

Port Severn Area Dams

Hydraulic Study Report
Main Dam - Downstream Navigation Channel Area

PWGSC Ontario

Draft

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1. Introduction

AECOM was retained by Public Works and Government Services Canada (PWGSC) to undertake the rehabilitation of the dams, the fixed bridge and the lock which are part of the Trent-Severn Waterway in the Port Severn area. Specifically, the scope of work included Dam A, Dam C, Dam D, the Main Dam, Fixed Bridge, Dam E (Bayview), Dam G (Little Chute), Lock 45/Dam Pier Common Wall, Lock 45 Lower Approach Walls, and Lock 45 Upper Approach Walls.

Also, as included in the general scope of work, AECOM was mandated to perform a hydraulic study to determine a means to reduce the turbulence at the Lower Approach Walls for safer boat access to Lock 45. According to the Client's Terms of Reference (ToR), there are conditions with moderate to high inflows coming from the Main Dam and Dam E that create currents in the navigation channel, making it difficult for approaching boats to safely access the lower approach wall and lock.

Finally, it is also mentioned in the ToR that the capacity for mooring of boats at the lower approach walls is inadequate and that it would be beneficial to lengthen one or both lower approach walls.

This report presents the results of the hydraulic study, which analyzes the flow conditions for the existing situation and various options for improving the use of the lock. The following subjects are treated within the report:

- Site location description;
- Main Dam arrangement description;
- Hydraulic field survey;
- Hydrodynamic modeling;
- Option feasibility and cost;
- Discussion and recommendations.

2. Site Location

The Port-Severn Main Dam, Lock 45 and Dam E are located in the town of Port Severn where the access is possible via Port Severn Road. The upper deck of the Main Dam serves as a bridge for the Port Severn Road. These structures are shown in Figure 2.1 below.

The lake formed by the Port Severn water-retaining structures is known as the Gloucester Pool and Little Lake. The outflows from the Main Dam and Dam E discharge into Georgian Bay. Table 2.1 presents the location of these structures in Universal Transverse Mercator (UTM) coordinates.



Figure 2.1 General layout of the Port Severn Main Dam

Table 2.1 UTM locations of some of the Port Severn Dams

Site	UTM Location	
Port Severn Main Dam		
Main Dam	44°48'13.36"N	79°43'11.91"W
Lock 45	44°48'14.56"N	79°43'13.85"W
Other Port Severn dam		
Dam E	44°48'12.53"N	79°43'20.74"W

3. Main Dam and Dame E Configuration

Based on the project ToR, the Main Dam should be either rehabilitated in order to enhance its structure or completely replaced. The final outcome was decided in 2018, and the chosen choice is the complete replacement of the dam. Since the present hydraulic study was undertaken previously, the current arrangement of the Main Dam and Dam E, in regards to the hydraulic passages, is used in a large part of hydraulic simulations.

After the final decision was given to completely replace the Main Dam, different configurations of spillway bay widths and sill elevations were studied. Following the analysis of different schemes, the final configuration for the new dam consists of reconstruction of 9 spillway bays of equal width corresponding to the width of the bays of the existing dam. It was also decided that all bays would have the same sill elevation, that being 177.38 m. Following this, a series of simulations considering the new Main Dam configuration were carried out in order to compare the results with the ones obtained using the existing Main Dam configuration. The correlation of the results from both configurations is presented in Section 7.

4. Field Survey and Water Levels

4.1 Bathymetric Survey

For the purpose of the project, ASI Marine has performed a bathymetric survey in autumn 2016. The upstream and downstream areas of the Main Dam were covered by this survey as shown in Figure 4.1. The data precision used to build the geometry of the numerical model is of 25 cm (distance between two points of the bathymetric survey).

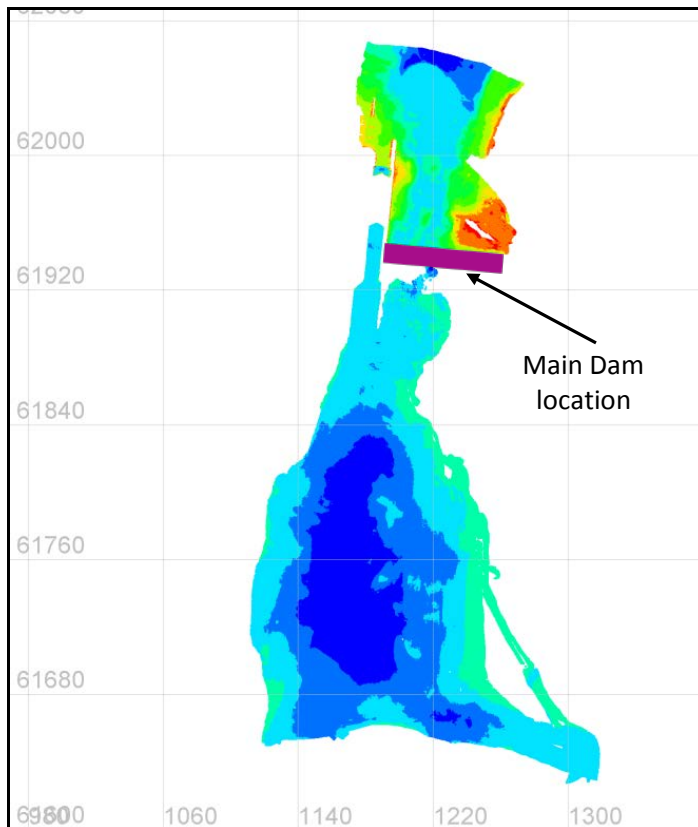


Figure 4.1 Bathymetric data, upstream and downstream of the Main Dam, as provided by ASI Marine (2016)

4.2 Hydraulic Survey

For the purpose of the hydraulic study, a field survey has been performed over a period of two days in March 2017 by ASI Marine (ref. [1]). The field survey consisted in a velocity measurement campaign which included water level readings and discharge computation as well. Those measurements have been performed on different hydraulic flow conditions where the estimated total discharge of the Main Dam is between 89 m³/s and 133 m³/s while for Dam E, the estimated total discharge is 25 m³/s.

The velocity data has been collected on predefined cross-sections using an Acoustic Doppler Current Profiler (ADCP) towed by a small boat. Along each cross-section, the flow velocity measurements in three directions were performed (U_x, U_y, U_z). The flow discharge across the Main Dam and Dam E has been calculated, and the upstream and downstream water levels were measured as well.

The cross-section locations are as shown in Figure 4.2. Note that cross-section 3 location is located partially in the navigation channel at its upstream portion and along the left side of the navigation channel at its downstream portion. Thus the results obtained from the model for this cross-section will be used for calibration and for the channel modification and design of a new deflecting wall analysis.

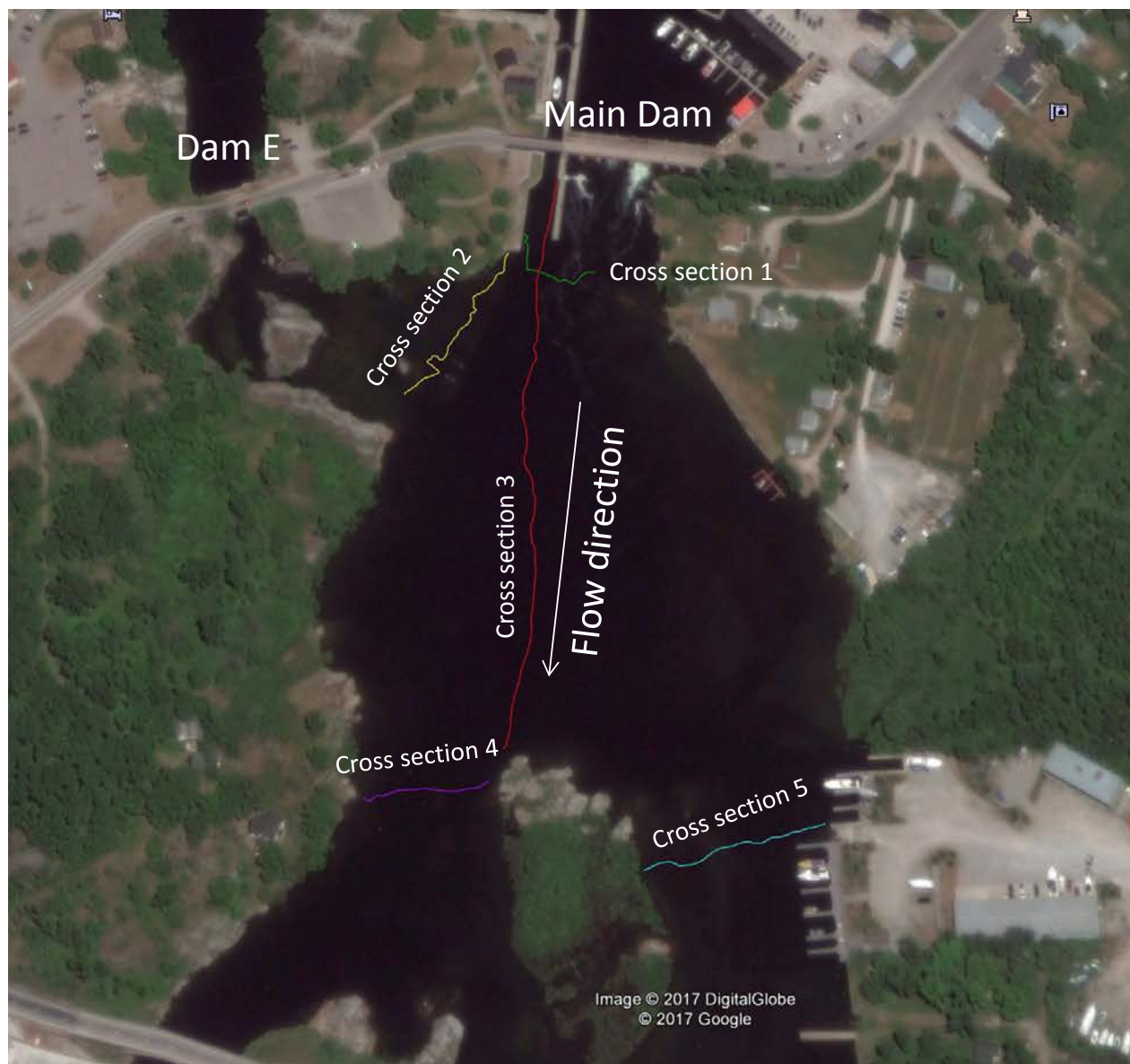


Figure 4.2 Cross-section locations for survey measurements

These measurements were localized in UTM coordinates with the use of an onboard DGPS (Differential Global Positioning System). ASI Marine proceeded in the morning of March 23rd where two series of velocity measurement were carried out. The total flow going through the Main Dam and Dam E on this first day of measurements was approximately 54 m³/s in the morning and was increased to approximately 78 m³/s in the afternoon after removing some stop logs from the Main Dam. Unfortunately, the stop logs setting was modified before the end of the morning survey given the fact that the dam operator had to increase the discharge at the Main Dam in order to control the reservoir water level. Also, the afternoon survey could not be completed given the limited time. The measurements continued on March 24th where some stop logs from the Main Dam sluices were removed in the morning, so that the total discharge measured at the Hamlet Bridge was approximately 95 m³/s (combination of water flow through the Main Dam and Dam E). The March 24th survey was completed as scheduled.

Table 4.1 presents the stop logs setup for the Main Dam and Dam E during the survey.

Table 4.1 Stop logs settings during survey

Structure	Sluice #	Maximum number of stop logs	Number of stop logs in place		
			March 23 rd morning	March 23 rd afternoon	March 24 th all day
MAIN DAM	1	10	10	10	10
	2	12	9	6	6
	3	12	5	5	5
	4	10	10	10	8
	5	10	10	10	8
	6	10	10	10	10
	7	10	10	10	10
	8	10	10	10	10
	9	10	10	10	10
DAM E	1	9	3	3	3

For reference, a sample of the pictures taken during the field survey is presented in Appendix A and the ASI Marine report is presented in Appendix B.

4.3 Water Levels

The upstream water level during the survey was measured at 180.55 m and was fairly stable throughout the survey period. The measurements were taken from the dam operator's database.

The downstream water level is obtained from the Monthly Water Level Bulletin from Fisheries and Oceans Canada, Government of Canada, which records the average water levels of Lake Michigan and Lake Huron based on a network of gauging stations on both sides of the border on each lake. The following stations are used: Thessalon, Tobermory, Milwaukee, Ludington, Mackinaw City and Harbor Beach. Based on available water level data, the downstream water level was 176.54 m. Also, the historical maximum and minimum recorded water levels, based on recordings from 1918 to 2017, are 177.5 m and 175.5 m respectively.

Also, for the downstream water level used for the calibration of the hydrodynamic 3D model, the Midland gauge station recording was used (ref. [7]).

5. Numerical Model

5.1 Hydraulic Model

The numerical model used in the present study is the Flow-3D software. Developed by Flow Science Inc., Flow-3D is three-dimensional computational fluid dynamic (CFD) software with several physical modules that gives valuable insight into many physical flow processes. With special capabilities for accurately predicting free-surface flows, Flow-3D provides accurate simulation results for a wide range of issues facing the water and environmental industry, from large hydroelectric power projects to small municipal wastewater treatment systems. It uses different pressure and solver options, where the implicit method Generalized Minimal Residual “GMRES” method was retained because of its algorithm that is able to converge with far fewer iterations than other solver schemes.

5.2 Geometry of the 3D Model

In order to obtain a complete terrain model, the bathymetric data obtained from the 2016 bathymetric survey was added to the topography using available topographic data extracted from the General Location Plan (ref. [1]). The bathymetric information taken from the same drawing was also used in order to cover areas not covered by the 2016 bathymetric survey. During the calibration process, it has been determined that a large portion of the bathymetric information presented in this AutoCAD file was inaccurate giving overestimated flow depths. Thus, shallow areas were added to the terrain model in order to represent adequately what could be seen on different satellite images, pictures and videos taken at the site. This is further discussed in Section 5.3 (calibration).

For the concrete structure of the Main Dam, two different configurations of the dam have been considered, the first one for the existing structure and the second one for the new reconstructed dam configuration with new sill elevations. For the existing configuration, the numerical model of the Main Dam has been designed in accordance to the Main Dam Plan, Elevation, Section and Detail (ref. [3]) and Main Dam Sections (ref. [4]) drawings. As for the new reconstructed dam configuration, since the new piers are very similar to the ones of the existing structure, only the sill of each spillway bays were adjusted in order to comply with the new arrangement. For this configuration, sill elevations are at 177.38 m. Also, each of the sills are followed by an inclined concrete apron with a downward slope.

For the concrete structure of Dam E, it has been designed according to the Bay View Dam E and Little Go Home Bay Dam Plan, Elevation and Sections drawing (ref. [5]).

The numerical model for the structures has been elaborated using CATIA software in order to provide an individual STL files (STereoLithography) for each structures that are integrated afterwards into the Flow-3D terrain model. Afterward, the Main Dam and Dam E structures are placed in the numerical model using their real coordinates.

The geometry of the 3D model as used in the numerical model is presented in Figure 5.1. It presents a 3D view from the downstream of the model showing the Main Dam (existing configuration) on the right and Dam E on the left. A zoomed view of the 3D model geometry of the existing configuration of the Main Dam from the downstream is shown in Figure 5.2. The rebuilt configuration of the Main Dam with the modified sills is shown in Figure 5.3 (sill elevations of 177.38 m with downward concrete aprons).

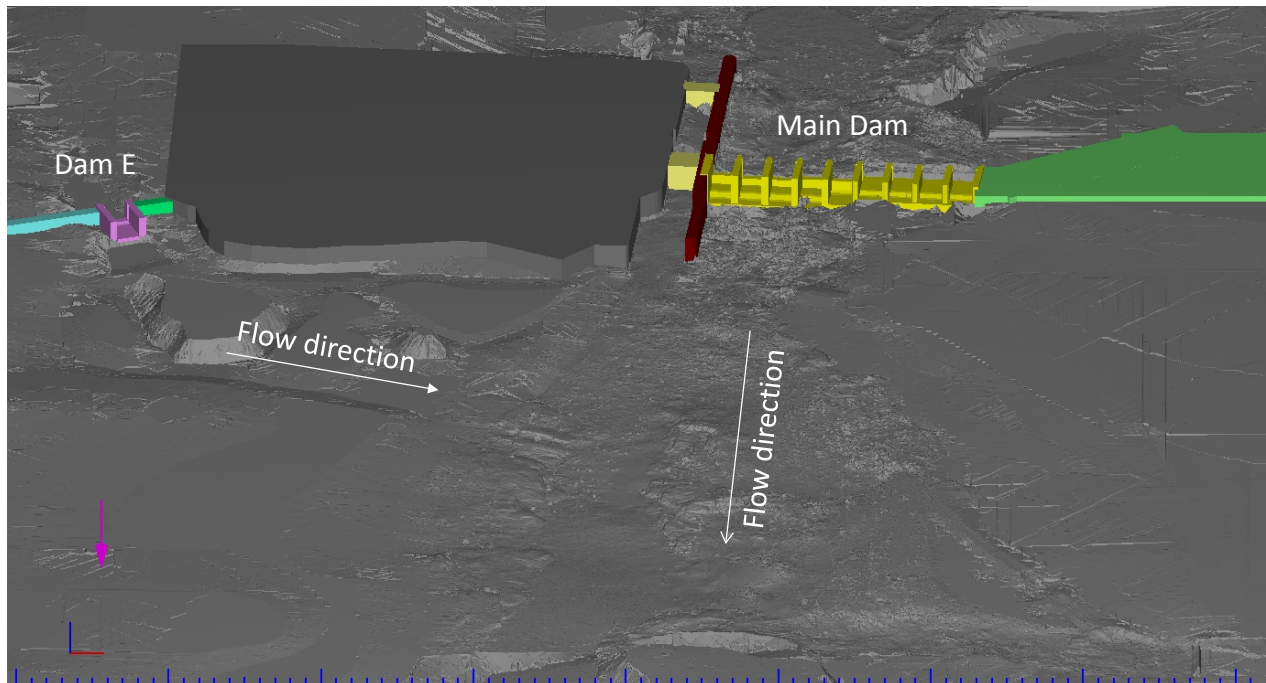


Figure 5.1 3D model geometry used in the numerical model (existing structure of the Main Dam)

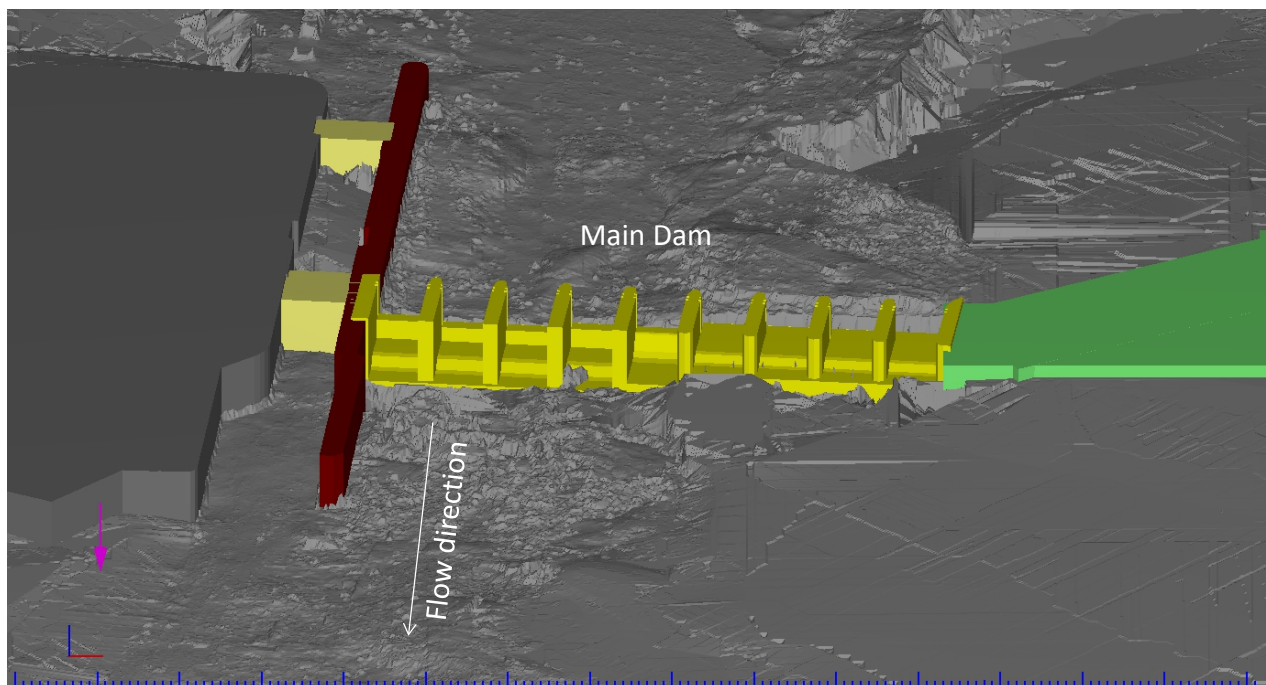


Figure 5.2 Zoomed 3D model geometry view of the Main Dam (existing structure)

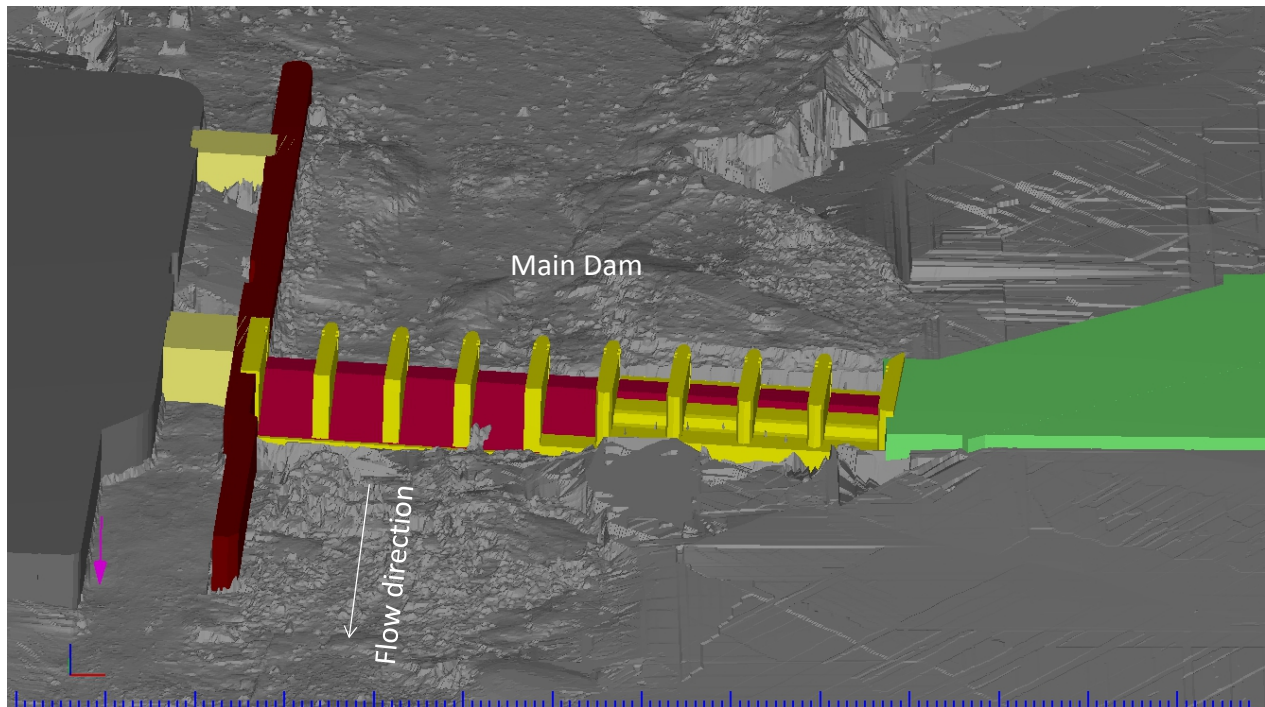


Figure 5.3 Zoomed 3D model geometry view of the Main Dam (rebuilt structure, new sill elevations)

A single spatial discretization covers the entire model. Different mesh block sizes are used for simulations as mesh block sizes drop from 1.5 m to 1.0 m, and finally 0.75 m which represents the finest discretization used. Figure 5.4 presents the mesh block boundaries that are considered on the model.

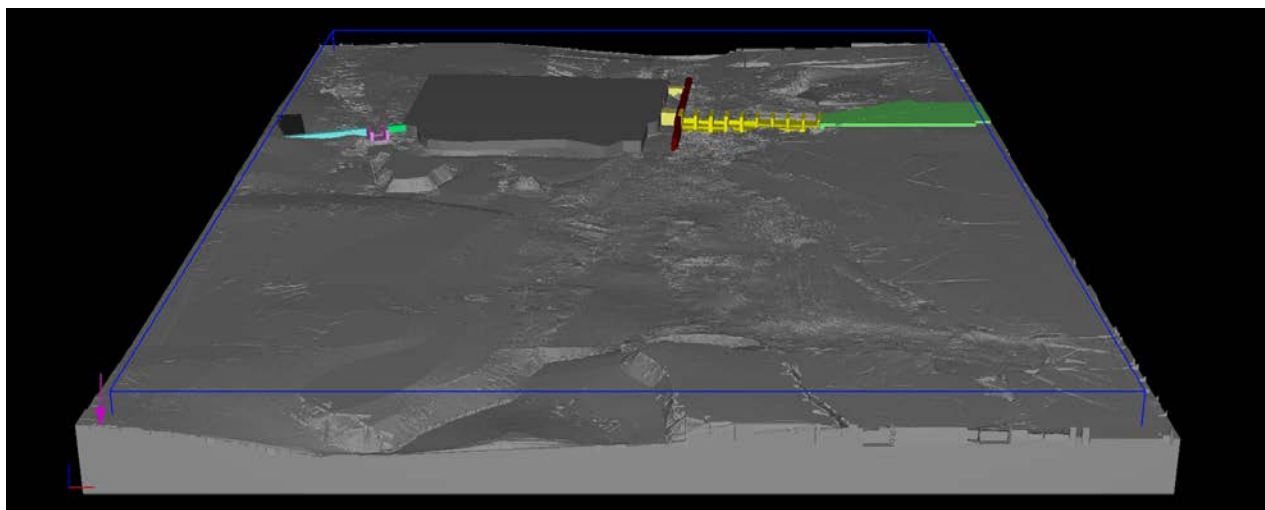


Figure 5.4 Single mesh block model

The Upstream boundary is located upstream of the Main Dam and Dam E in the reservoir while the downstream limit of the numerical domain crosses the island located just upstream of the Trans-Canada Highway bridge.

Figure 5.5 shows a 3D view of the preprocessor output of the terrain model once all input data has been incorporated. The initial water level condition is also shown in the figure. This is a representation of the model without any gates in the sluices. Depending on the study case, stop logs or lift gates are installed in each sluice. It is important to note that for the calibration of the model, stop logs are installed in the sluices while for the post-project condition (after reconstruction), lift gates are used.

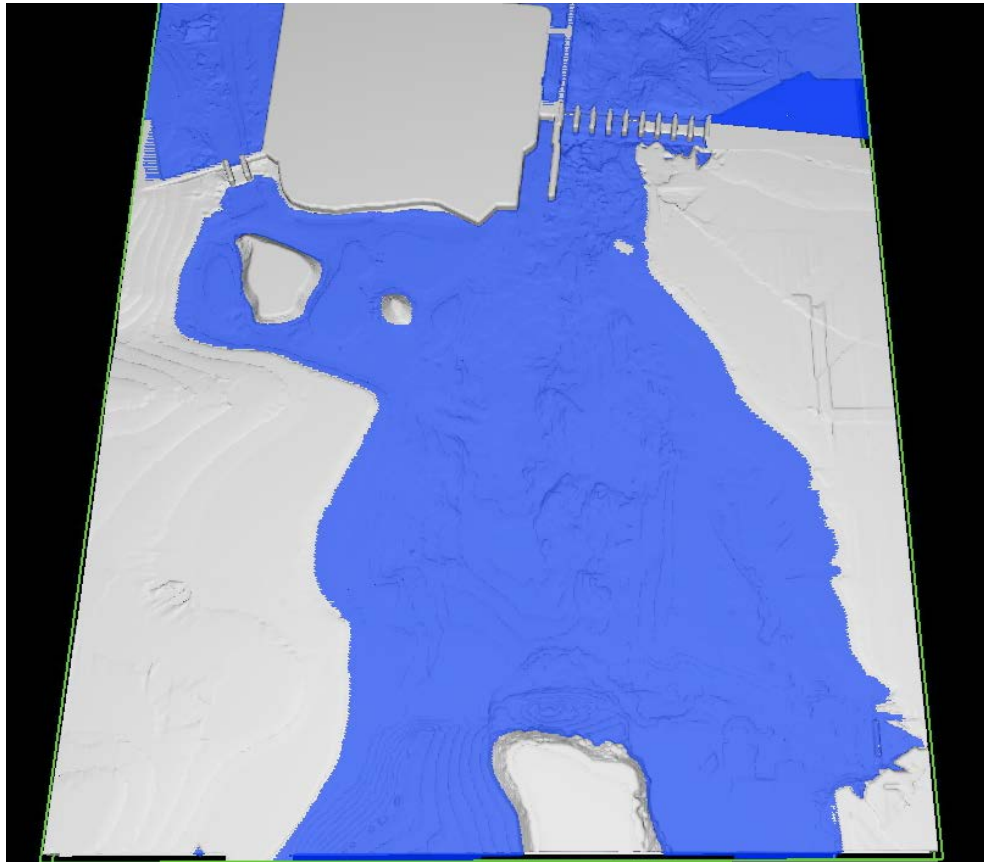


Figure 5.5 3D view of the preprocessor output of the terrain model

5.3 Calibration

The calibration was performed using the configuration of the stop logs as observed on site during the March 2017 survey (ref. Table 4.1). Given the fact that only the March 24th survey could be completed on site, calibration of the model is based on this survey. In the numerical model, the upstream water level of the Main Dam is 180.50 m, while the downstream water level is set to 176.54 m. The downstream water level is based on the Midland gauge station recordings (ref. [6]) for March 24th 2017.

In order to obtain flow velocities in the same order of magnitude that the ones recorded during the hydraulic survey, the bathymetry from the bathymetric survey was adjusted in elevation. Furthermore, as mentioned above, some shallow areas not covered by the bathymetric survey were added in the terrain model based on satellite images, pictures and videos taken on site.

As for the downstream boundary condition, in order to obtain the proper discharge distribution for each part of the island, a flow width on each side was set. From the discharge calculation obtained from the cross-sections 4 and 5 of the survey, it was possible to adjust the model to obtain the same discharge distribution. Nevertheless, given that the downstream boundary of the model is close to the surveyed cross-sections 4 and 5, the recorded flow patterns in these areas are not compared to the Flow 3D results since the downstream boundary condition of the model affects artificially the flow behavior.

Based on the stop logs setting during the hydraulic survey and the flow velocities recorded along cross-section 1, 2, 4 and 5, the discharge of the Main Dam, Dam E and both sides of the downstream island were calculated. The same stop logs setting was considered in the model. The first calibration check is to make sure that the discharges from the model at those 4 locations are the same as the ones obtained from the survey. Table 5.1 presents both survey calculated discharge and model discharge results. The values presented in this table show that the overall discharge from both calculated discharge from survey recordings and 3D model discharge results are similar, thus the condition in the model represents adequately the conditions at site during the survey.

Table 5.1 Discharge validation form the calibrated model

Discharge	Calculated discharge from survey recordings	3D model discharge results
	(m ³ /s)	(m ³ /s)
Main Dam	94	89
Dam E	25	34
Total inflow	119	123
Cross-section 4 (West passage of the island)	80	87
Cross-section 5 (East passage of the island)	47	36
Total outflow	127	123

Flow velocity patterns obtained from the hydraulic model are shown on Figure 5.6 as streamlines and on Figure 5.7 as velocity vectors. Since the waterway is aligned from the lock entrance to the right passage of the island (looking downstream), results show that there is substantial variations in flow velocities and flow directions along the route, with high velocity flows coming from the Main Dam, perpendicular flows coming from Dam E and some minor recirculating flows on each side.

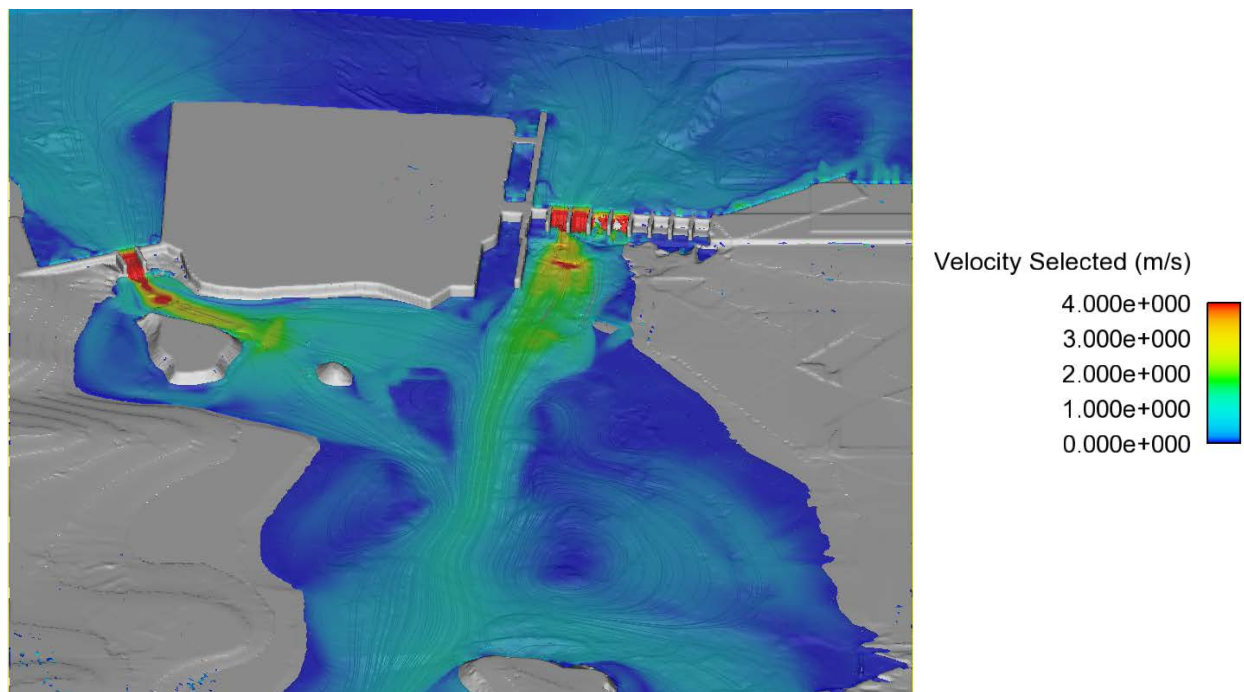


Figure 5.6 Flow patterns (streamline) reflecting the hydraulic conditions observed on March 24th, 2017

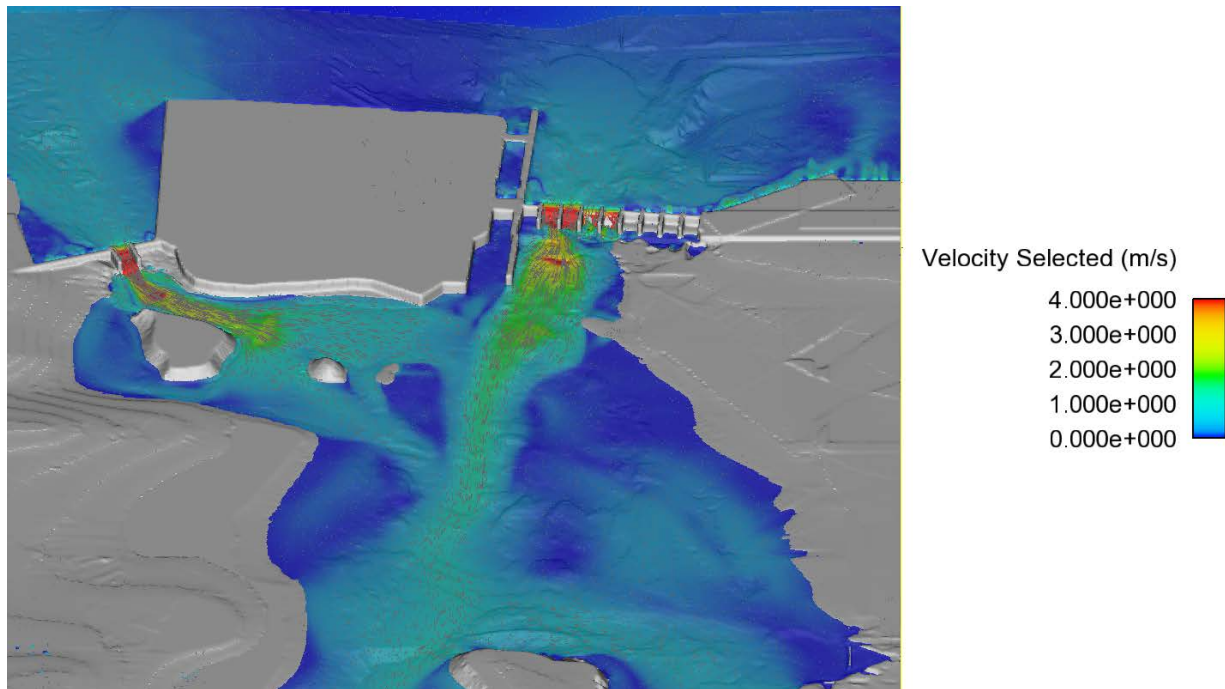


Figure 5.7 Flow patterns (vectors) reflecting the hydraulic conditions observed on March 24th, 2017

In order to validate the hydraulic model results, flow velocities from the 3D model along cross-sections 1, 2 and 3 (ref. Figure 4.2), in regards to the X axis (East-West direction), Y axis (North-South direction) and velocity magnitude (in 3D), are compared to the observed condition recorded on site on March 24th. For those cross-sections, flow velocities, in regards to their directions, are plotted on graphs for both survey recordings and 3D model results. For the East-West direction, a positive flow velocity means that the direction of the flow is from the West to the East and the opposite direction for a negative flow velocity. For the North-South direction, a positive flow velocity means that the direction of the flow is from the South to the North and the opposite direction for a negative flow velocity. The velocity magnitude is always positive.

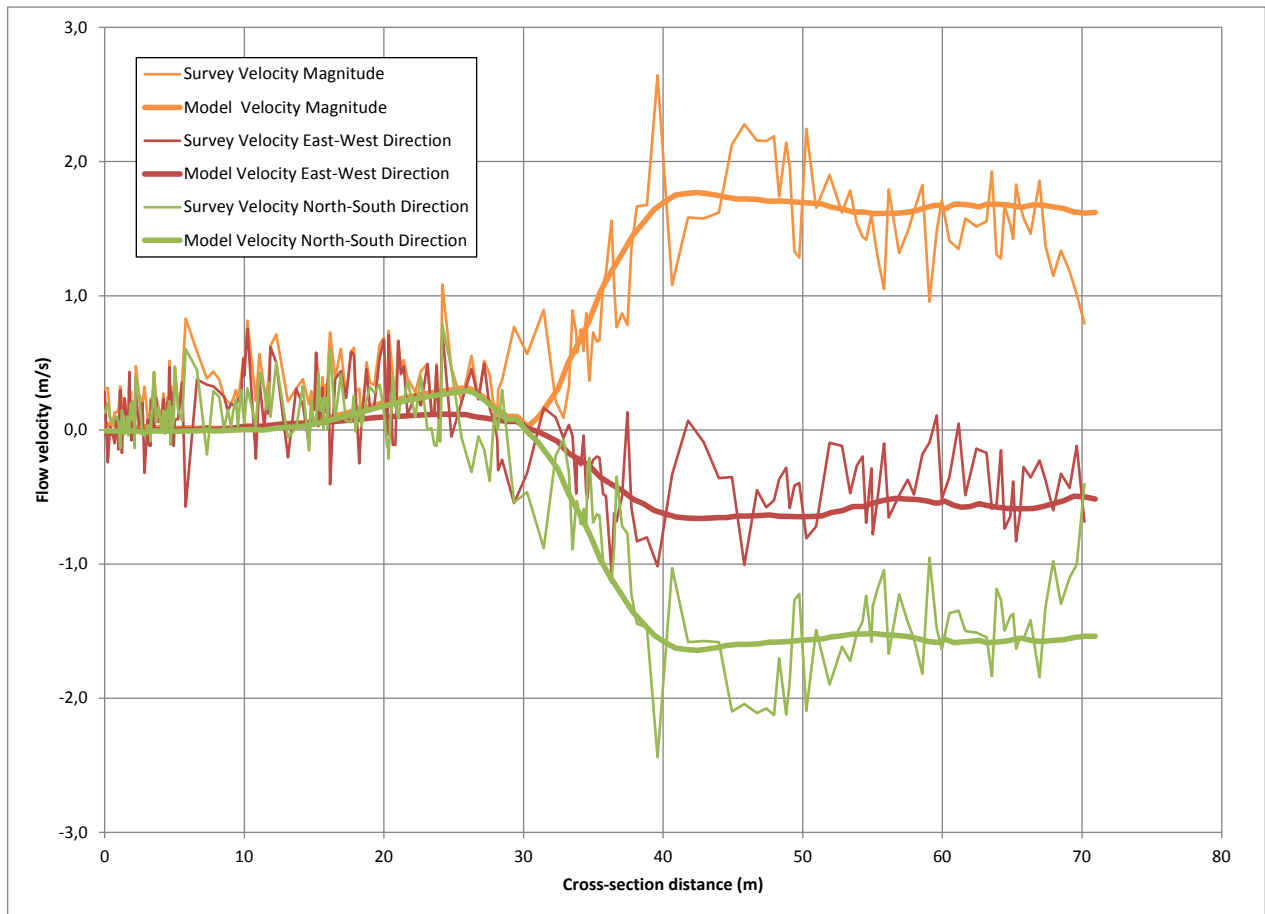


Figure 5.8 Cross-section 1 – 3D model results compared to survey recordings

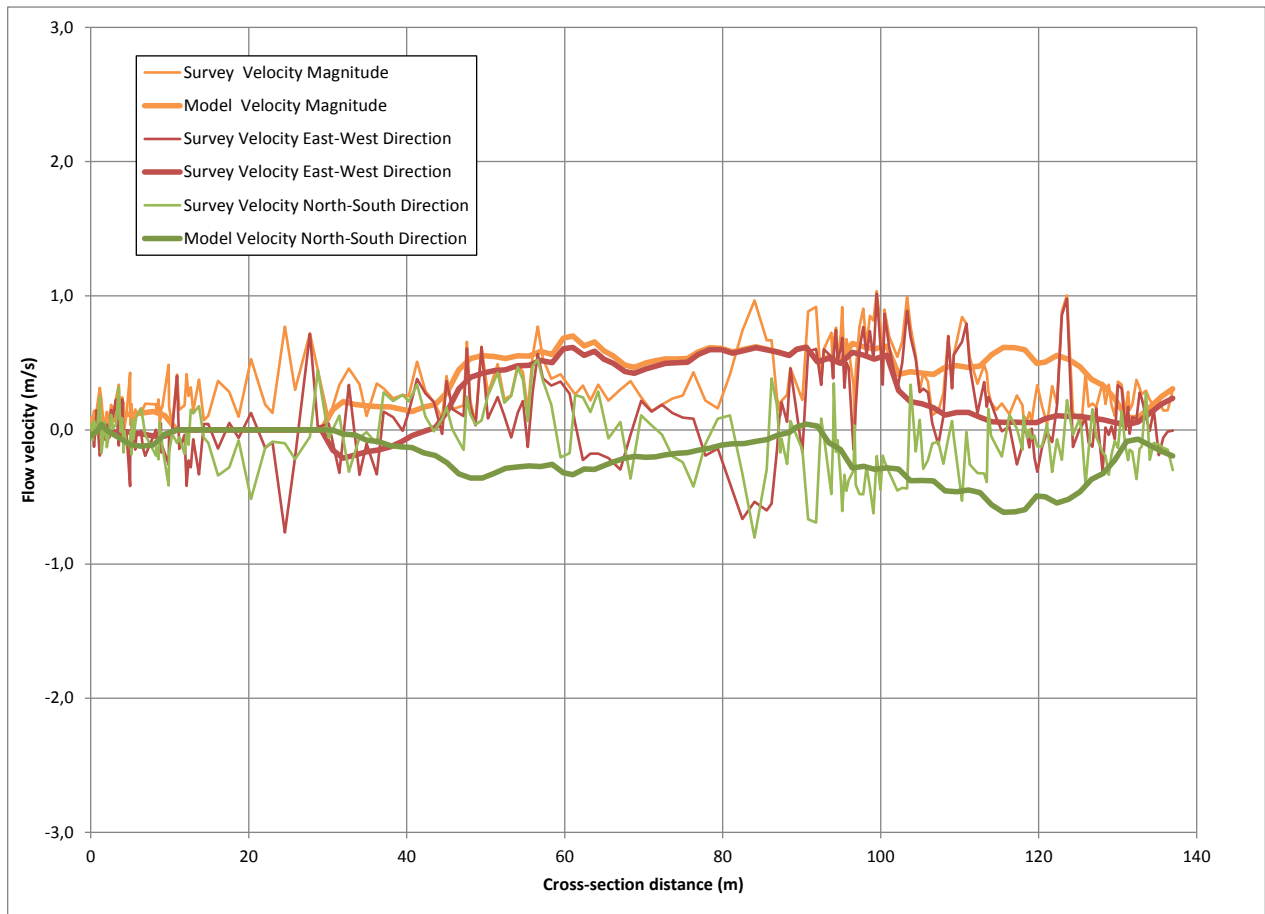


Figure 5.9 Cross-section 2 – 3D model results compared to survey recordings

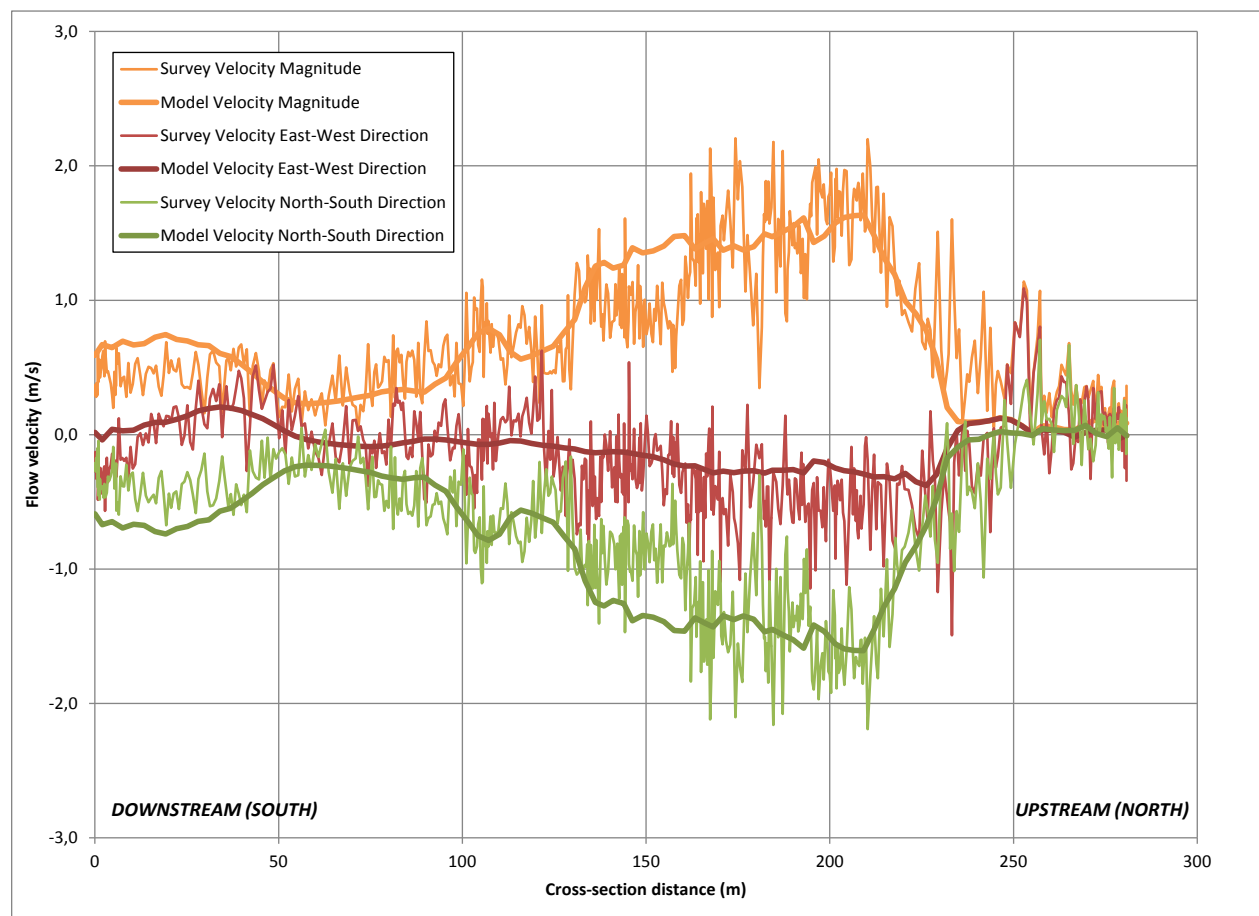


Figure 5.10 Cross-section 3 – 3D model results compared to survey recordings

The analysis of the calibration results shows that there is a very good correlation between the survey recordings and the 3D model results for cross-section 1 and 3.

Cross-section 1 is located perpendicular of the flow, downstream of the Main Dam and close the tip of the existing wall. The correlation at this location shows that the distribution of the flow patterns coming out of the Main Dam is well defined in the model. As seen on Figure 5.8, there is no significant flow velocity in the West portion of the cross-section, which is in the navigation channel. In the East portion of the cross-section, the flow patterns are oriented in the South-South-West direction, thus towards the navigation channel. The flow velocity magnitude is close to 1.8 m/s (3.5 kts). Boaters in the vicinity of this area may experience difficulty to navigate properly. The flow depth in this area may also cause concerns during low water level periods.

For cross-section 3 (Figure 5.10), surveyed flow velocity and model results show a similar flow pattern behavior which may be hard to manage by boaters since the flow velocity magnitude is close to 1.7 m/s (3.3 kts) in direction to the South-South-West. From downstream to upstream (approaching the lock from the downstream), the flow velocity increases as well as the tendency of the flow to push boaters to the West. Since the upstream portion of this cross-section is located directly in the navigation channel, results show that the majority of the flow coming out of the Main Dam is flowing pass the wall towards the navigation channel to the West, creating the navigation hazards identified by the owner and operator of the Dam.

As for the calibration results for cross-section 2, the analysis of Figure 5.9 shows that while the correlation is not as good as the other 2 cross-sections presented above, the model tends to give comparable results in terms of general flow behaviour (flow velocity) along the cross-section. Both surveyed velocity and model results show flow velocities close to 0.6 m/s (1.2 kts), which are relatively low compared to the flow velocities coming from the Main Dam. The absence of a defined bathymetric dataset upstream of the

cross-section up to Dam E is the main cause of local divergence between surveyed flow velocity and model results. Nonetheless, the average velocity magnitude is in the same order of magnitude and the flow coming out of Dam E has a limited effect on the flow patterns in the navigation channel given its low velocity.

5.4 Flow patterns analysis

The flow patterns obtained from the calibration demonstrate that the flow coming out of the Main Dam is deflected by the shape of the river bed downstream of the dam. The natural downward river bed slope from the left bank to the middle of the river diverts the flow towards the deepest section of the river (towards the navigation channel). Also contributing to the effect, there is an inline shallow area in the river that runs from the left bank to an area close to the tip of the East wall that creates an upstream pool (higher water level) during low water level periods which deflects the flow perpendicular to its alignment. This inline shallow area is shown in Figure 5.11 (flow depth in m).

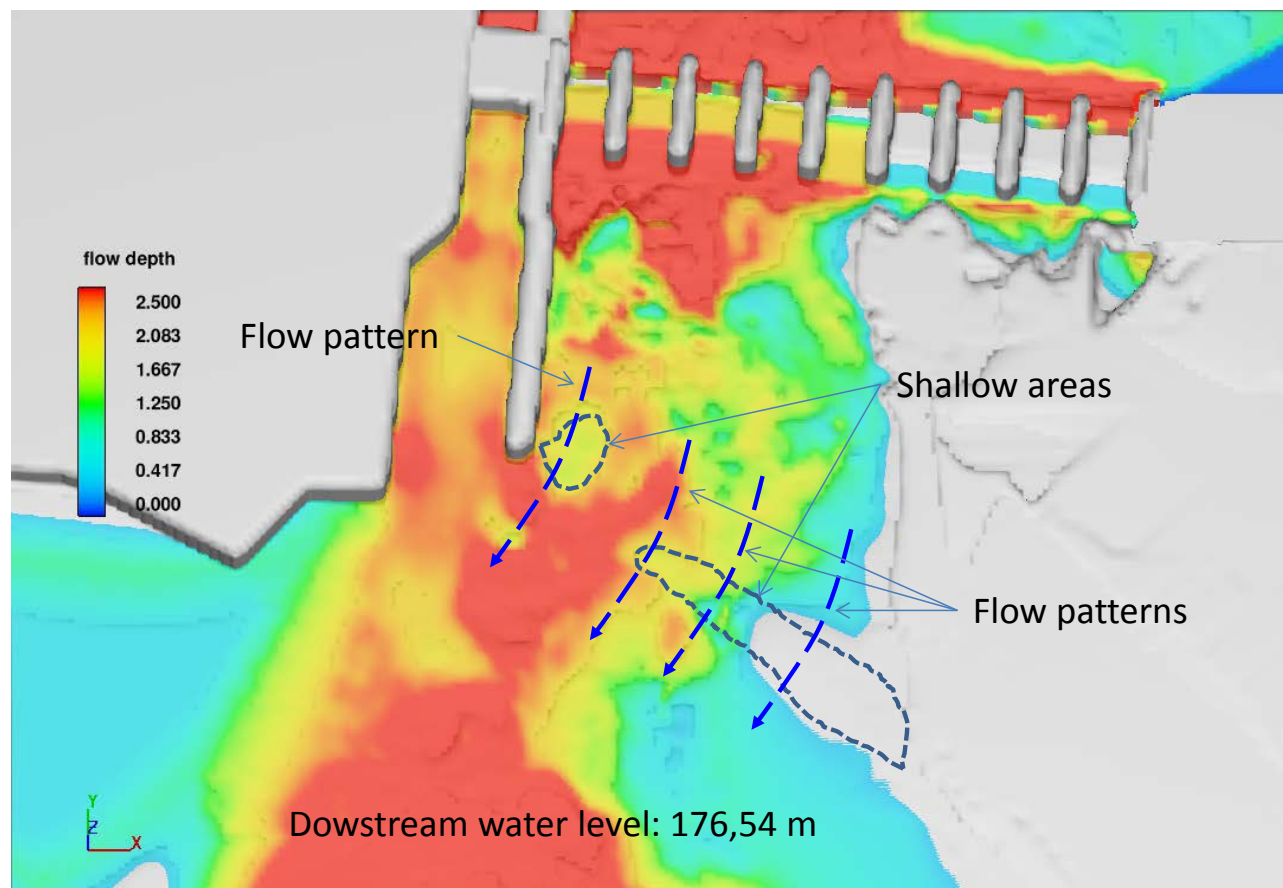


Figure 5.11 Inline shallow area location and hydraulic effect (flow depths in m)

The lower the downstream water level is, the more this shallow area pushes the flow towards the navigation channel. The fact that the effect of the shallow area on the flow pattern increases as the downstream water level drops is shown in Figure 5.12. For a same outflow from the Main Dam of 90 m³/s, the flow patterns are more diverted towards the navigational channel in the case of a lower water level.

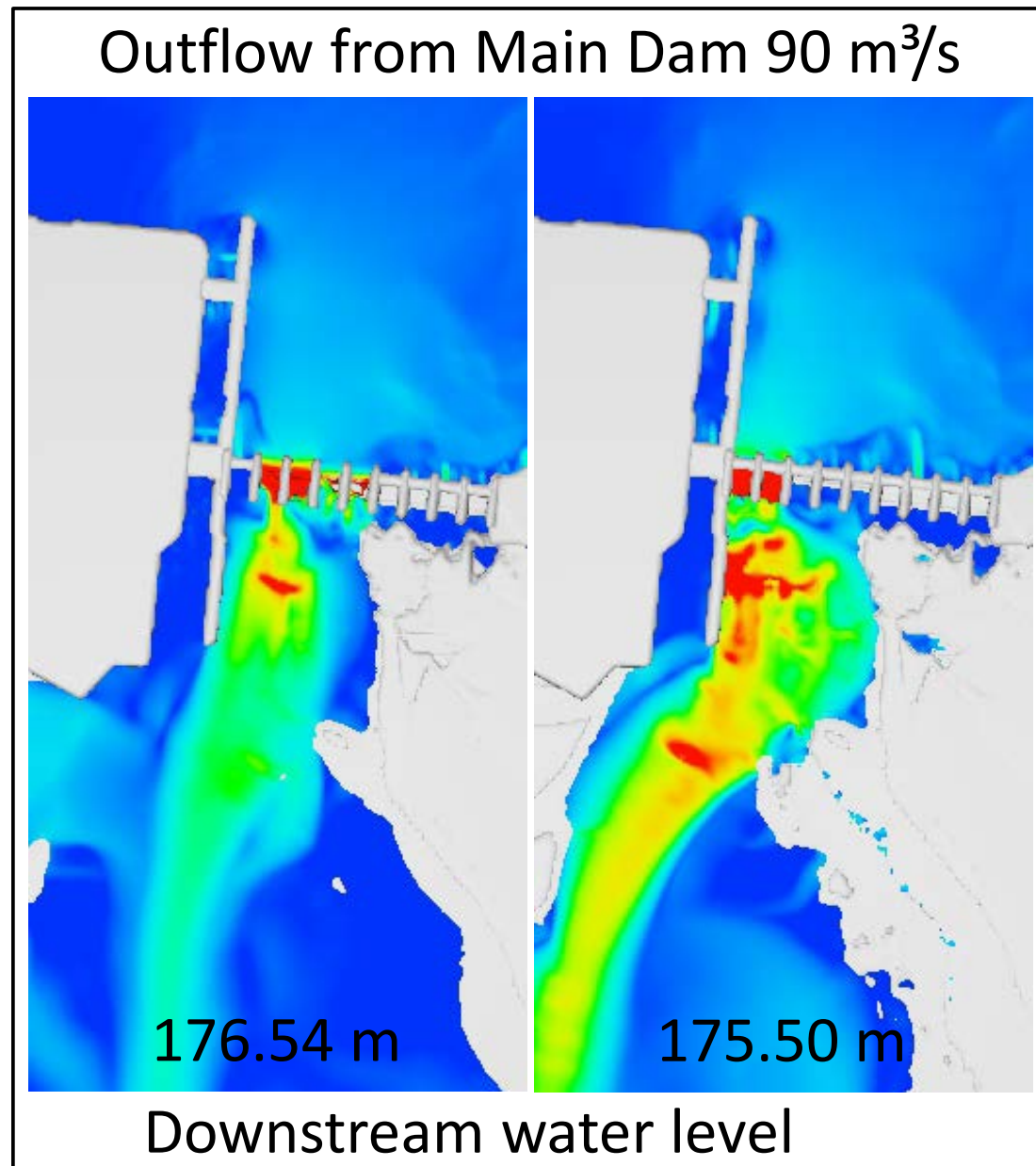


Figure 5.12 Flow pattern behaviour in regards of the downstream water level

6. Attenuation Measures

As discussed in Section 5.4, the bathymetry of the river downstream of the Main Dam diverts the flow towards the deepest section of the river being the navigation channel. The first studied measure consists of an excavated channel downstream of the spillway and parallel to the navigation channel. This channel would allow the flow patterns to stay in line and out of the navigation channel. While this new channel would realign the flow patterns towards the downstream island, this would require excavation work on a large submerge area. In order to limit the excavated area, and to increase the docking area for the lock, two additional measures are studied.

The studied attenuation measures are:

- An excavated channel in line with sluice bays 2, 3 and 4;
- A deflecting wall, installed from the tip of the existing East wall;
- A deflecting wall installed from the tip of the existing East wall in conjunction with a localized excavation area located near the tip of this deflecting wall.

In order to evaluate the effectiveness of the proposed measures, the 3D model is used for different hydraulic conditions of water levels and discharge scenarios. The following downstream water levels are considered:

- 175.5 m (lowest all time recorded water level of Lake Michigan-Huron, 1964);
- 176.4 m (mean water level of Lake Michigan-Huron, 1918-2016);
- 177.5 m (highest all time recorded water level of Lake Michigan-Huron, 1986).

In conjunction with those water levels, two gate configurations are considered at the Main Dam, giving total discharges of approximately 100 m³/s and 170 m³/s. In order to do so, gates from sluices 2 and 3 are opened accordingly.

6.1 Attenuation Measure 1: Excavated Channel

The first measure is to create a new channel with a minimum depth of 2 m in line with sluice gates 2, 3 and 4. The excavated area is located perpendicular to the Main Dam alignment. A sensitivity analysis on the required flow depth showed that a minimum depth of 2 m is required during very low water level of Lake Huron, giving a maximum bottom elevation of the channel of 173.5 m. Given its location, the maximum depth of the excavated area is no more than 2.8 m.

Three different widths were studied: 15 m, 20 m and 25 m. The total excavated length is 60 m.

Figure 6.1 shows the location of the excavated channel.

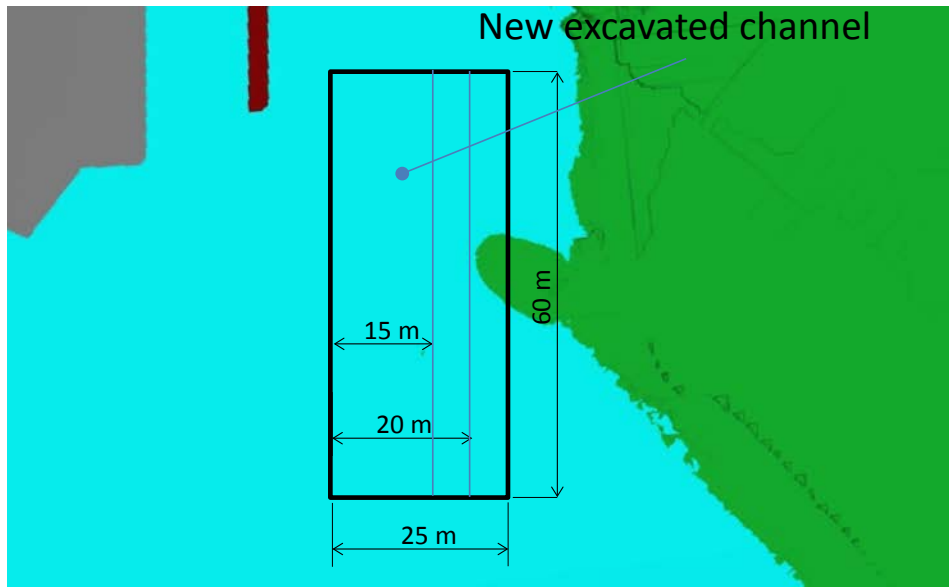


Figure 6.1 Location of the excavated channel

The simulations were carried out for downstream water levels of 175.5 m, 176.4 m and 177.5 m. As a first step, the study of the effectiveness of the added excavated channel is done for 100 m³/s.

For each downstream water level and channel width, a figure is presented hereafter with the output of the 3D model with the flow patterns and velocity in order to compare the effectiveness of excavated channel. For flow discharge of 100 m³/s, the results are presented in Figure 6.2 to Figure 6.10. All flow velocities are in m/s.

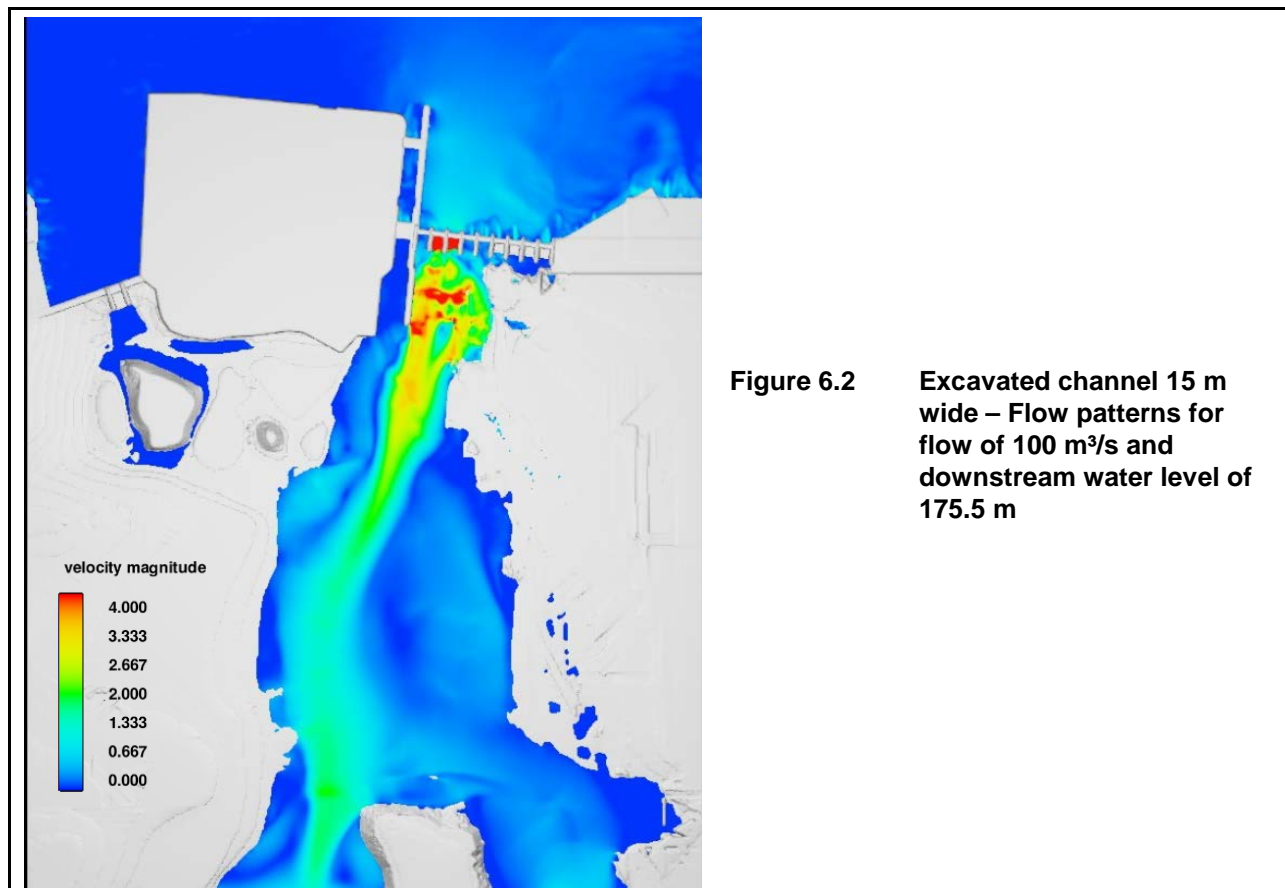


Figure 6.2 Excavated channel 15 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

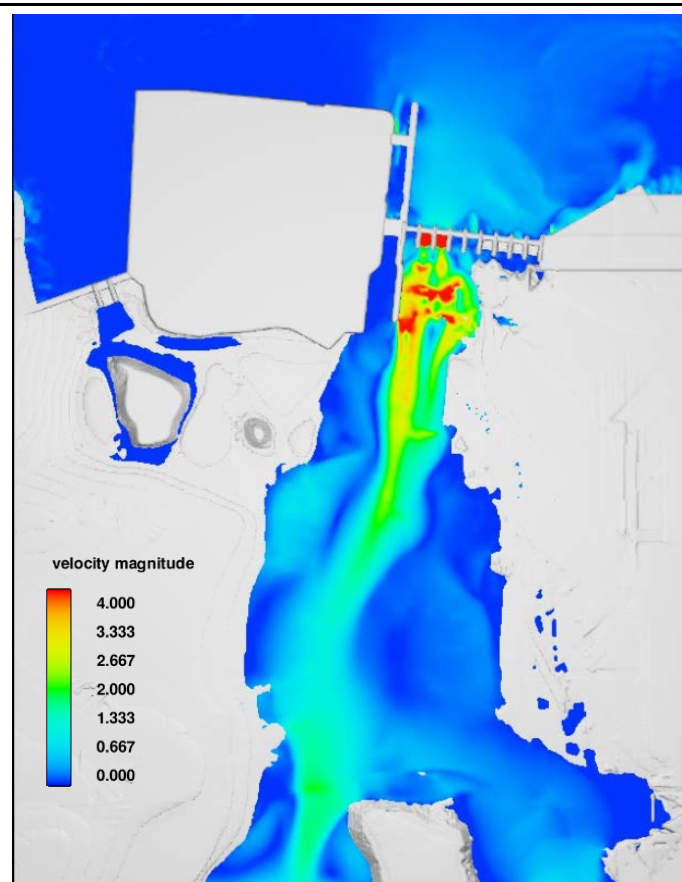


Figure 6.3 **Excavated channel 20 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m**

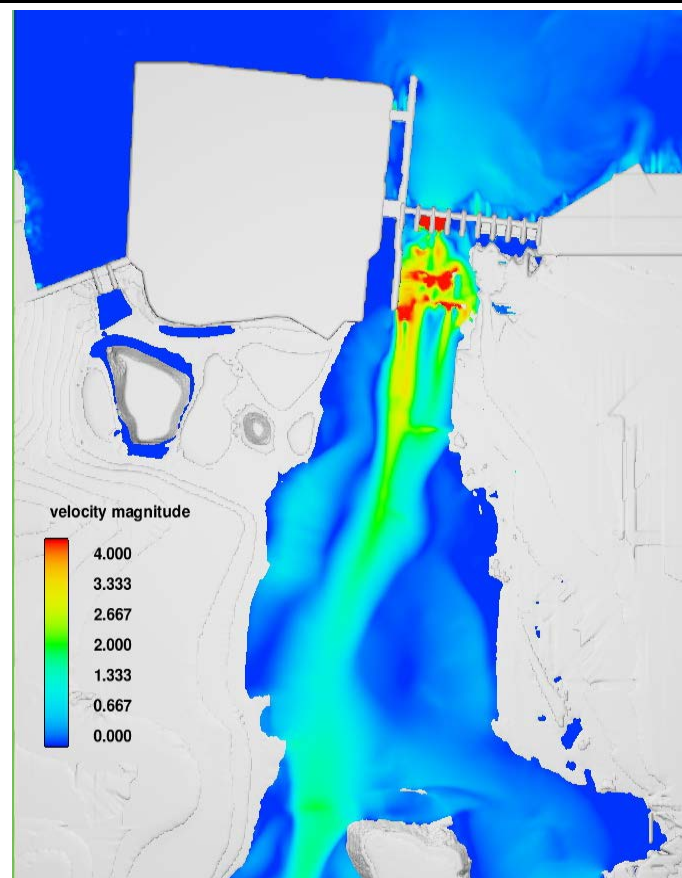


Figure 6.4 **Excavated channel 25 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m**

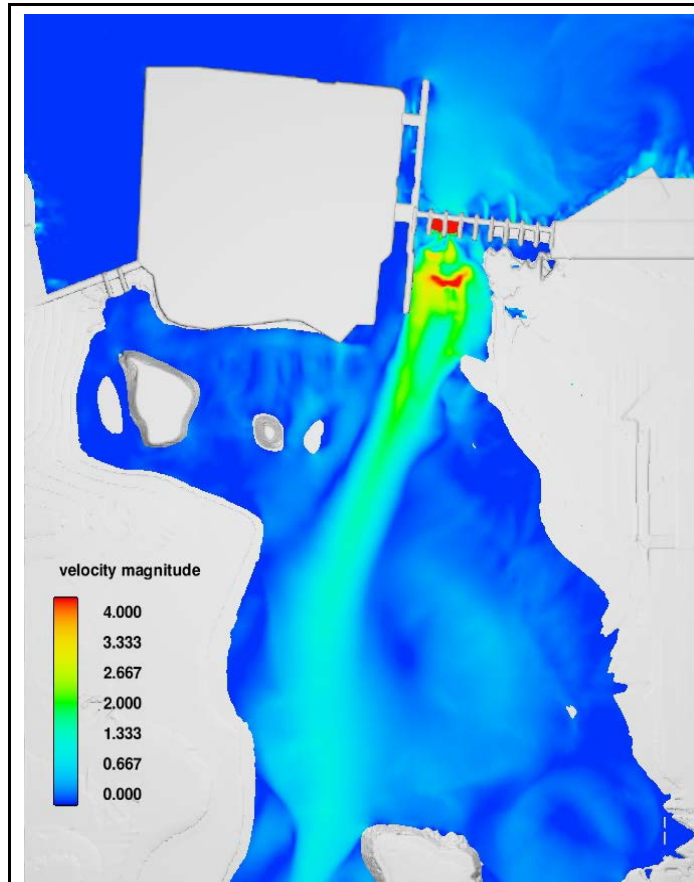


Figure 6.5 **Excavated channel 15 m wide – Flow patterns for flow 100 m³/s and downstream water level of 176.4 m**

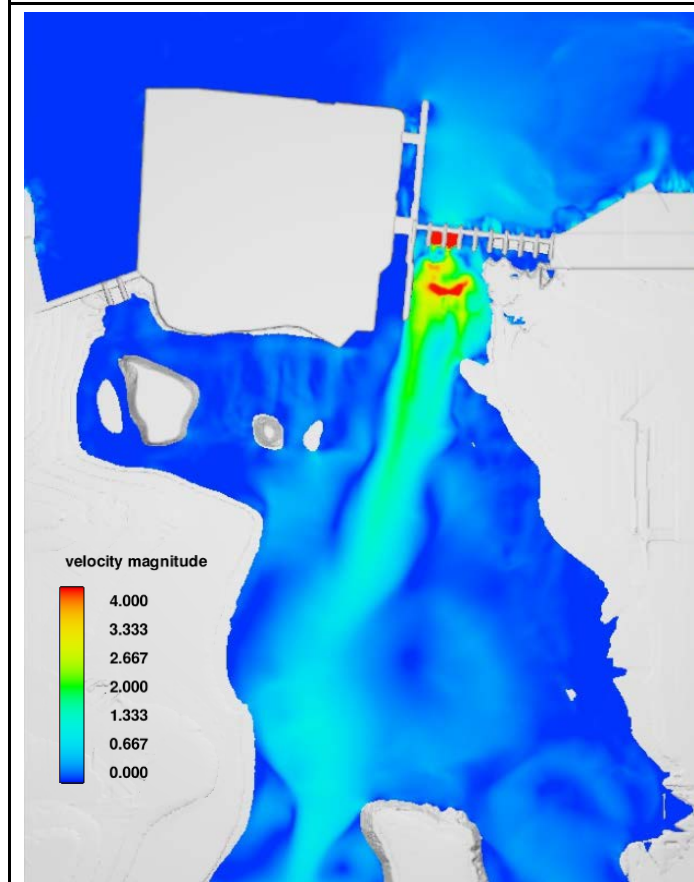


Figure 6.6 **Excavated channel 20 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 176.4 m**

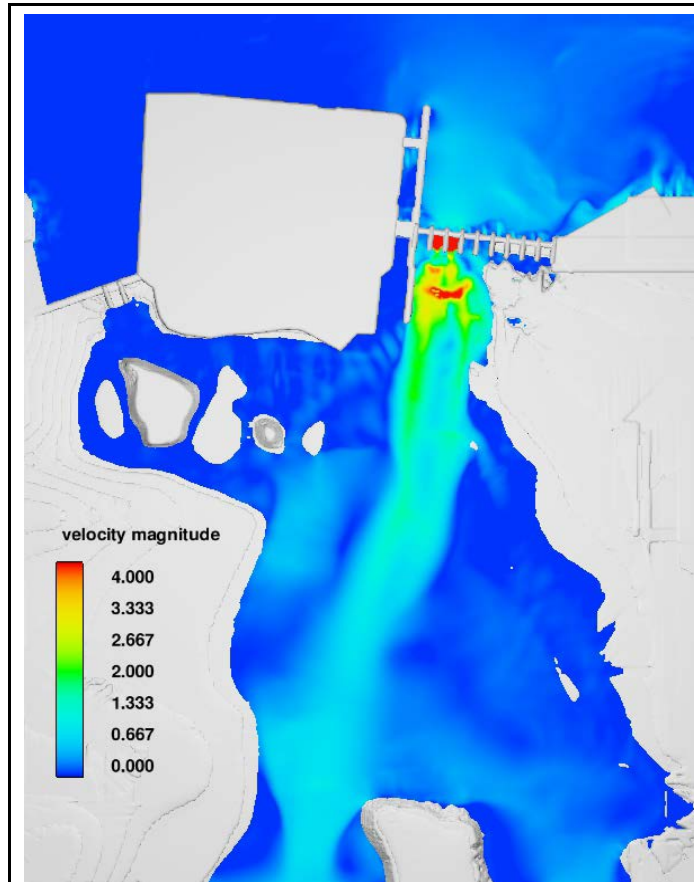


Figure 6.7 Excavated channel 25 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 176.4 m

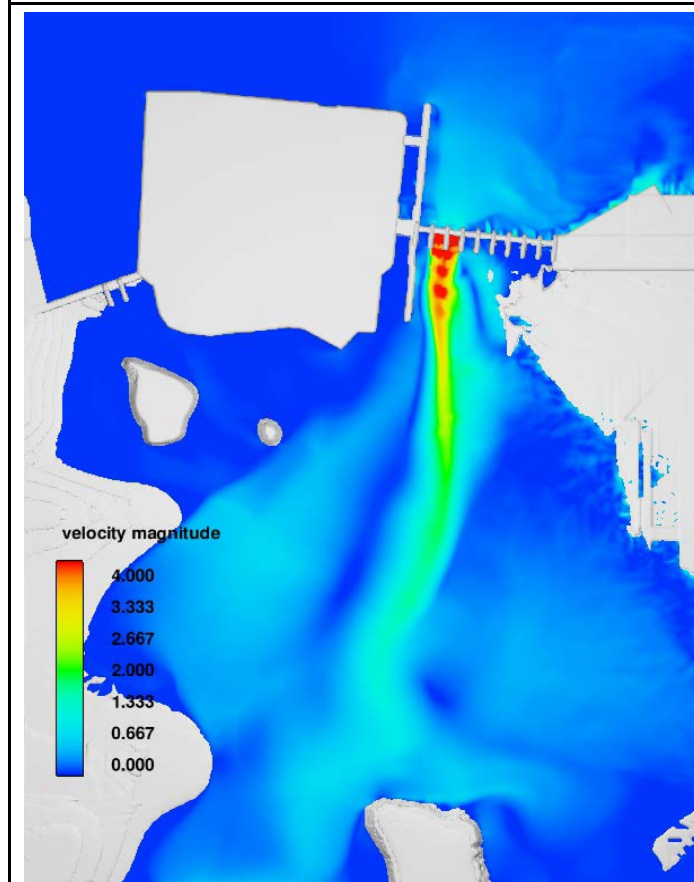


Figure 6.8 Excavated channel 15 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 177.5 m

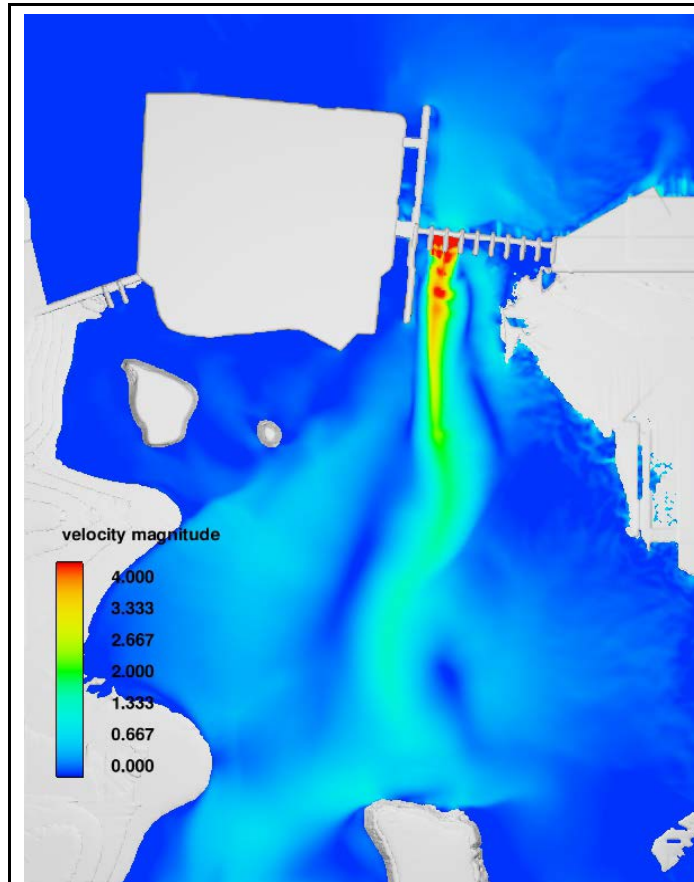


Figure 6.9 **Excavated channel 20 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 177.5 m**

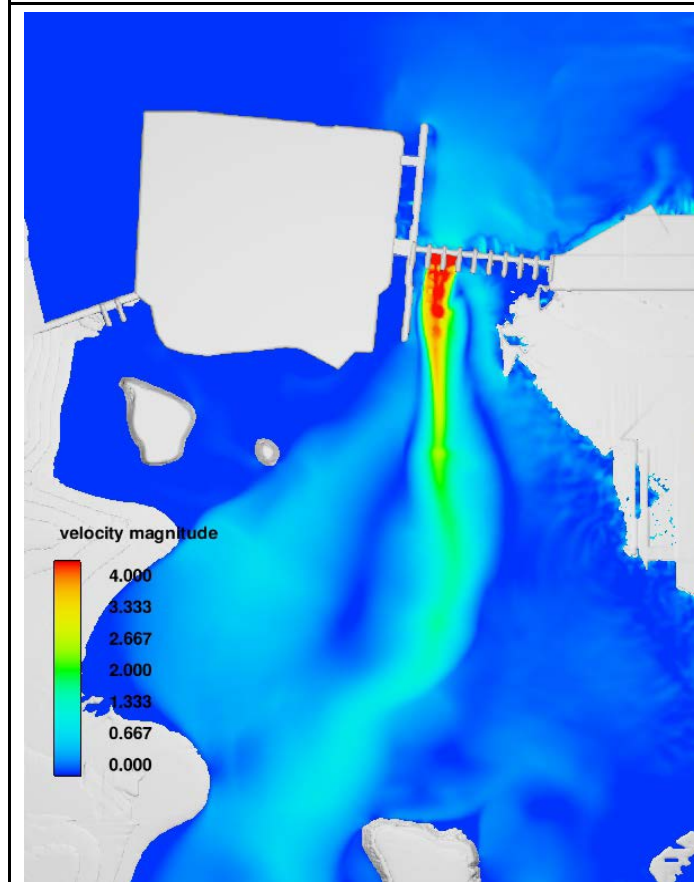
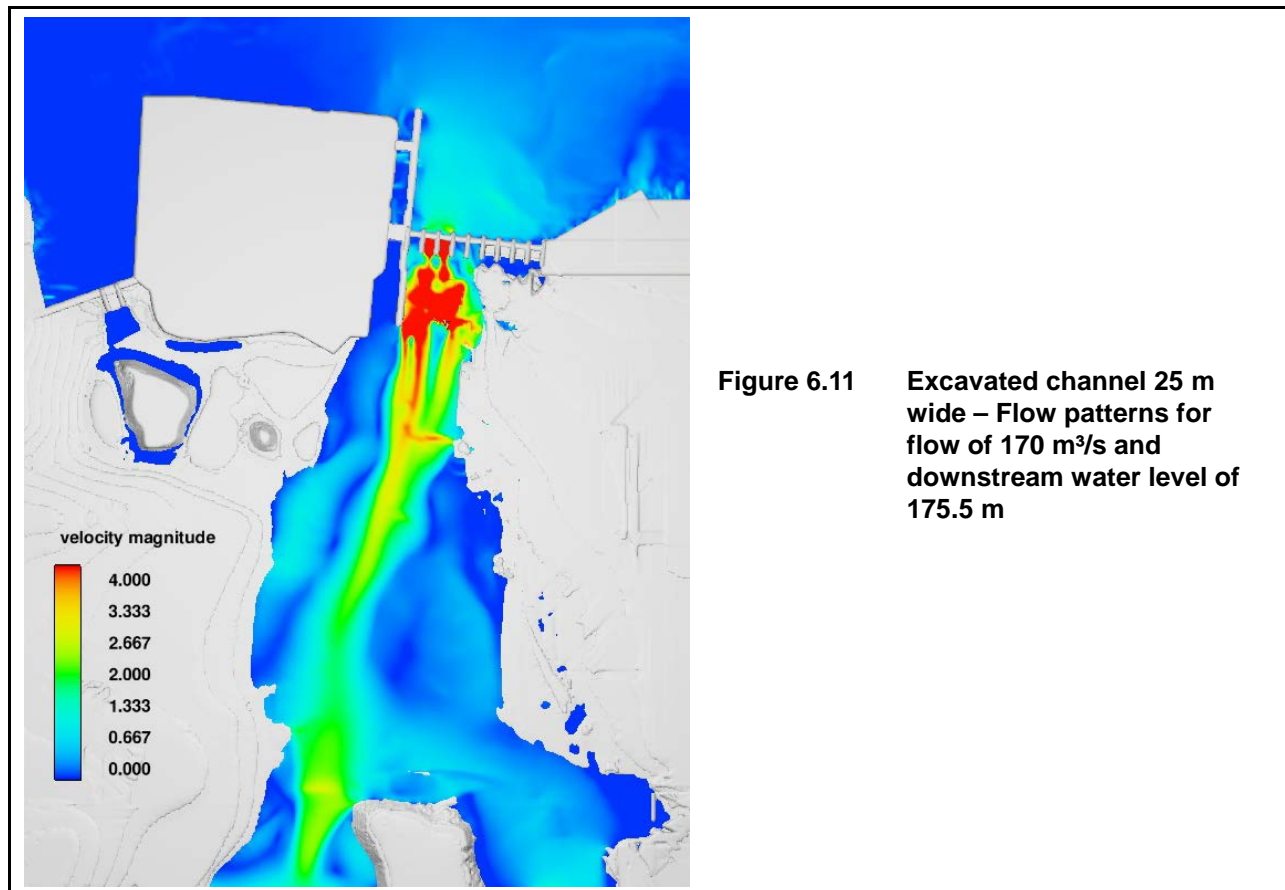


Figure 6.10 **Excavated channel 25 m wide – Flow patterns for flow of 100 m³/s and downstream water level of 177.5 m**

For a minimum downstream water level of 175.5 m, results show that the excavated channel must have a width of at least 20 m. At that water level, the flow patterns for a 20 m wide channel are quite similar to the one with a 25 m wide. For a downstream water level of 176.4 m, a 25 m wide channel has an advantage over a 20 m wide channel as flow patterns tend to flow parallel to the navigation channel for a greater distance.

Since the 15 m wide channel is not suitable for lower downstream water level and the 25 m wide channel is better than the 20 m wide channel for mean downstream water levels, only the 25 m wide channel is simulated for outflow of 170 m³/s. The flow patterns for downstream water levels of 175.5 m and 176.4 m are presented in Figure 6.11 and Figure 6.12.



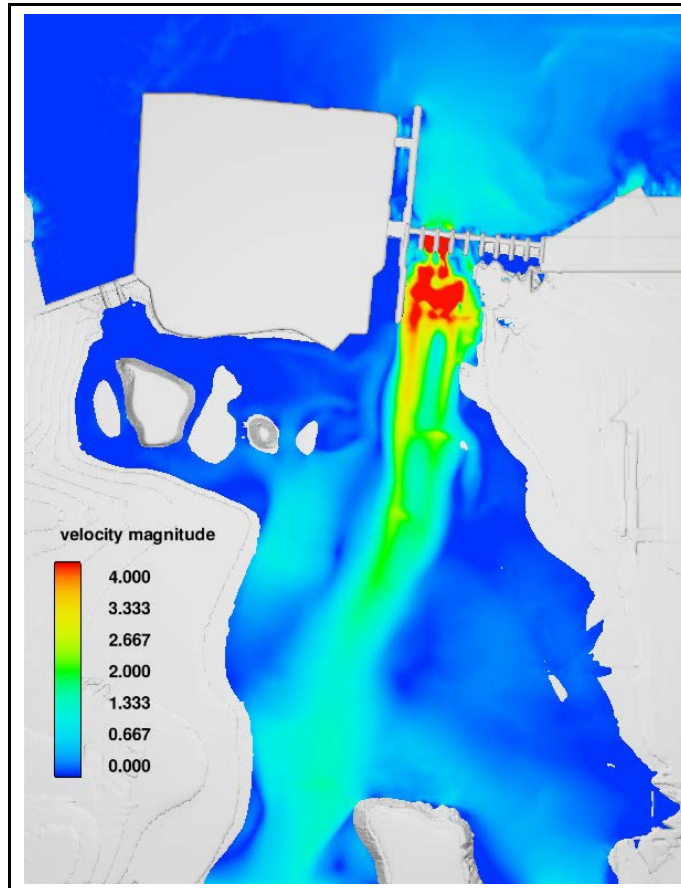


Figure 6.12 Excavated channel 25 m wide – Flow patterns for flow of 170 m³/s and downstream water level of 176.4 m

6.2 Attenuation Measure 2: Deflecting Wall

The second measure's goal is to stop the natural tendency of the flow coming out of the Main Dam to be diverted towards the navigation channel. A permanent deflecting wall structure is to be constructed from the tip of the East wall of Lock 45. This deflecting wall is 30 m long and has an angle of 10° to the East from the alignment of the East wall. The deflecting wall can consist of either sheet piles held in place by a steel structure or a concrete wall similar to the existing one. The benefit of a concrete wall is that it is similar to the existing wall and makes docking easier.

Figure 6.13 shows the location of the new deflecting wall.

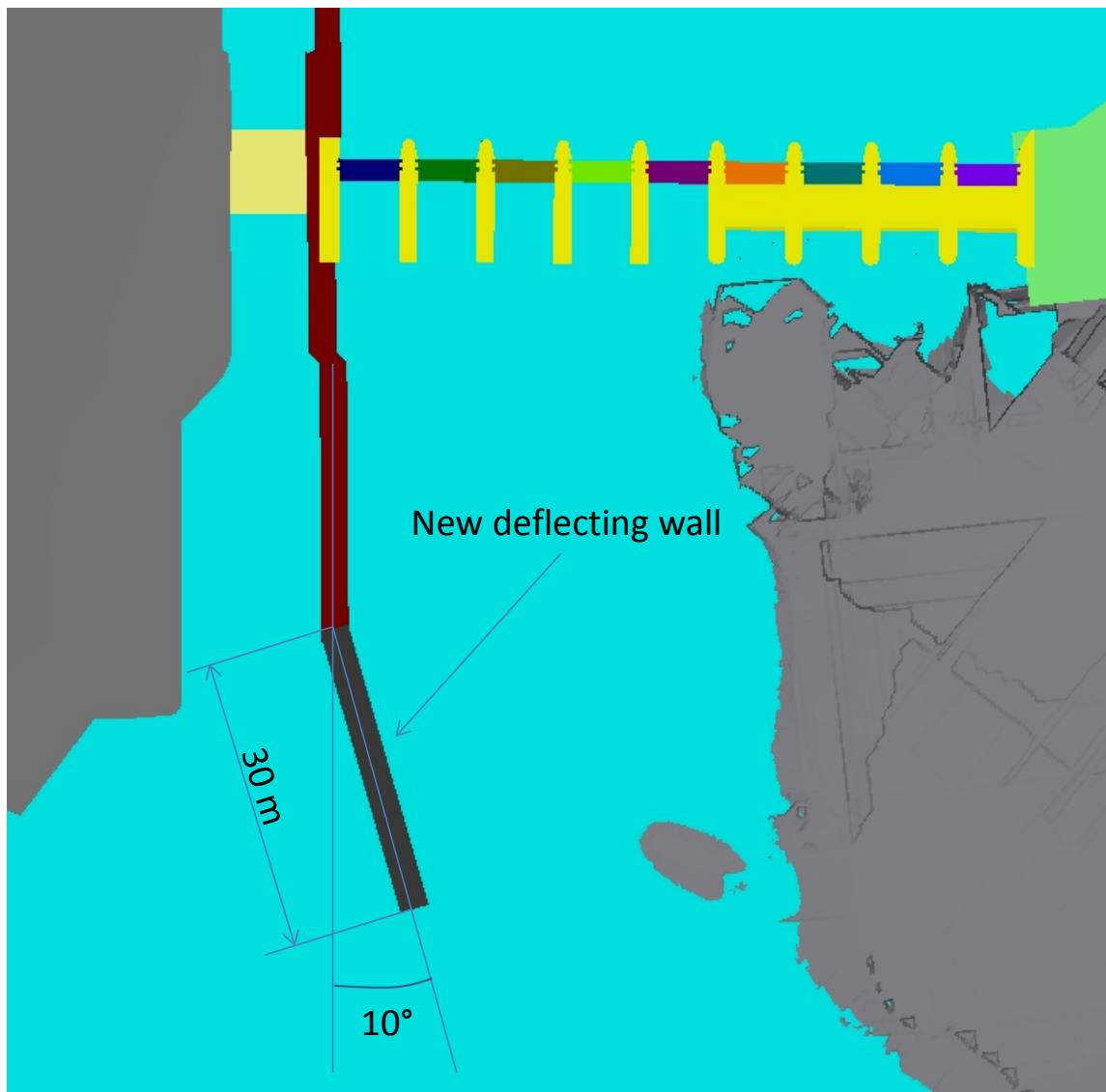


Figure 6.13 Location of the new deflecting wall

For this measure, the simulations were carried out for downstream water levels of 175.5 m, 176.4 m and 177.5 m and for discharges of 100 m³/s and 170 m³/s.

For each downstream water level and discharge considered, a figure of the 3D model output is presented hereafter with the flow patterns and velocity in order to compare the effectiveness of the deflecting wall under different flow conditions (Figure 6.14 to Figure 6.19). All flow velocities are in m/s.

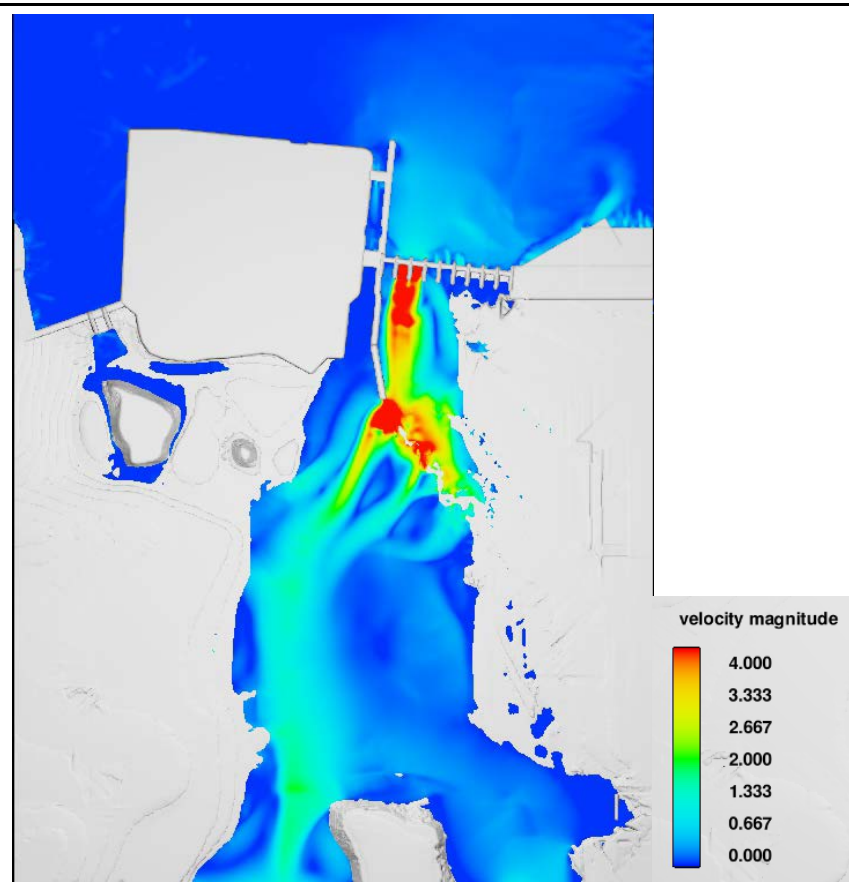


Figure 6.14 Deflecting wall – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

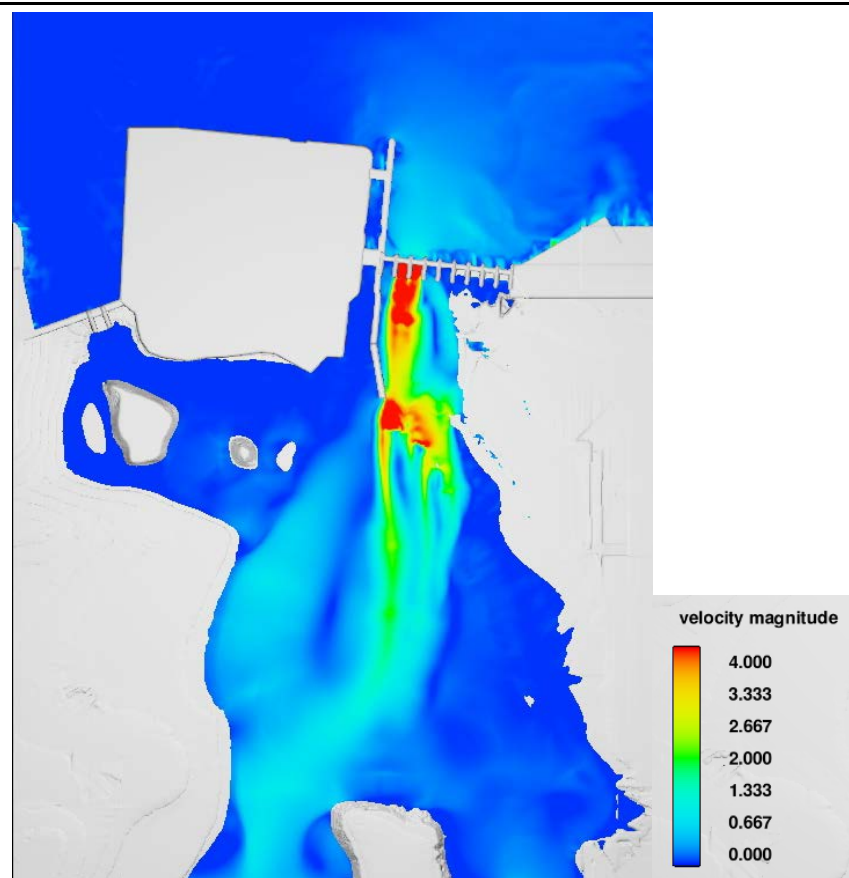


Figure 6.15 Deflecting wall – Flow patterns for flow of 100 m³/s and downstream water level of 176.4 m

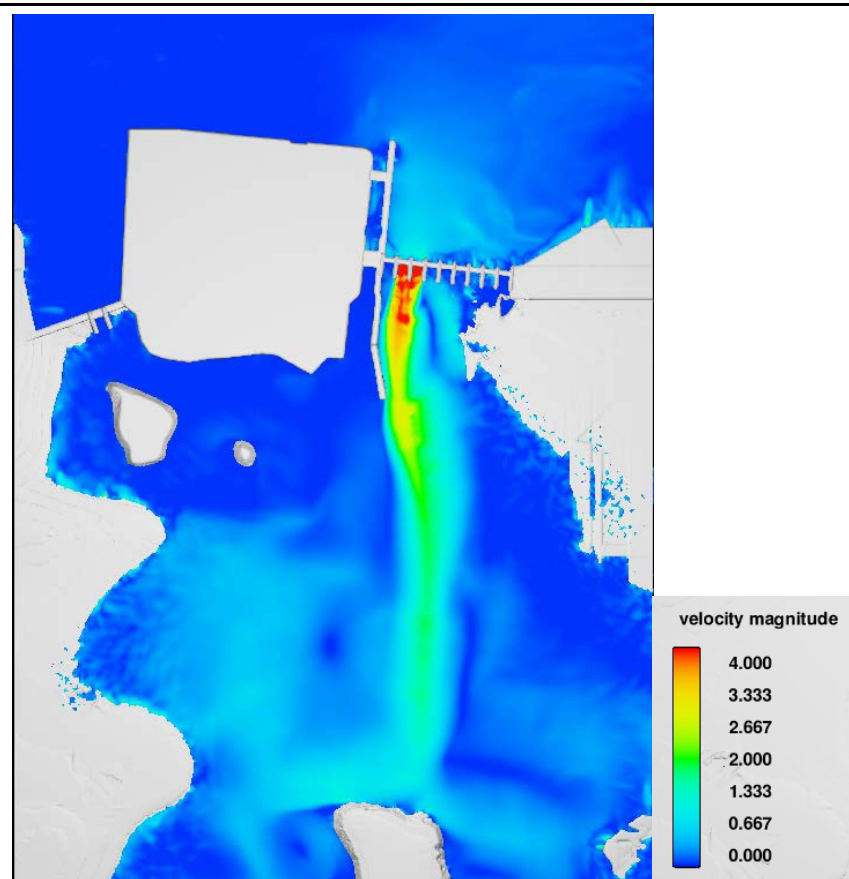


Figure 6.16 Deflecting wall – Flow patterns for flow of 100 m³/s and downstream water level of 177.5 m

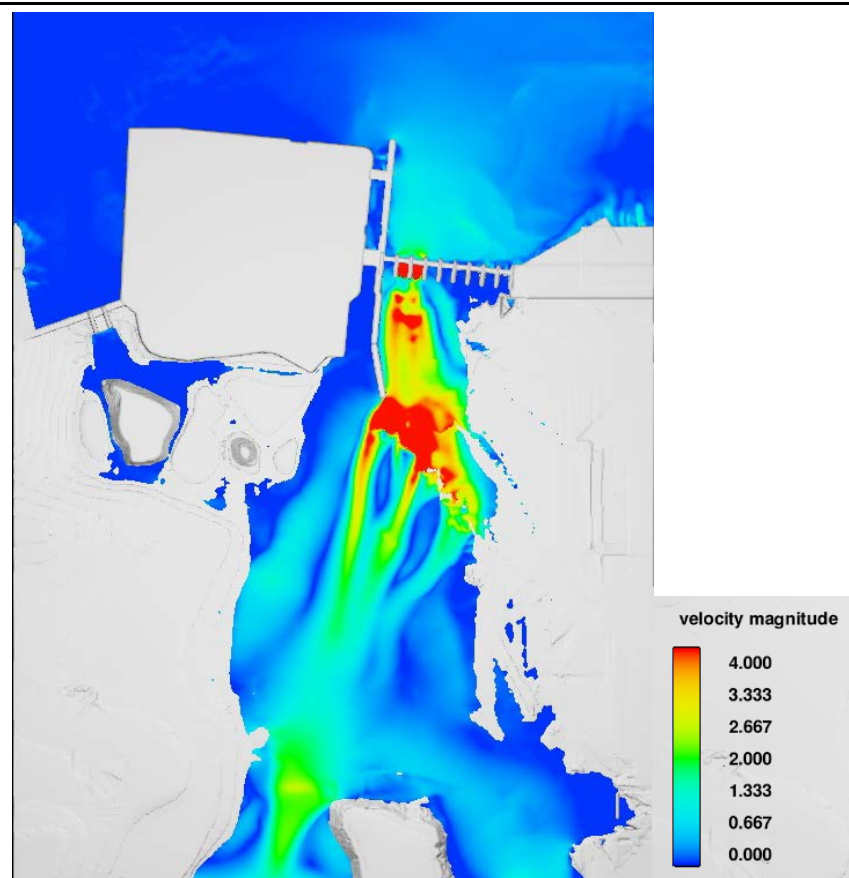


Figure 6.17 Deflecting wall – Flow patterns for flow of 170 m³/s and downstream water level of 175.5 m

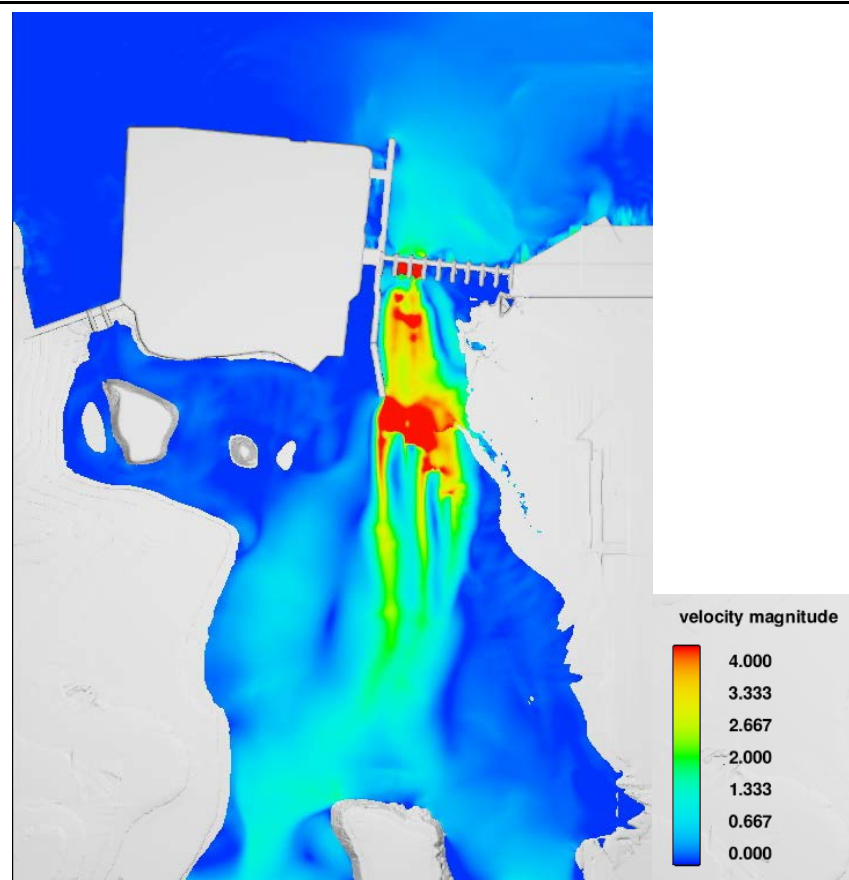


Figure 6.18 Deflecting wall – Flow patterns for flow of 170 m³/s and downstream water level of 176.4 m

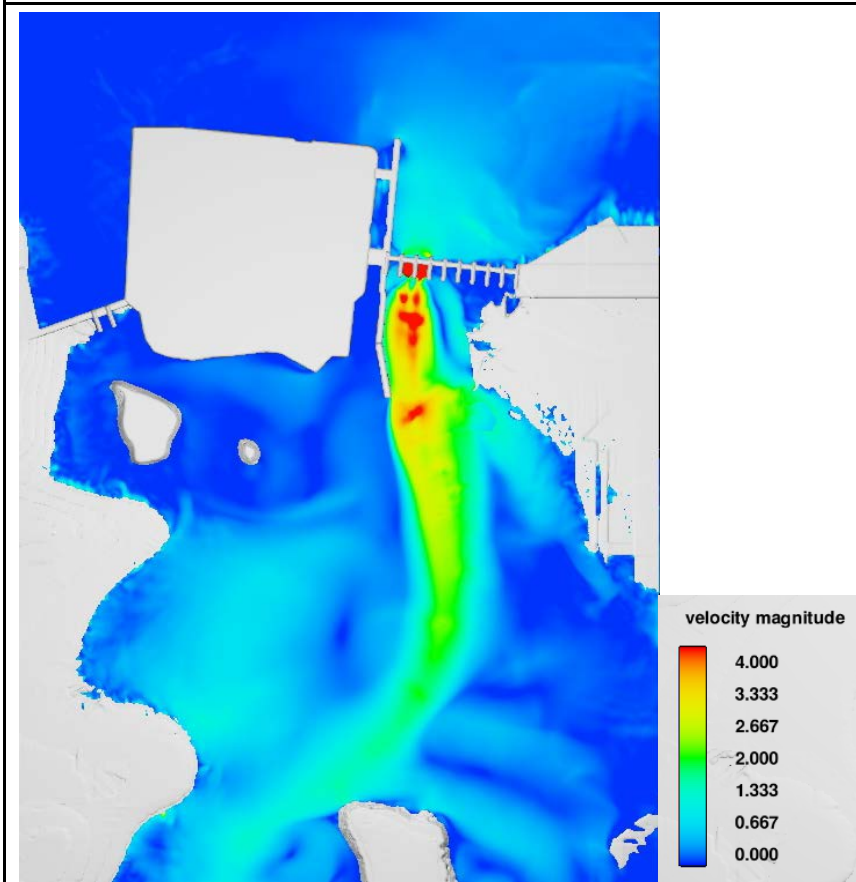


Figure 6.19 Deflecting wall – Flow patterns for flow of 170 m³/s and downstream water level of 177.5 m

The analysis of these results shows that the deflecting wall by itself effectively deflects away from the navigation channel the flow coming out of the Main Dam for downstream water levels of 176.4 m and 177.5 m (Figure 6.15, Figure 6.16, Figure 6.18 and Figure 6.19). For the minimum downstream water level of 175.5 m (Figure 6.14 and Figure 6.17), the deflecting wall by itself does not provide an adequate protection of the navigation channel. In fact, the shallow area identified in Section 5.4 creates the same behaviour by creating a higher water level pool upstream of this area and force the flow towards the navigation channel.

Given these results, the deflecting wall may be a favourable solution most of the time but with a limited effect during very low downstream water level of Lake Huron.

6.3 Attenuation Measure 3: Deflecting Wall with Local Excavated Channel

Although the deflecting wall described above does deflect adequately the flow most of the time for normal and high downstream water level conditions, there is still some adverse flow patterns in the navigation channel when the downstream water level becomes very low.

In order to minimize the effect of the shallow area located between the new deflecting wall tip and the left bank, an excavated channel is proposed. The channel is to be excavated to a level of 173.5 m which will create a minimum flow depth of 2.0 m during very low water level of Lake Huron. Given its location, there is no more than 2.8 m in depth to be excavated.

The excavated area is located beside the tip of the new deflecting wall perpendicular to the Main Dam alignment. Four different widths were studied: 5 m, 10 m, 15 m and 20 m. The total excavated length is 30 m.

Figure 6.20 shows the location of the new deflecting wall and the excavated channel.

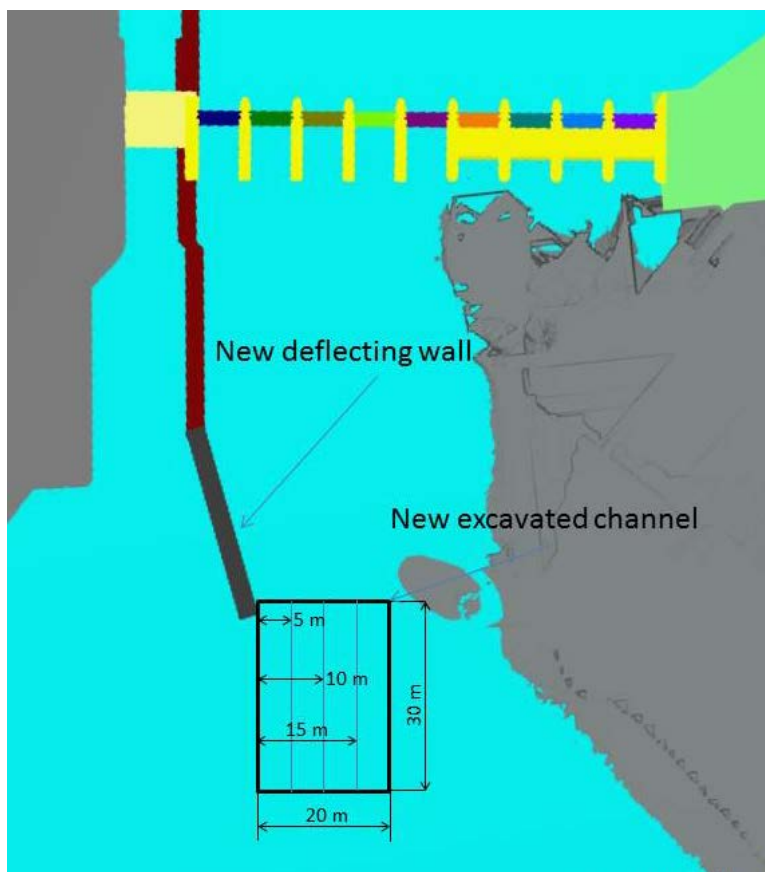
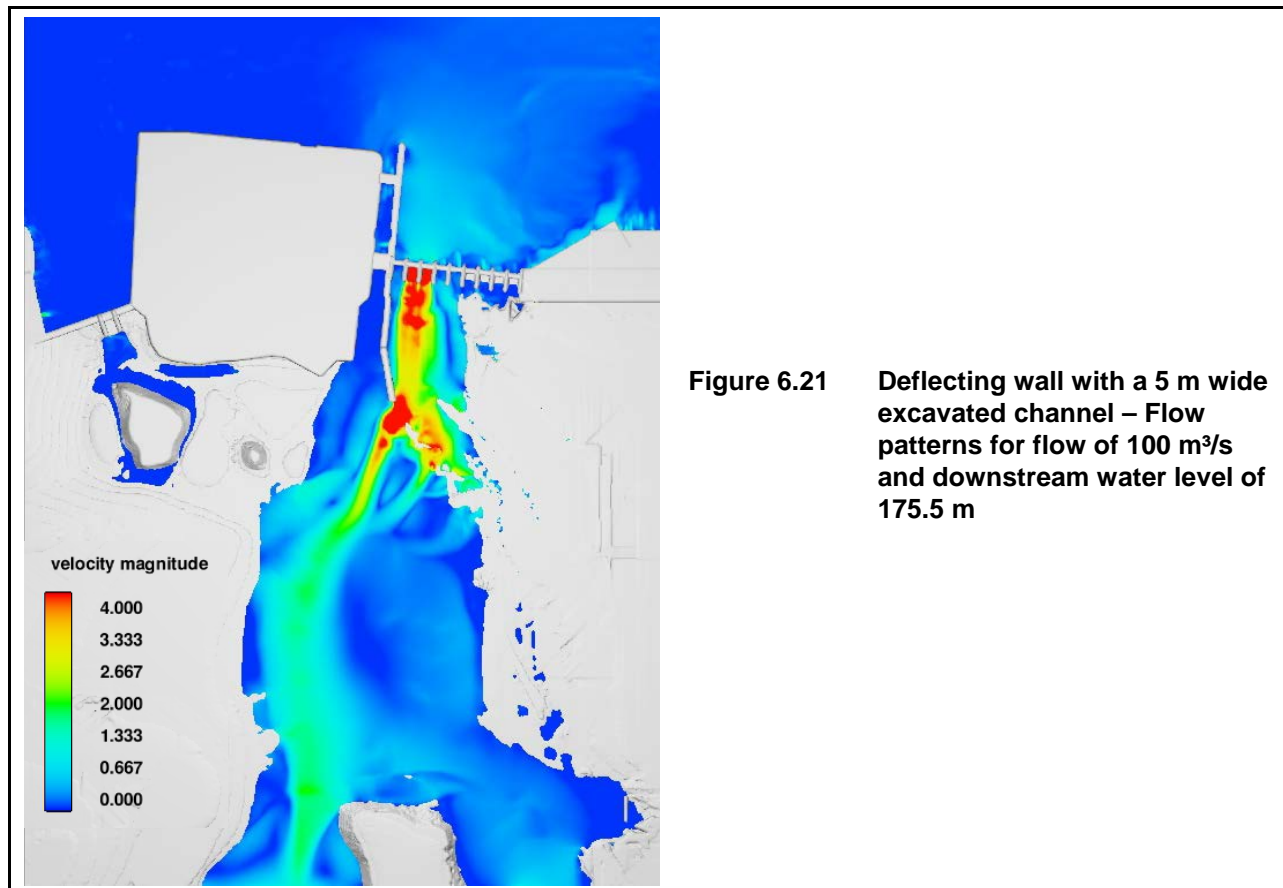


Figure 6.20 Location of the new deflecting wall and the excavated channel

Since the addition of an excavated channel at the tip of the new deflecting wall aims at eliminating adverse flow patterns in the navigation channel during very low downstream water level conditions, the simulations were carried out for downstream water levels of 175.5 m and 176.4 m only. The study of the effectiveness of the added excavated channel is done for 100 m³/s.

For each downstream water level, a figure is presented hereafter with the output of the 3D model with the flow patterns and velocity in order to compare the effectiveness of the deflecting wall with the addition of an excavated channel under different flow conditions and different channel widths (Figure 6.21 to Figure 6.26). All flow velocities are in m/s.



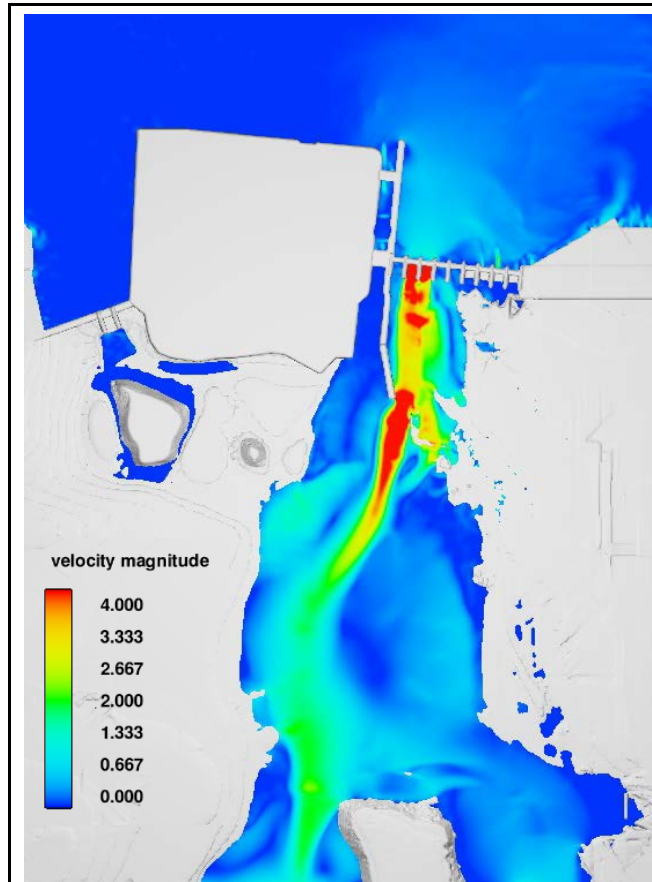


Figure 6.22 Deflecting wall with a 10 m wide excavated channel – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

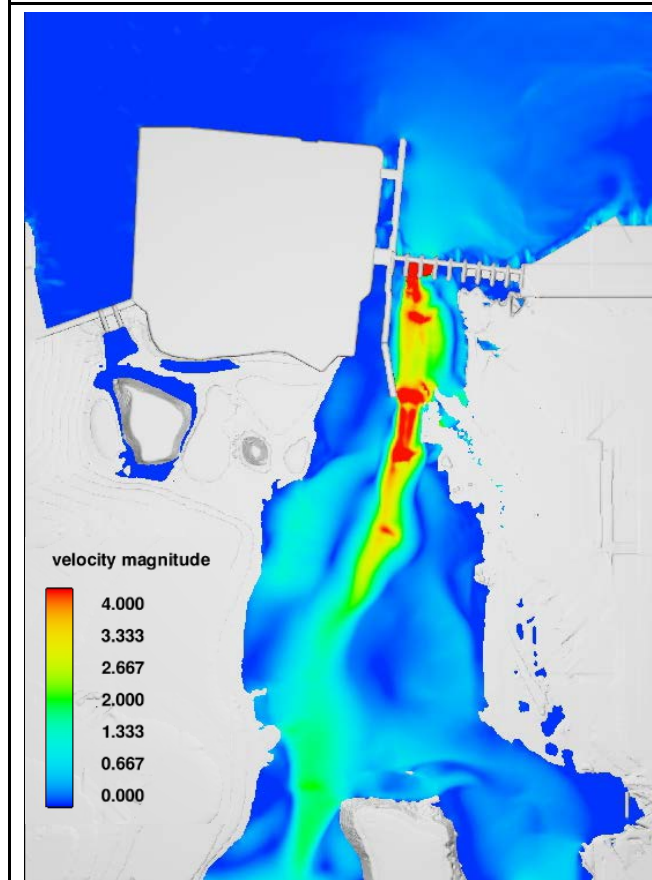


Figure 6.23 Deflecting wall with a 15 m wide excavated channel – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

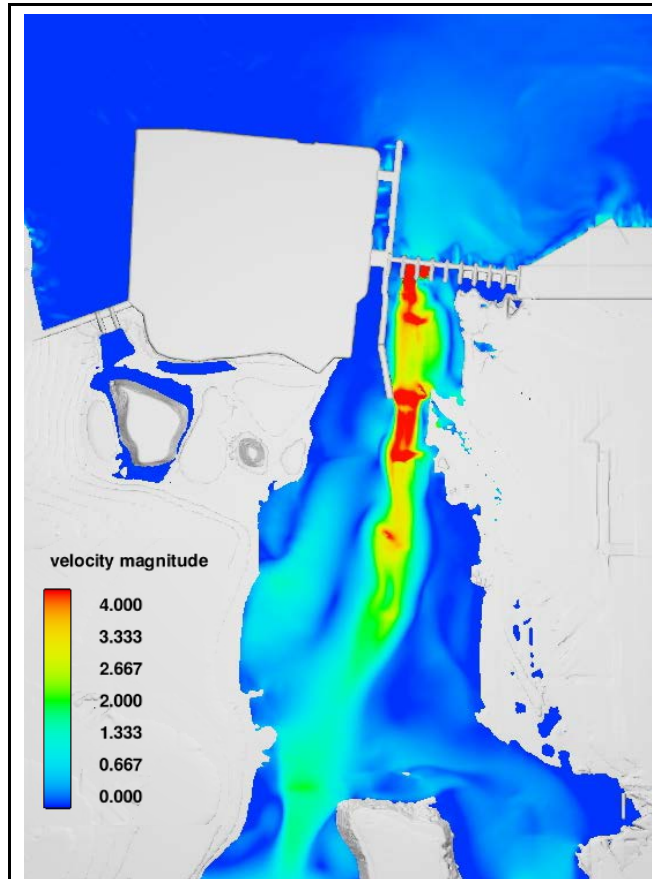


Figure 6.24 Deflecting wall with a 20 m wide excavated channel – Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

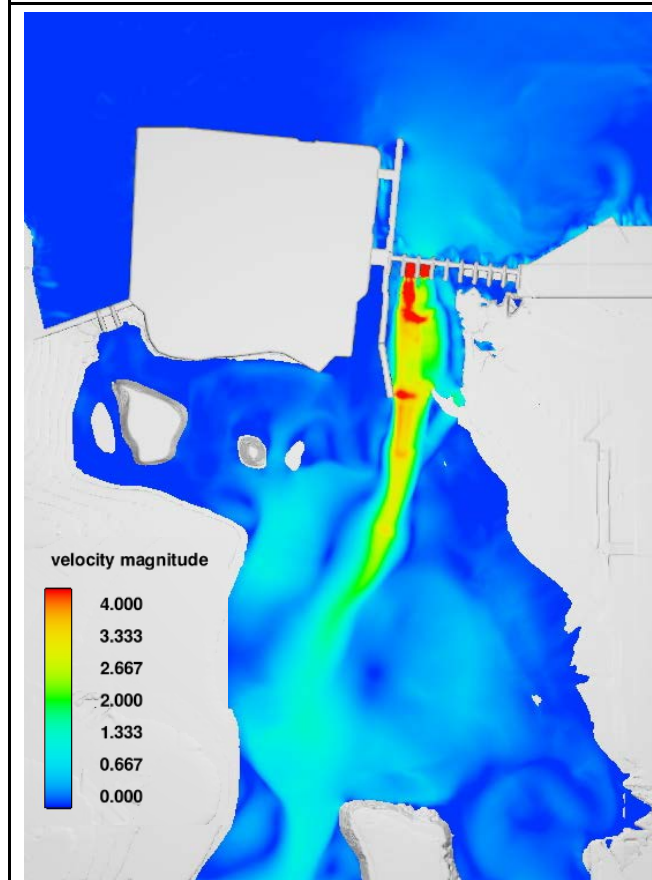
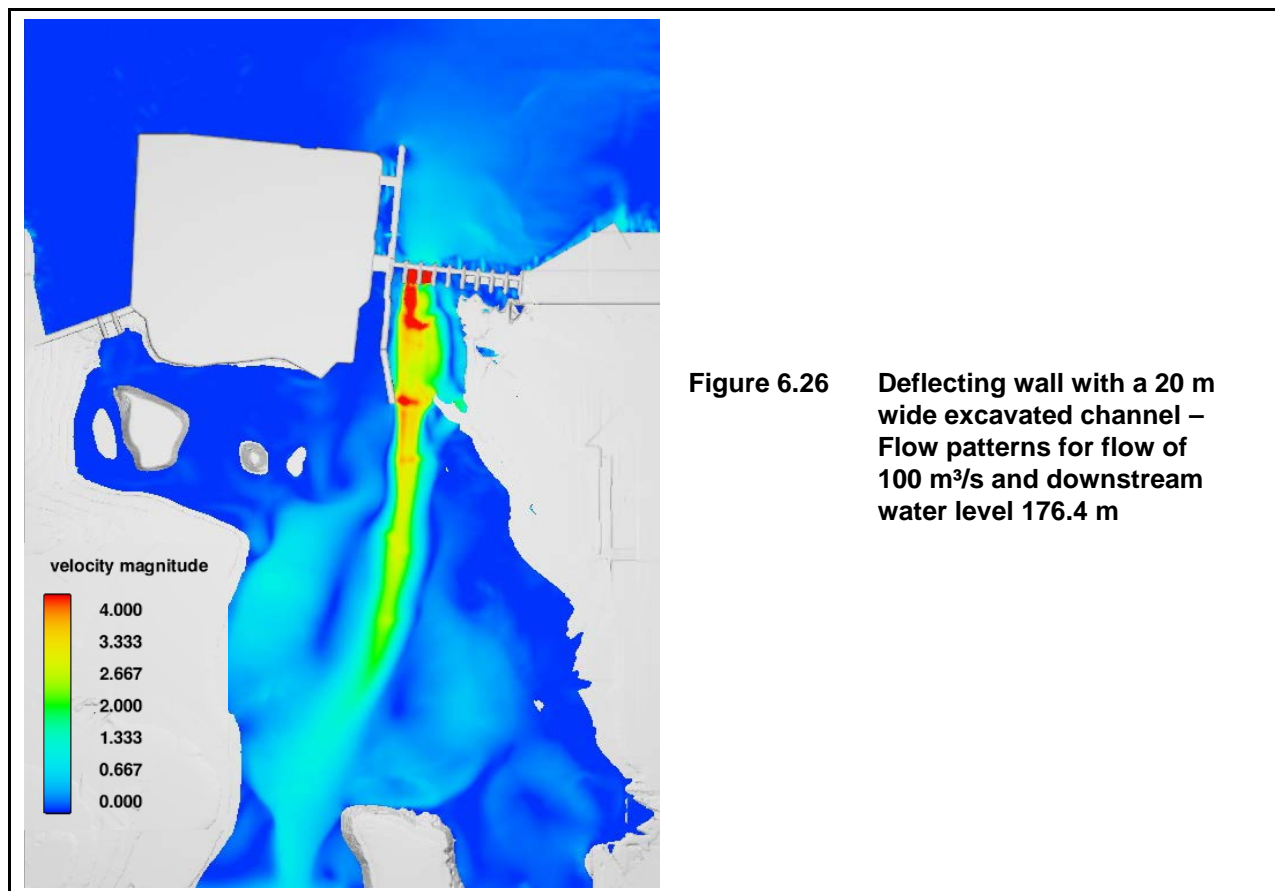


Figure 6.25 Deflecting wall with a 15 m wide excavated channel – Flow patterns for flow of 100 m³/s and downstream water level of 176.4 m



The analysis of these results clearly shows that the addition of an excavated channel near the tip of the deflecting wall effectively deflects away the flow for a channel width of 15 m or more (Figure 6.23 to Figure 6.26), although a 20 m wide channel is more effective (Figure 6.24 and Figure 6.26). The 5 m wide and 10 m wide excavated channel doesn't have a significant effect on the flow patterns (Figure 6.21 and Figure 6.22).

Given these results, the deflecting wall in conjunction with a 20 m wide by 30 m long excavated channel with a bottom at 173.5 m is a good solution for any downstream water level and normal flow conditions.

6.4 Attenuation Measures Selection

Based on the results obtained from the hydrodynamic model, two viable attenuation measures are identified:

- Measure 1, excavated channel of dimensions 60 m long, 25 m wide, with a bottom elevation not more than 173.5 m;
- Measure 3, construction of a deflecting wall 30 m long, from the tip of the Lock 45 Lower Approach Wall at a 10° angle from the existing wall towards the left bank, in conjunction with an excavated channel (East of the tip of the new wall) of dimensions 30 m long, 20 m wide, with a bottom elevation not more than 173.5 m.

Both attenuation measures give good improvements of the hydraulic conditions for the navigation channel by diverting the flow coming from the spillway away of this channel. The main advantages of the attenuation Measure 3 are the increased docking area and its effective protection at the total docking area.

In order to illustrate the effectiveness on both measures compared to the existing condition, both measures were simulated using the same hydraulic conditions used for the model calibration, i.e.

conditions observed during the March 2017 survey (same Main Dam and Dam E discharges, same downstream water level condition). For the 3 simulations (existing condition, Measure 1 and Measure 3), flow velocities were extracted from the model outputs to present the flow velocity conditions along the navigation channel (along a centre line that follows the navigation channel). The line used for flow velocity comparison is presented in Figure 6.27.

The 3D model results are presented for each simulation as flow velocity and patterns (plan view) in Figure 6.28 and on a graph shown in Figure 6.29. These figures show that both measures have significant effects on flow velocities along the navigation channel by decreasing them under 0.4 m/s, compared to flow velocities higher than 1.4 m/s for the existing condition.

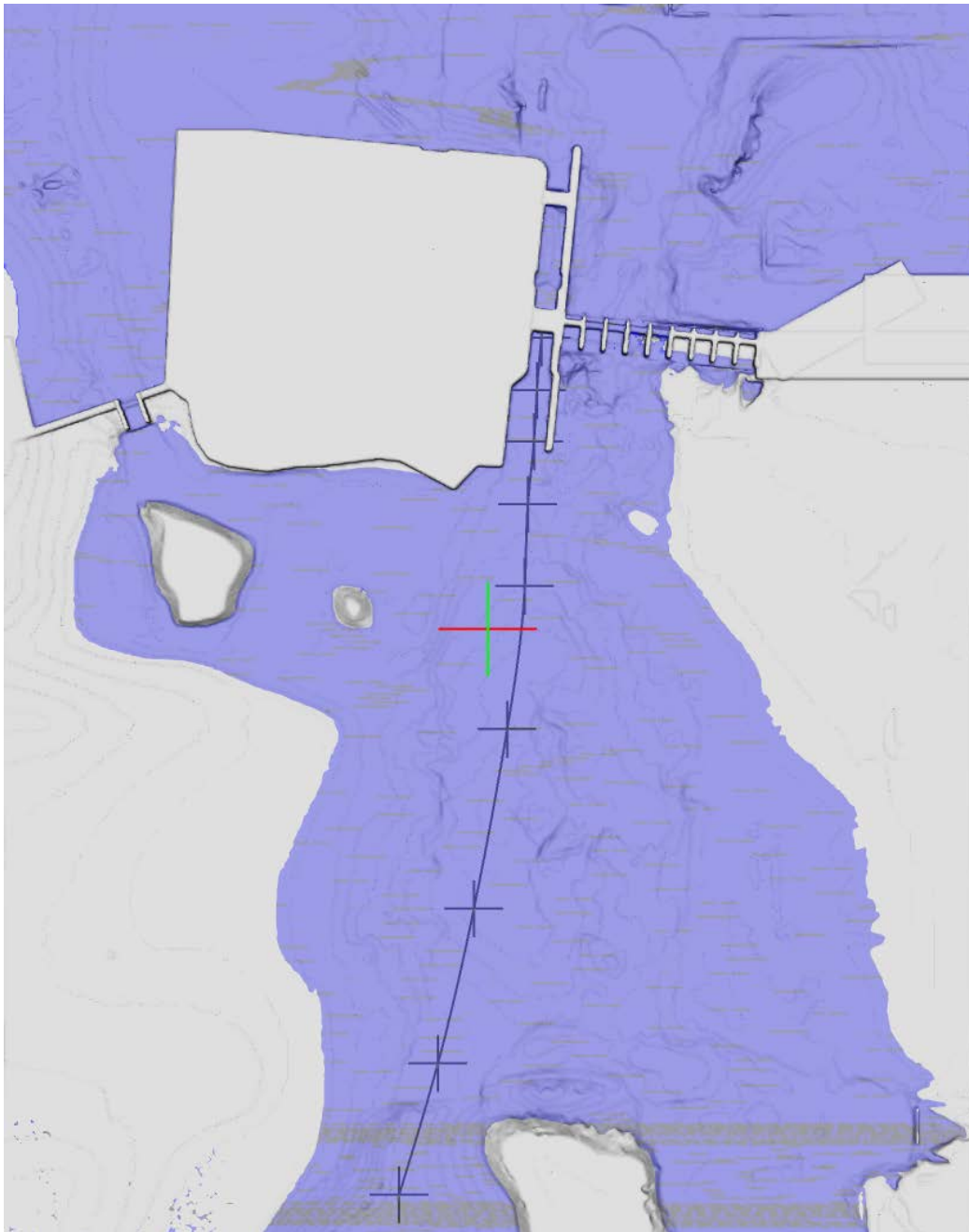


Figure 6.27 Middle line of the navigation channel used for flow velocity comparison

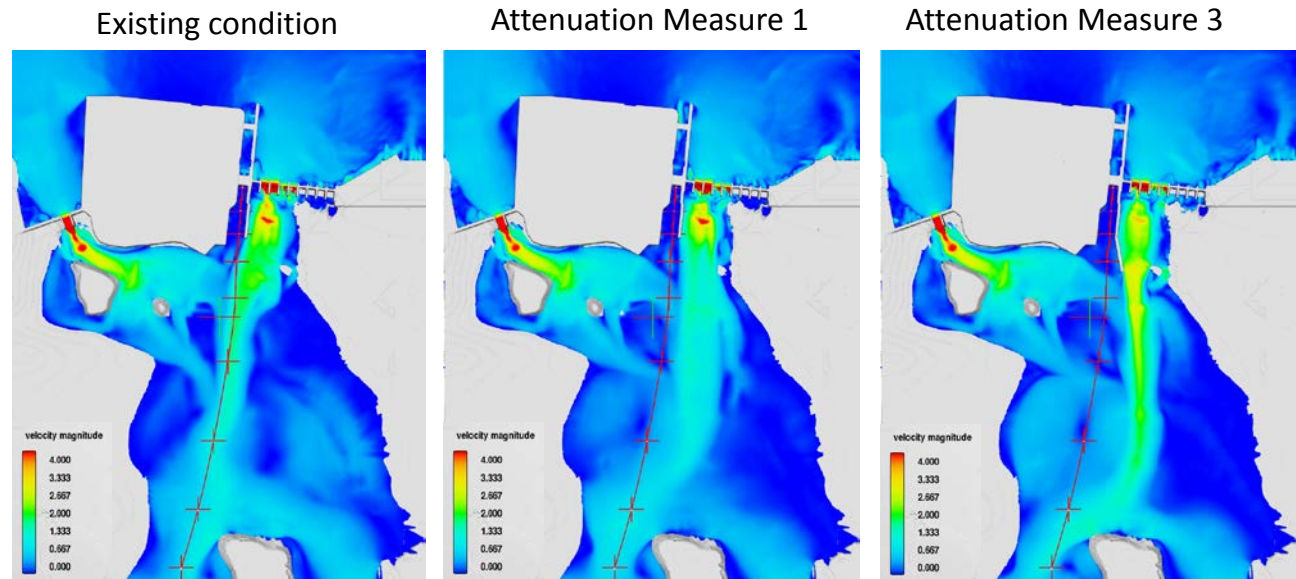


Figure 6.28 3D model results showing flow patterns and velocities (existing condition, Measure 1 and Measure 3) – Hydraulic conditions of March 2017 survey

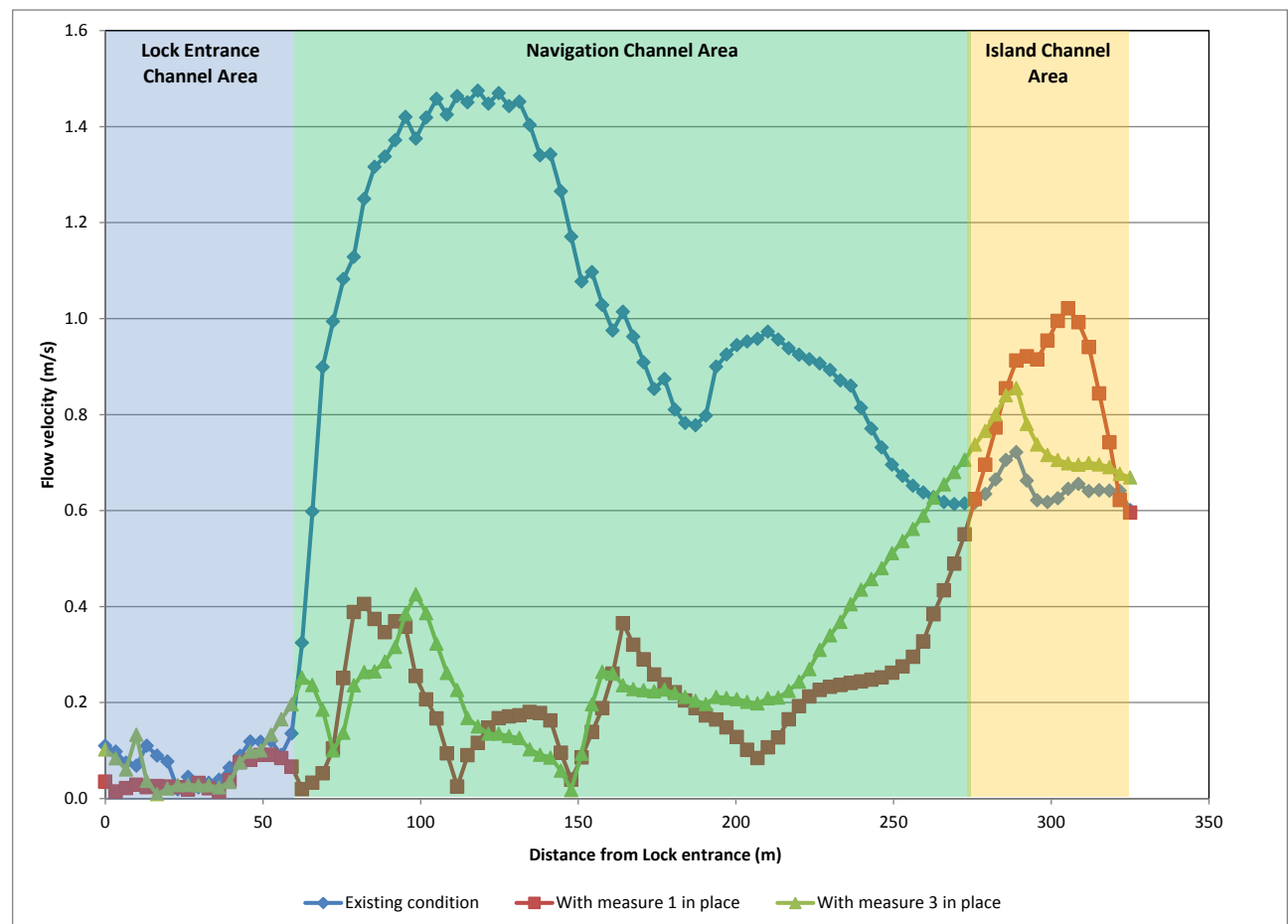


Figure 6.29 Flow velocity comparison for the navigation channel (existing condition, Measure 1 and Measure 3) – Hydraulic conditions of March 2017 survey

7. New Main Dam Configuration

All the model results presented above were obtained using the existing configuration of the Main Dam. In fact, this hydro technical study was started before the decision to rebuild the Main Dam was taken.

Since the new configuration of the Main Dam is similar to the existing configuration, model results considering both configurations should also be similar. In order to validate this, new simulations considering the new configuration of the Main Dam with the deflecting wall in place (attenuation Measure 2) were set up.

For each hydraulic condition considered, graphical results from both configurations of the the Main Dam (existing and rebuilt) are presented side by side for evaluation (Figure 7.1 to Figure 7.4). The following hydraulic conditions are considered:

- Total outflows of the Main Dam of 100 m³/s and 170 m³/s with a downstream water level of 175.5 m;
- Total outflow of the Main Dam of 170 m³/s with downstream water levels of 176.4 m and 177.5 m.

All flow velocities are in m/s.

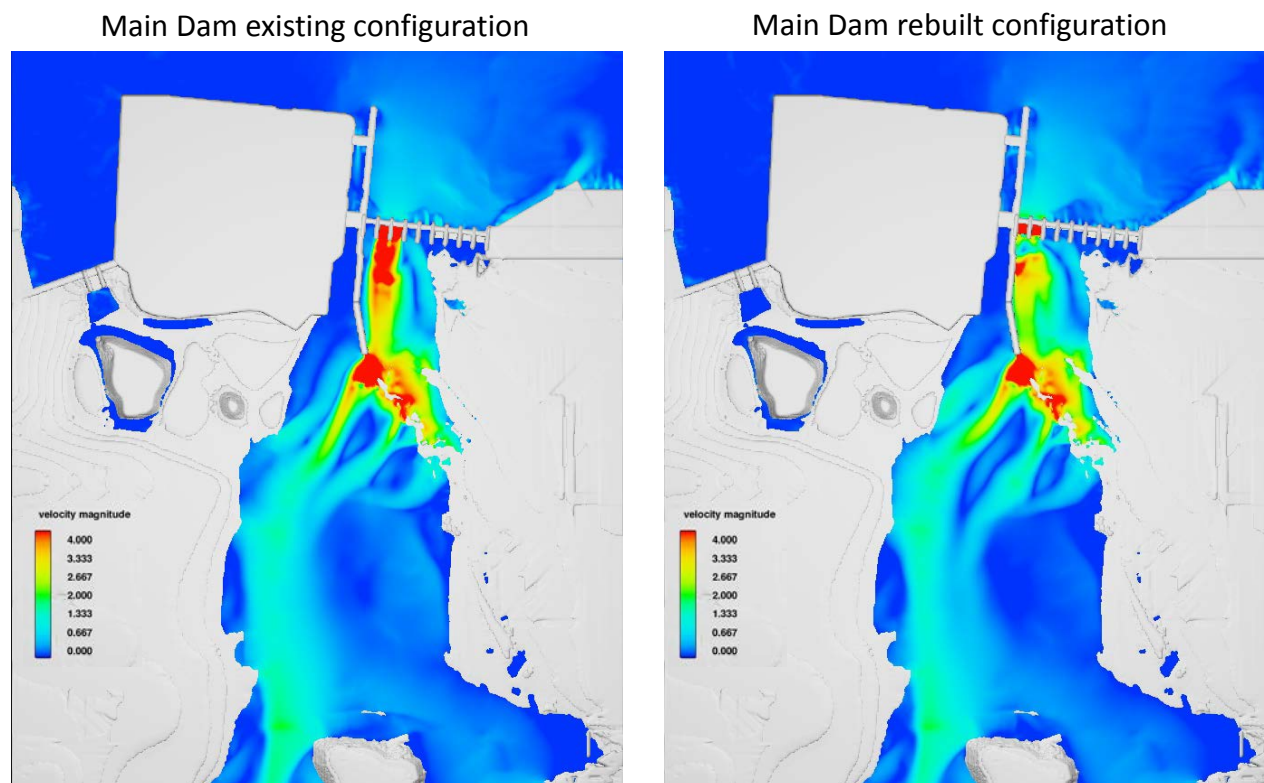
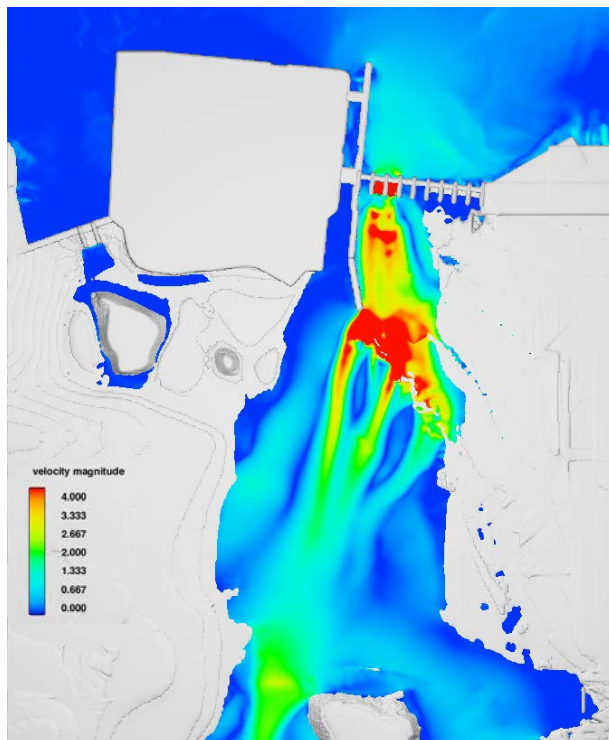


Figure 7.1 Main Dam existing and rebuilt configuration - Flow patterns for flow of 100 m³/s and downstream water level of 175.5 m

Main Dam existing configuration



Main Dam rebuilt configuration

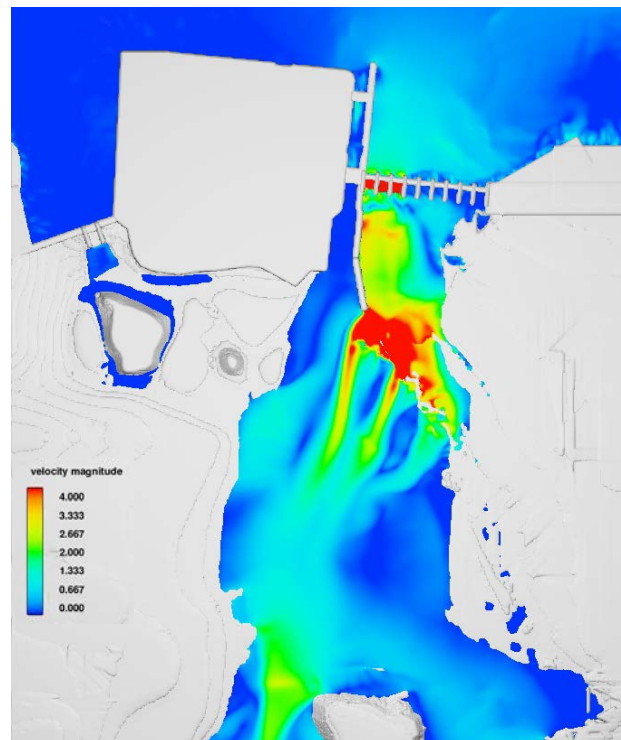
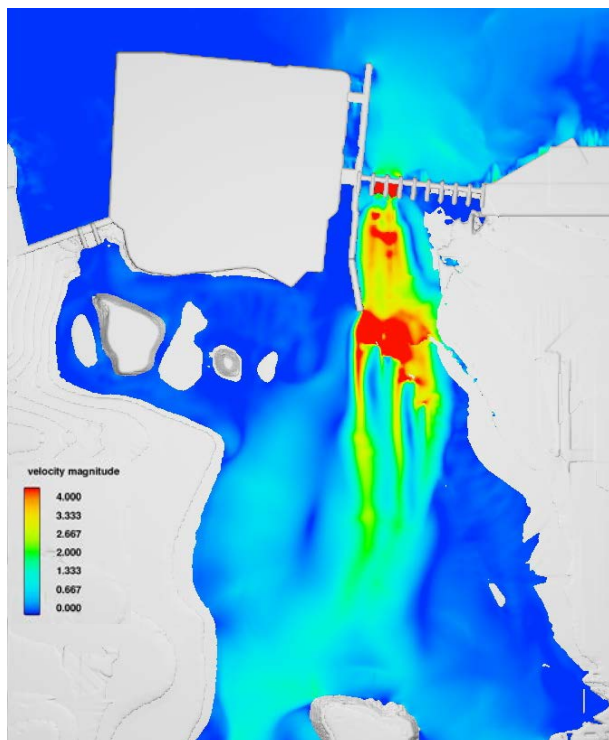


Figure 7.2 Main Dam existing and rebuilt configuration - Flow patterns for flow of 170 m³/s and downstream water level of 175.5 m

Main Dam existing configuration



Main Dam rebuilt configuration

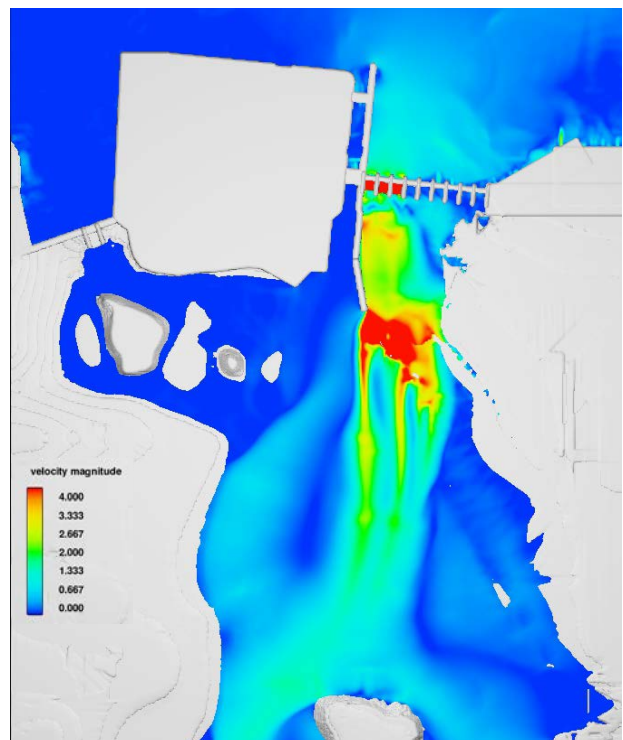


Figure 7.3 Main Dam existing and rebuilt configuration - Flow patterns for flow of 170 m³/s and downstream water level of 176.4 m

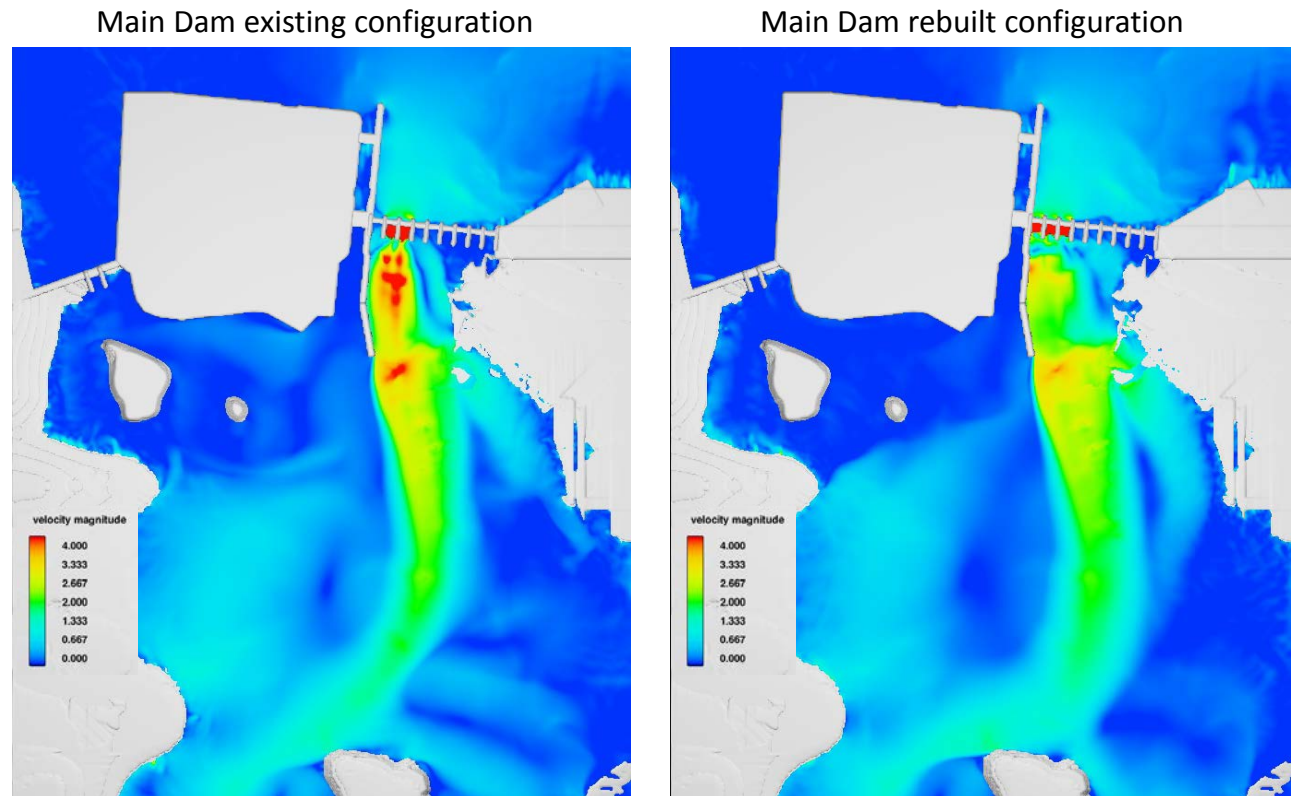


Figure 7.4 Main Dam existing and rebuilt configuration - Flow patterns for flow of 170 m³/s and downstream water level of 177.5 m

By analyzing these results, it is found that the effect of raising the sill elevation of all spillway bays to 177.38 m has a non-significant effect on the flow patterns in the area of interest, namely near the tip of the new deflecting wall (near the shallow area) and in the navigation channel. Thus, results presented in Chapter 6 can be used as presented in order to analyze the best measure to be applied in order to mitigate adverse flow conditions for boaters.

8. Feasibility and Estimation

In this section, each of the measures presented above are looked at from a constructibility and estimated costs point of view.

8.1 Measure 1 – Excavated Channel 60 m Long

The excavation of the channel consists of underwater bedrock excavation work. A work platform has to be constructed over the area to be excavated. Access to the platform is from the left bank. As outflow from the Main Dam will be diverted towards the navigation channel during construction, the excavation work must be undertaken outside of the navigation period. Bedrock has to be blasted and blasted material, platform materials and access ramp material must be removed to complete to work.

The excavation volume has been taken out of the terrain model used in the hydraulic model, considering the length, width and depth of the excavated channel. The estimated cost is obtained from unit costs commonly found in large hydro structure construction projects and are direct costs excluding all indirect costs. Considering the smaller overall size of all measures construction projects, unit costs may be significantly higher.

Table 8.1 shows the bedrock volume to be excavated. Also, based on a unit price, the direct cost is presented. Based on the hydraulic model results, a 25 m wide channel is proposed.

Table 8.1 Measure 1 – Volume and costs

Excavated channel	Excavated volumes	Unit cost of excavation	Direct construction cost
	(m ³)	(\$/m ³)	(\$)
60 m long, 25 m width, bottom elevation 173.5 m	2 300	115	264 500
Platform and ramp (installation and removal)	4 500	41	184 500
TOTAL			449 000

8.2 Measure 2 – Deflecting Wall 30 m Long

The deflecting wall consists of a new wall similar to the existing east wall. In order to evaluate its cost, the same unit costs as for the Main Dam reconstruction project were used.

For the construction of the wall, different construction approaches are possible; barge works, cofferdam works, temporary access, etc. Depending on the chosen approach, the overall construction cost will have to be reviewed. Access to the construction site must not completely block the water passage in order to let outflows from the Main Dam to pass. If the construction approach chosen requires an access to the site, it must be either from the Main Dam or from the right bank. Also, given the proximity of the new wall to the navigation channel, the construction period must be considered outside the navigation period.

The concrete volume, steel quantity and form work were considered in the direct cost estimation. Table 8.2 shows the cost estimation results.

Table 8.2 Measure 2 – Quantities and costs

Deflecting wall (crest elevation 177.39 m)	Quantity	Unit cost of excavation	Direct construction cost
		(\$/m³)	(\$)
Concrete	335 m³	1 500	502 500
Reinforced steel (70 kg/m³ of concrete)	23 450 kg	2.50	58 625
Form work	250 m²	50	12 500
Cofferdam (steel caissons)	600 m²	520	312 000
TOTAL			885 625

8.3 Measure 3 – Deflecting Wall 30 m with Excavated Channel 30 m

Measure 3 consists of the deflecting wall of measure 2 with an excavated channel of 30 m in length at the tip of the new wall. In order to evaluate the cost of the excavated channel, the estimated cost is obtained from unit costs commonly found in large hydro structure construction projects and are direct costs excluding all indirect costs. Considering the smaller overall size of all measures construction projects, unit costs may be significantly higher. For the cost of the deflecting wall, the same unit costs as for the Main Dam reconstruction project were used.

The excavation of the channel has to be done from an access from the left bank. The excavation of the channel is done by creating a platform with an access. Its construction has to be completed before the start of the construction of the wall in order to keep an open area to let flow pass.

As for measure 2, for the construction of the wall, different construction approaches are possible; barge works, cofferdam works, temporary access, etc. Depending on the chosen approach, the overall construction cost will have to be reviewed. Access to the construction site must not completely block the water passage in order to let outflows from the Main Dam to pass. If the construction approach chosen requires an access to the site, it must be either from the Main Dam or from the right bank. Also, given the proximity of the new wall to the navigation channel, construction period must be considered outside the navigation period.

The underwater excavation of bedrock, the concrete volume, the steel quantity and form work were considered in the direct cost estimation. Table 8.3 shows the cost estimation results.

Table 8.3 Measure 3 – Quantities and costs

Deflecting wall (crest elevation 177.39 m) with excavated channel 30 m long, 20 m width, bottom elevation 173.5 m	Quantity	Unit cost of excavation	Direct construction cost
		(\$/m³)	(\$)
Excavated volume	1 000	115	115 000
Concrete	335 m³	1 500	502 500
Reinforced steel (70 kg/m³ of concrete)	23 450 kg	2.50	58 625
Form work	250 m²	50	12 500
Platform and ramp (installation and removal)	1 050 m³	41	43 050
Cofferdam (steel caissons)	600 m²	520	312 000
TOTAL			1 043 675

9. Conclusion and Recommendation

AECOM was mandated to perform a hydraulic study to determine a means to reduce the turbulence at the Lower Approach Walls for safer boat access to Lock 45. It has been observed that there are conditions with moderate to high inflows coming from the Main Dam and Dam E that create currents in the navigation channel, making it difficult for approaching boats to safely access the lower approach wall and lock.

Also, it has been mentioned that the capacity for mooring of boats at the lower approach walls is inadequate and that it would be beneficial to lengthen one or both lower approach walls.

In order to respond to these issues, two different approaches were studied, one without additional mooring capacity and one with additional mooring capacity. In order to evaluate the effectiveness of proposed measures, a hydrodynamic 3D model is used for different hydraulic conditions of water levels and discharge scenarios.

Based on the results of the 3D model, the following two measures are proposed:

- The first measure (identified as Measure 1) consists of an excavated channel with a minimum depth of 2 m in line with sluice gates 2, 3 and 4. The excavated area is located perpendicular to the Main Dam alignment. Its dimensions are: a total length of 60 m, a width of 20 m and a bottom depth of 173.5 m. This measure does not have any effect of the mooring capacity at the site. The direct cost associated with this measure is estimated at 449 000 \$.
- The second measure (identified as Measure 3) consists of a permanent deflecting wall structure to be constructed from the tip of the East wall of Lock 45, in conjunction with an excavated channel near the tip of the wall. This deflecting wall is 30 m long and has an angle of 10° to the East from the alignment of the East wall. In order to protect the navigation channel during very low water level of Lake Huron, the excavated channel is located near the tip of the wall. Its dimensions are: a total length of 30 m, a width of 20 m and a bottom depth of 173.5 m. This measure does increase significantly the mooring capacity on the downstream side of the lock. The direct cost associated with this measure is estimated at 1 043 675 \$.

Both measures decrease significantly adverse flow conditions in the navigation channel for all water levels of Lake Huron. Modeling has been done for flows up to 170 m³/s. Nevertheless, the attenuation measure with the new deflecting wall and excavated channel (Measure 3) has some advantages over the other measure (Measure 1). The main advantages of Measure 3 are the increased mooring capacity on the downstream side of the lock and the increased calm water area along this new pier (lock side). Concerning the mooring capacity, the attenuation Measure 3 gives an additional 30 m of mooring space. The deflecting wall increases the area of calm water all the way to the tip because it blocks completely any adverse flow patterns and waves formed by the flow coming out of the Main Dam.

For construction schedule, Measure 3 should require more time to construct.

10. References

- [1] Inspection of port Severn Area Dams, Fixed Bridge and Lock, Hydraulic Velocity Survey Downstream of Lock 45, ASI Marine, April 25, 2017, ASI Marine Report RH17-002.
- [2] Dam Safety Reviews, Port Severn Dams, Main Dam, Lock 45, Upstream Shoreline and Dam D, AECOM, December 2013, PWGSC Project Number R.051116.002, Appendix A, Drawing 001 – General Location Plan.
- [3] Dam Safety Reviews, Port Severn Dams, Main Dam, Lock 45, Upstream Shoreline and Dam D, AECOM, December 2013, PWGSC Project Number R.051116.002, Appendix A, Drawing 005 – Main Dam Plan, Elevation, Section and Detail.
- [4] Dam Safety Reviews, Port Severn Dams, Main Dam, Lock 45, Upstream Shoreline and Dam D, AECOM, December 2013, PWGSC Project Number R.051116.002, Appendix A, Drawing 006 – Main Dam Sections.
- [5] Dam Safety Reviews, Port Severn Dams, Bayview Dam E, AECOM, December 2013, PWGSC Project Number R.051116.002, Appendix A, Drawing 011 – Bayview Dam E and Little Go Home Bay Dam Plan, Elevation and Sections.
- [6] Government of Canada, Fisheries and Oceans Canada, Tidal Observations at Midland gauge station (#11445), available on the Internet at <http://tides.gc.ca/>.
- [7] Government of Canada, Fisheries and Oceans Canada, Monthly Water Level Bulletin for Lake Superior, Lake Michigan/Huron, Lake St. Clair, Lake Erie and Lake Ontario, available on the Internet at <http://tides.gc.ca/>.

Appendix A

Field Survey Photos, March 2017



Photo 1 Main Dam: Turbulent flow coming out of the spillway - Looking upstream from the Lock 45 downstream Approach Wall



Photo 2 Turbulent flow diverted towards the navigation channel - Looking downstream from the left bank downstream of the Main Dam



Photo 3 Waves generated by the turbulent flow coming out of the Main Dam in the downstream approach channel of Lock 45 - Looking towards the left bank from the right bank downstream of Lock 45



Photo 4 Shallow area running from the left bank towards the tip of the Lock 45 downstream Approach Wall - Looking towards the right bank from the left bank downstream of the Main Dam



Photo 5 Closer view of the shallow area that creates a restriction to the free passage of the outflow from the Main Dam - Looking towards the right bank from the left bank downstream of the Main Dam



Photo 6 Outflow from Dam E and the right channel around the island - Looking upstream from the right bank downstream of Dam E



Photo 7 Flow patterns of the outflow from Dam E with the exit of the right channel and the flow passing in the left channel (around the island) - Looking upstream from the right bank downstream of Dam E



Photo 8 Flow patterns of the outflow from Dam E and the shallow areas in this portion of the river - Looking downstream towards the navigation channel from the right bank downstream of Dam E

Appendix B

ASI Marine Report, April 2017

ASI Marine | **REPORT**

Submitted to:

**AECOM Canada Ltd
300 Water Street
Whitby, Ontario L1N 9J2
Attention: James Wallace, P. Eng.**

Submittal Date:

April 25, 2017

Reference:

**Inspection of Port Severn Area Dams, Fixed Bridge and Lock
Hydraulic Velocity Survey Downstream of Lock 45**

ASI Marine Report: RH17-002

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REPORT

AECOM Canada Ltd

Inspection of Port Severn Area Dams, Fixed Bridge and Lock Hydraulic Velocity Survey Downstream of Lock 45

Survey Completed: March 24, 2017

1.0 INTRODUCTION

ASI Marine, a division of ASI Group Ltd. (ASI), was contracted by AECOM Canada Ltd. (AECOM) to perform a hydraulic velocity study downstream of Lock 45 located in Port Severn, Ontario. ASI collected hydraulic information for five cross-sections. The following numbered cross-sections correspond with those labeled in Figure 1:

- 1) West to east transect below the Main Dam sluices starting from the south tip of the Lock 45 lower approach wall and terminating at the east shore.
- 2) North-northeast to south-southwest transect across the side bay outlet of the Bayview Dam "E". The transect starts from the downstream west side of the Lock 45 lock wall and terminates at the south shore. This measures the hydraulic output from Bayview Dam "E".
- 3) North to south transect starting from the south tip of the Lock 45 lower approach wall and terminating at the north tip of the island in the basin. This measures the east/west hydraulics in the basin below Lock 45.
- 4) West to east transect on the west side of the island in the basin below Lock 45. This measures the hydraulics through the west channel.
- 5) West to east transect on the east side of the island in the basin below Lock 45. This measures the hydraulics through the east channel.

The collection of the velocity data for this project was requested by AECOM after ASI had completed bathymetric and structure surveys and video inspections of the area dams and lock, ASI project RH16-052.

The survey was completed by ASI on March 23 and 24, 2017 inclusively to provide AECOM with the required data pertaining to water velocities of the five transects. The collection of velocity data of the five transects was completed utilizing an Acoustic Doppler Current Profiler (ADCP) towed by a small boat.

1.1 Site Location

The Port Severn area dams and lock are located in Port Severn, Ontario on Port Severn Road. The area of study encompasses the waterway directly south of the Main Dam, Lock 45 and spillway for Dam E.

Figure 1 below outlines the survey area and individual cross-sections for the velocity survey.

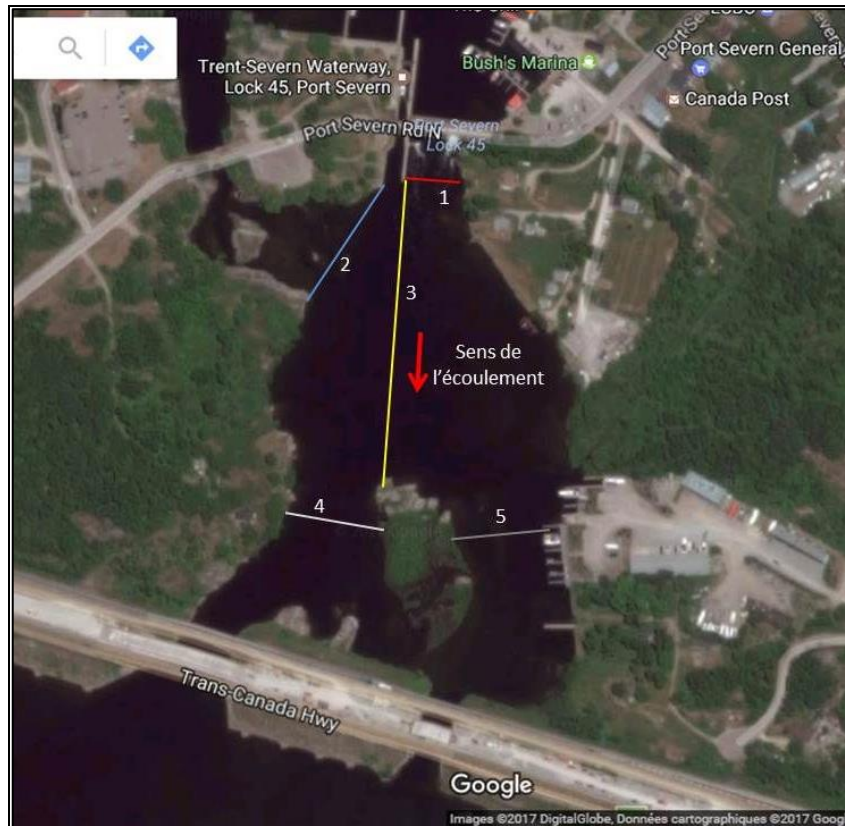


Figure 1: Port Severn area Lock 45 aerial view, with labelled cross sections

1.1.1 Main Dam

The Main Dam is a concrete gravity structure founded on bedrock and built in 1916. The length of the dam is 71.32 m with a surveyed height of 10.55 m. There are nine sluiceways with timber stop logs that are operated with a hydraulic log lifter. Each sluice is 6.1 m wide and the piers of the dam are 1.83 m wide. The Sluice 1 stop logs are only operational with a mechanical winch. The downstream areas of Sluices 7, 8, and 9 are located over non-submerged ground, and operating these sluices would result in flooding and erosion of the land (Figure 2).

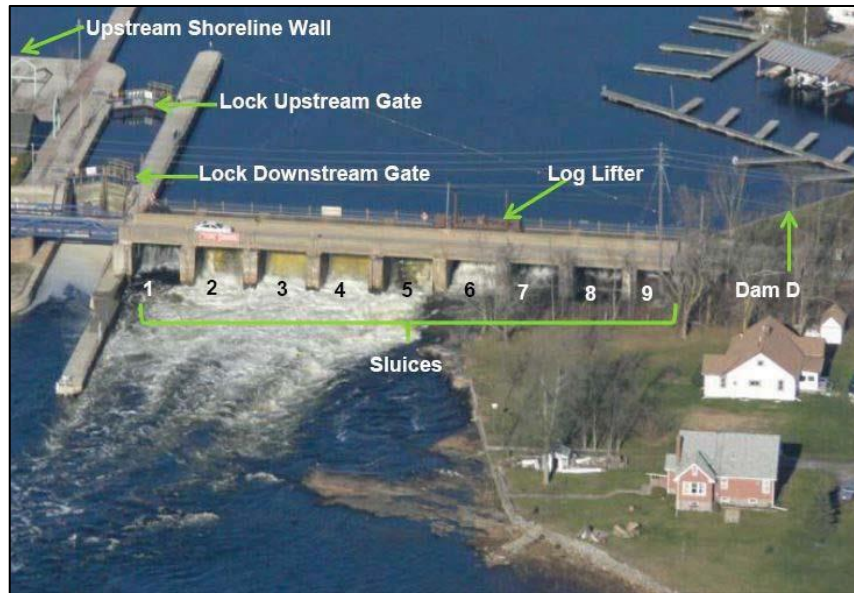


Figure 2: Main Dam with labelled sluice gates

1.1.2 Dam E

Dam E is located approximately 200 m west of the main dam. The dam is 35 m long and 4.93 m high. There is a single 6.1 m wide sluice in the dam. The dam is capable of operating with up to nine timber stop logs, which is completed with a manual winch (Figure 3).



Figure 3: Dam E upstream sluice

2.0 SCOPE OF WORK

The following scope of work was identified by AECOM's project number 60522156. It included hydraulic velocity surveys of five cross-sections in the waterway downstream of Lock 45. Velocity values were collected throughout the water column across each survey transect.

ASI utilized an ADCP current profiling sonar installed on a hydroboard to measure current flow in the basin below Lock 45 at the five cross-sections outlined by AECOM representatives. The ADCP was guided across the 5 transects by an aluminum boat which also served as a control platform for the recording of data.

The boat was launched by hand from the west shore on the downstream side of Lock 45 (Figure 4). The ADCP system was outfitted with Differential Global Positioning System (DGPS) and ADCP sensors to accurately measure current profiles.



Figure 4: Boat launch location directly south of Lock 45

2.1 Responsibilities of AECOM

The following were provided by AECOM:

- free and clear access downstream of Lock 45
- flow manipulation on the Main Dam
- adequate work area for ADCP and vehicle below Lock 45
- client representative present for manipulation of stop logs of the Main Dam
- shoreline access for current profiling operations.

3.0 EQUIPMENT

3.1 ADCP Trimaran System

ASI utilized the Sontek RiverSurveyor M9 current profiling system (Figure 5Figure 1). This system uses eight transducers to measure current velocity and one transducer to measure depth. Current velocity is correlated to real world coordinates with an onboard DGPS unit and across transect distances with acoustic bottom tracking. An additional RTK GPS is positioned on shore to provide horizontal accuracies of less than 20 cm and vertical accuracies of less than 40 cm.

ADCP pre-launch calibration and data collection was performed with Sontek's RiverSurveyor Live software. The software is a windows based application which connects to the ADCP through a wireless connection for direct control and data collection of the unit. The collected data is able to be post processed and exported from the software.

Output files from this system provide a horizontal coordinate and/or a chainage along transect and the velocity through the water column at that coordinate and/or chainage. Velocities are measured vertically in cells which can be set from 0.02 to 4 m in size at a maximum of 128 cells. Velocity resolution is 0.001 m/s accurate to +/-0.25% of measured velocity.



Figure 5: Sontek RiverSurveyor M9 ADCP installed on hydroboard

Sontek's RiverSurveyor Live for PC software allows for real-time data viewing. Collected data can be post processed with this software to generate ASCII files. The generated output format allows for further manipulation in other software suites.

4.0 SURVEY PROCESS

4.1 Shop Preparation and Mobilization

ASI personnel assembled the equipment packages and ancillary tools at ASI's shop prior to travelling to Port Severn. The ADCP and RTK GPS were fully function tested in a waterway and collected data was analysed for operational confirmation. The equipment was packaged into a transport vehicle, which was also utilized for a boat tow vehicle, for travel to the site location.

4.2 Site Operations

ASI personnel travelled to Port Severn on March 22, 2017 for a site assessment and with the intention of installing a guide line across transect 1. Upon arrival to site it was determined that the installation of the guide line would not be feasible due to the high current flows through the spillway and the operation would be completed solely from the boat. Due to the high currents it was also determined that positioning the ADCP hydroboard adjacent to the boat would be necessary for control.

On March 23, 2017 ASI personnel arrived on site and completed a site safety meeting regarding the hazards and mitigation of risks for the survey. Setup of the equipment commenced and was completed. ASI personnel launched the boat into the waterway downstream of Lock 45 and began the collection of data. The baseline survey was completed with 3 stoplogs removed from sluice 2 and 7 stoplogs removed from sluice 3 from the Main Dam. Dam E (Bayview) had 6 logs removed. The remaining sluices had no stoplogs removed and this equated to an estimated flow through the main dam of 54 m³/s, as per AECOM representatives. The measured water level was approximately 99 cm from the deck of the east lower approach wall. The following tables provide calculated flows for the referenced transect (cross section) numbers seen in Figure 1.

Table 1: Surveyed transects at 54 m³/s flow as provided by AECOM.

Time	Transect	Direction of Survey	Calculated Q (m ³ /s)
12:05	5	West-East	34.656
12:17	5	East-West	*
12:23	5	East-West	39.459
12:33	3	South-North	67.111
12:52	3	North-South	6.695*

*survey collection errors causing improper calculation

Upon completion of the survey of the above transects the data was confirmed and a backup was created on a secondary drive. The stoplogs were manipulated and the following survey was completed with 6 stoplogs removed from sluice 2 and 7 stoplogs removed from sluice 3 from the Main Dam. Dam E (Bayview) had 6 logs removed. The remaining sluices had no stoplogs removed and this equated to an estimated flow through the main dam of 77.7 m³/s, as per AECOM representatives. The measured water level was approximately 94 cm from the deck of the east lower approach wall. See Table 2 for calculated flows of transects.

Table 2: Surveyed transects at 77.7 m³/s flow as provided by AECOM.

Time	Transect	Direction of Survey	Calculated Q (m³/s)
14:06	1	West-East	93.721
14:13	1	East-West	133.308
14:20	3	North-South	82.814
14:32	5	West-East	45.825
14:43	4	West-East	73.243
14:57	2	South-North	23.142
15:40	1	West-East	89.491
15:51	5	West-East	44.130
16:01	4	West-East	72.810
16:07	3	South-North	134.797
16:27	2	North-South	42.689

The survey was completed and the collected data was confirmed and a backup was created on a secondary drive. The equipment was removed from the boat and packed into the ASI truck for overnight storage. The boat was removed from the waterway directly south of Lock 45 and ASI personnel left the site.

On the morning of March 24, 2017 ASI personnel arrived on and began the setup and integration of the equipment onto the boat. Calibration of the ADCP was completed and the boat was launched into the waterway downstream of Lock 45. The survey was completed with 6 stoplogs removed from sluice 2, 7 stoplogs removed from sluice 3, 2 stoplogs removed from sluice 4 and 2 stoplogs removed from sluice 5 from the Main Dam. Dam E (Bayview) had 6 logs removed. The remaining sluice had no stoplogs removed and this equated to an estimated flow through the main dam of 95.1 m³/s, as per AECOM representatives. The measured water level was approximately 91.5 cm from the deck of the east lower approach wall. See Table 3 for calculated flows of referenced transects.

Table 3: Surveyed transects at 95.1 m³/s flow as provided by AECOM.

Time	Transect	Direction of Survey	Calculated Q (m³/s)
9:36	1	West-East	93.913
9:46	5	West-East	46.545
9:53	4	West-East	80.510
9:58	3	South-North	59.909
10:14	2	North-South	24.623
10:23	3	South-North	57.276
10:40	1	West-East	13.188*
10:47	1	East-West	13.042*
10:54	2	North-South	0.076*
11:02	2	South-North	4.797*

*survey collection errors causing improper calculation

The survey was completed and the collected data was confirmed. A backup was created on a secondary drive. The equipment was removed from the boat and packed into the ASI truck for travel from site to ASI's office. The boat was removed from the waterway directly south of Lock 45 and ASI personnel left the site.

5.0 SURVEY OBSERVATIONS

During all operations, all data was recorded real-time to a hard drive. All data was reviewed on site to ensure adequate data acquisition. At the completion of the day's events, the data was backed up to an external portable hard drive.

A review of the collected data was completed in the ASI office and the assembly of this report was then completed. The collected data pertaining to the required value of each transect were parsed from the raw data and are available in Appendix 2.

Sample visual velocity representations through the water column of the transects from the RiverSurveyor software are provided in Figures 6-10 below.

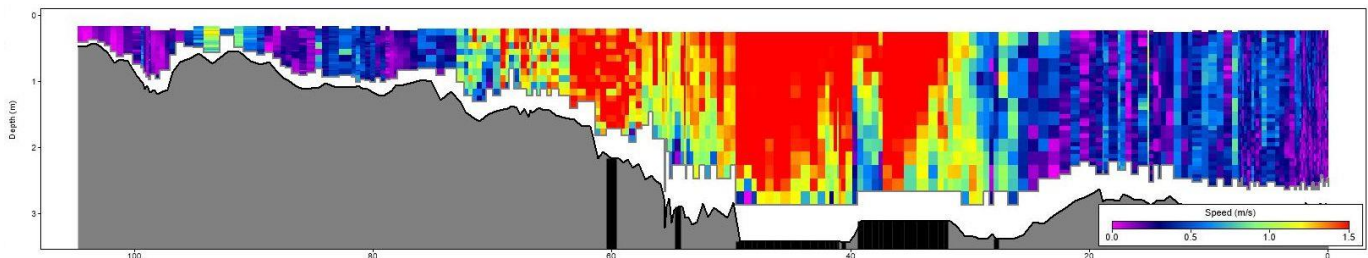


Figure 6: Transect 1 travelling in West-East direction at Main Dam flow of 77.7 m³/s as provided by AECOM

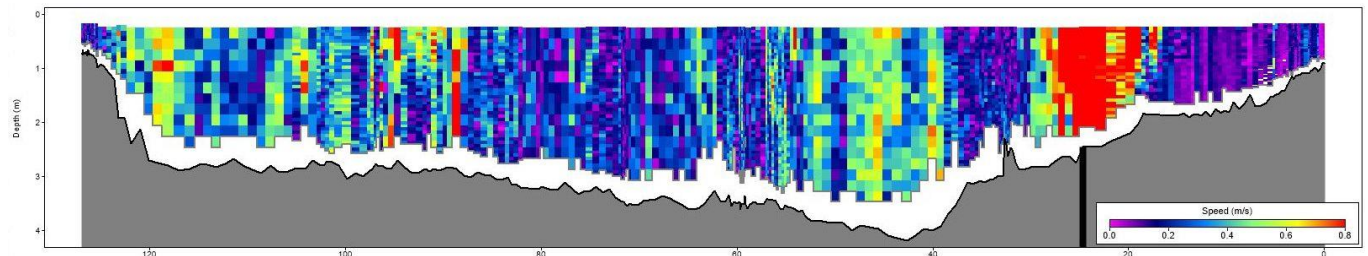


Figure 7: Transect 2 travelling in South-North direction at Main Dam flow of 77.7 m³/s as provided by AECOM

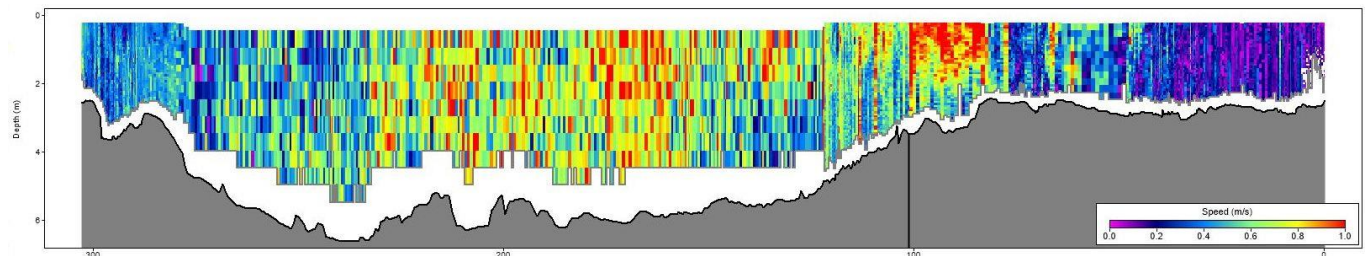


Figure 8: Transect 3 travelling in North-South direction at Main Dam flow of 54 m³/s as provided by AECOM

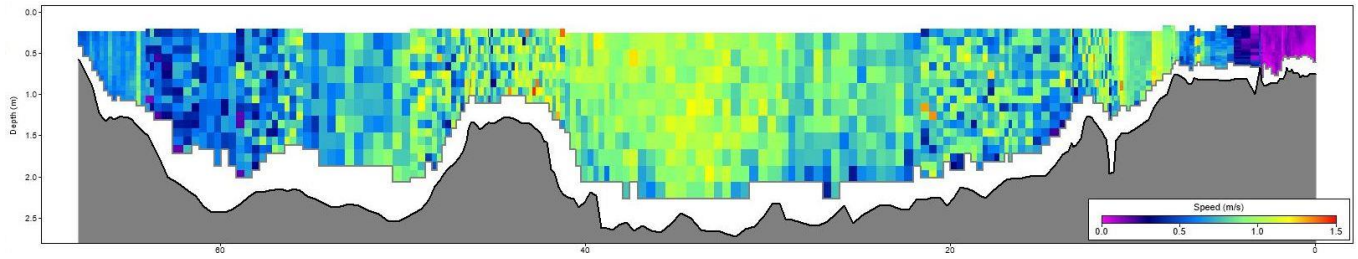


Figure 9: Transect 4 travelling in West-East direction at Main Dam flow of 77.7 m³/s as provided by AECOM

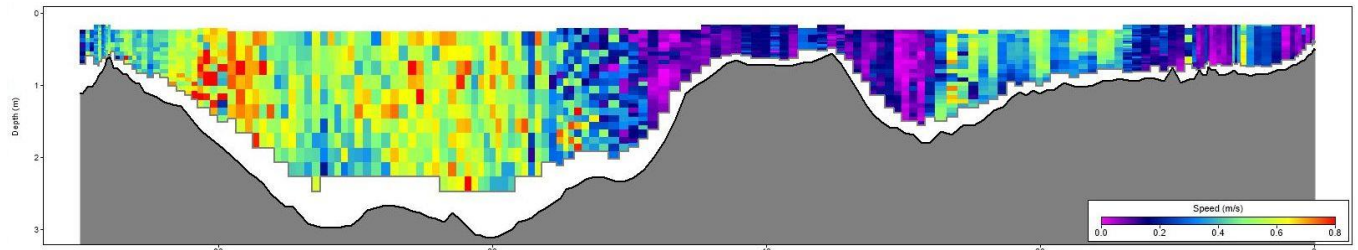


Figure 10: Transect 5 travelling in West-East direction at Main Dam flow of 95.1 m³/s as provided by AECOM

Appendix 1:

Equipment Description

RiverSurveyor ACCESSORIES AND SPECIFICATIONS



Mobile Handheld:
RiverSurveyor Live Mobile running on a SonTek-provided handheld and SonTek Bridge makes one-man system operation simple. (Model subject to change.)



Power/Communications:
The Power/Communications Module (PCM) for the S5 and the M9 features optional rechargeable battery packs. It can be factory-configured with 2.4 GHz telemetry, SBAS-GPS, or RTK GPS.



RTK GPS:
The optional SonTek RTK GPS³ solution is easy to use and offers an incredibly precise, fully integrated boat speed solution to augment, or be an alternative to, bottom tracking.



SonTek HydroBoard II:
All-in-one, rugged and easy to transport, this dive-resistant design allows the RiverSurveyor to be used in challenging flow conditions.



HydroBoard II Bags:
Outfitted with back pack and shoulder straps, these bags offer the perfect transportation option for both all SonTek HydroBoards.



Boat Mount:
Delrin/aluminum fixture that is custom designed for the M9 or S5 to facilitate mounting over the side of a boat. (Attachment to boat not included.)



Trimaran:
Contact SonTek for trimaran solutions to fit special applications.

	RiverSurveyor S5	RiverSurveyor M9
Velocity Measurement		
Profiling Range (Distance)	0.06m to 5m	0.06m to 40m
Profiling Range ¹ (Velocity)	+/- 20 m/s	+/- 20 m/s
Accuracy ¹	Up to +/- 0.25% of measured velocity; +/- 0.2cm/s	Up to +/- 0.25% of measured velocity; +/- 0.2cm/s
Resolution	0.001 m/s	0.001 m/s
Number of Cells	Up to 128	Up to 128
Cell Size	0.02m to 0.5m	0.02m to 4m
Transducer Configuration		
	Five (5) Transducers;	Nine (9) Transducers;
	4-beam 3.0 MHz Janus at 25° Slant Angle;	Dual 4-Beam 3.0 MHz/1.0 MHz Janus at 25° Slant Angle;
	1.0 MHz Vertical Beam Echosounder	0.5 MHz Vertical Beam Echosounder
Depth Measurement		
Range	0.20m to 15m	0.20m to 80m
Accuracy	1%	1%
Resolution	0.001m	0.001m
Discharge Measurement		
Range with Bottom-Track	0.3m to 5m	0.3m to 40m
Range with RTK GPS or DGPS	0.3m to 15m	0.3m to 80m
Computations	Internal	Internal

S5/M9 Additional Specifications

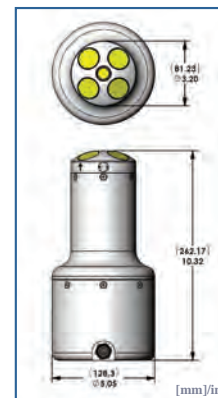
- Temperature Sensor
 - Resolution: $\pm 0.01^\circ\text{C}$
 - Accuracy: $\pm 0.1^\circ\text{C}$
- Compass/Tilt (Solid State Type)
 - Range: 360°
 - Heading Accuracy: $\pm 2^\circ$
 - Pitch/Roll: $\pm 1^\circ$
- Internal Recorder Size: 8GB
- Power/Communications
 - 12 - 18v DC
 - RS232 Communications
 - RS232 Serial GPS Input
 - Max Data Output Rate: 2 Hz
 - Internal Sampling Rate: Up to 70 Hz
- Physical/Environmental
 - Depth Rating: 50m
 - Operating Temperature: -5° to 45°C
 - Storage Temperature: -10° to 70°C

Power Communications Module

- Batteries
 - Type: Any AA-sized batteries
 - Capacity/duration: 8 hours of continuous operation (6 hours with RTK GPS enabled)
- GPS Options
 - SBAS GPS Horizontal Accuracy²: $<1.0\text{m}$
 - RTK GPS Horizontal Precision (repeatability)^{2,3}: $<0.03\text{m}$

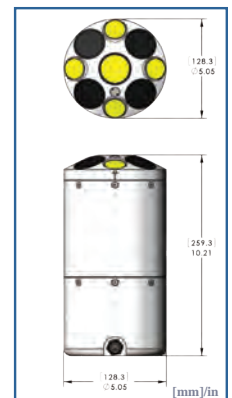
Range (Std.; 10 dBm)⁴ Range (High; 22dBm)⁴

- Base to Rover 1000 m 3000 m
- PC to Rover 450 m 1500 m
- Mobile to Rover 200 m 400 m



RiverSurveyor-S5

- Weight in Air: 1.1 kg (2.5 lb)
- Weight in Water: -0.3 kg (-0.7 lb)



RiverSurveyor-M9

- Weight in Air: 2.3 kg (5.0 lb)
- Weight in Water: -0.6 kg (-1.3 lb)

¹Please contact SonTek for accuracies better than 1%, or velocities $>10\text{ m/s}$.

²Depends on multipath environment, antenna selection, number of satellites in view, satellite geometry, and ionospheric activity.

³Contact SonTek for details about RTK GPS performance and specifications.

⁴High power may not be available in all countries; all ranges with default 2 dBi antenna and line-of-sight.

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Let's Solve Water

Founded in 1992 and advancing environmental science globally, SonTek manufactures acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, canals, estuaries, industrial pipes and laboratories. SonTek's sophisticated and proprietary technology serves as the foundation for some of the industry's most trusted flow data collection systems. SonTek is headquartered in San Diego, California, and is a division of Xylem Inc.

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S05-03

Appendix 2:

Media (USB)

