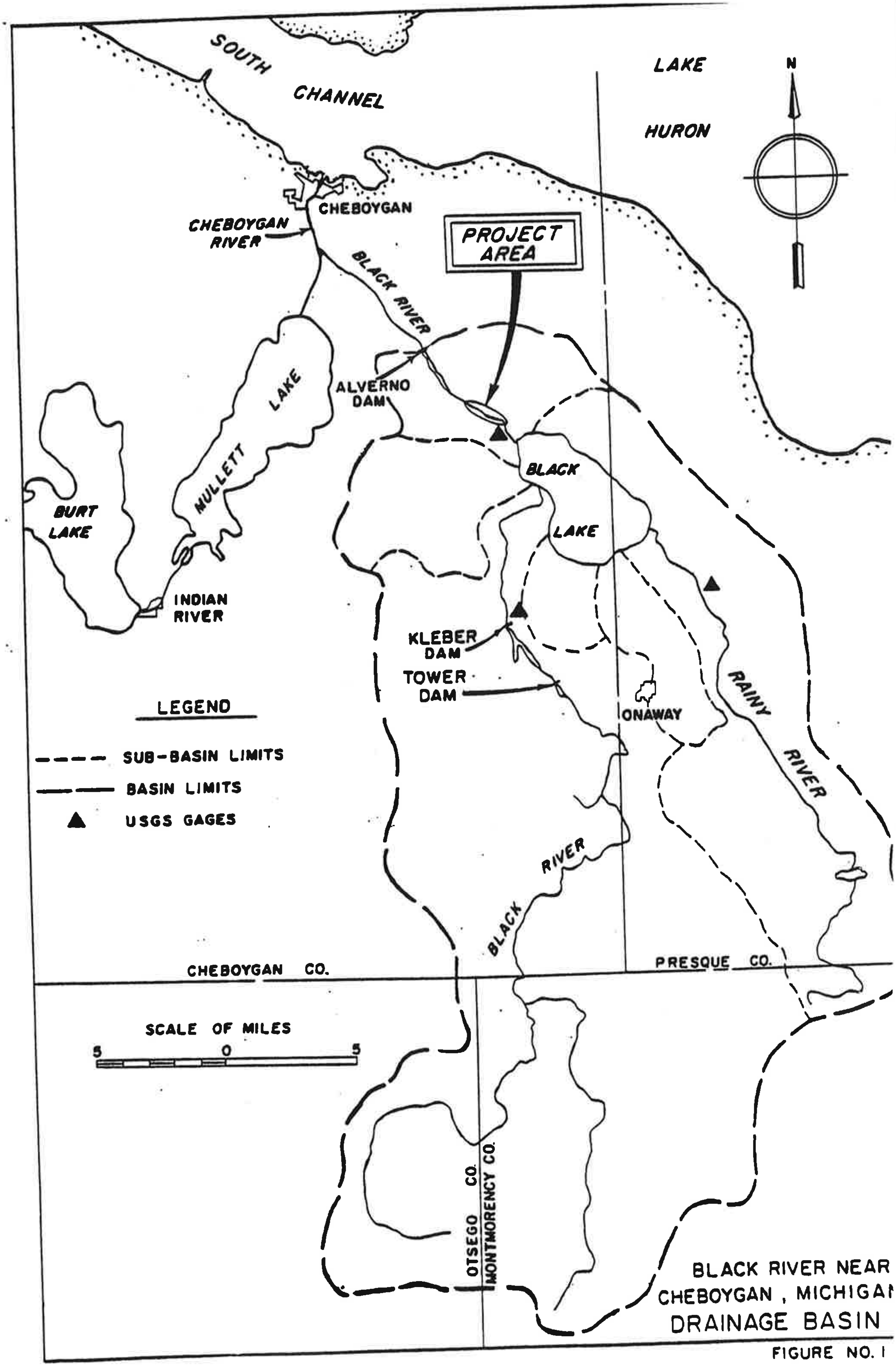
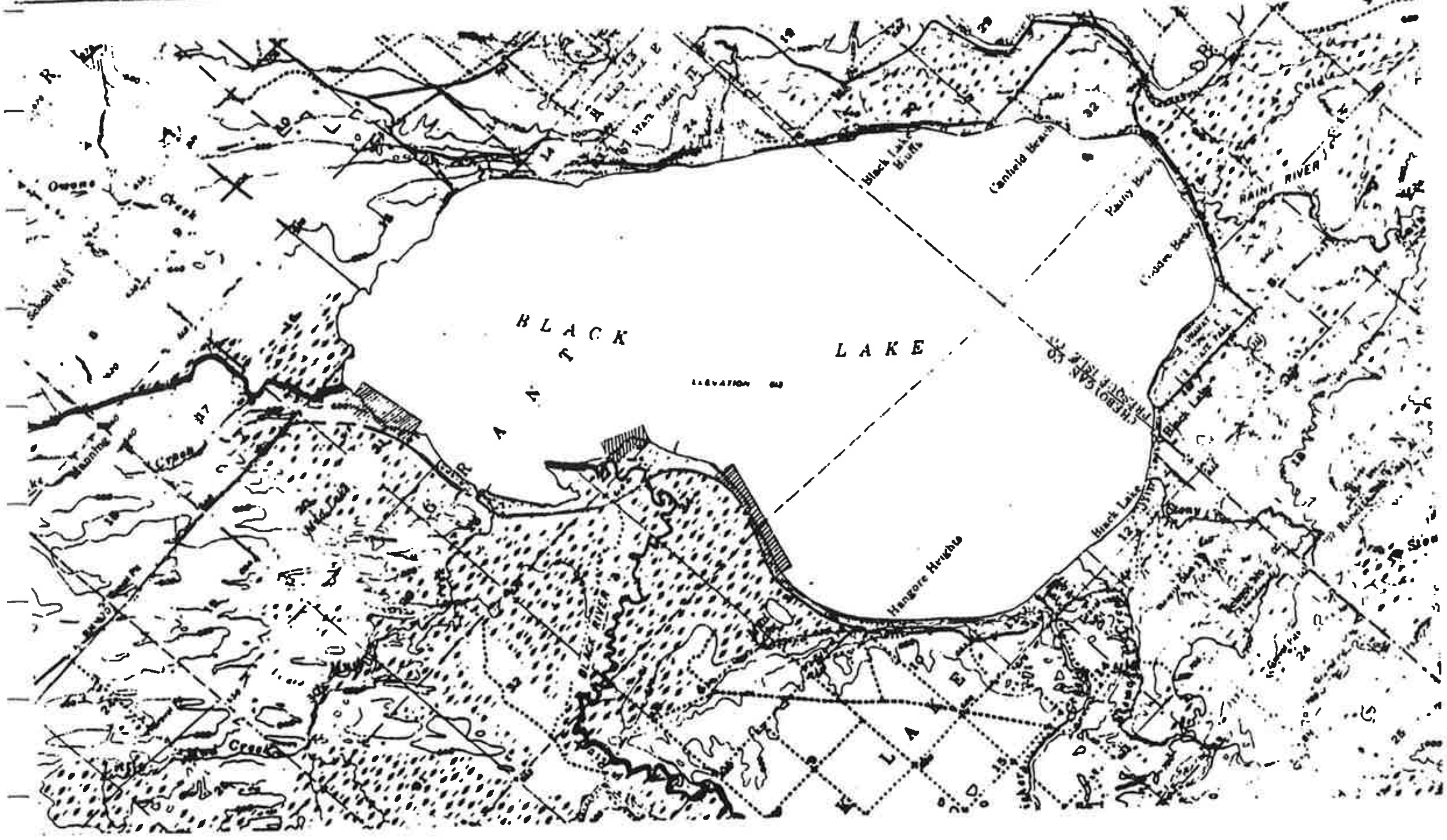
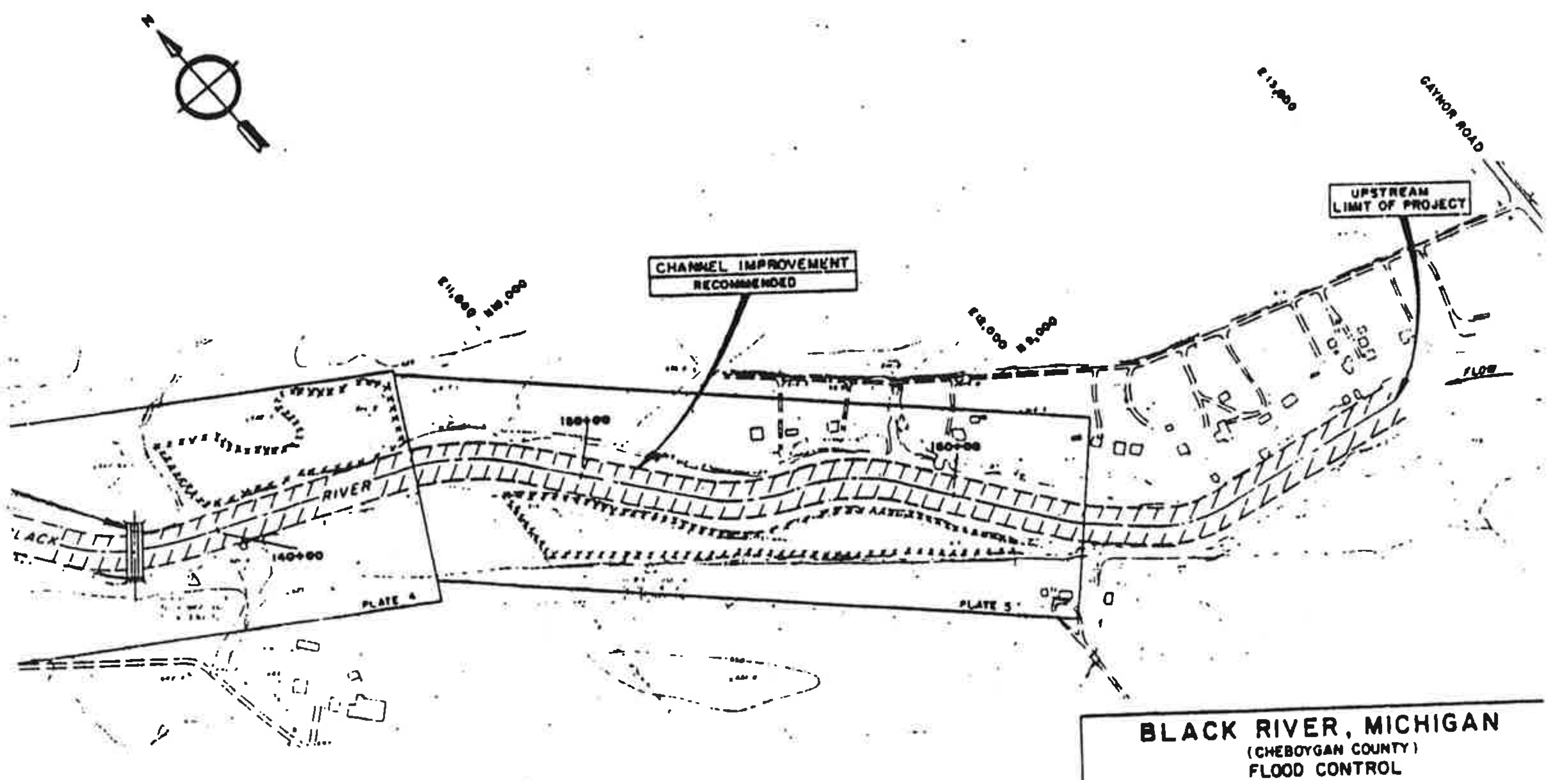

SOUTH CHANNEL
LAKE HURON
N
CHEBOYGAN
CHEBOYGAN RIVER
PROJECT AREA
BLACK RIVER
MULLETT LAKE
ALVERNO DAM
BURT LAKE
BLACK LAKE
INDIAN RIVER
KLEBER DAM
TOWER DAM
ONAWAY
RAINY RIVER
LEGEND
SUB-BASIN LIMITS
BASIN LIMITS
USGS GAGES
BLACK RIVER
CHEBOYGAN CO.
PRESQUE CO.
SCALE OF MILES
5 0 5
OTSEGO CO.
MONTMORENCY CO.
BLACK RIVER NEAR CHEBOYGAN, MICHIGAN
DRAINAGE BASIN

FIGURE NO. I





LEGEND

- CHANNEL IMPROVEMENT
- SPOIL DISPOSAL AREA
- FLOOD DAMAGE TO HOUSES DURING 1960 HIGH WATER

SCALE OF FEET

100 0 100 200 300 400 500 600 700 800 900

BLACK RIVER, MICHIGAN

(CHEBOYGAN COUNTY)

FLOOD CONTROL

PLAN OF IMPROVEMENT

In 1 Sheet Sheet No. 1 Scale as

U S Army Engineer District, Detroit

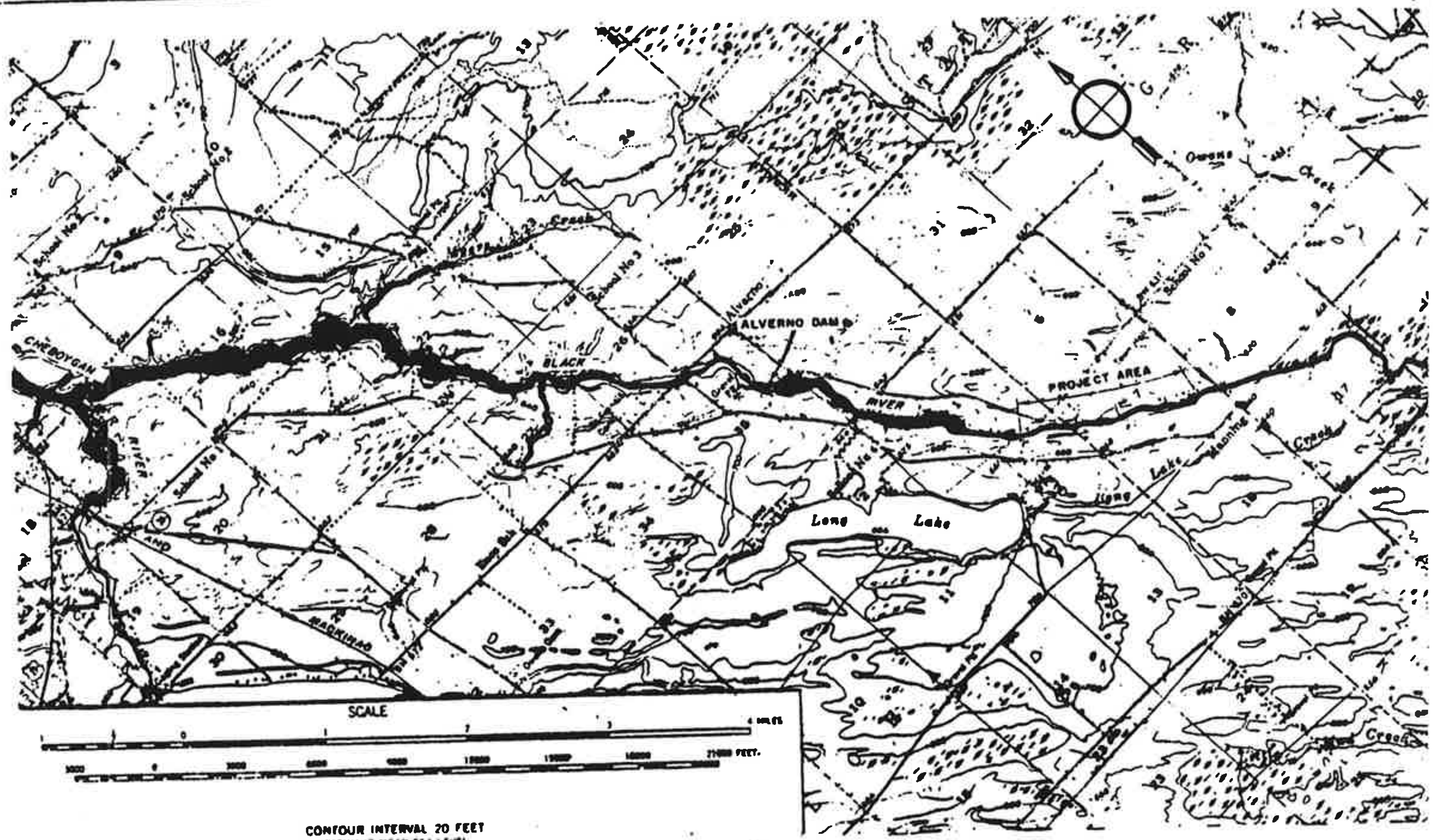
Submitted Recommended Approved

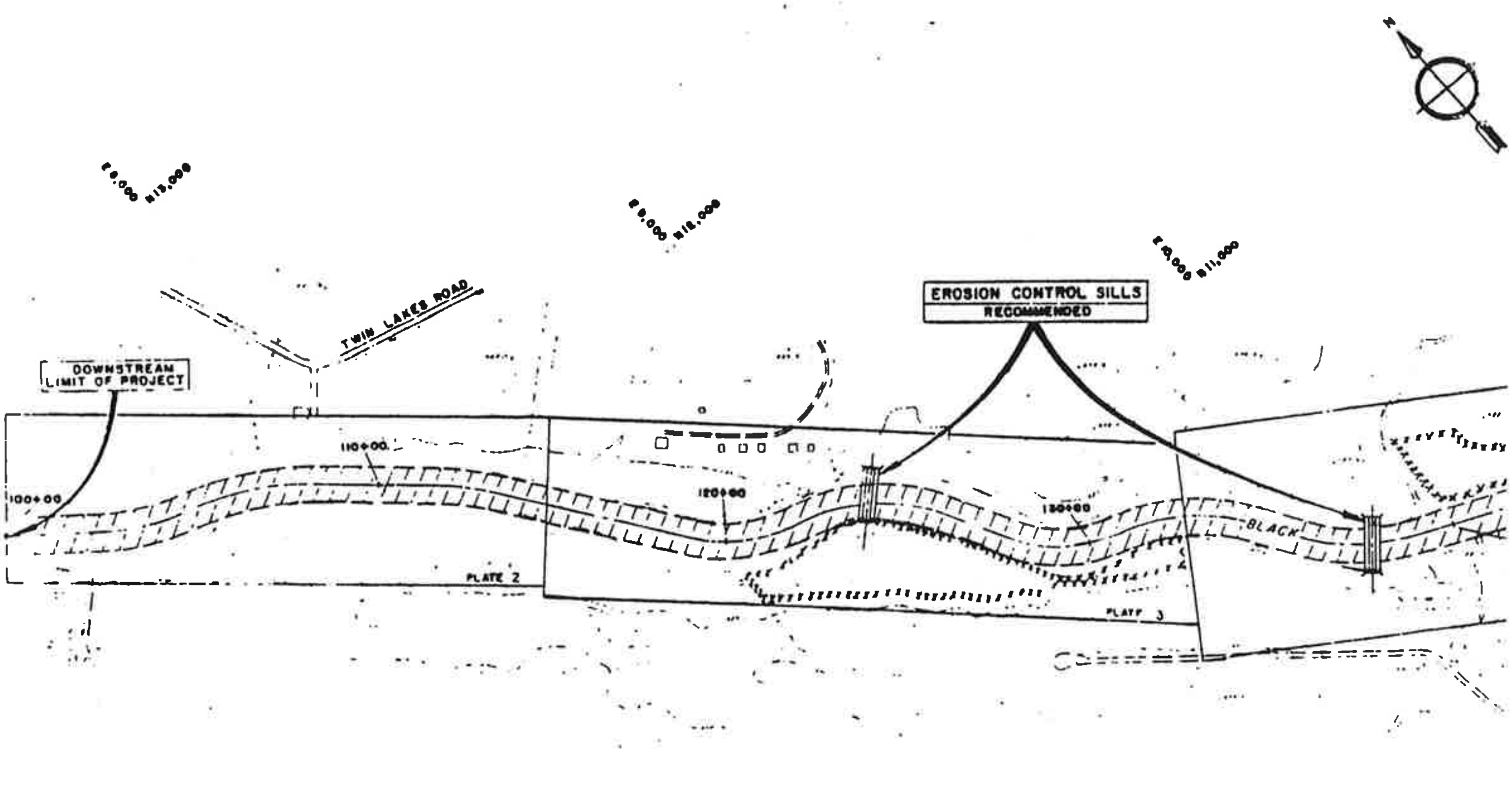
Chief, Basin Planning and Project Planning Branch Chief, Engineering Division. Col. C.E. District

Drawn by JPB File No To Accompany Detailed Pro

Checked by JES Report Dated 1960

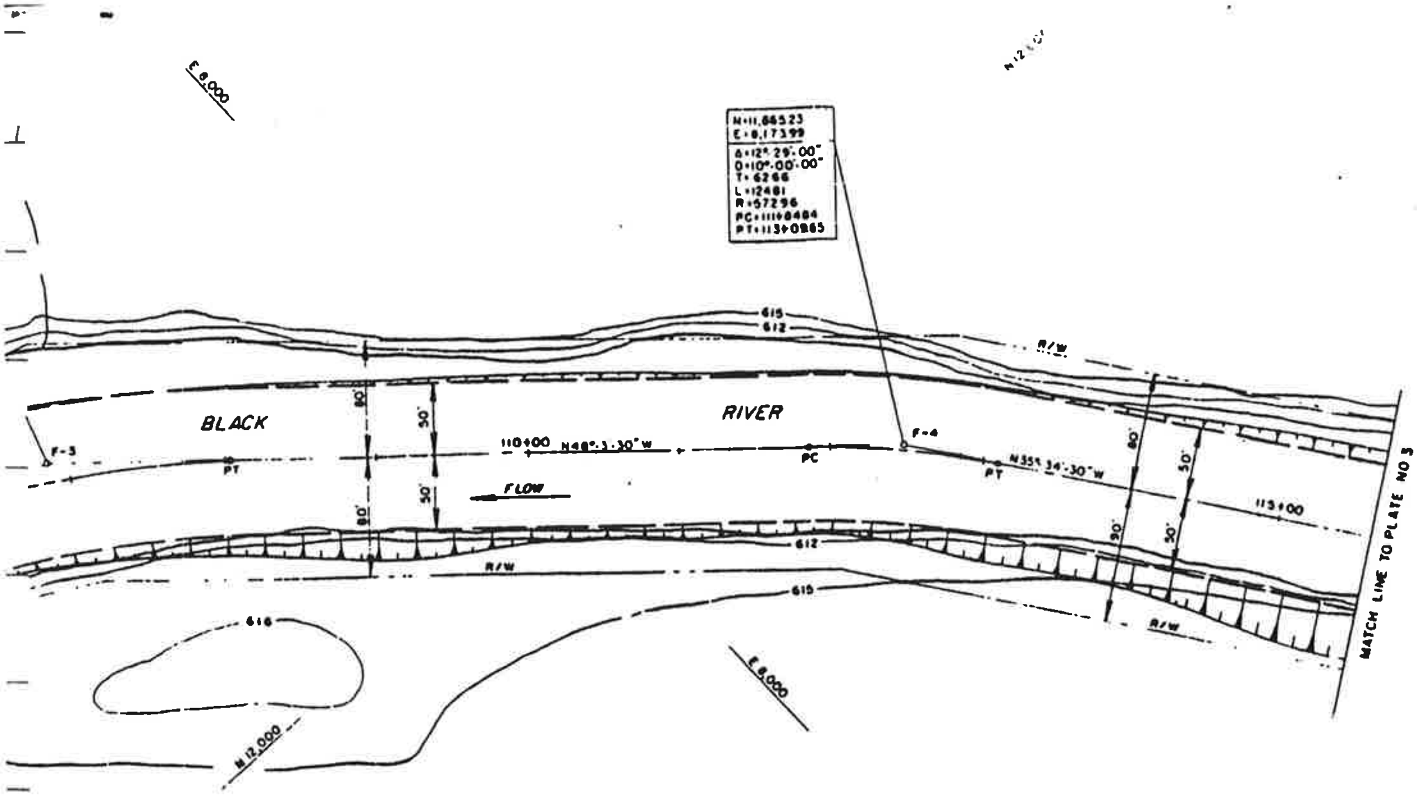
PLATE





SCALE OF FEET

PLATE



PLAN

Scale of Feet
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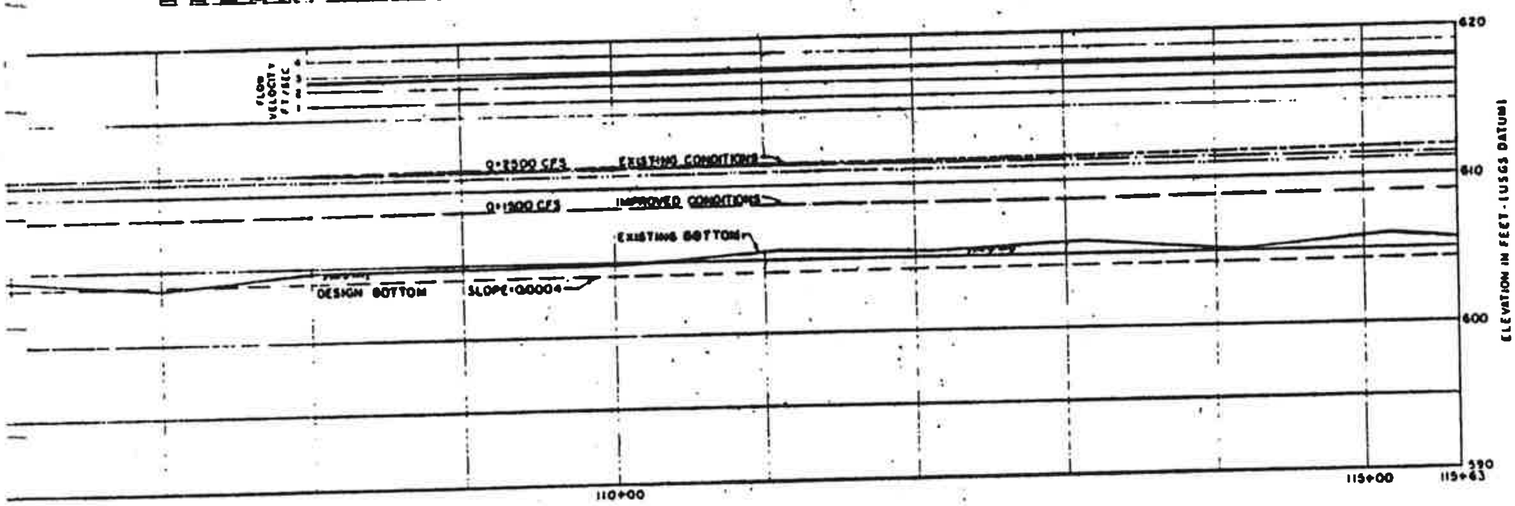


PROFILE ALONG CENTERLINE OF CHANNEL

NOTES

1 APPROX. STATIONING FROM D/S FACE OF ALVERNO DAM

BLACK RIVER, MICHIGAN

(CHEBOYGAN COUNTY)

FLOOD CONTROL

PLAN OF IMPROVEMENT

STA. 102+30 TO STA. 118+63

In 4 Sheets | Sheet No 1 | Scale as shown

U.S. Army Engineer District, Detroit

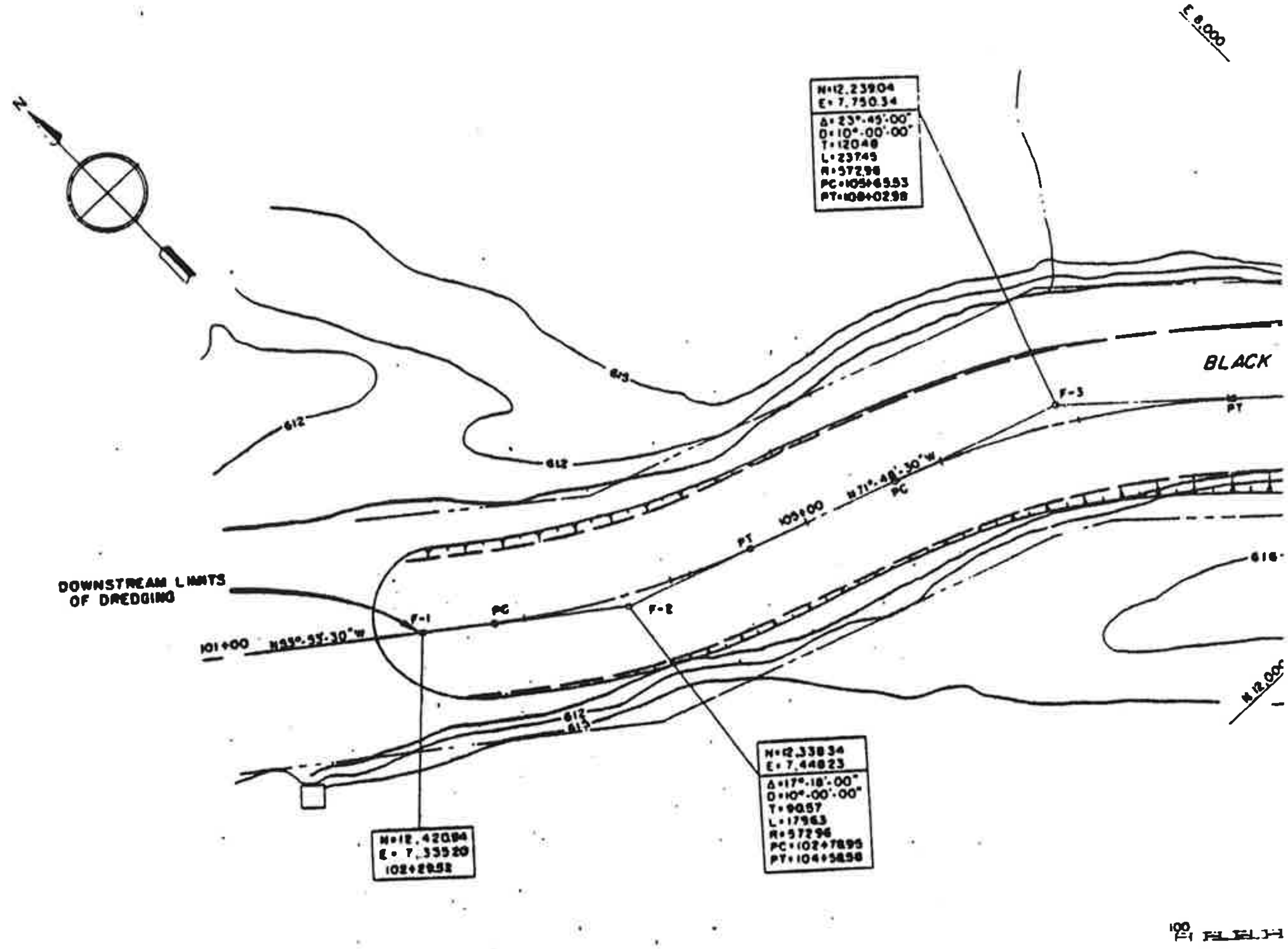
Submitted | Recommended | Approved

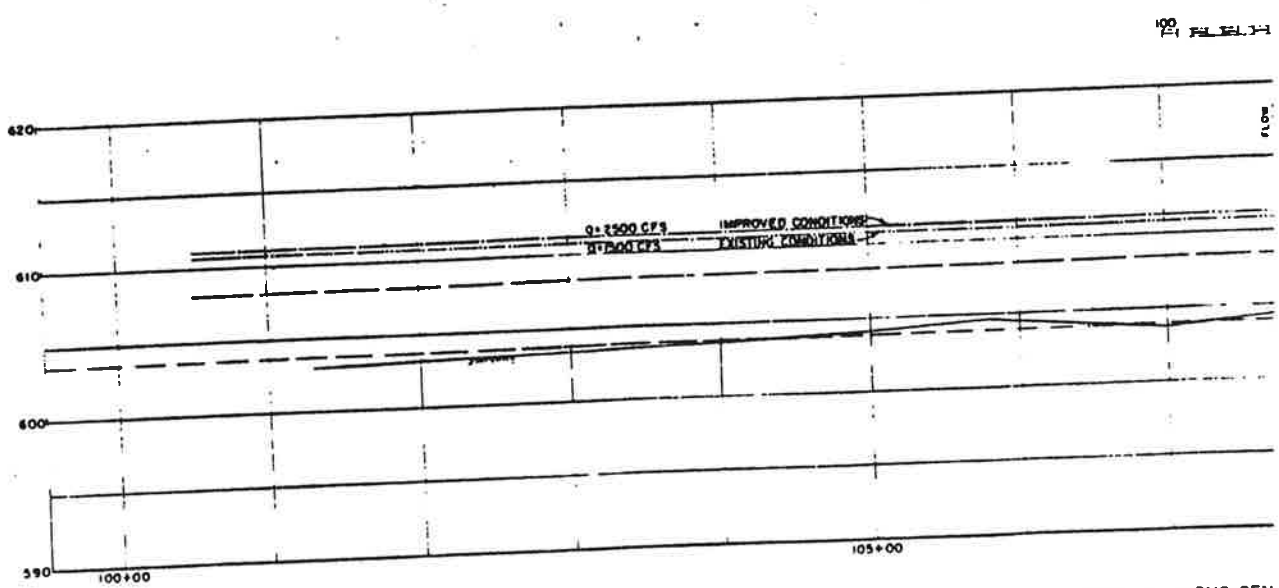
Chief, Basin Planning and Project Planning Branch | Chief, Engineering Division | Col., C.E., District Engineer

Drawn by J.P.B. | File No | To Accompany Detailed Project Report Dated: 1965

Checked by J.E.S.

PLATE 2





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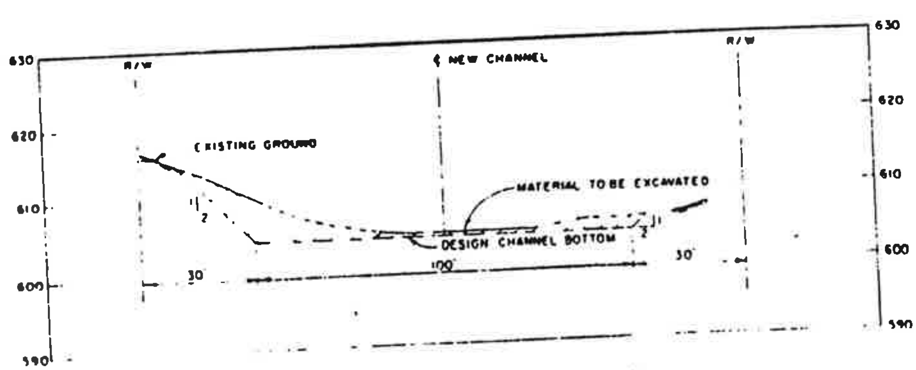
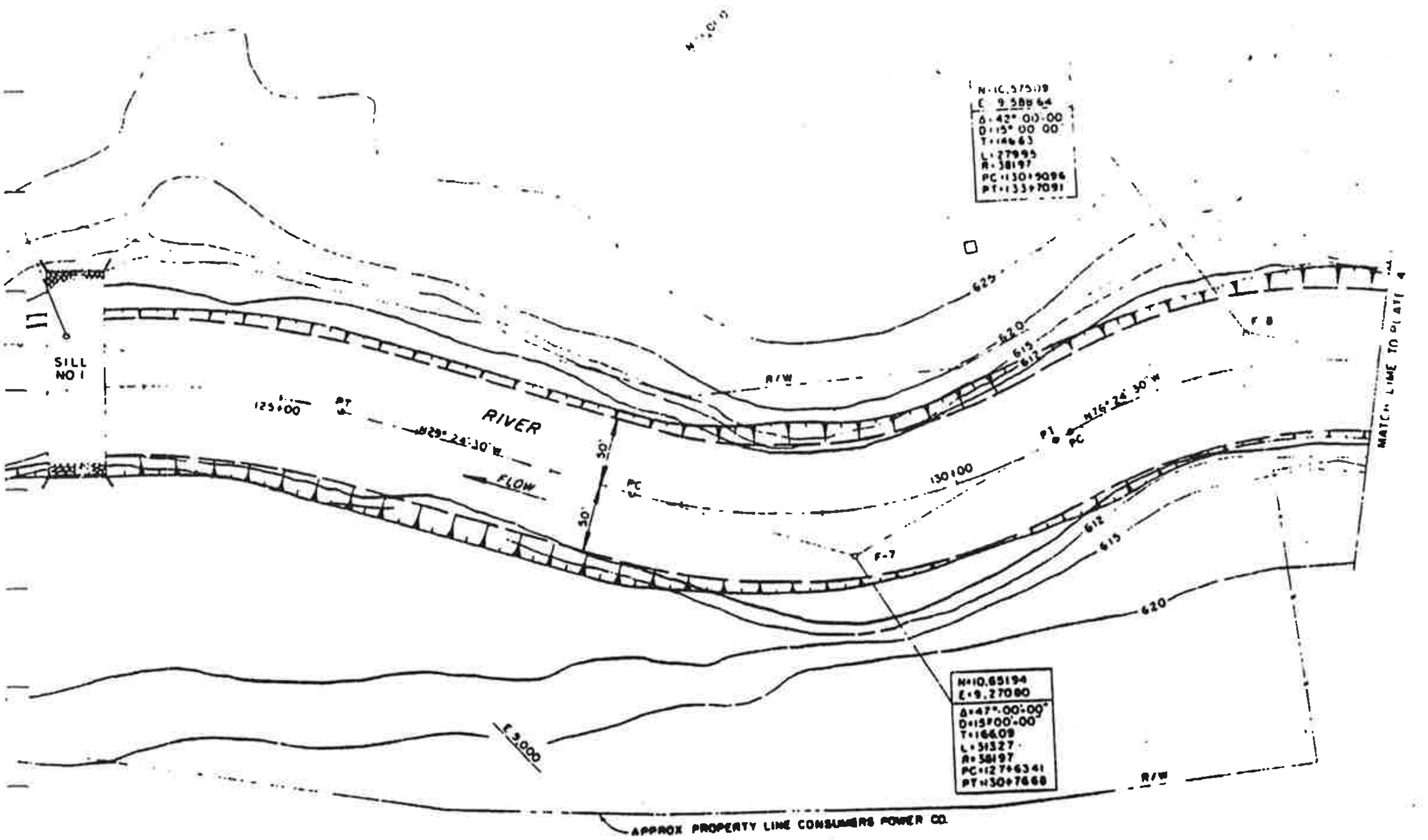


TYPICAL CROSS SECTION AT STA 109+10

PLATE 2



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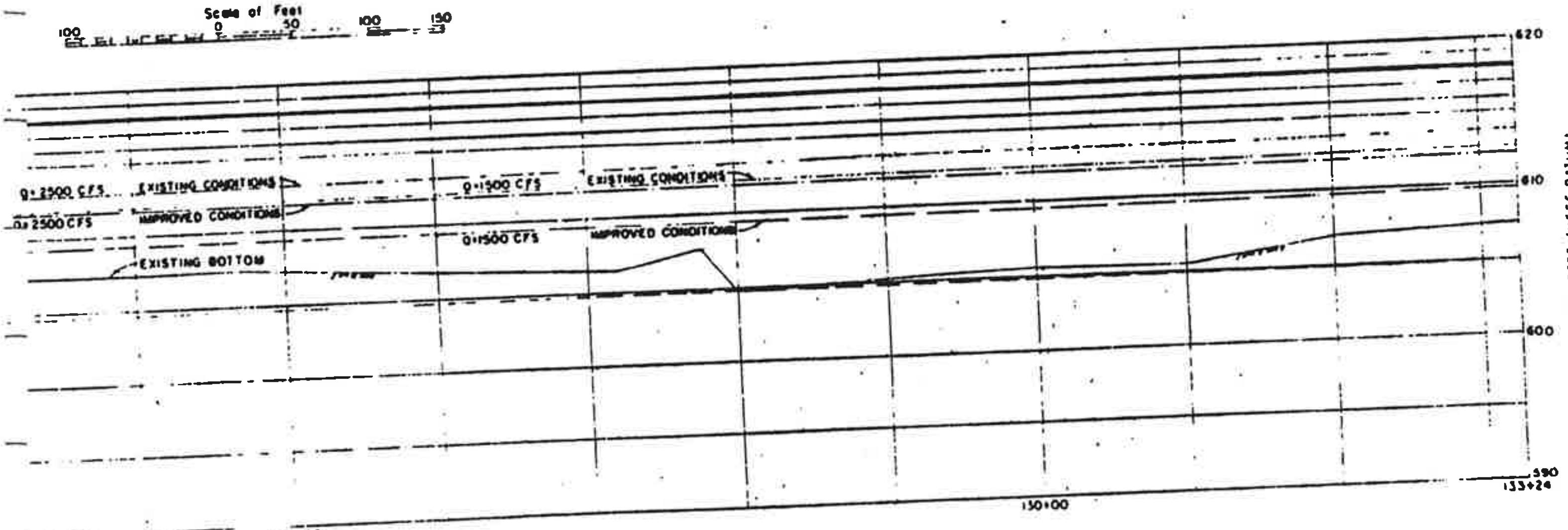
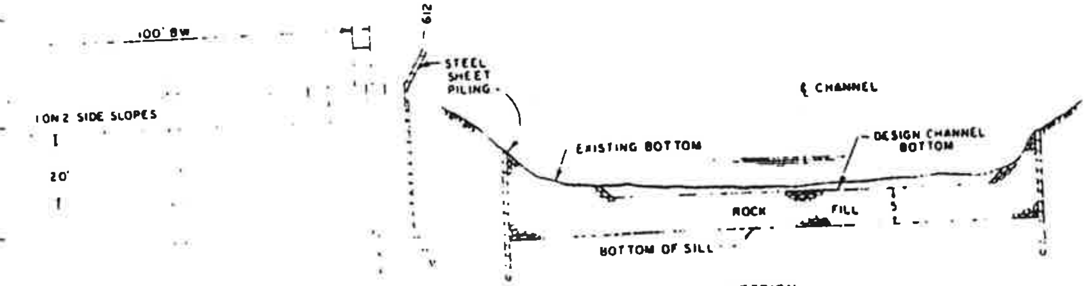


NOTES
1 APPROX. STATIONING FROM D/S FACE OF ALVERNO DAM

PROFILE ALONG CENTERLINE OF CHANNEL



TYPICAL SILL

BLACK RIVER, MICHIGAN
(CHEBOYGAN COUNTY)
FLOOD CONTROL
PLAN OF IMPROVEMENT
STA 115+63 TO STA 133+24

In 4 Sheets | Sheet No 2 | Scale as s

U S Army Engineer District, Detroit

Submitted | Recommended | Approve

Chief, Basin Planning and Project Planning Branch | Chief, Engineering Division | Col, C.E., District

Drawn by JPB | File No | To Accompany Detailed
Checked by JES | | Report Dated

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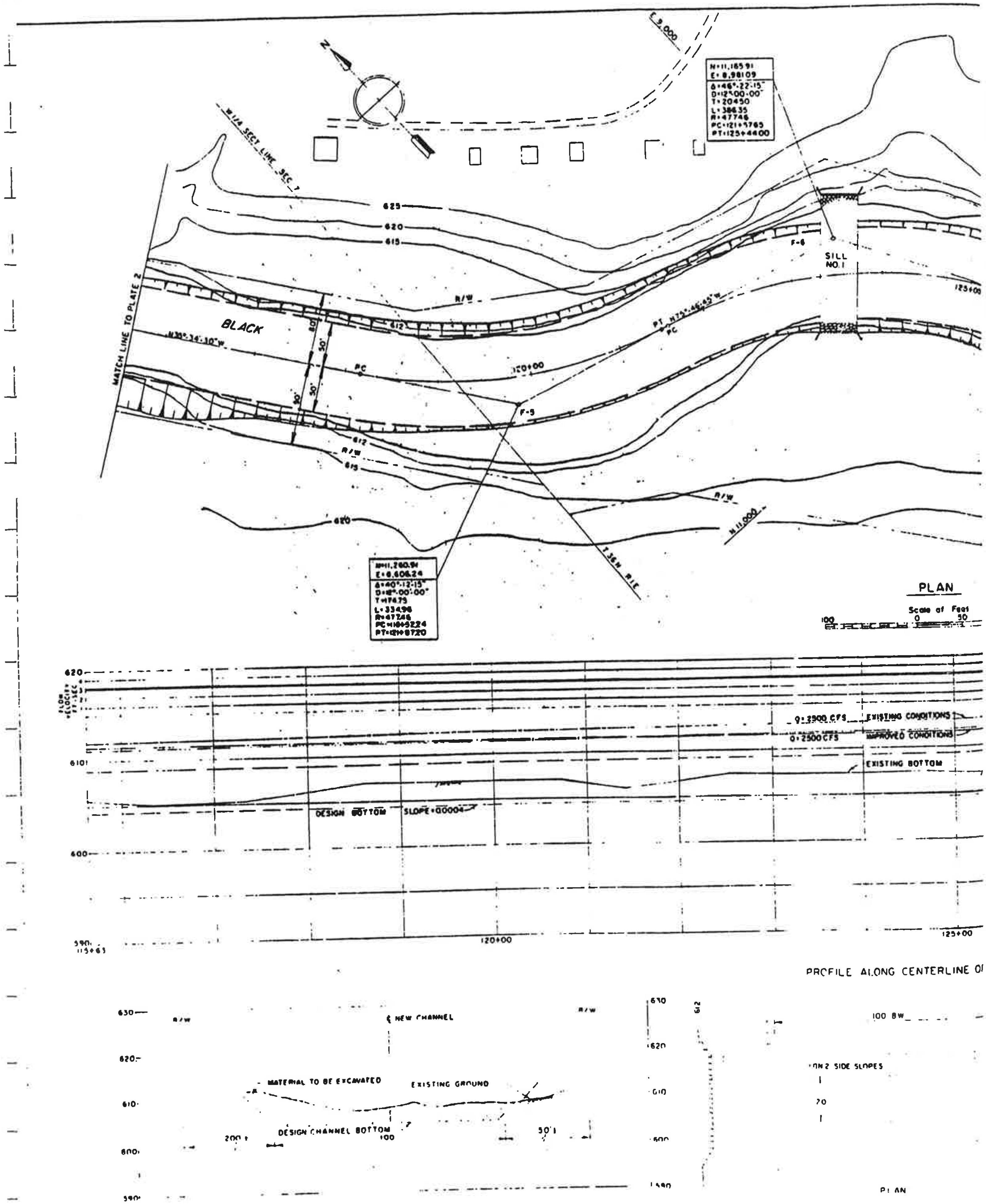
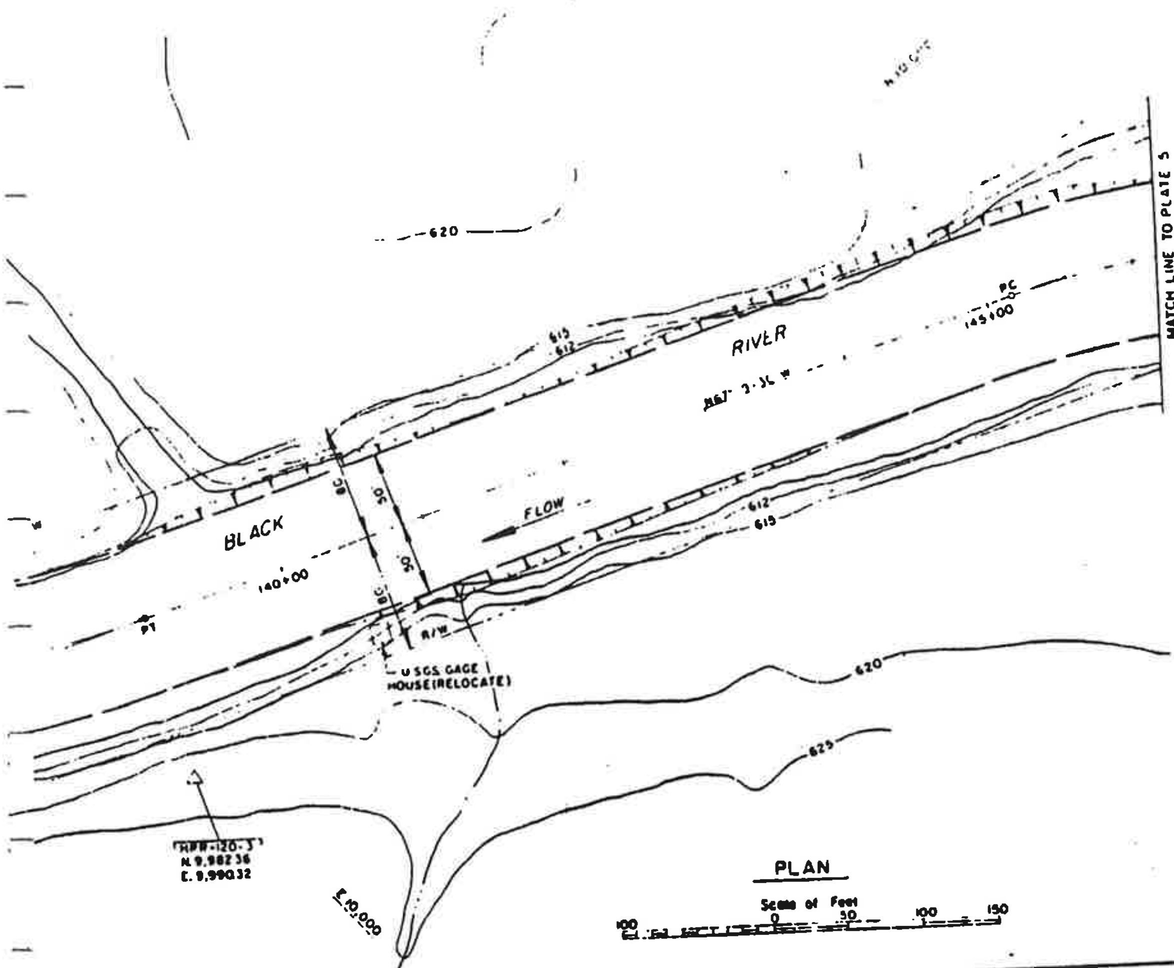
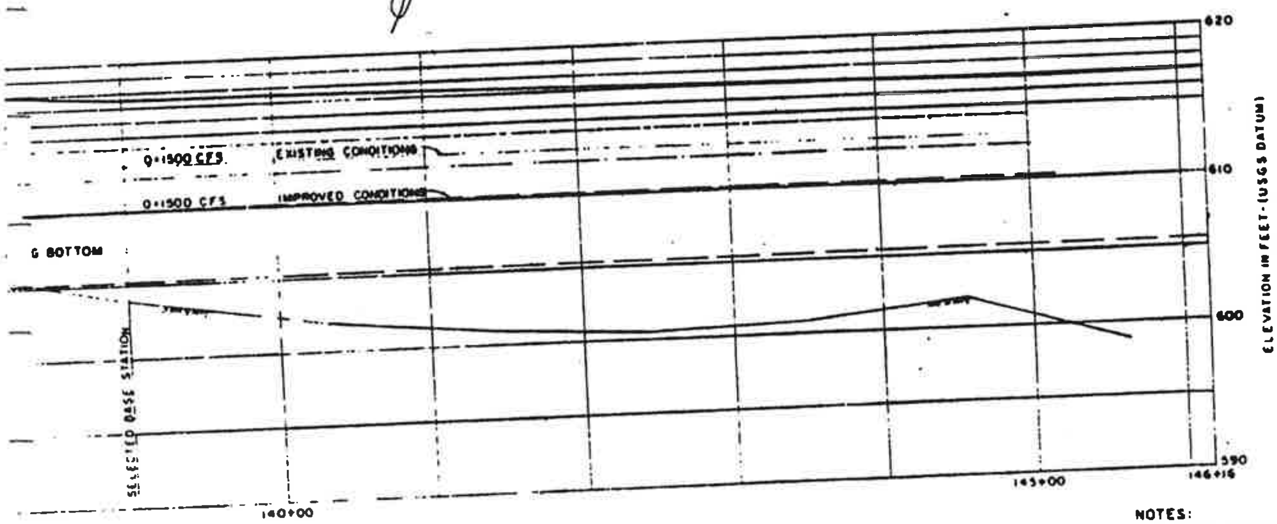


TYPICAL CROSS SECTION AT STA 123+55

PLATE 3





PROFILE ALONG CENTERLINE OF CHANNEL

NOTES:
APPROX. STATIONING FROM D/S FACE OF ALVERNO DAM

BLACK RIVER, MICHIGAN
(CHEBOYGAN COUNTY)
FLOOD CONTROL
PLAN OF IMPROVEMENT
STA 133+24 TO STA.146+16

In 4 Sheets | Sheet No 3 | Scale as shown

U S Army Engineer District, Detroit

Submitted | Recommended | Approved

Chief, Basin Planning and Project Planning Branch | Chief, Engineering Division | Col, C E, District Er

Drawn by JPB
Checked by J E S

File No

To Accompany Detailed Pr
Report Dated 19

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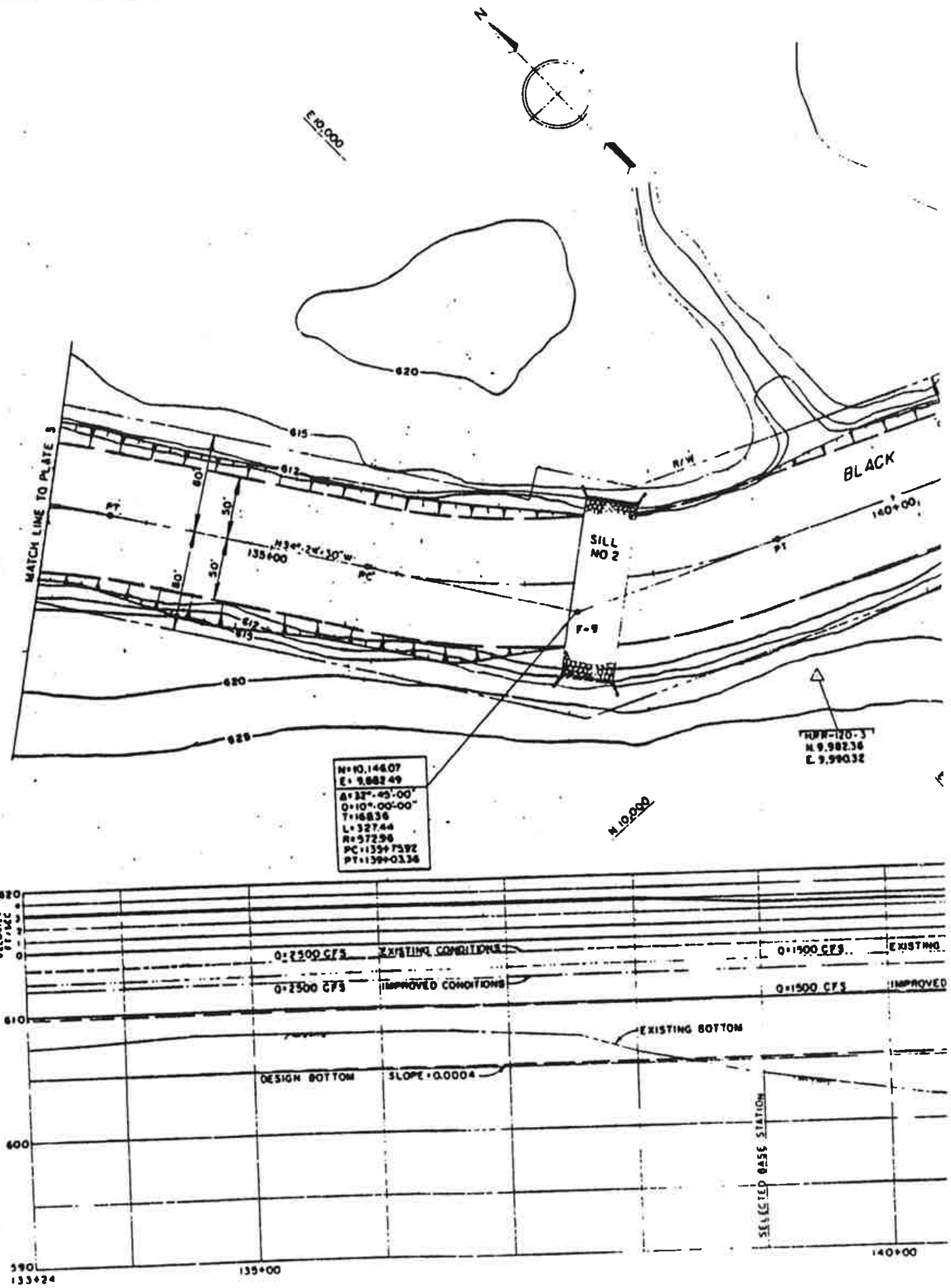

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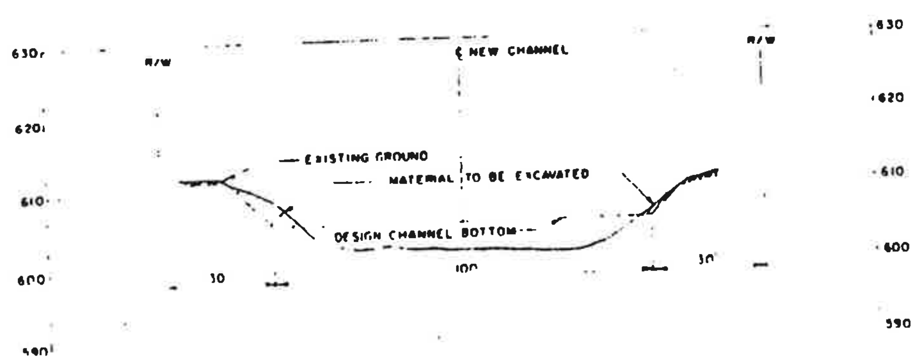
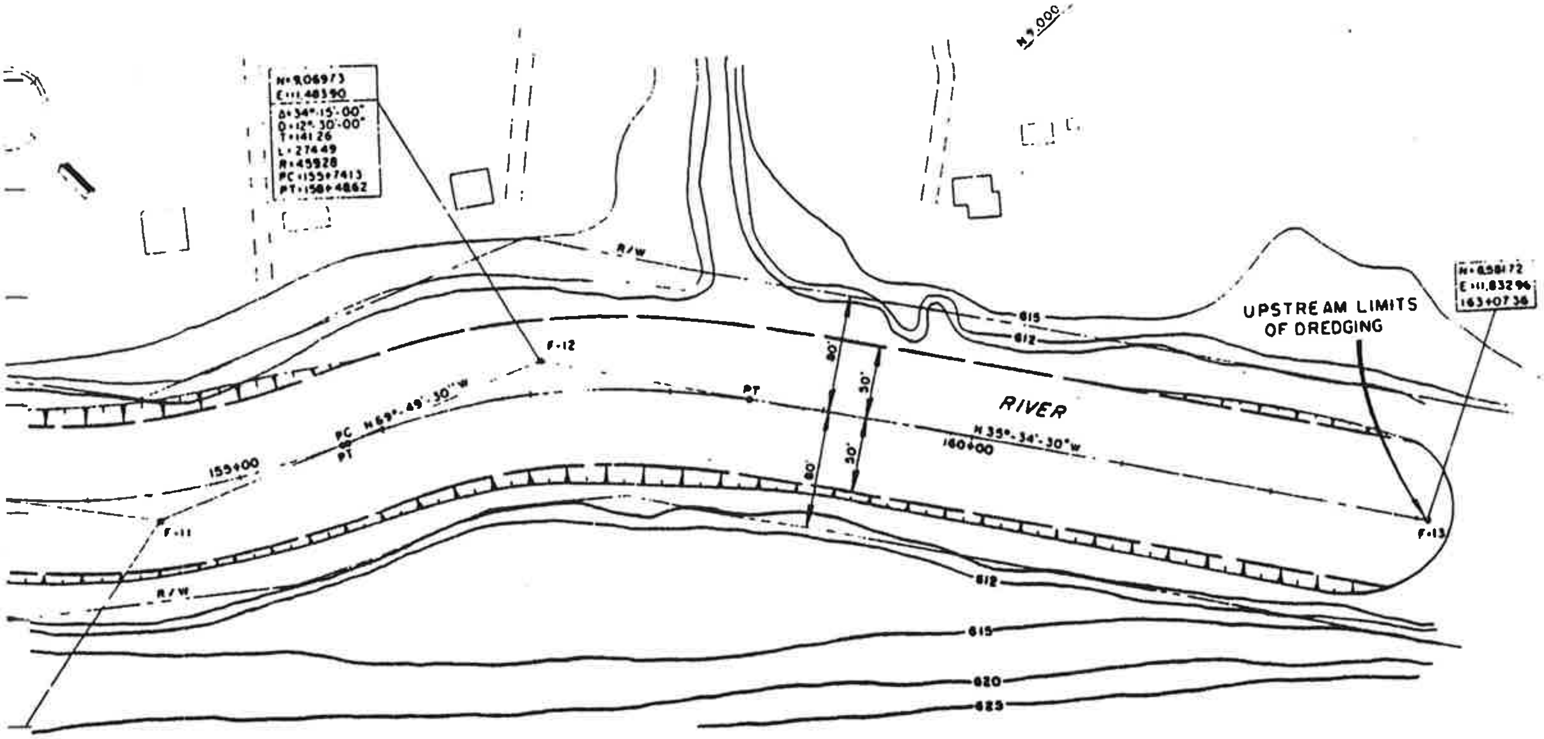


TYPICAL CROSS-SECTION AT STA 141+38

PLATE 4



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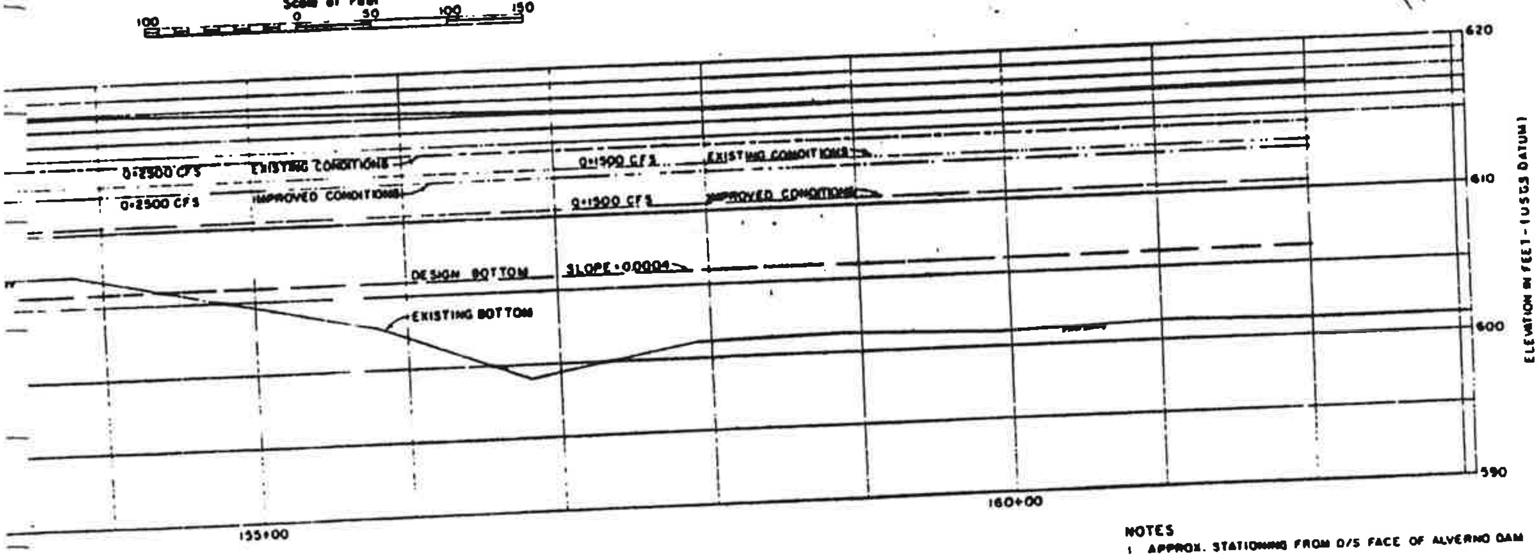

PROFILE ALONG CENTERLINE OF CHANNEL

NOTES

1. APPROX. STATIONING FROM D/S FACE OF ALVERNO DAM

BLACK RIVER, MICHIGAN

(CHEBOYGAN COUNTY)

FLOOD CONTROL

PLAN OF IMPROVEMENT

STA 146+18 TO STA. 163+07

In 4 Sheets — Sheet No 4 — Scale as sh

U S Army Engineer District, Detroit

Submitted	Recommended	Approved
Chief, Basin Planning and Project Planning Branch	Chief, Engineering Division	Col, C E, District E

Drawn by JPB — File No — To Accompany Detailed P

Checked by J.E.S — Report Dated: 19

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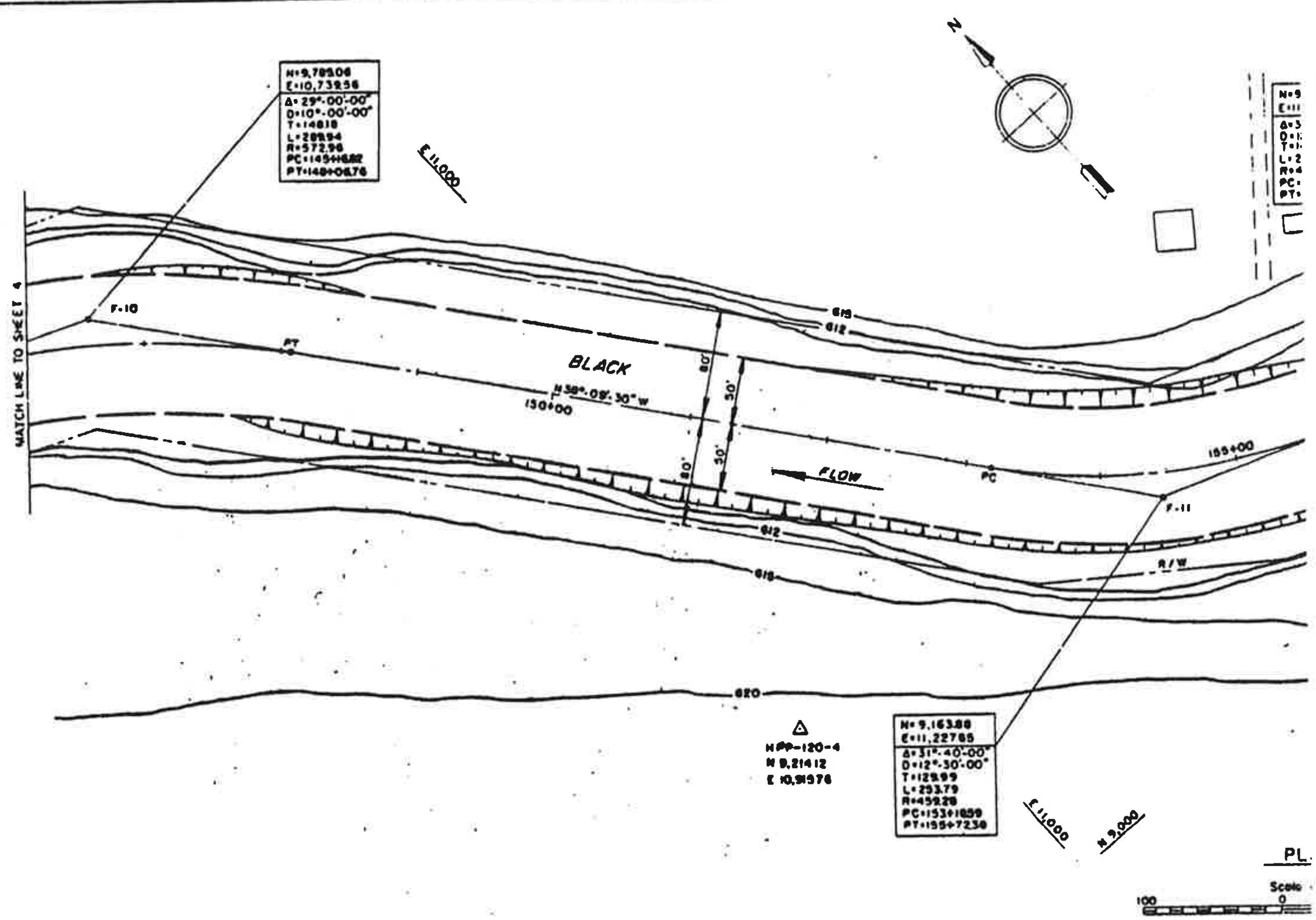

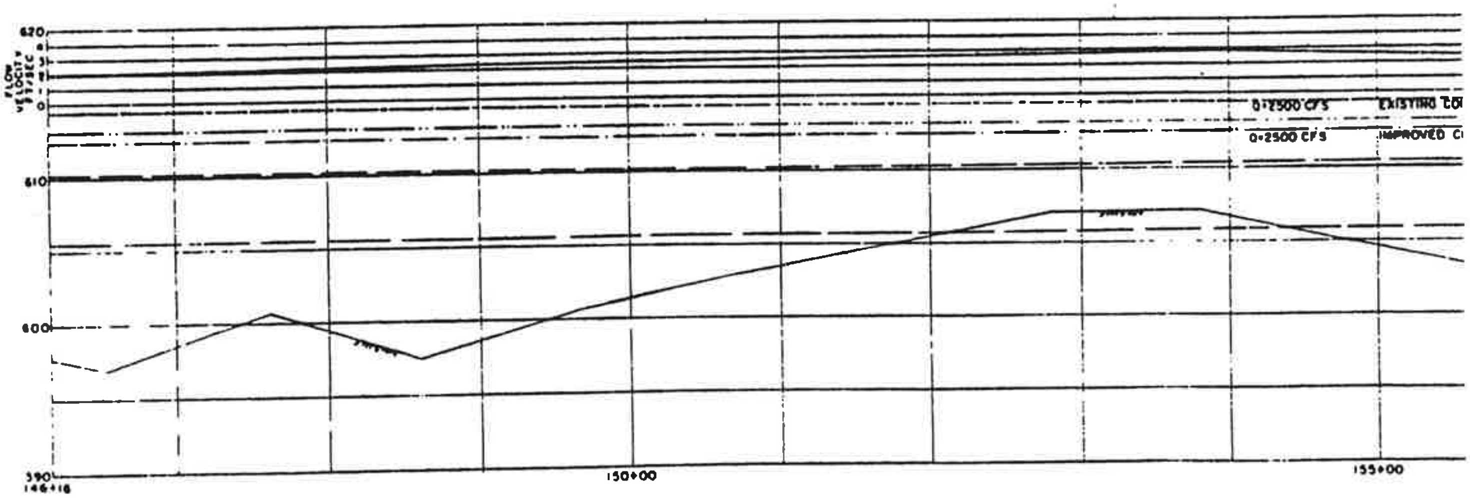

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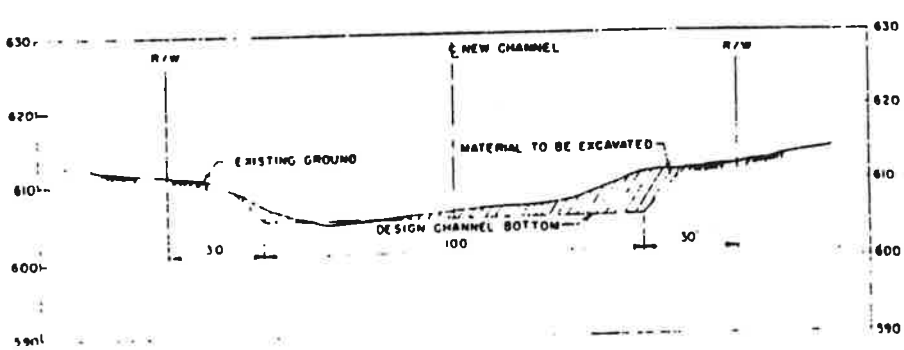

TYPICAL CROSS SECTION AT STA 154+80

PLATE 5

DETAILED PROJECT REPORT ON FLOOD CONTROL
FOR
BLACK RIVER, CHEBOYGAN COUNTY

APPENDIX A

HYDROLOGY AND HYDRAULIC ANALYSIS

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APPENDIX A

HYDROLOGY AND HYDRAULIC ANALYSIS

1. GENERAL

This appendix contains a discussion of the hydrologic and hydraulic analysis completed in connection with the design of the proposed flood control project on the lower Black River and the necessary supporting data.

DESCRIPTION

2. LOCATION

The Black River drainage basin is located in the extreme northern part of lower Michigan. Black River, Rainy River, and numerous tributary lakes and smaller streams constitute the Black River basin. The basin drains through Black Lake and Black River into the Cheboygan River and then into Lake Huron at Cheboygan, Michigan. The Black River basin and its tributary streams are presented on figure 1. Black Lake occupies the northern portion of the Black River drainage basin and tends to moderate Black River flows. A large percentage of the land surrounding Black Lake is part of the Black Lake State Forest. In general, the forest boundary terminates a short distance from the shore line of the lake and the intermediate property is privately owned. There are two exceptions: (a) about 4,000 feet of lake frontage is part of the Onaway State Park and (b) a section of beach about 2,000 feet long on the lake's northeast side is part of the State Forest. Forty percent of the lake's shore line consists of low marsh areas, State-owned lands, and two large private estates. These lands are not likely to undergo extensive development. The remaining lands will continue to be developed for private and rental cottage

3. CHEBOYGAN RIVER BASIN

Hydrologically, Black Lake is a link in the eastern half of the Cheboygan River basin. If the waterway is traced upstream, the following elements would be observed: the Cheboygan River empties into Lake Huron at Cheboygan, Michigan. About 1.5 miles upstream, a hydropower dam and lock form the Cheboygan Pond which is a relatively small reservoir. Two and one half miles further upstream the pond divides and forms the two major arms of the basin. The western arm contains Michigan's Inland Rout composed of Mullett, Burt and Crooked Lakes, with their connecting rivers associated lakes and tributary streams. The western fork, Black River, drains Black Lake and its associated tributaries. The reach of Black Riv between the Cheboygan River and Black Lake is approximately 10 miles long The natural river course is interrupted about midway by Alverno Dam, a low head private hydropower development. Backwater effects extend from this dam to Black Lake, especially during low flow periods. A channel restriction known as Smith's Rapids located about midway between the dam and Black Lake is the control during periods of high flow. Plates 2 thru 5 present the channel profile through the Smith's Rapids section of Black River.

4. BLACK LAKE

The lake has a major axis of 6 miles and a minor axis averaging about 3 miles. The major axis is oriented in a northwest-southeast direction. The area of the lake is slightly more than 10,000 acres.

5. Black Lake drains approximately 597 square miles, with most of the drainage being contributed by the two major tributaries; the upper Black River with 310 square miles and the Rainy River with 79 square miles. The remainder drains through numerous small streams and swamps. Two small hydropower dams are located on the upper Black River; Kleber and Tower Dams, with storage capacities of approximately 3,000 and 310 acre-feet, respectively. The two dams have little influence on the storage characteristics of the subbasin.

6. Black Lake was subjected to backwater flooding before modern maps were made to confirm its natural or its geologically formed shores. However, observing the Fisheries Institute's map, it is noted that the water depths in the lake vary from about 5 to 50 feet with about one half of the lake area averaging 30 to 35 feet. Normal lake elevations for present conditions vary between 611 and 613 feet with spring peaks somewhat higher. Significant beach erosion begins when the lake level is at 612.5 feet and cottage damage begins one foot higher. ?

7. ALVERNO DAM

Alverno Dam is located on Black River about 5 miles downstream from Black Lake. It was constructed in 1905 and has been repeatedly modified since that time. The original construction was of timber cribs filled with stones. The dam structure was composed of a lock, powerhouse, spillway, fish ladder and log sluice. The most significant change occurred between 1917 to 1920 when the present powerhouse with a new headrace and railrace was constructed off to the north side of the old dam. Although the timing is not clear, the following changes have occurred in the ensuing 40 years: (a) the original powerhouse has been removed, (b) old lock was filled in and replaced with boat tramway facilities, (c) concrete walls and floors have been added to the spillway, fish ladder, and log sluice, (d) a tainter gate has been added to the spillway, (e) steel sheet pile cutoff walls have been added to the upstream face of the old dam, (f) the log sluice and fish ladder have been blocked off.

8. The dam as it exists today is roughly 400 feet long and has an approximate crest elevation of 615.5 feet. The two operational components, the spillway and powerhouse, are separated by 180 feet of earth levee. A small island which is a portion of the original north bank

exists in front and behind the leveed section. The tramway facilities pass diagonally over this section extending from the tailrace channel to a point in the upper pool adjacent to the spillway. A service road was constructed on top of the earth dam and it bridges over the spillway and powerhouse opening. The spillway section has a 20-foot wide gate with an apron and two smaller flumes which served as the log sluice and fish ladder when operational. The powerhouse equipment consists of two generating units, each rated at 750 horsepower at 19 feet of head. Present-day operational head is slightly lower.

9. OPERATION OF ALVERNO DAM

Between 1905 and 1950, Alverno Dam was operated to maximize the hydropower output. Since 1950, increased recreational demands on the lake and development of other power sources have shifted the dam operational pattern toward lake regulation. The owner of the dam, Consumers Power Company, is planning to shut down the powerhouse and turn the dam over to a responsible local interest. It is anticipated that a local interest will undertake the ownership and the operation of the dam as a lake level control structure in the near future.

10. STREAM FLOW RECORDS

Presently, the U. S. Geological Survey operates three stream gaging stations in the Black River basin. One station is located on the lower Black River just below Black Lake and serves the dual purpose of a lake stage recorder and of a stream discharge recorder. The other two stations are located on the upper Black River and the Rainy River. These three gages along with most of the other stream gages in the Cheboygan River basin were installed in the fall of 1942.

11. The average annual outflow for Black Lake has been 421 cfs for the period of record. The recorded high discharge was 2,500 cfs on 20 April 1960 and the recorded low discharge was 11 cfs on 14 August 1949.

12. In the period since 1942, the most significant spring floods or periods of high lake stage have occurred in 1943, 1951, 1952, and 1960. There is no record of any flood prior to 1942, but it appears that this could be due to lack of development on the lake with the resulting lack of interest in lake levels and not an absence of flood stages. Pertinent data regarding the available stream flow records are summarized in table A-1.

CLIMATOLOGY

13. GENERAL

The climate of the area is influenced mainly by its latitude and by the effects of the surrounding Great Lakes. The Great Lakes have a stabilizing effect on temperature; thus, cooler springs, longer falls, and a more even distribution of precipitation throughout the year is found in the area when comparing it to other areas of equal latitude.

Table A-1

STREAM FLOW RECORDS - BLACK RIVER BASIN

Station	Drainage area sq. mi.	Length of record from	Length of record to	Maximum recorded discharge cfs	Maximum recorded discharge date	Minimum recorded discharge cfs	Minimum recorded discharge date	Average discharge cfs
Black River near Cheboygan	597	Oct. 1942	date	2,500	20 Apr. 1960	11	14 Aug. 1949	421
Black River near Tower	313	Oct. 1942	date	2,340	17 Apr. 1960	4	27 Nov. 1949	249
Rainy River near Ocqueoc	85	Oct. 1952	date	946	18 Apr. 1960	0.4	7 Sep. 1955	35.7

14. In general, the area has relatively severe winters, cool summers, and moderate falls. Normally after winter sets in, the basin acquires a blanket of snow and ice which remains until the spring breakup. Large amounts of snowfall may accumulate during the winter and not leave until late spring, depending on the temperatures. In this region, 50 to 100 inches of snow during a season is not uncommon.

15. Severe spring flooding normally occurs when the spring breakup coincides or is closely followed by heavy spring rains. Reasonably heavy spring rains are common for the region. The seriousness of these rains depend primarily on their timing with the antecedent conditions of the lake and the contributing watershed.

16. TEMPERATURE AND PRECIPITATION

A summary of temperature and precipitation data considered typical for the Black Lake region is presented in table A-2. The data presented are from the U. S. Weather Bureau station, known as Onaway, Black Lake Forest, located near the center of the Black River basin. This station is considered typical for the entire basin.

Table A-2

CLIMATOLOGY RECORDS FOR
ONAWAY - BLACK LAKE, MICHIGAN

Precipitation in Inches

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1931	1.11	1.12	2.23	1.90	3.38	5.19	1.53	1.28	5.55	3.28	3.10	1.44	31.11
1932	2.68	1.55	.65	1.59	3.32	2.88	2.61	2.33	1.62	4.92	1.56	2.53	28.24
1933	2.21	1.83	1.79	2.88	3.78	.92	1.21	.57	3.15	3.11	1.74	2.40	25.59
1934	-	.49	1.77	2.04	1.99	2.97	1.53	2.14	4.47	2.17	3.37	1.03	-
1935	1.51	.75	1.30	.41	.17	2.99	1.78	4.32	3.96	2.03	3.00	1.18	24.40
1936	2.02	-	.40	1.68	5.05	.92	1.52	3.30	2.42	3.63	.98	.97	-
1937	1.43	1.01	.08	1.78	.70	.55	4.73	.83	4.22	1.80	1.71	1.62	20.46
1938	3.01	2.34	3.06	1.93	3.57	4.24	1.37	3.00	2.55	1.65	1.70	3.16	31.48
1939	2.19	1.59	1.49	2.30	3.93	2.48	1.06	2.77	2.82	2.84	.78	1.70	25.95
1940	1.44	1.19	.40	1.71	2.64	2.29	2.96	3.75	5.08	2.11	3.07	1.95	28.59
1941	1.62	1.04	.70	3.32	2.40	1.28	1.27	2.60	4.94	-	-	1.43	-
1942	-	-	-	2.09	-	-	3.14	.69	4.08	1.08	.95	3.14	-
1943	1.62	1.99	3.73	1.23	1.97	4.43	1.65	1.43	2.47	1.09	2.94	.64	25.19
1944	.77	1.12	1.97	1.75	1.03	3.54	1.82	2.61	5.46	1.60	2.08	.75	24.50
1945	1.29	1.62	2.20	3.02	3.44	2.53	.96	3.09	3.65	4.05	3.35	1.15	30.35

Table A-2 (Cont'd)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1946	1.95	1.24	1.31	.88	3.85	4.06	3.62	3.75	3.29	.89	1.80	2.28	28.92
1947	1.47	.76	1.25	2.81	6.09	2.20	4.22	.36	5.53	1.24	2.99	.99	29.96
1948	1.41	1.46	2.52	2.34	1.27	3.02	-	2.32	.97	1.76	3.47	1.38	-
1949	2.05	1.81	1.26	.94	4.32	4.86	1.57	-	2.40	1.43	2.10	1.64	-
1950	3.31	1.93	1.44	3.44	1.07	1.81	2.56	4.39	3.36	.79	2.74	1.20	28.04
1951	1.83	1.28	2.86	2.99	2.42	1.70	5.05	2.98	3.58	4.43	3.30	2.54	34.96
1952	2.47	.51	2.14	2.44	1.67	2.19	5.67	2.41	1.35	.49	2.60	1.78	25.72
1953	2.24	3.39	2.00	2.37	3.28	2.98	2.01	1.99	4.05	.86	1.70	1.71	28.58
1954	1.34	1.41	1.50	5.39	1.85	5.71	2.80	2.15	4.75	4.57	1.19	1.32	33.98
1955	1.57	0.72	1.91	1.64	1.11	4.21	.66	1.54	1.02	2.72	2.84	0.89	22.43
1956	.90	.75	2.02	2.48	1.37	2.77	3.26	3.91	1.24	.68	2.69	1.48	23.55
1957	.93	.75	1.43	4.08	5.11	6.09	5.43	2.06	4.34	2.24	2.53	1.55	36.54
1958	1.20	.64	.78	1.77	1.33	2.50	1.93	3.72	4.97	3.72	2.37	1.83	26.76
1959	.99	1.75	1.88	3.22	3.74	1.48	1.55	4.68	5.00	3.89	3.16	1.80	33.09
1960	1.96	1.98	.89	3.72	5.08	3.90	2.50	2.52	3.25	1.44	3.66	1.09	31.99
1961	.29	1.08	1.56	1.79	1.52	5.38	3.53	1.08	9.36	2.41	2.33	1.81	32.14

Table A-2 (Cont'd)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1962	1.75	2.62	1.21	2.43	5.09	3.61	.96	4.05	2.57	1.49	.80	2.15	28.73
1963	.93	1.05	2.23	1.17	4.59	2.86	1.48	4.35	3.07	.53	2.27	1.23	25.76
Mean	1.67	1.38	1.63	2.29	2.88	3.08	2.44	2.59	3.65	2.20	3.21	1.63	27.76

Temperatures °F

Mean	20.6	20.0	27.5	40.4	53.0	63.0	68.6	66.6	58.2	48.0	35.0	24.4	43.8
Mean High	29.3	39.8	37.4	51.7	66.2	76.4	82.0	79.0	69.8	58.9	42.7	31.7	54.6
Mean Low	11.9	10.2	17.7	29.2	39.7	49.5	55.1	54.2	46.7	37.7	27.3	17.1	33.0

HYDRAULIC INVESTIGATION

17. FLOOD PROBLEMS

Flooding around Black Lake is mainly due to lake inflows exceeding the lower Black River channel capacities. Inflow in excess of outflow has caused damaging lake stages on frequent occasions. High lake stages cause damage by direct flooding and it provided conditions conducive to beach erosion and the movement of ice and debris.

18. Alverno Dam has been regulated since the early 1950's in an effort to minimize damaging lake stages. However, it was found that damage around Black Lake could not be significantly eliminated by regulation only. Accordingly, it became apparent that other methods would be required to obtain the desired lake regulation.

19. SOLUTIONS CONSIDERED

The general methods considered either singly or in combination for a solution of the flood problem in the Black Lake area were:

a. Impounding flows in upstream reservoirs

b. Levees

c. Evacuation of damage areas

d. Diversion

e. Channel improvement

20. There are no suitable reservoir sites upstream of Black Lake which are large enough to have a significant flood reducing effect on Black Lake. The almost negligible effect that the Tower and Kleber Dams have attest to this. The damage area is too expansive to consider levees. Also, they would offer only partial protection since some of the damage is due to loss of shore line installations, beach erosion, and beach cleanup. The high usage of the area for recreational purposes and to an increasing extent for residential purposes would rule out evacuation of the flood zone. Diversion of flow would require a large amount of excavation which makes this method not feasible. Improvement of the existing outlet channel was the only recourse to alleviate floods in the Black Lake area.

21. CHANNEL IMPROVEMENT

In the lower flow ranges, Alverno Dam controls the stages and discharges of Black Lake. In the higher flow ranges (say 1,500 cfs and upward), the constrictive channel sections between the lake and the dam provide the control and are responsible for damaging lake stages. Enlargement of the constrictive sections increases the channel discharge capacity and thereby reduces the magnitude and duration of flooding on Black Lake.

22. TECHNICAL PROBLEMS

Studies relating to soils investigations (in appendix B) indicate that soils in the proposed excavation zone will require special consideration. The present channel is analogous to a riprapped channel and once the surface layer is removed, the channel would be subject to scour and erosion during periods of higher flows. This needs special attention because although the improved channel would allow for greater flows at the lower ranges of the lake levels and would reduce the frequency of damaging stages, uncontrolled erosion would shift the control to Alverno Dam. This would require expensive alterations to be made at the dam.

23. CHANNEL SIZE

The size of the considered channel improvement was selected by testing several channel modification schemes. A channel bottom slope of 0.0004 was used in all designs. A basic channel bottom elevation of 605.2 at station 139/00, the selected control station, was selected. Then different channel depths were analyzed by using one foot increments. Channel bottom widths of 70 feet, 100 feet, and 150 feet were also used to select the most optimum channel design.

24. LAKE OUTLET CHANNEL RATING CURVE

Black Lake's natural outlet channel experiences wide variation in its flow-stage relationship. This unstable condition is caused by natural channel changes which are aggravated by backwater resulting from regulation at the Alverno Dam.

25. Alverno Dam was adopted as the control point for all discharge rating for two reasons: (1) the dam is capable of controlling river flows for the range of interest for most of the study, (2) the development of backwater profiles back to the lake by backwater computations provides a means to give consideration to a specific channel configuration between the dam and the lake and hence a means to test channel modification plans.

26. Rating curves for the dam were developed for a variety of operational conditions. Using the dam as a starting point, a series of backwater profiles were extended to the lake by means of backwater computations. Using these results, rating curves at the lake outlet were developed. Cross section data used in the flowline computations were obtained from a 1964 survey and supplemental information was obtained from a 1944 survey. Thus, the resulting existing channel rating curve is primarily representative of 1964 channel conditions. However, the rating curve is considered to yield acceptable results for the entire period of record. This selection is reinforced by the reasonably good agreement obtained when comparing the calculated rating curve with the USGS stream measurements taken intermittently during the 21 years of record.

27. Improved channel conditions were developed in the same manner, except the cross sections were modified to include the proposed channel modifications. The rating curves for both existing and improved conditions are presented on figure A-1.

28. FLOOD ROUTING

Recorded flows were routed through Black Lake with both existing and improved channel conditions. First, the period from 1 February through 30 June for the 21 years of record was reverse routed to determine lake inflows. Then, the inflows were routed through the lake using a common regulation plan and discharge curve so that historical floods could be compared on a common basis. The resulting data were used as the basis for the frequency study discussed in paragraph 31.

29. The more significant flood years were routed through each of the considered design channels to determine the effectiveness of each design. Once the final channel design was selected, enough of the entire record was routed through the channel to test the channel's behavior under a full range of inflows. In addition, the inflow hydrographs for a flood one and one-half and two times the 1959 flood peaks were routed with existing conditions and the selected design channel to check their behavior under larger floods than have been observed. The 1959 flood peaks were deemed to be typical of the annual spring flow conditions.

30. ROUTING TECHNIQUES.

A 24-hour period was used in all flood routing as this was the shortest period that observed data were available. Furthermore, the large size of the lake dampens out any sudden changes in lake stages and outflows. The outflow for the lake stage at the beginning of the period was used and this constant outflow was assumed for the entire period. The difference between inflows and outflows was converted to the proper units and added algebraically to lake stage to determine the new lake stage for the beginning of the next period. This simple flood routing approach is considered to give results consistent with accuracy needed for this study. Figure A-2 illustrates the recreation of the 1960 flood peak using the observed 1960 rating data. The adopted generalized rating tables give slightly higher results.

31. FREQUENCY

A stage frequency relationship based on lake inflows and calculated lake stages was adopted for Black Lake. All attempts to assign frequencies to observed lake stages were of no avail due to the varying effects of lake regulation over the years and to a lesser extent the natural variations between floods. It was realized that this variation must be reduced by some analytical means and yet must be tied to some natural phenomenon with its associated lake stages. The lake inflows during the spring flood season were selected as the natural parameter. Inflows were estimated by reverse routing of the observed lake outflows.

32. The lake being a natural reservoir, it was reasoned that the flood volume-frequency relationship would offer insight into its behavior pattern. The filling and emptying cycle is important when considering a reservoir problem. In defining the maximum lake stage, only the filling cycle and the start of the emptying cycle is significant. Unfortunately, the filling time as well as the maximum volume to be stored are variables. Inspection of the records indicate that within limits, the natural occurrence approaches a general pattern. Hence, a duration may be selected that reasonably defines this pattern. Obviously, this selection is primarily a matter of judgment.

33. The flood volume-frequency relationships were developed from the calculated inflows by the methods suggested in "Statistical Methods in Hydrology" by L. R. Beard, dated January 1962. Initially, durations of 1, 5, 10, 15, 20, 30, and 45 days were developed. Inspection of these data showed that 20 to 30 day durations were of special significance in defining a behavior pattern for the floods. Consequently, volume duration-frequency relationships were calculated for each day during this period.

34. The lake inflows for the flood season were routed through the lake under a common set of conditions. It was felt that the resulting lake levels are the best indicator of interrelations between lake flood levels since they are based on the entire flood season with no attempt to single out any event or series of events. The resulting lake levels were tabulated by rank for comparison with the ranks of the various durations. The ranking of flood frequencies based on several different durations compared favorably with the routed results. The best results occurred with durations of 22 to 28 days. In this group, good results occurred at extremes of the frequency scale with some variation or intermixing of points in the center group. It was judged that the 23-day duration gave the best alignment and was adopted. The frequency (assigned percentage) changes very slowly in this range and selection of any of the seven durations would give approximately the same recurrence values.

35. The peak lake stages were plotted against the frequency of its associated volume for a 23-day duration on arithmetic probability paper. Better definition of the upper portion of the scale was provided by two synthetic floods. The synthetic floods were developed by ratioing upwards by factors of 1.5 and 2.0 the peak 23 days of the 1959 flood which is considered a typical flood and then routing them under base conditions. The results were then plotted at the appropriate locations. As an aid in fitting the curve, the observed peak lake stages were also plotted. Realizing that the assumed base conditions were generalized and that they will not fit all of the natural conditions equally well, the curve considered most representative for all conditions was fitted through the points.

36. Stage-frequency relations for improved channel conditions are based on the stage reductions indicated by routing studies. Lake routings for selected floods were conducted for both existing and improved channel conditions using the same base conditions. The reduction in stage for these floods was plotted under the selected curve for existing conditions using the same frequency interval that the event had for the existing channel. The curve of best fit was then applied. The adopted frequency curves are inclosed as figure A-3.

37. UNIT HYDROGRAPH

Attempts to develop a representative unit hydrograph from observed rainfall and stream flow records have all been disappointing. A unit hydrograph developed from any one storm will not correlate with the results of another storm. An explanation for this phenomenon is found in the geology of the area. The watershed has localized sinks or inlets into the underlying limestone. These sinks have the ability to catch and transport large quantities of water through underground cavities or channels with maximum runoff tending to occur only after long periods of continuous precipitation or after short periods of extraordinarily heavy rainfall. The existence of these underground streams is verified by the numerous springs and artesian wells in the vicinity of Black Lake. This isolated occurrence of geological phenomenon is unique for Michigan even though it is common in other parts of the country.

38. In addition to the large underground runoff, normal runoff is further modified by the swamplike character of parts of the watershed. Approximately 25 percent of the Black Lake drainage area is swamp or composed of swamp soils. The degree to which runoff from these areas can be predicted is uncertain at best. The ability of these areas to retain and retard runoff is unassessable due to variations in antecedent conditions and this creates another almost unassessable factor for this basin. While these conditions are not readily measureable, their influence on the Black Lake basin are considerable. The effect of these runoff retarding factors can be illustrated in one example encountered. A late spring storm of 1.0 to 1.5 inches of precipitation was found when reviewing the precipitation data. When the stream gage records were inspected, no significant variation in base flow conditions could be found that would reveal that a storm of this size had occurred.

39. The influence of these unassessable factors along with the problems of snowmelt makes the development of a representative or theoretical unit hydrograph very difficult. Identical antecedent conditions would be necessary if the unit hydrograph is to be applicable and any identical antecedent conditions would be accidental at best.

40. The unit hydrograph used in the development of the standard project flood was derived from the storm causing the peak of the 1960 flood. During this flood, swamps and underground cavities in the watershed were almost completely saturated. Accordingly, this unit hydrograph is considered adequate for standard project flood development since the antecedent basin conditions were relatively similar to conditions that could be expected prior to a standard project flood.

41. STANDARD PROJECT FLOOD

An estimate of the standard project flood was made for the drainage area contributing to Black Lake in accordance with instructions contained in Civil Engineer Bulletin No. 52-8 titled "Standard Project Flood Determinations." The method followed in the determination consisted of applying standard project runoff values to the unit hydrograph developed for this purpose. Loss rates were estimated to be 0.10 inch per hour and were based largely on the highly retentive nature of the basin. The estimated peak inflow to the lake resulting from the standard project flood was about 22,500 cfs. This is about five times the 1960 peak inflow of 4,650 cfs. The 23-day volume was 120,000 day second feet as compared to 53,600 day second feet for the 1960 flood. The frequency curves indicated that a flood of this magnitude would have return periods of approximately once in 850 years. When the standard project flood was routed through the lake, it was determined that the lake didn't significantly modify the inflow and consequently the outflow was of the same order of magnitude as the inflows (20,000 cfs).

42. ADOPTED PLAN

The channel would have a bottom width of 100 feet, sideslopes of 1 on 2, an approximate control elevation of 605.8 feet, and a bottom grade of 0.004. The design depth would be 5.2 feet when Black Lake reaches elevation 612.2. The project limits extend from station 102/30 to station 163/07. Plates 2 thru 5 illustrate the channel thalweg along with the adopted channel grade and two water surface profiles.

43. Two sills would be constructed across the excavated channel in the vicinity of stations 123/62 and 135/50 as described in paragraph 23. These sills would be constructed at grade and would insure channel stability but will not interfere with the hydraulic properties of the channel.

44. PROPOSED PLAN OF OPERATION

Several different schemes of regulation for Black Lake were reviewed with a view of providing the means of alleviating flood damage without unduly interfering with the demands and needs of other lake usages. Local interests have formally expressed their desires to establish a legal lake level. These levels were established by a State court decree as elevation 612.2 from 15 May through 31 October and elevation 610.5 from 1 December through 15 April with the lake being raised or lowered as needed in the 30-day transition periods between summer and winter lake levels. A suggested plan of regulation consistent with the desires of local interests is illustrated below.

a. Draw the lake down to elevation 610.5 starting 31 October and completing it by 1 December.

b. Maintain the lake at elevation 610.5 or lower, conditions permitting, as long as possible. Slight fluctuation of lake levels before the spring inflows are allowable.(1)

c. When the spring breakup occurs and peak flows are past, lake levels would be permitted to rise to any level desired not to exceed elevation 612.2. This limit would be in effect until 31 October, when the lowering process to obtain the winter level would begin.

d. Coordination of changes in releases should be established between the four dams operated on the Black and Cheboygan Rivers. Arrangements should be made with the operators of Tower and Kleber Dams to notify the operator of Alverno Dam of major changes in releases. The personnel at Alverno Dam should in turn notify the operators at Cheboygan Dam of any significant changes in the operation of Alverno Dam. Based on flood routing study, it was determined that the amount of additional flood damage that could be eliminated by adopting a different method of operating the dam would be negligible. Alverno Dam tainter gate discharge rates for indicated lake levels are tabulated in table A-3.

Table A-3

ALVERNO DAM TAINTER GATE DISCHARGE TABLE

Black Lake elevation	Discharge in cfs for opening indicated in column heading				
	1 ft.	3 ft.	5 ft.	8 ft.	10 ft.
600.6	73				
602.6	163	377			
605.6	241	654	961		
607.6	281	786	1,200	1,644	
610.5	331	950	1,480	2,160	2,492
612.2	341	1,003	1,670	2,410	2,822
613.5	376	1,085	1,775	2,586	3,034

(1) Slight fluctuations in lake levels at the onset of spring breakup may aid in the early outflow of lake ice and thus, reducing the chance of ice jams before the major lake inflows occur.

CONSIDERATIONS FOR THE FUTURE OF ALVERNO DAM

45. ALVERNO DAM TODAY

While Alverno Dam is not part of the proposed project, the proper operation and maintenance of the dam is essential to the success of the project. At present, the dam is still being used for the generation of electrical energy. There are two turbine-generator sets which will pass up to about 870 cfs for the maximum headwater conditions. There is one spillway. It is 20.0 feet wide and has a crest elevation of 596.6. This spillway will discharge about 2,600 cfs at elevation 610.9, operational pool level, and about 4,300 cfs at an elevation corresponding to the top of dam (615.5). This gives the dam a total capacity of about 5,000 cfs before overtopping occurs. If made operational, the fish ladder and log sluice could add another 700 cfs.

46. A change of dam ownership along with physical and operational changes are anticipated in the near future, probably before construction of the project and certainly they would occur within the economical life of the project. The present owners, Consumers Power Company have indicated that they would like to turn the dam over to a responsible local interest. Consumers Power Company has not decided on how much of the generating equipment they would remove. This may require blockage of penstocks or some modification of them to allow their continued use if all the generating equipment is removed. It is expected that the use of the penstocks will be saved, if possible, since all the fine regulation of the lake levels has been accomplished through the turbines in the past. Also, the total discharge capacity of the dam is limited and any reduction in capacity reduces the safety of the dam.

47. CONTINUED USE OF PENSTOCKS

Feasibility studies on possible plans to utilize the existing installation with a minimum amount of alteration was conducted. Plans which would require any major amount of new construction were ruled out since any major expenditure would be better spent on a new spillway. The least expensive plan calls for leaving the turbines in place except for removal of the runners. The wicket gates would be used to control the flows as before. An electric or air motor would be used instead of the governor servomotor to activate the linkage which operates the wicket gate settings. Manual or automatic controls may be used to control the mechanism. The choice of controls depends on the type operation desired by local interest.

48. Additional ventilation should be provided at the throat of the turbine housing to prevent cavatation from occurring within the assembly. A large vent pipe could be easily placed through the top of each turbine housing to provide the necessary air supply.

49. The turbines are mounted horizontally with the shafts extending through a bulkhead to the generators. The flows, after passing the runner, strike the bulkhead and fall to the floor of the combination draft tube and tailrace below. If the runner and shaft were removed, the holes in the bulkhead would have to be plugged to maintain an effective draft tube and prevent the spraying of water into the powerhouse. The bulkhead would have to be reinforced as it would have to absorb the entire thrust of the incoming flows, part of which was formerly absorbed by the runner and then passed to the bearing assembly outside the housing.

50. If the plan to use the turbine housing and wicket gates is not workable or if the housing cannot be left in place, then gates could be substituted. A butterfly or streamseal gate could be fitted in the opening left by removal of the turbine housing. The bulkheading modifications would remain the same as in the plan which kept the turbine housing in place.

51. FLOW THROUGH THE TURBINES

From all indications, the flow through the turbines will remain substantially unchanged after the removal of the turbine runners. This was concluded after examination of available technical literature, inspection of available plans for the turbines and discussion with the turbine manufacturer's representative. The question of flow cannot be fully resolved without the running of field tests or without the gathering of additional data on the turbines for a thorough analytical analysis. Even if higher flows occurred, they could be restricted by adjusting the gate settings. Hence, for planning purposes, there is not enough evidence to justify use of any larger discharge capacity than the rated capacity of the turbines with runners in place.

52. IMPROVEMENT OF AUXILIARY SPILLWAYS

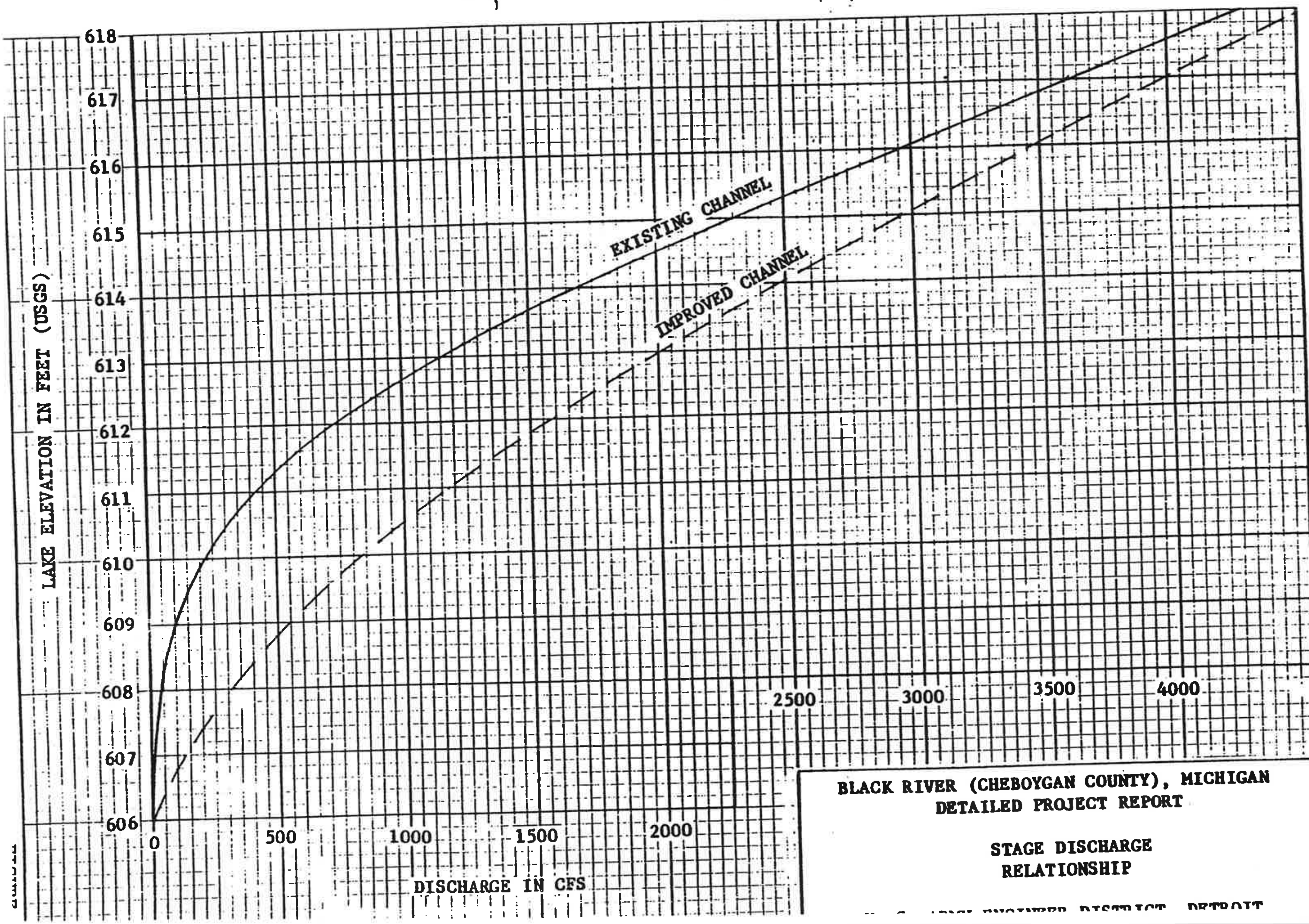
Use of both the log chute and fish ladder have been abandoned. At present, a steel sheet pile wall extends over the face of their openings. The structures are in disrepair and would need extensive repair before they could be used. However, after repair and the installation of new control gates, these two flumes would be useful, especially for finer regulation of flows. The log chute is 5.6 feet wide and has a crest of 607.1 feet. This flume could pass 176 cfs at a pool elevation of 610.9 and 465 cfs at the dam's crest elevation. It appears that the fish ladder could be restored to operate the same as the log sluice. The width of the modified flume would be only one half of the larger log flume. The combined flow for the restored flumes is estimated to be about 265 cfs at operational heads, and about 700 cfs under peak flow conditions. If the penstocks are not modified, the restoration of these flumes may be necessary for the lake level regulation needed during low flow periods.

53. NEW SPILLWAY CAPACITY

The existing 20-foot spillway will safely pass a flood of a severity of 100 to 140 years return period. If the dam were to be modified to pass the standard project flood, then an additional 15,000 cfs of emergency spillway capacity would be required. The most likely approach would be construction of the spillway off to one side of the existing structure where the channel would be excavated in native soil. A gated structure across the channel would control flows. Since the spillway wouldn't be used often, stoplog or similar·type gates might prove economically feasible. The size of the gates could vary over a wide limit, depending on the design. One possibility would be a gated areaway 15 feet high by 76 feet long. The approach and exist channels would be of the same approximate dimensions except with 1 on 2 sideslopes.

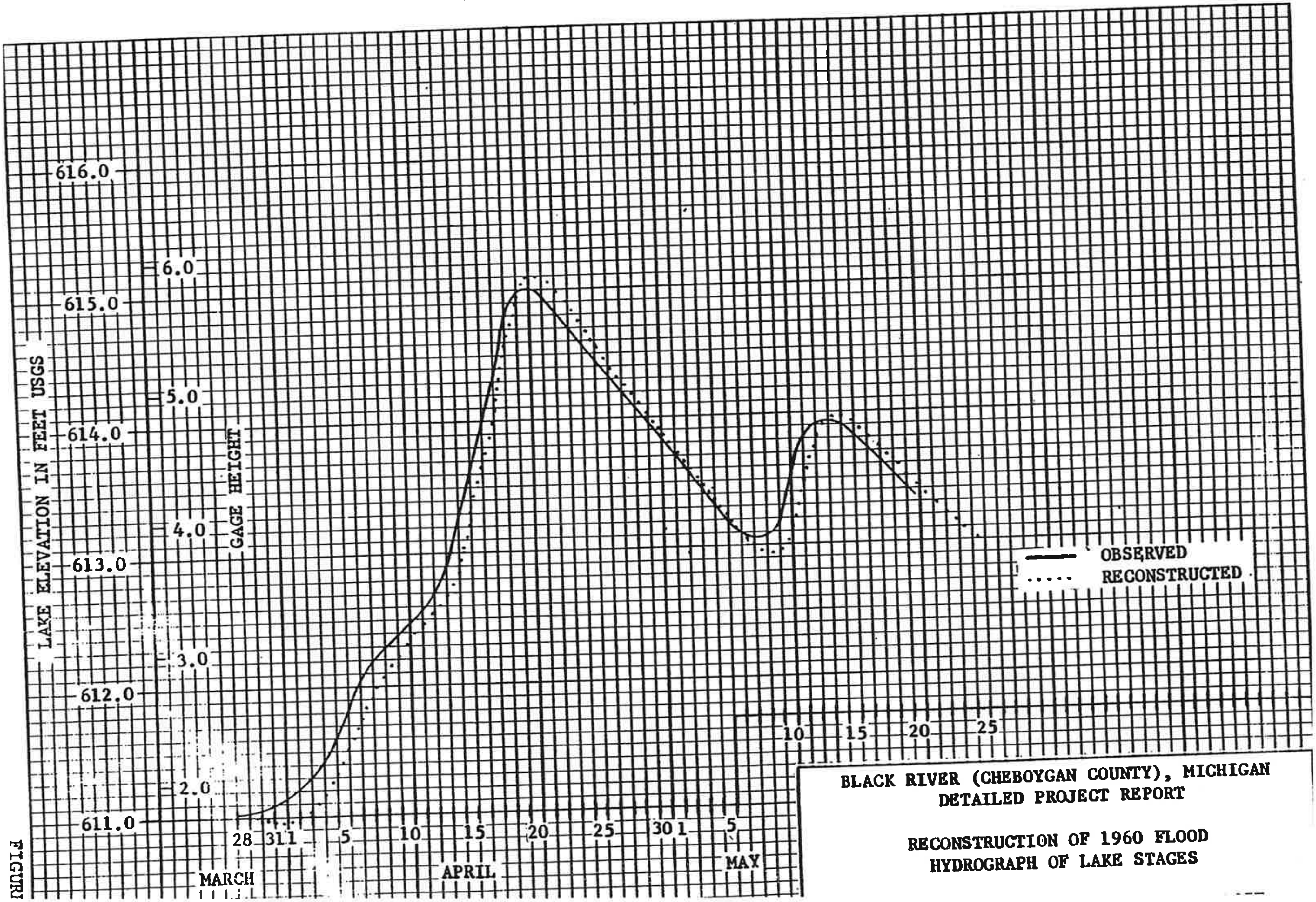
CONCLUSIONS

54. The considered 100-foot channel would provide marked relief from lake flooding. The channel would reduce lake stages approximately one foot under design conditions. The frequency of lake stages exceeding the legal lake level of 612.2 is reduced from about once a year on the average to about once in three years. The stage of 613.5 which corresponds to the beginning of serious damage would be reached only once in eleven years as compared to about once in three years under existing conditions.



BLACK RIVER (CHEBOYGAN COUNTY), MICHIGAN
DETAILED PROJECT REPORT

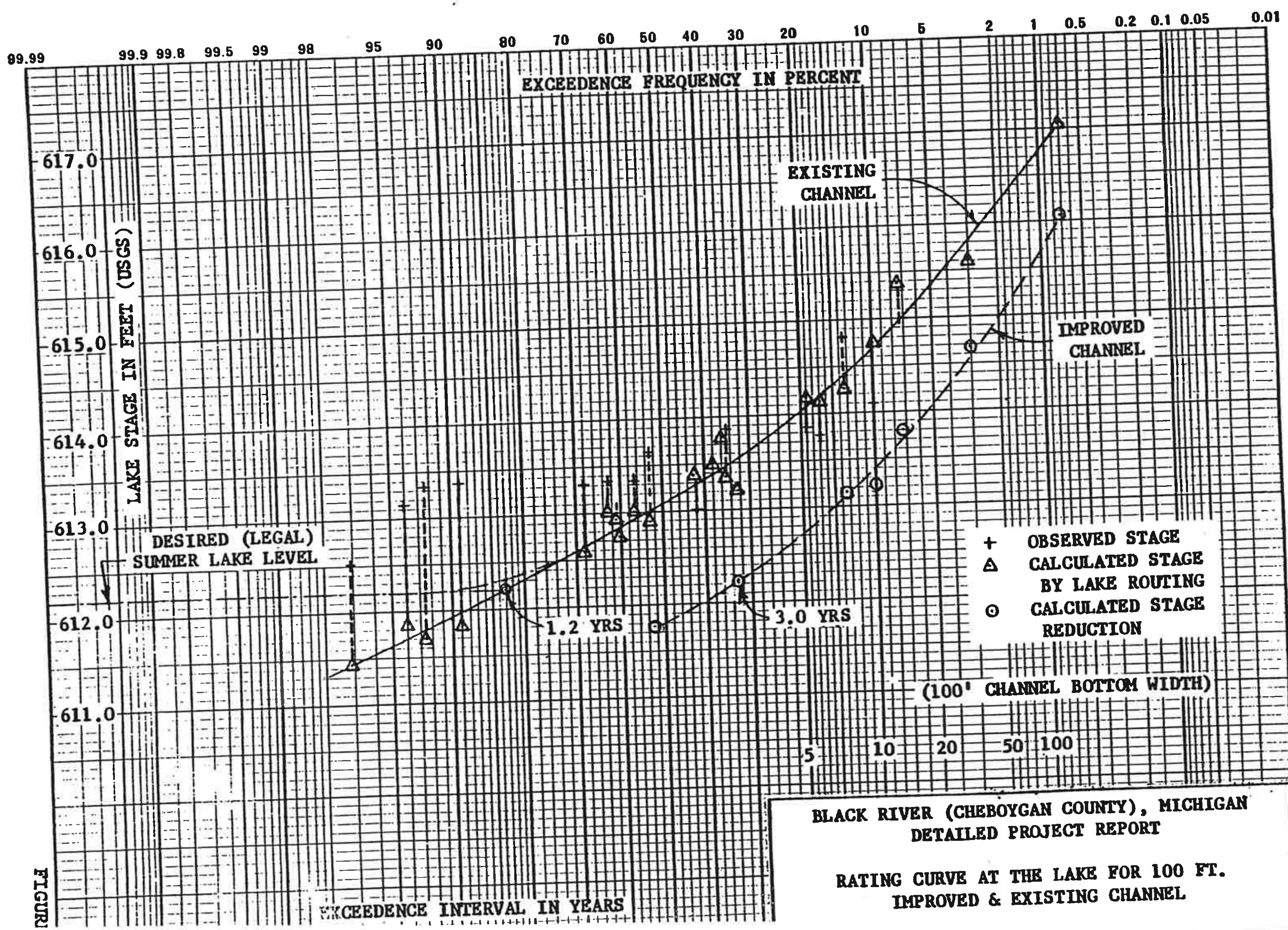
STAGE DISCHARGE
RELATIONSHIP



BLACK RIVER (CHEBOYGAN COUNTY), MICHIGAN
DETAILED PROJECT REPORT

RECONSTRUCTION OF 1960 FLOOD
HYDROGRAPH OF LAKE STAGES

FIGURI



BLACK RIVER (CHEBOYGAN COUNTY), MICHIGAN
DETAILED PROJECT REPORT

RATING CURVE AT THE LAKE FOR 100 FT. IMPROVED & EXISTING CHANNEL

FIGURE

DETAILED PROJECT REPORT ON FLOOD CONTROL
FOR
BLACK RIVER, CHEBOYGAN COUNTY

APPENDIX B

SUBSURFACE SOIL INVESTIGATIONS

TABLE OF CONTENTS

PLATES

APPENDIX B

SUBSURFACE SOIL INVESTIGATIONS

1. INTRODUCTION

The purpose of this appendix is to present the subsurface soil investigations and analyses pertinent to the improvement of Smith's Rapids on the Black River in Cheboygan County. The subsurface soil investigations made by the Michigan Conservation Department in 1943 are also included with the Corps investigation that was made for this report.

2. GEOLOGY

The geology of the region within which the Black River flows is summarized as follows: This region lies on the northern rim of the Michigan Basin where the rock formations are sediments of Devonian and Mississippian age. These rock formations dip rather steeply to the southward. The headwaters of both the Black and the Rainy Rivers originate in areas where the cold water and antrim shales are underlying the drift at probable depths of 150 to 200 feet throughout most of their course. As both streams flow northward, or in an up-dip direction if referred to bedrock, they flow over land where only a thin veneer of sand and/or clay separates the traverse limestone from the surface. This veneer is usually less than 25 feet, and in many cases is entirely absent, the limestone being exposed at the surface in road cuts, quarries, and as natural outcroppings along hillsides and in stream beds where it creates small rapids or falls. Spectacular sinkhole development has taken place within the confines of the Black-Rainy River basin. All of these sinks occur within that portion of the basin where the belt of high-calcium traverse limestone outcrops. The best known of this series of sinks is east of Shoepac Lake. One of these sinks is 120 feet deep. Other sinkhole areas occur in the northwest part of Montmorency Township, Montmorency County and in the northeast part of Corwith Township, Ostego County.

3. These sinks demonstrate the ability of the soluble, porous, limestone to catch and transport large quantities of water through underground cavities or channels. Maximum run off tends to occur only after long periods of continuous precipitation or after short periods of extraordinarily heavy rainfall. The thinness, or total absence, of drift is also an inducement for downward percolation rather than run off.

4. The Smith's Rapids section of the Black River is in a Lake Plain glacial area interspersed with drumlins composed of till. No rock is found at the surface anywhere in Cheboygan County. The rock is covered nearly everywhere with a blanket of mixed sand, gravel, boulders, and clay glacial drift.

5. GENERAL

Three borings were taken in 1964 to investigate the subsurface soil conditions in the detail required for this report. Of the three borings taken, two are in the area of Alverno Dam. Originally some modifications were considered necessary for the dam; however, since the Dam is not in the area of the final selected plan of improvement, the subsurface soil data obtained for stability analysis of Alverno Dam are not included. Only the soil data from boring 1-64 taken in the rapids area along with six borings made by the Michigan Department of Conservation are included. In addition to the borings, a probing survey was made in 1964 at the Smith's Rapids area. During the sounding operations by the Survey Party, boulders were encountered in the bottom of the existing channel. These boulders along with small rocks forms the Smith's Rapids.

6. PROBING INVESTIGATION

A probing survey was made of the river bottom in the Smith's Rapids area. The material within the depth of the probings was found to be generally the same as that shown by boring 1-64. The river bottom was found to be covered with scattered boulders and cobbles. A 1 inch probe rod was worked down thru the cobbles and boulders. As soon as the stone strata was fully penetrated, it was possible to advance the probe rod thru a soft clay stratum to a depth of 7.5 feet below the existing channel bottom. At about 1,000 feet downstream of boring 1-64, the material found within the probed depth was a Brown SANDY GRAVEL. In this material, the probe rod was worked down to a depth of about 7.0 feet below the existing bottom. The material that is visible on both banks in this area is a Reddish Brown soil. At cross section 127+68.78, the 1 inch probe rod was worked down to a depth of 7 feet below the existing channel bottom. The river bottom at this location consists of cobbles, 10 inches in diameter, resting on a soft clay containing some gravel. The very soft clay found in the Rapids area below the gravel, cobble bottom ceases to exist at about this cross section. At cross section 132+02.21, the bottom is the same as at cross section 127+68.78 except the clay below the cobbles and boulders is softer. At cross section 124+00 there was a change in material indicated. The top stratum of the river bottom is harder and the material is smaller, consisting of gravel instead of cobbles. At the depth of the bottom of the probe, which was about 7 feet below river bottom, the material was found to be a sandy gravel with a pink clay binder.

7. Section A-A as developed from borings 1L-43 and 2L-43 indicates that the material across the channel bottom to be a gravelly material. This checks with the material found at this same location by probings in the river. Upstream of section A-A the soil below the top strata of boulders and cobbles is a soft clay soil.

8. BOULDER INVESTIGATION

The river sounding survey serves as a boulder investigation. The locations of boulders found during the survey are shown on cross sections on Plate B-3. Boulders were found during the probing investigation to be present at other locations than on the sounding lines.

9. ANALYSES OF IMPROVEMENT TO THE RIVER CHANNEL AT SMITH'S RAPIDS

The removal of the gravel, cobbles, and boulders from the bottom of the existing channel will expose the underlying soft clay. This soft clay would be susceptible to erosion during high flow discharges with a resultant lowering of the new design channel bottom. This would occur over a period of time. At the present time, the Rapids are the controlling feature of the river with the Alverno Dam a secondary control. At some time prior to construction of the Alverno Dam, the Rapids were the sole control of Black Lake water levels. By lowering the elevation of the invert of the channel in the Rapids area, more reliance is placed on the Dam. Although investigation of subsurface soil conditions at the Dam were not completed, it is believed that we should not depend entirely on the Dam to control Black Lake water levels after improvements to the channel since erosion over a period of years could erode the channel bottom below its design elevation.

10. Two submerged rock sills have been designed to prevent the lowering of the channel bottom due to erosion. One would be located at cross section 123+60 and the other one located at cross section 137+60. These locations are approximately at the third points along the channel improvement. The sills are to be dug to elevation 600 and backfilled with boulders or cobbles or gravel to the design channel bottom elevation The side slopes of the sill excavation on the upstream and downstream sides are to be one vertical to two horizontal. The shore ends of the sill excavation are to be protected by steel sheet piling that is tied back into the banks.

11. SUBSURFACE SOIL CONDITIONS

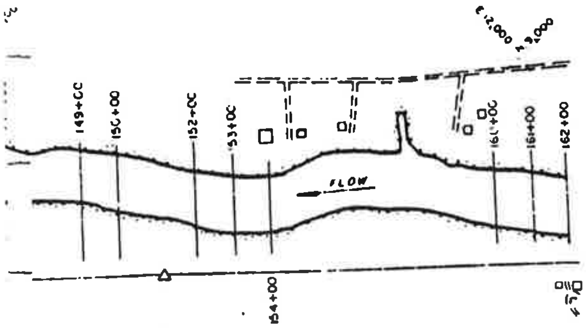
Plate B-2 has five soil profiles developed from eight borings made by the Michigan Conservation Department and one boring by the Corps of Engineers. Boring logs of the Michigan Conservation Department and the Corps of Engineers are shown on Plate B-1.

12. TEST DATA

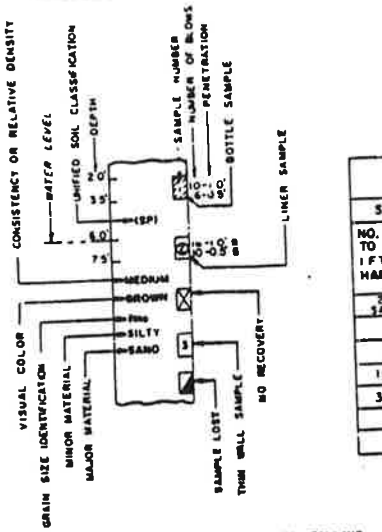
All soil tests made on samples from the borings made at Alverno Dam site are not included in this report. Gradation tests made on samples of boring 1-64 in the Smith's Rapids section are included as Plate B-4.

13. ADDITIONAL SUBSURFACE SOIL INVESTIGATIONS

Further subsurface soil borings are necessary and will be made subsequent to plans and specifications. One boring will be made at the location of each erosion control sills. The river bottom has been found by the probing investigation and the sounding survey to be covered with boulders and cobbles. Additional subsurface soil data is needed for the strata below the cobble and boulder strata. Borings will be taken along the length of the proposed channel improvement.



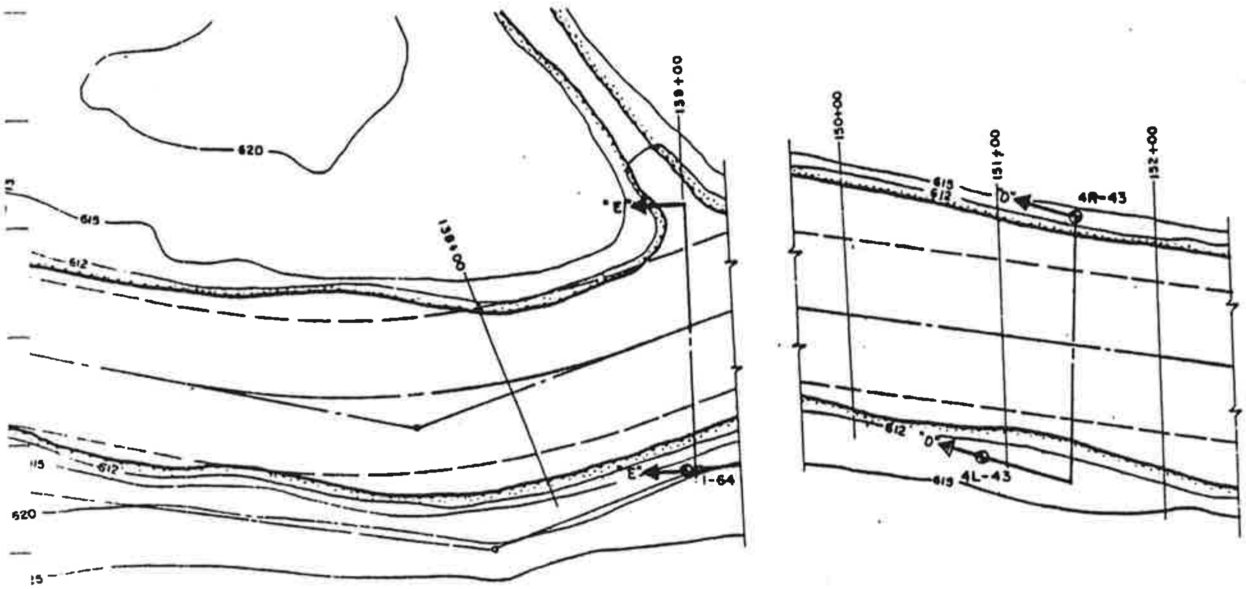
BORING LOG LEGEND



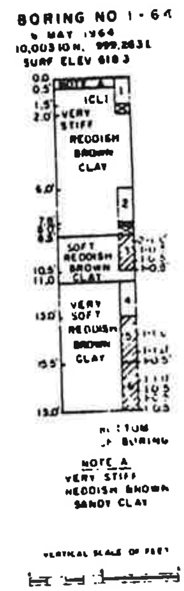
1. NUMBER OF BLOWS OF A 140 LB. HAMMER, FALLING 30" TO DRIVE A 2" O.D. SAMPLER, UNLESS OTHERWISE SPECIFIED.

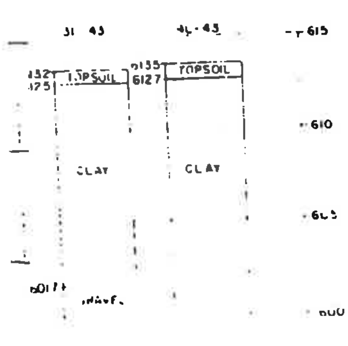
RELATIVE DENSITY AND CONSISTENCY TABLE

SAND AND SILT, RELATIVE DENSITY			CONSISTENCY OF CLAY		
NO. OF BLOWS REQ'D TO DRIVE A SAMPLER 1 FT. USING A 140# HAMMER FALLING 30"		RELATIVE DENSITY	NO. OF BLOWS REQ'D TO DRIVE A SAMPLER 1 FT USING A 140# HAMMER FALLING 30"		CONSISTENCY
2" O.D. SAMPLER	3" O.D. SAMPLER		2" O.D. SAMPLER	3" O.D. SAMPLER	
			< 2	< 8	VERY SOFT
< 4	< 8	VERY LOOSE	2 - 4	8 - 16	SOFT
4 - 10	8 - 16	LOOSE	4 - 8	16 - 55	MEDIUM
10 - 30	16 - 55	MEDIUM	8 - 15	55 - 110	STIFF
30 - 50	55 - 110	DENSE	15 - 30		VERY STIFF
> 50	> 110	VERY DENSE	> 30	> 110	HARD



LOCATION PLAN





ALL ELEVATIONS ARE IN FEET AND ARE REFERRED TO U.S.G.S. DATUM

BLACK RIVER
CHEBOYGAN COUNTY, MICHIGAN

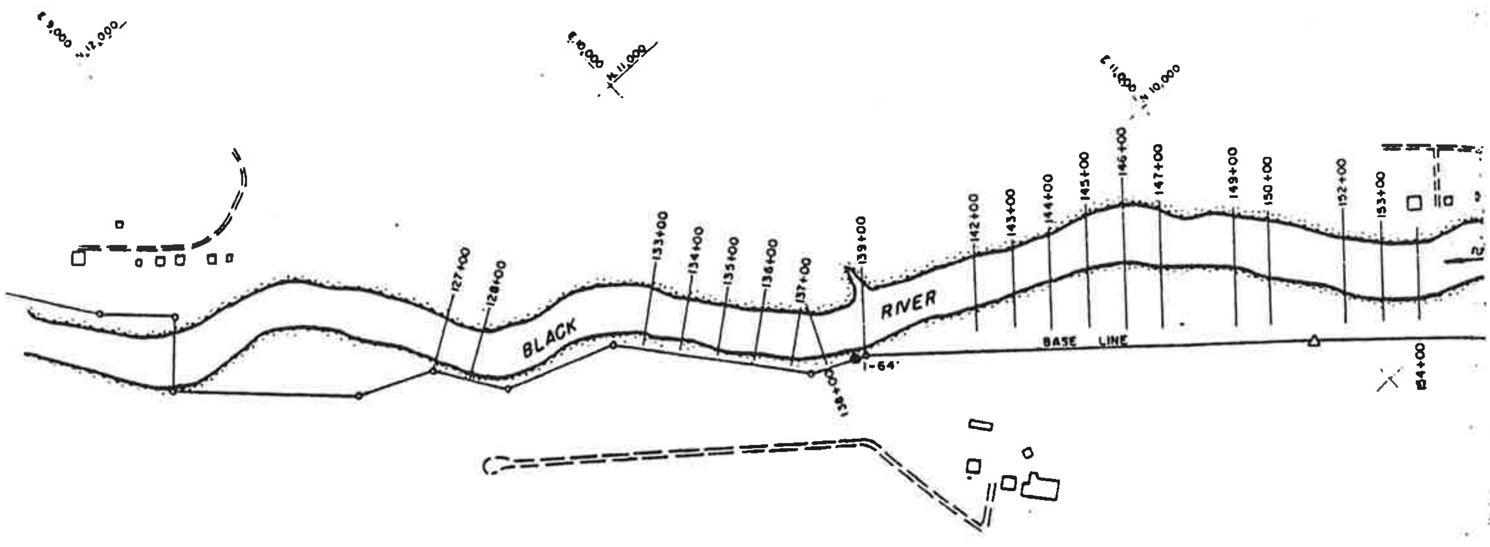
FLOOD CONTROL

LOGS AND LOCATIONS OF BORINGS

U.S. Army Engineer District, Detroit

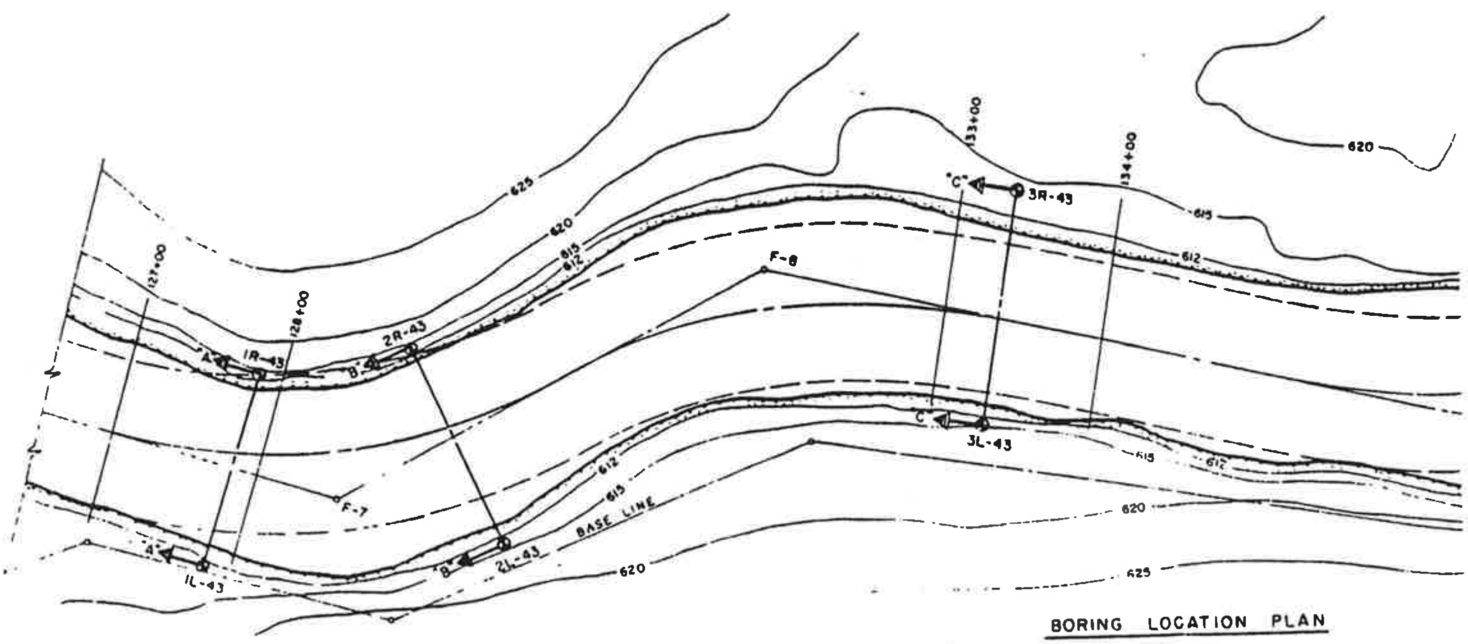
PLATE

CORPS OF ENGINEERS



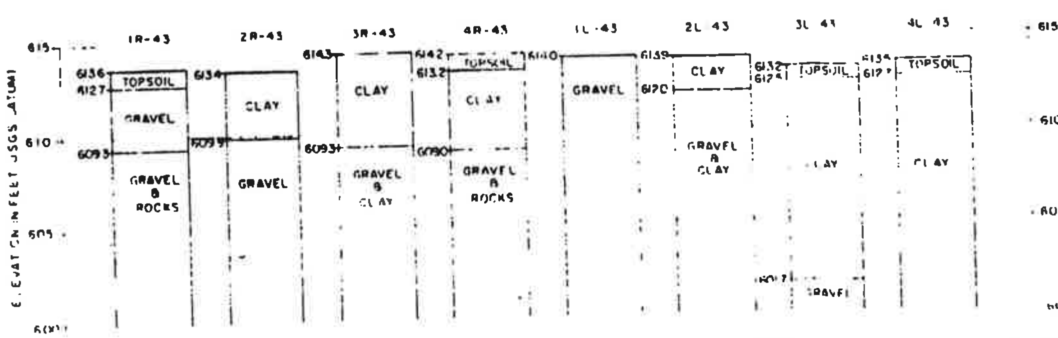
PLAN

SCALE OF FEET



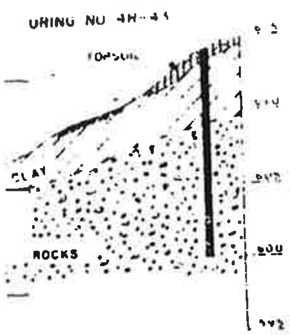
BORING LOCATION PLAN

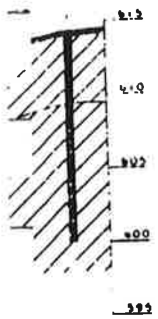
SCALE OF FEET

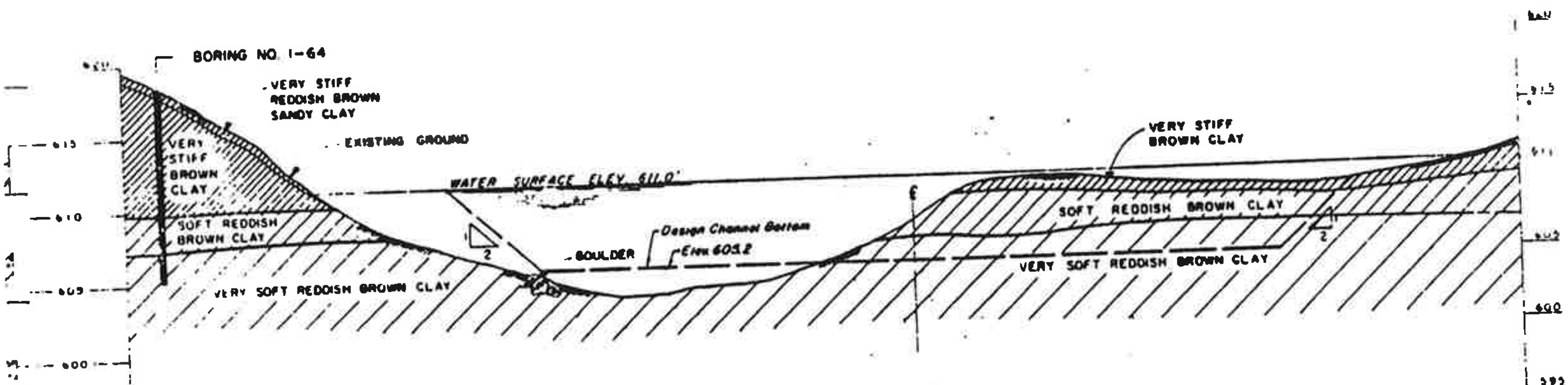


SOIL BORINGS (BY CONSERVATION DEPT)

PLATE B-1







SECTION E-E

All elevations are in feet and are referred to U.S.G.S. Datum

HORIZONTAL SCALE OF FEET

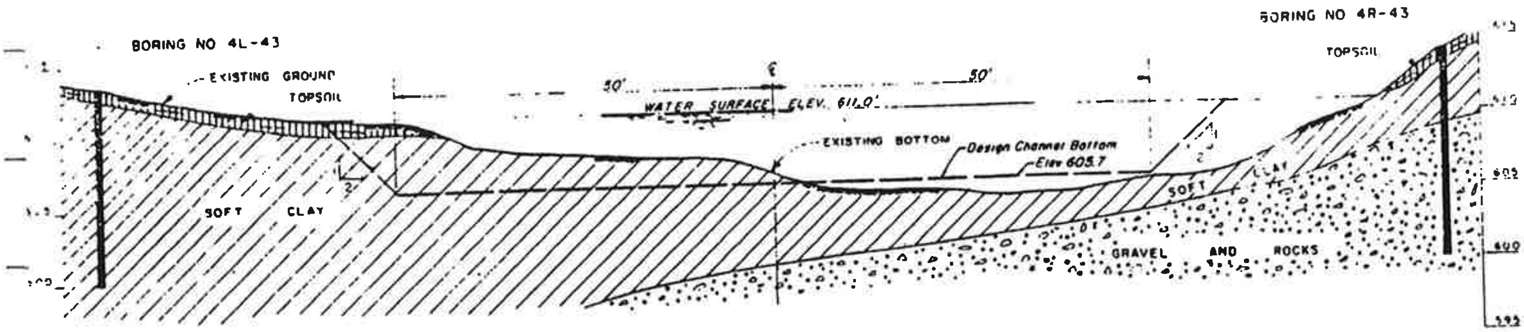
BLACK RIVER
CHEBOYGAN COUNTY, MICHIGAN

FLOOD CONTROL

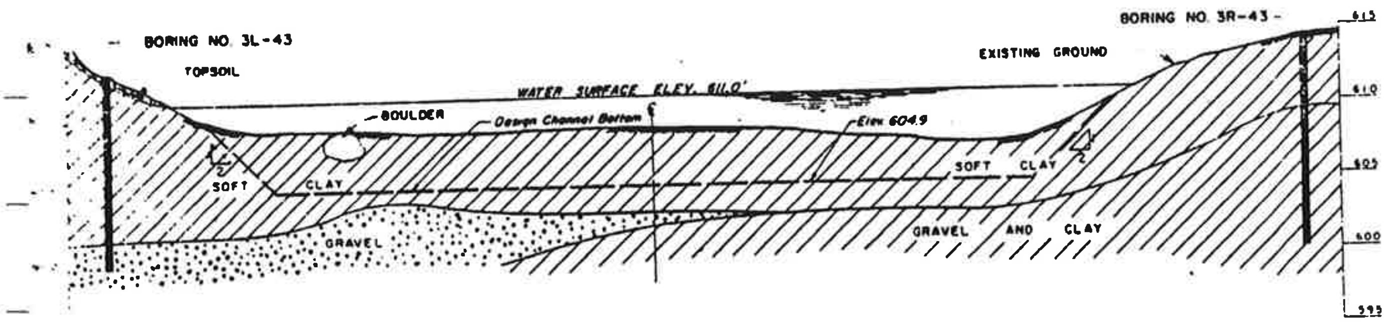
SUBSURFACE SOIL CONDITIONS
SMITH'S RAPID

U.S. Army Engineer District, Detroit

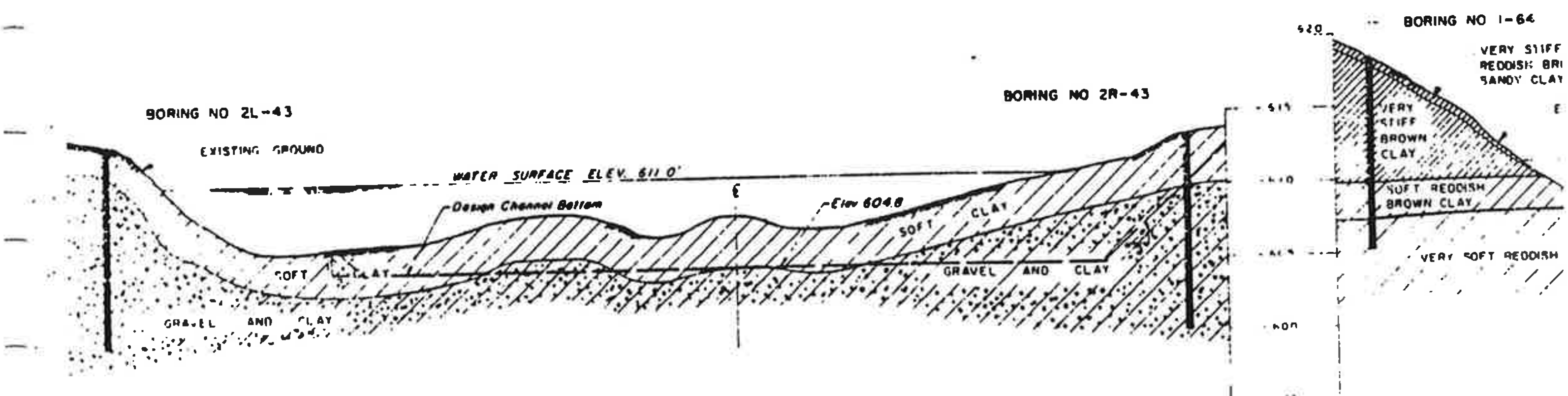
PLAT
B-



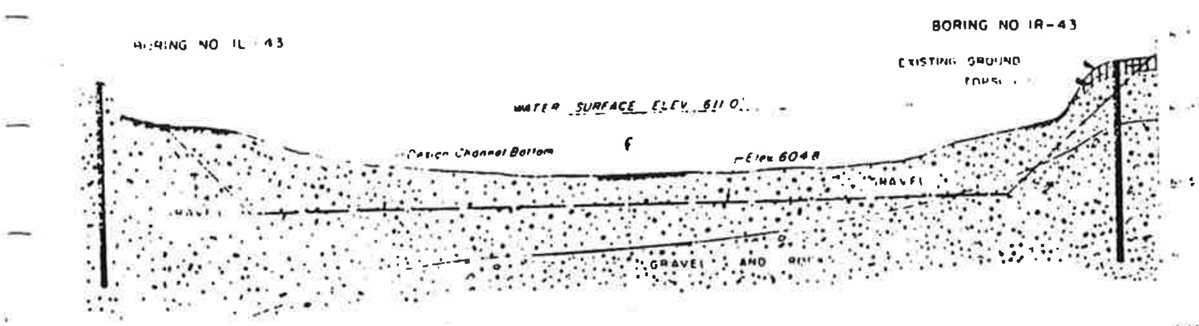
SECTION D-D



SECTION C-C

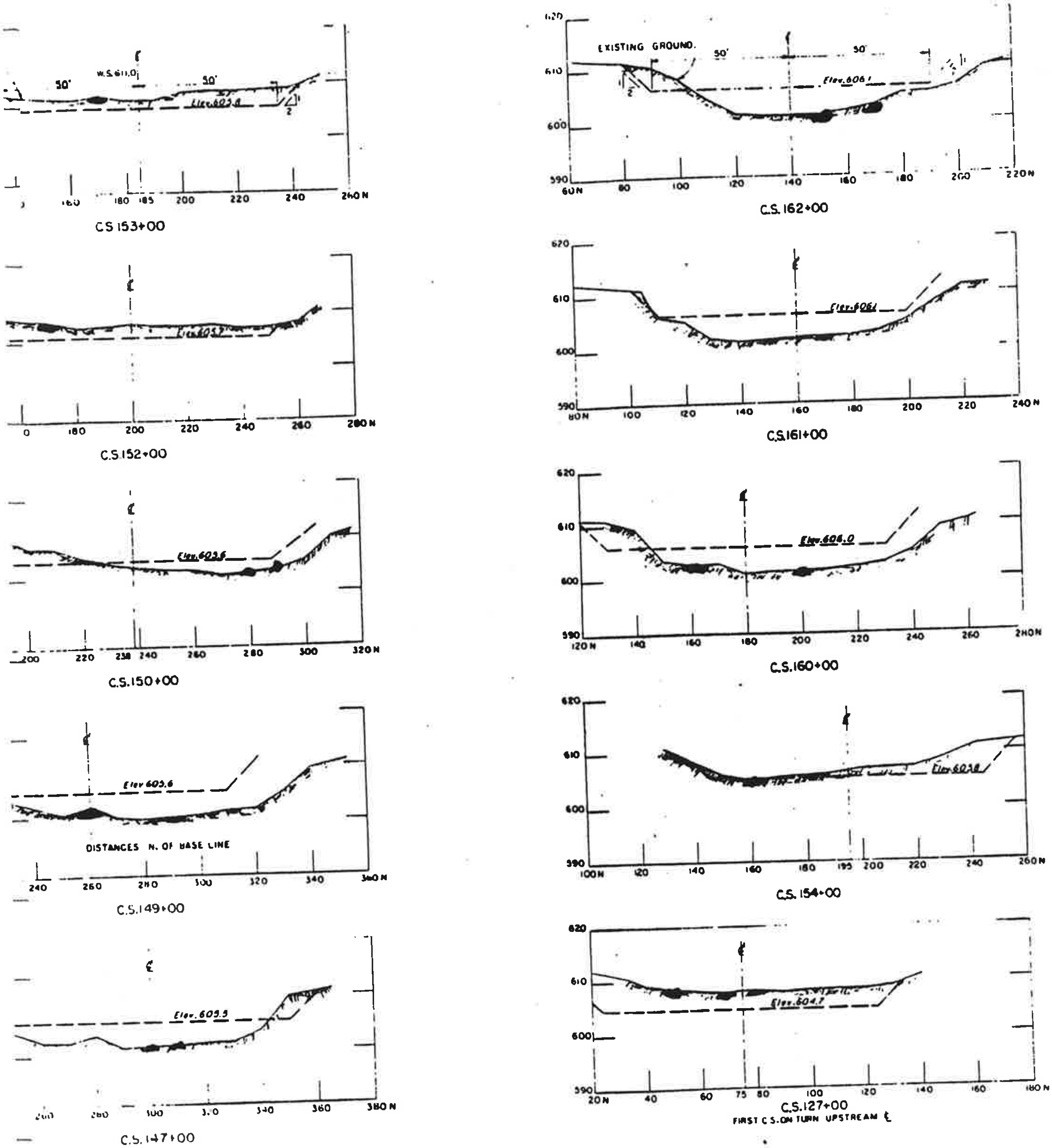


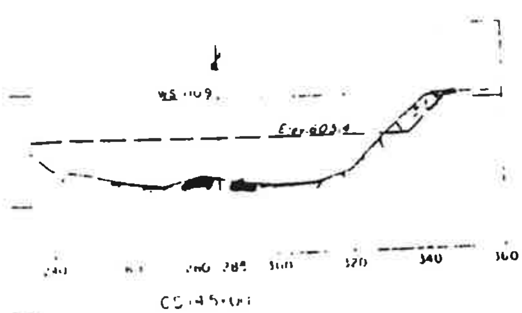
SECTION B-B



SECTION A-A

PLATE B-2





NOTES:

— — — INDICATES DESIGN CHANNEL BOTTOM

● INDICATES LOCATION OF BOULDERS

All elevations are in feet and are referred to U.S.G.S. Datum

BLACK RIVER
CHEBOYGAN COUNTY, MICHIGAN

FLOOD CONTROL

SECTIONS SHOWING BOULDER LOCATIONS

U. S. Army Engineer District, Detroit

PLATE

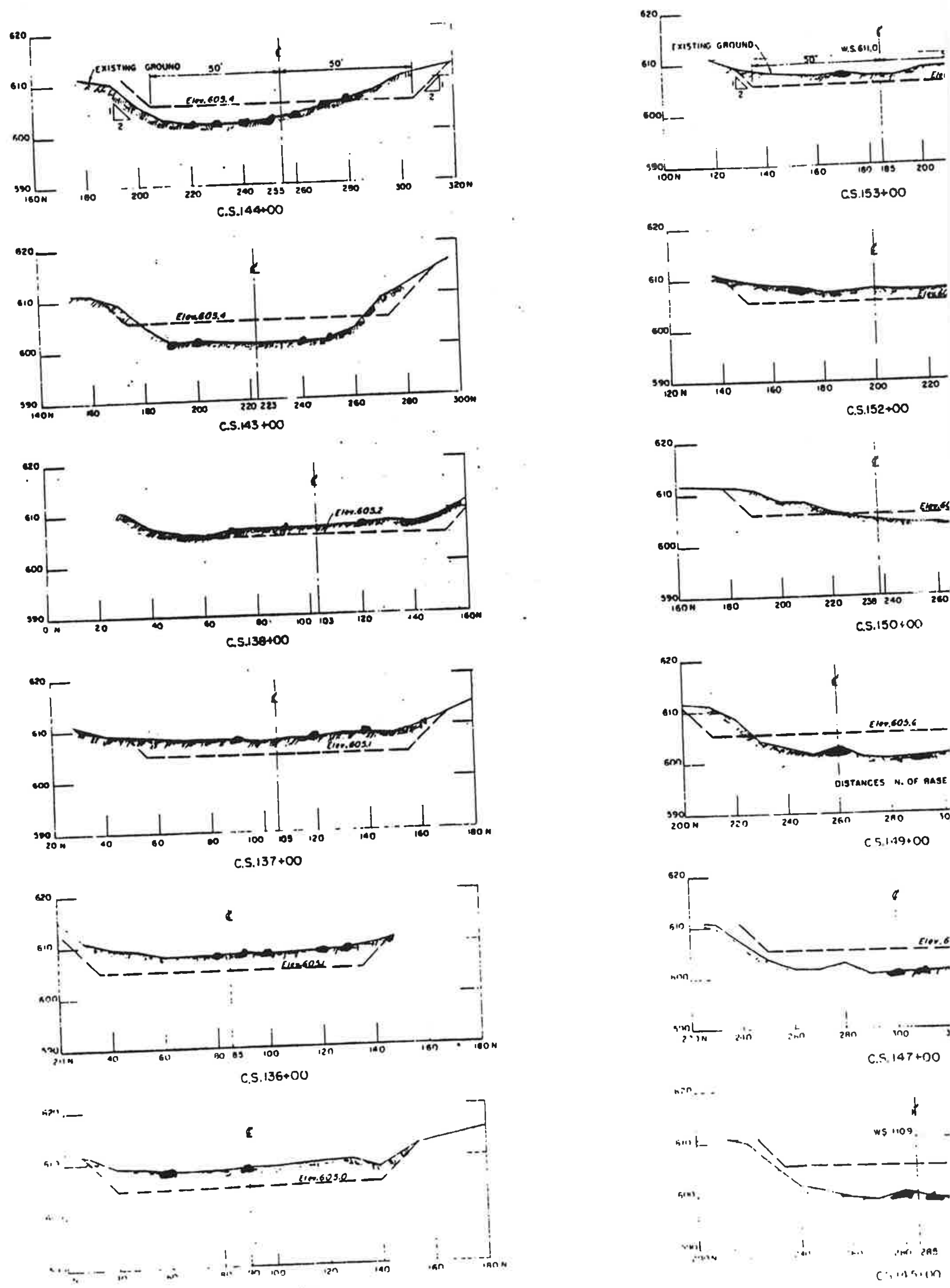
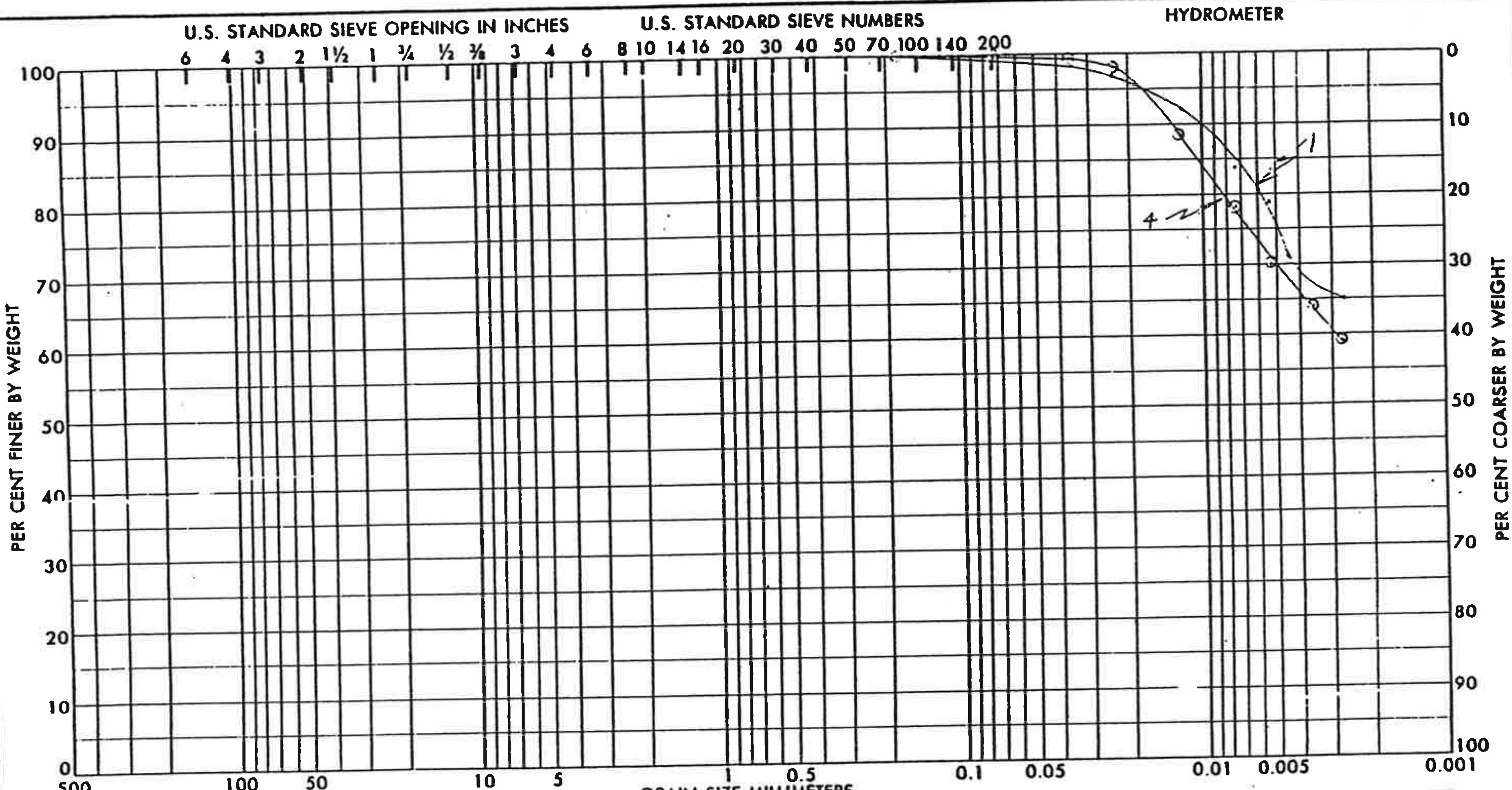

EXISTING GROUND
50'
50'
Elev. 605.4
C.S.144+00
Elev. 605.4
C.S.143+00
Elev. 605.2
C.S.138+00
Elev. 605.1
C.S.137+00
Elev. 605.1
C.S.136+00
Elev. 605.0
EXISTING GROUND
W.S. 611.0
C.S.153+00
C.S.152+00
C.S.150+00
Elev. 605.6
DISTANCES N. OF BASE
C.S.149+00
C.S.147+00
W.S. 609

PLATE B-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	~~ELEV. OR~~ DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
1/65D-80	0.0-1.5	Clay (CL) Change of material: Test specimen taken from bottom 13-3/4" of 20" tube sample. Top 6½" of tube sample - Sandy Clay (CL).				
4/65D-81	11.0-13.0	Clay (CL)		45.4	17.6	27.8

PROJECT Black Lake Flood Control

AREA 10003.10N, 9992.63E

BORING NO. 1-64

DATE September 1964

GRADATION CURVES

U.S. GOVERNMENT PRINTING OFFICE 1963 OF—709-126