THIEF RIVER FALLS RESERVOIR

RED LAKE WATERSHED DISTRICT PROJECT #63

1995 RESERVOIR DRAWDOWN REPORT

JANUARY 1996

Red Lake Watershed District
102 North Main, P.O. Box 803
Thief River Falls, MN 56701

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

[signature]	1-23-96	20378
	Date	Reg. No.

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Acknowledgement

This report was prepared by staff of the Red Lake Watershed District. The following people assisted in project monitoring, analyzing results, and report writing: Tammy Audette, Kurt Casavan, Dave Fink, Brad Johnson, Brent Johnson, Loren Sanderson and Scott Smith. We appreciate the assistance of staff of the City of Thief River Falls, especially Ron Lindberg and Arlo Rood. We thank Greg Spoden, State Climatology Office, and Kevin Guttormson,

Chapter 1

1.0 INTRODUCTION

The municipal dam on the Red Lake River in Thief River Falls creates a reservoir of 135 acres. This reservoir is used by the City for water supply and hydro-power generation. The reservoir is also used extensively for recreation. Much concern has been raised in recent years by the public, and their elected officials, that sediment and excessive weed growth are reducing the benefits of the reservoir. A report was prepared in 1992 by the Red Lake Watershed District which assessed the condition of the reservoir and identified a number of maintenance techniques to address reservoir problems.

A number of public meetings were held to discuss the 1992 report and the various reservoir maintenance techniques. A multi-agency task force chose to proceed with a reservoir drawdown project on May 13, 1993, and sent a letter of intent to the MnDNR (the letter is attached in Annex A). The drawdown was chosen to address the problems associated with sediment deposits which have accumulated within the reservoir. The City of Thief River Falls received a Department of Natural Resources Protected Waters Permit on September 20, 1993.

A trial drawdown was completed from October 29 through November 1, 1994. Observations made during the 1994 trial drawdown helped to guide work done during the 1995 drawdown. The City began a 60 day pool drawdown on August 14, 1995.

This report provides a summary of activities which took place during the drawdown. The goals and results of the drawdown are discussed, as well as the methods of monitoring and analysis that were used.

Chapter 2

2.0 PROJECT GOALS

Problems identified in the Thief River Falls Reservoir are tied to two phenomenon. These are dense weed growth and sediment deposition. Sediment deposition has reduced the storage volume of the reservoir by approximately 20 percent. A lush growth of weeds and algae, in combination with sediment deposits, is restricting many of the recreational uses of the reservoir.

Even though erosion and sedimentation rates are low in the Thief River Falls contributing area, the cumulative effects upon the reservoir are significant. The reservoir doesn't have adequate storage volume to allow sediment to accumulate indefinitely. Periodically the reservoir will require maintenance to address the sediment problems.

The overall goal of the 1995 drawdown was to consolidate the sediment deposits. Drying and draining the sediment will cause the sediment to consolidate. Sediment consolidation will reduce the volume of sediment within the reservoir and will increase the water depth in areas where the sediments settle. Reducing the sediment volume extends the useful life of the reservoir and frees up space in the reservoir for water storage and other uses (fish habitat, etc.).

Another goal of the drawdown was to reduce aquatic plant growth. Reducing plant growth will allow more of the reservoir to be used for recreation (swimming, boating, fishing, etc.).
Consolidating existing sediments may reduce aquatic plant growth. Increasing the depth of the reservoir by consolidating the sediments may reduce the amount of light which reaches rooted aquatic plants--limiting their growth. A drawdown also exposes the plants to drying and possibly freezing which may be damaging to them, especially lake species. Extensively drying certain plants (particularly non-rooted species) will effectively eliminate them. This is most likely a short-term control measure because most aquatic plants reproduce from seeds or plant fragments which both the Thief and Red Lake Rivers will continue to supply.

An ancillary benefit of the drawdown was the opportunity to perform construction within the reservoir. Work included the clean-up of debris to improve safety for reservoir users. With the water level lowered, access for public and private construction became much easier and cost effective.

Chapter 3

3.0 PROJECT OVERVIEW

The Thief River Falls reservoir was drawn down during a 60 day period. The reservoir water level was lowered on August 14 and maintained at a lower than normal pool level for approximately 60 days. The reservoir was restored to its normal operating level on October 13.

3.1 POOL LOWERING

The drawdown commenced on August 14, 1995. The gates on the Thief River Falls municipal dam were incrementally opened to allow controlled water discharge through the dam. The pool was initially lowered by approximately four feet to elevation 1111 over an 8 hour period. Following the excavation around the 1927 dam, and the installation of an additional water supply pump, the pool was lowered by an additional three to four feet. At this point water was allowed to flow freely through the open gates of the dam. The lowest level reached was approximately elevation 1107--which is eight feet below the normal pool level.

3.2 EXCAVATE 1927 DAM ABUTMENT

During the trial drawdown of October 29 - November 1, 1994, we verified that remnants of the 1927 dam were restrictive to flow. The dam remnants limited the effectiveness of a drawdown by creating an obstruction just upstream from the current 1946 municipal dam. The old dam remnants obstructed the flow in the river and limited the amount the reservoir could be lowered--to approximately four feet below the normal reservoir level.

On August 14, 1995 the City of Thief River Falls, and their contractor Charles Hedeen, Inc., excavated a channel around the east abutment of the 1927 dam. Soil, rock-filled timber cribs, and debris were removed from an area approximately 50 feet wide and 200 feet long. The channel was constructed with a bottom elevation of approximately 1104 feet M.S.L., which lowered the flowline of the river by approximately 5 to 6 feet. The excavation reduced the flow obstruction caused by the 1927 dam remnants. The channel allowed the reservoir level to be lowered an additional three to four feet beyond levels previously achieved.

3.3 WATER SUPPLY

The City of Thief River Falls uses the reservoir for a water supply. Water flows from the reservoir, through an intake pipe, to a pumping station. Water is pumped from the station into the water treatment plant. Lowering the reservoir level exposed the intake line and reduced the flow of water into the pumping station. There was concern that at reservoir levels below elevation 1111, the reduced flow to the pumping station could cause the pumps to cavitate--reducing their efficiency and possibly damaging the pumps.

In order to lower the reservoir below elevation 1111, while maintaining the required flow into the pumping station, city crews temporarily installed an additional pump. This pump was installed on August 25, 1995 and used for the remainder of the drawdown period. The temporary pump experienced mechanical problems on September 21 and 22. The reservoir level was raised to elevation 1111 to allow water to flow into the water plant while the temporary pump was out of service.

3.4 UPSTREAM DAMS

Operators of dams upstream of Thief River Falls were notified of the drawdown and encouraged to consider the drawdown when planning releases and discharge rates. The U.S. Army Corps of Engineers operates the dam on the Red Lake River at Red Lake. The U.S. Fish and Wildlife Service operates a number of dams on tributaries to the Thief River at Agassiz National Wildlife Refuge. The Minnesota Department of Natural Resources operates the Thief Lake Dam. The Red Lake Watershed District operates the Moose River, and Good Lake Projects. These agencies managed the timing and discharge of water from their dams, within operational constraints, to cooperatively reduce the flow at Thief River Falls. The combined efforts of the group served to lessen the flow in Thief River Falls, which was beneficial to the reservoir project.

3.5 PUBLIC RELATIONS, NOTIFICATION, SAFETY

Staff of the City of Thief River Falls and officers of the Red-Thief Reservoir Association notified the public of the drawdown through the use of news releases, and public announcements. Local media informed the public of the details of the project, as well as permit requirements for individual construction projects within the reservoir.

City crews closed the swimming beach, closed public boat accesses throughout the reservoir, and posted "closed to public access" notices on adjacent public property. The Pennington County Sheriffs Department also issued warnings to citizens about the danger associated with walking on the exposed mud flats (sediment deposits). On August 24, a 9 year old boy was rescued after he became mired in the loose sediments.

3.6 MONITORING

Staff of the City of Thief River Falls and the Red Lake Watershed District monitored water levels within the reservoir during the drawdown. The reservoir water level during the drawdown is shown in Figure 1. Figure 2 shows a profile of the Red Lake River within Thief River Falls. A profile of the water level within the reservoir during the drawdown is shown in Figure 2--as well as the normal reservoir level and flood profiles. The profile during the drawdown shows that the reservoir water level was approximately 2 feet higher at Finsbury Park than at the dam. The Figure 2 base profiles are from the Pennington County Flood Insurance Study.

Weather records were obtained from the Minnesota Department of Natural Resources State Climatology office in St. Paul. Flow records for the Thief and Red Lake Rivers were obtained from the U.S. Geological Survey.

Chapter 4

4.0 RESULTS

Sections 4.1 to 4.4 discuss the results of the drawdown, and Sections 5.1 and 5.2 discuss the flow and weather conditions during the drawdown. The following are brief summaries of these sections:

> There was a slight reduction in the elevation and volume of sediment within the reservoir. Results indicate that sediments consolidated by about .1 feet on the Red Lake River and about .2 feet on the Thief River. Sediment volume was reduced by about 5 to 10%.
>
> The movement of sediment probably had a greater effect on sediment reduction within localized areas than consolidation.
>
> The drawdown most likely will show short-term affects to the aquatic plant growth.
>
> With the improved access provided by the drawdown many construction activities took place.
>
> Lowering the water exposed the problem, and allowed the public a chance to view the sediment deposits within the reservoir.
>
> The weather during the drawdown period was close to the long term averages for temperature and precipitation.
>
> Flow during the drawdown was higher than we would have preferred, which resulted in less drainage and drying of sediments than we had hoped for.

4.1 SEDIMENT

Sediment consolidation was the overall goal of the drawdown. The survey results showed there was a slight reduction in the elevation, cross-sectional area, and volume of sediment within the reservoir. Results indicate that sediments consolidated by about .1 feet on the Red Lake River and about .2 feet on the Thief River. Sediment volume was reduced by about 5 to 10%. This is discussed in greater detail in Section 5.3.

The movement of sediment probably had a greater effect on sediment reduction within localized areas than consolidation. The erosion and slumping of some sediment deposits moved substantial amounts of sediment into the main river channels. We think it is likely that much of the translocated sediments were swept out of the reservoir, although it is possible that some of the material was redeposited. The cross sections that were performed after the reservoir was filled provide an average estimate of sediment reduction. Sediment reduction could involve both sediment consolidation and movement.

4.2 WEEDS

Another goal of the drawdown was to reduce aquatic plant growth. Reducing plant growth will allow more of the reservoir to be used for recreation (swimming, boating, fishing, etc.).
Consolidating existing sediments may reduce aquatic plant growth by increasing the depth of the reservoir. Increasing the depth may reduce the amount of light which reaches rooted aquatic plants--limiting their growth. A drawdown also exposes plants to drying and possibly freezing which may be damaging to them, especially lake species. Extensively drying certain plants (particularly non-rooted species) will effectively eliminate them. This is most likely a short-term control measure because most aquatic plants reproduce from seeds or plant fragments which both the Thief and Red Lake Rivers will continue to supply.

The next few growing seasons will determine how effective the drawdown was in reducing the intense weed growth. The drawdown most likely will show short-term affects to the aquatic plant growth. Most floating plant species will probably re-establish themselves in the backwater areas within 1 or 2 growing seasons. Also most rooted plants will propagate again within the next few growing seasons if intense drying or freezing didn't kill their roots.

4.3 CONSTRUCTION

With the improved access provided by the drawdown many construction activities took place. Private parties worked on their shoreline property and river banks. Public construction projects which took advantage of the drawdown include the following:

City of Thief River Falls:
- Excavated a channel around 1927 dam;
- Placed rock riprap at Fire Hall, Technical Services, and adjacent to Riverwalk;
- Replaced trash racks at intake to hydro generator units at the powerplant;
- Removed sheet piling from old raw water intake to restore the riverbank and improve site safety.

Pennington County:
- Inspected and maintained bridges crossing the Thief River;
- Sentence to Service cleaned up debris within reservoir.

Red Lake Watershed District:
- Placed rock riprap at Lafave Park.

Minnesota Department of Transporation
- Inspected and maintained 3rd Street and 8th Street bridges; work included removal of steel piling from bridge pier remnant and removal of debris beneath the bridges.

4.4 EDUCATION

A very important benefit that also resulted from the drawdown was public education. Lowering the water exposed the problem, and allowed the public a chance to view the sediment deposits within the reservoir. The historic river channel was easily identifiable. Many people commented on interesting things they observed such as the "rock pile" by the 8th Street Bridge (possibly a remnant structure from log sorting operations). The pilings for the abandoned electric railroad crossing of the Thief River near Long's Bridge were exposed, and allowed its location to be verified.

Chapter 5

5.0 DATA AND ANALYSIS

5.1 FLOW

The flow passing through the reservoir during a drawdown is directly related to the stage in the reservoir. Opening the gates on the dam allow the stored water to be drained from the reservoir. Channel characteristics and the rate of flow determine stage within the emptied reservoir -- just as in an undammed river. Low flow and corresponding low water levels provide the best conditions for draining and drying sediments. Flow during the drawdown was higher than we would have preferred, which resulted in less drainage and drying of sediments than we had hoped for.

The U.S. Geological Survey (USGS) maintains continuous stream gaging stations on the Red Lake River at Highlanding and the Thief River near Thief River Falls. We have received provisional records of streamflow for the drawdown period from the USGS. Figures 3 and 4 are hydrographs which show river flows on corresponding dates. Several monthly exceedance frequencies are also plotted on Figures 3 and 4. Flow duration-frequency curves for the Thief and Red Lake Rivers are included in Annex B.

Table 5.1

	Red Lake River		Thief River	
Month	Streamflow (cfs)	Exceedance Frequency %	Streamflow (cfs)	Exceedance Frequency %
Aug. Mean	659	41	106	17
Aug. Min.	519	51	40	27
Aug. Max.	710	38	177	13
Sept. Mean	459	51	82.5	22
Sept. Min.	371	57	57	25
Sept. Max.	667	40	210	14
Oct. Mean	523	43.5	Not available	Not available
Oct. Min.	435	50		
Oct. Max.	646	40		

Both rivers had flows which exceeded the median daily flows during the drawdown period. Flows in the Thief River were high--well above the median flows. Flows in the Red Lake River were closer to median flows for the period, but the mean and maximum flows did exceed the median. Table 5.1 lists the mean, minimum, and maximum daily flows for each month of the drawdown. The exceedance frequency corresponding to each flow rate is also shown in the table. The exceedance frequency means that the listed flow is equalled or exceeded this percent of the time. For example the maximum August 1995 flow in the Red Lake River has an exceedance frequency of 38%--which means that for all records of August flows only 38 percent of the recorded flows equalled or exceeded that flow.

5.2 WEATHER

The weather during a drawdown affects the drying of sediments and affects the control of exposed aquatic plants. Hot, dry weather aids a drawdown by increasing the drying of sediments and plants. Dry weather is also likely to correspond to reduced river flows and reservoir stages. The weather during the drawdown period was close to the long term averages for temperature and precipitation.

We received data on daily temperature and precipitation from the Minnesota Department of Natural Resources State Climatology office in St. Paul. The data cover the drawdown period and provide daily high and low temperatures and precipitation. These data are provided in Annex C.

5.2.1 Temperature

Figure 5 shows high, low and mean daily temperatures for the drawdown period as well as average temperatures for this period.

Figure 6 shows average daily temperatures for August, September, and October 1995 as well as the period of record. Observed temperatures in September appeared to be typical for the period of record. August temperatures were about 2°F warmer than the long term averages, and October temperatures were generally cooler than the long term averages.

Freezing temperatures occurred on the following dates:

9/20	28°F
9/21	32°F
9/22	26°F

Freezing temperatures may have been damaging to exposed aquatic plants. Coincidentally, the temporary water supply pump was out of service on September 21 and 22. The water level was increased three to four feet to elevation 1111 during this period--which may have inundated and protected some plants from freezing.

5.2.2 Precipitation

Figure 7 shows the months and corresponding precipitation amounts recorded at the Thief River Falls gage. Monthly rainfall totals are shown for August, September and October 1995 as well as the average rainfall for the 1951 to 1972 period. Rainfall in Thief River Falls appeared to be near the average for these months.

5.3 SURVEYS

The reservoir was surveyed before and after the drawdown. Ten cross sections were measured on the Red Lake River and five were done on the Thief River. Locations for the cross sections were chosen from data obtained from the 1991 cross sections of the reservoir. Survey locations that showed major sediment deposits were repeated. Figure 8 shows the location of each cross section. Control points were established on both banks of the river for each cross section so they could be repeated on the same alignment. Cross sections were performed using a boat and Geodimeter total station survey equipment. The total station was used to determine the location of the boat along each cross-section. A level rod was used to measure water depth to the top of the sediment. A conventional level was used to determine the water surface elevation throughout the reservoir for vertical control.

Most of the cross sections were surveyed from a boat with alignment directed from the shore. The location of measurements were repeated within reasonable accuracy. Precise replication of measurement location is most critical at points where the river bottom changes a lot within a small distance, such as transitional points between the sediment deposits and the main channel. Slight differences in boat alignment near these points allow a larger opportunity for error. We believe that these errors will cancel out since a similar number of measurements should be slightly higher or lower than those taken during earlier surveys. Slight differences in boat location in the flat bay areas should have little or no effect on the results of the surveys. We also expect results from the bay areas to be the primary indicator of sediment change.

Annex D shows the results of the before and after surveys of the reservoir. Average reduction in sediment depth in the Red Lake River was 0.25 feet and reduction in the Thief River was 0.29 feet. Some measurements show large decreases or increases in sediment depth which may skew the average values. Median reductions on the Red Lake River were .1 feet and on the Thief River were .2 feet. Large changes in measurements are probably located at transitional points. Other large changes are in areas where sloughing or erosion occurred near the main river channel. Changes in sediment depth measured across the broad deposit areas agree closely with the averages.

Sediment reduction was also analyzed on a volumetric basis. Annex E shows the results of this analysis. Data obtained from the 1991 survey of the reservoir was used for determining the firm bottom of the river. The before and after surveys were used to outline the top of sediment at each cross section. The average end area method was used to determine the sediment volume throughout the reservoir. Measurements which appear to be obvious errors (due to a shift in boat alignment, etc.) were omitted from the cross sections for the area calculations. The goal was to obtain a reasonable estimate of sediment consolidation. The results indicate approximately a 10% reduction in the Red Lake River sediment volume and an 11% reduction in the Thief River sediment volume. The method used in this analysis may overstate the sediment reduction slightly. This is a result of the assumption to disregard measurements which indicated an increase in sediment. Consideration of all measurements would probably result in a calculated sediment reduction ranging from about 5 to 10%. A 5 to 10% reduction in sediment volume extends the life of the reservoir by 2 to 3 years.

5.4 WEEDS

While surveying each cross section of the reservoir, the plant species compositions and intensity were noted in a log book. Annex F provides the compilation of these results. At certain locations intense growths of specific plant types were identified and measured in relation to control points. Later, we will re-inspect these control locations to assess how the drawdown affected specific species of plants within the reservoir.

5.5 SEDIMENT ANALYSIS

Sediment samples were taken during the drawdown at similar locations as were previously sampled in 1991. A 4 inch PVC pipe was again used to collect the sample. This was forced into the sediment. The open end was capped to prevent the sample from falling out as it was withdrawn.

As another measure of whether the sediment consolidated, the moisture content and the density of each sample was determined. The data is shown in Annex G. This information was compared to the previous sample results. The density of each sample was expected to increase during the drawdown indicating the sediment had consolidated. This, however, was not found to be the case.

We have reviewed our sampling procedures, testing methods, and results with soil physicists from the University of Minnesota. Our results were explained to be an aberration due to variances in density of the in-place sediments, and as a result of sampling a small data set. It is evidently coincidental that the results appear to be somewhat uniformly shifted from what was expected.

5.6 PHOTOS

Photos were taken by staff of the City of Thief River Falls and the Red Lake Watershed District to show conditions before and after the drawdown. These included both aerial and ground photos of the reservoir.

A continuous video of the shoreline of both the Red Lake River and the Thief River was completed by the City of Thief River Falls. This video was made in the fall of 1994 during the temporary drawdown.

5.7 VISUAL AND EMPIRICAL RESULTS

In general, most of the sediment deposits did not appear to have dried sufficiently to allow a great deal of consolidation. In some areas the surface dried and cracks formed in the sediment. Many areas remained wet and damp. Reservoir water levels achieved were only slightly below many of the deposits, especially when the reservoir was being held at elevation 1111. Figure 9 shows a typical cross-section of the reservoir. This typical section shows the sediment deposits and water levels at elevation 1108 and 1111.

During the drawdown Red Lake Watershed District staff performed cross-section surveys and soil testing on selected sediment deposits. Most areas did not dry enough to support a man's weight. The surveyors wore snow shoes to support their weight while walking on the deposits. Since much of the sediment remained wet and loose, consolidation was probably limited.

Some areas of the reservoir, especially along the Thief River, had large sediment deposits slump and slide into the main river channel. Sediment erosion also was noticeable, particularly near Finsbury Park on the Red Lake River. Due to the higher velocities and tractive forces present within the main river channels, we think it is likely that much of the translocated sediments were swept out of the reservoir, although it is possible that some of the material was redeposited. Sliding and erosion of sediments may have very significant benefits in localized areas. Some of these areas will easily be recognized as having reduced sediment and increased depth.

Chapter 6

6.1 SUGGESTIONS FOR OTHER DRAWDOWNS

The following suggestions are provided for consideration if the Thief River Falls reservoir is to be drawn down in the future. In retrospect, these are some of the things we would consider doing different in a future drawdown. Clearly other considerations such as water supply, recreation, and cost, play a role in decisions regarding a drawdown. If the drawdown goal is to consolidate sediments and control aquatic plants, the following may improve the effectiveness of a drawdown.

Drier Conditions:

It's hard to predict the weather, but conducting a drawdown during a drought is sure to result in better conditions. A drought would typically cause reduced river flows and result in a lower water level. Less precipitation and warmer, drier conditions would cause better drying of sediments and plants.

Longer Duration Drawdown:

Extending the time of a drawdown would allow for additional drainage and drying of sediments, and extend the time aquatic plants are exposed to the elements.

Include Freezing:

Extending a drawdown through periods of freezing temperatures will likely increase the control of aquatic plants--especially lake species.

Old Dam:

Increase excavation around the old dam to further reduce the obstruction it causes. The work done in 1995 allowed the reservoir level to be lowered three to four feet below previously attainable levels, but the reservoir level above the old dam was still about one foot higher than the level at the current dam. Additional excavation would further reduce the obstruction and corresponding backwater effects.

Pumps:

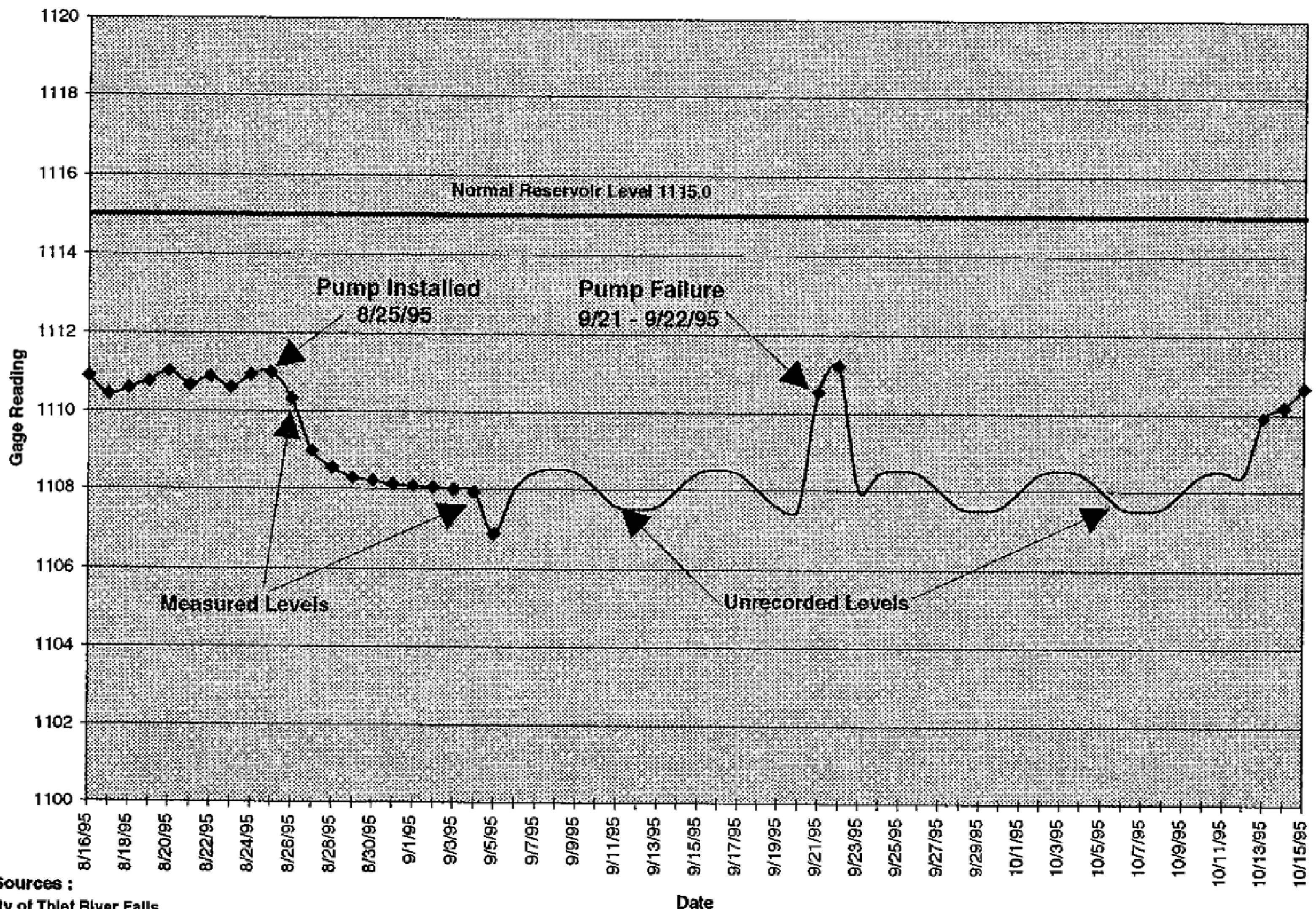
Install temporary water supply pumps prior to commencing a drawdown. This will remove the need for maintaining reservoir levels which provide gravity flow of water to the water plant pumping station.

Monitoring:

These monitoring suggestions will improve the effectiveness of monitoring the results of a drawdown, but won't improve the drawdown effectiveness.

- Install a continuous water level recorder within the reservoir.
- Install settlement plates to measure settlement or translocation of deposits.
- Record precise locations of sediment or plant sampling.
- Conduct surveys of sediment deposits before and after the drawdown using either a cable-stayed boat, or winter surveys on ice, to allow precise replication of measurements.

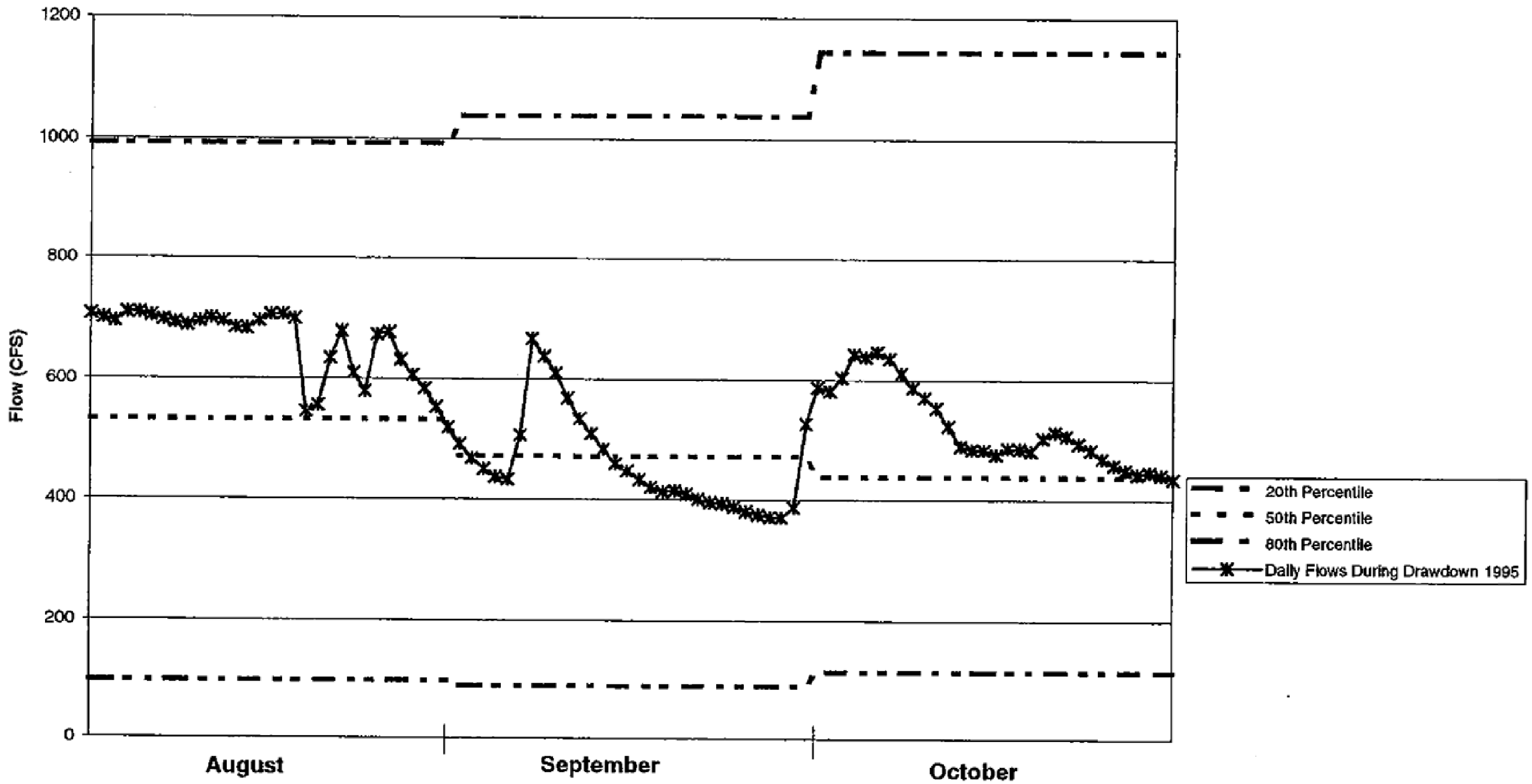
Reservoir Elevations During Drawdown



Sources :
City of Thief River Falls
Red Lake Watershed District

Figure 1

RED LAKE RIVER AT HIGHLANDING



Source :

United States Geological Survey

Figure 3

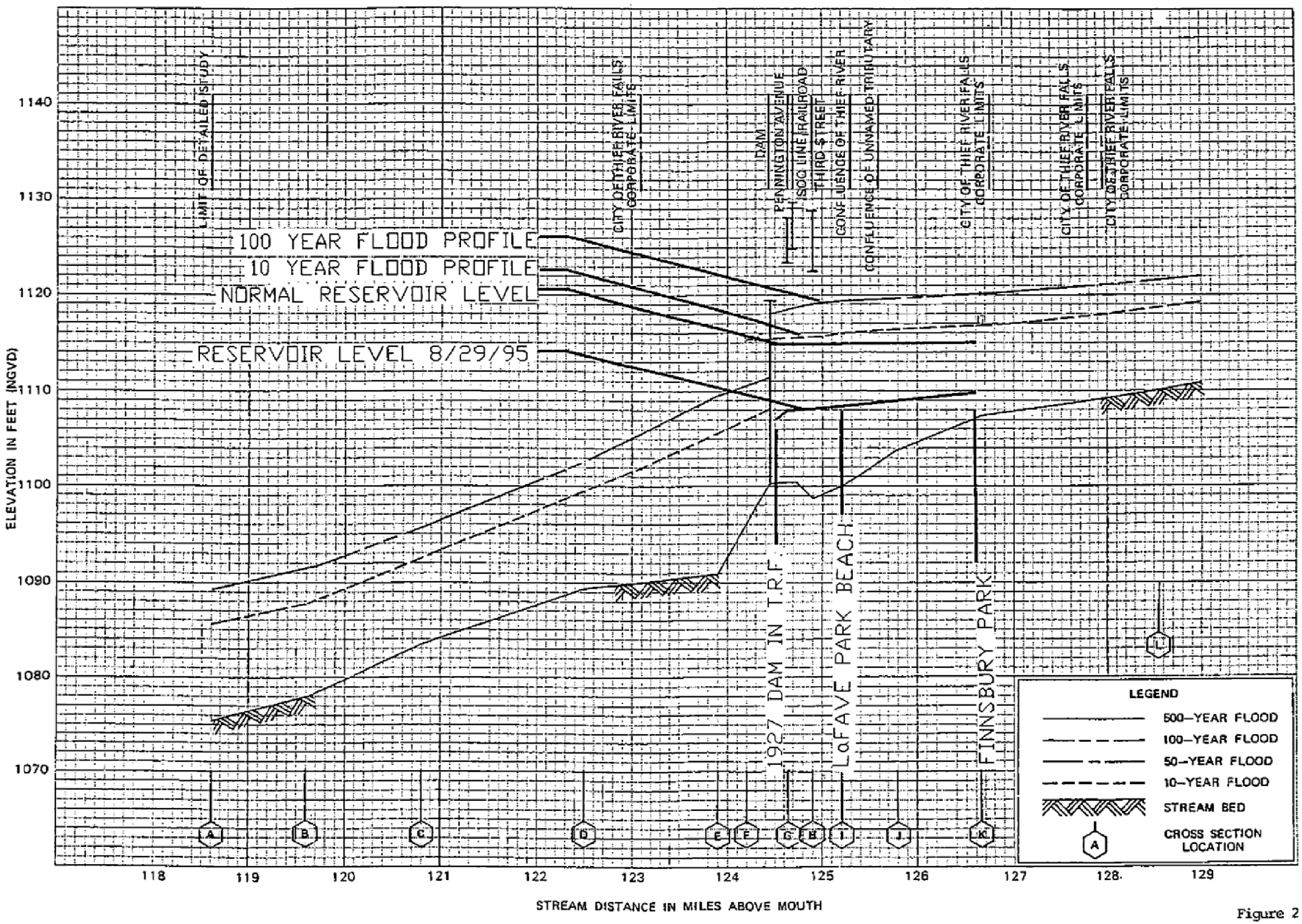


Figure 2

FLOOD PROFILES

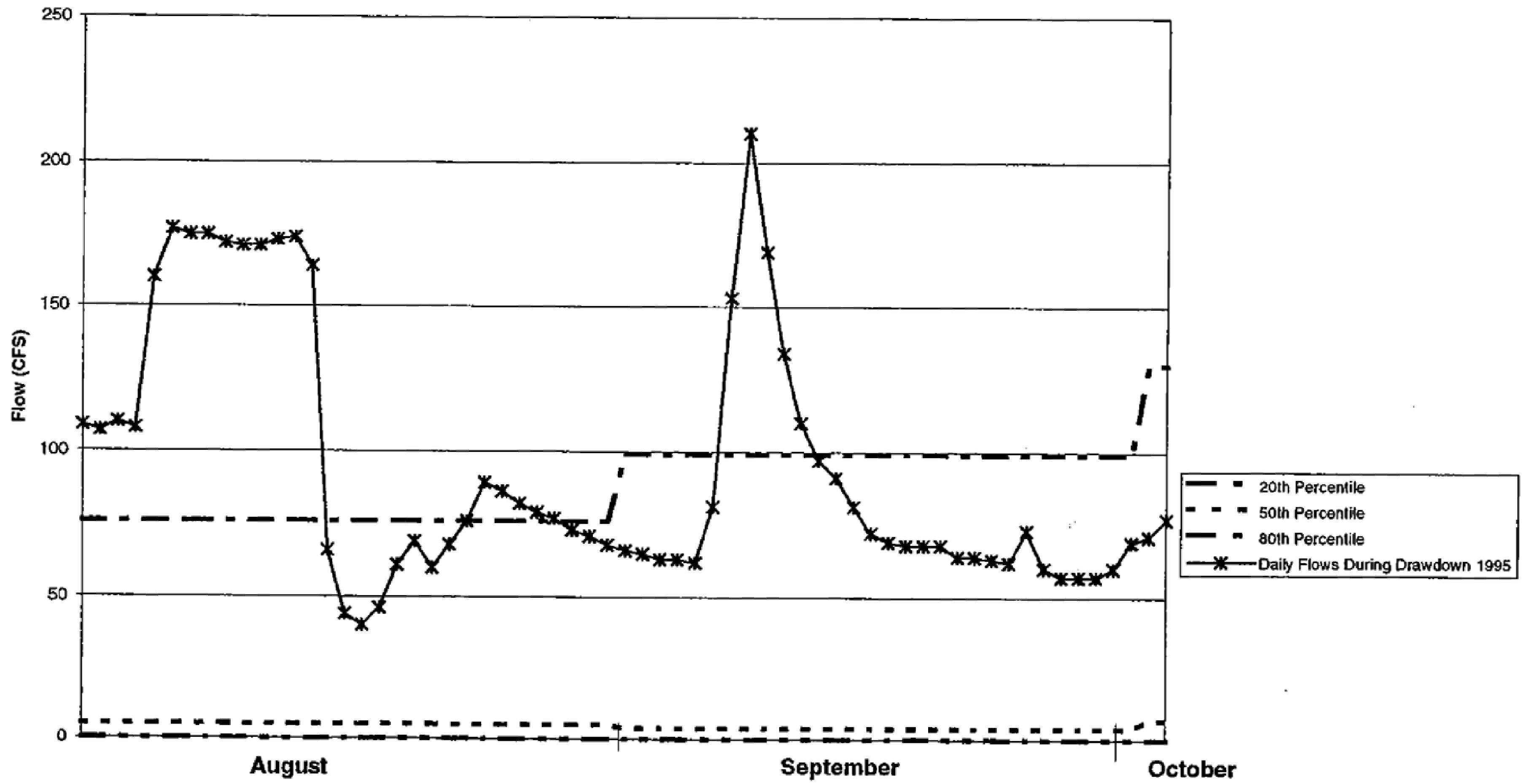
RED LAKE RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

PENNINGTON COUNTY, MN
AND INCORPORATED AREAS

01P

THIEF RIVER

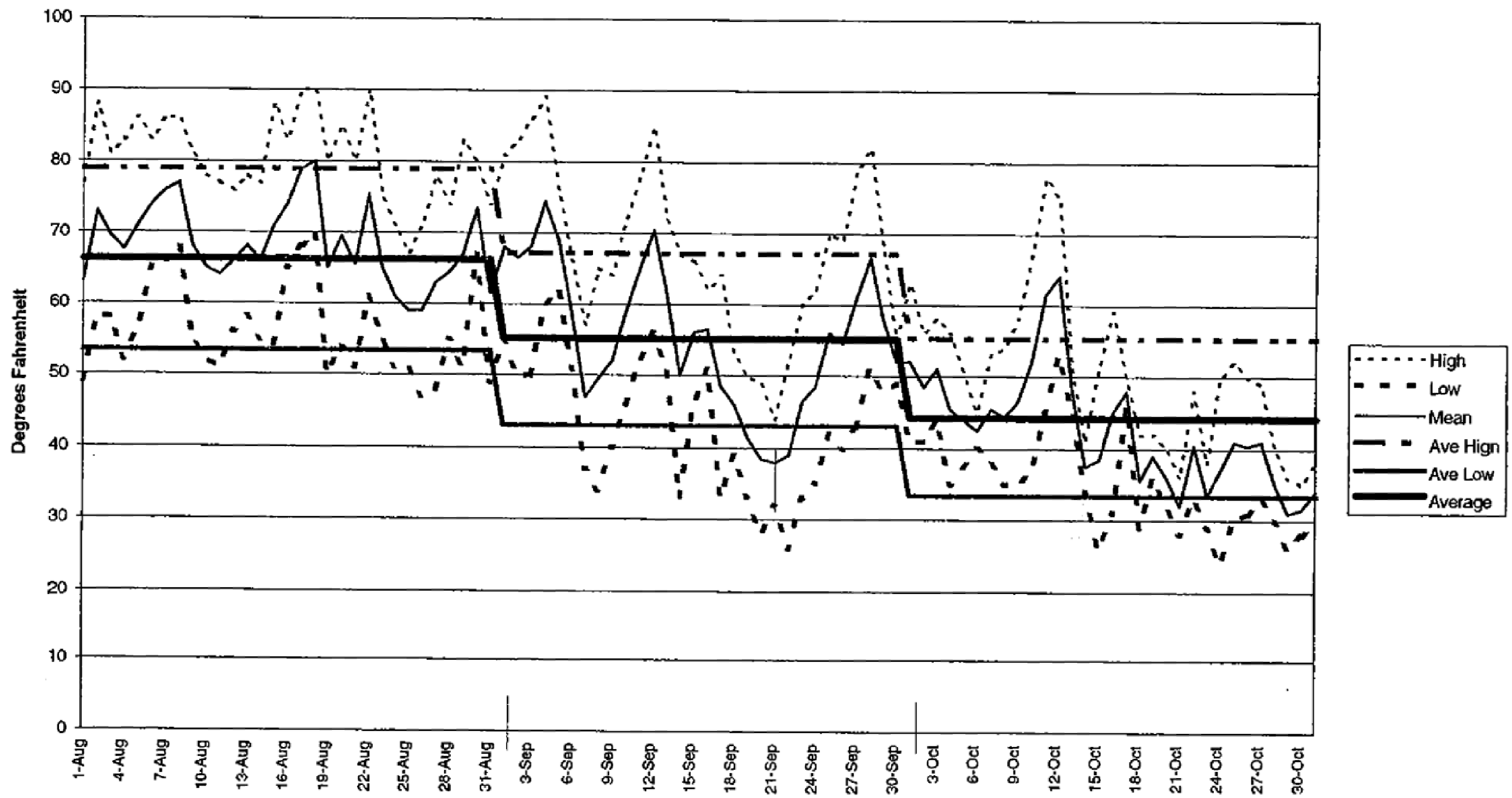


Source :

United States Geological Survey

Figure 4

OBSERVED AND AVERAGE RECORDED TEMPERATURES



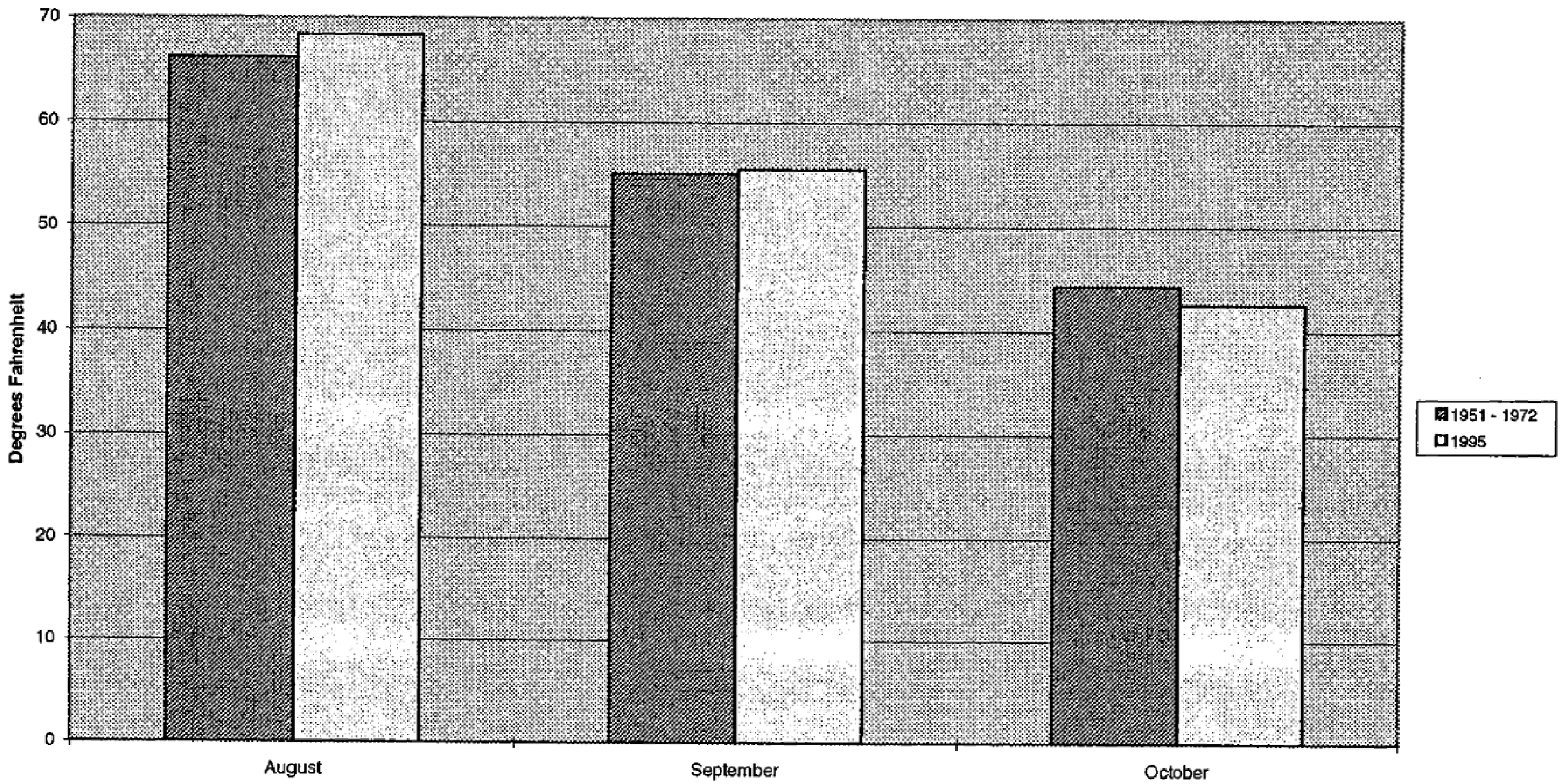
Source :

1995 : Mn Climatology Office

1951-72 : USDA, Pennington County Soil Survey

Figure 5

Average Temperature for Thief River Falls, Minnesota



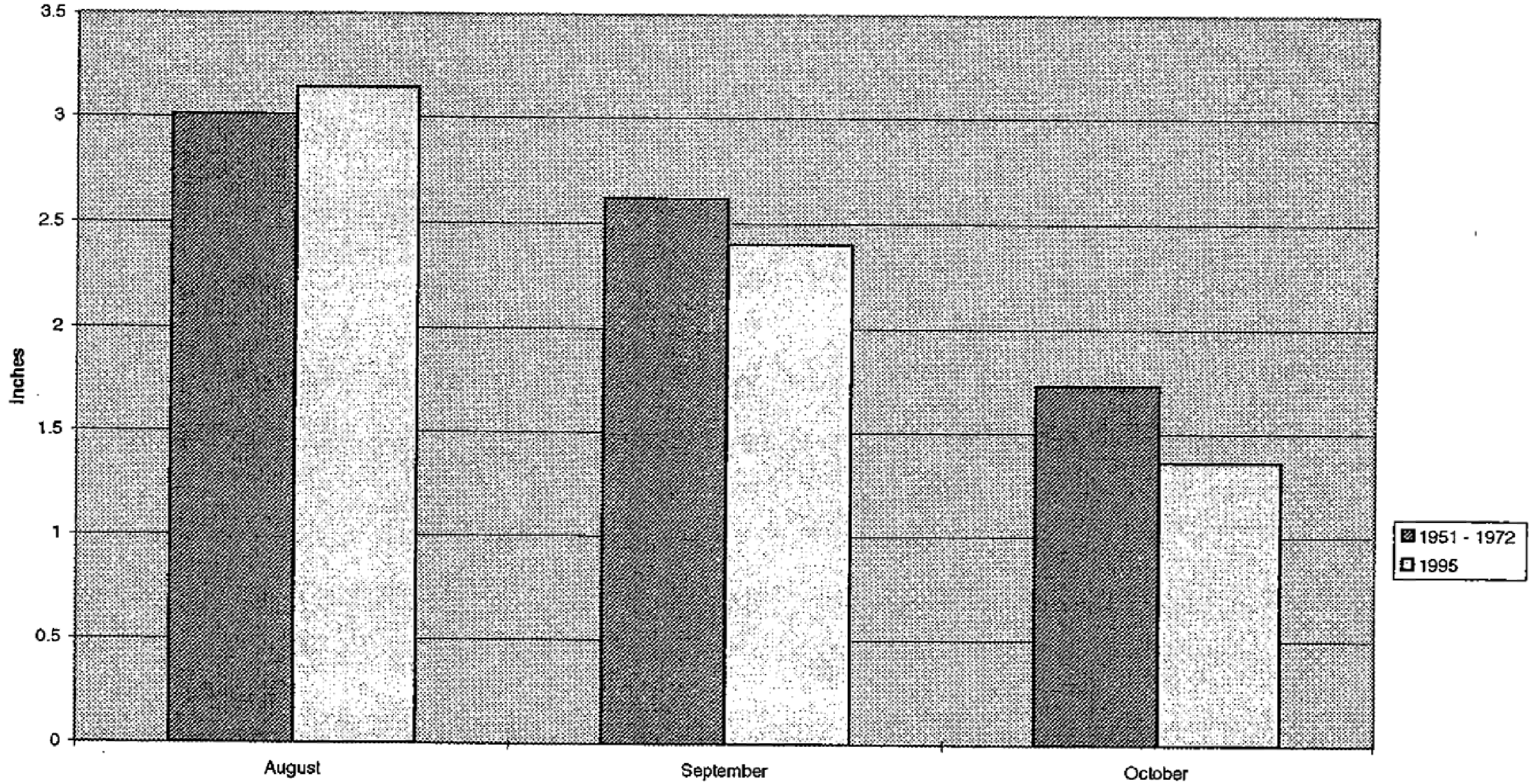
Sources :

1995 : Mn Climatology Office

1951-72 : USDA, Pennington County Soil Survey

Figure 6

Average Precipitation Amounts for Thief River Falls, Minnesota

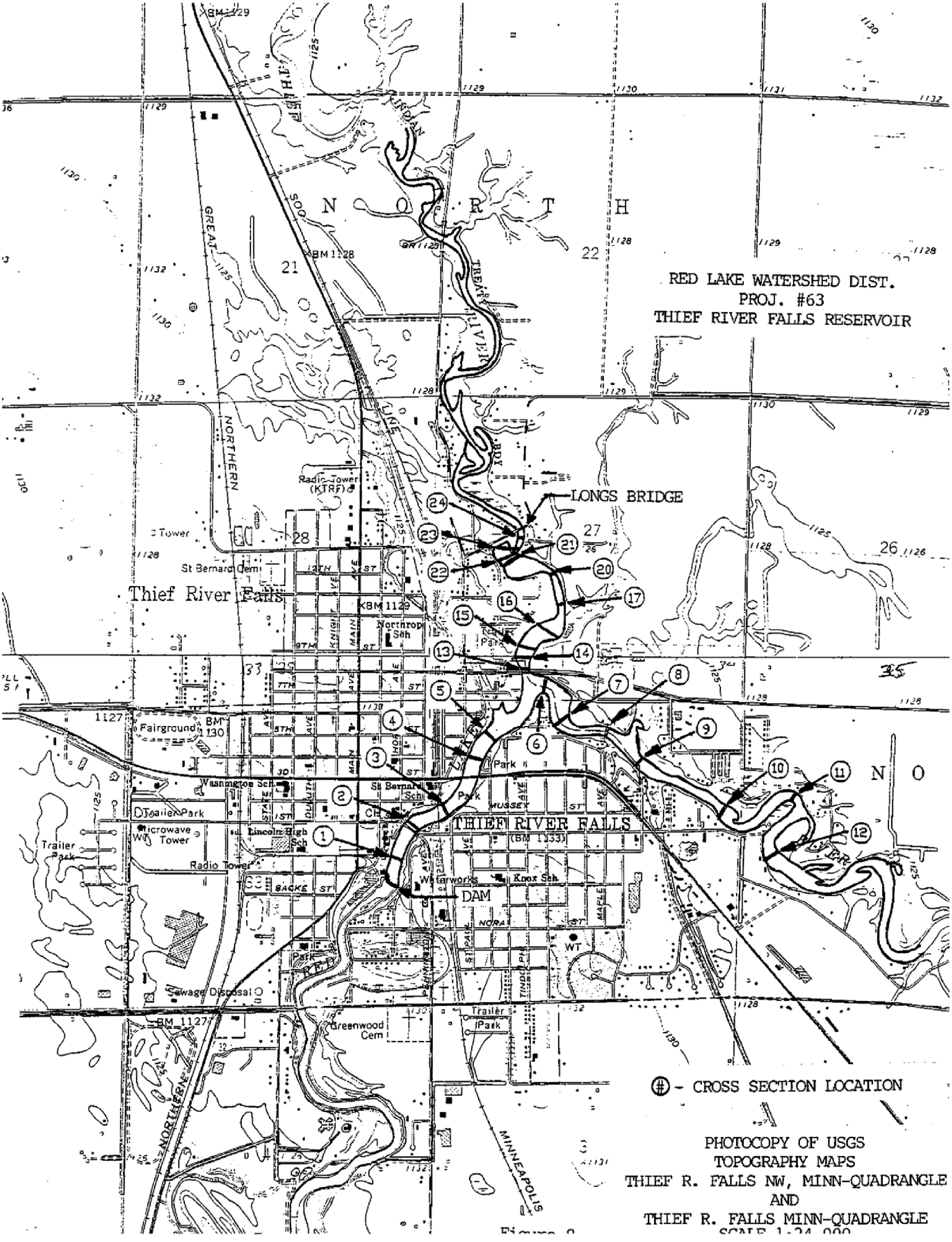


Sources :

1995 : Mn Climatology Office

1951-72 : USDA, Pennington County Soil Survey

Figure 7

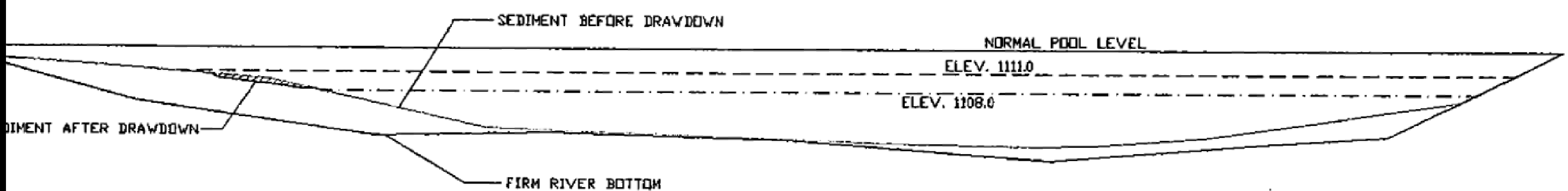

RED LAKE WATERSHED DIST.
PROJ. #63
THIEF RIVER FALLS RESERVOIR
LONGS BRIDGE
DAM
Thief River Falls
THIEF RIVER FALLS
NORTH
SOO LINE
GREAT NORTHERN
MINNEAPOLIS
Radio Tower (KTRF)
St Bernard Cem
Northrop Sch
Fairground
Washington Sch
Lincoln High Sch
Microwave Tower
Radio Tower
Trailer Park
Waterworks
Knox Sch
Sewage Disposal
Greenwood Cem
Park
WT
(#) - CROSS SECTION LOCATION
PHOTOCOPY OF USGS
TOPOGRAPHY MAPS
THIEF R. FALLS NW, MINN-QUADRANGLE
AND
THIEF R. FALLS MINN-QUADRANGLE

RED LAKE WATERSHED DISTRICT

PROJECT NO. 63

THIEF RIVER FALLS RESERVOIR DRAWDOWN

TYPICAL SECTION



TRF-RES.DWG

ANNEX A

RECEIVED
JUN 7 1993
CITY OF TH... FALLS
ENGINEERI... ...RTMENT

City of Thief River Falls

MINNESOTA 56701 BOX 528

PHONE 681-2943

Equal Opportunity Employer

MAYOR &
COUNCIL PRESIDENT
BOB REEVE

Ron Lindberg.
FOR YOUR INFORMATION
DATE 6-4-93
CITY OF THIEF RIVER FALLS
GERALD A. WIGNESS
Clerk - Treasurer

May 13, 1993

Jerry Paul
Department of Natural Resources
2115 Birchmont Beach Road NE
Bemidji, MN 56601

Dear Mr. Paul:

This is to inform you that a multi agency task force has met to procure a remedy to the accumulation of sediment within the reservoir at Thief River Falls. The group has decided to address the accumulated sediments by a temporary drawdown of the reservoir level with a result of consolidating the sediments. This maintenance technique for our reservoir will begin in August 1993. The contact person from this group is Bob Reeve, Mayor his phone number is 681-2943.

Bob Reeve

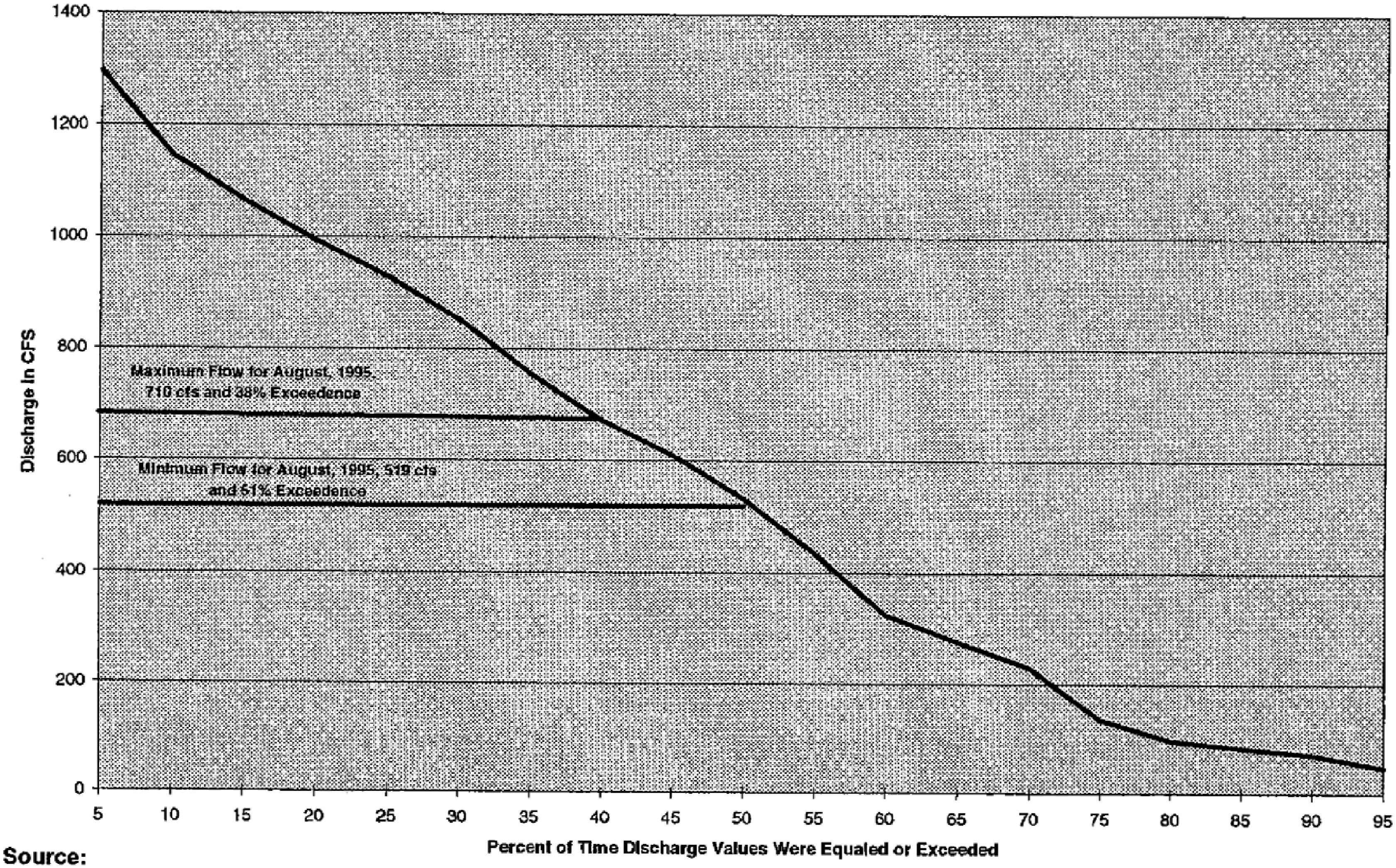
Bob Reeve, Mayor

Skip Swanson

Skip Swanson, Chairman

ANNEX B

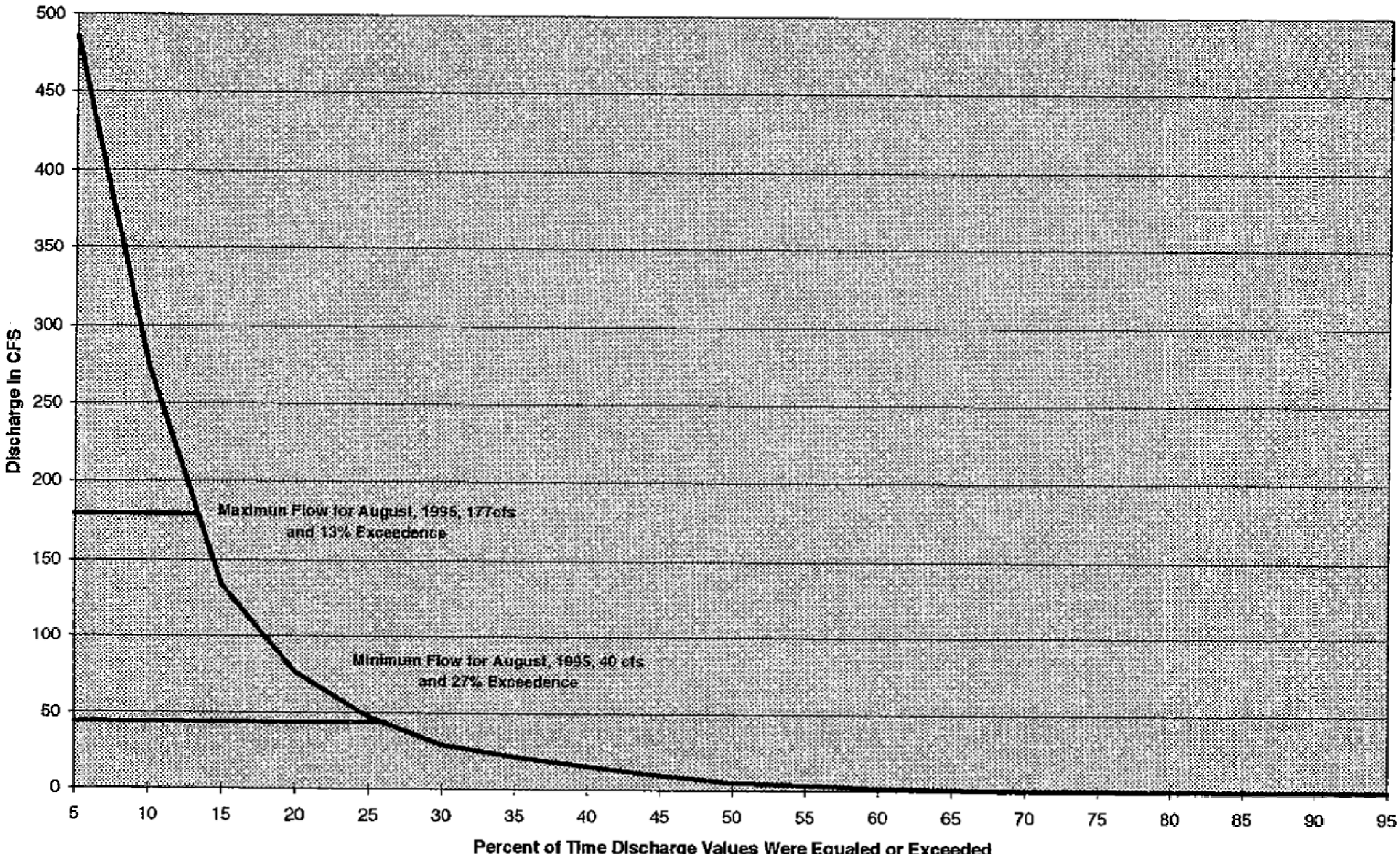
Duration Frequency Plot for the Red Lake River for August



Source:

United States Geological Survey

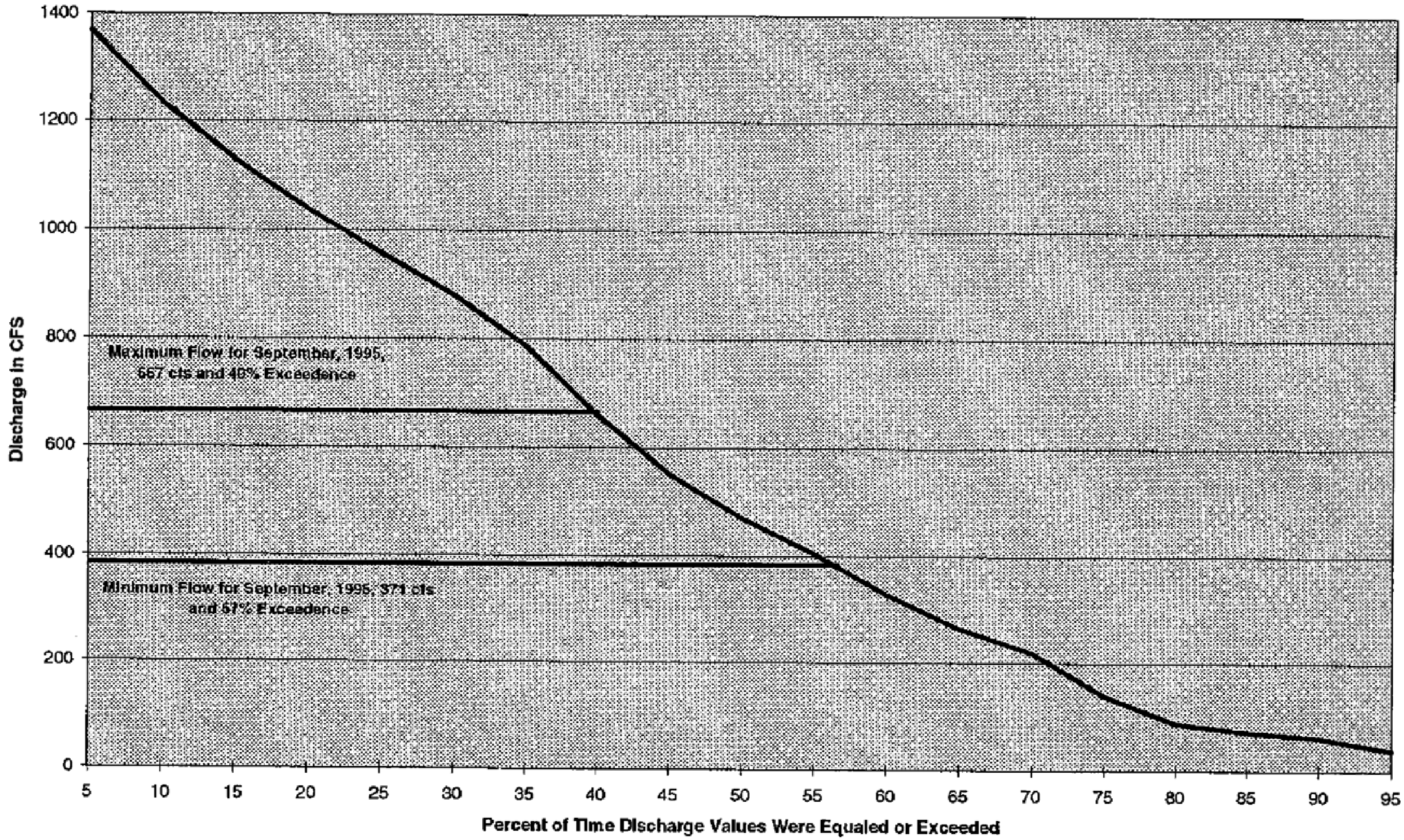
Duration Frequency Plot for the Thief River for August



Source :

United States Geological Survey

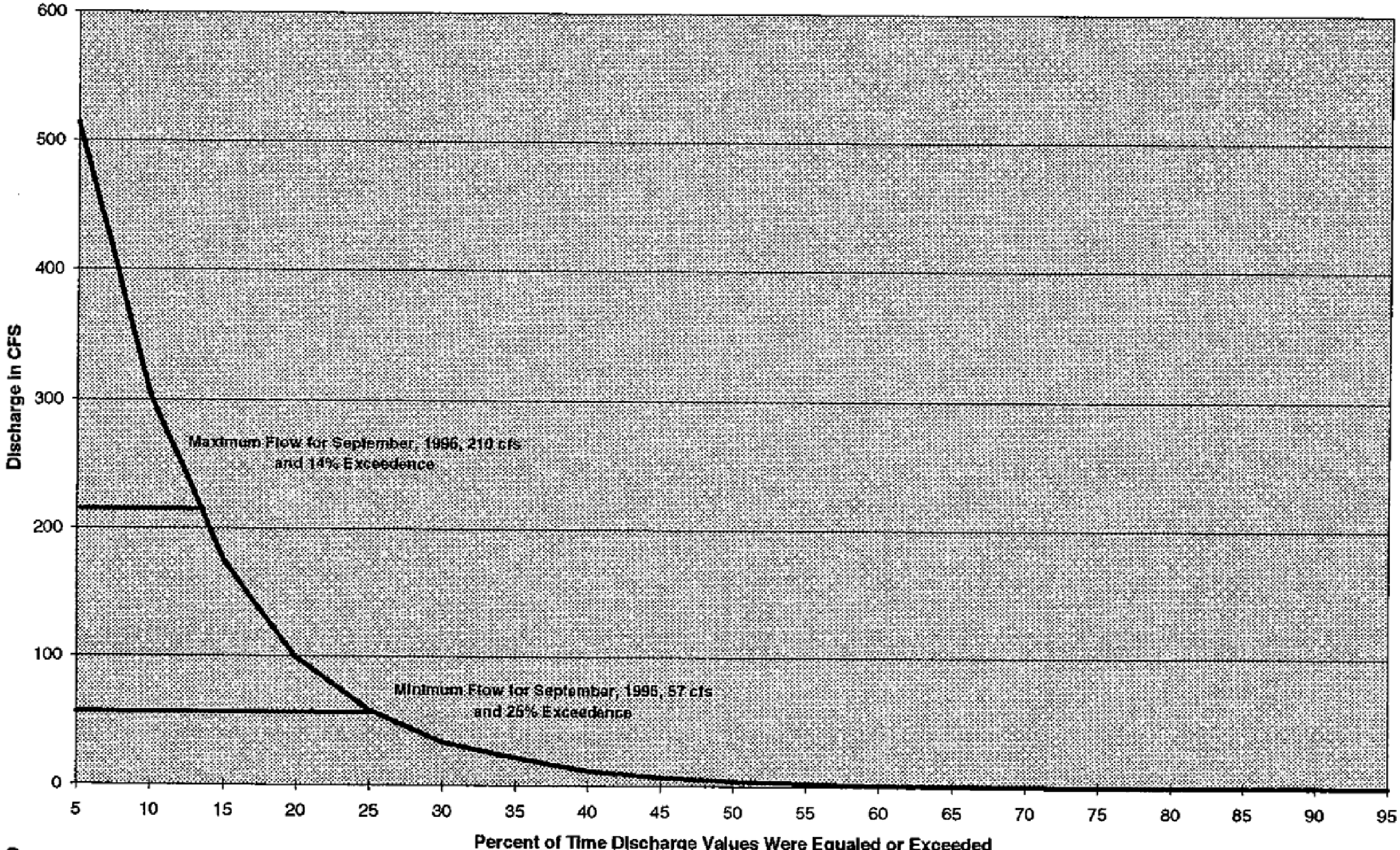
Duration Frequency Plot for the Red Lake River for September



Source :

United States Geological Survey

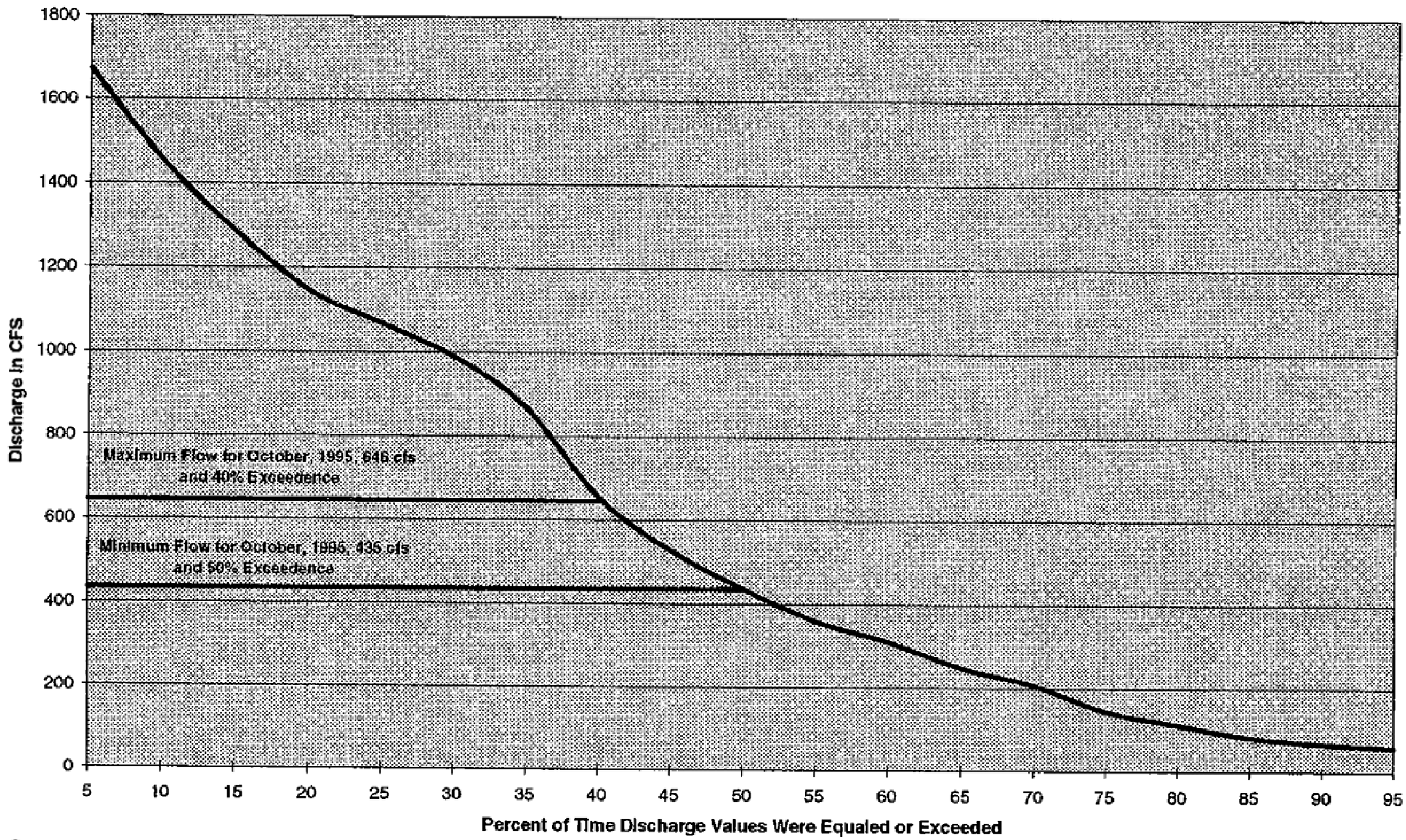
Duration Frequency Plot for the Thief River for September



Source :

United States Geological Survey

Duration Frequency Plot for the Red Lake River for October



Source :

United States Geological Survey

ANNEX C

Date : 11/3/95

To: Dave, Red Lake W.D.
From : State Climatology Office

The enclosed material may be of interest to you. Please phone if you have questions.

State Climatology Office
Department of Natural Resources - Division of Waters
(612) 296-4214

STATION: THIEF_RIVER_FALLS_2

Year	Mo	Dy	High (F)	Low (F)	Precip-itation (in)
1995	08	01	77	49	0.00
1995	08	02	88	58	0.00
1995	08	03	81	58	0.50
1995	08	04	83	52	0.00
1995	08	05	86	56	0.00
1995	08	06	83	65	0.00
1995	08	07	86	66	0.00
1995	08	08	86	68	0.00
1995	08	09	81	55	0.00
1995	08	10	78	52	0.00
1995	08	11	77	51	0.00
1995	08	12	76	56	0.15
1995	08	13	78	58	0.00
1995	08	14	77	55	0.00
1995	08	15	88	54	0.00
1995	08	16	83	65	0.00
1995	08	17	90	68	0.00
1995	08	18	90	70	1.57
1995	08	19	80	50	0.04
1995	08	20	85	54	0.00
1995	08	21	80	51	0.00
1995	08	22	90	61	0.33
1995	08	23	75	55	0.00
1995	08	24	71	51	0.45
1995	08	25	67	51	0.00
1995	08	26	71	47	0.00
1995	08	27	78	48	0.00
1995	08	28	74	55	0.10
1995	08	29	83	51	0.00
1995	08	30	80	67	0.00
1995	08	31	74	49	0.00
1995	09	01	81	55	0.00
1995	09	02	83	50	0.00
1995	09	03	86	50	0.00
1995	09	04	89	60	0.15
1995	09	05	76	62	0.00
1995	09	06	66	51	0.98
1995	09	07	57	37	0.00
1995	09	08	65	34	0.00
1995	09	09	64	40	0.00
1995	09	10	72	46	0.00
1995	09	11	78	52	0.00
1995	09	12	85	56	0.00
1995	09	13	72	51	0.00
1995	09	14	67	33	0.00
1995	09	15	66	46	0.00
1995	09	16	62	51	0.00
1995	09	17	64	33	0.00
1995	09	18	53	39	0.28
1995	09	19	50	33	0.00
1995	09	20	49	28	0.00
1995	09	21	44	32	0.15

	High (F)	Low (F)	Precipitation (in)
1995 09 22	52	26	0.00
1995 09 23	60	33	0.00
1995 09 24	62	35	0.00
1995 09 25	70	42	0.00
1995 09 26	69	40	0.00
1995 09 27	79	43	0.00
1995 09 28	82	51	0.00
1995 09 29	68	48	0.84
1995 09 30	55	49	0.00
1995 10 01	63	41	M
1995 10 02	56	41	0.39
1995 10 03	58	44	0.11
1995 10 04	56	35	M
1995 10 05	M	M	M
1995 10 06	45	40	0.01
1995 10 07	53	38	M
1995 10 08	54	35	M
1995 10 09	58	35	M
1995 10 10	67	37	M
1995 10 11	78	45	M
1995 10 12	75	53	M
1995 10 13	51	45	M
1995 10 14	41	34	0.09
1995 10 15	51	26	M
1995 10 16	59	31	M
1995 10 17	50	46	M
1995 10 18	42	29	M
1995 10 19	42	36	0.35
1995 10 20	40	32	0.05
1995 10 21	36	28	M
1995 10 22	48	33	M
1995 10 23	38	29	M
1995 10 24	50	24	M
1995 10 25	52	30	M
1995 10 26	50	31	M
1995 10 27	49	33	M
1995 10 28	40	30	0.11
1995 10 29	36	26	M
1995 10 30	35	28	M
1995 10 31	38	30	0.25

ANNEX D

TRF RESERVOIR STUDY						
SEDIMENT REDUCTION - RED LAKE RIVER						
				SEDIMENT		
		SEDIMENT ELEV.	SEDIMENT ELEV.	REDUCTION		
X-SECT.	STATION	BEFORE DRAWDOWN	AFTER DRAWDOWN	(FEET)		
3	0+59	1109.90	1108.90	-1.00		
	0+32	1111.90	1109.90	-2.00		AVERAGE
	0+10	1113.30	1113.30	0.00		SEDIMENT
4	2+19	1109.30	1109.20	-0.10		REDUCTION
	2+48	1110.50	1111.10	0.60		
	2+63	1111.60	1111.60	0.00		-0.25
5	3+26	1111.90	1113.20	1.30		
	3+01	1109.50	1110.50	1.00		
	2+67	1110.30	1110.40	0.10		
	2+45	1109.90	1110.20	0.30		
	2+24	1109.60	1109.80	0.20		
	2+01	1108.90	1108.20	-0.70		
6	0+62	1109.20	1108.60	-0.60		
	0+87	1109.30	1109.20	-0.10		
	1+16	1109.20	1109.10	-0.10		
	1+48	1109.30	1109.10	-0.20		
	1+77	1110.50	1109.20	-1.30		
	2+11	1109.50	1109.10	-0.40		
	2+44	1106.40	1105.20	-1.20		
	3+16	1103.80	1102.50	-1.30		
	3+44	1108.00	1109.00	1.00		
	3+54	1112.20	1112.10	-0.10		
7	2+60	1107.20	1105.70	-1.50		
	2+31	1104.50	1101.90	-2.60		
	2+12	1102.40	1102.00	-0.40		
	1+90	1102.40	1102.50	0.10		
	1+32	1107.50	1108.40	0.90		
	0+89	1108.00	1108.20	0.20		
	0+50	1107.90	1107.00	-0.90		
	0+23	1108.30	1107.50	-0.80		
8	0+19	1110.00	1110.60	0.60		
	0+33	1109.60	1109.10	-0.50		
	0+65	1109.80	1108.80	-1.00		
	0+97	1108.20	1106.60	-1.60		
	1+14	1106.10	1104.70	-1.40		
	1+38	1103.60	1103.20	-0.40		
	1+64	1103.20	1103.50	0.30		
	1+94	1103.20	1103.60	0.40		
	2+23	1111.90	1110.90	-1.00		
9	1+84	1108.80	1107.70	-1.10		
	1+60	1104.90	1104.40	-0.50		
	1+26	1104.20	1103.50	-0.70		
	1+05	1104.10	1104.00	-0.10		
	0+61	1105.00	1105.10	0.10		
	0+36	1108.80	1108.90	0.10		
	0+18	1112.80	1111.50	-1.30		

10	0+27	1113.40	1113.40	0.00			
	0+37	1112.40	1112.60	0.20			
	0+57	1111.80	1111.80	0.00			
	0+71	1112.80	1112.70	-0.10			
	0+96	1113.60	1113.70	0.10			
	1+10	1113.80	1113.50	-0.30			
	1+26	1113.00	1113.30	0.30			
	1+45	1109.10	1110.40	1.30			
	1+64	1107.40	1106.10	-1.30			
	1+88	1104.50	1104.80	0.30			
	2+21	1104.30	1104.50	0.20			
	2+52	1105.40	1106.00	0.60			
	2+64	1106.80	1108.90	2.10			
11	3+00	1110.70	1111.00	0.30			
	2+77	1108.90	1108.90	0.00			
	1+95	1108.80	1108.60	-0.20			
	1+69	1106.70	1108.00	1.30			
	0+89	1104.70	1107.00	2.30			
	0+71	1105.70	1105.40	-0.30			
	0+47	1108.50	1107.00	-1.50			
	0+29	1110.90	1110.90	0.00			
12	2+24	1108.70	1108.40	-0.30			
	2+15	1108.40	1107.60	-0.80			
	1+78	1108.20	1107.20	-1.00			
	1+47	1109.70	1107.20	-2.50			
	1+25	1110.70	1110.80	0.10			
	0+90	1109.60	1107.90	-1.70			
	0+44	1108.30	1108.60	0.30			
	0+21	1108.70	1108.30	-0.40			
	0+14	1112.40	1112.80	0.40			
Sample Size	**Mean**	**Median**	**Maximum**	**Minimum**	**St. Dev**	**-1 St. Dev**	**+ 1 St. Dev**
76	**-0.24**	**-0.10**	**2.30**	**-2.60**	**0.91**	**-1.15**	**0.67**

TRF RESERVOIR STUDY

SEDIMENT REDUCTION - THIEF RIVER

X-SECT.	STATION	SEDIMENT ELEV. BEFORE DRAWDOWN	SEDIMENT ELEV AFTER DRAWDOWN	SEDIMENT REDUCTION (FEET)		AVERAGE SEDIMENT REDUCTION
14	2+98	1112.60	1111.00	-1.60		
	2+57	1111.00	1108.40	-2.60		
	2+33	1108.50	1107.90	-0.60		
	2+00	1107.20	1107.50	0.30		
	1+55	1107.60	1108.00	0.40		
	1+04	1106.50	1104.50	-2.00		
	0+72	1102.00	1101.70	-0.30		
	0+43	1104.30	1105.80	1.50		-0.29
	0+31	1107.20	1108.20	1.00		
16	2+23	1109.60	1109.60	0.00		
	1+71	1110.90	1111.00	0.10		
	1+52	1111.60	1111.50	-0.10		
	1+10	1112.90	1112.80	-0.10		
	0+56	1112.20	1111.60	-0.60		
	0+32	1111.60	1111.30	-0.30		
	0+21	1112.80	1112.60	-0.20		
20	1+70	1110.70	1111.40	0.70		
	1+57	1103.70	1101.90	-1.80		
	1+43	1101.60	1101.80	0.20		
	1+23	1102.10	1100.90	-1.20		
	0+85	1107.50	1107.00	-0.50		
	0+52	1112.10	1111.80	-0.30		
	0+37	1112.30	1112.00	-0.30		
	0+22	1112.20	1112.70	0.50		
21	1+89	1113.40	1113.40	0.00		
	1+84	1113.20	1112.90	-0.30		
	1+73	1109.80	1109.70	-0.10		
	0+70	1110.60	1108.60	-2.00		
	0+48	1113.60	1112.90	-0.70		
	0+27	1114.00	1113.60	-0.40		
23	4+64	1112.80	1112.60	-0.20		
	4+59	1110.80	1111.50	0.70		
	3+26	1113.80	1113.40	-0.40		
	3+12	1113.90	1113.70	-0.20		
	2+88	1113.80	1113.50	-0.30		
	2+56	1113.50	1113.30	-0.20		
	2+21	1113.00	1112.90	-0.10		
	1+89	1113.00	1112.80	-0.20		
	1+52	1113.10	1112.90	-0.20		
	1+01	1112.60	1112.30	-0.30		
	0+76	1112.00	1112.20	0.20		
	0+56	1112.60	1112.60	0.00		
	0+42	1113.20	1113.00	-0.20		
	0+32	1113.30	1113.20	-0.10		

Sample Size	Mean	Median	Maximum	Minimum	St. Dev	-1 St. Dev	+ 1 St. Dev
44	-0.29	-0.20	1.50	-2.60	0.77	-1.06	0.48

ANNEX E

TRF RESERVOIR STUDY

SEDIMENT REDUCTION - RED LAKE RIVER

SEDIMENT VOLUME BEFORE DRAWDOWN:

X-SECT.	RIVER STATION	SEDIMENT AREA	AVERAGE SEDIMENT AREA	L	VOLUME (CU.YD.)
3	17+80	598.90			
			533.55	1182.00	23,358
4	29+62	468.20			
			565.00	473.00	9,898
5	34+35	661.80			
			850.55	1418.00	44,670
6	48+53	1039.30			
			731.55	709.00	19,210
7	55+62	423.80			
			437.95	867.00	14,063
8	64+29	452.10			
			359.35	946.00	12,591
9	73+75	266.60			
			377.90	1576.00	22,058
10	89+51	489.20			
			410.15	1773.00	26,933
11	107+24	331.10			
			295.35	1221.00	13,356
12	119+45	259.60			
					186,137

SEDIMENT VOLUME AFTER DRAWDOWN:

X-SECT.	RIVER STATION	SEDIMENT AREA	AVERAGE SEDIMENT AREA	L	VOLUME (CU.YD.)
3	17+80	568.90			
			518.65	1182.00	22,701
4	29+62	468.20			
			565.00	473.00	9,898
5	34+35	661.80			
			793.00	1418.00	41,647
6	48+53	924.20			
			598.05	709.00	15,704
7	55+62	271.90			
			301.30	867.00	9,675
8	64+29	330.70			
			292.85	946.00	10,261
9	73+75	255.00			
			370.70	1576.00	21,638
10	89+51	486.40			
			408.75	1773.00	26,841
11	107+24	331.10			

[redacted]

TRF RESERVOIR STUDY

SEDIMENT REDUCTION - THIEF RIVER

SEDIMENT VOLUME BEFORE DRAWDOWN:

X-SECT.	RIVER STATION	SEDIMENT AREA	AVERAGE SEDIMENT AREA	L	VOLUME (CU.YD.)
14	1+98	460.80			
			849.25	593.00	18,652
16	7+91	1237.70			
			743.55	1039.00	28,613
20	18+30	249.40			
			352.50	742.00	9,687
21	25+72	455.60			
			746.75	544.00	15,046
23	31+16	1037.90			
					71,998

SEDIMENT VOLUME AFTER DRAWDOWN:

X-SECT.	RIVER STATION	SEDIMENT AREA	AVERAGE SEDIMENT AREA	L	VOLUME (CU.YD.)
14	1+98	246.70			
			721.70	593.00	15,851
16	7+91	1196.70			
			691.40	1039.00	26,606
20	18+30	186.10			
			291.35	742.00	8,007
21	25+72	396.60			
			669.65	544.00	13,492
23	31+16	942.70			
					63,956
			REDCTION IN SEDIMENT VOLUME=	**11.17%**	

ANNEX F

Thief River Falls Reservoir Study
Plant Identification / Biomass

Cross Section #	Location	Species Present	Relative Abundance
	All are Red Lake River Cross Sections		A = Abundant C = Common S = Sparse
3	West Bank	Coontail, Sago Pondweed, Cattails Wildrice, Curled Pondweed	A, S, A S, S
	East Bank	N/A	
4	West Bank	Water Celery	S
	East Bank	Water Celery, Wildrice, Sago Pondweed Milfoil	S, S, S S
5	West Bank	Water Celery, Milfoil, Cattails	S, S, S
	East Bank	N/A	
6	North Bank	White Water Lily, Water Celery, Milfoil Coontail	C, S, C C
	South Bank	Wildrice	S
7	North Bank	Clasping Pondweed, Water Celery, Wildrice Coontail, Milfoil	S, S, C S, A
	South Bank	Sago Pondweed, White Water Lily	C, S
8	North Bank	White Water Lily, Wildrice, Water Celery Sago Pondweed, Coontail	S, S, A S, S
	South Bank	Wildrice, Water Celery Floating Leaf Pondweed	S, S A
9	North Bank	Water Celery, Milfoil, Coontail Sago Pondweed	C, A, S S
	South Bank	Water Celery	S
10	North Bank	Waterweed, Wildrice, Milfoil, Sago Pondweed asping PW, Coontail, Arrowhead, Floating Leaf P	C, A, S, C C, A, S, C
	South Bank	Wildrice, Sago Pondweed, Water Celery	C, S, S
11	North Bank	Wildrice, White Water Lily, Sago Pondweed	C, S, S
	Middle Bar	Wildrice	C
	South Bank	Wildrice, Clasping Pondweed Sago Pondweed, White Water Lily	A, A S, C
12	North Bank	Wildrice, Clasping Pondweed	A, C
	South Bank	Wildrice, White Water Lily	A, C

Thief River Falls Reservoir Study
Plant Identification / Biomass

Cross Section #	Location	Species Present	Relative Abundance
	All are Thief River Cross Sections		A = Abundant C = Common S = Sparse
14	West Bank	White Water Lily, Water Celery	C , S
	East Bank	Water Celery, Milfoil, Coontail	A , C , S
16	West Bank	Elodea, Coontail, Water Celery, Floating Leaf P.W Wild Rice, White Water Lily, Sago Pondweed, Milfo	A , S , C , S S , S , C , C
	East Bank	Water Celery, Typha, Floating Leaf Pondweed Duckweed, Milfoil, Sago Pondweed	S , C , A A , S , C
20	West Bank	Milfoil, Sago Pondweed, Clasping Pondweed ater Celery, Coontail, Elodea, Green Friuted Bure	S , S , S S , C , S , S
	East Bank	Water Celery	A
21	West Bank	Floating Leaf Pondweed, Coontail, Elodea Milfoil, Sago Pondweed	S , S , S C , A
	East Bank	Sago Pondweed, Water Celery Green Fruited Bureed	C , A S
22	West Bank	Milfoil, Green Fruited Bureed	A , C S , A
	East Bank	Floating Leaf Pondweed, Water Celery	A , C

Annex G

Annex G contains the results from the laboratory tests that were performed on the sediment samples collected from the reservoir. This includes the density and particle size analysis results.

By conducting a drawdown we expected to achieve consolidation of the sediments. This would include an overall settling of the material as the water drained out. By accomplishing this, the expected outcome would be an increase in sediment density.

The following tables show the results of the particle size and density analyses. June 1995 was before the drawdown, October 1995 was before refilling, and December 1995 was two months after refilling the reservoir. The observed results were contrary to what we expected. The October and December samples actually showed a decrease in sediment density.

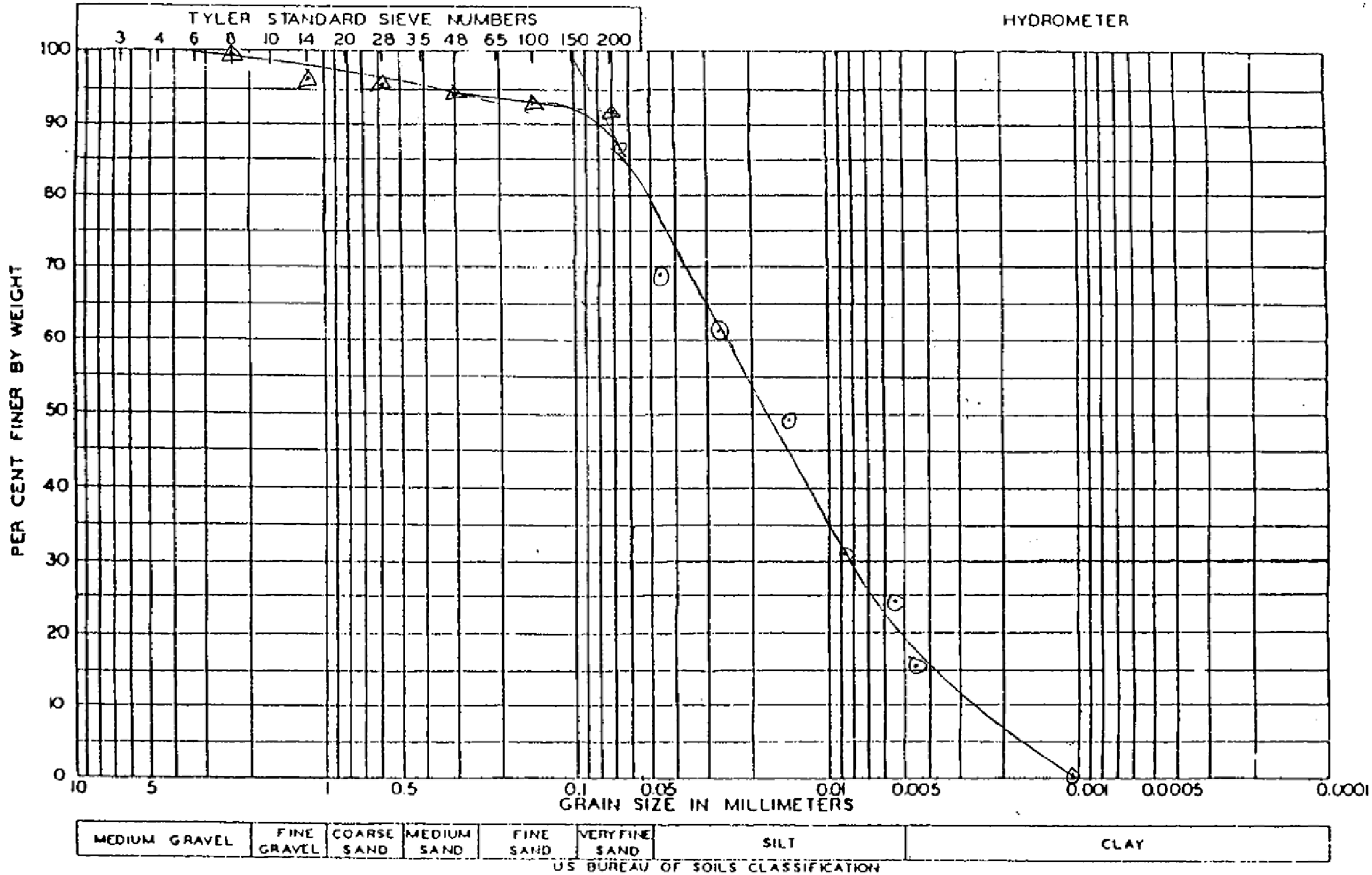
The consistently lower density of samples collected after the drawdown, contradicts the sediment consolidation theory. We consulted several soil scientists at the University of Minnesota regarding this. After studying our methods and results, their consensus was that these results could be attributed to field sampling variability. The December density analysis, which included duplicate sampling as well as the particle size analysis, was done to illustrate this sampling variability. Our density results again showed a decrease in sediment densities. The particle size analysis results differed greatly from our 1991 results. This illustrates field sampling variability, since the same sites were sampled both times.

Thief River Falls Reservoir Study
Sediment Density Analysis

Sample #	Date Sampled	Weight of Container (grams)	Volume of Container (mL)	Weight of Water and Sediment (grams)	Dry Weight of Sediment (grams)	Moisture Content	Density Inplace g/cm3	Dry Density g/cm3
	Jul-91					1.48		0.51
	Jun-95	14.2	75	110.6	47.6	1.32	1.48	0.64
6	Oct-95	14.1	75	91.4	24.6	2.72	1.22	0.33
	Dec-95	14.4	75	107.3	43.8	1.45	1.43	0.58
6 Duplicate	Dec-95	14.4	75	103.7	40.3	1.57	1.38	0.54
	Jul-91					1.06		0.66
	Jun-95	14.2	75	119.1	61.2	0.95	1.59	0.82
8	Oct-95	14.1	75	97.2	29.2	2.32	1.3	0.39
	Dec-95	14.1	75	102.5	87	1.77	1.37	0.49
	Jun-95	14.2	75	109.8	47.9	1.29	1.46	0.64
11	Oct-95	13.8	75	107.3	44.6	1.41	1.43	0.59
	Dec-95	14.4	75	94.7	25	2.78	1.26	0.33
11 Duplicate	Dec-95	14.4	75	93.6	24.4	2.84	1.25	0.33
	Jul-91					0.82		0.8
	Jun-95	14.2	75	139.5	92.1	0.52	1.86	1.23
16	Oct-95	13.9	75	109.1	52	1.1	1.45	0.69
	Dec-95	14.3	75	109.8	49	1.24	1.46	0.65
16 Duplicate	Dec-95	14	75	106.7	49.1	1.17	1.42	0.66
	Jun-95	13.2	75	131.9	81.4	0.62	1.76	1.09
22	Oct-95	13.9	75	118.5	60.4	0.96	1.58	0.81
	Dec-95	14.9	75	114.8	64.5	0.78	1.53	0.86

PARTICLE SIZE COMPARISONS

Sample #	6		6 Duplicate	8		11	11 Duplicate	16		16 Duplicate	22
Date Sampled	Jul-91	Dec-95	Dec-95	Jul-91	Dec-95	Dec-95	Dec-95	Jul-91	Dec-95	Dec-95	Dec-95
Sample I.D.	Red Lake River	Red Lake River	Red Lake River	Red Lake River	Red Lake River	Red Lake River	Red Lake River	Thief River	Thief River	Thief River	Thief River
Soil Classification	Loam	Silt Loam	Silty Clay Loam	Sandy Loam	Silt Loam	Silty Clay Loam	Sandy Loam	Sandy Clay Loam	Loam	Loam	Clay Loam
Sand .05 to 2.0 mm	43	21	13	56	28	17	57	62	35	51	27
Silt .005 to .05 mm	39	59	59	30	57	50	39	14	42	32	42
Clay 0.00 to .005 mm	18	20	28	14	15	33	4	24	23	17	31
Moisture Content (when received %)	148	145	138	106	177	278	284	82	124	117	78
Grain Size Analysis Particle Size (mm)											
5	99	100	100	97.5	100	100	100	100	100	100	100
3	99	99.5	100	97	100	100	100	100	100	100	100
2	99	99	99	95.5	97	97	97	99	97	97	98
1	99	97.5	97.5	91	90	92.5	77	96.5	91.5	91	96
0.75	98.5	97	97	88.5	88	91.5	72	94.5	90	88	95
0.5	98.5	96	96	84	86	91	68	93	88	85	93.5
0.2	98	94	95.5	69	83	90	60	75	82.5	72	85
0.1	83.5	92.5	94.5	56	81	87.5	52.5	49.5	77.5	59	80
0.075	75	88	92	51	78	85.5	48	44	76	55	77
0.05	57	80	87.5	44.5	72	83	42.5	40	65	48	72
0.02	35	54	63	29.5	37	70	20	32	45	35	58
0.01	25.5	35	45	21	24	51	7.5	28	32.5	25	44
0.005	18.5	20	27.5	14	15	32	4	24	22.5	17.5	26
0.001	8	0	0	7	5	0	0	17	5	0	4

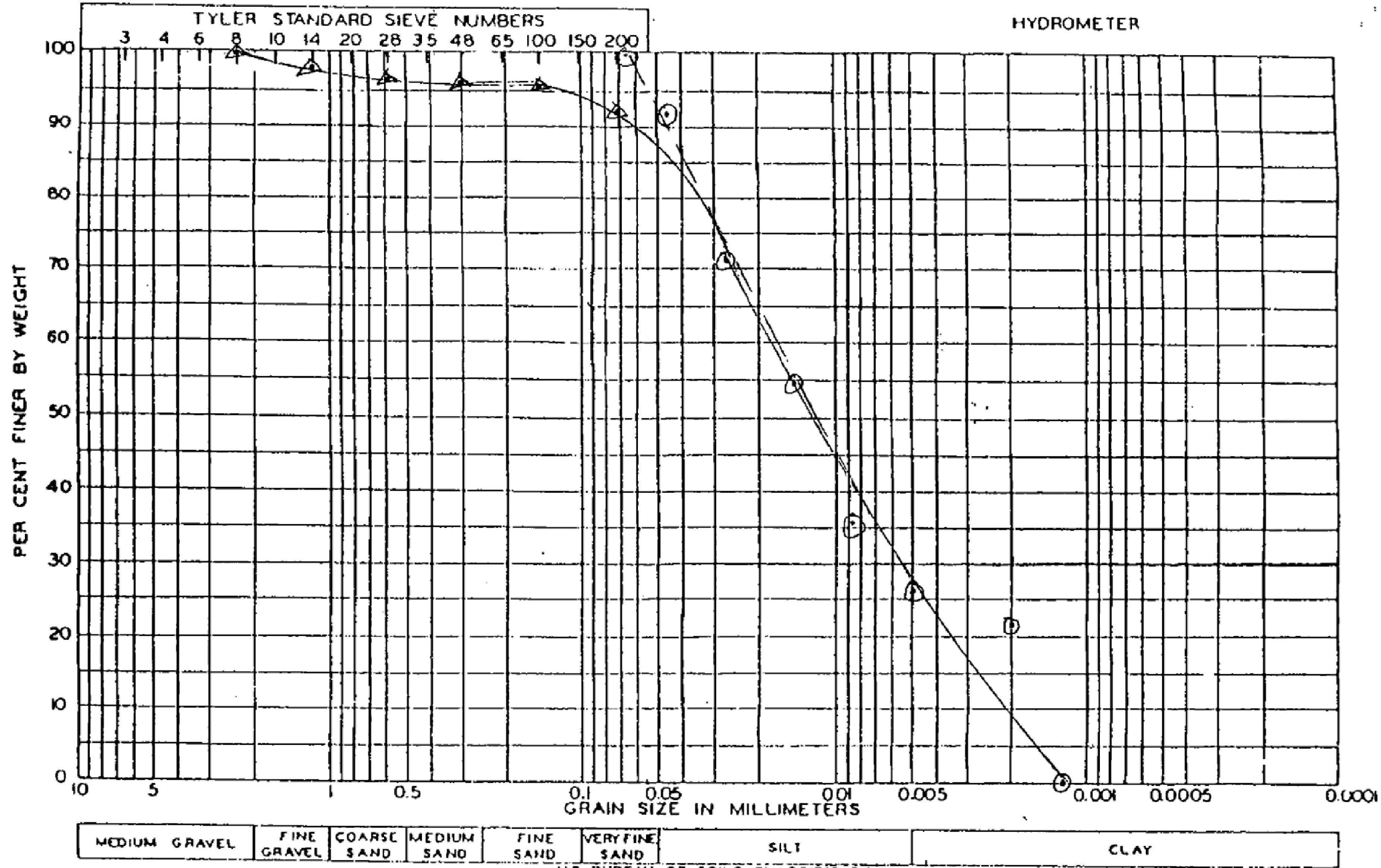


PROJECT ________ BORING NO ________ SAMPLE NO #6

DEPTH ____ ELEVATION ____ REMARKS ________

Δ = Sieve
ʘ = Hydrometer

GRAIN SIZE DISTRIBUTION DIAGRAM

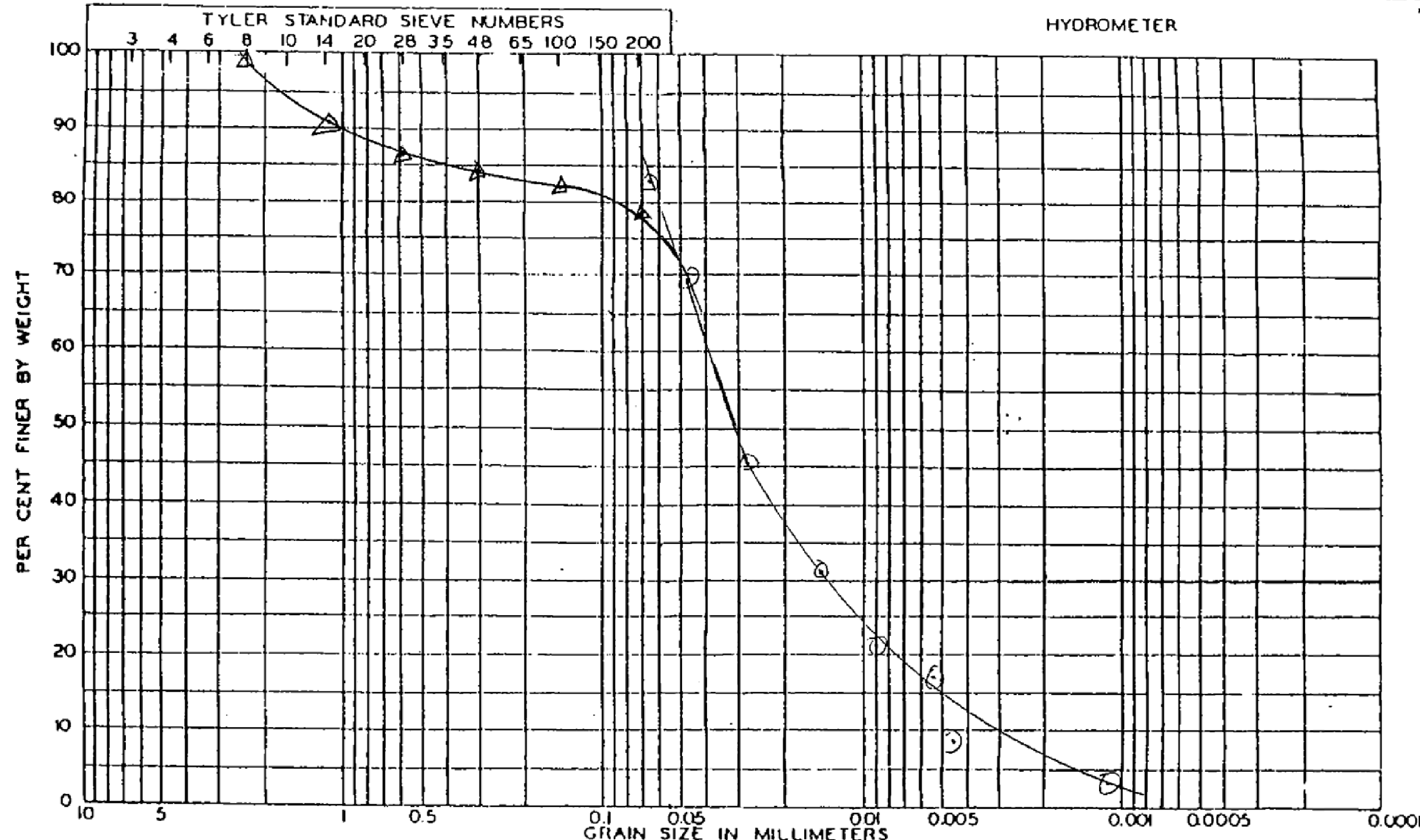


PROJECT TRF Drawdown BORING NO ______ SAMPLE NO X-section 6 Dup

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

Total Solids = 15.56



MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

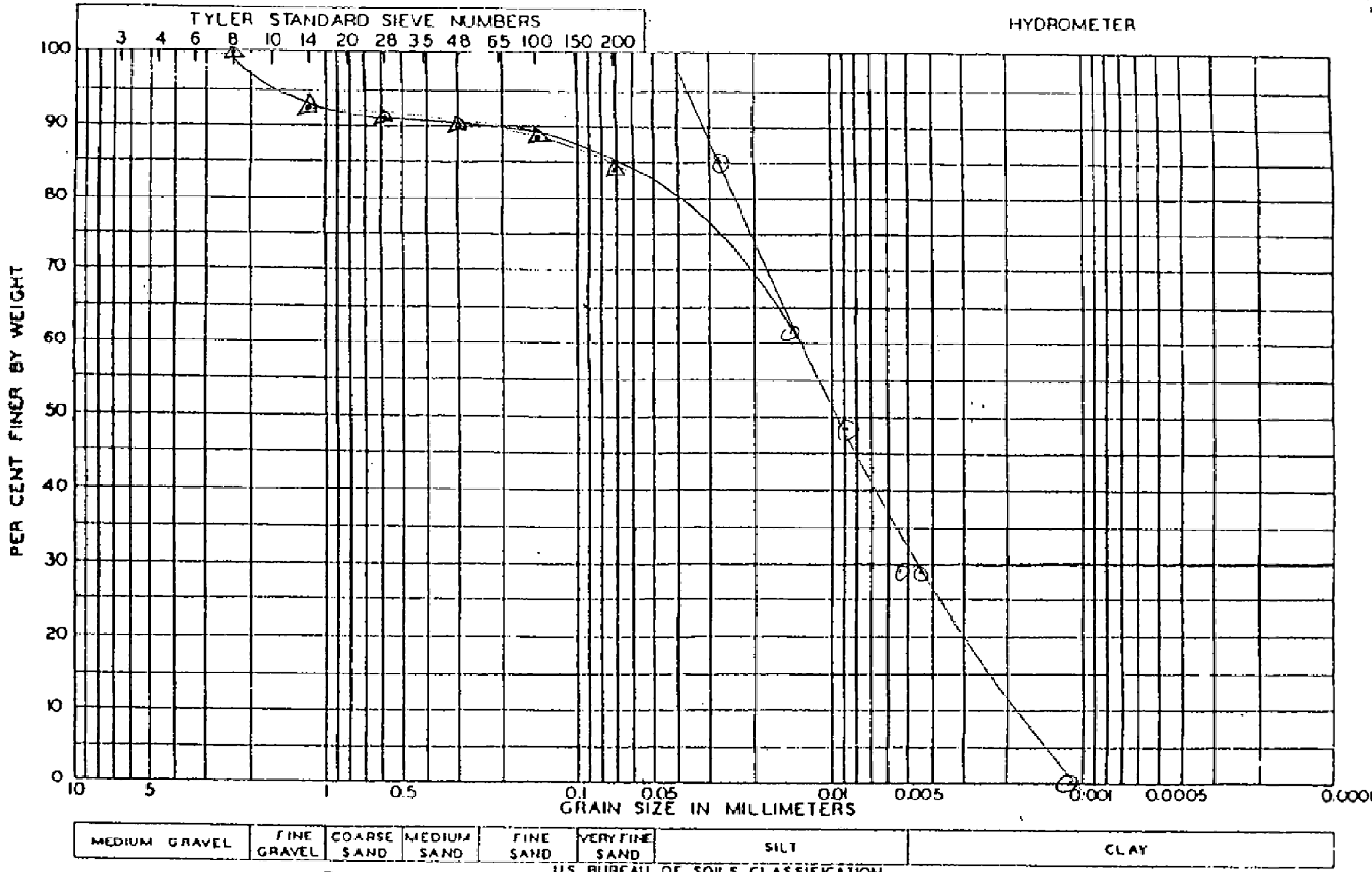
US BUREAU OF SOILS CLASSIFICATION

PROJECT TRF- Drawdown BORING NO ______ SAMPLE NO X-Section #8

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

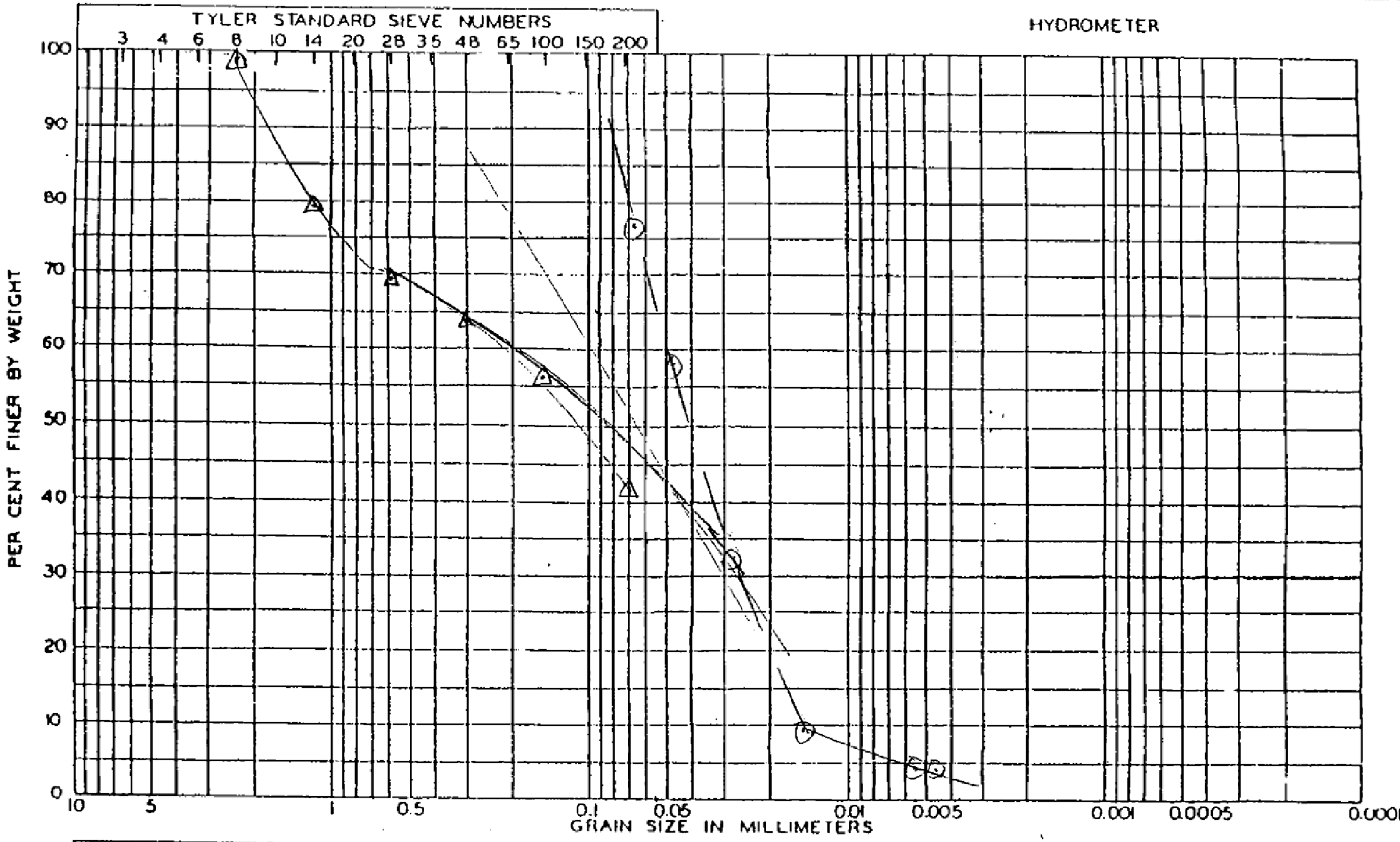
SOIL TEST INCORPORATED



PROJECT TRF Drawdown BORING NO ______ SAMPLE NO X-Section #11

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM



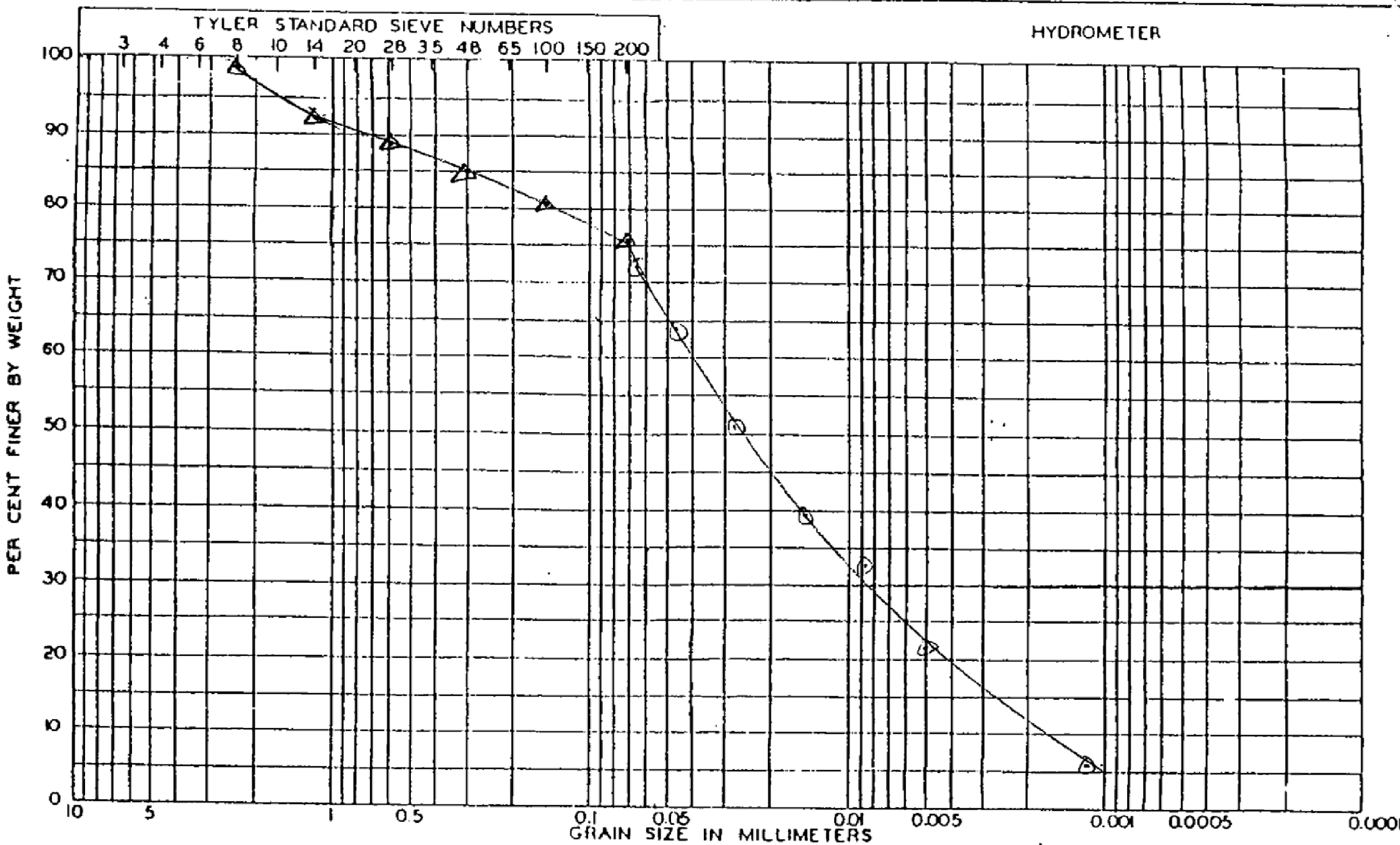
MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

US BUREAU OF SOILS CLASSIFICATION

PROJECT ______ BORING NO ______ SAMPLE NO ℄ - Section 11-Dup

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM



MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

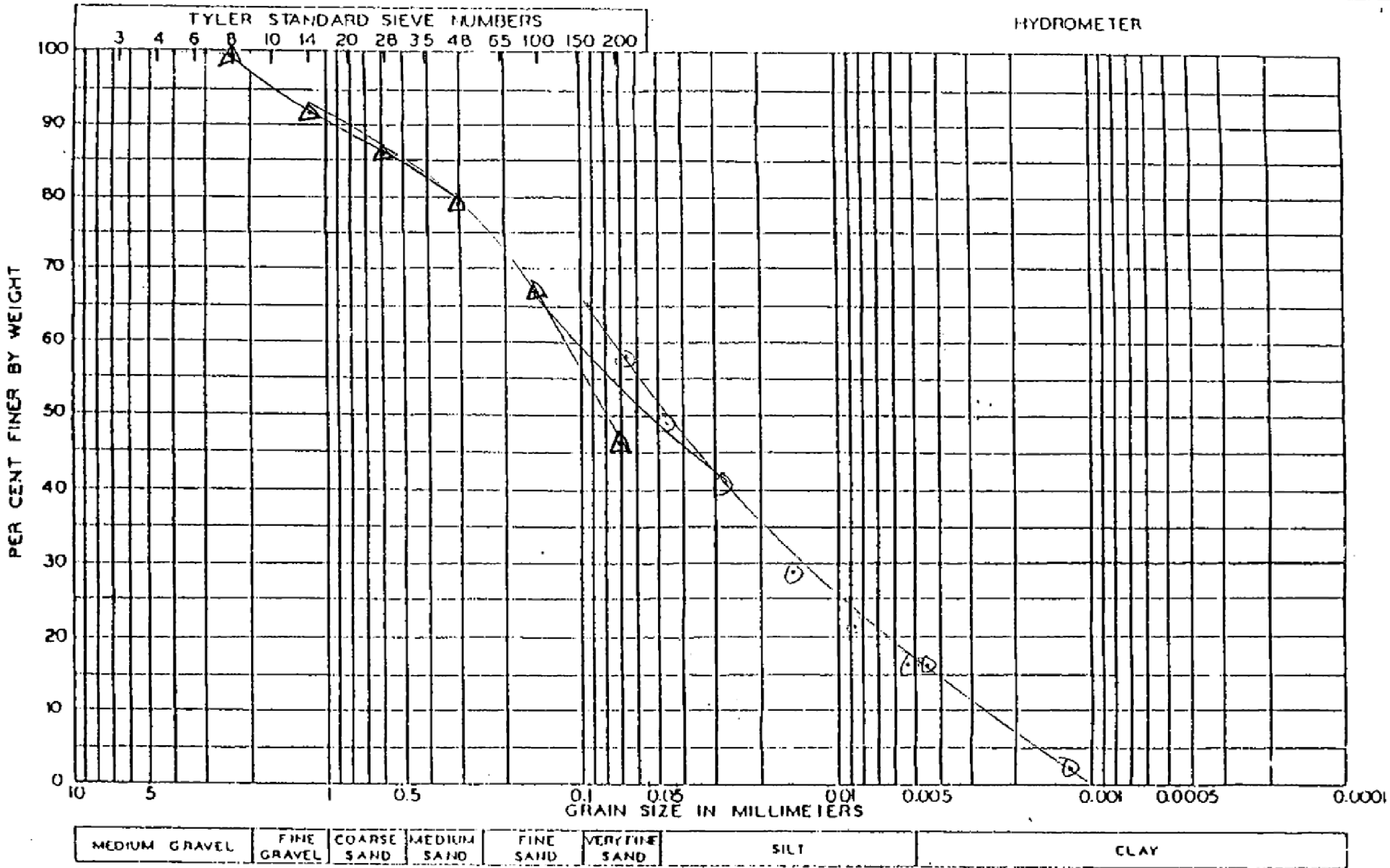
US BUREAU OF SOILS CLASSIFICATION

PROJECT TRF - Drawdown BORING NO ______ SAMPLE NO Y-Section #16

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

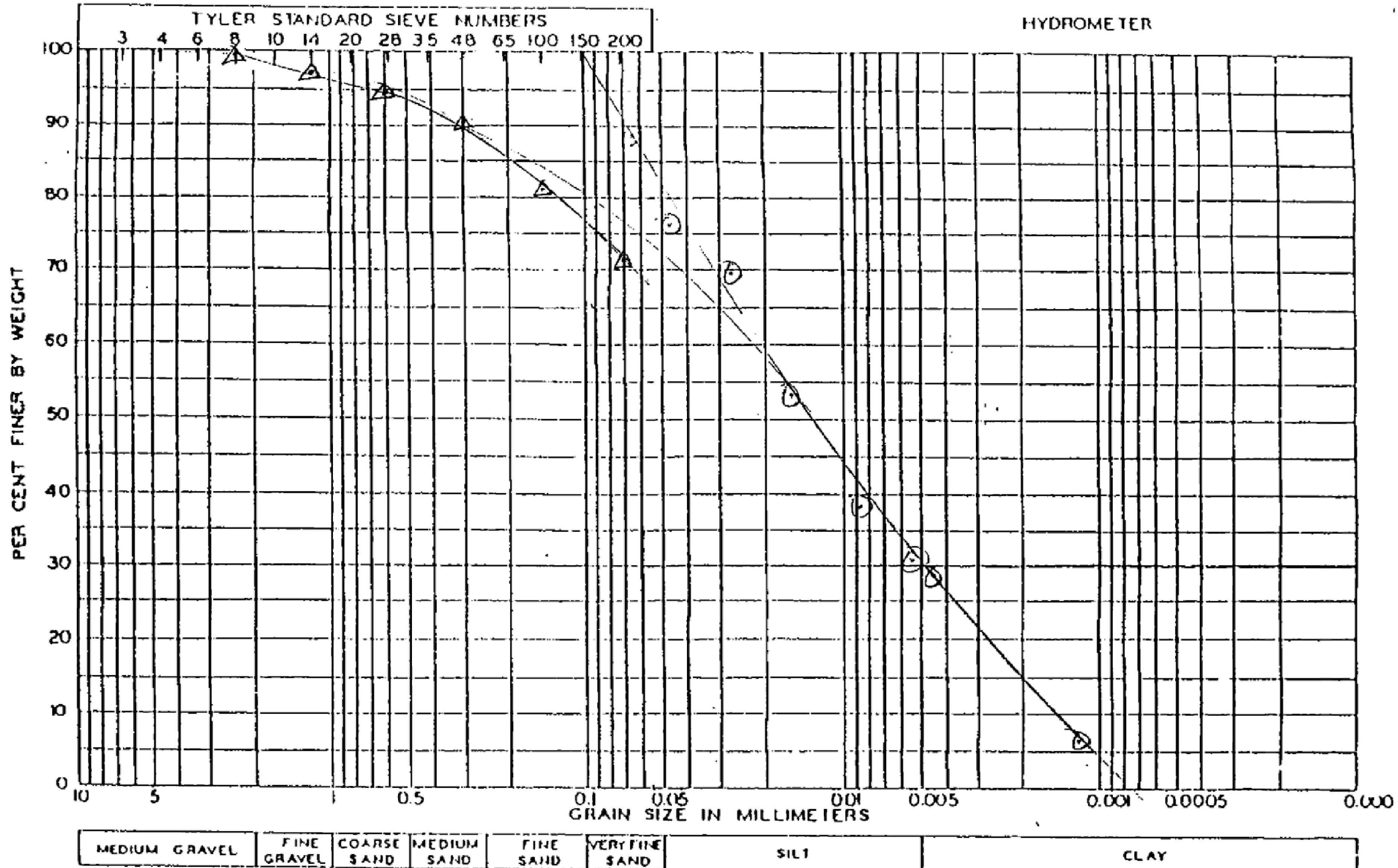
DCL-6



PROJECT TRF - Drawdown BORING NO ______ SAMPLE NO ⊄-Section 16-Dr

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM



PROJECT TRF Drawdown BORING NO ______ SAMPLE NO X-Section 22

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM