The effect of suspended sediment control measures during the construction of a waterski facility, Assiniboine River, Brandon, Manitoba

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Abstract: A suspended sediment monitoring programme was a term/condition of the Environmental Act Licence, issued to the Brandon 1997 Canada Games Society Incorporated, for development of a Water Skiing Facility on the Assiniboine River in Brandon Manitoba. A 420 m reach of the Assiniboine River had to be widened by 20 m to a depth of 2 m in order to accommodate venue requirements established by Water Ski Canada. A Floating Turbidity Barrier (sediment screen), was installed before dredging began on September 19, 1996. Construction was completed on November 5, 1996 after approximately 18,000 m^3 of material had been removed from the left bank of the Assiniboine River.

The sediment monitoring programme was to measure the suspended sediment load during the construction period and to assess the effectiveness of the sediment control measures implemented at the Waterski development site. Suspended sediment sampling occurred at three hydrometric cross-sections along the Assiniboine River; a control site located 14.9 km upstream of the development site (A-200), a second cross-section located just downstream of the development site (A-400), and a third cross-section 8.5 km further downstream (A-600). Daily suspended sediment concentrations, sampled at the three sites were subjected to the Wilcoxcon Matched Pairs Signed Ranks Test. Recorded suspended sediment loads at the A-200 site were significantly greater than those measured at either the A-400 or A-600 sites. The differences are attributed to the effect of a sediment screen at the construction site, an in channel weir located downstream of the development site but upstream of A-400, and the natural aggradation regime of the river during falling discharges.

Introduction

A sediment control and monitoring programme was a term/ condition of Environmental Act, Licence issued to the Brandon 1997 Canada Games Society Incorporated for development of a water skiing facility on the Assiniboine River. The proposed waterski facility is located along the left (east) bank of the Assiniboine River, approximately 400 metres upstream of the 3rd Street Weir, adjacent to Dinsdale Park in the City of Brandon, Manitoba (Figure 1).

A 420 m reach of the river had to be widened by 20 m to a depth of 2 m in order to accommodate venue requirements established by Water Ski Canada. During construction, approximately 18,000 m^3 of material was removed from the left bank of the Assiniboine River.

Purpose of the Sediment Monitoring Programme

The purpose of the sediment monitoring programme was to:

1. monitor the normal suspended sediment load in the Assiniboine River during the dredging period;
2. to estimate the amount of suspended sediment introduced into the river during dredging; and
3. to assess the effectiveness of the suspended sediment control measures implemented at the development site.

Sediment Monitoring Programme Specifications

Hydrometric Sampling Sites:

Suspended sediment sampling took place at three selected hydrometric cross-sections in the study area:

1) 4.8 km upstream of the development site; (A200),
2) 0.6 km downstream of the development site; (A400) and
3) 8.5 km downstream from the A400 site; (A600).

The first two suspended sediment sampling sites (A200 and A400) are located within the City of Brandon. The A600 site is located approximately 9.1 km downstream of the waterski venue at the eastern limits to the city (Figure 1).

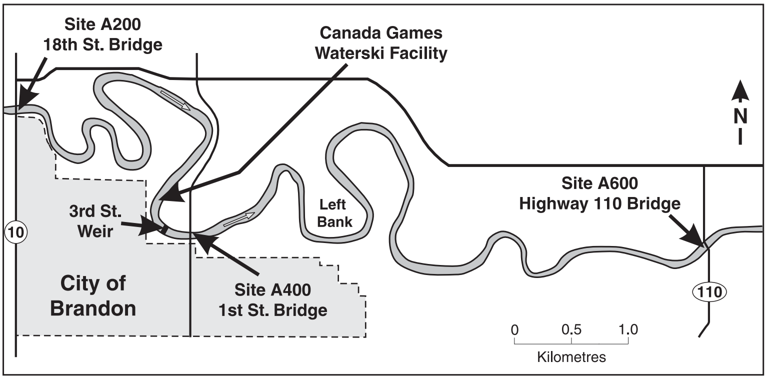

Figure 1: *Assiniboine River: the study reach (Waterski Facility).*

Sediment Mitigation:

Contractors were required to complete the dredging of the left bank as quickly as possible during low flow conditions (Environmental Act, Licence 2159). A Floating Turbidity Barrier Type IA, was installed before subsurface dredging began. The sediment barrier consisted of 10 panels of reinforced polyester vinyl laminate, each 100 feet (32.8 m) in length and 7 feet (2.30 m) deep. This screen was set 7 metres out from the bank and anchored with twenty pound (7.69 kg) weights placed approximately every 10 m along the 1000 foot (304.8 m) length of the screen.

The 3rd St. weir, located approximately 400 m downstream of the proposed waterski facility, impounds the river and raises water levels approximately 1.8 m (Crowther et al., 1995). This weir probably trapped many of the larger sized suspended sediments.

Sampling Procedures and Methodologies:

Dredging of the left bank began on September 19, 1996. Construction proceeded, six days a week, until late October when soft ground brought dredging to a halt on October 30, 1996. After two weeks of freezing temperatures construction resumed and the project was completed in late November, 1996.

In July and August, 1996, well before construction and dredging began, detailed cross-sections were measured at each hydrometric sampling site. Stream discharge measurements were taken according to the method outlined by Terzi (1981). At the same time, suspended sediment concentrations were sampled using the Equi-Discharge Increment (EDI) methodology as outlined by Tassone, Lapointe and Zrymiak (1992). Stream discharge values and suspended sediment concentrations are used to calculate the total suspended sediment load (Penner et al. 1985).

Once construction had begun, single vertical suspended sediment sampling normally took place each day at the three hydrometric cross-sections. The EDI suspended sediment concentration data, collected prior to construction, were used to identified the sampling verticals. Daily discharge values recorded at gauging station 05MH013, located 14.9 km upstream of the A200 site were used for the calculation of total suspended sediment load. It is estimated that the discharge measured at the gauge would pass completely through the study reach in 25 hours. Therefore, no temporal corrections were applied to the data.

Five additional EDI's were conducted at the three sampling sites during the dredging period. These detailed measurements were used for verification of gauged discharge values and to assure that single vertical sampling was conducted at the appropriate sampling vertical.

Samples were sent to Enviro-Test Laboratories, Manitoba Technology Centre in Winnipeg, Manitoba. Suspended sediment concentrations ($g\ L^{-1}$) were measured in the laboratory by the filtration method as prescribed by Environment Canada (Environment Canada, 1987).

Discussions of Results

Stream Discharge Regime:

Figure 2 illustrates the mean daily discharge for the period July 3 to November 12, 1996. On July 3, 1996 mean daily discharge was 82 $m^3\ s^{-1}$. During the next two weeks mean daily discharge fell to 59.6 $m^3\ s^{-1}$. On July 20 an event hydrograph began to move through the study area and mean daily discharges rose. The crest

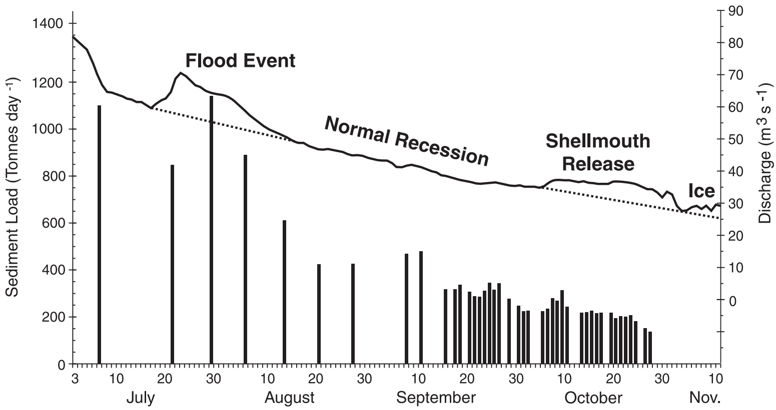

Figure 2: *Assiniboine River (A200) stream discharge and suspended sediment load.*

of this event occurred July 25 when a mean daily discharge of 70.6 $m^3\ s^{-1}$ was recorded at the 05MH013 stream gauge. By August 15 mean daily discharges had returned to recession limb values and continued to decrease throughout the month. In the first week of October mean daily discharge values were at approximately 35 $m^3\ s^{-1}$. On October 7, 1996 a significant discharge release from the Shellmouth Reservoir began to move through the study reach. Discharges rose to 37 $m^3\ s^{-1}$ and remained at values in excess of 36 $m^3\ s^{-1}$ until the end of October. Ice conditions prevailed through the remainder of the study period and recorded discharges declined from 34 $m^3\ s^{-1}$ to approximately 30 $m^3\ s^{-1}$.

Suspended Sediment Regime:

Figure 2 illustrates the total suspended sediment loads which were measured at the A200 site for the period July 3 to November 12, 1996. Suspended sediment load is positively correlated with measured stream discharge.

Relatively high suspended sediment loads (1100 tonnes day^{-1}) are associated with the large discharges recorded in early July. These values had decreased to approximately 850 tonnes day^{-1} by July 20. As the July 20 - August 15 event hydrograph moved through the study area, suspended sediment concentrations increased by approximately 50 g L^{-1}. The total load, recorded 12 days after the peak, had increased to 1142 tonnes day^{-1}. Decreasing suspended sediment loads paralleled the decline in discharge throughout August and September. By September 1, suspended sediment concentrations were approximately 100 g L^{-1} and total loads were calculated to be about 425 tonnes day^{-1}. Local rainfall events probably account for the increase in suspended sediment concentrations on or about September 10 and 26, 1997. In the first week of October mean daily suspended sediment loads were calculated to be approximately 250 tones day^{-1}. As the discharge release from the Shellmouth Reservoir began to move through the study reach (October 7, 1997), suspended sediment concentrations increased to 313 tonnes day^{-1}. As discharges dropped to 34 m^3 s^{-1} at the end of October, total suspended sediment loads fell to 135 tonnes day^{-1}.

Daily suspended sediment loads, measured at paired sites (A200 and A400), (A200 and A600) and (A400 and A600) were subjected to the Wilcoxon Matched Pairs Signed Ranks Test (Snedecor and Cochran, 1972).

Statistical Results:

Suspended sediment loads measured at the A400 and A600 site were expected to be less than those recorded at the A200 control site. This expectation is due to three factors:

1. The Floating Turbidity Barrier Type IA, installed at the waterski site, will limit the volume of sediment entering the Assiniboine River during dredging.
2. The 3rd St. Weir, located 200 km upstream of the A400 sampling site, acts as a small dam, impounding the Assiniboine River and slowing stream velocity. As stream competence is reduced, the larger suspended sediments are deposited in the settling basin which has formed upstream of the weir.
3. Decreasing mean daily discharges, common to the late summer and fall, result in reduced stream sediment capacity. As stream capacity declines, in channel sediment deposition occurs. Consequently, the aggrading stream sediment regime is expected to reduce suspended sediment loads in the downstream direction.

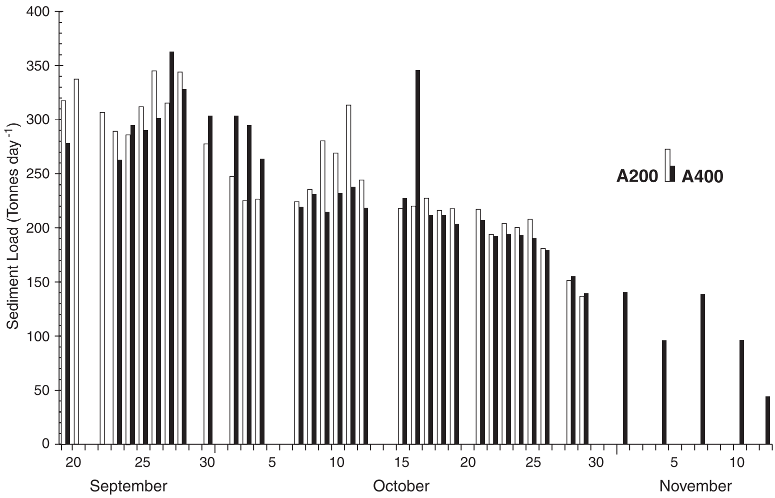

Figure 3: *Suspended Sediment Loads: A200 vs A400.*

Results Of A200 vs A400:

Figure 3 illustrates the suspended sediment loads measured at the 18th St Bridge (A200) hydrometric cross-section and the 1st St. Bridge (A400) sampling site.

Comparative sampling occurred on thirty dates during the dredging period (September 19 - November 15, 1996). The Wilcoxon Matched Pairs Signed Ranks Test indicates that there was a significant difference in the suspended sediment loads (= 0.01) recorded at the two sites. Suspended sediment loads were higher at the A200 control site on twenty of the sampling dates. This was expected. However, on 10 sampling dates, suspended sediment loads recorded at the A400 site were greater than the sediment loads measured at the control site. The difference between four of the matched pairs was within the range of measurement error (5 percent) and considered not significant. However six of the paired samplings indicate significantly greater suspended sediment loadings. In particular, the period from September 26 - October 4, recorded an average of 15% more sediment in suspension at the 1st St. Bridge site than was measured at the A200 control site located 5.6 km upstream. A second period of significantly higher suspended sediment loads at the A400 site was observed on

October 15 and 16. Particularly on October 16, there was a recorded 57 percent increase in the suspended sediment load measured at the 1st St. Bridge.

Results of A200 vs A600:

Comparative sampling occurred on 28 dates during the dredging period. The Wilcoxon Matched Pairs Signed Ranks Test indicates that there was a significant difference in the suspended sediment loads (= 0.01) recorded at the two sites. Suspended sediment loads were higher at the A200 control site on 26 of the 28 sampling dates. Since A600 is located 13.9 km downstream of the 18th St Bridge (A200), the Assiniboine's aggrading sediment regime was expected to significantly reduce suspended sediment loads through this length of channel. In addition, the 3rd St. Weir is situated between the two sites and was expected to trap significant volumes of suspended sediment.

The two anomalous matched pairs were within the 5 percent measurement error and considered not significantly different.

Results of A400 vs A600:

The Wilcoxon Test indicates that there was a significant difference in the suspended sediment loads (= 0.01) recorded at the two sites. Suspended sediment loads were higher at the A400 site on 25 of the 29 sampling dates. A600's location 8.5 km downstream of the 1st St Bridge (4200) and the Assiniboine's aggrading sediment regime effectively reduced suspended sediment loads through this length of channel.

There were only four dates when the suspended sediment loads recorded at the A600 site exceeded those measures at the A400 site. These differences were not considered to be significant as, in all matched pairs, they fell within the measurement error.

Discussion

Figure 3 and the results of the Wilcoxon Matched Pairs Signed Ranks Test demonstrate that there is a general decline in suspended sediment loads through the study reach in a downstream direction.

Suspended sediment loads measured at the Highway 110 Bridge (A600) were always less than the suspended sediment loads calculated for the A400 and A200 sites. This indicates that a potential sediment plume generated at the dredging site was undetectable 9.0 km downstream.

At the A400 site six of the paired samplings indicated significantly greater suspended sediment loadings than those recorded at the A200 cross-section. In particular, the period from September 26 to October 4 recorded an average of 15% more suspended sediment at the A400 site than was measured 5.6 km upstream at the 18th St. Bridge. During this period, maximum differences exceeded 22 percent. Clearly, sediment was entering the river during dredging. A second period of significantly high suspended sediment loads, measured at the 1st St. Bridge site, was observed on October 15 and 16. October 16, in particular, registered a 57 percent increase in the suspended sediment load compared to the 18th St. Bridge site. It is speculated that during these two days the floating turbidity barrier was relocated to a downstream position. Relocation of the turbidity barrier was required since the 420 m dredging reach was longer than the total length of the turbidity barrier (approximately 305 m).

Conclusion

From a statistical perspective, the construction of a waterski facility and the associated channel dredging appears to have had little impact on the normal suspended sediment regime in the Assiniboine River. Observed results are attributed to the effect of a floating turbidity barrier at the dredging site, an in channel weir located 400 m downstream of the dredging site but upstream of the A400 sampling location, and the normal aggrading regime of the river during falling discharges.

During channel bank dredging, the floating turbidity barrier could not prevent all the sediment from entering the Assiniboine River. For a nine day period in late September and early October suspended sediment loading increased by a mean of 15% and by as much as 22%. However, this increase in suspended sediment loading was not detectable at the Highway 110 Bridge 9.0 km downstream. A second sediment plume was detected on October 15 and 16 at the A400 site. Suspended sediment loads increased by 57%. It is suspected that the floating turbidity barrier was repositioned approximately 100 m downstream at this time. Removal of the turbidity barrier introduced significant volumes of trapped sediment into the flow. There was no evidence of this sediment plume extending to the A600 site and it is assumed that the dispersed material had been deposited in the river channel upstream of the Highway 110 Bridge.

Suspended sediment introduced into the Assiniboine River at the dredging site appears to have been deposited within the study reach. If this is the case, the construction of Brandon 1997 Canada Games Waterski Facility at the Dinsdale Park site had little or no impact on the riverine ecosystem beyond the study reach.

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