REMEDIAL ACTION OPTIONS REPORT REVISION 1

PORTAGE CANAL (SEGMENTS 2, 3, AND 4)

PORTAGE, WISCONSIN

BRRTS NUMBERS:

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Prepared for:
Wisconsin Department of Natural Resources

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RAMBOLL ENVIRON

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[1] The January 2018 revisions included adding and incorporating the hydrodynamic modeling.

ACRONYMS AND ABBREVIATIONS

AHI	Architecture and History Inventory
amsl	above mean sea level
BRRTS	Remediation and Redevelopment Tracking System
CBSQG	Consensus-Based Sediment Quality Guidelines
cfs	cubic feet per second
COCs	contaminants of concern
CPR	Canadian Pacific Railroad
CWA	Clean Water Act
CY	cubic yards
mg/kg	milligram(s) per kilogram
NCP	National Contingency Plan
OHWM	ordinary high watermark
POTW	Publically Owned Treatment Works
RAOR	Remedial Actions Options Report
STH	State Highway
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department of Natural Resources
WHS	Wisconsin Historical Society
WPDES	Wisconsin Pollutant Discharge Elimination System

EXECUTIVE SUMMARY

The Remedial Actions Options Report (RAOR) for the Portage Canal Site (the "Canal") was prepared by Ramboll Environ US Corporation (Ramboll Environ) on behalf of the Wisconsin Department of Natural Resources (WDNR). The RAOR was conducted in accordance with the Work Plan submitted to the WDNR on November 18, 2015, and presents and evaluates Remedial Action Options (RAOs) for addressing contaminated sediments within the Canal in Segments 2, 3, and 4.

The remedial objectives for the Canal are as follows:

- *Remedial Objective 1:* Reduce human exposures to contaminants of concern (COCs) associated with incidental sediment ingestion and fish consumption from the Portage Canal by reducing the bioavailability and/or concentration of COCs in sediments that are above protective levels.
- *Remedial Objective 2*: Reduce the exposure of the aquatic community and wildlife populations to sediment COCs at concentrations that are above protective levels.
- *Remedial Objective 3:* Minimize downstream transport of COCs during remedial action implementation.

Mercury was identified as the chemical risk driver at the Site, and the WDNR selected a cleanup goal for mercury of 0.36 milligrams per kilograms (mg/kg) for the Portage Canal sediment remediation. The Remedial Action Options (RAOs) for the Canal are evaluated, in part, on their ability to reduce risks at the site, achieve the remedial objectives, and achieve the clean-up goal.

The following remedial technologies were screened for the Segments 2, 3, and 4 of the Canal:

- No action
- Fill canal
- Sediment capping
- Placement of sediment amendments
- In-situ stabilization
- Sediment removal

The results from the initial screening were used to develop RAOs for the Canal. The five potential RAOs carried forward for further evaluation are as follows:

- RAO 1 – No Action
- RAO 2 – Fill The Canal and Reroute Storm Water
- RAO 3 – Sediment Capping
- RAO 4 – Sediment Removal and Backfill of Sediment Cover
- RAO 5 – Sediment Removal, Weir Removal, and Regrading of Canal Bottom

These RAOs are evaluated against the following performance criteria, as specified in Wisconsin Administrative Code (WAC) NR 722:

- *Technical Feasibility* – The technical feasibility of appropriate remedial action options are evaluated based on long-term effectiveness, short-term effectiveness, implementability and restoration timeframe.

- *Economic Feasibility* – The economic feasibility of each appropriate remedial action option is evaluated based on capital costs, annual operation and maintenance costs, total present worth of the costs, and costs associated with potential future liability.

The environmental laws and standards and required permits and licenses for each RAOs are also discussed. Findings from the evaluation of the RAOs will be used to select a remedial action for the Canal.

Potential RAO supplements are also considered in this RAOR, including the following:

- *Segment 2 Bike Path* – The development of a bike path in Segment 2 would connect the existing bike paths in Segments 1 and 3. The construction of a bike path along the southern bank of Segment 2 can be added to three of the RAOs: sediment capping (RAO 3); sediment removal and backfill of sediment cover (RAO 4); and sediment removal, weir removal, and regrading of Canal bottom (RAO 5).
- *Habitat Improvements* – Habitat improvements are to be considered if the removal with increased slope and weir removal remedial option (RAO 5) is selected. Based on results of the hydraulic modeling, removal of the weir at the downstream boundary of Segment 4 will increase flow rates in the Canal, leading to improved water quality. Additional habitat improvement techniques, such as increased channel sinuosity, the creation of submerged riffle/pool sequences, and the creation of a narrow channel in the center of the Canal may be used to improve flow complexity and oxygenation in the Canal and improve wetland habitat.

These supplements are not intended to further enhance the effectiveness of any of the RAOs to control contaminant exposures, but rather provide additional ecological and/or public use benefits to the Site following sediment remediation.

1. INTRODUCTION

Ramboll Environ prepared this RAOR for Segments 2, 3, and 4 of the Canal located in Portage, Wisconsin, on behalf of the WDNR. This report provides information required under Chapter NR 722 of the WAC. The RAOR was conducted in accordance with the Work Plan submitted to the WDNR on November 18, 2015. The purpose of the RAOR is to identify and evaluate remedial alternatives based on technical and economic feasibility and select a recommended remedial action.

1.1 General Information

Site or Facility Name: Portage Canal Segments 2 to 4

Site Location: *Segment 2* - Adams Street to Canadian Pacific Railroad (CPR) Bridge, part of NE ¼ of the NW ¼ of Section 8, SE ¼ of the SW ¼, SW ¼ of the SE ¼,SE ¼ of the SE ¼, and NE ¼ of the SE ¼ of Section 5, Township 12 North, Range 9 East

Segment 3 - Extends from the CPR Bridge to STH 33, part of NE ¼ of the SE ¼ of Section 5, NW ¼ of the SW ¼, SW ¼ of the NW ¼ of Section 4, Township 12 North, Range 9 East

Segment 4 - Extends from STH 33 to former Fort Winnebago Lock part of SW ¼ of the NW ¼, NW ¼ of the NW ¼, NE ¼ of the NW ¼ of Section 4 Township 12 North, Range 9 East and SE ¼ of the SW ¼, NE ¼ of the SW ¼ of Section 33

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1.2 Site Description and History

The 17-acre Canal is located in the City of Portage in Columbia County, Wisconsin (Figure 1-1). The Canal is divided into four segments based on crossings. These segments are referred to herein as Segments 1 through 4. Each segment has been assigned a separate Bureau for Remediation and Redevelopment Tracking System (BRRTS), recognizing that each Segment could have a unique remedial action. Segment 1 from the Wisconsin River to Adams Street is excluded from this RAOR as it was remediated in 2016. Segments 2, 3, and 4 are collectively referred to as the "Site."

Segments 2, 3, and 4 of the Canal are shown in Figure 1-2A to C. The segment descriptions and lengths to be used for the RAOR are provided below:

- Segment 2 extends from Adams Street to CPR Bridge (3,400 feet) BRRTS No. 02-11-577055;
- Segment 3 extends from the CPR Bridge to State Highway (STH) 33 (1,750 feet) BRRTS No. 02-11-577056; and
- Segment 4 extends from STH 33 to former Fort Winnebago Lock (4,650 feet) BRRTS No. 02-11-577057.

Between 1838 and 1876, the manmade Canal was excavated to a length of approximately 2.5 miles and widths between 52 and 80 feet. Connecting the Wisconsin and Fox Rivers, the Canal was used by recreational and commercial boats traveling between the Great Lakes and the Mississippi River.

A lock within the Canal at the Wisconsin River was constructed by the U.S. Army Corps of Engineers (USACE) in 1926 to 1928. The Canal was last (partially) dredged by the USACE in 1927, and since that time much of the Canal has filled with sediment. The Wisconsin River lock was deactivated in 1959 to 1960, and the Fort Winnebago Lock at the Canal entrance to the Upper Fox River was dismantled within the same time period. In 1998, the USACE completed construction of a levee system for flood control in Portage, which blocked off the Canal entrance at the Wisconsin River. Currently, the Canal receives storm water runoff from several outfalls that discharge into Segments 1 and 2 (Figure 1-3).

The State of Wisconsin assumed ownership of the Canal from the Federal Government upon decommissioning of the locks and construction of the levee system. The Canal was listed on the National Register of Historic Places in 1977, and the WDNR was designated control of the Canal in 1981. Additional characteristics of the Canal and surrounding areas that may be considered as part of remedy selection and implementation are discussed below.

1.2.1 Historical and Archaeological Significance

Information from the Wisconsin Historical Society (WHS) has identified the following known historically significant sites on or near the Portage Canal Site:

- CO-0330 Portage Canal - Also on WHS Architecture and History Inventory (AHI) as structure AHI 16025.
- CO-0336 = fur trade post.
- CO-0326 = Burial (Indian mounds and cemetery) and village, including prehistoric/historic Indian and E-American components.
- CO-0228 = Burial (cemetery) and village, including historic Indian and E-American components.
- CO-0331 = fur trade post.

Since the remedial activities will have the potential to disturb one or more of these historically significant sites, the WHS will need to approve the selected remedial action option.

1.2.2 Wetlands

Based on a survey conducted by Mead & Hunt, Inc. (Mead & Hunt) in 2002, which was approved by the WDNR in February 2004, the Canal is a jurisdictional water under the Clean Water Act (CWA) because it has a history of navigation for interstate commerce. Delineated wetland areas at or near the Site include a permanent pool with submerged, floating aquatic vegetation and some scattered shallow marsh vegetation (Mead & Hunt 2004). Wetland vegetation is comprised of silver maple, river birch, red osier dogwood, sedges, reed canary grass, cattails, pondweeds, and water lily. Other types of vegetation in the vicinity of the Canal include shallow marsh, shrub wetlands, riparian wet meadows, and riparian wet forest. The maximum vertical extent of wetland areas adjacent to the Site is 782 feet above mean sea level (amsl). Remedial action options included in this report are designed to minimize disturbance to wetland areas and will include restoration of impacted wetland areas. However, if the selected remedial alternative impacts wetlands above the ordinary high watermark (OHWM) of 781.4 feet amsl, mitigation requirements will be addressed and resolved separately by the WDNR. In addition, remedial work within these wetlands may require a USACE Section 404 permit, Wisconsin Section 401 Certification, and/or local government approvals, as discussed in Section 3.

1.2.3 Adjacent Properties

Land use on properties adjacent to the Canal varies by segment. In Segment 2, private residences and commercial properties border the Canal to the north and south, respectively. The majority of properties adjacent to Segments 3 and 4 are zoned for agricultural use and characterized by scattered residences and woodland areas. An industrial land use area and Superior Street lie to the southeast of Segment 3, and Agency House Road abuts Segments 3 and 4 to the northwest. Other areas in the vicinity of Segments 3 and 4 are comprised of vacant land and scattered residences, with the exception of the Old Indian Agency House, which is located at the downstream portion of Segment 4. Access to the Canal may be limited by the presence of residential, commercial, and industrial properties, particularly in Segment 2 and portions of Segment 3. In addition, access may be limited on the property surrounding the Old Indian Agency House, which is listed on the National Register of Historic Places.

Several bridges span the Site (Figure 1-1), including the Adams Street bridge at the upstream boundary of Segment 2, a CPR bridge at the boundary of Segments 2 and 3, STH 33 overpass at the boundary of Segments 3 and 4, a snowmobile/pedestrian bridge north of STH 33, and a pedestrian bridge near the downstream end of Segment 4. These bridges may restrict access to the Site and prevent the use of certain construction equipment during remedy implementation. With respect to the CPR bridge, working around railroad bridges and railroad owned properties may require additional care, permits and approvals from the rail line owner, during remedy design, to maintain the appropriate right-of-way and to ensure track stability. In some cases, rail line owners may require off-sets that limit construction in the immediate vicinity of the rail lines.

1.3 Nature and Extent of Contamination

As discussed in the Site Investigation Report (Ramboll Environ, 2017), a total of nine different heavy metals have exceeded their respective threshold effects concentrations, including cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc. Lead and mercury are the metals that exceed WDNR Consensus-Based Sediment Quality Guidelines (CBSQG) Interim Guidance (December 2003) consistently. Lead and mercury concentrations within the Canal are collocated and correlated. Mercury has been identified as the chemical risk driver for the site, such that remediation alternatives that address mercury contamination also are expected to address other COCs associated with the Site. Mercury concentrations generally increase with fines content. Mercury impacts are primarily confined to organic silt and silty sand sediment deposits within the Canal. It is estimated that approximately 60,000 to 65,000 cubic yards (CY) of impacted sediment are located within Segments 2 to 4 in the Canal. A range of impacted sediment is due to the variability in the bank conditions. A more detailed survey as part of design will narrow this estimate. The Site Investigation Report (Ramboll Environ 2016) describes the presence of all COCs measured at the Site, to date. In this report, we rely on mercury to identify and screen remedy alternatives; at the end of the report, we evaluate the efficacy of the selected remedy to address the full range of COCs measured at the Site.

1.4 Canal Hydrology, Bathymetry, and Sediment Characteristics

Flow within the Portage Canal is generally to the northeast toward the Fox River, although the flow is nominal and often results in stagnant water. Various inflow structures from the City of Portage storm water system flow into the Canal.

The United States geological Survey (USGS) was retained by the Department to monitor water elevations and temperature within and adjacent to the canal. Water elevations were measured just upstream of the CPR crossing. Water elevations, velocity measurements, and the cross sectional area was used to estimate flows and water velocity in the canal as well as develop a channel rating curve.

Based on this information, the average flow in the canal was estimated to be 6 cubic feet per second (cfs). The maximum flow was estimated to be 14 cfs after a 1-inch rain on June 1, 2014. As an indication of the flashiness of the canal, water elevations returned to pre rain levels within 7-hours of the event. The minimum estimated flow was 4 cfs on November 4, 2014. The average retention time within the canal (from Adams Street to the former Fort Winnebago lock) was 13 hours.

Water depths, which are influenced by historical sedimentation in the Canal and current grades, groundwater elevations, and the presence of a weir (former Fort Winnebago Lock) at the downstream portion of Segment 4, range between 2.5 and 3 feet. The Canal water levels are also influenced intermittently by storm water, which enters the Canal via several storm water outfalls as shown in Figure 1-3 and surface runoff discharges.

The maximum water temperature observed in the canal was 68°F, which is significantly lower than the upper Fox River, which can get up to 77°F during summer conditions. Further, 68°F meets the ambient temperature, sub-lethal criteria, and acute criteria for Ambient Temperatures for Water Quality Criteria (Table 2, NR 102) for a warm water community and nearly meets cold water community criteria for sub lethal. During that maximum temperature, groundwater fed the canal at 54°F. The temperature data suggests that since the canal is predominately groundwater fed, it stays cooler than the surrounding waterbodies temperature that become stressed in low flow, high temperature summer conditions.

Although the water temperature is cooler, dissolved oxygen is very low due to the high organic content and low water velocities. On August 4, 2006, the WDNR measured dissolved oxygen on two locations and sediment oxygen demand was less than 1 milligrams per liter (mg/L). The information dissolved oxygen concentration, water temperature, and velocity informs the RAOR and potential conditions post remedial action.

The soft sediment in the Canal consists primarily of dark brown and grey to black silty sand, which contains variable amounts of organics and clay. The lithology beneath the sediment consists of native brown sand with fewer fines. The underlying native brown sand is visually distinct from the overlying soft sediment, though a transitional layer of silty sand is present in some areas. Thicknesses of the soft sediment are estimated to be approximately 0.5 to 3.0 feet. Sediments closer to the banks appear to contain a larger amount of sand, whereas silt and organics comprise a larger portion of the sediments near the center of the Canal (Ramboll Environ 2016). COCs are associated with the soft sediment layer and, in general, not the underlying native material.

2. REMEDIAL OBJECTIVES AND REMEDIAL GOALS

Remedial objectives and remedial goals provide the framework for developing implementable and effective remedial alternatives that are protective of human health and the environment. Additionally, remedial objectives define the basis for evaluating different sediment remedy options and describe, in general terms, what the selected sediment remedial action is intended to accomplish. Remedial goals establish the targets necessary to achieve the remedial objectives. The remedial objectives for this project are provided below.

2.1 Remedial Objectives

- *Remedial Objective 1* – Reduce human exposures to COCs associated with incidental sediment ingestion and fish consumption from the Portage Canal by reducing the bioavailability and/or concentration of COCs in sediments that are above protective levels.
- *Remedial Objective 2* – Reduce the exposure of the aquatic community and wildlife populations to sediment COCs at concentrations that are above protective levels.
- *Remedial Objective 3* – Minimize downstream transport of COCs during remedial action implementation.

These remedial objectives address human health and ecological exposures to COCs in sediment, to the extent that sediment COCs contribute to adverse short-term and long-term risks. The sediment remedies will be evaluated, in part, on their ability to reduce risks at the site and achieve the remedial objectives.

2.2 Remedial Goal

As discussed in Section 1.3 and described in the Site Investigation Report (Ramboll Environ, 2016), various metals have been identified in canal sediments at levels greater than applicable CBSQGs (WDNR, 2003). A WDNR comparative analysis determined that in sediment samples with mercury concentrations less than 0.36 mg/kg, concentrations of lead and other metals (e.g., silver) also were below applicable screening levels. Therefore, mercury was identified as the chemical risk driver at the Site, and the WDNR selected a cleanup goal for mercury of 0.36 mg/kg for the Portage Canal sediment remediation based on the CBSQG and other available information.

Most of the surficial soft sediment in Segments 2 through 4 is contaminated with mercury, with 92 percent of samples containing mercury at concentrations above the cleanup goal of 0.36 mg/kg (Ramboll Environ, 2016). Therefore, the selected remedy will address the entire areal extent of soft sediment within Segments 2, 3, and 4 (Figures 1-2A to C). The lateral boundaries of remediation in each segment are defined by the canal boundaries, each bounded by aged wooden bulkheads, remnants of which exist on either side of the canal; those boundaries are evident in the LiDAR maps for each segment (Figures 1-2A to C).

3. EVALUTION OF REMEDIAL ACTION OPTIONS

This section performs an initial screening of potential remedial technologies for Segments 2, 3 and 4 of the Portage Canal. Results from the screening are then used to develop RAOs that are further evaluated against the performance criteria, as specified in WAC NR 722.

3.1 Screening of Remedial Technologies

The following remedial technologies were considered for the Segments 2, 3, and 4 of the Portage Canal.

- No Action
- Fill Canal
- Sediment Capping
- Placement of Sediment Amendments
- In-Situ Stabilization
- Sediment Removal

There were also a number of items reviewed and determined to be infeasible for use at the Portage Canal site. Items reviewed include the following:

- *Installation of Sheet pile along the canal and placement of contaminated material behind the sheet pile and cover the moved sediments to confine the material in place* – The type of sheet piling required to isolate the material is quite expensive and would add an additional 3-4 million dollars to the project. In addition the material would be remaining in place and the potential for leaching of contaminants into the surrounding groundwater or soils is possible.
- *Amending the sediments to be used as fill along the channel* – Based on pilot testing done during the segment 1 feasibility identified material that could potentially bind the contaminants and

allow them to be workable enough for placement, However there are space constraints for mixing areas as well as high costs for the amendment.

For both of these items, the entire shoreline on one or both sides of the canal would have to be completely cleared of trees for access.

3.1.1 No Action

No action reflects site conditions as they exist in the Canal, and this RAOR would entail no further action for remediation of Canal sediment. No action serves as a baseline comparison to the other alternatives and is retained for further evaluation.

3.1.2 Fill Canal

Filling the existing channel in Segments 2, 3, and 4 of the Canal to the tops of the banks would bury and isolate the contaminated sediment in the Canal. Filling the Canal would require diverting storm water and groundwater from Segments 2, 3 and 4 to a storm water conveyance system. Filling the Canal is retained for further evaluation.

3.1.3 Sediment Capping

The placement of suitable cap materials in Segments 2, 3, and 4 provides physical and/or chemical isolation of the contaminated sediment and stabilization/erosion protection. Continuing obligations, in combination with capping would reduce potential disturbances to the sediment cap as result of in-channel activities. Sediment capping is retained for further evaluation.

3.1.4 Placement of Sediment Amendment

The placement of surface sediment amendments, such as organoclay or activated carbon, are used to sorb dissolved phase contaminants, thus reducing contaminant concentrations in the pore water and limiting migration into the overlying surface water. Sediment amendments have been shown to be effective for organic contaminants, but the remediation of mercury- and other metal-contaminated sediments through the placement of amendments has not been demonstrated on a large scale, such as the Canal. Therefore, the placement of sediment amendments is not considered for further evaluation.

3.1.5 In-situ Stabilization

In-situ stabilization of sediment includes the injection and mixing of chemicals or cement into the sediment, thus rendering the contaminants less bioavailable or less toxic. However, the effectiveness of in-situ stabilization is uncertain for site-specific conditions in the Canal. Furthermore the effectiveness and implementability of in-situ stabilization on a scale as large as the Canal, have not been demonstrated. Therefore, in-situ stabilization is not considered for further evaluation.

3.1.6 Sediment Removal

Through sediment removal the contaminated sediment is physically removed from the Canal. Sediment removal can be conducted via dredging or excavation, and includes subsequent material management such as dewatering and disposal of the dredged or excavated sediment. Sediment removal is retained for further evaluation.

3.2 Evaluation of RAOs

The results from the initial screening in Section 3.1 were used to develop RAOs for the Segments 2, 3, and 4 of the Canal. The five potential RAOs carried forward for further evaluation are as follows:

- RAO 1 – No Action
- RAO 2 – Fill The Canal and Reroute Storm Water

- RAO 3 – Sediment Capping
- RAO 4 – Sediment Removal and Backfill of Sediment Cover
- RAO 5 – Sediment Removal, Weir Removal, and Regrading of Canal Bottom

These RAOs are intended to address impacted sediments and achieve the site-specific remedial objectives. The environmental laws and standards and required permits and licenses for each RAOs are discussed. The identified RAOs are evaluated against the following performance criteria, as specified in WAC NR 722:

- ***Technical Feasibility*** – The technical feasibility of appropriate remedial action options are evaluated using the following criteria:
  - *Long-term effectiveness* – Long-term effectiveness of appropriate remedial action options, considers the degree to which the toxicity, mobility and volume of the contamination is expected to be reduced, and the degree to which a remedial action option, if implemented, will protect public health and safety, and the welfare and the environment over time.
  - *Short-term effectiveness* – Short-term effectiveness considers any adverse impacts on public health and safety and the welfare and the environment that may be posed during the construction and implementation period.
  - *Implementability* – Implementability considers the technical and administrative feasibility of construction and implementation of the remedial action options.
  - *Restoration timeframe* – Restoration timeframe is the expected timeframe needed to achieve the necessary restoration.
- ***Economic Feasibility*** – The economic feasibility of each appropriate remedial action option is evaluated using the following criteria: capital costs, annual operation and maintenance costs, total present worth of the costs, and costs associated with potential future liability. The estimated remedial action option costs identified herein provide an accuracy of -30 percent to +50 percent.

- ***Flow Analyses for Different Remedy Alternatives*** – In support of the above evaluations of technical and economic feasibility for the various RAOs, a hydraulic model was used to assess changes in canal velocities associated with cross sectional changes with and without the weir removal. The model used for this effort was the Visual Analysis Simulation Program (VASP),[2] used extensively by Nordic municipalities to assess changes to their streams and canals, many of which are similar in magnitude to the Portage Canal and are being restored to more natural flows.

  The program was used to create cross-sections and longitudinal profiles based on the existing Lidar data for Portage Canal. All hydraulic calculations are based on the Manning Formula. Calculations were performed for a constant (static model) water flow and Manning number.

  Three scenarios were reviewed under the VASP model

  1. Remove 6.0-24 in of the muddy deposit layer and renewal of 4.0 in on top (RAO 4)
  2. Removal of the muddy deposit layer to build a bike trail in Segment 2. (RAO 4 +RAO Supplement 1)
  3. Removal of the muddy deposit and create a bike trail in Segment from dredged material. Create new grade and sinuosity in the canal and use existing weirs (momentarily water level

[2] http://www.ewre.com/prj-09-vasp.cshtml

changes) to optimize the physical parameters and oxidation of the water in the Canal to improve biological conditions. (RAO 5 + RAO Supplement 1)

Model outputs are included in Appendix A, and modelling results are discussed within the various scenarios. The figures presented for the various scenarios were prepared based on the output of this model.

3.3 RAO 1 – No Action

Under the No Action response, no active remediation and no short-term or long-term monitoring would be conducted at the Site. No Action may be appropriate if a site currently meets all of the remedial objectives or if a previous response (e.g., upland remedial activities and source control) eliminated the need for further action.

While this project is not bound by the requirements of the National Contingency Plan (NCP), it is customary within the requirements of the NCP to identify baseline environmental conditions in the absence of remediation. Therefore, the No Action remedial alternative is included in the analysis for comparison to other alternatives.

3.3.1 Compliance with Environmental Laws and Standards, Required Licenses, Permits, and/or Approvals

The No Action option would not include any active remediation or changes to current site conditions. Therefore, no action-specific or location-specific permitting or approvals would apply. However, through the No Action option, surface sediment concentrations of COCs would continue to exceed the site-specific remedial goals and CBSQGs.

3.3.2 Performance Evaluation

The No Action option would not address risks associated with Site COCs in the short or long term, as natural recovery processes have not been demonstrated at the Site. Because no action is proposed in this alternative, the No Action option is readily implementable. Through No Action, sediment chemistry conditions would not be restored to acceptable conditions in the future; however, habitat restoration would not be required because no active remediation would occur at the Site.

This alternative is lowest in terms of present worth cost. It has no associated capital costs or operation and maintenance costs. However, this option may incur costs associated with future liability, as Site COCs would not be addressed.

3.4 RAO 2 – Fill the Canal and Reroute Storm Water

Through RAO 2, the existing channel in Segments 2, 3, and 4 of the Canal would be filled to the tops of the Canal banks. Filling the Canal would involve diverting storm water from Segments 2, 3 and 4, placing soil in the Canal, and grading and compacting the soil fill material to ensure that the fill is at grade with the current northern and southern banks of the Canal. Prior to filling canal, woody vegetation along the canal would be removed. Fill material will be placed and compacted in accordance with all applicable local requirements. A representative cross-section of this remedial option is shown in Figure 3-1. This remedy requires approximately 199,000 CY of soil to fill Segments 2 through 4.

To accommodate flow from Segment 1 and storm water from all four segments, surface water runoff, and storm water point discharges that currently enter the Canal via 17 outfalls would have to be diverted via construction of a below-grade storm water conveyance system. The existing storm water outfalls and surface water flow from Segments 1 through 4 would be rerouted to a single storm water conveyance structure to be constructed near the existing Canal bottom; this conveyance would discharge to the Fox River, consistent with current flows. Design considerations for the storm water conveyance include the following: pipe elevations required to maintain sufficient hydraulic gradient to sustain flow into the Fox River; capacity to accommodate high storm water flows and prevent flooding, particularly given the level of commercial and residential development in Segment 2; presence of subgrade utilities in the vicinity of the proposed location of the conveyance; high groundwater infiltration in the vicinity of the Canal; surface water elevations associated with the Fox River; and, potential future land development.

A sediment treatment option is not included in this remedial alternative, as contaminated sediments would be permanently immobilized and isolated from human or ecological receptors through burial, provided that the fill material is maintained in place.

The need for storm water treatment has not been evaluated in this RAOR. Additional treatment requirements would have to be determined by the City of Portage, should this remedy be selected.

3.4.1 Compliance with Environmental Laws and Standards, Required Licenses, Permits, and/or Approvals

Applicable federal, state, and local permits and approvals will be obtained prior to implementing the fill option. Potential permitting or approval requirements for this remedial option are expected to include the following:

- *CWA Section 404* – Portage Canal is jurisdictional water under the CWA. The placement of fill material into waters of the United States requires a permit from the USACE in accordance with CWA Section 404. The wetland areas at or near the Site also are regulated under Section 404, so that fill, grade changes, road construction, or utility crossing additions or alterations within wetland areas require additional permitting under Section 404.
- *Wisconsin 401 Certification* – Depending on the type and scale of construction activity in wetland areas at or near the Site, a Wisconsin Section 401 Certification of any Section 404 permit may be required. Furthermore, local government approvals or changes to wetland mapping may also be necessary under the applicable shoreland/wetland, floodplain or other zoning ordinances.
- *Wisconsin Pollutant Discharge Elimination System (WPDES)* – For the remedial construction site, coverage will likely be required under the WPDES General Permit for Construction Site Storm Water Runoff (General Permit No. WI-S067831-5).

Several areas in the vicinity of the Canal and the Canal itself are registered under the WHS as places of historical or archeological significance. Therefore, WHS approvals and cooperation is required for remedy implementation

3.4.2 Performance Evaluation

With respect to technical feasibility, channel filling leaves contaminated sediments in place but isolates the sediment beneath several feet of clean fill material, preventing human and ecological exposures to Site COCs over the long term. Direct exposure to contaminated sediments during the placement of fill material poses minimal short-term risks to construction workers during remedy implementation.

RAO 2 implementability must consider the following:

- Storm water runoff discharges and flow from Segments 1 through 4 must be accommodated by the below-grade storm water conveyance prior to filling Segments 2 through 4 of the Canal.
- Support from the City of Portage Public Works Department is required, and the City's storm water management plan will likely need to be modified. Construction of the conveyance requires the excavation and construction of piping, pumps, and other civil structures supporting the conveyance of storm water to the Fox River, all of which could delay implementation of the remedy in Segments 2, 3, and 4.

- Access is required along both Canal banks to transport, place, and compact fill material within the Canal. Given the number of private individuals or companies that own property adjacent to the Canal, it may be difficult to obtain sufficient access to the Canal. In addition, remedy implementation requires the construction of access roads and staging areas near the Canal.
- Specialized equipment may be required to place fill material adjacent to the bridges that currently span the Canal, as maneuvering large construction equipment adjacent to these structures risks compromising their integrity.
- Because the Canal is included on the National Register of Historic Places, the channel filling option would require approval from the State Historical Society.
- Removal of water and channel filling destroys aquatic and riparian habitats within the Canal and would potentially impact wetland habitats adjacent to the Canal; wetland mitigation would be required.
- Filling the channel would eliminate the recreational value of the Canal.

The time to implement this remedial option is approximately two construction seasons. However, the design and construction of a runoff conveyance system for Segments 2, 3, and 4 will need to be completed as part of the channel filling option prior to remedy construction, which will delay implementation of the remedy.

The estimated cost for the import and compaction of clean fill materials, and construction documentation would be approximately $28,600,000. Table 3-2 provides a breakdown of the costs for RAO 2 (Costs distinguished by segments are provided in Tables 3-1 to 3-4).

3.5 RAO 3 – Sediment Capping

Sediment capping involves the controlled placement of suitable materials over contaminated sediment. The United States Environmental Protection Agency (USEPA) Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA, 2005) identifies the following three primary cap/cover functions: physical isolation, stabilization/erosion protection, and chemical isolation. Physical and chemical isolation separate contaminants from the surrounding environment, protect human or ecological receptors from chemical exposures, and minimize the potential for resuspension and transport. In Segments 2, 3, and 4 of the Canal, the cap would be comprised of 12 inches of clean sand placed on the Canal bottom, as depicted in Figure 3-2. A total of approximately 30,000 CY of material will be required to construct this cap. Cap materials would be placed in the Canal from land using one or a combination of approaches (e.g., hydraulic, mechanical, broadcasting).

Continuing obligations would be established as part of RAO 3 to minimize potential disturbance to the sediment cap as result of in-channel activities such as dredging or in-channel construction. Institutional controls are documents, informational devices, and legal restrictions that minimize, limit, or prevent potentially unacceptable exposures to contaminated media. Continuing obligations may include waterway use restrictions (e.g., no-dredging areas or no-anchoring areas), use of permitting processes (e.g., Section 404 permits), and deed restriction/environmental easements or notices.

A treatment option is not included as part of this RAO, as contaminated sediments would be stabilized and isolated from any human or ecological receptors, provided that potential disturbances to the sediment (i.e., dredging or in-channel construction) are restricted within the Canal.

3.5.1 Compliance with Environmental Laws and Standards, Required Licenses, Permits, and/or Approvals

Similar to the channel filling remedial option, the capping remedy may be subject to permitting or approval requirements under Section 404 of the CWA, state (i.e., Section 401) and local requirements regarding construction activities in wetland areas, permitting for construction site storm water runoff, and WHS approval and cooperation in remedy implementation. These requirements are discussed above in Section 3.4.1.

3.5.2 Performance Evaluation

Placement of a cap within the Canal will bury and isolate contaminated sediment, preventing human exposure to Site COCs via direct contact. This RAO will also significantly reduce potential ecological exposures and human exposures through fish consumption, as the cap will reduce the bioavailability of COCs in the Canal. Capping is effective in the short term as the placement of the sand layer immediately provides a clean sediment surface. The long-term effectiveness of the cap option would be ensured through monitoring and maintenance. Monitoring would demonstrate whether the cap continues to achieve the remedial objectives by successfully isolating underlying sediments from physical disturbance and biological contact.

A 12-inch sediment cap was selected to ensure long-term effectiveness. Bioturbation depths in freshwater sediment environments like the Canal are nominally 10 centimeters (4 inches) (USEPA, 2015). Further, the sediment cap would be designed to resist erosion under normal and high flow events; this is accomplished by selecting an appropriate grainsize to help armor the sediment cap. As previously indicated the average measured flow in the canal was estimated to be 6 cfs with a maximum flow of 14 cfs after a 1-inch rain. As an indication of the flashiness of the canal, water elevations returned to pre rain levels within 7-hours of the event. The developed rating curve, included in the Site Investigation Report, indicates that the canal currently has capacity within its banks for approximately 80 cfs, which is 13 times higher than the average flow in the canal.

Construction of the sediment cap can result in generation of turbidity plumes, though most turbidity during capping is associated with the cap material itself and not necessarily the existing contaminated sediment. Contemporary capping techniques greatly minimize the potential for contaminated sediment resuspension; however, the presence of construction equipment along the banks of the Canal during construction may result in increased resuspension of contaminated sediment, which decreases the short-term effectiveness of this remedial option.

Sediment capping has been demonstrated as a reliable remedial technology at other contaminated sediment sites. Capping is particularly effective in low flow environments that are not subject to erosion or scour, such as those conditions present in the Canal. The following factors impacting remedy implementability should also be considered as part of the evaluation of RAO 3:

- Due to the shallow nature of the canal, floating barges with material for capping may be difficult, which would require multiple access points along the canal for placement. This access may be difficult to obtain throughout the length of the Canal given the number of private individuals or companies that own property adjacent to the Canal. In addition, remedy implementation requires the construction of access roads and staging areas near the Canal which will require a great deal of tree clearing and various owner access agreements.
- Specialized equipment may be required to place cap materials adjacent to the bridges that currently span the Canal, as maneuvering large construction equipment adjacent to these structures may threaten their integrity.
- As discussed in Section 1, water depths within the Canal range between 0.5 feet and 3 feet, and water flow within the Canal is minimal, at 6 cfs. Therefore, placing a 12-inch cap within the Canal will have a drastic impact on Canal hydrology and will exacerbate already shallow water

depths in the Canal. This could negatively impact Canal aquatic habitats and adjacent wetland areas as well as recreational uses.

- Changes to the hydrology within the canal could also impact flood issues in and around the City of Portage.

Design and construction constraints include identifying and removing woody debris prior to capping. The time frame required to implement this remedial option is one construction season. The recovery of aquatic habitats and organisms covered by capping may take several years, but restoration efforts, such as replanting non-invasive aquatic plants may accelerate recovery after remediation.

The estimated cost for the import and placement of cap materials, construction documentation, and cap monitoring and maintenance would be approximately $8,100,000. Besides No Action (RAO 1) capping is the least expensive of the five evaluated RAOs. Table 3-3 provides a breakdown of the costs for RAO 3 (Costs distinguished by segments are provided in Tables 3-1 to 3-4).

3.6 RAO 4 – Sediment Removal and Backfill of Sediment Cover

RAO 4 includes the removal of sediment via dredging or excavation, often followed by placement of a 6-inch clean backfill layer of sediment cover, and subsequent material management such as dewatering and disposal of the dredged or excavated sediment. Dredging is used to describe the removal of sediment without water diversion or draining, while excavation is performed after water has been diverted or drained (often referred to as dry excavation). Due to the groundwater infiltration into the Canal, diversion of surface water flow to drain excavation areas appears to be technically difficult; therefore, excavation may not be a viable removal technology. Historical dredging operations on soft sediments have shown that residual contamination through resuspension of material during dredging is probable. Therefore, a thin sediment cover of clean materials is recommended to assist in dilution and burial of residual contaminants.

The dredge and backfill option is shown in Figure 3-3. Dredging is generally accomplished using one of two technologies: mechanical or hydraulic. Mechanical dredges for sediment remediation typically use digging buckets (e.g., clamshell buckets) suspended by cables from a crane or backhoe. Mechanical dredges remove sediment at close to the in-situ density. Hydraulic dredges suspend sediment in water to create slurry that is pumped via pipeline to a staging area (e.g., a dewatering site or barge). The sediment is usually suspended in a large amount of water to allow for transport through the pump and pipeline. This RAO assumes the mechanical dredging of soft sediment to the original bottom of the Canal (i.e., to depths between 3 and 5 feet), removing a total of approximately 60,000 CY of sediment, and placement of 6 inches of clean sand on the Canal bottom (approximately 15,000 CY) to manage any post-dredging residual contamination. Although mechanical dredging is assumed, hydraulic dredging or other removal techniques may be considered during design and via the construction bid process. However, during the sediment removal within Segment 1 a large amount of debris caused delays in the hydraulic dredging process. In addition, areas of Segment 2 would not have sufficient draft for a barge mounted hydraulic dredge. There may be potential advantages to the use of mechanical and hydraulic techniques in different portions of the canal to accommodate site characteristics, access issues, and water depths.

In addition to dredging the sediment from the Canal, the sediment removal option also includes dewatering the removed material, transporting the removed material to a disposal site, and disposing of the material.

Dredged sediments can be dewatered using passive (e.g., gravity dewatering, confined disposal facilities, or geotextile tubes) or active methods (e.g., belt presses, hydro-cyclones). Additives (polymers) may enhance dewaterability, but may increase the net sediment volume for disposal. The degree of dewatering effort necessary prior to transport depends on the physical properties (e.g., grain size and permeability) of the removed sediment and the amount of free water entrained during the removal process. RAO 4 would involve on-Site dewatering and transport to an off-site licensed facility for disposal.

A treatment option is not included in this remedial alternative, as contaminated sediments would be removed from the Canal and placed in a permitted disposal facility, eliminating Site COC exposures to human and ecological receptors from the removed sediment. The exposure risk of COC's in the residual sediment would be managed with a sediment cover.

3.6.1 Compliance with Environmental Laws and Standards, Required Licenses, Permits, and/or Approvals

Similar to RAOs 2 and 3, a sediment removal and cover remedy may be subject to permitting or approval requirements under Section 404 of the CWA, state (i.e., Section 401) and local requirements regarding construction activities in wetland areas, permitting for construction site storm water runoff, and WHS approval and cooperation in remedy implementation, all of which are discussed in Section 3.4.1. In addition, the treatment and discharge of wastewater generated by the dewatering process will likely require state or local permitting. Specifically, if treated wastewater is discharged to surface water, wastewater discharges require coverage under the WPDES General Permit for Carriage and Interstitial Water from Dredging Operations (General Permit No. WI-0046558-5) or a site-specific WPDES permit. If wastewater is discharged to the municipal publically owned treatment works (POTW), an industrial discharge permit or approval may be required by the municipality.

3.6.2 Performance Evaluation

RAO 4 involves the removal of contaminated sediments from the Site, disposal at an off-site licensed facility, and placement of a sand cover to prevent exposures to residual sediments. Removal of target sediment mass is expected to effectively reduce long-term human health and ecological risks at the Site. Dredging is a mature technology that has been effective at numerous sites with sediment contamination. However, removal can lead to short-term releases via resuspension, dissolution, and release to the water column. Resuspension of contaminants (dissolved or sorbed to suspended sediment particles) into the water column and potential downstream transport can result in downstream impacts. In addition, transportation of contaminated material increases human exposure risks due to extended sediment handling.

The following factors impacting remedy implementability should also be considered as part of the evaluation of RAO 4:

- Sediment removal could impact the integrity and stability of Canal shorelines in Segments 2, 3, and 4; bank soils may erode into the Canal during the dredging process. A geotechnical analysis is recommended during design to address this concern.
- Access is needed at certain points to allow dredging equipment into the Canal. Because dredging will be conducted longitudinally along the Canal, fewer access points may be required as compared to the channel filling and capping remedies. However, sediment removal requires the construction of access roads, staging areas, and dewatering/sediment management areas near the Canal.
- Dredging equipment will need to navigate around overhead structures, including power lines and bridges.
- Sediment removal may be impeded by in-Canal structures (e.g., bridge pilings or abutments) or debris (e.g., downed tree branches, rocks).
- Sediment removal activities may disturb subgrade utilities in the vicinity of the Canal. Therefore, a utility survey will be required prior to remedy implementation.

The time frame required to implement this remedial option is two construction seasons. The recovery of aquatic habitats and organisms impacted by dredging may take several years, but restoration efforts, such as replanting, may accelerate recovery after remediation.

The estimated cost for dredging, and dewatering, transport and disposal of the removed material, construction documentation, and import and placement of clean cover material is $13,800,000. Sediment dredging is more expensive than the No Action and capping options. Drying amendments and disposal of the dredged material accounts for a large portion of the total cost. Table 3-4 provides a breakdown of the costs for RAO 4 (Costs distinguished by segments are provided in Tables 3-1 to 3-4). The costs assume landfill tipping fees similar to those from Segment 1 which was lower than typical disposal costs due to negotiated rates and waiver of all state taxes. If other landfills are considered for disposal, costs would likely increase.

3.7 RAO 5 – Sediment Removal, Weir Removal, and Regrading of Canal Bottom

RAO 5 includes the removal of sediment, similar to that described for RAO 4. In summary, mechanical dredging will be used to remove approximately 80,000 CY of soft sediments from the Canal and removed sediment will be dewatered on-site and transported for off-site disposal at a permitted facility. The additional 20,000 CY volume of sediment includes over-dredging an additional 6-12 inches to insure the majority of contaminated sediment is removed. Following dredging, the weir which remains from the former Winnebago Lock at the downstream end of Segment 4 will be removed, and the Canal bottom between Segments 2 through 4 will be regraded using native material to create a post-removal cover. Based on the results of the VASP model, the weir removal and grading activities will result in water depths between 1 to 2 feet along the Canal and an increase in Canal bed slope by approximately 20 percent, as depicted in Figure 3-4. These activities also will result in an increase in water velocity, thus improving surface water oxygenation and ecological health of the Canal. Following regrading activities, analytical monitoring will be conducted to ensure that the surface of the Canal bottom does not contain Site COCs above levels protective of human health and the environment.

A treatment option is not included in this remedial alternative, as contaminated sediments would be removed from the Canal and placed in a permitted disposal facility, eliminating Site COC exposures to human and ecological receptors.

3.7.1 Compliance with Environmental Laws and Standards, Required Licenses, Permits, and/or Approvals

Permitting and approval requirements for RAO 5 are similar to those for the sediment removal and cover option (ROA 4). In summary, these may include requirements under Section 404 of the CWA, state (i.e., Section 401) and local requirements regarding construction activities in wetland areas, permitting for construction site storm water runoff, WHS approval and cooperation in remedy implementation, and permitting for dewatering wastewater discharges. These items are discussed in greater detail in Section 3.4.1.

3.7.2 Performance Evaluation

The long-term effectiveness, short-term effectiveness, and implementability of this remedial option are similar to RAO 4. However, the native material below the soft sediment will be regraded and serve as the post-removal cover to address any potential dredge residuals. Therefore, sampling will be required after regrading is complete to ensure Site COCs are not present above protective levels in the new surface of the Canal bottom. Short-term turbidity may also increase during regrading activities. Furthermore, removal of the weir in Segment 4 may be subject to administrative review, given the Canal's historic significance.

The time frame required to implement this remedial option would be two construction seasons. The recovery of aquatic habitats and organisms impacted by dredging and regrading of the Canal's native material may take several years, but restoration efforts, such as replanting, may accelerate recovery after remediation.

The estimated cost for dredging, and dewatering, transport and disposal of the removed material, regrading the existing native material, post-remediation surface sediment sampling, and construction documentation is $15,800,000. ROA 5 is more expensive than the No Action, capping, and dredging with sediment cover. Table 3-1 provides a breakdown of the costs for RAO 5 (Costs distinguished by segments are provided in Tables 3-1 to 3-4).

4. POTENTIAL RAO SUPPLEMENTS

The RAOs presented and evaluated in Section 3 are intended to address impacted sediments in Segments 2, 3, and 4 of the Canal and achieve the site-specific remedial objectives. Two potential supplements to the RAOs are described below. These supplements are not intended to further enhance the effectiveness of any of the RAOs to control contaminant exposures, but rather provide additional ecological and/or public use benefits to the Site following sediment remediation.

4.1 Segment 2 Bike Path

A bike path is proposed for Segment 2, connecting the existing bike paths at Segments 1 and 3. A cross-section of the proposed bike path is included in Figures 4-1 and 4-2 as a supplement to RAO3 and RAO 4, respectively. The construction of a bike path along the southern bank of Segment 2 can be added to all of the remedial options discussed above. The minimum width of the path would be 15 feet; a wider path may be accommodated during design. Cost differences would be dependent on how much material could be left in place versus how much additional fill would be required.

Based on the 1:1 slope assumption, construction of a 15-foot wide path requires approximately 3,500 CY of fill material. The path would be located within the southern portion of the Canal, reducing the amount of sediment requiring remedial action. Adding the bike path to the sediment capping option (RAO 3) increases the total volume of fill required by a net value of 1,500 CY (3,500 CY additional fill minus 2,000 CY less cover in the bike path area). Specifically, for RAOs 4 and 5, construction of the bike path would reduce the volume of sediment removed by 3,500 CY. If the bike path is included with Options 4 or 5, stabilized or solidified dredged material may potentially be beneficially reused as fill material for the bike path, provided that it meets constructability requirements (e.g., leachate tests and strength tests). Because the bike path will be constructed within the current boundaries of the Canal banks, standing vegetation would be removed along the southern bank.

If the material is left in place, path construction will likely require the use of some type of geosynthetic system to improve the soil bearing capacity. Geosynthetics are materials (usually made from synthetic polymers-plastics) used with soil or rock during construction. The geosynthetic acts as a reinforcing element in the soil mass or in combination with the soil to produce a composite structure that has improved strength and deformation properties. Construction of the bike path could aid in the stabilization of the southern bank wall.

In addition, the geosynthetic acts to separate two layers of soil that have different particle size distributions. For example, geotextiles are used to prevent gravel base materials from penetrating into soft underlying subgrade soils.

If all contaminated material is removed, the path would need to be constructed from the base of the canal up to the design grade with compacted imported soils or if possible by beneficially reusing the sediments after they are treated and dried to a condition that the material would have suitable geotechnical properties as a base for the path.

4.1.1 Implementability

The bike path along the southern portion of the Canal in Segment 2 would be similar to the bike path constructed in Segment 1 in 2006. The following factors impact the implementability of a bike path in Segment 2:

- Access is required along the southern bank of the Canal to construct the bike path. Given the number of commercial properties and density of business development in this area, it may be difficult to obtain sufficient access to the Canal.
- Access constraints may be associated with constructing the path at the downstream end of Segment 2, adjacent to the CPR Bridge.

4.1.2 Cost

As discussed above, the construction of a bike path can be added to RAO2, RAO 3, RAO 4, or RAO 5. Therefore, costs for constructing the bike path were developed relative to these three RAOs. Construction of the bike path in addition to RAO 3 (Sediment Capping) would increase the remedy cost by approximately $700,000. This additional cost is associated with the additional fill needed to create the bike path and the paving of the bike path. Adding the bike path to RAOs 4 and 5 would increase the cost of a dredge remedy by less than $300,000, because the fill and paving costs associated with the bike path are almost completely offset by the reduction in costs associated with the reduced removal volumes.

4.2 Habitat Improvements

Habitat improvement is another supplemental action to be considered if the removal with increased slope and weir removal remedial option (RAO 5) is selected. Based on the VASP model, removal of the weir at the downstream boundary of Segment 4 will increase flow rates in the Canal, leading to improved water quality. In addition to the weir removal, additional habitat improvement techniques may be used to improve flow complexity and oxygenation in the Canal, such as increased channel sinuosity, the creation of submerged riffle/pool sequences, and the creation of a narrow (approximately 8-foot wide) channel in the center of the Canal. These measures would improve biological and hydraulic conditions for aquatic species; introduce Canal complexity to promote ecological activity; create a more naturalized stream that will enhance visual beauty; and improve wetland habitat, which may benefit migrating birds. Figure 4-3 shows examples of potential habitat improvements, including increased channel sinuosity and deepening of the center of the channel.

The maximum water temperature observed in the canal was 68°F, which is significantly lower than the upper Fox River, which can get up to 77°F during summer conditions. Further, 68°F meets the ambient temperature, sub-lethal criteria, and acute criteria for Ambient Temperatures for Water Quality Criteria (Table 2, NR 102) for a warm water community and nearly meets cold water community criteria for sub lethal. During that maximum temperature, groundwater feed the canal at 54°F. The temperature data suggests that since the canal is predominately groundwater fed, it stays cooler than the surrounding waterbodies that become stressed in low flow, high temperature summer conditions.

Although the water temperature is cooler under current conditions, dissolved oxygen is very low due to the high organic content and low water velocities. On August 4, 2006, the WDNR measured sediment oxygen demand at two locations and it was less than 1 mg/L.

4.2.1 Implementability

Habitat improvement measures in Segments 2, 3, and 4 are implementable. However, the following factors impacting the implementability of these measures should be considered:

- Access is required along both Canal banks to conduct habitat restoration activities. Given the number of private individuals or companies that own property adjacent to the Canal, it may be difficult to obtain sufficient access to the Canal, specifically in the vicinity of the CPR Bridge.
- Habitat restoration activities may disturb subgrade utilities in the vicinity of the Canal. Therefore, a utility survey will be required. In general, this implementability concern should be already resolved with RAO 5.
- Specialized equipment may be required to conduct construction activities adjacent to the bridges that currently span the Canal, as maneuvering large construction equipment adjacent to these structures may compromise their integrity.
- Construction activities will be conducted in the vicinity of wetland areas, which may trigger permitting or other administrative requirements.

4.2.2 Cost

The estimated stand-alone cost of implementing habitat improvements is approximately $1,400,000. This estimate includes costs associated with regrading the canal during remedial activities to improve channel sinuosity and the creation of a narrow channel in the middle of the Canal. The cost estimate also assumes planting and seeding along the levees adjacent to the narrow channel within the Canal.

5. CONCLUSIONS AND RECOMMENDATIONS

A RAOR typically selects a preferred remedial alternative with more detail on schedule, cost, time to achieve remedial goals, performance monitoring, and the sustainability of the remedy. However, since it is unknown when and if funding will be available for the remedial action at the Portage Canal, writing about these topics would be somewhat presumptuous. Therefore, this document will instead discuss conclusions and recommendations developed over the course of evaluating this site and finish the report with a recommended option, but will ultimately leave the remedy selection to the Department.

The site investigation and feasibility for the Portage Canal revealed the following conclusions:

- Many remedial options have very similar implementability issues such as limited access to the canal, roadway, railway and pedestrian bridge crossings along the canal, shallow water depths that limit certain types of equipment, potential clearing of mature trees that overhang much of the canal, and access agreements with owners along the canal. Access points into and out of the canal would be critical for construction production.
- Phasing or implementing each Segment separately (see Table 3-2, 3-3, and 3-4) may be necessary to make progress on the site, but this will increase overall costs, particularly for separate mobilizations. To implement in three separate mobilizations for Segments 2, 3, and 4 versus everything at once is expected to increase costs by 10% to 20%, and likely more depending on timing, regulatory changes, or inflation.
- RAO 2 (filling in the canal) is not a viable option. While this option would isolate contaminates under several feet of fill it is significantly more expensive than other alternatives. Since the canal is used by the City and surrounding areas to convey stormwater, it would be a major infrastructure project to reroute the stormwater systems to prevent flooding issues. Furthermore, this option would eliminate the recreational value of the canal, permanently destroy wetlands and aquatic and riparian habitats. The canal is on the national registry of

historical properties and the historical society would likely have major issues with completely removing the canal.

- RAO 3, sediment capping is the least expensive remedy particularly suitable for low-flow environments such as the canal, however, implementing capping as a sole option as described in RAO 3 is not recommended. A 12-inch cap across the entire canal would have a drastic impact on canal hydrology and exacerbate issues associated with already shallow water depths; namely, negatively impacting canal aquatic habitat and adjacent wetland areas as well as desired recreational uses. In addition, high flow events could potentially erode the cap which would expose the contaminated sediments left in place. Capping would be ideally suited to be paired with reduced dredging cross-section from RAO 4.
- RAO 4, sediment removal and backfill of sediment cover. Dredging is a mature technology and the most commonly selected contaminated sediment remedy. Dredging physically removes contaminates from the environment thereby reducing the mass and concentration of contaminants at the site. Complete sediment removal is more costly than capping. However, dredging may not be technically feasibly in all areas of the canal, such as adjacent to bridge abutments, particularly the railroad bridge crossing. Additionally, due to the existing steep slope of the bank which may require clearing, the bank soils may erode into the Canal during dredging at the toe of the slope, which would necessitate a survey of all shoreline structures and a geotechnical investigation and analysis during design. Further, restoration of canal banks to existing conditions would be difficult given the steep slopes. Therefore, some means to avoid destabilizing the banks is recommended if dredging were selected.
- RAO Supplements
  - *Segment 2 bike path* – A bike path in Segment 2 would be compatible with all of the ROAs and slightly increases impact remedial costs for each.
  - *Habitat improvements* – Creating a more naturalized channel within the canal that is narrower and has more sinuosity with riffle/pool sequesters would potentially improve water quality and habitat for migratory birds.

Based on the above, the recommended remedy is a hybrid of RAO 3 through RAO 5, working with positive aspects of each remedial technology while limiting the negatives. Similar to what was implemented in Segment 1, dredging a set cross section and post sediment cover as the main remedy, and capping adjacent to the banks to remove the risk for destabilization and restoration of the banks and cost escalation. Dredging a center prism would open an area for natural and stormwater flow to pass through the canal. This cross section approach would be more geometrically complex than the flat canal that exists currently. The reduced dredging cross section combined with capping areas of the canal could be implemented with sinuous alignment to create a more natural stream which allows recreational use but is more cost effective and practical than regrading the entire canal. The approach outlined above would be the most effective use of each remedial technology for the given conditions.

Under the combined approach, the majority of COC mass concentrations would still be removed from the site with residual contaminants covered or capped, as necessary to minimize contaminant risk.

6. REFERENCES

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TABLES

Table 3-1
RAO Cost Summary - All Segments
Portage Canal ROAR

Activity	RAO 2 Fill Canal and Reroute Storm Water	RAO 3 Sediment Capping	RAO 4 Sediment Removal and Backfill Cover	RAO 5[1] Sediment Removal, Weir Removal, and Regrading of Canal	Combined Remedy Sediment Removal, Cover and Some Regrading	*Bike Path - Cap*	*Bike Path - Removal*	*Habitat Restoration*
General Construction Activities	$10,302,000	$891,000	$652,000	$784,000	$991,000	$68,000	$0	$438,000
Sediment Removal	$0	$0	$6,681,000	$7,966,000	$4,684,000	$0	($344,000)	$0
Fill/Capping	$6,569,000	$3,976,000	$1,370,000	$383,000	$2,433,000	$412,000	$579,000	$0
Sediment Regrading	$0	$0	$0	$660,000	$0	$0	$0	$398,000
Biological Preparation and Planting								$157,000
Total Direct Construction Costs	$16,871,000	$4,867,000	$8,703,000	$9,793,000	$8,108,000	$480,000	$235,000	$993,000
Total O&M Costs	$0	$760,000	$304,000	$215,000	$215,000	$0	$0	$0
Engineering & CM (13% of TDCC)	$2,194,000	$633,000	$1,132,000	$1,274,000	$1,055,000	$63,000	$31,000	$130,000
Contingency (30% of TDCC)	$5,062,000	$1,461,000	$2,611,000	$2,938,000	$2,433,000	$144,000	$71,000	$298,000
TOTAL	$24,127,000	$7,721,000	$12,750,000	$14,220,000	$11,811,000	$687,000	$337,000	$1,421,000

1) Costs for RAO 5 assume 25% of the dredge area will need to be backfilled with a 6-inch sand layer following post-regrading confirmation sampling

CM: Construction Management
O&M: Operation and Maintenance
RAO: Remedial Action Option
TDCC: Total Direct Construction Costs

Table 3-2
RAO Cost Summary - Segment 2
Portage Canal ROAR

Activity	RAO 2 Fill Canal and Reroute Storm Water	RAO 3 Sediment Capping	RAO 4 Sediment Removal and Backfill Cover	RAO 5[1] Sediment Removal, Weir Removal, and Regrading of Canal	Combined Remedy Sediment Removal, Cover and Some Regrading	*Bike Path - Cap*	*Bike Path - Removal*	*Habitat Restoration*
General Construction Activities	$7,942,000	$430,000	$551,000	$683,000	$551,000	$68,000	$0	$270,000
Sediment Removal	$0	$0	$2,236,000	$2,671,000	$1,610,000	$0	($344,000)	$0
Fill/Capping	$2,223,000	$1,326,000	$472,000	$102,000	$811,000	$412,000	$579,000	$0
Sediment Regrading	$0	$0	$0	$299,000	$0	$0	$0	$167,000
Biological Prepartation and Planting								$10,000
Total Direct Construction Costs	$10,165,000	$1,756,000	$3,259,000	$3,755,000	$2,972,000	$480,000	$235,000	$447,000
Total O&M Costs	$0	$422,000	$222,000	$189,000	$189,000	$0	$0	$0
Engineering & CM (13% of TDCC)	$1,322,000	$229,000	$424,000	$489,000	$387,000	$63,000	$31,000	$59,000
Contingency (30% of TDCC)	$3,050,000	$527,000	$978,000	$1,127,000	$892,000	$144,000	$71,000	$135,000
TOTAL	$14,537,000	$2,934,000	$4,883,000	$5,560,000	$4,440,000	$687,000	$337,000	$641,000

1) Costs for RAO 5 assume 25% of the dredge area will need to be backfilled with a 6-inch sand layer following post-regrading confirmation sampling

CM: Construction Management
O&M: Operation and Maintenance
RAO: Remedial Action Option
TDCC: Total Direct Construction Costs

Table 3-3
RAO Cost Summary - Segment 3
Portage Canal ROAR

Activity	RAO 2 Fill Canal and Reroute Storm Water	RAO 3 Sediment Capping	RAO 4 Sediment Removal and Backfill Cover	RAO 5[1] Sediment Removal, Weir Removal, and Regrading of Canal	Combined Remedy Sediment Removal, Cover and Some Regrading	*Habitat Restoration*
General Construction Activities	**$1,460,000**	**$430,000**	**$490,000**	**$563,000**	**$490,000**	**$270,000**
Sediment Removal	**$0**	**$0**	**$1,154,000**	**$1,492,000**	**$831,000**	**$0**
Fill/Capping	**$1,174,000**	**$750,000**	**$278,000**	**$54,000**	**$456,000**	**$0**
Sediment Regrading	**$0**	**$0**	**$0**	**$140,000**	**$0**	**$108,000**
Biological Preparation and Plantings						**$5,000**
Total Direct Construction Costs	**$2,634,000**	**$1,180,000**	**$1,922,000**	**$2,249,000**	**$1,777,000**	**$383,000**
Total O&M Costs	**$0**	**$349,000**	**$205,000**	**$185,000**	**$185,000**	**$0**
Engineering & CM (13% of TDCC)	**$343,000**	**$154,000**	**$250,000**	**$293,000**	**$232,000**	**$50,000**
Contingency (30% of TDCC)	**$791,000**	**$354,000**	**$577,000**	**$675,000**	**$534,000**	**$115,000**
TOTAL	**$3,768,000**	**$2,037,000**	**$2,954,000**	**$3,402,000**	**$2,728,000**	**$548,000**

1) Costs for RAO 5 assume 25% of the dredge area will need to be backfilled with a 6-inch sand layer following post-regrading confirmation sampling

CM: Construction Management
O&M: Operation and Maintenance
RAO: Remedial Action Option
TDCC: Total Direct Construction Costs

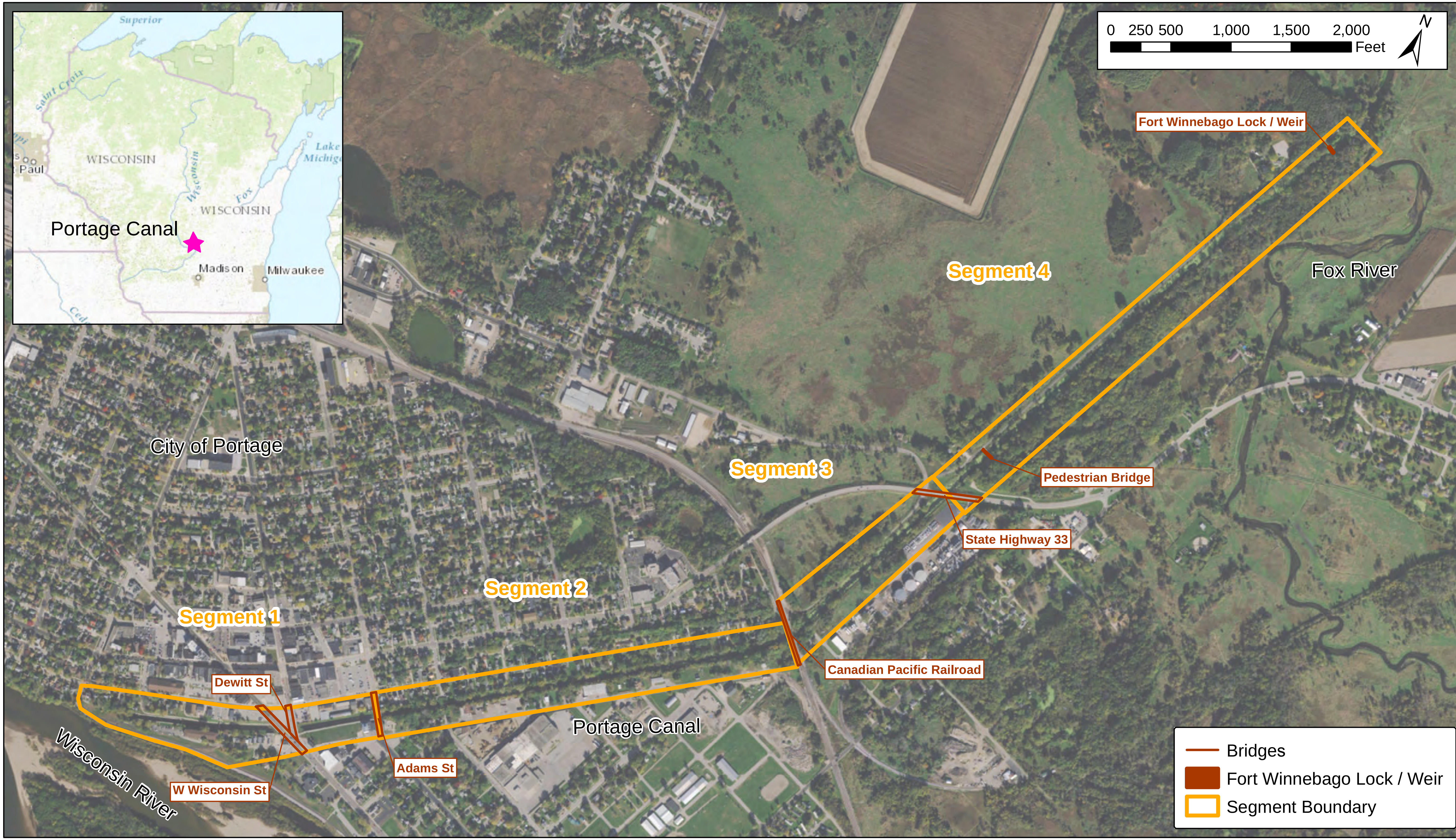
Table 3-4
RAO Cost Summary - Segment 4
Portage Canal ROAR

Activity	RAO 2 Fill Canal and Reroute Storm Water	RAO 3 Sediment Capping	RAO 4 Sediment Removal and Backfill Cover	RAO 5[1] Sediment Removal, Weir Removal, and Regrading of Canal	Combined Remedy Sediment Removal, Cover and Some Regrading	*Habitat Restoration*
General Construction Activities	$1,800,000	$490,000	$411,000	$543,000	$611,000	$338,000
Sediment Removal	$0	$0	$3,294,000	$4,126,000	$2,309,000	$0
Fill/Capping	$3,245,000	$2,034,000	$666,000	$223,000	$1,230,000	$0
Sediment Regrading	$0	$0	$0	$342,000	$0	$211,000
Biological Preparation and Plantings						$13,000
Total Direct Construction Costs	$5,045,000	$2,524,000	$4,371,000	$5,234,000	$4,150,000	$562,000
Total O&M Costs	$0	$514,000	$240,000	$201,000	$201,000	$0
Engineering & CM (13% of TDCC)	$656,000	$329,000	$569,000	$681,000	$540,000	$74,000
Contingency (30% of TDCC)	$1,514,000	$758,000	$1,312,000	$1,571,000	$1,245,000	$169,000
TOTAL	$7,215,000	$4,125,000	$6,492,000	$7,687,000	$6,136,000	$805,000

1) Costs for RAO 5 assume 25% of the dredge area will need to be backfilled with a 6-inch sand layer following post-regrading confirmation sampling

CM: Construction Management
O&M: Operation and Maintenance
RAO: Remedial Action Option
TDCC: Total Direct Construction Costs

FIGURES



RAMBOLL ENVIRON

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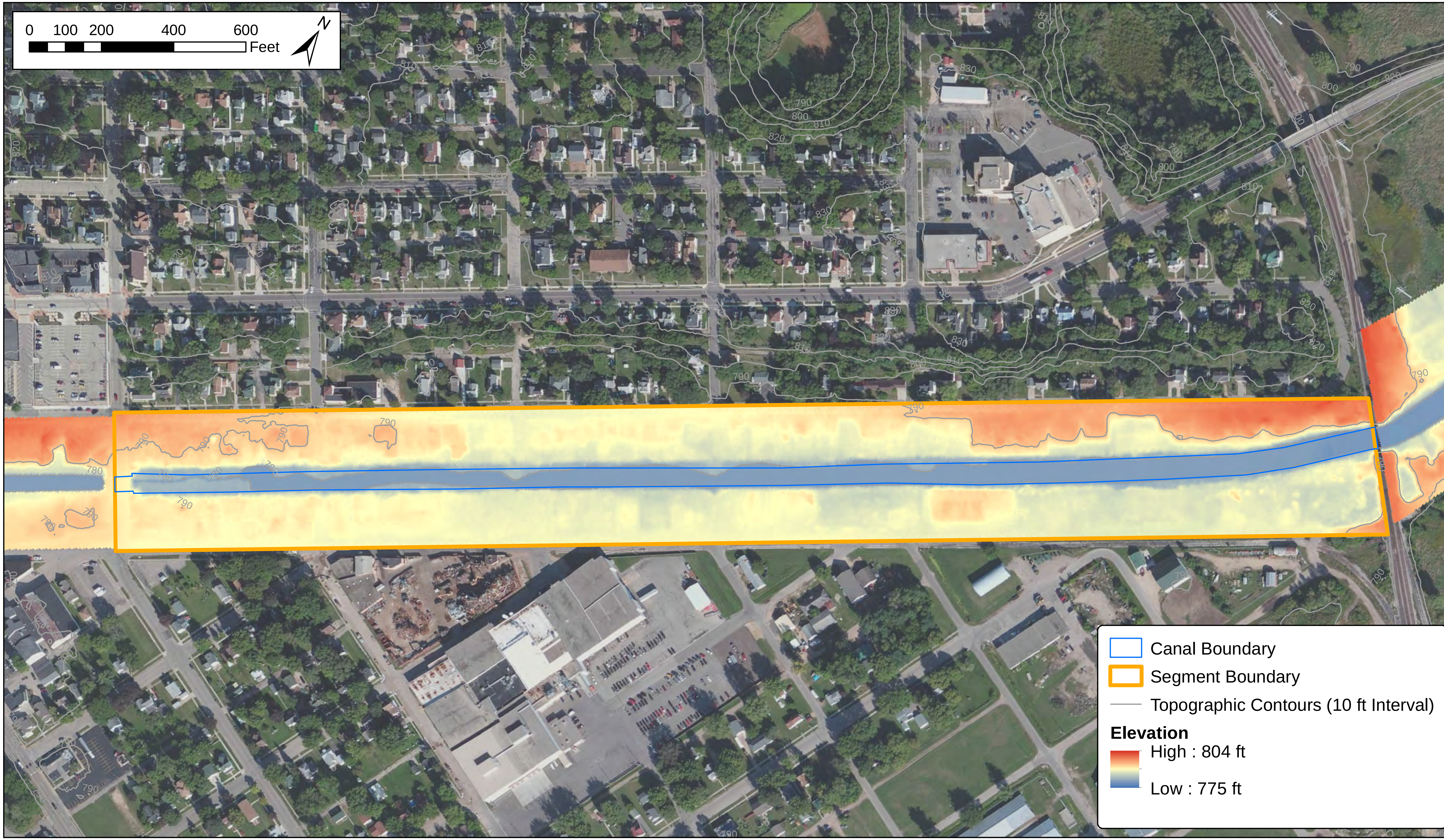
SITE OVERVIEW

Portage Canal Site - City of Portage, Wisconsin

Figure 1-1



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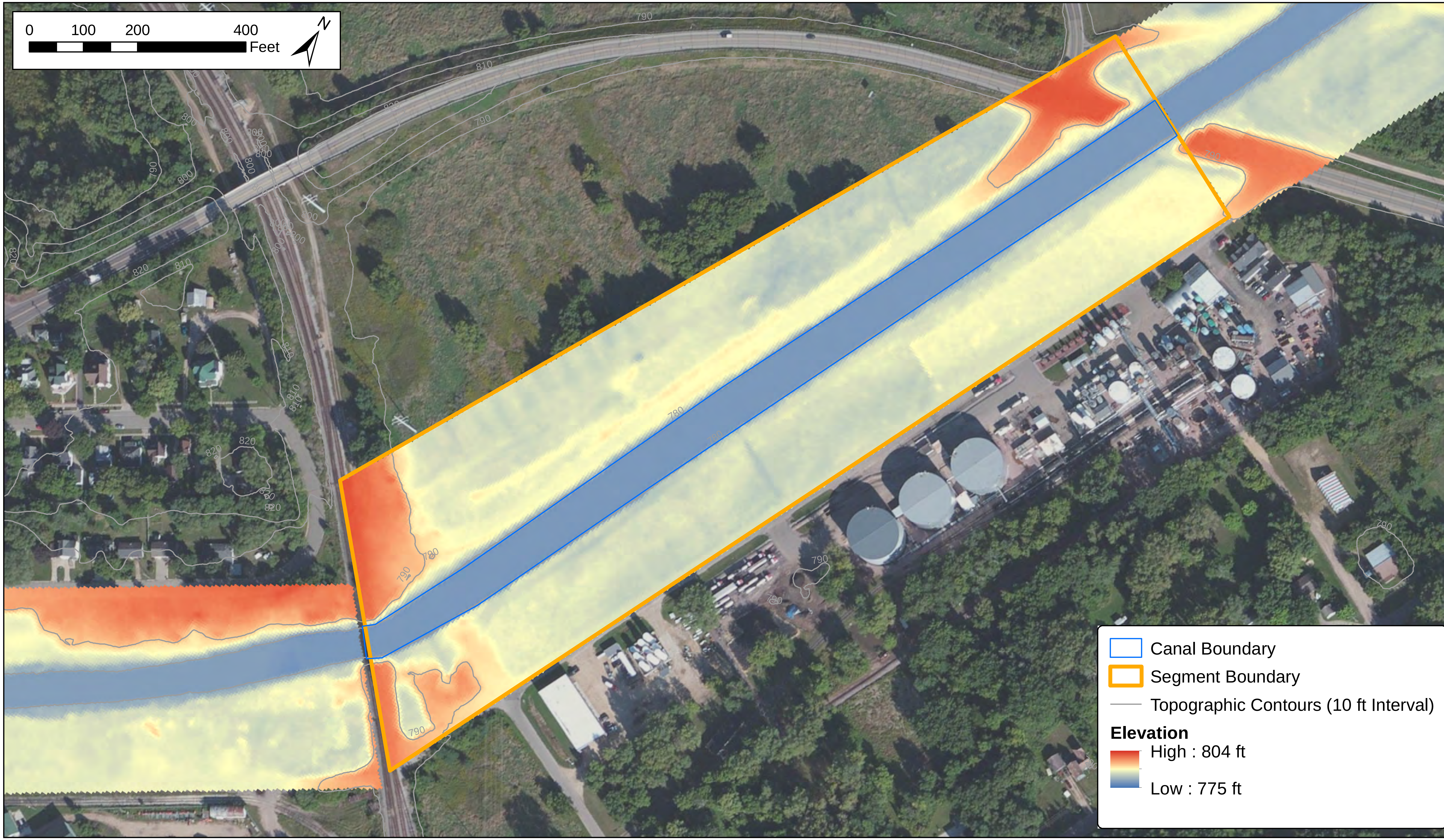
DATE: 02/28/2017

SEGMENT 2 ELEVATION MAP

Portage Canal Site - City of Portage, Wisconsin

Figure
1-2A



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DATE: 02/28/2017

SEGMENT 3 ELEVATION MAP

Portage Canal Site - City of Portage, Wisconsin

Figure
1-2B

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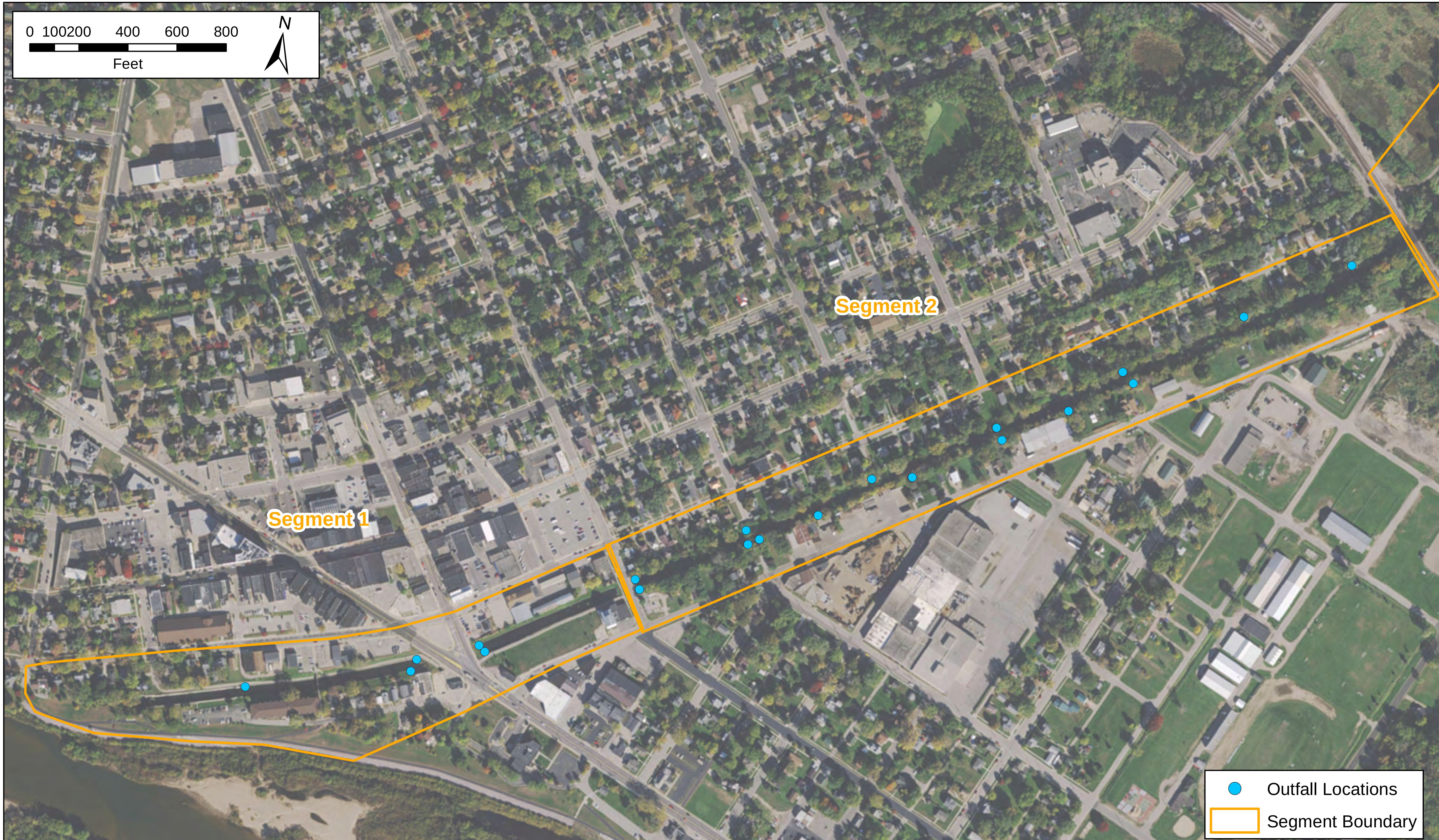
SEGMENT 4 ELEVATION MAP

Portage Canal Site - City of Portage, Wisconsin

Figure
1-2C



RAMBOLL ENVIRON

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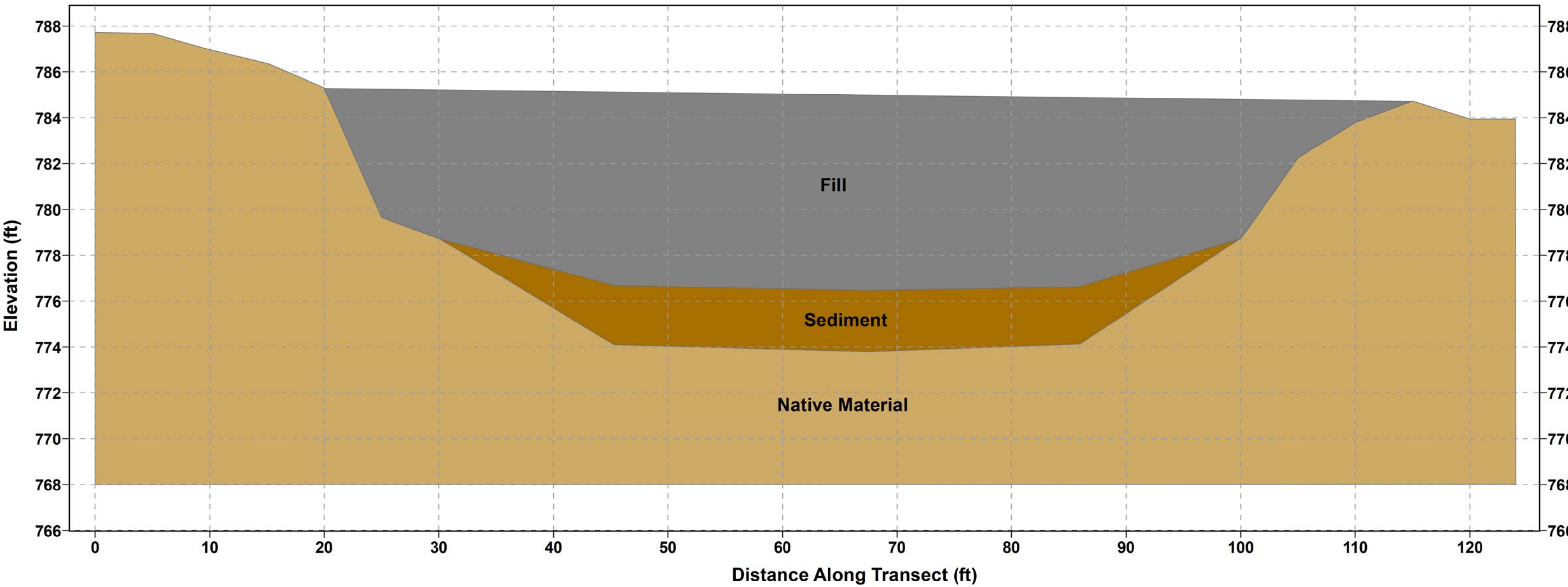
DATE: 12/07/2016

PORTAGE CANAL OUTFALL LOCATIONS

Portage Canal Site - City of Portage, Wisconsin

Figure
1-3



RAMBOLL ENVIRON

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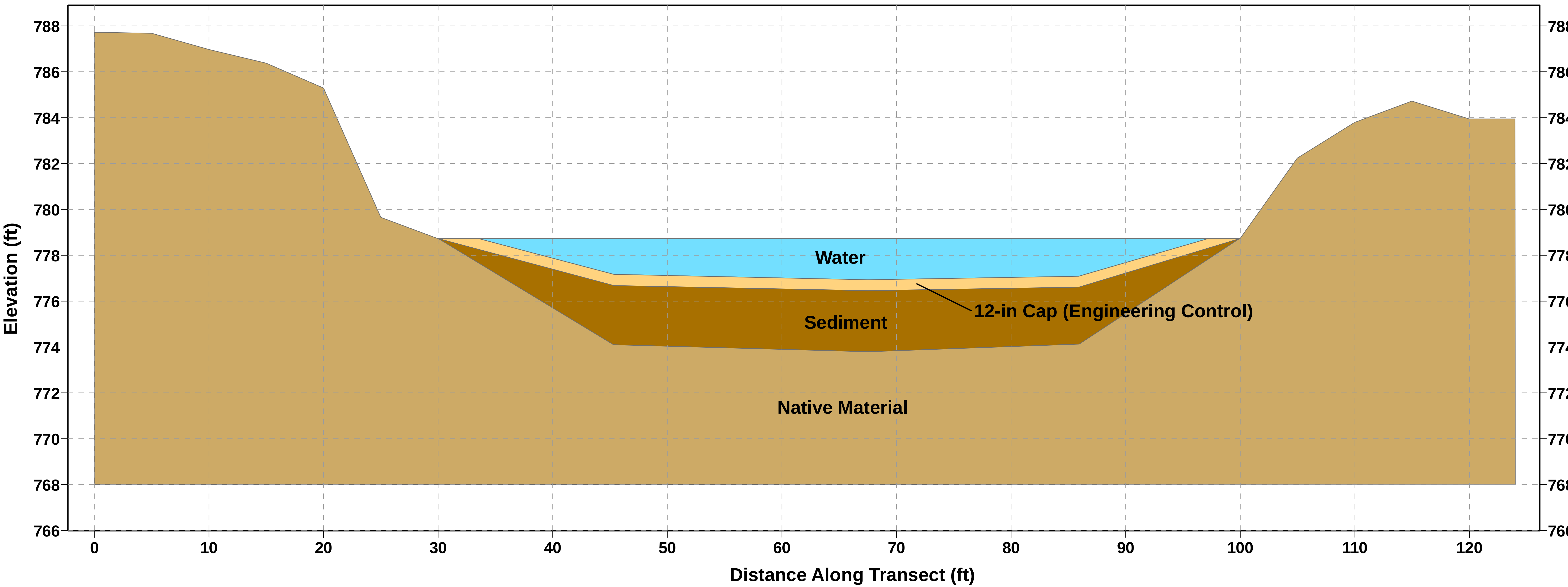
RAO 2 - FILL THE CANAL AND REROUTE STORMWATER

Portage Canal Site - City of Portage, Wisconsin

Figure **3-1**



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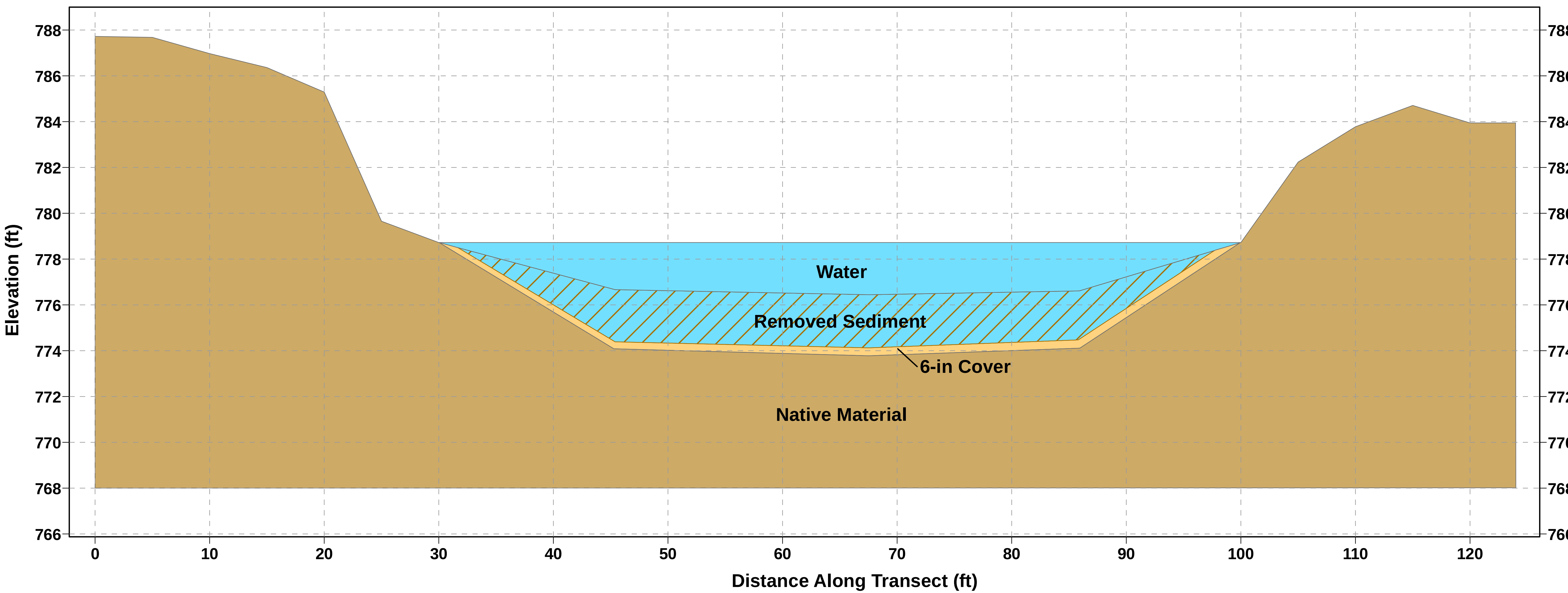
DATE: 02/28/2017

RAO 3 - SEDIMENT CAPPING

Portage Canal Site - City of Portage, Wisconsin

Figure
3-2



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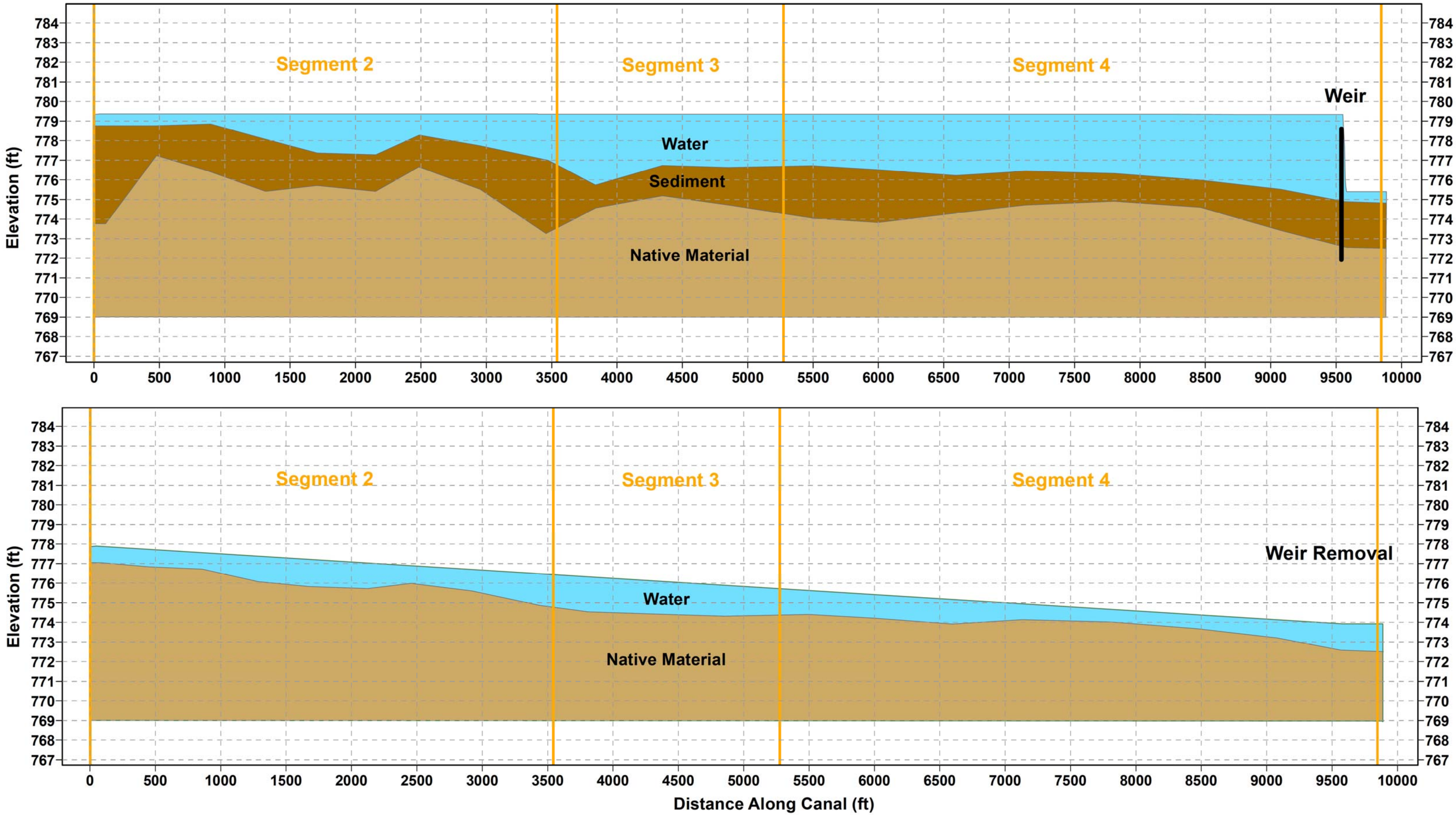
RAO 4 - SEDIMENT REMOVAL AND BACKFILL OF SEDIMENT COVER

Portage Canal Site - City of Portage, Wisconsin

Figure **3-3**



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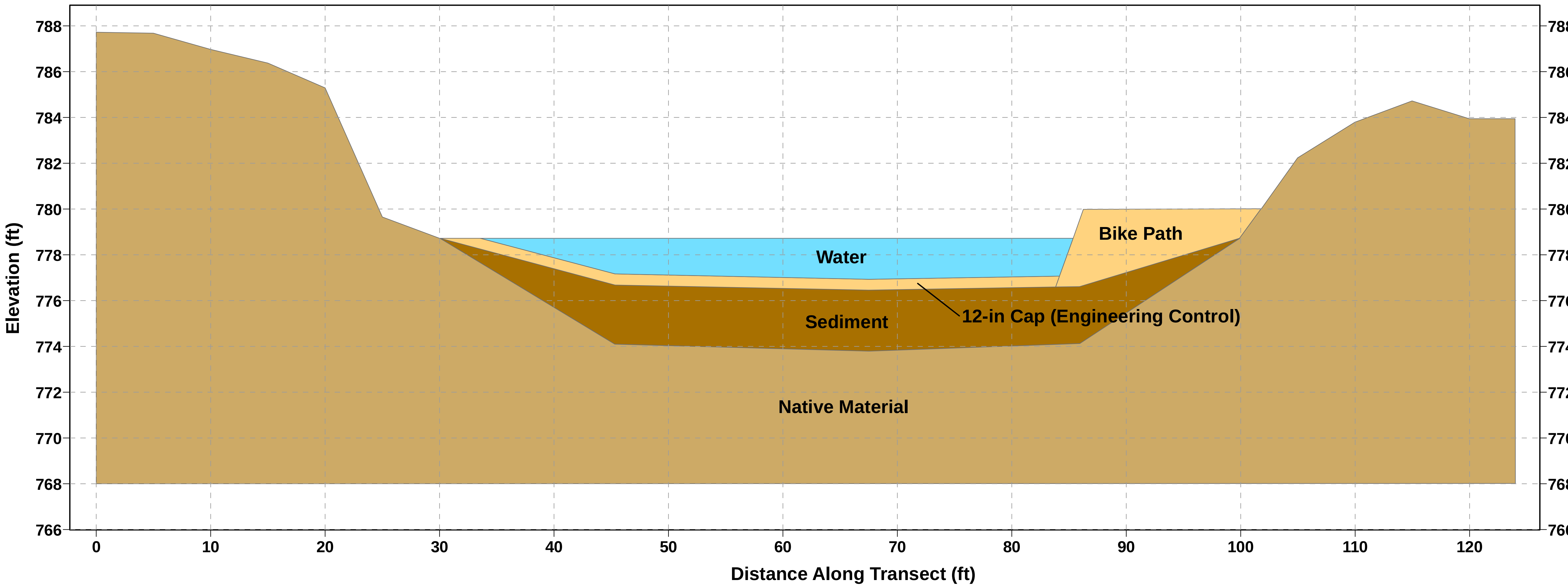
RAO 5 - SEDIMENT REMOVAL, WEIR REMOVAL, AND REGRADING OF CANAL BOTTOM

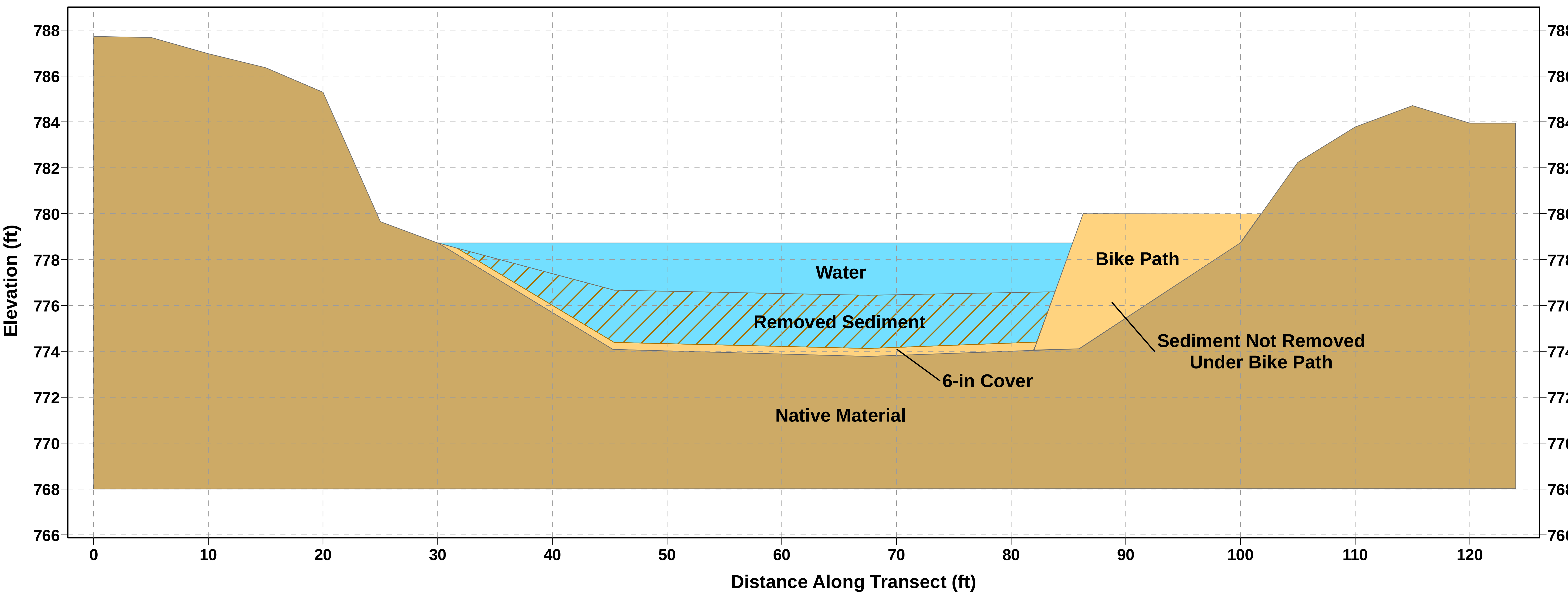
Portage Canal Site - City of Portage, Wisconsin

Figure **3-4**



Note: This figure shows Segment 2 bike path option in conjunction with ROA 3 (sediment capping), but the bike path is applicable with RAOs.

RAMBOLL ENVIRON	**BIKE PATH IN SEGMENT 2 - CAPPING OPTION** Portage Canal Site - City of Portage, Wisconsin	Figure **4-1**
DRAFTED BY: FK DATE: 02/28/2017		



RAMBOLL ENVIRON

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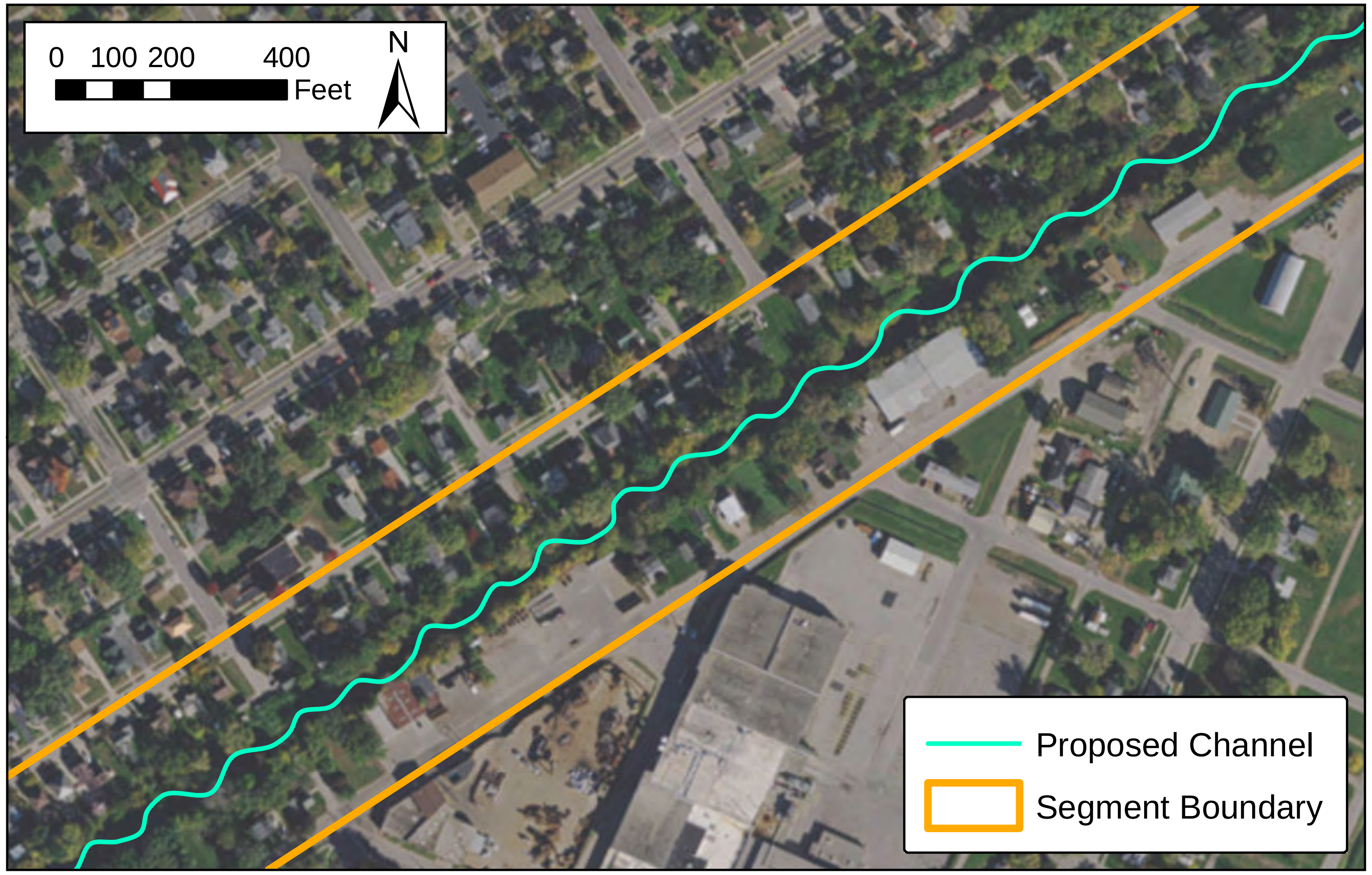
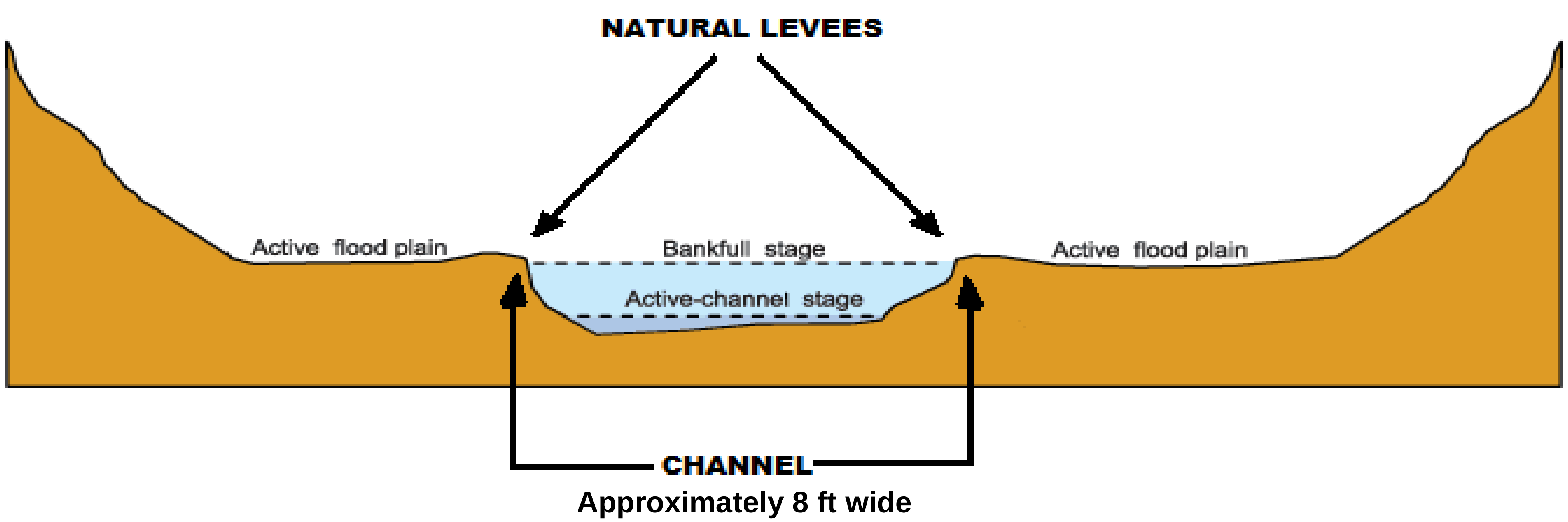
BIKE PATH IN SEGMENT 2 - DREDGING OPTION

Portage Canal Site - City of Portage, Wisconsin

Figure
4-2

Increase channel sinuosity





Create deeper channel within center of the canal

RAMBOLL ENVIRON	**HABITAT IMPROVEMENT**	Figure
DRAFTED BY: FK DATE: 03/01/2017	Portage Canal Site - City of Portage, Wisconsin	**4-3**

APPENDIX A

Hydrodynamic Model Information

Portage Canal – Hydrodynamic Model Notes

In support of the evaluations of technical and economic feasibility for the various Remedial Action Options (RAOs), a hydrodynamic model was used to assess changes in canal velocities associated with cross sectional changes for three scenarios, as well as for cases which the weir is present and removed. This appendix outlines the existing conditions in Portage Canal, discusses the hydrodynamic model inputs, and predicts, through simulation of different scenarios, how the model output under the proposed remedial options compare with the existing conditions.

Existing Conditions

- Appendix 1.1 Existing Conditions
- Appendix 1.2-1.4 Existing Conditions, Data Summary
- Appendix 2 Digital Terrain Model
- Appendix 3.1 Cross Sections
- Appendix 3.2 Longitudinal Profile

Proposed Conditions

- Appendix 4.1 Scenario 1 – Map Description
- Appendix 4.2 Scenario 2 – Map Description
- Appendix 4.3 Scenario 3 – Map Description
- Appendix 4.4 Scenario 3 – Example of Re-meandering of the Canal
- Appendix 5.1 Cross Section After Removal Of 6.0-24 in Sediment
- Appendix 5.2 Scenario 1 and 2 – Longitudinal Profile
- Appendix 5.3 Scenario 3 - Longitudinal Profile
- Appendix 5.4 Scenario 1, 2, 3 – Combination of Scenarios.

1. Existing Conditions

The 17-acre Portage Canal Site is located in the City of Portage in Columbia County, Wisconsin. The Portage Canal was excavated in the 1800s to a length of approximately 2.5 miles and width of 52 to 90 feet for the purpose of connecting the Wisconsin and Fox Rivers; it was not a natural drainage way. The Canal was used by recreational and commercial boats traveling between the Great Lakes and the Mississippi River. A lock within the Canal at the Wisconsin River was constructed by the United States Army Corps of Engineers (USACE) in 1926 to 1928. The Canal was last dredged by the USACE in 1927, and since that time, much of the Canal has filled with sediment, resulting in water depths generally ranging from 0 to 3 feet. The Wisconsin River lock was deactivated in 1959/1960, the same time the Fort Winnebago Lock at the Canal entrance to the Upper Fox River was dismantled. In 1998, the USACE completed construction of a levee system for flood control in Portage, which blocked off the Canal entrance at the Wisconsin River.

Water flow in the Canal is to the northeast toward the Upper Fox River, although the flow is nominal and often results in stagnant water. Water levels in the Canal are influenced by the level of the Wisconsin River, groundwater and to a lesser extent rain events. The Canal abuts a number of private residences, commercial businesses, and several historic sites. The Canal itself is listed on the National Register of Historic Places (DHS, 2014).

The Canal is divided into four segments based on crossings. These segments are referred to herein as Segments 1 through 4. For purposes of this study, Segment 1 from the Wisconsin River to Highway 51 is excluded as it does not contain sediment contamination. Segment 1 extends from Highway 51 to Adams Street (700 feet); the following presents the segment descriptions and lengths to be used for the study:

- Segment 2 extends from Adams Street to Canadian Pacific Railroad (CPR) Bridge (3,400 feet);
- Segment 3 extends from the CPR Bridge to State Highway (STH) 33 (1,750 feet); and
- Segment 4 extends from STH 33 to former Fort Winnebago Lock (4,650 feet).

Figure 1 is a coarse description of the true cross-sections where a small stream inside the broad cross section has developed primarily in Segment 2. When calculating water velocity, and water depth in the created cross-section, we rely on the surveyed cross sections, as shown in Figure 1 and Appendix 3.1.

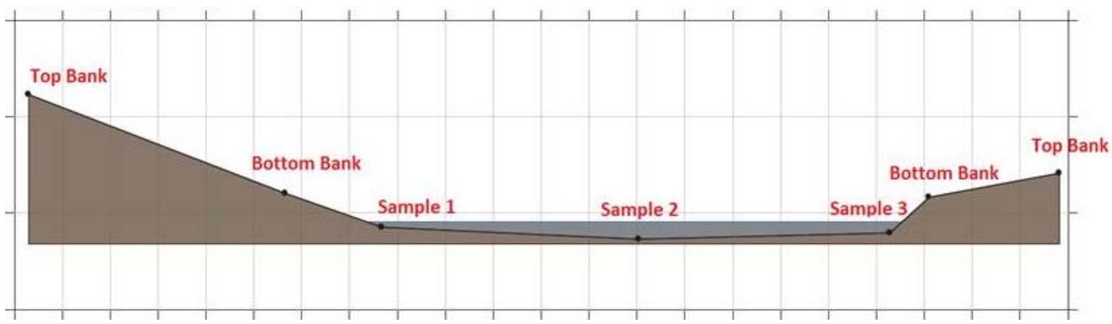


Figure 1. Created cross-sections in Portage Canal

In the model setup, the downstream boundary conditions are defined as a water level boundary. From the LiDAR the water level is estimated in the downstream end of Portage Canal; this forms the lower boundary condition at 780.7 feet (237.7 meters) elevation. Based on data logger information, the water level in Fox River is 776.5 feet (236.2 meters). The difference between the water level in Portage canal and the Fox river is controlled by the weir between the Canal and Fox River.

For each RAO, we determine whether this downstream boundary elevation is fixed or if the water elevation can be lowered to increase the grade and water velocities through the Portage Canal. For biological reasons, an increased velocity can increase oxygenation; thus the model evaluated conditions without the weir. The water level in the Portage Canal (Segment 2-4) is affected by the weir close to Fox River. This means Portage Canal has an unnaturally high water elevation and a low water velocity in the "slackwater" zone (Appendix 3.2).

If the weir is neglected in the modelling calculation, significant differences in the water elevations and velocity are observed (Figure 2 & Appendix 3.2). Elevated water velocity and a grade throughout the system are necessary to create oxygenation for good biological conditions. Hence, existing biological conditions can be improved just by removing the weir close to the Fox River. This also creates free migratory routes for fish and fauna between the Fox River and Portage Canal.

Discharge in Portage Canal is determined using data from Acoustic Doppler Current Profiler (ACDP) measurement collected June 2014. The discharge was 5.58 cubic feet per second (ft^3/s) (172 liters per second [L/s]), and is used as the primary flow condition; because this discharge represents only one measurement, the minimum discharge could be lower and the maximum discharge significantly larger.

To describe the roughness in the Canal, a Manning's number (M=20) is estimated. Using the discharge and Manning's number in the Visual Analysis Simulation Platform (VASP) hydraulic model, existing flow conditions (water level and velocity) in Portage Canal are calculated. The depth in the Canal is 2.0-3.3 feet with the weir present. If the weir is removed, the depth is 0.7-1.3 feet. The velocity in the Canal is 0.08 feet per second (ft/s) with the weir. If the weir is removed the velocity increases to 0.3-0.5 ft/s, calculated with the broad width of the canal.

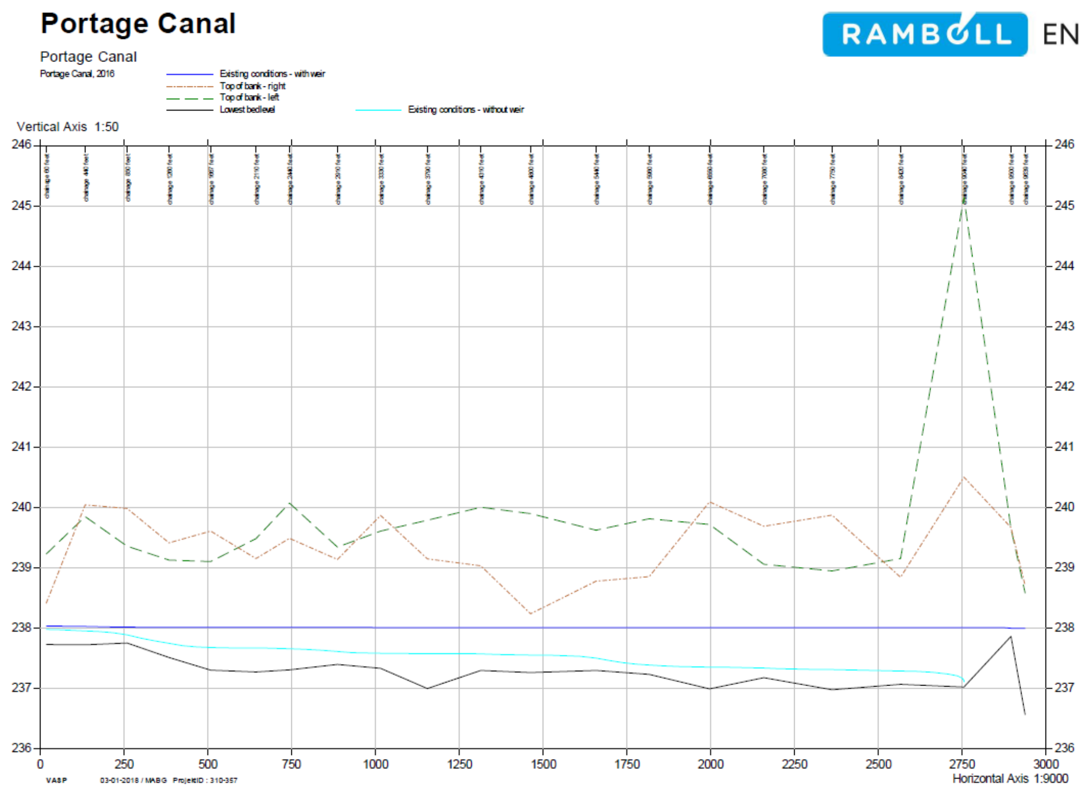


Figure 2. Longitudinal profile with and without the weir (Appendix 3.2)

2. Proposed Conditions

The remedial project goals are as follows:

- Removing or stabilizing the contaminated sediment
- Improving the biological conditions (oxygenation) in Portage Canal

The following three scenarios were simulated using the VASP model:

1. Remove 6.0-24 inches of the muddy deposit layer and backfill with 4.0 in.
2. Remove the muddy deposit layer to build a bike trail in Segment 2.

Remove the muddy deposit layer, and create a bike trail in Segment 2, and create new grade and sinuosity in the canal to optimize the physical parameters and oxygenation of the water in the Canal and to improve biological conditions. Longitudinal profile with existing waterlevel and bedlevel and scenario conditions is shown in appendix 5.2 (Scenario 1 and 2) and appendix 5.3 (Scenario 3).

In Appendices 4.1-4.4, a scenario description is shown on the map of Portage Canal. The creation of a new stream with a meandered course in Scenario 3 is illustrated in the Figure 3 & 4, below.

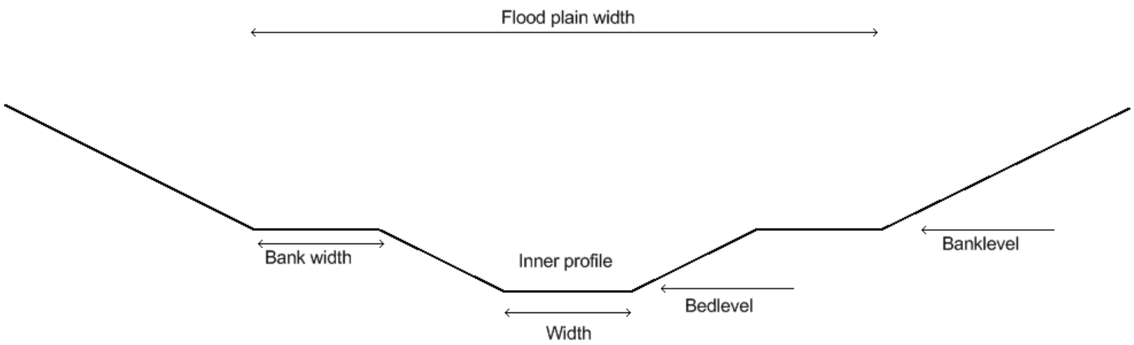


Figure 3. Conceptual double profile

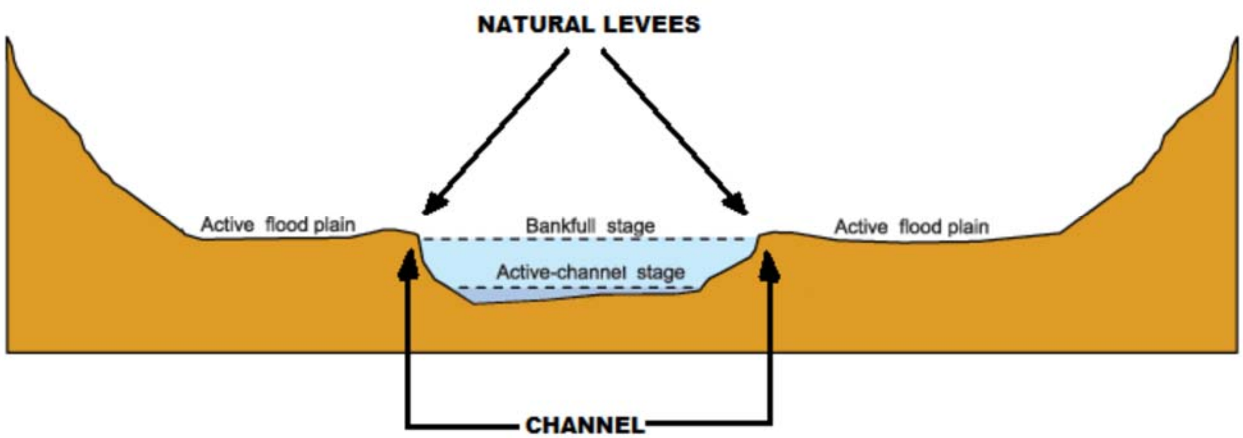


Figure 4. Natural stream / flood profile

3. Summary of Results / Conditions

In Scenarios 1 and 2, the depth and velocity in the stream will depend on whether the weir is removed. If the weir is maintained, water depth will increase and the velocity will decrease. If the weir is removed, water depth will depend on the water level in Fox River. Because the bed level is lowered when the weir is removed, the water level in the Canal will probably have a lower grade than in Scenario 3.

In Scenario 3, an average grade of 0.6% is created by lifting the bed elevation in the vicinity of Adam Street. To improve oxygenation and biological conditions in Portage Canal, it is necessary to remove the weir between Portage Canal and Fox River. Without weir removal, the water depth will be 2.5-5.2 feet and the velocity will be below 0.08 ft/s.

Without the weir, a combination of Scenarios 1, 2, and 3 can be evaluated. Segments of the streams can be restored with a grade of 1‰, and segment in-between can be used as small pools (riffle-pool sequences). This creates a stream with dynamic and diverse flows, which improves habitat for fish and fauna between the Canal and Fox River (Appendix 5.4).

Between Adams Street and the outlet into Fox River there is approximately 5 feet (1.5 meter) difference in bed elevations. In the project setup with a combination of Scenarios 1, 2, and 3, it is possible adjust the grade in Portage Canal so that 50% of the canal has a grade of 1% and the remaining 50% is relatively flat to form intermittent pools. If the reach with 1% grade is designed with an appropriate combination of gravel and other materials, it will serve as good spawning habitat for the resident fish.

Table 1 summarizes the depth and velocity values for the existing condition as well as the three scenarios discussed above.

Table 1. Summary of depth and velocity

Description	Depth (feet)	Velocity (ft/s)	Comment
Existing Profile	2.0 – 3.3	0.08	With Weir
	0.7 – 1.3	0.3-0.5	Without Weir
Scenario 1	+0.5-2.0	Lower than existing conditions with weir	
Scenario 2	0.5-2.0	Lower than existing conditions with weir	
Scenario 3	1.0	0.7	

The combination of the scenarios is illustrated in Appendix 5.4 and Figure 5 below.

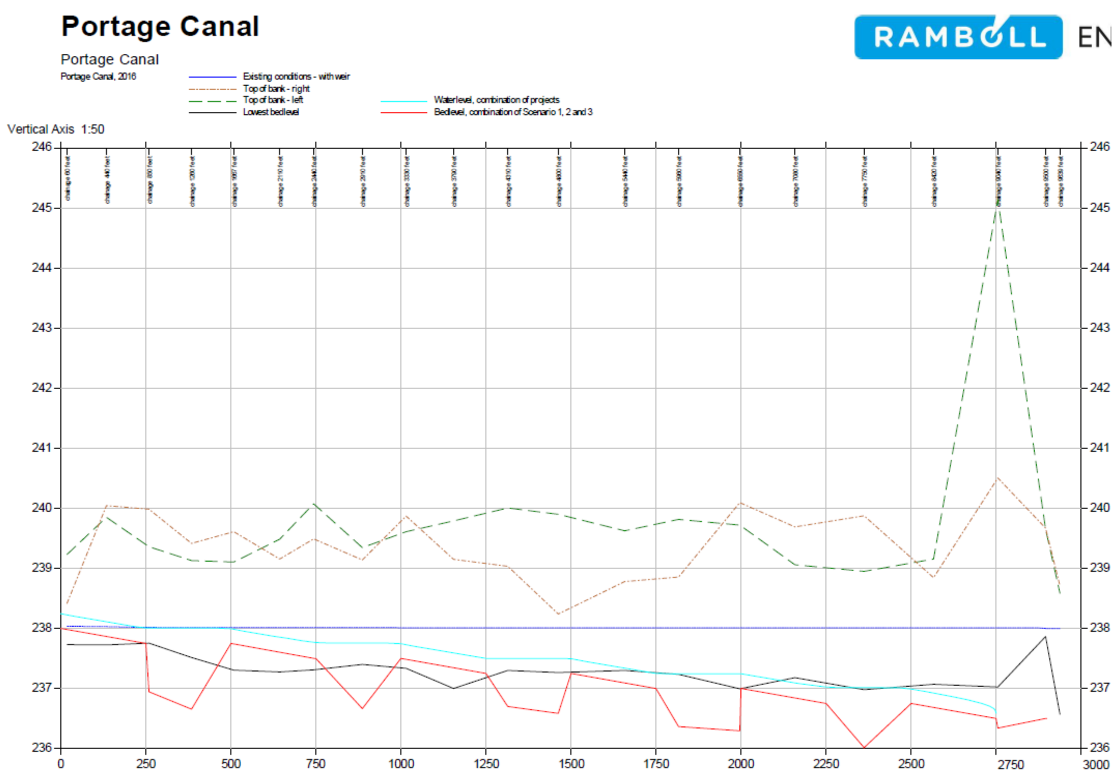
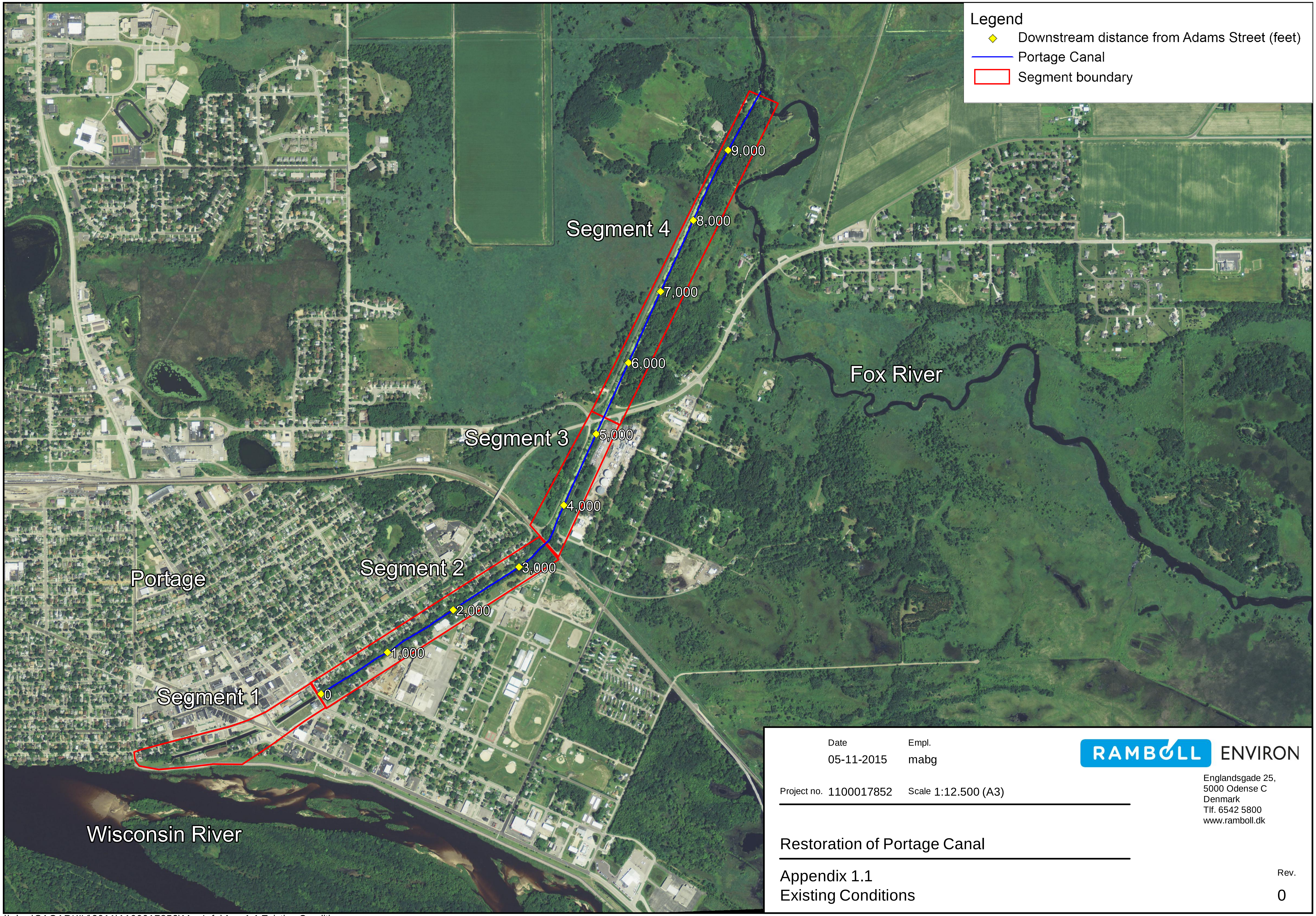


Figure 5. Combination of Scenarios 1, 2 and 3 compared to existing conditions (Appendix 5.4)

APPENDICES



Date 05-11-2015

Empl. mabg

Project no. 1100017852

Scale 1:12.500 (A3)

RAMBOLL ENVIRON

Englandsgade 25,
5000 Odense C
Denmark
Tlf. 6542 5800
www.ramboll.dk

Restoration of Portage Canal

Appendix 1.1
Existing Conditions

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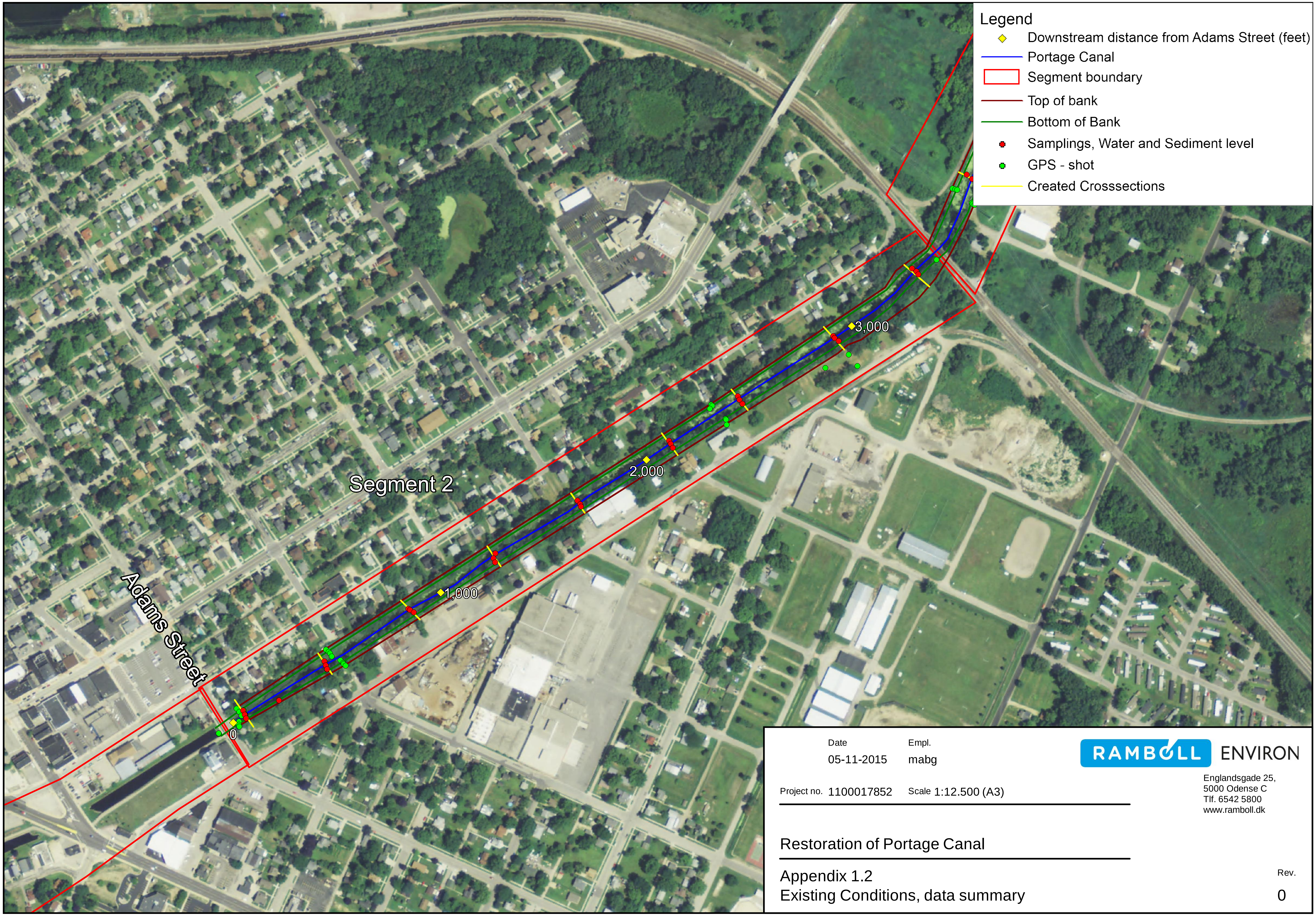

Date 05-11-2015

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Restoration of Portage Canal

Appendix 1.2
Existing Conditions, data summary

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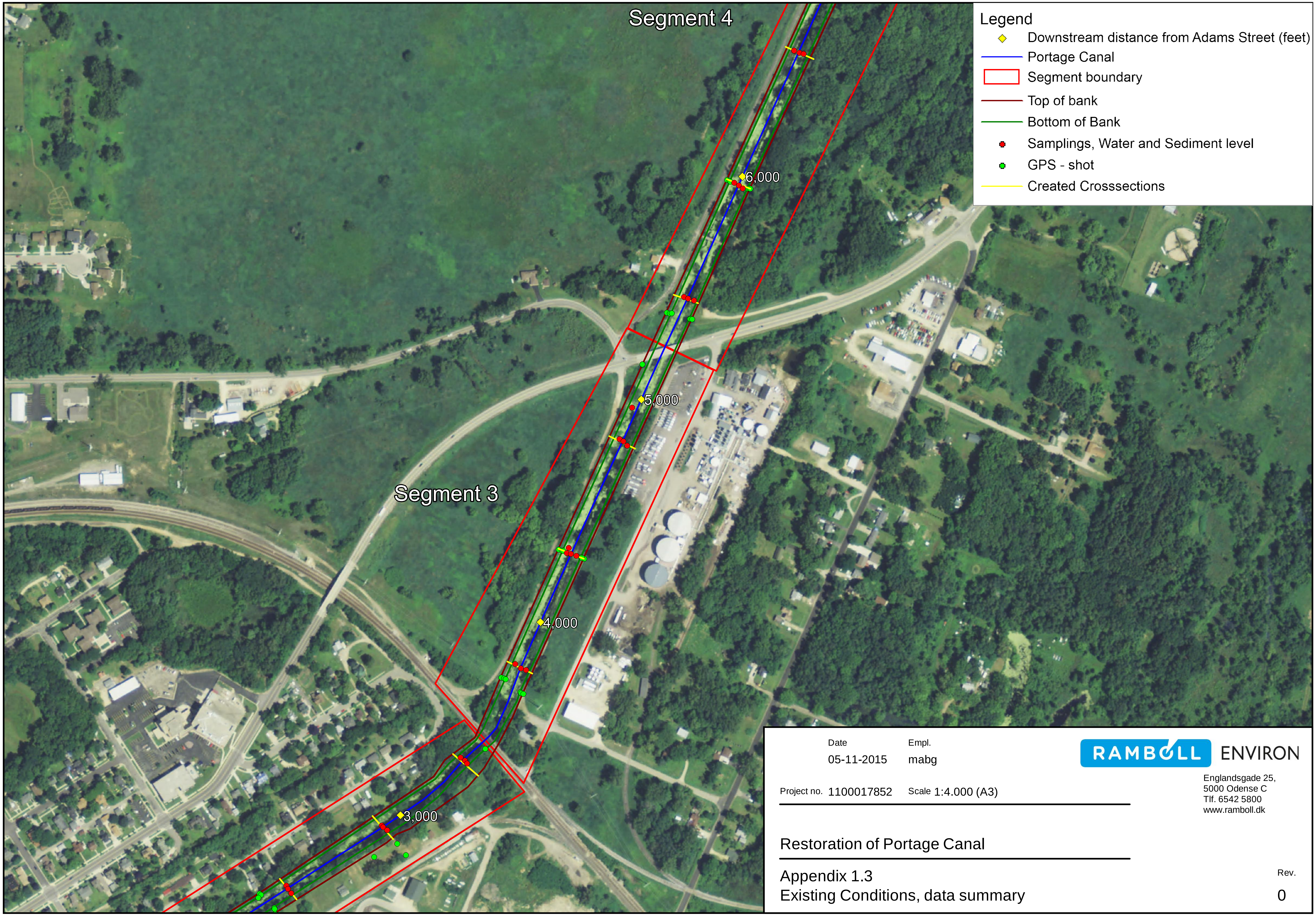
\\cher\SAGARKIV\2011\1100017852\MapInfo\App 1.2 Existing Conditions, data summary.wor



Date	Empl.
05-11-2015	mabg

Project no. 1100017852 Scale 1:4.000 (A3)

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Restoration of Portage Canal

Appendix 1.3
Existing Conditions, data summary

Rev.
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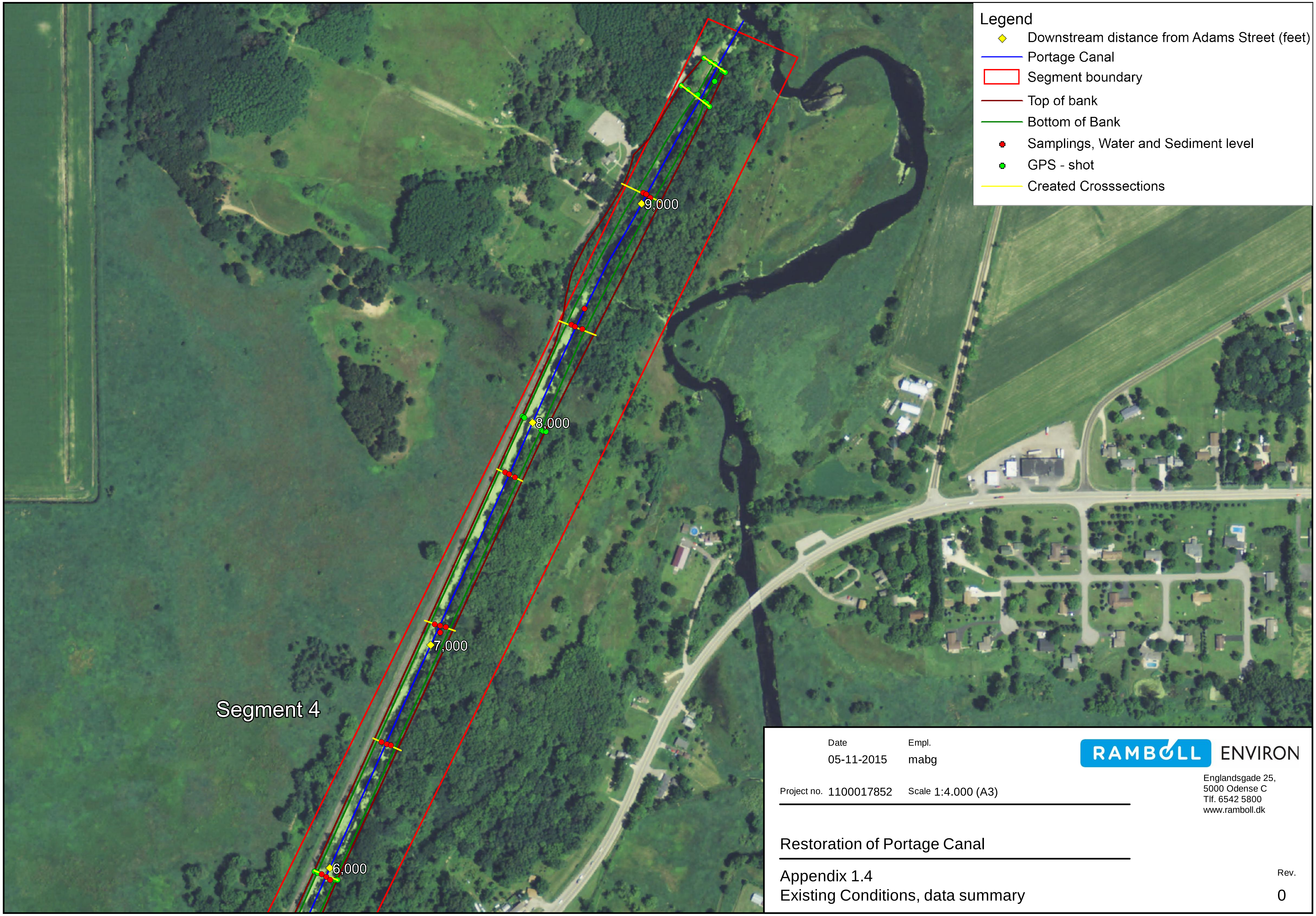

Date	Empl.
05-11-2015	mabg

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Restoration of Portage Canal

Appendix 1.4
Existing Conditions, data summary

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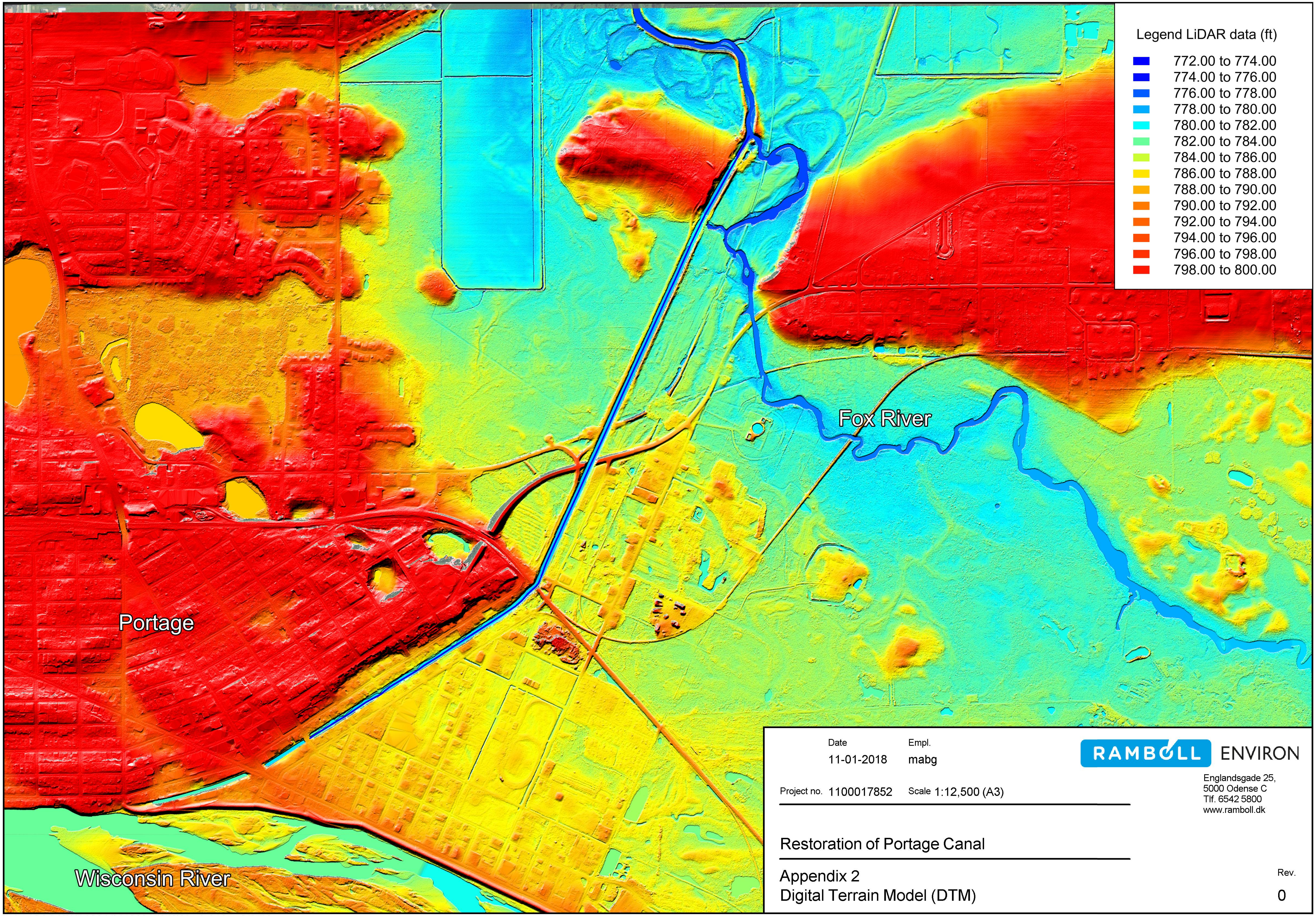

Date 11-01-2018
Empl. mabg

Project no. 1100017852
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Restoration of Portage Canal

Appendix 2
Digital Terrain Model (DTM)

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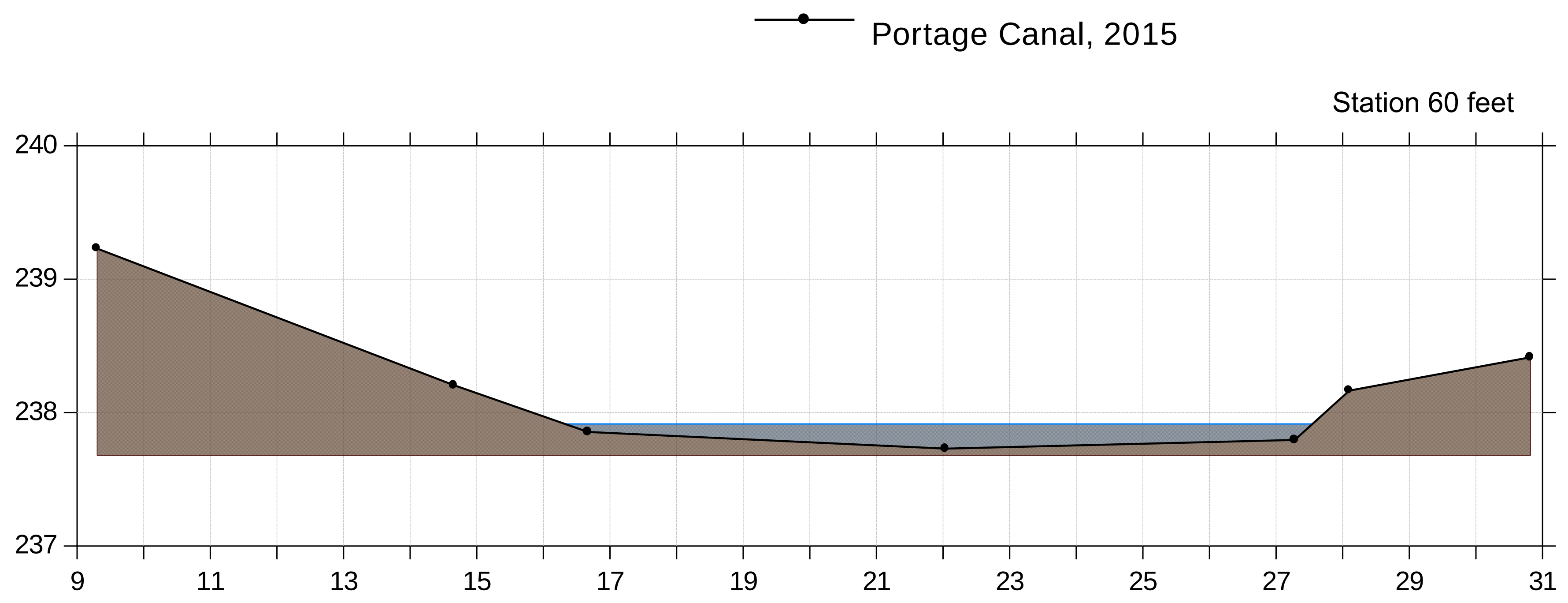
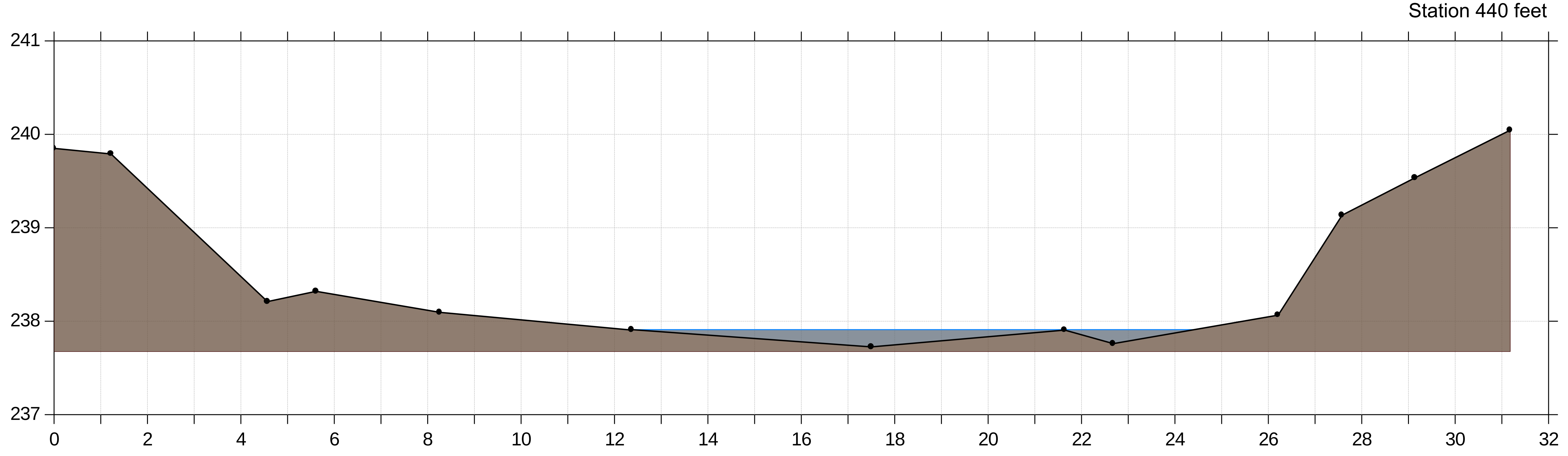
Portage Canal

Portage Canal

Appendix 3.1



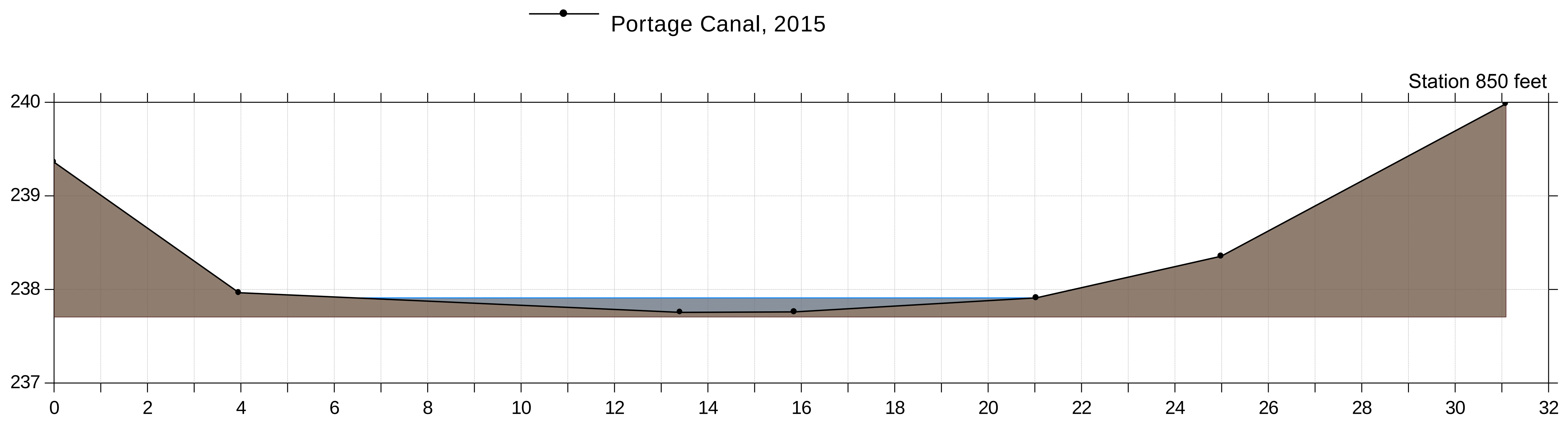


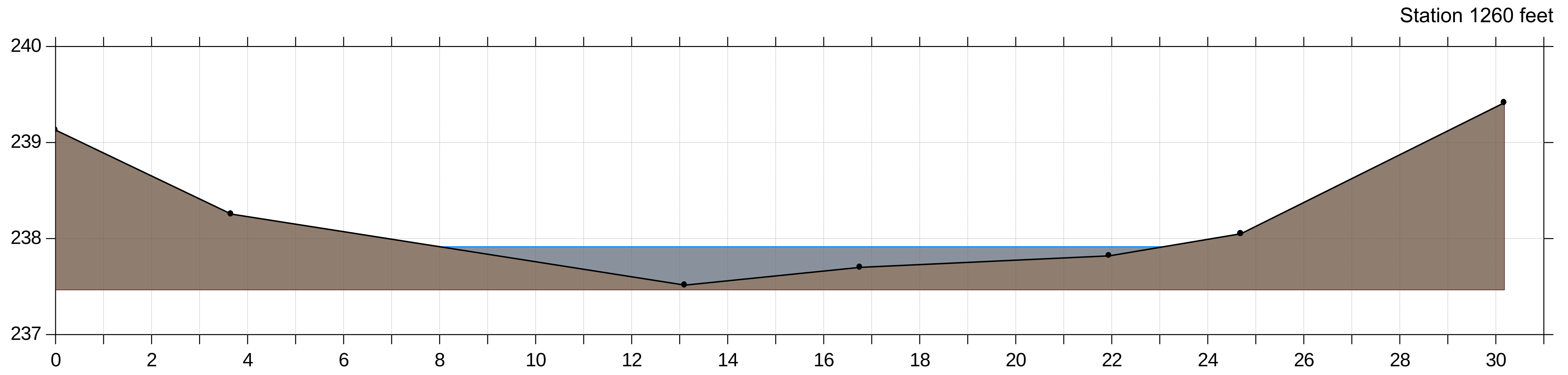
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

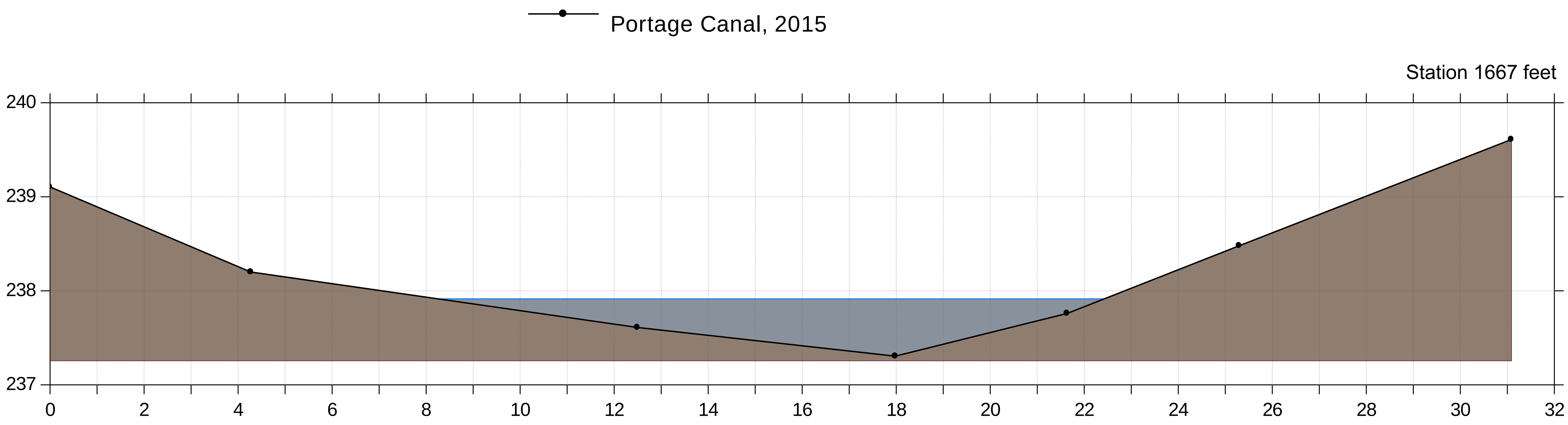
Appendix 3.1

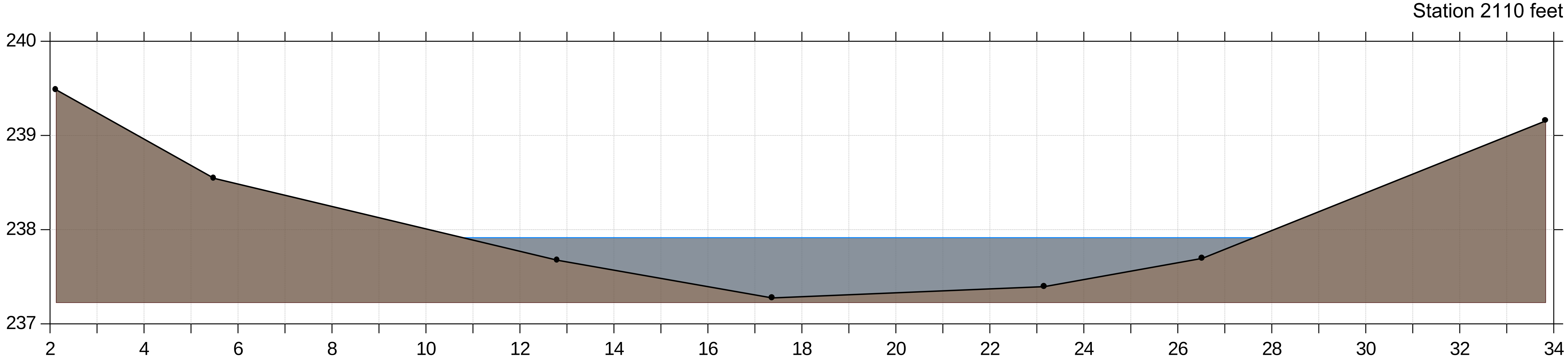




- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Appendix 3.1





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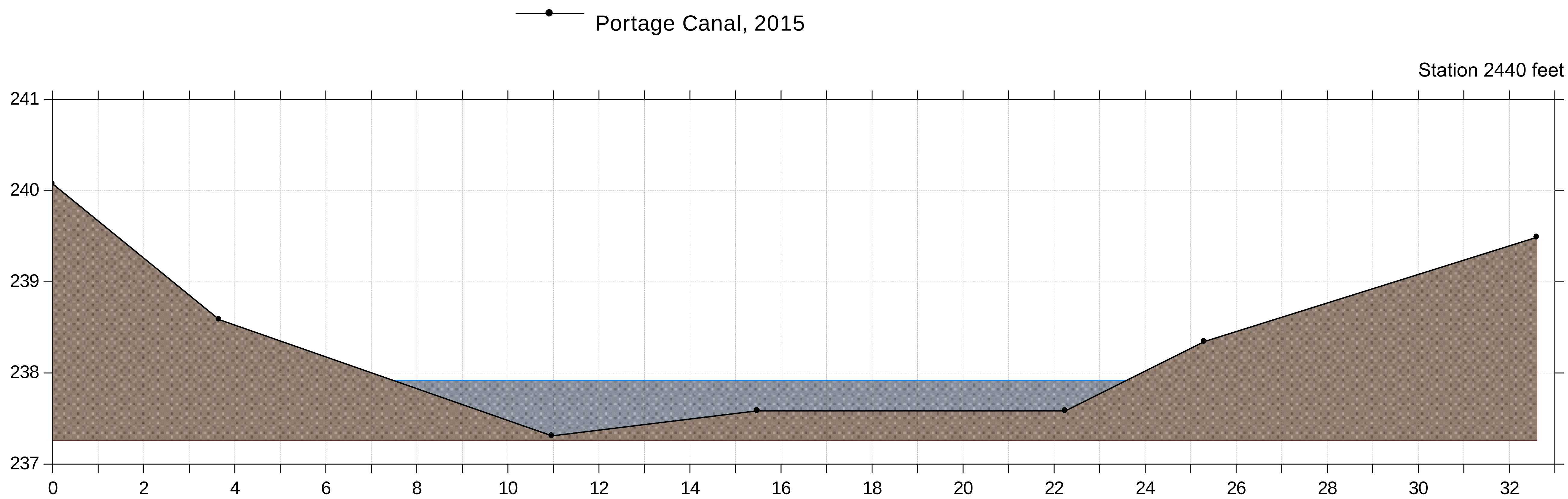
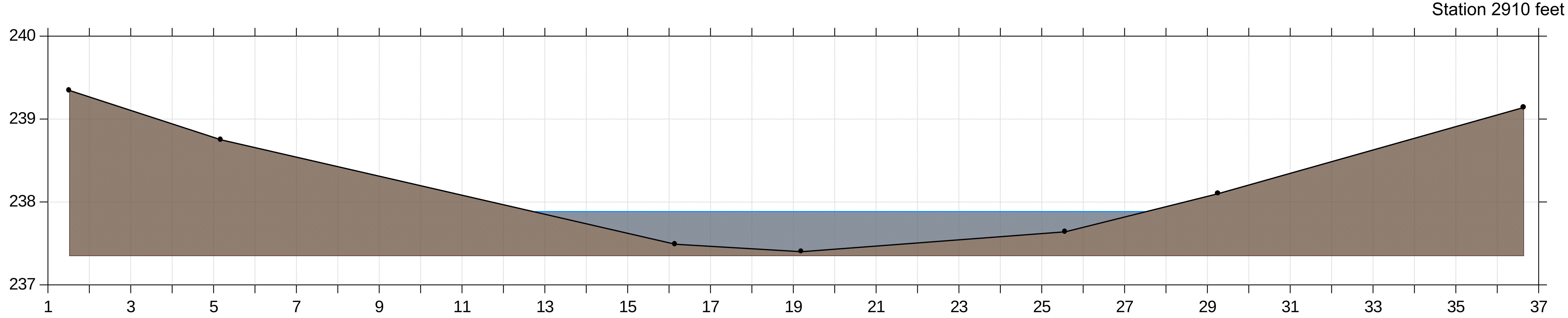
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)



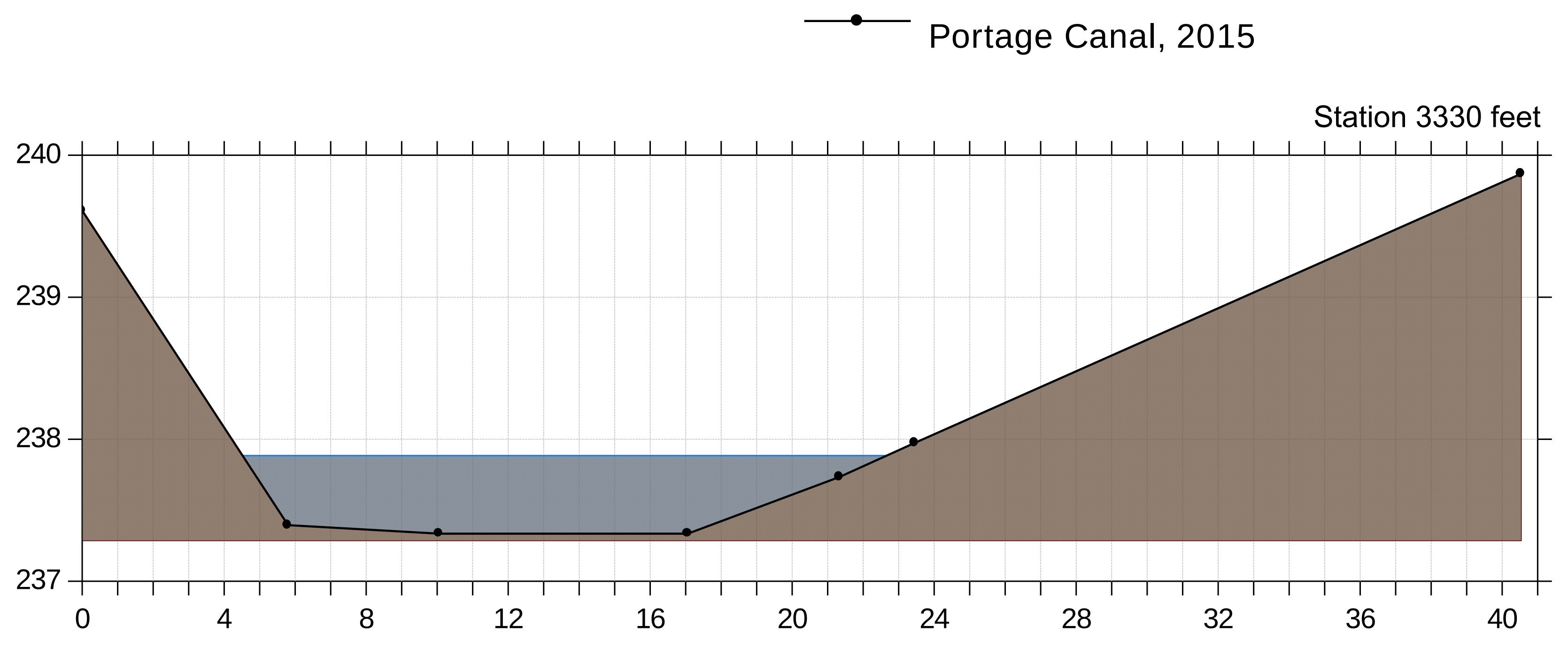


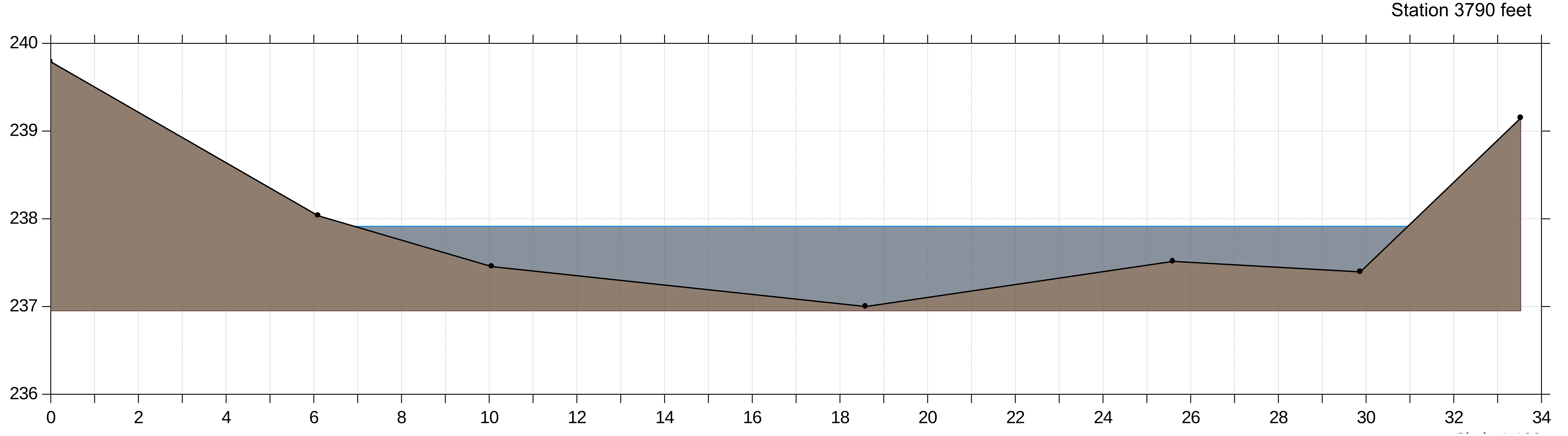
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

Appendix 3.1





- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
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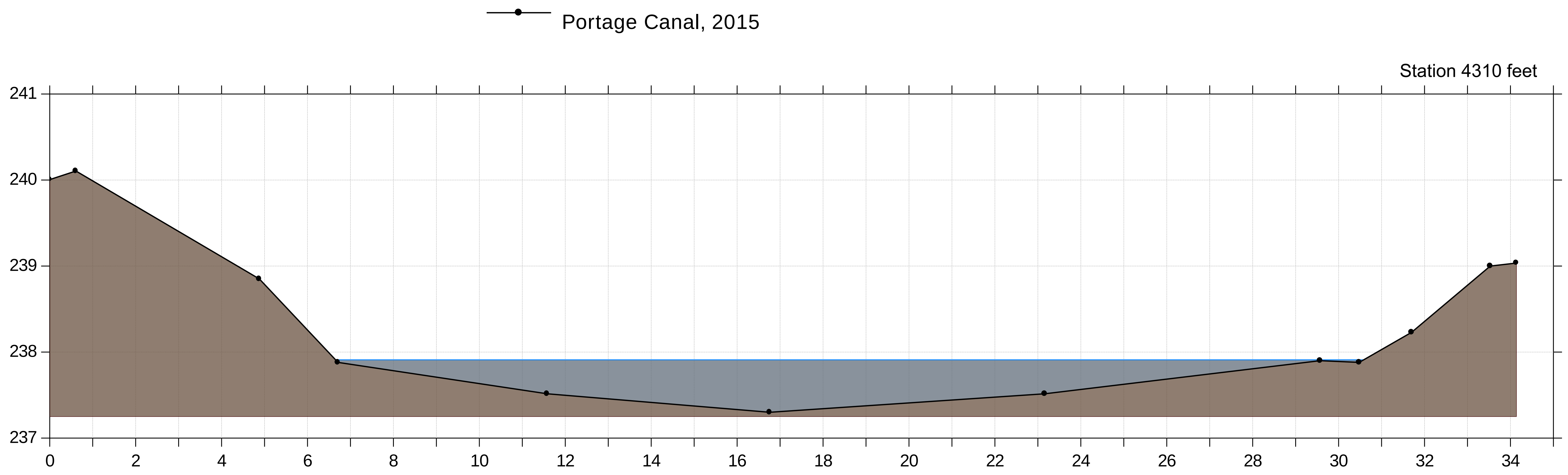
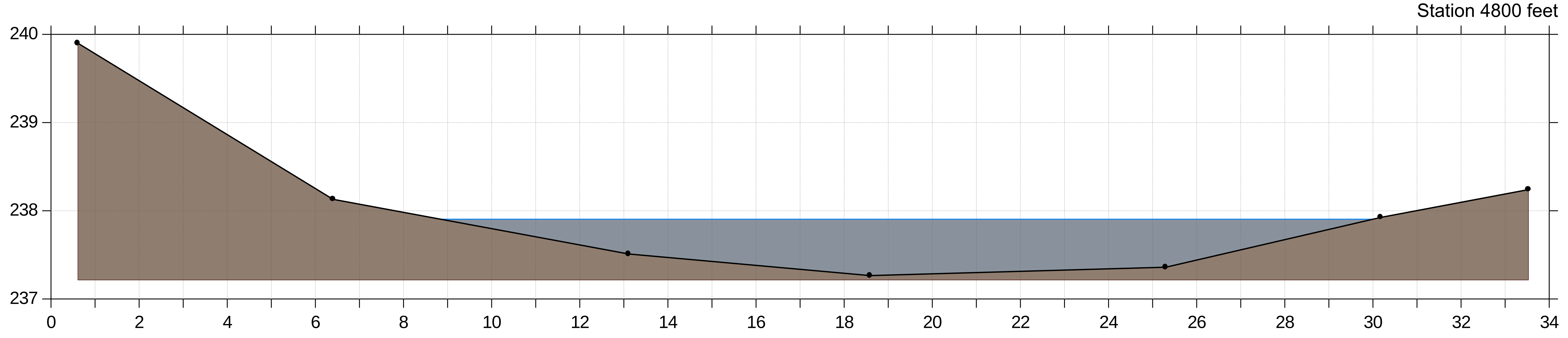
VASP 04-01-2018 / MABG ProjektID : 310-357

Portage Canal

Portage Canal

Appendix 3.1





VASP 04-01-2018 / MABG ProjektID : 310-357

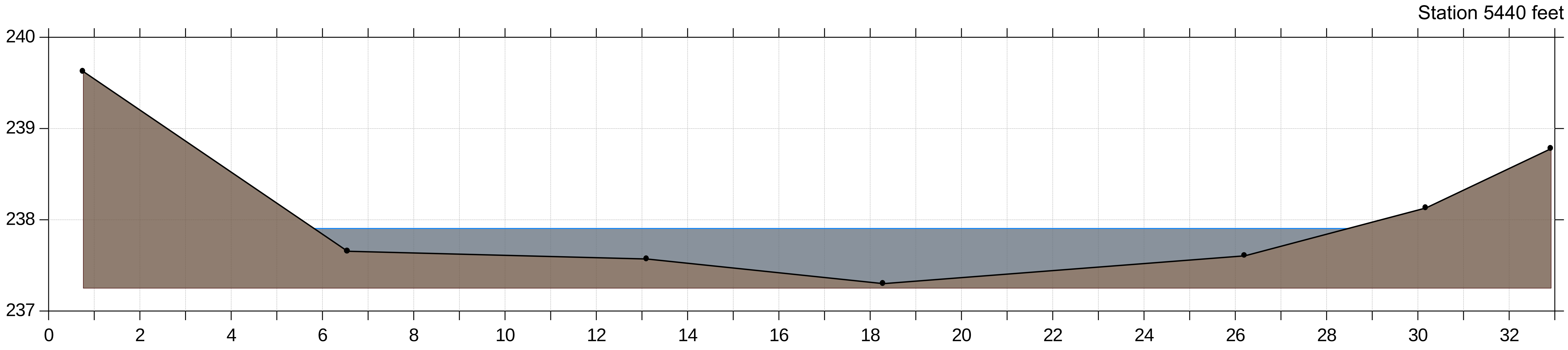
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

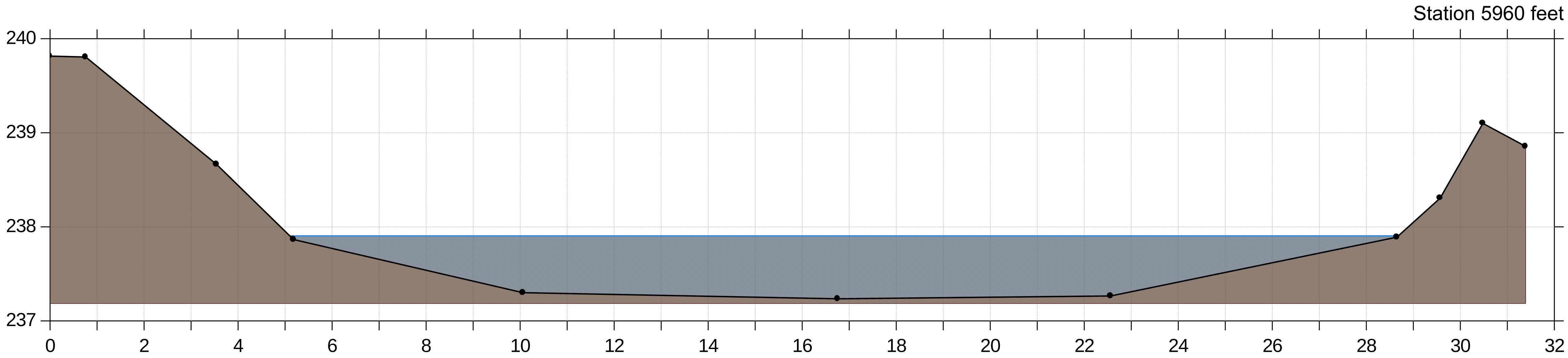
Portage Canal

Portage Canal

Appendix 3.1

Portage Canal, 2015





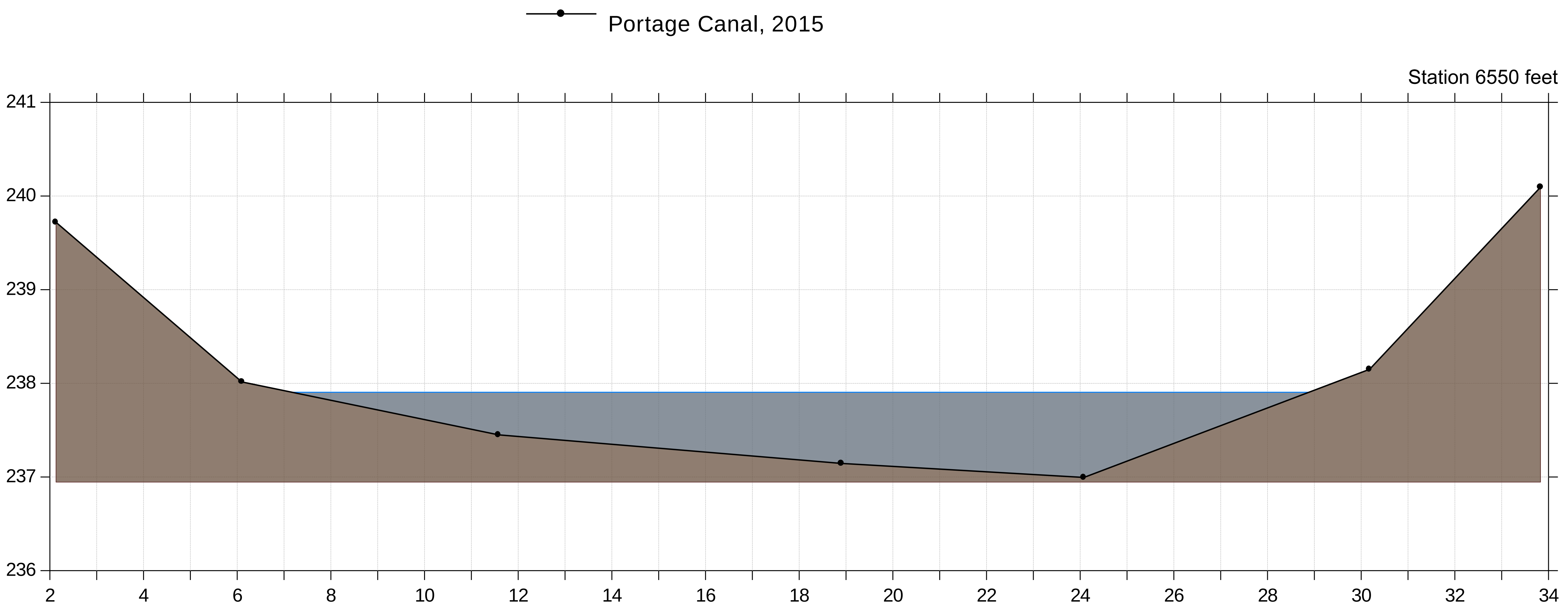
VASP 04-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

Appendix 3.1

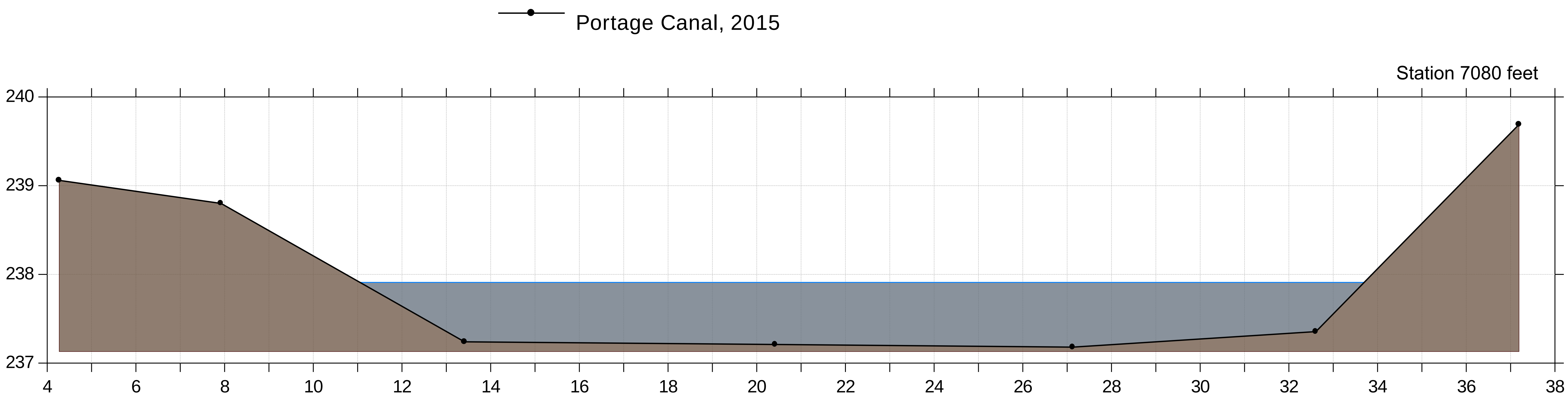


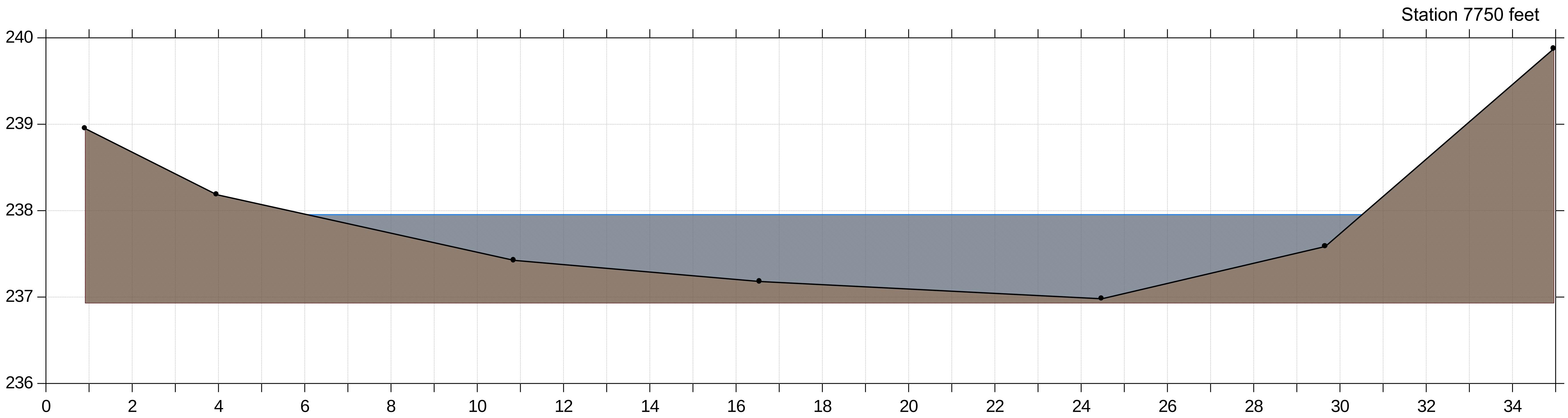
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

Appendix 3.1



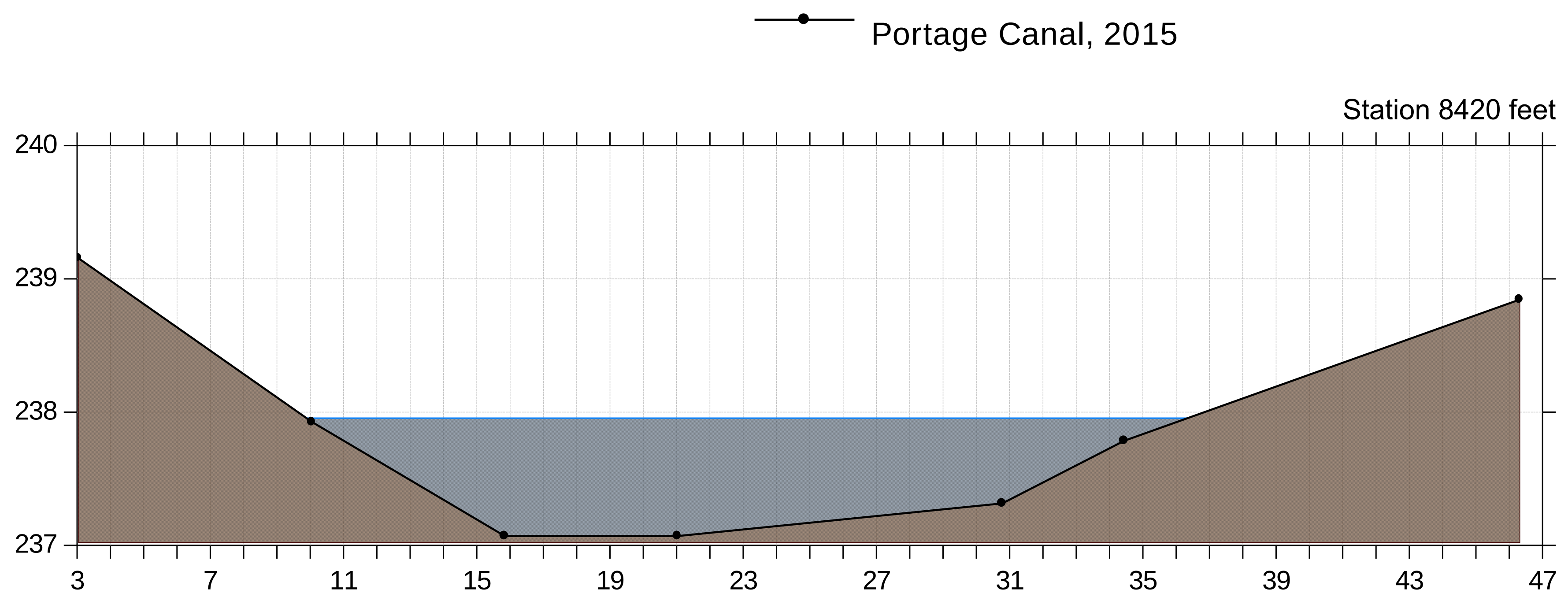


- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

Appendix 3.1

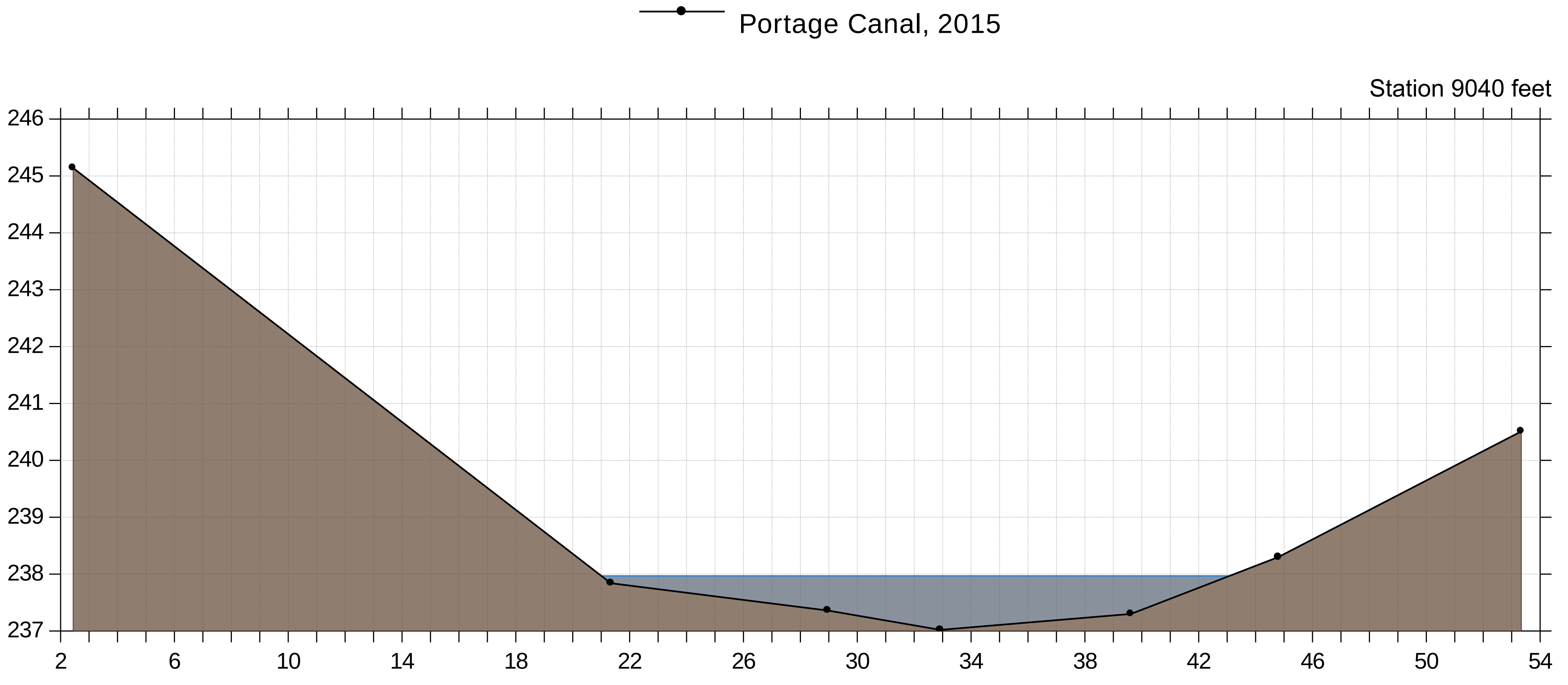


- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:200
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Portage Canal

Appendix 3.1



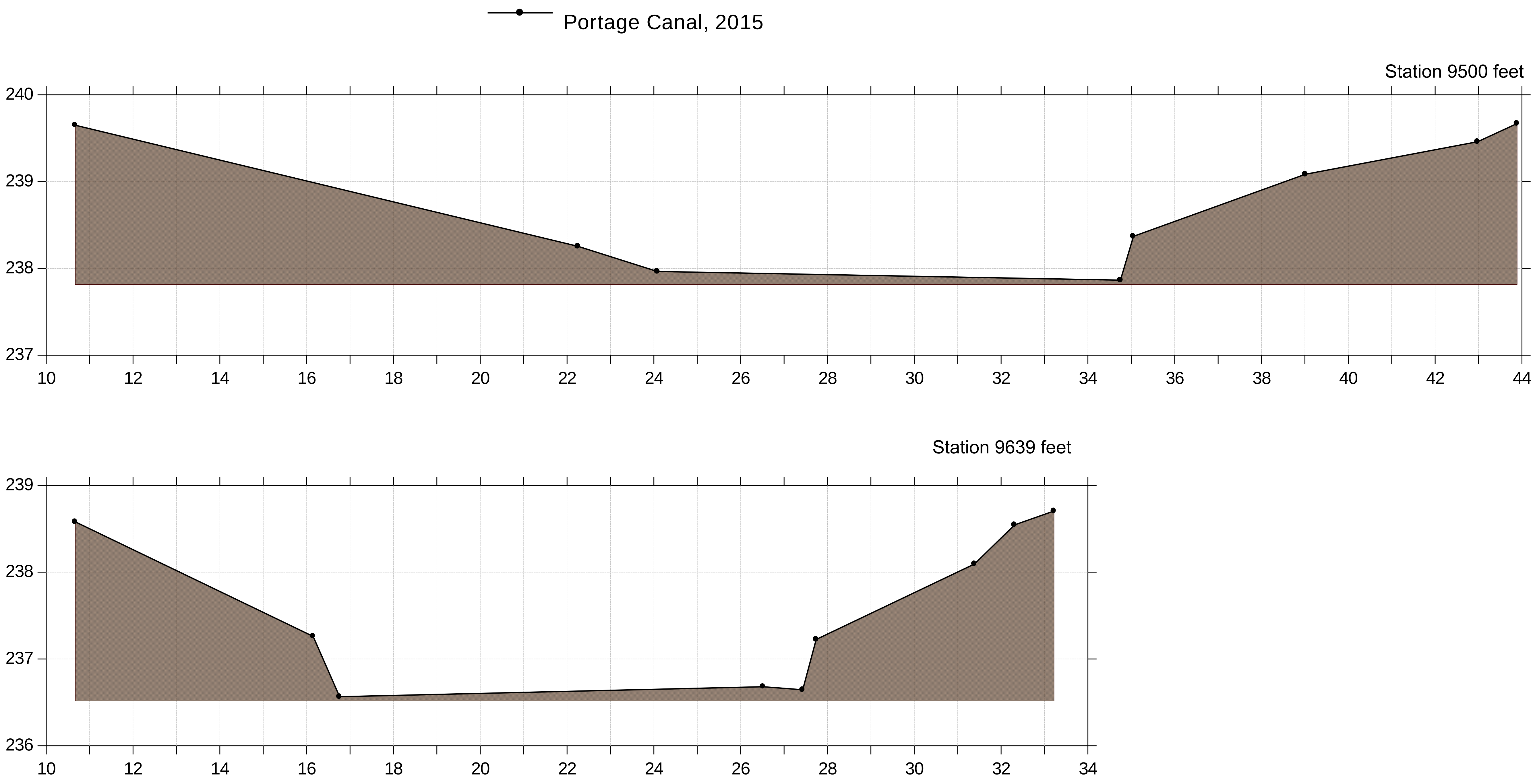
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:200
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

VASP 04-01-2018 / MABG ProjektID : 310-357

Portage Canal

Portage Canal

Appendix 3.1

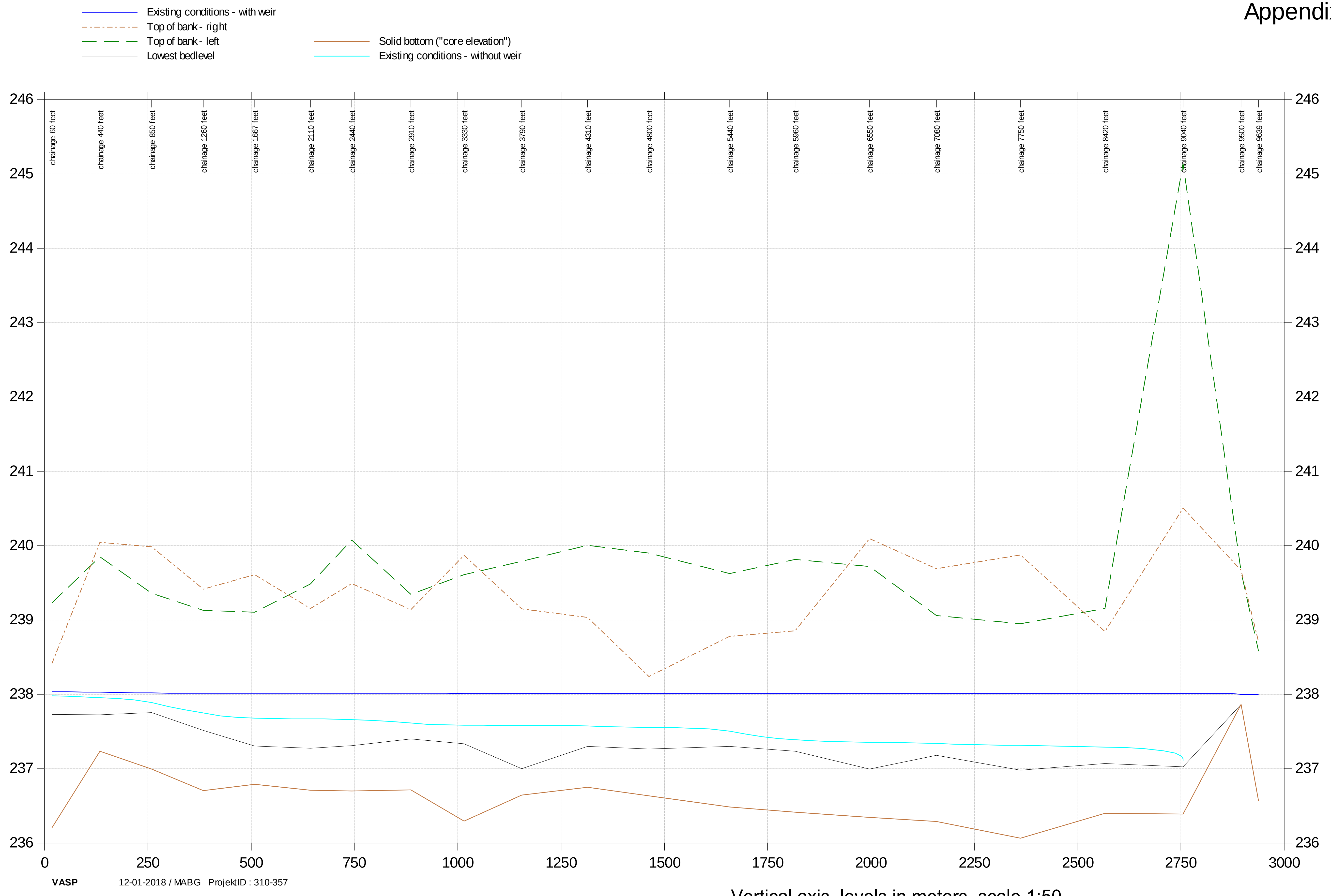


- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

VASP 04-01-2018 / MABG ProjektID : 310-357

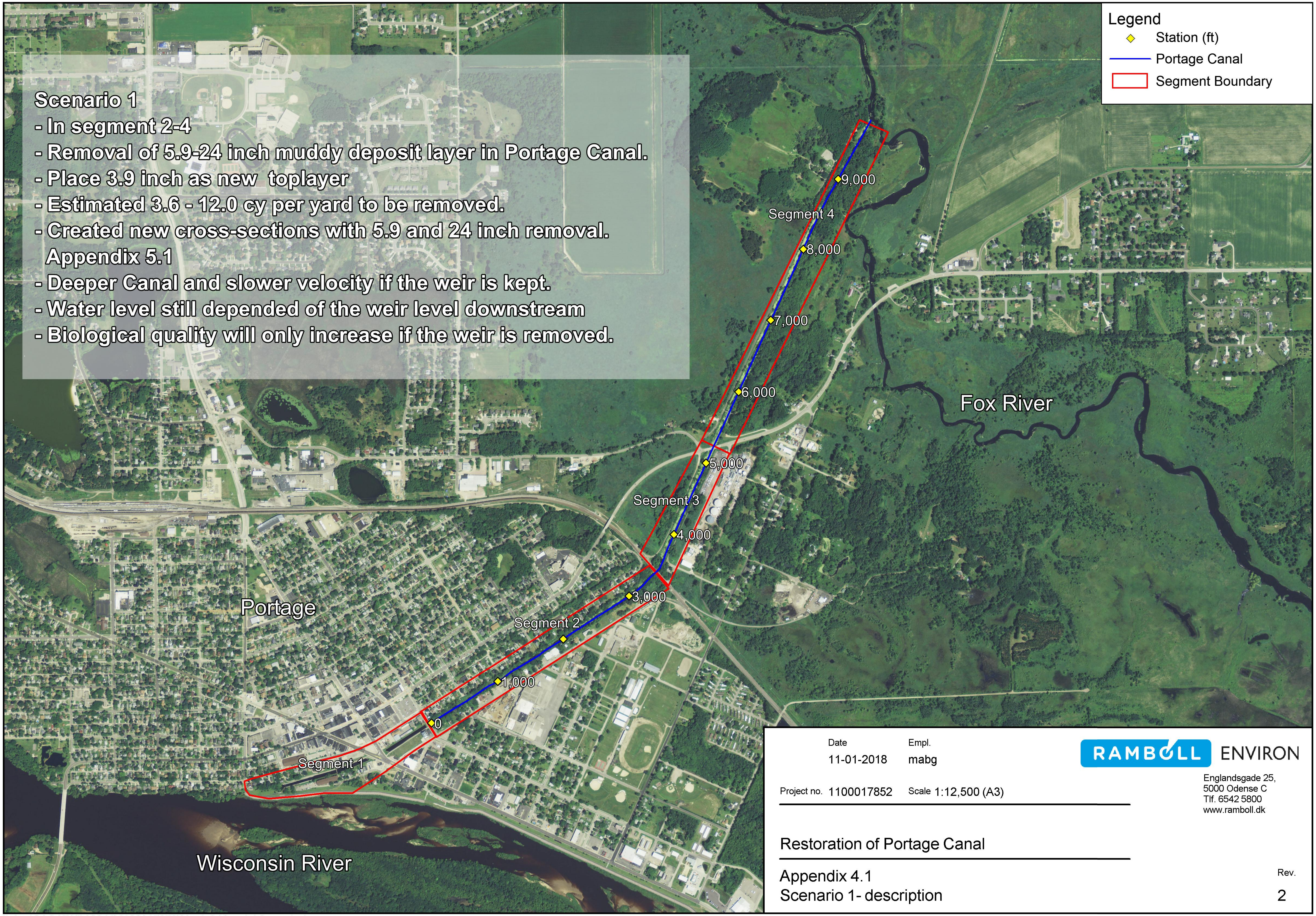
Portage Canal

Appendix 3.2 rev1



- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, Station in meters, scale 1:9,000
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Scenario 1
- In segment 2-4
- Removal of 5.9-24 inch muddy deposit layer in Portage Canal.
- Place 3.9 inch as new toplayer
- Estimated 3.6 - 12.0 cy per yard to be removed.
- Created new cross-sections with 5.9 and 24 inch removal. Appendix 5.1
- Deeper Canal and slower velocity if the weir is kept.
- Water level still depended of the weir level downstream
- Biological quality will only increase if the weir is removed.



Date	Empl.
11-01-2018	mabg

Project no. 1100017852 Scale 1:12,500 (A3)

RAMBOLL ENVIRON

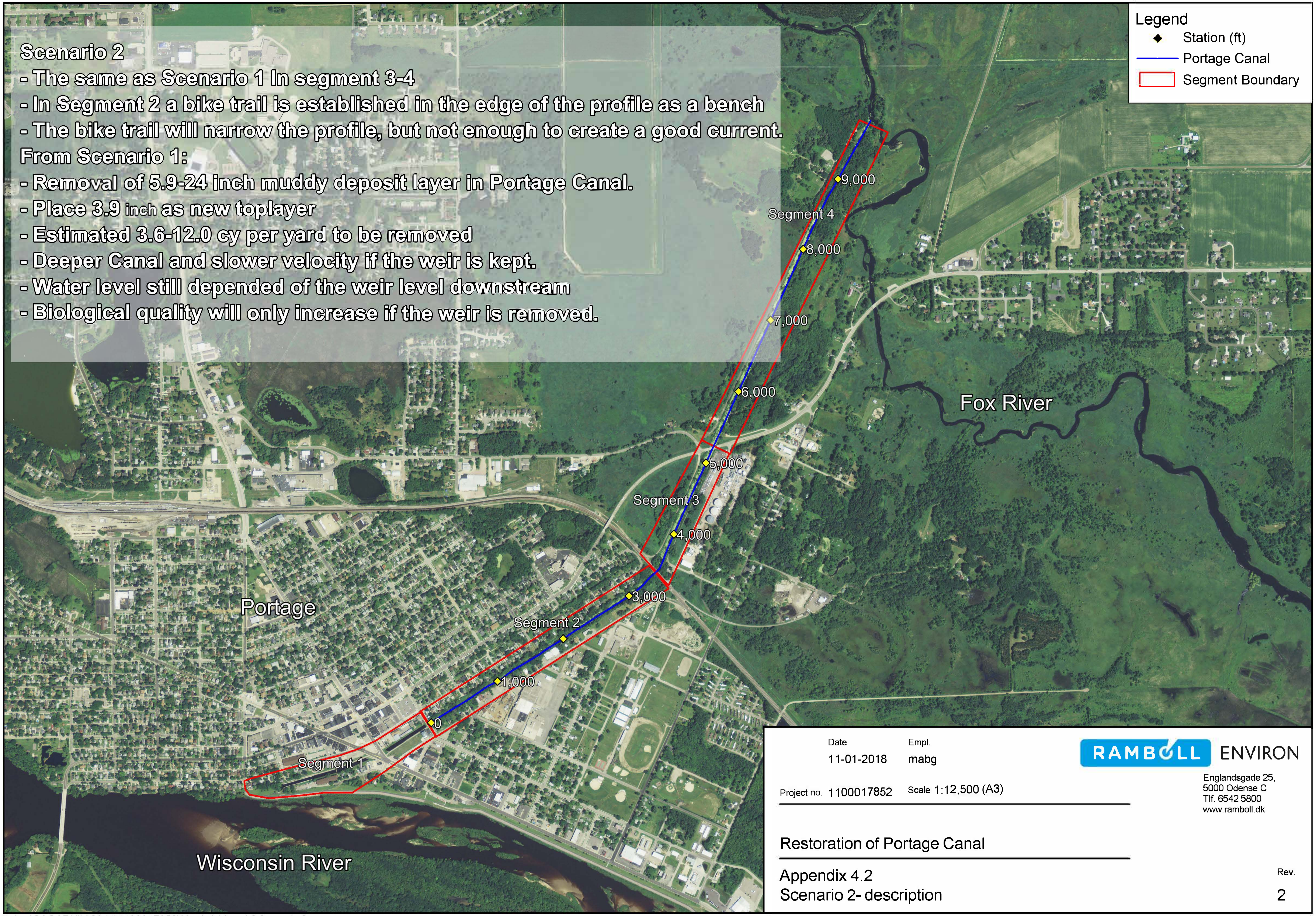
Englandsgade 25,
5000 Odense C
Tlf. 6542 5800
www.ramboll.dk

Restoration of Portage Canal

Appendix 4.1
Scenario 1- description

Rev.
2

\\cher\SAGARKIV\2011\1100017852\MapInfo\App 4.1 Scenario 1.wor



Date	Empl.
11-01-2018	mabg

Project no. 1100017852 Scale 1:12,500 (A3)

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5000 Odense C
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Restoration of Portage Canal

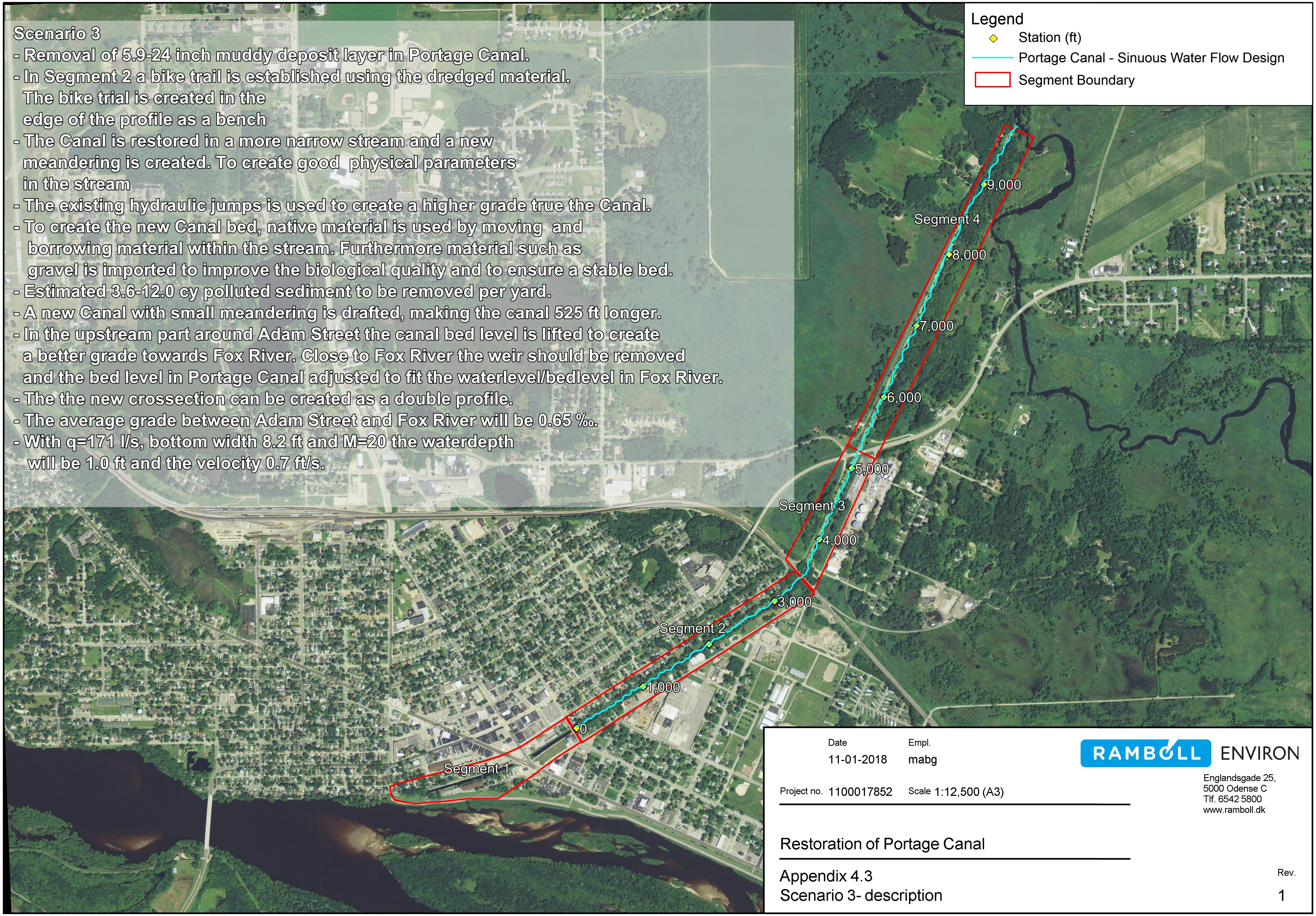
Appendix 4.2
Scenario 2- description

Rev.
2

\\cher\SAGARKIV\2011\1100017852\MapInfo\App 4.2 Scenario 2.wor

Scenario 3

- Removal of 5.9-24 inch muddy deposit layer in Portage Canal.
- In Segment 2 a bike trail is established using the dredged material. The bike trial is created in the edge of the profile as a bench
- The Canal is restored in a more narrow stream and a new meandering is created. To create good physical parameters in the stream
- The existing hydraulic jumps is used to create a higher grade true the Canal.
- To create the new Canal bed, native material is used by moving and borrowing material within the stream. Furthermore material such as gravel is imported to improve the biological quality and to ensure a stable bed.
- Estimated 3.6-12.0 cy polluted sediment to be removed per yard.
- A new Canal with small meandering is drafted, making the canal 525 ft longer.
- In the upstream part around Adam Street the canal bed level is lifted to create a better grade towards Fox River. Close to Fox River the weir should be removed and the bed level in Portage Canal adjusted to fit the waterlevel/bedlevel in Fox River.
- The the new crossection can be created as a double profile.
- The average grade between Adam Street and Fox River will be 0.65 ‰.
- With q=171 l/s, bottom width 8.2 ft and M=20 the waterdepth will be 1.0 ft and the velocity 0.7 ft/s.



Date	Empl.
11-01-2018	mabg

Project no. 1100017852 Scale 1:12,500 (A3)

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5000 Odense C
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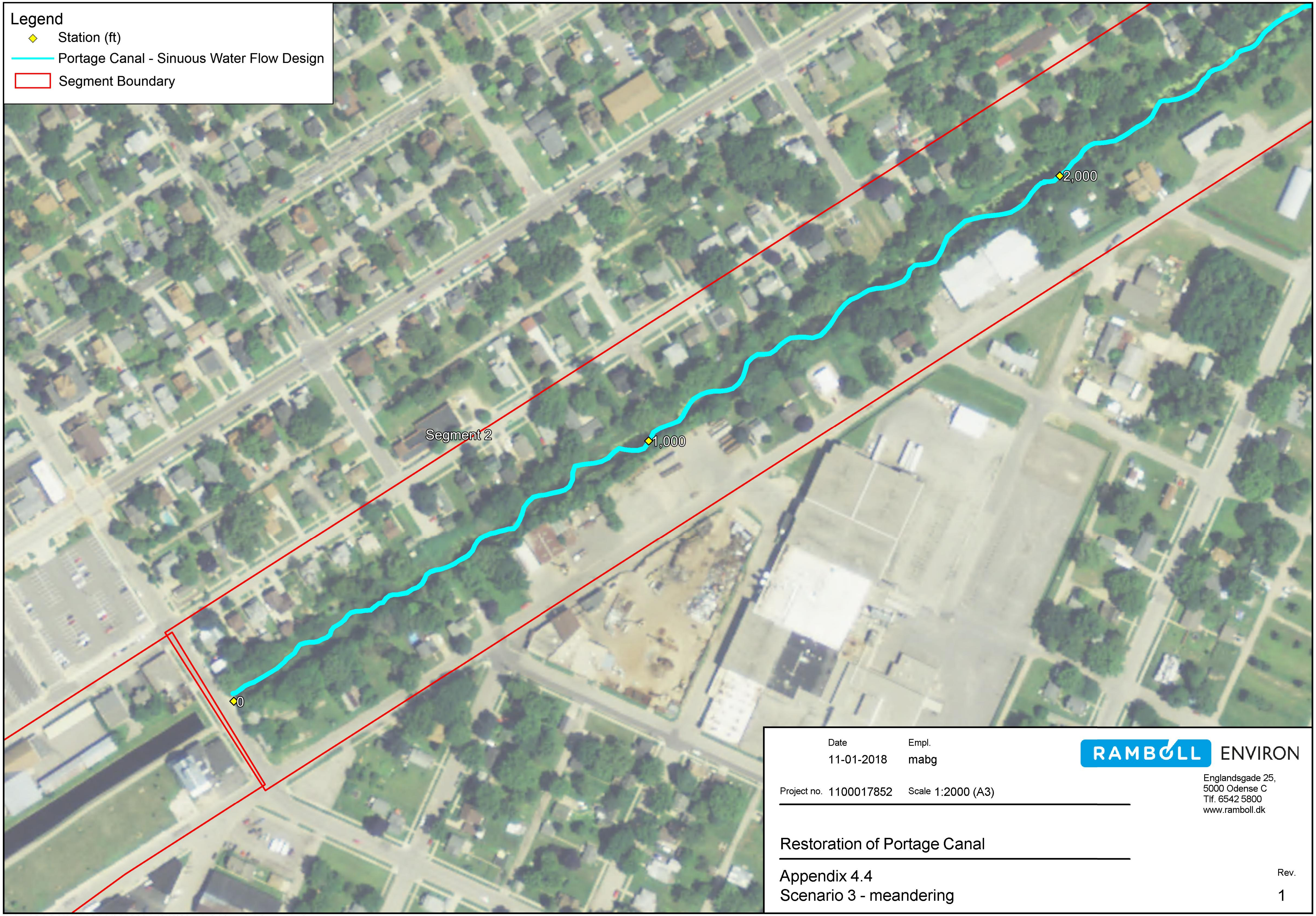
Restoration of Portage Canal

Appendix 4.3
Scenario 3- description

Rev.
1



Date 11-01-2018
Empl. mabg

Project no. 1100017852
Scale 1:2000 (A3)

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5000 Odense C
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Restoration of Portage Canal

Appendix 4.4
Scenario 3 - meandering

Rev. 1

Portage Canal

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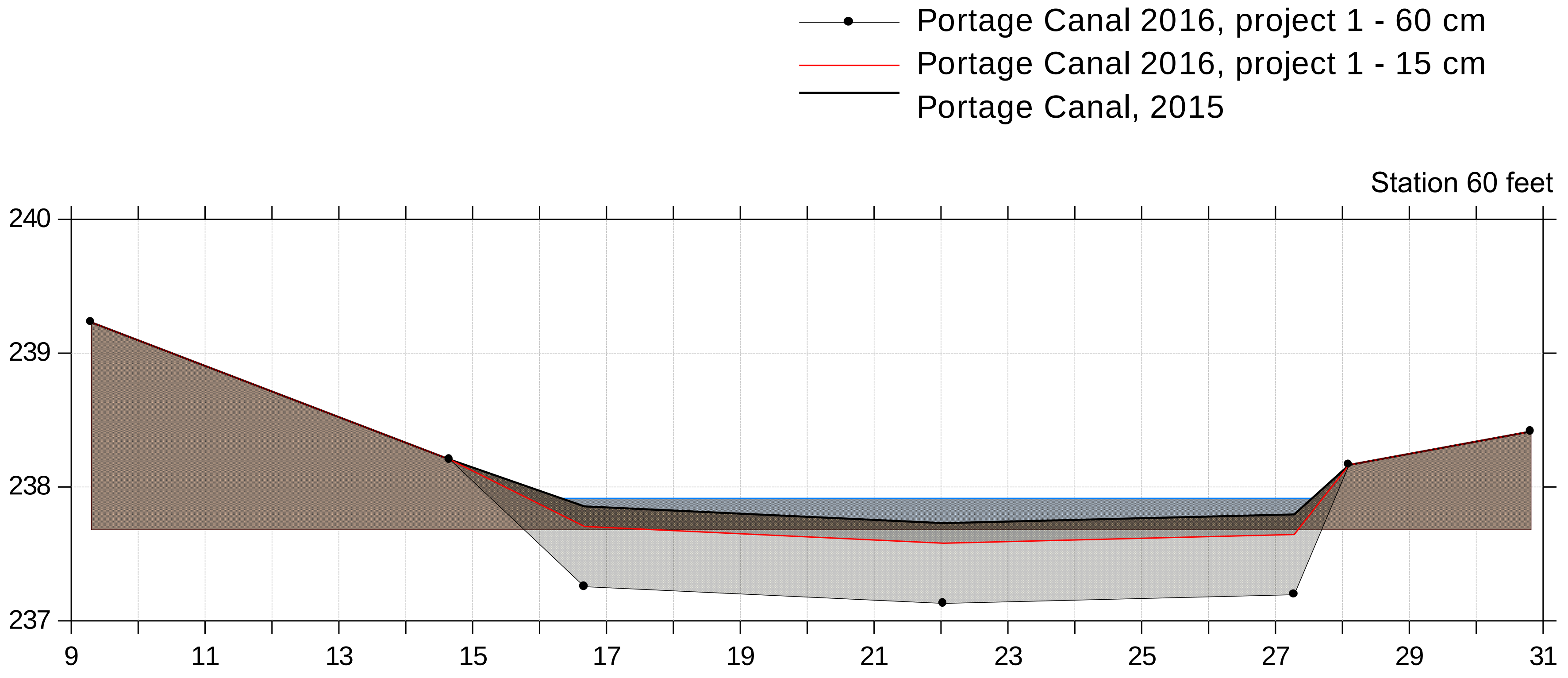
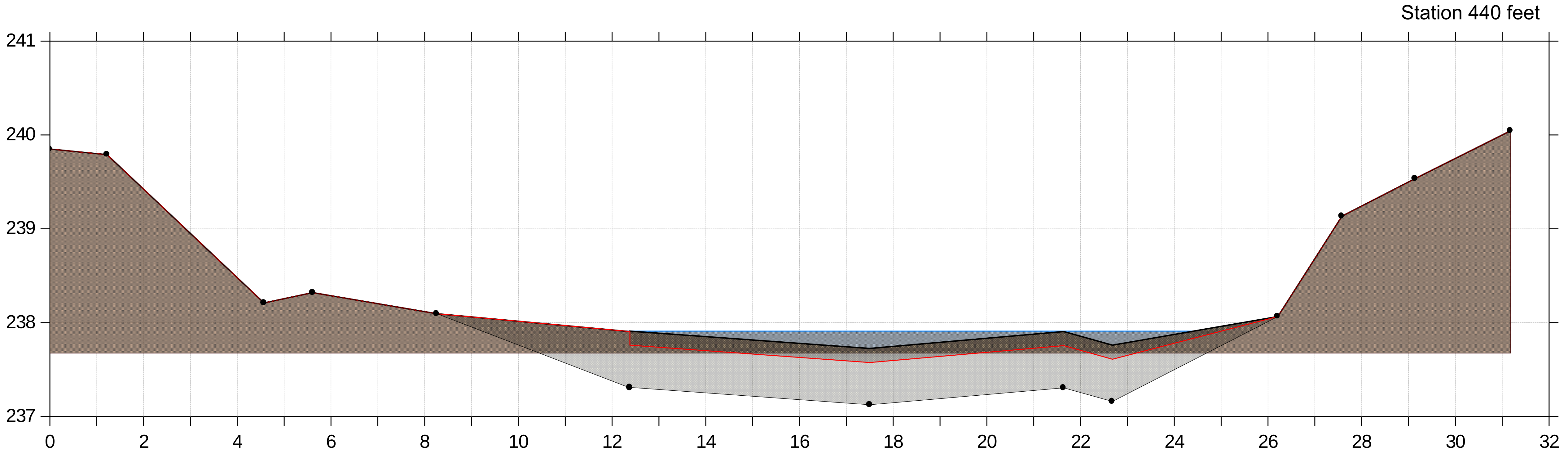
Appendix 5.1



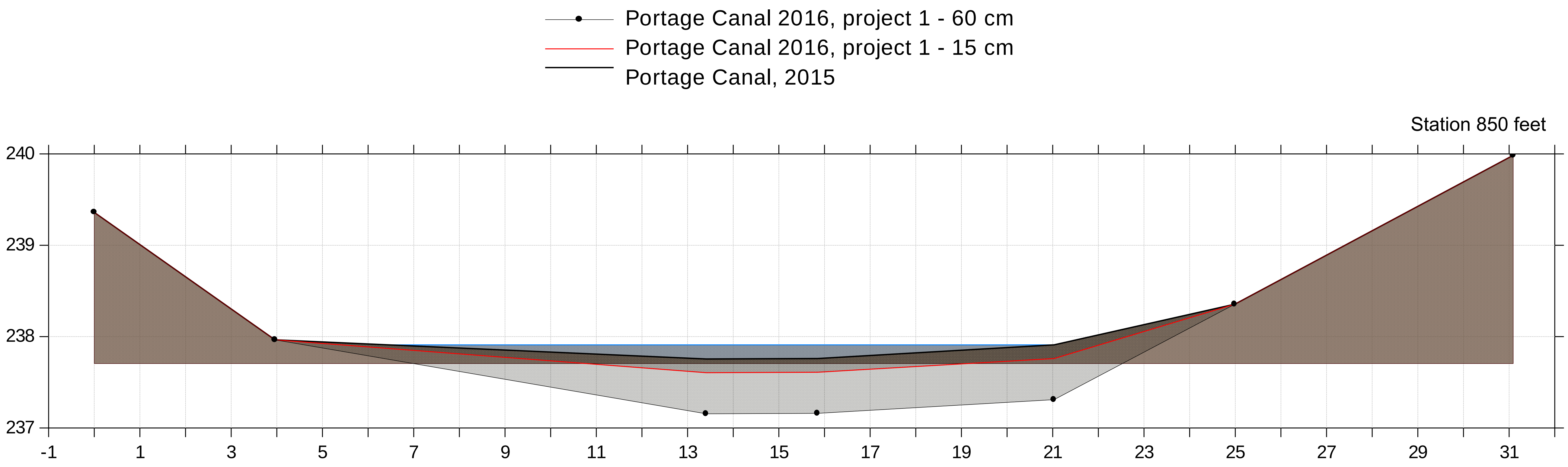


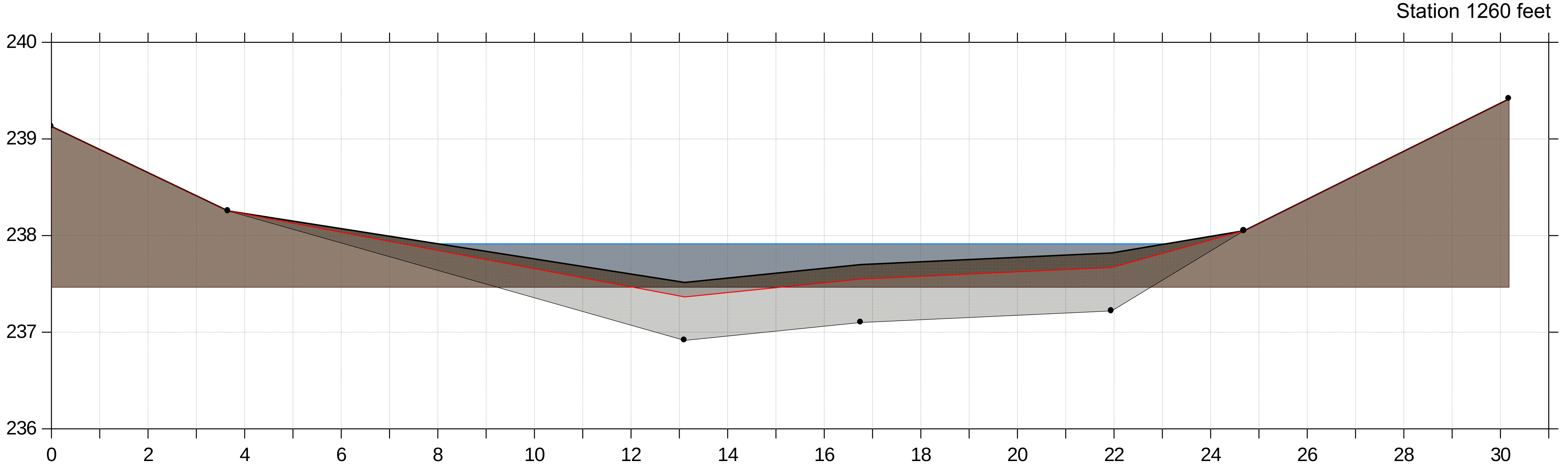
- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

VASP 12-01-2018 / MABG ProjektID : 310-357

Portage Canal

Appendix 5.1





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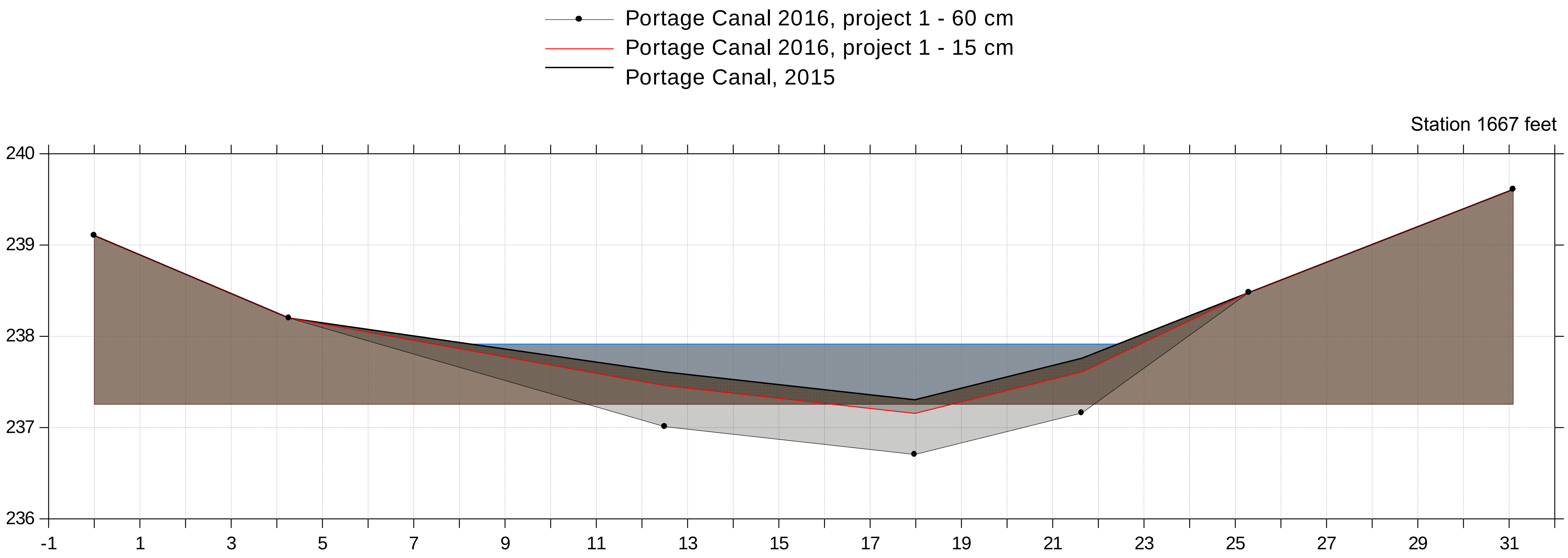
VASP 12-01-2018 / MABG ProjektID : 310-357

Portage Canal

RAMBOLL ENVIRON

Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

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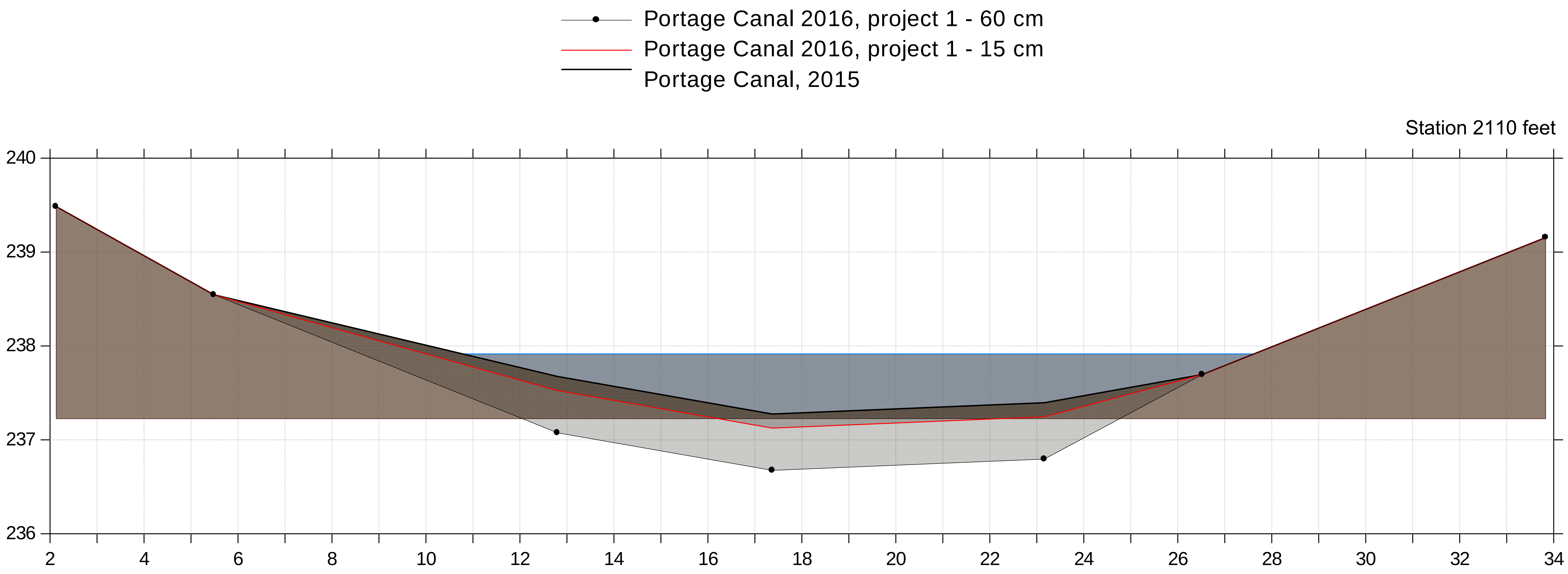
Portage Canal

RAMBOLL ENVIRON

Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

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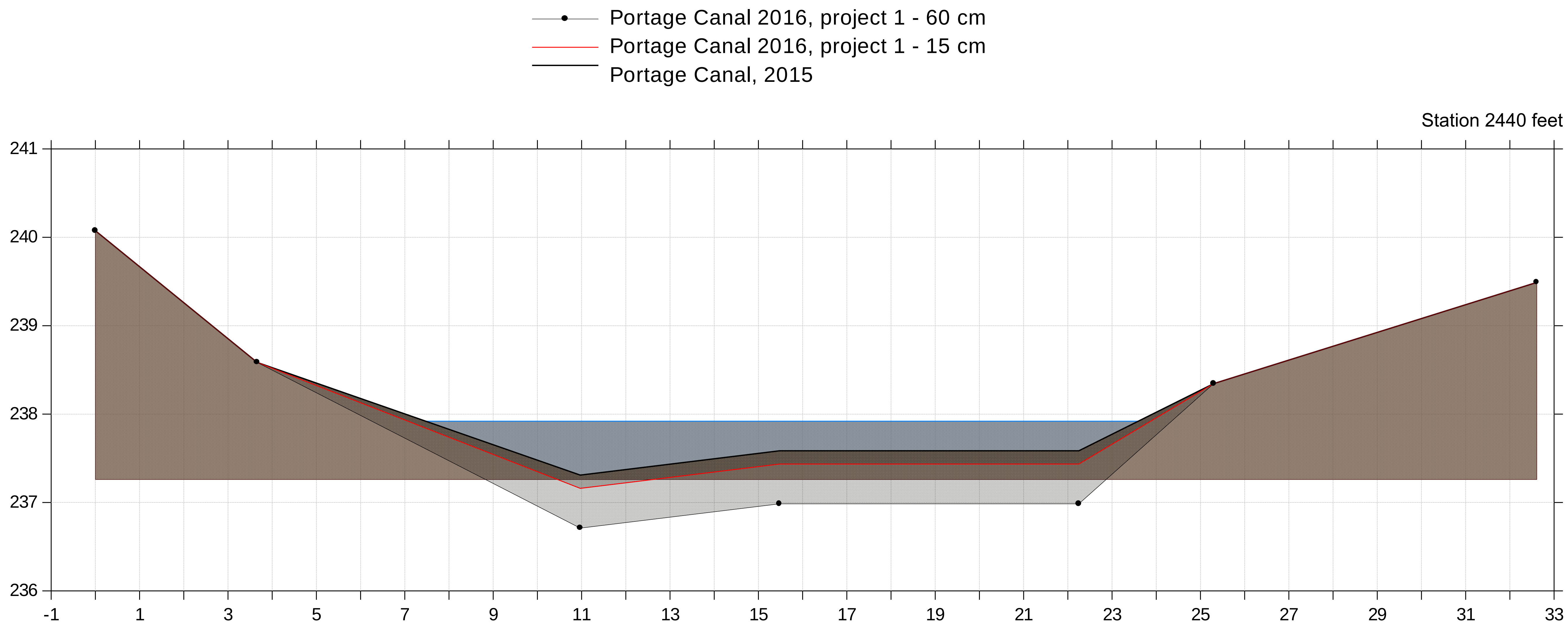
Portage Canal

Appendix 5.1



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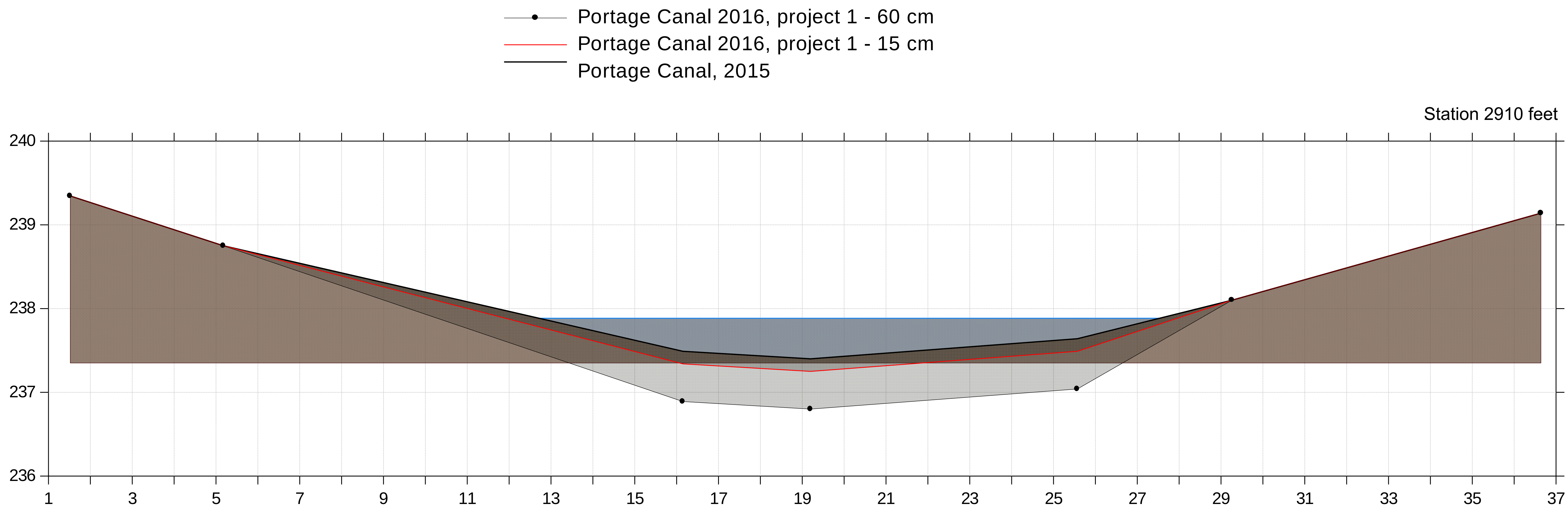
VASP 12-01-2018 / MABG ProjektID : 310-357

Portage Canal

Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

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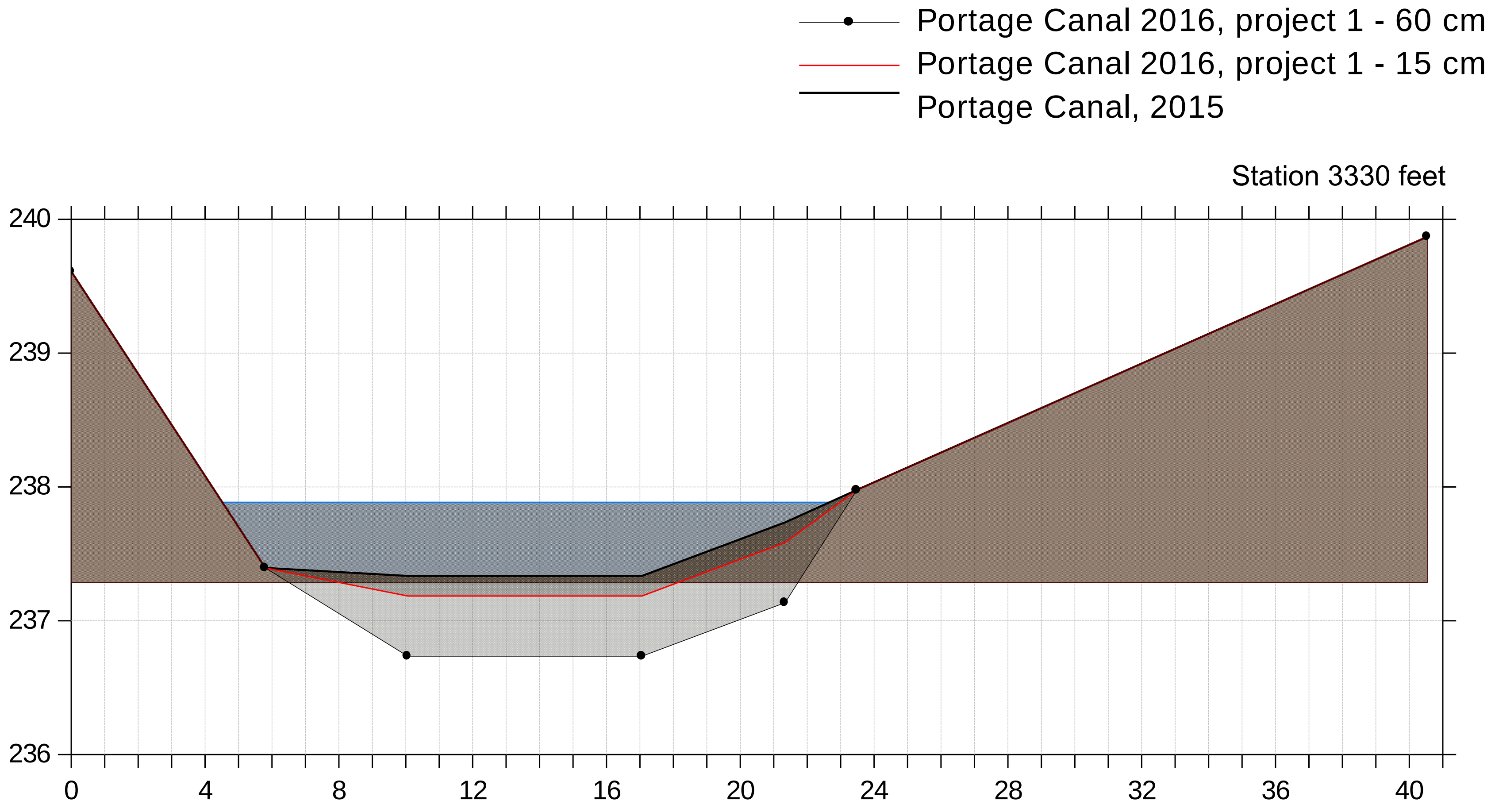
Portage Canal

Appendix 5.1

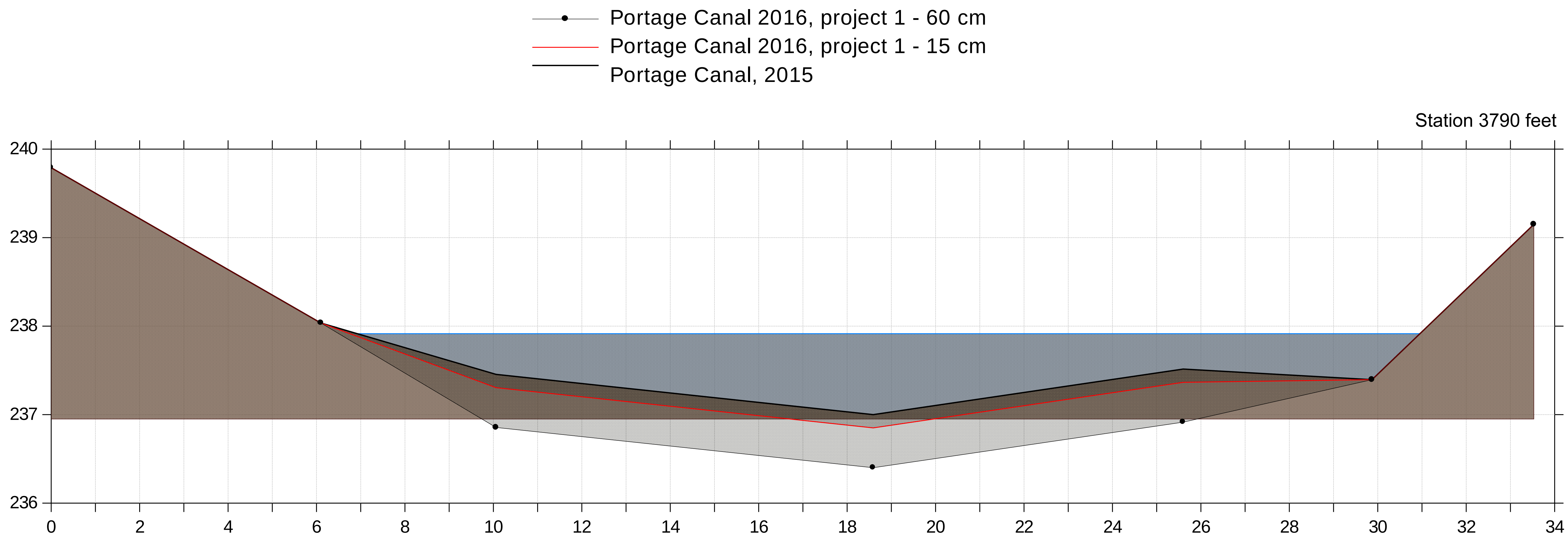


VASP 12-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:200
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Appendix 5.1



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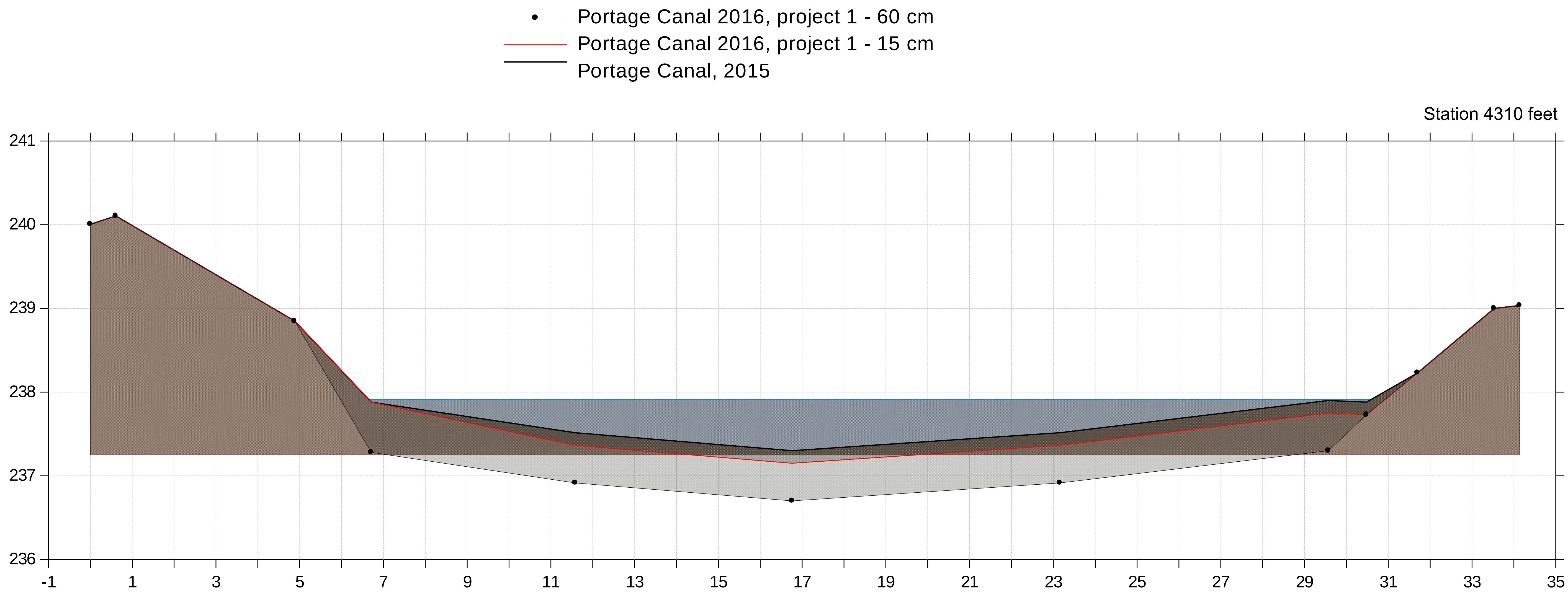
Portage Canal

Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

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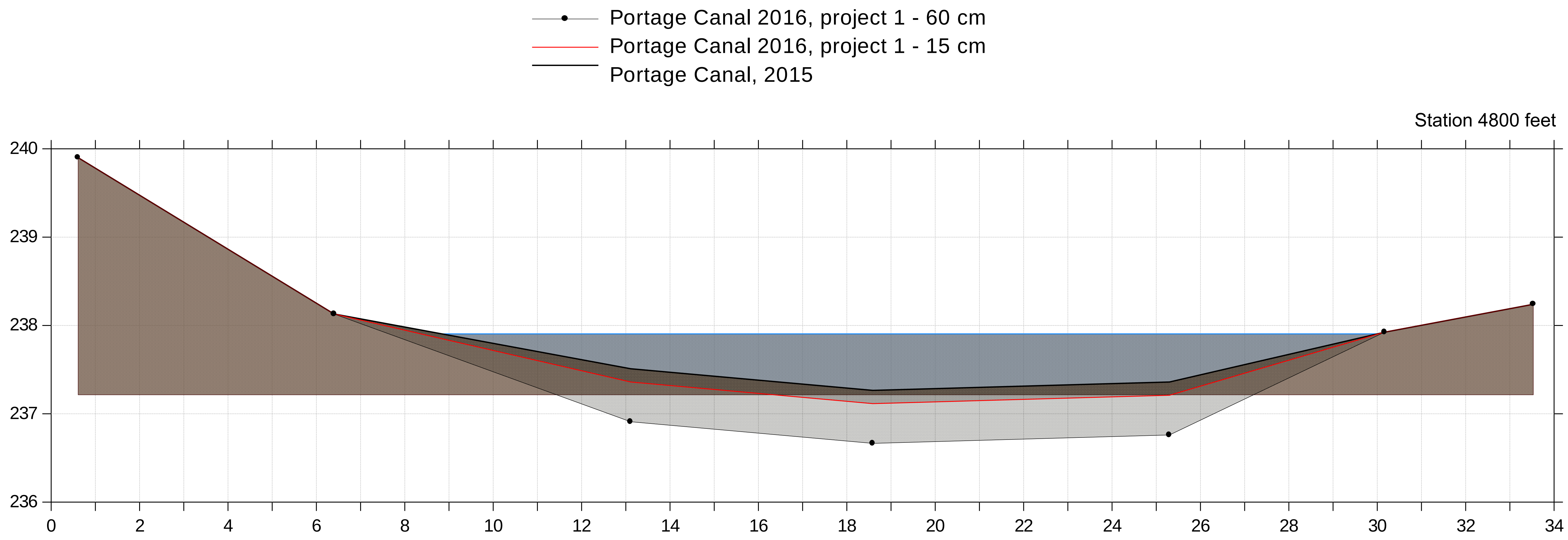
Portage Canal

Appendix 5.1



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Portage Canal

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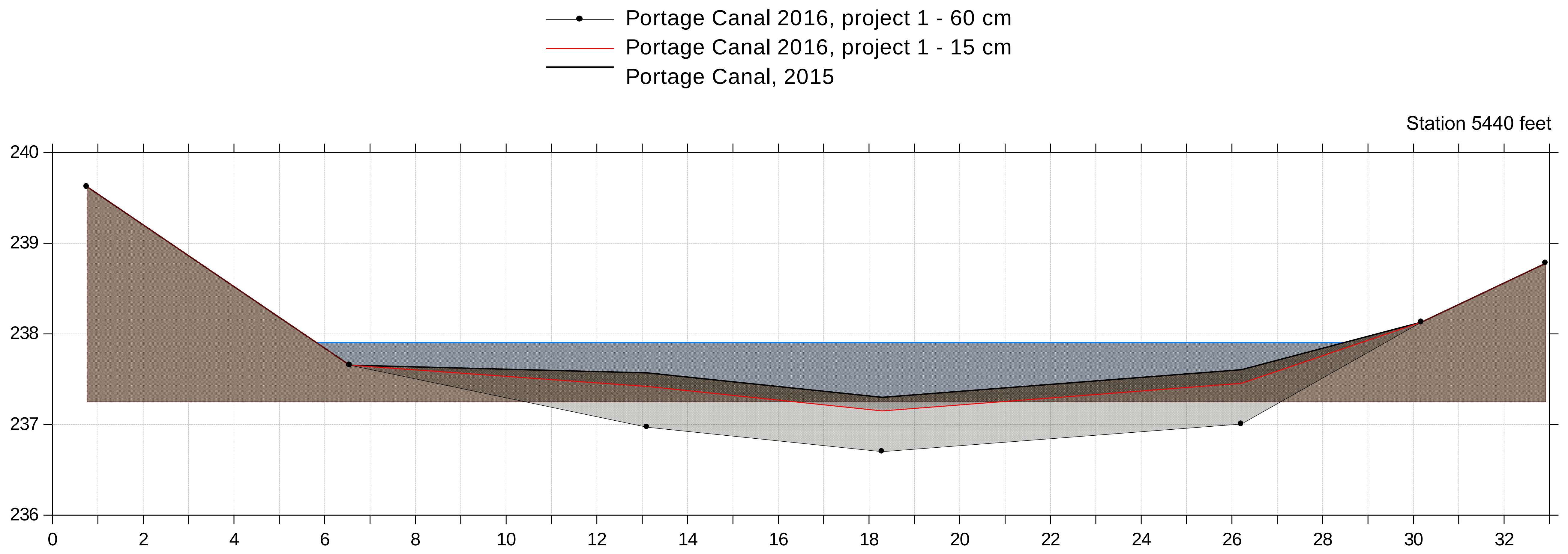

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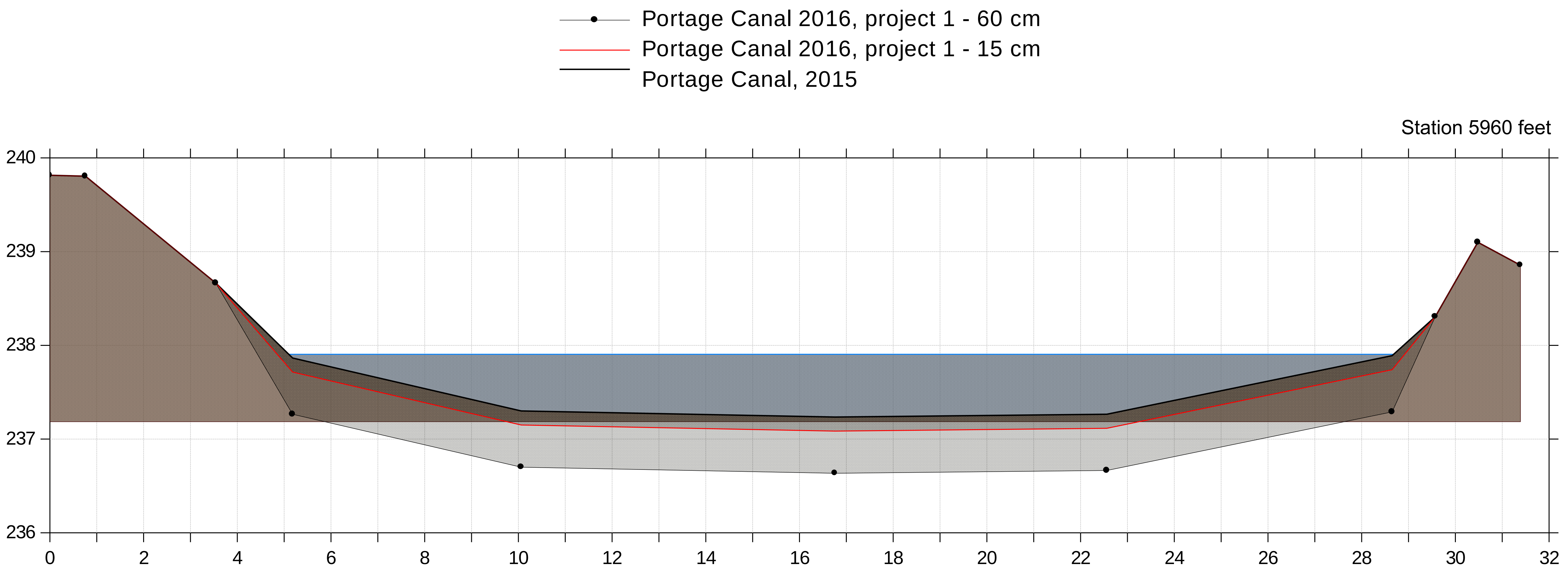
Portage Canal

Appendix 5.1



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- Horizontal axis, distance in meters, scale 1:100
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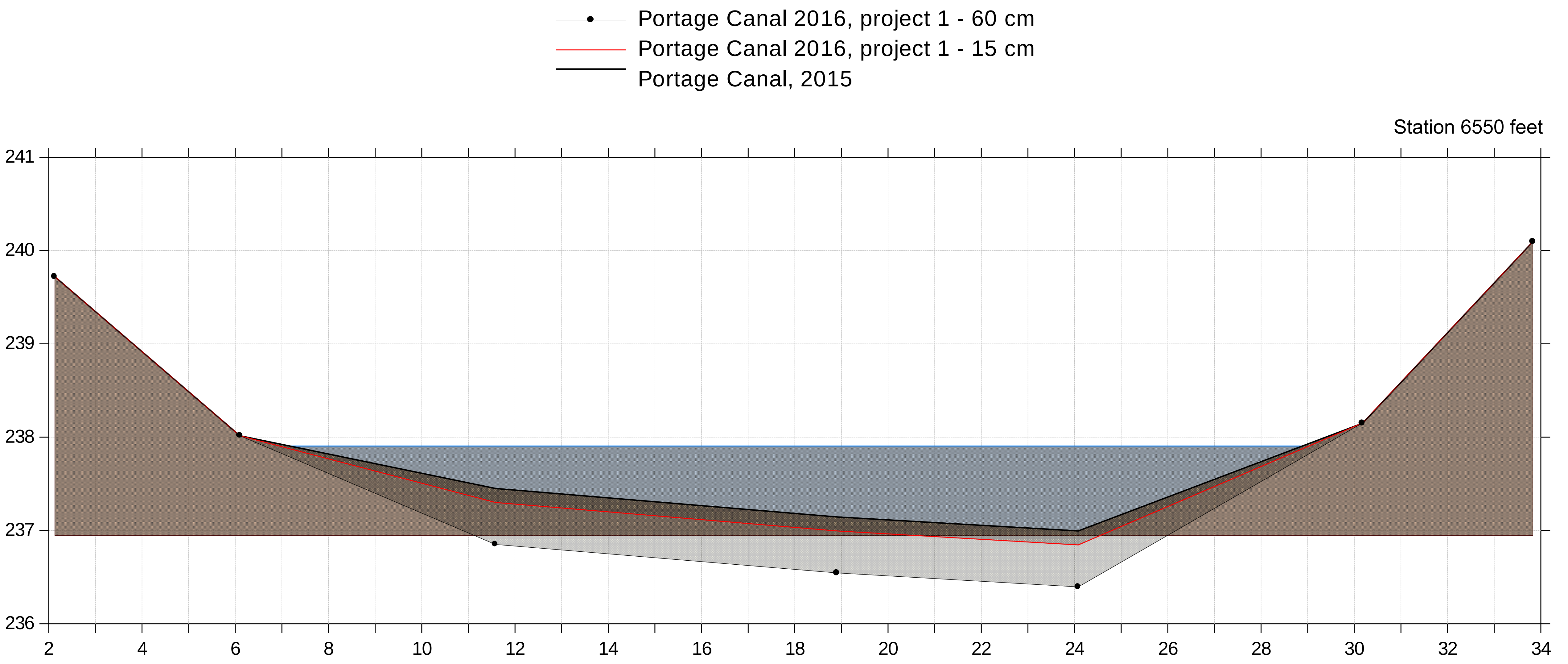
VASP 12-01-2018 / MABG ProjektID : 310-357

Portage Canal

Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
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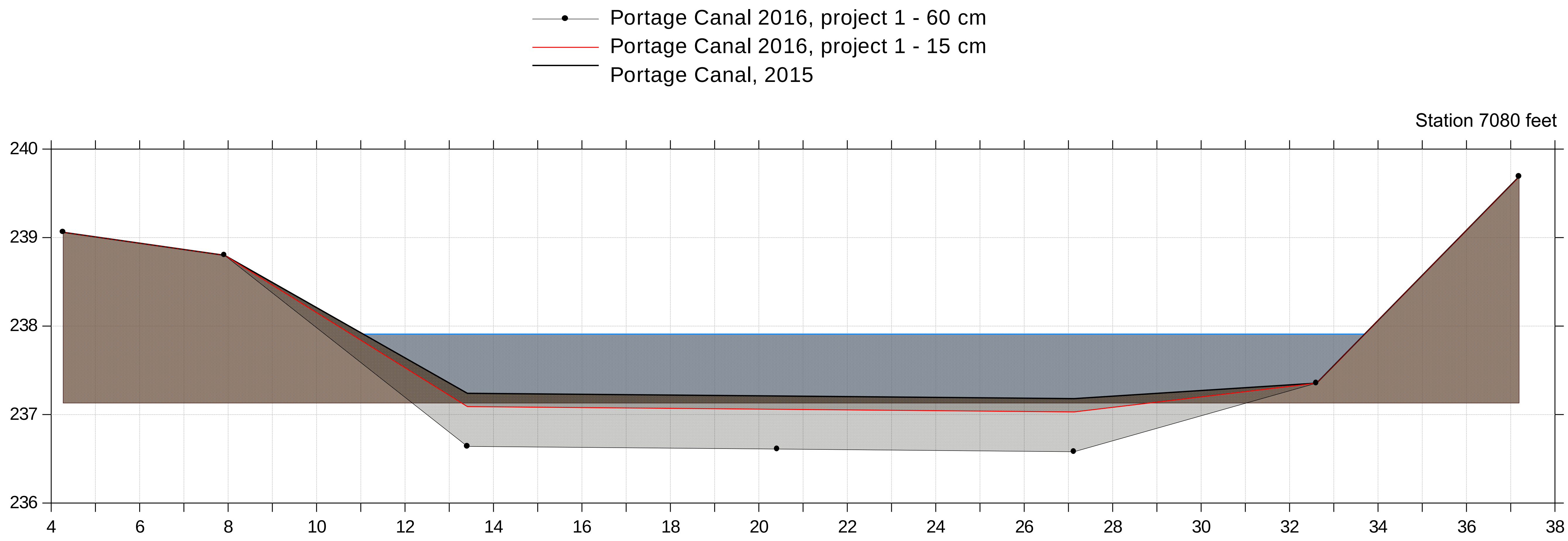
Portage Canal

Appendix 5.1



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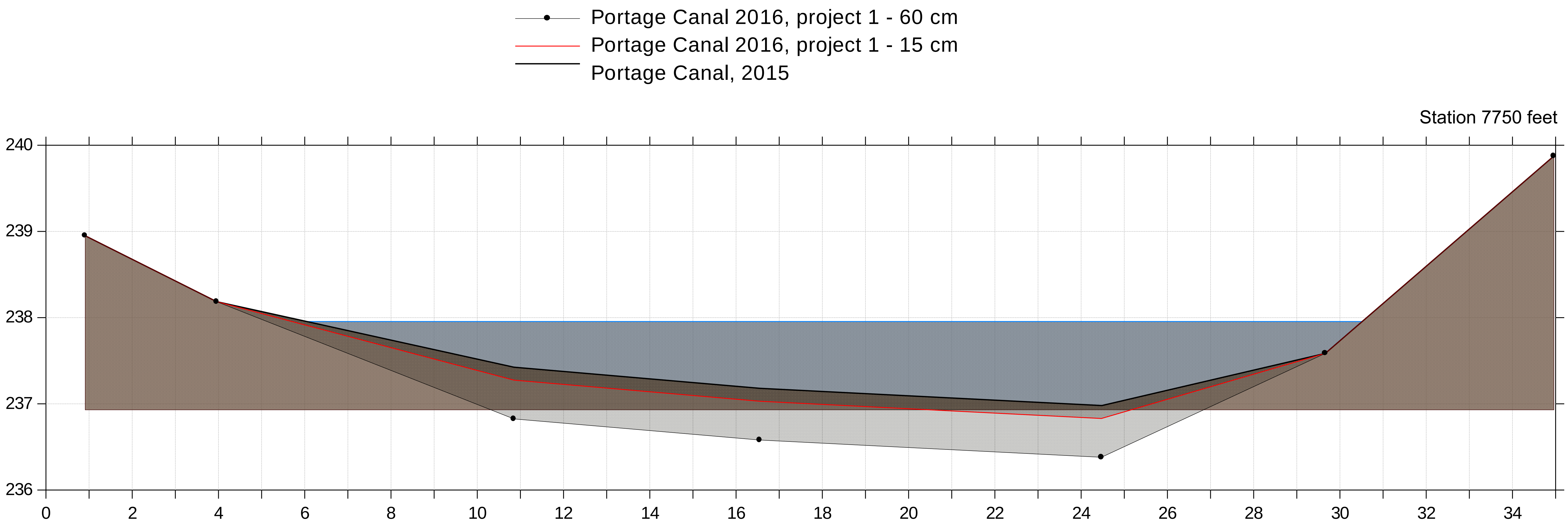
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Appendix 5.1

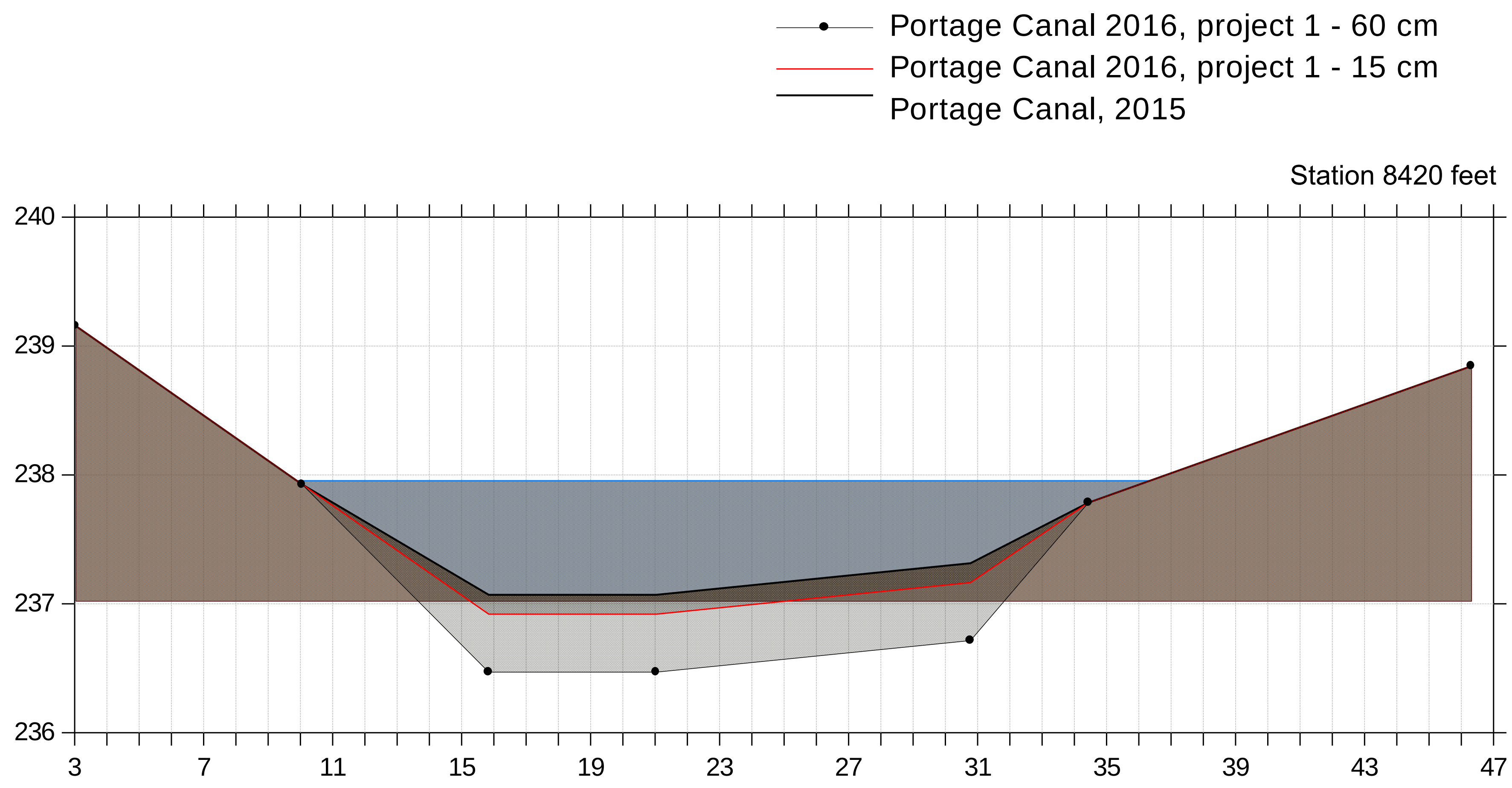


VASP 12-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:100
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

Portage Canal

Appendix 5.1

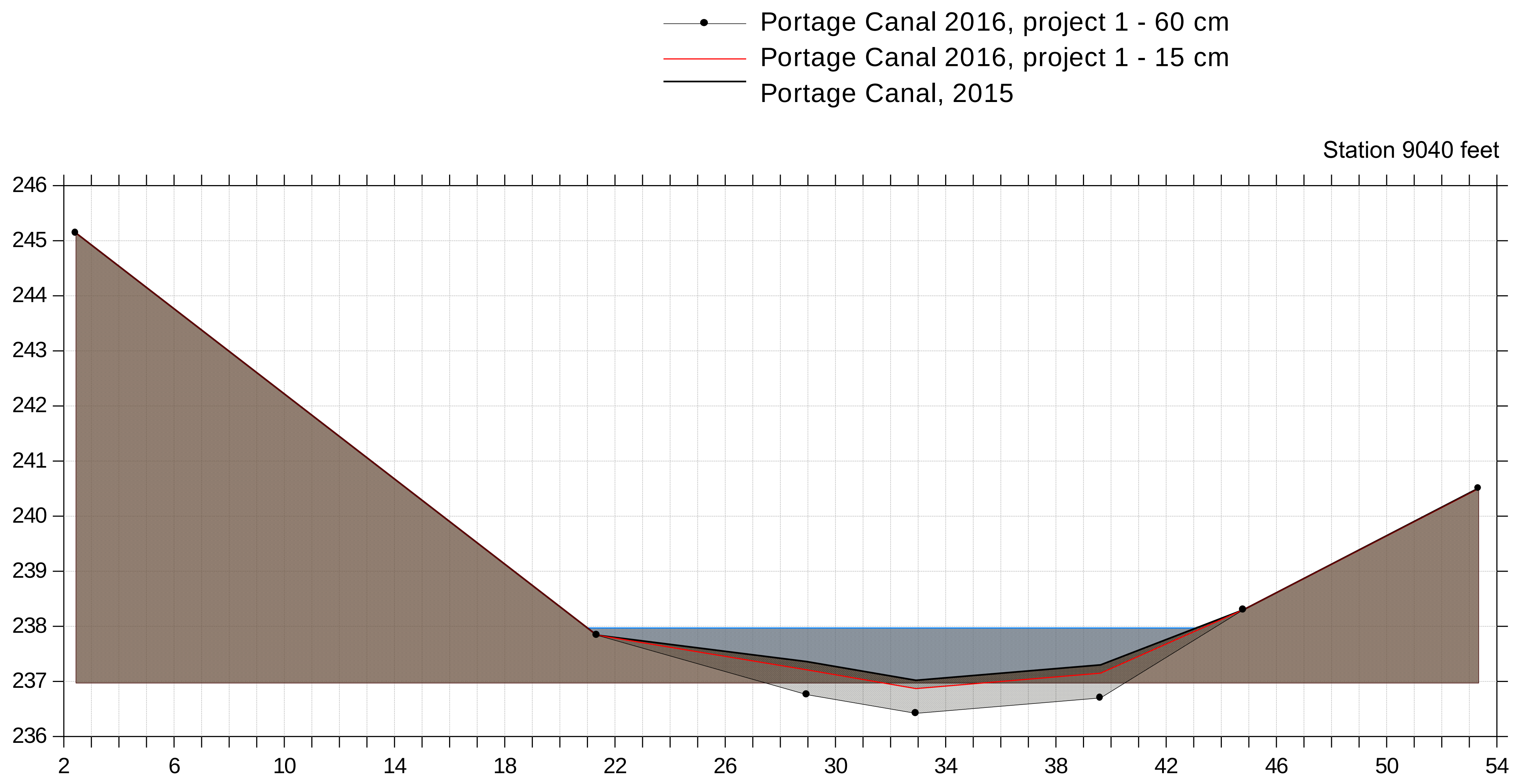


- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:200
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

VASP 12-01-2018 / MABG ProjektID : 310-357

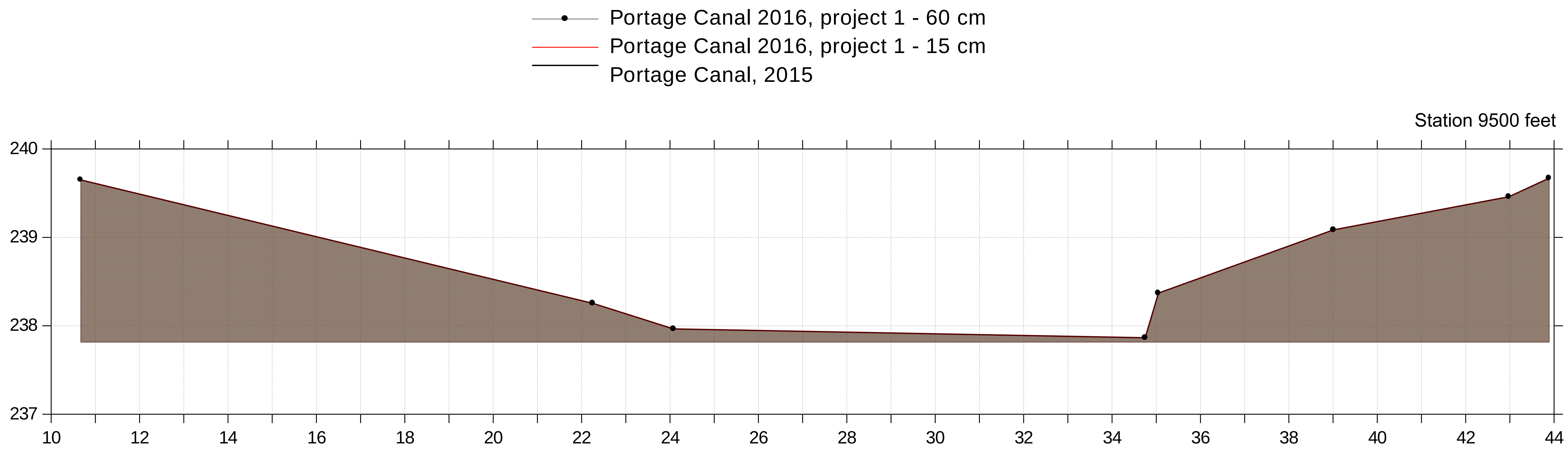
Portage Canal

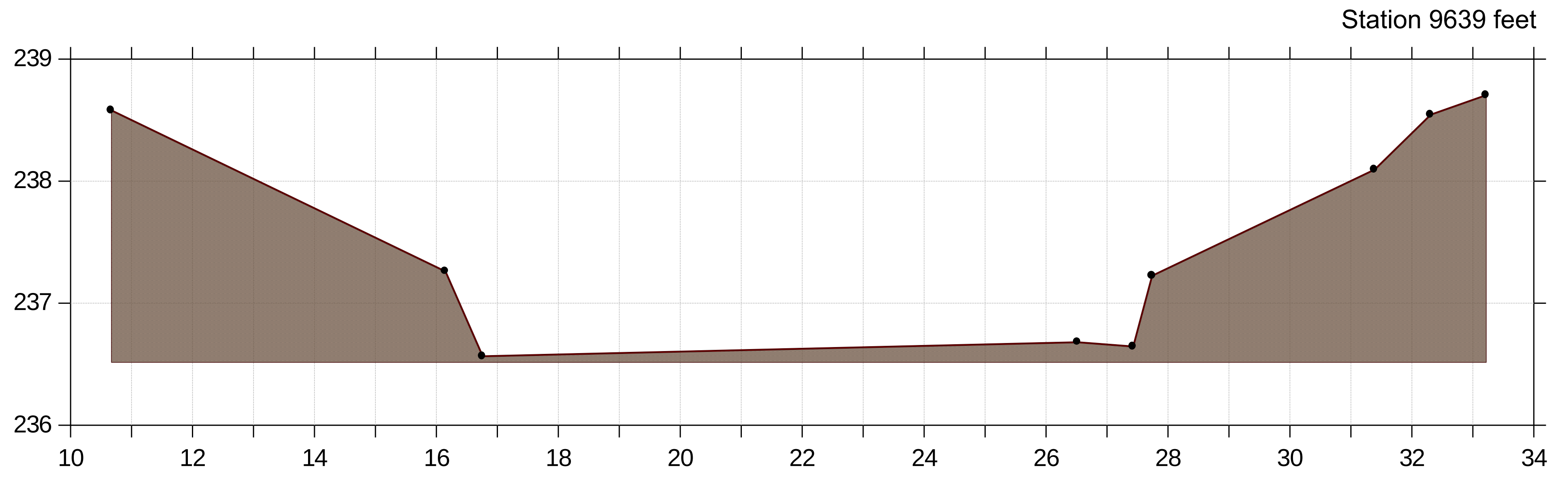
Appendix 5.1



VASP 12-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, distance in meters, scale 1:200
- Station represent the chainage distance from the beginning of Segment 2 (Appendix 1.1)

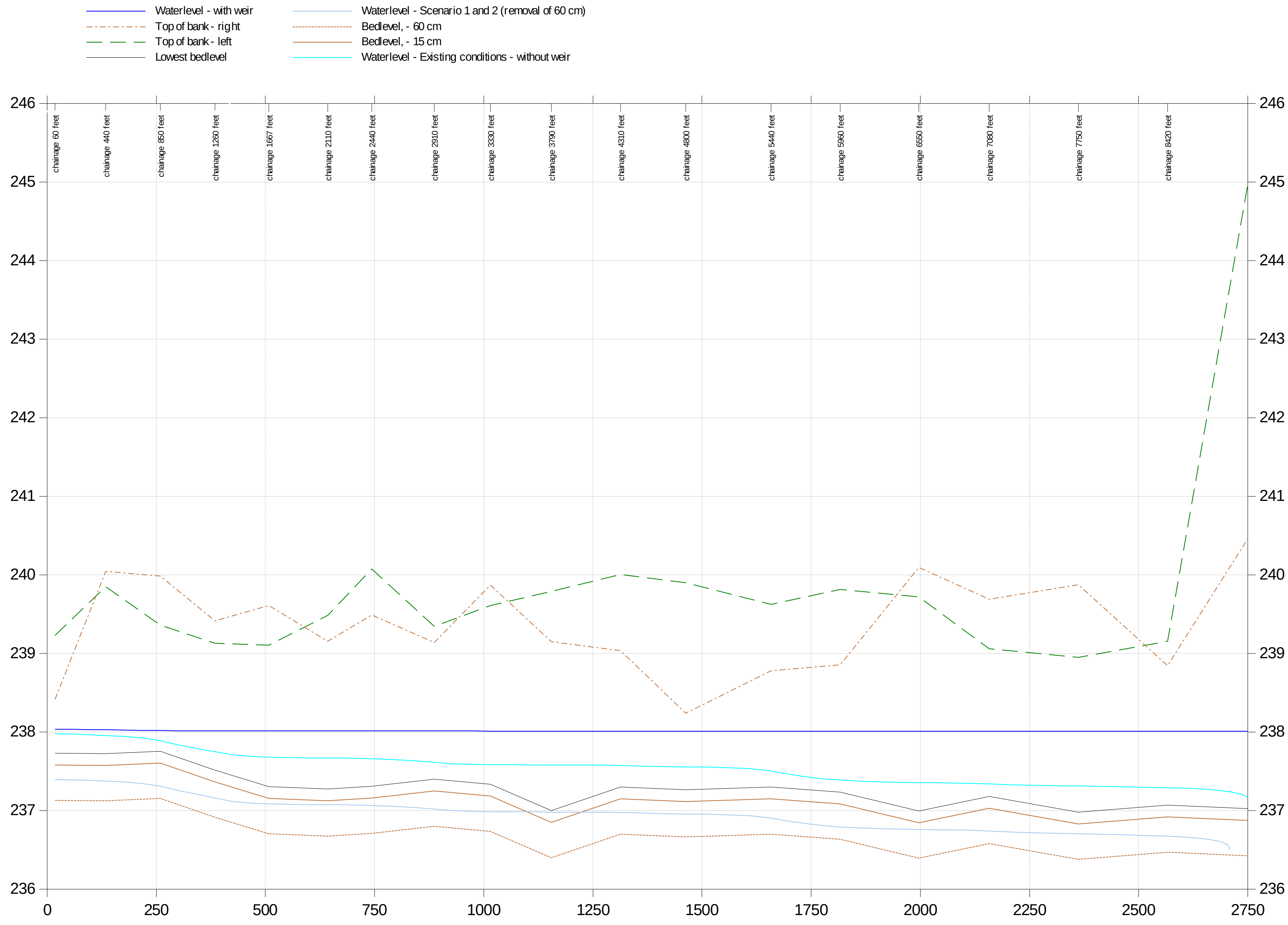




VASP 12-01-2018 / MABG ProjektID : 310-357

Portage Canal

Appendix 5.2



VASP 19-01-2018 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, Station in meter, scale 1:9.000
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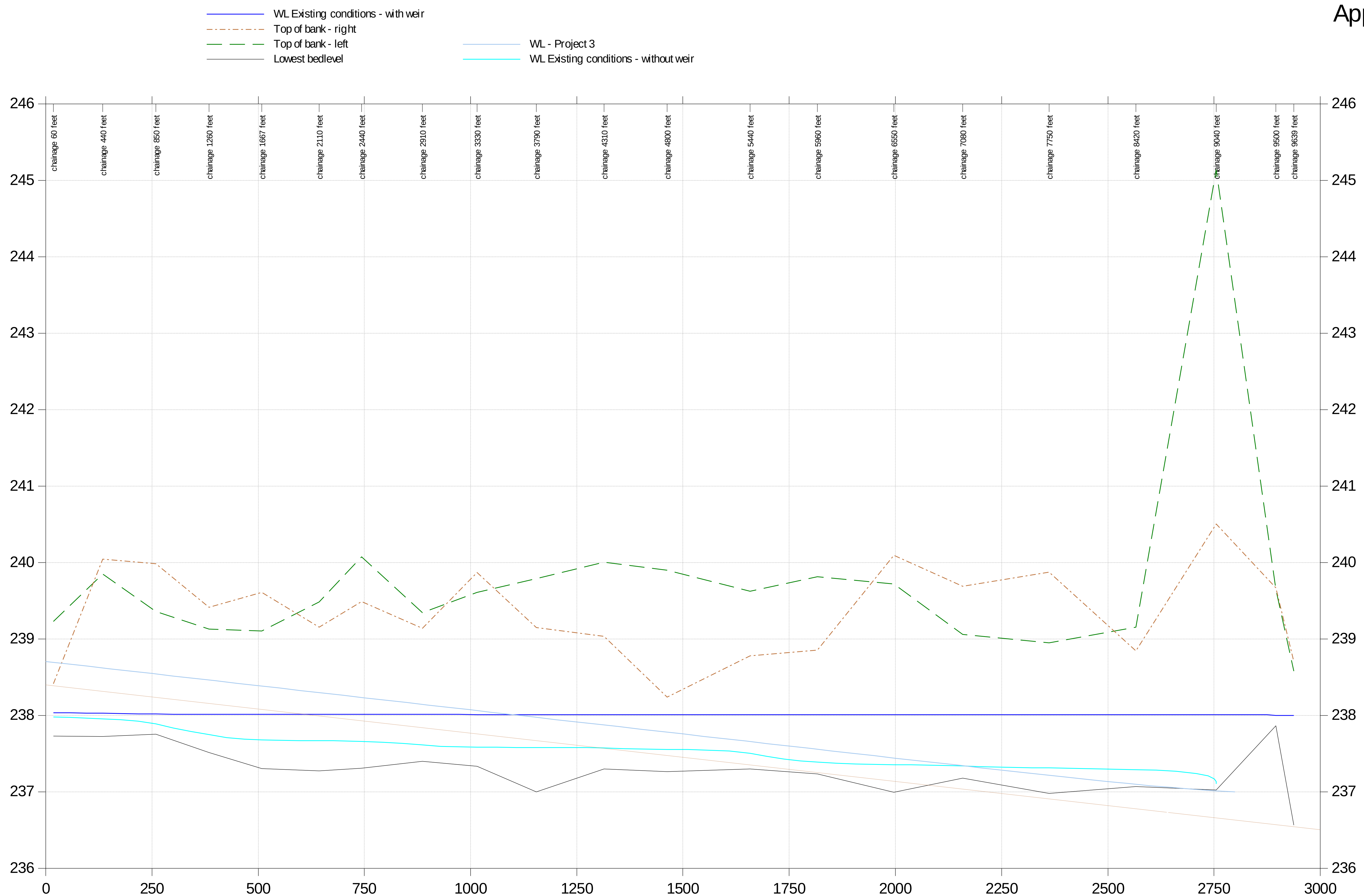
Portage Canal

Appendix 5.3



VASP 19-01-2016 / MABG ProjektID : 310-357

- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, Station in meters, scale 1:9,000
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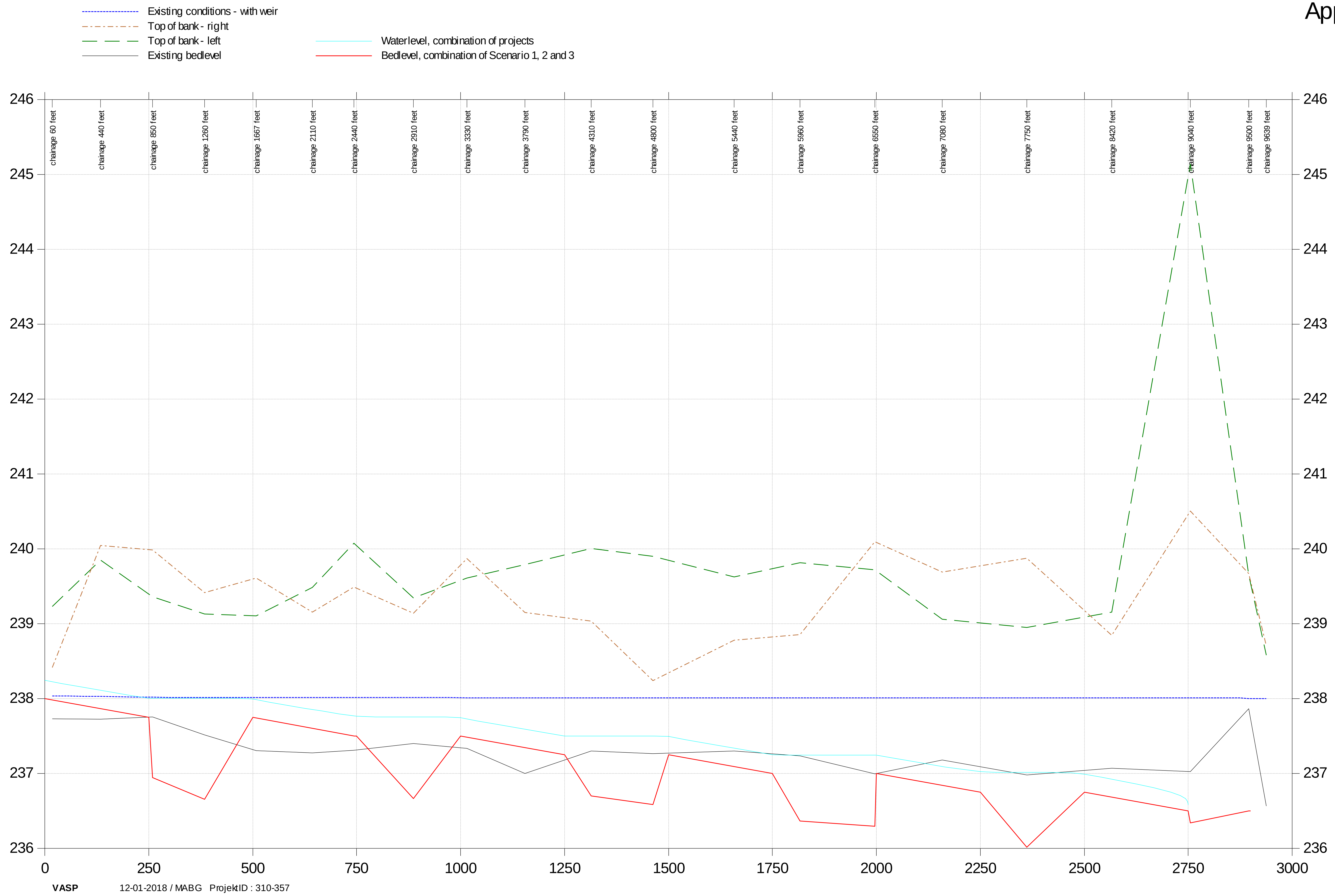
Portage Canal

Appendix 5.4



- Vertical axis, levels in meters, scale 1:50
- Horizontal axis, Station in meters, scale 1:9,000
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