HOUGHTON LAKE LEVEL CONTROL
SPECIAL ENGINEERING INVESTICATION
REEDSBURG DAM – HYDRO (DRAWDOWN) TEST
ROSCOMMON COUNTY
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MICHIGAN DEPARTMENT OF CONSERVATION
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Including Data and Graphs by
Water Resources Branch of the
United States Geological Survey

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Notation should be made that US-27, referenced in this document, is now* called Old 27. Also, the referenced Roscommon County Board of Supervisors is now* called the Roscommon County Board of Commissioners.

*2006

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I - SCOPE

A. History*

1. Houghton Lake Level Control Dam

The legal level of Houghton Lake was established by the Roscommon County Circuit Court on January 5, 1926, under the provisions of Act 377, Public Acts 1921, and for many years there was a timber dam across the Muskegon River approximately three-quarters of a mile downstream from Houghton Lake and this timber dam controlled the level of Houghton Lake to some extent. We have no information regarding the builders or original owners of the dam but do know that it was instrumental in retarding outflow from Houghton Lake and it did not have sufficient spillway capacity to handle flood flows. This dam was constructed on land owned by Louis Michelson except for the extreme southwest corner which was on Lot 3, Section 3, T.23 N., R. 4 W., and which was acquired from the U. S. Government by the Michigan Department of Conservation in the year 1931.

Method of control of flashboards on the timber dam previous to about 1937 is not known, but at that time Mr. Fred Crooks, who resided at the site of the dam, was employed and paid partly by Louis Michelson and partly by the county to control the lake level by operation of the flashboards. There was considerable trouble in the following years with the high and low water interests, Mr. Michelson being interested in providing water in the marsh below the dam for the benefit of muskrats, and the riparian owners (on Houghton Lake) being interested in higher water at times. The control was very indefinite, being affected by numerous interests who called on Mr. Crooks and influenced his operation of the dam.

* The material included in this “History” of Houghton Lake Level Control Dam and Reedsburg Dam is based on data from the files and personal knowledge of Mr. Otto H. Hall, Registered Professional Engineer, In Charge, of the Engineering and Architecture Section, Division of General Operations, Michigan Department of Conservation.

In 1937, the Roscommon County Board of Supervisors asked Mr. Martin Webb, Office Assistant, Game Division, to have the Department of conservation take over the county-owned timber dam and control the level of Houghton Lake. At that time, Mr. Webb advised them that it was not in accordance with policy and that the Department did not have the responsibility or authority for this action.

Due to the weakened condition of the timber dam, the Roscommon County Board of Supervisors decided to replace it with a concrete structure in 1938. In a memorandum to the files written by Martin Webb on May 9, 1938, it was indicated that the Roscommon County Board of Supervisors, through O. M. Arthur, Chairman of the Lake Level Committee, had contacted Director Hoffmaster for the services of a department engineer to aid them in preparing plans for the new structure. They were advised by the Director at that time that the Department did not have an engineer available for this purpose, but the Director recommended to Mr. Webb that he cooperate with them as much as possible.

Mr. Webb and Mr. Arthur contacted Mr. Otto Hall, Conservation Engineer, Michigan Department of conservation, Civilian Conservation Corps., Planning Division, one day in 1938 at the site of the Mud Lake Level Control Dam east of Houghton Lake to review the plans that had been prepared. At that time, Mr. Arthur was advised that they should take every precaution to construct the dam with sufficient spillway capacity. Later when the dam was under construction, Mr. Arthur called upon Mr. Hall and advised that they intended to reduce the length of the dam below that specified in the plans as it was the contractor's recommendation that it was not necessary to build a longer structure.

Mr. Arthur was warned against reducing the length of the structure at that time, again calling his attention to the need for sufficient spillway capacity and that it should be remembered that, while the lake level problem at that time might have been one of low water, high water problems could also be expected. Later Mr. Hall found that the length of the structure was reduced and, as completed, there were six bays at 7 feet making a total crest length of 42 feet + or -. This dam was completed in the fall of 1938.

The entire concrete dam built in 1938 was constructed on Lot 3, Section 3, T. 23 N., R. 4W., and is about 35 feet southwest of the end of the old dam. This new structure is entirely on state-owned land administered by the forestry division of the Department and no records have been found to date to indicate that the Roscommon County Board of Supervisors obtained approval from the state for the construction of this dam.

The old timber dam was removed as a CCC project in 1940, such project being sponsored by the Department of Conservation. The County Board of Supervisors contributed $200.00 at that time to furnish gasoline, oil and a shovel operator for the work. The project apparently was justified by the Department on the basis that it would provide access to Government Lot No. 2 of the SW ¼ of the SW ¼ of Section 3 which had been acquired by the State in 1938 Hart and Hartwick.

Authority for control of the level of Houghton Lake is vested in the Roscommon County Board of Supervisors in accordance with a Circuit Court Decree dated January 5, 1926, establishing the level at 1145.54 feet above sea level on Fargo Engineering Company datum. This legal level is equal to 1140.04 Army Engineer's datum and 1138.10 U. S. Coast and Geodetic Survey datum or present mean sea level datum used in this report and plans. The Court remarked that the level was being established at the elevation of water surface in September 1914 and that in September 1924, the water of Houghton Lake was 1.78 feet below the level being established.

Observations during past years indicate that considerable development has taken place around Houghton lake and that low marshy areas, previously considered undesirable, have been developed into lots and sold. Large marsh areas were platted and very shallow fills placed over these areas to prepare cottage sites for sale. As the years have gone by, the recreational public has observed Houghton Lake during the latter part of the summer and purchased lots when lake levels were low. After construction of cottages on those lots, at elevations very little above the ground surface, trouble developed from high water levels flooding out the land immediately around the cottages themselves.

To make matters worse, someone dynamited the end off of a pier of the present county-owned control structure, in the spring or early summer of 1947, in order to remove flashboards that had been wedged into place by the Lake Level Committee of the County Board of Supervisors. After this was done, the Lake Level Committee replaced the planks and filled in above the dam to the top of those planks with sand and gravel leaving only one seven foot wide bay for a spillway.

On October 19, 1948, Mr. Hall met with the Board of Supervisors at Roscommon and advised them tat it would be absolutely necessary to remove all the fill and make it possible to remove all flashboards in the entire length of the structure, during the spring months, if they wish to avoid damage to private property around the lake. Numerous angles of the Houghton lake Level Control Problem were discussed with t hem at that time and they were reminded that

the county owned structure does definitely not have spillway capacity enough even if the entire length is maintained in a usable condition.

The Board of Supervisors was also advised that this Department, if requested, would make a complete engineering investigation of the Houghton Lake Level Control Problem and provide them with recommendations concerning the type, length, and estimated cost of a dam that would maintain the legal level except at times when a deficiency in precipitation might result in a lower than legal level during some months of the year.

2. Reedsburg Dam

The Reedsburg Dam was constructed, approximately 6 miles downstream from the county owned dam, by the Department of Conservation through a CCC project in 1940. Mr. Otto H. Hall was responsible for the field surveys, design of the control structure and supervision of construction for the Reedsburg Dam. It was started in January 1940 and completed in October of 1940. Permission is on file by resolution of the Roscommon County Board of Supervisors allowing the Department to construct the dam at that location but specifying further, that the Department make necessary road repairs in the area. The County Board of Supervisors agreed to maintain the roads in the future but required that they be held free of all responsibility and liability for damages as a result of the construction of the dam. This resolution was dated July 3, 1937.

When the Reedsburg Dam was designed, it was agreed between the Game Division and Mr. Hall, who was responsible for that design, that the pond level of 1139 feet above sea level, Army Engineer's datum, (1137 U. S. coast and Geodetic Survey datum) or 1.0 feet below the legal level of Houghton Lake, would be maintained in order that we would be held free from responsibility for the control of the level of Houghton Lake. Hereafter, all elevations in this report will refer to U. S. Coast and Geodetic Survey Datum. Additional factors taken into consideration in using an elevation of 1137.0 feet included: (1) the limits of marsh area that would be flooded at this elevation. (2) the additional area that would be flooded at an elevation of 1138.0 feet, and (3) the elevation of numerous county roads in the area that would be affected by the pond level.

Mr. Hall discusses the reasons for not complying with requests to control Houghton lake levels with the Reedsburg Dam in the following paragraphs:

If the pond were maintained at a level much above elevation 1137 feet, it would be necessary to raise the grade of a considerable mileage of county road in order to avoid a water table elevation too near the surface of these roads. for instance: if the level of the pond were maintained at the legal level of Houghton Lake (elevation 1138.1), it would be necessary in our opinion to raise the grade of considerable road mileage to avoid a complete breakup in the spring and expensive road repairs. In addition, backwater effect on Hay marsh Creek and Dead Stream was taken into consideration in picking the desired pond elevation.

Structure design was based on elevation for the reservoir of 1137 feet, U. S. Coast and Geodetic Survey datum, and all stresses were distributed according to best engineering practice in accordance with the head that would result from this elevation. It is true that the structure was designed sufficiently strong to take a higher head during the short period of high spring flow. However, operation of the dam in such a way as to maintain this higher head throughout the year would result in a continuous pressure that might be more harmful below the spillway floor than if it only existed for a short period of time.

The emergency spillway required by the Washington Office of the CCC was built with an inlet elevation such that water would by-pass the dam if discharge quantities exceeded that for which the main spillway was designed. If a higher pond elevation were to be maintained, it would be necessary to construct a small earth dam across the inlet end of the emergency spillway to an elevation to maintain the new desired level. It would also be necessary to build the present Reedsburg Dam piers to a higher elevation resulting in a very large expense. This process would include rebuilding of the entire structural steel superstructure and possibly additional work along the downstream toe.

In 1947, U. S. Geological Survey gages were erected at the site of the Reedsburg Dam and at the new US-27 bridge across the Muskegon River. Later, another gage was erected at Meade's Landing. Forms for recording the readings were prepared and furnished Mr. Borgerson, Higgins Lake district Forester, who has the gages read and provides copies of the readings to the U. S. Geological Survey and Engineering and Architecture, Department of Conservation. These readings provide a record of pond and lake levels, and may be used as a guide to operation of both Reedsburg Dam and the County Dam.

B. Special Hydro-Test

A hydro-test was made during the period from March 30 to April 5, 1953, to determine the effect of Reedsburg Dam on Houghton Lake levels and to determine what other restrictions in the Muskegon River might be causing the undesirable levels on the lake, Standard U. S. Geological Survey staff gages were placed at numerous locations on the river to keep a check on water surface fluctuations during the test. Following is a list of these gages, the locations of which are shown on Graph No. 1 "Plan – Profile of Muskegon River" in the back of this report:

* 1. Houghton Lake – near Prudenville

2. Muskegon River – County Bridge near Houghton Lake

* 3. Muskegon River – US-27 Bridge

4. Muskegon River – County Dam – Headwater

5. Muskegon River – County Dam – Tailwater

* 6. Muskegon River – Meade's Bridge

7. Muskegon River –Between Meade's and Dead Stream

8. Muskegon River – At Dead Stream Junction

9. Muskegon River – Near Reedsburg Pond headwater

10. Muskegon River – at Michelson's

* 11. Muskegon River – Reedsburg Dam Headwater

* 12. Muskegon River –Reedsburg Dam Tailwater

Water surface readings were observed and recorded every half hour for 108 hours (4 ½ days) at each of the eleven stations, and continued at 2 hour intervals for an additional 36 hours on key stations. Houghton Lake (Station No. 1) was checked every 4 hours and showed practically no variation.

* Observations have been made at Stations 1,2,6, and 11 at regular intervals for several years and will probably be continued. The rest of the stations were established for the April 1953 hydro-test and will be removed and readings discontinued.

Special Hydro-Test (continued)

Frequent and regular observations were made possible by cooperation of personnel from all divisions of the Conservation Department located in the Roscommon and Grayling Areas.

Complete cooperation of personnel, from the Grayling office of he U. S. Geological Survey, made stream flow data available during the test. This agency gave their undivided attention to this job during the entire period of the Hydro-Test, and the data provided proved tremendously helpful.

All stop logs were removed from Reedsburg Dam lowering the pond more than 2 feet in three days. All stop logs were out, and had been out, of the County Dam for an extensive period because of high water conditions on Houghton Lake. River cross sections and a bottom profile previously surveyed were correlated with various water surface profiles that occurred during the Hydro-Test.

Data from the Hydro-Test showed that the effect of Reedsburg Dam on Houghton Lake levels in negligible, if any, under test conditions, and that the river itself and the County Dam are the controlling factors, therefore, the river channel and County Dam must be improved to carry expected flows, if desirable Houghton Lake levels are to be maintained.

C. Suggested Improvements to Facilities and Operation

Improvement of the Muskegon River Channel to provide more waterway area will be required, if adequate control of Houghton Lake levels is to be achieved. Excavation of portions of the river channel between Houghton Lake and the headwater of Reedsburg Pond should be included in those improvements.

The size of the County Dam should be increased about 70% to eliminate this existing restriction and provide the capacity required for design flows.

Computations show that the existing bridges have adequate spans, and restrictions at these points can be eliminated by increasing the waterway opening without disturbing footings or supporting piles.

Results of the Hydro-Test show that Reedsburg Dam has adequate capacity and flexibility for control of pond levels and the pond can be maintained at the top of the piers, elevation 1136.9, during all periods of the year under all but very exceptional flood flow conditions. Regular checks on watershed conditions will be required to serve as a guide to manipulation of stop logs.

The suggested increase in County Dam capacity will provide for control of Houghton Lake levels provided the operator considers watershed conditions and anticipates the need for manipulation of stop logs. Houghton Lake should be held at the legal level, elevation 1138.1, unless it is deemed advisable to draw down one-half foot in the fall to provide freeboard protection against winter ice damage. This lower winter level will also provide some storage for spring flood flows below the legal level.

The Roscommon County Board of supervisors is vested with the authority and responsibility for maintaining Houghton Lake levels as established by the Circuit Court. Improvements suggested and operation of the control facilities can be paid for by creation of a special assessment district consisting of property owners benefited.

II - DISCUSSION OF THE PROBLEM

A. PAST LAKE LEVELS

A study of past levels on Houghton Lake and Reedsburg Pond was made from hydrographs prepared by U. S. Geological Survey and the Michigan Department of Conservation. The available records for Houghton Lake cover a period from June 3, 1942, to date, while those for the Reedsburg Pond include levels from January 29, 1948, to date. Because of the broad expanse of water in Houghton Lake, the lake state records show many erratic fluctuations which are probably due to wind and must be taken into consideration when studying the records. The following observations appear noteworthy:

1. Houghton Lake

The main problem on Houghton Lake appears to be high lake levels, which have occurred during the spring runoff, causing the inundation of septic tank installations, beaches and other shore installations, and contributing to the possibility of ice damage resulting from winter ice push and spring breakup. The highest recorded level occurred on April 19, 1952, when the lake rose to elevation 1139.63 or 1.53 feet above the legal level of elevation 1138.10. Is should be noted that one of the reasons for this unusually high level is the fact that the average winter level for that year (1952) was elevation 1138.9 or about 0.8 feet above the desired level, a condition which existed at no other time during the period covered by available records. This high winter level coupled with an average spring rise on the lake of about 1.7 feet resulted in the undesirable high water condition.

The greatest spring rise on the lake occurred during March, April and May of 1951, when the lake rose about 1.2 feet as a result of spring runoff, but this rise did not result in an extremely high lake level because the winter level that year was only slightly above the legal level.

Low water has not been a problem in the past although the lake did recede to elevation 1137.19 or 0.91 feet below the legal level on October 23, 1946. This condition might have been improved by careful operation of the county dam.

Due to the large amount of available storage on the lake's 19,600 acres of surface area, the yearly fluctuations of lake levels have been held within reasonable limits. The largest fluctuation, about 2.0 feet, occurred during 1952 when the lake rose to elevation 1139.63 on April 19 and receded to elevation 1137.60 during the latter part of October.

Data on Houghton Lake levels prior to the start of regular records are very meager, but a series of observations of Muskegon River stages immediately below Houghton Lake were made during flood flows in the spring of 1938, before Reedsburg Dam was built. A comparison of this 1938 record with the April 1953 hydro-test record reveals the following water surface elevations:

	Water Surface Elevations		
	March 22	April 2	
Location	1938	1953	Difference
Reedsburg	1130.7	1134.6	3.9 feet
Michelson's	1130.7	1134.9	4.2 feet
Meade's Bridge	1137.8	1138.1	0.3 feet
Houghton Lake	1138.5 *	1138.8	0.3 feet

* Assuming same difference between Meade's Bridge and Houghton Lake as existed in 1953.

In 1938 the old timber dam, with a total span of about 39 feet, was used to control Houghton Lake and the above figures are based on the assumption that the dam was wide open during the high flood flows that existed.

These records indicate that a pond condition, at least under high runoff conditions, existed between the Reedsburg Dam Site and Michelson's before the dam was built. They also show that although the level at Reedsburg was about 4 feet lower in 1938 than in 1953, the level at Meade's was only 0.3 of a foot lower in 1938 than in 1953. The water surface slope and water depth between Michelson's and Meade's was about seven feet in 1938 while the difference in channel bottom, as indicated on Graph #1, is about four feet or a difference in depth of three feet, indicating a restriction between these two points which may have been responsible for the greater depth or ponded effect at or below Meade's Bridge.

Consideration of the conditions that existed in the Houghton Lake outlet during the 1953 Hydro-Test, as summarized in Graph #1, would lead to the conclusion that a change in channel conditions existed somewhere between Meade's Bridge and Michelson's. The water surface slope above cross section number 9 was not as steep as the slope below, pointing to the possible existence of a restricted condition at or above cross section number 9.

This interpretation of the data in Graph number 1, coupled with the 1938 and 1953 comparison, would indicate that a similar restriction existed between Meade's Bridge and Michelson's before the Reedsburg Dam was built, and without a doubt this had some effect on the level of Houghton Lake.

2. Reedsburg Pond

Conservation Department Personnel have attempted to maintain the Reedsburg Pond at the top of the piers on the Reedsburg Dam 9elevation 1136.88 but the pond has actually fluctuated between, a high of elevation 1137.46 or 0.58 feet above this design level on April 4 and 5, 1951, and a low elevation of 1136.14 or 0.74 feet below the design level on March 5, 1952, showing a maximum difference of 1.32 feet over the period of 4.5 years covered by available records. In order to keep this fluctuation at a minimum, some of the stop logs are usually removed from the Reedsburg Dam during spring runoff to compensate for flood flows.

Relative lake and pond stages indicate that the effect of Reedsburg Pond on Houghton Lake levels is negligible. For example: from March 29 to April 2, 1948, the pond was lowered 0.62 feet by the removal of stop logs at the dam, and stayed at this lower level for 12 days, while at the same time, the spring rise on Houghton Lake was not affected. during August and September, 1950, the pond was raised about 0.7 feet while the lake remained at a constant level, with flows slightly above normal.

B. Existing Outlet

1. Muskegon River – General

The Muskegon River is the outlet of Houghton Lake, leaving the lake at its northwestern tip and following a winding westerly course for approximately 3.6 miles to the junction with Dead Stream and then a southerly winding course for about 5.5 miles to Reedsburg Dam.

As it leaves the lake, the river flows under a County Road Bridge (a steel and wood piling structure); then under the US-27 Bridge 0.4 miles below the lake (a concrete structure having one pier in the center) and then to the County Dam (a concrete structure having six 7 foot bays). Approximately 2.0 miles below the lake, the river passes under Meade's Bridge (a wood piling structure); and 3.6 miles below the lake the river is joined by the Dead Stream, a stream of about the same width and depth as the Muskegon River, but with less slope and velocity.

Between the lake and Meade's Bridge, the channel is winding with low banks and it varies in width from 80 feet to 120 feet. From Meade's Bridge to a point one mile below the bridge, the river is winding and comparatively shallow and has a width of approximately 100 feet. The remainder of the channel to the Dead Stream Junction is deeper and narrower with a width of roughly 80 feet. The banks are low with large expanses of swamp on both sides.

Below the Dead Stream Junction, the river is 80 feet to 120 feet wide, and the banks are again low with large expanses of swamp on either side. The river broadens out into the Reedsburg Pond at a point about 5 miles below Houghton Lake.

2. Hydro-Test - Spring 1953

The hydro-test of March 30, 1953, to April 5, 1953, was made to determine:

1. What effect Reedsburg Dam has on Houghton Lake levels.

2. Whether or not there is nay other restriction in the river which might prevent adequate control of Houghton Lake levels with the existing County Dam.

a. <u>Flows during Test</u>

The inflow to Reedsburg Pond during the test, varied from about 450 to 550 cubic feet per second which is only slightly above the mean inflow for March and April 1953 (about 450 c.f.s.) while the outflow from Houghton Lake, contributing inflow to Reedsburg Pond, was fairly constant at approximately 240 cubic feet per second.

b. Pond and Lake Levels

Reedsburg Pond at the beginning of the test on March 30 was at elevation 1137.1 or only 0.2 feet above the normal operating level and was drawn down 2.5 feet by April 2, or more than 2 feet below the normal level. This draw down was accomplished by removing 64 stop logs from Reedsburg Dam which included all stop logs, except three in the bay containing the fish ladder and one in each of two other bays. The latter five stop logs were stuck and could not be removed. The stop logs were replaced on April 2 and 3.

Houghton Lake was at elevation 1138.8 or 0.7 feet above the legal level on March 30 at the beginning of the test, and on April 2, the lake was still at the same level, showing only minor fluctuations (hundredths of a foot) during this time, probably due to wind and/or human error in reading the gage.

c. Water Surface Slopes – Muskegon River

During the test period, the first point below the lake which showed any drop in water surface was Meade's Bridge where the water surface dropped 0.1 feet. There was no change in water surface elevation above Meade's Bridge except for minor fluctuations of .01 or.02 feet, apparently due to wind. All stop logs were out of the County Dam during the test, having been removed several months prior to the test.

Although the stop logs were replaced in Reedsburg Dam before the water surface at various points below Meade's Bridge had stopped receding, an investigation of the rate of recession at various points showed that if the stop logs had not been replaced, Reedsburg Pond would have dropped only about 0.2 feet farther and that the water surface at the Dead Stream Junction would not have dropped more than a few hundredths of a foot. No change was reflected at Dead Stream Junction during the last 12 hours of the draw down test. Therefore, a continuation of the test would not have produced any marked effect on Houghton Lake.

These conclusions are based on draw down curves plotted for individual stations and extended on the slope indicated by the trend. These curves are not included herein but are available as supplements.

Water surface slopes for twenty-four hour intervals during the test are shown on graph #1. It will be noted that the water surface slope at the end of the test is broken into two distinct slopes, that from the County Dam to Dead Stream Junction and that from Dead Stream Junction to Michelson's. Each of these slopes is approximately parallel to the average stream bottom, indicating that the channel simply could not carry any more water at existing lake and river stages. It will also be noted that the water surface slope below the Dead Stream Junction is much steeper than that above the Dead Stream Junction.

d. Waterway Area in the Channel

An investigation of typical cross sections above and below the Dead Stream Junction shows that the water way area is approximately the same size and shape, but the water entering the Muskegon River from Dead Stream during the hydro test increased the flow in the Muskegon River below the junction to 180% of that above the junction. Therefore, the junction is much more restricted than that above the junction, requiring more velocity to carry the increased volume as is indicated by the steeper water surface slope recorded during the hydro-test.

e. Other Restrictions

The drop in water surface through the County Dam was never more than 0.1 feet during the test. Meade's Bridge has a relatively narrow span and at one time during the test, a drop in water surface through the bridge of a little more than 0.1 feet was measured. Under present channel conditions, these losses are not excessive but channel improvements must include these structures to avoid excessive losses at these locations.

It is evident that the existing channel does not have enough capacity to maintain Houghton Lake at a desirable level under the conditions of flow which existed during the hydro-test and which past discharge records show are equivalent to average daily high winter flows. Maintaining Reedsburg Pond at a lower level would be of little or no help. It will be necessary to increase the capacity of the river, enabling it to carry these high winter flows at lower river and lake stages if Houghton Lake is to be maintained within reasonable limits.

III - DESIGN

A. Desirable Levels – Houghton Lake

Houghton Lake hydrographs show spring rises of 0.4 to 1.2 feet which are not considered excessive, as long as the range of fluctuation occurs within one foot above or below the legal level. High levels have occurred in the past because the outlet does not have capacity to maintain the lake at the desired level prior to the spring rise and as a result, the spring rise, added to a high winter or early spring level, produces undesirable and damaging levels on Houghton Lake. If the outlet is improved to the extent that it will maintain the lake at or below the desired level prior to the spring rise, then the lake can take the majority of spring runoff as storage and the outlet will be required to discharge high base flows only. The spring rise resulting from such storage can be expected to be 0.8 of a foot or less as indicated by 1942 to 1953 hydrographs; and a maximum lake level of elevation 1138.9 (1138.1 + 0.8) should not cause serious shoreline damage. Therefore, the outlet channel will be designed to carry maximum expected base flows prior to and during the spring breakup.

B. Design Flows and Capacity Requirements

1. Designing Flow above Dead Stream Junction

The design flows used herein were based on records of the Muskegon River near Merritt from October 1946 to 1953. This gauging station is located at the M-55 bridge about 2 miles below Reedsburg Dam, and has a drainage area of 309 square miles. Two design flows were used, one for the channel between Houghton Lake and Dead Stream Junction, and the other for the channel between Dead Stream Junction and the headwater of Reedsburg Pond.

The Houghton Lake outflow, in all but exceptional years, can be expected to be fairly constant over a period of a few months because of the equalizing effect of lake storage on the outflow and was therefore assumed to be proportional to the mean monthly flow at M-55, by the ratio of the drainage areas. The Houghton Lake hydrographs for a period of eleven years (1942-53) indicate that the highest mean flows prior to the spring rise occurred in 1952. Discharge records at M-55 show mean monthly flows as high as 350 c.f.s. in 1952-53, so allowing a safety factor and using a mean monthly flow at M-55 of 400 c.f.s., the design flow for the channel from Houghton Lake to Dead Stream Junction is:

$$\left(\frac{400 \times 189 \text{ square miles}}{309 \text{ square miles}}\right) = 250 \text{ c.f.s}$$

(drainage area at Houghton Lake outlet= 189 square miles)

This design flow was selected because Houghton Lake can store the entire expected spring runoff from the watershed on its 19,600 acres of lake area, and still not show a rise that will cause shoreline damage, provided the lake is at or below the legal level prior to the runoff period. The lake would rise only 0.8 feet during a storm with maximum daily runoff of 20 cubic feet per second per square mile based on storm distribution graphs from the Jordan Lake watershed adjusted to the Houghton Lake area, and including a safety factor to compensate for varying flows from Higgins Lake to Houghton Lake. In this area, a runoff rate of half that amount (10 c.f.s./ sq. mi.) is considered exceptional and a runoff rate of 3 c.f.s. sq. mi. can be considered high.

The design flow for Houghton Lake outlet, should then indicate the channel capacity required to pass high flows that may be expected prior to the spring runoff, so that Houghton Lake can be maintained at or below the legal level before the spring flows start.

2. Design Flow – Dead Stream

The design flow from Dead Stream was assumed proportional to the maximum daily discharge at M-55 rather than the mean monthly flow because of the relative lack of storage. The discharge records at M-55 show a maximum daily discharge prior to the spring rise as high as 550 c.f.s. Assuming a design flow of 550 c.f.s. at M-55 and a design flow of 250 c.f.s. from Houghton Lake, there is then 300 c.f.s. from the remaining drainage area of 120 square miles (309 minus 189). The Dead Stream drainage area is 67 square miles and the design flow from Dead Stream is then $300 \times \frac{67}{200} = 170$ c.f.s.

3. Design Flow – Below Junction

This gives a design flow for the channel between Dead Stream and the headwater of Reedsburg Pond of 420 c.f.s. (170 c.f.s. from Dead Stream and 250 from Houghton Lake).

Of the remaining drainage area (120 minus 67 or 53 square miles), the major portion contributes to Reedsburg Pond where channel capacity is adequate or below Reedsburg Dam where channel conditions have no affect on the Houghton Lake problem. The portion of the watershed contributing directly to the river between the lake and the end of the improved channel (pond headwater) is relatively small and was neglected.

4. Design Improvements

Several combinations of Reedsburg Pond levels and Houghton Lake levels were investigated and compared as to cost of channel improvements and benefits derived, i.e.,

(1) Holding the pond 0.5 of a foot below the top of the piers required less channel excavation, but the savings in cost is not enough to justify the possible harm to wildlife which may result from this lower level.

(2) Holding the lake 0.2 to 0.3 of a foot above the legal level would also require less channel excavation, but the savings in cost is not enough to justify the resulting higher spring lake levels.

(3) Final computations show that the most economical method is to maintain Houghton Lake at the legal level and Reedsburg Pond at the top of the piers. Design of the improved channel, as proposed, included consideration of minor backwater effect and channel capacities were provided to include this.

It was also found that a savings in overall cost is possible by increasing the capacity of the County Dam, thus decreasing the drop in water surface through the dam from as high as 0.2 feet to less than 0.05 feet. This will increase the available drop in water surface for the channel and thereby reduce the amount of the required excavation.

IV - PROPOSED IMPROVEMENTS

A. Channel Improvements

In order to develop adequate capacities, channel improvements will be required from the lake to the headwater of Reedsburg Pond. The channel width required, varies from 100 feet to 150 feet depending on the existing channel, and exceeds the width of the existing channel by zero to 20 feet in the upper reaches and by as much ad 50 feet below the Dead Stream Junction. Estimates show that approximately 120,000 cubic yards of excavation will be required. The three bridges, i.e., the County Road Bridge at the lake, the US-27 Bridge and Meade's Bridge, have sufficient spans and adequate waterway openings can be developed by removal of streambed material within the spans, without affecting footings or supporting piles.

B. County Dam

The capacity of the County Dam should be increased by adding to the existing structure four 7 foot bays with a fixed crest elevation of 1134.85 and with provisions for stop logs to elevation of 11.38.0. To facilitate operation, the steel plate stop logs used in the existing structure should be replaced with wood stop logs, such as are suggested for the addition to the dam. The cost of these additions is estimated to be $9000. Steel gates with hoists are desirable for ease in operation but are much more expensive.

C. County Dam Operation

Maintenance of desirable levels on Houghton Lake will depend to a great extent on the operation of the County Dam. It appears that at certain times in the past the dam has not been properly operated to maintain the most desirable levels. This may be due to the type of stop log used; that is, large steel plates which are probably very difficult to handle and provide little flexibility. Replacing these steel plates with wood stop logs will provide for easier and more satisfactory operation.

The staff gage at US-27 Bridge is more conveniently located to use as a guide to County Dam operation than is the Prudenville gage on Houghton Lake. The US-27 gage is less likely to be effected by winds that have in the past affected the Prudenville gage. The US-27 gage is also affected by wind but to a much lesser degree, and will generally show a water surface of 0.1 feet to 0.2 feet below the lake level, therefore, the water surface at this gage should be maintained at 0.1 to 0.2 feet below the desired lake level. The gage at US-27 Bridge should read 8.00 when Houghton Lake is at the legal level (elevation 1138.10) under normal flow conditions.

The County Dam operator should carefully observe the watershed condition, i.e. snow cover, frozen or ice-covered ground and so forth, particularly prior to the spring breakup. This will allow him to anticipate the amount of runoff before it occurs and to adjust the dam capacity accordingly.

It is important that gage readings be taken at intervals not to exceed every two or three days, and at one day intervals during the spring runoff period. An up-to-date graphical record of these water levels, together with a record of stop log positions, will prove to be a valuable aid in future operation of the County Dam. A complete record of water levels and stop log position will help the operator in determining the number of stop logs to be removed under future conditions.

It is suggested that the lake be held not higher than the legal level of elevation 1138.10 during the winter. A lake level 0.5 feet below the legal level (elevation 1137.6) will provide additional freeboard protection against ice damage. Improvements and additions to the County Dam, along with channel improvements as suggested herein, can be expected to provide for control of Houghton Lake levels within the limits of 0.8 feet above and 0.5 feet below the legal level unless flood flows in excess of 25 year frequency occur. Under normal conditions, it should be possible to hold Houghton Lake within1/2 foot of the desired level.

D. Reedsburg Dam Operation

Although the operation of the Reedsburg Dam has had no appreciable effect on the functioning of the existing channel as far as the level of Houghton Lake is concerned, as was shown by the hydro-test and past lake and pond stages; the functioning of the new channel will depend to a certain extent on the operation of Reedsburg Dam. It is, therefore, necessary that the pond not be allowed to go above the proposed level of 1136.88, which is the top of the piers. Anticipation of flood flows applies to Reedsburg Dam as well as to the County Dam. The level of the pond will fluctuate much more rapidly than the level of Houghton Lake (neglecting fluctuations due to wind), so it will be necessary to watch Reedsburg Pond levels closely. Here, as at the County Dam, a gage reading every two or three days will be sufficient, except during the spring when daily readings should be made. Up-to-date graphical records of pond levels, along with records of stop logs in place, will aid in operation of this dam.

Results of Proposed Improvements and Operation

If the necessary improvements to the outlet channel and County Dam are carried out and, if the County Dam and Reedsburg Dam are intelligently operated by responsible persons, it will be possible to maintain Houghton Lake at the legal level except during the spring. Under extreme conditions, the lake can be expected to rise about 0.8 feet to a maximum level of elevation 1138.9 from an initial lake elevation of 1138.1. A study of past lake stage records show that should the lake rise to 1138.9 during the spring, it will be possible to lower the lake back to the legal level in 1 ½ months or less.

It is, however, considered desirable to have the lake below the legal level prior to spring flows so the peak elevation, with 0.8 feet of storage, will be elevation 1138.4 or 1138.5. This can be accomplished, even in exceptional years, if the lake is drawn down one foot to elevation 1137.6 prior to the arrival of flood flows.

V - SUMMARY

1. A legal level was established for Houghton Lake by the Roscommon Circuit Court on January 5, 1926. The decree established t he legal level at elevation 1145.54 Fargo Engineering Datum. This is equivalent to elevation 1140.04 Army Engineers' Datum used during design and construction of Reedsburg Dam and equal to elevation 1138.10 U.S. coast and Geodetic survey Datum used for the hydro-test on which this report is based.

2. A concrete control structure with six 7 foot bay openings has had a marked effect on Houghton Lake levels but has been inadequate to control lake levels within desirable limits. The control structure (dam) is owned and operated by the Roscommon County Board of Supervisors.

3. Houghton Lake levels have been below the legal level during fall and winter seasons since 1943, except in 1950-1951 and 1951-1952, when they were from 0.1 to 0.9 of a foot above the legal level.

4. During the spring and most of the resort season, Houghton Lake has been above the legal level by as much as 1.7 feet since 1943, except in 1946 and 1949 when levels were at or below the legal level.

5. Reedsburg Dam was built, by the Civilian Conservation Corps. in cooperation with the Michigan Department of Conservation, during the year 1940. It developed a flooded area of about 2170 acres known as the Muskegon River Biological Development.

6. Reedsburg Dam is located about six miles downstream from Houghton Lake to minimize any backwater effect which would interfere with control of Houghton Lake levels by the County Dam.

7. Reedsburg Dam was designed to create a flooded area on the Muskegon River below the junction with the Dead Stream and is not adaptable to alterations that would make it a control structure for Houghton Lake levels.

8. the Muskegon River below Houghton Lake during high flows in 1938 assumed surface slope conditions similar to the water surface slopes recorded during the 1953 Hydro-Test. A comparison of all available data indicates, that a restriction existed in the channel below Meade's Bridge before Reedsburg Dam was built, and that construction of the dam has not changed high water elevation at Meade's appreciably (see Section II A-1 for details).

9. The Michigan Department of Conservation has a definite policy (as set up by law in Act 194, 1939, Lake Level Determination) of furnishing engineering information only, upon request of the County Board of Supervisors for use by the Court in setting legal levels for inland lakes. The authority for construction and operation of dams for controlling lake levels is vested in the County Board of Supervisors and the Department is definitely against accepting the responsibility for operation of structures for control of lake levels. The Department may contribute its proportional share of assessments based on the amount of state-owned inland lake property.

10. A hydro-test was made at Reedsburg Dam and ponded area in late March and early April 1953. During this test, the stop logs were removed from Reedsburg Dam and the pond drawn down to a point at which water surface elevations between Dead Stream and Houghton Lake were no longer affected.

11. During the period of March 30 to April 2, 1953, Reedsburg Pond was drawn down 2 ½ feet while Houghton Lake rose and fell only 0.05 of a foot March 30, 31 and April 1 and rose 0.12 of a foot from April 1 to April 4, 1953. These fluctuations were probably the result of varying winds and for all practical purposes, Houghton Lake level was unaffected by the 2 ½ foot draw down or drop at Reedsburg Dam.

12. Water surface readings were observed and recorded every half hour at eleven stations along the Muskegon River between Houghton Lake and Reedsburg Pond during the entire period of the draw down portion of the hydro-test March 30 through April 2, 1953. A summary of these readings was plotted and is included as Graph #1 in the Appendix of this report.

13. Interpretation of the data shown on Graph #1 points to the following conclusion:

(a) Houghton Lake level not affected when Reedsburg Dam was opened to full capacity and Reedsburg Pond lowered 2 ½ feet.

(b) No appreciable change in slope between the lake and the County Dam indicating practically no change in discharge, confirmed by U. S. Geological Survey stream measurements.

(c) The water surface slope was consistently steeper below Dead Stream Junction, than above. This indicates different hydraulic conditions above and below this point.

(d) Upstream limit of measurable backwater from Reedsburg Dam occurred downstream from cross section number 9, more than a mile below Dead Stream Junction. A minor backwater effect may extend as far upstream as Meade's Bridge at the normal pond elevation. However, any effect on County Dam discharge is negligible.

(e) Water surface slopes and bottom profile elevations point to need for widening and deepening of channel and for increasing the discharge capacity of the County Dam.

14. Channel improvements should include removal of 120,000 cubic yards of earth and the County Dam should have 70% additional capacity according to preliminary estimates.

15, Increased channel and county dam capacities, as outlined in Item 14, will provide facilities for maintaining lower levels on Houghton Lake during winter months, which in turn will reduce peak spring levels.

16. During the period from September to December, under normal flow conditions, it will be possible to lower Houghton Lake one-half foot (from legal level elevation 1138.1 to elevation 1137.6) in 45 days, with Reedsburg Pond at the design level of elevation 1136.9, provided improvements are completed as suggested herein.

17. If Houghton Lake can be maintained at lower winter levels than in the past, less ice and wave damage to shoreline installations can be expected in the future.

18. Houghton Lake has enough area (19,600 acres) to store the entire runoff from a storm of maximum recorded intensity similar to the one that occurred in 1943 in this area. Such a storm run-off would raise the lake 0.8 of a foot and if this were to occur above the legal level or to a final elevation of (1138.1 + 0.8) 1138.9 some shoreline damage might occur. Therefore, it is suggested that storage start ½ foot below the legal level, elevation 1137.6 (winter level), so that the maximum expected level would be elevation 1138.4. Design flows used for outlet facilities in this report are based on maximum daily pre-spring flows recorded at the Merritt Station on the Muskegon River below Houghton Lake.

19. The lowering of Houghton Lake peak levels, by increased channel and county dam capacities, can be expected to result in less interference with septic tank installations which may be only slightly above lake level.

20. It is possible that, at lower lake levels, the pond backwater will extend upstream far enough to exert an effect on the capacity of the lake outlet. However, such lake levels are most likely to exist at times of low flow, when it is desirable to store water in the lake, rather than to waste water through the outlet.

21. Reasonably stable levels can be maintained on Houghton Lake if provision is made for discharging expected flood flows and for holding summer levels. This can be done independent of the Reedsburg Dam and impoundment, as long as Reedsburg Dam operation is correlated with operation of improved facilities to obtain optimum Houghton Lake levels.

22. During each and every period of the year, it is recommended that the County Dam operator and the Reedsburg Dam operator study the watershed conditions and weather reports, and anticipate high or low flows before they occur, to serve as a guide to optimum pond and lake levels.

The vast storage potential on Houghton Lake prevents instantaneous control of levels and the County Dam must be operated with these conditions in mind for most favorable Houghton Lake levels.

XI - APPENDIX

- CONTENTS -

Graph 1 - Plan Profile of Reedsburg Dam Hydro-Test

1942	Hydrograph	-	Houghton Lake
1942 – 43	“	“	“
1943 – 44	“	“	“
1944 – 45	“	“	“
1945 – 46	“	“	“
1946 – 47	“	“	“
1947 – 48	Combined Hydrograph	*	
1948 – 49	“	“	“
1949 – 50	“	“	“
1950 – 51	“	“	“
1951 – 52	“	“	“
1952 - 53	“	“	“

* Hydrographs of water surface at Houghton Lake, US-27, Meade’s Bridge and Reedsburg Pond, combined on one sheet for each water year shown.

Supplemental Data – available on request, not included in report.

Draw down Curves:

Reedsburg
Michelson’s
Head Pond
Dead Stream Junction
Cross Section No. 7