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QU'APPELLE RIVER CHANNELIZATION PROJECT: RECOMMENDATIONS FOR A MORPHOLOGICAL MONITORING PROGRAM

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Canada

Western and Northern Region

QU'APPELLE RIVER
CHANNELIZATION PROJECT

RECOMMENDATIONS FOR A
MORPHOLOGICAL MONITORING PROGRAM

Prepared for:

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ABSTRACT

This report discusses the probable future morphological evolution of a major channelization project along the Qu'Appelle River in south-eastern Saskatchewan. A monitoring program is proposed to document any morphological changes and to provide timely warning in case of unforeseen detrimental developments.

Along most of its course, the Qu'Appelle River consists of a small, tortuously meandering channel in a relatively large and deep valley formed by glacial meltwater. The river flows through several shallow lakes, which are formed where alluvial fans of tributaries block the main valley. The flow regime of the Qu'Appelle River is characterized by extreme variability both within the year and from year to year. This in turn is the main cause of long-standing water supply, water quality and flooding problems.

A major water management effort to address these problems is mostly completed and includes diversion of South Saskatchewan water into the Qu'Appelle River, flow control structures at several lake outlets and channelization of the Qu'Appelle River from Craven to Pasqua Lake; this being the subject of the present report. The channelized river reach is to be shortened from 110 km to 75 km by cutting off particularly tortuous meander bends, and the channel capacity is to be increased from around 5 m^3/s to 14 m^3/s, mostly by enlarging the natural channel. Only some two thirds of this latter part of the Qu'Appelle project is presently completed.

The channelization was designed as a rigid channel without any explicit allowances for sediment transport, erosion, deposition or vegetation encroachment. There has been some concern that the increased energy gradient and increased velocities could lead to degradation and erosion problems. A computer study using the sediment routing model "MOBED" predicted extensive degradation near Craven and led to some initial monitoring work. These results were also indirectly responsible for the commissioning of the present study. To date the channelized reaches of the Qu'Appelle River show no significant evidence of degradation but, due to the very low flows of the last few years, this does not alleviate all concerns.

Comparison of the pre- and post-construction channel of the Qu'Appelle River with various published channel design criteria and with documented case histories for comparable rivers on the Canadian prairies, indicates the following:

(i) The post-project channel has a bankfull capacity that is probably somewhat larger (17-32 m^3/s) than the design flow of 14.2 m^3/s;

(ii) The project does not appear to affect channel width and the final channel is, if anything, somewhat wider than necessary for the expected flows; and

(iii) Both the pre- and post-project gradients are very low, even for prairie rivers. Significant bed load transport or significant channel bed degradation are therefore most unlikely.

Based on evidence from case histories, the morphological evolution of the channelized reach is predicted qualitatively at three time scales; short term (years), medium term (decades) and long term. Morphological parameters are not expected to change dramatically at any of these time scales.

In view of the predicted slow rates of morphological change, only a very limited monitoring program appears necessary, consisting of the following:

(i) river channel cross section surveys;

(ii) collection of some bed material samples;

(iii) photographic documentation of morphological changes and vegetation encroachment;

(iv) documentation of changes in channel plan from air photos, if and when suitable photos become available from other projects;

(v) monitoring water level trends at the two Water Survey of Canada gauges in the channelized reach; and

(vi) field inspection during or immediately after any large floods.

An initial monitoring interval of 5 years is suggested, but this needs to be varied according to the occurrence of floods. There is little point in repeating any surveys unless there have been some significant flows since the previous one. Major floods might justify immediate re-surveys.

RÉSUMÉ

Le présent rapport traite de l'évolution morphologique qui devrait survenir par suite d'un important projet de canalisation le long de la rivière Qu'Appelle dans le sud-est de la Saskatchewan. On propose la réalisation d'un programme de surveillance afin de documenter toute modification d'ordre morphologique et de donner, en temps opportun, des avertissements s'il survenait des développements imprévus et nuisibles.

La rivière Qu'Appelle consiste, sur la majeure partie de son cours, en un petit chenal qui serpente de façon sinueuse une vallée relativement vaste et profonde formée par l'eau de fonte des glaciers. La rivière s'écoule par plusieurs petits lacs peu profonds formés à l'endroit où des cônes de déjection d'affluents bloquent la vallée principale. Le régime d'écoulement de la Qu'Appelle est extrêmement variable tant pendant l'année que d'une année à l'autre, ce qui en retour constitue la cause principale des problèmes de longue date entourant l'approvisionnement en eau et sa qualité ainsi que les inondations.

Afin de résoudre ces problèmes, d'importantes mesures de gestion des eaux ont été prises, et les travaux relatifs à la majorité d'entre elles sont achevés. Ces mesures comprennent la dérivation de l'eau de la rivière Saskatchewan Sud vers la rivière Qu'Appelle, l'érection d'ouvrages de régularisation à plusieurs décharges de lacs et la canalisation de la Qu'Appelle entre Craven et Pasqua Lake, laquelle fait l'objet du présent rapport. Le tronçon de la rivière qui sera canalisé doit être raccourci de 110 à 75 km en supprimant les méandres particulièrement sinueux, et la capacité du chenal doit être accrue d'environ 5 à 14 m^3/s en procédant surtout à l'élargissement du chenal naturel. Cette dernière partie des travaux n'est complétée qu'aux deux tiers à l'heure actuelle.

La canalisation a été conçue comme un chenal rigide sans tenir compte de façon précise du transport des sédiments, de l'érosion, de la sédimentation et de la croissance de végétation. Cela a suscité certaines préoccupations du fait que l'augmentation de la pente de la ligne de charge et des vitesses pourrait entraîner des problèmes de dégradation et d'érosion. Une forte dégradation près de Craven a été prédite par suite d'une étude sur ordinateur à l'aide du modèle de transport des sédiments «MOBED», ce qui a donné lieu à des activités initiales de surveillance. Ces résultats ont aussi contribué indirectement à commander la présente étude. Jusqu'à ce jour, les tronçons canalisés de la Qu'Appelle n'offrent pas de signes importants de dégradation en raison des faibles niveaux d'eau enregistrés ces dernières années; cette constatation ne vient toutefois pas dissiper toutes les inquiétudes.

La comparaison du chenal de la rivière Qu'Appelle avant et après sa construction avec divers critères publiés pour la conception de chenaux et des cas documentés de rivières comparables dans les Prairies indique ce qui suit :

i) Le chenal après construction a une capacité de débordement probablement assez supérieure (17–32 m^3/s) au débit de référence de 14,2 m^3/s.

ii) Les travaux ne semblent pas avoir modifié la largeur du chenal, et ce dernier est peut-être un peu plus large que nécessaire comparativement aux débits prévus.

iii) Les pentes de la ligne de charge avant et après la construction sont très faibles, et ce, même pour les rivières des Prairies. Il est donc très peu probable qu'on enregistre un important transport du charriage ou une grave dégradation du lit du chenal.

En se fondant sur les cas documentés, on prévoit, sur le plan qualitatif, une évolution morphologique du tronçon canalisé à court (années), à moyen (décennies) et à long terme. Les paramètres morphologiques ne devraient pas changer de façon dramatique pour aucune de ces échelles de temps.

Compte tenu de la lenteur prévue avec laquelle les changements morphologiques devraient se produire, il s'avère opportun de procéder uniquement à un programme très restreint de surveillance qui comporterait les éléments suivants :

i) des études de la coupe transversale du chenal;

ii) le prélèvement de quelques échantillons de matériaux du lit;

iii) la documentation photographique des changements morphologiques et de la croissance de la végétation;

iv) la documentation des changements dans le plan du chenal à partir de photographies aériennes si l'on pouvait en obtenir auprès des responsables d'autres projets;

v) la surveillance des tendances des niveaux d'eau aux jauges installées par la Division des relevés hydrologiques du Canada dans le tronçon canalisé;

vi) des inspections sur le terrain avant ou immédiatement après toute inondation importante.

On suggère de réaliser au départ la surveillance à un intervalle de cinq ans, ce qui pourrait être appelé à changer si des inondations se produisaient. Il n'y a pas lieu de répéter des relevés à moins d'enregistrer des écoulements importants depuis le relevé précédent. Des relevés immédiats pourraient se justifier si des inondations importantes survenaient.

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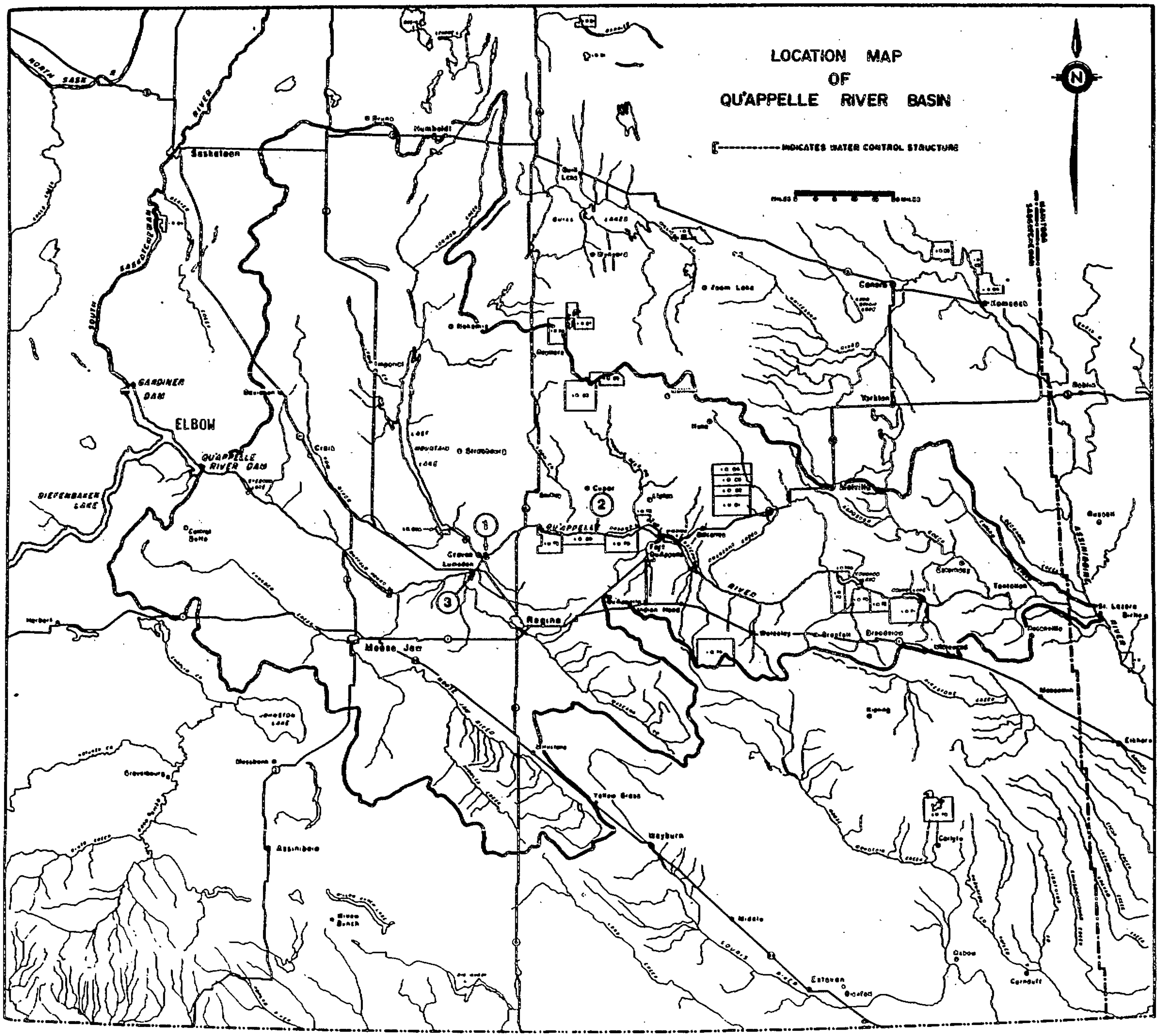
1.0 INTRODUCTION

1.1 THE QU'APPELLE CONVEYANCE PROJECT

1.1.1 The General Setting

The Qu'Appelle River drains an area of some 51,000 km^2 of southeastern Saskatchewan (Figure 1.1). Physiographically, the entire drainage area lies within the Saskatchewan Plain, (Gordon, 1979), a vast area of gently rolling terrain with very low relief. The basin outlet, where the Qu'Appelle River joins the Assiniboine River, some 13 km east of the Manitoba border, lies at an elevation 390 m, while the highest point of the basin appears to be in the Dirt Hills, with an elevation of 880 m. Most of the plains lie between elevations 500 and 650 m. The Qu'Appelle Valley is a large glacial spillway trench which was formed by one of the major meltwater channels draining the margin of the Wisconsin ice sheet some 12,500 years ago. As the ice margin retreated northwards, the meltwater channel found a new route, heading north at Elbow, to become the Saskatchewan River. Below Elbow the valley was left to carry only local runoff.

The trench of the Qu'Appelle Valley is 1 to 2.5 km wide and incised into the surrounding plains by 100 to 150 m. It is the outstanding topographic feature of the general region (Plate 1.1). The modern Qu'Appelle River is a classic underfit river, i.e. a river flowing in a valley shaped by a much larger, earlier river. Over the approximately 12,000 years since the main meltwater channel shifted northward, the valley wall slopes have been lowered and rounded off by slumping and ravelling, and most sediment carried into the trench by small and large tributaries has remained there in the form of alluvial fans and flood plain deposits. Given the very gentle slope of the trench floor (140 m



KEY

① Qu'Appelle River
Below Craven Dam
Stn. 05JK002

② Qu'Appelle River
Below Loon Creek
Stn. 05JK007

③ Qu'Appelle River
Near Lumsden
Stn. 05JF001

Figure 1.1: Qu'Appelle River Basin.

Mar 24, 1988 M88-37-29

Plate 1.1: Looking downstream on the Qu'Appelle River Valley from a site 5 km east of Fairy Hill, showing natural and enlarged sections of river channel.

over a total length of around 360 km, S = 0.00039) the small remaining local runoff has only been able to move the very finest sediments, out of which has built up an extensive, almost continuous flood plain. The river channel follows a tortuous path on this flood plain. Several tributary fans have accumulated sufficiently rapidly to impound the mainstem river to form shallow lakes (Plate 1.2).

The hydrology of the Qu'Appelle River is characterized by extreme variability, both within the year and between years. The annual discharge is characterized by a spring freshet in May or June and periods of low flow in both late-summer and mid-winter (Figure 1.2). [Note that all monthly minimum flows are too small to show up at the scale of Figure 1.2.] The seasonal pattern in suspended sediment transport (Figure 1.3) reflects this discharge regime. Discharge data from below Craven Dam indicate the largest observed annual peak in 43 years of record is more than 40 times greater than the smallest one (Figure 1.4) and the range of annual runoff involves a corresponding factor greater than 70 (Figure 1.5).

The stream channel formed by such an exceedingly variable flow regime is naturally not adjusted to the larger floods, which consequently inundate the entire valley floor, by up to several metres in some places. Since the valley contains several settlements and there are extensive cottage developments along the lakes, there is a definite flooding problem. Ideally the cottagers would like stable, relatively high lake levels.

The extreme variability of annual runoff has similarly given rise to a general water supply problem. Several large towns, including Regina and Moose Jaw, depend on the Qu'Appelle or its tributaries for their water supply, as do some industrial develop-

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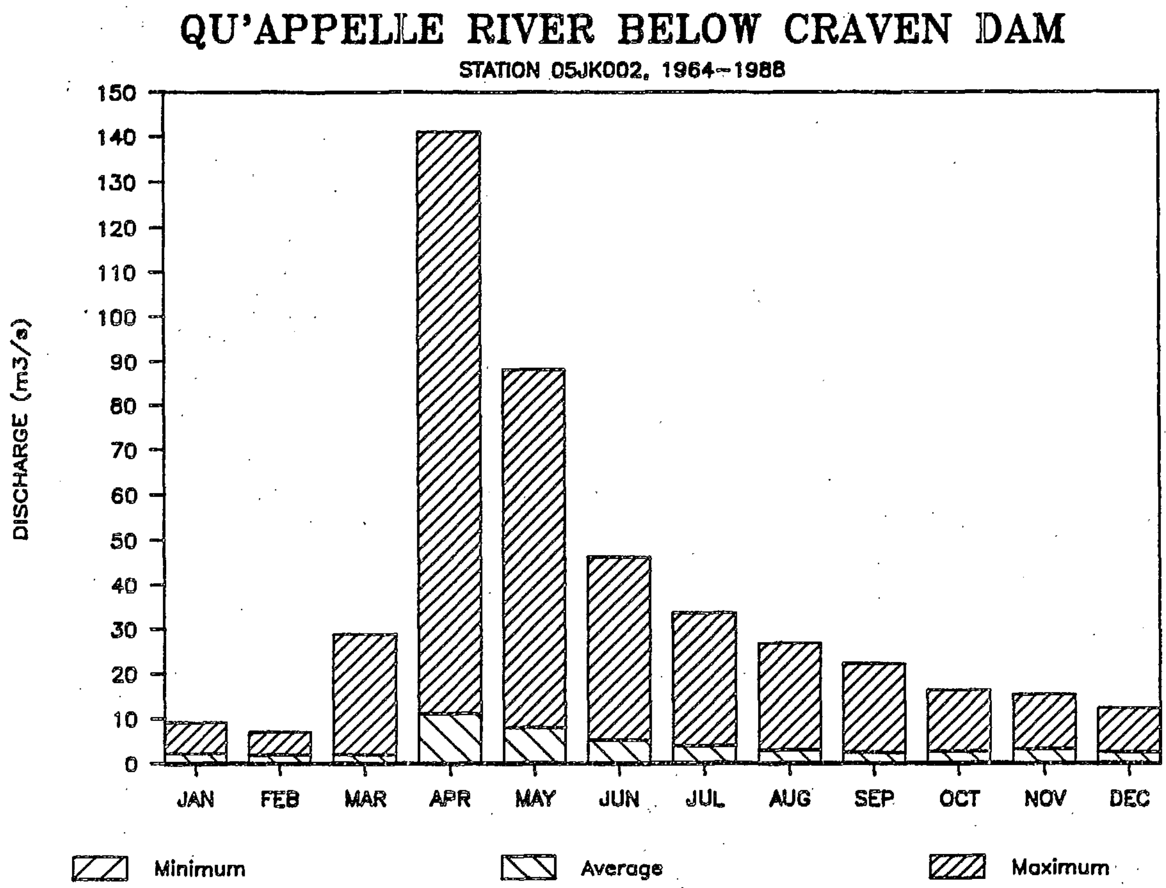
Plate 1.2: This view, looking downstream from the west end of Pasqua Lake, illustrates how fans extending across the valley impound shallow lakes.



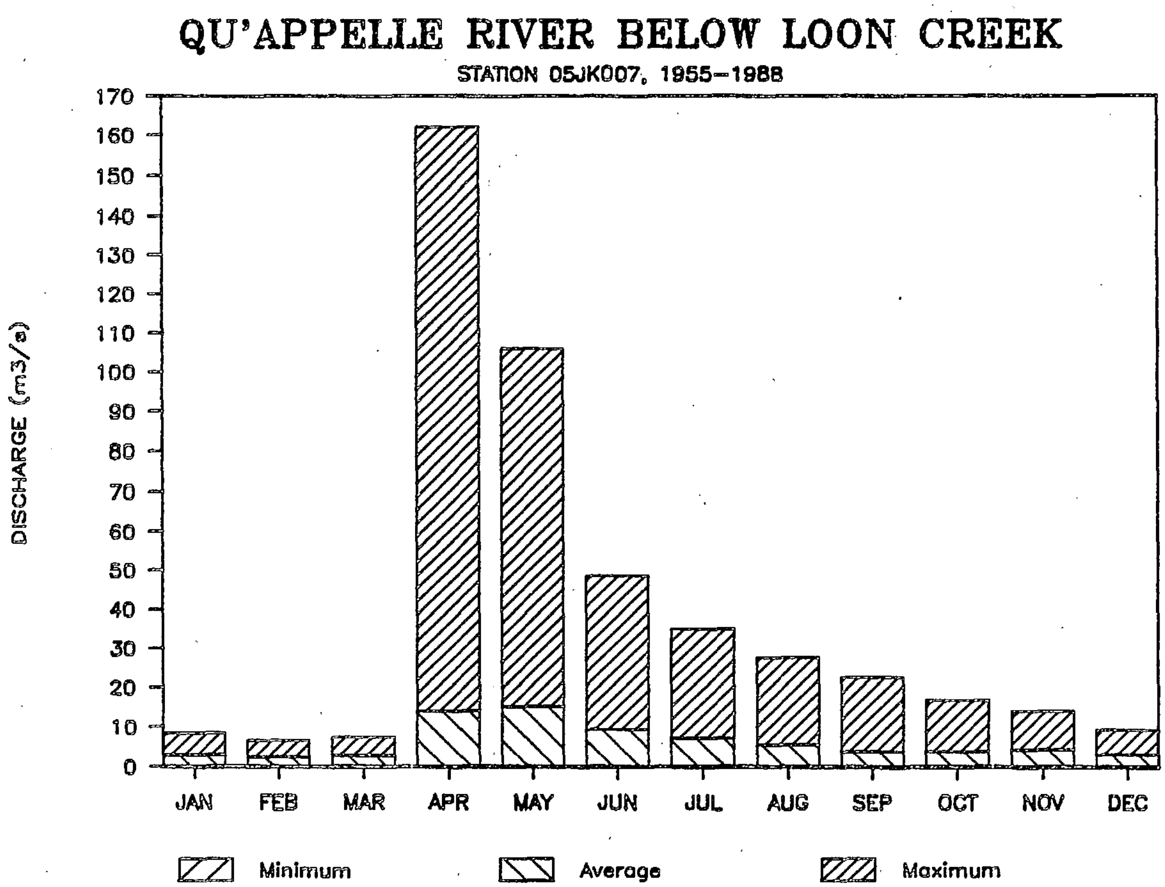


Figure 1.2: Seasonal variation in runoff of the Qu'Appelle River (data from Environment Canada, 1988a and 1989).

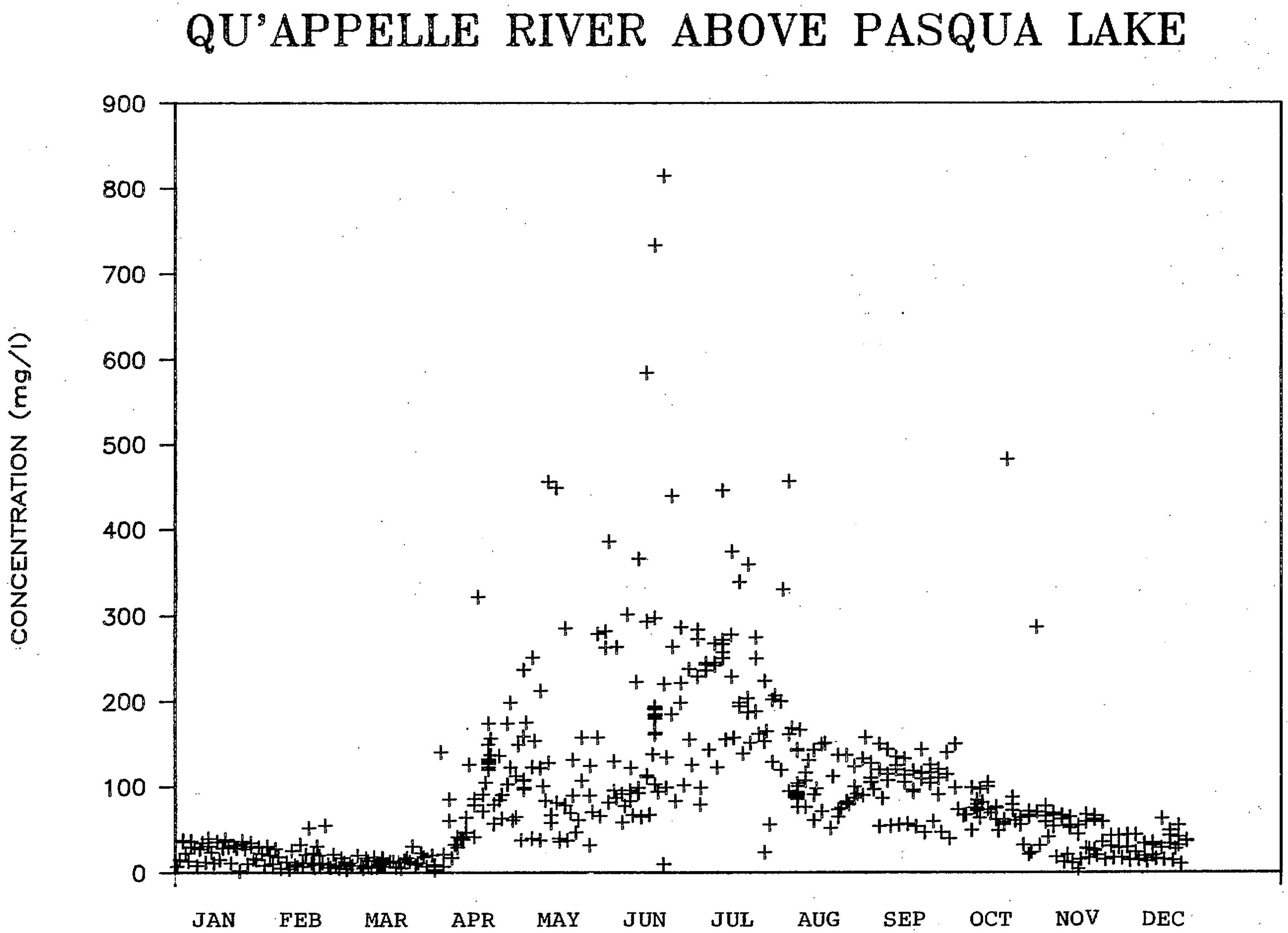
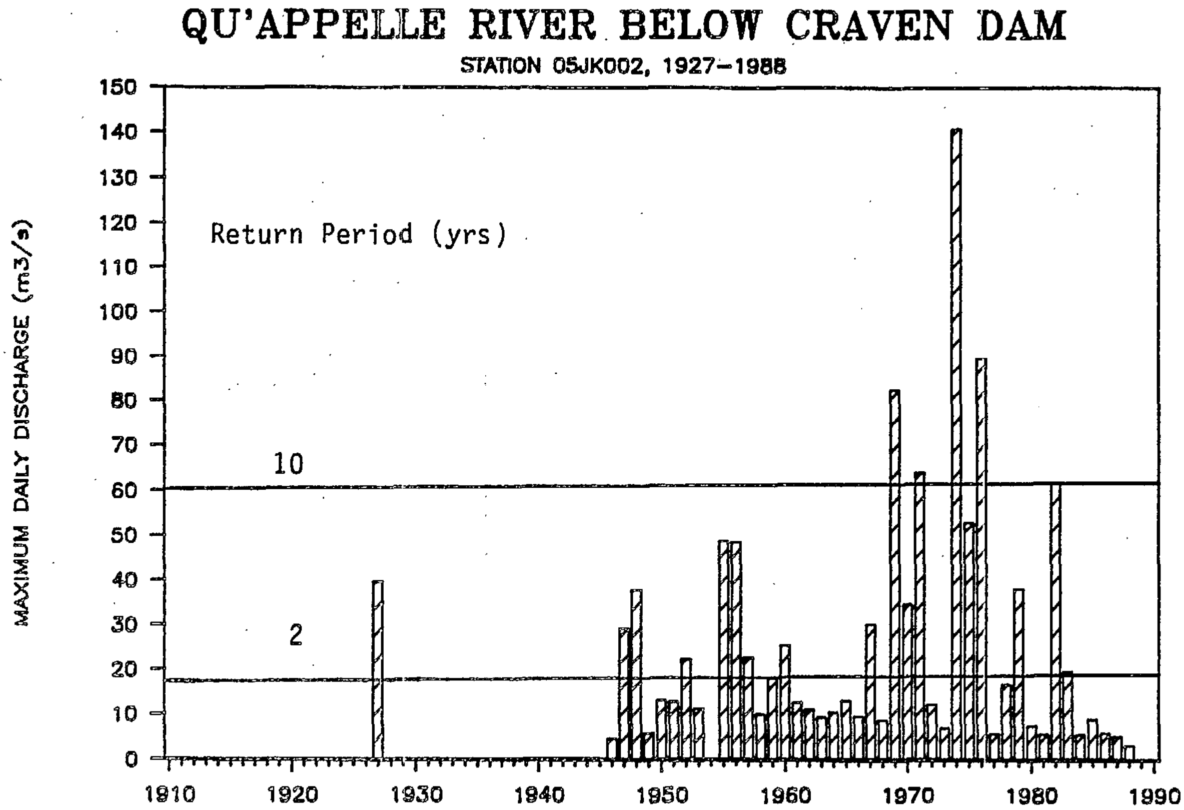


Figure 1.3: Seasonal variation in the concentration of non-filterable residue (data from Environment Canada, 1988b).



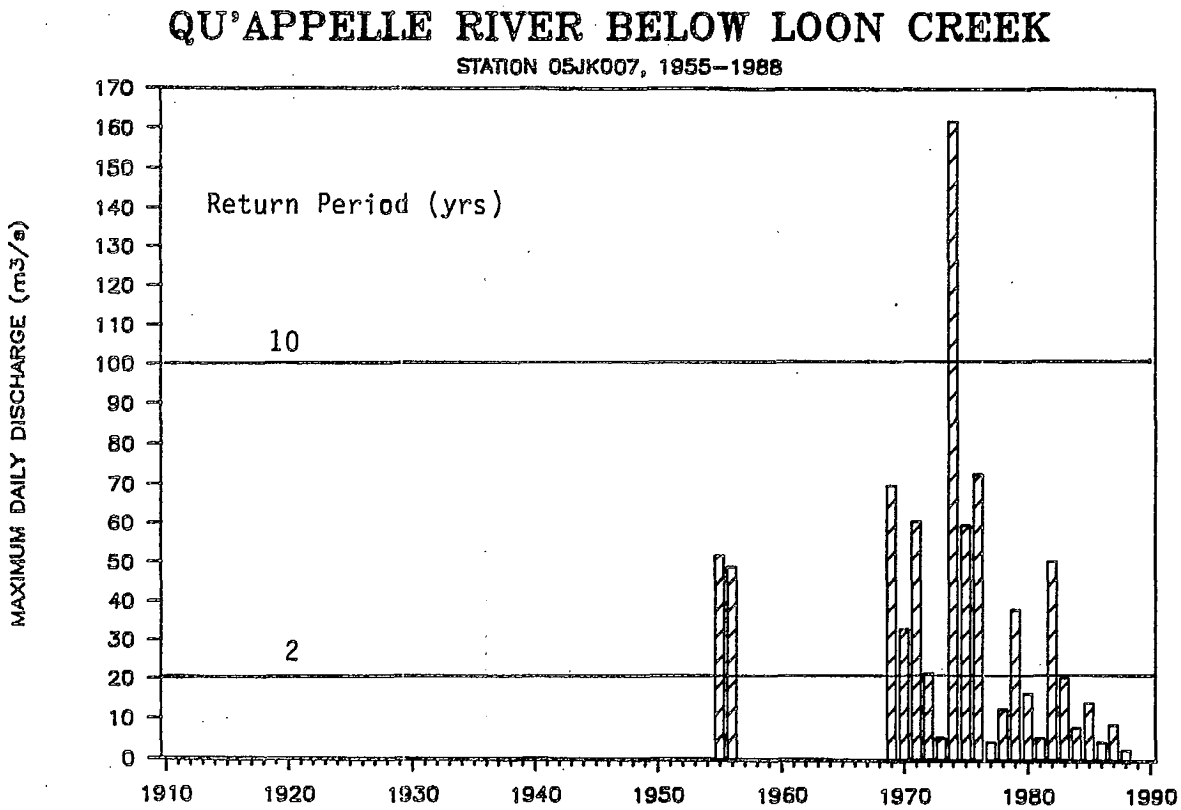
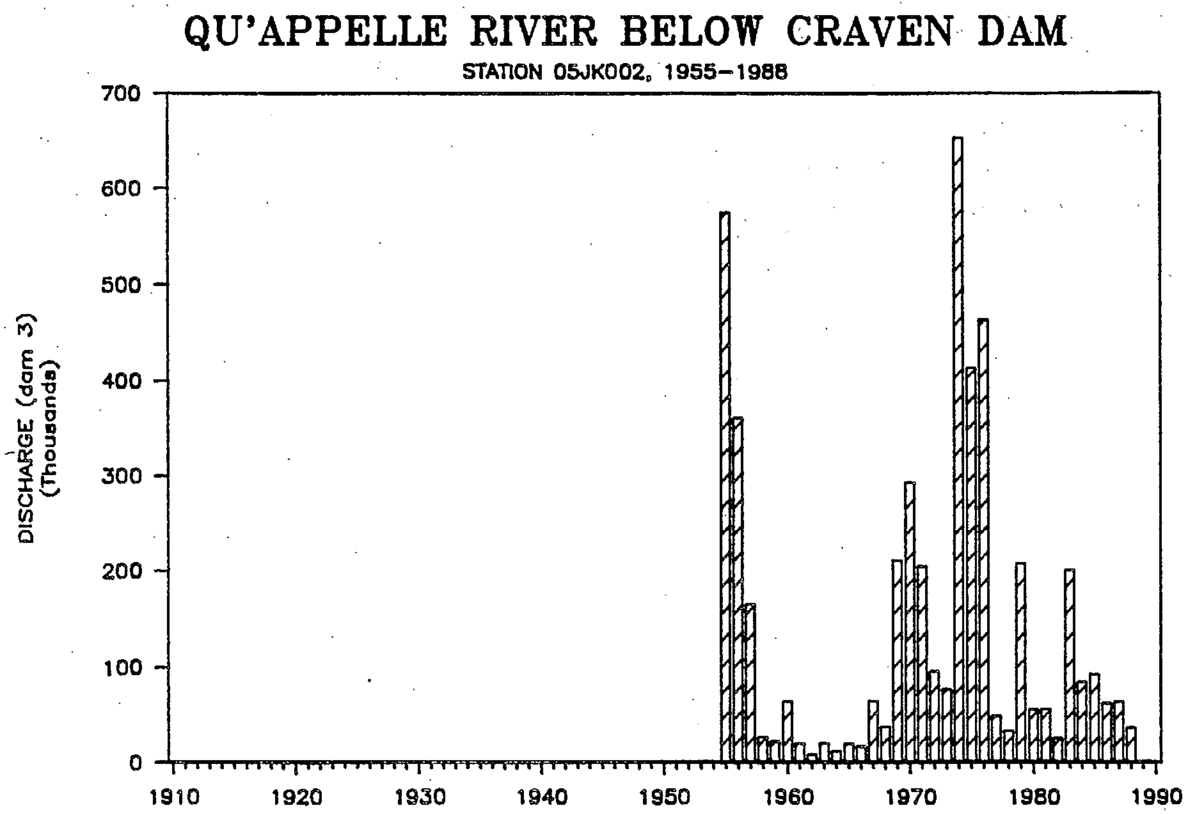


Figure 1.4: Historical variation in annual maximum daily flows of the Qu'Appelle River (data from Environment Canada, 1989).



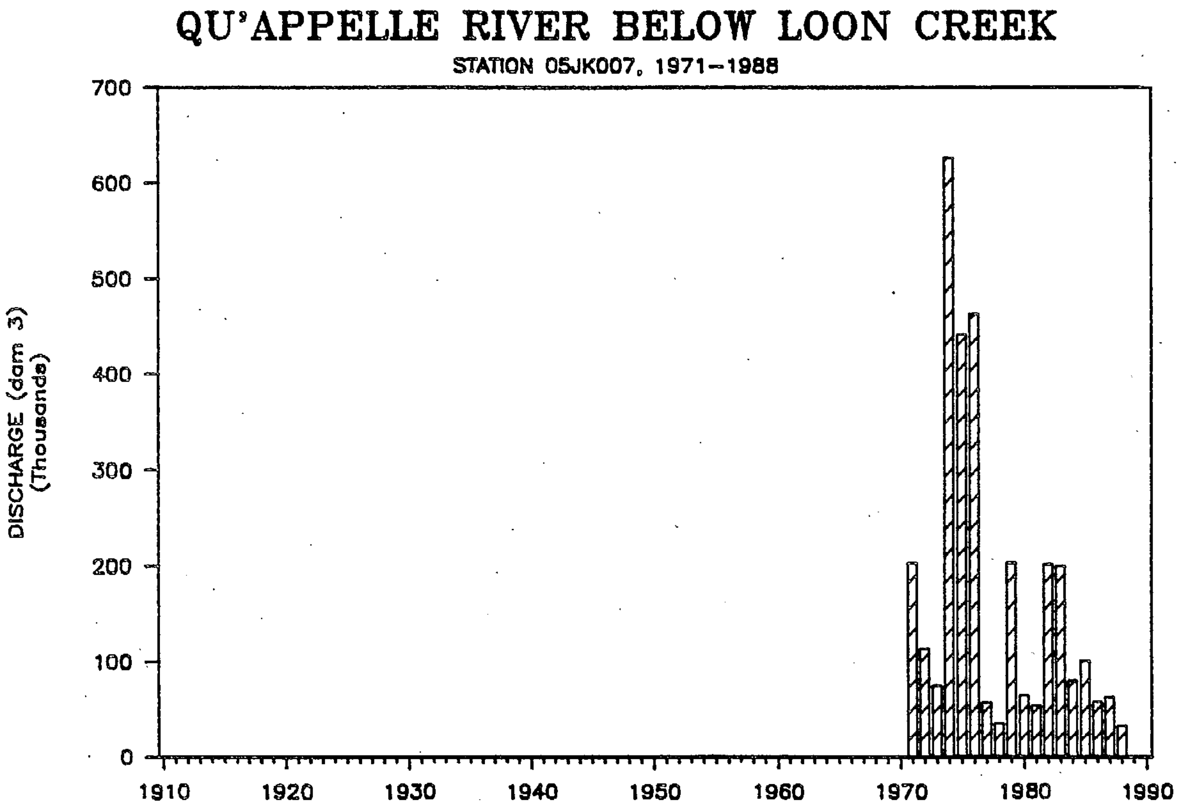


Figure 1.5: Historical variation in annual total discharge of the Qu'Appelle River (data from Environment Canada, 1989).

ments. The traditional flood irrigation of extensive hay fields on the flood plain uses considerable volumes of water too.

Finally, there is also a severe water quality problem, brought on mainly by a combination of hot summer weather, large, shallow lakes and nutrient-laden runoff water.

1.1.2 Project History

The water quality, water supply and flooding problems mentioned above eventually led to the formation of a Qu'Appelle Basin Study Board, set up by the governments of Canada, Manitoba and Saskatchewan, in 1970. It reported in October, 1972 and presented a list of 64 recommendations (Mitchell et al., 1972). Most relevant in the present context is item 43, which recommends:

> "...that the conveyance capacity of the Qu'Appelle River system be increased in certain reaches..."

The completion of Gardiner Dam on the South Saskatchewan River in 1967 has added to the urgency of addressing the conveyance problem. That project includes a saddle dam on the divide to the Qu'Appelle valley with outlet works capable of discharging up to 68 m^3/s, a flow far in excess of the downstream channel capacity (Wiens, 1987). A significant volume of South Saskatchewan water is reserved for diversion into the Qu'Appelle Valley and there can be little doubt that increased flows, combined with relatively high and stable lake levels, could alleviate both the water quality and the water supply problems. Increased channel capacity also helps to alleviate some of the flooding problems, particularly those associated with Last Mountain Lake.

In 1975 an agreement was signed between the governments of Canada and Saskatchewan to implement the recommendations of the Study Board over a period of 10 years. Amongst many other items addressed, a project to improve the channel conveyance of the Qu'Appelle River was developed. It involved improvements to various lake outlet control structures and channel enlargement and meander cutoffs along some of the most critical natural river sections. The 115 km of river channel from the Craven Control Structure to Pasqua Lake were identified as, by far, the longest river reach with low natural capacity. The natural capacity along that reach is in the order of 5 to 9 m^3/s, but dropping as low as 2.1 m^3/s locally. The project calls for a capacity of 14 m^3/s, to be achieved by channel enlargement along most of the reach, combined with channel straightening and meander cutoffs to reduce the channel length by 35 per cent to 75 km. Some diking was also proposed (Qu'Appelle Multidisciplinary Design Team, 1981). Various land acquisition problems prevented much of the channel conveyance project from being implemented within the 10 year implementation agreement, which expired in 1984. In particular, none of the work between the Craven Control Structure and Pasqua Lake was carried out. Since 1984 there have been renewed efforts to complete the Qu'Appelle Conveyance Project under a new federal/provincial agreement which expired on March 31, 1989. As of Summer 1989, most of the project has been completed, but only approximately two thirds of the river reach addressed by this report, the section from the Craven Control Structure to Pasqua Lake had been enlarged and straightened. The completed, enlarged channel reaches are:

(i) a short section extending approximately 2 km downstream from the Craven control structure; and

(ii) the entire reach from Highway No. 6 to Pasqua Lake.

As under the previous program, various land ownership and water-rights problems stood in the way of project completion under the extended program. The issues are apparently close to resolution now and project completion over the next 3 to 5 years is a distinct possibility (Wiens, L.H., personal comm.).

1.2 STUDY OBJECTIVES

The present study concerns the Qu'Appelle River reach from the Craven control structure to Pasqua Lake, which is the major alluvial (self-formed) river channel reach to be enlarged and straightened under the Qu'Appelle Conveyance Project. The work is only partially completed and presently at a standstill.

Since the natural Qu'Appelle River channel is alluvial and since the project does not call for any significant bed or bank stabilization with immovable materials, such as rock rip-rap, the man-made, enlarged and steepened river resulting from this project should remain capable of morphological work, such as enlarging, infilling or shifting its channel.

The two main objectives of the study are:

(i) to try and predict the general nature and magnitude of morphological changes to be expected over the next few decades; and

(ii) to recommend a long-term monitoring program to document any such changes.

Item (i) is a pre-requisite to item (ii); the more successfully future morphological change can be predicted, the easier it becomes to design an effective monitoring program.

Some initial monitoring has already been carried out. Reviewing this material and incorporating it as best as possible into the proposed future program is an additional objective. There has also been a sediment routing study, based on the computer program MOBED (Krishnappan, 1986). Its prediction of rather dramatic local aggradation and degradation also needs to be considered.

2.0 PRESENT SITUATION

2.1 PROJECT DESCRIPTION

The two main elements of the Qu'Appelle Conveyance Project between the Craven control structure and Pasqua Lake are channel enlargement and meander cut-offs, with both the enlarged natural channel reaches and the newly excavated meander cutoffs forming a continuous channel of relatively uniform cross-section. A concise project description is available in the report of the Qu'Appelle Multidisciplinary Design Team (1981). A summary of the most pertinent aspects in the present context follows:

The main project objective was to achieve a channel conveyance of 14.2 m^3/s with a minimum freeboard allowance of 0.3 m. The hydraulic design was carried out on the basis of Manning's equation with a constant "n" value of 0.03. The enlarged channel follows the existing river channel as closely as possible, but many of the severe bends are cut off with the overall result of shortening the channel from its pre-project length of 115 km to a design length of 75 km, a 35 per cent reduction. Note that the valley length is approximately 50 km so that even the post-project channel still retains a sinuosity of 1.5. Locally the channel length reduction is far greater than 35 per cent. Immediately below the Craven control structure, 5 km of natural river channel are being replaced by 1.4 km of excavated channel, a 72 per cent reduction.

In general the post-project channel maintains a relatively natural-looking curved alignment, except for the 3.5 km reach along the Muscowpetung Indian Reserve. In order to avoid work on that Reserve, the new channel follows its northern boundary wherever the existing river channel passes through the Reserve. Figures 1 to 5 in Appendix 1 show a plan view of the project at a scale of 1:12,500.

With a channel length of 74.9 km and an elevation difference of 10.8 m between Pasqua Lake and the Craven tailwater (at a flow of 14.2 m^3/s) the overall project channel gradient is 1.44×10^{-4}. The overall natural channel gradient was 0.96×10^{-4} and the overall flood plain slope is 2.2×10^{-4}. The original hydraulic design distinguished two reaches, above and below Highway No. 6. Table 2.1 lists the design parameters for these two reaches as stated in Figure 1 of the Multidisciplinary Design Team (1981) report. There have been considerable modifications and refinements since. Table 2.2 lists the "as-built" parameters for the completed, downstream, reach of Table 2.1. Other important aspects evident from the "as-built" drawings are that the channel is generally excavated somewhat deeper than the design bed level, probably due to the difficulties of excavating a truly trapezoidal section in muddy water. The average "as-built" bed level is approximately 0.2 to 0.6 m below the design bed level. More importantly, the design water level at a flow of 14.2 m^3/s is generally well below the terrain levels on either side. Except along the last 4 km of ditch above Pasqua Lake, and some very short sections occurring all along the project, the freeboard is normally at least 1 m and often considerably more. In practical terms this means that, although flooding of low-lying parts of the flood plain may start at 14.2 m^3/s, the actual channel capacity of most of the "as-built" channel is considerably greater and significant overbank flow will not occur until this actual channel capacity is exceeded. Assuming a bed level 0.2 m below the design bed level and 1 m of freeboard indicates an actual bankfull channel capacity of around 32 m^3/s.

TABLE 2.1: ORIGINAL PROJECT DESIGN PARAMETERS
(from: Multidisciplinary Design Team, 1981, Figure 1)

REACH BOUNDARY	CHAINAGE km	ELEVATION m asl	LENGTH km	FALL m	SLOPE $\times 10^{-4}$	BED WIDTH m	SIDE SLOPE	DEPTH OF FLOW m	VELOCITY *1 m/s
CRAVEN CONTROL STRUCTURE	2.3	489.78							
			30.4	5.86	1.92	10	2:1	1.84	0.56
HIGHWAY NO: 6	46.8	483.92							
			44.5	4.95	1.11	12	*2 2:1	1.95	0.46
PASQUA LAKE	77.2	478.99							

*1 based on Manning's n of 0.03

*2 locally reduced to 3:1 based on geotechnical considerations

TABLE 2.2: "AS-BUILT HYDRAULIC PARAMETERS, HIGHWAY NO: 6 TO PASQUA LAKE

REACH	CHAINAGE *1 (km)	REACH LENGTH (m)	WATER SURFACE ELEV. *1 (m)	MEAN BED ELEV. *1 (m)	FALL (m)	SLOPE ($\times 10^{-4}$)	BED WIDTH (m)	SIDE SLOPE	DEPTH (m)	VELOCITY (m/s)
PASQUA LAKE	0.000	2.375	479.1	n/a	NO APPLICABLE DATA					
	2.375		479.1	476.9						
MUSKOWPETUNG I. RESERVE DITCH 1A	2.375	21.963	479.1	476.9	2.3	1.00	12.0	2:1	2.00	0.44
	24.338		481.3	479.2						
PIAPOT I. RESERVE DITCH 2A	23.963	9.787	481.3	479.2	1.4	1.44	8.5	3:1	1.99	0.49
	33.750		482.6	480.6						
PIAPOT I. RESERVE DITCH 2A	33.750	3.000	482.6	480.6	0.4	1.44	10.5	2:1	1.93	0.51
	36.750		482.9	481.0						
DITCH 3A	36.635	8.020	482.9	481.0	0.9	1.10	12.0	2:1	1.95	0.46
	44.655		483.8	481.9						

NOTES: *1 at reach boundaries
Project Length: 42.770 km; Drop: 5.00 m; Overall Slope: 1.169×10^{-4}

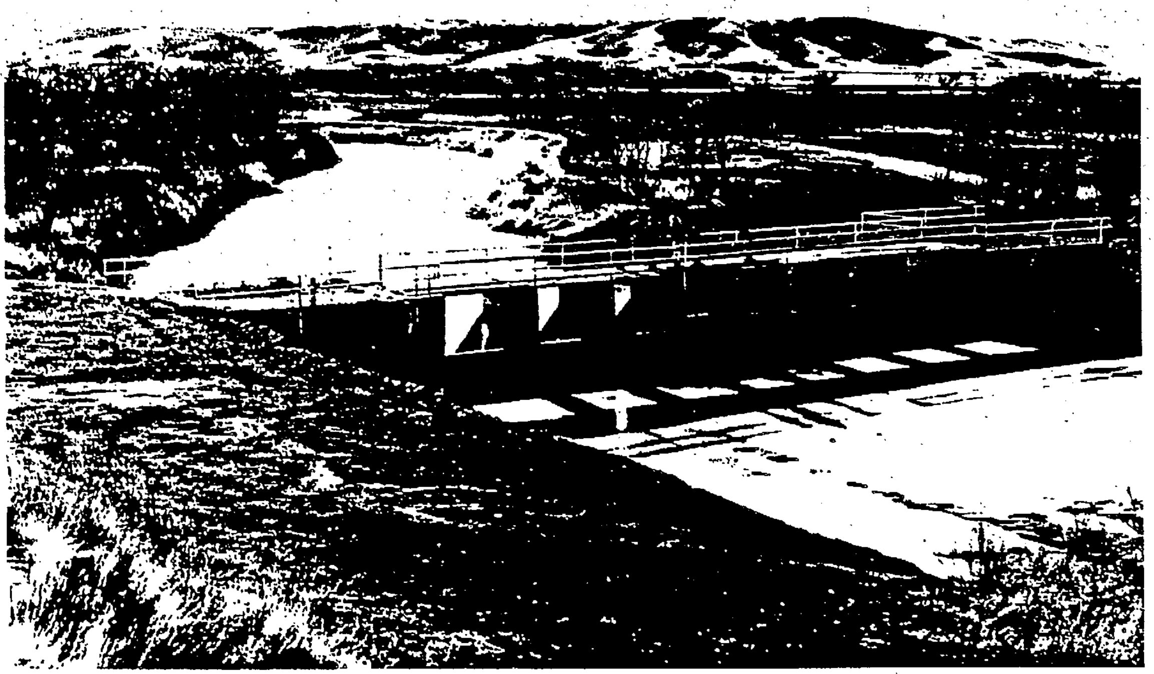
In order to minimize disturbance of the flood plain and river channel, the channel excavation is generally carried out from one side only, leaving the opposite bank and its vegetative cover as undisturbed as possible. Some time after completion of the excavation, the large spoil piles are being spread out, levelled and re-vegetated. Plates 2.1 to 2.10 illustrate the works, as seen in March, 1988.

As of August, 1989 the project is essentially completed between Highway No. 6 and Pasqua Lake, which corresponds to the entire downstream reach of 44.5 km in Table 2.1. Above Highway No. 6, only 2.0 km immediately below the Craven control structure are completed. Work on the intermediate reach of 28.4 km (project channel length) is presently at a standstill, but is scheduled to resume in 1990. In order to satisfy the wish of some riparian landowners to flood-irrigate their hay fields in spring, several check dams (such as illustrated on Plate 2.11) may well be incorporated into the remaining channel reach, but no details are as yet available.

2.2 SEDIMENT TRANSPORT CONSIDERATIONS

In designing the Qu'Appelle Conveyance Project, the alluvial nature of the existing channel and the on-going morphological processes were largely ignored. The design is based on a standard open channel flow formula that assumes a prismatic channel with immovable boundaries and an arbitrarily selected, constant channel roughness. The main factors ignored by this approach to the Qu'Appelle River are:

(i) vegetation encroachment;



March 23, 1988 M 88-30-03

Plate 2.1: Looking downstream to the control structure on the Qu'Appelle River at Craven.

March 24, 1988 M 88-36-34

Plate 2.2: Looking west (upstream) to the section of enlarged and shortened channel located downstream of Craven.

March 23, 1988 M 88-30-8

Plate 2.3: Looking upstream on an enlarged section of channel located east of Craven, illustrating vegetation development and bank erosion on the outside of a bend.

March 24, 1988 M 88-37-10

Plate 2.4: Looking northeast 5 km upstream of the Highway No. 6 Bridge to a section of the Qu'Appelle River where channel enlargements are proposed, but have not yet been undertaken.

March 24, 1988 M 88-37-18

Plate 2.5: Looking downstream from the Highway No. 6 Bridge illustrating the enlarged channel and spoil piles.

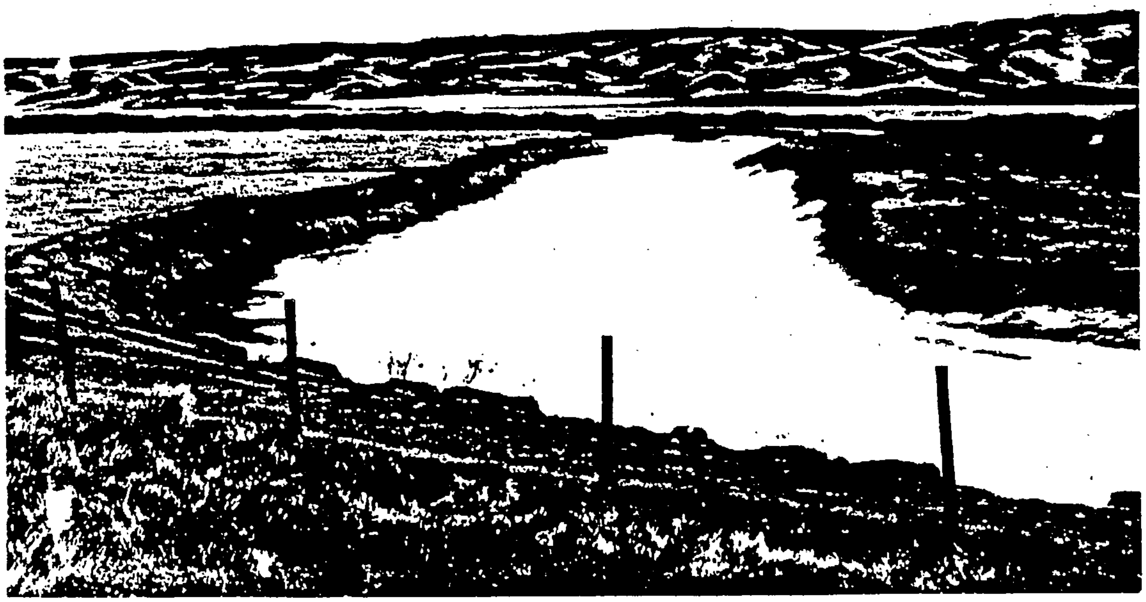


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Plate 2.6: Looking downstream from the vicinity of the Highway No. 6 Bridge showing the enlarged channel cross-section and the, as yet unspread, spoil piles.

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Plate 2.7: Looking upstream (from a bridge located 3 km west of Loon Creek), illustrating the enlarged river channel and the spoil piles which remain to be spread out along the edge of the channel.

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Plate 2.8: Looking downstream in the vicinity of Loon Creek showing the enlarged channel and the spread out spoil with swales across it to promote drainage of the flood plain.

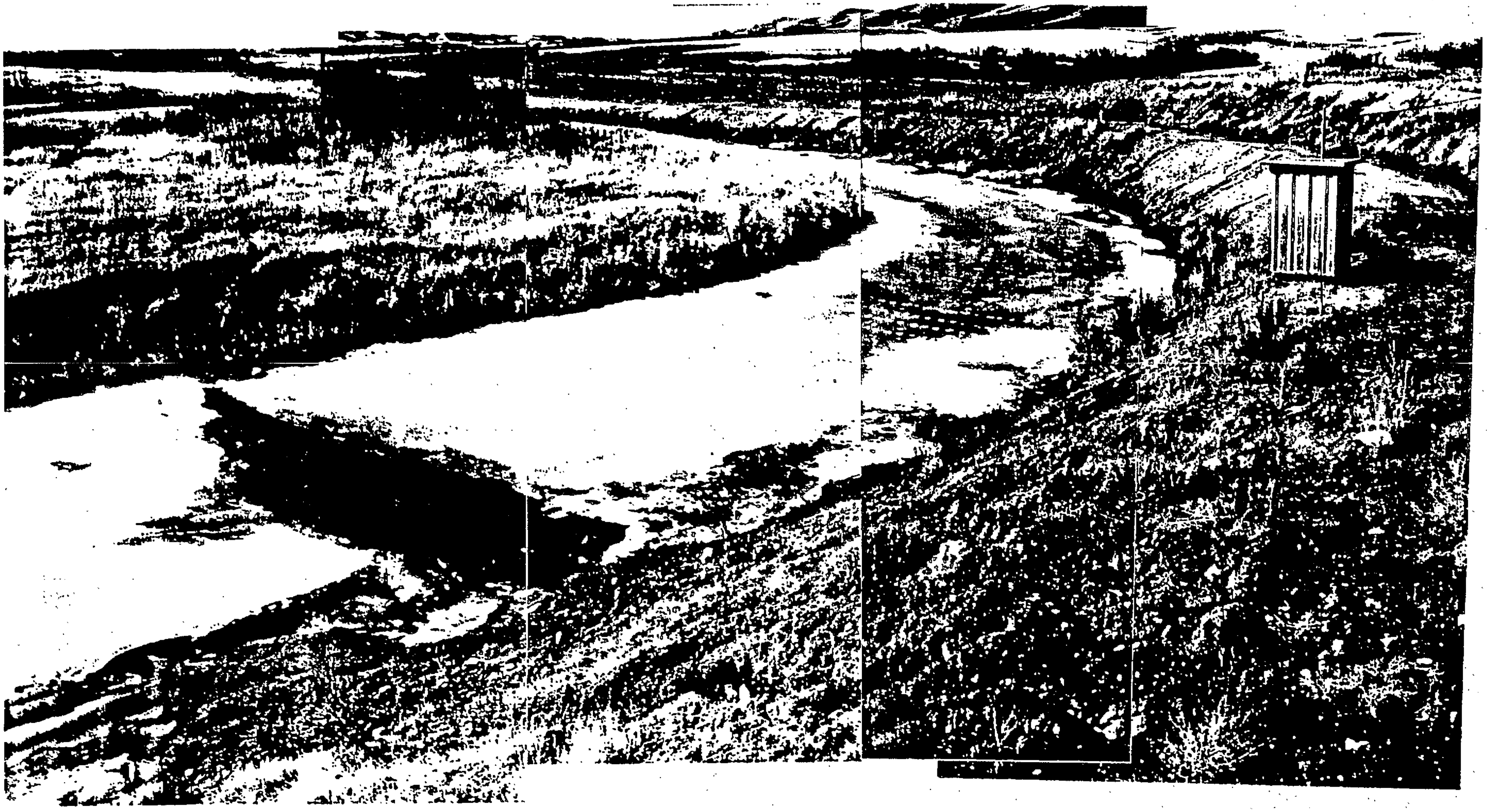

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Plate 2.9: Water Survey of Canada gauging site "Qu'Appelle River below Loon Creek", illustrating sediment production into the Creek and gravel placed across the channel to facilitate wading.

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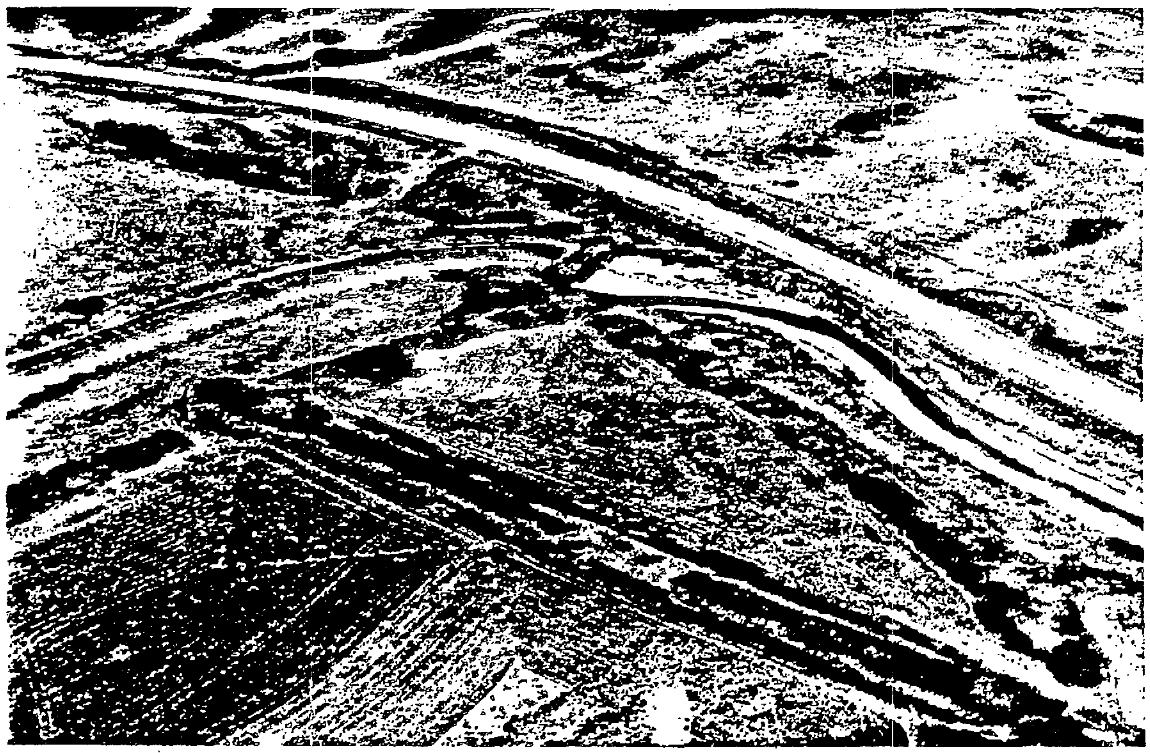
Plate 2.10: Looking east towards Pasqua Lake over completed sections of the project.



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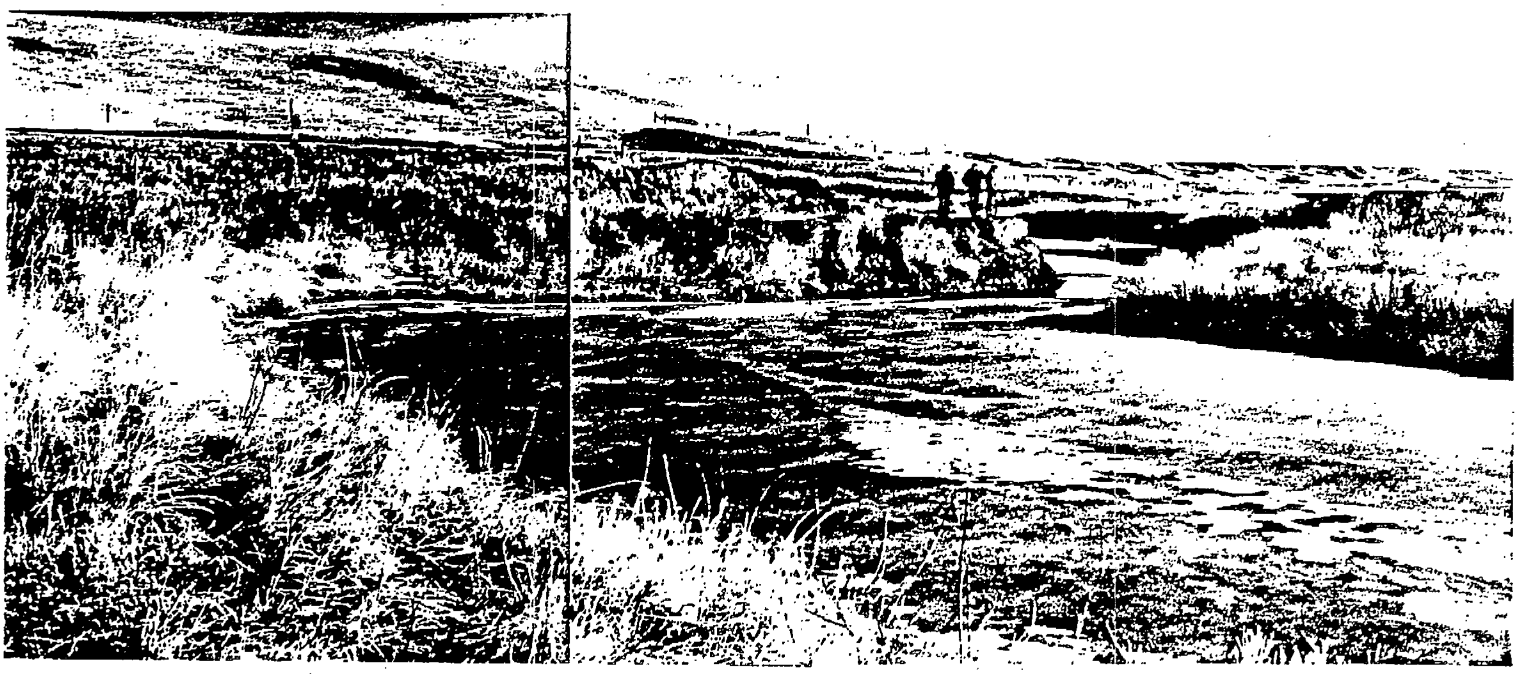

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Plate 2.11: Looking north towards a back-flooding dam, 3 km downstream of the "Sixth Base Line" Bridge.

(ii) sediment transport in the main channel leading to bank erosion and bank reconstruction, channel deformation in bends with the formation of point bars on the inside of bends, general bed lowering (channel degradation) and general, extended sediment accumulation in the channel (aggradation);

(iii) sediments carried to the enlarged channel by tributaries, and;

(iv) delta formation in Pasqua Lake.

In 1985 an attempt was made to evaluate the effect of one of these neglected processes, sediment transport in the main channel, item (ii) in the above list (Krishnappan, 1986). The sediment routing computer model of the National Water Research Institute, MOBED, was applied to the channel.

MOBED is a two-dimensional (channel width is fixed and the channel is assumed to be straight and prismatic) routing model which uses standard concepts of open channel hydraulics to model the flow, but the model also includes routines which allow it to deal with a channel bed (assumed horizontal across any cross-section) consisting of mobile sedimentary materials. The flowing water can rearrange these materials into various types of bed forms (e.g. dunes). Sediment can also be picked up, moved and deposited. In other words, channel roughness is no longer assumed and fixed, as it was in the original hydraulic design studies, but is flow dependent. Similarly, the bed levels are now also subject to gradual change. If more sediment is transported into a reach than out of it, bed level will rise (aggrade). Alternatively, they may also degrade.

Initially the model was applied to the pre-project, natural river channel, for which there are extensive cross-section surveys. Bed materials were characterized on the basis of four grab samples each, at three sites, indicating bed materials consisting of approximately 50 to 70 per cent fine sand, the remainder being primarily silt. At the project flow of 14.2 m^3/s the model predicted extensive flooding downstream of Highway No. 6, but little flooding upstream of the highway. By progressively reducing the flow rate the model was used to show that a flow of 8.5 m^3/s could be carried by the channel without flooding anywhere along the reach.

Neither of these two results are confirmed by field evidence. There was significant overbank flooding upstream of Highway 6 at a flow of 14.2 m^3/s and the observed pre-project channel capacity of the entire reach was only one half of the predicted 8.5 m^3/s (Qu'Appelle Implementation Office, 1979). The discrepancies are probably due to some or all of the following factors:

(i) There are many localized irregularities in the Qu'Appelle River channel, such as beaver dams, debris accumulations, remnants of bulldozed, temporary back-flooding dams built by local farmers and constrictions due to bouldery lag deposits (e.g. Plates 2.2, 2.9 and 2.11). None of these flow obstructions were incorporated into the model, because they do not show up in the cross-section surveys.

(ii) The natural Qu'Appelle River channel has densely vegetated banks and in some reaches the channel capacity may be severely reduced due to this vegetation (e.g. Plate 2.3). The degree of vegetation encroachment into the active channel probably varies over time, with the seasons, with the size of recent floods and particularly with the amount of runoff during the growing season.

(iii) MOBED's bed roughness routine is based on data describing the flow in prismatic channels with sand beds. In view of the silty sand bed material, which probably exhibits a certain amount of cohesion, and the almost continuous, severe channel curvature, it would be most surprising if the type of bed roughness calculated by MOBED did in fact correspond to the actual channel roughness.

A real test of MOBED's capability to model the sediment transport regime of the Qu'Appelle River would have required the routing of many years of observed flow hydrographs through the pre-project channel to show that, given reasonable sediment inflow assumptions at Craven, the natural channel remains free of significant local aggradation or degradation, as indicated by observation. This type of computation was, unfortunately, not carried out.

Following the initial application of MOBED to the pre-project Qu'Appelle River channel, the model was then applied to the enlarged and shortened design channel. Krishnappan's assumed "design channel" appears to differ somewhat from both Tables 2.1 and 2.2, but the discrepancies are relatively minor. Assuming an incoming sediment load balancing the transport capacity of the upstream reaches, and assuming further a constant flow of 14.2 m^3/s, the MOBED water levels closely confirm those of the project designers. This simply indicates that the channel roughness computed by MOBED must be close to the roughness assumed by the designers (Mannings n = 0.03).

In view of the fact that MOBED appears to over-estimate the capacity of the natural pre-project channel one might wonder whether the predicted capacity of the project channel may not turn out to be an over-estimate too, particularly after several years of progressive bank revegetation, point bar formation, beaver activity, etc. However, as an initial post-project assumption, the Mannings n value of 0.03 is certainly reasonable.

In order to study the long-term evolution of the Qu'Appelle River profile, the model was run with a constant flow of 14.2 m^3/s and the computed pre-project sediment transport at Craven as upstream input. Running the model for a period of 3 years produced the results shown here in Figure 2.1. The model predicts almost 5 m of degradation at Craven, with the degrading reach extending over at least 14 km after three years. Near Pasqua Lake there is 1 to 2 m of aggradation over a 25 km reach, pushing water levels well above flood plain levels locally. The intermediate 35 km reach is characterized by irregular aggradation and degradation of order 1 m after 3 years.

As a further test the model was also run with a synthesized hydrograph based on 67 years of observed flows producing the results shown here as Figure 2.2. The derived hydrograph obviously produced somewhat slower and more irregular changes than the constant flow. After 7 years, degradation at Craven reaches 8 m and maximum aggradation near Pasqua Lake is estimated as 3.5 m.

If the main MOBED predictions of aggradation and degradation were to materialize, they would seriously endanger the viability of the project. The key MOBED prediction evident in both Figures 2.1 and 2.2 is the extremely flat channel gradient developing near Craven and extending itself gradually downstream. Provided the model was run over much longer time periods, this flat gradient

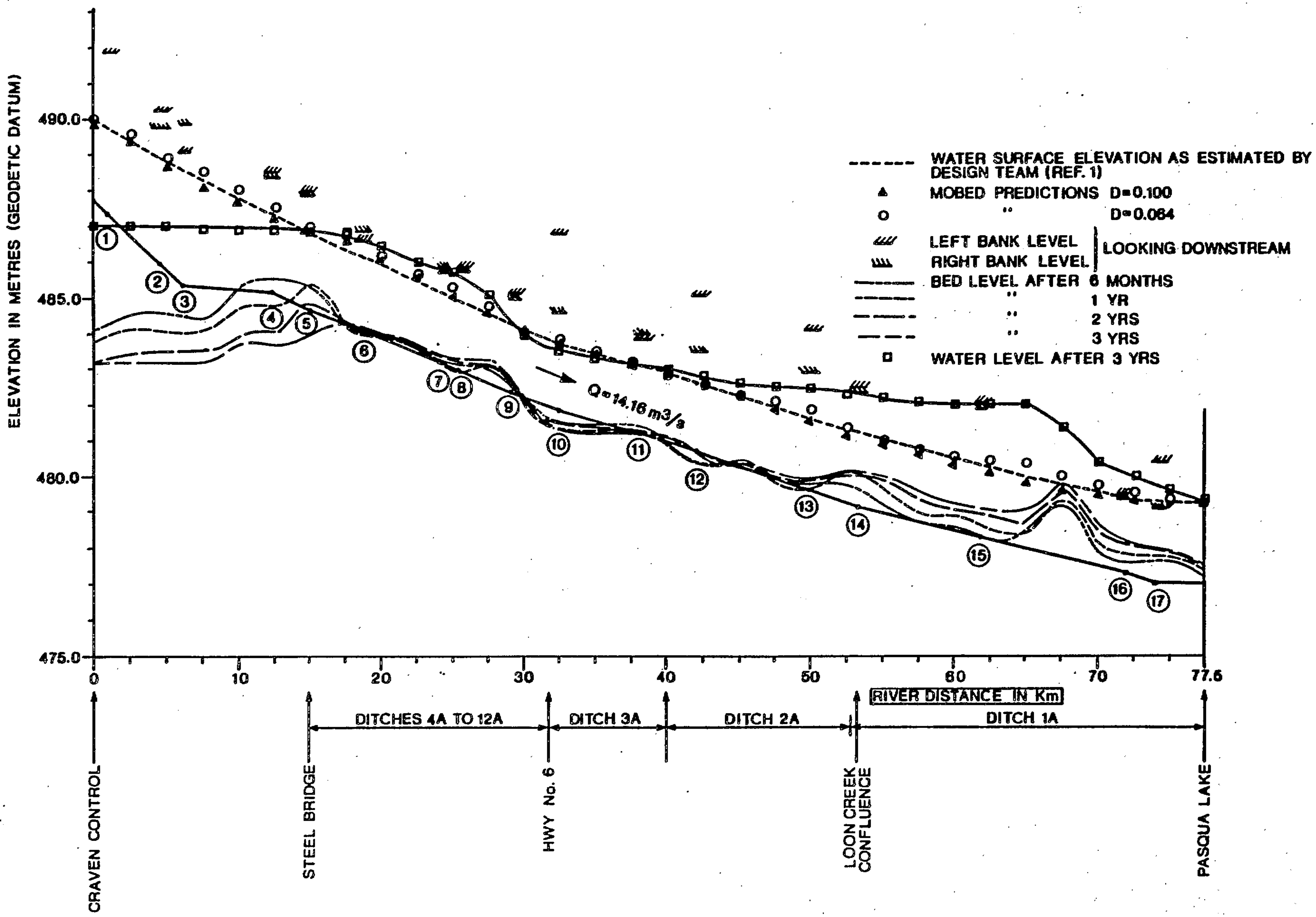

Figure 2.1: Variation of bed levels as predicted by MOBED for the Qu'Appelle River Reach between Craven and Pasqua Lake (from Krishnappan, 1986).

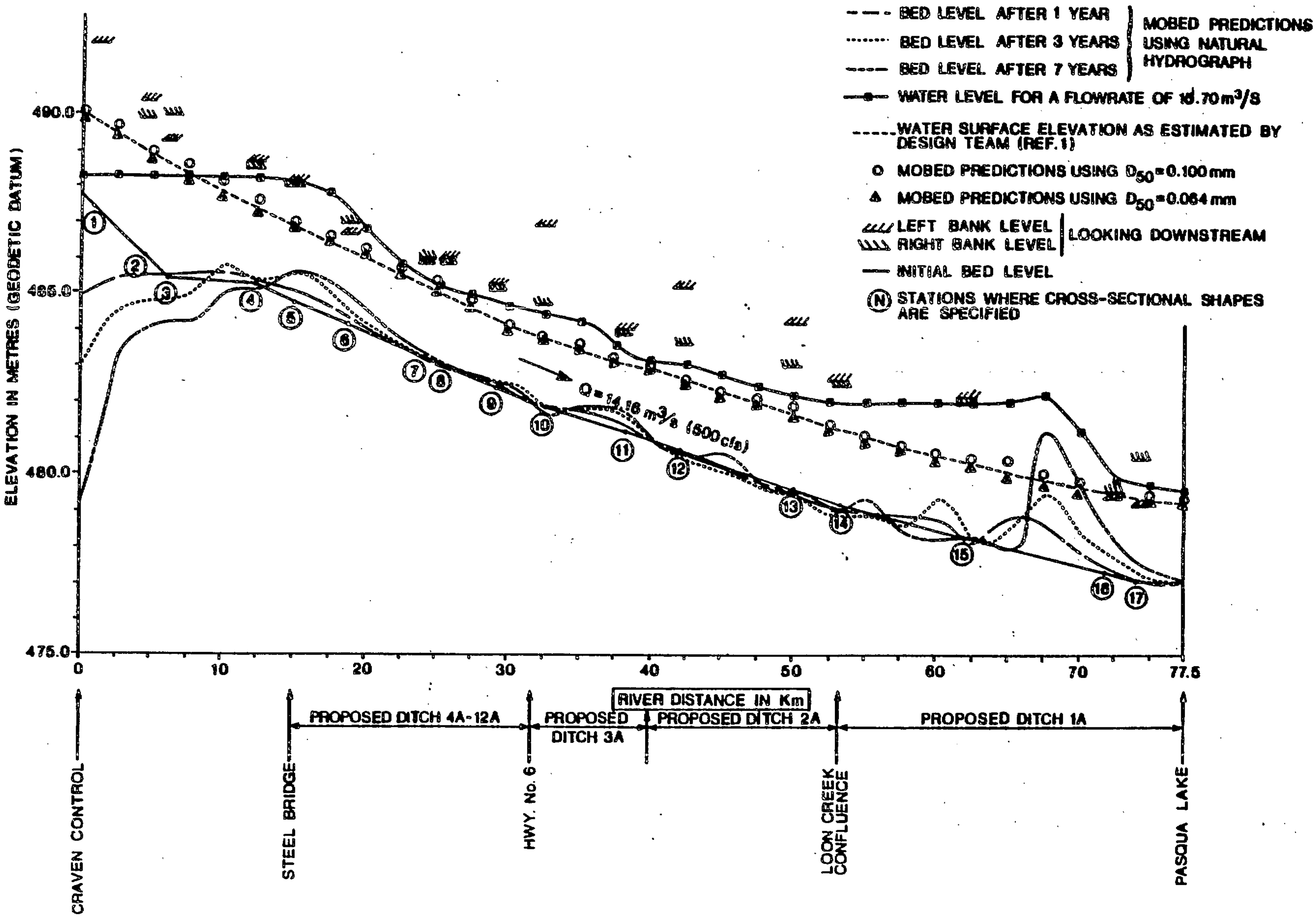

Figure 2.2: Variation of bed levels as predicted by MOBED for the Qu'Appelle River between Craven and Pasque Lake using natural hydrograph (from Krishnappan, 1986).

would probably become established over much of the reach, with correspondingly massive degradation near Craven. Channelization of tortuously meandering rivers is well known to have the potential for effects such as incision and upstream degradation (see Section 3 below), so that this prediction cannot simply be dismissed as a computational accident. MOBED does, however, ignore several factors and processes that could limit or even invalidate the prediction of upstream degradation. They are:

(i) The bed materials of the Qu'Appelle River are not nearly as uniform as assumed for the MOBED computer runs. There are localized, coarse lag deposits in the Qu'Appelle Valley which, if encountered by the river, would limit degradation. More importantly, most of the sediments underlying the Qu'Appelle Valley floor are considerably finer and more cohesive than indicated by the few bed material samples which were used to characterize the MOBED bed material. These samples characterize the pre-project Qu'Appelle River bed material and probably do this quite adequately. However, most of this silty-sand has now been excavated and the post-project bed materials, as indicated by the composition of the spoil piles (Plate 2.12), are generally finer and more cohesive. There are probably many reaches, particularly at meander cutoffs, where the post-project channel flows on clay or silty-clay. The MOBED sediment transport routine is not applicable to such sediments and it would tend to over-estimate their mobility if a fine, non-cohesive sand is used instead, as was done here.

(ii) The combination of channel curvature which will lead to the formation of point bars on the inside of chan-

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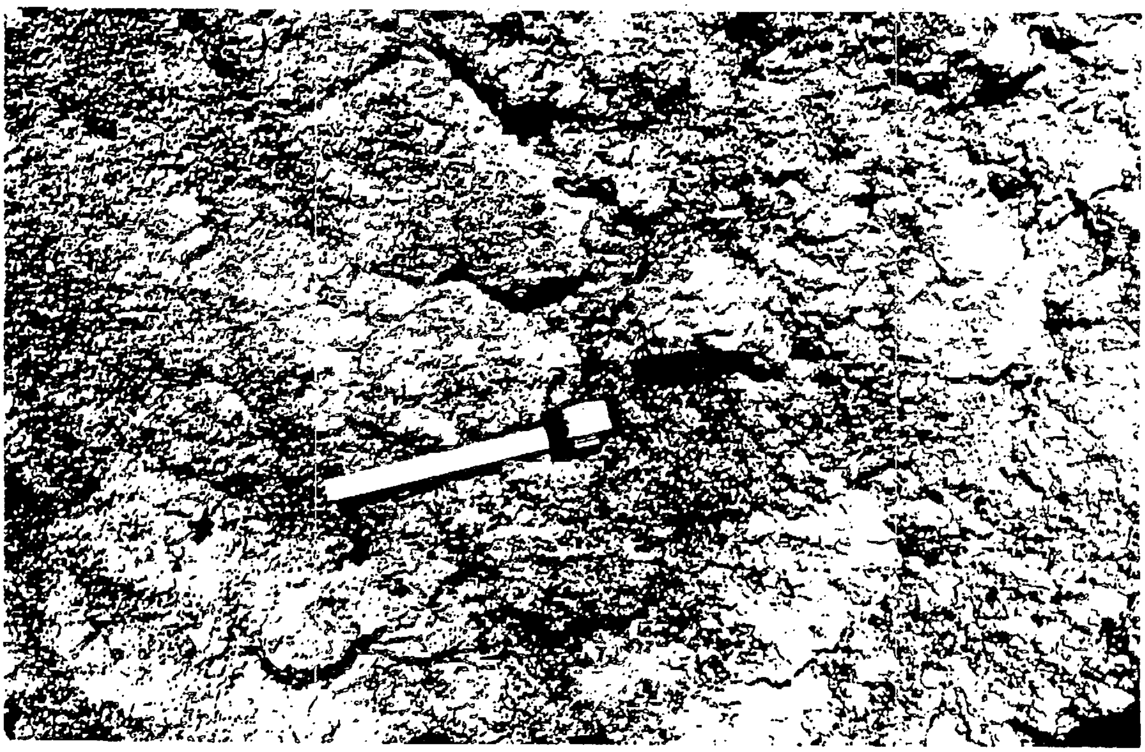

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[illegible]: [illegible] illustrate [illegible] the sediments in the channel excavation spoil piles (see Plate 2.7 for a site overview).

nel bends, and vegetation encroachment onto these bars creating favourable conditions for accelerated further deposition, will probably lead to energy losses considerably greater than those computed by MOBED, with its assumptions of rigid sides and a flat, mobile bed. The Mannings n value of 0.03 assumed by the project designers might well prove to be rather low after a few years of bar formation and vegetation encroachment.

(iii) The project channel cross-section with its relatively constant 2:1 (locally 3:1) bank slope and flat bed does not correspond to natural river sections for gently sloping flood plains with predominantly cohesive sediments. Natural river sections would tend to have steeper banks along straight reaches and particularly along the outside of bends. Over time the Qu'Appelle will probably work towards re-establishing a more natural channel cross-section. This is another effect that cannot presently be computer modelled.

(iv) Finally, it is quite inconceivable for a 10 to 15 m wide excavated drainage channel, such as the enlarged Qu'Appelle, to degrade by several metres without also trying to widen. Since the enlarged Qu'Appelle channel does not have protected (rip-rap lined) banks and there is little difference between the bed and lower bank materials, any tendency towards bed degradation would immediately lead to some bank erosion which, in turn, would increase the sediment supply, thereby slowing bed degradation.

The other important MOBED prediction besides degradation, the massive aggradation indicated for a relatively short channel reach some 10 km upstream of Pasqua Lake, is different in so far as it does not correspond to any known river process and, to the writer's knowledge, there are no reported case histories that would lend support to such aggradation. This prediction can safely be dismissed as a computational accident without any basis in reality. Minor aggradation in the deltaic reach is possible, although improbable. The vast bulk of the sediment eroded out of any degrading reaches would clearly end up in Pasqua Lake, not at the site 10 km upstream of the lake predicted by MOBED.

2.3 INITIAL MONITORING

The project designers are well aware that the Qu'Appelle River channelization over a 75 km reach constitutes a severe interference with the natural river regime which might initiate a not altogether predictable sequence of future channel changes. Because of the exceedingly low energy-line gradient over this reach, it was assumed that any such changes would be very gradual, leaving lots of time for remedial measures, if needed. Consequently, no systematic post-construction monitoring was initially planned. In view of the rather startling predictions of the MOBED computer model, a small monitoring program was, however, initiated by Environment Canada in 1986.

Five monitoring cross-sections were established in 1985 along the 2 km section of enlarged channel below the Craven control structure. The location of these sections is shown on the plans in Appendix 1. The sections were surveyed and monumented in 1986 and checked again in 1988 without finding any significant changes.

As a second monitoring site, a reach of 2.3 km of flood control channel (4.4 km of pre-project length) a short distance downstream of the Highway No. 6 crossing at Fairy Hill was documented with 15 cross-sections surveyed in May, 1987 (pre-project) and re-surveyed in November, 1987 (post-project). Further downstream, six post-project cross-sections were surveyed in October, 1987 on the Piapot Indian Reserve, along a 19.2 km section of flood control channel. The location of all these sections is shown in Appendix 1.

All the above sections are surveyed and plotted but the condition of the end-of-section monuments is presently unknown. As there have not been any significant flows on the Qu'Appelle River since 1985 when the project was initiated (see Section 1.1.1), and visual inspection indicates that no significant changes have occurred, there has been no incentive to re-survey the monitoring cross-sections.

As part of a training exercise in the summer of 1989, crews from the Water Survey of Canada (Environment Canada) have also surveyed short channel reaches in the vicinity of the two stream gauging sites, Qu'Appelle River below Craven Dam and Qu'Appelle River below Loon Creek. The surveys consist of 15 and 11 cross-sections, respectively, centred on the gauging section. Attempts to re-establish the 1985 cross-sections in the vicinity of Craven Dam met with limited success due to difficulties in relocating the end-of-line markers. As a result only one of the 1985 sections was re-established (Ted Yuzyk, pers. comm.).

All the cross-section sites established in 1989 are permanently monumented. The two reaches are each approximately 600 m long. Given the exceedingly flat slope of the Qu'Appelle River, this study reach is unfortunately considerably too short to give any reasonable definition of an energy line gradient. To make matters worse, both reaches contain a rip-rapped cross-section where, at least at low flows, a significant drop (0.6 m and 0.2 m, respectively) occurs. In addition to the cross-section surveys, the two Water Survey reaches are also documented with numerous ground photographs and bed and bank material samples. A summary of the information collected below Craven Dam and below Loon Creek is included here in Appendices 2 and 3, respectively.

Based on the gauge rating curves the two surveys do allow an independent determination of local bankfull flows. Below Craven Dam, the average river bank elevation is approximately 491.7 m and, according to Rating Table No. 13 (April 4, 1979) the corresponding bankfull flow at that time was 48.6 m^3/s. At the gauge below Loon Creek the average river bank elevation is approximately 481.6 m and the corresponding flow, based on Rating Table No: 7 of May 13, 1977 is 24.8 m^3/s. Note that both of these flows are <u>pre-project</u> estimates of "bankfull flow". Why they are so much greater than the "channel capacities" listed in various engineering reports is not entirely clear, although arguments presented in Section 3.2 may help explain at least some of the discrepancy.

3.0 RELEVANT CASE HISTORIES

3.1 INTRODUCTION

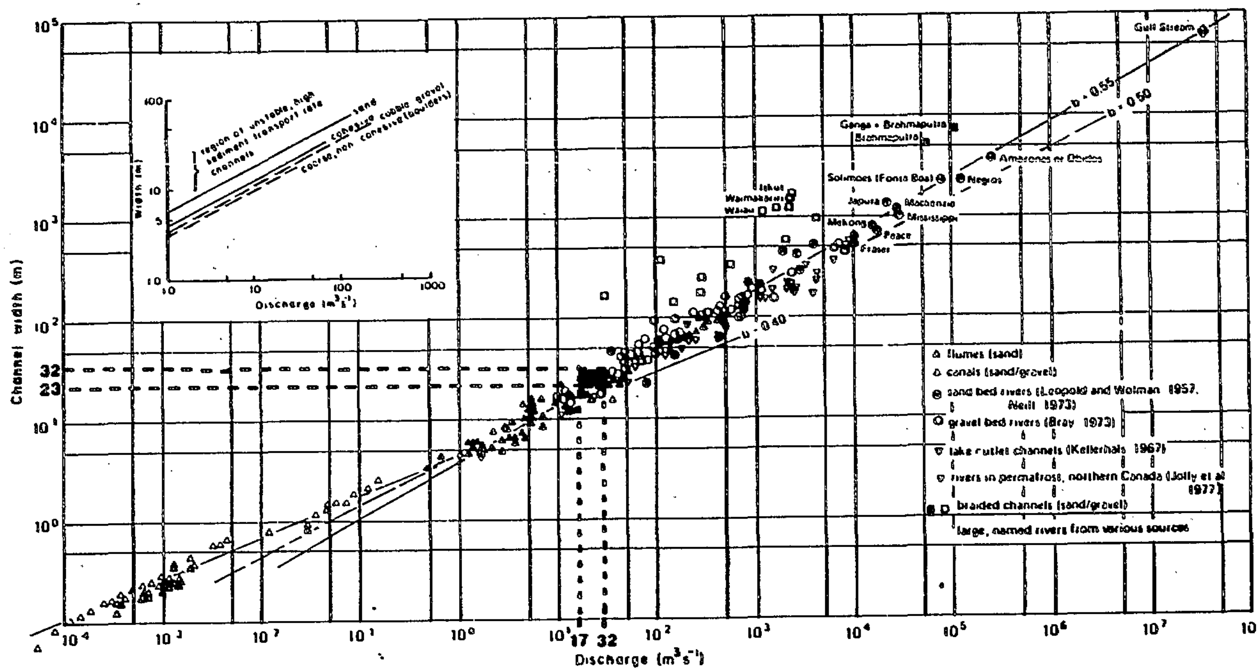
In order to develop an understanding of the Qu'Appelle River and it's probable response to man-made interferences, one first needs to determine where and how it fits into the broad continuum of alluvial rivers. This, in turn provides a basis for finding more or less comparable rivers and for transferring any lessons learned there to the Qu'Appelle. In view of the severe degradation predicted by the sediment routing model (MOBED), channel and flood plain slope are particularly important parameters to be reviewed.

3.2 CHANNEL WIDTH

Channel width is the most obvious and also the most reliable measure of the "size" of a river. In the case of a single-channel river, meandering across a broad flood plain, such as the Qu'Appelle, it also tends to be a remarkably stable and relatively easily defined and measured morphological parameter. Numerous studies have shown that it is closely related to some consistently defined "channel forming" or "dominant" discharge. Commonly used measures of such a discharge are either the bankfull flow or the 2-year flood. Figure 3.1, from Kellerhals and Church (1989), shows that channel width is proportional to approximately the square root of discharge over a range of many orders of magnitude, but there are clearly some secondary factors that also affect channel width. The main ones are:

(i) the sediment transport regime;

(ii) bed and bank materials;



NOTE: 17 m³/s represents the 2-year return period flow.
32 m³/s represents the post-project bankfull flow.

QU'APPELLE FLOOD CONTROL CHANNEL

Figure 3.1: Scale relation for channel width vs. flow. Small straight channels have $\omega \propto Q^{0.4}$ indicating that dynamical similarity is maintained. However, large large river channels have $\omega \propto Q^{0.55}$, approximately, indicating that they become distorted to relatively greater width as they grow larger. Inset: variation in channel width at a given discharge due to material, properties based on Simons and Albertson (1960)(from Kellerhals and Church, 1989).

(iii) valley slope; and

(iv) the discharge regime.

These factors are responsible for up to an order of magnitude of scatter in observed W_s values at any given discharge.

If one accepts observed channel capacities as estimates of bankfull flow, the indicated values for the Qu'Appelle River appear to be around 7.1 to 8.5 m^3/s (Saskatchewan Water Resources Commission, 1972). Entering with this range into Figure 3.1 suggests that channel width should fall in the range of 8 to 20 m. Table 3.1 summarizes various pre- and post-project surveys which indicate that the pre-project bankfull channel width was significantly greater than 20 m, probably more in the range of 22 to 27 m. This discrepancy is probably caused by the difference between channel capacity, as see from an engineering point-of-view, and the morphologically relevant "bankfull" flow. In a valley with a broad and very low flood plain there can be extensive flooding long before the channel reaches morphologically "bankfull" conditions because major flood plain areas are lower than much of the channel banks. The process of natural levee building tends to raise terrain levels near the channel, but there are generally enough low spots to ensure that all the low flood plain areas are flooded as soon as the river reaches the appropriate level.

The 2-year flood discharge is also frequently used as an estimate of the channel-forming discharge It is both more stable and easier to determine than bankfull flow and there does appear to be a reasonably close correspondence between the 2-year flood and bankfull flow on many rivers. For the two Water Survey of Canada gauges along the study reach, at Craven and below Loon Creek, the mean daily 2-year floods are 16 and 19 m^3/s, respec-

TABLE 3.1: BANKFULL WATER SURFACE WIDTH
(from various sources)

SITE	AVERAGE BANKFULL WATER SURFACE WIDTH				SOURCE, COMMENTS
	PRE-PROJECT (m)	NUMBER OF SECTIONS	POST-PROJECT (m)	NUMBER OF SECTIONS	
TYPICAL FOR PROJECT	32.3	3	32.3	3	Krishnappan, 1986, Figure 3
ALONG PIAPOT INDIAN RESERVE			27.2	6	In a reach with side slopes specified at 3:1 (rather than 2:1 as used elsewhere)
NEAR FAIRY HILL	22.2	11	23.0	10	Surveyed by Environment Canada, Water Management
BELOW LOON CK.			30.9	11	Surveyed by Water Survey crew, in the vicinity of the gauge
BELOW CRAVEN	24.0	2	26.5	11	as above
BELOW CRAVEN			24.7	4	Surveyed by Environment Canada, Water Management

tively.[1] According to Figure 3.1 this suggests width values of 15 to 30 m, which appears to agree closely with the field data of Table 3.1.

Post-construction surveys of the flood control channel indicate that, in general, the project results in only minor increases in channel width (Table 3.1). The observed range is 23 m to 32 m. The bankfull flow is however increased significantly and may be as high as 32 m^3/s along much of the post-project channel (Section 2.1). Since width only varies as Q to the half power, even this much higher flow does not appear to require a significantly wider channel than what is available. If anything, the channel is possibly somewhat too wide for the available flows.

Figure 3.2 shows a proposed width-discharge relationship for flood control channel design (Neill and Yaremko, 1988). It too indicates that the observed post-construction bankfull width, ranging from 23 to 32 m, corresponds to a discharge range of 23 to 130 m^3/s, confirming again that the channel is, if anything, somewhat on the wide side.

3.3 CHANNEL SLOPE

Only an overall reach value of natural, pre-project channel slope is available. Based on a channel length of 115 km and a drop of 10.8 m it amounts to 0.000094. There was probably considerable variation and a general trend of flattening out towards Pasqua Lake. The corresponding post-project slopes are listed in

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[1] Estimates based on log normal distribution fitted by method of maximum likelihood. A representative value of 17 m^3/s has been adopted in subsequent calculations.

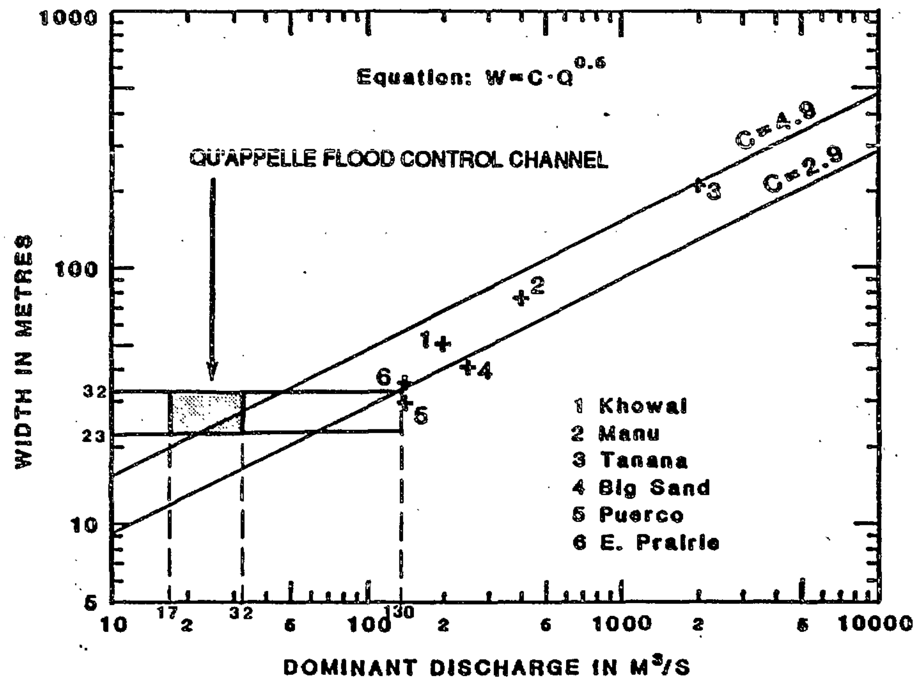

Figure 3.2: Form of regime width plot showing data for quoted rivers (from Neill and Yaremko, 1988).

Tables 2.1 and 2.2. They range from 0.00010 near Pasqua Lake to 0.00019 upstream of Highway No: 6. As in the case of channel width, numerous studies have shown that channel slope varies with discharge, generally declining with increasing discharge, but, contrary to channel width, channel slope is affected by at least two other factors of equal or even greater importance than discharge. They are:

(i) bed materials; and
(ii) bed load transport rate.

At any particular channel-forming discharge, channel slope can range over at least three orders of magnitude. The Qu'Appelle River, with its silt to fine sand bed and its low sediment transport rate, can be expected to occupy the very low end of all observed slopes within its channel-forming discharge range of 17 m^3/s (2-year flood) to 32 m^3/s (post-project bankfull flow in the flood control channel).

Figure 3.3 shows some sand bed canal and river data from Neill, 1973, with the Qu'Appelle range superimposed. Figure 3.4 is a similar chart proposed for the design of flood control channels in Neill and Yaremko, 1988. The Qu'Appelle flood control channel appears to operate at a slope that would not allow it to transport any significant sand load if such a load were to be carried into the river reach from upstream or out of tributaries. The fact that the channel is, if anything, somewhat too wide for the available flows (Figure 3.2) also tends to reduce the sediment transport capacity.

Of the flood control channelization case histories discussed in Neill and Yaremko, 1988, only the East Prairie River channeli-

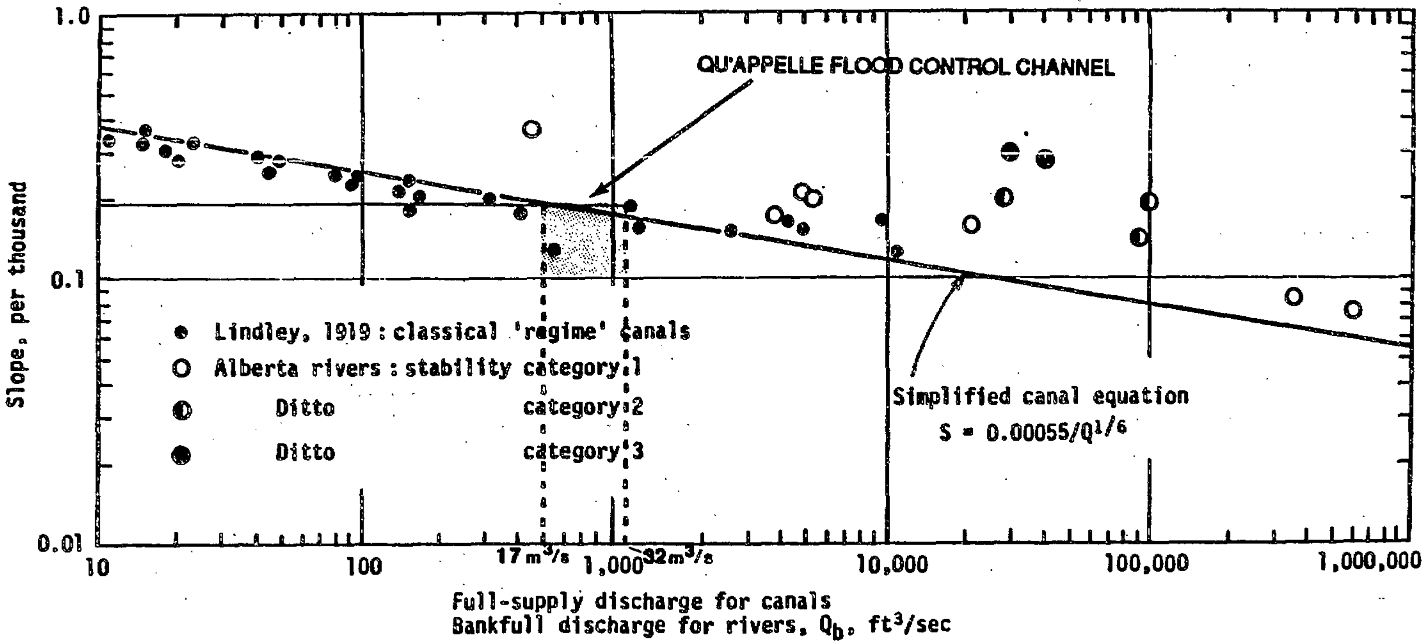

Figure 3.3: Slope vs. channel-forming discharge for sand-bed canals and rivers (from Neill, 1973).

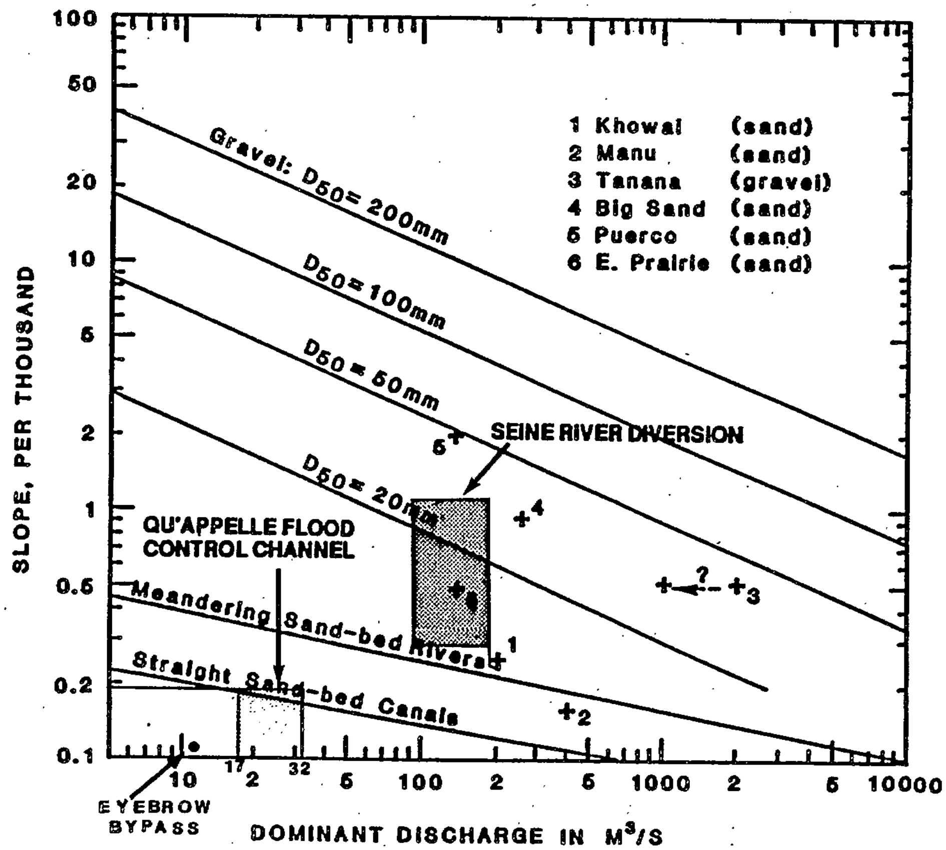

Figure 3.4: Form of regime slope plot showing data for quoted rivers (from Neill and Yaremko, 1988).

zation in Alberta is potentially relevant to the Qu'Appelle River. It is described as follows:

> "In its natural state the river had a serpentine meander pattern and dense bank vegetation with channel debris, and frequently flooded adjacent agricultural land. The bed was of medium sand overlying lacustrine clay or glacial till at shallow depths. The slope was 0.5 per 1000 or less and the bankfull discharge about 60 m^3/s. In 1962 a length of about 14 km above the mouth was replaced with a straight excavated channel and low setback dikes for a design capacity of about 140 m^3/s on a slope of 1 per 1000 over the upper 11 km and 0.5 per 1000 over the lower 3 km.
>
> The slope response between 1968 and 1984 is illustrated in Figure 6 [Figure 3.5 in this report]. By 1984 the lower half of the channelized length where sand is depositing had adjusted to a slope of about 0.3 per 1,000, and the upper degradational half to about 0.5 per 1,000. A steeper "nick zone" (Schumm et al., 1984) had advanced in silt and clay materials to about 5 km upstream of the channelization. Assuming that bed-sediment transport will be low after stability is achieved, a final regime slope of about 0.2 per 1000 or less has been estimated for the channelized reach."

The important differences between the East Prairie River and the Qu'Appelle River are that the East Prairie has an entirely non-cohesive sand bed and plots significantly above the Qu'Appelle on the slope-discharge plot of Figure 3.4. This difference between

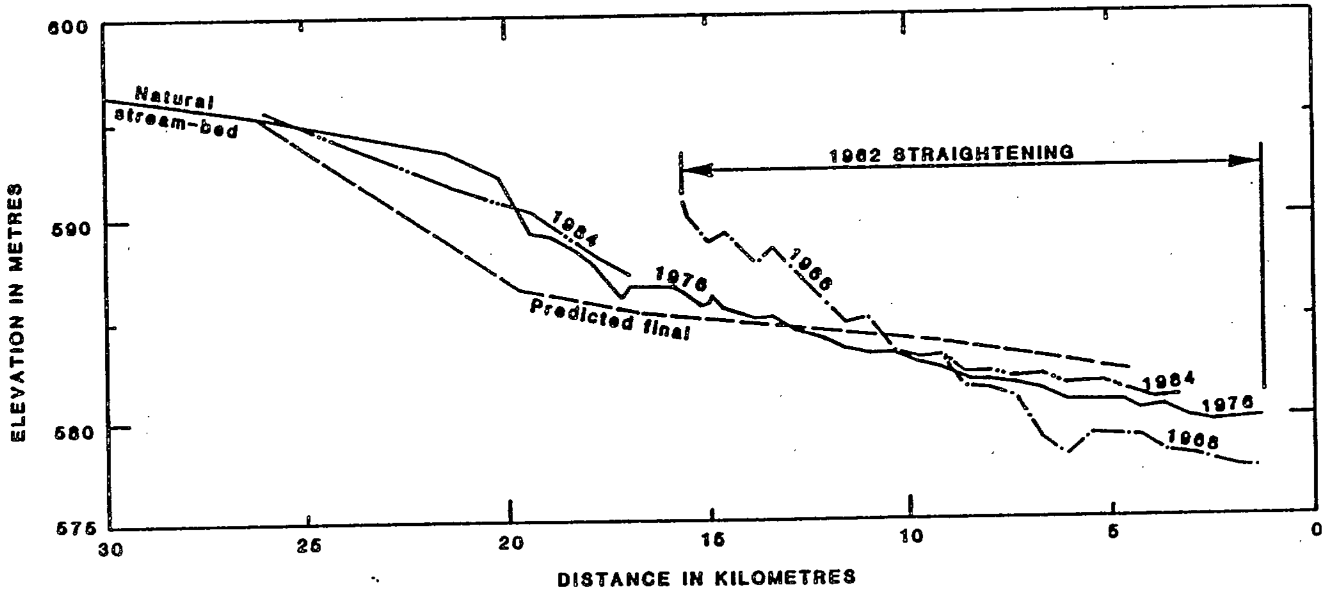

Figure 3.5: Slope profiles of East Prairie River channelization, Alberta (from Neill and Yaremko, 1988).

the Qu'Appelle and East Prairie Rivers is also indicated by Figure 3.6, from Keller and Brooks, 1983, which is another study of the effects of channelization. Lines A, B and C have been proposed by various authors as the location of the transitions from stable to unstable channels. Here too the channelized Qu'Appelle River is much further removed from instability than the East Prairie River.

The Seine River diversion, south of Winnipeg, is a more relevant case history than the East Prairie River because it is excavated into the lacustrine silts of Lake Agassiz (Galay, Block and Caron, 1970). The diversion is approximately 30 km long, with the design capacity ranging from 93 m^3/s at the inlet to 190 m^3/s at the confluence with the Red River (outlet). Mean annual flood peaks (daily) range from 16.2 m^3/s to 68 m^3/s. Slopes range from 0.0011 to 0.00028 and design velocities, with a Manning's n of 0.025, from 1.02 m/s to 1.75 m/s. This diversion experienced serious degradation problems almost immediately. Several drop structures had to be built to dissipate excess energy. The Seine River positions on Figures 3.4 and 3.6 confirm the conclusion of Galay <u>et al.</u> (1970) that the steepest design slopes were an order of magnitude too steep and the design velocities correspondingly too high also.

A further relevant case history is provided by the Eyebrow Lake bypass channel, which is a channelization of the upper Qu'Appelle River around Eyebrow Lake (Figure 1.1 and Plates 3.1 to 3.3). The design capacity is 11.3 m^3/s and the overall slope is 0.00012 over a reach of 9.8 km length. After two years of operation, during which flows reached design capacity on several occasions, the channel shows no signs of degradation and only minor bank erosion. Sediment deposition and vegetation encroachment have occurred, as illustrated on Plates 3.2 and 3.3.

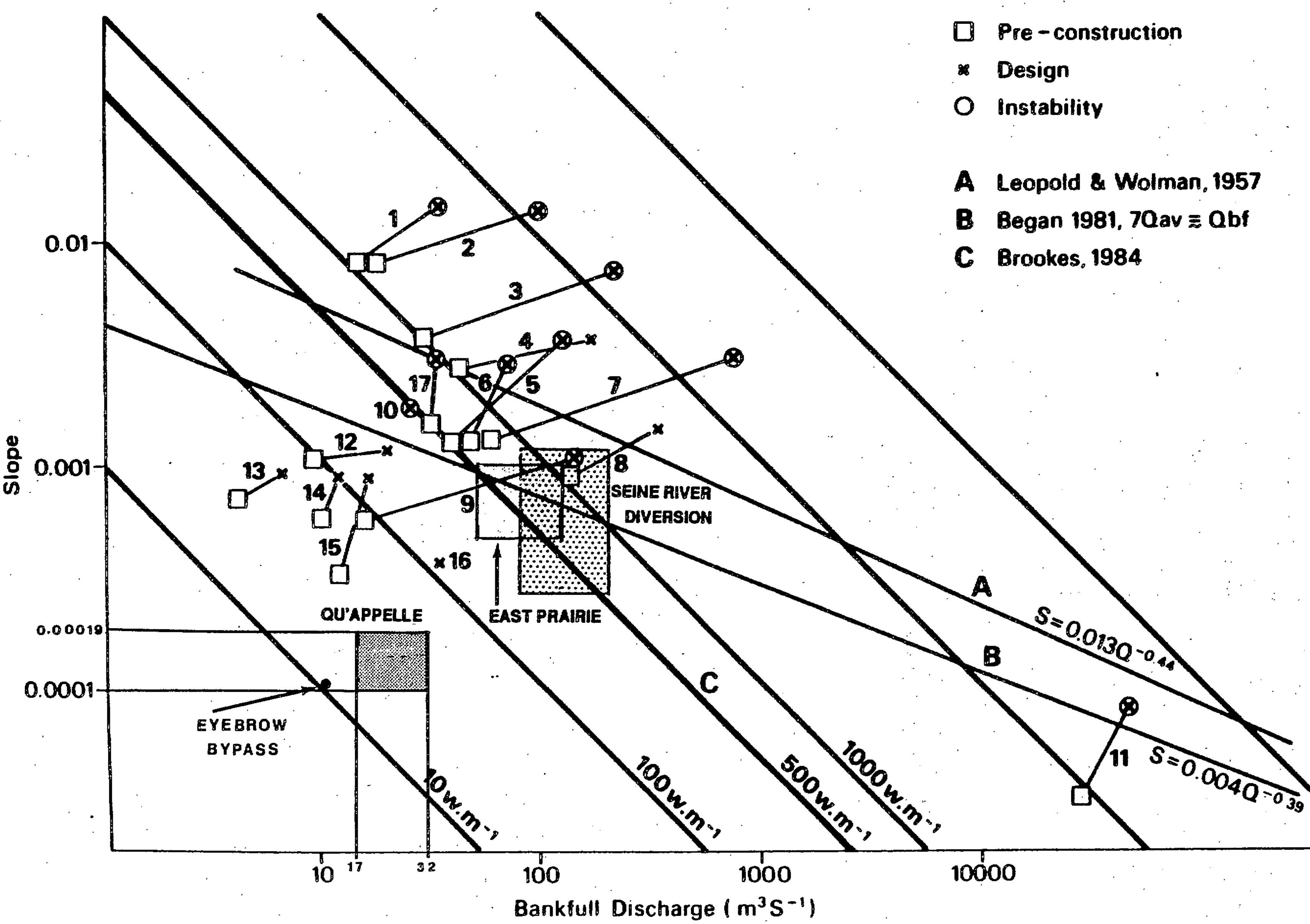

Figure 3.6: Lines of equal stream power and change in stream power due to channelization are illustrated (from Keller and Brooks, 1983).

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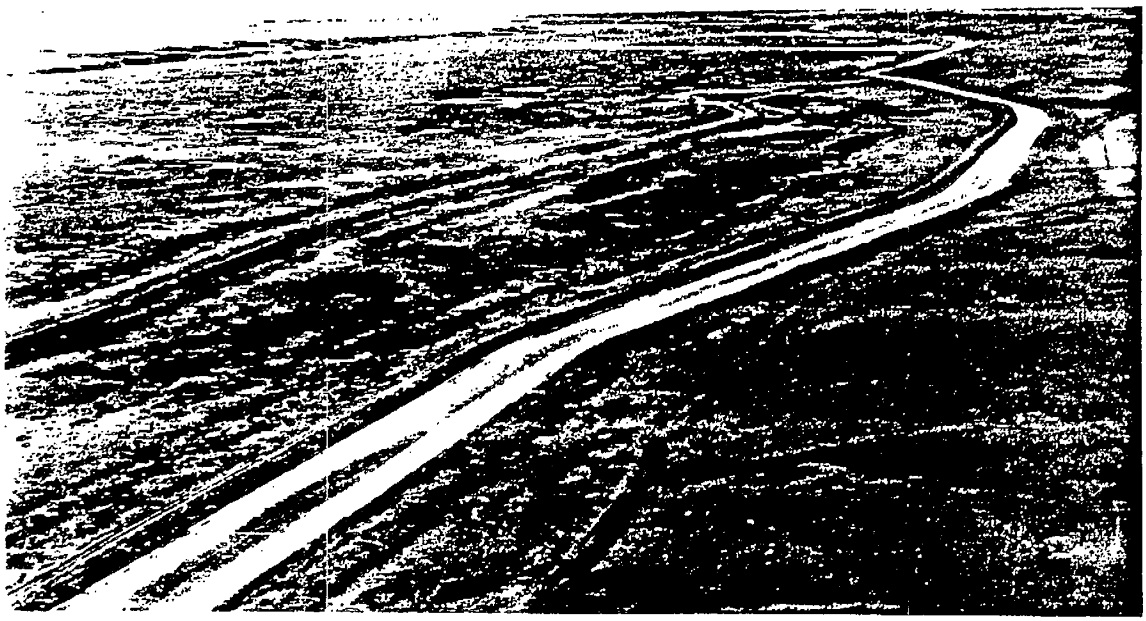
Looking south, downstream of Eyebrow Lake



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Looking north at Eyebrow Lake

Plate 3.1: Enlarged section of the Qu'Appelle River in the vicinity of Eyebrow Lake.

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March 24, 1988 M 88-34-04

Plate 3.2: Enlarged section of the Qu'Appelle River downstream of Eyebrow Lake illustrating minor bank erosion, point bar development and vegetation encroachment into the channel.

March 24, 1988 M 88-35-21

March 24, 1988 M 88-35-24

Plate 3.3: Qu'Appelle River downstream of Eyebrow Lake, showing minor bank erosion and point bar development.

The Assiniboine River (Portage) Diversion and the Red River Floodway are both straight, low-gradient flood-bypass channels built mostly in lacustrine clay. Their design flows are one to two orders of magnitude greater than the design flow of the Qu'Appelle channel, but the gradients, which range from 0.00009 to 0.00023 are similar to the Qu'Appelle River gradient. A study by Penner and Vitkin (1978) found very little evidence of erosion after 7 to 8 years of operation. Since both the velocities and the boundary shear forces (tractive force) are considerably greater in the two flood-bypass channels than in the enlarged and shortened Qu'Appelle River channel, these results indicate that significant degradation of the Qu'Appelle into the underlying cohesive sediments is most unlikely.

No case histories indicating bed degradation in the slope-discharge range of the Qu'Appelle flood control channel could be located. It appears that the channel slope falls somewhat below the slopes of comparable stable, straight irrigation canals, indicating that the design slope is, if anything, relatively low. Since the natural, meandering river channel operated at an even flatter slope, the incoming bed material load must be exceptionally low.

4.0 PREDICTED MORPHOLOGICAL CHANGES

4.1 TIME SCALES FOR MORPHOLOGICAL CHANGES

Morphological change operates at a very broad range of time scales. While flow-dependent aspects of morphology such as velocity, depth, local sediment transport and type of bed forms might change at a scale of hours, channel plan form (pattern) or reach slopes might be subject to changes that take centuries to become clearly defined. Cross-sectional parameters such as channel width or channel depth (below the flood plain) are likely to change at rates that become definable over periods of a few years to a few decades.

In the present context, where a natural, stable and well-defined channel morphology has been disturbed abruptly by human interference, it may be most appropriate to look at four time scales of morphological change:

(i) the initial abrupt man-made disturbance;

(ii) expected short-term changes over periods of a few years;

(iii) expected medium-term changes over periods of a few decades; and

(iv) long term changes over many centuries.

Since the rate at which morphological changes can take place depends greatly on the occurrence of floods, the stated time ranges need to be interpreted accordingly. After a ten-year period of very low floods one might still see "short-term" changes, but a major flood might place one immediately into the "medium" term.

Table 4.1 is set up to summarize the morphological changes on the basis of the above time scales. The alternative approach of addressing change according to the affected parameter is adopted for the remainder of this section.

4.2 CHANNEL WIDTH, BANK EROSION, CROSS-SECTIONAL SHAPE AND SINUOSITY

The intent of the project designers was not to widen the channel significantly and what little monitoring data is available bears this out. As indicated by Table 3.1, the new channel may have a slightly greater bankfull width than the existing channel, but it also has significantly greater bankfull flows. The river could readily increase its width by way of bank erosion. Width reduction is only possible through deposition of suspended load onto the excavated banks, a very slow process.

Since the available evidence suggests that the new channel is, if anything, slightly too wide, we expect no significant width changes on the intermediate term. The long-term equilibrium width will probably also not differ greatly from the design channel width.

Localized bank erosion should be expected at numerous sites, particularly on the outside banks of sharp bends. In long straight reaches the river will probably develop a meandering tendency, attacking alternate banks at reasonably regular spacing. Straight reaches with sharp upstream bends such as those shown on Plate 2.10 (Muscowpetung Reserve) are most likely to develop meandering tendencies.

TABLE 4.1: SUMMARY OF ANTICIPATED CHANGES IN CHANNEL MORPHOMETRY, SEDIMENT TRANSPORT AND CONVEYANCE

MORPHOLOGIC FEATURE	INITIAL CHANGE	SHORT TERM (years)	MEDIUM TERM (decades)	LONG TERM
Bankfull Channel Width	minor increase	no change	minor change direction unknown	minor change direction unknown
Bank Erosion Rate	not applicable	increase	increase	decline to pre-project value
Sinuosity	massive reduction	no change	no change	very slow increase
Channel Slope	massive increase	no change	local adjustments	very slow decrease
Channel Depth Below Flood Plain	increase	local increase	overall decrease with local increases	decrease
Sediment Transport	increase	decrease	decrease	very slow decrease towards pre-project value
Conveyance	increase	decrease	decrease	very slow decrease towards pre-project value

On the inside of bends, point bars will gradually accumulate and change the shape of the sections from their present trapezoidal form to a more natural, triangular shape. Material accumulating in the channel will gradually reduce the cross-sectional area, but it will only revert back to its natural size on the long term.

In the past the meander bends of the Qu'Appelle River have migrated slowly across the flood plain. This process will continue at a somewhat faster rate, due to the increased river slope and due to the increased in-channel flows. On the very long term this process will try to re-establish the much greater, pre-project sinuosity.

4.3 SLOPE, DEPTH AND CONVEYANCE

Since the steepened, post-project channel slope is well within the stable range of slopes for the prevailing bed materials, there will be not widespread channel degradation. On the medium term there might be minor local degradation of order 1 m at sites where there has been particularly severe channel shortening, such as at Craven. Aggradation will be the prevailing, albeit slow, process along most of the channel length. Due to sediment accumulation in the enlarged channel, average bed levels will probably rise, but only very slowly. This will gradually reduce the channel depth and with it the channel conveyance.

Vegetation encroachment into the channel will affect conveyance almost immediately, however the reduction in capacity will become more noticeable over the medium term as shrubs, such as willows, gradually replace the initial ground cover of herbaceous plants. Beavers are also likely to become more widespread following shrub development and dam construction will cause a further reduction in conveyance.

4.4 SEDIMENT TRANSPORT

Many channelization projects have resulted in unstable channels with excessive sediment transport capacity. Such channels degrade their bed or erode their banks to satisfy the excess transport capacity. These processes are self-perpetuating and may take centuries to run their course. In the case of the Qu'Appelle, all the comparative evidence suggest that the threshold towards an unstable, eroding channel has not been crossed. The overall trend will likely be towards slow sediment accumulation in the channel on the medium to long term, local bank erosion not withstanding. The Qu'Appelle delta in Pasqua Lake will receive significant slugs of sediment during the first few post-project floods, but on the medium to long term there will be only minor increases in sediment delivery to the delta. Elsewhere along the channel, local sediment transport rates will be somewhat greater than natural, but mainly due to the more active bank erosion and point bar deposition. The overall sediment budget of the study reach should not change significantly, even on the long term.

5.0 RECOMMENDED MONITORING PROGRAM

5.1 OBJECTIVES

On the basis of the analyses presented in Sections 3 and 4, the objectives of any program to monitor the effects of the Qu'Appelle River channelization project should be as follows:

(i) to determine the general style and rates of channel response to the conveyance improvements.

(ii) to provide sufficient cross-sectional information to determine whether the substantial channel degradation and aggradation predicted in Krishnappan, 1986 are, or are not, occurring; and

(iii) to assess whether the channel improvements have indeed resulted in the projected conveyance capacity and to determine whether this capacity is maintained over time.

The information collected by such a program would allow the early detection of any potentially developing problems and provide a basis for predicting the effects of any similar project which might be undertaken in the future.

As indicated by the discussion in Section 4, the anticipated effects of the Qu'Appelle River Channelization project will most likely occur slowly and progressively. Nevertheless some rapid changes in river morphometry could occur during a large flood. The recommended monitoring program (discussed below) is therefore principally directed towards quantifying long term progressive changes, however the ability to document the effects (or absence of effects) arising from a large flood have also been incorporated.

5.2 RECOMMENDED STUDIES

In order to achieve the specified objectives a monitoring program is proposed which includes:

(i) river cross-sectional surveys;

(ii) obtaining a small number of bed material samples in the vicinity of the river cross-section sites;

(iii) obtaining periodic 35 mm photographs or video imagery at representative locations to document changes in river morphometry;

(iv) determining on-going changes in channel planimetry on the basis of aerial photographs (taken by the provincial government or other agencies);

(v) monitoring water level trends at WSC gauging sites; and

(vi) undertaking field inspections to document the effects of any large flood, should one occur.

Given the limited nature of the anticipated morphological changes, an extensive (and hence expensive) monitoring program is not justified. The recommended studies are therefore limited either to a small number of sites of particular interest or are for work that can be undertaken with relatively little effort.

The details of the recommended program are outlined below:

5.2.1 River Cross-Sectional Surveys

As indicated in Section 3 and Appendix 1, as-constructed river cross-sections have been previously surveyed at the following sites;

# of Sections	Location
5	downstream of the Craven Control Structure
15	vicinity "Qu'Appelle River below Craven Dam" gauging station
15	downstream of the Highway 6 crossing of Fairy Hill
11	vicinity "Qu'Appelle River below Loon Creek" gauging station
6	Piapot Indian Reserve

These sections provide a sufficient breadth of coverage that any massive degradation or aggradation as predicted by Krishnappan (1976) would be detected. It would however be desirable to establish one or two more cross-sections in the vicinity of the gauging stations so that the slope of the river can be determined accurately. In addition, a small number of sections should be established near Pasqua Lake. Suggested locations for such surveys are shown in Appendix 1.

It is important that all cross-section survey lines be permanently monumented and identified in the field. The authors have found that 2-3 ft. sections of 15 mm diameter rebar make good markers, but their ability to withstand frost-heave in the fine-textured sediments of the Qu'Appelle Valley needs to be ascertained by asking a local surveyor. Plastic survey tags can be used to identify each piece of rebar, however experience indicates such tags disintegrate after 3 to 5 years exposure to the sun. A better approach is therefore to stamp reference numbers onto small pieces of plate aluminium and attach these to each pin with galvanized wire.

Even with the establishment of permanent monuments it can be time-consuming to relocate the cross-sections after a period of a few years, due to vegetation growth, overbank sediment deposition, etc. With the use of a so-called "total station", it is now possible to establish a survey grid quickly which will allow the "rod man" to be directed to within a few centimetres of the previously-established pins. Cross-sections can also be rapidly surveyed with these instruments and their use is therefore to be encouraged.

The frequency with which cross-sectional surveys should be repeated will to some extent depend on the results of the photographic monitoring program discussed in Section 5.2.3. A reasonable initial schedule would be approximately 5-year intervals. Monitoring should be continued until at least 3 sizeable floods have occurred, or until it is felt that the channel response to the improvement project has been adequately documented.

All cross-section surveys should be plotted up at the same scale and overlaid to show any changes (or lack thereof) in channel morphometry. Where changes are found, the ground photos (discussed in Section 5.2.3) should be inspected to determine the cause and spatial extent of the processes responsible. This information should be documented in a "working report" as soon as it is noticed.

5.2.2 Bed Material Sampling

Bed material size can be expected to change if any significant aggradation or degradation occurs. Approximately three bed material samples should therefore be taken in each of the areas where cross-section data has been obtained. The samples should be taken from mid-channel and the site identified in a manner which would allow subsequent samples to be taken from the same location. Samples should be obtained and analyzed using standard Water Survey of Canada techniques (Ashmore, Yuzyk and Herrington, 1988).

It would be desirable to obtain all bed material samples at a fixed time of year in order to reduce the potential for seasonal variation in flow to influence the results. The grain size distribution curves should be plotted up and data from individual sites compared in order to detect any trends towards increasing or decreasing size.

5.2.3 35 mm or Video Imagery Taken on the Ground

Vegetation encroachment and sediment deposition are factors which will affect both the channel cross-sectional area and channel conveyance capacity. As illustrated on Plates 3.2 and 3.3, sediment deposition and vegetation establishment will not occur uniformly along the river channel and hence a large number of cross-sectional surveys would be required to document the magnitude and spatial extent of these processes. This effort is not justified as 35 mm (or other format) photography can adequately document these changes. To be of most benefit, photographs should be taken at permanently marked sites such that repetitive photography can be obtained from the same position and can be readily compared. Early fall is likely the best time to take the photos as the water levels will be relatively low and the extent of annual vegetation development should still be evident. It would be desirable to take the photography with a "standard lens" rather than a wide-angle or variable lens as this facilitates photo comparisons, particularly if different cameras are employed over the course of the project.

Repetitive photographic studies tend to result in the collection of many photographs and this material can be difficult to summarize in a manner which can be readily distributed, due to both the volume of material collected and the cost of preparing duplicate colour prints. Videotape has the potential for partially overcoming these problems as this medium is well-suited for displaying large quantities of imagery at nominal cost. It might therefore be desirable to obtain video imagery at each of the permanently monumented photographic sites as this would eventually allow the preparation of an edited tape documenting the results of the study. A variety of video formats are now in use and these provide a range in image quantity. If possible a "high resolution camera" (i.e > 400 lines per inch) should be used such that high quality duplicate copies can be prepared.

Sites at which it would be desirable to obtain ground imagery are as follows:

(i) looking upstream and downstream towards all river cross-sections discussed in Section 5.2.1; and

(ii) looking upstream and downstream from all bridges over Qu'Appelle River in the area between Lumsden and Pasqua Lake.

Imagery should be taken:

(i) whenever the cross-sections are re-surveyed;

(ii) during or following a flood large enough to cause bankfull conditions or, in the absence of either (i) or (ii);

(iii) every 5 years until such time as the effects of the Qu'Appelle River Channelization Project are thought to be understood and are well documented.

All photos should be systematically catalogued and dated. Each new set of photos should also be reviewed and a "working report" should be prepared documenting what changes have occurred to date. The photographic program should be modified, as required, to reduce coverage at sites where little change is occurring or allow better illustration of areas of particular interest.

5.2.4 Analysis of Aerial Photography

Comparison of a historical sequence of aerial photographs provides an excellent method of documenting changes in river planimetry and morphometry. However, based on the assessment in Section 4, it is unlikely that this monitoring project justifies the expense of flying special photography and therefore air photos flown for other purposes will likely have to be used for this part of the monitoring program. Never-the-less, aerial photography provides the best method of documenting the spatial extent of any change in river morphometry and would allow the extrapolation of the results obtained from the cross-sectional survey sites.

The aerial photography scale determines how much change in river position must occur between successive photo flights in order to be detected. For example, using a high resolution analytical plotting instrument, the planimetric accuracy of measurements from air photographs can be roughly estimated from the following equation. [1]

$$\mathbf{PA = 0.000166 \times S}$$

where **PA** is the planimetric accuracy in metres and **S** is the photo scale denominator (e.g. 12,000 for 1:12,000 photography). For example, the 1987 photography was flown at a scale of 1:20,000 and the planimetric accuracy achievable using a high precision photogrammetric plotter is approximately +/- 3.3 m. Greater than approximately 7 m of bank retreat must therefore occur between successive air photographs in order for the change in river bank position to be reliably discriminated. Corresponding average annual rates of recession, based on different periods between successive air photo coverage, are shown on Table 5.1 for a variety of air photo scales. If comparisons of river bank positions are to be undertaken with less sophisticated equipment, the planimetric accuracy would be correspondingly less and hence larger scale photography (or a larger time period between successive measurements) would be required. Using simpler equipment (such as an enlarging mirror stereoscope and a digitizing tablet) and assuming changes in river bank position can be detected by comparative measurements of the distance to a well-defined reference point (rather than through changes in bank position), horizontal

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[1] Joe Car, Surveys and Resource Mapping Branch, B.C. Ministry of Environment and Parks.

TABLE 5.1: AVERAGE RIVERBANK RECESSION RATES WHICH CAN BE RELIABLY DISCRIMINATED USING A PRECISION (1st Order) STEREO PLOTTER AS A FUNCTION OF ELAPSED TIME BETWEEN SUCCESSIVE AIR PHOTO COVERAGE AND AIR PHOTOGRAPH SCALE

	PHOTO SCALE 1:								
	5000	10000	12000	15000	20000	25000	30000	40000	60000
PLANIMETRIC ACCURACY (m)	0.83	1.66	1.99	2.49	3.32	4.15	4.98	6.64	9.96
MINIMUM DETECTABLE EROSION (m)	1.66	3.32	3.98	4.98	6.64	8.30	9.96	13.28	19.92
PERIOD BETWEEN AIR PHOTOS (yrs)	DETECTABLE AVERAGE ANNUAL RECESSION (m)								
1	1.66	3.32	3.98	4.98	6.64	8.30	9.96	13.28	19.92
5	0.33	0.66	0.80	1.00	1.33	1.66	1.99	2.66	3.98
10	0.17	0.33	0.40	0.50	0.66	0.83	1.00	1.33	1.99
20	0.08	0.17	0.20	0.25	0.33	0.41	0.50	0.66	1.00
30	0.06	0.11	0.13	0.17	0.22	0.28	0.33	0.44	0.66
40	0.04	0.08	0.10	0.12	0.17	0.21	0.25	0.33	0.50
50	0.03	0.07	0.08	0.10	0.13	0.17	0.20	0.27	0.40
60	0.03	0.06	0.07	0.08	0.11	0.14	0.17	0.22	0.33
70	0.02	0.05	0.06	0.07	0.09	0.12	0.14	0.19	0.28
80	0.02	0.04	0.05	0.06	0.08	0.10	0.12	0.17	0.25
90	0.02	0.04	0.04	0.06	0.07	0.09	0.11	0.15	0.22
100	0.02	0.03	0.04	0.05	0.07	0.08	0.10	0.13	0.20

distances can be measured to an accuracy of approximately +/- 0.25 mm. Corresponding rates of erosion which can be detected for various scales and periods between photography are shown on Table 5.2.

The field inspection of the enlarged channel in the vicinity of Eyebrow Lake in March of 1988 suggested that maximum bank erosion has been on the order of 1 m in the 2-year period since construction. Aerial photography would therefore have to be flown at a scale of approximately 1:5,000 in order to detect this low rate of bank recession over a period of 5 to 10 years. Flying such large scale photography would have the advantage that sediment accumulations and vegetation establishment would also be visible.

Another factor which influences the choice in photographic scale is the width of the valley flat as it is generally desirable for the full valley flat width to be visible on one air photo. In order to minimize the effects of distortion (particularly when using simple measuring devices which do not allow photogrammetric restitution) it is beneficial to have the valley flat area centred in the middle one-third to one-half of the photographs. As the valley flat width is 1,500 to 2,000 m, the required scale of photography would be on the order of 1:20,000. Air photos at two scales would be ideal, one set to show channel details and another to show overall changes within the entire valley flat area. These requirements should be brought to the attention of the government agencies who routinely fly aerial photography of Saskatchewan, if there is any possibility of influencing their programs.

The optimum time interval between successive photo flights will, of course, also vary with the scale of the photography and the amount of bank recession that has occurred. Given the low rates of bank recession that have been predicted, there may be

TABLE 5.2: AVERAGE RIVERBANK RECESSION RATES WHICH CAN BE RELIABLY DISCRIMINATED USING A MIRROR STEREOSCOPE AND DIGITIZING TABLET AS A FUNCTION OF ELAPSED TIME BETWEEN SUCCESSIVE AIR PHOTO COVERAGE AND AIR PHOTOGRAPH SCALE

	PHOTO SCALE 1:								
	5000	10000	12000	15000	20000	25000	30000	40000	60000
PLANIMETRIC ACCURACY (m)	1.25	2.50	3.00	3.75	5.00	6.25	7.50	10.00	15.00
MINIMUM DETECTABLE EROSION (m)	2.50	5.00	6.00	7.50	10.00	12.50	15.00	20.00	30.00
PERIOD BETWEEN AIR PHOTOS (yrs)	DETECTABLE AVERAGE ANNUAL RECESSION (m)								
1	2.50	5.00	6.00	7.50	10.00	12.50	15.00	20.00	30.00
5	0.50	1.00	1.20	1.50	2.00	2.50	3.00	4.00	6.00
10	0.25	0.50	0.60	0.75	1.00	1.25	1.50	2.00	3.00
20	0.13	0.25	0.30	0.38	0.50	0.63	0.75	1.00	1.50
30	0.08	0.17	0.20	0.25	0.33	0.42	0.50	0.67	1.00
40	0.06	0.13	0.15	0.19	0.25	0.31	0.38	0.50	0.75
50	0.05	0.10	0.12	0.15	0.20	0.25	0.30	0.40	0.60
60	0.04	0.08	0.10	0.13	0.17	0.21	0.25	0.33	0.50
70	0.04	0.07	0.09	0.11	0.14	0.18	0.21	0.29	0.43
80	0.03	0.06	0.08	0.09	0.13	0.16	0.19	0.25	0.38
90	0.03	0.06	0.07	0.08	0.11	0.14	0.17	0.22	0.33
100	0.03	0.05	0.06	0.08	0.10	0.13	0.15	0.20	0.30

NOTE: This table assumes that changes in riverbank position can be detected by comparative measurements of the distance to a well-defined reference point. Achievable results will vary depending on the availability of appropriate reference points.

little benefit in obtaining photography more frequently than every 5 to 20 years.

Another option for obtaining low-cost aerial imagery would be to use a high-resolution video camera. While this format would not permit the photogrammetric analyses which could be undertaken with conventional photography, it would:

(i) document any changes in river conditions in the region between areas being monitored on the ground; and

(ii) provide an overview of the study area which could be edited into the video imagery taken of the long-term monitoring sites established as part of Recommendation 5.2.2.

Another advantage of this oblique video imagery is that it is ideally suited for documenting the extent of overbank flooding, given that a small plane can be quickly and inexpensively obtained in Regina.

5.2.5 Monitoring Water Level Trends at Water Survey of Canada Gauging Sites

The rating tables showing the relationship between water level and stream discharge at the Water Survey of Canada gauging sites provide a basis for monitoring changes in channel conveyance capacity. Water levels associated with a range in discharges at the gauging sites "Qu'Appelle River below Craven Dam" and "Qu'Appelle River below Loon Creek" are shown on Figures 5.1 and 5.2. The data from "below Loon Creek" are particularly interesting as they show a substantial decrease in water levels in 1986. These graphs should be extended as new rating tables are prepared in

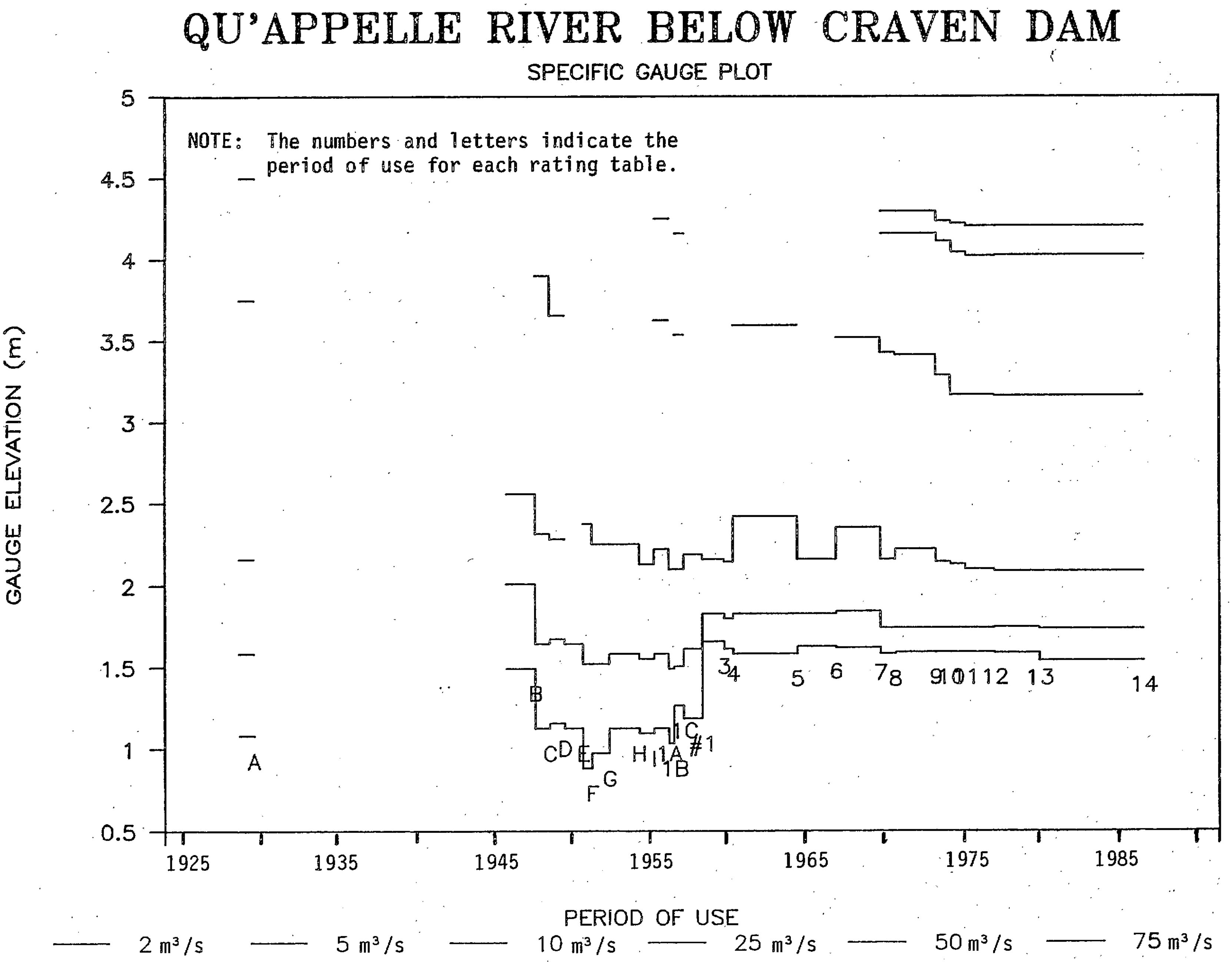

Figure 5.1: Historical variations in water level corresponding to a range in river discharges at the Water Survey of Canada gauge "Qu'Appelle River Below Craven Dam".

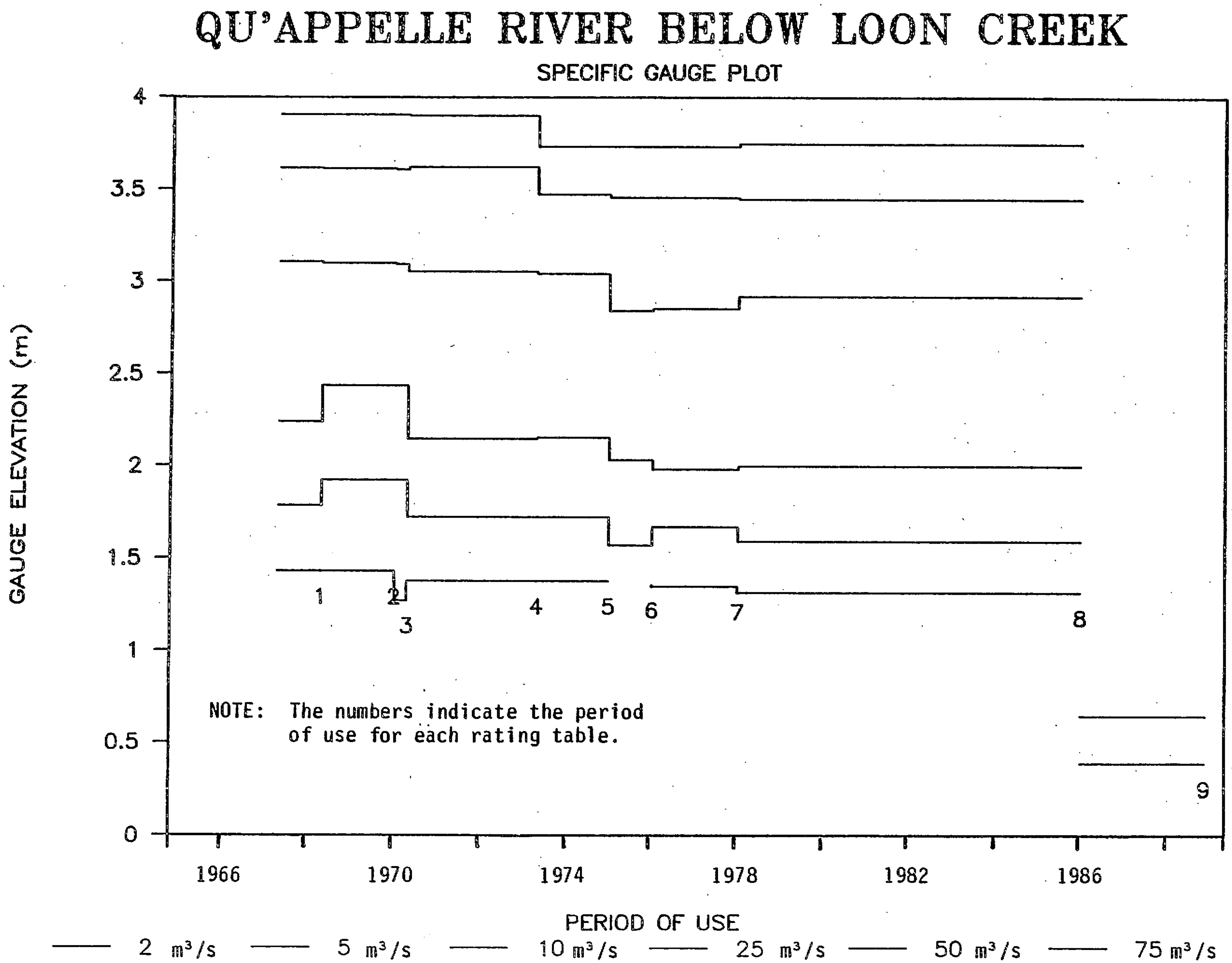

Figure 5.2: Historical variations in water level corresponding to a range in river discharges at the Water Survey of Canada gauge "Qu'Appelle River Below Loon Creek".

order to document how the channel conveyance improvements have affected water levels and how these effects vary over time.

5.2.6 Verification of Channel Capacity and Documentation of the Effects of Flood Discharges

As indicated in Section 2.2, the main objective of the Qu'Appelle River Project was to achieve a channel conveyance of 14.2 m^3/s with a minimum freeboard allowance of 0.3 m. However analysis of "as-built" drawings suggest that bankfull capacity may actually be on the order of 32 m^3/s (see Section 2.1). It would therefore be desirable to verify what the actual bankfull capacity is. Flows approaching bankfull capacity are also those which will most likely result in significant changes in channel morphometry (as larger flows will be accommodated by overbank flooding). A program to observe these flows, map the areas of overbank flooding and document ice jams or other processes which adversely affect channel stability or capacity therefore appears to be warranted.

The gauging station Qu'Appelle River below Craven Dam is equipped with a Satellite Collection Platform and real-time estimates of river discharge are therefore available. These flows should be monitored each spring and a field inspection should be conducted when flows approach the predicted bankfull capacity. Highwater levels within the improved section of channel should be noted (along with the time of observation) and areas of overbank flooding should be mapped either onto air photos or project maps. Areas undergoing significant erosion should be photographed and any processes (such as ice jams) which are adversely affecting bank stability or channel conveyance should be documented.

The above field inspection could be undertaken by car, but it would be more efficient to conduct an initial survey by small fixed-wing aircraft to map areas of overbank flooding and identify sites requiring field investigation. It would be desirable to obtain some oblique aerial photographs or video imagery to illustrate any report which might be produced as a result of this field work. Any camera used for such purposes should, of course, be fitted with a polarizing filter as this can frequently enhance the ability to discriminate in-situ melt water from more heavily sediment-laden overbank flood discharges.

5.3 CONCLUDING COMMENTS

The field component of the monitoring program described in this report can probably be undertaken by a crew of 2 in approximately 1 to 2 weeks. In comparison to latter cycles, the initial survey will however require some additional effort in order to establish the required permanent monuments. Data reduction and report preparation will likely require 2 to 3 person weeks.

Given the relatively small changes which we feel are likely to result from this project, there is some question whether even the small amount of monitoring work described above is justified. Given the dramatic results predicted by Krishnappan (1986), and given the probability of other, similar channelization projects being built in Saskatchewan, we believe that a well-documented case study would be well worth the effort. One way of reducing staff time would be to undertake the recommended field studies as part of a periodic training exercise for Inland Waters Directorate or Saskatchewan Government personnel. The cross-section surveys undertaken in the summer of 1989 were conducted as part of such a training program and, given the relatively easy access from Regina, this project appears ideally suited for such purposes.

6.0 SOURCES OF INFORMATION

6.1 REFERENCES

Ashmore, P.E., T.R. Yuzyk and R. Herrington. 1988. Bed material sampling in sand-bed streams. Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Conservation and Protection, Environment Canada. Report # IWD-HQ-WRB-SS-88-4. 47 p. plus figures.

Environment Canada. 1988a. Daily discharges in metric units, Saskatchewan. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada. 41 microfiche sheets.

Environment Canada. 1988b. Computer listing of non-filterable residue data (parameter code 10401L) for Site 00SA05JK0003. Inland Waters Directorate, Water Quality Branch.

Environment Canada. 1989. Historical Stream Flow Summary Saskatchewan, to 1988. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa. 421 pp.

Galay, V.J., S. Block and O. Caron. 1970. Degradation of the Seine River Diversion. Paper presented to the ASCE Hydraulics Specialties Conference, Minneapolis, 19 Aug. 25 p., plus figs.

Gordon, Anthony. 1979. Geology of Saskatchewan, a historical approach. Western Extension College Educational Publishers, Saskatoon. 56 p.

Keller, E.A. and A. Brooks. 1983. Consideration of Meandering in Channelization Projects: Selected Observations and Judgements. In: Charles M. Elliott, Ed. River Meandering; Proceedings of the Conference Rivers' 83. ASCE, New York, pp. 384-397.

Kellerhals, Rolf and Michael Church. 1989. The Morphology of Large Rivers: Characterization and Management. In: D.P. Dodge (Ed.) Proceedings of the International Large River Symposium. Can. Spec. Publ. Fish. Aquat. Sci. 106, p. 31-48.

Krishnappan, B.G. 1986. Application of MOBED to Qu'Appelle River between Craven and Pasqua Lake. National Water Research Institute, Contribution 85-20.

Mitchell, G.C. *et al.* 1972. Report of the Qu'Appelle Basin Study Board. Queen's Printer, Regina. 65 p.

Neill, C.R. 1973. Hydraulic geometry of sand rivers in Alberta. In: Fluvial processes and sedimentation. Proceedings of Hydrology Symposium held at Univ. of Alberta, May 8-19, 1973. National Research Council of Canada, Ottawa. pp. 453-461.

Neill, C.R. and E.K. Yaremko. 1988. Regime aspects of flood control channelization. In: White, R.W. (Ed.). International conference on river regime, 18-20 May, 1988, Wallingford, England. Wiley, Chichester, England. 456 p.

Penner, Frank and N. Vitkin. 1978. Erosion and sedimentation study of the Assiniboine River diversion and Red River floodway. Manitoba Natural Resouces, Water Resources, Planning Branch. Report 22 p. + figures.

Qu'Appelle Implementation Office. 1979. Qu'Appelle River System and Operation, Technical Document. Report. 29 p.

Qu'Appelle Multidisciplinary Design Team. 1981. Qu'Appelle valley conveyance program: a proposal for channel improvement Craven Control to Pasqua Lake. Summary Report. 36 p.

Saskatchewan Water Resources Commission. 1972. A historical review of flooding in the Qu'Appelle River Basin, 1952-1971. Qu'Appelle Flood Study, App. C.

Schumm, S.A., M.D.Harvey and C.C. Watson. 1984. Incised channels -morphology, dynamics and control. Water Resources Publications, Fort Collins, Colorado.

Wiens, L.H. 1987. The South Saskatchewan - Qu'Appelle diversion: history and future prospects. In: Proceedings of the symposium on interbasin transfer of water: impacts and research needs for Canada. National Hydrology Research Centre, Saskatoon. pp. 105-119.

6.2 PERSONAL COMMUNICATIONS

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Larry H. Wiens, P.Eng.	Water Resources Engineer Engineering Division Water Planning & Management Branch Inland Waters Directorate Regina, Saskatchewan
Ted Yuzyk	Sediment Survey Section Water Survey of Canada Environment Canada, Ottawa

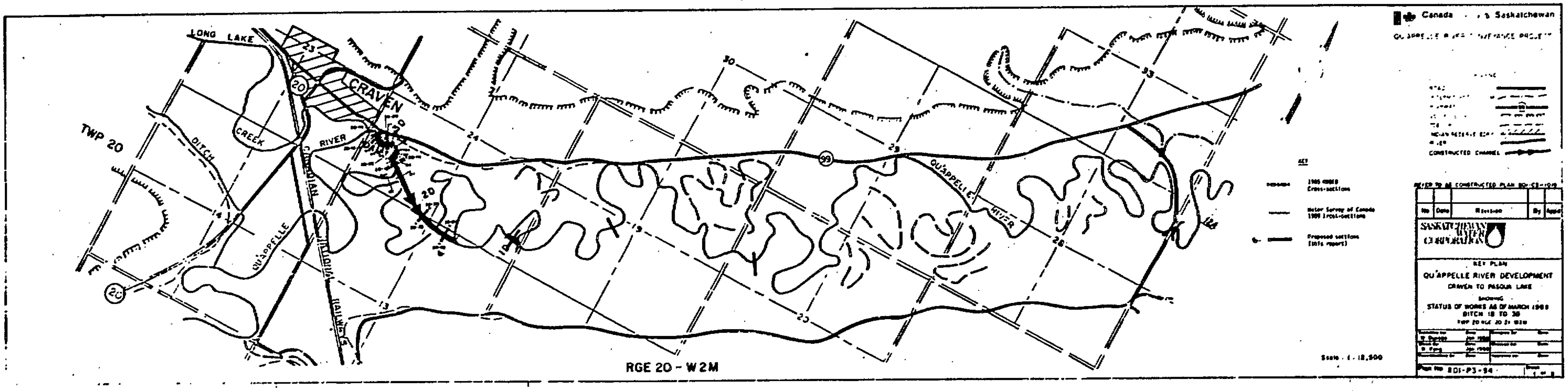
APPENDIX 1

Plan of the Qu'Appelle River Conveyance Improvement Project showing the location of established and proposed river cross-section surveys.

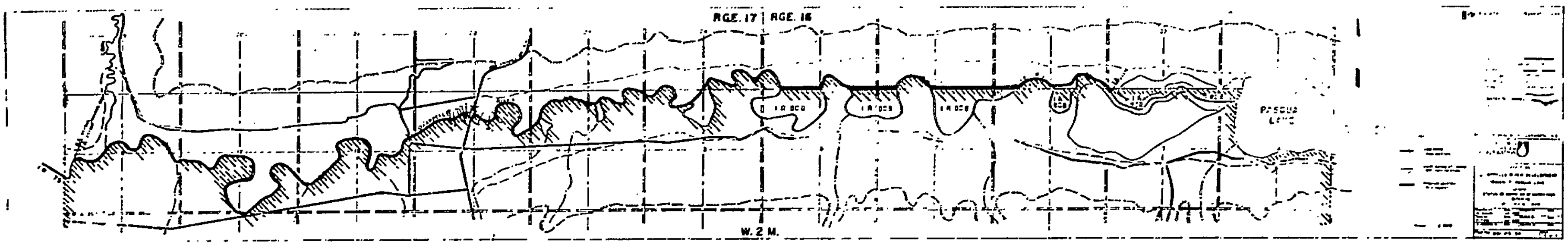
These plans have been reduced to fit the publication. If larger prints are required please contact:

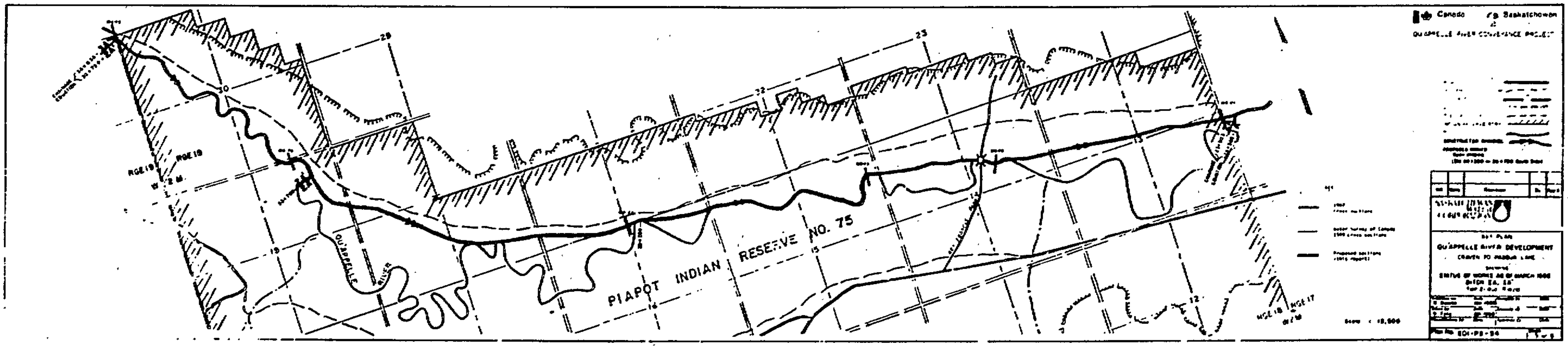
Regional Chief
Water Resources Branch
Environment Canada
Room 300, Park Plaza
2365 Albert Street
Regina, Saskatchewan
S4P 4K1

306-780-5338

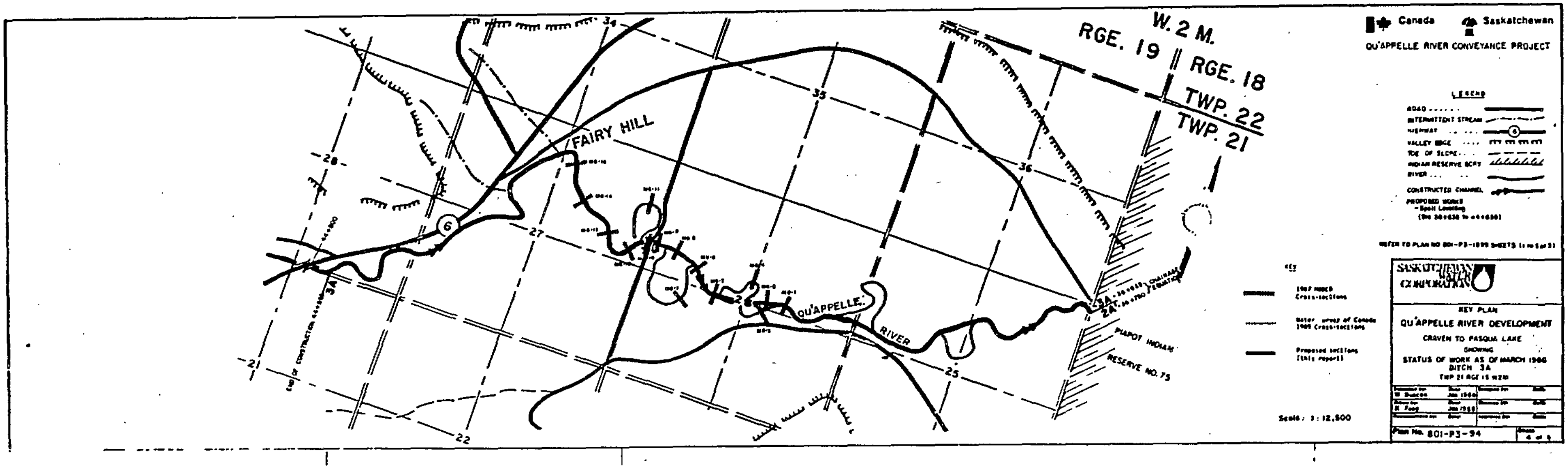


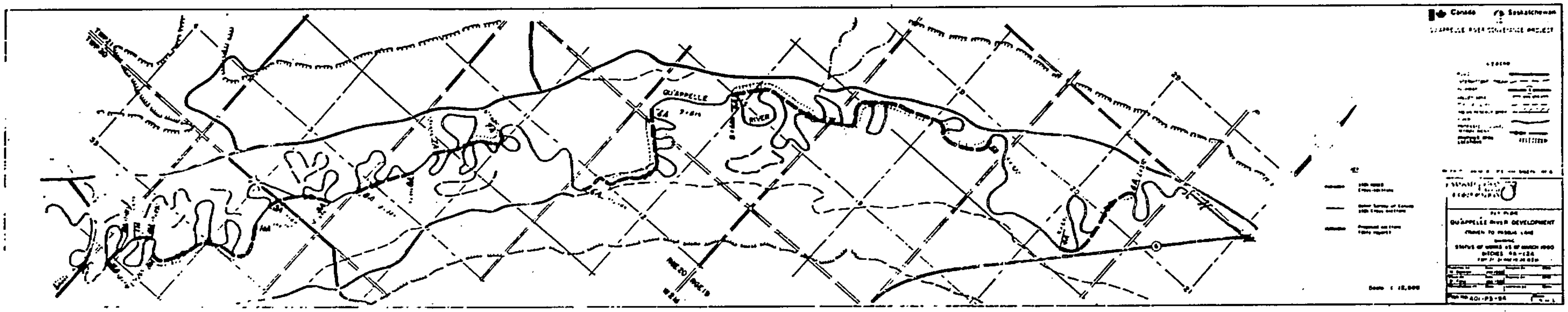
Canada
Saskatchewan
LONG LAKE
CRAVEN
TWP 20
DITCH
CREEK
RIVER
QU'APPELLE
QU'APPELLE RIVER
RGE 20 - W2M
CONSTRUCTED CHANNEL
Water Survey of Canada
Proposed sections
No
Date
Revision
By
SASKATCHEWAN WATER CORPORATION
KEY PLAN
QU'APPELLE RIVER DEVELOPMENT
CRAVEN TO PASQUA LAKE
SHOWING
STATUS OF WORKS AS OF MARCH 1988
DITCH 18 TO 30
Plan No 801-P3-94


RGE. 17
RGE. 16
W. 2 M.



Canada
Saskatchewan
QU'APPELLE RIVER DEVELOPMENT
PIAPOT INDIAN RESERVE NO. 75
QU'APPELLE RIVER
RGE 19
RGE 18
RGE 17
20
23
22
15
14
12


W. 2 M.
RGE. 19
RGE. 18
TWP. 22
TWP. 21
FAIRY HILL
QU'APPELLE
RIVER
PIAPOT INDIAN
RESERVE NO. 75
3A
2A
Scale: 1:12,500
Canada
Saskatchewan
QU'APPELLE RIVER CONVEYANCE PROJECT
ROAD
HIGHWAY
VALLEY EDGE
TOE OF SLOPE
INDIAN RESERVE BDRY
RIVER
CONSTRUCTED CHANNEL
PROPOSED WORKS
SASKATCHEWAN WATER CORPORATION
KEY PLAN
QU'APPELLE RIVER DEVELOPMENT
CRAVEN TO PASQUA LAKE
SHOWING
STATUS OF WORK AS OF MARCH 1986
DITCH 3A
Plan No. 801-P3-94


Canada
Saskatchewan
QU'APPELLE RIVER DEVELOPMENT
STATUS OF WORKS AS OF MARCH 1990
401-P3-94
QU'APPELLE
RIVER

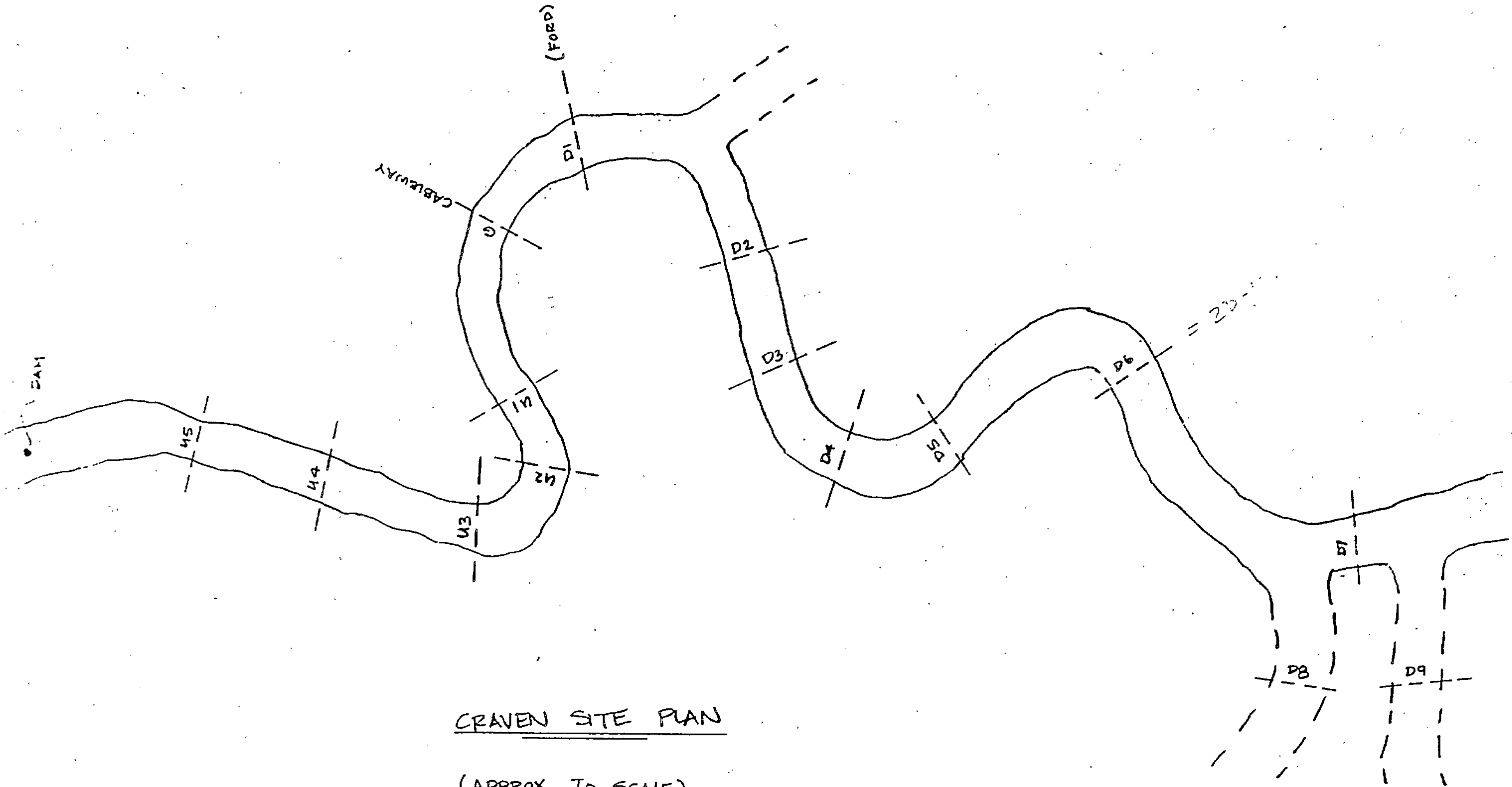
APPENDIX 2

QU'APPELLE RIVER BELOW CRAVEN DAM

Results of river cross-section surveys and bed material sampling conducted by Water Survey of Canada staff in June, 1989.

NOTE:

All Figures, Tables and Plates were supplied by Ted Yuzyk, Sediment Survey Section, Water Survey of Canada, Environment Canada, Ottawa.



CRAVEN SITE PLAN

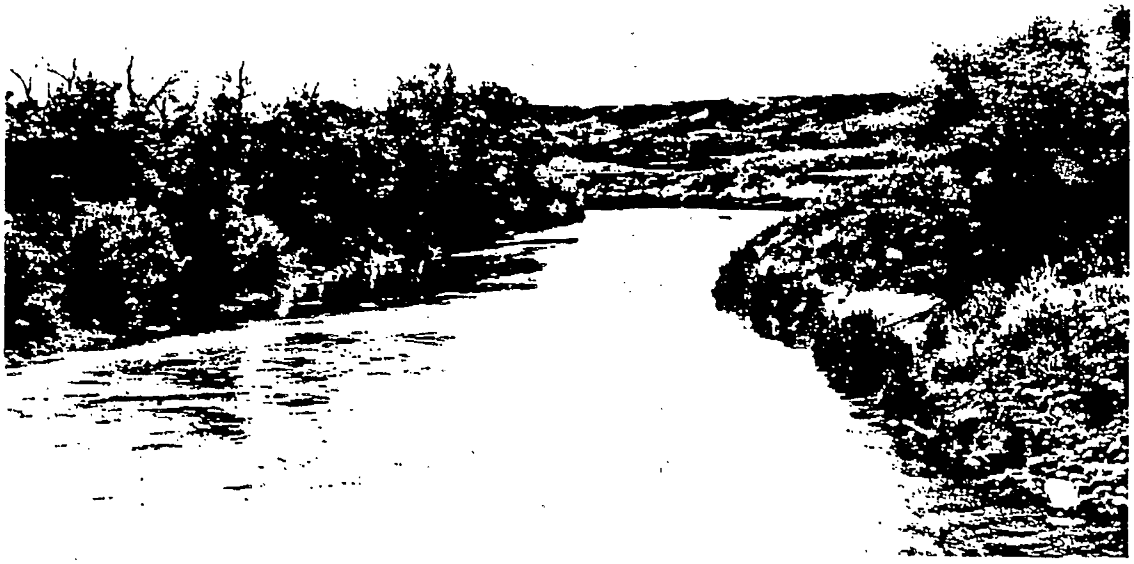
(APPROX. TO SCALE)

15 CROSS SECTIONS

Locations of cross-sections surveyed by the Water Survey of Canada in June, 1989

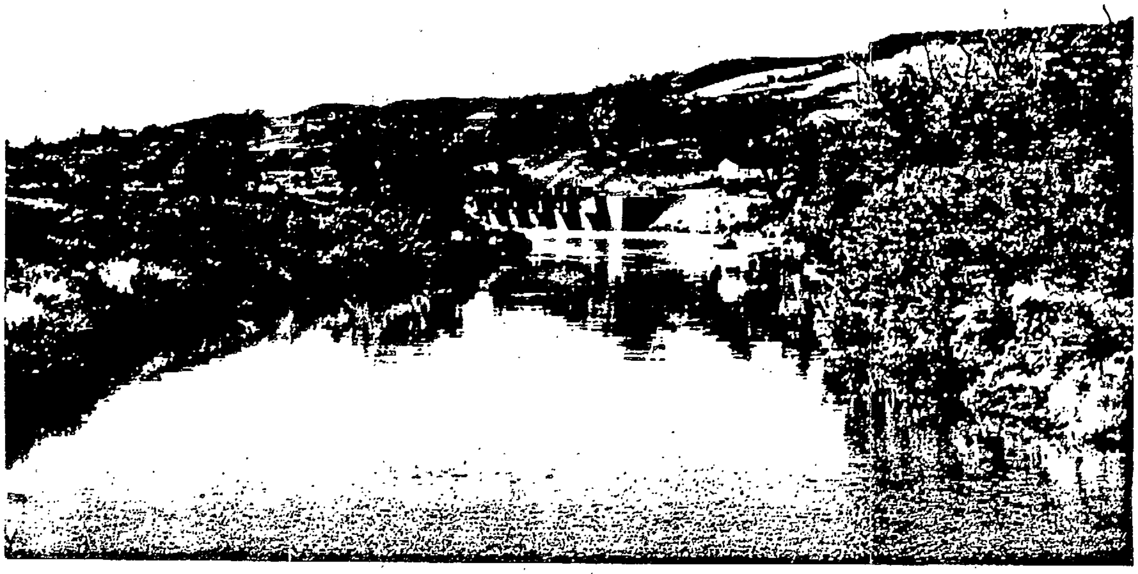
REPRESENTATIVE PHOTOGRAPHS

NOTE: All photos were taken in June, 1989

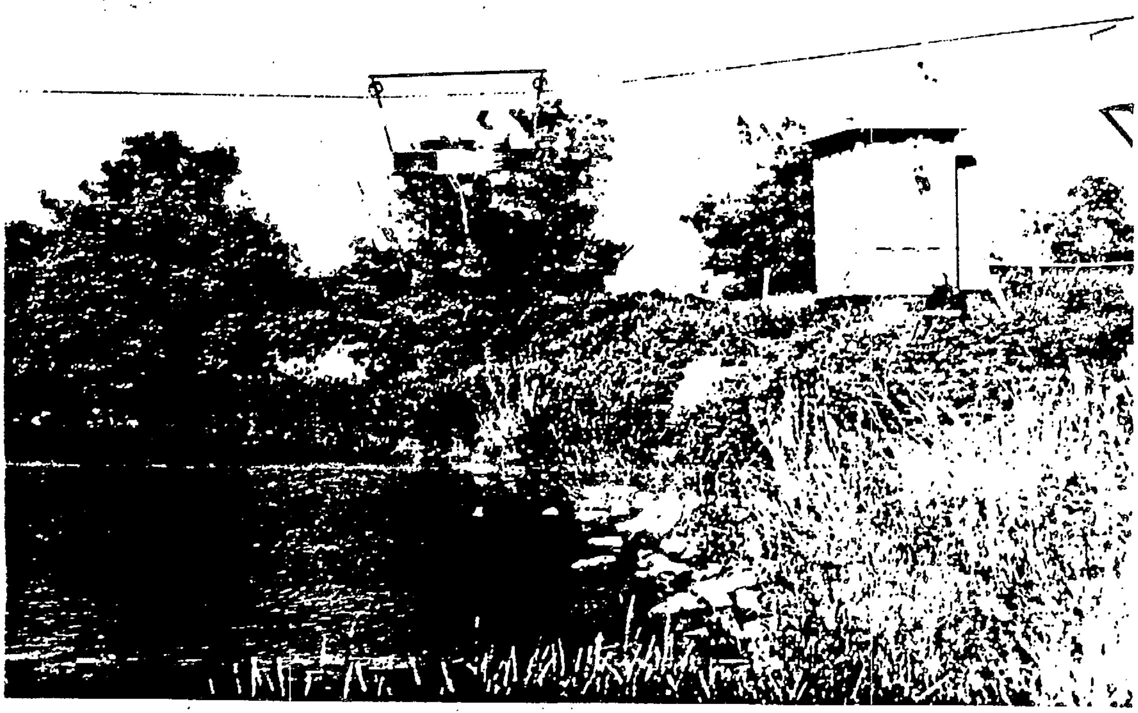


Looking downstream to cross-section U5.

Looking to the left bank at cross-section U4.

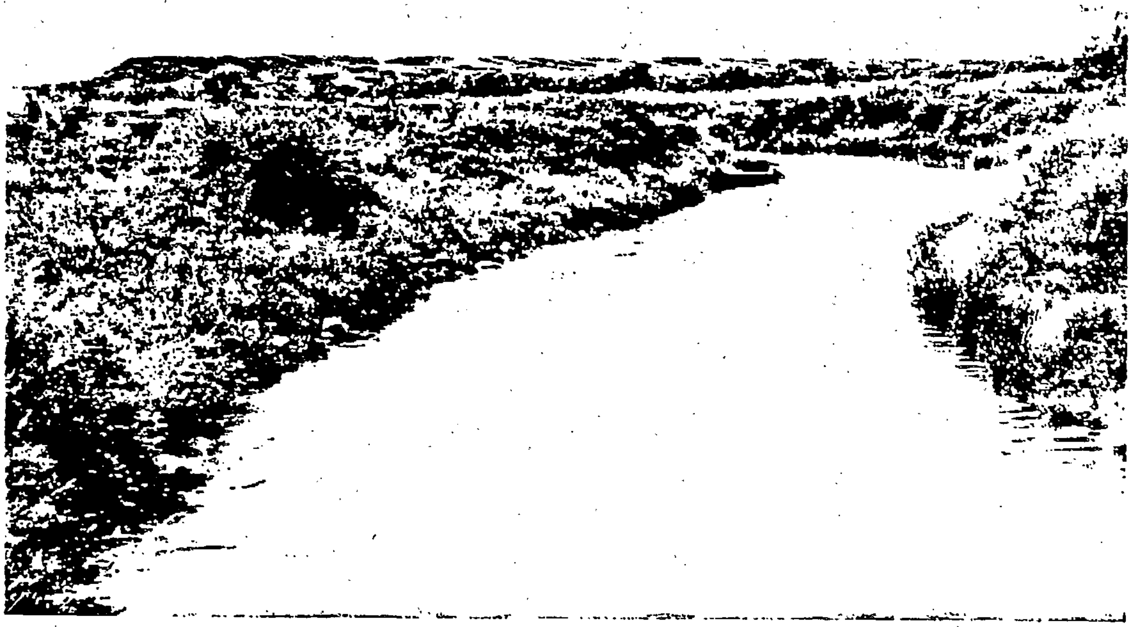


Looking upstream to cross-section U3.

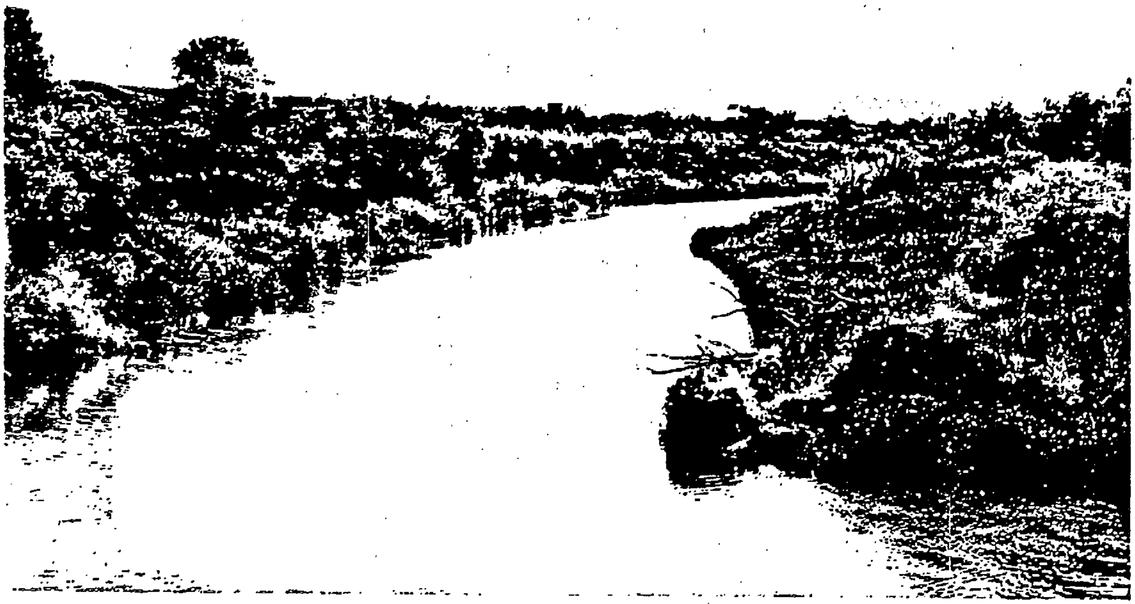


Looking [illegible] to the [illegible] bank at the [illegible]

Looking upstream to the weir located downstream of the cableway.

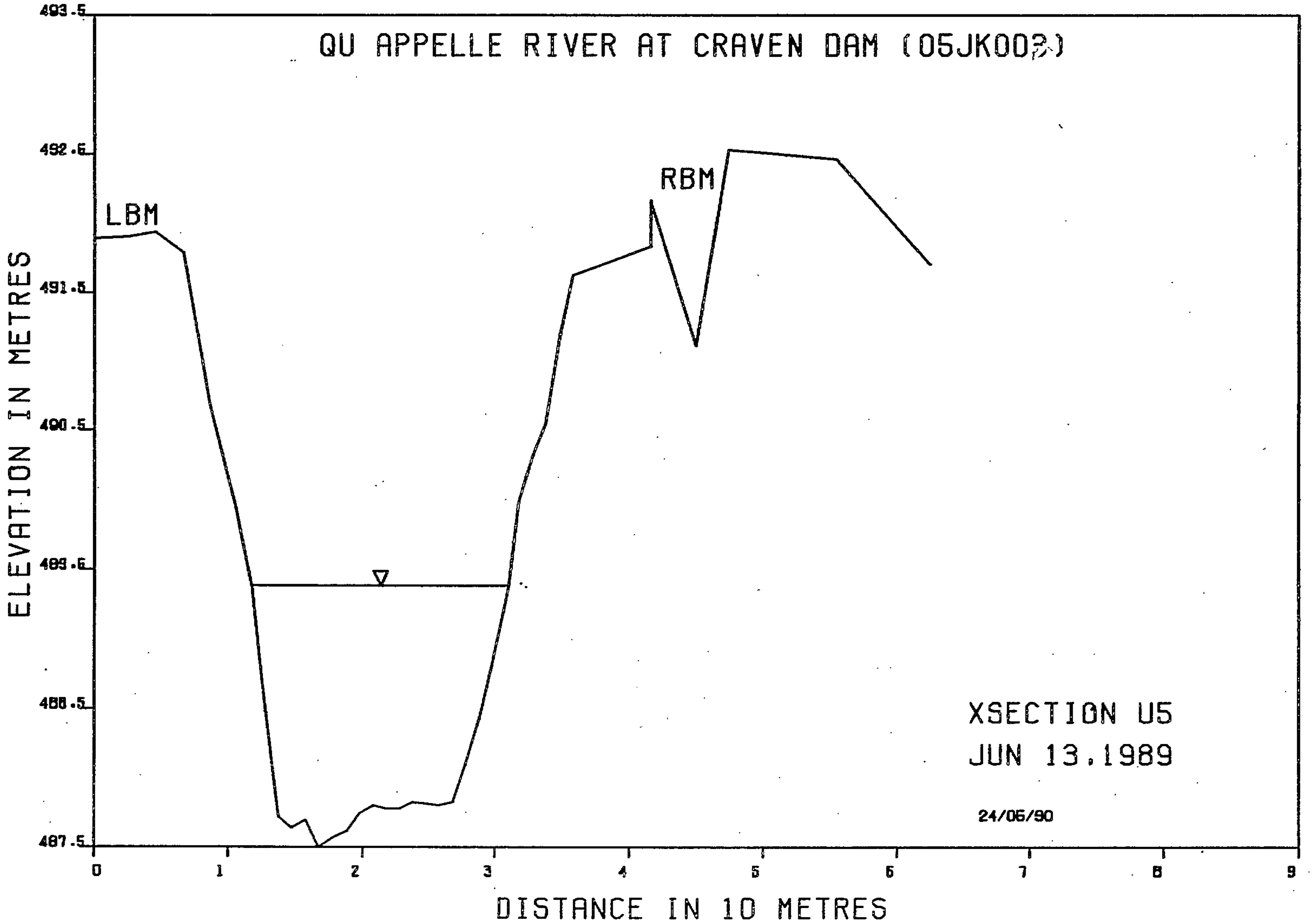


Looking downstream to cross-section D2.



Looking upstream to cross-section D7.

RIVER CROSS-SECTION SURVEYS



QU APPELLE RIVER AT CRAVEN DAM (05JK002)
LBM
RBM
ELEVATION IN METRES
493.5
492.5
491.5
490.5
489.5
488.5
487.5
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION U5
JUN 13,1989
24/06/90

WATER SURVEY OF CANADA
20/04/90 . PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID U5   SURVEY DATE JUN 13,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.88	LBM												
2.6	491.89													
4.6	491.92													
6.6	491.78													
8.6	490.68													
10.6	489.93													
11.8	489.38	WL												
12.8	488.54													
13.8	487.71													
14.8	487.63													
15.8	487.69													
16.8	487.49													
17.8	497.56													
18.8	487.61													
19.8	487.74													
20.8	487.79													
21.8	487.77													
22.8	487.77													
23.8	487.82													
24.8	487.81													
25.8	487.79													
26.8	487.82													
27.8	488.08													
28.8	488.42													
29.8	488.80													
31.0	489.38	WL												
31.8	489.97													
32.8	490.31													
33.8	490.54													
34.8	491.19													
35.7	491.61													
41.6	491.82													
41.6	492.15	RBM												
45.0	491.10													
47.5	492.53													
55.5	492.45													
62.5	491.69													

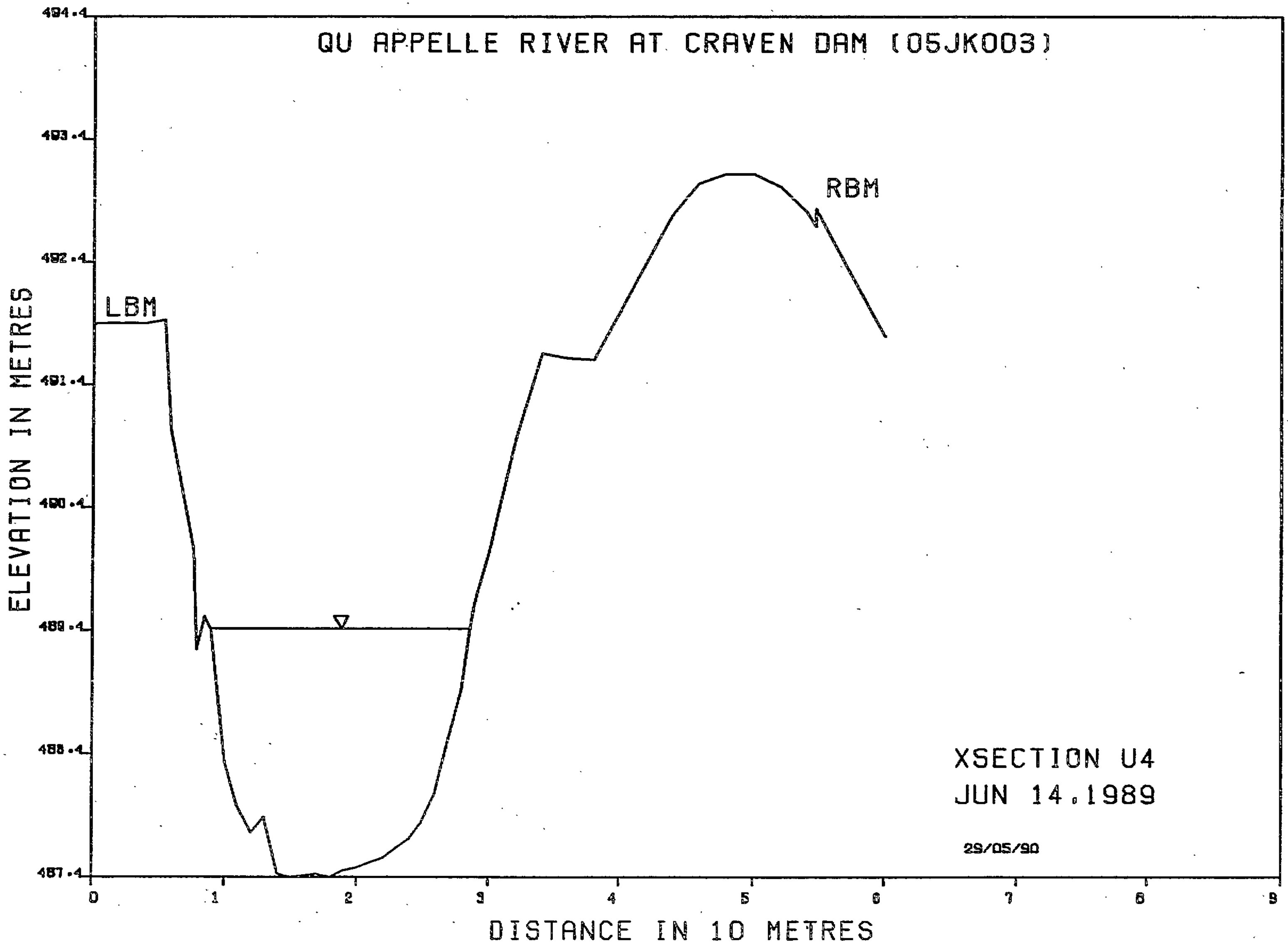
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-U5
SURVEYED JUN 13,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.50

*** ELEVATION - AREA TABLE ***

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	.00						
487.75	.80						
488.00	3.88						
488.25	7.53						
488.50	11.45						
488.75	15.61						
489.00	20.00						
489.25	24.59						
489.50	29.39						
489.75	34.40						
490.00	39.64						
490.25	45.19						
490.50	51.11						
490.75	57.40						
491.00	63.92						
491.25	70.70						
491.50	78.01						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
DISTANCE IN 10 METRES
LBM
RBM
XSECTION U4
JUN 14,1989
29/05/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID U4 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.86	LBM												
.2	491.89													
4.0	491.89													
5.5	491.91													
6.0	491.02													
7.7	490.05													
8.0	489.24													
8.5	489.51													
9.0	489.40	WL												
10.0	488.32													
11.0	487.97													
12.0	487.75													
13.0	487.88													
14.0	487.41													
15.0	487.39													
16.0	487.40													
17.0	487.41													
18.0	487.39													
19.0	487.44													
20.0	487.47													
21.0	487.51													
22.0	487.54													
23.0	487.62													
24.0	487.70													
25.0	487.82													
26.0	488.07													
27.0	488.48													
28.0	488.92													
28.6	489.40	WL												
29.0	489.62													
30.0	490.03													
32.0	490.95													
34.0	491.65													
36.0	491.61													
38.0	491.60													
44.0	492.77													
46.0	493.03													
48.0	493.11													
50.0	493.11													
52.0	493.01													
54.0	492.80													
54.7	492.68													
54.7	492.83	RBM												
60.0	491.79													

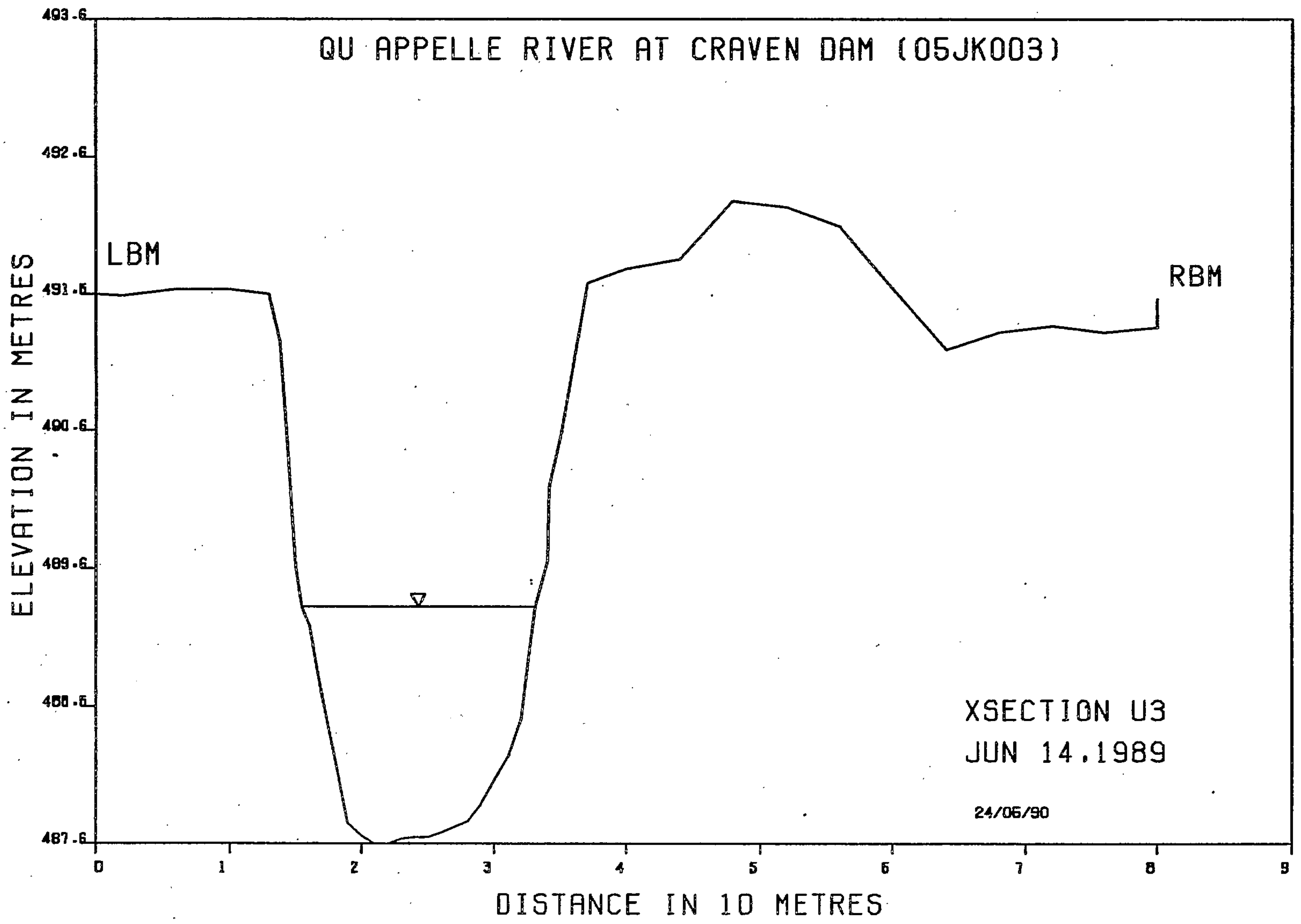
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-U4
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

*** ELEVATION - AREA TABLE ***

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	.55						
487.75	2.91						
488.00	6.26						
488.25	10.15						
488.50	14.35						
488.75	18.75						
489.00	23.35						
489.25	28.10						
489.50	33.08						
489.75	38.37						
490.00	43.84						
490.25	49.50						
490.50	55.40						
490.75	61.55						
491.00	67.95						
491.25	74.59						
491.50	81.44						
491.75	89.08						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
493.6
492.6
491.6
490.6
489.6
488.6
487.6
LBM
RBM
XSECTION U3
JUN 14,1989
24/06/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID U3 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.77	LBM												
0.0	491.65													
2.0	491.64													
4.0	491.66													
6.0	491.68													
8.0	491.68													
10.0	491.68													
12.0	491.66													
13.0	491.65													
13.8	491.30													
15.0	489.67													
15.4	489.37	WL												
16.0	489.23													
17.0	488.74													
18.0	488.25													
19.0	487.80													
20.0	487.71													
21.0	487.65													
22.0	487.65													
23.0	487.69													
24.0	487.70													
25.0	487.70													
26.0	487.73													
28.0	487.81													
29.0	487.93													
30.0	488.12													
31.0	488.29													
32.0	488.55													
33.0	489.37	WL												
34.0	489.71													
34.1	490.25													
35.0	490.64													
37.0	491.73													
40.0	491.83													
44.0	491.90													
48.0	492.33													
52.0	492.28													
56.0	492.14													
60.0	491.69													
64.0	491.24													
68.0	491.37													
72.0	491.41													
76.0	491.37													
80.0	491.40													
80.0	491.61	RBM												

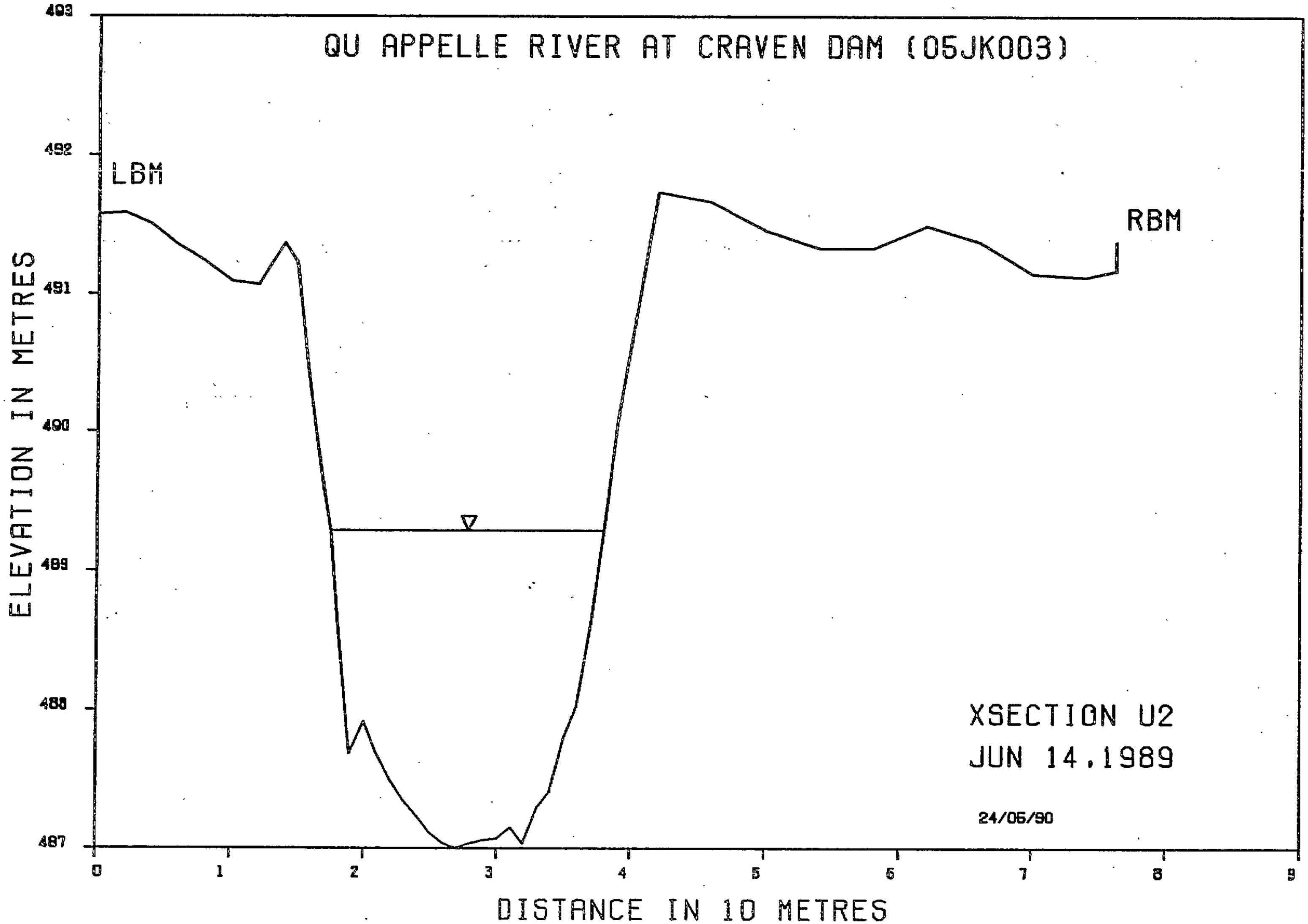
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-U3
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 488.
ASSUMED MINIMUM DATUM = 487.50

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.75	.40						
488.00	2.78						
488.25	5.72						
488.50	9.12						
488.75	12.83						
489.00	16.75						
489.25	20.87						
489.50	25.27						
489.75	29.93						
490.00	34.73						
490.25	39.58						
490.50	44.56						
490.75	49.72						
491.00	55.05						
491.25	60.55						
491.50	68.65						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
DISTANCE IN 10 METRES
493
492
491
490
489
488
487
0
1
2
3
4
5
6
7
8
9
LBM
RBM
XSECTION U2
JUN 14,1989
24/06/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID U2 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.77	LBM	76.2	491.46	RBM									
0.0	491.65													
2.0	491.66													
4.0	491.58													
6.0	491.43													
8.0	491.32													
10.0	491.17													
12.0	491.14													
14.0	491.45													
15.0	491.31													
16.0	490.38													
17.0	489.72													
17.6	489.37	WL												
18.0	488.77													
19.0	487.77													
20.0	488.00													
21.0	487.77													
22.0	487.57													
23.0	487.43													
24.0	487.32													
25.0	487.20													
26.0	487.12													
27.0	487.08													
28.0	487.12													
29.0	487.14													
30.0	487.15													
31.0	487.23													
32.0	487.12													
33.0	487.37													
34.0	487.49													
35.0	487.87													
36.0	488.10													
37.0	488.70													
38.0	489.37	WL												
39.0	490.20													
42.0	491.81													
46.0	491.75													
50.0	491.54													
54.0	491.41													
58.0	491.41													
62.0	491.57													
66.0	491.46													
70.0	491.23													
74.0	491.20													
76.2	491.25													

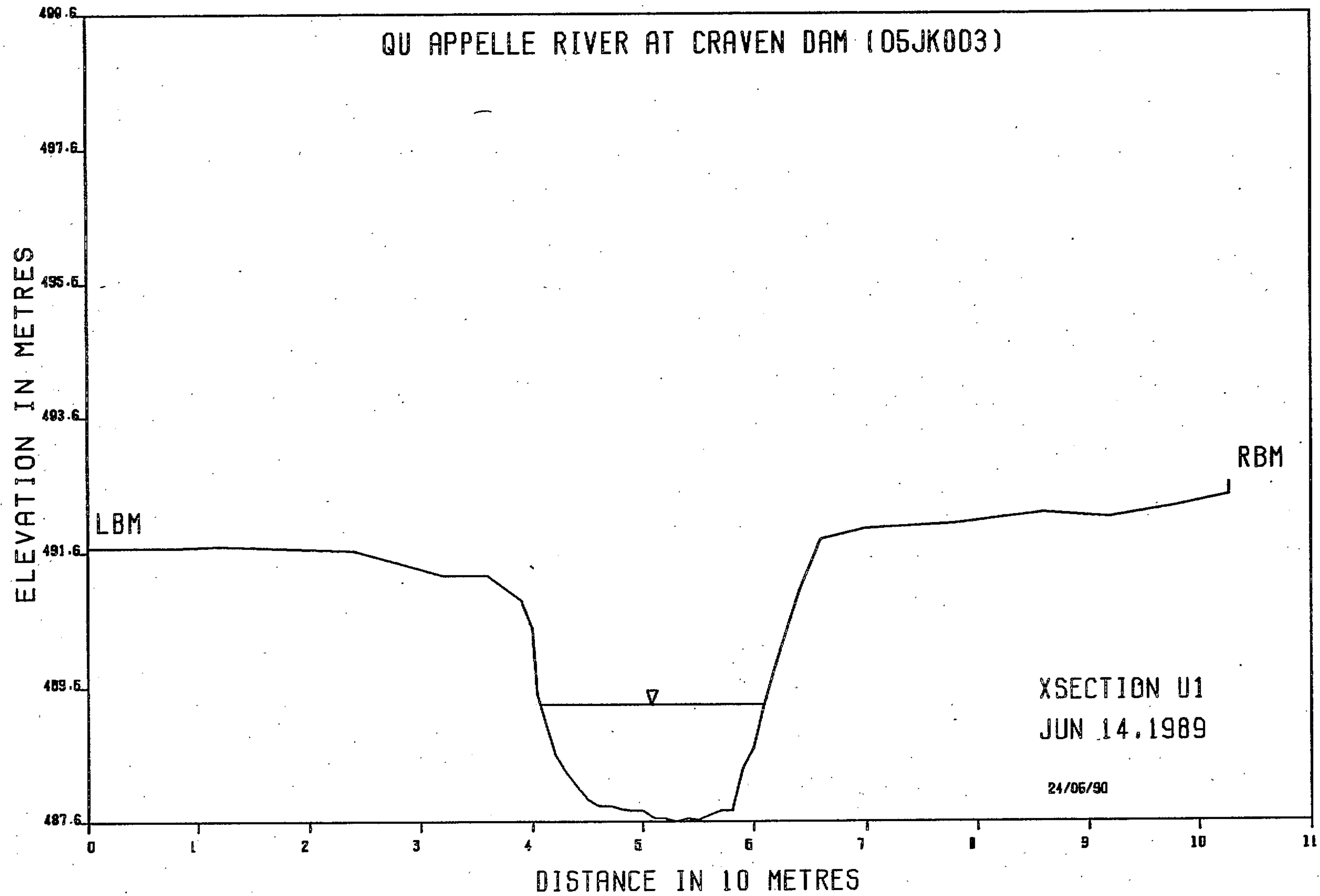
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA, ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-U2
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 486.50

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.25	.79						
487.50	3.21						
487.75	6.36						
488.00	10.13						
488.25	14.47						
488.50	18.98						
488.75	23.67						
489.00	28.50						
489.25	33.47						
489.50	38.58						
489.75	43.86						
490.00	49.32						
490.25	54.96						
490.50	60.78						
490.75	66.80						
491.00	72.99						
491.25	79.84						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
499.6
497.6
495.6
493.6
491.6
489.6
487.6
LBM
RBM
XSECTION U1
JUN 14,1989
24/06/90
0
1
2
3
4
5
6
7
8
9
10
11
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID U1 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.77	LBM												
0.0	491.71													
4.0	491.72													
8.0	491.72													
12.0	491.74													
16.0	491.71													
20.0	491.69													
24.0	491.67													
28.0	491.49													
32.0	491.31													
36.0	491.30													
39.0	490.93													
40.0	490.52													
40.4	489.54													
40.7	489.39	WL												
42.0	488.65													
43.0	488.39													
44.0	488.17													
45.0	487.99													
46.0	487.90													
47.0	487.90													
48.0	487.85													
49.0	487.82													
50.0	487.81													
51.0	487.71													
52.0	487.71													
53.0	487.65													
54.0	487.71													
55.0	487.67													
56.0	487.74													
57.0	487.81													
58.0	487.81													
59.0	488.44													
60.0	488.74													
60.9	489.39	WL												
62.0	490.01													
64.0	491.07													
66.0	491.83													
70.0	491.99													
78.0	492.07													
86.0	492.22													
92.0	492.16													
98.0	492.31													
102.8	492.48													
102.8	492.67	RBM												

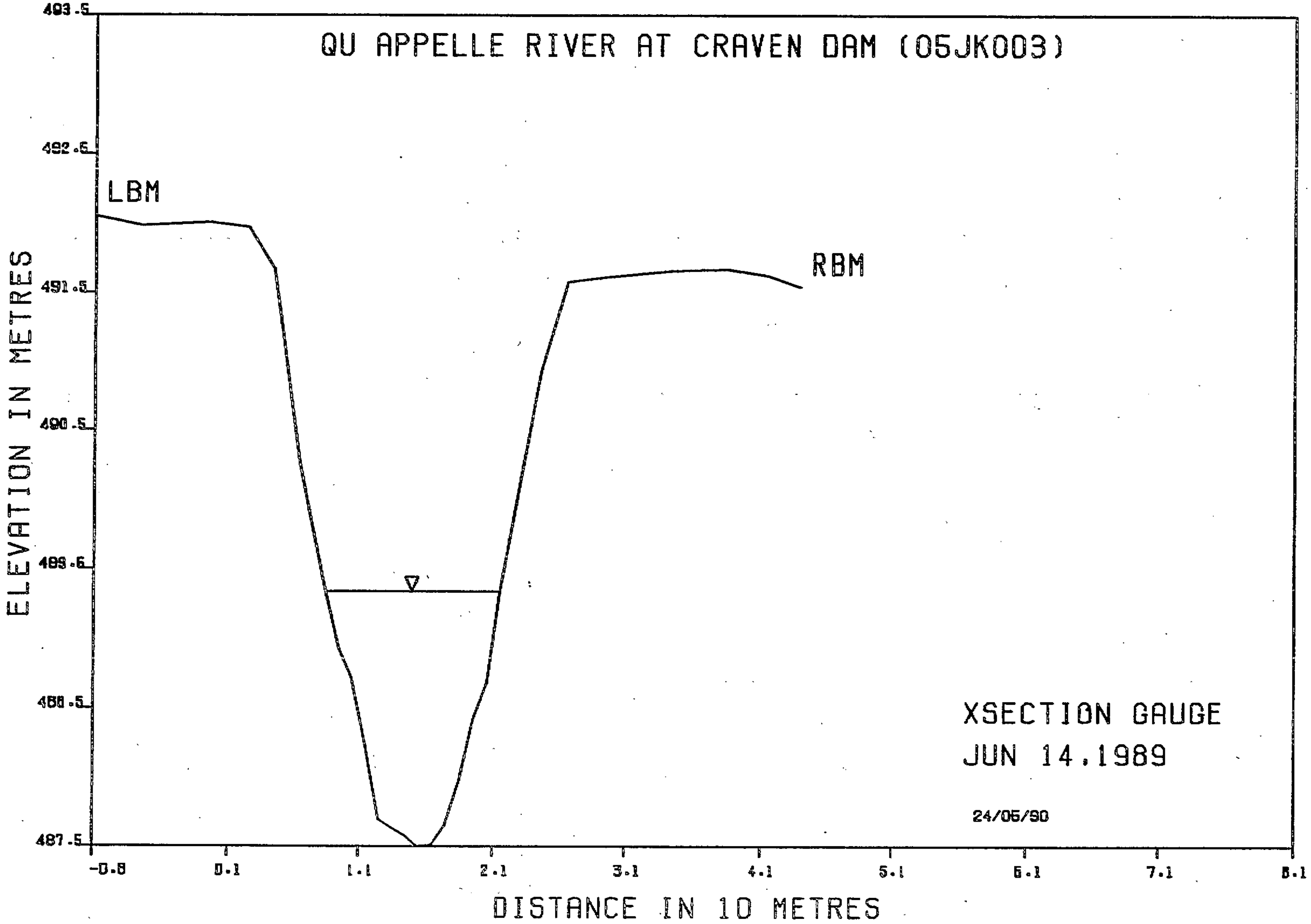
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-U1
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 488.
ASSUMED MINIMUM DATUM = 487.50

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.75	.29						
488.00	2.85						
488.25	6.41						
488.50	10.36						
488.75	14.73						
489.00	19.38						
489.25	24.22						
489.50	29.26						
489.75	34.50						
490.00	39.87						
490.25	45.39						
490.50	51.05						
490.75	56.90						
491.00	63.04						
491.25	69.72						
491.50	78.09						
491.75	89.06						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
ELEVATION IN METRES
DISTANCE IN 10 METRES
XSECTION GAUGE
JUN 14,1989
24/05/90
493.5
492.5
491.5
490.5
488.5
487.5
0.1
1.1
2.1
3.1
4.1
5.1
7.1

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID GAUGE SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
-8.5	492.03	LBM												
-5.0	491.96													
0.0	491.98													
3.0	491.95													
5.0	491.65													
7.0	490.24													
9.0	489.32	WL												
10.0	488.90													
11.0	488.69													
12.0	488.22													
13.0	487.68													
14.0	487.62													
15.0	487.57													
16.0	487.48													
17.0	487.50													
18.0	487.63													
19.0	487.97													
20.0	488.38													
21.0	488.66													
22.0	489.32	WL												
25.0	490.91													
27.0	491.56													
30.0	491.59													
35.0	491.64													
39.0	491.65													
42.0	491.60													
44.5	491.52	RBM												

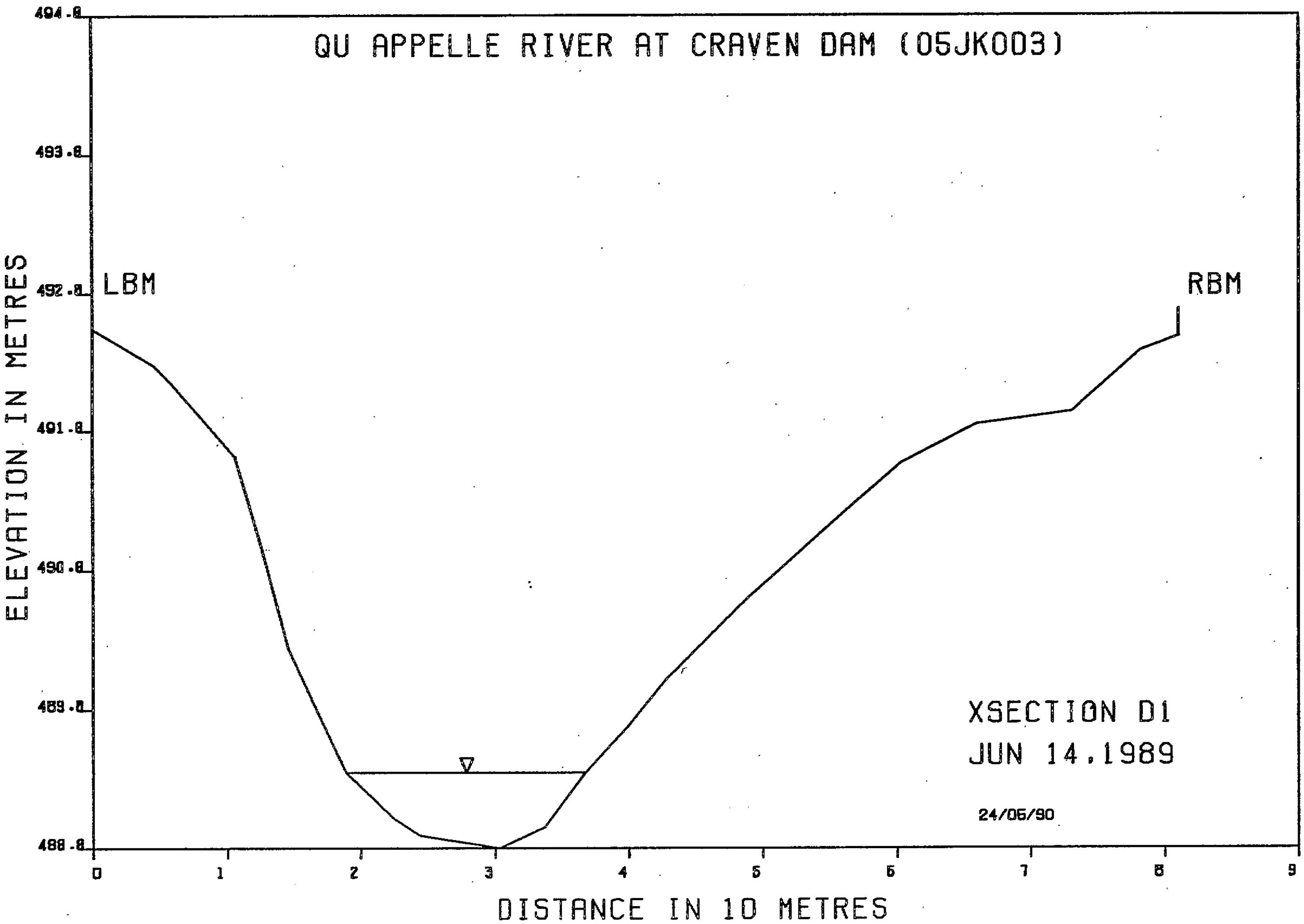
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-GAUGE
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	.01						
487.75	.95						
488.00	2.47						
488.25	4.27						
488.50	6.36						
488.75	8.79						
489.00	11.58						
489.25	14.64						
489.50	17.95						
489.75	21.51						
490.00	25.32						
490.25	29.39						
490.50	33.68						
490.75	38.18						
491.00	42.90						
491.25	47.88						
491.50	53.14						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
494.8
493.8
492.8
491.8
490.8
489.8
488.8
ELEVATION IN METRES
LBM
RBM
XSECTION D1
JUN 14,1989
24/06/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D1 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	492.69	LBM												
0.0	492.52													
4.6	492.26													
5.8	492.13													
10.6	491.60													
12.4	491.02													
14.6	490.23													
19.0	489.33	WL												
22.4	489.00													
24.4	488.88													
30.4	488.78													
33.8	488.93													
36.8	489.33	WL												
39.8	489.65													
42.8	490.00													
49.0	490.58													
60.4	491.55													
66.0	491.83													
73.2	491.92													
78.2	492.36													
81.0	492.46													
81.0	492.66	RBM												

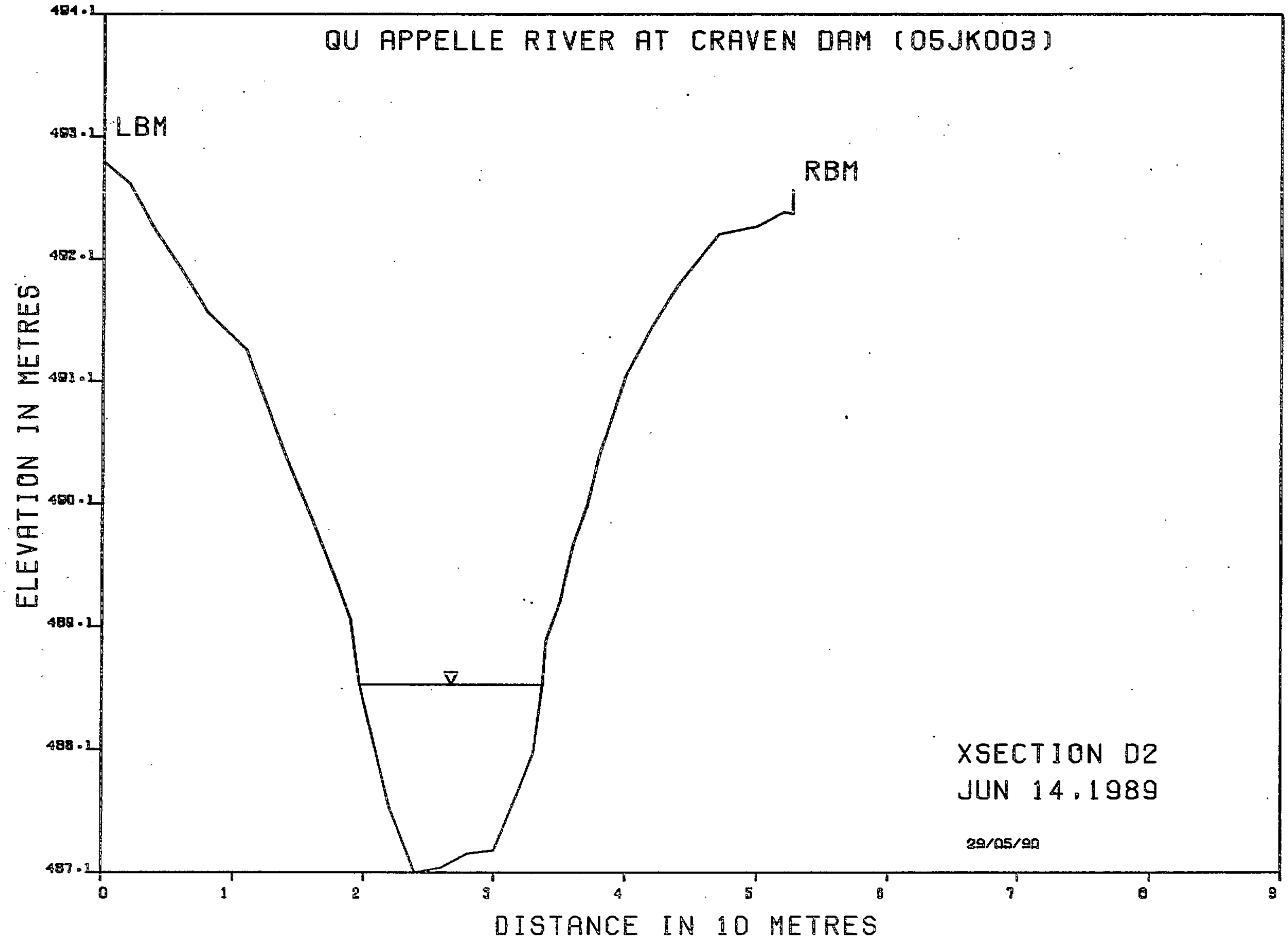
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D1
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 489.
ASSUMED MINIMUM DATUM = 488.50

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
489.00	1.65						
489.25	5.19						
489.50	9.79						
489.75	15.29						
490.00	21.63						
490.25	28.89						
490.50	37.04						
490.75	46.05						
491.00	55.97						
491.25	66.80						
491.50	78.56						
491.75	91.48						
492.00	106.83						
492.25	124.25						
492.50	143.34						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
ELEVATION IN METRES
494.1
493.1
492.1
491.1
490.1
489.1
488.1
487.1
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION D2
JUN 14,1989
29/05/90

WATER SURVEY OF CANADA QU APPELLE RIVER AT CRAVEN DAM (05JK003)
20/04/90 . PAGE 1
SEDIMENT SURVEY SECTION

PROFILE DATA

XSEC. ID D2 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	493.04	LBM												
0.0	492.92													
2.0	492.74													
4.0	492.36													
6.0	492.04													
8.0	491.70													
11.0	491.38													
14.0	490.52													
16.0	490.00													
18.0	489.46													
19.0	489.20													
19.7	488.66	WL												
22.0	487.66													
24.0	487.13													
26.0	487.17													
28.0	487.28													
30.0	487.31													
32.0	487.82													
33.0	488.11													
33.7	488.66	WL												
34.0	489.02													
35.0	489.34													
36.0	489.80													
37.0	490.12													
38.0	490.54													
40.0	491.18													
42.0	491.58													
44.0	491.92													
47.0	492.34													
50.0	492.40													
52.0	492.52													
52.8	492.50													
52.8	492.69	RBM												

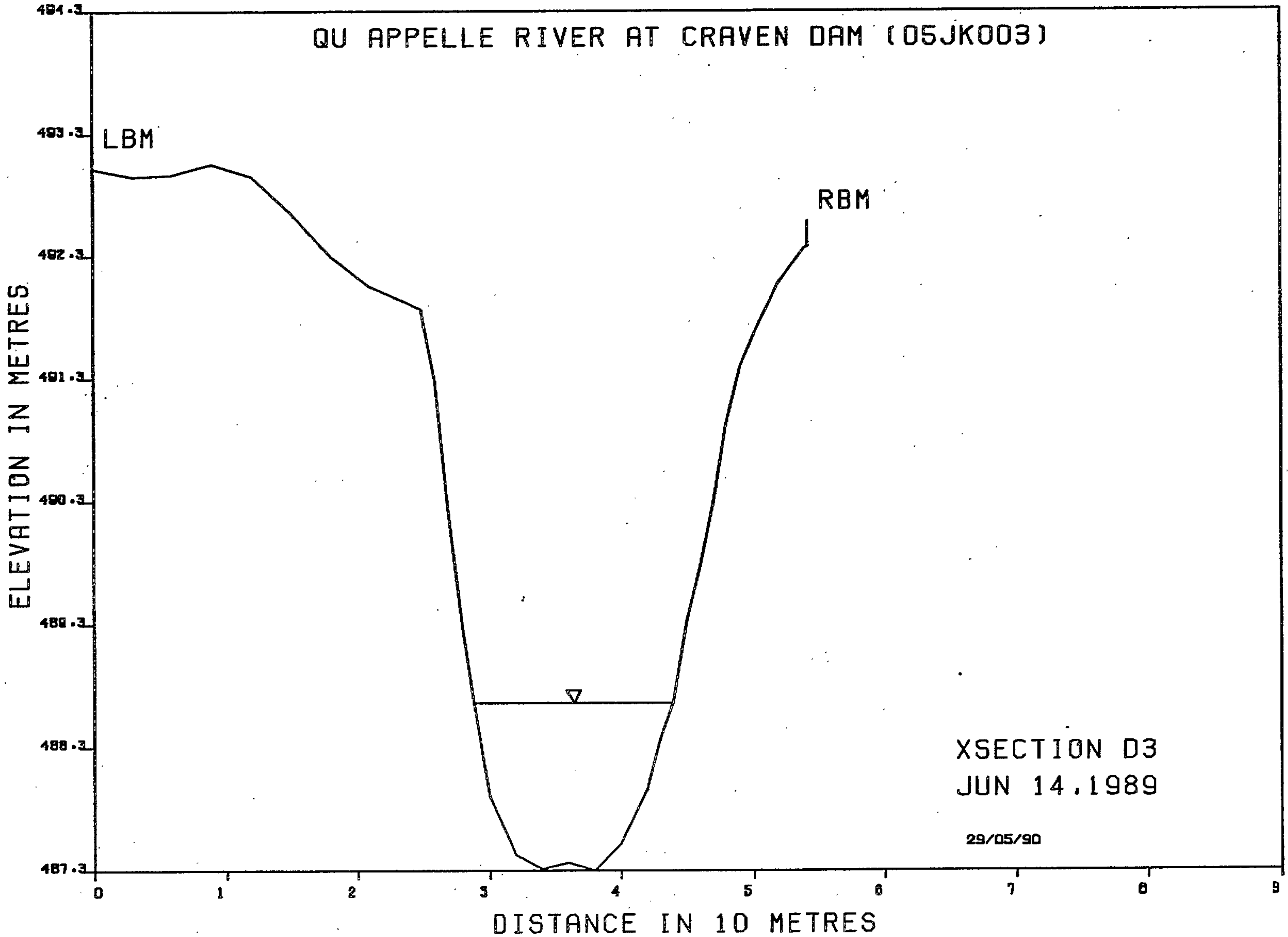
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D2
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.25	.29						
487.50	1.99						
487.75	4.26						
488.00	6.93						
488.25	9.94						
488.50	13.18						
488.75	16.65						
489.00	20.26						
489.25	24.07						
489.50	28.26						
489.75	32.81						
490.00	37.76						
490.25	43.12						
490.50	48.89						
490.75	55.05						
491.00	61.62						
491.25	68.61						
491.50	76.14						
491.75	84.53						
492.00	93.72						
492.25	103.72						
492.50	114.93						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
ELEVATION IN METRES
494.3
493.3
492.3
491.3
490.3
489.3
488.3
487.3
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION D3
JUN 14,1989
29/05/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D3 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	493.10	LBM												
0.0	493.01													
3.0	492.95													
6.0	492.96													
9.0	493.04													
12.0	492.94													
15.0	492.65													
18.0	492.29													
21.0	492.04													
24.0	491.91													
25.0	491.85													
26.0	491.27													
27.0	490.24													
28.0	489.26													
28.8	488.65	WL												
30.0	487.89													
32.0	487.42													
34.0	487.30													
36.0	487.35													
38.0	487.29													
40.0	487.51													
42.0	487.95													
43.0	488.37													
44.0	488.65	WL												
45.0	489.33													
46.0	489.72													
47.0	490.28													
48.0	490.89													
49.0	491.37													
50.0	491.64													
52.0	492.07													
54.0	492.35													
54.3	492.37													
54.3	492.57	RBM												

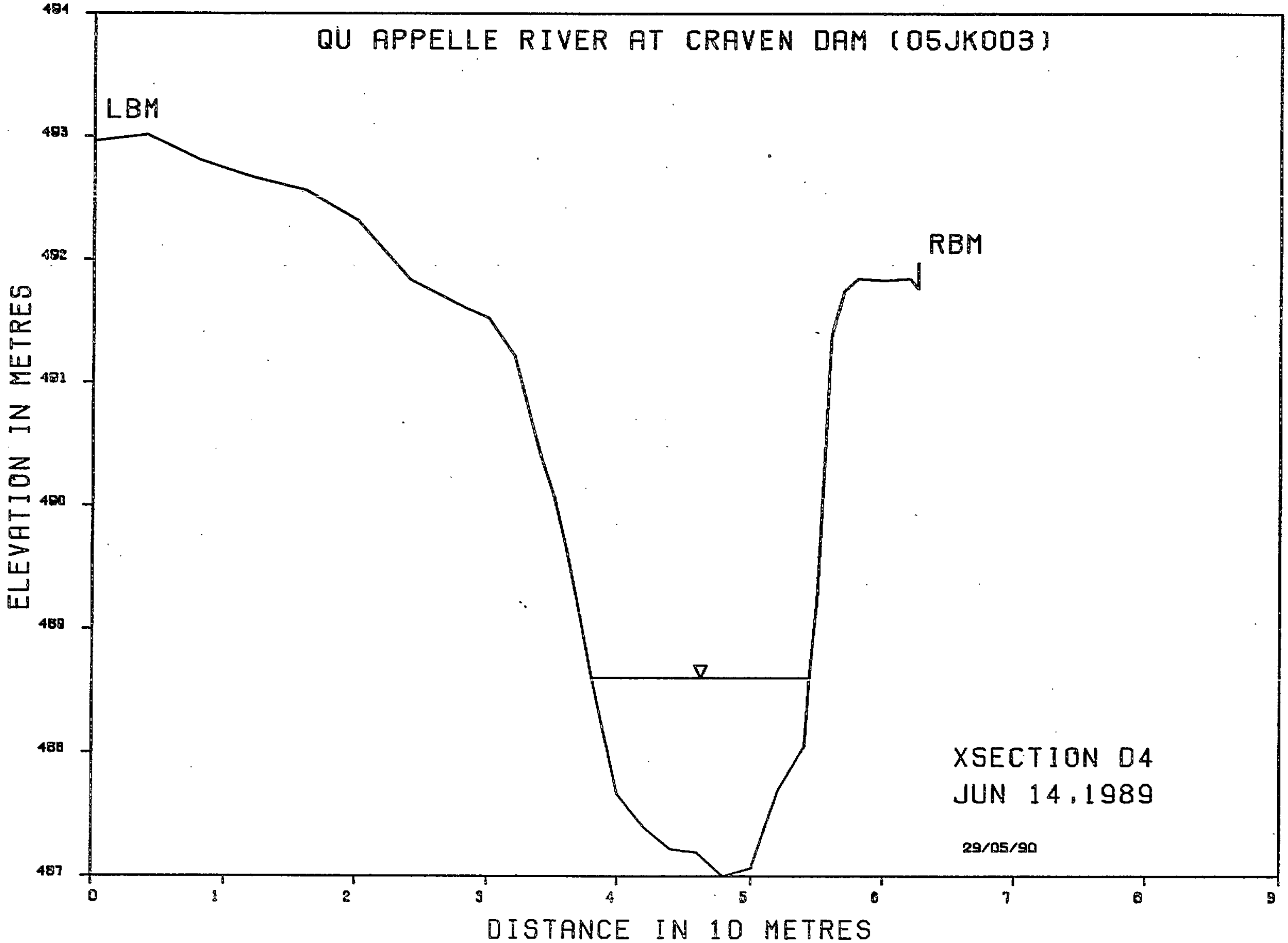
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D3
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	1.20						
487.75	3.55						
488.00	6.43						
488.25	9.63						
488.50	13.08						
488.75	16.84						
489.00	20.80						
489.25	24.93						
489.50	29.24						
489.75	33.77						
490.00	38.50						
490.25	43.40						
490.50	48.47						
490.75	53.70						
491.00	59.10						
491.25	64.69						
491.50	70.50						
491.75	76.65						
492.00	83.38						
492.25	91.48						
492.50	100.66						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
XSECTION D4
JUN 14,1989
29/05/90
ELEVATION IN METRES
DISTANCE IN 10 METRES
494
493
492
491
490
489
488
487
0
1
2
3
4
5
6
7
8
9

WATER SURVEY OF CANADA
20/04/90 . PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D4 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	493.10	LBM												
0.0	493.01													
4.0	493.06													
8.0	492.86													
12.0	492.72													
16.0	492.62													
20.0	492.37													
24.0	491.88													
28.0	491.66													
30.0	491.58													
32.0	491.27													
34.0	490.46													
35.0	490.12													
36.0	489.70													
37.0	489.15													
38.0	488.65	WL												
40.0	487.72													
42.0	487.45													
44.0	487.27													
46.0	487.24													
48.0	487.05													
50.0	487.12													
52.0	487.74													
54.0	488.10													
54.4	488.65	WL												
55.0	489.28													
56.0	491.43													
57.0	491.79													
58.0	491.90													
60.0	491.88													
62.0	491.90													
62.6	491.82													
62.6	492.02	RBM												

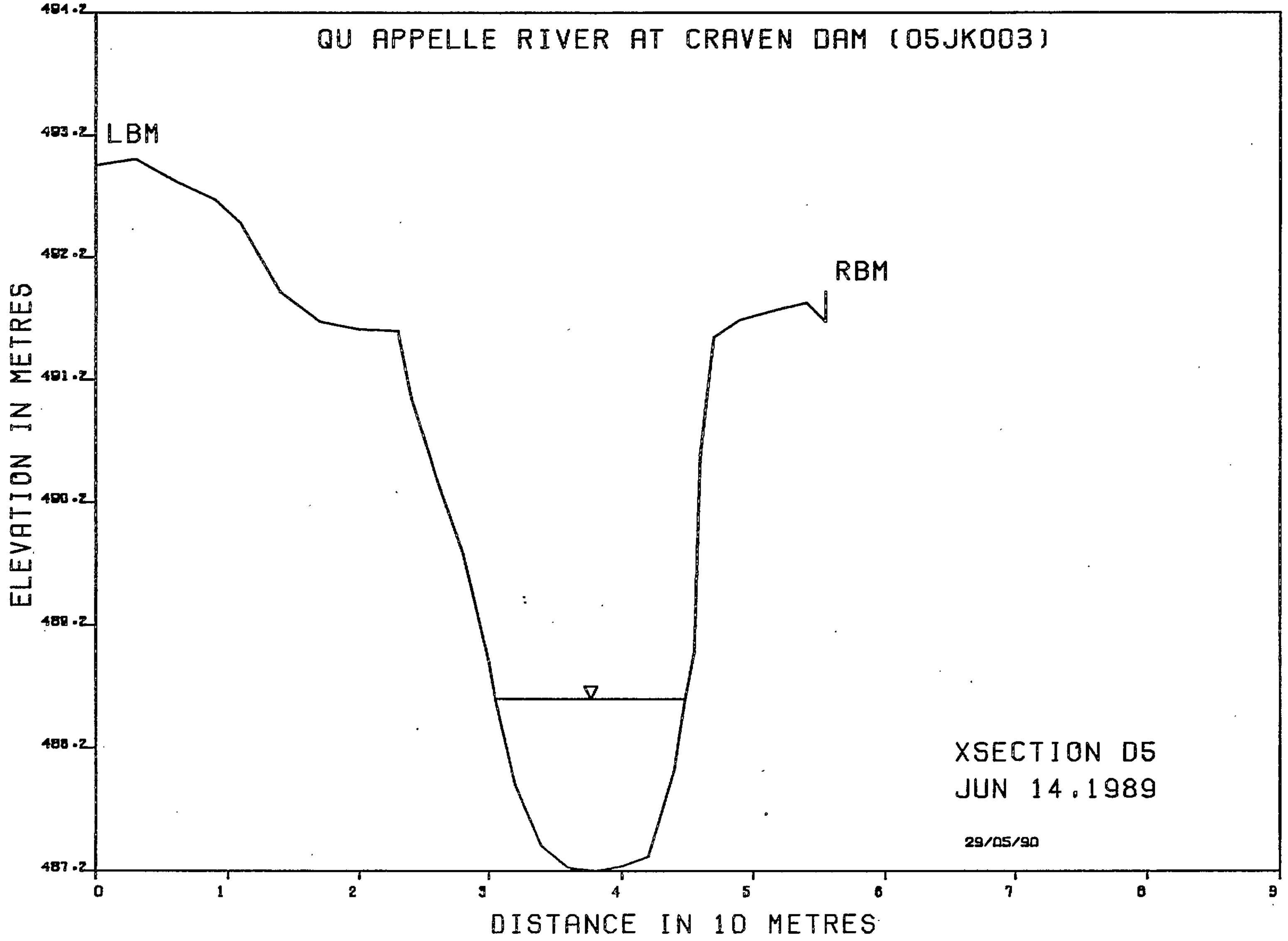
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D4
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 486.50

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.25	.57						
487.50	2.55						
487.75	5.28						
488.00	8.55						
488.25	12.25						
488.50	16.15						
488.75	20.23						
489.00	24.50						
489.25	28.95						
489.50	33.56						
489.75	38.32						
490.00	43.24						
490.25	48.35						
490.50	53.66						
490.75	59.17						
491.00	64.86						
491.25	70.74						
491.50	76.91						
491.75	83.86						
492.00	92.69						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
XSECTION D5
JUN 14,1989
29/05/90
ELEVATION IN METRES
494.2
493.2
492.2
491.2
490.2
489.2
488.2
487.2
DISTANCE IN 10 METRES
0
1
2
3
4
5
6
7
8
9

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D5   SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	493.10	LBM												
0.0	493.00													
3.0	493.06													
6.0	492.88													
9.0	492.73													
11.0	492.53													
14.0	491.97													
17.0	491.72													
20.0	491.66													
23.0	491.65													
24.0	491.10													
26.0	490.43													
28.0	489.83													
30.0	488.94													
30.5	488.65	WL												
32.0	487.95													
34.0	487.45													
36.0	487.27													
38.0	487.25													
40.0	487.29													
42.0	487.37													
44.0	488.07													
44.8	488.65	WL												
45.5	489.03													
46.0	490.64													
47.0	491.60													
49.0	491.74													
52.0	491.83													
54.0	491.88													
55.4	491.72													
55.4	491.97	RBM												

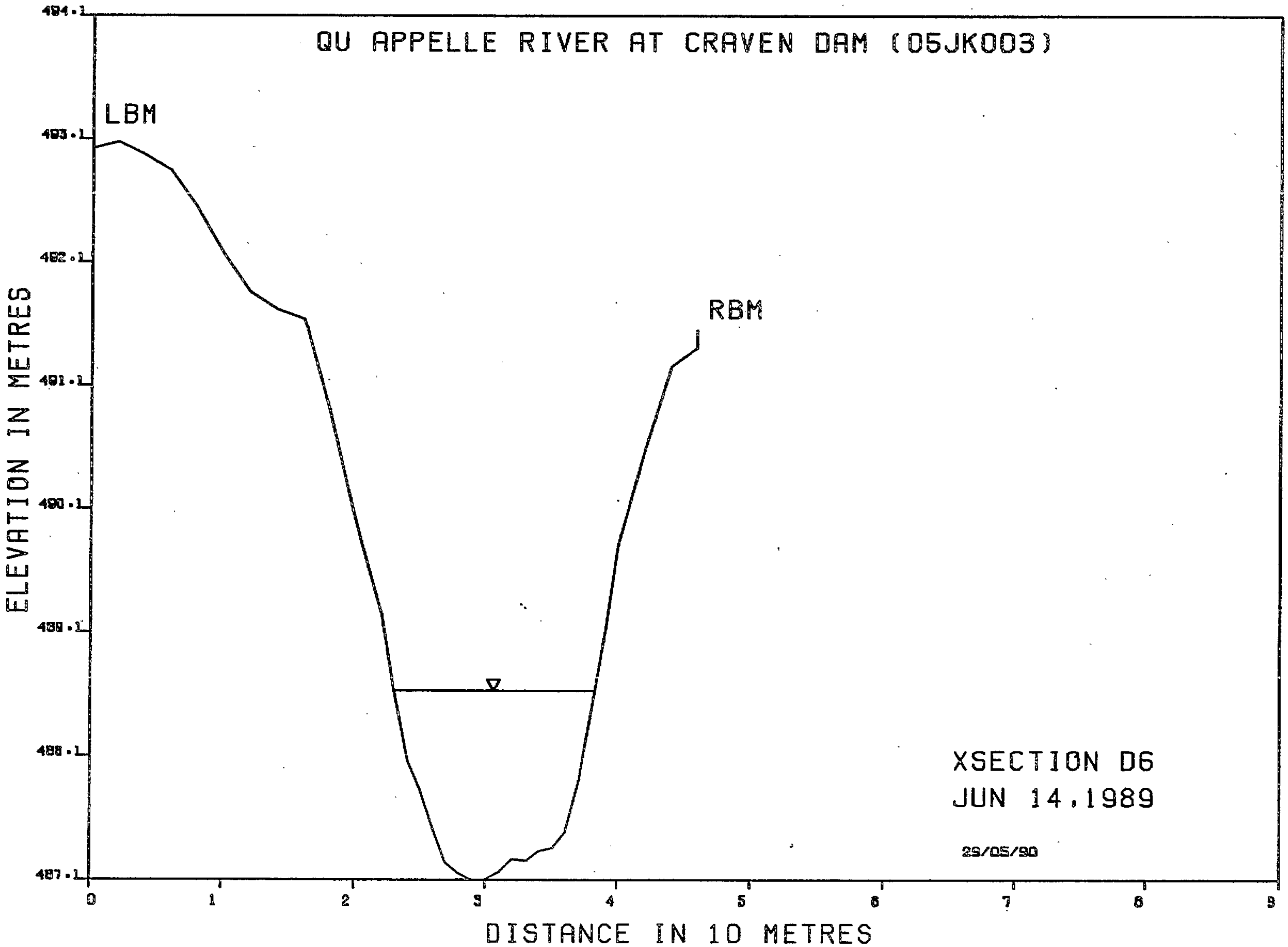
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D5
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	1.59						
487.75	3.95						
488.00	6.73						
488.25	9.84						
488.50	13.17						
488.75	16.72						
489.00	20.50						
489.25	24.49						
489.50	28.63						
489.75	32.94						
490.00	37.42						
490.25	42.13						
490.50	47.06						
490.75	52.21						
491.00	57.60						
491.25	63.23						
491.50	69.05						
491.75	75.66						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
XSECTION D6
JUN 14,1989
29/05/90
ELEVATION IN METRES
494.1
493.1
492.1
491.1
490.1
489.1
488.1
487.1
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA   QU APPELLE RIVER AT CRAVEN DAM (05JK003)
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

PROFILE DATA

XSEC. ID D6   SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	493.15	LBM												
0.0	493.04													
2.0	493.09													
4.0	492.99													
6.0	492.86													
8.0	492.57													
10.0	492.19													
12.0	491.88													
14.0	491.73													
16.0	491.66													
16.3	491.59													
18.0	490.93													
20.0	490.03													
22.0	489.26													
23.0	488.64	WL												
24.0	488.08													
25.0	487.85													
26.0	487.52													
27.0	487.26													
28.0	487.17													
29.0	487.12													
30.0	487.12													
31.0	487.19													
32.0	487.29													
33.0	487.27													
34.0	487.35													
35.0	487.38													
36.0	487.50													
37.0	487.93													
38.2	488.64	WL												
39.0	489.15													
40.0	489.82													
42.0	490.60													
44.0	491.27													
46.0	491.43													
46.0	491.57	RBM												

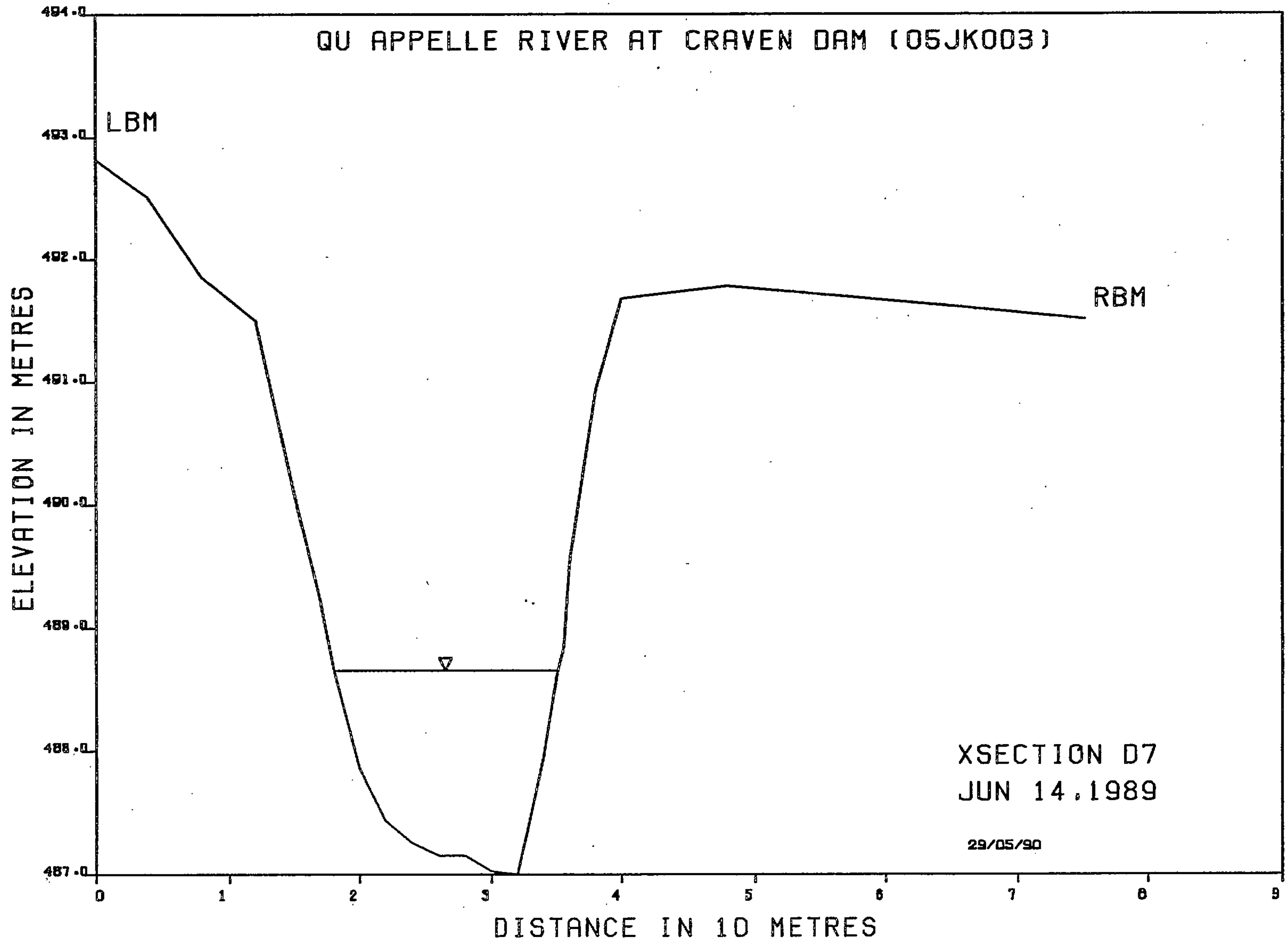
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-06
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.25	.38						
487.50	2.34						
487.75	4.99						
488.00	7.99						
488.25	11.34						
488.50	14.91						
488.75	18.69						
489.00	22.68						
489.25	26.86						
489.50	31.27						
489.75	35.94						
490.00	40.87						
490.25	46.12						
490.50	51.67						
490.75	57.52						
491.00	63.70						
491.25	70.21						
491.50	77.30						


QU APPELLE RIVER AT CRAVEN DAM (05JK003)
LBM
RBM
ELEVATION IN METRES
DISTANCE IN 10 METRES
494.0
493.0
492.0
491.0
490.0
489.0
488.0
487.0
0
1
2
3
4
5
6
7
8
9
XSECTION D7
JUN 14,1989
29/05/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D7 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	492.94	LBM												
0.0	492.79													
4.0	492.48													
8.0	491.83													
12.0	491.47													
15.0	490.06													
17.0	489.20													
18.0	488.63	WL												
20.0	487.83													
22.0	487.41													
24.0	487.23													
26.0	487.13													
28.0	487.13													
30.0	486.99													
32.0	486.97													
34.0	487.93													
35.0	488.63	WL												
35.5	488.81													
36.0	489.54													
38.0	490.91													
40.0	491.65													
48.0	491.75													
64.0	491.60													
75.0	491.48	RBM												

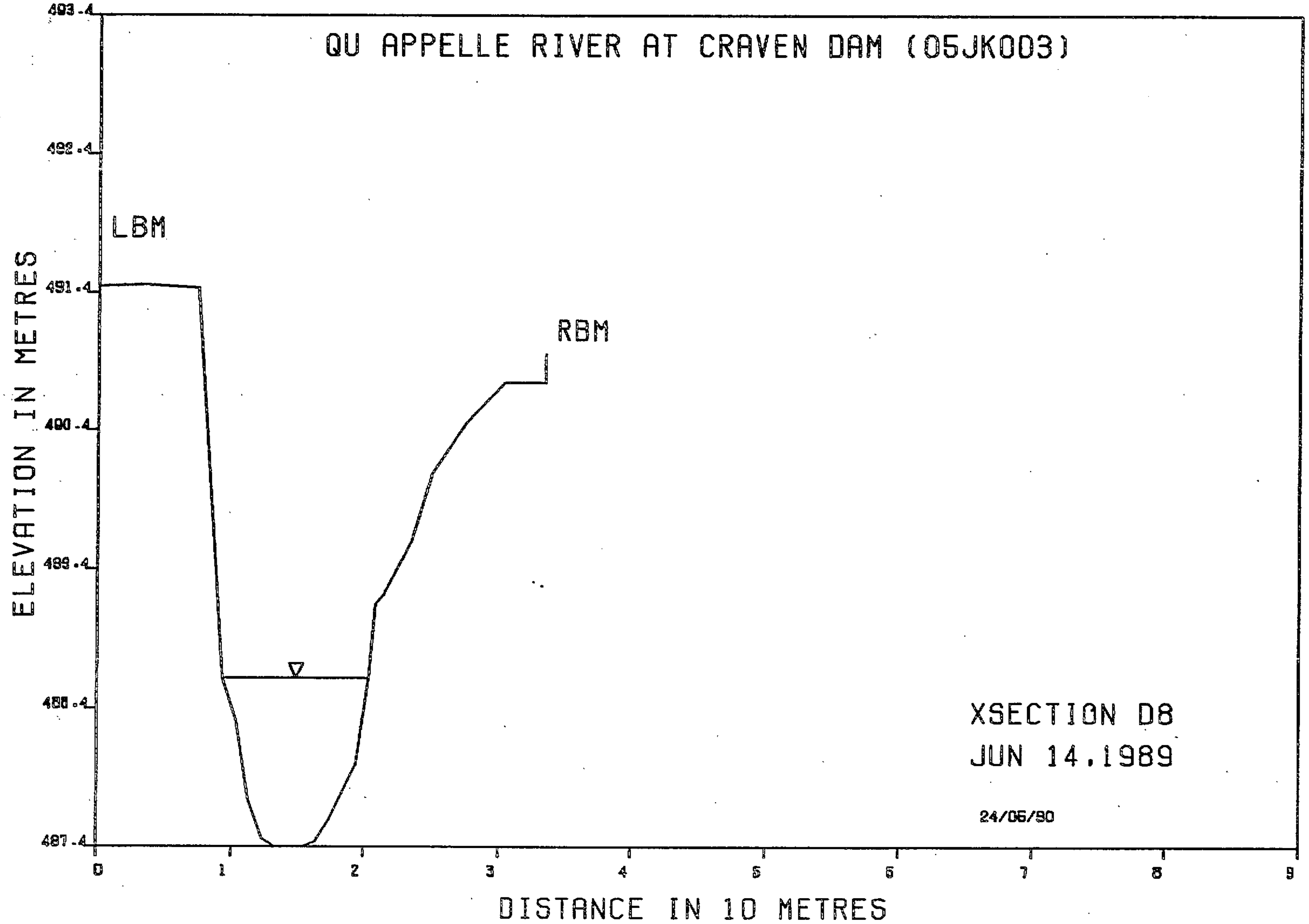
SEDIMENT SURVEY SECTION
20/04/90 . PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D7
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 486.50

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.00	.04						
487.25	1.38						
487.50	3.97						
487.75	7.07						
488.00	10.56						
488.25	14.31						
488.50	18.31						
488.75	22.56						
489.00	27.05						
489.25	31.70						
489.50	36.52						
489.75	41.55						
490.00	46.82						
490.25	52.31						
490.50	58.04						
490.75	63.98						
491.00	70.16						
491.25	76.62						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
493.4
492.4
491.4
490.4
489.4
488.4
487.4
LBM
RBM
XSECTION D8
JUN 14,1989
24/06/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D8 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.74	LBM												
0.0	491.48													
3.4	491.49													
7.4	491.47													
9.4	488.66	WL												
10.4	488.34													
11.4	487.78													
12.4	487.50													
13.4	487.44													
14.4	487.44													
15.4	487.44													
16.4	487.48													
17.4	487.64													
18.4	487.82													
19.4	488.03													
20.4	488.66	WL												
20.9	489.19													
21.4	489.26													
23.4	489.64													
24.9	490.13													
27.4	490.49													
30.4	490.79													
33.4	490.79													
33.4	491.00	RBM												

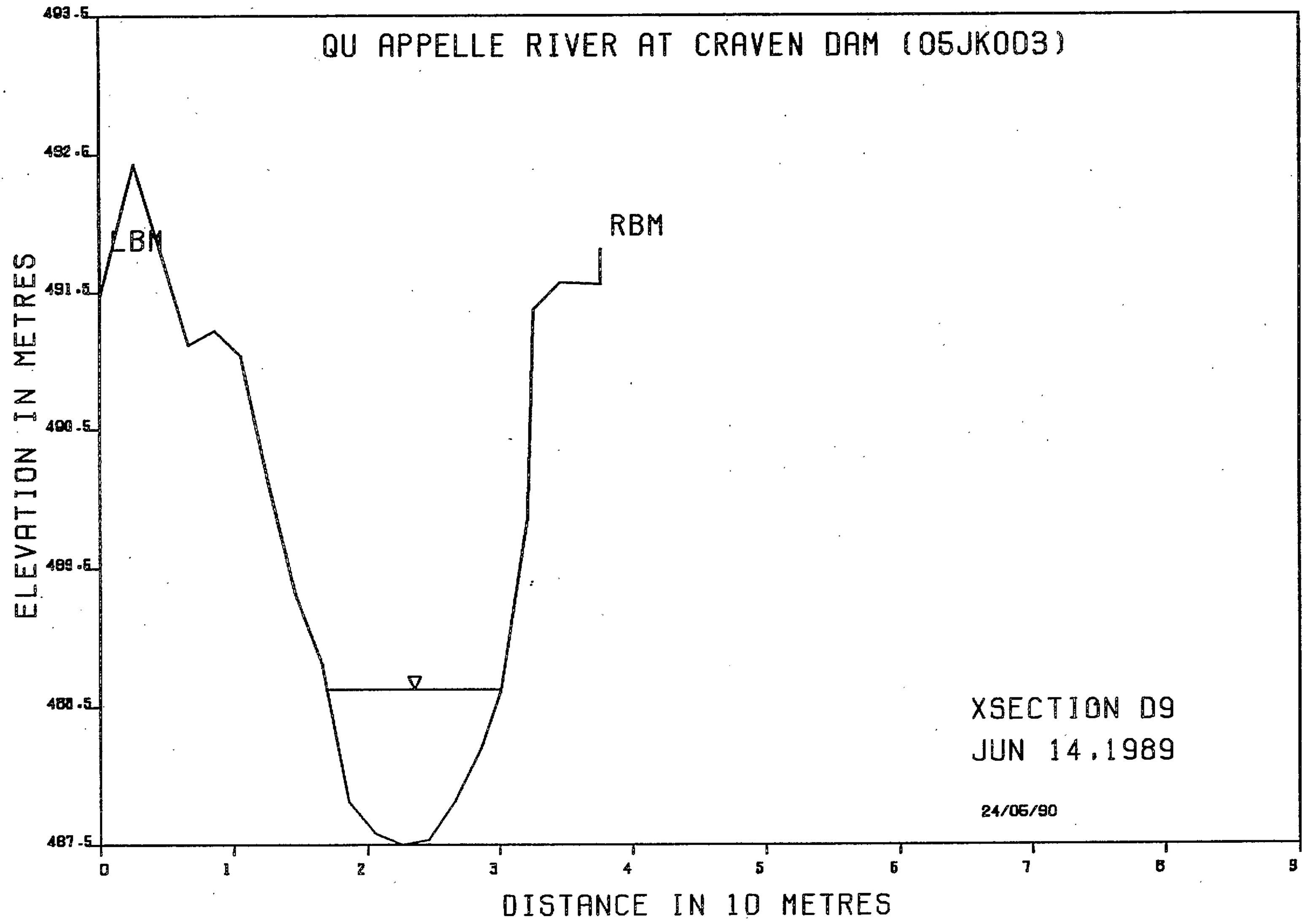
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D8
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 487.
ASSUMED MINIMUM DATUM = 487.00

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.50	.19						
487.75	1.53						
488.00	3.38						
488.25	5.57						
488.50	7.99						
488.75	10.69						
489.00	13.53						
489.25	16.48						
489.50	19.76						
489.75	23.40						
490.00	27.29						
490.25	31.45						
490.50	36.06						
490.75	41.24						
491.00	47.51						



QU APPELLE RIVER AT CRAVEN DAM (05JK003)
ELEVATION IN METRES
493.5
492.5
491.5
490.5
489.5
488.5
487.5
LBM
RBM
XSECTION D9
JUN 14,1989
24/05/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

PROFILE DATA

XSEC. ID D9 SURVEY DATE JUN 14,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	491.74	LBM												
0.0	491.48													
2.6	492.46													
6.6	491.14													
8.6	491.25													
10.6	491.06													
12.6	490.15													
14.6	489.34													
16.6	488.84													
17.0	488.65	WL												
18.6	487.85													
20.6	487.61													
22.6	487.53													
24.6	487.57													
26.6	487.85													
28.6	488.23													
30.1	488.65	WL												
32.1	489.89													
32.6	491.40													
34.6	491.59													
37.6	491.58													
37.6	491.84	RBM												

SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER AT CRAVEN DAM (05JK003)

XSEC. ID.-D9
SURVEYED JUN 14,1989
MINIMUM ELEVATION = 488.
ASSUMED MINIMUM DATUM = 487.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
487.75	.96						
488.00	2.96						
488.25	5.46						
488.50	8.35						
488.75	11.58						
489.00	15.09						
489.25	18.94						
489.50	23.13						
489.75	27.57						
490.00	32.26						
490.25	37.14						
490.50	42.18						
490.75	47.38						
491.00	52.73						
491.25	58.52						
491.50	65.25						

BED MATERIAL SAMPLES

Station Number: 05JK002 Year: 1989

Station Name: QU'APPELLE RIVER below Craven Dam

i) Bed Material Sampling

Date	Vertical	Sampler Type	Sample Number	Sample Net Wt (g)	4	8	16	31	62	125	250	500	1000	2000	4000	8000	16000	32000	64000
					Finer Than Size (um) Indicated (%)														
Jun 14	1/6LB	BMH60	U1 - 1	18.0					46	66	83	98	98	99	99	100			
Jun 14	1/3LB	BMH60	U1 - 2	10.8					39	81	90	95	98	99	100				
Jun 14	1/2LB	BMH60	U1 - 3	88.7	12	13	15	16	22	38	49	69	82	90	97	100			
Jun 14	2/3LB	BMH60	U1 - 4	29.6					16	33	53	77	92	97	99	100			
Jun 14	5/6LB	BMH60	U1 - 5	193.2					12	18	32	50	70	86	97	100			
Jun 14	1/6LB	BMH60	U2 - 1	126.3					41	70	89	98	99	99	100				
Jun 14	1/3LB	BMH60	U2 - 2	47.6					37	83	95	98	99	100					
Jun 14	1/2LB	BMH60	U2 - 3	83.0	18	20	22	25	32	53	73	94	99	100					
Jun 14	2/3LB	BMH60	U2 - 4	78.7					30	48	73	93	99	100					
Jun 14	5/6LB	BMH60	U2 - 5	57.8					19	27	49	81	95	99	100				
Jun 14	1/6LB	BMH60	U3 - 1	103.0					56	83	98	100							
Jun 14	1/3LB	BMH60	U3 - 2	90.7					51	90	98	99	100						
Jun 14	1/2LB	BMH60	U3 - 3	38.3	18	20	23	26	36	72	87	94	98	100					
Jun 14	2/3LB	BMH60	U3 - 4	117.5					32	53	74	87	93	96	98	100			
Jun 14	5/6LB	BMH60	U3 - 5	102.8					34	44	65	83	92	97	99	100			
Jun 13	1/6LB	BMH60	U4 - 1	85.0					33	70	92	99	100						
Jun 13	1/3LB	BMH60	U4 - 2	48.8					40	75	97	99	100						
Jun 13	1/2LB	BMH60	U4 - 3	49.9	26	30	34	39	43	73	97	99	100						
Jun 13	2/3LB	BMH60	U4 - 4	82.3					42	82	97	99	100						
Jun 13	5/6LB	BMH60	U4 - 5	82.8					35	63	88	98	99	100					
Jun 13	1/6LB	BMH60	U5 - 1	NO SAMPLE															
Jun 13	1/3LB	BMH60	U5 - 2	215.2					2	3	6	11	14	21	40	73	86	100	
Jun 13	1/2LB	BMH60	U5 - 3	165.5	29	35	42	47	52	62	81	95	99	100					
Jun 13	2/3LB	BMH60	U5 - 4	99.0					36	55	76	88	94	97	99	100			
Jun 13	5/6LB	BMH60	U5 - 5	234.1					23	28	43	59	66	70	76	88	100		
Jun 14	1/6LB	BMH60	G - 1	NO SAMPLE															
Jun 14	1/3LB	BMH60	G - 2	70.5					14	17	24	37	50	60	71	85	91	100	
Jun 14	1/2LB	BMH60	G - 3	54.3					7	12	23	44	60	71	81	95	100		
Jun 14	2/3LB	BMH60	G - 4	102.6					22	41	59	73	81	87	93	100			
Jun 14	5/6LB	BMH60	G - 5	96.4					23	46	79	96	98	99	99	99	100		

U = Upstream x-section; D = Downstream x-section; G = @ gauge (flow metering x-section)

Station Number: 05JK002 Year: 1989

Station Name: QU'APPELLE RIVER below Craven Dam

i) Bed Material Sampling

Date	Vertical	Sampler Type	Sample Number	Sample Net Wt (g)	Finer Than Size (um) Indicated (%) 4	8	16	31	62	125	250	500	1000	2000	4000	8000	16000	32000	64000
			D1	NO SAMPLES															
Jun 14	1/4LB	BMH60	D2 - 1	203.5					18	27	46	58	65	76	92	100			
Jun 14	1/2LB	BMH60	D2 - 2	104.6	11	13	15	18	20	40	80	92	97	99	100				
Jun 14	3/4LB	BMH60	D2 - 3	147.6					32	76	97	99	100						
Jun 14	1/4LB	BMH60	D3 - 1	103.2					27	59	91	96	98	99	100				
Jun 14	1/2LB	BMH60	D3 - 2	166.4	14	16	18	21	31	71	96	99	100						
Jun 14	3/4LB	BMH60	D3 - 3	66.9					37	74	94	98	99	100					
Jun 14	1/4LB	BMH60	D4 - 1	69.4					25	60	83	94	98	99	100				
Jun 14	1/2LB	BMH60	D4 - 2	116.3	19	23	27	31	44	73	86	91	94	96	99	100			
Jun 14	3/4LB	BMH60	D4 - 3	79.4					68	85	96	99	100						
Jun 14	1/4LB	BMH60	D5 - 1	226.7					28	49	54	67	82	93	98	100			
Jun 14	1/2LB	BMH60	D5 - 2	38.2	14	16	19	21	29	53	66	78	86	93	99	100			
Jun 14	3/4LB	BMH60	D5 - 3	111.9					36	56	79	92	96	98	99	100			
Jun 14	1/4LB	BMH60	D6 - 1	64.7					82	88	91	95	97	99	100				
Jun 14	1/2LB	BMH60	D6 - 2	56.1	16	19	22	25	34	56	70	87	97	100					
Jun 14	3/4LB	BMH60	D6 - 3	76.4					45	87	95	98	99	100					
Jun 14	1/4LB	BMH60	D7 - 1	67.9					60	90	98	99	99	100					
Jun 14	1/2LB	BMH60	D7 - 2	44.1	19	23	27	34	62	95	99	100							
Jun 14	3/4LB	BMH60	D7 - 3	114.8					62	89	98	99	100						
Jun 14	1/2LB	BMH60	D8 - 1	169.5	25	31	40	55	74	89	98	100							
Jun 14	1/2LB	BMH60	D9 - 1	159.4	27	35	44	58	78	95	100								

U = Upstream x-section; D = Downstream x-section; G = @ gauge (flow metering x-section)

Station Number: 05JK002

Year: 1989

Station Name: QU'APPELLE RIVER below Craven Dam

ii) Bank Sampling

Date	Vertical	Sampler Type	Sample Number	Sample Net Wt (g)	4	8	16	31	62	125	250	500	1000	2000	4000	8000	16000	32000	64000
					Finer Than Size (um) Indicated (%)														
Jun 13	@ U2-RB	SCOOP		1317.5	28	32	37	44	62	90	100								
Jun 13	@ U4-LB	SCOOP		1082.2	26	29	35	44	71	96	99	100							
Jun 14	@ D1-RB	SCOOP		1518.4	32	39	48	64	90	99	100								
Jun 14	@ D6-RB	SCOOP		1067.9	24	28	33	43	62	86	94	100							
Jun 14	@ D7-LB	SCOOP		1492.3	27	32	39	49	64	94	100								
Jun 14	@ D7-RB	SCOOP		1282.0	34	39	46	59	82	98	99	100							

U = Upstream x-section; D = Downstream x-section; G = @ gauge (flow metering x-section)

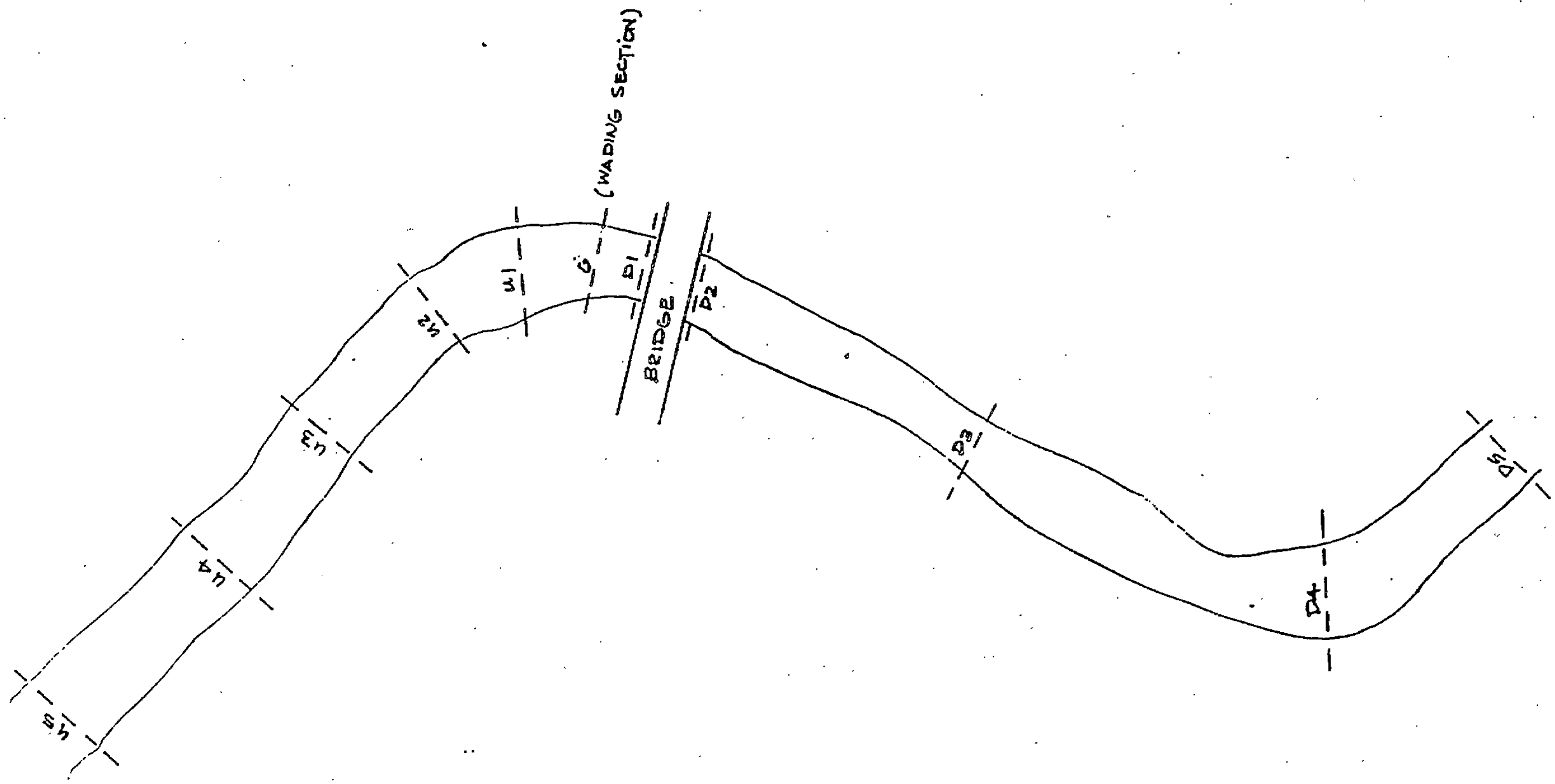
APPENDIX 3

QU'APPELLE RIVER BELOW LOON CREEK

Results of river cross-section surveys and bed material sampling conducted by Water Survey of Canada staff in June, 1989.

NOTE:

All Figures, Tables and Plates were supplied by Ted Yuzyk, Sediment Survey Section, Water Survey of Canada, Environment Canada, Ottawa.



LOON CREEK SITE PLAN

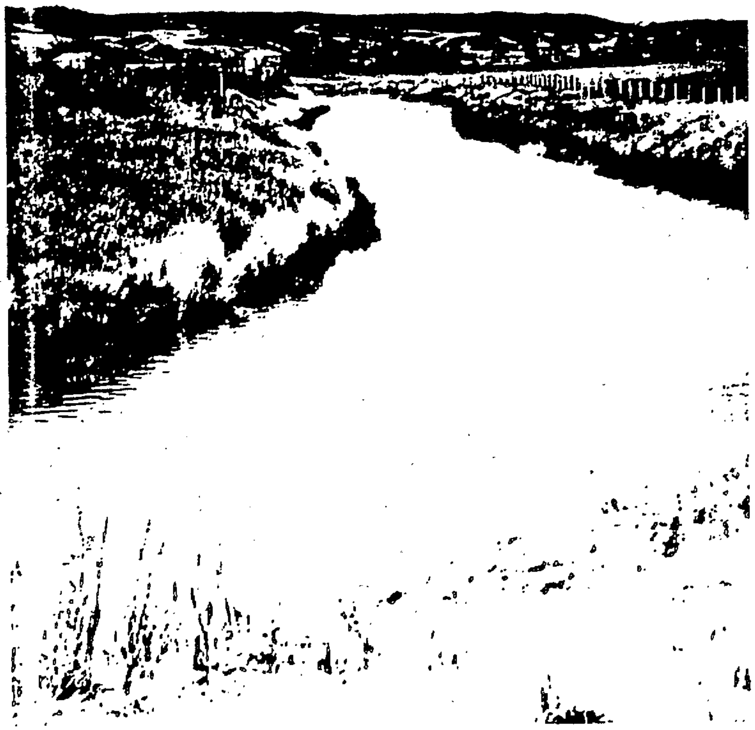
(APPROX. TO SCALE)

11 CROSS SECTIONS

Locations of cross-sections surveyed by the Water Survey of Canada in June, 1989.

REPRESENTATIVE PHOTOGRAPHS

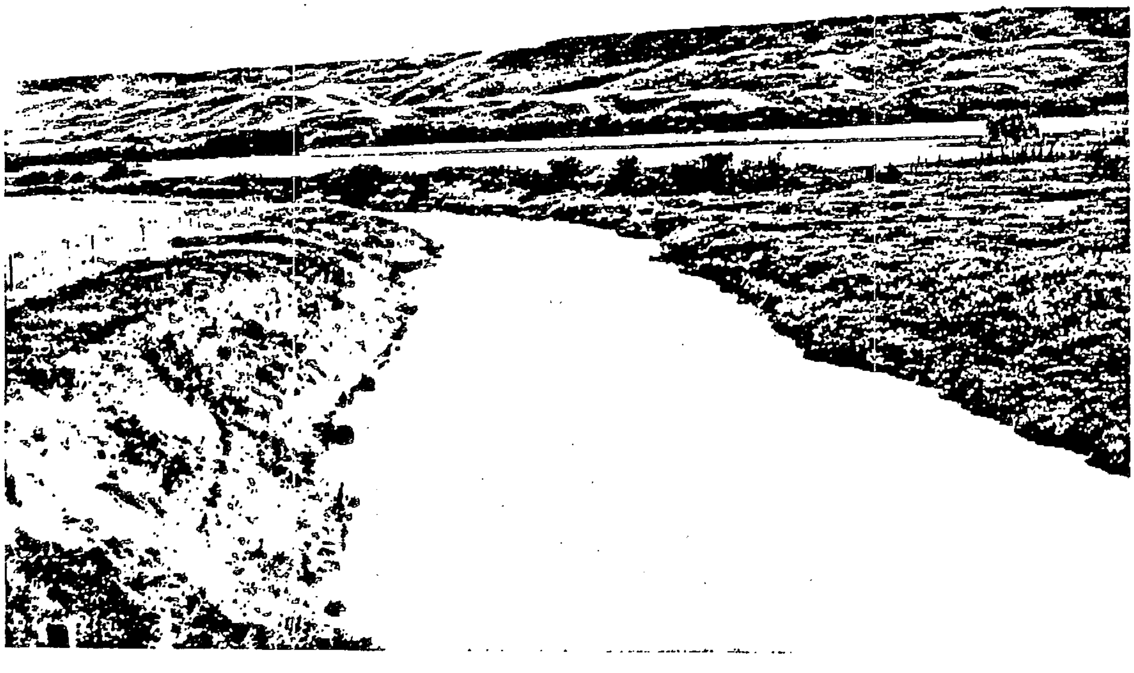
NOTE: All photos were taken in June, 1989



Looking upstream from cross-section U2

Looking to the right bank at the gauge

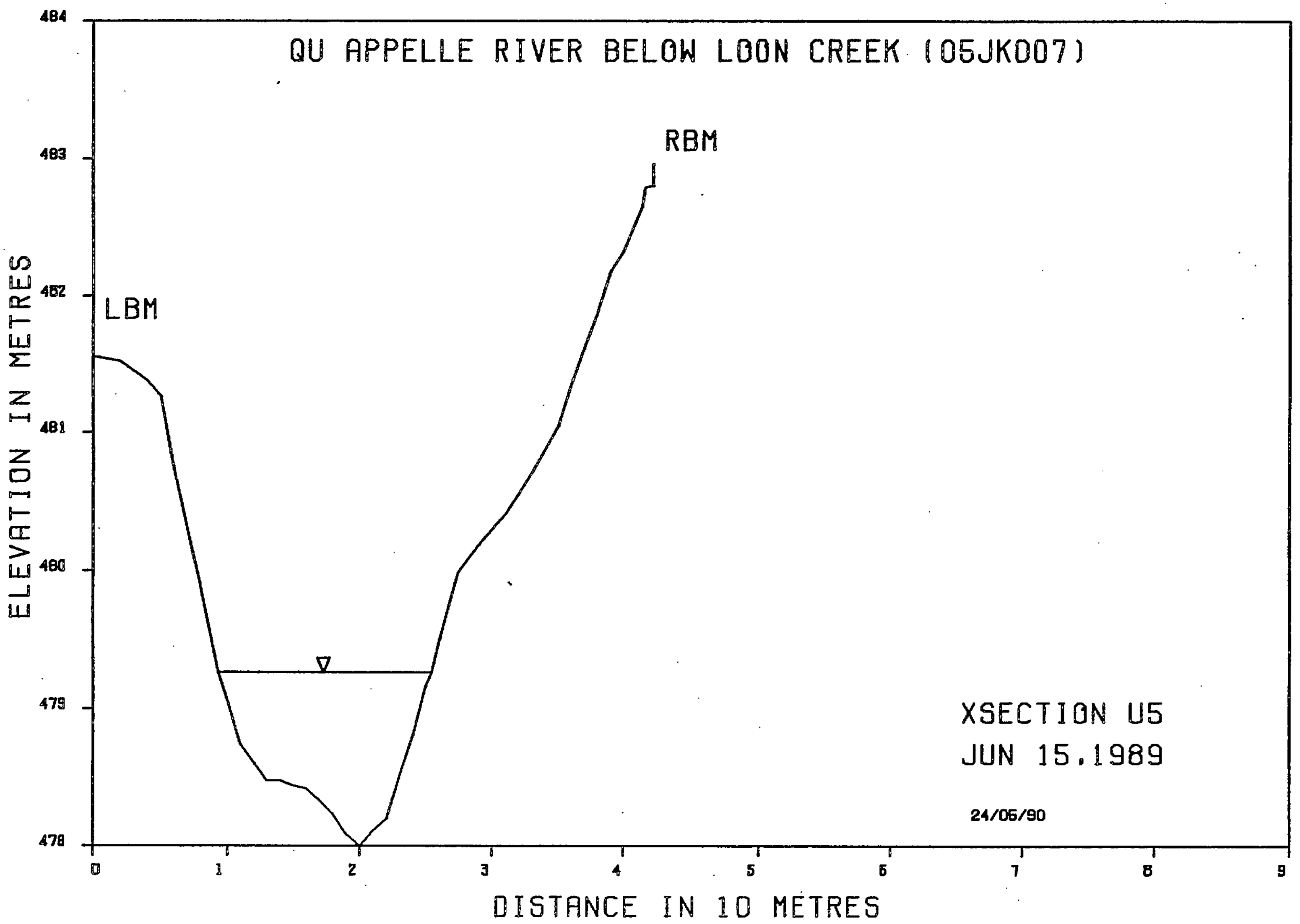
Looking to the left bank at the gauge.



Looking downstream from cross-section D2.

Looking upstream from cross-section D4.

RIVER CROSS-SECTION SURVEYS



QU APPELLE RIVER BELOW LOON CREEK (05JK007)
RBM
LBM
ELEVATION IN METRES
484
483
482
481
480
479
478
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION U5
JUN 15,1989
24/05/90

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID U5 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	481.75	LBM												
0.0	481.58													
2.0	481.54													
4.0	481.41													
5.0	481.29													
6.0	480.78													
8.0	479.94													
9.3	479.28	WL												
10.0	479.07													
11.0	478.76													
12.0	478.62													
13.0	478.50													
14.0	478.50													
15.0	478.46													
16.0	478.44													
17.0	478.36													
18.0	478.26													
19.0	478.12													
20.0	478.02													
21.0	478.13													
22.0	478.22													
23.0	478.52													
24.0	478.83													
25.0	479.18													
25.4	479.28	WL												
26.0	479.52													
27.4	480.01													
29.0	480.20													
31.0	480.43													
32.0	480.57													
33.0	480.74													
35.0	481.07													
36.0	481.36													
37.0	481.64													
38.0	481.88													
39.0	482.20													
40.0	482.34													
41.4	482.67													
41.6	482.81													
42.2	482.82													
42.2	482.99	RBM												

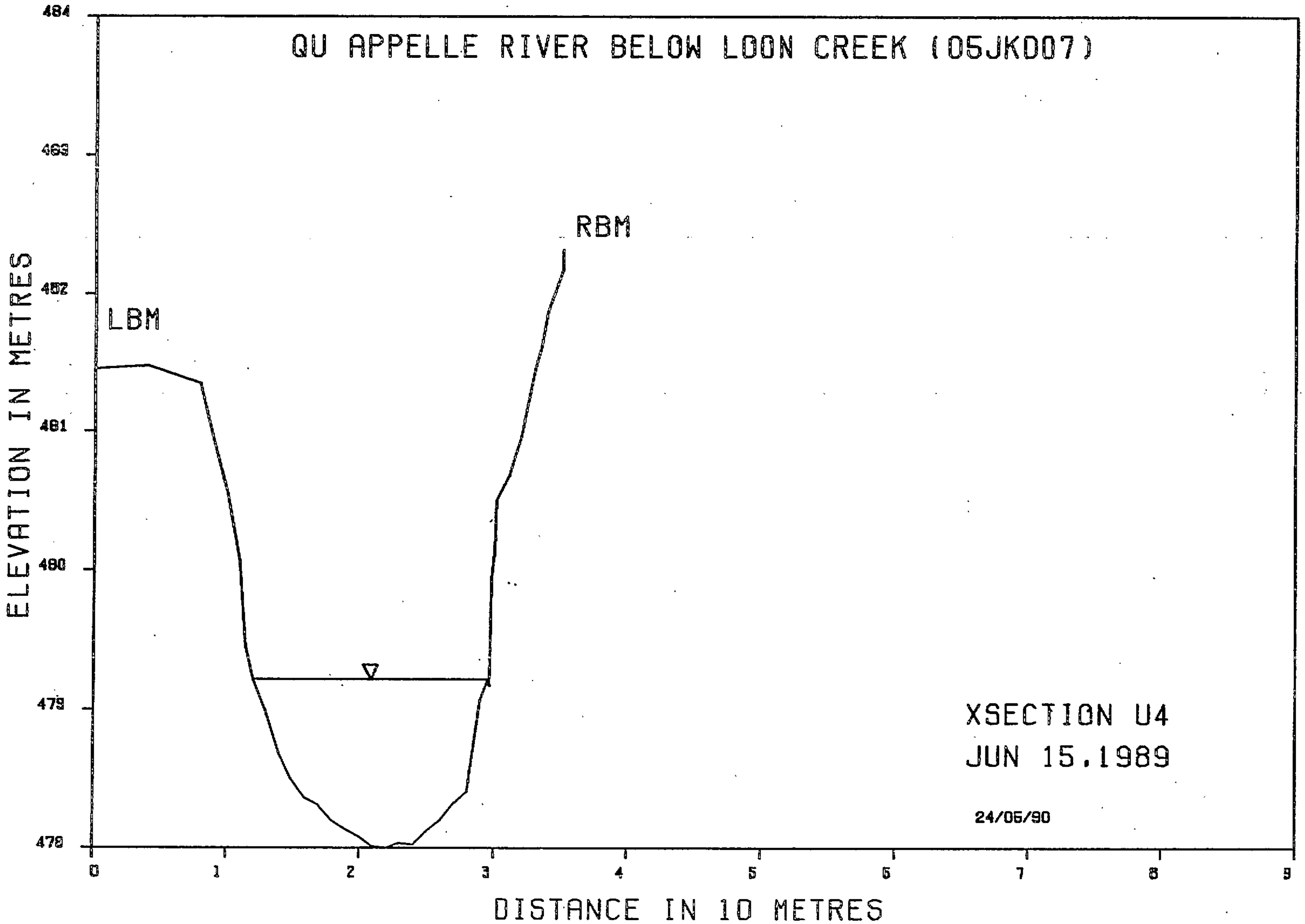
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-U5
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.48						
478.50	1.96						
478.75	4.79						
479.00	8.16						
479.25	11.92						
479.50	16.04						
479.75	20.46						
480.00	25.18						
480.25	30.38						
480.50	36.26						
480.75	42.74						
481.00	49.74						
481.25	57.19						
481.50	65.16						
481.75	74.26						


QU APPELLE RIVER BELOW LOON CREEK (05JKD07)
484
483
482
481
480
479
478
ELEVATION IN METRES
LBM
RBM
XSECTION U4
JUN 15.1989
24/06/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID U4 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	481.70	LBM												
0.0	481.51													
4.0	481.54													
8.0	481.41													
9.0	481.00													
10.0	480.61													
11.0	480.13													
11.5	479.52													
12.1	479.28	WL												
13.0	479.06													
14.0	478.74													
15.0	478.56													
16.0	478.42													
17.0	478.38													
18.0	478.26													
19.0	478.20													
20.0	478.15													
21.0	478.08													
22.0	478.06													
23.0	478.10													
24.0	478.09													
25.0	478.18													
26.0	478.26													
27.0	478.38													
28.0	478.47													
29.0	479.13													
29.5	479.28	WL												
29.7	479.23													
29.8	480.00													
30.0	480.21													
30.1	480.57													
31.0	480.74													
32.0	481.03													
33.0	481.51													
33.5	481.67													
34.0	481.93													
35.2	482.24													
35.2	482.38	RBM												

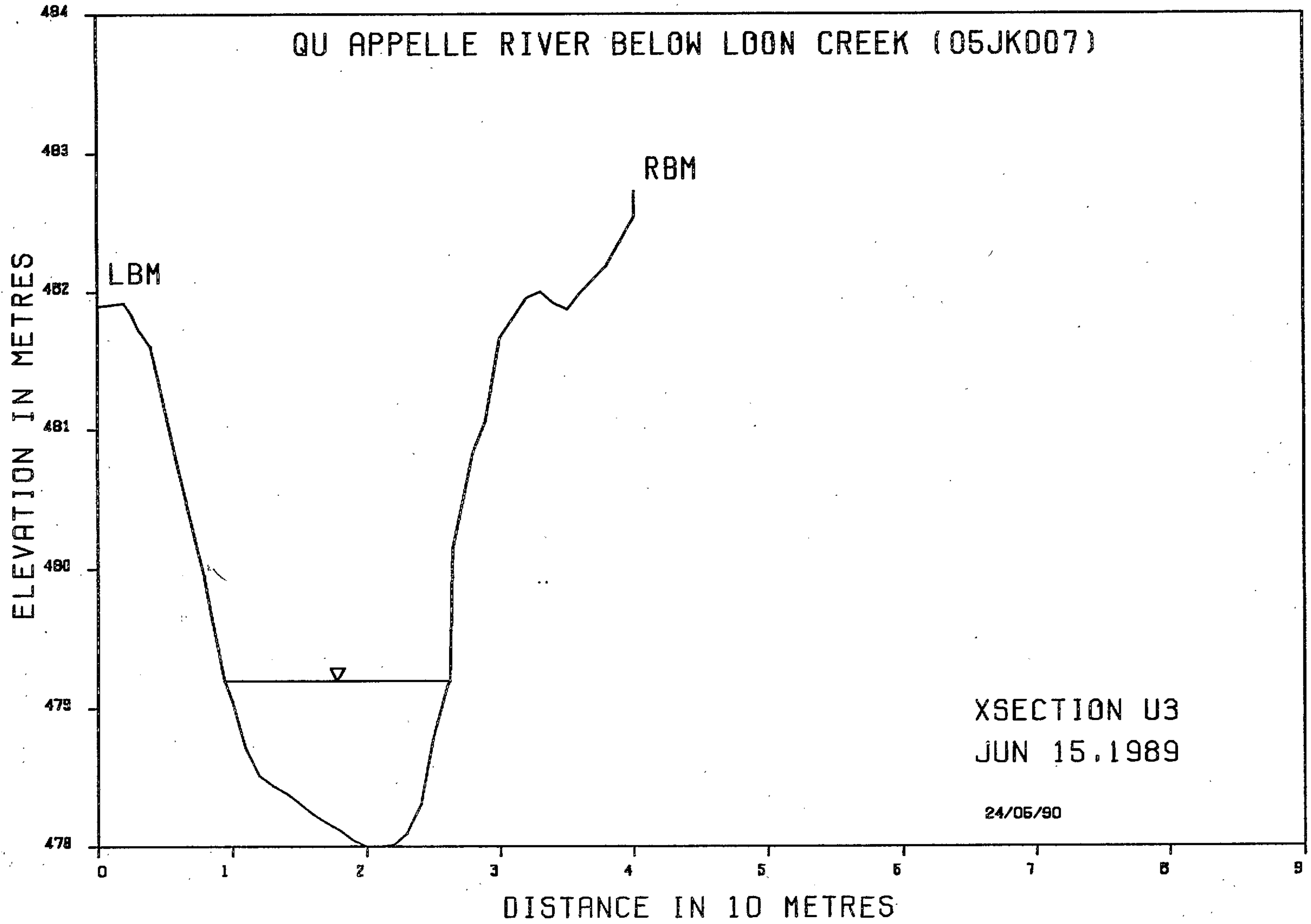
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-U4
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.87						
478.50	3.41						
478.75	6.81						
479.00	10.56						
479.25	14.64						
479.50	19.10						
479.75	23.68						
480.00	28.32						
480.25	33.06						
480.50	37.95						
480.75	43.07						
481.00	48.60						
481.25	54.47						
481.50	60.74						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
RBM
LBM
ELEVATION IN METRES
484
483
482
481
480
479
478
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION U3
JUN 15,1989
24/06/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID U3 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	482.05	LBM												
0.0	481.98													
2.0	482.00													
2.5	481.93													
3.0	481.82													
4.0	481.69													
6.0	480.84													
8.0	480.04													
9.0	479.53													
9.5	479.29	WL												
10.0	479.13													
11.0	478.81													
12.0	478.60													
13.0	478.53													
14.0	478.47													
15.0	478.40													
16.0	478.33													
17.0	478.27													
18.0	478.21													
19.0	478.14													
20.0	478.09													
21.0	478.09													
22.0	478.11													
23.0	478.19													
24.0	478.39													
25.0	478.87													
26.0	479.24													
26.2	479.28	WL												
26.5	480.24													
27.0	480.45													
28.0	480.92													
29.0	481.15													
30.0	481.75													
32.0	482.04													
33.0	482.09													
34.0	482.00													
35.0	481.96													
36.0	482.08													
38.0	482.27													
40.1	482.63													
40.1	482.81	RBM												

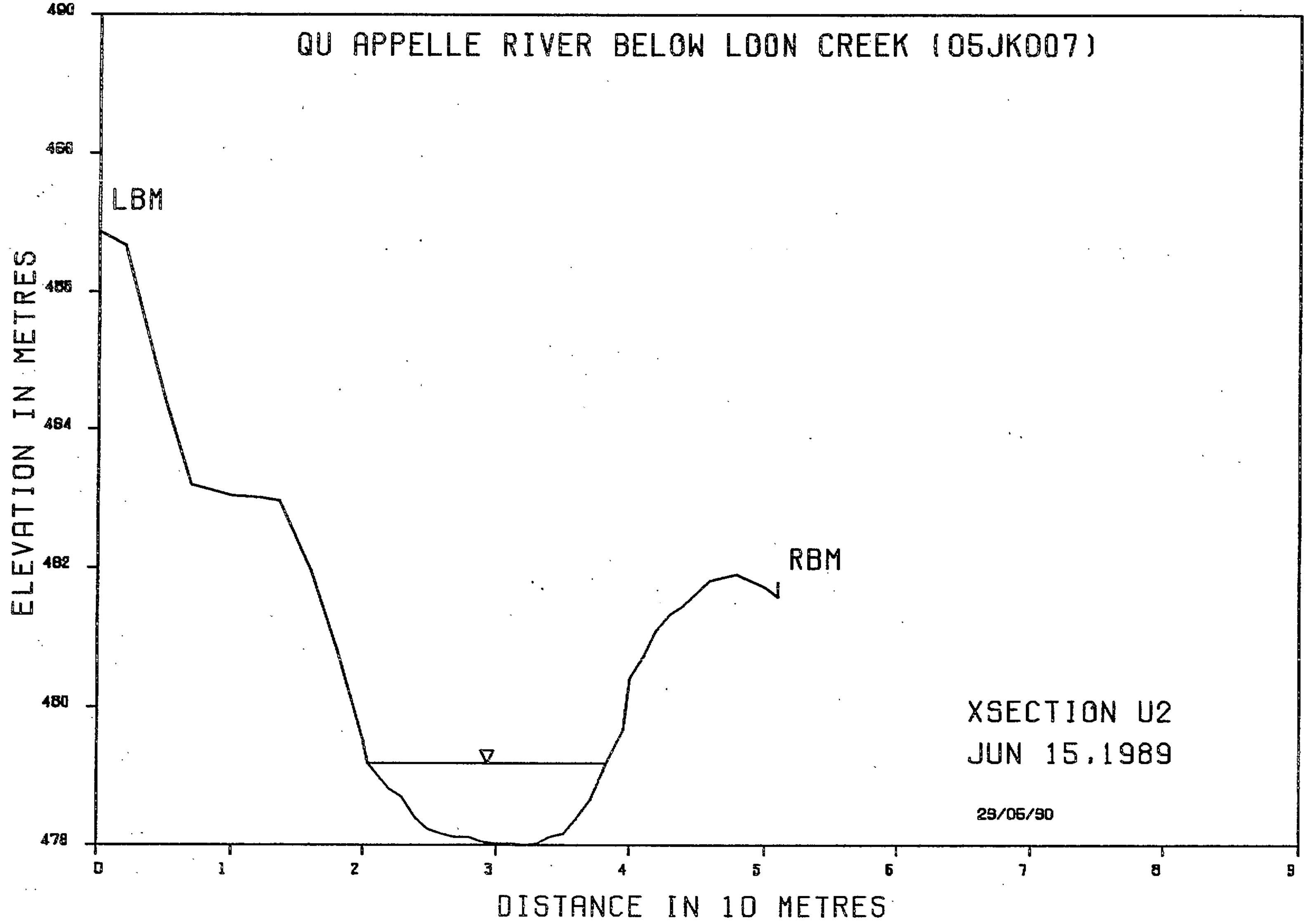
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA, ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-U3
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.63						
478.50	2.74						
478.75	5.84						
479.00	9.39						
479.25	13.30						
479.50	17.53						
479.75	21.90						
480.00	26.41						
480.25	31.08						
480.50	35.99						
480.75	41.20						
481.00	46.70						
481.25	52.58						
481.50	58.73						
481.75	65.15						
482.00	72.21						



QU APPELLE RIVER BELOW LOON CREEK (05JK007)
ELEVATION IN METRES
DISTANCE IN 10 METRES
LBM
RBM
XSECTION U2
JUN 15,1989
29/06/90
490
488
486
484
482
480
478
0
1
2
3
4
5
6
7
8
9

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID U2 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	487.08	LBM												
0.0	486.95													
2.0	486.75													
5.0	484.56													
7.0	483.28													
10.0	483.14													
12.0	483.10													
13.6	483.07													
16.0	482.04													
18.0	480.92													
20.0	479.59													
20.4	479.27	WL												
22.0	478.91													
23.0	478.79													
24.0	478.49													
25.0	478.33													
26.0	478.27													
27.0	478.21													
28.0	478.21													
29.0	478.15													
30.0	478.13													
31.0	478.11													
32.0	478.09													
33.0	478.13													
34.0	478.21													
35.0	478.25													
36.0	478.47													
37.0	478.75													
38.0	479.15													
38.2	479.27	WL												
39.5	479.76													
40.0	480.49													
41.0	480.83													
42.0	481.18													
43.0	481.42													
44.0	481.54													
46.0	481.90													
48.0	481.99													
50.0	481.82													
51.0	481.67													
51.0	481.89	RBM												

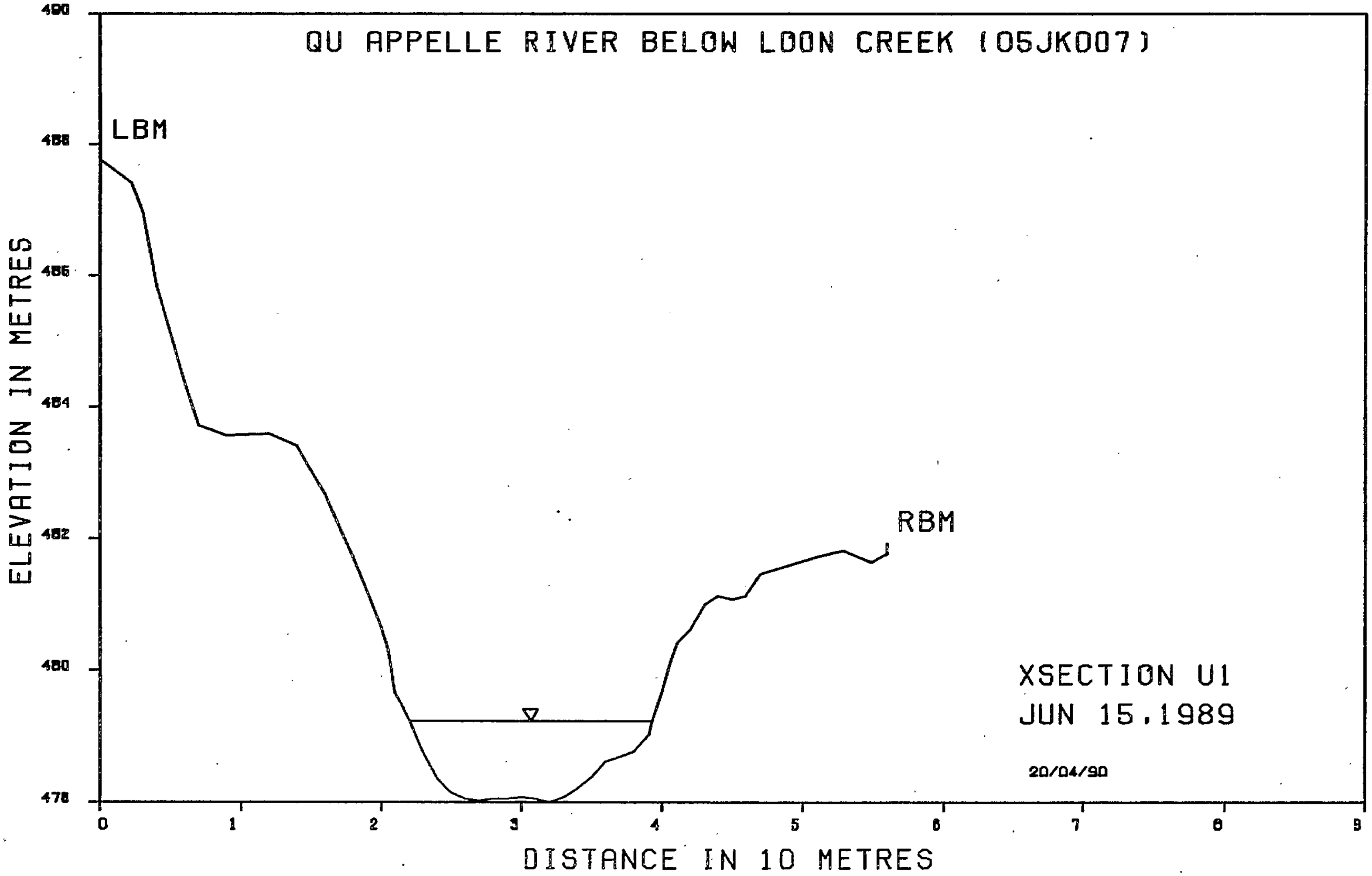
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-U2
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.74						
478.50	3.41						
478.75	6.65						
479.00	10.39						
479.25	14.61						
479.50	19.16						
479.75	23.96						
480.00	28.96						
480.25	34.10						
480.50	39.37						
480.75	44.86						
481.00	50.62						
481.25	56.67						
481.50	63.09						
481.75	70.04						



QU APPELLE RIVER BELOW LOON CREEK (05JK007)
LBM
RBM
XSECTION U1
JUN 15,1989
20/04/90
ELEVATION IN METRES
DISTANCE IN 10 METRES
490
488
486
484
482
480
478
0
1
2
3
4
5
6
7
8
9

WATER SURVEY OF CANADA
20/04/90 . PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID U1   SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	487.96	LBM	51.0	481.78										
0.0	487.83		53.0	481.90										
2.2	487.47		55.0	481.72										
3.0	487.02		56.0	481.85										
4.0	485.95		56.0	482.00	RBM									
6.0	484.47													
7.0	483.80													
9.0	483.64													
12.0	483.66													
14.0	483.47													
16.0	482.77													
18.0	481.78													
20.0	480.71													
20.5	480.39													
21.0	479.74													
21.5	479.51													
22.0	479.29	WL												
23.0	478.83													
24.0	478.43													
25.0	478.23													
26.0	478.13													
27.0	478.09													
28.0	478.11													
29.0	478.13													
30.0	478.15													
31.0	478.13													
32.0	478.07													
33.0	478.15													
34.0	478.27													
35.0	478.45													
36.0	478.69													
37.0	478.75													
38.0	478.85													
39.0	479.09													
39.3	479.29	WL												
40.0	479.77													
40.5	480.21													
41.0	480.47													
42.0	480.69													
43.0	481.08													
44.0	481.21													
45.0	481.15													
46.0	481.19													
47.0	481.53													
49.0	481.65													

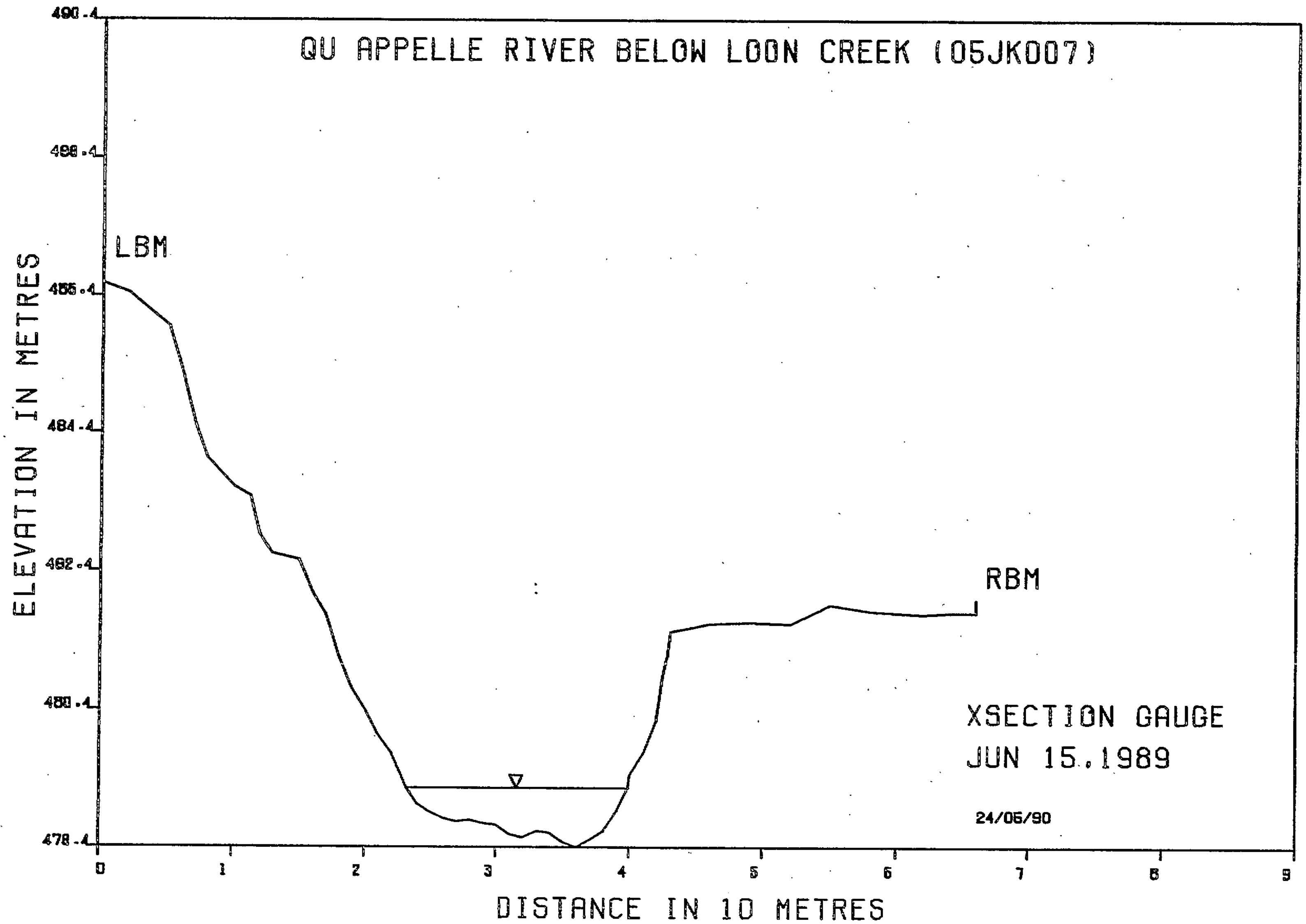
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-U1
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	1.02						
478.50	3.59						
478.75	6.66						
479.00	10.43						
479.25	14.59						
479.50	18.99						
479.75	23.62						
480.00	28.43						
480.25	33.35						
480.50	38.43						
480.75	43.82						
481.00	49.51						
481.25	55.70						
481.50	62.64						
481.75	70.22						
482.00	79.40						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
ELEVATION IN METRES
490.4
488.4
486.4
484.4
482.4
480.4
478.4
LBM
RBM
XSECTION GAUGE
JUN 15,1989
24/06/90
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID GAUGE SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	486.74	LBM	52.0	481.64										
0.0	486.56		55.0	481.90										
2.0	486.43		58.0	481.81										
5.0	485.95		62.0	481.76										
6.0	485.33		64.0	481.80										
7.0	484.51		66.0	481.78										
8.0	484.02		66.0	481.98	RBM									
10.0	483.62													
11.3	483.48													
12.0	482.91													
13.0	482.65													
15.0	482.55													
16.0	482.06													
17.0	481.76													
18.0	481.15													
19.0	480.70													
20.0	480.38													
21.0	480.03													
22.0	479.76													
23.2	479.24	WL												
24.0	479.03													
25.0	478.90													
26.0	478.81													
27.0	478.77													
28.0	478.78													
29.0	478.74													
30.0	478.71													
31.0	478.58													
32.0	478.53													
33.0	478.62													
34.0	478.61													
35.0	478.47													
36.0	478.39													
37.0	478.51													
38.0	478.63													
39.0	478.92													
39.8	479.24	WL												
40.0	479.44													
41.0	479.75													
42.0	480.21													
42.4	480.86													
42.8	481.16													
43.0	481.51													
46.0	481.63													
49.0	481.65													

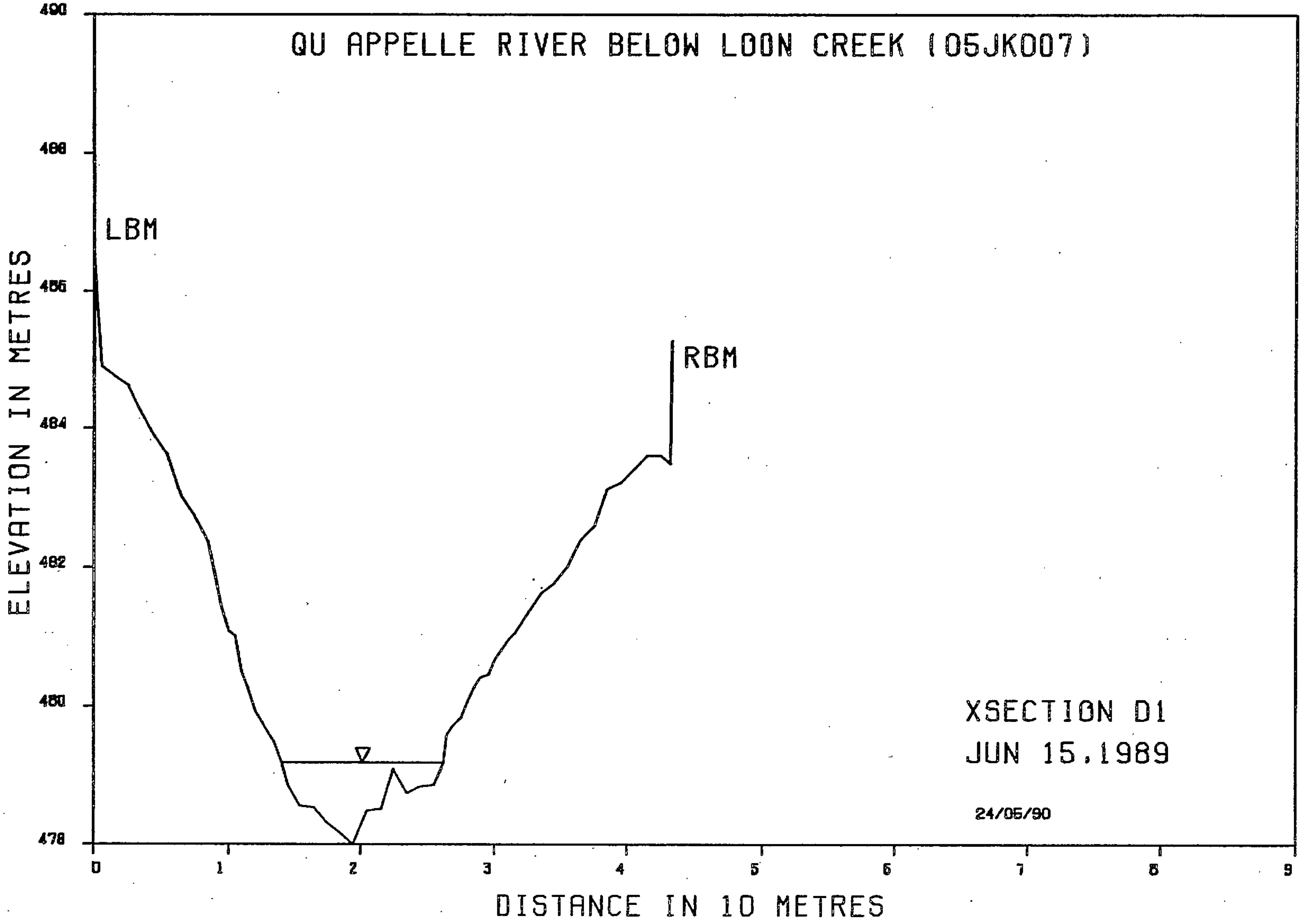
SEDIMENT SURVEY SECTION
14/05/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-GAUGE
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.50	.12						
478.75	1.65						
479.00	4.96						
479.25	8.92						
479.50	13.18						
479.75	17.75						
480.00	22.67						
480.25	27.94						
480.50	33.46						
480.75	39.22						
481.00	45.17						
481.25	51.34						
481.50	57.66						
481.75	65.34						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
LBM
RBM
XSECTION D1
JUN 15,1989
24/05/90
ELEVATION IN METRES
DISTANCE IN 10 METRES
490
488
486
484
482
480
478
0
1
2
3
4
5
6
7
8
9

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LODN CREEK (05JK007)

PROFILE DATA

XSEC. ID D1 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	486.63	LBM	32.0	481.27										
0.0	486.59		32.5	481.40										
.5	484.97		33.5	481.69										
1.5	484.85		34.5	481.84										
2.5	484.70		35.5	482.09										
3.5	484.33		36.5	482.47										
4.5	483.96		37.5	482.67										
5.5	483.72		38.5	483.20										
6.5	483.10		39.5	483.30										
7.5	482.84		40.5	483.49										
8.5	482.44		41.5	483.69										
9.5	481.54		42.5	483.68										
10.0	481.15		43.2	483.56										
10.5	481.08		43.4	485.35										
11.0	480.57		43.4	484.78	RBM									
11.5	480.35													
12.0	480.00													
13.0	479.70													
13.5	479.56													
14.1	479.26	WL												
14.5	478.92													
15.5	478.63													
16.5	478.60													
17.5	478.40													
18.5	478.23													
19.5	478.07													
20.5	478.57													
21.5	478.59													
22.5	479.16													
23.5	478.81													
24.5	478.91													
25.5	478.93													
26.0	479.13													
26.3	479.26	WL												
26.5	479.64													
27.0	479.79													
27.5	479.89													
28.0	480.14													
28.5	480.33													
29.0	480.48													
29.5	480.53													
30.0	480.73													
30.5	480.88													
31.0	481.04													
31.5	481.12													

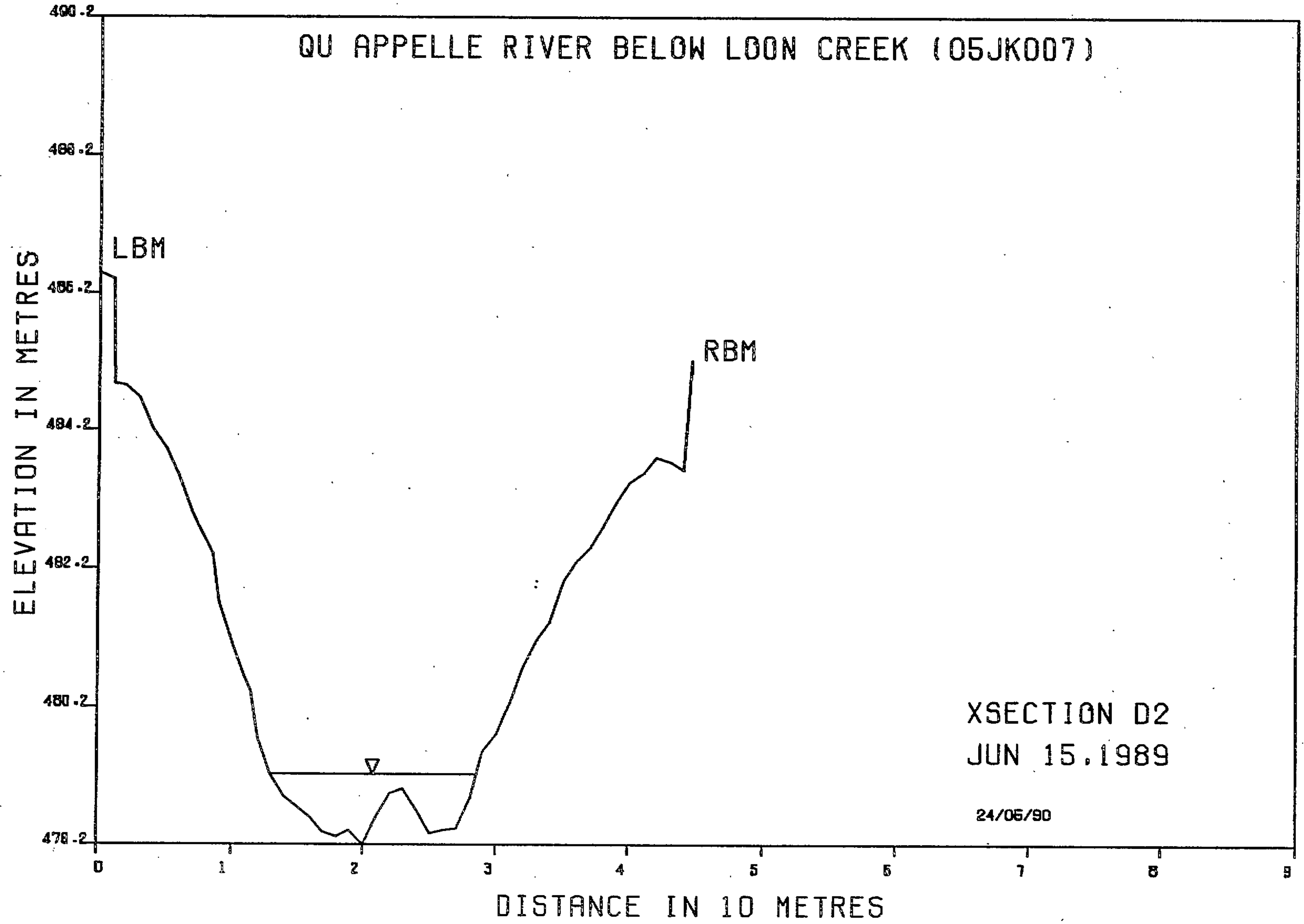
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-D1
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 477.50

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.13	484.50	141.82				
478.50	.74	484.75	151.98				
478.75	2.05						
479.00	4.15						
479.25	7.02						
479.50	10.14						
479.75	13.47						
480.00	17.20						
480.25	21.24						
480.50	25.54						
480.75	30.23						
481.00	35.17						
481.25	40.48						
481.50	46.15						
481.75	52.12						
482.00	58.48						
482.25	65.16						
482.50	72.08						
482.75	79.38						
483.00	87.01						
483.25	94.98						
483.50	103.43						
483.75	112.45						
484.00	122.05						
484.25	131.85						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
ELEVATION IN METRES
DISTANCE IN 10 METRES
490.2
488.2
486.2
484.2
482.2
480.2
478.2
0
1
2
3
4
5
6
7
8
9
LBM
RBM
XSECTION D2
JUN 15,1989
24/06/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID D2   SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	486.48	LBM	42.0	483.79										
1.0	486.38		43.0	483.72										
1.1	484.86		44.0	483.62										
2.0	484.84		44.6	485.20										
3.0	484.66		44.6	485.02	RBM									
4.0	484.20													
5.0	483.90													
6.0	483.52													
7.0	482.96													
8.5	482.38													
9.0	481.70													
10.0	481.10													
11.0	480.62													
11.5	480.40													
12.0	479.71													
13.0	479.21	WL												
14.0	478.87													
15.0	478.75													
16.0	478.57													
17.0	478.37													
18.0	478.31													
19.0	478.39													
20.0	478.18													
21.0	478.59													
22.0	478.93	PIER												
23.0	479.00	PIER												
24.0	478.67													
25.0	478.35													
26.0	478.39													
27.0	478.42													
28.0	478.85													
28.5	479.21	WL												
29.0	479.53													
30.0	479.78													
31.0	480.23													
32.0	480.74													
33.0	481.13													
34.0	481.40													
35.0	482.00													
36.0	482.28													
37.0	482.48													
38.0	482.79													
39.0	483.16													
40.0	483.42													
41.0	483.56													

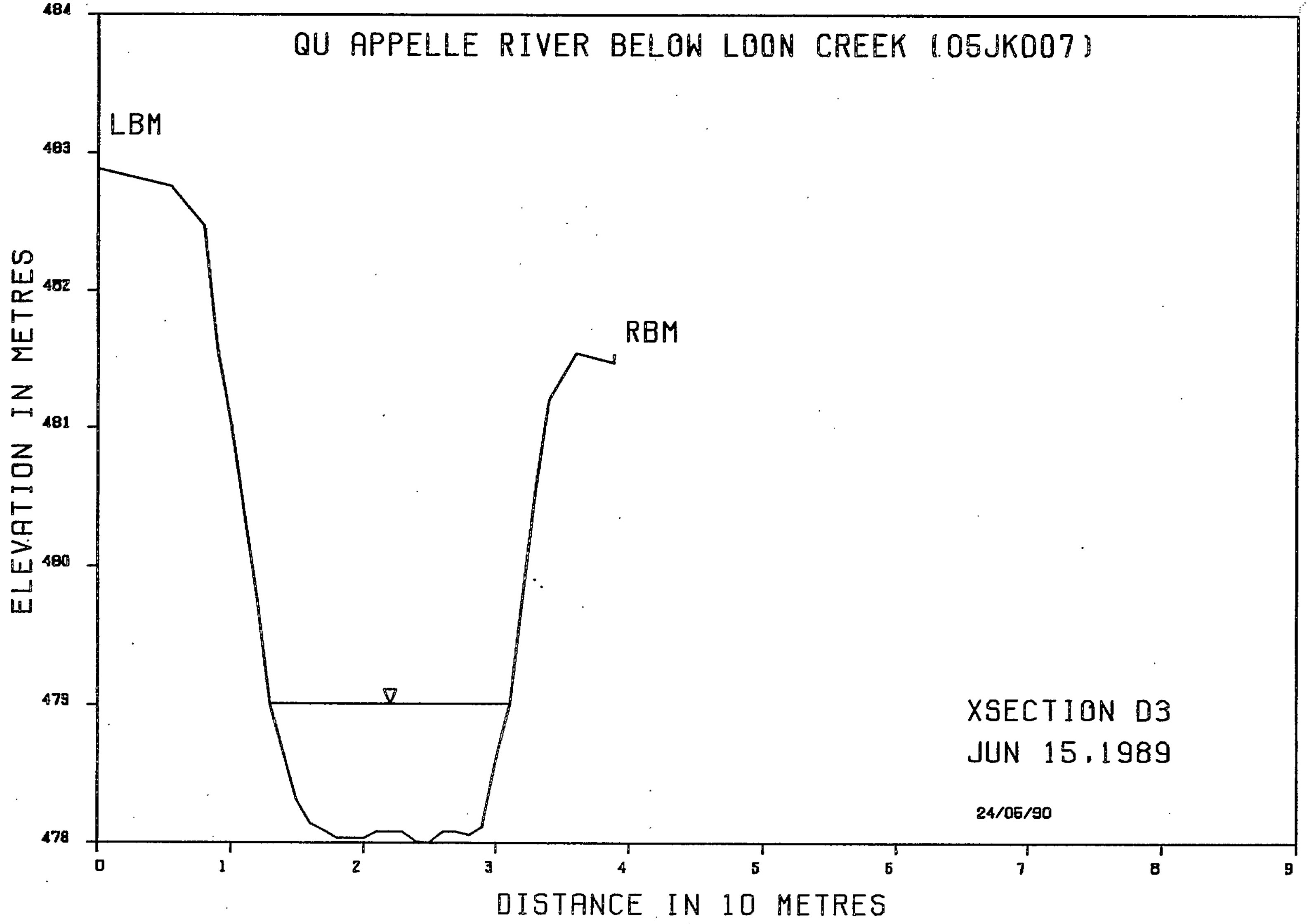
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-D2
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 478.00

*** ELEVATION - AREA TABLE ***

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	.02	484.50	152.06				
478.50	.95	484.75	162.40				
478.75	3.13	485.00	173.13				
479.00	6.23						
479.25	10.01						
479.50	14.03						
479.75	18.33						
480.00	22.91						
480.25	27.68						
480.50	32.62						
480.75	37.82						
481.00	43.28						
481.25	49.05						
481.50	55.12						
481.75	61.43						
482.00	67.91						
482.25	74.60						
482.50	81.60						
482.75	89.00						
483.00	96.75						
483.25	104.80						
483.50	113.20						
483.75	122.17						
484.00	131.91						
484.25	141.89						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
LBM
RBM
XSECTION D3
JUN 15,1989
24/06/90
ELEVATION IN METRES
DISTANCE IN 10 METRES
484
483
482
481
480
479
478
0
1
2
3
4
5
6
7
8
9

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID D3 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	483.06	LBM												
0.0	482.90													
5.5	482.78													
8.0	482.49													
9.0	481.58													
10.0	481.03													
12.0	479.78													
13.0	479.03	WL												
14.0	478.66													
15.0	478.34													
16.0	478.16													
17.0	478.12													
18.0	478.06													
19.0	478.06													
20.0	478.06													
21.0	478.10													
22.0	478.10													
23.0	478.10													
24.0	478.04													
25.0	478.02													
26.0	478.10													
27.0	478.10													
28.0	478.08													
29.0	478.14													
30.0	478.64													
31.0	479.03	WL												
32.0	479.80													
33.0	480.64													
34.0	481.23													
36.0	481.57													
38.8	481.50													
38.8	481.56	RBM												

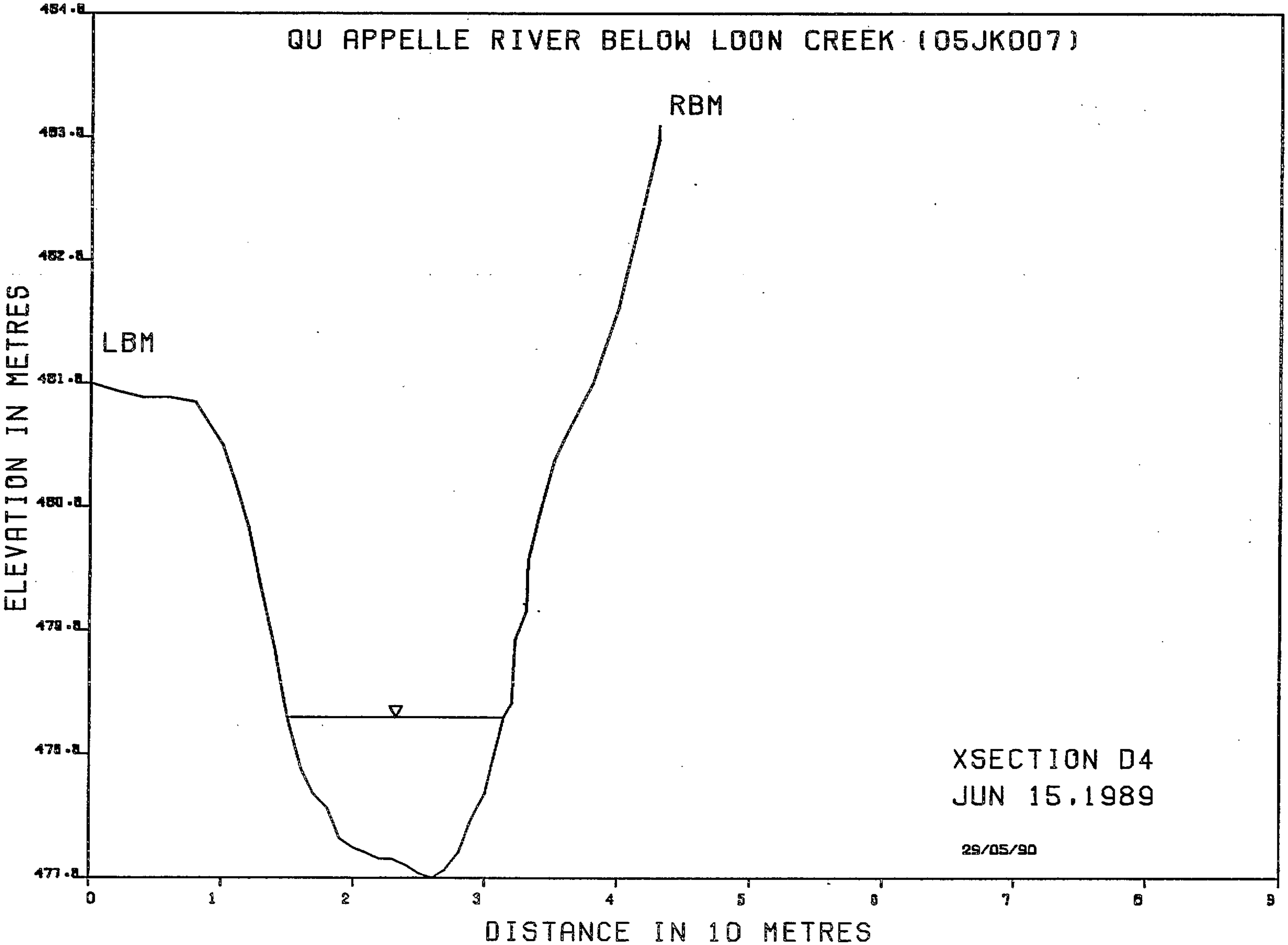
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-D3
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 477.50

ELEVATION - AREA TABLE

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.25	2.17						
478.50	5.80						
478.75	9.76						
479.00	14.06						
479.25	18.62						
479.50	23.34						
479.75	28.23						
480.00	33.29						
480.25	38.52						
480.50	43.93						
480.75	49.52						
481.00	55.30						
481.25	61.30						
481.50	67.67						



QU APPELLE RIVER BELOW LOON CREEK (05JK007)
RBM
LBM
ELEVATION IN METRES
484.0
483.0
482.0
481.0
480.0
479.0
478.0
477.0
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION D4
JUN 15,1989
29/05/90

WATER SURVEY OF CANADA
20/04/90 , PAGE 1
SEDIMENT SURVEY SECTION

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID D4 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	481.95	LBM												
0.0	481.79													
2.0	481.72													
4.0	481.68													
6.0	481.68													
8.0	481.63													
10.0	481.29													
11.0	480.99													
12.0	480.62													
13.0	480.15													
14.0	479.65													
15.0	479.08	WL												
16.0	478.67													
17.0	478.47													
18.0	478.35													
19.0	478.11													
20.0	478.03													
21.0	477.99													
22.0	477.95													
23.0	477.95													
24.0	477.89													
25.0	477.83													
26.0	477.79													
27.0	477.85													
28.0	477.99													
29.0	478.25													
30.0	478.47													
31.4	479.08	WL												
32.0	479.20													
32.2	479.71													
33.0	479.95													
33.2	480.36													
34.0	480.74													
35.0	481.16													
36.0	481.38													
38.0	481.79													
40.0	482.41													
43.0	483.76													
43.0	483.88	RBM												

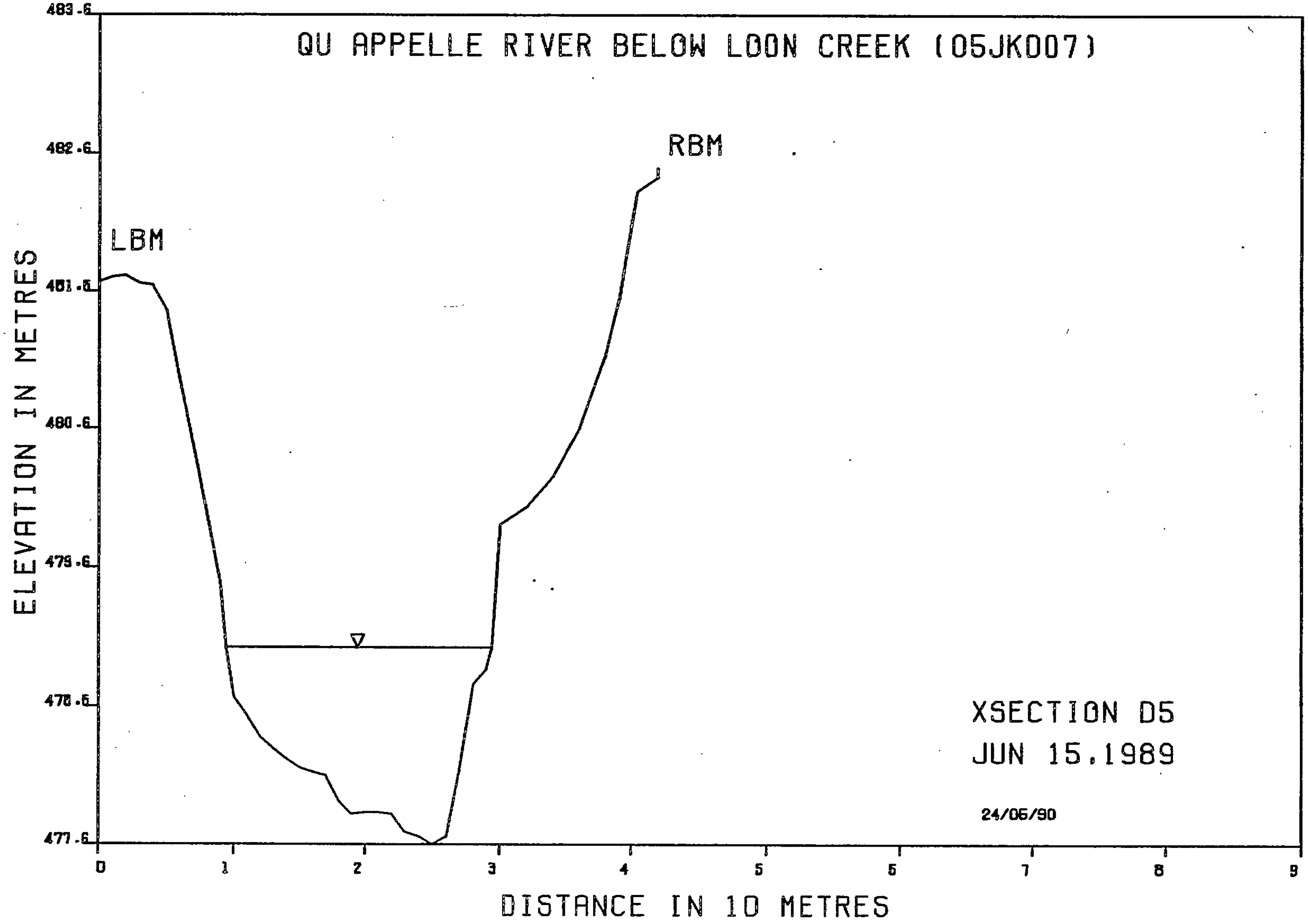
SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-D4
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 477.50

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
478.00	.74						
478.25	3.07						
478.50	6.03						
478.75	9.55						
479.00	13.40						
479.25	17.58						
479.50	21.97						
479.75	26.51						
480.00	31.30						
480.25	36.31						
480.50	41.49						
480.75	46.94						
481.00	52.69						
481.25	58.79						
481.50	65.40						
481.75	73.08						


QU APPELLE RIVER BELOW LOON CREEK (05JK007)
RBM
LBM
ELEVATION IN METRES
483.6
482.6
481.6
480.6
479.6
478.6
477.6
0
1
2
3
4
5
6
7
8
9
DISTANCE IN 10 METRES
XSECTION D5
JUN 15,1989
24/06/90

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

PROFILE DATA

XSEC. ID D5 SURVEY DATE JUN 15,1989

STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS	STA	ELEV	RMKS
0.0	481.83	LBM												
0.0	481.70													
1.0	481.73													
2.0	481.74													
3.0	481.68													
4.0	481.67													
5.0	481.49													
6.0	481.00													
7.0	480.51													
8.0	480.05													
9.0	479.53													
9.5	479.05	WL												
10.0	478.70													
11.0	478.57													
12.0	478.41													
13.0	478.33													
14.0	478.25													
15.0	478.19													
16.0	478.15													
17.0	478.13													
18.0	477.95													
19.0	477.85													
20.0	477.87													
21.0	477.87													
22.0	477.85													
23.0	477.73													
24.0	477.69													
25.0	477.63													
26.0	477.69													
27.0	478.17													
28.0	478.79													
29.0	478.89													
29.4	479.05	WL												
30.0	479.94													
32.0	480.07													
34.0	480.29													
36.0	480.63													
38.0	481.16													
39.0	481.58													
40.3	482.35													
41.8	482.46													
41.8	482.53	RBM												

SEDIMENT SURVEY SECTION
20/04/90 , PAGE 1
OTTAWA,ONT.

QU APPELLE RIVER BELOW LOON CREEK (05JK007)

XSEC. ID.-D5
SURVEYED JUN 15,1989
MINIMUM ELEVATION = 478.
ASSUMED MINIMUM DATUM = 477.50

* ELEVATION - AREA TABLE *

ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)	ELEVATION (M.)	ACC. AREA (SQ M.)
477.75	.22						
478.00	1.78						
478.25	4.42						
478.50	8.11						
478.75	12.39						
479.00	17.13						
479.25	22.13						
479.50	27.24						
479.75	32.48						
480.00	37.91						
480.25	44.06						
480.50	50.85						
480.75	58.13						
481.00	65.80						
481.25	73.82						
481.50	82.14						
481.75	90.98						

BED MATERIAL SAMPLES

Station Number: 05JK007 Year: 1989

Station Name: QU'APPELLE RIVER below Loon Creek

i) Bed Material Sampling

Date	Vertical	Sampler Type	Sample Number	Sample Net Wt (g)	4	8	16	31	62	125	250	500	1000	2000	4000	8000	16000	32000	64000
					Finer Than Size (um) Indicated (%)														
Jun 15	1/4LB	RBMH80	U1 - 1	142.7					91	95	97	98	99	100					
Jun 15	1/2LB	RBMH80	U1 - 2	152.7	23	29	36	44	55	72	89	97	99	99	99	100			
Jun 15	3/4LB	RBMH80	U1 - 3	123.1					98	100									
Jun 15	1/4LB	RBMH80	U2 - 1	262.4					64	76	85	94	97	98	99	100			
Jun 15	1/2LB	RBMH80	U2 - 2	152.6	52	63	74	82	90	97	99	99	99	99	99	100			
Jun 15	3/4LB	RBMH80	U2 - 3	202.3					71	87	94	98	99	100					
Jun 15	1/4LB	RBMH80	U3 - 1	148.6					97	100									
Jun 15	1/2LB	RBMH80	U3 - 2	150.0	56	69	79	86	93	99	100								
Jun 15	3/4LB	RBMH80	U3 - 3	158.6					92	97	98	99	99	100					
Jun 15	1/4LB	RBMH80	U4 - 1	154.5					96	100									
Jun 15	1/2LB	RBMH80	U4 - 2	133.5	55	67	78	86	93	99	100								
Jun 15	3/4LB	RBMH80	U4 - 3	288.4					80	85	89	92	94	95	98	98	100		
Jun 15	1/4LB	RBMH80	U5 - 1	156.1					90	96	98	99	100						
Jun 15	1/2LB	RBMH80	U5 - 2	266.4	25	30	36	43	49	55	66	94	99	100					
Jun 15	3/4LB	RBMH80	U5 - 3	150.6					61	66	76	84	88	90	92	97	100		
			G	NO SAMPLES															
			D1	NO SAMPLES															
			D2	NO SAMPLES															
Jun 15	1/4LB	RBMH80	D3 - 1	341.4					32	36	41	56	76	91	98	100			
Jun 15	1/2LB	RBMH80	D3 - 2	328.2	10	12	15	17	18	23	36	83	97	100					
Jun 15	3/4LB	RBMH80	D3 - 3	245.1					67	87	99	100							
Jun 15	1/4LB	RBMH80	D4 - 1	234.7					71	91	97	98	99	99	100				
Jun 15	1/2LB	RBMH80	D4 - 2	212.1	18	22	26	31	37	66	95	99	100						
Jun 15	3/4LB	RBMH80	D4 - 3	265.5					28	36	55	89	97	99	99	100			
Jun 15	1/4LB	RBMH80	D5 - 1	166.6					86	97	98	99	100						
Jun 15	1/2LB	RBMH80	D5 - 2	189.7	36	45	55	65	78	95	99	100							
Jun 15	3/4LB	RBMH80	D5 - 3	266.0					75	91	97	99	99	100					

U = Upstream x-section; D = Downstream x-section; G = @ gauge (flow metering x-section)

Station Number: 05JK007

Year: 1989

Station Name: QU'APPELLE RIVER below Loon Creek

ii) Bank Sampling

Date	Vertical	Sampler Type	Sample Number	Net Wt (g)	4	8	16	31	62	125	250	500	1000	2000	4000	8000	16000	32000	64000
					Finer Than Size (um) Indicated (%)														
Jun 15	@ G-RB	Scoop	LC - 1	780.3	42	50	61	72	82	91	97	99	100						
Jun 15	@ G-LB	Scoop	LC - 2A	3698.5	6	7	8	10	13	17	27	42	54	63	72	82	94	100	
Jun 15	@ G-LB	Scoop	LC - 2T	2239.0	28	34	41	51	63	75	82	86	89	91	93	96	97	100	
Jun 15	@ U3-RB	Scoop	LC - 3	1431.6	28	33	42	53	65	76	93	99	100						
Jun 15	@ U5-RB	Scoop	LC - 4	2616.7	4	5	6	8	10	14	19	31	40	46	54	63	78	92	100
Jun 15	@ U5-RB	Scoop	LC - 5	1185.2	28	33	41	51	66	82	89	94	97	98	100				
Jun 15	@ D3-LB	Scoop	LC - 6	1687.0	27	31	37	45	57	75	90	97	98	99	99	100			
Jun 15	@ D3-LB	Scoop	LC - 7	4446.6					3	5	10	16	26	44	68	86	92	98	100
Jun 15	@ D3-RB	Scoop	LC - 8	1212.8	40	46	53	60	67	78	95	100							

U = Upstream x-section; D = Downstream x-section; G = @ gauge (flow metering x-section)