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MANITOBA NATURAL RESOURCES SUBMISSION TO THE MANITOBA WATER COMMISSION

BACKGROUND INFORMATION CONCERNING
MANITOBA NATURAL RESOURCES
INVOLVEMENT IN THE 1997 FLOODING
OF THE RED RIVER VALLEY

October, 1997

Manitoba Natural Resources
Honourable J. Glen Cummings
Minister

EFK

FORWARD

The following information forms the initial submission of the Department of Natural Resources to the Manitoba Water Commission in its review of the 1997 Red River flood.

This submission is intended as background information. It outlines the responsibilities of the various segments of the department that were involved in the 1997 flood and provides information on the activities carried out by the department prior to and during the flooding emergency.

TABLE OF CONTENTS

INTRODUCTION

Manitoba Natural Resources is comprised of four divisions: Regional Operations, Resources Programs, Land Information Centre, and Administration and Finance. The Regional Operations Division includes five regions and Headquarters Operations and is generally responsible for the delivery of programs and services to the public. The Regional Operations boundaries are shown in Figure 1. The Resource Programs Division is made up of the Fisheries, Forestry, Parks and Natural Areas, Policy Coordination, Wildlife and Water Resources Branches. This division is generally responsible for program and policy development and planning.

During the 1997 Red River flood, Manitoba Natural Resources' flood planning was the responsibility of the Water Resources Branch with the delivery of flood related services being carried out mainly by the Central Region. As such the majority of the information contained in the following report has been contributed by these two organizations.

values.

- construct, operate and maintain provincial water supply and water control works to optimize the use of our water resources and minimize economic and environmental damages.

- ensure that regulatory controls are applied and developments are planned so that the optimum uses of water are not impaired and that damage to water quality, property, and the environment is minimized.

- monitor the condition, use, and development of the water resources, and maintain comprehensive and easily accessible water management data bases.

- enhance the public's awareness and knowledge of Manitoba's water resources.

The Water Resources Branch is responsible for the administration of the following Acts:

The Dyking Authority Act
The Water Commission Act
The Water Resources Administration Act
The Water Rights Act
The Ground Water and Water Well Act
The Rivers and Streams Act
The Lake of the Woods Control Board Act
The Water Power Act
The Water Supply Commissions Act

The Dyking Authority Act, Water Commission Act, Water Resources Administration Act, Water Rights Act and Ground Water and Water Well Act are included in the Appendices.

FLOOD FIGHTING

The Water Resources Branch has the primary responsibility for flood management. This includes flood forecasting, operation of flood control works, monitoring of flows and levels and dissemination of flood information. The branch also interfaces with other branches, regional operations, the City of Winnipeg and municipal governments.

1.2 REGIONAL OPERATIONS - CENTRAL REGION

GENERAL ROLES AND RESPONSIBILITIES

Regional Operations coordinates delivery of natural resources programs and services at the community level, including field services for resource management, enforcement of legislation, operation of Provincial Parks, waterways and water control works, emergency response to forest fires, floods and drought, and coordination of hunter safety training and guide licensing.

FLOOD FORECASTING SUPPORT

Regional engineering field staff conduct snow surveys as requested by the Water Resources Branch. These surveys are used to ground truth, calibrate and supplement snow depth and moisture content data collected from airborne gamma radar surveys. The ground surveys are normally conducted during February and March in years when significant runoff is anticipated.

FLOOD FIGHTING

Regional engineering staff are responsible for on-going maintenance and operation of the flood protection systems existing at the communities of Emerson, Letellier, Dominion City, St. Jean, Morris, Rosenort, Brunkild and St. Adolphe.

Regional engineering staff are responsible for the direct operation and maintenance of the Red River Floodway. Operation of the inlet control structure gates is undertaken in accordance with adjustment instructions from the Water Resources Branch. Regional engineering staff are also responsible for the direct operation and maintenance of the Portage Diversion.

In addition, Regional engineering is normally responsible for monitoring and emergency flood damage repair associated with spring run-off on Provincial Waterways.

During the 1997 flood DNR Operations Division took on additional responsibilities of providing security and liaison within the dyked communities, the provision of a search and rescue component within the flood zone and the control of access to the flooded zone. These functions were organized and implemented primarily by Natural Resource Officers using the organizational structure developed for actioning project wild fires.

2. 1997 FLOOD ACTIVITIES

2.1 FLOOD CONTROL OPERATIONS

2.1.1 RED RIVER FLOODWAY

DESCRIPTION

The Red River Floodway consists of the dyked channel, the west dyke, and the inlet control structure.

The channel is essentially a huge ditch, excavated out of the prairie east of Winnipeg; the bottom of this ditch is about 20 ft. above the bottom of the Red River.

- It runs for 29.4 miles from just south of St. Norbert to just north of Lockport.
- The average depth of the channel is 30 ft., but it is up to 66 ft. deep going through the Birds Hill ridge.
- The bottom width ranges from 380 ft. to 540 ft.; the topwidth ranges from 700 ft. to 1000 ft.
- A total of 12 bridges (for highways and railways) cross the floodway channel.
- At the start of the floodway channel is a 7 foot high earth plug that is called the lip. This earth lip prevents river ice from entering the channel; ice in the channel could get hung up on the top of the earth lip or get jammed in the piers of the bridges, and significantly reduce the carrying capacity of the floodway channel.
- Where the floodway channel re-enters the Red River, just north of Lockport, there is a concrete outlet structure. Its function is to ensure that floodway water re-entering the Red River does not cause erosion of the river bed and banks.
- During the 1997 flood, the outlet structure was reinforced so that it could safely convey flows larger than its design flows of 60,000 cfs.

The second component of the Red River Floodway is the West Dyke.

- Its function is to keep flood waters on the west side of the Red River from entering Winnipeg.
- This dyke starts on the west bank of the Red River and runs west and south.
- When constructed in the 1960's, it ran 20 miles in length, ending about 11 miles west of Ste. Agathe.
- In 1997, because of the high river levels and the possibility of Red River water flowing into Winnipeg around the West Dyke's western end, an additional 21 miles were added and portions of the existing West Dyke were raised.

The third component of the Red River Floodway is the Inlet Control Structure.

- It is located on the Red River just south of St. Norbert.
- Its function is to regulate the flood water levels on the Red River at the entrance of the floodway channel.
- The water levels are regulated via two gates. During low flows the gates sit at the bottom of the river, under 8 ft. of water. But during flood flows, they are raised to regulate the upstream water levels.
- The gates are each 112.5 feet long and 34.8 ft. high when fully raised.
- These heavy, large gates are anchored to a huge concrete structure that exists to hold the gates.
- It is made up of over 100,000 yd^3 of concrete, 85% of which is below the bottom of the river. It sits on bedrock.
- Just downstream of the gates is a concrete flip bucket, which absorbs the energy of the water as it flows over the gates.

OPERATING RULES

Following the construction of the Floodway, the rules of operation were finalized. They are summarized here:

ICE CONTROL:

If the water level at James Avenue is under 15.0 ft., and if the water level at the Floodway Channel Inlet is under 750.0 ft., and if heavy ice floes are occurring on the Red River, raising the Floodway gates is postponed to prevent ice floes from entering the Floodway channel. This is in order to limit the amount of erosion that the ice could cause in the inlet area of the floodway channel.

- Since that time, experience has demonstrated that ice entering the floodway channel can hang up on the lip, or jam up against the bridge piers, and so reduce the capacity of the channel. Therefore, the rule was revised to require delaying of the raising of the floodway gates until ice is flowing in relatively small pans, regardless of what the water level is at James Avenue or at the Inlet.

CONTROL OF EROSION ON THE FLOODWAY LIP:

Delay raising the Floodway gates until such time when raising the gates would result in at least a one foot depth of flow occurring over the lip. This is in order to reduce the amount of erosion damage on the lip.

- Since that time, experience has shown that 752 ft. is a better initial water level at the Inlet for preventing erosion.

To reduce the amount of erosion damage on the lip near the end of a flood, when water levels are falling, the gates should be fully lowered when the water level at the Inlet approaches 751 ft.

- Since that time, experience has shown that the City of Winnipeg's pumping costs increase dramatically when water levels are above 15 ft. at James Avenue (and there is a coincident rain), and that lowering the gates in one 'shot' results in a fairly significant wave travelling down the river. Therefore, the water level at the Inlet is kept at 752 ft. or so until the James Avenue level drops well below 15 ft., and the gate is lowered in two 'shots' to minimize the size of the wave.

FLOOD CONTROL OPERATION:

There were a set of rules developed for that period when ice is no longer a problem, but prior to the late part of the falling stages; this period could be called the period of 'high stages' These rules dictated what water levels were to be maintained at the Inlet and within Winnipeg:

1. For natural flows on the Red River north of the Assiniboine River up to 169,000 cfs:
   - maintain natural water levels on the Red River at the Floodway Inlet

2. For natural flows on the Red River north of the Assiniboine River from 169,000 cfs to 189,000 cfs:
   - maintain a water elevation of 751.5 ft. at the Redwood Bridge (which is equal to 25.5 ft. at James Avenue)
   - raise water levels at the Inlet above natural to a maximum of 775.8 ft.

3. For natural flows on the Red River north of the Assiniboine River from 189,000 cfs to 199,000 cfs:
   - when flows reach 190,000 cfs, the City's primary dykes will be raised to level 30.5 ft.
   - the water elevation at the Redwood Bridge will be allowed to reach 755.5 ft. (29.5 ft. at James Avenue), with the water elevation at the Inlet being 775.8 ft.
   - if there are construction delays in raising the primary dykes:
     - water elevation at the Redwood Bridge will be kept at 751.5 ft. (25.5 ft. at James Avenue)
     - the water elevation at the Inlet cannot exceed 778.0 ft.

4. For natural flows on the Red River north of the Assiniboine River from 199,000 cfs to 217,000 cfs:
   - the water elevation at the Redwood Bridge will be maintained at 755.5 ft. (29.5 ft. at James Avenue)

- water levels at the Inlet will be raised, as required, to a maximum of 778.0 ft.

5. For natural flows on the Red River north of the Assiniboine River above 217,000 cfs:
   - water levels at the Inlet will not be allowed to exceed 778.0 ft.

1997 OPERATION

In 1997, during the period of high flows, operating rule 2 was used, except with one modification: a water level of 24.5 ft. was maintained at James Avenue. A water level of 24.5 ft. was used for three reasons:

i With a James Avenue elevation of 25.5 ft., the theoretical freeboard on the primary dykes would be only 1 ft.. With waves during windy spring days, the uncertainty in calculating the design elevations for the dyke for such an elevation at James Avenue, the uncertainties in dyke elevations given dyke erosion and dyke settling, and given limitations in surveying accuracies, the actual freeboard would be less in certain reaches. Overtopping of these reaches of dykes would be a real possibility.

ii A large number of surface drains in the newer parts of Winnipeg that are designed to carry rainfall runoff directly into the Red or Assiniboine Rivers enter the river roughly at a James Avenue elevation of 24.5 ft. With a James Avenue elevation of 25.5 ft., significant amounts of back flow would occur; some of this would get into the sewer system, resulting in significant amounts of basement flooding.

iii The secondary dykes in certain parts of the City, especially those at the south end, would have been overtopped. Even under the rule used in 1997, in which James Avenue was allowed to go only up to 24.5 ft., the secondary dykes in the St. Norbert area were within inches of being overtopped.

The City Government had grave concerns about the impact of a James Avenue water level of 25.5 ft.; it explicitly asked that the James Avenue elevation not be allowed to go above 24.5 ft. The City simply would not have been able to cope with upgrading secondary dykes, blocking the surface drains, and upgrading the primary dyke where necessary, even with the help of the Canadian Army. Therefore, with James Avenue at 25.5 ft., Winnipeg would have experienced a major increase in damages.

The revised operating rule for the first gate operation of the spring states that the Floodway gates shouldn't be raised until the Red River ice is broken up into relatively small floes, and these floes are moving down the river.

- However, this past spring, the ice on the Red River at the Floodway Inlet remained in large, stationary pans much longer than usual. By the evening of April 21, the water level at James Avenue had risen to near 18 ft. and the Red River at the Floodway Inlet was over 4 ft. higher than the lip of the Floodway channel. Nearly 7,000 cfs was flowing into the Floodway channel.
- Based on the Red River flow forecast, the James Avenue water level was predicted to be well over 19 ft. by the morning of April 22 if the gates weren't operated.
- Given the depth of flow over the channel lip, ice hanging up on the lip seemed very unlikely.
- The gates were raised at 10 pm, April 21. This point in time is indicated by the boxed "1" in attached Figure 2.
- Ice jammed on the piers of the St. Mary's Road bridge on the night of April 21/22. Initial attempts at breaking the jam by blasting were unsuccessful, but the jam broke up around 6 am of the 22nd.

Large pans of stationary ice were in place in the river upstream of the Inlet Control Structure till the late afternoon of the 22nd.

- The gates were operated to keep upstream water levels as low as practicable to reduce the possibility that upstream ice would flow into the floodway channel.

- The pans of ice broke up and started flowing freely in the late afternoon of the 22nd. The gates were then raised in a series of steps to bring the upstream water level up to natural levels.

Late on the 24th, it was observed that the riprap at the downstream toe of the Inlet Control Structure was eroding. To facilitate placement of new rip rap, the gates were raised to keep the downstream water level from rising too much. This point in time is indicated by the boxed "2" in attached Figure 2.

- Raising of the gates to accomplish this resulted in the water level at the Inlet going 0.2 feet above natural.
- To maintain natural water levels at the inlet the gates needed to be lowered as flows on the Red River increased.

An engineering consulting firm had identified that the anchor bolts on the gate cylinder servo-motor support beams were possibly weakened by corrosion. A decision was made to install supplemental thrust blocks on top of the support beams. (see "3" on Figure 2).

- During examination of the anchors it was discovered that the west gate was slightly higher than the east gate. After examining the operation records it was concluded that the manometer that records the amount that the west gate is raised or lowered had malfunctioned.
- Installation of the supplemental thrust blocks for the west gate was completed late on April 27 (see "4" on Figure 2). The west gate was lowered in a series of steps on April 28 to make it equal in height to the east gate.
- Installation of the supplemental thrust blocks for the east gate was completed in the morning of April 29 (see "5" on Figure 2).

The gates were then lowered incrementally in order to bring the water level at the Inlet back down to natural; this would have brought the water level at James Avenue back up to where it should have been.

- During this series of gate adjustments, it was observed that the water level just south of the Inlet Control Structure rose higher than expected, given the flows on the river and the gate elevations. It was suspected that the equations used in determining the water level at different gate settings were developed, back in the 1950's and 60's, using natural water levels at the Inlet that were too low. That is, the estimated natural water levels for this range of flows may be actually higher than estimated in the 1950's and 60's. This still needs to be determined.

On April 30 (see point "6" on Figure 2), a new forecast indicated that, in a day or two, the gates would have to be raised to keep water levels in Winnipeg from rising above 24.5 ft. (at James Avenue). Therefore, no further gate drops took place.

On May 1st (see point "7" on Figure 2) the gates were raised 1/2 ft. to keep the James Avenue water level from exceeding 24.5 ft. This resulted in a peak water elevation at the Inlet of 771.3 on May 3rd and 4th.

- Using the natural water level curves developed in the 1950's and 60's, this peak water level at the Inlet was slightly over 1 ft. above natural. If the estimate of the true natural water level being around 1/2 ft. higher is correct, the actual peak was a bit over 1/2 ft. above natural.

The gates were lowered during May 5 and 6 in order to keep James Avenue around 24.5 ft.; the water level at the Inlet dropped until it reached natural levels (as calculated in the 1950's and 60's).

Flows on the Red River began to drop quite quickly at this point (see "8" on Figure 2). The geotechnical experts in the City were very concerned that a sharp drop in water levels would result in major dyke failures. To help reduce the rate of drop of the water levels in the City, the gates were operated in such a way on May 7th and 8th so as to lower the Inlet elevation a bit below natural, and so reduce the rate of drop in the City.

From May 9th (point "9") to 30th (point "10") the gates were operated to keep the Inlet elevation at natural.

From May 31st to June 2nd the gates were operated to minimize erosion on the lip, and to minimize the size of the wave travelling down the river once the gate was dropped. Since it was not raining at the time, and there was no forecast of rain, keeping the water level at James Avenue below 15 ft. was not a concern.

A list of gate operations is given in the Appendices.

2.1.2 PORTAGE DIVERSION

DESCRIPTION

The Portage Diversion consists of a dyked channel, a diversion dam, and a spillway dam.

The channel consists of an excavated channel with dykes on both sides. It begins at the Assiniboine River and ends at Lake Manitoba. At its north end, at Delta Marsh, the west dyke has a low section called the failsafe that acts a spill section at higher flows.

- The channel's capacity is near 25,000 cfs. However, at about 15,000 cfs water flows over the failsafe into Delta Marsh.
- The channel is 18 miles long. Its width varies from 175 feet to 1,200 feet, with an average width of 600 ft.
- There is a drop of over 55 ft. in the 18 miles of the channel. To keep the water velocities down to acceptable levels, three concrete drop structures were constructed along the length of the channel.

The diversion dam is located at the upstream end of the diversion channel.

- It holds the gates that control how much water flows into the diversion channel.
- There are 4 vertical lift gates, 40 ft. wide and 14.5 ft. high. As the gates are raised, the flow down the diversion increases.

The spillway dam is located on the Assiniboine River, just east (ie. downstream) of the entrance of the diversion channel.

- This dam creates a reservoir covering about 1,600 acres.
- During the summer and fall, the reservoir is kept at elevation 869 ft.; its maximum depth is over 20 ft.. Over winter, it's kept at 855 ft.
- Within this dam is a concrete control structure with 2 Bascule fish-belly type gates 13 ft. high by 75 ft. wide. During the spring they are raised and lowered to control the amount of water flowing down the Assiniboine River. During the summer, they are usually left in their fully-raised position, and no water flows over them.

- In the centre pier of the dam is a gated pipe which allows for summer-time releases when the Bascule gates are fully raised.
- In the dam there are two pipes for Portage la Prairie's water supply.

OPERATING RULES

There is one operating rule and a number of operating objectives for the Portage Diversion.

- The rule states that the flow on the diversion channel must not exceed 25,000 cfs.
- The main objective is to keep water levels in Winnipeg at James Avenue below 17 ft. or 18 ft.
- Secondary objectives are:
  - Keep flows on the diversion channel below 15,000 cfs, so that the failsafe is not overtopped.
  - When there is ice on the Assiniboine River east of the Spillway Dam, keep flows in the river below 5,000 cfs. This is to reduce the chance of ice jams east of Portage.
  - When there is no longer ice on the Assiniboine River east of the Spillway Dam, keep flows in the river below 10,000 cfs, to minimize agricultural damages and damage to the dykes along the river.
  - Keep water levels on Lake Manitoba below 812.87 ft.
  - Keep the daily water level changes in the Assiniboine River east of Portage below 1 ft., to minimize bank and dyke slumping.

Operation of the Portage Diversion structures during the early part of spring is greatly complicated in some years by ice jams on the Assiniboine River west of the structures.

- Large ice jams occur at several locations; large quantities of water and ice pile up, and when the jam breaks, a slug of water and ice flows downstream, into the Portage reservoir.
- When this slug of ice and water enters the Portage

reservoir, some of the water is stored but usually the volume of water is large and much flows down the Diversion channel and/or over the Spillway gates.

- The sheet of ice in the reservoir acts as a barrier to the upstream ice. Depending on the year, this barrier keeps most of the upstream ice from flowing further downstream on the river, or down the Diversion channel. In other years, significant quantities of ice flow out of the reservoir and down the river and/or channel. Then, ice jamming in the river or in the channel or where the channel enters Lake Manitoba can happen. Ice jamming on the river can cause flooding of adjacent property. Ice jamming on the diversion or on the Lake can reduce the diversion channel's capacity.

1997 OPERATIONS

- The large ice jams that had developed on the Assiniboine River west of Portage broke on April 19 and 20. Large volumes of water along with large quantities of ice flowed into the Portage Reservoir.
- The diversion and spillway gates were operated to minimize the amount of ice and water flowing down the Assiniboine River and to minimize the chances of ice jams and flooding along the river east of Portage.
- It was not possible to store the incoming ice in the Reservoir area, so a fairly significant amount of ice flowed down the diversion channel.
- A relatively large ice jam occurred on Lake Manitoba where the channel outlets into the lake, in spite of ice weakening due to limited drilling of holes through the ice. This ice jam caused a backwater up the channel, reducing its capacity. The large flows down the channel, in combination with this reduction in channel capacity, resulted in the failsafe being breached for a few days. The failsafe area was eroded away, as it always is when water flows over it. Some flow also occurred to the east for several hours. The ice jam on the lake ice was blasted, and it broke up on April 21.
- Up to April 28th the flows in the diversion channel were kept low enough so that repairs could be done on the failsafe area. The forecasts indicated that it would be necessary to divert well over 10,000 cfs into the channel in a few days, to minimize the amount of Assiniboine River water flowing into Winnipeg when the peak on the Red River occurred. Providing the failsafe repairs could be done in time, it would not have to

be breached again, reducing the flood damages there.

- To enable the diversion channel to be repaired, the flows over the Spillway gates were kept over 5,000 cfs for a number of days. Considering the local inflows, flows on the Assiniboine River east of Portage were quite high for a number of days. Ice jams, with the resulting higher water levels, occurred on the Assiniboine River between Baie St. Paul and Winnipeg on April 24 to 26. The actual damages caused by these high water levels was quite small, although the high levels did cause, understandably, a lot of concern on the part of affected citizens. A good portion of these flows were due to local runoff.
- From April 29 to May 5, flows over the Spillway gates were reduced to near zero as the peak on the Red River reached Winnipeg.
- Then, as the water level in Winnipeg decreased, flows over the Spillway gates were increased.
- When the James Avenue water level reached approximately 17 ft., the flows over the Spillway gates were increased and diversion flows were decreased.

2.1.3 SHELLMOUTH RESERVOIR

DESCRIPTION

- The Shellmouth Dam and Reservoir are located on the Assiniboine River near Russell, several miles east of the Manitoba - Saskatchewan boundary.
- The works consist of an earthfill dam with an overflow spillway and an associated reservoir.
- The reservoir is 35 miles long with a maximum depth of 40 feet. The maximum storage at the spillway crest is 387,000 acre-feet.
- The spillway crest elevation is 1408.5 feet.
- To allow discharge other than over the spillway there is a conduit through the dam. The maximum discharge capacity of this conduit is 7,000 cfs.

OPERATING RULES

The generalized operating guidelines which have been developed to ensure that the reservoir can provide reasonable levels of both flood protection and water supply capability are indicated on Figure 3:

1. The reservoir is gradually lowered over the fall and winter period

to provide flood storage capacity for the spring runoff which usually begins around the end of March. The winter drawdown target level is somewhat variable, dependent upon the spring inflow forecast. The original operating rule was to draw the reservoir down to a fixed winter target level of about 1391.0 feet. However, with improved probabilistic forecasting techniques the reservoir may now be lowered well below this point to increase flood storage capacity, or held well above this point to increase the likelihood that the available runoff will provide sufficient storage for water supply and recreational use during the summer period.

2. During spring runoff, primary consideration is to control reservoir outflows to minimize downstream flooding. Excess inflows are stored in the reservoir until the water level nears the spillway crest elevation of 1408.5 feet. If inflow forecasts indicate that the spillway will be overtopped, outflows will be increased sooner, so as to minimize the eventual peak outflow. The intent is to minimize overbank flooding along the river below the dam and during flood periods to keep outflows to a value no greater than what the river flow would have been without the dam in place. At present, an attempt is made to maintain outflows to a maximum of about 1600 cfs to prevent localized flooding and facilitate land drainage.

3. After spring runoff, reservoir levels are gradually lowered by conduit releases to a summer target level of about 1402.5 feet to optimize recreational and fishery conditions. The reservoir level may be held a few feet above this point to reduce the chances of water supply shortages when summer drought conditions are anticipated.

4. In the event of summer rainfall floods the available reservoir storage above the target summer level of 1402.5 feet is used to reduce downstream flow rates and minimize flooding. Outflows are increased if the level exceeds 1405 feet in order to reduce flooding of recreation facilities and to minimize the chance of overtopping the spillway.

5. During normal summer operation, primary consideration is to make reservoir releases to meet water allocation commitments to

downstream licensed users and domestic users and to meet instream flow needs. Reservoir release rates are dependent upon the prevailing inflow rates, long-term inflow forecasts, and downstream tributary flows and water demands. Reservoir release rates are varied throughout the year to meet a minimum target instream flow for 25 cfs immediately below the dam and 200 cfs at Headingley. Consideration must also be given to other factors such as travel time of Shellmouth Reservoir releases and maintaining an adequate reservoir level for recreational and fishery purposes.

PROCEDURES:

General seasonal operation strategies for the reservoir are planned about three times per year - once in late fall for the winter drawdown period, once in late winter in preparation for the impending spring runoff, and once in late spring for summer water supplies after the spring runoff period is over. These seasonal strategies are based largely on runoff forecasts and past experience, acknowledging the risks associated with the possibility that extreme conditions may rapidly develop.

While operation strategies set out the ideal operation scenario, the actual operations follow regular updates on hydrologic conditions and forecasts. These updates are done monthly from November to March, weekly or daily during spring runoff, and following major rainstorms during the summer.

1997 OPERATIONS

- Runoff commenced in mid April.
  - The inflow sources were:

- Assiniboine River at Kamsack	70%
- Shell River	19%
- Local runoff	11%

  - Shellmouth Reservoir at 1385.73 feet at the start of runoff (historic low).
  - Shellmouth Reservoir reached a peak level of 1407.10 feet (21.4

foot increase in water level).

- The total inflow into Shellmouth Reservoir was 360,000 acre-feet.

- Shellmouth Reservoir stored 254,000 acre-feet of water (70% of the total spring inflow). Peak flow on the river at the Reservoir was reduced from 10,600 cfs to 1,650 cfs.

- At Russell, the peak flow was reduced by 8,300 cfs (from 10,200 to 1,870 cfs), a reduction of about 10 feet in stage.

- At St. Lazare, the peak flow was reduced by 7,000 cfs (from 12,000 to 5,000 cfs), a reduction of about 4 feet in stage.

- The 1996/1997 Shellmouth Reservoir operation is depicted in Figure 4.

2.1.4 RING DYKE CLOSURES

Permanent ring dykes have been constructed around the valley towns of Emerson, St. Jean, Letellier, Dominion City, Morris, Rosenort, Brunkild and St. Adolphe. Regional engineering staff are responsible for operational elements of these eight ring-dyked community flood protection systems. In general this work involves earthen closures in all dyke openings (roads, railroads, etc.) set-up and operation of permanent and temporary internal drainage pumping facilities, dyke integrity monitoring, closure removal, pumping demobilization and dyke clean-up and restoration.

A set of operating and maintenance manuals have been developed for the valley towns. These manuals give the details for the closures of highways and railways within the town diking systems. Copies of these manuals are kept at the Water Resources Branch, 1577 Dublin Avenue, Winnipeg.

2.2 FLOOD FORECASTING

2.2.1 FLOOD FORECASTING METHODOLOGIES

Manitoba Natural Resources employs an index type of model to predict the runoff volume and peak discharge for the Red River at Emerson. This is used in the preparation of flood outlooks which are issued during the winter and early spring. Once spring runoff is well underway, Manitoba depends on U.S. National Weather Service predictions for the Red River at Pembina, North Dakota located just south of the International Boundary.

The index model used for runoff outlooks consists of statistical relationships for the U.S. portion of the watershed, treating the entire area as one basin for computational purposes. Autumn soil moisture is represented by an Antecedent Precipitation Index (API) based on weighted monthly precipitation from May to October. The appropriate monthly weights have been carefully selected based on analysis of data from 1941 onward. Other variables used are the cumulative winter precipitation which includes effective spring precipitation, and a degree-day type of melt index. Also a winter temperature index is used to approximate sublimation losses and soil temperatures. Information from airborne gamma snow surveys, conventional snow surveys, satellite microwave snow surveys, modelled soil moisture, airborne gamma soil surveys and measured soil temperatures etc. has been increasingly used in recent years to improve estimates of soil and snowpack conditions.

Flood routings are performed using the Muskingum method from Emerson to Winnipeg. For both outlooks and operational forecasts, daily predicted flows at Emerson are routed together with daily predicted flows for 13 Manitoba tributaries including the Assiniboine River. The Muskingum procedure performed very well for the 1997 flood. However, it does not enable predictions of flood levels on the floodplain well away from the river.

2.2.2 DESCRIPTION OF EVENTS

ANTECEDENT CONDITIONS

The Red River in Manitoba had experienced a minor flood in 1995 and a significant flood in 1996, the latter having peak stages only one foot or so lower than the 1979 and 1950 floods. The summer following the 1996 flood was relatively dry which seemed to be a good harbinger for 1997 at the time. Autumn soil moisture is a very important factor affecting the flood potential due to heavy clay soils (gumbo) which are relatively impermeable when wet. However, weather patterns changed following mid September, 1996. Significant rains on September 27, October 17-18, October 25-26 and October 28-30 greatly increased soil moisture, setting the stage for another possible flood.

Soil moisture was measured by the airborne gamma technique (T.R. Carroll et al, 1992) in early November, 1996. It averaged 29 percent soil moisture by weight for the upper 20 cm of soil over the entire watershed in Canada and the United States, excluding the Assiniboine River. South of Grand Forks, this moisture level was the third highest since 1979 when the U.S. National Weather Service began these surveys. From Grand Forks to Emerson it was the seventh highest. Surveys in the Manitoba portion began in 1994; the 1996 moisture level of 28.5 % was higher than that of 1995 but below the 33.5 % of late October, 1994.

Soil moisture for October 31, 1996, modelled by the Winnipeg Climate Centre of Environment Canada with the assistance of Manitoba's Department of Agriculture, showed soil moisture by volume generally in the 60% to 90% of capacity range, with some areas greater than 90%. Soil moisture is modelled to a depth of 120 centimetres.

In summary, the soil moisture at freeze-up in the autumn of 1996 was above average and in some areas well above average. It was much higher than for the 1979 flood. However, it was not extremely high as it has been in some other years.

WINTER CONDITIONS (November 1/96 - March 20/97)

The winter was unusually long and cold with snowcover developing in early November, 1996 and remaining until mid April, 1997. There were four blizzards producing heavy snow and blowing snow and resulting in closure of major highways. Snowfall was difficult to measure due to the strong winds and heavy drifting, likely resulting in significant underestimation of precipitation at many sites. Reported precipitation was well above average in November, December and January. Manitoba Water Resources has computed monthly averages of precipitation reports in the watershed since 1940 based on data provided by Environment Canada and The U.S. National Weather Service.

The recorded precipitation for the 1996-1997 season and the 1940-1996 averages are as follows:

	Nov.	Dec.	Jan.	Feb.	Mar.	Total
1996-97 Season	47	31	37	11	28	154
1940-96 Average	22	16	15	13	24	90

Weekly snowcover maps issued by Minnesota's Department of Natural Resources showed the snowcover at the 95th to 99th percentile over most of the watershed throughout the winter. Generally below average winter temperatures and high snowpack albedos combined to produce minimal losses from the snowpack.

Despite below average winter temperatures, soil frost depths were generally below average with many areas reporting virtually no frost. This can be attributed to heavy snowcover which began early in the winter.

An airborne gamma snow survey conducted February 6-12, 1997 further quantified the snowcover. The water content of the snow averaged 140 mm upstream of Fargo, 122 mm from Fargo to Grand Forks, 115 mm from Grand Forks to Emerson and 112 mm from Emerson to Winnipeg. The snow cover in the United States portion was the highest on record and in the Manitoba portion among the highest on record. This factor, together with the above average soil moistures, was not good news for the Red River valley. Spring weather would be critical.

SPRING WEATHER (March 21 - June 23)

A two week period of very gradual melting began on March 21 and continued until April 4. Temperatures during this period ranged generally from -5° C to +5° C with some melting during the daytime and freezing at night. There was plenty of sunshine and dew points were low. From Grand Forks to Winnipeg much snow disappeared, probably more through sublimation than by melting. Field surveys in southern Manitoba showed that by early April snowcover in many areas had decreased to much less than 100 percent, and as low as 50 percent on western tributaries. There was little evidence of ponded water or runoff as melt water was soaking into the generally unfrozen soil. At this point in time comparisons could be made to the 1956 situation when a record snowpack melted very slowly, resulting in minimal flooding. The department was considering downgrading its flood forecast when at the beginning of April, weather forecasts in both Canada and the United States began to mention the possibility of a "Colorado Low".

Weather forecasts proved to be very accurate as a full-blown Colorado Low developed and, in characteristic form, moved in a north-northeasterly path across eastern Minnesota into northwestern Ontario. The Red River Valley, situated just west of its path in the area of maximum overrunning and vertical motion took the brunt of the storm.

Winds of 80 kph reduced visibilities to zero, created huge drifts and brought transportation to a standstill for days. The movement of the low was quite slow due to its deepening as strong troughing aloft nearly caused the low to become a vertical cut-off low. The resultant long duration of precipitation was a key factor resulting in storm precipitation totals reaching as high as 90 mm. The trajectory of the low resulted in the entire Red River Watershed from the northeast tip of South Dakota to Lake Winnipeg receiving the heavy precipitation. An important feature of the storm was that it produced a lot of rain in the headwater area (upstream of Halstad) where runoff from winter snow was already more advanced. Freezing rain, ice pellets and snow predominated in the northern half of the U.S. portion while Manitoba received ice pellets followed by heavy snow. Cold weather followed the storm with temperatures as low as -20° C. Thawing did not resume until April 13, a week later.

A reasonable approximation of reported precipitation for the April storm is given on Figure 5 which shows total April precipitation. Precipitation for the remainder of the month was only about 5 mm in the U.S. portion and 5-10 mm in most Manitoba regions. Average reported April precipitation for the basin was 67 mm compared to the normal of 40 mm. It is likely that the true precipitation for April was considerably greater than reported, perhaps as much as 90 mm on average. The difficulties of estimating snowfall under extreme winds have been well documented by Environment Canada (B.E Goodison, 1981).

Precipitation following the early April blizzard up to the time of the crest of the Red River in early May was well below average.

Melt of the snowpack was not particularly rapid on the whole, although some rapid melting occcurred April 18-19 in the northern United States portion. In the Manitoba portion the snow melted gradually from April 13-25. The melt rate was much slower than in 1979 when a somewhat lesser snowpack melted entirely in three days.

TOTAL WINTER/SPRING PRECIPITATION

Total basin precipitation from the start of winter to near the crest of the Red River in early May (Nov.1/96-Apr 30/97) as reported totals 221 mm, much above the normal of 130 mm. A bar graph of total winter and effective spring precipitation for each year from 1950 onward is shown on Figure 6. It is likely that the true total for the 1996-97 season was considerably greater than 221 mm due to the fact that there were four major snowstorms with strong winds.

An airborne gamma snow survey was conducted April 10-12 following the storm. It showed that the net moisture input since early November, 1996 had risen to 150 to 170 mm at most Manitoba points. In the U.S. portion the net inputs were 100 to 150 mm. These are the highest values on record. The observed water contents, adjusted to values above 35 percent soil moisture by weight, are shown on Figure 7. The gross moisture input must have been considerably greater since sublimation losses would have been at least 25 mm and water soaking below the 20 cm soil depth is not recorded. The latter would have been substantial, especially in the portion of the watershed south of Halstad.

RUNOFF CONDITIONS

Runoff was underway in the Fargo area prior to the April storm but had barely begun in the area from Grand Forks to Winnipeg. This type of situation favours strong growth in the peak discharge as it moves northward. Simultaneous melt and runoff throughout the watershed, which has often occurred in past years, results in mainstream crests arriving from the south after peaks on northern tributaries have passed. In such cases the peak grows little and may even decrease as it moves northward. Growth of the peak flow in 1997 was further favoured by the April storm which produced rain in the south and snow in the north. The rain quickened runoff in the south but the high albedo of heavy snow in the north retarded melting. As a consequence peak flows from two main source areas in the United States, the southern portion upstream of Halstad and the Red Lake River, arrived at Grand Forks simultaneously. The peak continued to grow somewhat from Grand Forks to

Winnipeg because northern tributaries were still running high when the mainstem peak arrived.

The spring runoff volume for the Red River at Emerson up to June 15 was 6.75 million acre-feet (8.33 million cubic dekameters), representing an average runoff depth of 135 mm. This is almost identical to the 1950 runoff volume. Yet the 1997 peak discharge at Emerson was about 130,000 cubic feet per second compared to that of 94,000 cfs in 1950. The peak at the Floodway Inlet just south of Winnipeg was 138,000 cfs compared to that of 94,000 in 1950. The higher 1997 peaks resulted mainly from the unfavourable timing effects described above.

The 1997 spring runoff was particularly heavy in the headwater area upstream of Halstad, in the lower Pembina River Watershed and on most eastern tributaries of the Red River in Manitoba. Many streams in these areas recorded record or near record high flows. Flows on western tributaries in Manitoba were high but well below those of 1974 and 1979.

The 1997 spring runoff could have been considerable greater had it not been for the snowpack losses prior to the April blizzard and the four weeks of dry weather following the blizzard. Additional precipitation would have had a very high runoff coefficient due to the saturated and flooded fields. An 1826 flood magnitude could have developed with the occurrence of one additional major storm or several moderate storms.

2.2.3 ACTUAL FORECASTS

Forecasts of Red River 1997 crest elevations were issued by Manitoba's River Forecast Centre from February through the spring. These forecasts were quite accurate considering information on watershed conditions at the time the forecasts were issued.

Observed crest elevations from Emerson to Morris were within the range predicted on April 9, 1997 just after the major blizzard. At Ste. Agathe and St. Adolphe the actual crest was equal to the top of the range given in the April 9 forecast. Crests above and below the Floodway Inlet were 1.7 feet and 1.5 feet higher than the top of the range on the April 9 forecast. In downtown Winnipeg the crest was 0.2 feet above the top of the forecast range.

The increase in level forecasts on April 9 after the blizzard was not very great due to favourable weather during the two weeks prior to the blizzard, which had greatly depleted snowcover with little evidence of runoff or ponding. The April 9 forecast was issued based on an assessment of the flood potential by Manitoba Natural Resources soon after the early April blizzard which produced heavy precipitation throughout the watershed.

Forecast crest elevations were revised upward April 18th and 20th when it became apparent that the crest at Grand Forks and Drayton would be higher than earlier predicted by the U.S. National Weather Service. The volume forecast was also increased significantly at this time.

Late in April, crest forecasts for points from Ste. Agathe northward were revised upward somewhat when it became apparent that high crests on many Manitoba tributaries would occur at virtually the same time that peak flows arrived from the United States.

Crest forecasts issued in February and March, 1997 and subsequent forecasts updates are shown on Table 1 together with the main reasons for the forecast revisions.

Flood outlooks for southern Manitoba, daily flood conditions and forecast reports and daily flood information sheets for the Red River, Assiniboine River, Red River tributaries and the City of Winnipeg are contained in the Appendices. Daily flood information sheets for the Souris River, Pembina River, Swan River/The Pas and Interlake/Eastern region are also available but have not been included as part of this report.

2.3 EMERGENCY CONSTRUCTED INFRASTRUCTURE

2.3.1 VALLEY TOWN DYKES

Permanent ring dykes have been constructed around the communities of Emerson, Rosenort, Dominion City, Letellier, St. Jean, Brunkild, Morris and St. Adolphe. These dykes are called the valley town dykes. In late March the revised forecasts for spring water levels on the Red River resulted in the recommendation to begin emergency dyke raising operations on the eight existing ring-dyke systems. Operations began shortly after the April 7, 1997 snowstorm. The communities of Emerson and Rosenort had the dykes topped up with the installation of temporary wooden flash boarding. Dominion City, Letellier, St. Jean, Brunkild, Morris and St. Adolphe were raised primarily through excavation and placement of additional clay borrow material on the existing dyke tops where necessary to reach an elevation sufficient to provide two feet of freeboard above the upper decile forecast.

After the flood on those portions of the dykes where the additional height could be maintained in a stable configuration the additional material was trimmed and re-seeded in place. On those portions of the dykes where the temporary additional height could not be accommodated in a permanent configuration within the existing right-of-way, the temporary additional material was returned to the borrow pits.

2.3.2 Z DYKE

The Z Dyke was constructed under emergency conditions to prevent flood waters from the Red River entering the La Salle River watershed. The dyke was located along road systems and defined waterway systems to prevent flooding of communities and individual residences in the La Salle River watershed and into Winnipeg. Initially the dyke was designed to extend westward from the end of the existing West Dyke along PR 305 to Brunkild. However, there was insufficient dry borrow material for constructing the dyke along this alignment, so the route was moved two miles north to the top of an existing dyke along King Drain. When completed the total length of the Z Dyke was some 32 km. The work carried out also included raising of the already in place West Dyke for some 13 km. Location of the West dyke and the Z dyke are shown in Figure 8. Construction of the Z dyke began on April 24, 1997 and was completed on April 30, 1997. Reinforcing work was done over the next week. The construction of such a dyke would normally take some four to five months. The Z dyke required some 750,000 cubic metres of earth and 142,000 tonnes of limestone. Up to 400 pieces of equipment were used at the peak of construction. Other materials utilized included 4,000 large round bales of straw along with 8.3 kms of oil boom to help absorb wave uprush, 20,000 sandbags and 2,000 "super sandbags" each weighing 1.5 tonnes, 40 km of poly wrap, 40 km of snow fence and 2.5 km of derelict vehicles along PR #305 west from the eastern extremity of the Z Dyke.

Manitoba Highways and Transportation was responsible for the construction of the Z dyke and provided 100 people during construction including engineers, survey crews, dyke walkers, dispatchers and support staff. Highways and Transportation was assisted by approximately 350 people from the heavy construction industry.

Manitoba Highways also received personnel and equipment assistance from Manitoba Natural Resources, the 1st Combat Engineering Regiment of Edmonton and the 1st Canadian Royal Horse Artillery, the R.C.M.P., Canada Coast Guard, Manitoba Hydro, Manitoba Telephone System as well as the Canadian National Railway and the Canadian Pacific Railway.

2.3.3 LOCAL DYKES

In addition to their direct responsibilities for Provincial infrastructure the on-site regional engineering staff also became involved in direct supervision and co-ordination of emergency diking operations on private dykes adjacent to the Provincial dykes in the communities of Rosenort and St. Adolphe.

2.4 EMERGENCY PREPAREDNESS AND FLOODFIGHTING

2.4.1 ICE WEAKENING

In previous flood years significant problems caused by ice damming during break-up of the Red River have occurred in the Selkirk area and downstream. This year regional engineering undertook to have numerous holes drilled through the ice to weaken it and speed break up. During two weeks in April, prior to river levels rising, local fishermen utilizing 12 Bombardiers bored 45,000 holes through the river ice in areas where ice blockages causing backwater effects had traditionally formed. The holes were spaced at 10 foot centres in the problem areas from the Selkirk Bridge to north of Breezy Point. Operations ceased when water showed along the edges of the river.

During river break-up no ice blockages causing water backup were experienced on the Red River and no ice damage was experienced at Breezy Point. This was a significant change in river and ice behaviour from the previous spring and other flood years when backwater from ice blockages damaged numerous buildings in the Selkirk area and ice damaged cottages and other buildings at Breezy Point.

2.4.2 SAND BAG PREPARATION

In 1997 the department actively encouraged municipalities to purchase sand bags from dealers and the department facilitated this process.

It has always been the responsibility of municipalities to arrange for sand and the filling of the bags. Recognizing the demand for sand bags would be extremely high in some areas, the department purchased a sand bag filling machine (similar to those owned by the City of Winnipeg) and made it available to municipalities. It was set up and used in St. Adolphe and Ile des Chenes, both of whom arranged for the operating crews and equipment. Department staff assisted in sand bag filling, transport and placing in many locations.

Information provided in response to enquiries regarding sandbags is included in the Appendices.

2.4.3 ROAD CUTS

During the construction of the Z Dyke and the raising of a section of the west dyke certain road cuts were necessary to ensure that the work area was not at risk. The location of these road cuts is shown in Figure 9.

The road cuts undertaken were as follows in chronological order:

Cut #1 Three cuts were made in the connector road from the West Dyke onto the roads running east and south. This connector road was being overtopped at the time of the cuts. The three cuts were each approximately 15 feet long and 2-3 feet deep. The frost line was still relatively high. The cuts were made on April 28 between 8:00 a.m. and 10:00 a.m. These sections were subsequently widened and deepened on May 1, 1997.

Cut #2 This cut was made in the afternoon on April 28. This road was relatively high and was causing high water against the West Dyke. Water was already overtopping the road. Three cuts were made at distances of 100 feet, 200 feet and 500 feet east of the West Dyke. Each cut was approximately 25 feet long and 2-3 feet deep.

Cut #3 This cut was made by a converted Army tank with a backhoe attachment. The water had been overtopping the road all day and the cut proved to be relatively ineffective.

Cut #4 On April 30 a representative from Highways and a representative from Water Resources observed that the water level adjacent to the West Dyke was still at a high level. It was determined that the height of the Glenlea Road (old PR 420) was the reason for the water level remaining relatively high. The relative head differential from upstream to downstream of the road was some 3-4 feet. The area downstream of the Glenlea Road was flown by helicopter and the sandbag dykes that had been erected by individual landowners had more than two feet of freeboard above the existing water level. At the time MTS were attempting to save a fibre optics exchange building and were carrying out a sand-bagging operation with the assistance of a helicopter and zodiac boat. There was also a threat to a number of landowners that had raised a common dyke around three residences as well as a number of individual dykes on the west side of the Glenlea road. Contact with Emergency Measures was made to ensure the people were made aware of the potential for higher water levels and some were ordered evacuated. The cut was made at approximately 2:30 p.m. The initial cut was approximately 75 feet long by 3 feet deep. This was later lengthened to about 120 feet long by 3 feet deep. This cut was located just over 4 miles east of the West Dyke. This cut was effective in relieving the pressure against the West Dyke and also enabled the MTS fibre optics station as well as a number of residences to be saved from flooding.

Cut #5 This cut was made by Natural Resources through the road approximately one half mile east of the West Dyke on April 29.

Cut #6 This cut was made in the afternoon of May 1 by the Army's tank/backhoe. It proved to be relatively ineffective as water had been overtopping the road since April 28.

At all cut locations the water flowed in a northerly direction.

2.4.4 DYKE MONITORING

Twenty-four hour monitoring of the valley town dykes was supervised and staffed by DNR regional engineering, as has traditionally been the case. DNR staff (primarily fire tac crews) assisted many other groups in monitoring temporary dykes in various locations.

2.4.5 EVACUATION COORDINATION

Although the primary responsibility for evacuation coordination lies with Manitoba Emergency Measures Organization (MEMO), at the field level the department played a significant role through the Natural Resource Officer liaison officers placed in each of the ring dyked communities. Others involved in this coordination included the local MEMO coordinator, RCMP, Department of National Defense and local government officials. A common role of NRO liaison officers was to seek clarification and interpretation of evacuation orders in specific situations.

2.4.6 MANAGEMENT OF EQUIPMENT AND AIRCRAFT

i) Aircraft:

Civilian helicopters were hired using the operation procedures developed for the department when working on forest fires. Our fire team staff are familiar with these machines and how to use them safely. However, other government department officials did arrange for their own machinery. Provisions were put in place through the Air Traffic Control Centre in Winnipeg to control movement of aircraft in the flood zone.

ii) Equipment:

Natural Resource Operations Division's acquisition of equipment proceeded smoothly as the same operational procedures as those used on forest fires were followed.

There were problems with some local government agencies in acquiring equipment and supplies.

2.4.7 SECURITY AND ENFORCEMENT

Staff from the department were involved in security and enforcement in three broad areas:

1. Security and Liaison within the dyked communities.
2. Search and Rescue.
3. Security and Traffic control.

A team consisting of a Natural Resource Officer and some support staff was established in each ring dyked community in the early stages of the flood. This afforded the officer the opportunity to assess the values and risks, find out where staff were needed, and how the team could be of the most assistance. Personal contact with individuals from other agencies assisted them in their role as Liaison Officers. These officers met with the other agencies in the communities and gave situational reports to the Flood Boss each day.

The Search and Rescue Component operated out of the Floodway field office. One Resource Officer was assigned to work with each of the nine helicopters and one officer was assigned to work with each of the three boats. The flooded area was separated into divisions. The officers were assigned a division and normally worked in this division for several days. Inter-agency interaction was through direct contact in the field as well as through the communication system established at the floodway base.

Security and Traffic control required a large compliment of staff. Manitoba Natural Resources initiated a Travel Pass and Occupancy Permit system. These permits provided a visible authority for people to be present in an evacuated area. Three Resource Officers coordinated the program. They worked with the Rural Municipalities, the RCMP and the Military. A Liaison Officer from the RCMP worked closely with these officers setting up check points and roving patrols. There was a need for continual inter-agency communication at the field level. Daily planning meetings and meetings to deal with special requests occurred at the Floodway field office.

2.4.8 STAFFING

Operations Division of Natural Resources coordinated the movement of more than 340 people into flood related operations. Coordination was provided through the Provincial Fire Centre with the Superintendent responsible for fire operations support sitting on the Operations Committee at MEMO. Air Operations and Communications support was provided by the Supervisor of Air Operations. The Supervisor of Fire Operations and staff were responsible for equipment ordering and staff movement.

Staff from all areas of the department were used on security, access control, safety of evacuees, sand bag movement, patrols and community liaison. The deployment of provincial fire teams who are used to emergency operations provided a much needed provincial government presence in the evacuated area and communities. The local authorities came to respect and work closely with our NRO staff. Operations staff trained in water resources functions were freed up to handle water problems with NRO staff engaged in security, evacuation and community liaison.

2.4.9 COMMUNICATIONS SYSTEMS

Modern communication systems were in place that met the needs. The use of Fleetnet, cellular phones and MNR radios served the needs.

2.4.10 WATER MOVEMENT MONITORING

Regular regional engineering staff provided the Water Resources Branch with daily water levels along the Red River from Emerson to Winnipeg at established gauging stations.

Supplementary staff including ex-department engineers on contract and seconded Water Resources Branch engineering staff operating from the Floodway field office emergency centre provided daily monitoring of overland flow patterns in the vicinity of the West Dyke, The Z Dyke, Ste. Agathe and Grande Point.

During the early rising limb of the Red River hydrograph, regional staff provided information on ice movement on the Red River to the Water Resources Branch and other anecdotal information to assist in detailed forecast preparation. Limited flow metering was done on major tributaries.

2.5 LAND USE POLICIES

2.5.1 DESIGNATED FLOOD AREA REGULATION AND ENFORCEMENT

- The Red River Valley Designated Flood Area was established in 1979 under Section 17 of The Water Resources Administration Act.

- A permit is required for the construction or reconstruction of any structure within the Designated Flood Area.

- Application for the permit is made through the municipality or directly to the Water Resources Branch. The permit is issued by the Director of Water Resources on behalf of the Minister.

- The permit specifies main floor and finished grade elevations, which are set in the field by surveyors from the Central Region.

- Dependant on staff availability, inspections are made annually to record elevations of completed structures.

- The regulation requires that a notice of compliance be issued, but does not set a time period. In 1988 and 1989 letters were sent to all permit holders advising them of their compliance or non-compliance with the conditions of the permits. This caused some concern as the letters of non-compliance advised people that they may not be eligible for future compensation programs.

- If an applicant requests an inspection the regulation requires that the department do so within 10 days. There have been relatively few requests, but the department has always complied and advised the permit holders of the results. The same information is provided on request at any time, to permit holders or potential purchasers. For the last two years it has been provided through the Niverville Flood Liaison Office prior to and during flooding.

- The program has been operated to encourage flood protection. Building grades are provided free of charge and individuals encouraged to comply, but the regulation has never been rigidly enforced. While the Act does permit the Minister to order a non-compliant structure removed, this has never been seriously considered. There is some control in the small portion of the designated flood area within the City of Winnipeg, where a building permit is not issued by the City until the foundation is inspected and found to comply.

- Prior to this year's flood 866 permits were issued for a variety of structures including houses, garages, farm buildings and dykes. Sixty-three percent of new homes have complied with the criteria which requires the main floor of a home with a basement to be 3.0 feet above the 100 year flood level. Ninety-five percent have the main floor above the 100 year flood level.

2.5.2 DYKING AND RAISING PROGRAM (1979)

- A flood proofing program was set up following the 1979 flood. The program was applied in the designated flood area using the 1979 flood as a standard and was administered by the Manitoba Disaster Assistance Board.

- The program provided assistance to individuals to move, raise or dyke residences, businesses and farmyards.

- The 1979 program awarded 4.9 million dollars to 912 participants. Owner's costs were 1.6 million dollars and additional costs were estimated at 0.6 million dollars for a total cost of 7.1 million dollars. Each participant could access 75% of the total cost up to a maximum of $11500

2.6 PUBLIC INFORMATION

2.6.1 LIAISON OFFICES

The department established four flood liaison offices in different parts of the province to provide information to the public regarding flooding. Offices in the Red River valley were located at Niverville and Selkirk. These offices opened around April 7 and were discontinued around May 15. The Niverville office, which was the busiest, was staffed by up to four departmental staff as well as two staff on temporary secondment from Manitoba Environment.

2.6.2 MEDIA CONTACTS

The department designated a spokesperson to act as a media contact prior to and during the flood. The spokesperson was responsible for handling media briefings and subsequent questions. Prior to the flood media and municipalities were briefed on the flood outlook. During the flooding emergency media briefings were carried out on a daily basis, in conjunction with personal from Manitoba Emergency Measures Organization. The department, again in conjunction with MEMO, also issued a number of news releases. These news releases are included in the Appendices.

2.6.3 INTERAGENCY RELATIONS AND COMMUNICATIONS

During the flood the department received numerous Road Information Reports from Manitoba Highways, which were sent to the flood liaison offices and subsequently made available to the public.

Meetings were held with the railways to inform them of the water elevations in relation to the Floodway railway bridges.

Staff from the department were temporarily seconded to the Emergency Operations Centre at Manitoba Emergency Measures Organization.

Daily conference calls were held between the Water Resources Branch, all liaison offices, the department's head office and regional offices in Morris, Grosse Isle, Gimli and the Floodway field office.

Staff from the department also participated in daily meetings at MEMO headquarters on flood fighting operations.

LIST OF FIGURES

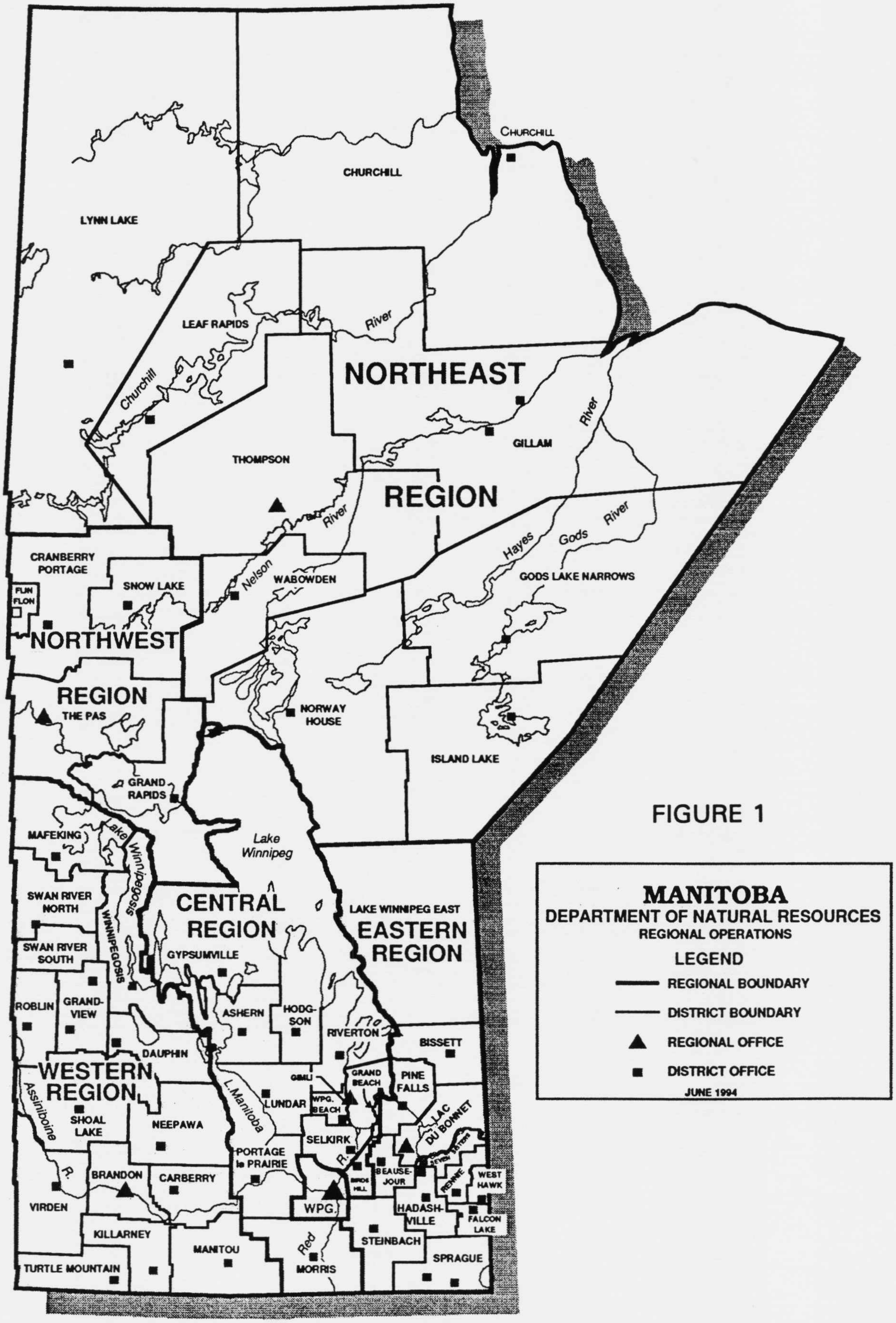
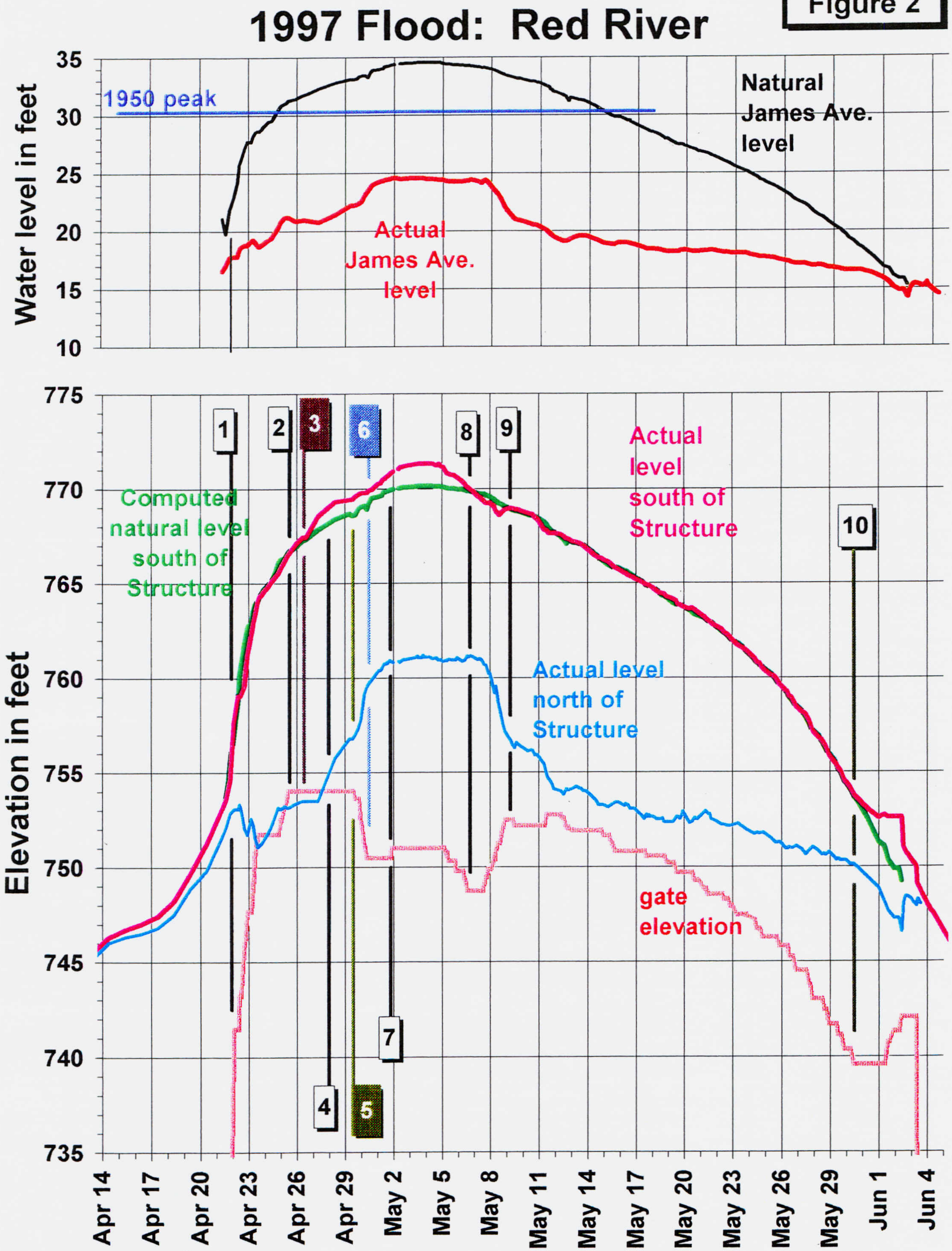

MANITOBA
DEPARTMENT OF NATURAL RESOURCES
REGIONAL OPERATIONS
LEGEND
REGIONAL BOUNDARY
DISTRICT BOUNDARY
REGIONAL OFFICE
DISTRICT OFFICE
JUNE 1994
NORTHEAST
REGION
NORTHWEST
REGION
CENTRAL
REGION
EASTERN
REGION
WESTERN
REGION
CHURCHILL
CHURCHILL
LYNN LAKE
LEAF RAPIDS
Churchill
River
THOMPSON
GILLAM
River
Nelson
River
Hayes
Gods
River
GODS LAKE NARROWS
CRANBERRY
PORTAGE
FLIN
FLON
SNOW LAKE
WABOWDEN
NORWAY
HOUSE
ISLAND LAKE
THE PAS
GRAND
RAPIDS
MAFEKING
Lake
Winnipegosis
Lake
Winnipeg
SWAN RIVER
NORTH
SWAN RIVER
SOUTH
WINNIPEGOSIS
GYPSUMVILLE
LAKE WINNIPEG EAST
ROBLIN
GRAND-
VIEW
ASHERN
HODG-
SON
RIVERTON
BISSETT
DAUPHIN
GIMLI
GRAND
BEACH
PINE
FALLS
LUNDAR
WPG.
BEACH
LAC
DU BONNET
Assiniboine
R.
SHOAL
LAKE
NEEPAWA
L. Manitoba
SELKIRK
R.
PORTAGE
la PRAIRIE
BRANDON
CARBERRY
BEAUSE-
JOUR
WEST
HAWK
WPG.
HADASH-
VILLE
FALCON
LAKE
VIRDEN
KILLARNEY
STEINBACH
MANITOU
Red
SPRAGUE
TURTLE MOUNTAIN
MORRIS

FIGURE 1

Figure 2



1997 Flood: Red River
Water level in feet
35
30
25
20
15
10
1950 peak
Natural
James Ave.
level
Actual
James Ave.
level
Elevation in feet
775
770
765
760
755
750
745
740
735
1
2
3
6
8
9
10
7
4
5
Computed
natural level
south of
Structure
Actual
level
south of
Structure
Actual level
north of
Structure
gate
elevation
Apr 14
Apr 17
Apr 20
Apr 23
Apr 26
Apr 29
May 2
May 5
May 8
May 11
May 14
May 17
May 20
May 23
May 26
May 29
Jun 1
Jun 4

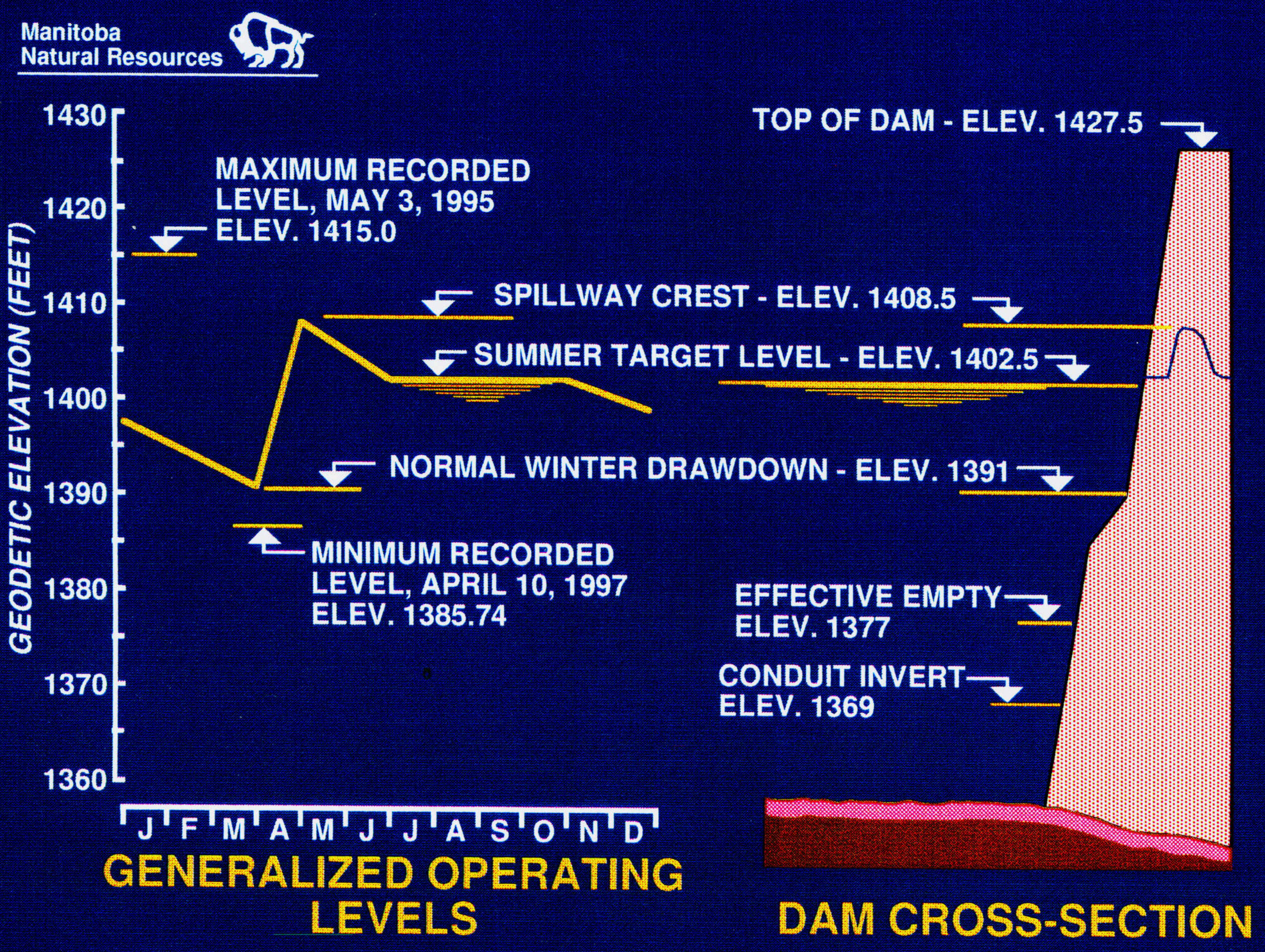
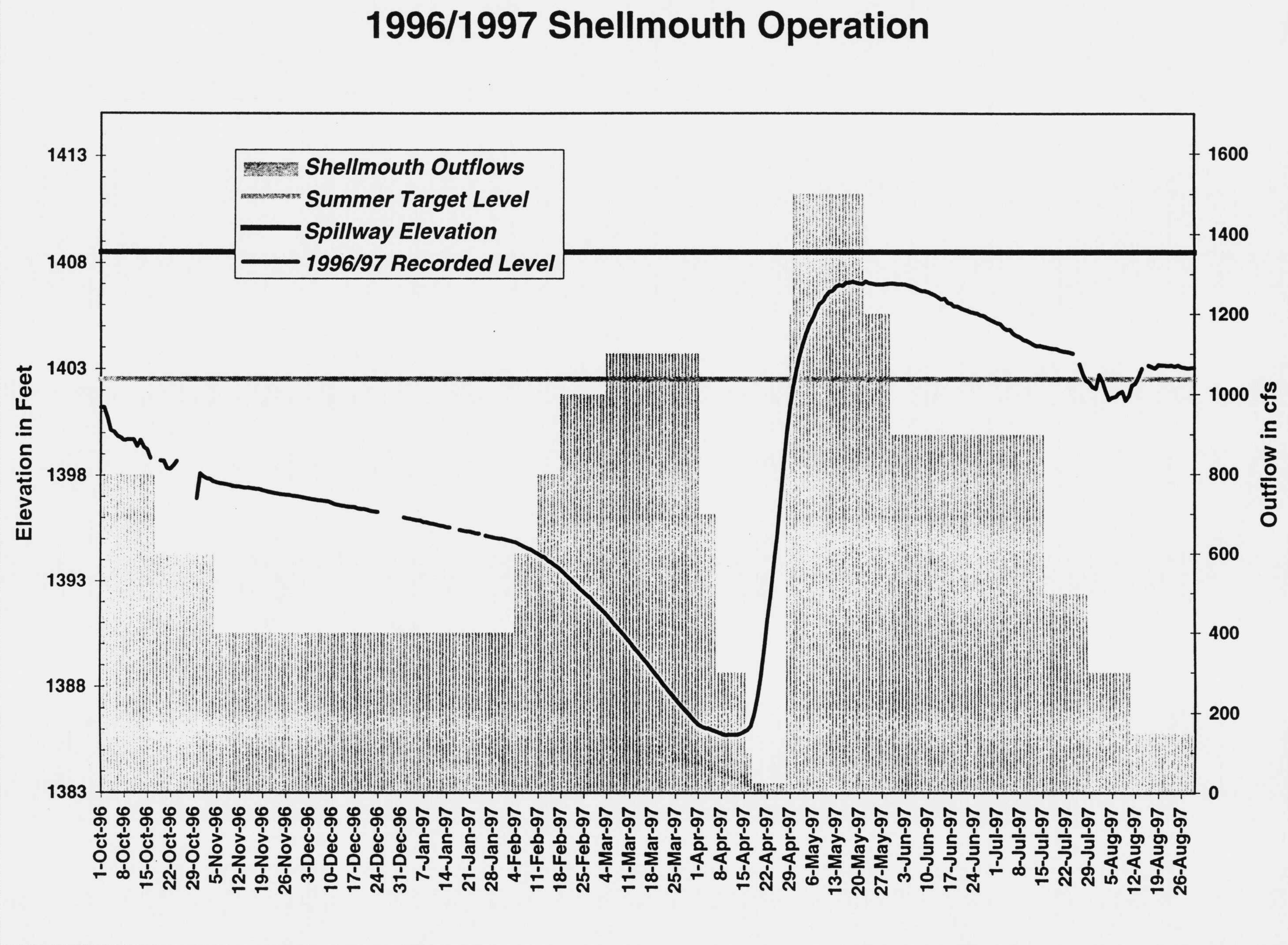

Manitoba
Natural Resources
1430
1420
1410
1400
1390
1380
1370
1360
GEODETIC ELEVATION (FEET)
MAXIMUM RECORDED
LEVEL, MAY 3, 1995
ELEV. 1415.0
SPILLWAY CREST - ELEV. 1408.5
SUMMER TARGET LEVEL - ELEV. 1402.5
NORMAL WINTER DRAWDOWN - ELEV. 1391
MINIMUM RECORDED
LEVEL, APRIL 10, 1997
ELEV. 1385.74
J F M A M J J A S O N D
GENERALIZED OPERATING
LEVELS
TOP OF DAM - ELEV. 1427.5
EFFECTIVE EMPTY
ELEV. 1377
CONDUIT INVERT
ELEV. 1369
DAM CROSS-SECTION

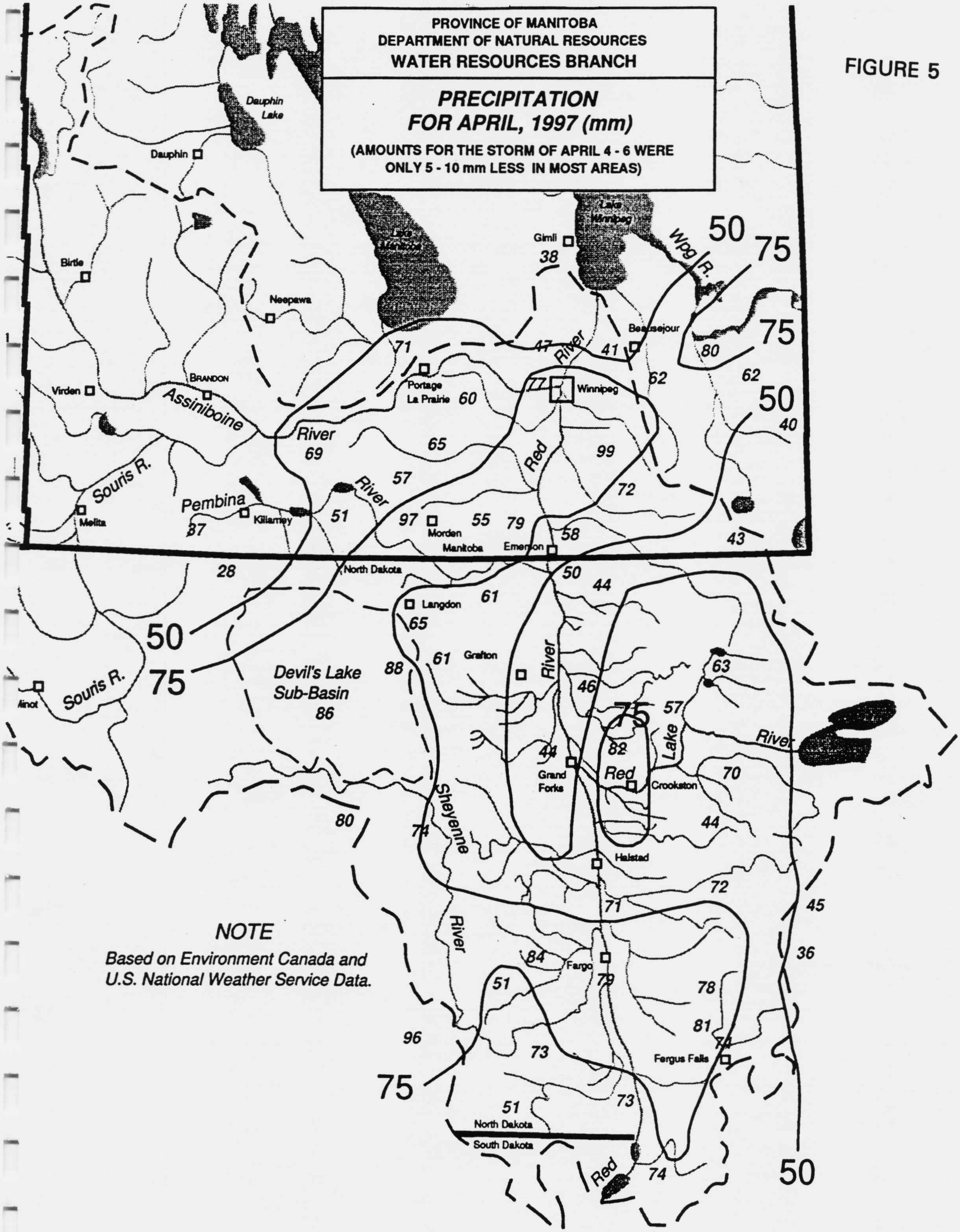
fig. 3

FIGURE 4



1996/1997 Shellmouth Operation
Shellmouth Outflows
Summer Target Level
Spillway Elevation
1996/97 Recorded Level
Elevation in Feet
Outflow in cfs
1413
1408
1403
1398
1393
1388
1383
1600
1400
1200
1000
800
600
400
200
0
1-Oct-96
8-Oct-96
15-Oct-96
22-Oct-96
29-Oct-96
5-Nov-96
12-Nov-96
19-Nov-96
26-Nov-96
3-Dec-96
10-Dec-96
17-Dec-96
24-Dec-96
31-Dec-96
7-Jan-97
14-Jan-97
21-Jan-97
28-Jan-97
4-Feb-97
11-Feb-97
18-Feb-97
25-Feb-97
4-Mar-97
11-Mar-97
18-Mar-97
25-Mar-97
1-Apr-97
8-Apr-97
15-Apr-97
22-Apr-97
29-Apr-97
6-May-97
13-May-97
20-May-97
27-May-97
3-Jun-97
10-Jun-97
17-Jun-97
24-Jun-97
1-Jul-97
8-Jul-97
15-Jul-97
22-Jul-97
29-Jul-97
5-Aug-97
12-Aug-97
19-Aug-97
26-Aug-97

FIGURE 5



PROVINCE OF MANITOBA
DEPARTMENT OF NATURAL RESOURCES
WATER RESOURCES BRANCH
PRECIPITATION
FOR APRIL, 1997 (mm)
(AMOUNTS FOR THE STORM OF APRIL 4 - 6 WERE
ONLY 5 - 10 mm LESS IN MOST AREAS)
NOTE
Based on Environment Canada and
U.S. National Weather Service Data.
Dauphin Lake
Dauphin
Lake Winnipeg
Lake Manitoba
Gimli
Wpg R.
Birtle
Neepawa
Beausejour
Brandon
Virden
Portage La Prairie
Winnipeg
Assiniboine River
Souris R.
Pembina River
Red River
Melita
Killarney
Morden
Manitoba
Emerson
North Dakota
Langdon
Grafton
Devil's Lake Sub-Basin
Minot
Grand Forks
Crookston
Red Lake River
Sheyenne River
Halstad
Fargo
Fergus Falls
North Dakota
South Dakota
Red
50
75

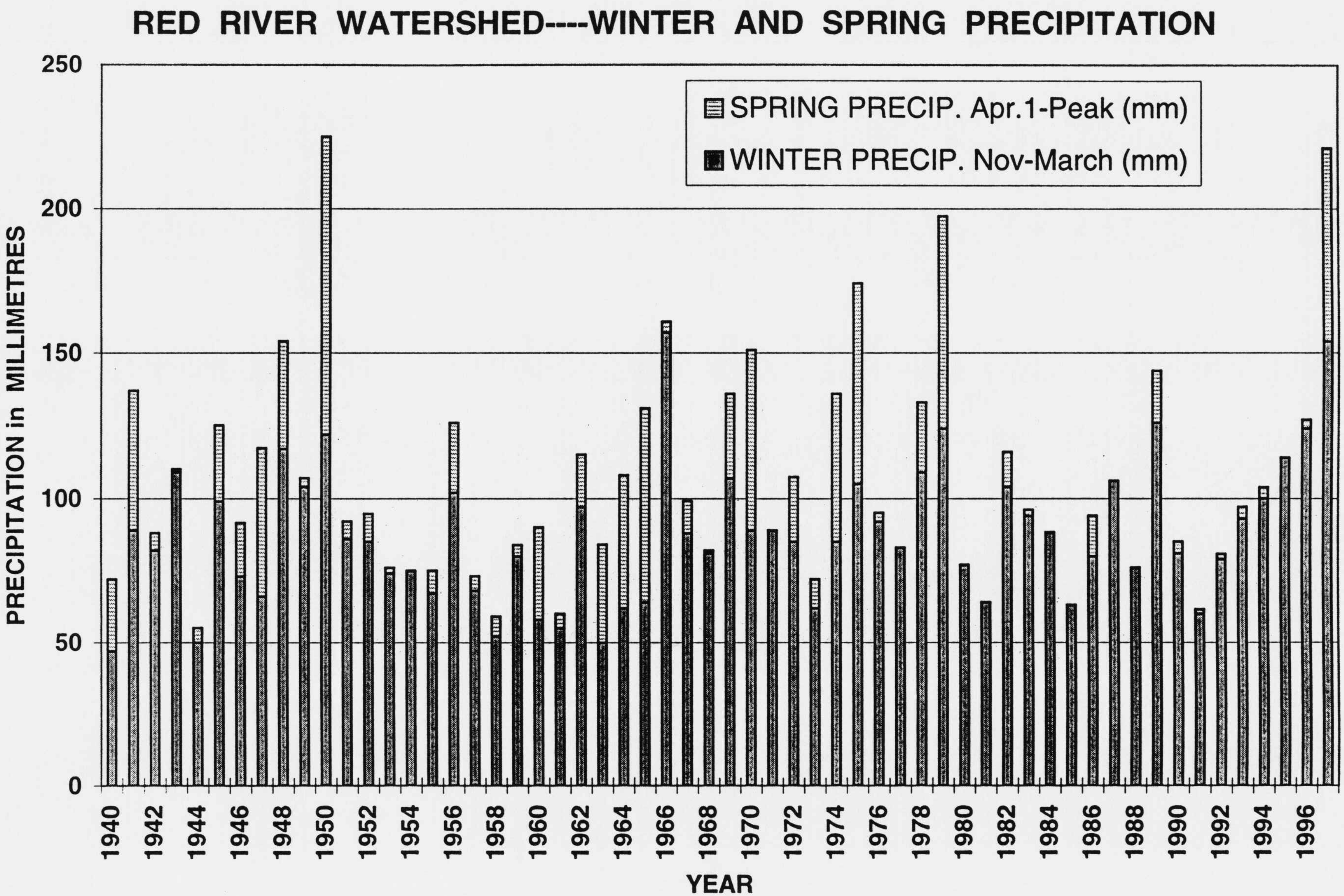
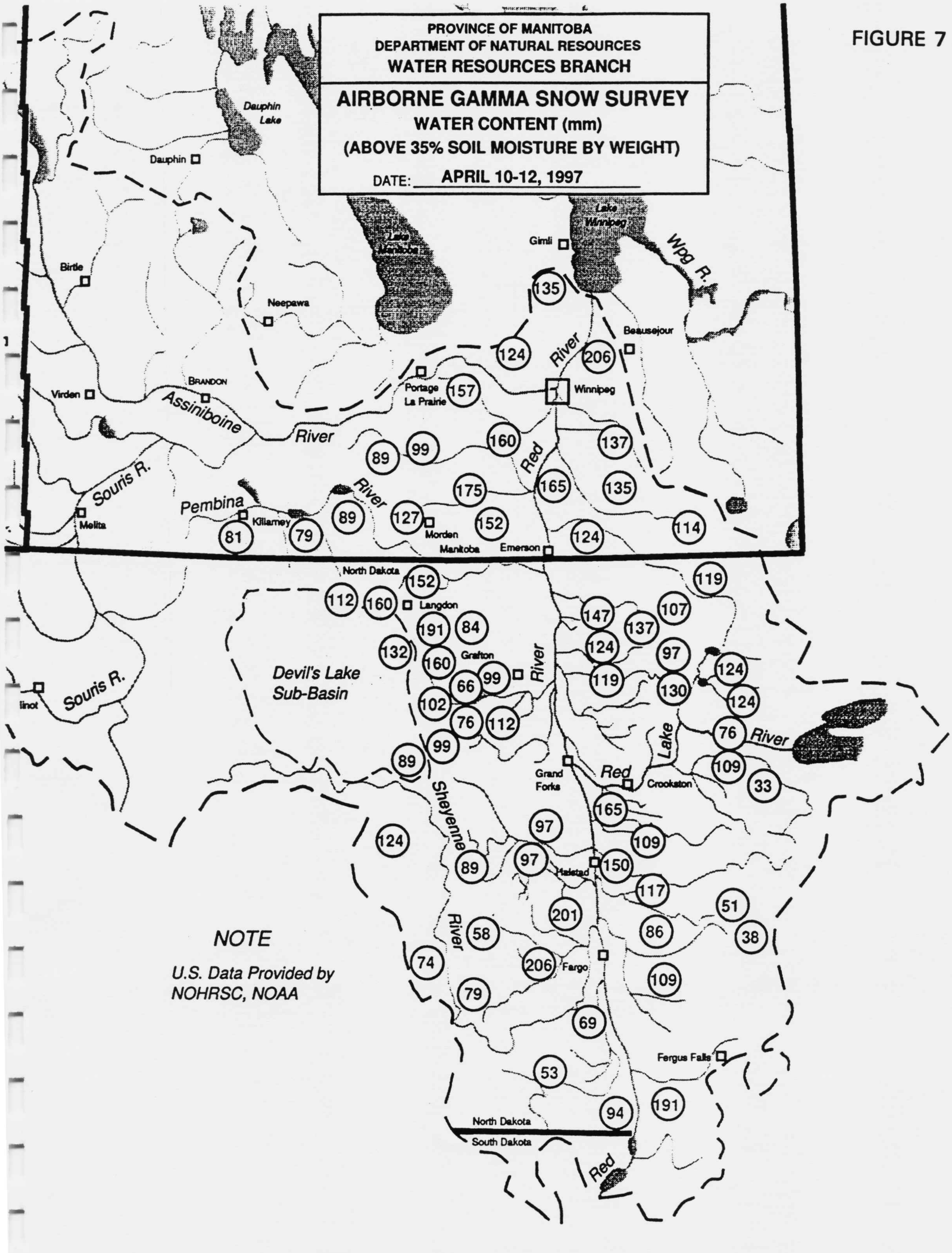

RED RIVER WATERSHED----WINTER AND SPRING PRECIPITATION
SPRING PRECIP. Apr.1-Peak (mm)
WINTER PRECIP. Nov-March (mm)
PRECIPITATION in MILLIMETRES
250
200
150
100
50
0
YEAR
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996

FIGURE 6

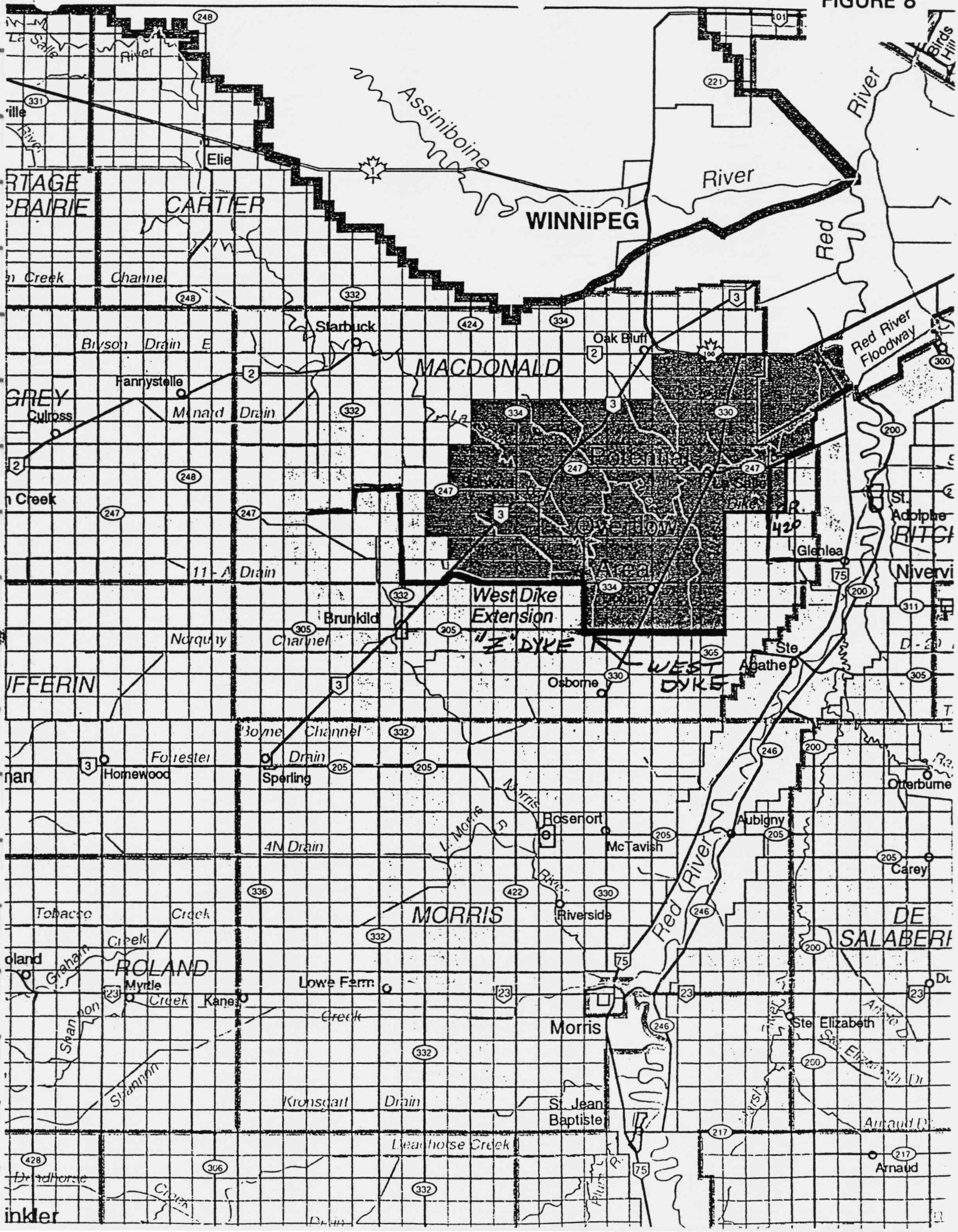
FIGURE 7



NOTE

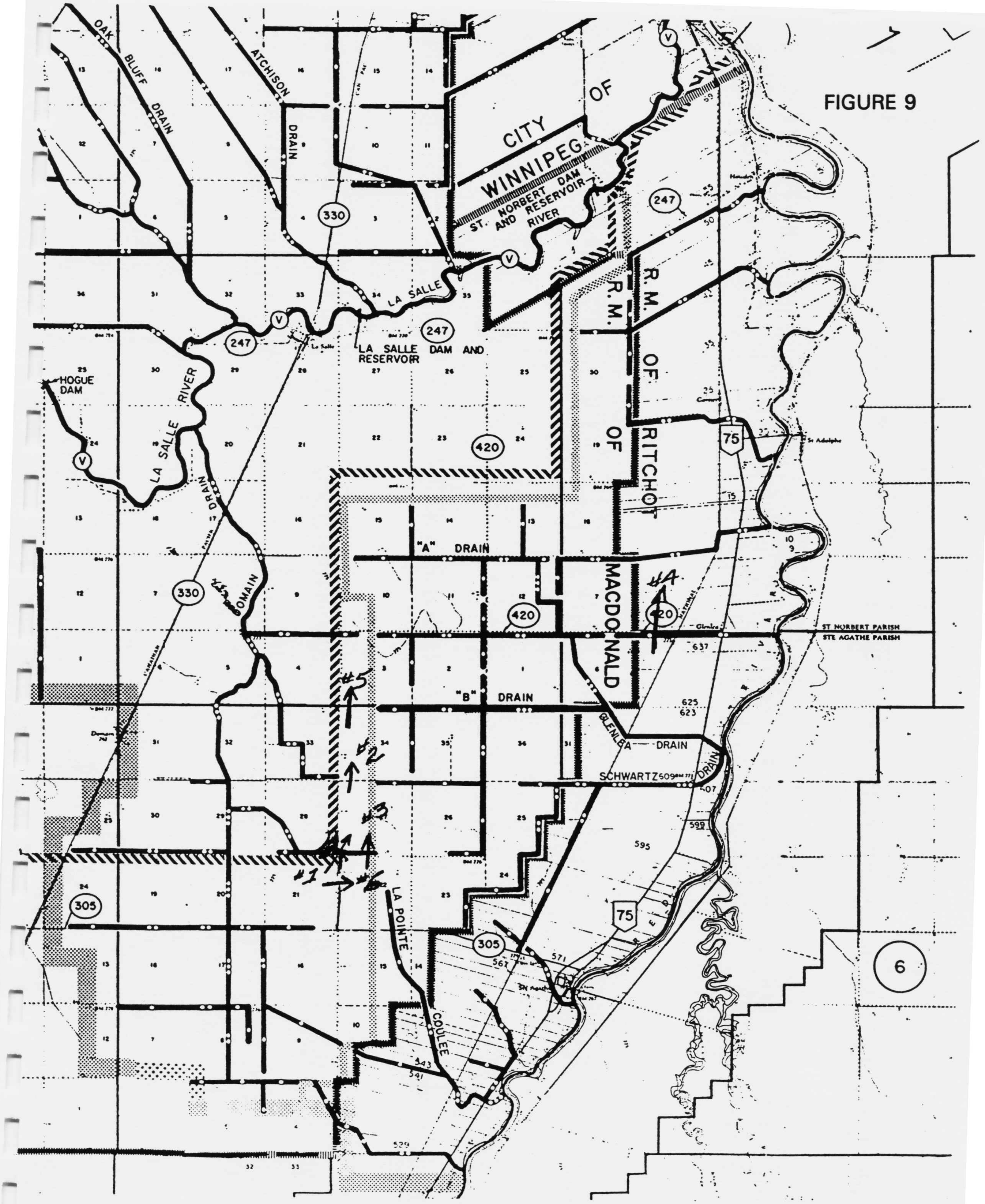
U.S. Data Provided by NOHRSC, NOAA

FIGURE 8



WINNIPEG
Assiniboine
River
Red River
Red River Floodway
MACDONALD
CARTIER
RTAGE
PRAIRIE
GREY
FFERIN
MORRIS
ROLAND
DE SALABER
RITCH
Potential Overflow Area
West Dike Extension
"Z" DYKE
WEST DYKE
La Salle Dike
P.R. 420
Elie
Starbuck
Oak Bluff
Fannystelle
Culross
Brunkild
Osborne
Ste Agathe
Glenlea
St. Adolphe
Niverville
Homewood
Sperling
Rosenort
McTavish
Aubigny
Otterburne
Carey
Riverside
Lowe Farm
Myrtle
Kane
Morris
Ste Elizabeth
St. Jean Baptiste
Arnaud
Winkler
Bryson Drain
Menard Drain
11 - A Drain
Norquay Channel
Boyne Channel
Forester Drain
4N Drain
Tobacco Creek
Graham Creek
Shannon Creek
Kronsgart Drain
Deadhorse Creek
La Salle River
Morris River
Plum R.

FIGURE 9



RGE. 3E.

LIST OF TABLES

Manitoba Water Resources Branch
River Forecast Centre

REVIEW OF RED RIVER CREST FORECASTING SPRING OF 1997

Predicted Crest Elevations in Feet						
Forecast Date	Emerson	Morris	Ste. Agathe	Floodway Inlet	Winnipeg (James Ave.)	Selkirk (PTH #4)
February 24	790.5-793.0	780.5-783.5	773.0-775.5	765.8-769.2	19.3-22.5	
March 21	791.0-793.0	781.0-783.5	773.0-775.5	765.2-769.0	19.3-22.3	
Favourable Melt Followed by April 4-6 Blizzard						
April 10	792.0-793.5	782.0--784.0	774.5-776.0	767.3-769.6	19.7-24.3	725.0-727.5
River Levels at Grand Forks rise much higher than predicted						
April 18	793.0-793.5	783.0-784.0	775.5-776.5	768.3-769.5	20.4-24.3	725.0
Crest Levels at Grand Forks revised upward significantly						
April 20	794.0-795.0	784.5-785.5	776.5-777.5	769.0-770.0	23.5-24.5	726.5-727.5
Manitoba Tributaries crests coincident with Emerson Crest						
April 27	Near Peak	784.5-785.5	777.0-778.0	769.5-770.5	24.0-25.0	727.0-728.0
Update Based On Flow Measurements at Ste. Agathe						
April 29	Crested	Near Peak	776.5	770.0-770.5	24.0-25.0	727.0-728.0
Observed Conditions						
Actual Crest	792.5	783.0	776.5	771.3	24.5	726.2
Crest Date	April 27	April 30	May 2	May 4	May 2-4	May 4-5
Total Rise (ft.)	40.3	39.8	37.0	38.3	24.0	N/A

TABLE 1

APPENDICES

A. WATER RESOURCE LEGISLATION

B. RED RIVER FLOODWAY GATE OPERATIONS

C. 1997 ACTUAL FORECASTS

D. SAND BAG INFORMATION

E. NEWS RELEASES

THE APPENDICES HAVE BEEN COMPILED AS A SEPARATE DOCUMENT