Mississippi Valley Conservation Authority

Casey Creek Flood Plain Mapping Study

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Executive Summary

In co-operation with and funding support from the City of Ottawa, Mississippi Valley Conservation Authority (MVCA), Rideau Valley Conservation Authority (RVCA), and South Nation Conservation (SNC) undertook a five-year program of updating flood hazard maps throughout the City of Ottawa. This report was prepared by MVCA and is the summary of analysis and findings for the flood plain analysis of Casey Creek.

Located in the northeast end of the City of Ottawa, Casey Creek is tributary to Constance Lake. With a total drainage area of approximately 55 km^2, the main channel of Casey Creek extends a distance of approximately 6.5 km from Marchurst Road, at the upstream end, to its outlet at Constance Lake. The outlet of Casey Creek discharges to Constance Lake through the Provincially Significant Constance Creek Wetland.

There are three main tributary branches of Casey Creek that join the watercourse immediately upstream of Dunrobin Road and between Dunrobin Road and Old Second Line Road. The watershed is dominated by agricultural land uses, wooded areas, some rural residential development and wetlands in the extreme upstream watershed.

Section 2.0 of the report documents the hydrologic analysis conducted for this study to estimate the flows for the Casey Creek watershed for use in defining the Regulatory flood levels. The return period flows generated by employing the 12-hour SCS rainfall simulations produced the highest and similar peak flows, to other methods, for Casey Creek.

Section 3.0 documents the hydraulic analysis conducted for this study to estimate the flood levels for the 2, 5, 10, 25, 50 and 100-year (Regulatory event) for the study reaches. The study reaches include the main branch of Casey Creek from its outlet at Constance Lake upstream to Marchurst Road and the northwest tributary from the confluence with the main branch upstream to Thomas Dolan Parkway, the middle tributary from the confluence with the main branch upstream to Marchurst Road and the south tributary from the confluence with the main branch upstream to Murphy Side Road.

Section 4.0 documents the delineation of the Regulatory flood plain. The Regulatory (100-year) flood plain elevations were used to plot the Regulatory flood lines using ArcGIS. The Regulatory flood levels were used to produce a Triangulated Irregular Network (TIN) surface in ArcGIS. The intersection of the TIN and the Light Detection and Ranging (LiDAR)-derived terrain determines the location of the Regulatory flood line. The flood-prone areas are documented, although no existing structures and only one road is impacted by floodwaters.

Section 5.0 documents the process used in determining the extent of the Regulation Limit for Ontario Regulation 153/06 (MVCA's regulation under Section 28 of the *Conservation Authorities Act*) the presence of all potential hazards must be considered to determine the requisite (most extensive) hazard. The Regulation Limit is defined by a 15 m buffer beyond the requisite hazard.

1.0 Introduction

1.1 General

Flooding in Canada can occur from such diverse sources as snowmelt, extra-tropical storms, flash thunderstorms or jamming of ice during spring break-up. Inundation of the flood plain of a river or lake during such times is a natural occurrence. However, the flood damages which often result are not. They are the consequence of human development of flood plain lands.

Such development has historically occurred because of the use of rivers as transportation routes, sources of power and water and because much of the best agricultural land is located in the flood plain. The resulting conflict with the river at flood times has led to a variety of approaches to controlling flooding. The earliest records of attempts, in North America, to modify the relationship between humans and floods stretch back to 1617. This involved the use of dykes by early French settlers in the Bay of Fundy region to protect areas for agricultural purposes [1]. Methods have generally focussed on various structural measures such as flood control dams, channelization or diversion works. In the absence of such works, the alternative has often been the payment of disaster assistance from the public purse to the sufferers of flood damages.

Floods are the most commonly occurring natural hazard in Canada and account for the largest portion of disaster recovery costs on an annual basis [2]. In light of trends towards increases in flood disaster assistance payments, greater pressure for flood plain development and the potential environmental problems associated with structural flood control measures, it has been recognized that a more comprehensive approach to flood plain management is required. Policies based on a full evaluation of both structural and non-structural alternatives, such as restriction of flood vulnerable development in high flood risk areas, as well as structural approaches are necessary.

One of the responsibilities of the Mississippi Valley Conservation Authority (MVCA) is the identification of flood hazards and flood plain lands for the implementation of regulations made under Section 28 of the *Conservation Authorities Act* and to support the Authority's delegated role to represent the Provincial interest with respect to natural hazards under Section 3.1 of the *Provincial Policy Statement* (PPS). As detailed in Ontario Regulation 153/06, the applicable Regulatory flood event standard used to determine the susceptibility to flooding of lands or areas within the watersheds, for the MVCA, is the 100-year flood event. For the MVCA watershed, this is referred to as the Regional Flood. The 100-year flood event standard, as defined in Ontario Regulation 153/06, means the rainfall or snowmelt, or a combination of rainfall and snowmelt, which produces at any location in a river, creek, stream, or watercourse, a peak flow that has a probability of occurrence or exceedance of one percent during any given year. Accurate flood plain mapping is required for effective flood plain management.

Within the City of Ottawa there are three Conservation Authorities; the MVCA, Rideau Valley Conservation Authority (RVCA), and South Nation Conservation (SNC). In 2012, the MVCA, RVCA, and SNC, in co-operation with and financial assistance from the City of Ottawa, developed a 5-year plan to update flood plain mapping within the City of Ottawa and produce new flood plain mapping where it currently does not exist. In 2017 a second five-year contribution agreement was signed to continue the flood plain mapping work. The priority watercourses for study and the production of flood plain maps were ranked based on the presence and intensity of existing and predicted future development.

There is no existing flood plain mapping for Casey Creek. It was determined as a priority watercourse to complete a flood plain mapping study and development of flood plain maps due to its proximity to village boundaries and the potential for rural estate development within the watershed. Previously, the MVCA had no formal methodology to update the mapping on an ongoing basis, although it should be noted that, as part of the above noted agreements, a protocol has been established for updating flood plain mapping regularly.

The objectives of the *Casey Creek Flood Plain Mapping Study* were:

1. To determine the magnitude of design flows for various return periods and the Regional flood event for the study area.
2. To delineate the flood plain under the Regulatory (100-year) flood event for Casey Creek within the study limits.
3. To have the flood hazard areas incorporated in the City of Ottawa planning documents (Official Plan and Comprehensive Zoning document) and for use in administering Ontario Regulation 153/06.

This study was carried out in accordance with the *Technical Guide: River & Stream Systems: Flooding Hazard Limit* Ontario Ministry of Natural Resources [3] and with consideration of the City of Ottawa *Sewer Design Guideline* [4].

1.2 Study Area

Located in the northeast end of the City of Ottawa, Casey Creek is tributary to Constance Lake as shown in Figure 1. With a total drainage area of approximately 55 km^2, the main channel of Casey Creek extends a distance of approximately 6.5 km from Marchurst Road, at the upstream end, to its outlet at Constance Lake. The outlet of Casey Creek discharges to Constance Lake through the Provincially Significant Constance Creek Wetland.

There are three main tributary branches of Casey Creek that join the watercourse immediately upstream of Dunrobin Road and between Dunrobin Road and Old Second Line Road. The watershed is dominated by agricultural land uses, wooded areas, some rural residential development and wetlands in the extreme upstream watershed as shown in Figure 2.

For much of the watershed, the flood plain valley section is ill-defined so that there are some wider flood plain sections and some spills along the watercourse reach. There are some reaches where the flood plain is relatively narrow and is generally confined within a valley system, considering the context of the flow to be conveyed. At the downstream end of the watershed, around Constance Lake, there is a wetland area and flows can spill overland to the lake.

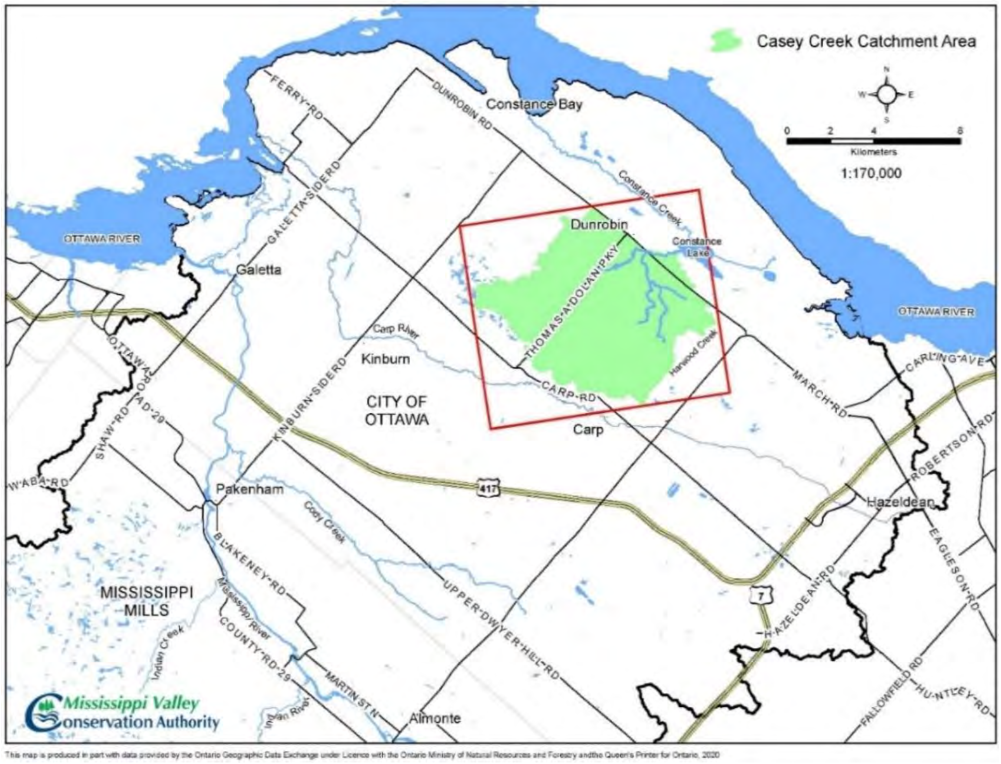

Figure 1: Casey Creek Watershed Location Plan

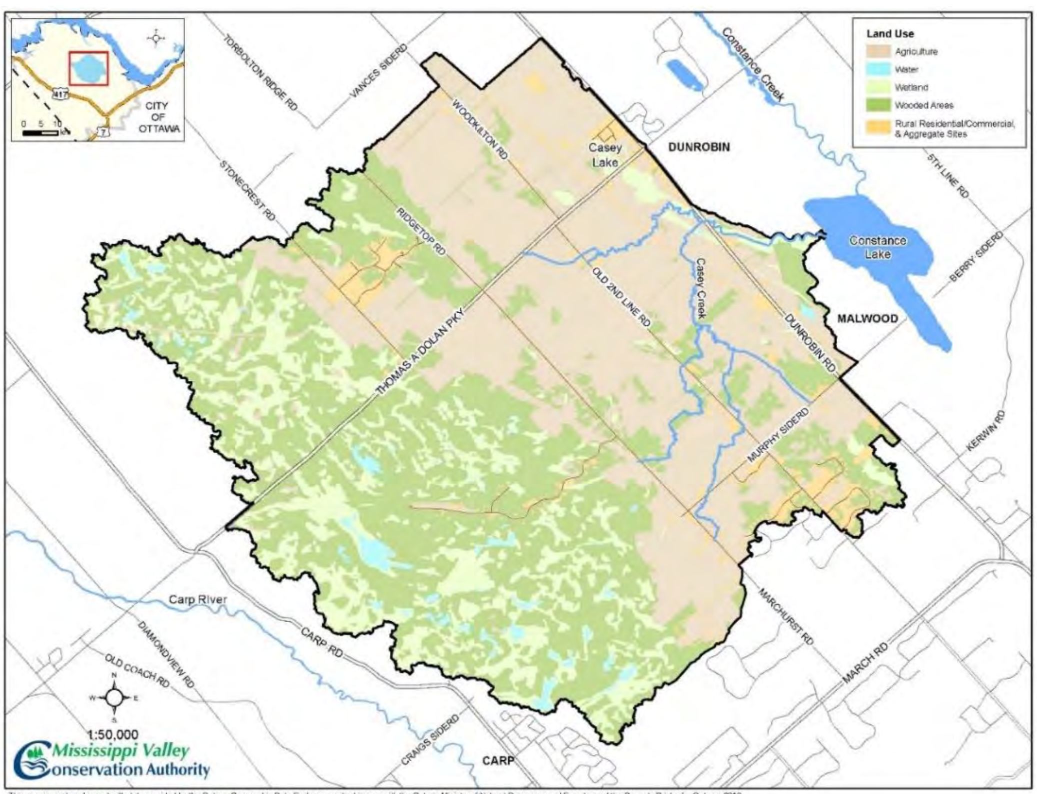

Figure 2: Casey Creek Watershed Land Use

The major road crossings within the watershed, from downstream to upstream, along the main channel of the Casey Creek, include:

- Dunrobin Road
- Abandoned railway line (now used as a trail)
- Old Second Line Road
- Murphy Side Road
- Marchurst Road

This study produced flood plain maps for the main branch of Casey Creek from Marchurst Road downstream to Constance Lake, the northwest tributary upstream to Thomas Dolan Parkway, the middle tributary upstream to Marchurst Road and the south tributary upstream to Murphy Side Road as shown on Figure 3.

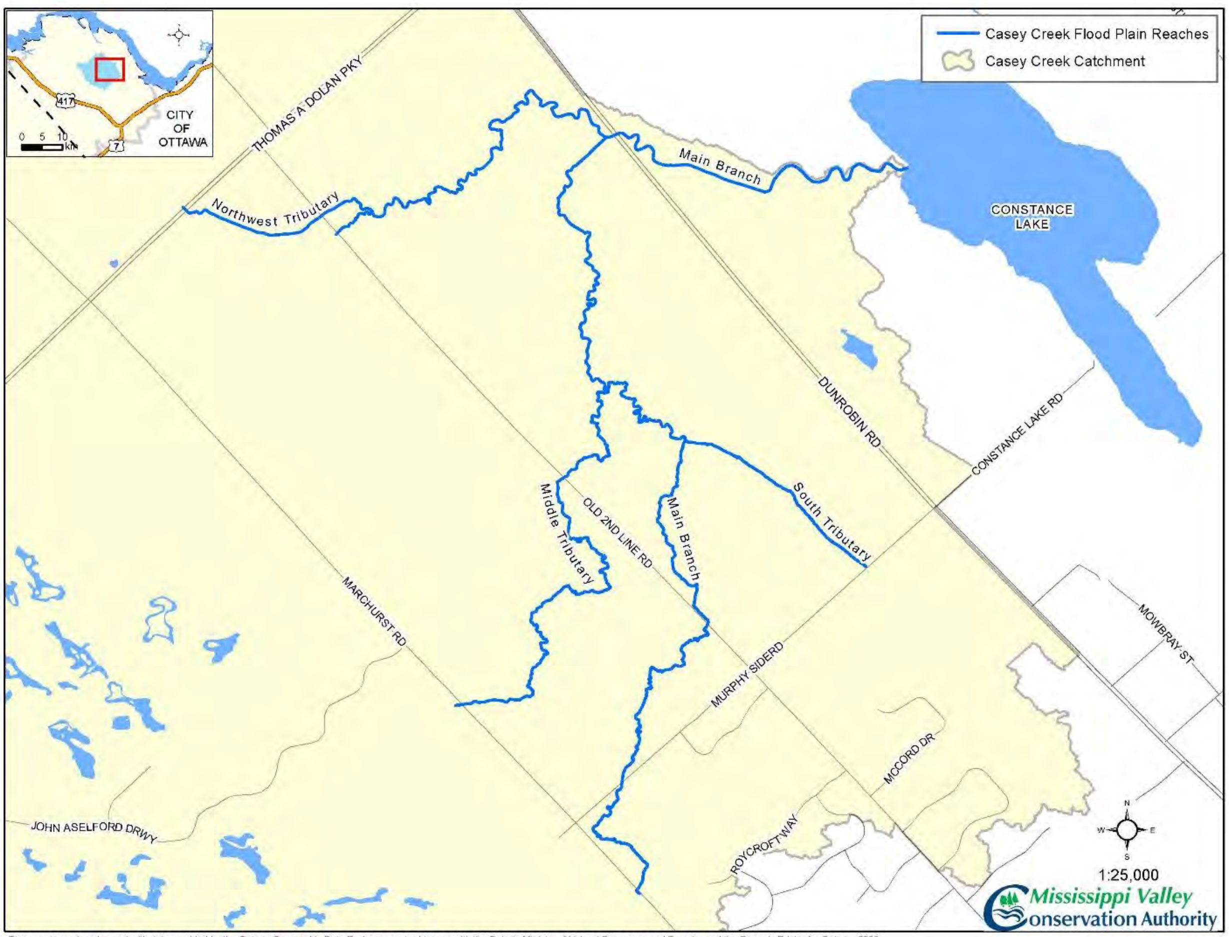

Figure 3: Casey Creek Study Reaches

1.3 Previous Studies

As stated above, no flood plain mapping has previously been produced for Casey Creek. However, previous hydrologic analyses have been produced as part of:

- *Constance Creek Flood Plain Mapping Study* (April 2017), Mississippi Valley Conservation Authority [5].
- *Constance Creek Flood Plain Mapping Study* (October 1994), M. E. Andrews and Associates [6].

1.4 Flood Plain Analysis and Stormwater Management Design

The main purpose of a flood plain mapping study is to delineate the area that would be physically flooded for the specified flood event as part of the assessment of flood risk. Stormwater management facilities/measures are constructed or implemented to address the impact of development and can include many more functions than simply quantity control, such as water quality and erosion control. Stormwater management design criteria and assumptions are generally set by the municipality when a development application is received under the *Planning Act*. Often watershed studies are completed to assess the potential impact of various stormwater management measures, implemented with development, on a watershed basis.

Therefore, the results from this flood plain mapping should be used to determine the location of features that should be located outside of the flood plain and in the assessment of floodproofing measures (e.g. as a boundary condition for hydraulic grade line calculations for the determination of minimum basement elevations) or flood risk assessments. The results of this study should be considered when reviewing new development proposals, but, are not meant to necessarily set or specify stormwater management criteria or targets.

2.0 Hydrology

2.1 Methodology

The objective of the hydrologic analysis conducted during this study was to estimate flows for the Casey Creek watershed for use in calculating Regulatory flood levels.

The selection of an appropriate method of hydrologic analysis is dependent upon several factors, these include:

i. The purpose of the analysis – this will dictate, in many cases, the type of appropriate procedures. For example, if a flow hydrograph produced by a historic rainstorm is required, then a modelling approach will be necessary.
ii. Available flow data – if records of flows are available within the study area of sufficient duration and quality, these can be used to directly estimate flows of various return periods.
iii. Availability of regional flow relationships – in the absence of actual flow data, it may be feasible to use regional relationships.

In this case, there are no actual flow records for Casey Creek and there are no flow gauges in nearby watersheds of similar size and land use characteristics. There is a flow gauge on the Carp River at Kinburn (southwest of Constance Lake), with 50 years of recorded data. However, the land use and watershed characteristics of the two watersheds are quite different. The Carp River has intense urban development at the upstream end of the watershed (Kanata) as opposed to the more distributed agricultural and rural residential land use in the Casey Creek watershed. Also, the watershed drainage area of the Carp River, upstream of the flow gauge location, is over 4 times larger than Casey Creek. Since the watershed characteristics of the Carp River are quite different than the watershed characteristics of Casey Creek it is not believed that directly transposing the flows from a frequency analysis of the Carp River flow gauge data would result in representative flow values for Casey Creek.

Therefore, it was decided to estimate the flows using a hydrologic model and verify the results by comparison to results from regional equations. A wide variety of hydrologic models are available for use in estimating flows in Ontario. One commonly used model in Ontario flood plain mapping studies is known as HEC-HMS [7]. HEC-HMS can use single rainfall events (observed or synthetic) or continuous rainfall records to simulate the transformation of rainfall into surface runoff. Computed hydrographs can be routed through river channels or stormwater management ponds and reservoirs. Its main advantage is its use of a simple structure to allow a simple representation of a drainage area discretized into sub-catchments. For this study, HEC-HMS version 4.7.1 was used.

2.2 Watershed Characteristics Affecting Runoff

The general characteristics of Casey Creek are described in Section 1.2. The hydrologic soil groups in the watershed are shown in Figure 4. As shown, the dominant hydrologic soil group in the drainage area is class B and D. Based on the dominant soil type and land use, the watershed area would be expected to produce moderate runoff volumes and peak flow rates.

It is anticipated that the period of highest runoff and flow rates on Casey Creek could be during the snowmelt and the highest flow months are probably March and April. High peak flows may also occur in the fall and/or summer, as a result of a severe rainfall event. Very low runoff rates tend to occur during the winter when the watershed is snow covered and the wetlands and watercourse are frozen. Based on the above, it is speculated that the higher flows may occur during a spring runoff condition resulting from rainfall and snowmelt or a severe summer or fall rainfall event. Both of these conditions were examined, as described in the later sections of this report.

2.3 Development of the HEC-HMS Model of Casey Creek

For Casey Creek, being a tributary of Constance Creek, a SWMHYMO [8] model was previously assembled as part of the hydrologic analysis for Constance Creek in the MVCA *Constance Creek Flood Plain Mapping Study*. For the original analysis, the total Casey Creek watershed was discretized into eight sub-catchments. In the current study, the total watershed was divided into sixteen sub-catchments for the hydrologic analysis as shown in Figure 5. The sub-catchments were delineated in the current study to provide flow points at appropriate locations for the watercourse reaches where flood plain maps were produced.

The total watershed drainage area for Casey Creek used in the current study (55.16 km^2) is only 0.15 % smaller in size, as compared to the drainage area used in the MVCA *Constance Creek Flood Plain Mapping Study*. This small difference in total drainage would not impact the hydrologic results.

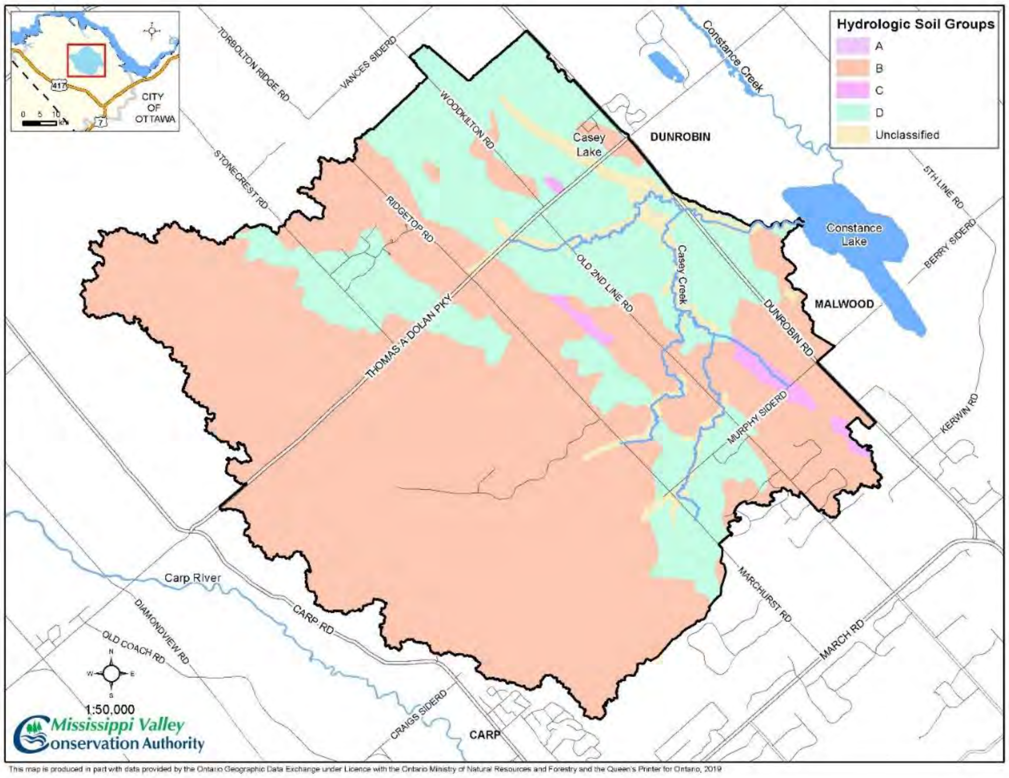

Figure 4: Casey Creek Hydrologic Soil Group

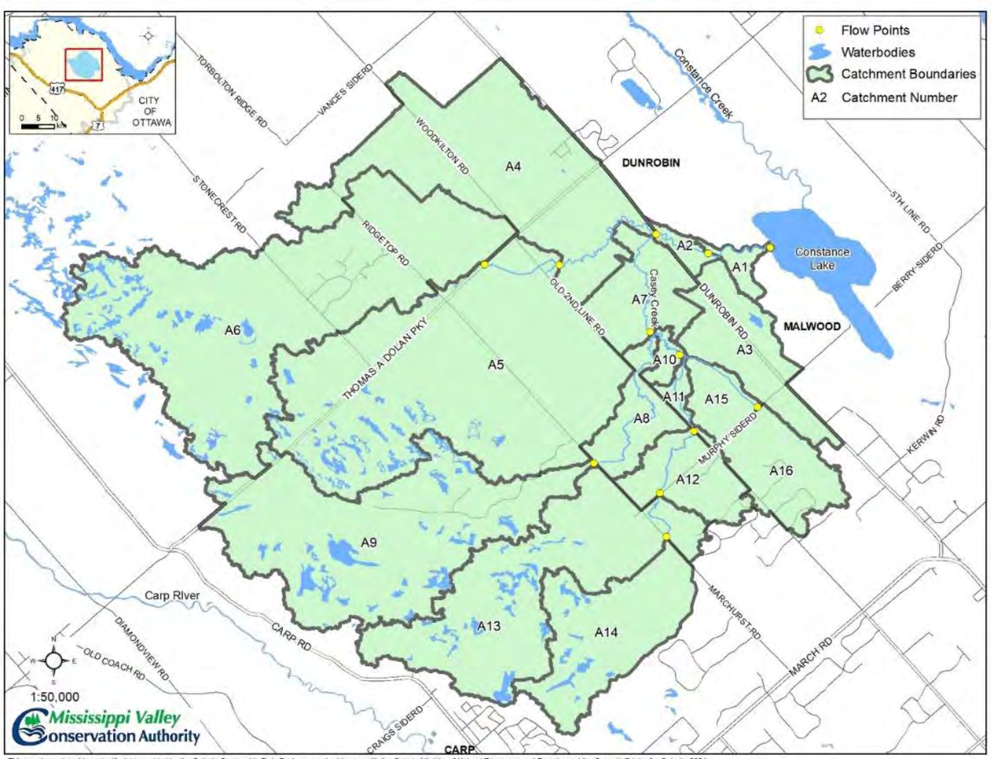

Figure 5: Casey Creek Sub-catchment Delineation

Figure 6 shows the HEC-HMS model schematic. The watershed representation consists of:

- Sixteen sub-catchment elements to estimate infiltration losses and transform excess precipitation into surface runoff.
- Eleven reach elements to model the effect of channel/flood plain routing from the downstream boundary of one sub-catchment to another.
- Twelve junction elements to combine hydrographs from sub-catchments and reaches and provide flow points for hydraulic modelling.

Each of these components requires certain physical data to describe the watershed. These were obtained from the following sources:

- Sub-catchment area, basin and channel slopes, watershed lengths and stream lengths were obtained from the Digital Elevation Model (DEM) developed by the City of Ottawa using LiDAR information acquired by the City (LiDAR Acquisition Report contained in Appendix A).
- Soil information was obtained from the *Soils of the Regional Municipality of Ottawa-Carleton* (Soil Report No. 58). This information was justified and the hydrologic soil group class was obtained from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) information database.
- Land use/vegetation cover was based on data sets obtained from the Land Information Ontario data warehouse.

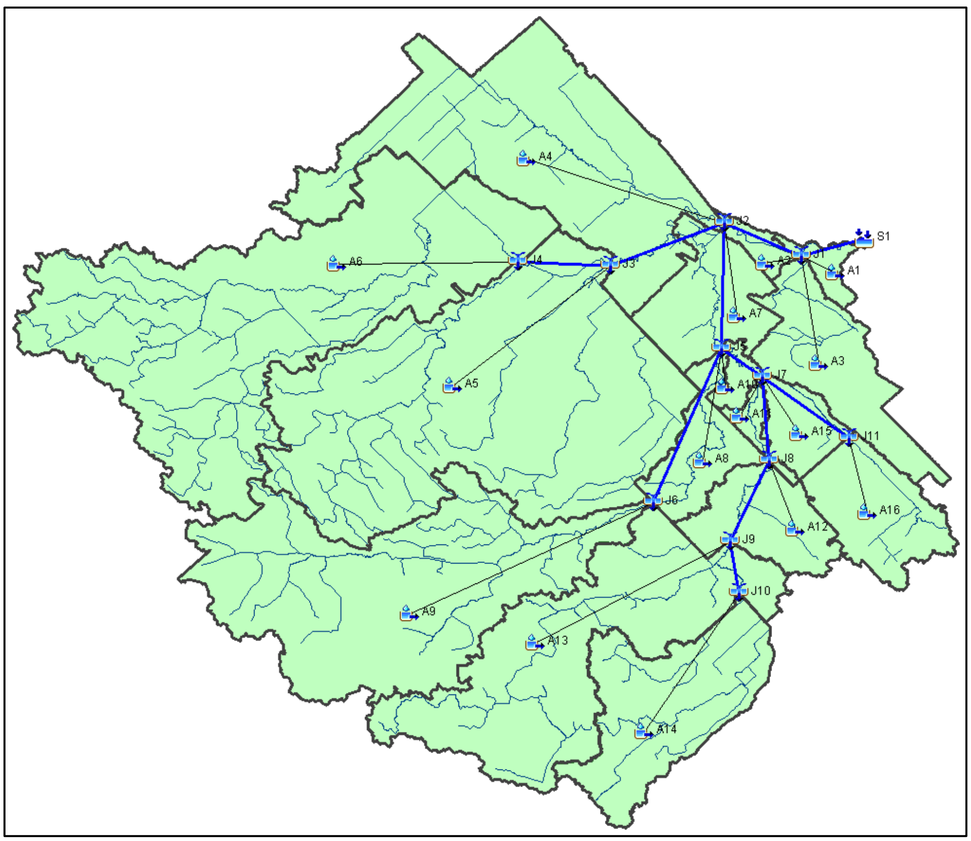

Figure 6: HEC-HMS Model Schematic

To assist in delineating the northwest boundary of sub-catchment A14, the stormwater management report for the estate residential subdivision [9] to the northwest was reviewed to ensure that the sub-catchment divide conformed to the boundary detailed in the report.

Based on all data and data sources noted, the appropriate model parameters, as shown in Table 1, were developed. Appendix B contains the calculations for the parameters shown in Table 1.

Table 1: HEC-HMS Parameters

Sub-catchment ID	Area (ha)	CN Value (AMCII)	Time to Peak (Tp) (hrs)
A1	31.4	58.9	1.5
A2	28.2	75.7	0.6
A3	208.3	73.0	2.0
A4	667.4	80.5	3.2
A5	1111.9	66.4	3.5
A6	1068.1	63.6	3.5
A7	169.4	79.7	0.9
A8	117.8	69.6	1.4
A9	764.0	57.7	3.3
A10	26.2	78.5	0.7
A11	26.1	67.0	0.7
A12	147.7	80.0	0.8
A13	587.0	60.0	3.2
A14	314.3	63.0	2.5
A15	74.9	69.7	0.5
A16	172.9	69.5	0.9

Time to Peak Values

The Time to Peak (Tp) was calculated based on 0.67 times the Time of Concentration (Tc) for the sub-catchments. To calculate the Tc value the Airport Formula and the Bransby-Williams Formula were considered (Appendix B). The Airport Formula and the Bransby-Williams equations are the most frequently used and applicable equations for rural basins in Ontario. The MTO Drainage Management Manual [10], for example, lists only these two equations. These methods were considered based on the drainage basin characteristics and representative results.

The Kirpich Formula was also considered as another alternative method for the calculation of Tc. It was developed for natural/rural drainage basins with well-defined channels and steep slopes (3%-10%). The maximum weighted watershed slope for the drainage basins in Casey Creek is 1.0% or less and the application of the formula did not result in representative values. The SCS Lag equations were also considered as another formula. It is applicable for drainage basins with CN values between 50 and 95 and where overland flow dominates. The overland flow mechanism is a major flow length factor only for sub-catchment A1 and a minor or absent factor for the remaining Casey Creek sub-catchments so, when applied to the drainage basins, the equation resulted in overestimated (long) Tc results. Therefore, the Airport Formula and the Bransby-Williams equations and processes were considered since they are the most applicable methods for Ontario and the sub-catchment characteristics.

The Airport Formula is applicable for sub-catchments with a Runoff Coefficient (C) value of less than 0.4. As shown in Table B2 (Appendix B) the C values for sub-catchments A1, A9, A13 and A14 are less than 0.4 and therefore the Airport Formula is applicable for those sub-catchments. The Bransby-Williams equation was used for the remaining sub-catchments.

Appendix B contains the calculations for Tc and Tp. Table B1, in Appendix B, shows the sub-catchment areas, 10% and 85% channel/overland flow lengths, percent slope and runoff coefficient. From these parameters, the total longest flow length (path) and weighted slope were calculated for use in the Tc equations. The slope calculations utilized the MTO 85/10 method which avoids the distorting effects of a steep upper portion of a sub-catchment or a highly irregular or convex/concave profile.

The Tc values as shown in Table B2 resulting from the applicable formula, based on the sub-catchment characteristics, were then multiplied by 0.67 to obtain the Tp value for input to the HEC-RAS model.

CN Values

The Curve Number (CN) values to calculate the rainfall-runoff response for the various land uses in the watershed were generated based on land use and soils, and a weighted average was calculated for each sub-catchment. The land uses and hydrologic features are spread throughout the watershed and there is not a high enough concentration in any one sub-catchment to require further specific delineation or separate consideration in the hydrologic model, to obtain representative results.

Table B3, in Appendix B, shows the overall CN values corresponding to the land use and hydrologic soil groups found in the Casey Creek watershed and the final CN value based on the detailed weighted CN calculations shown in Table B4.

The Soil Conservation Service of the U. S. Department of Agriculture originally developed the SCS Method to estimate runoff for agricultural applications. The runoff volume was based on the following equation:

$Q = (P-Ia)^2/P+S-Ia$

Where: Q = runoff volume (mm)

P = total depth of runoff (mm)

S = Soil Storage (mm)

Ia = initial abstraction (mm)

The CN is a measure of runoff potential and is related to soil storage (S) through the equation:

$S = (25400/CN)-254$

The Initial Abstraction (Ia) defines the amount of precipitation that must fall before surface excess results. Initial Abstraction is not the same as an initial interception or initial loss since changing the initial abstraction changes the infiltration response later in the storm [7]. In HEC-HMS, the value of Ia is calculated as 0.2 times the potential retention, which is determined from the curve number.

Precipitation Input

A previous study completed at MVCA for the Casey Creek watershed explored different design storm and snowmelt events to determine what precipitation input produces the highest peak flow response. For the rainfall hyetographs, a 12- and 24-hour SCS and 4-hour Chicago distribution, representing a long duration, high volume storm and a thunderstorm type storm, respectively, were used in the study. The appropriate rainfall durations and depths were obtained from the City of Ottawa *Sewer Design Guidelines* which contains Intensity-Duration-Frequency (IDF) curves derived from the rainfall recorded at the Ottawa International Airport between 1967 and 1997 analyzed using the Gumbel Distribution.

Synthetic spring rainfall-snowmelt hyetographs were developed based on the snowmelt + rainfall relationships developed by the Meteorological Service of Canada. They were derived from statistical analysis (Gumbel Extreme Value) of maximum annual snowmelt + rainfall volumes and were developed for 1- to 30-day periods based on observed precipitation and temperature. Annual volumes were estimated using a snowpack accumulation/depletion algorithm. Considering the watershed area of Casey Creek, a 1-, 3- and 5-day melt event was considered in developing the rainfall hyetographs.

The results of the study showed that the 12-hour SCS rainfall hyetograph produced the highest peak flow results in the Casey Creek watershed. For some of the more frequent storm events, the snowmelt + rainfall hyetographs resulted in slightly higher calculated flow values. Since the SCS rainfall distributions are, the standard distribution patterns and resulted in conservation results, the 12-hour SCS rainfall hyetograph simulation was recommended for use in the hydraulic flood plain mapping analysis.

Table 2 provides the total rainfall depths for the 12-hour design storm. These rainfall depths were derived from Table 5.1 in the City of Ottawa *Sewer Design Guidelines* and the SCS Type II rainfall distributions from the MTO *Drainage Management Manual* (Design Chart 1.05) were employed.

Table 2: Rainfall Depths (mm)

Return Period (yrs)	12-hour
2	43.2
5	57.8
10	67.2
25	79.2
50	87.6
100	96.0

2.4 Verification of Model Performance

In common with all existing hydrologic models, HEC-HMS is a simplified representation of the real world. Empirical equations and established guidelines are available to estimate the input parameters for the model. However, the best approach in assuring the model gives realistic flow estimates is to calibrate the model with observed data. This would generally consist of carrying out a series of simulations and comparing the results to observed flows. If necessary, the input parameters of the model would be adjusted to match the observations. To complete a full calibration exercise two main pieces of information are required; flow records of high flow events and records of the rainfall and/or rainfall/snowmelt that initiated the flow events.

There are no actual flow records on Casey Creek. Therefore, to verify the results from the HEC-HMS model other methods were used to calculate flows, for comparison purposes.

2.4.1 Ontario Flow Assessment Tool

The Ontario Flow Assessment Tool III (OFAT) developed by the Ontario Ministry of Natural Resources and Forestry [11] was employed. OFAT is an online, spatially based application to automate a series of labour-intensive technical hydrology tasks and view select hydrology information such as low flow and flood flow statistics. To provide flood flow estimates OFAT employs two regional hydrology models:

1. Index Flood with Expected Probability Adjustments (Moin and Shaw 1985)
2. Primary Multiple Regression Method (Moin and Shaw 1985)

Index Flood Method

The regional frequency analysis identified twelve regions in Ontario with relatively homogenous flood frequency characteristics. A total of 247 hydrometric stations with a record length of 10 or more years were used for the study. These stations have either natural or minimal regulation inflow. The data was fitted to the Three Parameter Log-Normal Distribution and the flow versus drainage area relationship was developed. The general form of the equation for index flood is shown below:

$Q_2 = CA^n$

Where Q_2 = 2-year flow (m^3/s)
A = drainage area (km^2)
C = constant derived for each region
n = exponent (slope) derived for each region

As shown in Figure 7, Casey Creek is within Region 1. For Region 1 the range of drainage areas for use of the regression equation is between 0.11 km^2 and 9,270 km^2, therefore it is applicable for the Casey Creek watershed. The applicable coefficients (Area < 60 km^2) are:

C = 0.22

N = 1.0

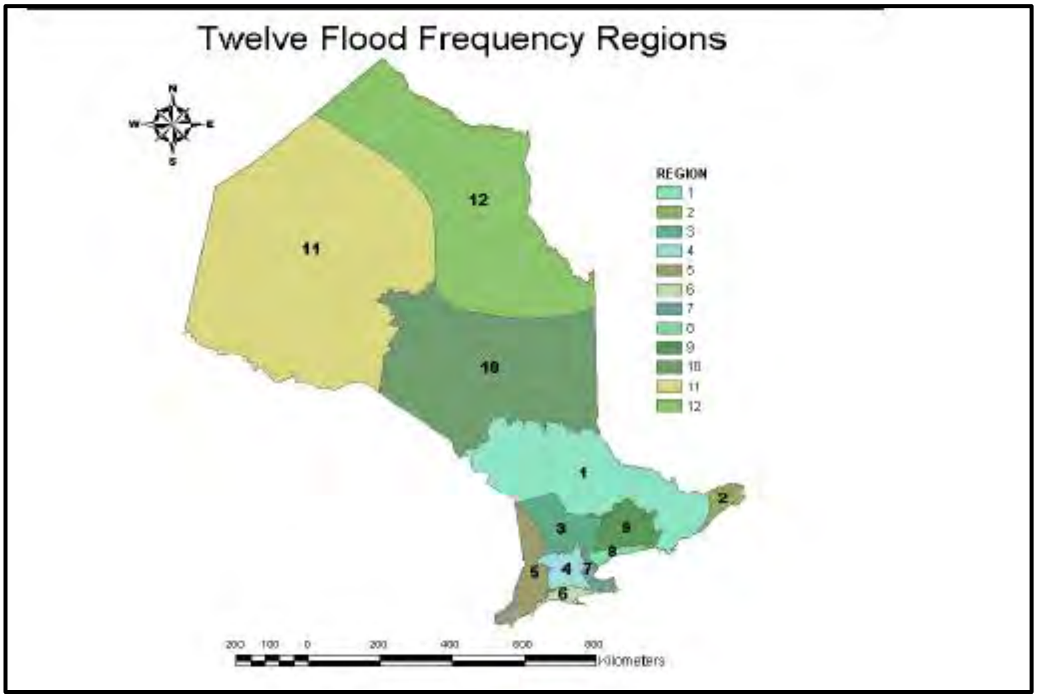

Figure 7: Twelve Flood Frequency Regions

Similarly, for each region, a curve showing the ratio of flows of different return periods to the index flood was derived. This can be used to estimate the flow for any required return period once the index flood has been calculated. Again, for Region 1 the applicable ratios are:

$Q_{1.25}/Q_2$ – 0.95

Q_2/Q_2 – 1.0

Q_5/Q_2 – 1.24

Q_{10}/Q_2 – 1.43

Q_{20}/Q_2 – 1.62

Q_{50}/Q_2 – 1.86

Q_{100}/Q_2 – 2.04

Q_{200}/Q_2 – 2.23

Q_{500}/Q_2 – 2.48

Multiple Regression Method

As in the Index Flood Method, the variable used for single station analysis, for the Multiple Regression Method, is annual peak instantaneous flow. Gauging stations in Ontario were classified according to the degree of regulation. Regulated gauging stations were included in the 50- and 100-year return periods with the premise that regulation has less impact on large events.

The main feature of this method is the delineation of homogenous regions within Ontario using standardized residuals from the 100-year return level. Three homogenous regions as shown in Figure 8 were found by grouping the residuals of similar magnitude and sign.

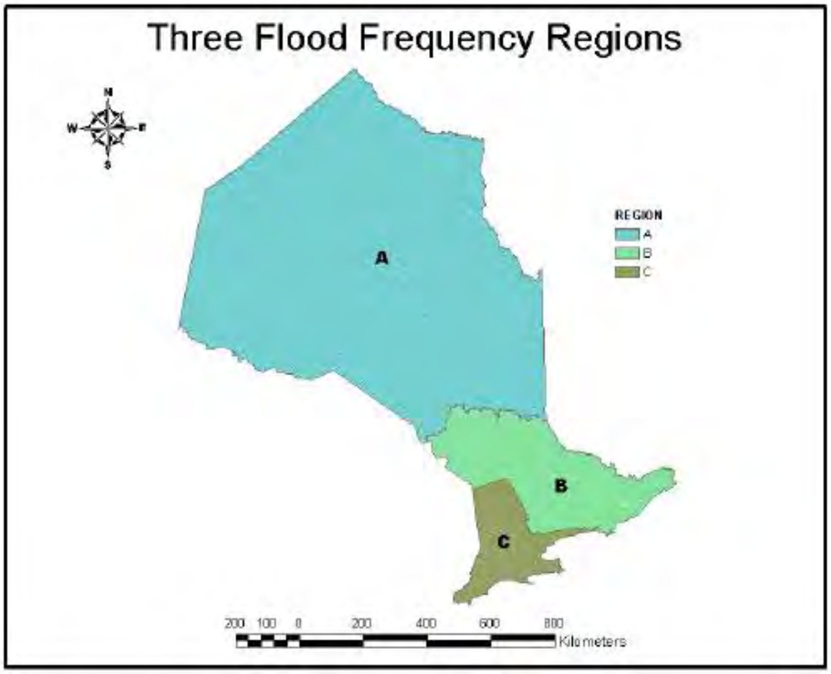

Figure 8: Three Flood Frequency Regions (OFAT)

Regression equations were developed for each of the three homogeneous regions. The parameters significant in the regression equations in the order of importance are:

- DA – Drainage Area (km^2)
- BFI - Base Flow Index (dimensionless)
- SLP - Slope of the Main Channel (m/km)
- ACLS - Area Controlled by Lake (water) and Wetlands (%)
- MAR – Mean Annual Runoff (mm)
- MAP – Mean Annual Precipitation (mm)
- SF - Shape Factor (dimensionless)

The regression equation is:

$$Log(QT)= a_0+a_1Log(DA)+a_2(BFI)^{1/2}+a_3(SLP)^{1/3}+a_4(ACLS)^{1/2}+a^5(SLP)+a_6Log(MAR)+a_7(MAR)+a_8Log(ACLS+1)+a_9(MAP)+a_{10}(SF)$$

With the regression coefficients developed for each region and an all Ontario category. Casey Creek is within Region B and applicable coefficients are shown below.

Region B							
Flow m3/sec	a0	a1	a3	a4	a10	SE	R2
Q2	0.2143	0.7464	-0.2172	-0.0194	-0.0077	0.14	0.91
Q5	0.2746	0.7443	-0.1961	-0.0198		0.14	0.89
Q10	0.3795	0.7217	-0.1799	-0.0202		0.15	0.87
Q20	0.2311	0.7461		-0.0197	-0.0081	0.15	0.87
Q50	0.3659	0.6989		-0.0275		0.15	0.85
Q100	0.4471	0.6839		-0.0276		0.16	0.83

All Ontario							
Flow m3/sec	a0	a1	a3	a4	a7	SE	R2
Q2	-1.5689	0.8509	0.1635	-0.0339	0.0013	0.22	0.95
Q5	-1.3629	0.8370	0.2023	-0.0341	0.0012	0.21	0.85
Q10	-1.2251	0.8261	0.2154	-0.0341	0.0012	0.21	0.84
Q20	-1.1478	0.8205	0.2353	-0.0333	0.0012	0.21	0.84
Q50	-0.8744	0.8006	0.2315	-0.0359	9.7E-4	0.21	0.84
Q100	-0.7947	0.7950	0.2424	-0.0357	9.3E-4	0.22	0.83

The data used for watershed delineation in OFAT III is based on data in the Water Resources Information Programs' (WRIP) Ontario Integrated Hydrology Data Packages. The Ontario Integrated Hydrology Data packages are currently stored and distributed through Land Information Ontario (LIO) (www.lio.gov.on.ca).

Specific input data includes:

- Watershed Shape factor – the square of the length of the Main Channel divided by the drainage area.
- Watershed Mean Elevation – calculated by averaging the values from the DEM contained in the Integrated Hydrology Package, within the watershed.
- Watershed Mean Slope – calculated by averaging the mean slope percent grid within the watershed.
- Length of the Main Channel – measured from a user-defined pour point and is obtained by a query to an Upstream Flow Length grid at the pour point.
- Maximum Channel Elevation – the elevation value from the DEM contained in the Integrated Hydrology Package, at the most upstream point along the main flow path.
- Minimum Channel Elevation - the elevation value from the DEM contained in the Integrated Hydrology Package, at the pour point.
- Slope of the Main Channel – computed using the Upstream Flow Length as determined in Length of the Main Channel together with elevation values from the pour point and the most upstream point along the main flow path.
- Areas of Lakes and Wetlands – the area within the watershed covered by a lake, major river or wetland is determined by summarizing a data layer created for OFAT III called WaterBodyArea Raster.
- Mean Annual Runoff – the Mean Annual Runoff Surface is a 1 km resolution raster data set that represents the mean annual runoff in millimetres at a particular location.
- Base Flow Index – the Base Flow Index Surface is a 1 km resolution raster data set that represents the portion of the flow in a stream derived from soil moisture or groundwater (baseflow).

2.4.2 Comparison of Flows and Verification

Table 3 shows a comparison of peak flows calculated by the HEC-HMS model of Casey Creek at the watershed outlet (confluence with Constance Lake, see location S1 on Figure 6) with the peak flows obtained by the Index Flood Method and the Multiple Regression Method. It should be noted that the sub-catchment drainage areas calculated and used by the OFAT tool (Index Flood Method and the Multiple Regression Method) were only a maximum of 3% different when compared to the areas delineated in this current study and therefore this variation would not impact the flow comparison presented in the tables.

Overall, the flows generated from the HEC-HMS model correspond well with the peak flows generated by the empirical Index Flood and Multiple Regression Methods. The higher frequency HEC-HMS peak flows are slightly lower than the Index Flood and Multiple Regression peak flows and the lower frequency peak flows are slightly higher, but overall the results are not systematically biased (consistently underestimated or overestimated).

Although the peak flows calculated employing the HEC-HMS hydrologic model may be slightly overestimated for the 100-year return period when compared to other methods, the results are conservative. It can therefore be concluded that the HEC-HMS model representation of Casey Creek, given the limitations of the data, is sufficiently accurate for purposes of estimating flows for the Regulatory flood event.

Table 3: Peak Flows at the Watershed Outlet) (m3/s)

Return Period (yrs)	HEC-HMS	OFAT	
		Index Flood Method	Multiple Regression
2	3.94	12.3	10.0
5	10.4	15.1	15.6
10	17.8	17.6	19.6
20		20.4	23.9
25	29.5	-	-
50	39.0	24.3	28.2
100	49.4	27.4	32.5

2.5 Flows for Flood Plain Delineation

As detailed in the *Technical Guide River and Stream Systems: Flood Hazard Limit* [3], the calculation of flood lines should be based on future development conditions with a planning horizon preferably extending 20 years into the future. The Casey Creek watershed is outside of the present City of Ottawa urban boundary as shown in the Official Plan. There are some Village Residential zones (e.g. Dunrobin) within the watershed, but no substantial development, that would significantly change the hydrologic model parameters, on a watershed basis, would be assumed to occur within the prescribed planning horizon. Since the HEC-HMS model verification process, detailed in Section 2.5 of this report, resulted in generally conservative flow results (i.e. higher than other methods), the analysis documented in Table 3 will be considered as also accounting for any increase in flows due to development within the 20-year planning time frame horizon.

The peak flows calculated as part of this study are not meant to necessarily set specific targets for stormwater management or to suggest that stormwater management is not required (and it is expected that stormwater management will be implemented when development occurs). Stormwater management facilities address many more functions than to simply control the quantity, such as water quality and erosion control and are a required element to address the impacts of development. Section 1.4 describes the relationship between flood plain analysis and stormwater management design and how the result of this study should be used.

Also, as shown in Figure B-1 in the MNRF Technical Guide, the MVCA watershed jurisdiction is within Zone 2 and therefore the Regulatory flood hazard criterion is the 100-year flood. Ontario Regulation 153/06 Mississippi Valley Conservation Authority: Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses also specifies that the applicable flood event standard to be used and, in the area of jurisdiction of the Mississippi Valley Conservation Authority, is the 100-year Flood Event Standard. Therefore, the 100-year event was employed to delineate the Regulatory flood line for Casey Creek. To apply a different standard would require prior approval from the Minister and a revision to Ontario Regulation 153/06.

2.5.1 Comparison to Previous Studies

As detailed in Section 1.3, previous studies that include hydrologic analyses for Casey Creek are:

- *Constance Creek Flood Plain Mapping Study,* Mississippi Valley Conservation Authority [5].
- *Constance Creek Flood Plain Mapping Study,* M. E. Andrews and Associates [6].

Table 4, below, shows a comparison of calculated flow values, at the downstream end of the Casey Creek watershed, calculated in the previous studies and the present study. All calculated flows shown in Table 4 employed the 12-hour SCS rainfall hyetograph. The M. E. Andrews 1994 study only reviewed the 100-year flood event, so there are no additional return period flows documented in that study.

Table 4: Flow Comparison at the Downstream End of the Casey Creek Watershed (m^3/s)

Return Period (yrs)	Present Study	M. E. Andrews and Associates Study	MVCA Constance Creek Study
5	10.4	-	15.8
25	29.5	-	30.5
100	49.4	27.3	44.6

The 2017 *Constance Creek Flood Plain Mapping Study* focused specifically on Constance Creek and Casey Creek, as a tributary of Constance Creek/Lake (Tributary B in that study). The peak flows obtained in this study correspond very well with the peak flows calculated in the present study. The 100-year peak flow calculated in the 1994 M. E. Andrews study is approximately 40% lower than the present study. The sub-catchment delineation in the 1994 M. E. Andrews study is coarser and the drainage area slightly different in size, but, there are two main reasons that could result in calculation differences:

1. In the 1994 M. E. Andrews study, the Modified Williams equation was used to calculate Tp and Recession Constant (K) values for use in the OTTHYMO hydrologic model. This empirical relationship was developed based on the southern United States watershed and may not be applicable in other areas. The Williams formulas are now not recommended for use in Ontario and therefore comparison of flows calculated employing the formula may also not be valid.

2. The CN values shown in Table 1 are higher than those documented in the 1994 M. E. Andrews study. This is mainly due to the fact that the 1994 study designates the soils in the upstream portion of the watershed as hydrologic soil group A, whereas the Ontario Ministry of Agriculture, Food and Rural Affairs classifies these soils as hydrologic soil group B. Since there is not a specific source for the soil information documented in the 1994 M. E. Andrews study, the OMAFRA data was employed in this present study.

The flows calculated in the present study better represent the watershed hydrology and thus are more representative for the Casey Creek watershed.

As a final check of the calculated flow values, Figure 9 shows a comparison of specific flows (L/s/ha) calculated as part of other flood plain mapping studies completed by the MVCA and the Rideau Valley Conservation Authority (RVCA). The total watershed area of the watercourses included are between 10 and 95 km^2 and are similar in land use (i.e. generally rural). The exception is Feedmill Creek which is partly developed with ongoing development and thus has a higher imperviousness than the other watersheds. As expected the calculated flows are the highest for Feedmill Creek. As shown in Figure 9 the calculated flow values for Casey Creek are in the middle range of the watersheds reviewed, adding further confidence in the hydrologic modelling.

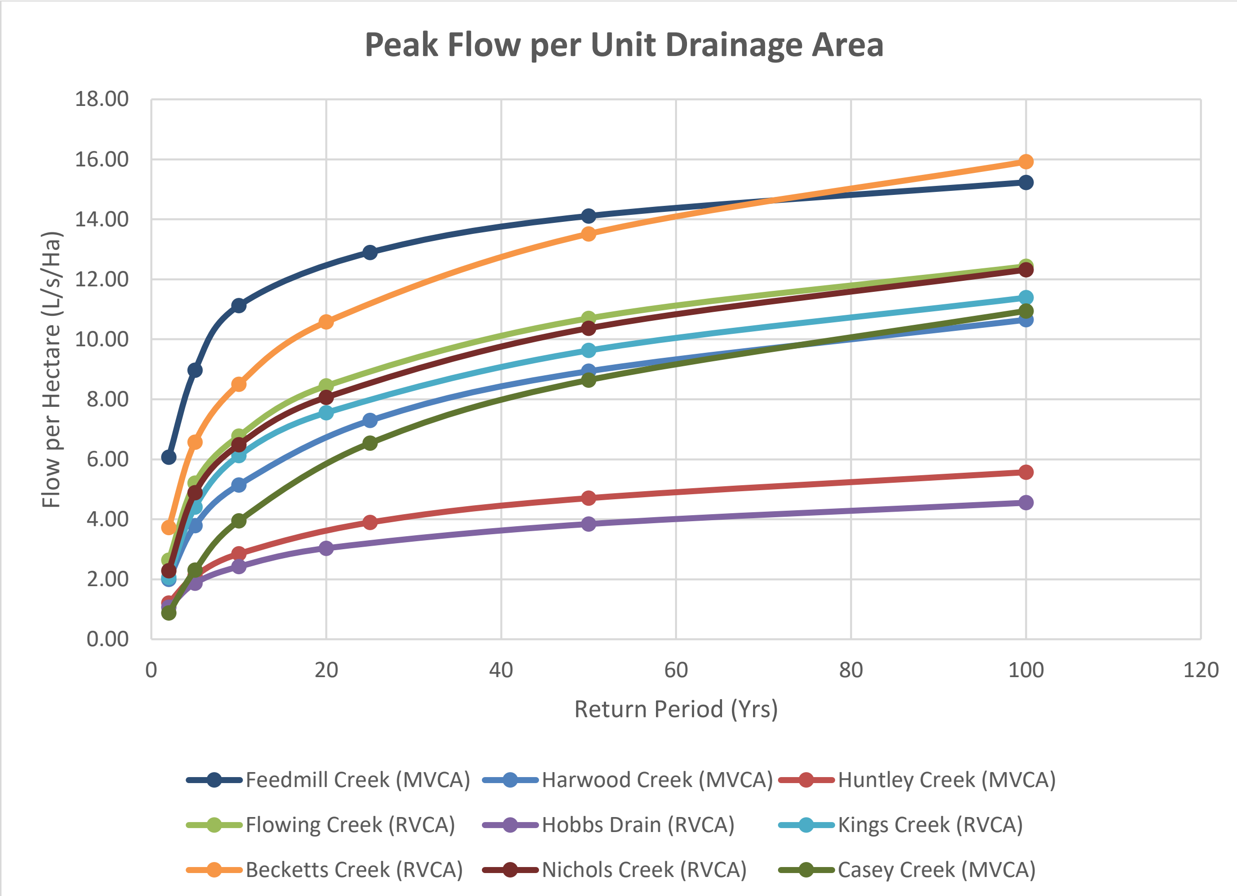

Figure 9: Peak Flow per Unit Area

2.6 Conclusions and Recommendations

The following summarizes the conclusions and recommendations of the hydrologic studies completed in connection with the delineation of the Regulatory flood levels for Casey Creek.

I. It was concluded that a hydrologic modelling approach was appropriate to estimate design flows for the study area due to the lack of complete long-term flow data for the watershed.
II. It was concluded that the HEC-HMS model was suitable for use in simulating design flows and hydrographs for the watershed based on the results of comparison with return period flows calculated using Regional Equations.
III. It is required that the Regulatory flood levels for Casey Creek be calculated based on flows from the 100-year flood event.
IV. The flow values calculated using the 12-hour SCS rainfall hyetograph and rainfall depth as detailed in Section 2.5 (Table 3) were recommended for use in the hydraulic analysis.

3.0 Hydraulic Analysis

3.1 Methodology

The objective of the hydraulic analysis conducted during this study was to estimate the flood levels for the 2, 5, 10, 25, 50, and 100-year (Regulatory event) for the study reach as shown in Appendix C. As shown, the study reaches include the main branch of Casey Creek from its outlet at Constance Lake upstream to Marchurst Road and the northwest tributary from the confluence with the main branch upstream to Thomas Dolan Parkway, the middle tributary from the confluence with the main branch upstream to Marchurst Road and the south tributary from the confluence with the main branch upstream to Murphy Side Road (see Figure 3). It should be noted that the flood plain mapping, on the main branch of Casey Creek, was not produced upstream of Marchurst Road since grading, topographic and channel alteration works have been completed as part of the development of an estate residential subdivision, subsequent to the collection of the Lidar information used to develop the Digital Elevation Model (DEM) used as input for this study. Therefore, the topographic information for input to the hydraulic model and base mapping to delineate the flood line is not available. The flood plain analysis and delineation should be extended further upstream for this reach when new updated topographic information is available.

The HEC-RAS (version 5.0.7) hydraulic backwater model developed by the US Army Corps of Engineers, simulated in steady flow analysis with mixed flow regime, was utilized to establish flood elevations in Casey Creek using flows corresponding to the applicable return periods. There is no history of ice jams causing flooding issues on Casey Creek, so any potential for ice jam flooding has not been included in the hydraulic analysis.

3.2 Input Parameters

Flows

Table 5 shows the flow values employed in the HEC-RAS analysis based on cross-section locations shown in the Exhibits in Appendix C. The flows shown in Table 5 are based on the hydrologic analysis employing the 12-hour SCS rainfall hyetograph as detailed in Section 2.6 of this report. The flows were generally only changed at the flow points shown in Figure 5.

Cross-Sections

The LiDAR-derived terrain provided by the City of Ottawa was used to produce a digital elevation model (DEM). The topographic data for each cross-section (channel and flood plain) were extracted from the DEM using the GeoHECRAS utility program. The cross-sections were oriented left to right looking downstream.

The LiDAR returns water surface elevations and does not return the underlying channel bed elevation. The cross-sections as derived from the DEM were used and a “low flow” channel was not added. This is

Table 5: Flows Values Used in HEC-RAS Analysis (m3/s)

	HEC-RAS Reach Name										
	Main DS-1-DS-0		Main DS-1	Main DS-2	Main			Trib 1		Trib 2	Trib 3
Return Period (yrs)	Cross-Section 1 to 1160[a]	Cross-Section 1509 to 2091[a]	Cross-Section 2 to 1849[a]	Cross-Section 3 to 784[a]	Cross-Section 4 to 1296[a]	Cross-Section 1313 to 2714[a]	Cross-Section 2748 to 3689[a]	Cross-Section 7 to 2377[a]	Cross-Section 2546 to 3577[a]	Cross-Section 6 to 3418[a]	Cross-Section 5 to 1228[a]
2	3.94	3.58	1.49	1.28	1.16	0.099	0.069	0.625	0.203	0.004	0.177
5	10.4	9.72	4.88	4.11	2.91	0.84	0.421	3.17	1.25	0.400	0.905
10	17.7	16.7	7.94	6.63	4.28	1.74	0.845	5.89	2.41	0.927	1.65
25	29.5	27.8	12.6	10.4	6.24	3.39	1.58	10.4	4.40	1.95	2.88
50	38.9	36.8	16.2	13.4	7.70	4.83	2.21	14.1	6.07	2.89	3.89
100	49.4	46.8	20.1	16.6	9.21	6.47	2.92	18.2	8.95	3.98	4.99

Note [a]: HEC-RAS Cross-Section

a conservative assumption and during field visits, it was noted that the channel of Casey Creek had a continuous flow and thus, during a storm event, the full capacity of the low flow channel would not be available to convey flow. Also, for the study reach the capacity of the low flow channel would be minimal in comparison to the wide flood plain area.

Figures showing the study reach and cross-section locations can be found in Appendix C. Cross-section and profile plots are contained in Appendix D.

Watercourse Crossings

Watercourse crossings were field surveyed using GPS equipment to establish benchmarks where other vertical control was not available. Structure geometry, invert elevations, size, condition, materials, and other features were noted, to be able to guide other input parameters (e.g. Manning's n values). The top of road profiles was determined from information extracted from the DEM. The length of the crossing was derived by measurements from the aerial photography and the expansion and contraction coefficients employed at all crossing were 0.3 and 0.5, respectively. All crossings, except for the Dunrobin Road crossing, were modelled in the HEC-RAS program using the culvert routine. The Dunrobin Road Crossing was modelled employing the standard step (energy) bridge routine. The structure database is found in Appendix E.

Any pedestrian/trail/ low level farm crossings of Casey Creek, within the study reach, were not included in the HEC-RAS backwater model. These crossings are generally clear spans of the low flow channel and the trails/walkways/roads on both sides leading to the crossings are at grade in the overbank flood plain area. As such, the crossings would have minimal impact on the channel and flood plain conveyance (i.e. minimal obstruction to flow).

Manning's n Values

Channel and overbank roughness values were assigned on a reach-by-reach basis, with values for Manning's n determined from the vegetation and surface features visible in the aerial photography and confirmed by on-site reconnaissance and observations during the field survey of watercourse crossings.

The Natural Stream category in Table 5-6 in *Open-Channel Hydraulics* [12] was consulted to determine appropriate Manning's n values. A Manning's n value of 0.032 was used for the channel in all simulations. For the flood plain (left and right overbanks), the flood plain vegetation is fairly uniform for most of the study reaches of Casey Creek consisting of pasture or crop field with some isolated areas of light brush. Therefore, a Manning's n value of 0.045 was used for most of the flood plain areas. In a few short reaches, this value was increased to 0.06 to represent more dense and mature vegetation. Downstream of Dunrobin Road, the vegetation becomes heavier. Therefore, a Manning's n value of 0.1, as noted in Table 5-6 [12], corresponds to a flood plain with medium to dense brush in summer was used for that reach in the HEC-RAS model. At the watercourse crossings, for the concrete culverts a Manning's n value of 0.013 was employed and for the corrugated steel pipe (CSP) crossings a Manning's n value of 0.024.

Boundary Conditions

In accordance with the *Technical Guide River and Stream Systems: Flood Hazard Limit* (OMNR 2002) the flood standard of any tributary (Casey Creek) flowing into a larger watercourse (Constance Lake/Creek) is based the greater of:

- The backwater of the larger watercourse during the Regulatory (100-year) flood, represented by the mean annual flood in the tributary watercourse calculated assuming the Regulatory flood level in the larger watercourse; or
- The Regulatory (100-year) flood level in tributary watercourse calculated assuming an average (mean annual) flood level in the larger watercourse.

Since the watershed area of the Constance Creek is three times larger than the watershed area of Casey Creek, it is reasonable to assume that the high-water levels at the confluence of these two watercourses will be generated by two independent flood events and the above noted procedure to calculate the flood standard is applicable.

From the report *Constance Creek Flood Plain Mapping Study* (April 2017), Table 6 below shows the applicable water levels, for the various return period flood events for Constance Lake. Also, in accordance with the *Technical Guide River and Stream Systems: Flood Hazard Limit* (OMNR 2002), where the maximum effective fetch length of a lake is less than 3 km, which is the case for Constance Lake, the lake can be treated as an integral part of the river system and no specific calculation or addition for wind setup and wave run up is required. Thus, the flood standard and elevation, for the lake, are the same as applied for the river system.

Table 6: Constance Lake Flood Elevations

Return Period (yrs)	Water Elevation (m)
2	60.20
5	60.32
10	60.39
25	60.48
50	60.60
100	60.92

To determine the Regulatory (100-year) flood elevations for Casey Creek to be used for Regulatory flood plain delineation and the implementation of regulations under Section 28 of the *Conservation Authorities Act*, the following scenarios were reviewed:

1) The mean annual flood in Casey Creek, represented by the 2-year peak flows, with the Constance Lake 100-year water level (60.9 m) as the downstream boundary condition; and
2) The 100-year peak flow in Casey Creek, with the downstream starting water level set at the 2-year water level for Constance Lake as a surrogate of the average (mean annual) flood level.

3.3 Flood Plain Elevations

Table 7 shows the calculated 100-year water levels for the two above noted scenarios. As shown in Table 7, 100-year peak flows produced by the Casey Creek watershed combined with the 2-year lake water levels produced the most conservative (highest) calculated water elevations. Therefore, the 100-year flow produced by the Casey Creek watershed is governing for determining the Regulatory (100-year) flood elevation and delineating the Regulatory flood plain and that flow, utilizing a 2-year downstream starting water elevation, was used. The 2-year starting water level downstream boundary condition was also used for all return period hydraulic simulations.

Table 7: Casey Creek Calculated 100-year Water Elevations

Cross-Section Number	2-year Flow in Casey Creek with 100-year Water Level in Constance Lake (m)	100-year Flow in Casey Creek with the 2-year Water Level in Constance Lake (m)
1	60.90	60.23
164	60.90	60.45
460	60.90	60.72
737	60.90	60.79
1160	60.90	61.04
1509	60.94	61.65
2062	61.04	62.22

3.3.1 Sensitivity Analysis

There is no measured water level information for Casey Creek, within the study reach, for hydraulic calibration/verification. Therefore, sensitivity analyses of various input parameters were completed to determine the impact of the calculated 100-year water elevations on Casey Creek.

3.3.1.1 Design Flows

A sensitivity analysis was completed by increasing the calculated 100-year flow by 20 percent. This sensitivity analysis indicates the potential impact of changes in flood flows and flood levels that might result from gradual trends such as climate variability or change. Table 8 shows the 100-year peak water levels and flows at four locations upstream of road crossings along the main branch of Casey Creek.

As shown in Table 8, the maximum increase in calculated 100-year water elevation as a result of potential flow increases is 0.3 m or less. The exception is upstream of the abandoned railway line crossing (now utilized as a trail). The crossing has a fairly small opening (3.0 m span by 1.0 m rise) and there is over 4.5 m of cover (fill) above the obvert of the culvert to the top of the minimum top of the road/trail. This crossing orientation does cause a substantial increase in the upstream water elevation. With the calculated 100-year flows, water elevations upstream of the crossing increased more than 0.3 m as compared to the downstream water elevations. Increasing the flow value only increases the rise in water elevation and the increase in flow results in the trail being overtopped, which would also impact the calculated water elevation.

This potential increase in calculated water elevation, assuming the 20% increase in flow, would only potentially result in a substantial difference in the geographic extent of the Regulatory flood line delineated on the flood plain maps in one isolated area (upstream of the abandoned railway line).

The Province of Ontario determines the flood standard to be used to define Regulatory flood lines and the Ministry of Natural Resources and Forestry (MNRF) has defined the 100-year flood for the MVCA watershed. To employ a different flood standard than the 100-year, as the Regulatory flood, would require prior approval of the Minister of Natural Resources and Forestry and a revision to the MVCA regulation.

Table 8: 100-year Water Elevation Results - Increased Flow Values

			Calculated Water Level (m)	
Location	HEC-RAS Reach	Cross-section	Standard Flow Value[1]	Standard Flow Value + 20%
Dunrobin Road	Main DS-1	2	63.36	63.43
Abandoned Railway	Main DS-1	978	67.93	68.23
Second Line Road	Main	1411	85.50	85.60
Murphy Side Road	Main	2868	91.45	91.46

Note : 1 - Flow values as shown in Table 7

3.3.1.2 Manning's n Value

The Manning's n values for the channel and flood plain which represent the "roughness" or resistance the flow encounters were increased by a factor of 1.5 and 2.0 and decreased by a factor of 0.5 from the values documented in Section 3.2. Table 9 shows the peak 100-year water levels at various locations upstream of road crossings within the watershed.

As shown in Table 9, the maximum increase in calculated water elevation, considering the increased Manning's n values, is generally less than 0.01 m.

This potential increase in calculated water elevation would not result in a substantial difference in the geographic extent of the Regulatory flood line delineated on the flood plain maps since where the greatest potential increase calculated water elevation occurs is also a reach within a relatively confined valley section.

Water elevations for all return period events are shown in Appendix F.

Table 9: 100-year Water Elevation Results- Varied Manning's n Values

			Calculated Water Level (m)			
Location	HEC-RAS Reach	Cross-section	Standard Manning's n Values[1]	Standard Manning's n Values x 0.5	Standard Manning's n Values x 1.5	Standard Manning's n Values x 2.0
Dunrobin Road	Main DS-1	2	63.	63.36	63.36	63.37
Abandoned Railway	Main DS-1	977	67.93	67.93	67.93	67.93
Second Line Road	Main	1408	85.50	85.50	85.50	85.51
Murphy Side Road	Main	2864	91.45	91.45	91.45	91.45

Note: 1 - Values as documented in Section 3.2

3.3.1.3 Boundary Condition

To test the sensitivity of the boundary condition selected in the study and the conclusion that the high-water levels at the confluence of the two watercourses will be generated by two independent flood events, the impact of scenario with 100-year water level for Constance Lake as a surrogate of the average (mean annual) flood level in combination with 100-year peak flow on Casey Creek was analyzed. As shown in Table 10, there is no difference in calculated water elevations at cross-sections upstream of 1160.

Table 10: 100-year Water Elevation Results - 100-year Flow on Casey Creek with the 100-year Water Level on Constance Lake

Cross-Section Number	100-year Flow in Casey Creek with the 2-year Water Level in Constance Lake (m)	100-year Flow on Casey Creek with the 100-year Water Level on Constance Lake (m)
1	60.23	60.90
164	60.45	60.90
460	60.72	60.92
737	60.79	60.96
1160	61.04	61.08
1509	61.65	61.65
2062	62.22	62.22

4.0 Regulatory Flood Plain Delineation

The Regulatory (100-year) flood plain elevations were used to plot the Regulatory flood lines using ArcGIS. The Regulatory flood levels at each cross section were used to produce a Triangulated Irregular Network (TIN) surface in ArcGIS. The TIN surface is a plane between each cross section based on the Regulatory flood plain elevations as shown in Figure 10. The intersection of the TIN and the LiDAR-derived terrain determines the location of the Regulatory flood line.

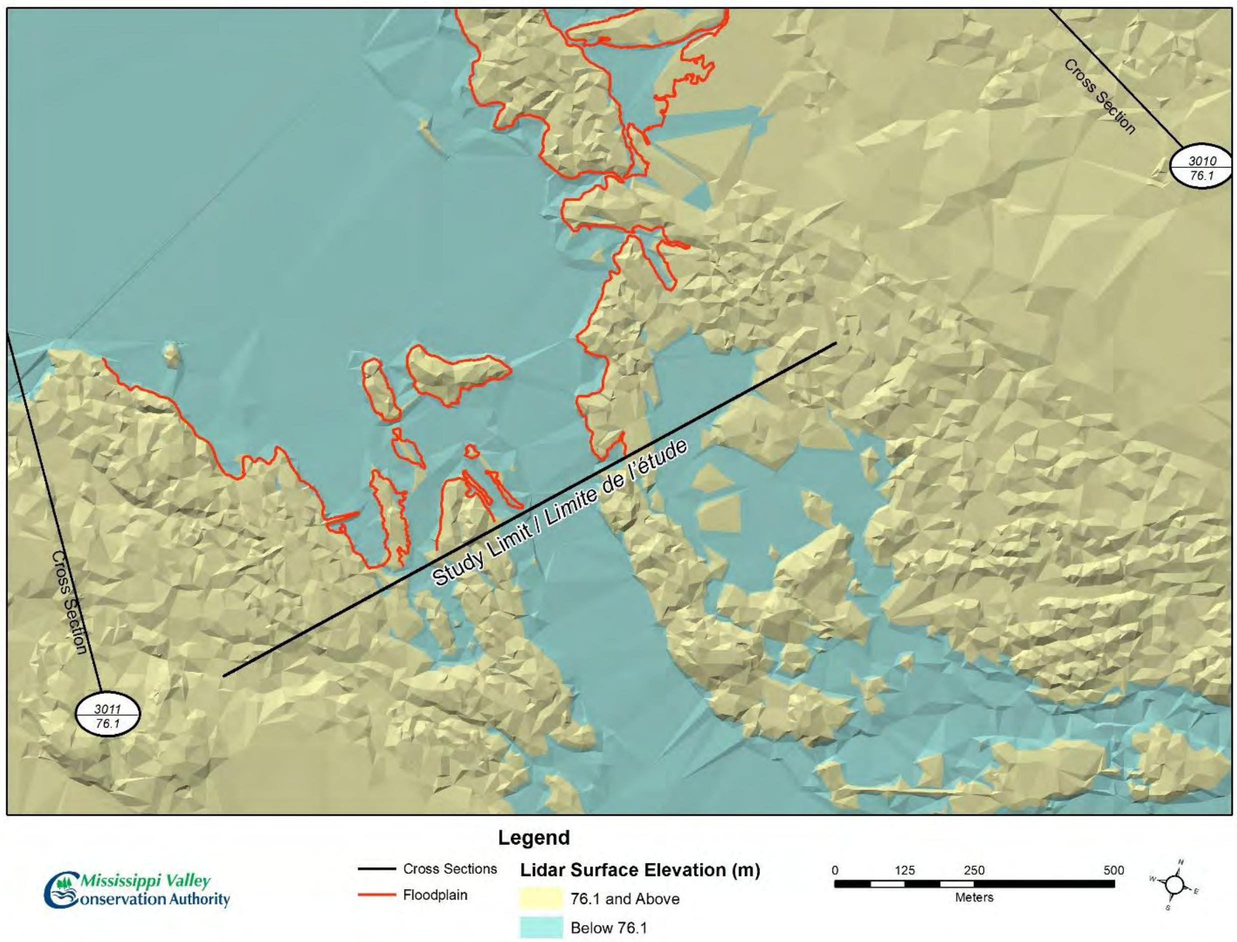

Figure 10: Flood Line Delineation

After the initial plotting of the Regulatory flood plain line, it was reviewed by the engineer and any revisions to define spill areas etc. were made. The only reaches that required revisions or close re-examination were the locations of abrupt bends in the Casey Creek channel. Potential road overtopping was also reviewed to ensure the upstream calculated water elevation was used to determine when overtopping occurred. As well, some generalization techniques were employed to improve the visualization of the flood plain line such as smoothing and simplification. Other quality assurance measures were incorporated per recommendations from engineers including ensuring the flood plain line is continuous along the river reaches.

The flood plain maps were produced, on 10 individual map sheets at a scale of 1:2000 showing an overall contour interval of a 0.5 m contour and employing 2017 aerial photography.

As documented in the *Final Report LiDAR for the City of Ottawa Mapping Program* prepared by Airborne Imaging (Appendix A), the accuracy of point cloud on a flat ground surface without vegetation (Fundamental Vertical Accuracy) was found to be 13.0 cm. The Supplemental Vertical accuracy considering crop/pasture, forested/wooded and thicket/shrubland cover was 25.5 cm and the Consolidated Vertical Accuracy, merging all land cover types with open flat surfaces, was found to be 30.3 cm.

The document *Data Capture Specifications for Hydrographic Features Version 1.3* prepared by the Ministry of Natural Resources and Forestry [13] lists the vertical scale and accuracy criteria based on map scale as shown in table 11.

Table 11: Map Scale

Absolute	Spot Elevation	Contours	Map Scale
0.5 m	0.3 m	1.0 m	1:2000
1.25 m	2.0 m	2.0 m	1:5000

Therefore, at a scale of mapping for Casey Creek of 1:2000, the accuracy of the LiDAR data and the DEM derived from the data is suitable for the production of flood plain delineation and mapping.

MVCA staff also completed a field survey at 21 locations, shown in Figure 11, to check the surveyed elevations compared to the elevations derived from the Digital Elevation Model (DEM) used in the analysis. As shown in Table 12, most of the surveyed spot elevations are within a 10 cm or less variance with only one location being just below the 30 cm tolerance.

4.1 Flood Prone Areas

The flood plain maps (under separate cover) show a fairly narrow flood plain, in the upper reaches of the Casey Creek study reaches. Upstream of the abandoned railway crossing on the main and northwest tributary reaches, the backwater from the relatively small culvert and high fill does result in wider flood plain areas. Upstream of Dunrobin Road where the flood plain areas are flat there is a more extensive flood plain, as the flood plains from the Main reach and Tributary 1 merge.

Spills

- On Map Sheet 4 there are four spill locations across existing agricultural fields.
- Map Sheet 6 shows another spill area to the east of the Main reach. This spill is south of the intersection of Dunrobin Road and Thomas A Dolan Parkway.
- The flood plain on Map Sheet 8 shows a spill location, to the north.

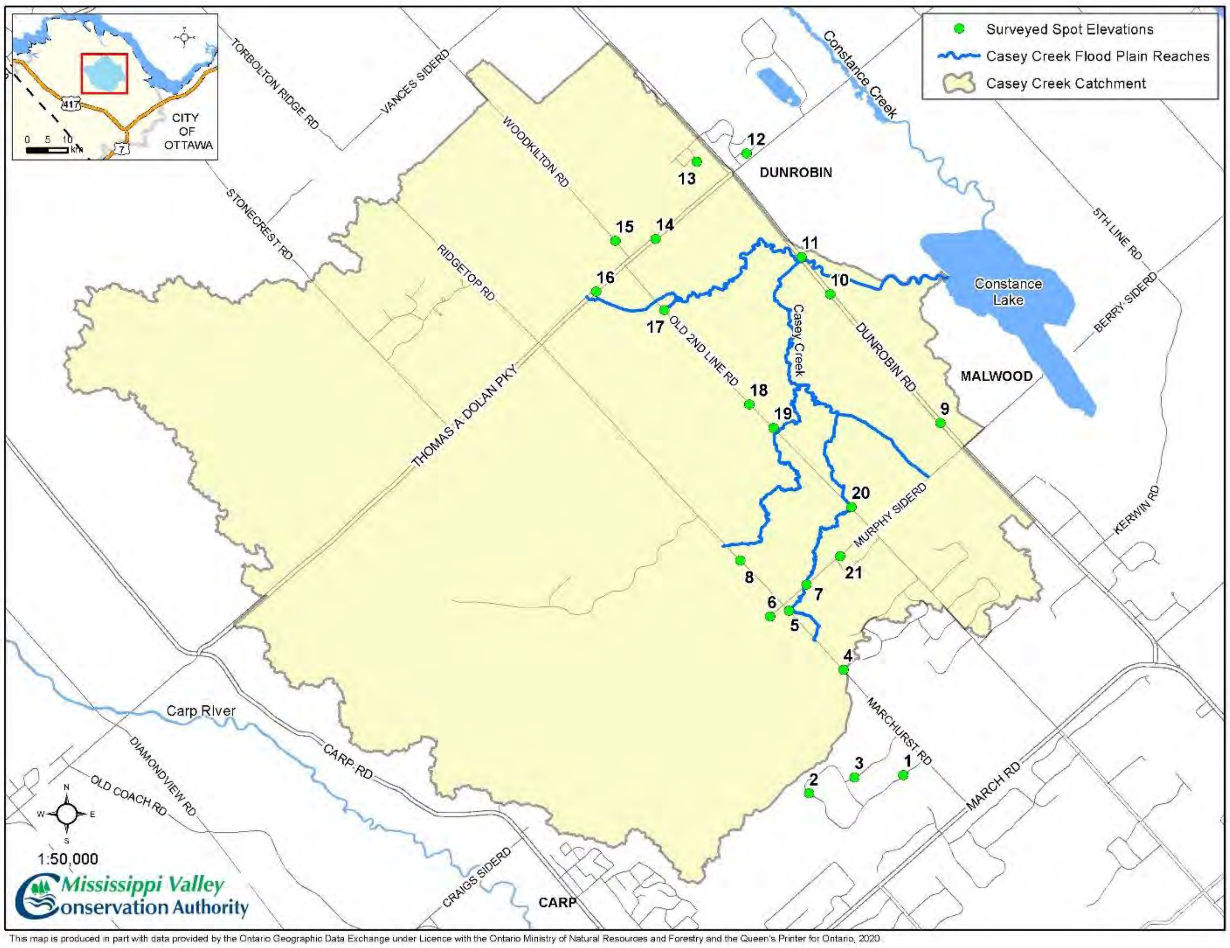

Figure 11: Topographic Map Check Points

Although these spill areas are not anticipated to result in major flood risk, determining the extent and specific direction of flood waters is beyond the scope of this study. The hydraulic analysis did not include any reduction in flow values as a result of these spills. So, if they are eliminated in the future, to confine the flood plain, the hydraulic analysis is still valid for the watercourse.

Existing Development

There is one house that is partially within the Regulatory (100-year) flood plain at 2535 Dunrobin Road.

Existing Roads

The only road that crosses Casey Creek that is flooded or overtopped during the Regulatory (100-year) flood event is the Second Line Road crossing on the Main branch (Map Sheet 3) by a maximum depth of approximately 0.1 m. There are three properties (2554 Dunrobin, 2565 Dunrobin, and 2535 Dunrobin) that do not have safe access as their driveways will be more than 0.3m below the 100-year flood level (Map Sheet 9).

Table 12: Topographic Map Check Results			
Spot Elevation Point	Survey Elevation (m)	DEM Elevation (m)	Difference (m)
1	100.30	100.33	-0.02
2	103.91	103.94	-0.03
3	101.80	101.84	-0.04
4	98.50	98.60	-0.10
5	93.11	93.19	-0.08
6	94.68	94.74	-0.06
7	91.42	91.52	-0.11
8	96.95	96.66	0.29
9	78.40	78.33	0.07
10	63.94	63.97	-0.03
11	62.25	62.31	-0.07
12	62.91	62.95	-0.04
13	65.39	65.45	-0.07
14	69.28	69.28	-0.00
15	75.22	75.16	0.06
16	69.49	69.49	-0.00
17	68.46	68.51	-0.04
18	74.52	74.50	0.02
19	77.10	77.04	0.06
20	86.15	86.15	-0.00
21	91.21	91.24	-0.03

4.2 Remedial Measures

Since there are no existing structures within the Regulatory flood plain and one crossing of Second Line Road is subject to flooding, at present, minimal remedial measures would be required. Remedial measures could include undertaking a maintenance program to raise and/or increase the crossing conveyance capacity of the impacted road to reduce the threat of overtopping.

A full cost/benefit analysis should be completed to assess the implications of any maintenance or upgrading options.

5.0 Regulation Limit

Potential hazards associated with rivers, stream and their valley lands include flooding, slope instability, stream bank and valley erosion and the erosion associated with meandering rivers or streams. In determining the extent of the Regulation Limit for Ontario Regulation 153/06 (MVCA's regulation under Section 28 of the *Conservation Authorities Act*) the presence of all these potential hazards must be considered to determine the requisite (most extensive) hazard. The Regulation Limit is defined by a 15 m buffer beyond the requisite hazard.

The extent of the Regulation Limit was determined using the flow chart and procedure documented in Appendix G and then also delineated on the maps.

6.0 Conclusions and Recommendations

The Regulatory flood plain for Casey Creek is delineated on 10 individual map sheets prepared at a scale of 1:2000. The 2017 air photos were used and clearly show Casey Creek, buildings, infrastructure, vegetation, and other details.

The analysis, documented in this report, meets the standards found in the *Technical Guide River & Stream Systems: Flooding Hazard Limit* (OMNR 2002) and therefore, the resulting Regulatory (100-year) flood plain delineation is suitable for use in MVCA's Regulation mapping as well as for municipal land use planning purposes.

There are limited flood-prone structures or roads along Casey Creek, however, all new development should be restricted from locating within the Regulatory flood plain.

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Appendices

Appendix A

LiDAR Acquisition Report

Final Report

For project:

LiDAR for City of Ottawa Mapping Program
RFT No. 01912-90510-T01

Prepared for:

City of Ottawa
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March 2013

Contents

Introduction

The City of Ottawa contracted Airborne Imaging, A Clean Harbors Company, in October of 2012 to acquire and deliver digital elevation data derived from airborne LiDAR (Light Detection and Ranging) to cover two areas in the Ottawa region.

This report focuses on LiDAR acquisition details, such as flight parameters, project control, ground truthing results and data processing technique and deliverables for the combined 2345.1 sq km for the Ottawa area (2218.7 sq km) and the Conservation Authority area (126.4 sq km) over Mississippi Lake.

See Appendix A for an overview map of the project.

Personnel

Forming a crew of seven, personnel assigned to acquire the LiDAR data included one Project Manager, two System & Base Operators, one surveyor, two pilots, and one AME (Aircraft Maintenance Engineer). The Project Manager, Allyson Fox, had a key role ensuring the project was completed on schedule. Her responsibilities included processing and verifying the integrity of all LiDAR and GPS data immediately after each flight mission. Allyson has extensive experience in the Lidar industry, and in the past 8 years has worked exclusively in the LiDAR industry.

For this project the crew was based in Ottawa and utilized the Carp airport for aircraft maintenance, fuel, and system calibration.

Project Schedule

On November 3rd 2012, Allyson Fox, the project manager and Roly Tang, the surveyor arrived in Ottawa. They spent eleven days in the field locating existing control, establishing a geodetic network and collecting ground truth survey data. The two system/base operators, Troy Sentner and Trace Trithardt arrived in Ottawa on November 11th and the aircraft and crew arrived on November 14th.

LiDAR System & Flight Parameters

The aircraft assigned to this project was a Cessna Caravan with call sign C-FARQ, and is owned and operated by Airborne Energy Solutions (AES), an air charter company located in Whitecourt, Alberta. Because of AES's robust safety program and efficient work practices, AES has been under contract with Airborne Imaging for 7 years without incident.

The LiDAR system utilized on this project was a Leica ALS70-HP, capable of laser pulse rates up to 500,000 Hz with Multiple Pulse in the Air (MPIA) technology. For this project the LiDAR data was acquired at an altitude of 1800m AGL (Above Ground Level) with the laser pulse rate set at 250 kHz, resulting in a data set with a point density averaging 4.4 points per meter^2. The total density is based on two overlapping flight line swaths flown in opposing directions to provide redundancy and to ensure there are no data holes (or slivers). The following details the flight parameters used:

Flight Height: 1800 m AGL
Speed: 160 knots
Flightline Spacing: 600 m
Single Pass Swath width: 1200 m
Overlap: 50%
Scan Angle or FOV: 40^{o} effective (42^{o} minus 1^{o} clipped on each side of the scan edge)
Scan Frequency: 42Hz
Scan Pulse Rate: 250 KHz
4.4 Points per Sq meter with overlap

Project Control

Control for this project consisted of a fully constrained closed loop static control network. All baselines for the network were kept to 50km or less and all observations were duplicated whenever possible. Control points for this project were strategically chosen so that they would have both federal NAD83CSRS (1997 Epoch V3) and provincial "NAD83 Original" coordinates associated with them. This allowed two separate instances of the control network to be processed. The first instance was processed in the NAD83CSRS datum and the second instance was processed in "NAD83 Original". Both networks were fixed vertically to CGVD28 and the HT2.0 geoid was used.

The rationale behind this maneuver is that the federal 3D densification network is a known entity to Airborne Imaging. By processing the data using the coordinates provided by NRCAN, Airborne Imaging is able to gain confidence in the quality of the network and the control points occupied. It also provides the framework to transform data for this project should the city of Ottawa ever transition to NAD83CSRS.

The NAD83CSRS network was built using 7 control points; 5 were bench marks occupied by Airborne imaging while the final two are members of the Canadian Active Control System (CACS). Of the seven control points used by Airborne Imaging, 4 were constrained horizontally and 6 were constrained vertically. As NRCAN publishes confidence intervals for the station, each station could be weighted in the fully constrained network. Appropriate standard deviations were associated with each station and the network was allowed to balance itself.

One of the CACS stations (943020) did not have published "NAD83 Original" coordinates associated with it and was not held as a constraint in the "NAD83 Original" network adjustment. As a result, the "NAD83 Original" network adjustment was constrained to 3 stations horizontally and 6 vertically.

Since Cosine does not publish the confidence intervals for control points, Airborne Imaging was left with two choices; hold all control points “fixed” or to give all the control points a reasonable estimated standard deviation. Holding the base stations “fixed” would effectively force errors inherent to the network into the floating stations (newly established control points A458 & A459 used for processing all the missions). Since multibase processing was to be used on this project and a high relative precision between base stations is required, holding stations fixed was deemed undesirable and all control points were given a standard deviation of 2cm horizontally and 5cm vertically.

Note that the Lidar survey was all based on the NAD83 (Original) network.

See Appendix B for the NAD83 (Original) control report.

<u>Destroyed monuments</u>

Difficulties were encountered during the first day of building the control network. Several control points were either not found, destroyed or found to be unusable due to their proximity to GNSS line of sight obstacles (tree cover) or their orientation (vertical rock face). Points that were found to be unusable are:

00119773030 - Condition unknown; access is blocked.
0011986u017 - Found in good condition but unusable.
0011986u144 - Found in good condition but unusable.
01919680197 - Destroyed. Location plots underneath a road.
00819758197 - Found in good condition but unusable.

Additional details can be found in Appendix C.

Check Points

Check points were surveyed to support the vertical accuracy assessment. For greater accuracy, the points have been surveyed in close proximity to control points that are part of our geodetic network. This way, the baseline distances were kept to a minimum distance for post-processing differential GPS.

The points collected on open flat surfaces were surveyed by rapid-static GPS with a minimum of 15 minutes of observations. The coordinates were derived by post-processing the GPS data. These points were used for calculating the Fundamental Vertical Accuracy.

For the Supplemental Vertical Accuracy, the check points were surveyed by two different methods. When skies were not obstructed, the surveyor would collect GPS data on a survey rod and walk to the check point location. The surveyor would collect data without moving for a few seconds. The coordinates were then derived by post-processing the data in kinematic mode. Most of the points in land cover categories “crop/pasture” and “thicket/shrub” were collected this way. For the “forested/wooded” land cover, the points were surveyed by total station.

Calibration

Calibration of raw LiDAR data before and after each flight mission is essential to LiDAR acquisition and is carried out post mission to fine tune systematic GPS & Inertial errors associated with aircraft & sensor roll, pitch, and heading. For the most part these errors are minimal but provide consistency for the data from mission to mission and also alleviates any gross errors that may have occurred during each flight mission.

A “Calibration Site” was established at the Carp airport, which consists of a primary control station, A458, and surveyed kinematic points on Carp Road collected at 1 second intervals over a distance of 1.4 km as to cover one full swath of data. Approximately 2km long strips of Lidar data was then flown twice in opposing directions, centered over the kinematic points and nearby buildings, once at the start of mission, and a second time at the end of mission.

Lidar Acquisition

Good weather was on our side and for a project this size, the data acquisition of the Lidar data took place during a short period of time. The fact that we had the personnel to fly two flights (or missions) per day helped us finish the acquisition within eight days. Seven missions were required to cover both areas of interest.

Two missions were flown on November 15. Then, an evening aircraft inspection revealed a faulty part requiring replacement. The part was ordered and replaced by November 19. Fortunately, the flying conditions were still good and two missions were flown on November 20, two more on November 21 and one on November 22 to complete the acquisition. As per contract requirements, there was no snow on the ground during the data acquisition period, and there were no leafs in the trees.

The orientation of the flight lines was designed to minimize the amount of aircraft turns and was flown at various azimuths. The aircraft was kept to a maximum distance of 45 kilometers from the nearest base station to achieve required GPS accuracies. GPS receivers were deployed on two base stations during flights and the trajectories were computed using multi-base solutions. See Appendix C for a Missions Map and Flight Logs.

LiDAR Data Processing

<u>Calibration</u>

After each mission, the point cloud strips from the “calibration passes” are compared to each other to ensure relative accuracy. The outside edges of scan can be compared in open areas to detect vertical differences which would point to roll or scale miscalibration values. Man-made features such as pitched-roof buildings are also useful to check for horizontal alignment. If the calibration values (angles between the laser sensor and the IMU) are found to have changed from the previous mission, it would show in the repeatability of the measured data sets. Corrective measures would then be taken to fine tune the proper angular values. Once the data fit well together, it is compared to a ground profile to validate the elevations in an absolute accuracy point of view. Statistics and visual graphs of the elevation differences are produced to confirm accuracy requirements. Once the final calibration values are obtained, the final point cloud data can be generated.

Occasionally, the point cloud generated from the manufacturer's software has a vertical bias which can be detected when compared to the ground truth. This behavior is not necessarily consistent from mission to mission but is monitored closely and shifted vertically accordingly. See Appendix D for a list of point cloud files by mission and the vertical shifts applied.

Since the raw point cloud is part of the deliverables and the maximum file size was not to exceed 2 GB per file, the point cloud strip files had to be split into smaller segments. Since the ALS70 system has a dual beam and the returns are saved in different classes for the two receivers, each strip was split by receiver into two different files. After splitting by receiver, some files (longer flight lines) were still greater than 2 GB in size, so another split was done for the first 70 million points into one file and then the rest into a second file. Appendix D also shows the split files and their numbering convention. They are divided into the Conservation Authority area (UTM18) and the main Ottawa area (MTM9).

Tiling

The entire point cloud was originally produced in its native UTM zone 18. The raw LiDAR strips were then imported into tiles of 1000m X 1000m tiles conforming to the client's requirements. In the file naming convention, the first three digits represent the easting in kilometers and the next four digits represent the northing in kilometers. These tiles contain points of all-returns from the LiDAR unit and are stored in individual binary files in .LAS 1.2 format.

Preliminary Classification

In order to eliminate the effects of artifacts left in the bare-earth, the tiles are processed with an automated, artifact removal technique and then followed up by manual inspection of the data. Point classification or artifact removal is done using a product by TerraSolid software running on Microstation V8 called TerraScan and TerraModel. The TerraScan software uses macros that are set-up to measure the angles and distances between points to determine what classification a point should be: ground, vegetation, other. The angle and distance values in the macros can be adjusted to be more or less aggressive with the classification of points by varying the incidence angles and estimated distances among neighboring points. The lower points are generally classified as ground returns, with the points above separated in low, medium and high vegetation.
After an automated macro is run to determine classes, a manual QC is performed to fine tune the classification of points for the ground class. To better understand areas for improvement, the points that are classified as bare earth are extracted and turned into viewable TIN and grid surfaces. These surfaces are inspected for areas that appear rough, artificially flattened or truncated, no data areas, or have other viewable errors.

In cleaning up ground points, the focus is concentrated in areas where few ground points have been left in the bare earth model and the ground appears rough or lower and flatter than it may be in reality. The scarcity of ground points may be a result from no penetration through a dense vegetation layer, water bodies, low reflectivity objects, or too aggressive values with the macro. A manual inspection of these areas plays a major role in resolving any issues or irregularities with the bare earth model.

Hydro-Flattening & Final Classification

Once the ground class has reached a final level of classification accuracy, the hydro-flattening process is initiated. The rivers and water bodies are digitized as break lines according to specifications with the support of aerial photography and Lidar intensity & surface model images. Elevations for the break lines are derived from the Lidar point cloud. The break lines are then used to classify the laser returns inside the polygons to the water class. A 1.5 meter buffer was created outside of the water body break lines and any points from the ground class falling within this buffer was re-classified to class 10 – "Breakline proximity".

The final point cloud has points in the following classes:

2	Ground
3	Low Vegetation (0 to 0.7m)
5	High Vegetation (above 0.7m)
7	Low Points (noise)
9	Water
10	Break line proximity
11	Withheld

Deliverables

The Conservation Authority area was delivered in the UTM zone 18 projection. For the main Ottawa area, the data was converted to the MTM zone 9 projection.

The deliverable formats consist of:

Raw Point Cloud: 1 file per swath, split not to exceed 2GB
.LAS v1.2 format

Classified Point Cloud: .LAS v1.2 format (tiled)

Bare Earth DEM: 1m grids, hydro-flattened
(elevations from the ground TIN, constrained to the 3D breaklines)
Delivered in 32bit Geotiff format, tiled with 10m buffer

Break lines: 3D shape files of the rivers and lakes

Metadata: FGDC compliant .xml file
1 file describing each deliverable formats for the project.

Vertical Accuracy Assessment

The assessment of vertical accuracy follows the ASPRS methodology of Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy (SVA) and Consolidated Vertical accuracy (CVA).
The FVA defines the accuracy of the point cloud on flat hard surfaces without vegetation obstructions. The SVA determines the accuracy of the ground surface under different classes of vegetation type. The following land cover types have been selected for this project:

Crop / Pasture
Forested / Wooded
Thicket / Shrub

The CVA is calculated by merging all the land cover type with the open flat surfaces.

Below is a summary table of the accuracies achieved for this project.

Accuracy type	Accuracy achieved	Contract Accuracy requirements	Statistical method
FVA	13.0 cm	<= 36.3 cm	95% (2 sigma)
CVA	25.5 cm	<= 50 cm	95th percentile
SVA	30.3 cm	<= 60 cm	95th percentile

Below is a breakdown of accuracy types for both the Conservation Authority area and the Ottawa area with a list of vertical differences between the control points and the ground surface.

Fundamental Vertical Accuracy

The accuracy statements for FVA are based on the premise that the 2-sigma confidence level (95% of the time) is twice the RMS value.

Conservation area (UTM18)

A comparison was made between the Lidar derived ground surface and the surveyed points on open flat surfaces.

The FVA (95%) is 13.0 cm.

Below are the statistics and list of vertical differences.

Average dz	-0.035
Minimum dz	-0.160
Maximum dz	+0.034
Average magnitude	0.045
Root mean square	0.065
Std deviation	0.056

Number	Easting	Northing	Known Z	Laser Z	Dz
0000027	408321.771	4998433.840	138.476	138.450	-0.026
0000030	408321.726	4998433.840	138.524	138.450	-0.074
0000031	406790.219	4998316.384	145.441	145.440	-0.001
0000033	406665.054	4995368.393	135.118	135.020	-0.098
0000034	406818.938	4995183.789	136.371	136.380	+0.009
0000038	406811.510	4995167.537	136.415	136.410	-0.005
0000041	406727.787	4995288.094	135.393	135.370	-0.023
0000085	406768.006	4995251.773	135.836	135.720	-0.116
0000086	406762.799	4995247.240	135.750	135.740	-0.010
0000087	406802.379	4995185.496	136.396	136.430	+0.034
0000088	406826.190	4995214.216	135.847	135.850	+0.003
0000089	406828.519	4995213.828	135.828	135.760	-0.068
0000095	406813.181	4995155.200	136.270	136.110	-0.160
0000096	406808.449	4995156.817	136.486	136.500	+0.014
000A460	407928.410	4998193.734	142.046	142.060	+0.014
0TMP_12	406818.938	4995183.790	136.371	136.380	+0.009
0TMP_13	406665.054	4995368.394	135.118	135.020	-0.098

Ottawa area (MTM9)

A comparison was made between the Lidar derived ground surface and the surveyed points on open flat surfaces.

The FVA (95%) is 12.8 cm.

Below are the statistics and list of vertical differences.

```
Average dz          -0.007
Minimum dz          -0.228
Maximum dz          +0.257
Average magnitude    0.045
Root mean square     0.064
Std deviation        0.064
```

Number	Easting	Northing	Known Z	Laser Z	Dz
0000002	343498.617	5020015.358	116.295	116.340	+0.045
0000003	391233.824	5029446.332	66.059	66.050	-0.009
0000017	391210.115	5029446.304	64.368	64.310	-0.058
0000018	394465.525	5032457.605	83.970	83.990	+0.020
0000019	401482.567	5026083.691	73.925	73.920	-0.005
0000020	383929.275	5009499.550	84.002	83.990	-0.012
0000021	384562.221	5005945.788	92.474	92.340	-0.134
0000022	359331.262	4993587.740	104.582	104.620	+0.038
0000023	359202.997	4993471.243	104.479	104.510	+0.031
0000024	351545.133	4993625.087	125.002	124.850	-0.152
0000025	351523.442	4993713.488	125.877	125.800	-0.077
0000042	336561.020	5040030.222	64.969	64.970	+0.001
0000043	335624.603	5033664.310	82.508	82.590	+0.082
0000044	333833.259	5032133.610	110.453	110.420	-0.033
0000045	328698.178	5027607.916	94.755	94.760	+0.005
0000046	323704.988	5023194.027	99.032	99.030	-0.002
0000047	343588.777	5020127.938	117.747	117.730	-0.017
0000048	384213.302	5005730.266	91.370	91.410	+0.040
0000049	368747.595	4996821.420	87.867	87.840	-0.027
0000054	336576.023	5040081.947	64.734	64.740	+0.006
0000055	336535.631	5040044.880	64.802	64.790	-0.012
0000061	336638.652	5040049.498	65.414	65.430	+0.016
0000065	359341.610	4993576.274	105.238	105.010	-0.228
0000067	351523.450	4993713.461	125.863	125.800	-0.063
0000071	351536.812	4993640.544	125.336	125.370	+0.034
0000072	384213.283	5005730.255	91.370	91.410	+0.040
0000078	384180.087	5005704.616	92.152	92.170	+0.018
0000079	401418.015	5026219.491	73.665	73.710	+0.045
0000099	394629.216	5031990.215	82.720	82.740	+0.020
0000102	394668.722	5031986.460	82.803	82.740	-0.063
0000110	394470.440	5032438.372	84.048	84.010	-0.038
0000112	394597.512	5031983.351	82.681	82.700	+0.019
0000113	394550.940	5031960.516	82.083	82.340	+0.257
0000123	381497.192	5008749.054	83.448	83.520	+0.072
0000124	381488.138	5008774.487	83.965	84.070	+0.105
0000125	381500.753	5008780.448	83.578	83.600	+0.022
0000129	381507.407	5008767.248	85.197	85.160	-0.037
0000135	343706.623	5019618.961	117.913	117.920	+0.007
0000141	343910.869	5019746.486	118.439	118.460	+0.021
0000142	343889.690	5019763.984	118.018	118.030	+0.012
0000143	343875.856	5019768.547	118.531	118.520	-0.011
0000144	343453.623	5020229.534	116.015	115.990	-0.025
0000145	343465.739	5020227.001	116.383	116.370	-0.013
0000148	335605.563	5033679.022	82.363	82.320	-0.043
0000149	335617.047	5033691.822	82.284	82.250	-0.034
0000150	335626.387	5033701.219	81.892	81.890	-0.002
0000164	335629.450	5033670.499	82.541	82.510	-0.031
0000175	380461.318	5012746.058	92.751	92.690	-0.061

0000177	380479.176	5012664.932	93.749	93.710	-0.039
0000178	380499.141	5012618.305	94.462	94.390	-0.072
0000179	329046.417	5024140.712	120.582	120.600	+0.018
0000181	329063.871	5024114.004	120.611	120.580	-0.031
0000182	329116.980	5024056.614	120.901	120.850	-0.051
0000195	329240.831	5023910.696	122.225	122.280	+0.055
0000196	329249.674	5023912.752	122.404	122.360	-0.044
0000197	329266.526	5023923.427	122.275	122.220	-0.055
0000198	329248.551	5023936.942	121.975	121.990	+0.015
000A458	343498.664	5020015.341	116.295	116.340	+0.045
000A459	383697.649	5010038.373	86.905	86.960	+0.055
0TMP_01	391233.785	5029446.296	66.059	66.050	-0.009
0TMP_02	401482.567	5026083.691	73.926	73.920	-0.006
0TMP_03	401417.274	5026234.513	73.411	73.340	-0.071
0TMP_06	384562.221	5005945.788	92.474	92.340	-0.134
0TMP_07	384227.041	5005738.546	91.177	91.220	+0.043
0TMP_08	359331.262	4993587.740	104.582	104.620	+0.038
0TMP_09	359202.997	4993471.243	104.480	104.510	+0.030
0TMP_10	351545.133	4993625.088	125.003	124.850	-0.153
0TMP_11	351523.442	4993713.488	125.877	125.800	-0.077
0TMP_14	328698.178	5027607.916	94.756	94.760	+0.004
0TMP_15	335624.603	5033664.310	82.509	82.590	+0.081
0TMP_16	336561.020	5040030.223	64.970	64.970	+0.000
0TMP_17	336612.704	5040116.091	64.717	64.700	-0.017
0TMP_18	368189.855	5000401.001	88.632	88.580	-0.052
0TMP_20	380511.908	5012582.703	94.506	94.500	-0.006
0TMP_21	380450.050	5012751.297	92.752	92.700	-0.052
0TMP_22	381513.902	5008747.879	83.973	84.040	+0.067
0TMP_23	329216.615	5023934.988	122.000	122.010	+0.010
0TMP_24	329046.418	5024140.703	120.573	120.600	+0.027
TMP_07N	384213.302	5005730.267	91.370	91.410	+0.040

Supplemental Vertical Accuracy (by land cover type)

Since the SVA is expressed in percentile, the accuracy values below were derived by sorting the absolute differences and using the following formula:

$$n = \frac{P}{100} \times N + \frac{1}{2}$$

Crop / Pasture

The SVA (95th percentile) is 12.2 cm.

Conservation area (UTM18)

No crop/pasture were available and/or accessible for the Conservation Authority area.

Ottawa area (MTM9)

Average dz	+0.012
Minimum dz	-0.156
Maximum dz	+0.122
Average magnitude	0.041
Root mean square	0.054
Std deviation	0.053

Number	Easting	Northing	Known Z	Laser Z	Dz
004	391203.138	5029435.207	64.496	64.450	-0.046
006	391276.319	5029243.373	62.503	62.470	-0.033
009	391297.029	5029144.106	63.033	63.090	+0.057
104	394519.229	5032352.330	83.039	83.070	+0.031
105	394451.184	5032547.728	83.217	83.250	+0.033
106	394307.290	5032828.760	83.772	83.800	+0.028
107	394417.671	5032538.203	83.231	83.300	+0.069
108	394455.881	5032437.281	82.998	83.010	+0.012
111	394485.954	5032442.036	83.115	83.180	+0.065
114	381515.911	5008743.211	83.844	83.830	-0.014
115	381555.437	5008738.765	83.649	83.650	+0.001
116	381512.479	5008716.887	83.638	83.760	+0.122
117	381452.064	5008684.559	83.585	83.700	+0.115
118	381395.827	5008650.624	83.424	83.510	+0.086
119	381346.809	5008616.677	83.526	83.560	+0.034
120	381295.803	5008585.042	83.376	83.450	+0.074
121	381266.034	5008572.981	83.511	83.530	+0.019
130	343858.552	5019766.488	117.635	117.630	-0.005
131	343844.503	5019777.883	117.617	117.650	+0.033
132	343803.440	5019741.882	117.526	117.540	+0.014
133	343742.942	5019722.709	117.196	117.200	+0.004
134	343713.115	5019648.102	117.381	117.380	-0.001
136	343692.103	5019555.830	117.549	117.590	+0.041
137	343733.830	5019591.536	117.465	117.490	+0.025
138	343780.289	5019630.216	117.670	117.710	+0.040
139	343829.703	5019671.983	117.947	117.940	-0.007
140	343873.863	5019711.571	118.078	118.070	-0.008
152	335635.668	5033736.441	79.629	79.680	+0.051
153	335649.364	5033750.883	79.226	79.230	+0.004
154	335669.649	5033775.408	78.970	79.000	+0.030
155	335721.798	5033828.000	78.217	78.160	-0.057
156	335751.789	5033865.950	77.760	77.720	-0.040

158	335742.910	5033917.052	78.596	78.440	-0.156
159	335729.974	5033906.633	78.106	78.070	-0.036
160	335693.280	5033944.946	78.415	78.340	-0.075
161	335654.075	5033989.101	78.453	78.420	-0.033
162	335628.889	5034016.139	78.519	78.500	-0.019

Forested / Wooded

The SVA (95th percentile) for both areas is 21.8 cm.

Conservation area (UTM18)

Average dz	+0.022
Minimum dz	-0.071
Maximum dz	+0.230
Average magnitude	0.093
Root mean square	0.125
Std deviation	0.142

Number	Easting	Northing	Known Z	Laser Z	Dz
040	406674.064	4995375.179	134.260	134.490	+0.230
084	406764.518	4995225.609	134.813	134.810	-0.003
094	406814.785	4995154.942	135.511	135.440	-0.071
098	406639.255	4995382.372	134.627	134.560	-0.067

Ottawa area (MTM9)

Average dz	+0.020
Minimum dz	-0.215
Maximum dz	+0.256
Average magnitude	0.081
Root mean square	0.108
Std deviation	0.107

Number	Easting	Northing	Known Z	Laser Z	Dz
050	336544.147	5040142.788	65.047	65.110	+0.063
051	336571.236	5040153.610	66.147	66.200	+0.053
052	336563.485	5040138.216	65.788	65.820	+0.032
053	336557.546	5040114.308	64.518	64.620	+0.102
062	359284.180	4993583.573	104.378	104.460	+0.082
063	359308.753	4993652.784	105.633	105.670	+0.037
068	351553.656	4993636.897	123.819	123.950	+0.131
069	351564.817	4993729.580	124.829	124.870	+0.041
074	384240.189	5005716.829	91.016	91.190	+0.174
075	384269.826	5005721.023	91.074	91.230	+0.156
077	384229.693	5005672.585	92.109	92.280	+0.171
080	401503.188	5026088.849	72.761	72.800	+0.039
081	401498.622	5026107.041	72.568	72.590	+0.022
100	394708.889	5031976.647	81.902	82.120	+0.218
122	381495.566	5008736.814	83.509	83.470	-0.039
165	380450.369	5012712.074	92.087	92.000	-0.087
167	380442.959	5012746.473	91.844	91.740	-0.104
168	380435.383	5012765.381	92.412	92.310	-0.102
169	380430.965	5012776.338	92.531	92.500	-0.031
170	380433.169	5012801.409	92.126	92.110	-0.016
171	380431.353	5012773.065	91.994	92.250	+0.256
172	380455.429	5012787.749	91.814	91.660	-0.154
173	380474.789	5012747.440	91.881	91.910	+0.029
174	380471.287	5012753.970	91.983	91.770	-0.213

176	380470.207	5012720.310	92.555	92.340	-0.215
185	329198.818	5023989.758	121.458	121.460	+0.002
188	329188.763	5023932.503	121.534	121.570	+0.036
189	329191.585	5023923.905	121.552	121.540	-0.012
190	329200.295	5023917.932	121.540	121.540	+0.000
191	329211.734	5023913.796	121.674	121.670	-0.004
192	329220.827	5023915.786	121.864	121.980	+0.116
194	329231.245	5023910.620	122.056	122.170	+0.114
199	329237.978	5023948.034	121.865	121.740	-0.125
200	329237.785	5023952.599	121.867	121.870	+0.003
201	329241.444	5023967.976	121.906	121.890	-0.016
202	329241.227	5023980.642	121.888	121.940	+0.052
203	329248.736	5023984.422	122.118	122.090	-0.028
208	329252.195	5023893.034	122.484	122.470	-0.014

Thicket / Shrubs

The SVA (95th percentile) for both areas is 50.8 cm.

Conservation area (UTM18)

Average dz	+0.079
Minimum dz	+0.015
Maximum dz	+0.180
Average magnitude	0.079
Root mean square	0.101
Std deviation	0.069

Number	Easting	Northing	Known Z	Laser Z	Dz
026	407928.410	4998193.733	142.045	142.060	+0.015
036	406818.541	4995166.440	135.354	135.400	+0.046
037	406817.191	4995166.834	136.086	136.110	+0.024
039	406671.485	4995366.764	134.319	134.470	+0.151
083	406671.379	4995366.287	134.300	134.480	+0.180
097	406428.110	4995656.117	135.012	135.070	+0.058

Ottawa area (MTM9)

Average dz	+0.158
Minimum dz	-0.303
Maximum dz	+0.597
Average magnitude	0.181
Root mean square	0.232
Std deviation	0.172

Number	Easting	Northing	Known Z	Laser Z	Dz
001	383697.635	5010038.394	86.907	86.960	+0.053
007	391303.306	5029167.602	63.283	62.980	-0.303
010	391305.743	5029227.775	62.905	63.410	+0.505
015	391317.620	5029172.770	62.289	62.460	+0.171
016	391320.188	5029173.401	63.331	63.380	+0.049
064	359353.202	4993607.286	104.665	104.750	+0.085
066	359457.594	4993675.188	103.572	103.820	+0.248
070	351509.572	4993786.206	124.832	124.930	+0.098
073	384327.386	5005784.900	90.602	90.960	+0.358
076	384220.165	5005705.246	91.831	91.940	+0.109
082	401502.708	5026053.882	72.385	72.640	+0.255
101	394733.713	5031990.022	82.805	82.870	+0.065
103	394581.896	5032187.872	82.652	82.800	+0.148

109	394458.636	5032435.228	82.995	82.950	-0.045
126	381578.774	5008800.227	83.260	83.550	+0.290
127	381588.111	5008805.831	83.333	83.530	+0.197
128	381568.471	5008793.987	83.243	83.550	+0.307
146	343454.118	5020258.669	115.961	116.140	+0.179
147	343419.231	5020298.817	116.017	116.310	+0.293
151	335633.880	5033713.352	80.814	80.860	+0.046
157	335776.118	5033877.330	78.187	78.370	+0.183
163	335765.756	5033845.803	77.792	78.300	+0.508
166	380449.074	5012724.083	91.813	92.410	+0.597
180	329216.598	5023935.005	122.041	121.990	-0.051
183	329162.270	5024022.307	121.180	121.300	+0.120
184	329178.247	5024003.973	121.452	121.580	+0.128
186	329206.551	5023937.898	122.136	122.260	+0.124
187	329194.384	5023940.311	121.990	122.220	+0.230
193	329227.743	5023921.078	122.149	122.200	+0.051
204	329224.760	5023970.486	121.653	121.720	+0.067
205	329219.704	5023962.793	121.654	121.840	+0.186
206	329240.103	5023910.504	122.280	122.330	+0.050
207	329250.608	5023901.054	122.393	122.460	+0.067
209	329259.148	5023886.205	122.712	122.710	-0.002

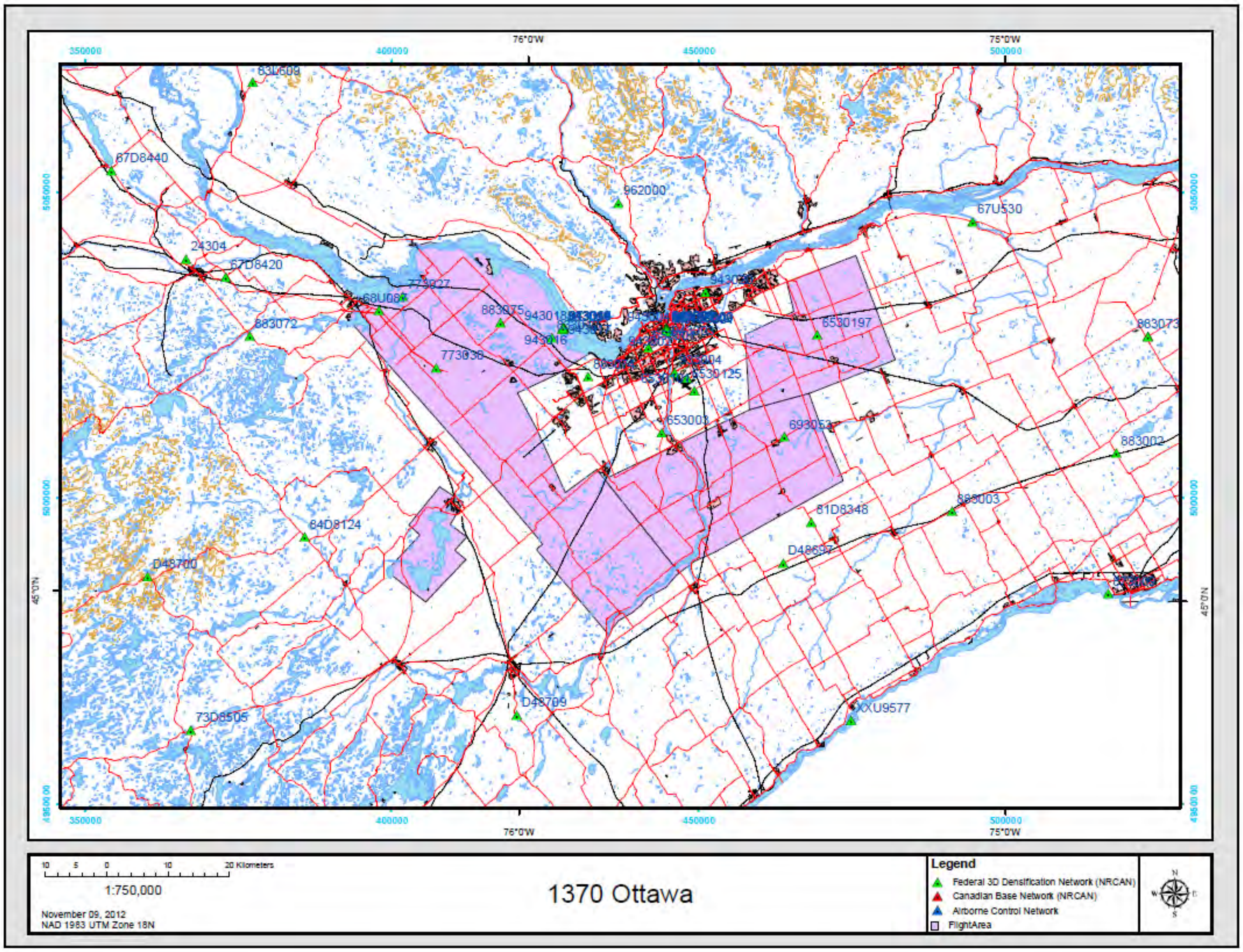
Conclusion

Unfortunately, there were some delays during the delivery of the final products, mostly due to the digitizing of the water bodies. Our workflow was adjusted and the resulting hydro-flattened DEMs were much improved.

Overall, this project went really well especially during the field acquisition, covering over 2,300 square kilometers within eight calendar days. The accuracy of the data also proved to be excellent, being approximately twice more accurate than the contract requirements. It exceeds by far expectations.

Appendix A

Overview Map



The purple areas represent the Lidar areas of interest.

Appendix B

NAD83 (Original)

Static Control Report

V. Static Control Report

a.) Final Adjusted Coordinates
b.) Traverse Overview
c.) Control Sheets
d.) Traverse Report
e.) Minimally Constrained Network Adjustment
f.) Fully Constrained Network Adjustment

a.) Final Adjusted Coordinates

```
Project:     1370_Ottawa_Cosine-Full
Program:     GrafNet Version 8.40.2823
Profile:     Aii Network Summary
Source:      Network

Datum:       NAD83 - Original, (processing datum)
Control IDs: 6530105, 693053, 93u864, 86u020, 962000, 833001
Geoid:       HT2_0-Canada.wpg (Absolute correction)

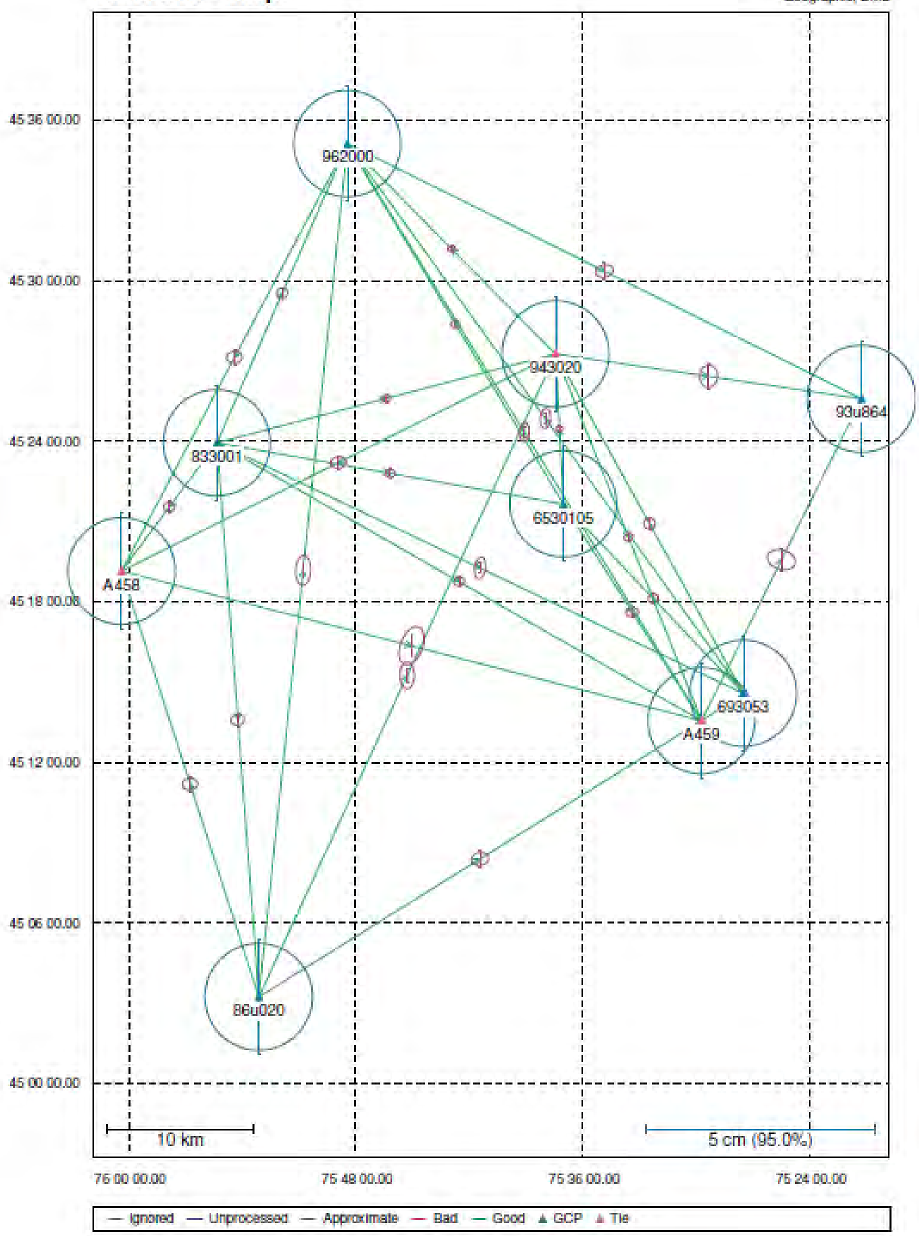
Map projection Info:
  Defined grid: UTM, Zone 18
```

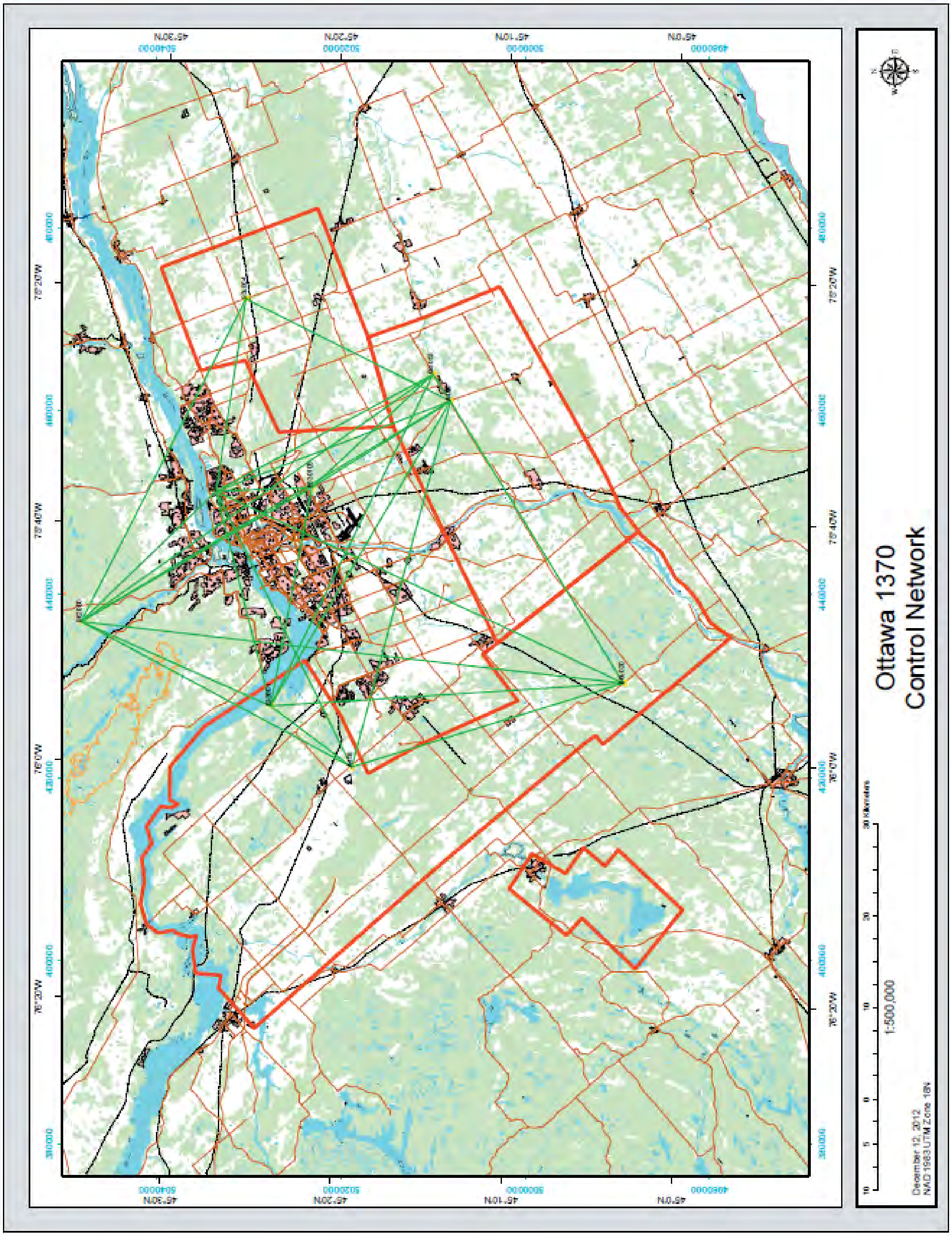
Station	Latitude (+/-D M S)	Longitude (+/-D M S)	H-Ell (m)	Undulation (m)	H-MSL (m)	Northing (m)	Easting (m)
6530105	45 21 38.76363	-75 37 01.42340	62.353	-32.709	95.063	5023213.563	451672.249
693053	45 14 34.16547	-75 27 30.11428	70.243	-32.491	102.734	5010027.795	464026.740
833001	45 23 55.94936	-75 55 20.13842	43.913	-33.216	77.129	5027675.545	427817.892
86u020	45 03 14.29119	-75 53 07.35308	90.152	-32.972	123.123	4989327.043	430284.381
93u864	45 25 34.56318	-75 21 15.56335	50.614	-32.411	83.025	5030366.150	472281.760
A458	45 19 08.48081	-76 00 23.02443	83.032	-33.294	116.326	5018883.333	421122.067
A459	45 13 33.20076	-75 29 43.07762	54.426	-32.509	86.936	5008163.625	461116.531
962000	45 35 06.05164	-75 48 26.36350	236.011	-32.885	268.897	5048258.361	437021.452
943020	45 27 14.96199	-75 37 25.76426	83.552	-32.743	116.295	5033592.650	451223.151

A I R B O R N E
I M A G I N G
A Clean Harbors Company

b.) Traverse Overview

Network - Map


Geographic, DMS
45 36 00.00
45 30 00.00
45 24 00.00
45 18 00.00
45 12 00.00
45 06 00.00
45 00 00.00
962000
943020
93u864
833001
6530105
A458
693053
A459
86u020
10 km
5 cm (95.0%)
76 00 00.00
75 48 00.00
75 36 00.00
75 24 00.00
Ignored
Unprocessed
Approximate
Bad
Good
GCP
Tie


Ottawa 1370
Control Network
1:500,000
December 12, 2012
NAD 1983 UTM Zone 18N

c.) Control Sheets

STATION: 0011986U020

Also known as:	00186U020, 86U020, CP88211
Monument status:	Existing
NTS mapsheet:	31 G/4
OBM mapsheet:	10 18 4300 49850
Horizontal datum:	NAD-1927:SCAL
Horizontal accuracy:	UNCLASSIFIED
Latitude:	N45°03'10.0xxxx"
Longitude:	W75°53'06.0xxxx"
Ellipsoidal elevation:	124.xxx
UTM-18 Easting:	E430312.xxx
UTM-18 Northing:	N4989194.xxx
UTM-18 Cmbd sc-fact:	0.99964028
UTM-18 Mrdnl convg:	-0°37'35.0"
MTM-09 Easting:	E353241.xxx
MTM-09 Northing:	N4990494.xxx
MTM-09 Cmbd sc-fact:	0.99990940
MTM-09 Mrdnl convg:	0°26'07.0"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	First order
Orthometric elev:	123.129
Meridional defl:	
Prime vert defl:	
Undulation:	
Location:	Township: DWYER HILL ROCK OUTCROP ALONG HWY NO 3 SE OF DWYER HILL, 1.7 KM NW OF INTER WITH ROGER STEVENS RD (HWY NO 6), 22 M NW OF TELEPHONE POLE, 9.7 M NE OF C/L OF HWY, 3.6 M SW OF FENCE LINE, TABLET IN TOP OF ROCK APPROX 1.0 M ABOVE RD LEVEL.
Maintenance:	GSC; last inspected: 1988
Number of Ref Sketches:	0

STATION: 0011993U864

Also known as:	00193U864, 93U864, N8U94
Monument status:	Existing
NTS mapsheet:	31 G/6
OBM mapsheet:	10 18 4700 50300
Horizontal datum:	NAD-1927:SCAL
Horizontal accuracy:	UNCLASSIFIED
Latitude:	N45°25'33.0xxxx"
Longitude:	W75°21'14.0xxxx"
Ellipsoidal elevation:	83.xxx
UTM-18 Easting:	E472315.xxx
UTM-18 Northing:	N5030317.xxx
UTM-18 Cmbd sc-fact:	0.99959642
UTM-18 Mrdnl convg:	-0°15'07.5"
MTM-09 Easting:	E394486.xxx
MTM-09 Northing:	N5032405.xxx
MTM-09 Cmbd sc-fact:	0.99998585
MTM-09 Mrdnl convg:	0°48'59.3"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	First order
Orthometric elev:	82.993
Meridional defl:	
Prime vert defl:	
Undulation:	
Location:	Township: SARSFIELD GROUND ROD UNDER ACCESS COVER ON SOUTHWEST SIDE OF REGIONAL ROAD NO. 35 (DUNNING ROAD), 1.3 KM SOUTHEAST OF JUNCTION WITH COLONIAL ROAD (REGIONAL ROAD NO. 28), 0.5 KM NORTHWEST OF WATSON ROAD, OPPOSITE POINT ON HIGHWAY 24 M NORTHWEST OF "MAXIMUM 60 KM/HR BEGINS" SIGN FOR SOUTHBOUND TRAFFIC, 12.2 M FROM DUNNING ROAD CENTRE LINE, 5.2 M SOUTHEAST OF POWER POLE, 65 CM NORTHEAST OF FENCE LINE, DIRECTLY BENEATH POWER LINE, 1 M BELOW HIGHWAY LEVEL.
Maintenance:	GSC; last inspected: 1993
Number of Ref Sketches:	0

STATION: **00119693053**

Also known as:	001693053, 693053, G.S. METCALFE, METCALFE
Monument status:	Existing
Station type:	FRTR
NTS mapsheet:	31 G/3
OBM mapsheet:	10 18 4600 50100
Horizontal datum:	NAD-1983:ORIG
Horizontal accuracy:	First order
Latitude:	N45°14'34.16402"
Longitude:	W75°27'30.11505"
Ellipsoidal elevation:	70.xxx
UTM-18 Easting:	E464026.724
UTM-18 Northing:	N5010027.750
UTM-18 Cmbd sc-fact:	0.99960488
UTM-18 Mrdnl convg:	-0°19'31.8"
MTM-09 Easting:	E386573.748
MTM-09 Northing:	N5011957.010
MTM-09 Cmbd sc-fact:	0.99997116
MTM-09 Mrdnl convg:	0°44'22.9"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	UNCLASSIFIED
Orthometric elev:	102.xxx
Meridional defl:	-1.5"
Prime vert defl:	4.4"
Undulation:	
Location:	Township: METCALFE LOCATED AT THE SITE OF A UNITEL COMMUNICATIONS TOWER, 1.4 KM NORTHEAST OF THE MAIN INTERSECTION IN THE TOWN OF METCALFE. THE STATION IS SOUTHWEST FROM THE TOWER. MARKED BY A GSC BRASS TABLET STAMPED 693053 SET 15 CM ABOVE GROUND IN A 30 CM SQUARE CONCRETE PIER ON BEDROCK. REFERENCED BY 3 GSC REFERENCE TABLETS STAMPED 1 TO 3 SET IN THE CONCRETE BASES FOR THE TOWER GUY WIRES. NOTE: KEY TO GATE REQUIRED.
Maintenance:	GSC
Other horiz data [ord]:	**NAD-1927:1974** [1], **NAD-1927:1976** [1]
Networks [usage]:	0060 [fix], 1002 [fix], 1048 [fix], 1503 [fix], 1512 [fix]
Number of Ref Sketches:	2


STATION: 00119833001

Also known as:	001833001, 833001, BOSSLER 6A, G.S. BOSSLER, G.S. PIER6A
Monument status:	Existing
Monument type:	CPillar
Station type:	GPS
NTS mapsheet:	31 G/5
OBM mapsheet:	10 18 4250 50250
Horizontal datum:	NAD-1983:ORIG
Horizontal accuracy:	First order
Latitude:	N45°23'55.95047"
Longitude:	W75°55'20.13754"
Ellipsoidal elevation:	44.xxx
UTM-18 Easting:	E427817.912
UTM-18 Northing:	N5027675.579
UTM-18 Cmbd sc-fact:	0.99965715
UTM-18 Mrdnl convg:	-0°39'24.1"
MTM-09 Easting:	E350031.235
MTM-09 Northing:	N5028933.080
MTM-09 Cmbd sc-fact:	0.99991823
MTM-09 Mrdnl convg:	0°24'40.9"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	UNCLASSIFIED
Orthometric elev:	77.xxx
Meridional defl:	-0.3"
Prime vert defl:	1.7"
Undulation:	
Location:	SHIRLEYS BAY(BOSSLER)-NATIONAL PCBL-CBN PILLAR. CONCRETE PILLAR WITH STEEL TOP PLATE (CBN PILLAR) ON SOUTHEAST SIDE OF RIDDELL DRIVE, 3.9 KM NORTHEAST OF JUNCTION WITH COUNTY ROAD 9 (DUNROBIN ROAD), 0.25 KM SOUTHWEST OF ROAD TO "DND CONNAUGHT RANGE", 16.3 M FROM CENTRE LINE OF ROAD, OPPOSITE POINT ON ROAD 6.2 M SOUTHWEST OF "40 KM/HR" SIGN WITH WARNING LIGHT FOR NORTHBOUND TRAFFIC, ABOUT 1 M ABOVE ROAD LEVEL. ELEVATION TAKEN ON TOP AT CENTRE OF MAIN CIRCULAR PLATE ANCHORED ON TOP OF PILLAR.
Maintenance:	Inspected by Geodetic Survey Division in 1999. Status: Good Accessible by passenger car or light truck and a walk of less than 50 m.
Other horiz data [ord]:	**NAD-1983:CSRS:CBNv3-1997.0** [A]
Networks [usage]:	1002 [fix], CBN31A [wtd]


STATION: **00119943020**

Monument status:	Existing
Monument type:	CAP
Station type:	GPS
NTS mapsheet:	31 G/5
OBM mapsheet:	10 18 4500 50300
Horizontal datum:	NAD-1983:CSRS:CBNv3-1997.0
Horizontal accuracy:	CSRS class B
Latitude:	N45°27'14.95142"
Longitude:	W75°37'25.76671"
Ellipsoidal elevation:	83.573
UTM-18 Easting:	E451223.095
UTM-18 Northing:	N5033592.324
UTM-18 Cmbd sc-fact:	0.99961615
UTM-18 Mrdnl convg:	-0°26'40.6"
MTM-09 Easting:	E373328.876
MTM-09 Northing:	N5035287.148
MTM-09 Cmbd sc-fact:	0.99994462
MTM-09 Mrdnl convg:	0°37'28.1"
Vertical data:	N/A
Location:	Created on 2007/12/14.
Networks [usage]:	CBN318 [wtd]
Number of Ref Sketches:	0

STATION: **00119962000**

Also known as:	001962000, 962000, GATINEAU CAGS
Monument status:	Existing
NTS mapsheet:	31 G/12
OBM mapsheet:	10 18 4350 50450
Horizontal datum:	NAD-1927:SCAL
Horizontal accuracy:	UNCLASSIFIED
Latitude:	N45°35'06.0xxxx"
Longitude:	W75°48'26.0xxxx"
Ellipsoidal elevation:	269.xxx
UTM-18 Easting:	E437029.xxx
UTM-18 Northing:	N5048256.xxx
UTM-18 Cmbd sc-fact:	0.99960659
UTM-18 Mrdnl convg:	-0°34'35.8"
MTM-09 Easting:	E358859.xxx
MTM-09 Northing:	N5049688.xxx
MTM-09 Cmbd sc-fact:	0.99989375
MTM-09 Mrdnl convg:	0°29'41.5"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	First order
Orthometric elev:	268.901
Meridional defl:	
Prime vert defl:	
Undulation:	
Maintenance:	GSC; last inspected: 1999
Number of Ref Sketches:	0

STATION: 001196530105

Also known as:	0016530105, 6530105, NCC 105, VANO
Monument status:	Existing
NTS mapsheet:	31 G/5
OBM mapsheet:	10 18 4500 50200
Horizontal datum:	NAD-1983:ORIG
Horizontal accuracy:	UNCLASSIFIED
Latitude:	N45°21'38.7xxxx"
Longitude:	W75°37'01.4xxxx"
Ellipsoidal elevation:	59.xxx
UTM-18 Easting:	E451672.xxx
UTM-18 Northing:	N5023213.xxx
UTM-18 Cmbd sc-fact:	0.99961947
UTM-18 Mrdnl convg:	-0°26'20.7"
MTM-09 Easting:	E373971.xxx
MTM-09 Northing:	N5024915.xxx
MTM-09 Cmbd sc-fact:	0.99994956
MTM-09 Mrdnl convg:	0°37'41.8"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	First order
Orthometric elev:	95.084
Meridional defl:	
Prime vert defl:	
Undulation:	
Location:	Township: OTTAWA FOR DESCRIPTIONS CONTACT SURVEY SECTION, N.C.C. Township: OTTAWA FOR DESCRIPTIONS CONTACT SURVEY SECTION, N.C.C.
Maintenance:	GSC; last inspected: --
Other horiz data [ord]:	**NAD-1927:SCAL** [-]
Number of Ref Sketches:	0

STATION: 01919680105

Also known as:	019680105, 6530105, STA. 105
Monument status:	Existing
Station type:	TRAV
NTS mapsheet:	31 G/5
OBM mapsheet:	10 18 4500 50200
Horizontal datum:	NAD-1983:ORIG
Horizontal accuracy:	Second order
Latitude:	N45°21'38.76398"
Longitude:	W75°37'01.42352"
Ellipsoidal elevation:	62.xxx
UTM-18 Easting:	E451672.247
UTM-18 Northing:	N5023213.574
UTM-18 Cmbd sc-fact:	0.99961900
UTM-18 Mrdnl convg:	-0°26'20.7"
MTM-09 Easting:	E373971.649
MTM-09 Northing:	N5024915.159
MTM-09 Cmbd sc-fact:	0.99994909
MTM-09 Mrdnl convg:	0°37'41.8"
Vertical datum:	CGVD-1928:1978
Vertical accuracy:	UNCLASSIFIED
Orthometric elev:	95.xxx
Meridional defl:	-1.1"
Prime vert defl:	3.9"
Undulation:	
Other horiz data [ord]:	**NAD-1927:1974** [2], **NAD-1927:1976** [2]
Networks [usage]:	0953 [fix], 1042 [free], 1505 [fix], 1510 [fix]
Number of Ref Sketches:	1

d.) Traverse Report

```
***********************************************
* GrafNet - GRAPHIC GPS NETWORK PROCESSING    *
*          SOFTWARE PACKAGE                   *
*                                             *
* TRAVERSE SOLUTION:                          *
*                                             *
* Copyright NovAtel Inc. (2012)               *
*                                             *
* Version: 8.40.3116                          *
*                                             *
* PROJECT: 1370_Ottawa_Cosine-Min             *
***********************************************

DATUM:  NAD83 - Original
GRID:   UTM, Zone 18
UNITS:  metres (see preferences to change)
GEOID:  C:\Programs\CommonFiles\WaypointGeoids\HT2_0-Canada.wpg


********************************
  STATIONS (STATUS):
********************************

Station  Type        HgtStatus      Result  Coordinates derrived from...
6530105  Control-3D OK              Pub(3D) (-)
693053   Check-H    OK              Good    6530105
833001   Check-H    OK              Good    6530105
86u020   Check-V    OK              Good    833001   6530105
93u864   Check-V    OK              Good    943020   6530105
943020   Loop Tie   OK              Good    6530105
962000   Check-V    OK              Good    6530105
A458     Loop Tie   OK              Good    833001   6530105
A459     Loop Tie   OK              Good    6530105


********************************
  STATIONS (COORDINATES):
********************************

Station         Latitude        Longitude       Grid-E       Grid-N    EllHgt  OrthoHgt
                   (D M S)          (D M S)         (m)          (m)       (m)       (m)
6530105  45 21 38.76398  -75 37 01.42352  451672.247  5023213.574    62.375    95.084
693053   45 14 34.16578  -75 27 30.11434  464026.739  5010027.805    70.270   102.761
833001   45 23 55.94976  -75 55 20.13860  427817.888  5027675.558    43.937    77.153
86u020   45 03 14.29160  -75 53 07.35321  430284.378  4989327.055    90.173   123.145
93u864   45 25 34.56339  -75 21 15.56341  472281.759  5030366.157    50.641    83.052
943020   45 27 14.96240  -75 37 25.76432  451223.150  5033592.663    83.572   116.316
962000   45 35 06.05203  -75 48 26.36357  437021.450  5048258.373   236.036   268.921
A458     45 19 08.48115  -76 00 23.02470  421122.062  5018883.343    83.060   116.355
A459     45 13 33.20083  -75 29 43.07794  461116.524  5008163.627    54.449    86.959
```

****
LOOP, CHECK & DUPLICATE TIES:
****

Name/Session	Type	Result	DEast (m)	DNorth (m)	DHeight (m)
POINT 693053	CheckPnt	Good	0.0154	0.0542	
POINT 833001	CheckPnt	Good	-0.0229	-0.0219	
693053 to 833001	LoopTie	Good	0.0085	0.0025	-0.0023
POINT 86u020	CheckPnt	Good	(-)	(-)	0.0163
833001 to 86u020 (1)	Duplicate	Good	0.0004	-0.0024	-0.0005
943020 to 86u020	LoopTie	Good	-0.0083	-0.0040	0.0013
962000 to 86u020	LoopTie	Good	-0.0080	-0.0013	-0.0036
A459 to 86u020	LoopTie	Good	0.0076	0.0164	-0.0150
A459 to 86u020 (2)	Duplicate	Good	0.0080	0.0169	-0.0057
POINT 93u864	CheckPnt	Good	(-)	(-)	0.0593
943020 to 93u864 (2)	Duplicate	Good	0.0014	-0.0071	0.0098
962000 to 93u864	LoopTie	Good	-0.0008	-0.0024	0.0008
962000 to 93u864 (2)	Duplicate	Good	0.0003	-0.0050	0.0010
A459 to 93u864 (1)	Duplicate	Good	0.0039	-0.0014	0.0111
A459 to 93u864	LoopTie	Good	0.0049	-0.0045	0.0061
693053 to 943020	LoopTie	Good	0.0003	-0.0004	-0.0015
833001 to 943020	LoopTie	Good	0.0024	0.0018	-0.0062
POINT 962000	CheckPnt	Good	(-)	(-)	0.0196
693053 to 962000	LoopTie	Good	-0.0004	0.0010	0.0095
833001 to 962000 (1)	Duplicate	Good	0.0025	-0.0000	-0.0070
833001 to 962000	LoopTie	Good	0.0012	0.0001	0.0018
943020 to 962000 (1)	Duplicate	Good	0.0004	-0.0020	0.0094
943020 to 962000 (2)	Duplicate	Good	-0.0001	-0.0001	-0.0002
943020 to 962000	LoopTie	Good	0.0000	-0.0023	-0.0013
833001 to A458 (1)	Duplicate	Good	-0.0020	-0.0027	0.0036
943020 to A458	LoopTie	Good	-0.0041	-0.0032	0.0074
943020 to A458 (2)	Duplicate	Good	-0.0021	-0.0037	0.0081
962000 to A458 (1)	Duplicate	Good	-0.0038	-0.0009	0.0099
962000 to A458	LoopTie	Good	-0.0028	-0.0024	0.0084
A459 to A458 (1)	Duplicate	Good	-0.0008	0.0160	-0.0025
A459 to A458	LoopTie	Good	0.0021	0.0166	0.0004
86u020 to A458 (1)	Duplicate	Good	-0.0011	-0.0007	0.0025
86u020 to A458	LoopTie	Good	0.0000	-0.0008	-0.0008
6530105 to A459 (2)	Duplicate	Good	-0.0007	-0.0051	0.0056
693053 to A459	LoopTie	Good	-0.0049	-0.0055	-0.0081
693053 to A459 (2)	Duplicate	Good	-0.0061	-0.0087	-0.0038
833001 to A459	LoopTie	Good	-0.0081	-0.0174	0.0069
833001 to A459 (2)	Duplicate	Good	-0.0004	-0.0018	0.0029
833001 to A459 (3)	Duplicate	Good	0.0010	-0.0036	0.0006
943020 to A459 (3)	Duplicate	Good	-0.0002	-0.0049	0.0041
943020 to A459 (2)	Duplicate	Good	-0.0021	0.0001	0.0045
943020 to A459 (1)	Duplicate	Good	-0.0062	-0.0063	0.0017
943020 to A459	LoopTie	Good	-0.0104	-0.0191	0.0136
962000 to A459 (3)	Duplicate	Good	-0.0029	-0.0121	-0.0035
962000 to A459 (2)	Duplicate	Good	0.0133	0.0008	-0.0015
962000 to A459	LoopTie	Good	-0.0047	-0.0031	-0.0157
962000 to A459 (4)	Duplicate	Good	-0.0049	-0.0178	0.0025
RMS (tie points)			0.0047	0.0079	0.0065
RMS (check points)			0.0195	0.0414	0.0373

e.) Minimally Constrained Network Adjustment

```
           ************************************************
           * NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT    *
           *                                              *
           * (c) Copyright NovAtel Inc., (2012)           *
           *                                              *
           * Version: 8.40.2823                           *
           *                                              *
           * FILE: 1370_Ottawa_Cosine-Min.net             *
           ************************************************

  DATUM:             'NAD83 - Original'
  SCALE_FACTOR:      1.0000
  CONFIDENCE LEVEL: 39.40 %   (Scale factor is 1.0009)


**************************************************************
    INPUT CONTROL/CHECK POINTS
**************************************************************

STA_ID     TYPE    -- LATITUDE --  -- LONGITUDE --  ELLHGT -   HZ-SD   V-SD
6530105    GCP-3D  45 21 38.76398  -75 37 01.42352     62.375 0.02000 0.05000
693053     CHK-HZ  45 14 34.16402  -75 27 30.11505
833001     CHK-HZ  45 23 55.95047  -75 55 20.13754
86u020     CHK-VT                                      90.157
93u864     CHK-VT                                      50.582
962000     CHK-VT                                     236.016


**************************************************************
    INPUT VECTORS
**************************************************************

SESSION NAME           VECTOR(m)   ------ Covariance (m) [unscaled] ------
                        DX/DY/DZ          standard deviations in brackets
6530105 to 693053 (1) 14380.9703  1.0983e-006 (0.0010)
                      -5919.1208  -4.5997e-007 2.9878e-006 (0.0017)
                      -9214.2995  3.1686e-007 -2.0565e-006 3.3923e-006 (0.0018)

6530105 to 833001 (1) -23915.3118  7.2199e-007 (0.0008)
                      -2941.6521  -4.5076e-007 2.2929e-006 (0.0015)
                       2961.7213  3.3055e-007 -1.4387e-006 2.7565e-006 (0.0017)

6530105 to 943020 (1) -2344.6249  3.7602e-007 (0.0006)
                       7013.8458  -2.4703e-007 1.1821e-006 (0.0011)
                       7301.9796  1.5923e-007 -7.1155e-007 1.3263e-006 (0.0012)

6530105 to 962000 (1) -18772.7616  6.5384e-007 (0.0008)
                      13429.0816  -4.3023e-007 2.0395e-006 (0.0014)
                      17601.3773  2.7497e-007 -1.2319e-006 2.3043e-006 (0.0015)

6530105 to A459 (1)   11905.6608  1.1016e-006 (0.0010)
                      -7929.2105  -7.2047e-007 3.7042e-006 (0.0019)
                      -10550.9089  4.3494e-007 -2.0495e-006 3.8901e-006 (0.0020)

6530105 to A459 (2)   11905.6596  1.0834e-006 (0.0010)
                      -7929.2031  -6.5614e-007 3.1875e-006 (0.0018)
                      -10550.9093  5.2142e-007 -2.2215e-006 4.2571e-006 (0.0021)
```

```
693053 to 833001 (1)  -38296.2895  6.3693e-006 (0.0025)
                       2977.4633  -1.0160e-006 3.8837e-006 (0.0020)
                      12176.0208  1.0815e-006 -1.8648e-006 2.4886e-006 (0.0016)

693053 to 943020 (1)  -16725.5954  1.4130e-006 (0.0012)
                      12932.9658  -5.6379e-007 3.6986e-006 (0.0019)
                      16516.2804  3.9807e-007 -2.4421e-006 3.9653e-006 (0.0020)

693053 to 962000 (1)  -33153.7330  5.0314e-006 (0.0022)
                      19348.2082  -5.8554e-007 3.7283e-006 (0.0019)
                      26815.6694  8.4634e-007 -1.7741e-006 2.2855e-006 (0.0015)

693053 to A459 (1)    -2475.3042  2.4925e-007 (0.0005)
                      -2010.0903  -1.7464e-007 7.9714e-007 (0.0009)
                      -1336.5998  9.9773e-008 -4.4230e-007 8.1577e-007 (0.0009)

693053 to A459 (2)    -2475.3044  2.8179e-007 (0.0005)
                      -2010.0849  -1.8050e-007 7.0750e-007 (0.0008)
                      -1336.6005  1.2583e-007 -4.6045e-007 9.1949e-007 (0.0010)

833001 to 86u020 (1)   9444.8815  2.4499e-006 (0.0016)
                      -25718.2431  -1.6148e-006 8.1986e-006 (0.0029)
                      -26964.5139  9.1619e-007 -4.6785e-006 7.7834e-006 (0.0028)

833001 to 86u020 (2)   9444.8822  1.6470e-006 (0.0013)
                      -25718.2443  -1.0401e-006 4.9441e-006 (0.0022)
                      -26964.5160  7.1333e-007 -3.2457e-006 5.5963e-006 (0.0024)

833001 to 943020 (1)  21570.6860  6.5300e-007 (0.0008)
                       9955.4918  -4.6399e-007 1.9087e-006 (0.0014)
                       4340.2614  2.9314e-007 -1.1672e-006 2.1220e-006 (0.0015)

833001 to 962000 (1)   5142.5490  6.2180e-007 (0.0008)
                      16370.7283  -4.4010e-007 1.8202e-006 (0.0013)
                      14639.6611  2.7916e-007 -1.1153e-006 2.0339e-006 (0.0014)

833001 to 962000 (2)   5142.5488  1.3594e-006 (0.0012)
                      16370.7346  -5.0127e-007 3.6322e-006 (0.0019)
                      14639.6546  3.7283e-007 -2.4078e-006 3.9678e-006 (0.0020)

833001 to A458 (1)    -4857.3548  1.0635e-006 (0.0010)
                      -7751.5543  -7.7319e-007 3.3892e-006 (0.0018)
                      -6208.1479  4.4387e-007 -1.8980e-006 3.3744e-006 (0.0018)

833001 to A458 (2)    -4857.3557  1.0151e-006 (0.0010)
                      -7751.5592  -5.8655e-007 3.0053e-006 (0.0017)
                      -6208.1472  5.0513e-007 -2.1160e-006 4.2035e-006 (0.0021)

833001 to A459 (1)    35820.9762  1.0077e-006 (0.0010)
                      -4987.5397  -7.1133e-007 2.9402e-006 (0.0017)
                      -13512.6229  4.5922e-007 -1.8248e-006 3.3340e-006 (0.0018)

833001 to A459 (2)    35820.9722  3.2336e-006 (0.0018)
                      -4987.5551  -2.6643e-006 1.2719e-005 (0.0036)
                      -13512.6310  3.7195e-007 -6.7847e-006 1.1194e-005 (0.0033)

833001 to A459 (3)    35820.9709  2.1145e-006 (0.0015)
                      -4987.5558  -1.2482e-006 6.1734e-006 (0.0025)
                      -13512.6281  1.0671e-006 -4.4070e-006 8.7991e-006 (0.0030)
```

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86u020 to A458 (1)    -14302.2374  1.8273e-006 (0.0014)
                      17966.6876  -1.1049e-006 6.3241e-006 (0.0025)
                      20756.3675  6.0586e-007 -3.5632e-006 6.0893e-006 (0.0025)

86u020 to A458 (2)    -14302.2379  1.8617e-006 (0.0014)
                      17966.6851  -9.2963e-007 5.7379e-006 (0.0024)
                      20756.3700  7.9984e-007 -4.0668e-006 7.7354e-006 (0.0028)

943020 to 86u020 (2)  -12125.7975  8.0859e-006 (0.0028)
                      -35673.7365  7.5852e-007 7.7081e-006 (0.0028)
                      -31304.7723  3.2002e-007 -3.2957e-006 4.0029e-006 (0.0020)

943020 to 93u864 (1)  20961.0352  5.4770e-006 (0.0023)
                       3167.7466  -6.9436e-007 1.6015e-005 (0.0040)
                      -2198.2966  8.8623e-007 -1.2368e-005 1.6222e-005 (0.0040)

943020 to 93u864 (2)  20961.0308  1.3060e-006 (0.0011)
                       3167.7578  -9.2622e-007 3.3312e-006 (0.0018)
                      -2198.2985  7.3966e-007 -2.1968e-006 4.0449e-006 (0.0020)

943020 to 962000 (1)  -16428.1390  3.3821e-006 (0.0018)
                       6415.2435  -3.0003e-006 1.0476e-005 (0.0032)
                      10299.3924  4.6056e-007 -3.1336e-006 9.9023e-006 (0.0031)

943020 to 962000 (2)  -16428.1366  4.9104e-007 (0.0007)
                       6415.2357  -3.2168e-007 1.4773e-006 (0.0012)
                      10299.3979  1.9636e-007 -9.0508e-007 1.7295e-006 (0.0013)

943020 to 962000 (3)  -16428.1369  4.3836e-007 (0.0007)
                       6415.2365  -2.7020e-007 1.3422e-006 (0.0012)
                      10299.4003  1.7662e-007 -8.4579e-007 1.6325e-006 (0.0013)

943020 to A458 (1)    -26428.0403  1.8337e-006 (0.0014)
                      -17707.0488  -1.2629e-006 5.9512e-006 (0.0024)
                      -10548.4084  7.3413e-007 -3.3083e-006 6.0942e-006 (0.0025)

943020 to A458 (2)    -26428.0425  1.9399e-006 (0.0014)
                      -17707.0485  -1.1253e-006 5.7298e-006 (0.0024)
                      -10548.4086  9.7467e-007 -4.0401e-006 8.0313e-006 (0.0028)

943020 to A459 (1)    14250.2904  7.1279e-007 (0.0008)
                      -14943.0493  -4.9832e-007 2.0401e-006 (0.0014)
                      -17852.8853  3.1283e-007 -1.2612e-006 2.3337e-006 (0.0015)

943020 to A459 (2)    14250.2871  2.0990e-006 (0.0014)
                      -14943.0529  -1.4687e-006 8.4905e-006 (0.0029)
                      -17852.8917  6.6398e-008 -4.7487e-006 8.2570e-006 (0.0029)

943020 to A459 (3)    14250.2844  1.4095e-006 (0.0012)
                      -14943.0502  -8.7196e-007 3.9547e-006 (0.0020)
                      -17852.8879  6.7527e-007 -2.7910e-006 5.4367e-006 (0.0023)

943020 to A459 (4)    14250.2901  7.5137e-007 (0.0009)
                      -14943.0314  -5.3759e-007 2.1814e-006 (0.0015)
                      -17852.8847  3.4499e-007 -1.3379e-006 2.4604e-006 (0.0016)

962000 to 93u864 (1)  37389.1721  2.2879e-006 (0.0015)
                      -3247.4868  -1.6101e-006 7.4527e-006 (0.0027)
                      -12497.6932  7.2197e-007 -4.4251e-006 8.4183e-006 (0.0029)
```

```
962000 to 86u020 (2)   4302.3402  9.8420e-006 (0.0031)
                      -42088.9776  1.2744e-006 8.6923e-006 (0.0029)
                      -41604.1685  -3.7981e-007 -4.0042e-006 4.8476e-006 (0.0022)

962000 to 93u864 (2)  37389.1704  1.9656e-006 (0.0014)
                      -3247.4851  -1.3805e-006 5.2292e-006 (0.0023)
                      -12497.6916  1.0531e-006 -3.4354e-006 6.3037e-006 (0.0025)

962000 to A458 (1)    -9999.9040  1.8169e-006 (0.0013)
                      -24122.2846  -1.2427e-006 5.9135e-006 (0.0024)
                      -20847.8097  7.2287e-007 -3.2920e-006 6.0808e-006 (0.0025)

962000 to A458 (2)    -9999.9050  1.9267e-006 (0.0014)
                      -24122.2848  -1.1155e-006 5.6958e-006 (0.0024)
                      -20847.8075  9.6921e-007 -4.0220e-006 8.0128e-006 (0.0028)

962000 to A459 (1)    30678.4292  4.3294e-006 (0.0021)
                      -21358.2995  -1.7304e-007 3.2689e-006 (0.0018)
                      -28152.2730  5.3724e-007 -1.5375e-006 2.0444e-006 (0.0014)

962000 to A459 (2)    30678.4099  2.7063e-005 (0.0052)
                      -21358.2970  -1.1243e-006 6.3565e-006 (0.0025)
                      -28152.2857  3.7311e-006 -3.3069e-006 5.7467e-006 (0.0024)

962000 to A459 (3)    30678.4237  1.4164e-005 (0.0038)
                      -21358.2855  -1.5872e-006 2.1200e-005 (0.0046)
                      -28152.2753  3.6439e-006 -6.0518e-006 7.5441e-006 (0.0027)

962000 to A459 (4)    30678.4236  5.3608e-006 (0.0023)
                      -21358.2770  -7.2756e-007 3.9230e-006 (0.0020)
                      -28152.2755  7.1993e-007 -1.8934e-006 2.4183e-006 (0.0016)

A459 to 93u864 (2)     6710.7427  4.4127e-006 (0.0021)
                      18110.8090  -1.5710e-006 2.3748e-005 (0.0049)
                      15654.5907  8.3536e-007 -8.0878e-006 1.0952e-005 (0.0033)

A459 to 86u020 (1)    -26376.0924  2.3809e-006 (0.0015)
                      -20730.7092  -1.5965e-006 8.2248e-006 (0.0029)
                      -13451.8867  8.1231e-007 -4.6084e-006 7.5314e-006 (0.0027)

A459 to 86u020 (2)    -26376.0944  1.6221e-006 (0.0013)
                      -20730.7033  -1.0246e-006 4.7604e-006 (0.0022)
                      -13451.8937  7.0887e-007 -3.1361e-006 5.5372e-006 (0.0024)

A459 to 93u864 (1)     6710.7434  2.7893e-006 (0.0017)
                      18110.8105  -1.3693e-006 7.0546e-006 (0.0027)
                      15654.5850  -7.2468e-007 -2.6245e-006 9.1427e-006 (0.0030)

A459 to A458 (1)      -40678.3244  3.7249e-005 (0.0061)
                      -2764.0133  -5.9376e-006 9.0878e-006 (0.0030)
                       7304.4736  5.8402e-006 -4.3996e-006 6.4618e-006 (0.0025)

A459 to A458 (2)      -40678.3276  2.1837e-005 (0.0047)
                      -2764.0124  -9.0764e-006 1.9182e-005 (0.0044)
                       7304.4710  4.5561e-006 -7.7183e-006 7.8860e-006 (0.0028)
```

****

OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)

****

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)		- PPM -	DIST (km)	- STD - (m)
6530105 to 693053 (1)	-0.0011	0.0006	-0.0038		0.224	18.1	0.0027
6530105 to 833001 (1)	0.0002	-0.0018	-0.0016		0.100	24.3	0.0024
6530105 to 943020 (1)	-0.0014	-0.0020	0.0018		0.293	10.4	0.0017
6530105 to 962000 (1)	-0.0013	-0.0013	-0.0018		0.090	29.0	0.0022
6530105 to A459 (1)	0.0041	0.0080	-0.0005	$	0.505	17.8	0.0029
6530105 to A459 (2)	0.0035	0.0029	0.0051		0.383	17.8	0.0029
693053 to 833001 (1)	0.0098	0.0001	-0.0000		0.243	40.3	0.0036
693053 to 943020 (1)	0.0000	-0.0030	0.0041		0.191	26.8	0.0030
693053 to 962000 (1)	-0.0006	-0.0009	0.0115	$	0.247	46.8	0.0033
693053 to A459 (1)	0.0003	0.0019	-0.0047	$	1.476	3.5	0.0014
693053 to A459 (2)	-0.0009	-0.0013	-0.0005		0.486	3.5	0.0014
833001 to 86u020 (1)	-0.0005	-0.0030	0.0033		0.118	38.4	0.0043
833001 to 86u020 (2)	-0.0009	-0.0006	0.0039		0.104	38.4	0.0035
833001 to 943020 (1)	0.0008	0.0016	-0.0028		0.139	24.2	0.0022
833001 to 962000 (1)	0.0010	0.0005	-0.0072	$	0.325	22.6	0.0021
833001 to 962000 (2)	-0.0004	0.0006	0.0016		0.078	22.6	0.0030
833001 to A458 (1)	-0.0009	-0.0020	0.0005		0.206	11.1	0.0028
833001 to A458 (2)	0.0011	0.0007	-0.0031		0.305	11.1	0.0029
833001 to A459 (1)	-0.0041	-0.0077	0.0081	$	0.308	38.6	0.0027
833001 to A459 (2)	0.0035	0.0080	0.0040		0.248	38.6	0.0052
833001 to A459 (3)	0.0050	0.0061	0.0017		0.209	38.6	0.0041
86u020 to A458 (1)	0.0009	0.0006	-0.0044		0.147	31.0	0.0038
86u020 to A458 (2)	0.0020	0.0005	-0.0078		0.261	31.0	0.0039
943020 to 86u020 (2)	-0.0077	-0.0044	0.0017		0.185	49.0	0.0044
943020 to 93u864 (1)	-0.0000	0.0062	-0.0071		0.443	21.3	0.0061
943020 to 93u864 (2)	0.0014	-0.0009	0.0027		0.148	21.3	0.0029
943020 to 962000 (1)	0.0005	-0.0013	0.0058		0.293	20.4	0.0049
943020 to 962000 (2)	0.0000	0.0007	-0.0038		0.188	20.4	0.0019
943020 to 962000 (3)	0.0001	-0.0016	-0.0049		0.253	20.4	0.0018
943020 to A458 (1)	-0.0015	-0.0023	0.0009		0.086	33.5	0.0037
943020 to A458 (2)	0.0005	-0.0028	0.0016		0.098	33.5	0.0040
943020 to A459 (1)	-0.0007	0.0037	-0.0005		0.140	27.3	0.0023
943020 to A459 (2)	0.0034	0.0100	0.0022		0.398	27.3	0.0043
943020 to A459 (3)	0.0053	0.0051	0.0018		0.278	27.3	0.0033
943020 to A459 (4)	-0.0048	-0.0091	0.0113	$	0.561	27.3	0.0023
962000 to 93u864 (1)	-0.0010	0.0031	-0.0027		0.106	39.6	0.0043
962000 to 86u020 (2)	-0.0074	-0.0024	0.0004		0.132	59.3	0.0048
962000 to 93u864 (2)	0.0002	0.0005	-0.0024		0.063	39.6	0.0037
962000 to A458 (1)	-0.0013	-0.0007	0.0070		0.215	33.4	0.0037
962000 to A458 (2)	-0.0003	-0.0022	0.0055		0.178	33.4	0.0040
962000 to A459 (1)	0.0007	0.0062	-0.0143	$	0.334	46.8	0.0031
962000 to A459 (2)	0.0188	0.0101	-0.0001	$	0.455	46.8	0.0063
962000 to A459 (3)	0.0026	-0.0028	-0.0021		0.093	46.8	0.0066
962000 to A459 (4)	0.0006	-0.0086	0.0038		0.201	46.8	0.0034
A459 to 93u864 (2)	-0.0006	-0.0082	0.0013		0.336	24.9	0.0063
A459 to 86u020 (1)	0.0028	0.0059	-0.0122	$	0.383	36.1	0.0043
A459 to 86u020 (2)	0.0032	0.0065	-0.0029		0.215	36.1	0.0035
A459 to 93u864 (1)	-0.0017	-0.0052	0.0062		0.332	24.9	0.0044
A459 to A458 (1)	-0.0036	0.0069	-0.0067		0.248	41.4	0.0073
A459 to A458 (2)	-0.0007	0.0076	-0.0038		0.205	41.4	0.0070
RMS	0.0039	0.0047	0.0052				

$ - This session is flagged as a 3-sigma outlier

```
***************************************************************
    CHECK POINT RESIDUALS (East, North, Height - Local Level)
***************************************************************

STA. NAME    -- RE --    -- RN --    -- RH --
                (m)         (m)         (m)
693053         0.0143      0.0548
833001        -0.0228     -0.0237
86u020                                 0.0186
93u864                                 0.0540
962000                                 0.0178
            --------------------------------
RMS            0.0191      0.0422      0.0345


***************************************************************
    CONTROL POINT RESIDUALS (ADJUSTMENT MADE)
***************************************************************

STA. NAME    -- RE --    -- RN --    -- RH --
                (m)         (m)         (m)
6530105       -0.0000      0.0000      0.0000
            --------------------------------
RMS            0.0000      0.0000      0.0000


***************************************************************
    OUTPUT STATION COORDINATES (LAT/LONG/HT)
***************************************************************

STA_ID       -- LATITUDE --  -- LONGITUDE -- - ELLHGT -
6530105      45 21 38.76398  -75 37 01.42352    62.3750
693053       45 14 34.16579  -75 27 30.11439    70.2660
833001       45 23 55.94970  -75 55 20.13859    43.9358
86u020       45 03 14.29152  -75 53 07.35325    90.1755
93u864       45 25 34.56353  -75 21 15.56348    50.6360
943020       45 27 14.96233  -75 37 25.76439    83.5741
962000       45 35 06.05199  -75 48 26.36363   236.0338
A458         45 19 08.48112  -76 00 23.02464    83.0556
A459         45 13 33.20109  -75 29 43.07775    54.4490


***************************************************************
    OUTPUT VARIANCE/COVARIANCE
***************************************************************
                                              2
STA_ID       SE/SN/SUP  --------- CX matrix (m )-----------
             (39.40 %)  (not scaled by confidence level)
                (m)          (ECEF, XYZ cartesian)
6530105         0.0200  4.6397e-004
                0.0200  -2.4947e-004 1.3728e-003
                0.0500  2.6080e-004 -1.0170e-003 1.4632e-003

693053          0.0200  4.6420e-004
                0.0200  -2.4959e-004 1.3734e-003
                0.0501  2.6088e-004 -1.0174e-003 1.4639e-003
```

```
833001          0.0200  4.6417e-004
                0.0200  -2.4959e-004 1.3734e-003
                0.0501  2.6088e-004 -1.0174e-003 1.4639e-003

86u020          0.0200  4.6441e-004
                0.0200  -2.4969e-004 1.3740e-003
                0.0501  2.6094e-004 -1.0177e-003 1.4644e-003

93u864          0.0200  4.6449e-004
                0.0200  -2.4978e-004 1.3743e-003
                0.0501  2.6099e-004 -1.0179e-003 1.4649e-003

943020          0.0200  4.6413e-004
                0.0200  -2.4956e-004 1.3733e-003
                0.0501  2.6086e-004 -1.0173e-003 1.4638e-003

962000          0.0200  4.6416e-004
                0.0200  -2.4957e-004 1.3733e-003
                0.0501  2.6087e-004 -1.0173e-003 1.4638e-003

A458            0.0200  4.6431e-004
                0.0200  -2.4966e-004 1.3738e-003
                0.0501  2.6093e-004 -1.0176e-003 1.4643e-003

A459            0.0200  4.6414e-004
                0.0200  -2.4956e-004 1.3733e-003
                0.0501  2.6087e-004 -1.0173e-003 1.4638e-003


****************************************************************
    VARIANCE FACTOR = 7.1427

    Note: Values < 1.0 indicate statistics are pessimistic, while
          values > 1.0 indicate optimistic statistics. Entering this
          value as the network adjustment scale factor will bring
          variance factor to one.
****************************************************************
```

A I R B O R N E
I M A G I N G
A Clean Harbors Company

f.) Fully Constrained Network Adjustment

```
          ************************************************
          * NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT      *
          *                                                *
          * (c) Copyright NovAtel Inc., (2012)             *
          *                                                *
          * Version: 8.40.3116                             *
          *                                                *
          * FILE: 1370_Ottawa_Cosine-Full.net              *
          ************************************************

  DATUM:             'NAD83 - Original'
  SCALE_FACTOR:      7.8672
  CONFIDENCE LEVEL: 95.00 %   (Scale factor is 2.4479)


****************************************************************
    INPUT CONTROL/CHECK POINTS
****************************************************************

STA_ID     TYPE    -- LATITUDE --  -- LONGITUDE --  ELLHGT -   HZ-SD   V-SD
6530105    GCP-3D  45 21 38.76398  -75 37 01.42352     62.375 0.02000 0.05000
693053     GCP-HZ  45 14 34.16402  -75 27 30.11505            0.02000
833001     GCP-HZ  45 23 55.95047  -75 55 20.13754            0.02000
86u020     GCP-VT                                      90.157         0.05000
93u864     GCP-VT                                      50.582         0.05000
962000     GCP-VT                                     236.016         0.05000


****************************************************************
    INPUT VECTORS
****************************************************************

SESSION NAME            VECTOR(m)    ------ Covariance (m) [unscaled] ------
                         DX/DY/DZ           standard deviations in brackets
6530105 to 943020 (1) -2344.6249  3.7602e-007 (0.0006)
                       7013.8458  -2.4703e-007 1.1821e-006 (0.0011)
                       7301.9796  1.5923e-007 -7.1155e-007 1.3263e-006 (0.0012)

6530105 to 962000 (1) -18772.7616  6.5384e-007 (0.0008)
                      13429.0816  -4.3023e-007 2.0395e-006 (0.0014)
                      17601.3773  2.7497e-007 -1.2319e-006 2.3043e-006 (0.0015)

6530105 to A459 (1)   11905.6608  1.1016e-006 (0.0010)
                      -7929.2105  -7.2047e-007 3.7042e-006 (0.0019)
                      -10550.9089  4.3494e-007 -2.0495e-006 3.8901e-006 (0.0020)

6530105 to A459 (2)   11905.6596  1.0834e-006 (0.0010)
                      -7929.2031  -6.5614e-007 3.1875e-006 (0.0018)
                      -10550.9093  5.2142e-007 -2.2215e-006 4.2571e-006 (0.0021)

693053 to 6530105 (1) -14380.9670  1.0958e-006 (0.0010)
                       5919.1176  -4.6020e-007 2.9861e-006 (0.0017)
                       9214.3003  3.1482e-007 -2.0529e-006 3.3805e-006 (0.0018)

693053 to 943020 (1)  -16725.5954  1.4130e-006 (0.0012)
                      12932.9658  -5.6379e-007 3.6986e-006 (0.0019)
                      16516.2804  3.9807e-007 -2.4421e-006 3.9853e-006 (0.0020)
```

```
693053 to 962000 (1)   -33153.7330  5.0314e-006 (0.0022)
                        19348.2082  -5.8554e-007 3.7283e-006 (0.0019)
                        26815.6694  8.4634e-007 -1.7741e-006 2.2855e-006 (0.0015)

693053 to A459 (1)     -2475.3042  2.4925e-007 (0.0005)
                       -2010.0903  -1.7464e-007 7.9714e-007 (0.0009)
                       -1336.5998  9.9773e-008 -4.4230e-007 8.1577e-007 (0.0009)

693053 to A459 (2)     -2475.3044  2.8179e-007 (0.0005)
                       -2010.0849  -1.8050e-007 7.0750e-007 (0.0008)
                       -1336.6005  1.2583e-007 -4.6045e-007 9.1949e-007 (0.0010)

833001 to 6530105 (1) 23915.3088  7.2159e-007 (0.0008)
                        2941.6506  -4.4981e-007 2.2929e-006 (0.0015)
                       -2961.7200  3.2911e-007 -1.4388e-006 2.7583e-006 (0.0017)

833001 to 693053 (1)  38296.2821  6.3592e-006 (0.0025)
                       -2977.4627  -1.0169e-006 3.8846e-006 (0.0020)
                       -12176.0198  1.0838e-006 -1.8663e-006 2.4905e-006 (0.0016)

833001 to 86u020 (1)    9444.8815  2.4499e-006 (0.0016)
                       -25718.2431  -1.6148e-006 8.1986e-006 (0.0029)
                       -26964.5139  9.1619e-007 -4.6785e-006 7.7834e-006 (0.0028)

833001 to 86u020 (2)    9444.8822  1.6470e-006 (0.0013)
                       -25718.2443  -1.0401e-006 4.9441e-006 (0.0022)
                       -26964.5160  7.1333e-007 -3.2457e-006 5.5963e-006 (0.0024)

833001 to 943020 (1)  21570.6860  6.5300e-007 (0.0008)
                        9955.4918  -4.6399e-007 1.9087e-006 (0.0014)
                        4340.2614  2.9314e-007 -1.1672e-006 2.1220e-006 (0.0015)

833001 to 962000 (1)    5142.5490  6.2180e-007 (0.0008)
                       16370.7283  -4.4010e-007 1.8202e-006 (0.0013)
                       14639.6611  2.7916e-007 -1.1153e-006 2.0339e-006 (0.0014)

833001 to 962000 (2)    5142.5488  1.3594e-006 (0.0012)
                       16370.7346  -5.0127e-007 3.6322e-006 (0.0019)
                       14639.6546  3.7283e-007 -2.4078e-006 3.9678e-006 (0.0020)

833001 to A458 (1)     -4857.3548  1.0635e-006 (0.0010)
                       -7751.5543  -7.7319e-007 3.3892e-006 (0.0018)
                       -6208.1479  4.4387e-007 -1.8980e-006 3.3744e-006 (0.0018)

833001 to A458 (2)     -4857.3557  1.0151e-006 (0.0010)
                       -7751.5592  -5.8655e-007 3.0053e-006 (0.0017)
                       -6208.1472  5.0513e-007 -2.1160e-006 4.2035e-006 (0.0021)

833001 to A459 (1)     35820.9762  1.0077e-006 (0.0010)
                       -4987.5397  -7.1133e-007 2.9402e-006 (0.0017)
                       -13512.6229  4.5922e-007 -1.8248e-006 3.3340e-006 (0.0018)

833001 to A459 (2)     35820.9722  3.2336e-006 (0.0018)
                       -4987.5551  -2.6643e-006 1.2719e-005 (0.0036)
                       -13512.6310  3.7195e-007 -6.7847e-006 1.1194e-005 (0.0033)

833001 to A459 (3)     35820.9709  2.1145e-006 (0.0015)
                       -4987.5558  -1.2482e-006 6.1734e-006 (0.0025)
                       -13512.6281  1.0671e-006 -4.4070e-006 8.7991e-006 (0.0030)
```

```
86u020 to 943020 (2)  12125.7975  8.1039e-006 (0.0028)
                      35673.7365  7.6212e-007 7.7122e-006 (0.0028)
                      31304.7724  3.2021e-007 -3.2895e-006 3.9955e-006 (0.0020)

86u020 to 962000 (2)  -4302.3402  9.8667e-006 (0.0031)
                      42088.9775  1.2758e-006 8.6999e-006 (0.0029)
                      41604.1687  -3.7951e-007 -3.9956e-006 4.8351e-006 (0.0022)

86u020 to A458 (1)    -14302.2374  1.8273e-006 (0.0014)
                      17966.6876  -1.1049e-006 6.3241e-006 (0.0025)
                      20756.3675  6.0586e-007 -3.5632e-006 6.0893e-006 (0.0025)

86u020 to A458 (2)    -14302.2379  1.8617e-006 (0.0014)
                      17966.6851  -9.2963e-007 5.7379e-006 (0.0024)
                      20756.3700  7.9984e-007 -4.0668e-006 7.7354e-006 (0.0028)

86u020 to A459 (1)    26376.0929  2.3795e-006 (0.0015)
                      20730.7070  -1.5932e-006 8.2288e-006 (0.0029)
                      13451.8891  8.0656e-007 -4.6072e-006 7.5277e-006 (0.0027)

86u020 to A459 (2)    26376.0950  1.6207e-006 (0.0013)
                      20730.7010  -1.0226e-006 4.7636e-006 (0.0022)
                      13451.8960  7.0472e-007 -3.1360e-006 5.5345e-006 (0.0024)

943020 to 93u864 (1)  20961.0352  5.4770e-006 (0.0023)
                       3167.7466  -6.9436e-007 1.6015e-005 (0.0040)
                      -2198.2966  8.8623e-007 -1.2368e-005 1.6222e-005 (0.0040)

943020 to 93u864 (2)  20961.0308  1.3060e-006 (0.0011)
                       3167.7578  -9.2622e-007 3.3312e-006 (0.0018)
                      -2198.2985  7.3966e-007 -2.1968e-006 4.0449e-006 (0.0020)

943020 to 962000 (1)  -16428.1390  3.3821e-006 (0.0018)
                       6415.2435  -3.0003e-006 1.0476e-005 (0.0032)
                      10299.3924  4.6056e-007 -3.1336e-006 9.9023e-006 (0.0031)

943020 to 962000 (2)  -16428.1366  4.9104e-007 (0.0007)
                       6415.2357  -3.2168e-007 1.4773e-006 (0.0012)
                      10299.3979  1.9636e-007 -9.0508e-007 1.7295e-006 (0.0013)

943020 to 962000 (3)  -16428.1369  4.3836e-007 (0.0007)
                       6415.2365  -2.7020e-007 1.3422e-006 (0.0012)
                      10299.4003  1.7662e-007 -8.4579e-007 1.6325e-006 (0.0013)

943020 to A458 (1)    -26428.0403  1.8337e-006 (0.0014)
                      -17707.0488  -1.2629e-006 5.9512e-006 (0.0024)
                      -10548.4084  7.3413e-007 -3.3083e-006 6.0942e-006 (0.0025)

943020 to A458 (2)    -26428.0425  1.9399e-006 (0.0014)
                      -17707.0485  -1.1253e-006 5.7298e-006 (0.0024)
                      -10548.4086  9.7467e-007 -4.0401e-006 8.0313e-006 (0.0028)

943020 to A459 (1)    14250.2904  7.1279e-007 (0.0008)
                      -14943.0493  -4.9832e-007 2.0401e-006 (0.0014)
                      -17852.8853  3.1283e-007 -1.2612e-006 2.3337e-006 (0.0015)

943020 to A459 (2)    14250.2871  2.0990e-006 (0.0014)
                      -14943.0529  -1.4687e-006 8.4905e-006 (0.0029)
                      -17852.8917  6.6398e-008 -4.7487e-006 8.2570e-006 (0.0029)
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943020 to A459 (3)    14250.2844  1.4095e-006 (0.0012)
                      -14943.0502  -8.7196e-007 3.9547e-006 (0.0020)
                      -17852.8879  6.7527e-007 -2.7910e-006 5.4367e-006 (0.0023)

943020 to A459 (4)    14250.2901  7.5137e-007 (0.0009)
                      -14943.0314  -5.3759e-007 2.1814e-006 (0.0015)
                      -17852.8847  3.4499e-007 -1.3379e-006 2.4604e-006 (0.0016)

962000 to 93u864 (2)  37389.1704  1.9656e-006 (0.0014)
                      -3247.4851  -1.3805e-006 5.2292e-006 (0.0023)
                      -12497.6916  1.0531e-006 -3.4354e-006 6.3037e-006 (0.0025)

962000 to 93u864 (1)  37389.1721  2.2879e-006 (0.0015)
                      -3247.4868  -1.6101e-006 7.4527e-006 (0.0027)
                      -12497.6932  7.2197e-007 -4.4251e-006 8.4183e-006 (0.0029)

962000 to A458 (1)    -9999.9040  1.8169e-006 (0.0013)
                      -24122.2846  -1.2427e-006 5.9135e-006 (0.0024)
                      -20847.8097  7.2287e-007 -3.2920e-006 6.0808e-006 (0.0025)

962000 to A458 (2)    -9999.9050  1.9267e-006 (0.0014)
                      -24122.2848  -1.1155e-006 5.6958e-006 (0.0024)
                      -20847.8075  9.6921e-007 -4.0220e-006 8.0126e-006 (0.0028)

962000 to A459 (1)    30678.4292  4.3294e-006 (0.0021)
                      -21358.2995  -1.7304e-007 3.2689e-006 (0.0018)
                      -28152.2730  5.3724e-007 -1.5375e-006 2.0444e-006 (0.0014)

962000 to A459 (2)    30678.4099  2.7063e-005 (0.0052)
                      -21358.2970  -1.1243e-006 6.3565e-006 (0.0025)
                      -28152.2857  3.7311e-006 -3.3069e-006 5.7467e-006 (0.0024)

962000 to A459 (3)    30678.4237  1.4164e-005 (0.0038)
                      -21358.2855  -1.5872e-006 2.1200e-005 (0.0046)
                      -28152.2753  3.6439e-006 -6.0518e-006 7.5441e-006 (0.0027)

962000 to A459 (4)    30678.4236  5.3608e-006 (0.0023)
                      -21358.2770  -7.2756e-007 3.9230e-006 (0.0020)
                      -28152.2755  7.1993e-007 -1.8934e-006 2.4183e-006 (0.0016)

A458 to A459 (1)      40678.3202  3.7178e-005 (0.0061)
                       2764.0122  -5.9775e-006 9.1048e-006 (0.0030)
                      -7304.4731  5.8610e-006 -4.4119e-006 6.4701e-006 (0.0025)

A458 to A459 (2)      40678.3185  2.1785e-005 (0.0047)
                       2764.0109  -9.0586e-006 1.9206e-005 (0.0044)
                      -7304.4706  4.5610e-006 -7.7312e-006 7.8939e-006 (0.0028)

A459 to 93u864 (2)     6710.7427  4.4127e-006 (0.0021)
                      18110.8090  -1.5710e-006 2.3748e-005 (0.0049)
                      15654.5907  8.3536e-007 -8.0878e-006 1.0952e-005 (0.0033)

A459 to 93u864 (1)     6710.7434  2.7893e-006 (0.0017)
                      18110.8105  -1.3693e-006 7.0546e-006 (0.0027)
                      15654.5850  -7.2468e-007 -2.6245e-006 9.1427e-006 (0.0030)
```

****

OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)

****

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)	- PPM -	DIST (km)	- STD - (m)
6530105 to 943020 (1)	-0.0012	-0.0019	0.0011	0.236	10.4	0.0048
6530105 to 962000 (1)	-0.0010	-0.0011	-0.0025	0.100	29.0	0.0063
6530105 to A459 (1)	0.0042	0.0082	-0.0010	0.522	17.8	0.0083
6530105 to A459 (2)	0.0035	0.0032	0.0046	0.370	17.8	0.0082
693053 to 6530105 (1)	-0.0010	0.0012	0.0013	0.113	18.1	0.0077
693053 to 943020 (1)	0.0005	-0.0033	0.0043	0.203	26.8	0.0085
693053 to 962000 (1)	0.0001	-0.0012	0.0116	0.250	46.8	0.0093
693053 to A459 (1)	0.0006	0.0017	-0.0045	1.391	3.5	0.0038
693053 to A459 (2)	-0.0006	-0.0016	-0.0002	0.489	3.5	0.0039
833001 to 6530105 (1)	0.0022	0.0014	0.0012	0.119	24.3	0.0067
833001 to 693053 (1)	-0.0039	-0.0020	0.0013	0.113	40.3	0.0100
833001 to 86u020 (1)	-0.0008	-0.0029	0.0027	0.105	38.4	0.0120
833001 to 86u020 (2)	-0.0013	-0.0005	0.0032	0.091	38.4	0.0098
833001 to 943020 (1)	0.0002	0.0018	-0.0025	0.126	24.2	0.0061
833001 to 962000 (1)	0.0005	0.0006	-0.0069	0.307	22.6	0.0059
833001 to 962000 (2)	-0.0009	0.0007	0.0020	0.102	22.6	0.0084
833001 to A458 (1)	-0.0011	-0.0019	0.0003	0.201	11.1	0.0078
833001 to A458 (2)	0.0009	0.0009	-0.0033	0.317	11.1	0.0080
833001 to A459 (1)	-0.0049	-0.0074	0.0086	0.320	38.6	0.0076
833001 to A459 (2)	0.0027	0.0082	0.0045	0.253	38.6	0.0146
833001 to A459 (3)	0.0042	0.0064	0.0022	0.205	38.6	0.0116
86u020 to 943020 (2)	0.0074	0.0044	-0.0008	0.177	49.0	0.0125
86u020 to 962000 (2)	0.0073	0.0024	0.0004	0.129	59.3	0.0136
86u020 to A458 (1)	0.0010	0.0006	-0.0040	0.134	31.0	0.0106
86u020 to A458 (2)	0.0021	0.0005	-0.0074	0.248	31.0	0.0110
86u020 to A459 (1)	-0.0032	-0.0060	0.0100	0.335	36.1	0.0119
86u020 to A459 (2)	-0.0037	-0.0063	0.0007	0.204	36.1	0.0097
943020 to 93u864 (1)	-0.0000	0.0063	-0.0072	0.449	21.3	0.0172
943020 to 93u864 (2)	0.0014	-0.0009	0.0025	0.140	21.3	0.0083
943020 to 962000 (1)	0.0006	-0.0013	0.0058	0.293	20.4	0.0137
943020 to 962000 (2)	0.0001	0.0007	-0.0038	0.188	20.4	0.0054
943020 to 962000 (3)	0.0002	-0.0016	-0.0049	0.254	20.4	0.0052
943020 to A458 (1)	-0.0011	-0.0023	0.0003	0.077	33.5	0.0104
943020 to A458 (2)	0.0009	-0.0028	0.0011	0.094	33.5	0.0111
943020 to A459 (1)	-0.0009	0.0038	-0.0004	0.144	27.3	0.0063
943020 to A459 (2)	0.0032	0.0101	0.0024	0.399	27.3	0.0122
943020 to A459 (3)	0.0051	0.0052	0.0019	0.276	27.3	0.0092
943020 to A459 (4)	-0.0051	-0.0091	0.0114	0.565	27.3	0.0065
962000 to 93u864 (2)	0.0001	0.0005	-0.0026	0.067	39.6	0.0103
962000 to 93u864 (1)	-0.0011	0.0031	-0.0028	0.110	39.6	0.0120
962000 to A458 (1)	-0.0010	-0.0007	0.0065	0.197	33.4	0.0104
962000 to A458 (2)	0.0000	-0.0022	0.0050	0.163	33.4	0.0111
962000 to A459 (1)	0.0004	0.0063	-0.0142	0.332	46.8	0.0087
962000 to A459 (2)	0.0184	0.0102	-0.0000	0.450	46.8	0.0176
962000 to A459 (3)	0.0022	-0.0027	-0.0020	0.086	46.8	0.0184
962000 to A459 (4)	0.0003	-0.0085	0.0039	0.200	46.8	0.0096
A458 to A459 (1)	0.0073	-0.0072	0.0071	0.300	41.4	0.0204
A458 to A459 (2)	0.0092	-0.0083	0.0046	0.320	41.4	0.0196
A459 to 93u864 (2)	-0.0004	-0.0083	0.0010	0.337	24.9	0.0175
A459 to 93u864 (1)	-0.0015	-0.0052	0.0059	0.324	24.9	0.0122
RMS	0.0040	0.0047	0.0050			

$ - This session is flagged as a 3-sigma outlier

```
****************************************************************
    CONTROL POINT RESIDUALS (ADJUSTMENT MADE)
****************************************************************

STA. NAME    -- RE --    -- RN --    -- RH --
               (m)         (m)         (m)
6530105       0.0027     -0.0105     -0.0218
693053        0.0168      0.0447
833001       -0.0193     -0.0342
86u020                               -0.0049
93u864                                0.0314
962000                               -0.0047
            --------------------------------
RMS           0.0148      0.0331      0.0194



****************************************************************
    OUTPUT STATION COORDINATES (LAT/LONG/HT)
****************************************************************

STA_ID      -- LATITUDE --  -- LONGITUDE -- - ELLHGT -
6530105     45 21 38.76364  -75 37 01.42340    62.3532
693053      45 14 34.16547  -75 27 30.11428    70.2434
833001      45 23 55.94936  -75 55 20.13843    43.9130
86u020      45 03 14.29118  -75 53 07.35310    90.1521
93u864      45 25 34.56319  -75 21 15.56334    50.6134
943020      45 27 14.96200  -75 37 25.76425    83.5516
962000      45 35 06.05166  -75 48 26.36349   236.0113
A458        45 19 08.48078  -76 00 23.02449    83.0326
A459        45 13 33.20075  -75 29 43.07762    54.4266



****************************************************************
    OUTPUT VARIANCE/COVARIANCE
****************************************************************
                                              2
STA_ID      SE/SN/SUP  --------- CX matrix (m )-----------
            (95.00 %)  (not scaled by confidence level)
               (m)          (ECEF, XYZ cartesian)
6530105       0.0283  1.4882e-004
              0.0283  -5.8819e-005 3.6388e-004
              0.0614  6.1293e-005 -2.4003e-004 3.8472e-004

693053        0.0283  1.4898e-004
              0.0283  -5.9028e-005 3.6456e-004
              0.0615  6.1492e-005 -2.4065e-004 3.8512e-004

833001        0.0283  1.4888e-004
              0.0283  -5.8915e-005 3.6416e-004
              0.0614  6.1393e-005 -2.4033e-004 3.8491e-004

86u020        0.0285  1.5075e-004
              0.0286  -5.9093e-005 3.6661e-004
              0.0615  6.1179e-005 -2.4026e-004 3.8665e-004

93u864        0.0286  1.5150e-004
              0.0288  -5.9503e-005 3.6793e-004
              0.0616  6.1181e-005 -2.4046e-004 3.8907e-004
```

```
943020          0.0283  1.4894e-004
                0.0284  -5.8740e-005 3.6354e-004
                0.0614  6.1146e-005 -2.3945e-004 3.8428e-004

962000          0.0283  1.4913e-004
                0.0284  -5.8637e-005 3.6329e-004
                0.0613  6.1052e-005 -2.3905e-004 3.8378e-004

A458            0.0284  1.5011e-004
                0.0285  -5.9362e-005 3.6666e-004
                0.0616  6.1583e-005 -2.4126e-004 3.8754e-004

A459            0.0283  1.4883e-004
                0.0283  -5.8765e-005 3.6355e-004
                0.0614  6.1199e-005 -2.3960e-004 3.8415e-004


****************************************************************
    VARIANCE FACTOR = 1.0002

    Note: Values < 1.0 indicate statistics are pessimistic, while
          values > 1.0 indicate optimistic statistics. Entering this
          value as the network adjustment scale factor will bring
          variance factor to one.
****************************************************************
```

Appendix C

Unusable Monuments

Points that we went looking for and were not found, destroyed or not used because there were in poor GPS locations.

00119773030

This point may still exist, but if it does, it's under a log pile. Either way, it's not usable.

0011986u017

Again, located but unusable for GPS due to tree cover.

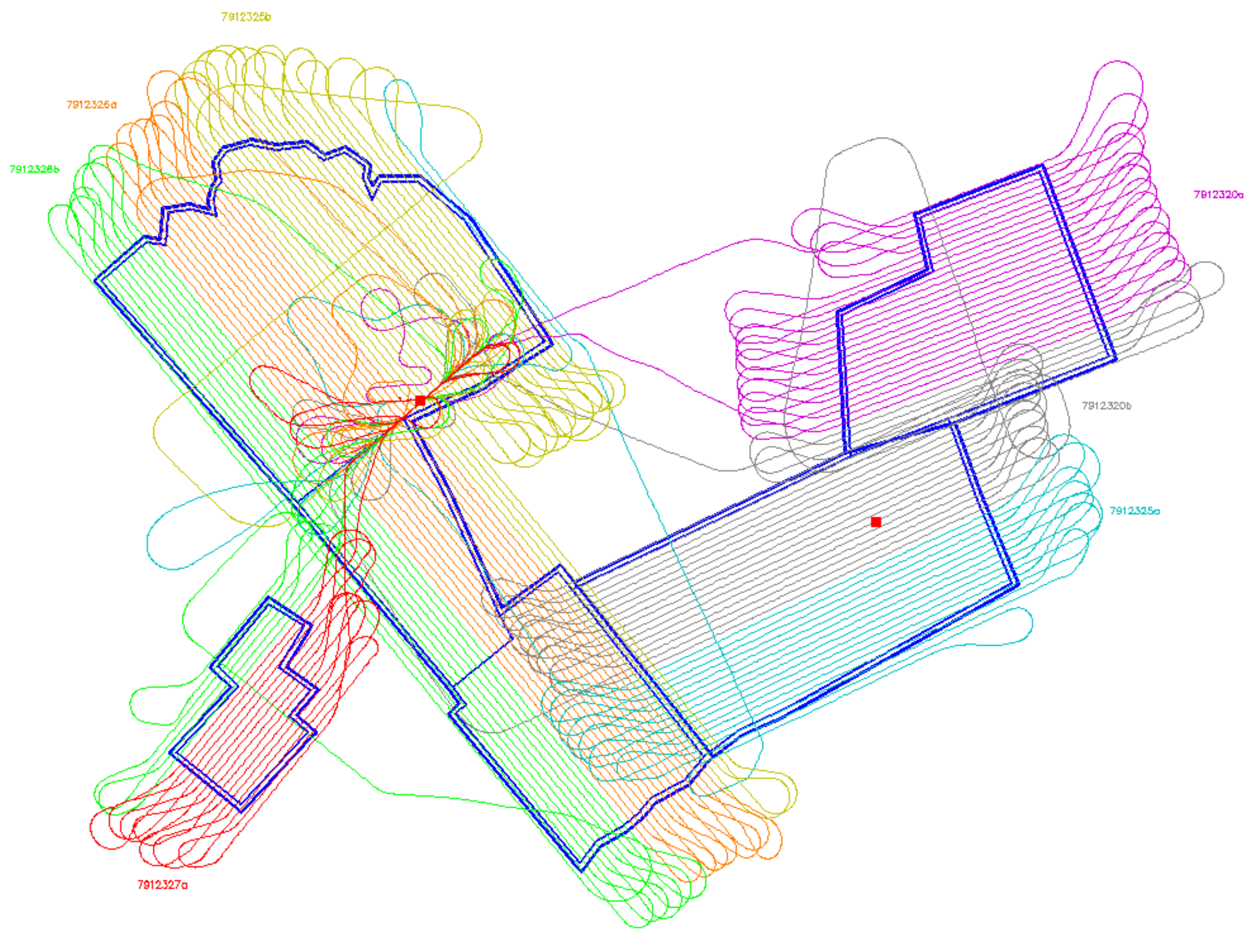
0011986u144
Located, but unusable due to tree cover (and a poor setup).

01919680197 (AKA 6530197 by NRCAN)
Location of published coordinates puts it under a road.

00819758197
Located but not usable. Had I read the description I would have seen that it was located in a vertical rock face.

Appendix D

Missions Map and Flight Logs



LIDAR Flight Log

Julian Day 320	Flight A

Date 2012 11 15	Aircraft 208B CFARQ
Project 1370 OTTAWA	Pilot CHRIS MATHESON
Location CARP ON CYRP	Operator TROY SENTNER
Mission Objective START ON BLOCK 3	

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	
Data Drive	2

Additional Notes

COVER [illegible] NOT KEPT ON POWER UP

AIRBORNE IMAGING

Aircraft Block Time		
Engine On 15:05	Ramp Out	Takeoff 15:22
Engine Off 20:01	Ramp In	Landing 19:47
Total 4.9 hrs	Total hrs	Total 4.4 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	15:13	15:19
Post Mission	19:49	19:54

Flight Line	LIDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
CYRP CALIB	791232001	228	15:29	15:30			152952	140 KTS @ 1700 MAGL
CYRP CALIB	02	048	15:35	15:36			153555	145 KTS @ 1650 MAGL
84	03	069	15:46	15:48			154608	
85	04	249	15:54	15:57			155425	
86	05	069	16:02	16:04			160201	
87	06	249	16:09	16:12			160934	
88	07	069	16:16	16:19			161634	
89	08	249	16:23	16:26			162324	
90	09	069	16:30	16:33			163018	
91	10	249	16:37	16:40			163700	
92	11	069	16:45	16:50			164545	
93	12	249	16:54	16:58			165405	
94	13	069	17:02	17:07			170254	
95	14	249	17:11	17:16			171110	
96	15	069	17:19	17:24			171955	

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LIDAR Flight Log

Julian Day	320	Flight	A

AIRBORNE IMAGING

Date	2012 11 15	Aircraft	208B CFARQ
Project	1370 OTTAWA	Pilot	CHRIS MATHESON
Location	CARP ON CYRP	Operator	T. [illegible]
Mission Objective			

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	NA
Data Drive	2

Additional Notes

Aircraft Block Time					
Engine On		Ramp Out		Takeoff	15:22
Engine Off		Ramp In		Landing	
Total	hrs	Total	hrs	Total	hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission		
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
97	791232016	249	17:28	17:33			172817	
98	17	069	17:37	17:41			173706	
99	18	249	17:45	17:51			174548	
100	19	068	17:54	17:59			175448	
101	20	249	18:03	18:09			180335	
102	21	068	18:12	18:17			181247	
103	22	249	18:21	18:26			182127	
104	23	068	18:30	18:35			183042	
105	24	249	18:39	18:45			183934	
106	25	068	18:48	18:54			184858	
107	26	249	18:57	19:03			185750	
108	27	068	19:07	19:12			190710	
109	28	249	19:16	19:21			191627	
CYRP CALIB	29	228	19:30	19:31			193025	140 KTS @ 1700 mAGL
CYRP CALIB	30	048	19:35	19:36			193519	141 KTS @ 1700 mAGL

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LIDAR Flight Log

Julian Day 320	Flight B

AIRBORNE IMAGING

Date 2012 NOV 15	Aircraft C208 C-FARQ
Project 1370 OTTAWA	Pilot C. ROSS
Location CYRP CARP, ON	Operator TRITHARDT
Mission Objective	

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	
Data Drive	4

Additional Notes

Aircraft Block Time		
Engine On 2056	Ramp Out	Takeoff 2110
Engine Off 0226	Ramp In	Landing 0217
Total 5.5 hrs	Total hrs	Total 5.1 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	2102	2107
Post Mission	0218	0223

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
CAL CYRP	791232031	228	2120	2120			121115_212006	1680 mAGL@ 130 Kts
CAL CYRP	32	048	2125	2126			212538	1690 mAGL@ 128 Kts
110	33	068.4	2134	2139			213406	
111	34	248.6	2144	2150			214442	
112	35	068.4	2154	2159			215412	
113	36	248.6	2203	2209			220334	
114	37	068.4	2213	2218			221300	
115	38	248.6	2222	2228			222215	
X TIE AREA 3	39	159	2236	2241			223610	
51	40	244.2	2246	2254			224626	
52	41	063.9	2257	2305			225750	
53	42	244.2	2309	2317			230937	
54	43	063.9	2321	2328			232114	
55	44	244.2	2332	2340			233240	
56	45	063.9	2344	2351			234408	

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LIDAR Flight Log

AIRBORNE IMAGING

Julian Day 320	Flight B

Date 2012 NOV 15	Aircraft C208 C-FARQ
Project 1370 OTTAWA	Pilot C. ROSS
Location CYRP CARP ON	Operator T. TRITHARDT
Mission Objective	

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	
Data Drive	4.

Additional Notes

Aircraft Block Time		
Engine On 2056	Ramp Out	Takeoff 2110
Engine Off 0226	Ramp In	Landing 0217
Total 5.5 hrs	Total hrs	Total 5.1 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	2102	2107
Post Mission	0218	0223

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission D	Comments
57	791232046	244.2	2355	0003			121115_235512	
58	47	063.9	0006	0014			000643	
59	48	244.2	0017	0025			001756	
60	49	063.9	0029	0036			002915	
61	50	244.2	0040	0047			004005	
62	51	064.0	0051	0058			005114	
63	52	244.2	0102	0109			010202	
64	53	064.0	0113	0120			011300	
65	54	244.2	0123	0130			012324	
66	55	064.0	0134	0141			013410	
67	56	244.2	0144	0152			014443	
CAL CYRP	57	048	0202	0203			020239	1710 mAGL@ 131 Kts
CAL CYRP	58	228	0207	0208			020715	1700 mAGL@ 137 Kts

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LIDAR Flight Log

AIRBORNE IMAGING

Julian Day 325	Flight A

Date 2012 11 20	Aircraft 208B CFARQ	System	Leica ALS 70
Project 1370 OTTAWA	Pilot Chris Mitchison	Unit	7179
Location CARP ON CYRP	Operator T. Sextmur	IMU	Honeywell Micro IRS
Mission Objective START ON LINE 68 → TO		GPS Rx	NovAtel OEMV
		GPS Rx	NA
		Data Drive	2

Additional Notes

PILOT RESTRICTED TO DAY TIME FLIGHT
DARK 4:30 LOCAL · ON GROUND BY 5:00 pm LOCAL
HAZE IN AIR

FCMS
ERROR ON POWER UP · POD · LASER PULSE SYNC RESTART OK

Aircraft Block Time					
Engine On	17:34	Ramp Out		Takeoff	17:55
Engine Off	22:07	Ramp In		Landing	21:55
Total	4.5 hrs	Total	hrs	Total	4.0 hrs

Mission Plan					
AGL Height	1800	m	Pulse Rate	250	KHz
Target Speed	160	kts	Scan Rate	42	Hz
Laser Current	100	%	FOV	42	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	17:46	17:51
Post Mission	21:59	22:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
CYRP CALIB	791232501	048	18:09	18:10			180939	140 KTS @ 1700 mAGL (6000 ft AGL)
CYRP CALIB	02	228	18:14	18:15			181453	150 KTS @ 1700 mAGL
68	03	064	18:23	18:30			182341	
69	04	244	18:35	18:42			183522	
70	05	064	18:46	18:54			184642	
71	06	244	18:58	19:05			185850	
72	07	064	19:10	19:17			191011	
73	08	244	19:21	19:28			192127	
74	09	064	19:32	19:39			193243	
75	10	244	19:43	19:50			194348	
76	11	064	19:54	20:01			195452	
77	12	244	20:06	20:12			200624	
78	13	064	20:16	20:24			201652	
79	14	244	20:27	20:34			202755	
80	15	064	20:38	20:45			203837	

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Julian Day 325	Flight A

LIDAR Flight Log

AIRBORNE IMAGING

Date 2012 11 20	Aircraft 208B CFARQ
Project 1370 OTTAWA	Pilot C. MATHISON
Location CARP CYRP	Operator T. Sentner
Mission Objective	

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	N/A
Data Drive	2

Additional Notes

Aircraft Block Time		
Engine On 17:34	Ramp Out	Takeoff 17:55
Engine Off 22:07	Ramp In	Landing 21:55
Total 4.5 hrs	Total hrs	Total 4.0 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	166 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time	
	Start	End
Pre Mission		
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
81	79123251 6	244	20:48	20:55			204852	
82	17	064	20:58	21:04			205842	
83	18	244	21:08	21:12			210800	
BLOCK2 XTIE	19	334	21:14	21:19			211435	
50	20	320	21:23	21:26			212305	
49	21	140	21:30	21:34			213624	
CYRP CALIB	22	228	2137	2138			213742	145 Kts @ 1750m AGL
CYRP CALIB	23	048	21:44	21:45			214458	145 Kts @ 1725m AGL

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LIDAR Flight Log

Julian Day 325	Flight B

AIRBORNE IMAGING

Date 2012 NOV 20	Aircraft C-208 C-FARQ	System	Leica ALS 70
Project 1370 OTTAWA	Pilot ROSS	Unit	7179
Location CYRP CARP, ON	Operator TRITHARDT	IMU	Honeywell Micro IRS
Mission Objective		GPS Rx	NovAtel OEMV
		GPS Rx	
		Data Drive	4

Additional Notes

Aircraft Block Time		
Engine On 2240	Ramp Out	Takeoff 2254
Engine Off 0404	Ramp In	Landing 0355
Total 5.4 hrs	Total hrs	Total 5.0 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	2247	2252
Post Mission	0356	0401

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
CAL CYRP	791232524	228	2302	2303			121120_230238	1780 mAGL@ 140 Kts
CAL CYRP	25	048	2307	2308			230720	1770 mAGL@ 137 Kts
48	26	320.1	2314	2318			231404	
47	27	140.0	2322	2327			232240	
46	28	320.1	2330	2335			233044	
45	29	140.0	2339	2344			233928	
44	30	320.1	2348	2353			234807	
43	31	140.0	2357	0002			235703	
42	32	320.1	0005	0011			121121_000554	
41	33	139.9	0015	0020			001514	
40	34	320.1	0024	0030			002440	
39	35	139.9	0034	0040			003417	
38	36	320.1	0043	0049			004338	
37	37	139.9	0053	0059			005312	
36	38	320.1	0103	0109			010259	

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LIDAR Flight Log

Julian Day	Flight
325	B

AIRBORNE IMAGING

Date	2012 NOV 20	Aircraft	C-208 C-FARQ
Project	1370 OTTAWA	Pilot	ROSS
Location	CYRP CARP, ON	Operator	TRITHARDT
Mission Objective			

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	
Data Drive	4

Additional Notes

Aircraft Block Time					
Engine On	2240	Ramp Out		Takeoff	2254
Engine Off		Ramp In		Landing	0355
Total	hrs	Total	hrs	Total	5.0 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time	
	Start	End
Pre Mission	2247	2252
Post Mission	0356	0401

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
35	791232539	139.9	0112	0119			121121_011244	
34	40	320.1	0122	0128			012238	
33	41	139.9	0132	0139			013239	
32	42	320.1	0142	0149			014247	
31	43	139.9	0152	0159			015251	
30	44	320.1	0202	0209			020242	
29	45	139.9	0212	0226			021232	
28	46	320.3	0230	0244			023030	
27	47	139.9	0248	0302			024809	
26	48	320.3	0306	0320			030608	
X TIE AREA 1	49	230	0327	0334			032716	
CAL CYRP	50	048	0341	0341			034113	1790 mAGL@ 136 Kts
CAL CYRP	51	228	0346	0346			034609	1780 mAGL@ 132 Kts

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LIDAR Flight Log

Julian Day 326	Flight A

AIRBORNE IMAGING

Date	2012 11 21	Aircraft	208B CFARG
Project	1370 OTTAWA	Pilot	CHRIS MATHISON
Location	CARP, ON CYRP	Operator	T. SOUTAR
Mission Objective	START LINE 25 WORKING WEST		

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	NA
Data Drive	2

Additional Notes

ATC - LOST MAP
trembmi @ navcanada.ca

Aircraft Block Time					
Engine On	14:24	Ramp Out		Takeoff	14:43
Engine Off	19:54	Ramp In		Landing	19:39
Total	5.5 hrs	Total	hrs	Total	4.9 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	14:35	14:40
Post Mission	19:42	19:47

Flight Line	LIDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
CYRP CALIB	791232601	228	14:51	14:52			145118	150 KTS @ 1700 mAGL
CYRP CALIB	02	048	14:57	14:57			145732	150 KTS @ 1700 mAGL
25	03	140	15:08	15:22			150850	
24	04	320	15:27	15:41			152706	
23	05	140	15:46	16:00			154618	
22	06	320	16:03	16:18			160350	
21	07	140	16:22	16:35			162212	
20	08	320	16:39	16:54			163932	
19	09	140	16:57	17:11			165729	
18	10	320	17:14	17:29			171432	
17	11	140	17:32	17:46			173227	
16	12	320	17:49	18:04			174932	
15	13	140	18:07	18:21			180732	
14	14	320	18:24	18:39			182429	@ 155 KTS all
13	15	140	18:42	18:55			184215	@ 165 KTS day

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Julian Day 326	Flight A

LIDAR Flight Log

AIRBORNE IMAGING

Date 2012 11 21	Aircraft 208B CFARQ	System	Leica ALS 70
Project 1370 OTTAWA	Pilot C MATHISON	Unit	7179
Location CARP ON, CYRP	Operator T SCHNARR	IMU	Honeywell Micro IRS
Mission Objective		GPS Rx	NovAtel OEMV
		GPS Rx	NA
		Data Drive	2

Additional Notes

Aircraft Block Time		
Engine On 14:24	Ramp Out	Takeoff 14:43
Engine Off 19:54	Ramp In	Landing 19:39
Total 5.5 hrs	Total hrs	Total 4.9 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:35	14:40
Post Mission	1942	1947

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
12	791232616	320	18:58	19:13			185852	
CYRP CALIB	17	228	19:22	19:22			192201	140KTS @ 1725 mAGL
CYRP CALIB	18	048	19:26	19:26			192600	150KTS @1725 mAGL

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Julian Day 326	Flight B

LIDAR Flight Log

AIRBORNE IMAGING

Date	2012 NOV 21	Aircraft	C208 C-FARQ
Project	1370 OTTAWA	Pilot	ROSS
Location	CYRP CARP ON	Operator	TRITHARDT
Mission Objective			

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	
Data Drive	4

Additional Notes
1st START - INIT FAILURE
LASER TRIGGER

Aircraft Block Time		
Engine On 2024	Ramp Out	Takeoff 2045
Engine Off 0144	Ramp In	Landing 0134
Total 5.3 hrs	Total hrs	Total 4.8 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time	
	Start	End
Pre Mission	2038	2043
Post Mission	0136	0141

Flight Line	LIDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
CAL CYRP	791232619	228	2055	2055			121121_205510	1800mAGL@ 134 Kts
CAL CYRP	20	048	2100	2101			210016	1790 mAGL@ 138 Kts
11	21	139.8	2111	2125			211140	
10	22	320.2	2129	2143			212921	
9	23	139.8	2147	2201			214728	
8	24	320.2	2205	2219			220504	
7	25	139.8	2223	2236			222310	
6	26	320.2	2240	2254			224045	
5	27	139.8	2258	2311			225801	
4	28	320.2	2315	2329			231526	
3	29	139.8	2332	2346			233248	
2	30	320.2	2350	0004			235000	
1	31	139.8	0007	0021			121122_000736	
X TIE AREA 4	32	308	0029	0033			002944	
116	33	218.2	0038	0040			003805	

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LIDAR Flight Log

Julian Day 326	Flight B

Date 2012 Nov 21	Aircraft C208 CFARQ	System	Leica ALS 70
Project 1370 OTTAWA	Pilot ROSS	Unit	7179
Location CYRP CARP, ON	Operator TRITHARDT	IMU	Honeywell Micro IRS
Mission Objective		GPS Rx	NovAtel OEMV
		GPS Rx	
		Data Drive	4

Additional Notes

Aircraft Block Time		
Engine On 2024	Ramp Out	Takeoff 2045
Engine Off 0144	Ramp In	Landing 0134
Total 5.3 hrs	Total hrs	Total 4.8 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	2038	2043
Post Mission	0136	0141

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
117	791232634	038.2	0043	0045			121122_004352	
118	35	218.2	0049	0053			004913	
119	36	038.1	0056	0059			005616	
120	37	218.2	0103	0107			010326	
121	38	038.1	0110	0114			011044	
CAL CYRP	39	048	0118	0119			011835	1800mAGL@ 135 Kts
CAL CYRP	40	228	0123	0124			012325	1810 mAGL@ 130 Kts

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LIDAR Flight Log

AIRBORNE IMAGING

Julian Day 327	Flight A

Date	2012 11 22	Aircraft	208B CFARQ
Project	1370 OTTAWA	Pilot	CHRIS MATHISON
Location	CARP ON, CYRP	Operator	T SCHINDLER
Mission Objective	START LINE 122 → 135 FINISH PROJECT AREA		

System	Leica ALS 70
Unit	7179
IMU	Honeywell Micro IRS
GPS Rx	NovAtel OEMV
GPS Rx	NA
Data Drive	2

Additional Notes
RESTARTED SYSTEM BEFORE FLIGHT
3rd TIME !! IN OTTAWA
ALS ERROR SYSTEM CONTROLLER IN FIRE MODE BUT RX START PULSE

Aircraft Block Time					
Engine On	16:34	Ramp Out		Takeoff	16:55
Engine Off	19:23	Ramp In		Landing	19:13
Total	2.8 hrs	Total	hrs	Total	2.3 hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	16:46	16:52
Post Mission	19:15	19:20

Flight Line	LIDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
CYRP CALIB	791232701	048	17:02	17:03			170254	150 KTS 1750 @ mAGL
CYRP CALIB	02	228	17:07	17:08			170741	140 KTS 1750 @ mAGL
122	03	218	17:13	17:17			171302	140 KTS
123	04	038	17:21	17:25			172142	165 KTS
124	05	218	17:29	17:33			172946	
125	06	038	17:37	17:41			173755	
126	07	218	17:45	17:49			174547	
127	08	038	17:53	17:56			175340	
128	09	218	18:00	18:03			180025	
129	10	038	18:07	18:10			180724	
130	11	218	18:14	18:17			181421	
131	12	038	18:21	18:24			182141	
132	13	218	18:28	18:31			182840	
133	14	038	18:35	18:38			183550	
134	15	218	18:42	18:44			184224	

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Julian Day 327	Flight A

LIDAR Flight Log

Date 2012 11 22	Aircraft 208B CFARQ	System	Leica ALS 70
Project 1370 OTTAWA	Pilot C MATHISON	Unit	7179
Location CARP ON	Operator T. SEYMOUR	IMU	Honeywell Micro IRS
Mission Objective		GPS Rx	NovAtel OEMV
		GPS Rx	NA
		Data Drive	Z

Additional Notes

Aircraft Block Time		
Engine On	Ramp Out	Takeoff
Engine Off	Ramp In	Landing
Total hrs	Total hrs	Total hrs

Mission Plan			
AGL Height	1800 m	Pulse Rate	250 KHz
Target Speed	160 kts	Scan Rate	42 Hz
Laser Current	100 %	FOV	42 Deg's

Static Alignment	GPS Time	
	Start	End
Pre Mission		
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End		
135	791232716	038	18:48	18:50			184807	
CYRP CALIB	17	048	18:56	18:57			185642	140 KTS @ 1750 mAGL
CYRP CALIB	18	228	19:01	19:02			190137	140 KTS @ 1750 mAGL

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Appendix E

Point Cloud Strips by Flight Lines

Lidar for City of Ottawa

Conservation area (UTM18)

Flight line naming/numbering

System	Year	Mission	Raw LAS File Name	Type	Receiver 1 LAS File Name	Flight Line Number	Receiver 3 LAS File Name	Flight Line Number	Shift Applied
79	12	326b	791232619	Calibration Pass	791212619	12619	791232619	32619	+6cm
79	12	326b	791232620	Calibration Pass	791212620	12620	791232620	32620	+6cm
79	12	326b	791232632	Cross-tie Line	791212632	12632	791232632	32632	+6cm
79	12	326b	791232633	Production over project	791212633	12633	791232633	32633	+6cm
79	12	326b	791232634	Production over project	791212634	12634	791232634	32634	+6cm
79	12	326b	791232635	Production over project	791212635	12635	791232635	32635	+6cm
79	12	326b	791232636	Production over project	791212636	12636	791232636	32636	+6cm
79	12	326b	791232637	Production over project	791212637	12637	791232637	32637	+6cm
79	12	326b	791232638	Production over project	791212638	12638	791232638	32638	+6cm
79	12	326b	791232639	Calibration Pass	791212639	12639	791232639	32639	+6cm
79	12	326b	791232640	Calibration Pass	791212640	12640	791232640	32640	+6cm
79	12	327a	791232701	Calibration Pass	791212701	12701	791232701	32701	None
79	12	327a	791232702	Calibration Pass	791212702	12702	791232702	32702	None
79	12	327a	791232703	Production over project	791212703	12703	791232703	32703	None
79	12	327a	791232704	Production over project	791212704	12704	791232704	32704	None
79	12	327a	791232705	Production over project	791212705	12705	791232705	32705	None
79	12	327a	791232706	Production over project	791212706	12706	791232706	32706	None
79	12	327a	791232707	Production over project	791212707	12707	791232707	32707	None
79	12	327a	791232708	Production over project	791212708	12708	791232708	32708	None
79	12	327a	791232709	Production over project	791212709	12709	791232709	32709	None
79	12	327a	791232710	Production over project	791212710	12710	791232710	32710	None
79	12	327a	791232711	Production over project	791212711	12711	791232711	32711	None
79	12	327a	791232712	Production over project	791212712	12712	791232712	32712	None
79	12	327a	791232713	Production over project	791212713	12713	791232713	32713	None
79	12	327a	791232714	Production over project	791212714	12714	791232714	32714	None
79	12	327a	791232715	Production over project	791212715	12715	791232715	32715	None
79	12	327a	791232716	Production over project	791212716	12716	791232716	32716	None
79	12	327a	791232717	Calibration Pass	791212717	12717	791232717	32717	None
79	12	327a	791232718	Calibration Pass	791212718	12718	791232718	32718	None

Lidar for City of Ottawa

Ottawa area (MTM 9)

Flight line naming/numbering

System	Year	Mission	Raw LAS File Name	Type	Receiver 1 LAS File Name	Flight Line Number	Receiver 3 LAS File Name	Flight Line Number	Shift Applied
79	12	320a	791232001	Calibration Pass	791212001	12001	791232001	32001	+6cm
79	12	320a	791232002	Calibration Pass	791212002	12002	791232002	32002	+6cm
79	12	320a	791232003	Production over project	791212003	12003	791232003	32003	+6cm
79	12	320a	791232004	Production over project	791212004	12004	791232004	32004	+6cm
79	12	320a	791232005	Production over project	791212005	12005	791232005	32005	+6cm
79	12	320a	791232006	Production over project	791212006	12006	791232006	32006	+6cm
79	12	320a	791232007	Production over project	791212007	12007	791232007	32007	+6cm
79	12	320a	791232008	Production over project	791212008	12008	791232008	32008	+6cm
79	12	320a	791232009	Production over project	791212009	12009	791232009	32009	+6cm
79	12	320a	791232010	Production over project	791212010	12010	791232010	32010	+6cm
79	12	320a	791232011	Production over project	791212011	12011	791232011	32011	+6cm
79	12	320a	791232012	Production over project	791212012	12012	791232012	32012	+6cm
79	12	320a	791232013	Production over project	791212013	12013	791232013	32013	+6cm
79	12	320a	791232014	Production over project	791212014	12014	791232014	32014	+6cm
79	12	320a	791232015	Production over project	791212015	12015	791232015	32015	+6cm
79	12	320a	791232016	Production over project	791212016	12016	791232016	32016	+6cm
79	12	320a	791232017	Production over project	791212017	12017	791232017	32017	+6cm
79	12	320a	791232018	Production over project	791212018	12018	791232018	32018	+6cm
79	12	320a	791232019	Production over project	791212019	12019	791232019	32019	+6cm
79	12	320a	791232020	Production over project	791212020	12020	791232020	32020	+6cm
79	12	320a	791232021	Production over project	791212021	12021	791232021	32021	+6cm
79	12	320a	791232022	Production over project	791212022	12022	791232022	32022	+6cm
79	12	320a	791232023	Production over project	791212023	12023	791232023	32023	+6cm
79	12	320a	791232024	Production over project	791212024	12024	791232024	32024	+6cm
79	12	320a	791232025	Production over project	791212025	12025	791232025	32025	+6cm
79	12	320a	791232026	Production over project	791212026	12026	791232026	32026	+6cm
79	12	320a	791232027	Production over project	791212027	12027	791232027	32027	+6cm
79	12	320a	791232028	Production over project	791212028	12028	791232028	32028	+6cm
79	12	320a	791232029	Calibration Pass	791212029	12029	791232029	32029	+6cm
79	12	320a	791232030	Calibration Pass	791212030	12030	791232030	32030	+6cm
79	12	320b	791232031	Calibration Pass	791212031	12031	791232031	32031	+6cm
79	12	320b	791232032	Calibration Pass	791212032	12032	791232032	32032	+6cm
79	12	320b	791232033	Production over project	791212033	12033	791232033	32033	+6cm
79	12	320b	791232034	Production over project	791212034	12034	791232034	32034	+6cm
79	12	320b	791232035	Production over project	791212035	12035	791232035	32035	+6cm

79	12	320b	791232036	Production over project	791212036	12036	791232036	32036	+6cm
79	12	320b	791232037	Production over project	791212037	12037	791232037	32037	+6cm
79	12	320b	791232038	Production over project	791212038	12038	791232038	32038	+6cm
79	12	320b	791232039	Cross-tie Line	791212039	12039	791232039	32039	+6cm
79	12	320b	791232040	Production over project	791212040	12040	791232040	32040	+6cm
79	12	320b	791232041	Production over project	791212041	12041	791232041	32041	+6cm
79	12	320b	791232042	Production over project	791212042	12042	791232042	32042	+6cm
79	12	320b	791232043	Production over project	791212043	12043	791232043	32043	+6cm
79	12	320b	791232044	Production over project	791212044	12044	791232044	32044	+6cm
79	12	320b	791232045	Production over project	791212045	12045	791232045	32045	+6cm
79	12	320b	791232046	Production over project	791212046	12046	791232046	32046	+6cm
79	12	320b	791232047	Production over project	791212047	12047	791232047	32047	+6cm
79	12	320b	791232048	Production over project	791212048	12048	791232048	32048	+6cm
79	12	320b	791232049	Production over project	791212049	12049	791232049	32049	+6cm
79	12	320b	791232050	Production over project	791212050	12050	791232050	32050	+6cm
79	12	320b	791232051	Production over project	791212051	12051	791232051	32051	+6cm
79	12	320b	791232052	Production over project	791212052	12052	791232052	32052	+6cm
79	12	320b	791232053	Production over project	791212053	12053	791232053	32053	+6cm
79	12	320b	791232054	Production over project	791212054	12054	791232054	32054	+6cm
79	12	320b	791232055	Production over project	791212055	12055	791232055	32055	+6cm
79	12	320b	791232056	Production over project	791212056	12056	791232056	32056	+6cm
79	12	320b	791232057	Calibration Pass	791212057	12057	791232057	32057	+6cm
79	12	320b	791232058	Calibration Pass	791212058	12058	791232058	32058	+6cm
79	12	325a	791232501	Calibration Pass	791212501	12501	791232501	32501	None
79	12	325a	791232502	Calibration Pass	791212502	12502	791232502	32502	None
79	12	325a	791232503	Production over project	791212503	12503	791232503	32503	None
79	12	325a	791232504	Production over project	791212504	12504	791232504	32504	None
79	12	325a	791232505	Production over project	791212505	12505	791232505	32505	None
79	12	325a	791232506	Production over project	791212506	12506	791232506	32506	None
79	12	325a	791232507	Production over project	791212507	12507	791232507	32507	None
79	12	325a	791232508	Production over project	791212508	12508	791232508	32508	None
79	12	325a	791232509	Production over project	791212509	12509	791232509	32509	None
79	12	325a	791232510	Production over project	791212510	12510	791232510	32510	None
79	12	325a	791232511	Production over project	791212511	12511	791232511	32511	None
79	12	325a	791232512	Production over project	791212512	12512	791232512	32512	None
79	12	325a	791232513	Production over project	791212513	12513	791232513	32513	None
79	12	325a	791232514	Production over project	791212514	12514	791232514	32514	None
79	12	325a	791232515	Production over project	791212515	12515	791232515	32515	None
79	12	325a	791232516	Production over project	791212516	12516	791232516	32516	None
79	12	325a	791232517	Production over project	791212517	12517	791232517	32517	None
79	12	325a	791232518	Production over project	791212518	12518	791232518	32518	None
79	12	325a	791232519	Cross-tie Line	791212519	12519	791232519	32519	None
79	12	325a	791232520	Production over project	791212520	12520	791232520	32520	None
79	12	325a	791232521	Production over project	791212521	12521	791232521	32521	None
79	12	325a	791232522	Calibration Pass	791212522	12522	791232522	32522	None
79	12	325a	791232523	Calibration Pass	791212523	12523	791232523	32523	None

79	12	325b	791232524	Calibration Pass	791212524	12524	791232524	32524	+6cm
79	12	325b	791232525	Calibration Pass	791212525	12525	791232525	32525	+6cm
79	12	325b	791232526	Production over project	791212526	12526	791232526	32526	+6cm
79	12	325b	791232527	Production over project	791212527	12527	791232527	32527	+6cm
79	12	325b	791232528	Production over project	791212528	12528	791232528	32528	+6cm
79	12	325b	791232529	Production over project	791212529	12529	791232529	32529	+6cm
79	12	325b	791232530	Production over project	791212530	12530	791232530	32530	+6cm
79	12	325b	791232531	Production over project	791212531	12531	791232531	32531	+6cm
79	12	325b	791232532	Production over project	791212532	12532	791232532	32532	+6cm
79	12	325b	791232533	Production over project	791212533	12533	791232533	32533	+6cm
79	12	325b	791232534	Production over project	791212534	12534	791232534	32534	+6cm
79	12	325b	791232535	Production over project	791212535	12535	791232535	32535	+6cm
79	12	325b	791232536	Production over project	791212536	12536	791232536	32536	+6cm
79	12	325b	791232537	Production over project	791212537	12537	791232537	32537	+6cm
79	12	325b	791232538	Production over project	791212538	12538	791232538	32538	+6cm
79	12	325b	791232539	Production over project	791212539	12539	791232539	32539	+6cm
79	12	325b	791232540	Production over project	791212540	12540	791232540	32540	+6cm
79	12	325b	791232541	Production over project	791212541	12541	791232541	32541	+6cm
79	12	325b	791232542	Production over project	791212542	12542	791232542	32542	+6cm
79	12	325b	791232543	Production over project	791212543	12543	791232543	32543	+6cm
79	12	325b	791232544	Production over project	791212544	12544	791232544	32544	+6cm
79	12	325b	791232545	Split (First 70 million pts)	791212545	12545	791232545	32545	+6cm
				Split (Rest)	791212595	12595	791232595	32595	+6cm
79	12	325b	791232546	Split (First 70 million pts)	791212546	12546	791232546	32546	+6cm
				Split (Rest)	791212596	12596	791232596	32596	+6cm
79	12	325b	791232547	Split (First 70 million pts)	791212547	12547	791232547	32547	+6cm
				Split (Rest)	791212597	12597	791232597	32597	+6cm
79	12	325b	791232548	Split (First 70 million pts)	791212548	12548	791232548	32548	+6cm
				Split (Rest)	791212598	12598	791232598	32598	+6cm
79	12	325b	791232549	Cross-tie Line	791212549	12549	791232549	32549	+6cm
79	12	325b	791232550	Calibration Pass	791212550	12550	791232550	32550	+6cm
79	12	325b	791232551	Calibration Pass	791212551	12551	791232551	32551	+6cm
79	12	326a	791232601	Calibration Pass	791212601	12601	791232601	32601	+6cm
79	12	326a	791232602	Calibration Pass	791212602	12602	791232602	32602	+6cm
79	12	326a	791232603	Split (First 70 million pts)	791212603	12603	791232603	32603	+6cm
				Split (Rest)	791212653	12653	791232653	32653	+6cm
79	12	326a	791232604	Split (First 70 million pts)	791212604	12604	791232604	32604	+6cm
				Split (Rest)	791212654	12654	791232654	32654	+6cm
79	12	326a	791232605	Split (First 70 million pts)	791212605	12605	791232605	32605	+6cm
				Split (Rest)	791212655	12655	791232655	32655	+6cm
79	12	326a	791232606	Split (First 70 million pts)	791212606	12606	791232606	32606	+6cm
				Split (Rest)	791212656	12656	791232656	32656	+6cm
79	12	326a	791232607	Split (First 70 million pts)	791212607	12607	791232607	32607	+6cm
				Split (Rest)	791212657	12657	791232657	32657	+6cm
79	12	326a	791232608	Split (First 70 million pts)	791212608	12608	791232608	32608	+6cm
				Split (Rest)	791212658	12658	791232658	32658	+6cm

79	12	326a	791232609	Split (First 70 million pts)	791212609	12609	791232609	32609	+6cm
				Split (Rest)	791212659	12659	791232659	32659	+6cm
79	12	326a	791232610	Split (First 70 million pts)	791212610	12610	791232610	32610	+6cm
				Split (Rest)	791212660	12660	791232660	32660	+6cm
79	12	326a	791232611	Split (First 70 million pts)	791212611	12611	791232611	32611	+6cm
				Split (Rest)	791212661	12661	791232661	32661	+6cm
79	12	326a	791232612	Split (First 70 million pts)	791212612	12612	791232612	32612	+6cm
				Split (Rest)	791212662	12662	791232662	32662	+6cm
79	12	326a	791232613	Split (First 70 million pts)	791212613	12613	791232613	32613	+6cm
				Split (Rest)	791212663	12663	791232663	32663	+6cm
79	12	326a	791232614	Split (First 70 million pts)	791212614	12614	791232614	32614	+6cm
				Split (Rest)	791212664	12664	791232664	32664	+6cm
79	12	326a	791232615	Split (First 70 million pts)	791212615	12615	791232615	32615	+6cm
				Split (Rest)	791212665	12665	791232665	32665	+6cm
79	12	326a	791232616	Split (First 70 million pts)	791212616	12616	791232616	32616	+6cm
				Split (Rest)	791212666	12666	791232666	32666	+6cm
79	12	326a	791232617	Calibration Pass	791212617	12617	791232617	32617	+6cm
79	12	326a	791232618	Calibration Pass	791212618	12618	791232618	32618	+6cm
79	12	326b	791232619	Calibration Pass	791212619	12619	791232619	32619	+6cm
79	12	326b	791232620	Calibration Pass	791212620	12620	791232620	32620	+6cm
79	12	326b	791232621	Split (First 70 million pts)	791212621	12621	791232621	32621	+6cm
				Split (Rest)	791212671	12671	791232671	32671	+6cm
79	12	326b	791232622	Split (First 70 million pts)	791212622	12622	791232622	32622	+6cm
				Split (Rest)	791212672	12672	791232672	32672	+6cm
79	12	326b	791232623	Split (First 70 million pts)	791212623	12623	791232623	32623	+6cm
				Split (Rest)	791212673	12673	791232673	32673	+6cm
79	12	326b	791232624	Split (First 70 million pts)	791212624	12624	791232624	32624	+6cm
				Split (Rest)	791212674	12674	791232674	32674	+6cm
79	12	326b	791232625	Split (First 70 million pts)	791212625	12625	791232625	32625	+6cm
				Split (Rest)	791212675	12675	791232675	32675	+6cm
79	12	326b	791232626	Split (First 70 million pts)	791212626	12626	791232626	32626	+6cm
				Split (Rest)	791212676	12676	791232676	32676	+6cm
79	12	326b	791232627	Split (First 70 million pts)	791212627	12627	791232627	32627	+6cm
				Split (Rest)	791212677	12677	791232677	32677	+6cm
79	12	326b	791232628	Split (First 70 million pts)	791212628	12628	791232628	32628	+6cm
				Split (Rest)	791212678	12678	791232678	32678	+6cm
79	12	326b	791232629	Split (First 70 million pts)	791212629	12629	791232629	32629	+6cm
				Split (Rest)	791212679	12679	791232679	32679	+6cm
79	12	326b	791232630	Split (First 70 million pts)	791212630	12630	791232630	32630	+6cm
				Split (Rest)	791212680	12680	791232680	32680	+6cm
79	12	326b	791232631	Split (First 70 million pts)	791212631	12631	791232631	32631	+6cm
				Split (Rest)	791212681	12681	791232681	32681	+6cm
79	12	326b	791232632	Cross-tie Line	791212632	12632	791232632	32632	+6cm
79	12	326b	791232633	Calibration Pass	791212633	12633	791232633	32633	+6cm
79	12	326b	791232634	Calibration Pass	791212634	12634	791232634	32634	+6cm

Appendix B

HEC-HMS Parameters

HEC-HMS Parameters

1) **Time of Concentration Calculations**

Table B1: Basin Parameters

Table B1: Casey Creek Basin Parameters						
Catchment ID	Area (ha)	Channel/Overland Flow Lengths		Length (m)	Percent Slope	Runoff Coefficient
		10%	85%			
A1	31.36	60.28	68.13	2010.17	0.52	0.35
A2	28.20	60.28	63.25	1123.73	0.35	0.52
A3	208.30	62.56	81.04	4656.66	0.53	0.51
A4	667.39	67.20	86.56	7728.18	0.33	0.58
A5	1111.93	69.26	91.14	8761.77	0.33	0.44
A6	1068.12	69.74	113.63	9972.90	0.59	0.40
A7	169.42	60.45	69.24	2167.68	0.54	0.58
A8	117.81	68.46	89.07	3315.59	0.83	0.48
A9	763.95	98.40	118.43	6755.65	0.40	0.29
A10	26.23	64.17	72.68	1419.26	0.80	0.57
A11	26.14	71.41	89.37	1723.60	1.39	0.45
A12	147.72	84.47	95.69	1899.82	0.79	0.62
A13	587.06	99.90	123.65	7712.96	0.41	0.35
A14	314.25	99.08	113.39	4997.96	0.38	0.39
A15	74.91	69.08	76.53	1215.92	0.82	0.45
A16	172.90	80.22	91.83	2231.92	0.69	0.49

Table B2: Time to Peak

Table B2: Time of Concentration (T_c)			
Catchment ID	Airport Formula (hrs)	Bransby-Williams Formula (hrs)	Time to Peak (0.67 * T_c) (min)
A1	2.27	-	91
A2	-	0.94	38
A3	-	2.95	118
A4	-	4.77	192
A5	-	5.14	207
A6	-	5.25	211
A7	-	1.39	56
A8	-	2.03	82
A9	4.90	-	197
A10	-	1.02	41
A11	-	1.11	44
A12	-	1.15	46
A13	4.80	-	193
A14	3.76	-	151
A15	-	0.78	31
A16	-	1.36	55

Airport Formula

For use when the runoff coefficient is less than 0.4

$$T_c = 3.26 * (1.1 - C) * L^{0.5} * S_w^{-0.33}$$

Where:

T_c = time of concentration in minutes

C = runoff coefficient

L = watershed length in metres

S_w = watershed slope in %

Source: MTO Drainage Manual 1997 – Chapter 8, page 28

Bransby-Williams Formula

For use when the runoff coefficient is 0.4 or greater

$$T_c = 0.057 * L * S_w^{-0.2} * A^{-0.1}$$

Where:

T_c = time of concentration in minutes

L = watershed length in metres

S_w = watershed slope in %

A = watershed area in hectares

Source: MTO Drainage Manual 1997 – Chapter 8, page 28

2) CN Value Calculations

Table B3: CN Values

Table B3: CN Values					
	Hydrologic Soil Group				
Land Use[1]	A	AB[2]	B	C	D
Aggregate[3]	50	50	50	50	50
Crop and Pasture[4]	53	61	70	80	87
Wetland[5]	50	50	50	50	50
Settlement/Transportation[6]	98	98	98	98	98
Woodland	25	40	55	70	77
Water[5]	50	50	50	50	50
Grassland[7]	30	44	58	71	78

Source: Design Chart 1.09 MTO Drainage Management Manual (1997)

Note: 1 – Considered Good Hydrologic Condition except as noted

2 – Average of A and B hydrologic soil groups

3 – Assumed low runoff potential similar to wetlands

4 – Average of Row Crops (straight rows) and Pasture/Range (contoured)

5 – Lakes and Wetlands from 2nd Page of Design Chart 1.09

6 – Impervious areas (paved) from 2nd page of Design Chart 1.09

7 - Meadow

Table 4: Detailed CN Value Calculations

Table B4: Weighted CN Values										
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A1		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	0.0%	0.00	0.0%	0.00	5.8%	1.20	
	Wetland	0.0%	0.00	4.5%	0.94	0.0%	0.00	0.5%	0.11	
	Settlement/Transportation	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Woodland	0.0%	0.00	77.8%	16.15	0.0%	0.00	10.6%	2.20	
	Water	0.0%	0.00	0.7%	0.14	0.0%	0.00	0.0%	0.01	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		17.23		0.00		3.52	
	Weighted CN Value	0.00		45.41		0.00		13.48		Total Weighted CN for Basin A1 58.89
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A2		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	0.0%	0.00	0.0%	0.00	58.3%	7.91	
	Wetland	0.0%	0.00	0.4%	0.06	0.0%	0.00	12.4%	1.68	
	Settlement/Transportation	0.0%	0.00	0.0%	0.00	0.0%	0.00	13.1%	1.78	
	Woodland	8.8%	1.20	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	6.9%	0.93	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		1.20		0.06		0.00		12.30	
	Weighted CN Value	2.21		0.22		0.00		73.24		Total Weighted CN for Basin A2 75.67
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		

A3		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	39.5%	75.77	0.4%	0.72	23.8%	45.64	
	Wetland	0.0%	0.00	1.4%	2.65	0.0%	0.00	1.4%	2.63	
	Settlement/Transportation	0.0%	0.00	5.4%	10.36	0.3%	0.66	3.8%	7.24	
	Woodland	0.0%	0.00	21.8%	41.93	0.9%	1.70	1.2%	2.34	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.1%	0.26	0.0%	0.00	0.0%	0.00	
	Total		0.00		130.97		3.08		57.85	
	Weighted CN Value	0.00		45.72		1.26		26.01		Total Weighted CN for Basin A3 72.99
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A4		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	13.6%	79.04	0.2%	1.39	64.3%	373.18	
	Wetland	0.0%	0.00	1.2%	7.08	0.4%	2.38	3.0%	17.44	
	Settlement/Transportation	0.0%	0.00	2.1%	11.96	0.0%	0.00	4.1%	23.95	
	Woodland	0.0%	0.00	9.3%	54.22	0.0%	0.08	1.7%	9.97	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		152.30		3.85		424.54	
	Weighted CN Value	0.00		17.29		0.41		62.78		Total Weighted CN for Basin A4 80.47
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A5		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	

	Crop and Pasture	0.0%	0.00	31.3%	310.92	1.6%	15.42	19.5%	193.55	
	Wetland	0.0%	0.00	5.7%	56.65	0.0%	0.00	0.1%	1.06	
	Settlement/Transportation	0.0%	0.00	0.3%	2.94	0.0%	0.00	0.3%	2.77	
	Woodland	0.0%	0.00	40.1%	398.66	0.0%	0.00	0.7%	7.12	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.5%	4.53	0.0%	0.00	0.0%	0.00	
	Total		0.00		773.70		15.42		204.50	
	Weighted CN Value	0.00		47.38		1.24		17.83		Total Weighted CN for Basin A5 66.44
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A6		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	11.7%	110.53	0.0%	0.00	15.1%	142.82	
	Wetland	0.0%	0.00	14.7%	138.69	0.0%	0.00	0.1%	1.20	
	Settlement/Transportation	0.0%	0.00	1.0%	9.60	0.0%	0.00	3.7%	34.89	
	Woodland	0.0%	0.00	47.9%	451.66	0.0%	0.00	2.5%	23.78	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	3.0%	28.59	0.0%	0.00	0.2%	1.63	
	Total		0.00		739.07		0.00		204.32	
	Weighted CN Value	0.00		44.64		0.00		18.93		Total Weighted CN for Basin A6 63.57
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A7		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	23.2%	32.02	0.0%	0.00	60.3%	83.38	
	Wetland	0.0%	0.00	0.3%	0.37	0.0%	0.00	4.0%	5.47	
	Settlement/Transportation	0.0%	0.00	0.2%	0.27	0.0%	0.00	1.1%	1.53	

Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
	Woodland	0.0%	0.00	3.4%	4.65	0.0%	0.00	7.4%	10.17	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.3%	0.44	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		37.31		0.00		100.99	
	Weighted CN Value	0.00		18.38		0.00		61.33		Total Weighted CN for Basin A7 79.72
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A8		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	54.0%	52.05	0.0%	0.00	13.8%	13.33	
	Wetland	0.0%	0.00	1.1%	1.04	0.0%	0.00	0.0%	0.00	
	Settlement/Transportation	0.0%	0.00	4.2%	4.05	0.0%	0.00	0.0%	0.00	
	Woodland	0.0%	0.00	25.4%	24.46	0.0%	0.00	1.5%	1.47	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		81.60		0.00		14.80	
	Weighted CN Value	0.00		56.41		0.00		13.20		Total Weighted CN for Basin A8 69.61
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A9		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	0.2%	1.07	0.0%	0.00	0.5%	3.02	
	Wetland	0.0%	0.00	18.5%	114.25	0.0%	0.00	0.0%	0.00	
	Settlement/Transportation	0.0%	0.00	1.5%	9.39	0.0%	0.00	0.0%	0.00	
	Woodland	0.0%	0.00	60.7%	374.15	0.0%	0.00	13.2%	81.11	
	Water	0.0%	0.00	3.8%	23.21	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	1.6%	9.81	0.0%	0.00	0.0%	0.00	

	Total		0.00		531.88		0.00		84.13	
	Weighted CN Value	0.00		47.10		0.00		10.57		Total Weighted CN for Basin A9 57.67
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A10		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	15.2%	2.80	0.0%	0.00	54.7%	10.04	
	Wetland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Settlement/Transportation	0.0%	0.00	6.8%	1.24	0.0%	0.00	0.0%	0.00	
	Woodland	0.0%	0.00	19.7%	3.61	0.0%	0.00	3.7%	0.68	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		7.65		0.00		10.72	
	Weighted CN Value	0.00		28.09		0.00		50.40		Total Weighted CN for Basin A10 78.49
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D		
A11		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Crop and Pasture	0.0%	0.00	50.0%	12.01	0.0%	0.00	14.2%	3.42	
	Wetland	0.0%	0.00	0.7%	0.16	0.0%	0.00	0.0%	0.00	
	Settlement/Transportation	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Woodland	0.0%	0.00	35.1%	8.42	0.0%	0.00	0.0%	0.01	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Total		0.00		20.59		0.00		3.43	
	Weighted CN Value	0.00		54.61		0.00		12.42		Total Weighted CN for Basin A11 67.03

Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D	
A12		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00
	Crop and Pasture	0.0%	0.00	28.6%	35.88	0.0%	0.00	44.6%	55.96
	Wetland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00
	Settlement/Transportation	0.0%	0.00	7.1%	8.87	0.0%	0.00	6.8%	8.51
	Woodland	0.0%	0.00	11.0%	13.80	0.0%	0.00	2.0%	2.48
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00
	Total		0.00		58.55		0.00		66.95
	Weighted CN Value	0.00		32.99		0.00		46.96	

Total Weighted CN for Basin A12 79.95

Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D	
A13		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00
	Crop and Pasture	0.0%	0.00	10.6%	51.00	0.0%	0.00	12.0%	57.49
	Wetland	0.0%	0.00	15.7%	75.46	0.0%	0.00	0.0%	0.00
	Settlement/Transportation	0.0%	0.00	0.5%	2.21	0.0%	0.00	0.6%	2.89
	Woodland	0.0%	0.01	58.3%	279.93	0.0%	0.00	0.0%	0.21
	Water	0.0%	0.00	2.1%	10.07	0.0%	0.00	0.0%	0.00
	Grassland	0.0%	0.00	0.3%	1.23	0.0%	0.00	0.0%	0.00
	Total		0.01		419.90		0.00		60.59
	Weighted CN Value	0.00		48.97		0.00		11.03	

Total Weighted CN for Basin A13 60.00

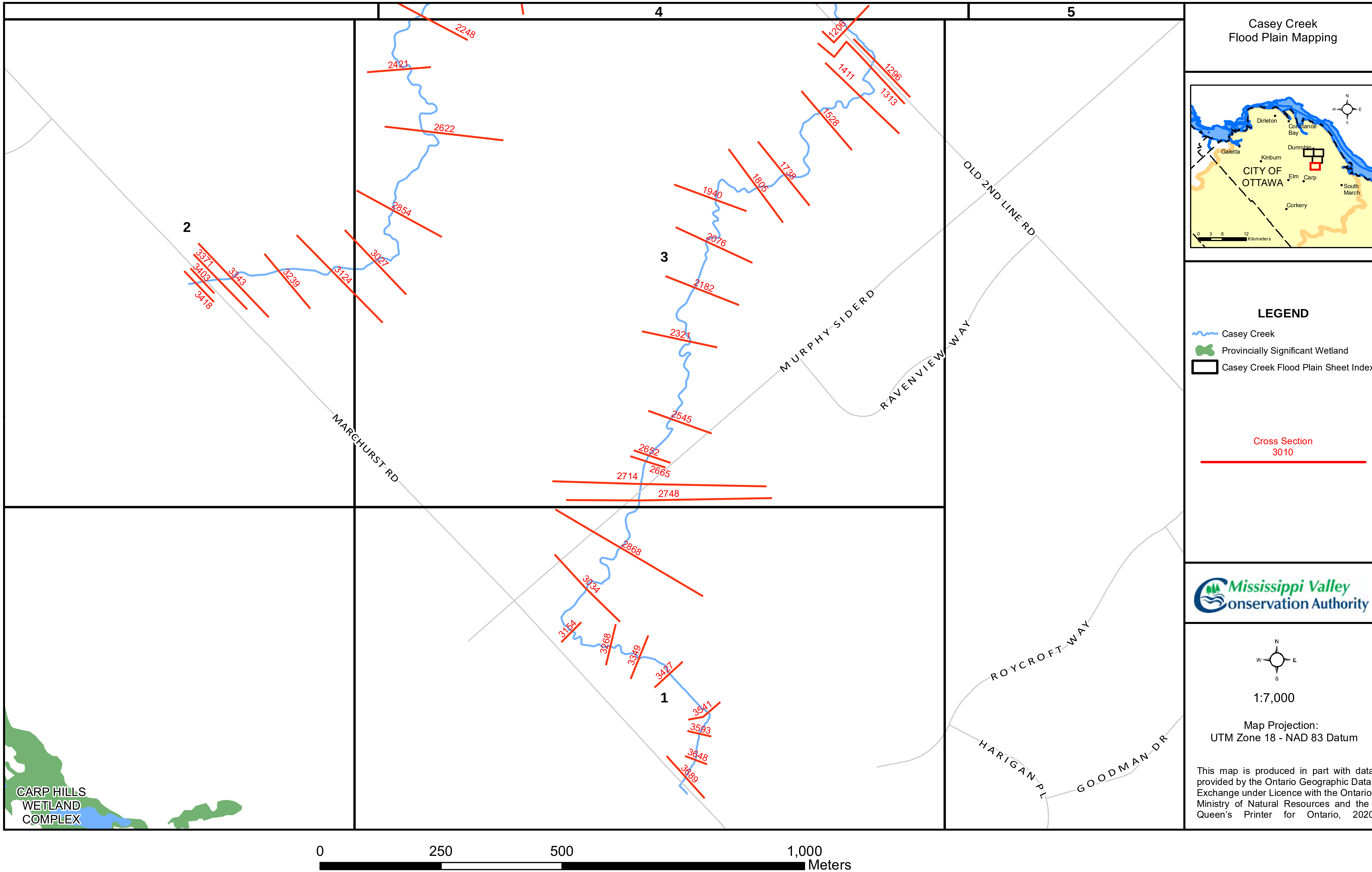
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D	
A14		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)

	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Crop and Pasture	0.0%	0.00	14.4%	38.96	0.0%	0.00	18.6%	50.52		
	Wetland	0.0%	0.00	12.8%	34.82	0.0%	0.00	0.0%	0.00		
	Settlement/Transportation	0.0%	0.00	0.7%	1.85	0.0%	0.00	0.3%	0.70		
	Woodland	0.0%	0.00	52.7%	142.91	0.0%	0.00	0.4%	1.07		
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Grassland	0.0%	0.00	0.2%	0.59	0.0%	0.00	0.0%	0.00		
	Total		0.00		219.13		0.00		52.29		
	Weighted CN Value	0.00		46.22		0.00		16.75		Total Weighted CN for Basin A14	62.97
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D			
A15		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)		
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Crop and Pasture	0.0%	0.00	37.8%	27.35	27.8%	20.07	4.0%	2.90		
	Wetland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Settlement/Transportation	0.0%	0.00	0.4%	0.32	0.3%	0.22	0.0%	0.00		
	Woodland	0.0%	0.00	26.9%	19.48	2.3%	1.69	0.4%	0.26		
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Grassland	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Total		0.00		47.15		21.98		3.16		
	Weighted CN Value	0.00		41.74		24.15		3.77		Total Weighted CN for Basin A15	69.65
Basin	Land Use	Soil Group A		Soil Group B		Soil Group C		Soil Group D			
A16		%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)		
	Aggregate	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00		
	Crop and Pasture	0.0%	0.00	20.5%	33.51	5.2%	8.55	0.3%	0.53		
	Wetland	0.0%	0.00	5.4%	8.91	1.4%	2.22	0.0%	0.00		

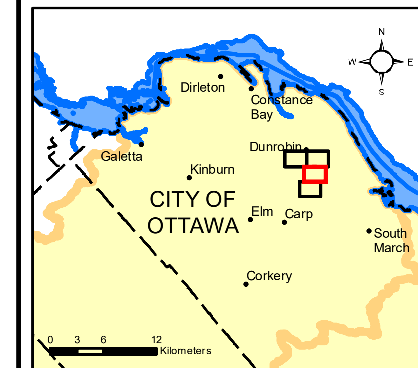
	Settlement/Transportation	0.0%	0.00	21.2%	34.69	1.3%	2.19	0.0%	0.00	
	Woodland	0.0%	0.00	39.4%	64.48	3.5%	5.68	0.3%	0.44	
	Water	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	
	Grassland	0.0%	0.00	1.4%	2.33	0.0%	0.00	0.0%	0.00	
	Total		0.00		143.92		18.64		0.97	
	Weighted CN Value	0.00		60.37		8.61		0.49		Total Weighted CN for Basin A16 69.46

Appendix C

Reach Overview Figures


Casey Creek
Flood Plain Mapping
1
2
3
4
5
LEGEND
Casey Creek
Provincially Significant Wetland
Casey Creek Flood Plain Sheet Index
Cross Section
3010
CITY OF OTTAWA
Dirleton
Constance Bay
Dunrobin
Galetta
Kinburn
Elm
Carp
South March
Corkery
Kilometers
Mississippi Valley
Conservation Authority
1:7,000
Map Projection:
UTM Zone 18 - NAD 83 Datum
This map is produced in part with data provided by the Ontario Geographic Data Exchange under Licence with the Ontario Ministry of Natural Resources and the Queen's Printer for Ontario, 2020
MARCHURST RD
MURPHY SIDE RD
OLD 2ND LINE RD
RAVENVIEW WAY
ROYCROFT WAY
HARIGAN PL
GOODMAN DR
CARP HILLS
WETLAND
COMPLEX
1206
1296
1313
1411
1528
1738
1805
1940
2076
2182
2248
2321
2421
2545
2622
2652
2665
2714
2748
2854
2868
3027
3034
3124
3154
3239
3268
3343
3349
3371
3403
3418
3427
3541
3593
3648
3689
0
250
500
1,000
Meters

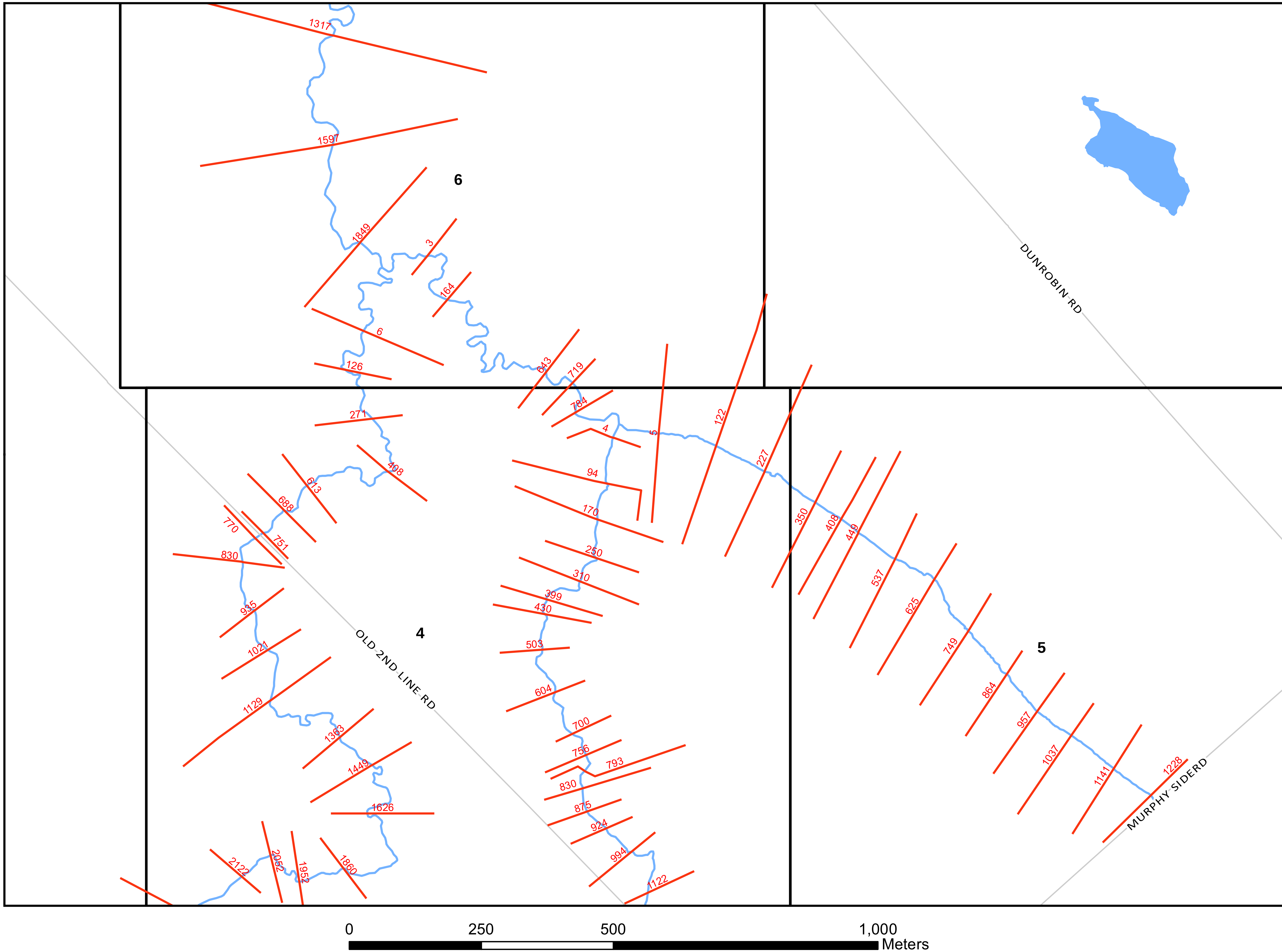
Casey Creek
Flood Plain Mapping



LEGEND

Casey Creek
Provincially Significant Wetland
Casey Creek Flood Plain Sheet Index

Cross Section
3010

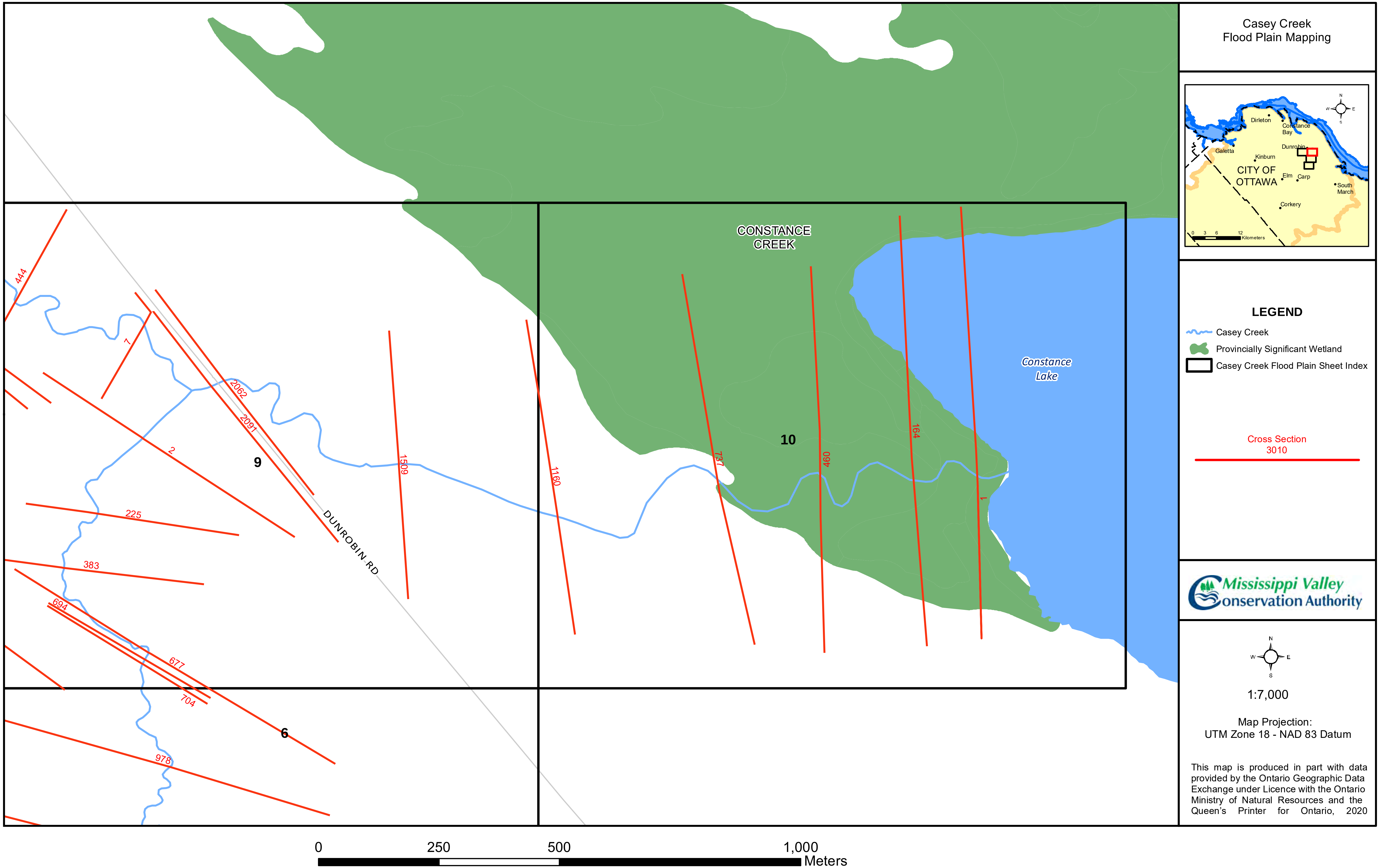


Mississippi Valley Conservation Authority

1:7,000

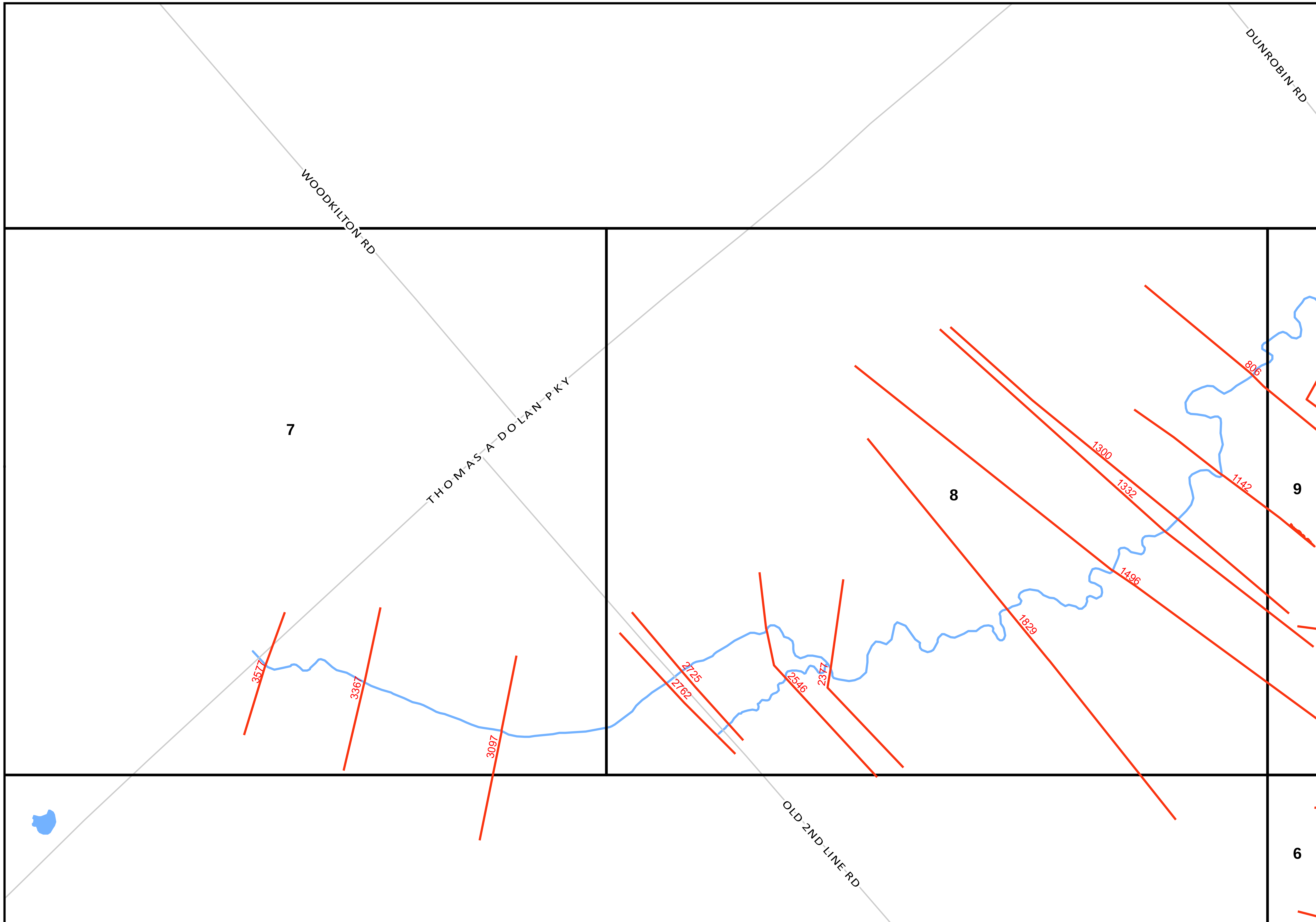
Map Projection:
UTM Zone 18 - NAD 83 Datum

This map is produced in part with data provided by the Ontario Geographic Data Exchange under Licence with the Ontario Ministry of Natural Resources and the Queen's Printer for Ontario, 2020



Casey Creek
Flood Plain Mapping
CITY OF OTTAWA
Dirleton
Constance Bay
Dunrobin
Galetta
Kinburn
Elm
Carp
South March
Corkery
Kilometers
LEGEND
Casey Creek
Provincially Significant Wetland
Casey Creek Flood Plain Sheet Index
Cross Section
3010
CONSTANCE CREEK
Constance Lake
DUNROBIN RD
9
10
6
444
7
2062
2091
2
225
383
694
677
704
978
1509
1160
737
490
164
1
Mississippi Valley Conservation Authority
1:7,000
Map Projection:
UTM Zone 18 - NAD 83 Datum
This map is produced in part with data provided by the Ontario Geographic Data Exchange under Licence with the Ontario Ministry of Natural Resources and the Queen's Printer for Ontario, 2020
0
250
500
1,000
Meters

Casey Creek
Flood Plain Mapping



LEGEND

- Casey Creek
- Provincially Significant Wetland
- Casey Creek Flood Plain Sheet Index

Cross Section
3010

Mississippi Valley Conservation Authority

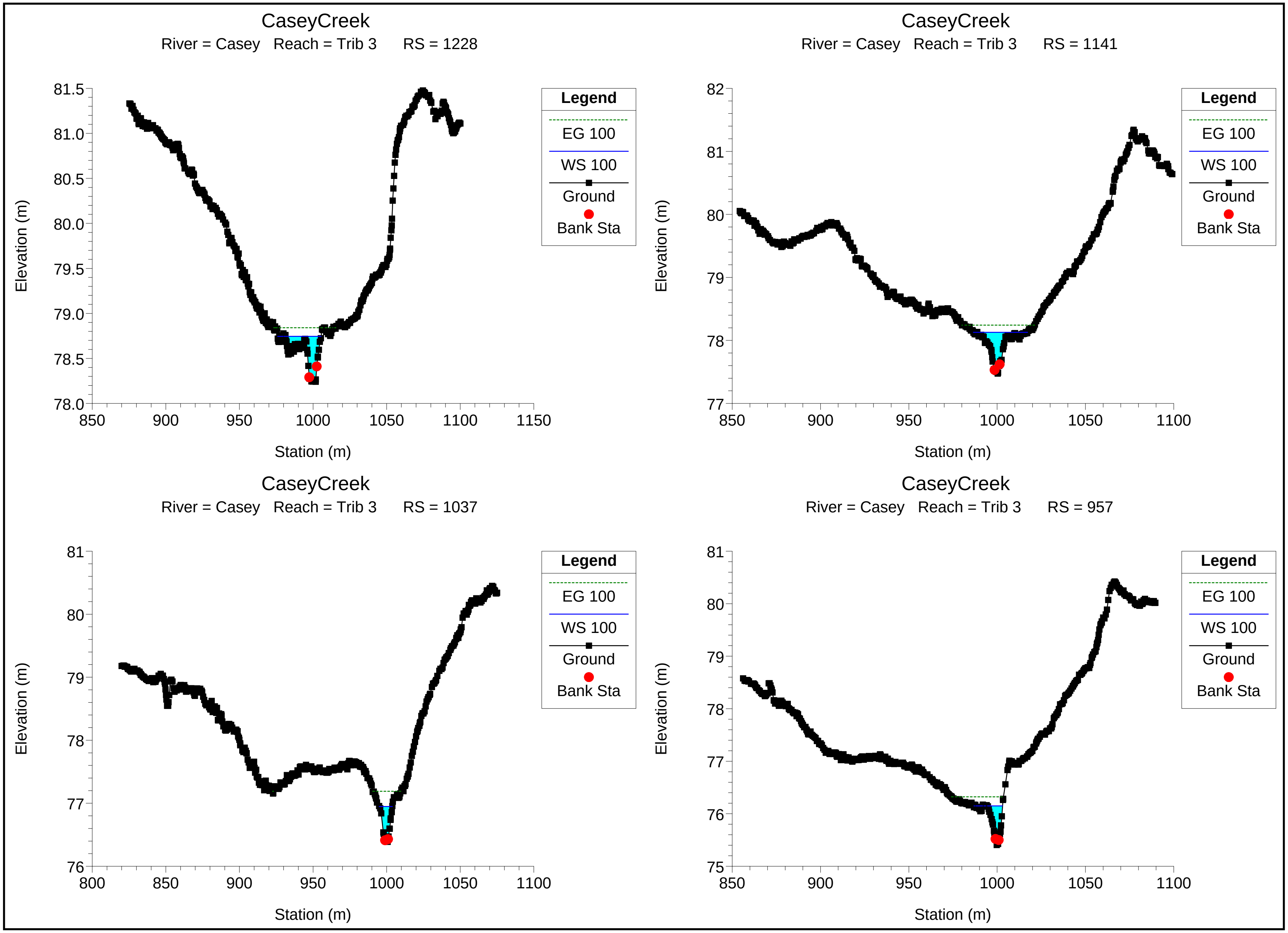
1:7,000

Map Projection:
UTM Zone 18 - NAD 83 Datum

0 250 500 1,000 Meters

Appendix D

Cross-Section Plots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WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
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Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Trib 3 RS = 1037
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
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Legend
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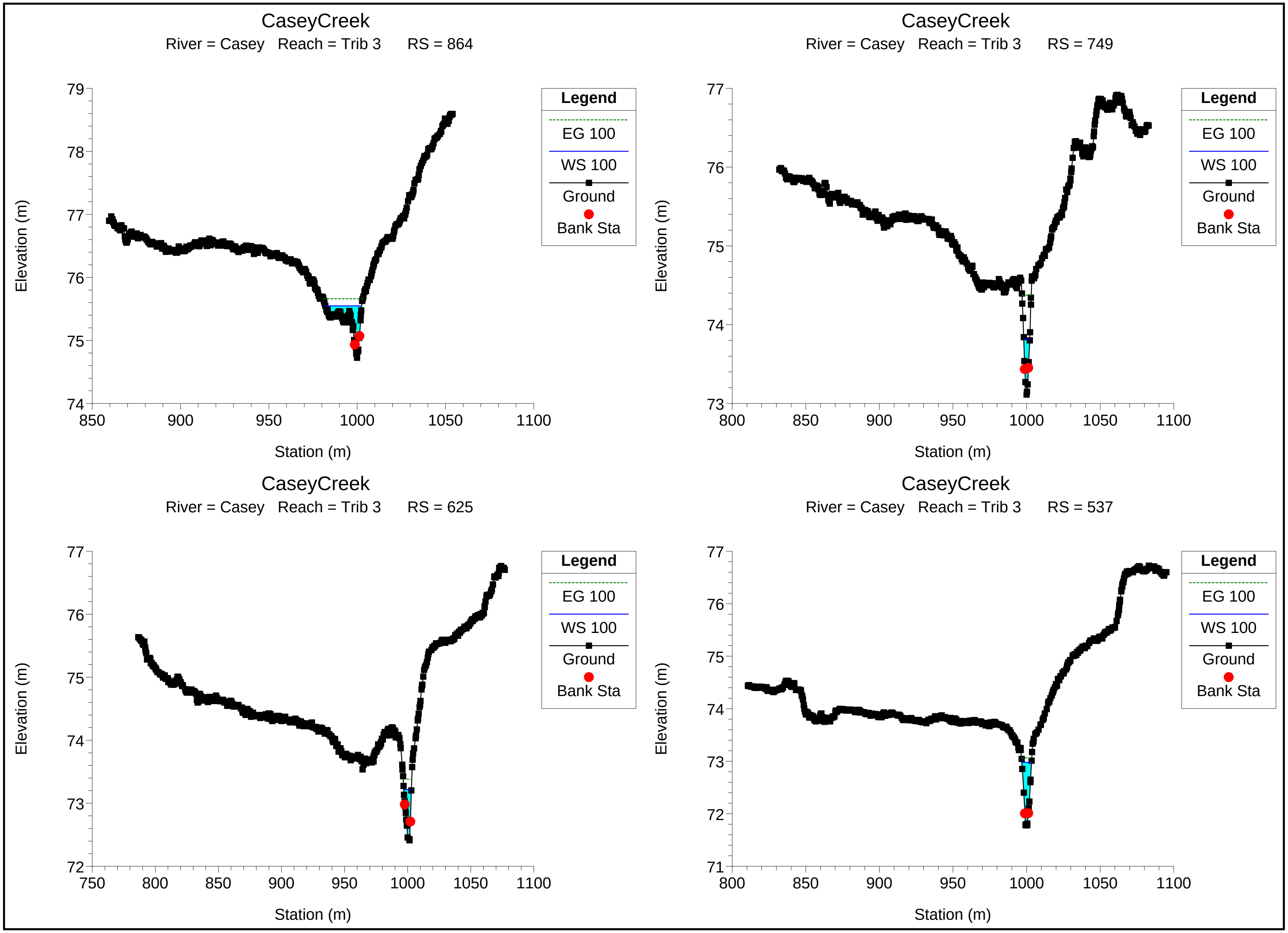
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)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Station (m)
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WS 100
Ground
Bank Sta
CaseyCreek
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Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Trib 3 RS = 625
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
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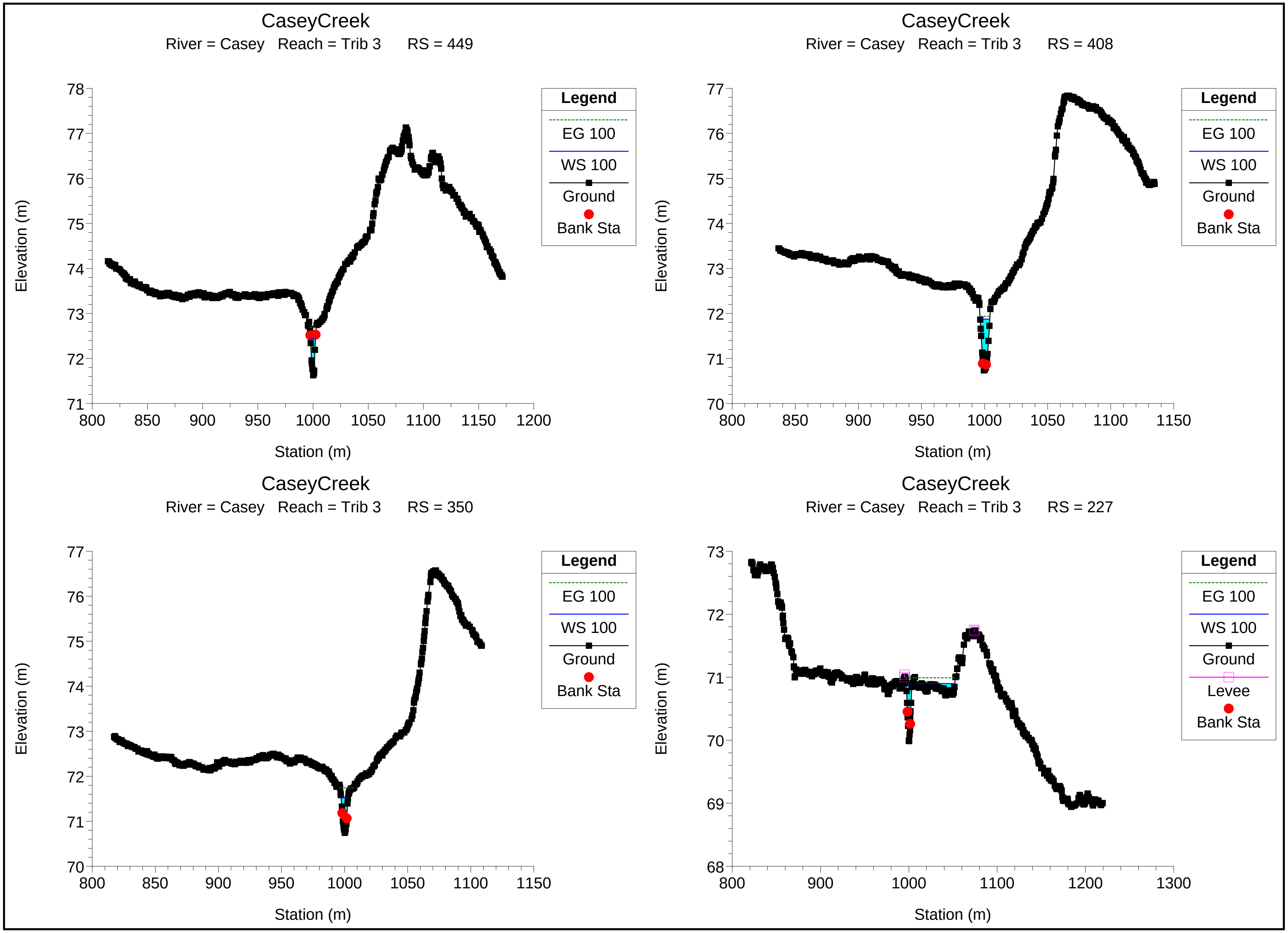
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta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Bank Sta
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Station (m)
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EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Trib 3 RS = 350
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
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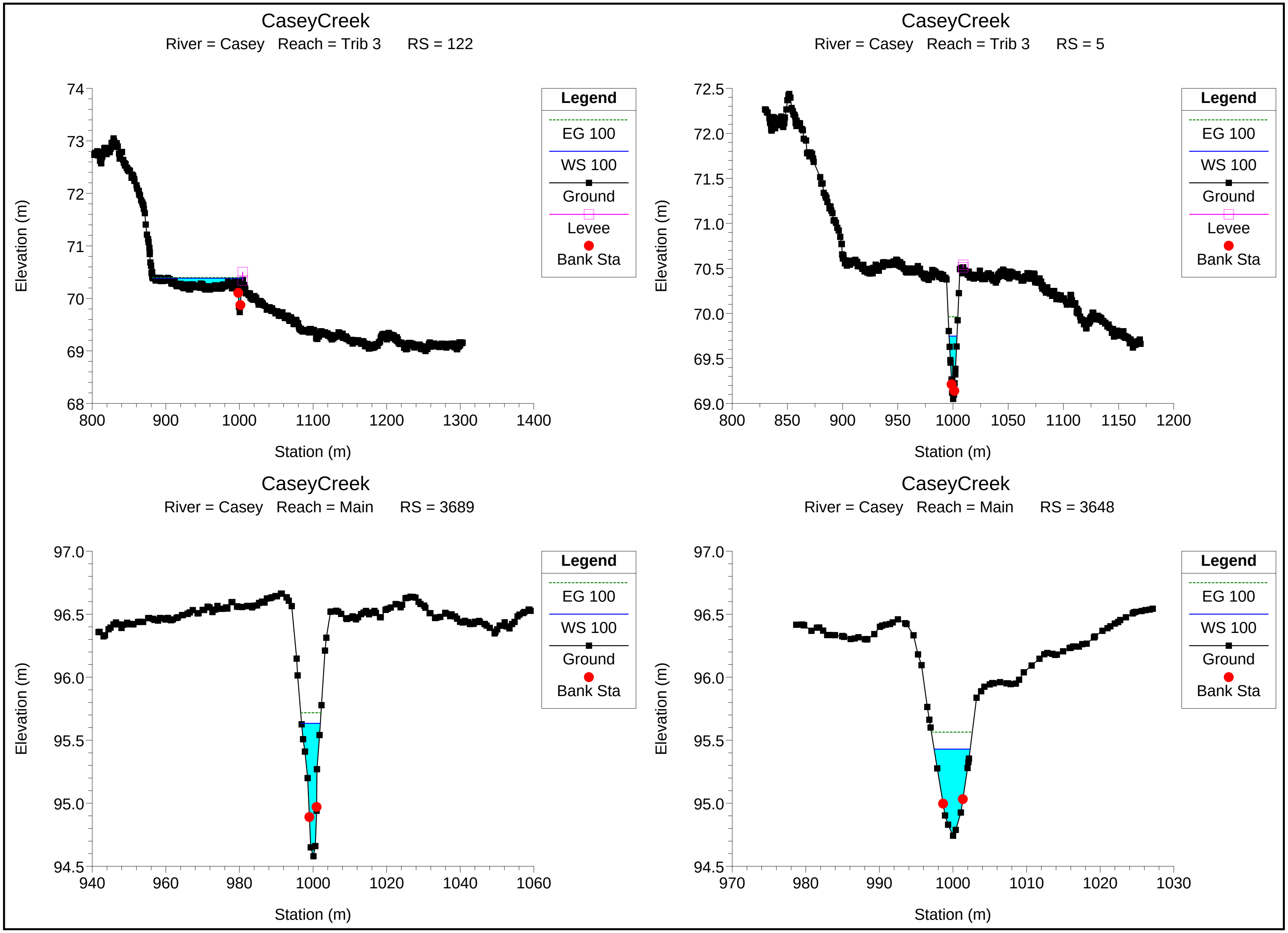
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)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WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
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Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 3689
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
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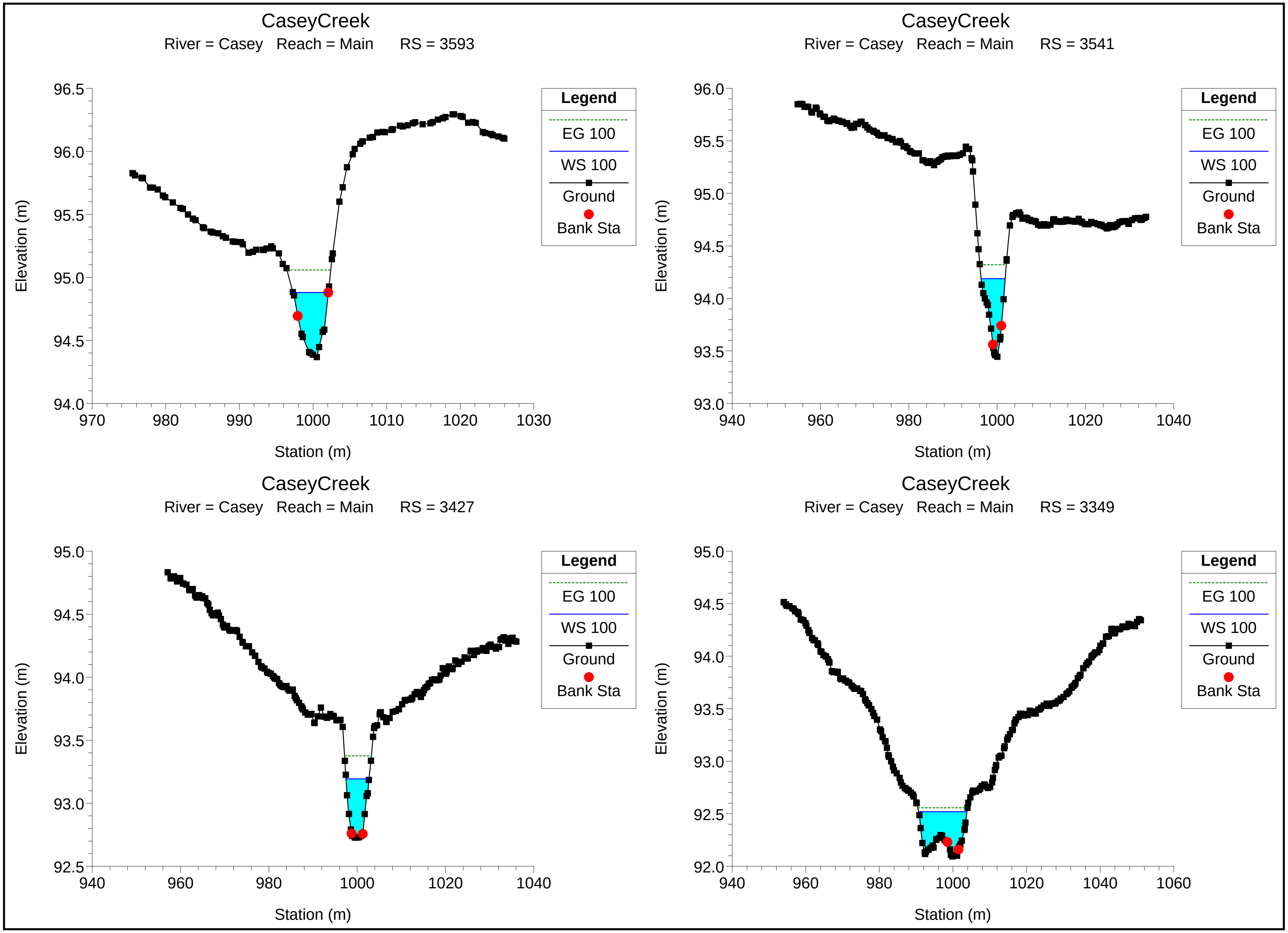
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)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WS 100
Ground
Bank Sta
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Station (m)
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Ground
Bank Sta
Elevation (m)
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Elevation (m)
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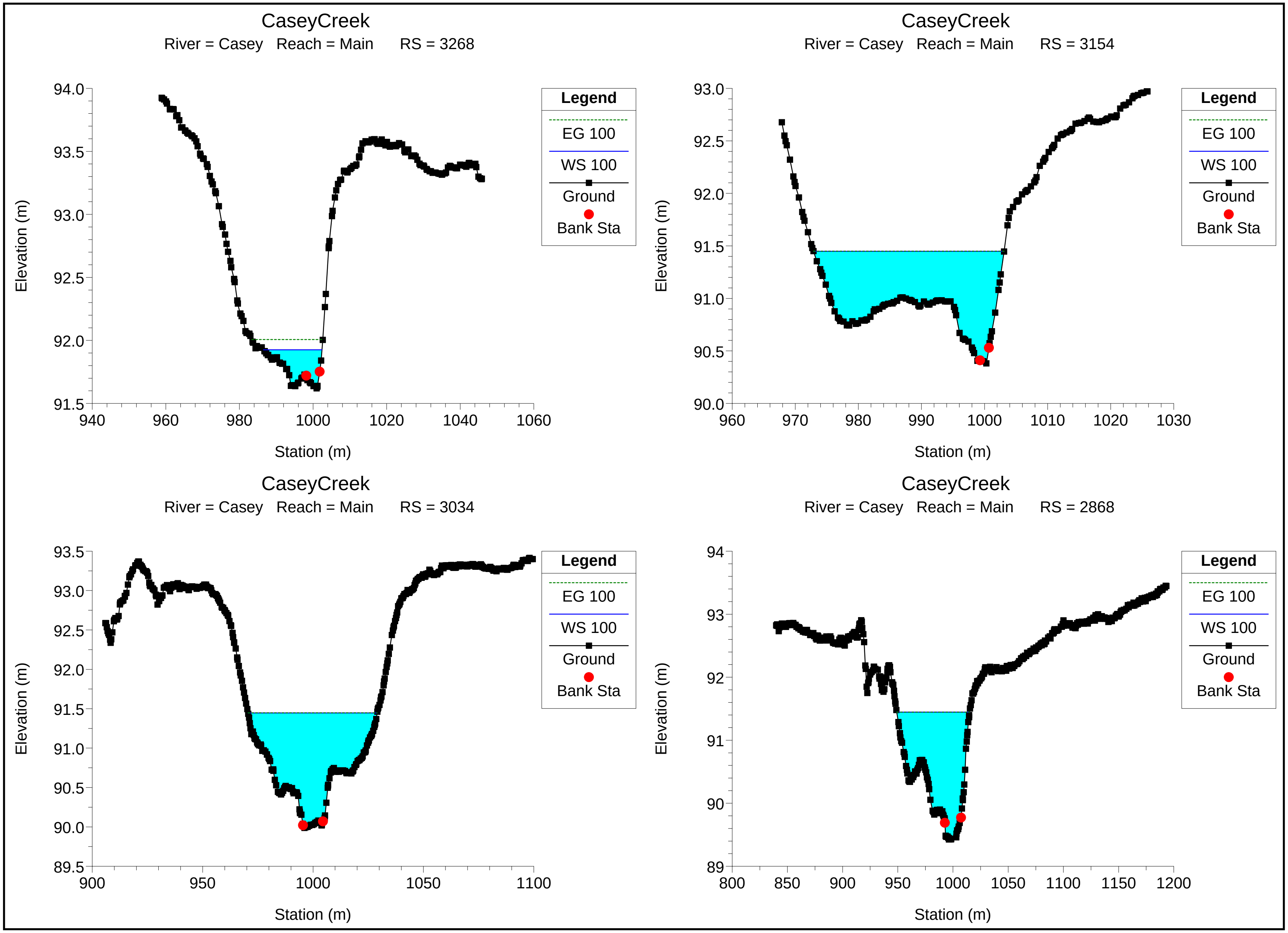
Bank Sta
Elevation (m)
Station (m)



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Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
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CaseyCreek
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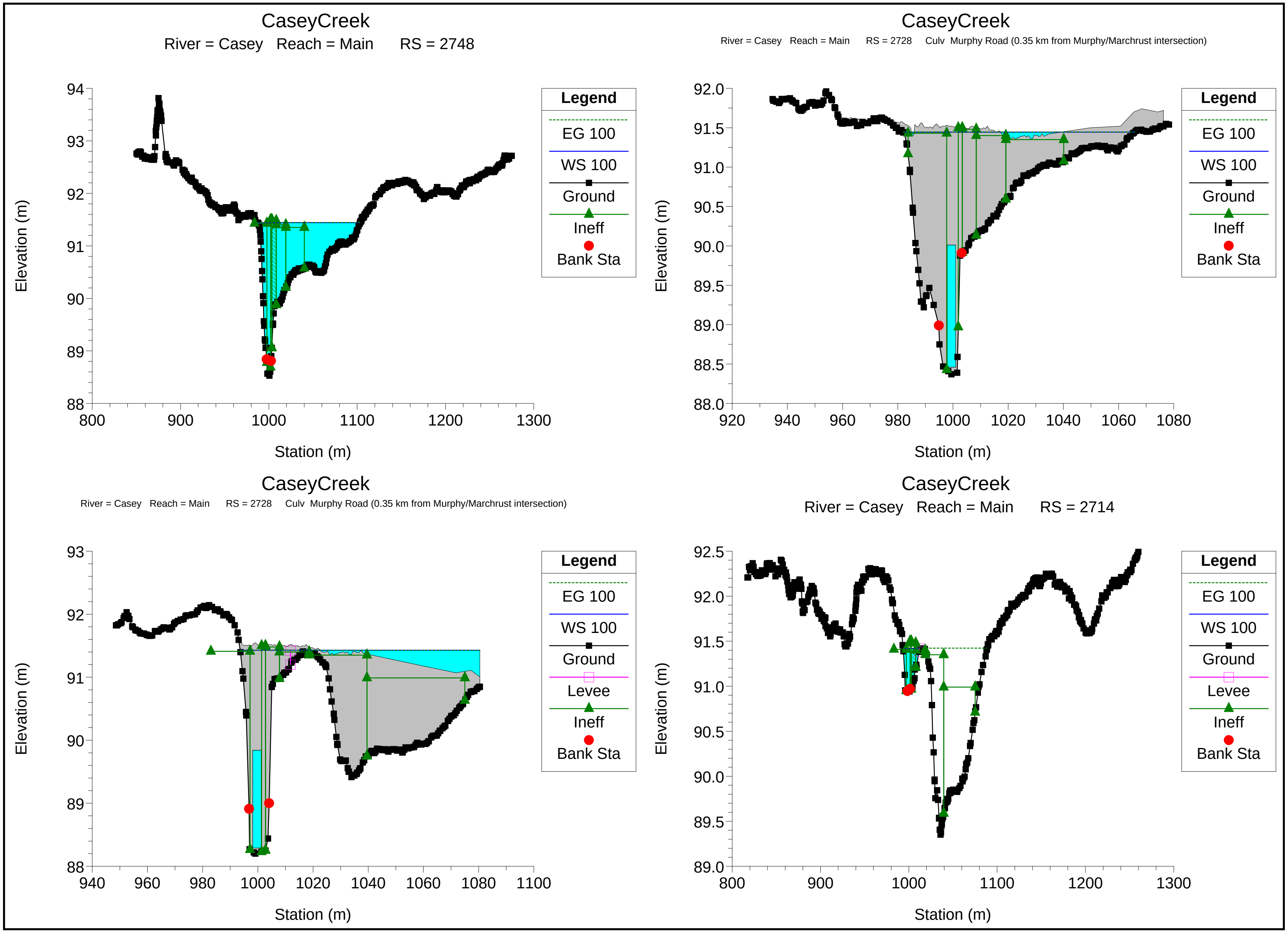

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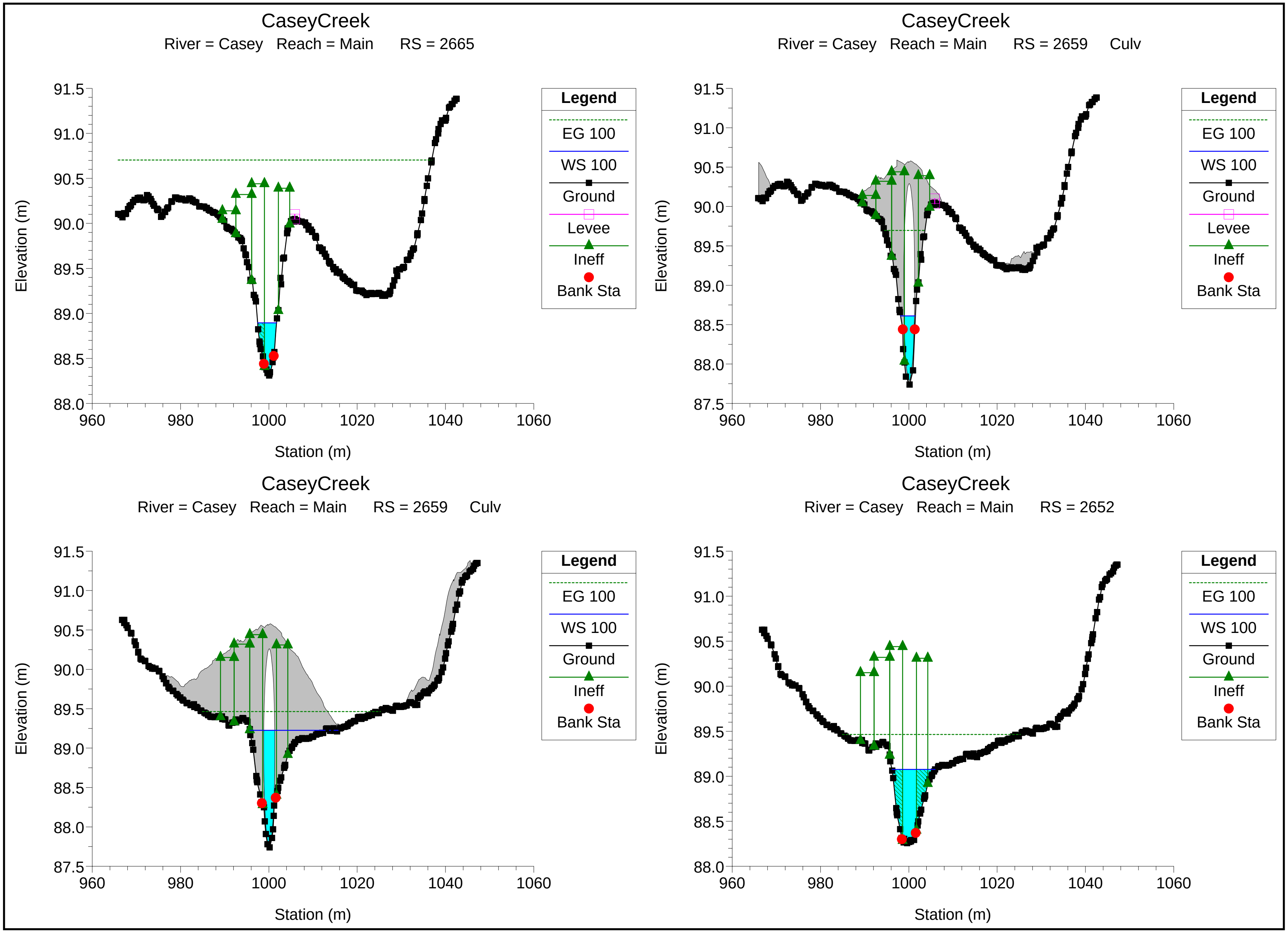
Elevation (m)
94
93
92
91
90
89
88
800
900
1000
1100
1200
1300
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2728 Culv Murphy Road (0.35 km from Murphy/Marchrust intersection)
Elevation (m)
92.0
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
920
940
960
980
1000
1020
1040
1060
1080
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2728 Culv Murphy Road (0.35 km from Murphy/Marchrust intersection)
Elevation (m)
93
92
91
90
89
88
940
960
980
1000
1020
1040
1060
1080
1100
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2714
Elevation (m)
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
800
900
1000
1100
1200
1300
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta



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WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
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Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
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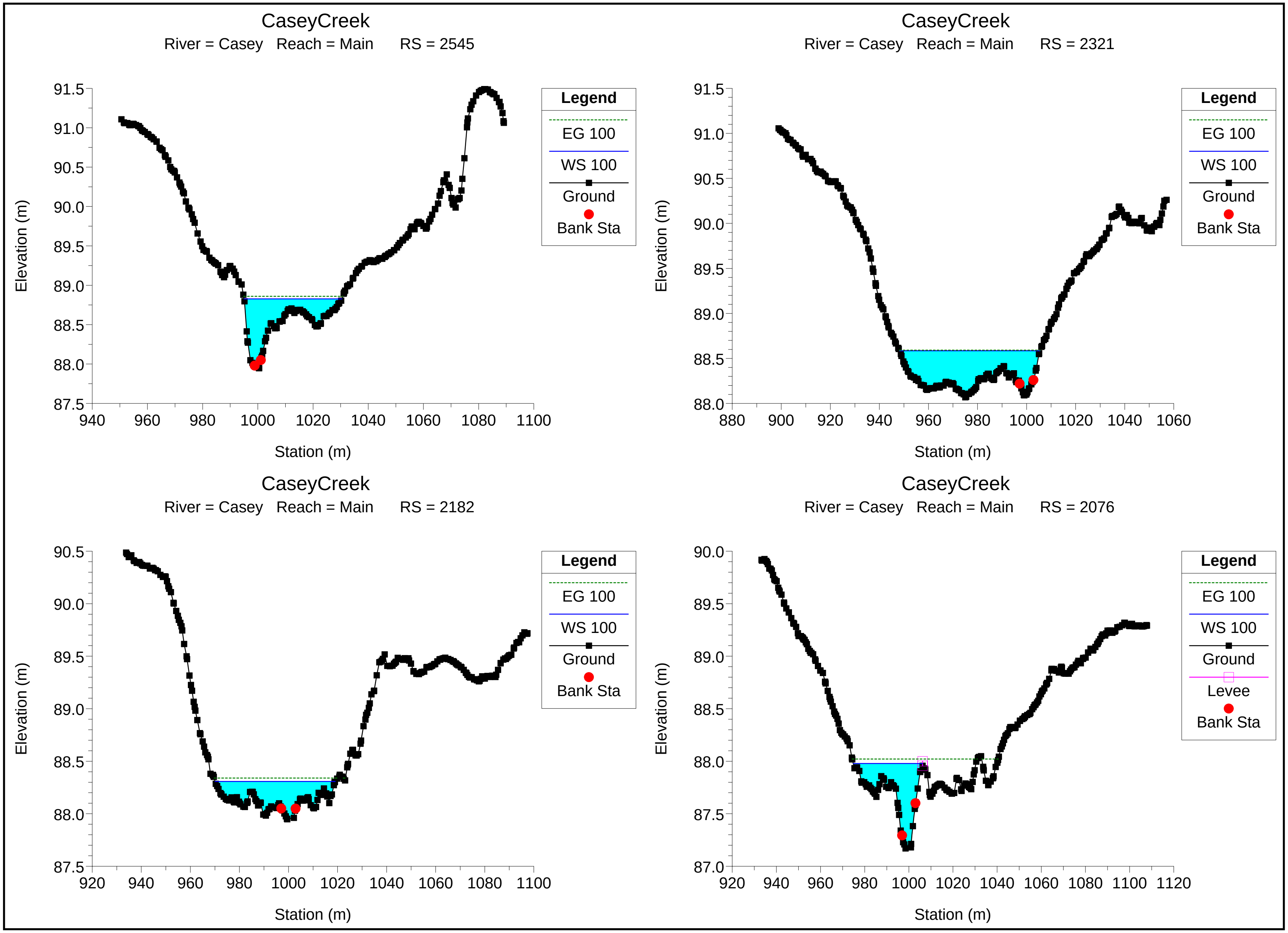
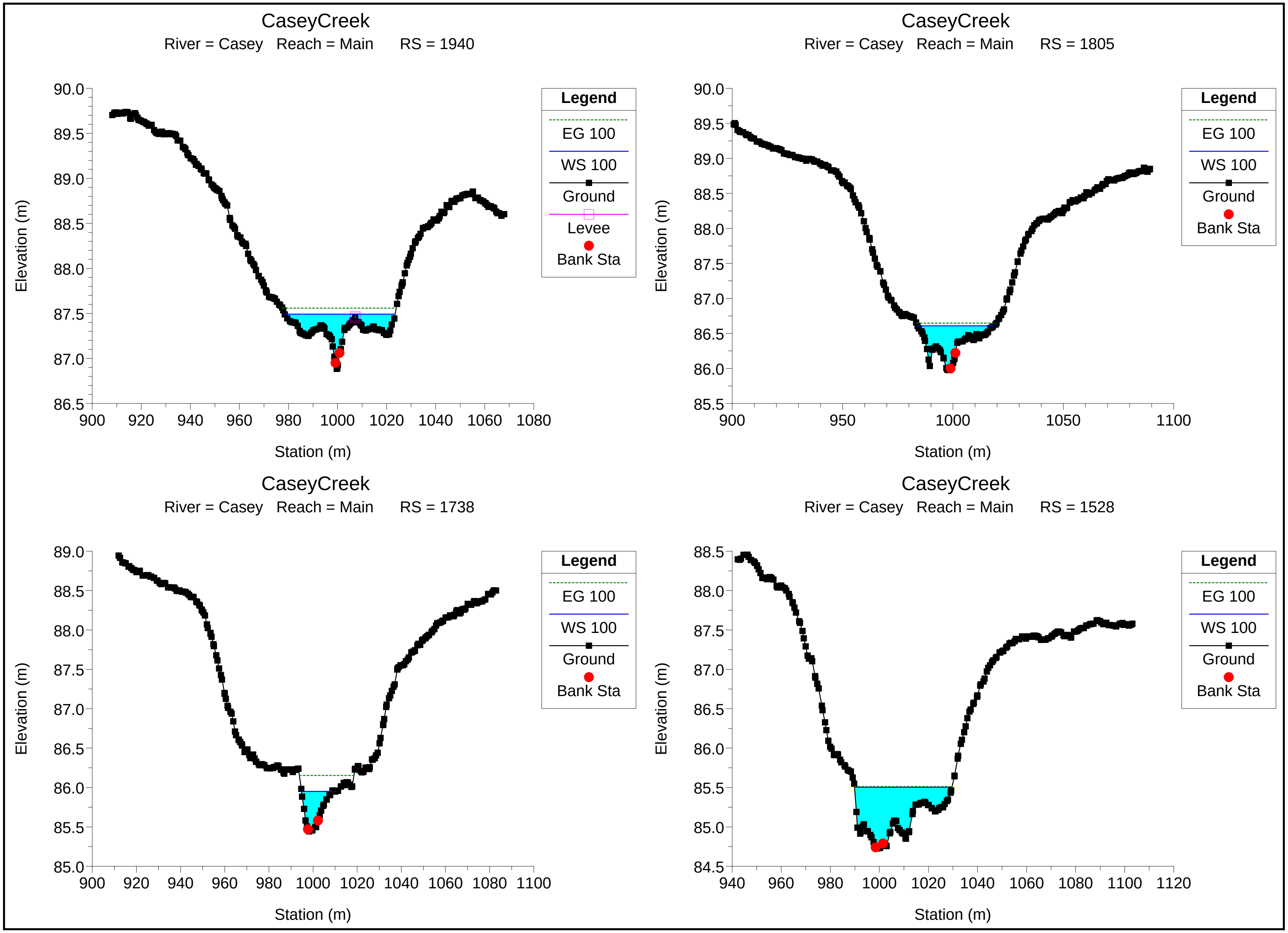
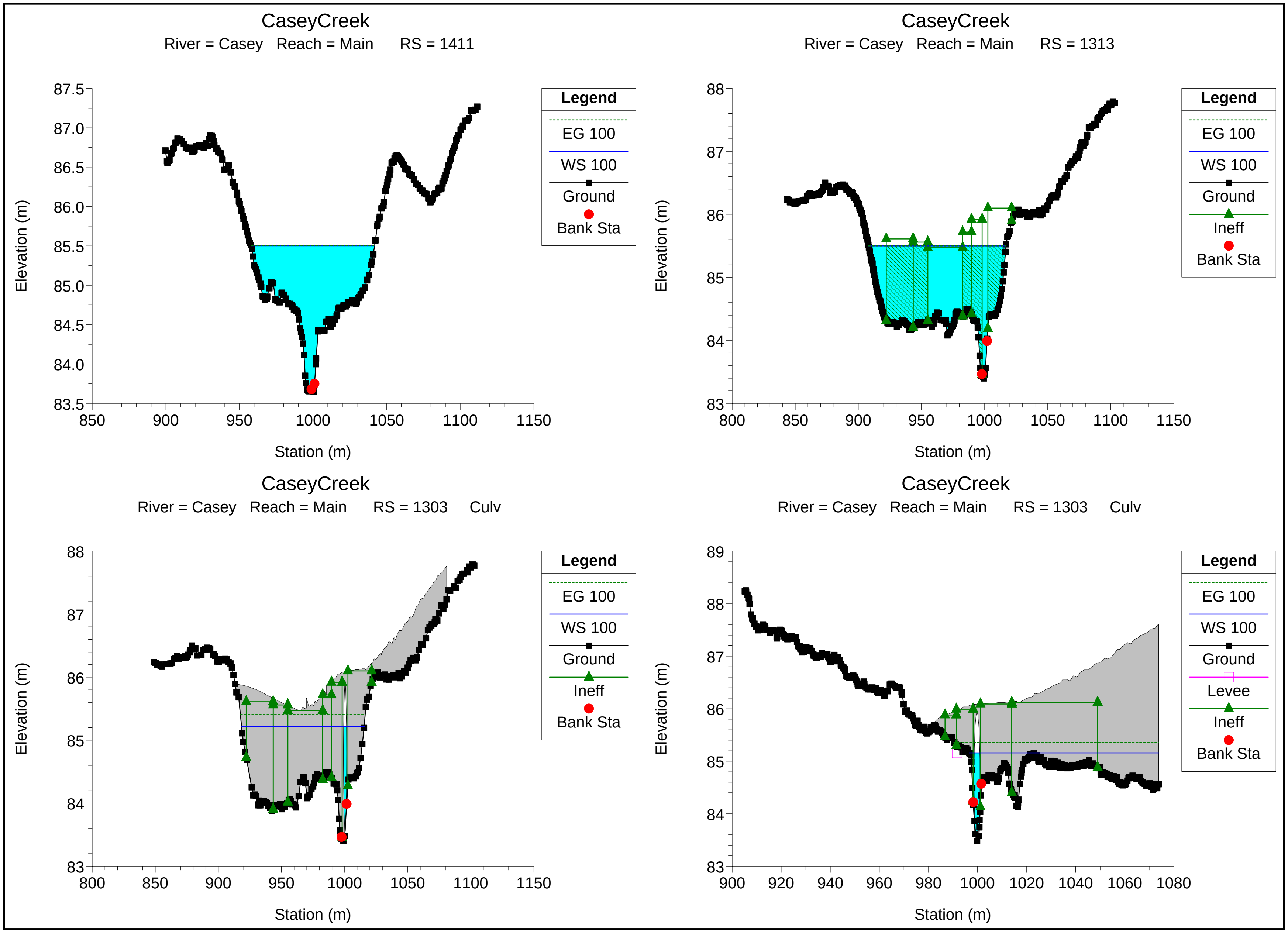
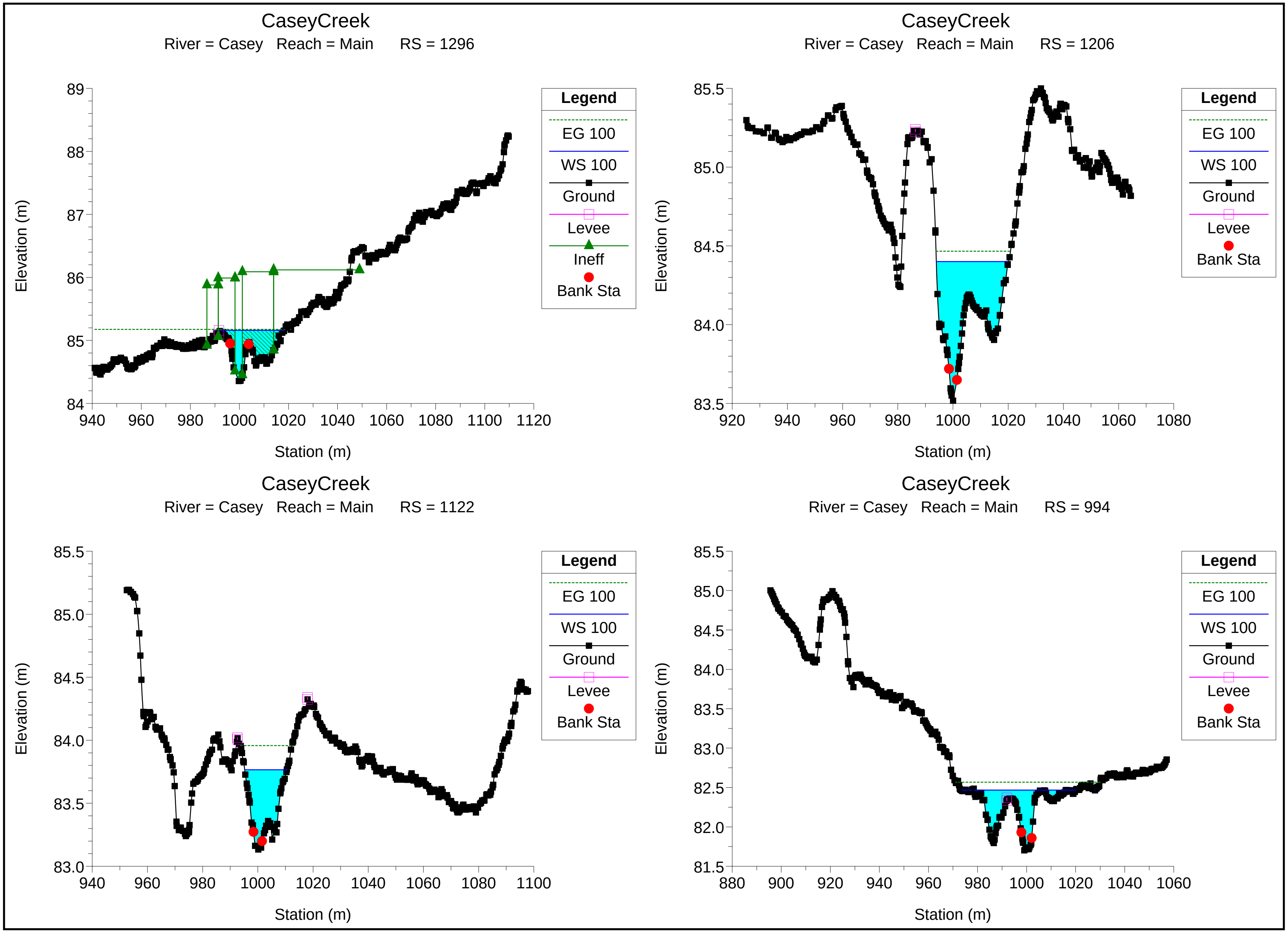
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 2652
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

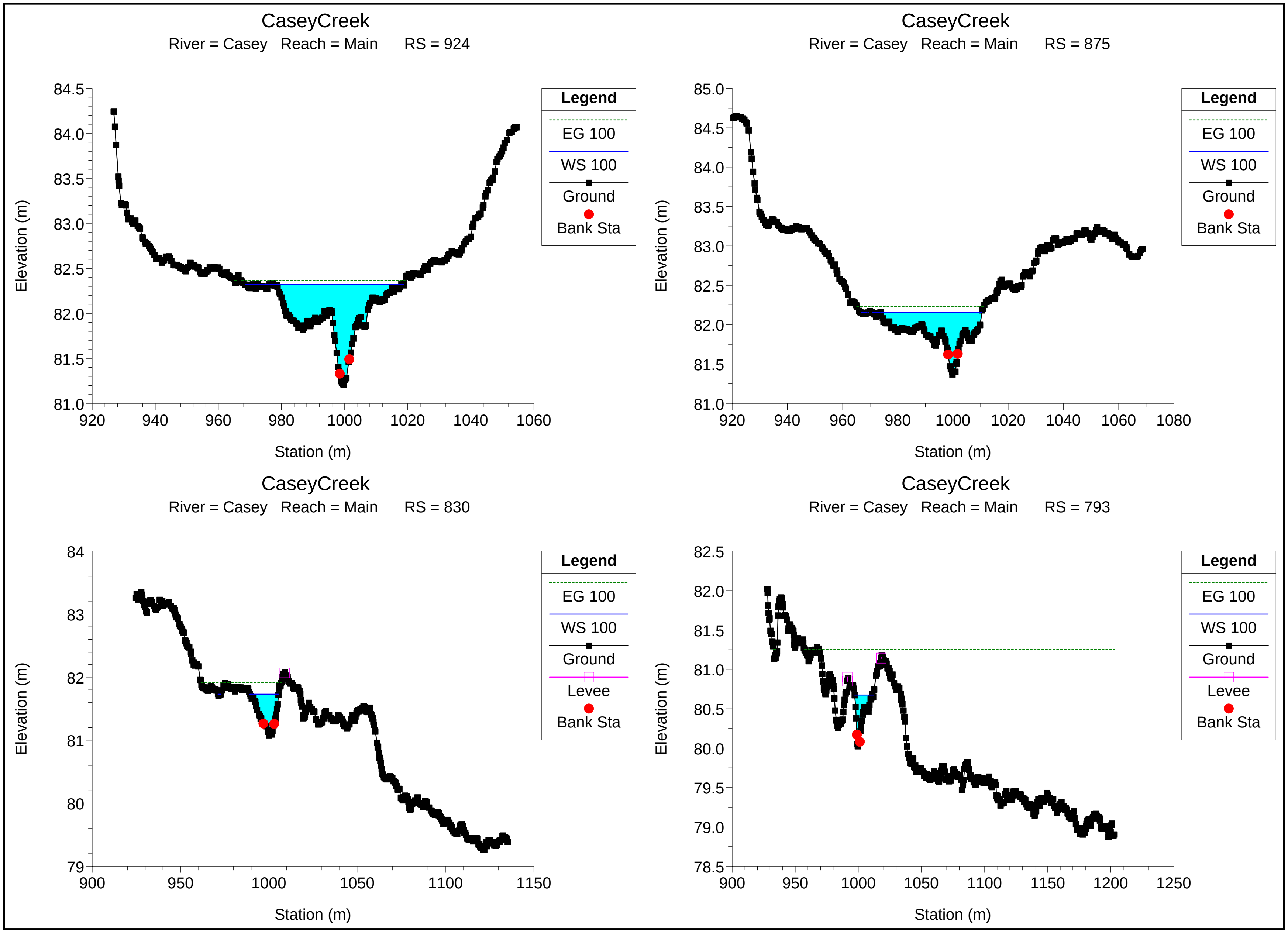

CaseyCreek
River = Casey Reach = Main RS = 2545
Elevation (m)
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
87.5
940 960 980 1000 1020 1040 1060 1080 1100
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2321
Elevation (m)
91.5
91.0
90.5
90.0
89.5
89.0
88.5
88.0
880 900 920 940 960 980 1000 1020 1040 1060
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2182
Elevation (m)
90.5
90.0
89.5
89.0
88.5
88.0
87.5
920 940 960 980 1000 1020 1040 1060 1080 1100
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 2076
Elevation (m)
90.0
89.5
89.0
88.5
88.0
87.5
87.0
920 940 960 980 1000 1020 1040 1060 1080 1100 1120
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta


CaseyCreek
River = Casey Reach = Main RS = 1940
Elevation (m)
Station (m)
90.0
89.5
89.0
88.5
88.0
87.5
87.0
86.5
900 920 940 960 980 1000 1020 1040 1060 1080
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 1805
Elevation (m)
Station (m)
90.0
89.5
89.0
88.5
88.0
87.5
87.0
86.5
86.0
85.5
900 950 1000 1050 1100
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 1738
Elevation (m)
Station (m)
89.0
88.5
88.0
87.5
87.0
86.5
86.0
85.5
85.0
900 920 940 960 980 1000 1020 1040 1060 1080 1100
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 1528
Elevation (m)
Station (m)
88.5
88.0
87.5
87.0
86.5
86.0
85.5
85.0
84.5
940 960 980 1000 1020 1040 1060 1080 1100 1120
Legend
EG 100
WS 100
Ground
Bank Sta

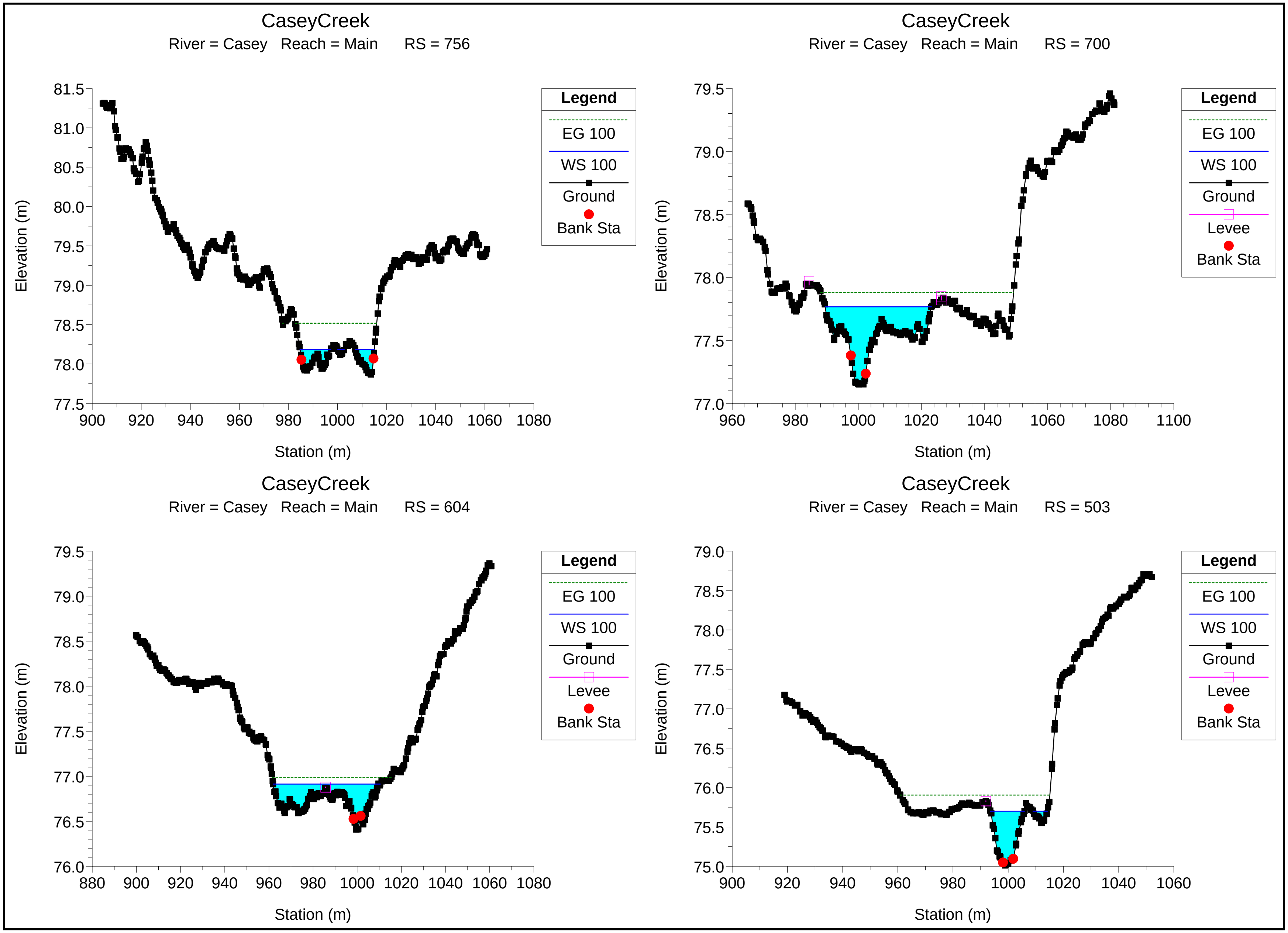


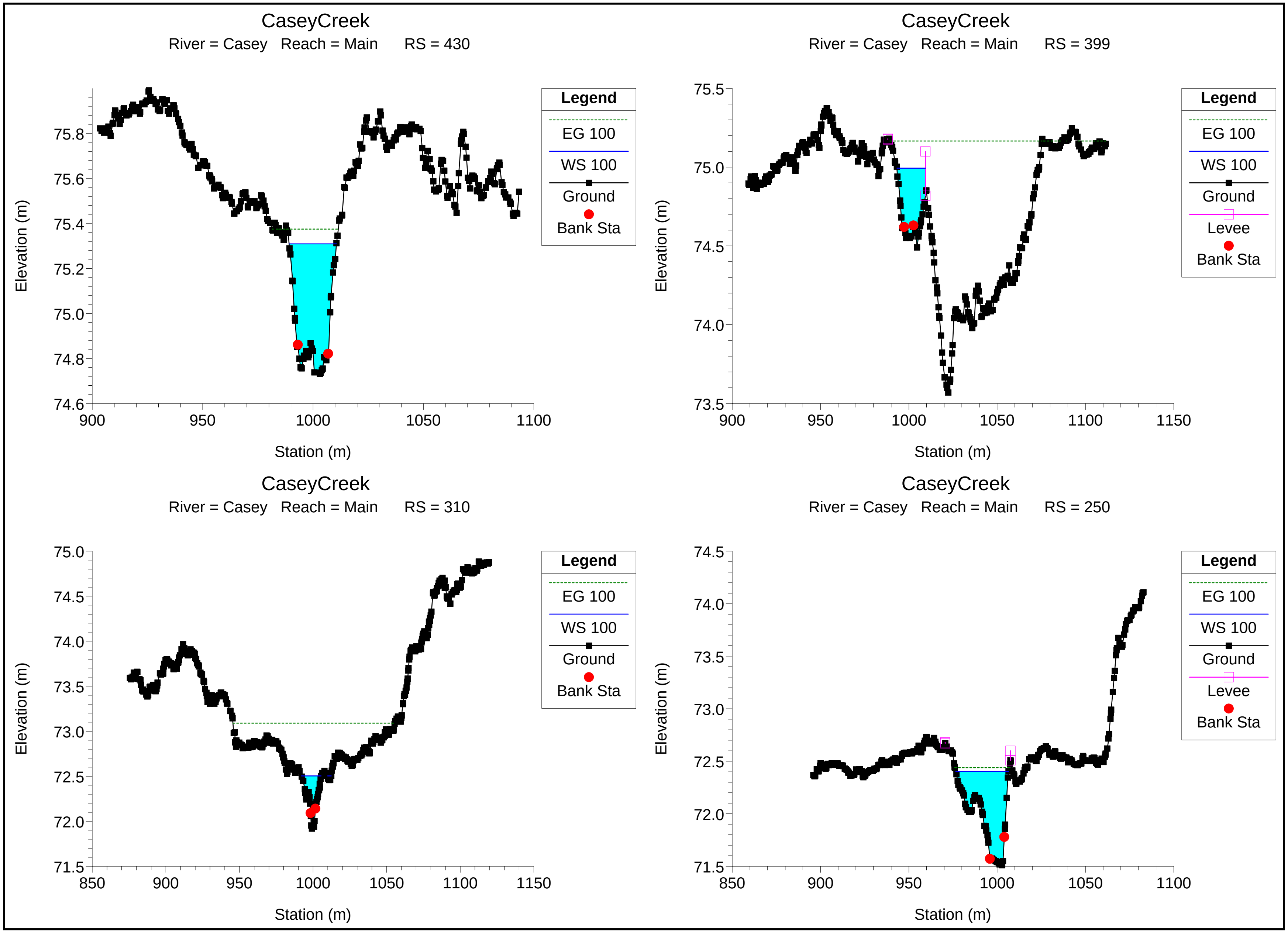
CaseyCreek
River = Casey Reach = Main RS = 1411
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 1313
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 1303 Culv
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 1303 Culv
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)

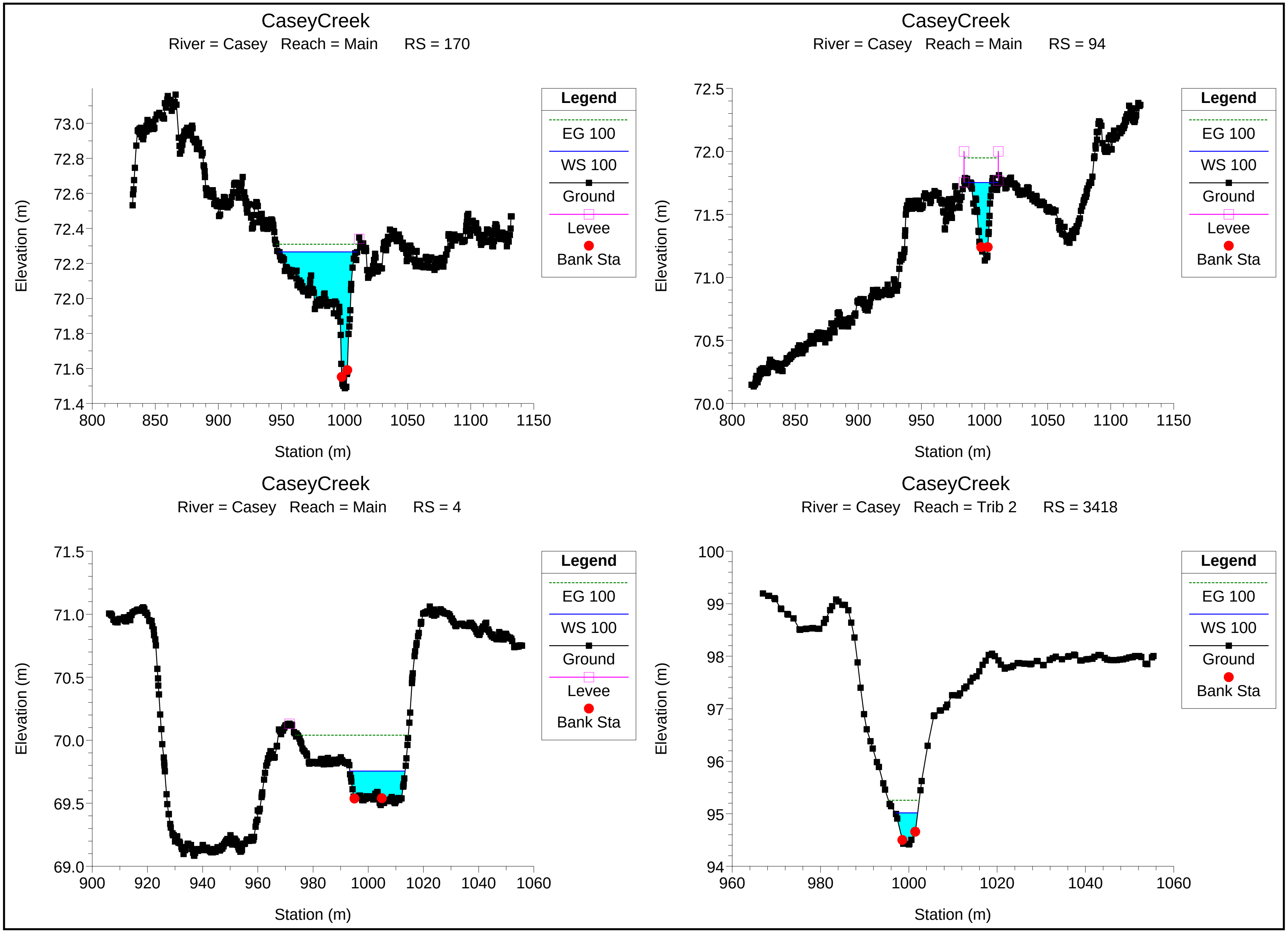

CaseyCreek
River = Casey Reach = Main RS = 1296
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
89
88
87
86
85
84
940 960 980 1000 1020 1040 1060 1080 1100 1120
CaseyCreek
River = Casey Reach = Main RS = 1206
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
85.5
85.0
84.5
84.0
83.5
920 940 960 980 1000 1020 1040 1060 1080
CaseyCreek
River = Casey Reach = Main RS = 1122
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
85.5
85.0
84.5
84.0
83.5
83.0
940 960 980 1000 1020 1040 1060 1080 1100
CaseyCreek
River = Casey Reach = Main RS = 994
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
85.5
85.0
84.5
84.0
83.5
83.0
82.5
82.0
81.5
880 900 920 940 960 980 1000 1020 1040 1060

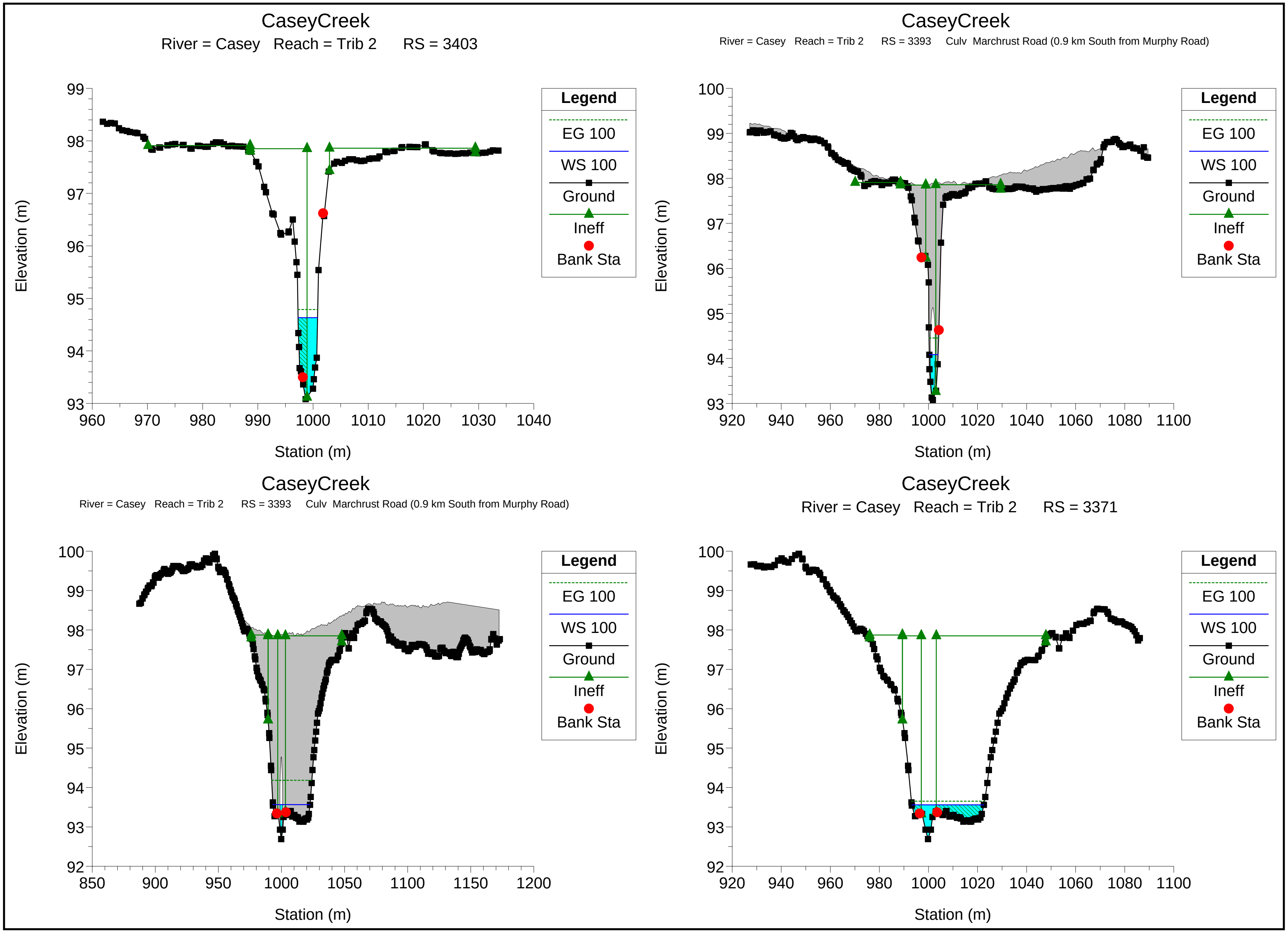


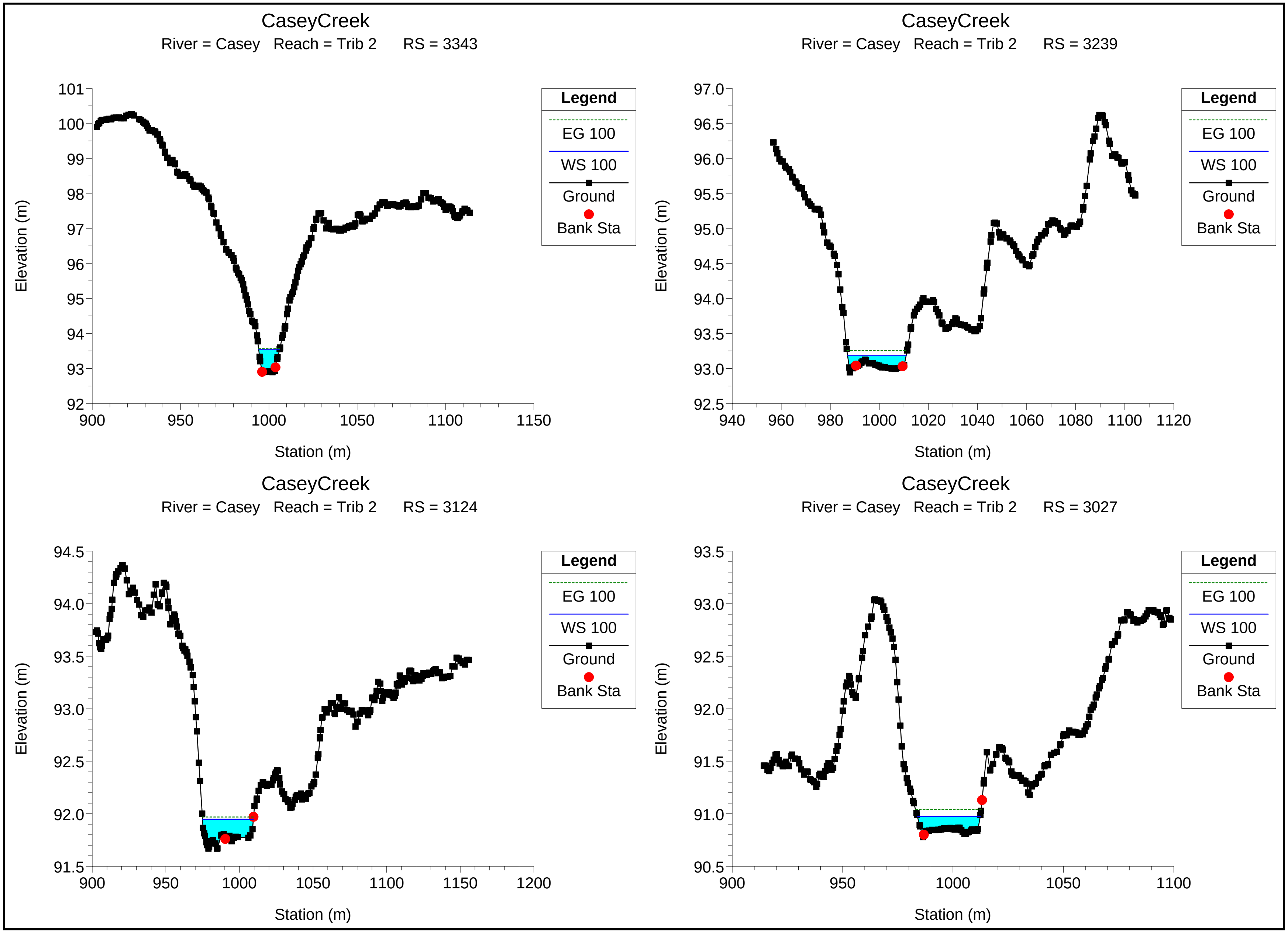
CaseyCreek
River = Casey Reach = Main RS = 924
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 875
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 830
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main RS = 793
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)

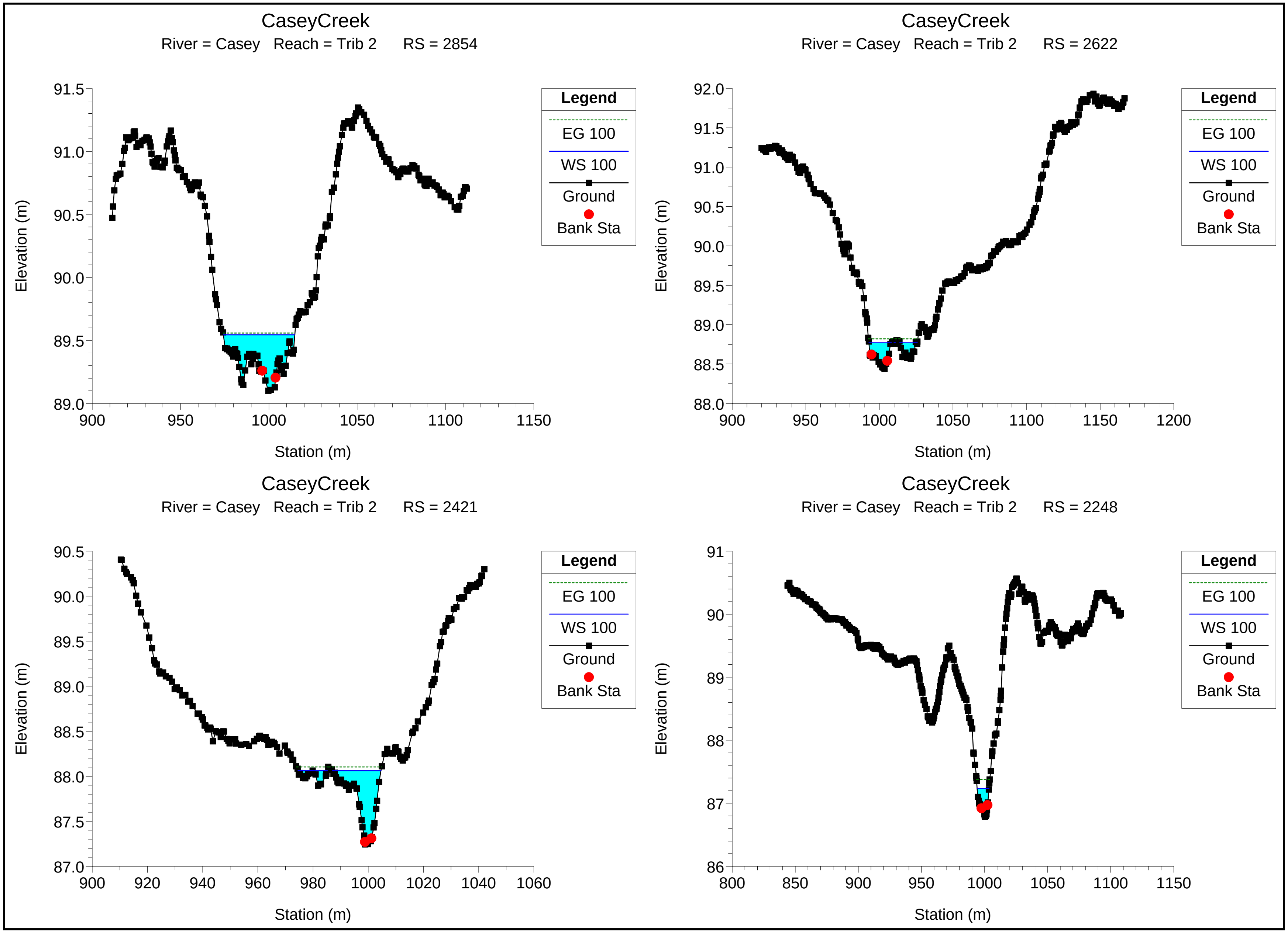

CaseyCreek
River = Casey Reach = Main RS = 756
Elevation (m)
Station (m)
81.5
81.0
80.5
80.0
79.5
79.0
78.5
78.0
77.5
900 920 940 960 980 1000 1020 1040 1060 1080
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 700
Elevation (m)
Station (m)
79.5
79.0
78.5
78.0
77.5
77.0
960 980 1000 1020 1040 1060 1080 1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 604
Elevation (m)
Station (m)
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
880 900 920 940 960 980 1000 1020 1040 1060 1080
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 503
Elevation (m)
Station (m)
79.0
78.5
78.0
77.5
77.0
76.5
76.0
75.5
75.0
900 920 940 960 980 1000 1020 1040 1060
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

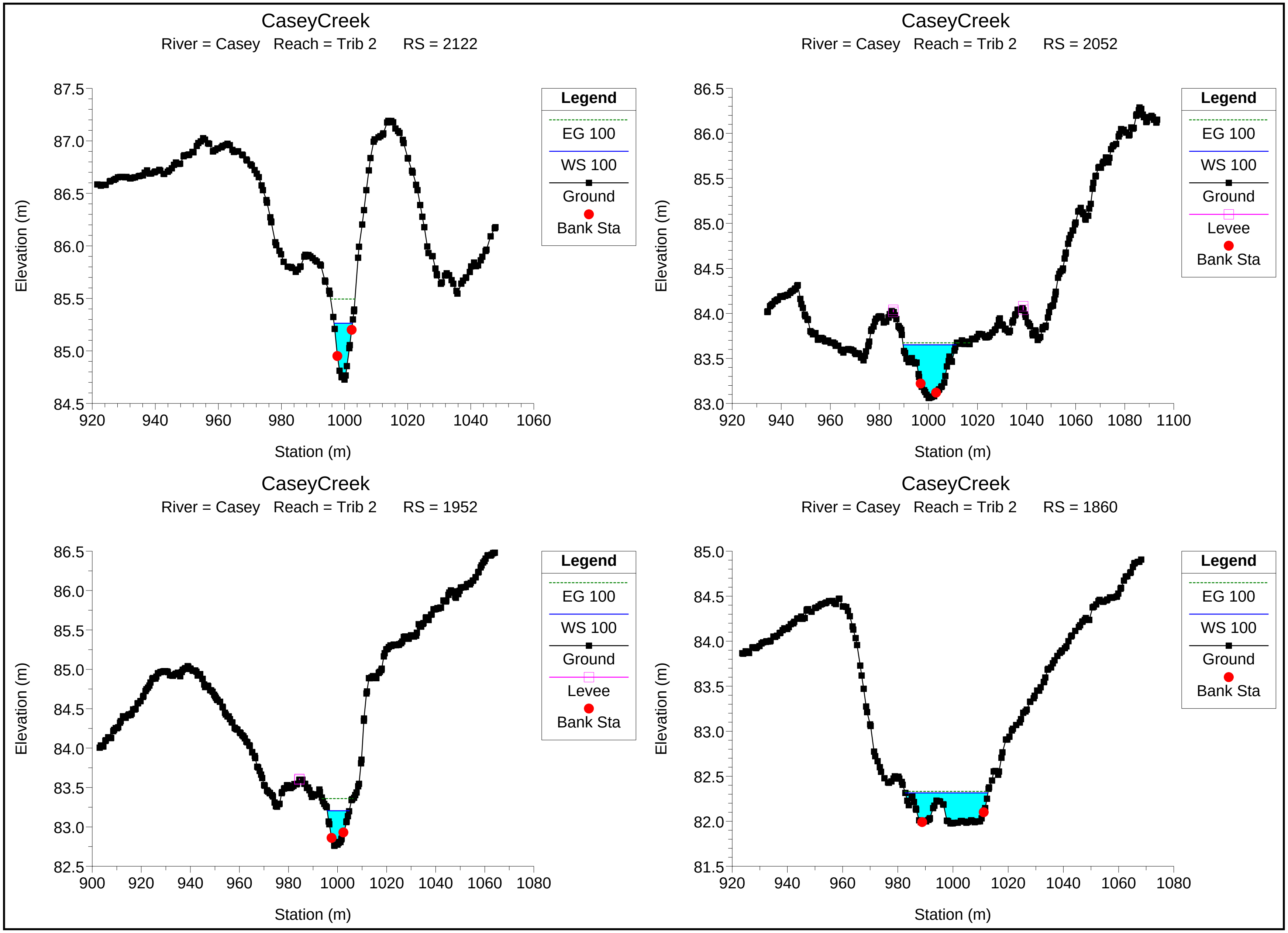

CaseyCreek
River = Casey Reach = Main RS = 430
Elevation (m)
75.8
75.6
75.4
75.2
75.0
74.8
74.6
900
950
1000
1050
1100
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 399
Elevation (m)
75.5
75.0
74.5
74.0
73.5
900
950
1000
1050
1100
1150
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 310
Elevation (m)
75.0
74.5
74.0
73.5
73.0
72.5
72.0
71.5
850
900
950
1000
1050
1100
1150
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 250
Elevation (m)
74.5
74.0
73.5
73.0
72.5
72.0
71.5
850
900
950
1000
1050
1100
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

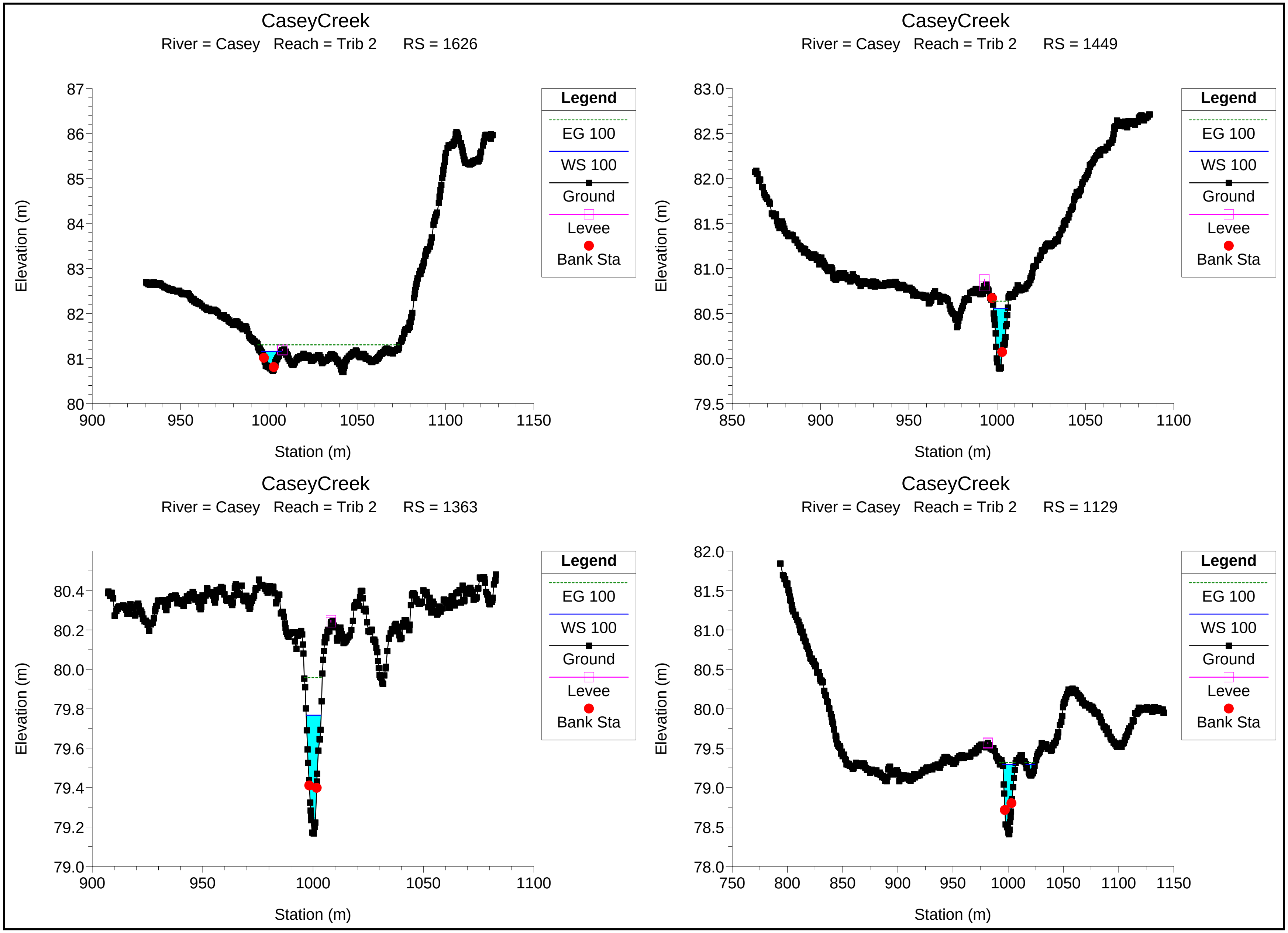

CaseyCreek
River = Casey Reach = Main RS = 170
Elevation (m)
73.0
72.8
72.6
72.4
72.2
72.0
71.8
71.6
71.4
800 850 900 950 1000 1050 1100 1150
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 94
Elevation (m)
72.5
72.0
71.5
71.0
70.5
70.0
800 850 900 950 1000 1050 1100 1150
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main RS = 4
Elevation (m)
71.5
71.0
70.5
70.0
69.5
69.0
900 920 940 960 980 1000 1020 1040 1060
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 3418
Elevation (m)
100
99
98
97
96
95
94
960 980 1000 1020 1040 1060
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta

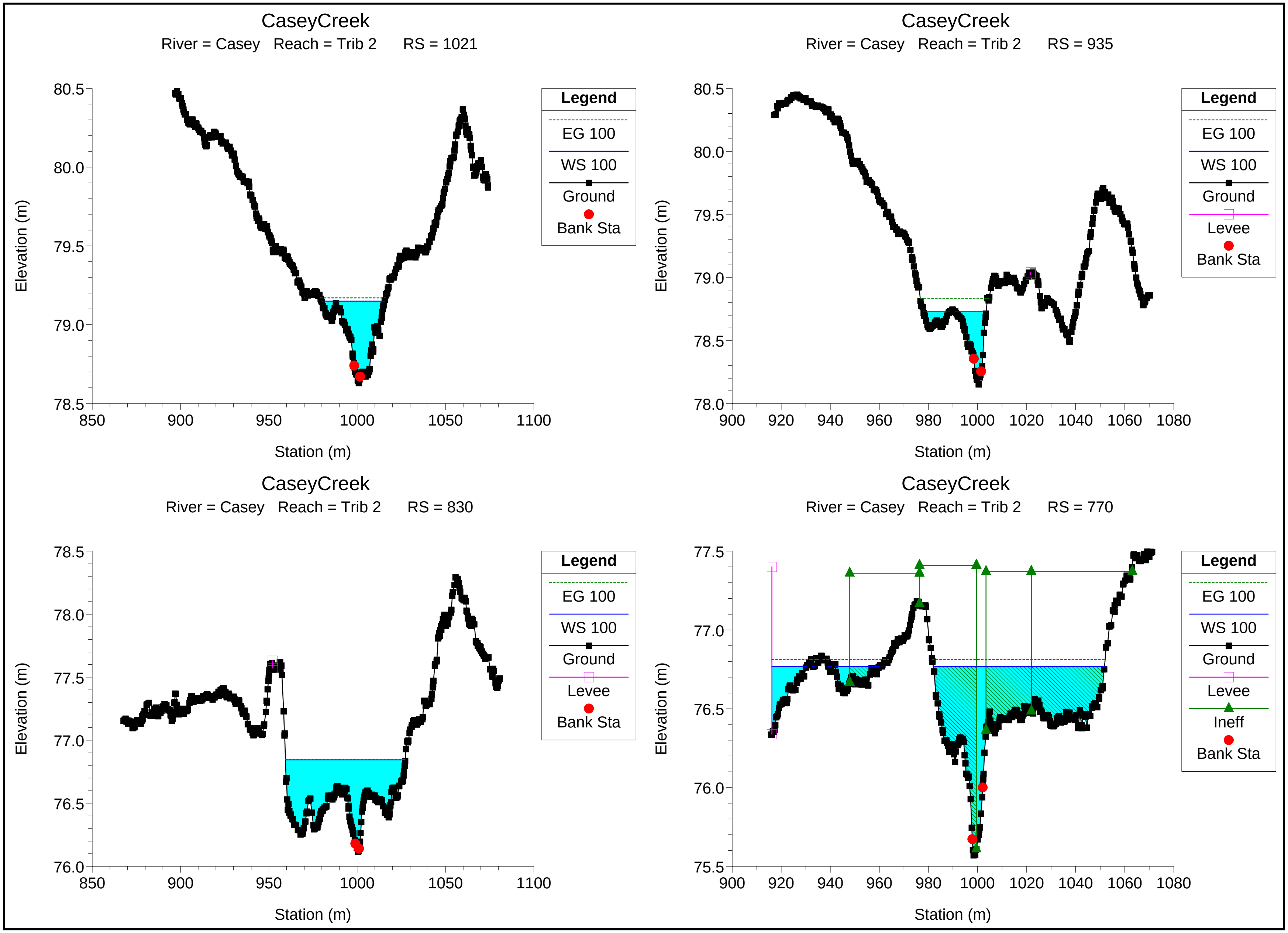

CaseyCreek
River = Casey   Reach = Trib 2   RS = 3403
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
CaseyCreek
River = Casey   Reach = Trib 2   RS = 3393   Culv   Marchrust Road (0.9 km South from Murphy Road)
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
CaseyCreek
River = Casey   Reach = Trib 2   RS = 3393   Culv   Marchrust Road (0.9 km South from Murphy Road)
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
CaseyCreek
River = Casey   Reach = Trib 2   RS = 3371
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta


CaseyCreek
River = Casey Reach = Trib 2 RS = 3343
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 3239
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 3124
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 3027
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)

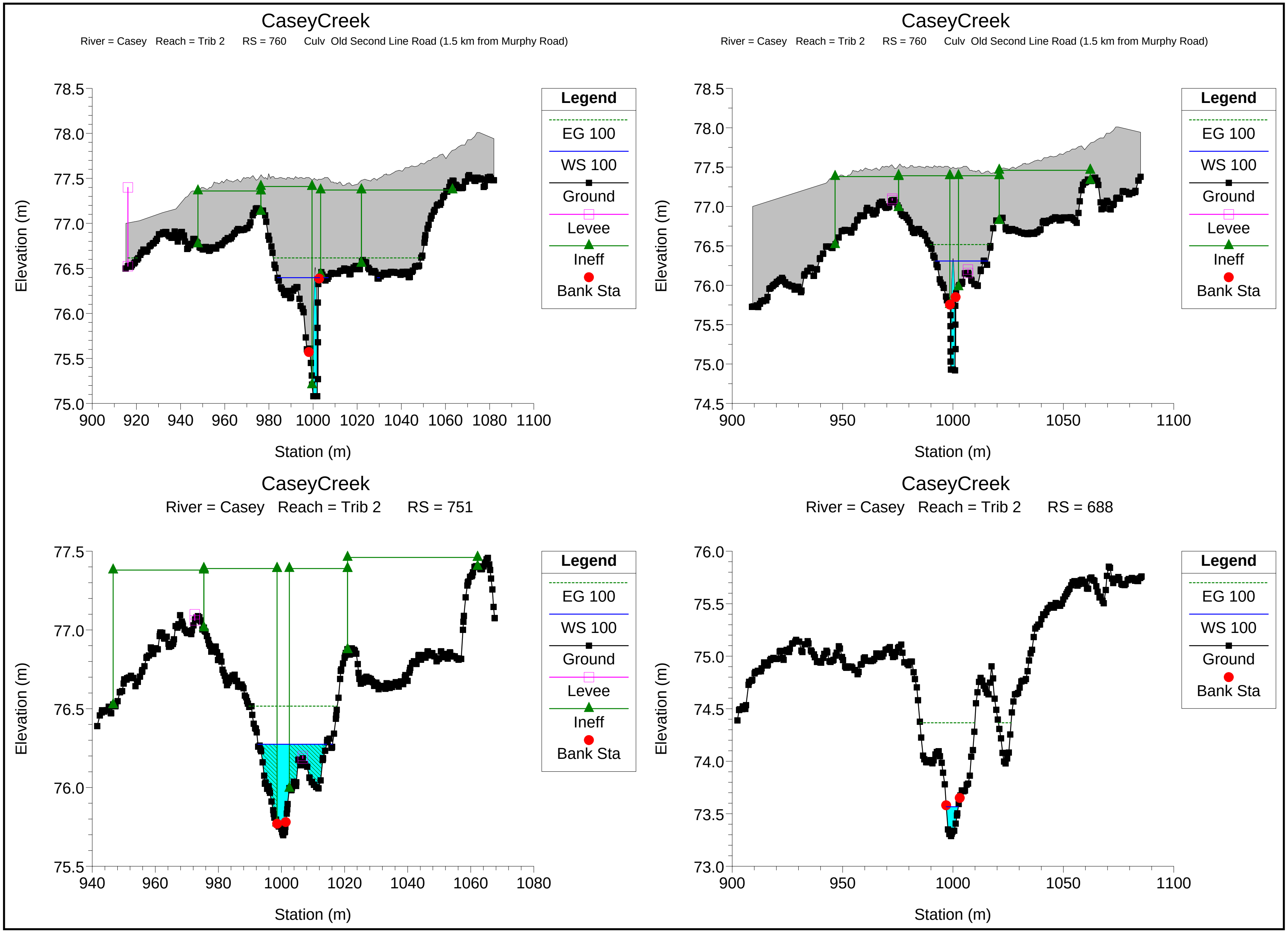

CaseyCreek
River = Casey Reach = Trib 2 RS = 2854
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 2622
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 2421
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 2248
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta


CaseyCreek
River = Casey Reach = Trib 2 RS = 2122
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
87.5
87.0
86.5
86.0
85.5
85.0
84.5
920
940
960
980
1000
1020
1040
1060
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 2052
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
86.5
86.0
85.5
85.0
84.5
84.0
83.5
83.0
920
940
960
980
1000
1020
1040
1060
1080
1100
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 1952
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
86.5
86.0
85.5
85.0
84.5
84.0
83.5
83.0
82.5
900
920
940
960
980
1000
1020
1040
1060
1080
Station (m)
CaseyCreek
River = Casey Reach = Trib 2 RS = 1860
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
85.0
84.5
84.0
83.5
83.0
82.5
82.0
81.5
920
940
960
980
1000
1020
1040
1060
1080
Station (m)

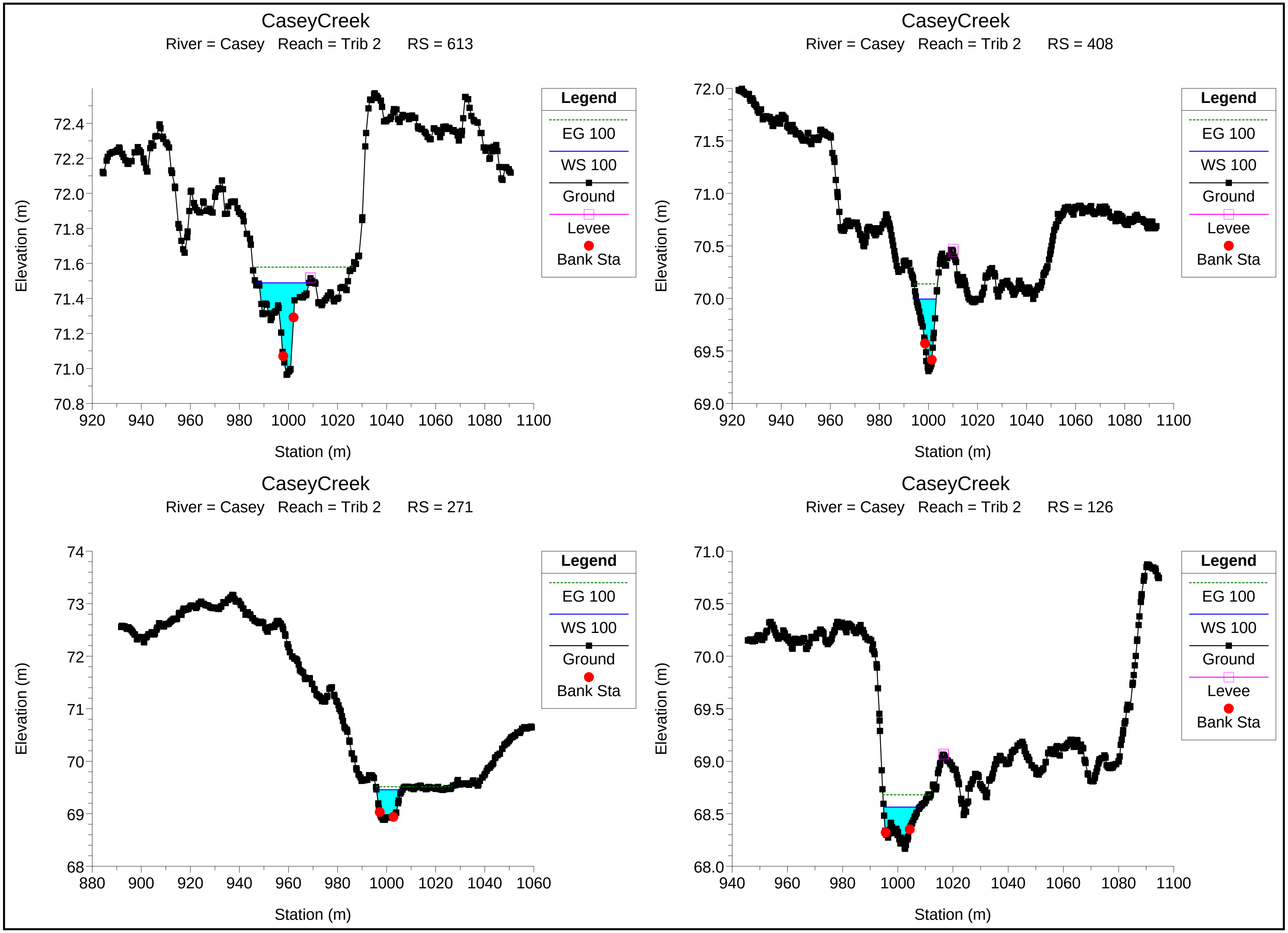

CaseyCreek
River = Casey Reach = Trib 2 RS = 1626
Elevation (m)
Station (m)
87
86
85
84
83
82
81
80
900
950
1000
1050
1100
1150
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 1449
Elevation (m)
Station (m)
83.0
82.5
82.0
81.5
81.0
80.5
80.0
79.5
850
900
950
1000
1050
1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 1363
Elevation (m)
Station (m)
80.4
80.2
80.0
79.8
79.6
79.4
79.2
79.0
900
950
1000
1050
1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 1129
Elevation (m)
Station (m)
82.0
81.5
81.0
80.5
80.0
79.5
79.0
78.5
78.0
750
800
850
900
950
1000
1050
1100
1150
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

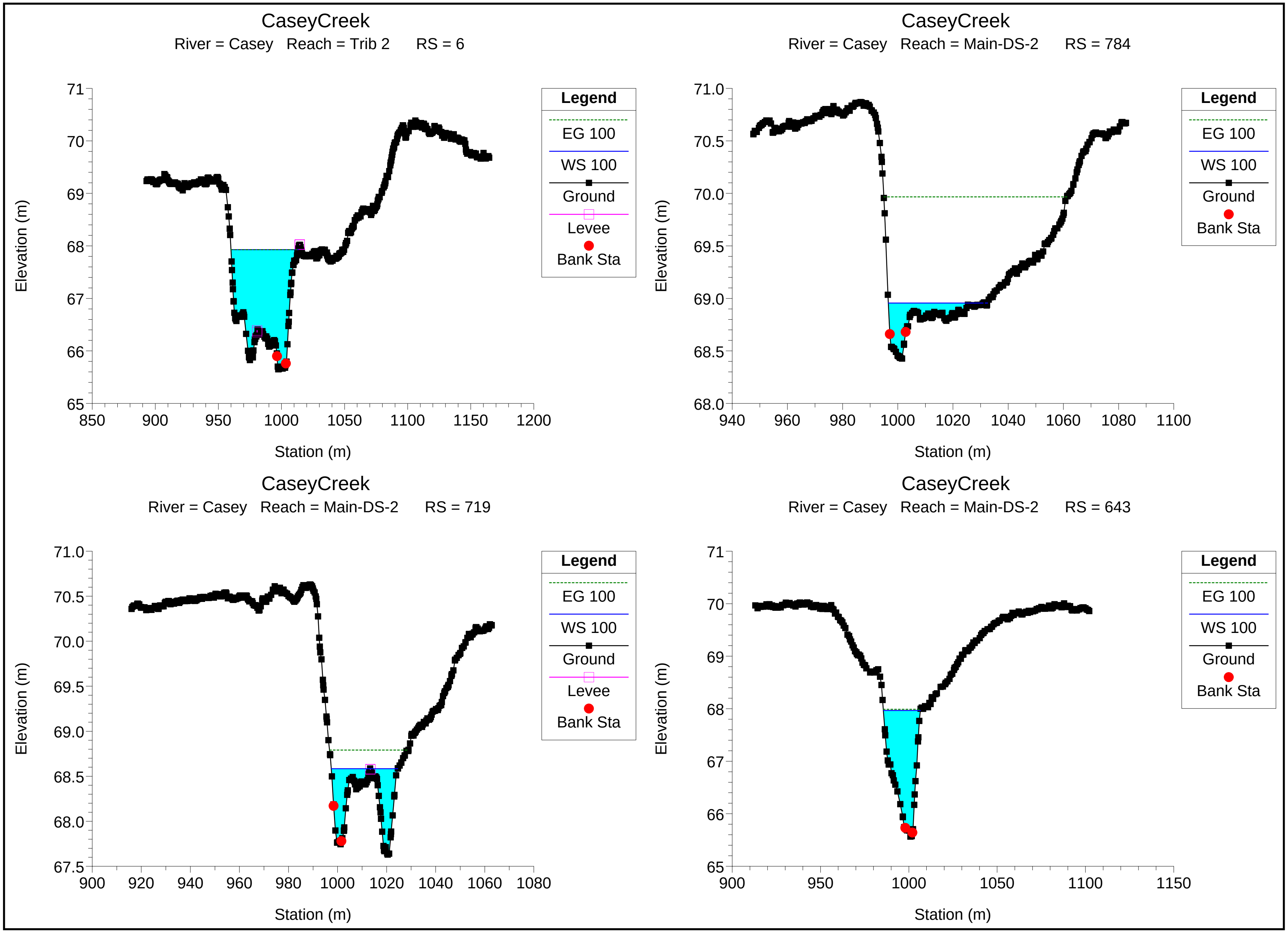


CaseyCreek
River = Casey Reach = Trib 2 RS = 1021
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
80.5
80.0
79.5
79.0
78.5
850
900
950
1000
1050
1100
CaseyCreek
River = Casey Reach = Trib 2 RS = 935
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
80.5
80.0
79.5
79.0
78.5
78.0
900
920
940
960
980
1000
1020
1040
1060
1080
CaseyCreek
River = Casey Reach = Trib 2 RS = 830
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
78.5
78.0
77.5
77.0
76.5
76.0
850
900
950
1000
1050
1100
CaseyCreek
River = Casey Reach = Trib 2 RS = 770
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
77.5
77.0
76.5
76.0
75.5
900
920
940
960
980
1000
1020
1040
1060
1080

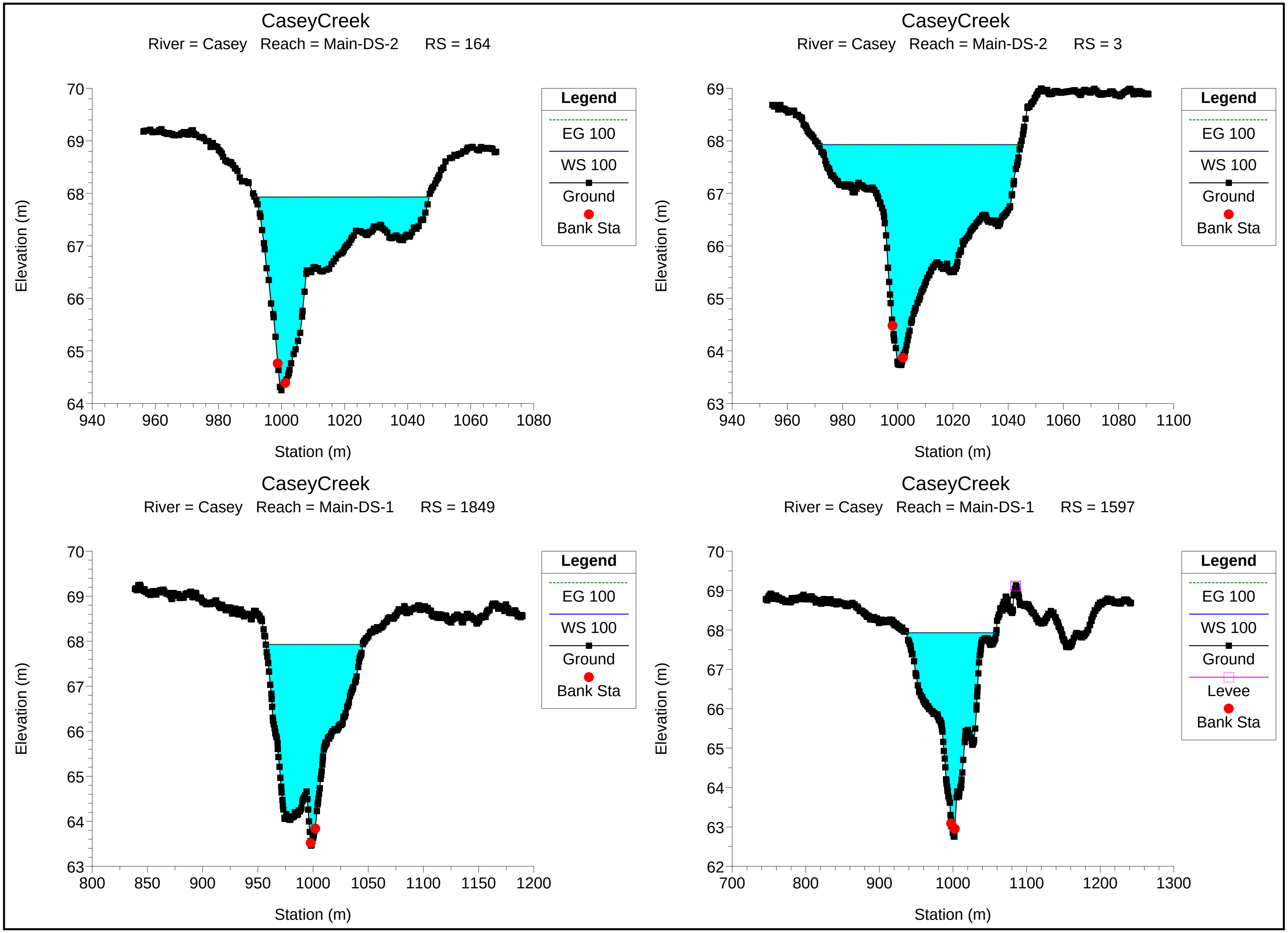


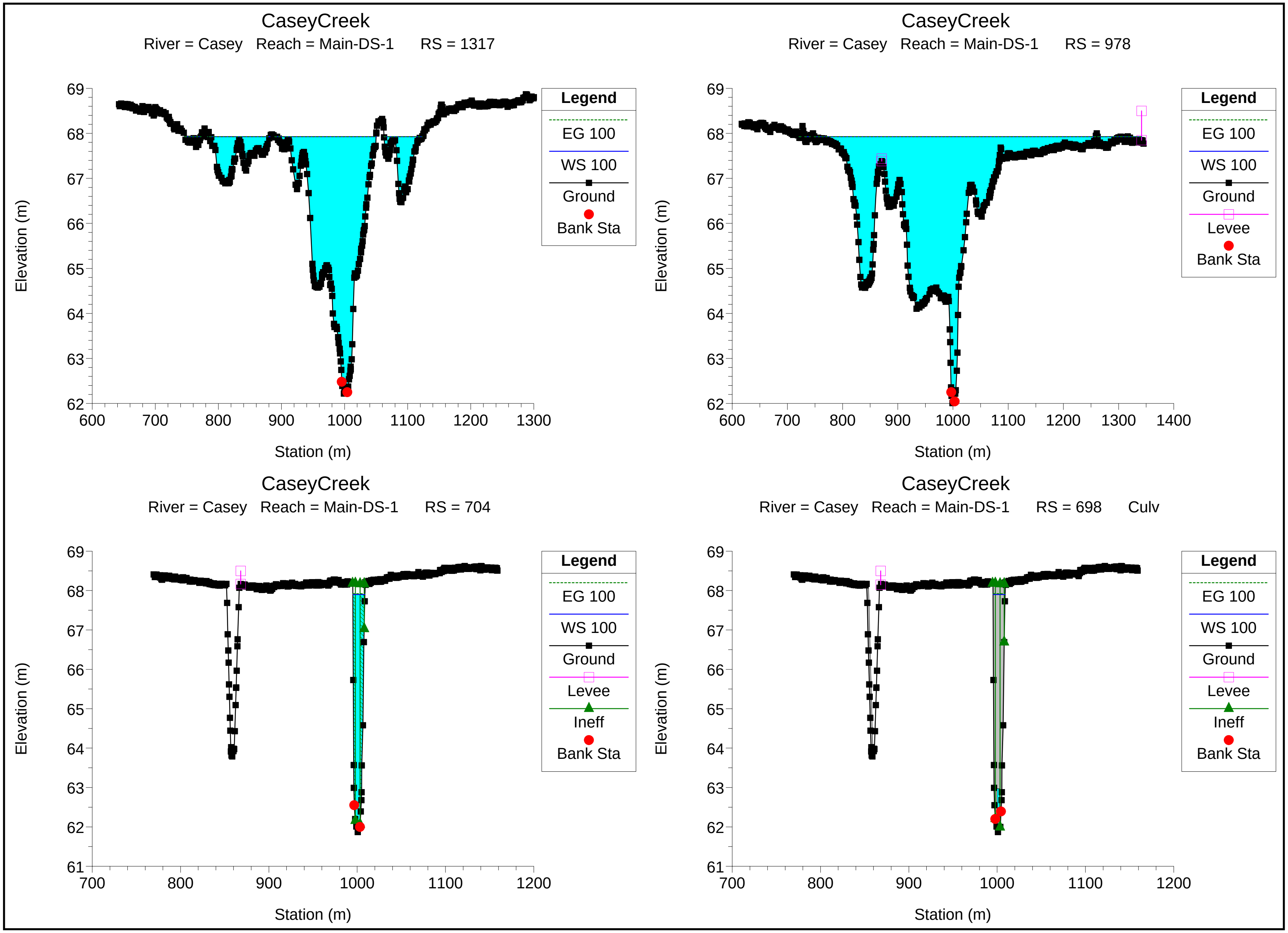
CaseyCreek
River = Casey Reach = Trib 2 RS = 760 Culv Old Second Line Road (1.5 km from Murphy Road)
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 760 Culv Old Second Line Road (1.5 km from Murphy Road)
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 751
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 688
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta

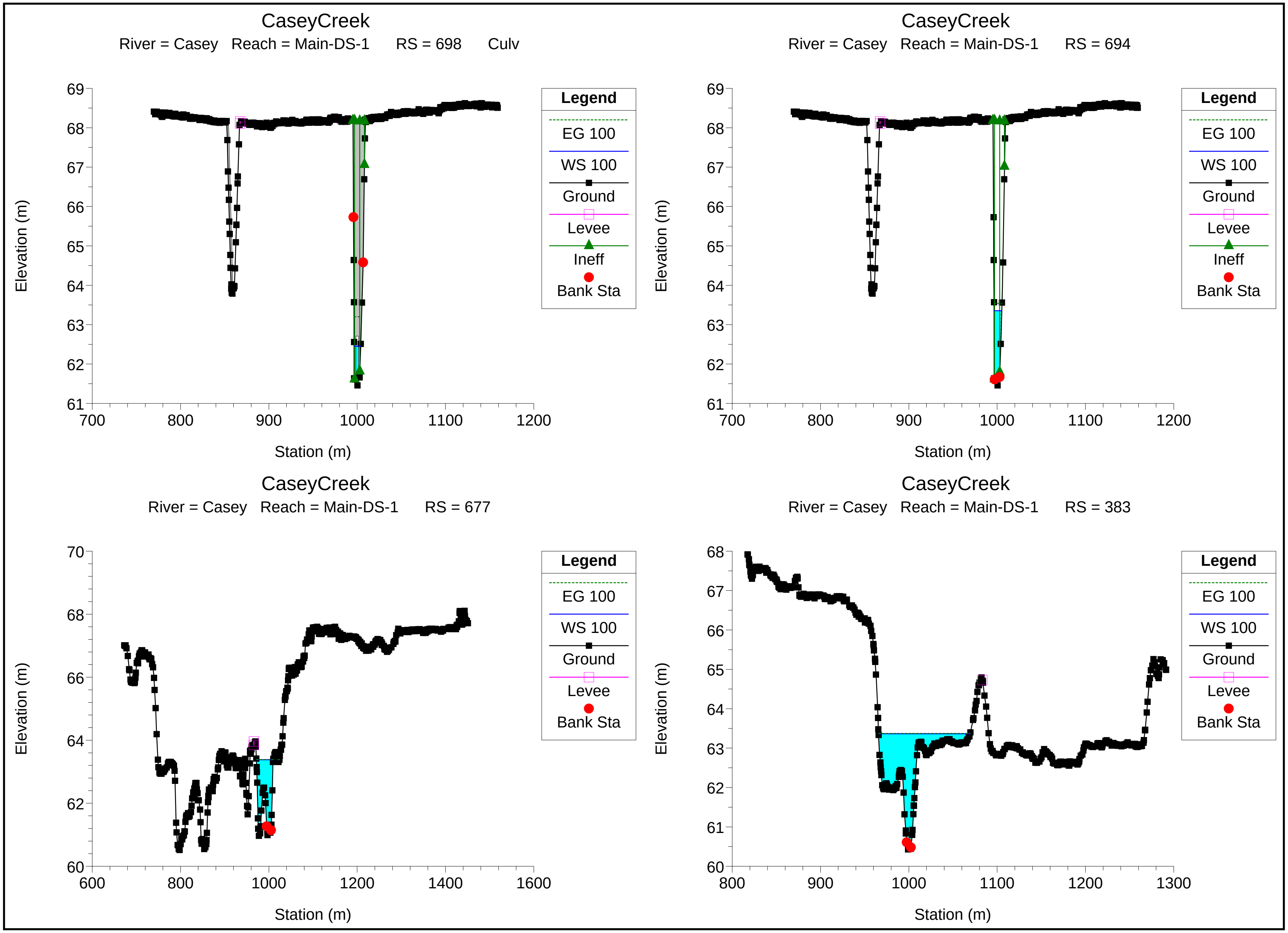

CaseyCreek
River = Casey Reach = Trib 2 RS = 613
Elevation (m)
Station (m)
72.4
72.2
72.0
71.8
71.6
71.4
71.2
71.0
70.8
920 940 960 980 1000 1020 1040 1060 1080 1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 408
Elevation (m)
Station (m)
72.0
71.5
71.0
70.5
70.0
69.5
69.0
920 940 960 980 1000 1020 1040 1060 1080 1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 271
Elevation (m)
Station (m)
74
73
72
71
70
69
68
880 900 920 940 960 980 1000 1020 1040 1060
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Trib 2 RS = 126
Elevation (m)
Station (m)
71.0
70.5
70.0
69.5
69.0
68.5
68.0
940 960 980 1000 1020 1040 1060 1080 1100
Legend
EG 100
WS 100
Ground
Levee
Bank Sta



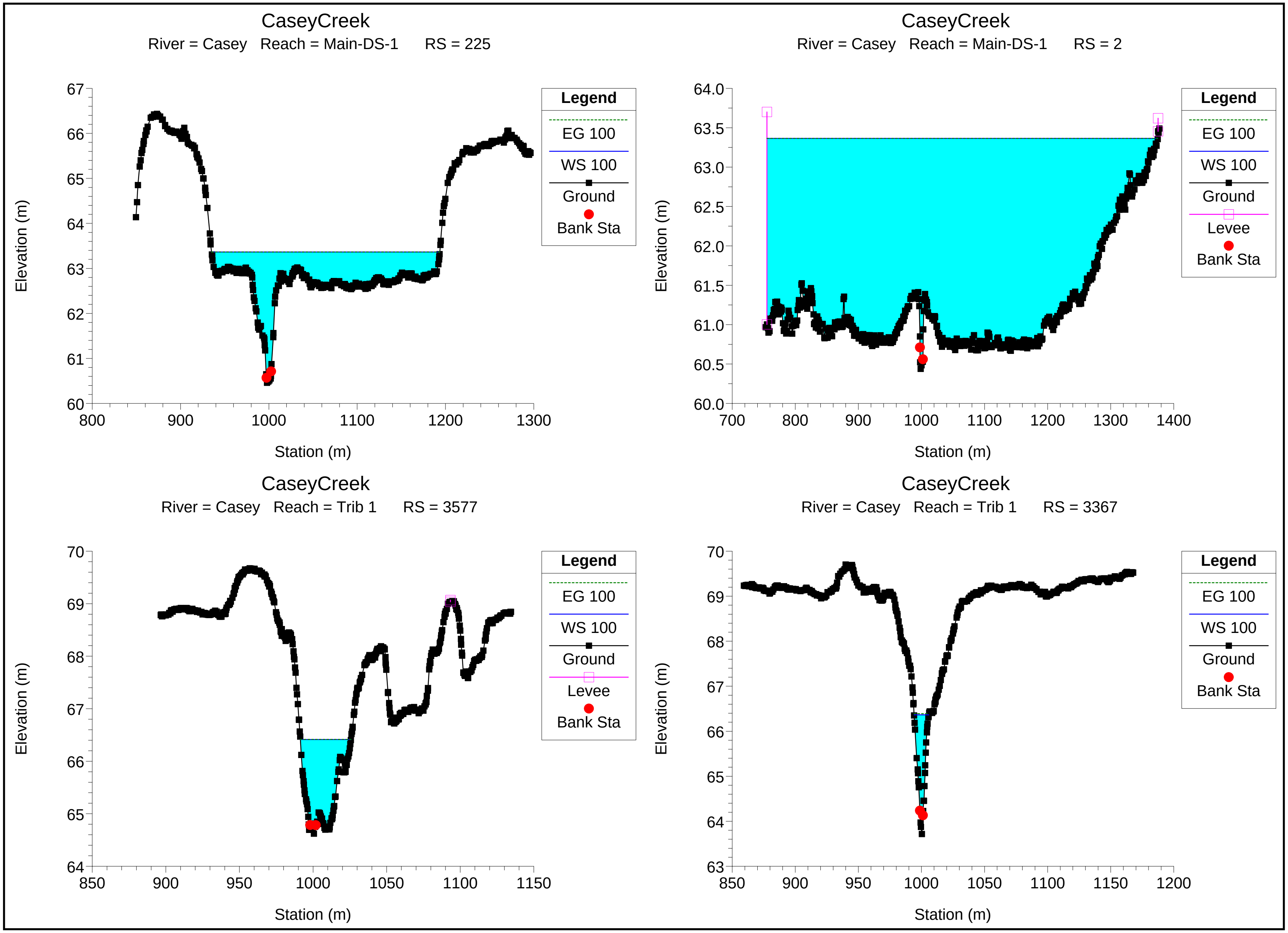
CaseyCreek
River = Casey Reach = Trib 2 RS = 6
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-2 RS = 784
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-2 RS = 719
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-2 RS = 643
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)

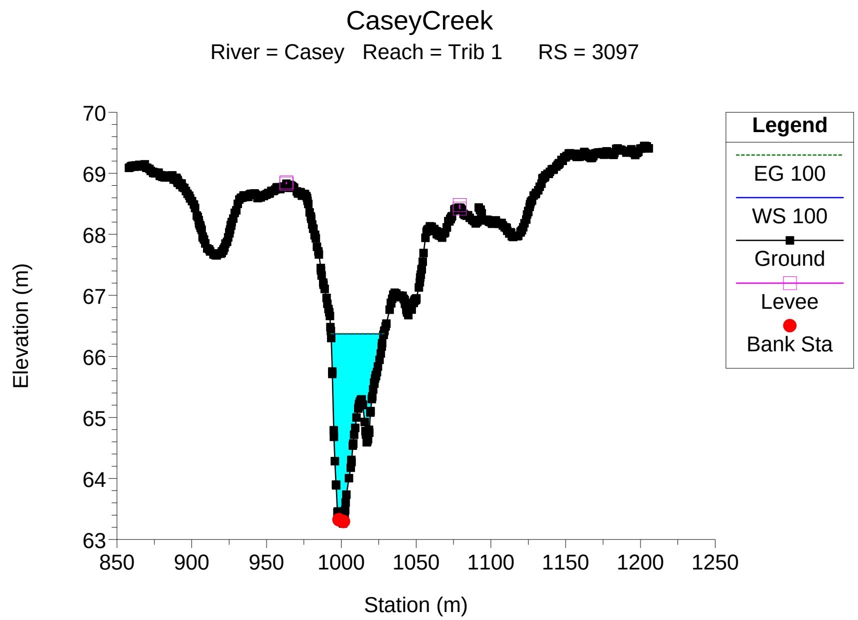

CaseyCreek
River = Casey Reach = Main-DS-2 RS = 164
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-2 RS = 3
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 1849
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 1597
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

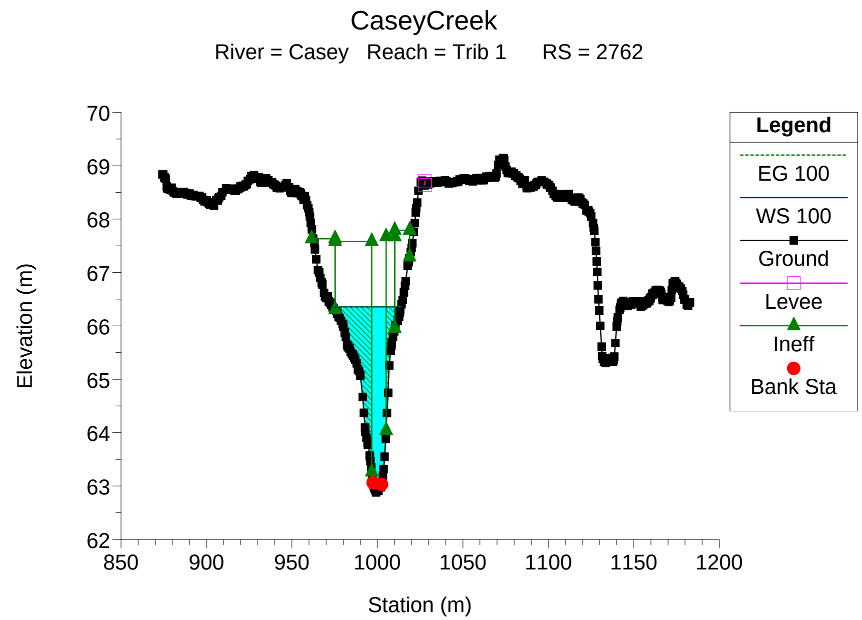

CaseyCreek
River = Casey Reach = Main-DS-1 RS = 1317
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 978
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 704
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 698 Culv
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta

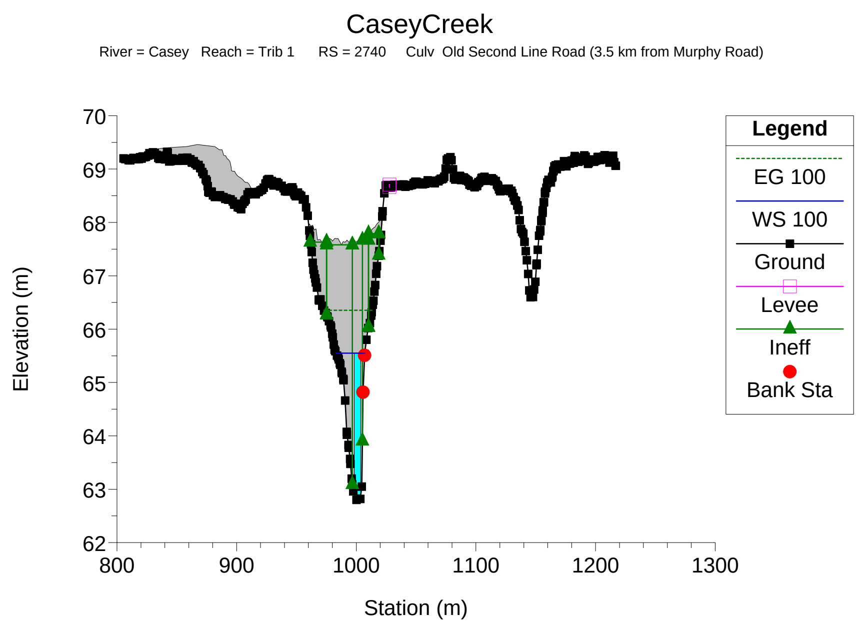


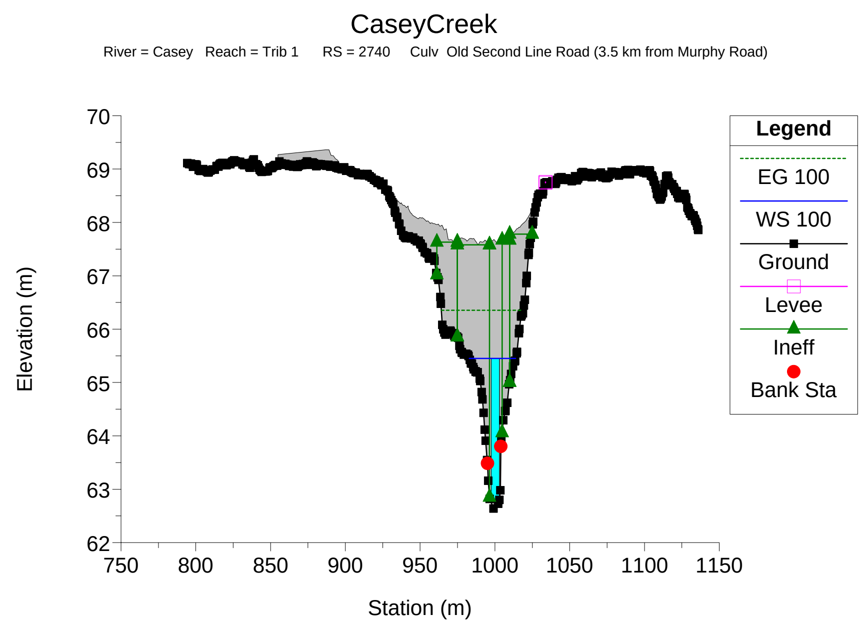
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 698 Culv
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 694
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 677
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 383
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)

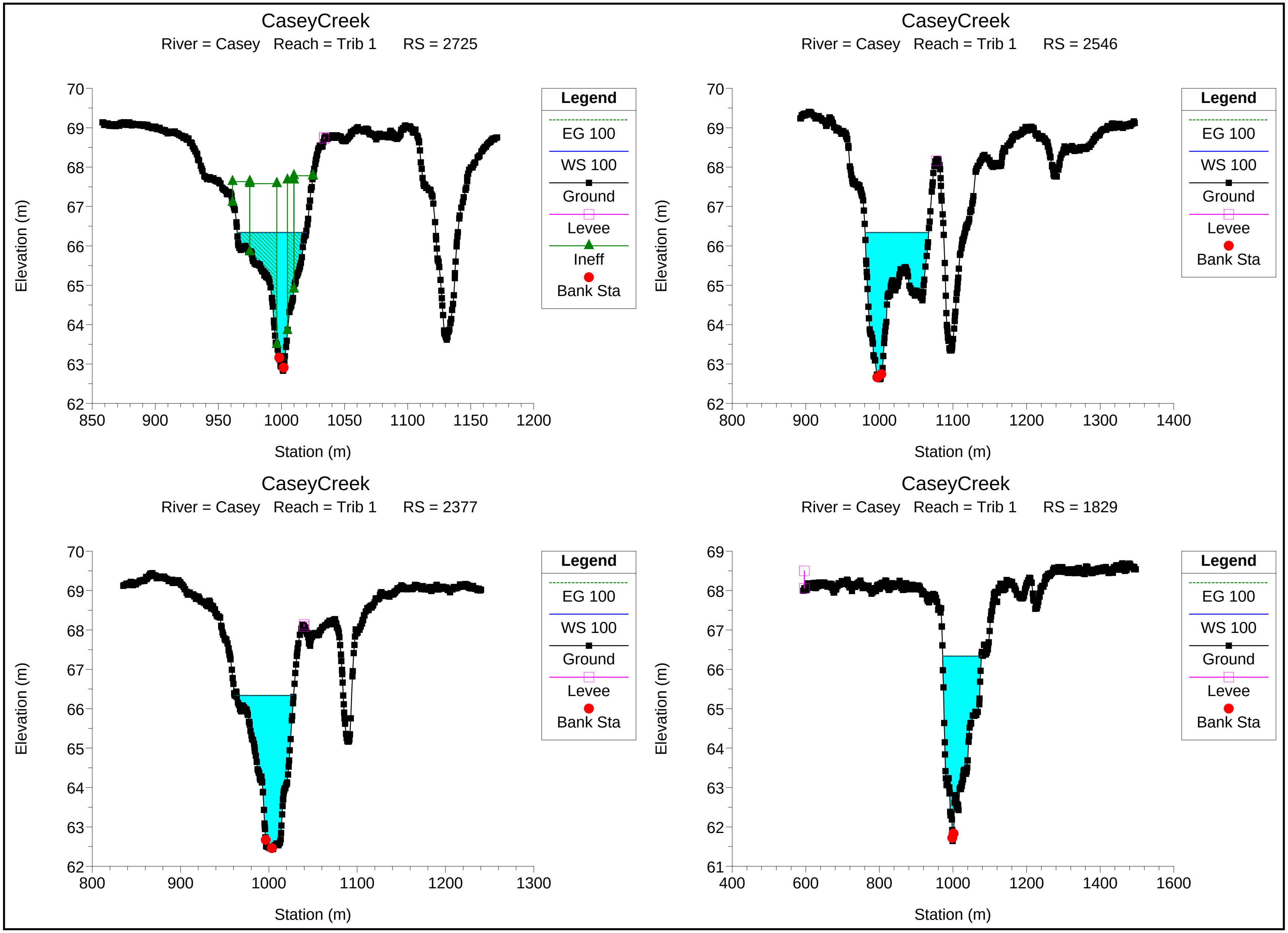

CaseyCreek
River = Casey Reach = Main-DS-1 RS = 225
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
60
61
62
63
64
65
66
67
800
900
1000
1100
1200
1300
CaseyCreek
River = Casey Reach = Main-DS-1 RS = 2
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
60.0
60.5
61.0
61.5
62.0
62.5
63.0
63.5
64.0
700
800
900
1000
1100
1200
1300
1400
CaseyCreek
River = Casey Reach = Trib 1 RS = 3577
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
64
65
66
67
68
69
70
850
900
950
1000
1050
1100
1150
CaseyCreek
River = Casey Reach = Trib 1 RS = 3367
Legend
EG 100
WS 100
Ground
Bank Sta
Elevation (m)
Station (m)
63
64
65
66
67
68
69
70
850
900
950
1000
1050
1100
1150
1200


CaseyCreek
River = Casey Reach = Trib 1 RS = 3097
Elevation (m)
70
69
68
67
66
65
64
63
850 900 950 1000 1050 1100 1150 1200 1250
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

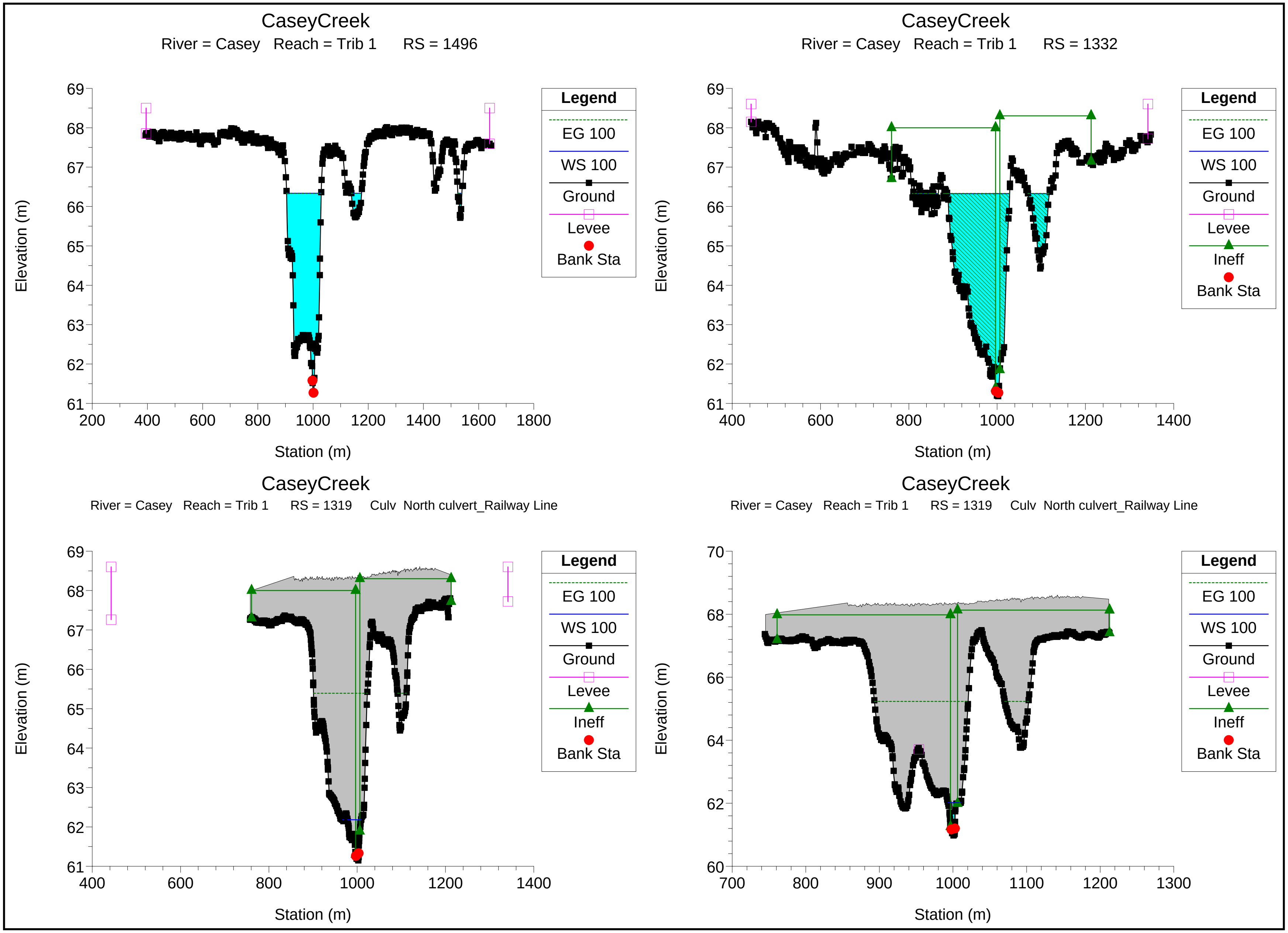

CaseyCreek
River = Casey Reach = Trib 1 RS = 2762
Elevation (m)
70
69
68
67
66
65
64
63
62
850 900 950 1000 1050 1100 1150 1200
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta


CaseyCreek
River = Casey Reach = Trib 1 RS = 2740 Culv Old Second Line Road (3.5 km from Murphy Road)
Elevation (m)
70
69
68
67
66
65
64
63
62
800 900 1000 1100 1200 1300
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta

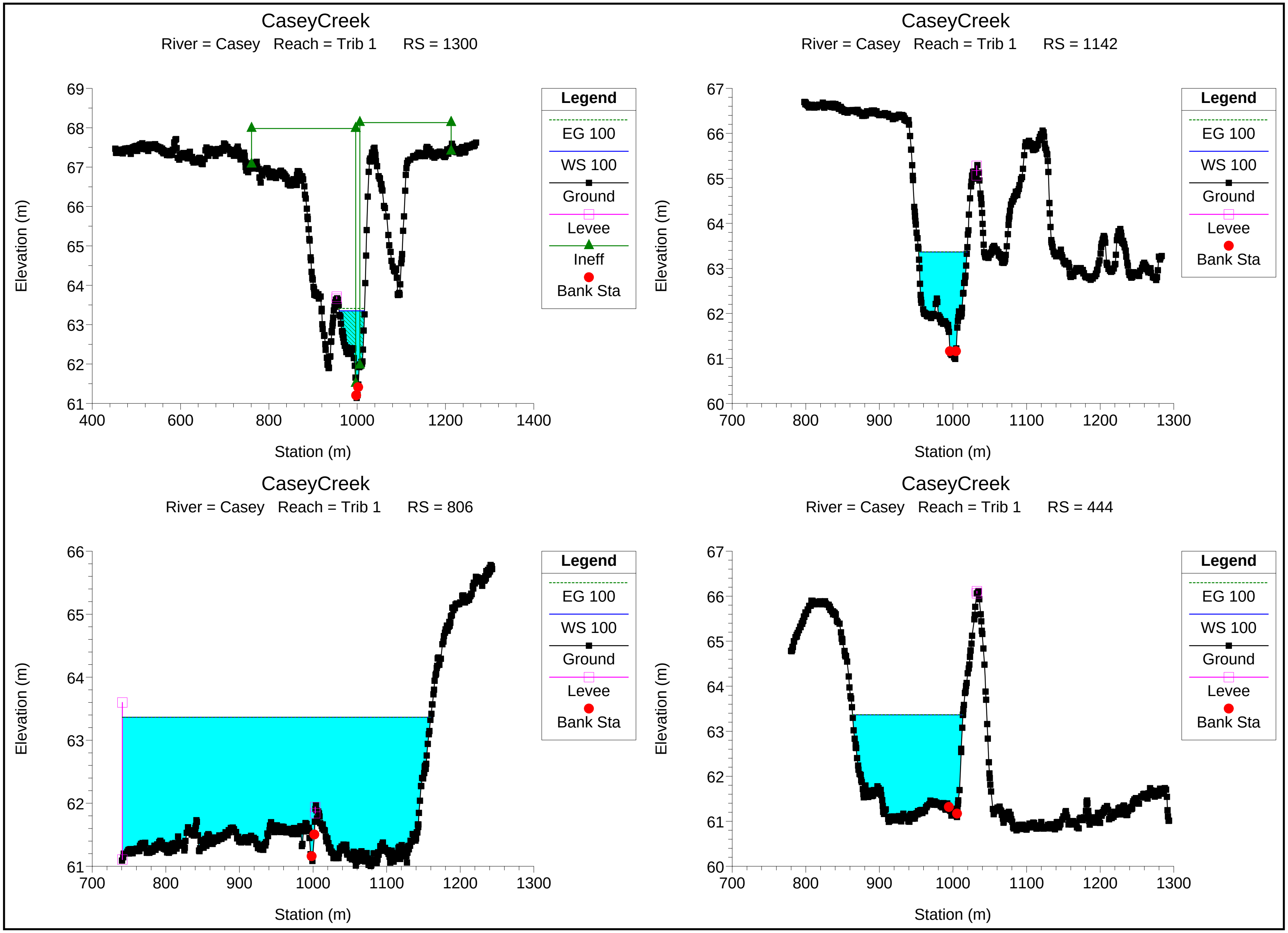

CaseyCreek
River = Casey Reach = Trib 1 RS = 2740 Culv Old Second Line Road (3.5 km from Murphy Road)
Elevation (m)
70
69
68
67
66
65
64
63
62
750 800 850 900 950 1000 1050 1100 1150
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta

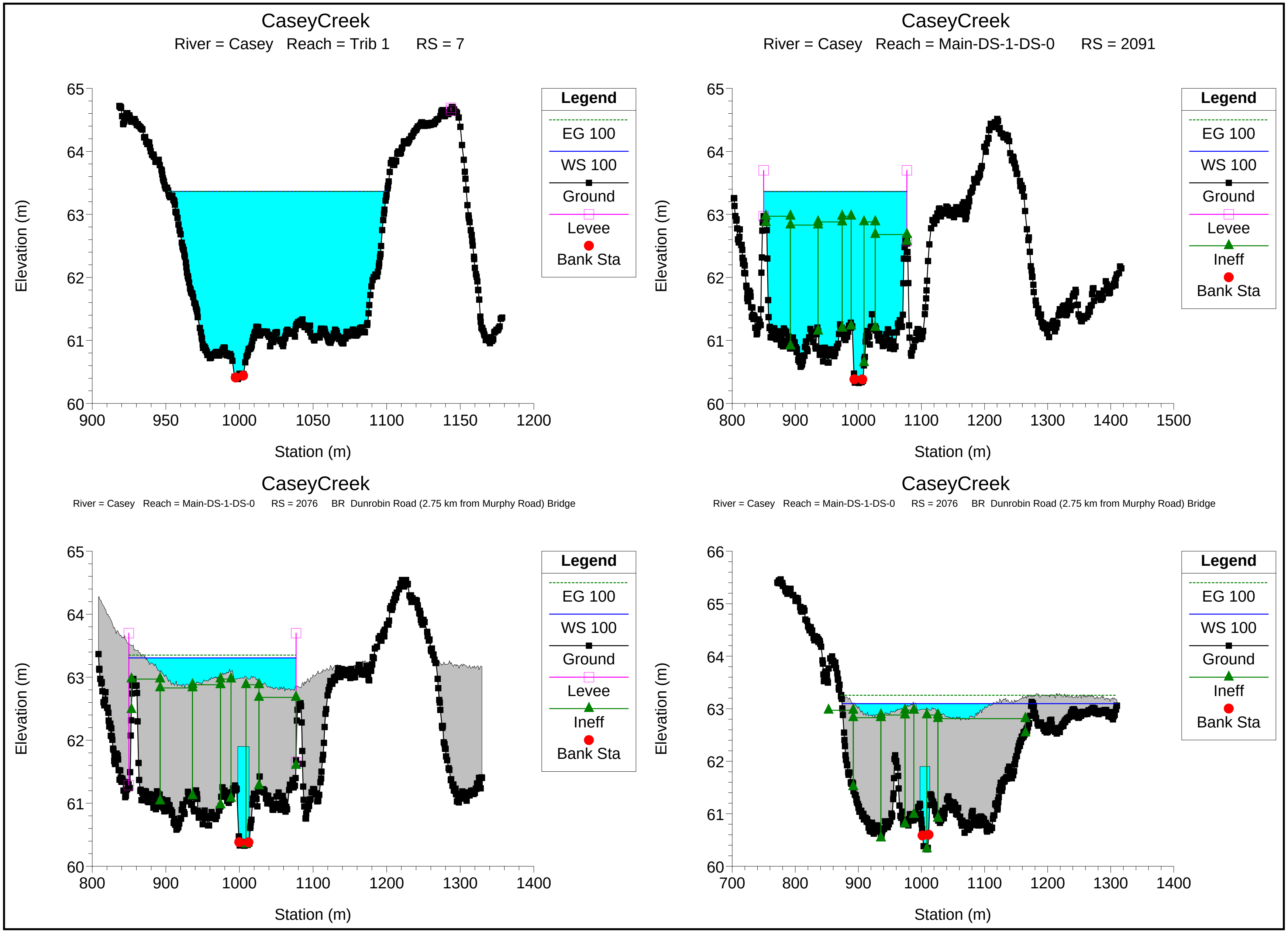


CaseyCreek
River = Casey Reach = Trib 1 RS = 2725
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 2546
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 2377
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 1829
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta

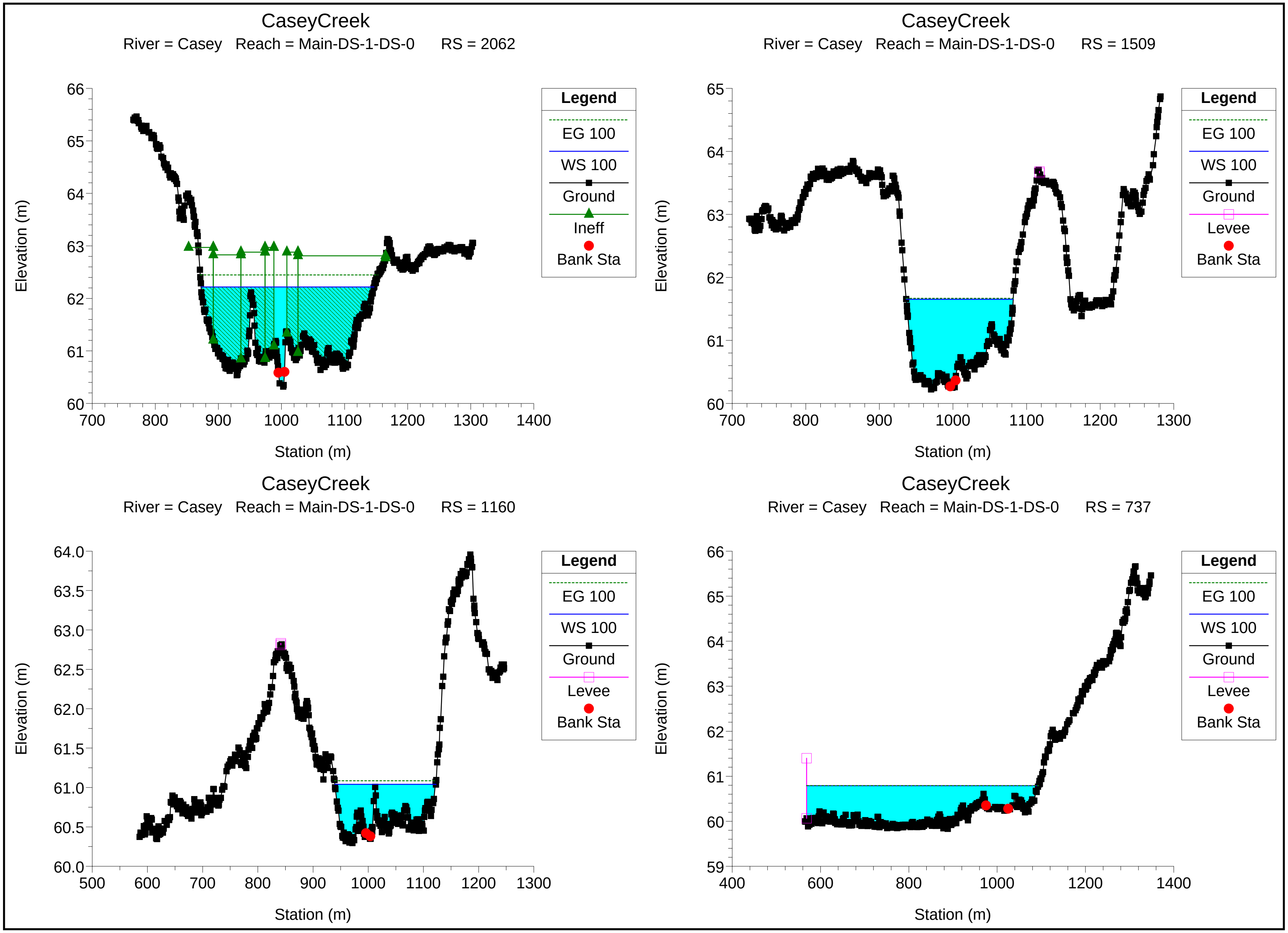


CaseyCreek
River = Casey Reach = Trib 1 RS = 1496
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 1332
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 1319 Culv North culvert_Railway Line
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Trib 1 RS = 1319 Culv North culvert_Railway Line
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta

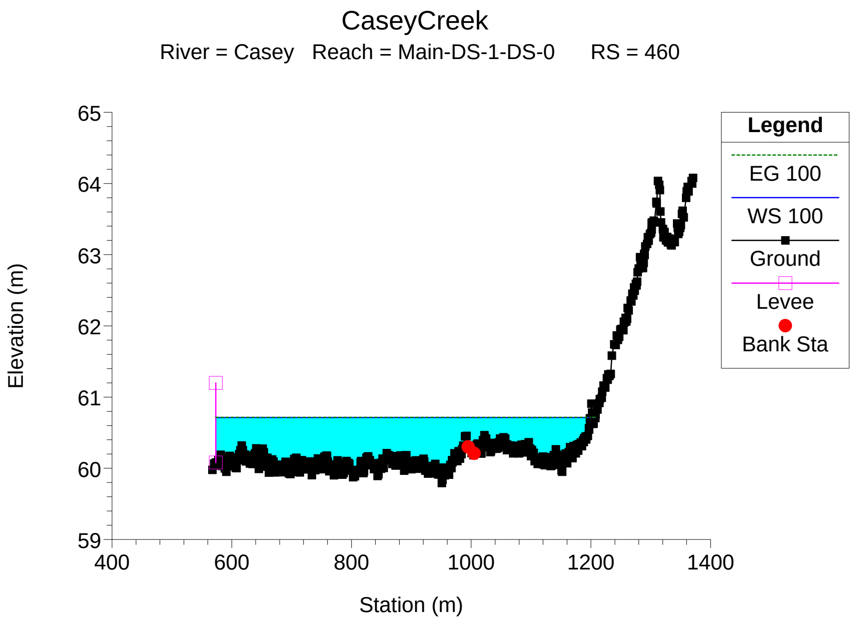

CaseyCreek
River = Casey Reach = Trib 1 RS = 1300
CaseyCreek
River = Casey Reach = Trib 1 RS = 1142
CaseyCreek
River = Casey Reach = Trib 1 RS = 806
CaseyCreek
River = Casey Reach = Trib 1 RS = 444
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
Elevation (m)
Station (m)

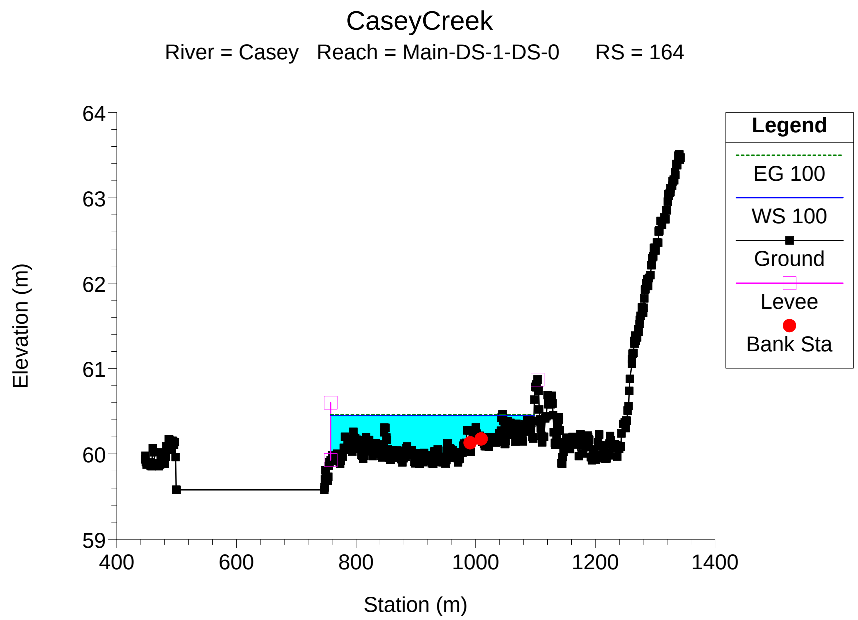


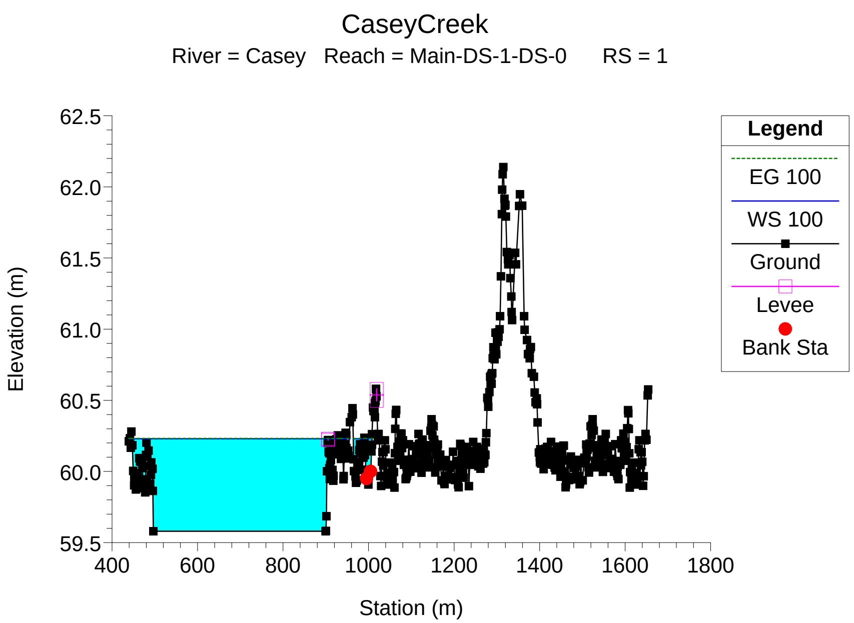
CaseyCreek
River = Casey Reach = Trib 1 RS = 7
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 2091
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 2076 BR Dunrobin Road (2.75 km from Murphy Road) Bridge
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Levee
Ineff
Bank Sta
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 2076 BR Dunrobin Road (2.75 km from Murphy Road) Bridge
Elevation (m)
Station (m)
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta

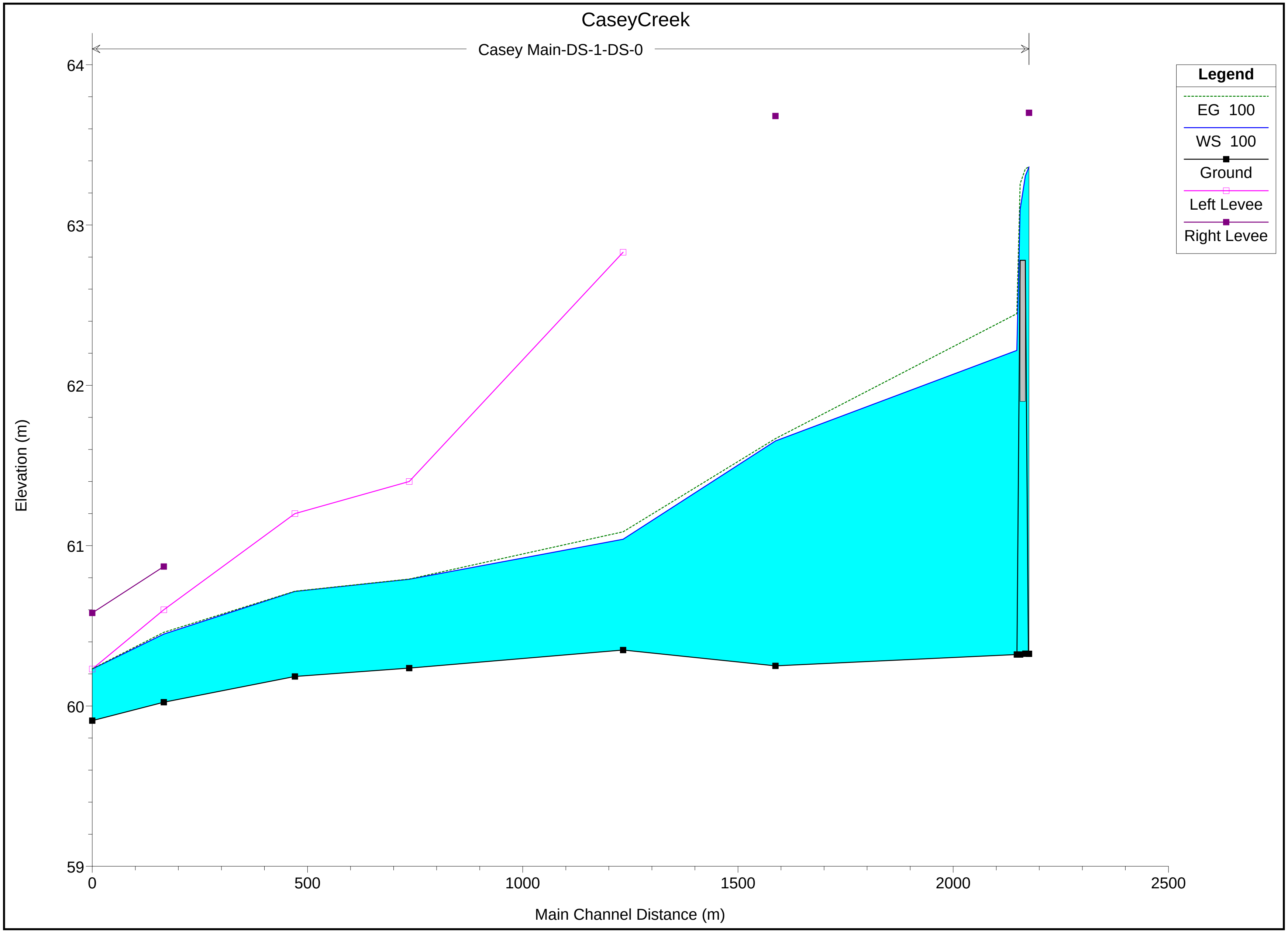


CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 2062
Legend
EG 100
WS 100
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 1509
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 1160
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 737
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)

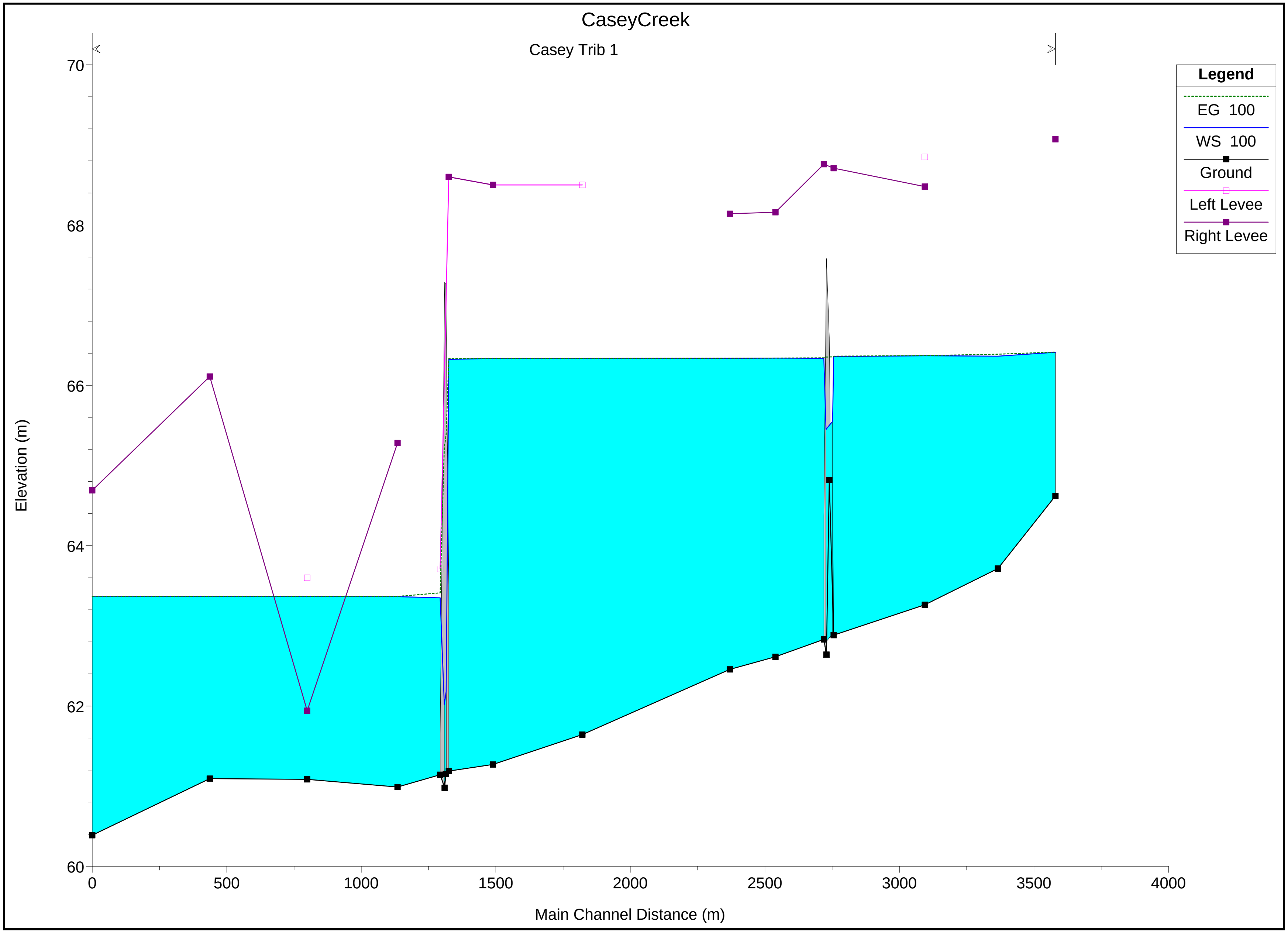

CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 460
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
65
64
63
62
61
60
59
400
600
800
1000
1200
1400

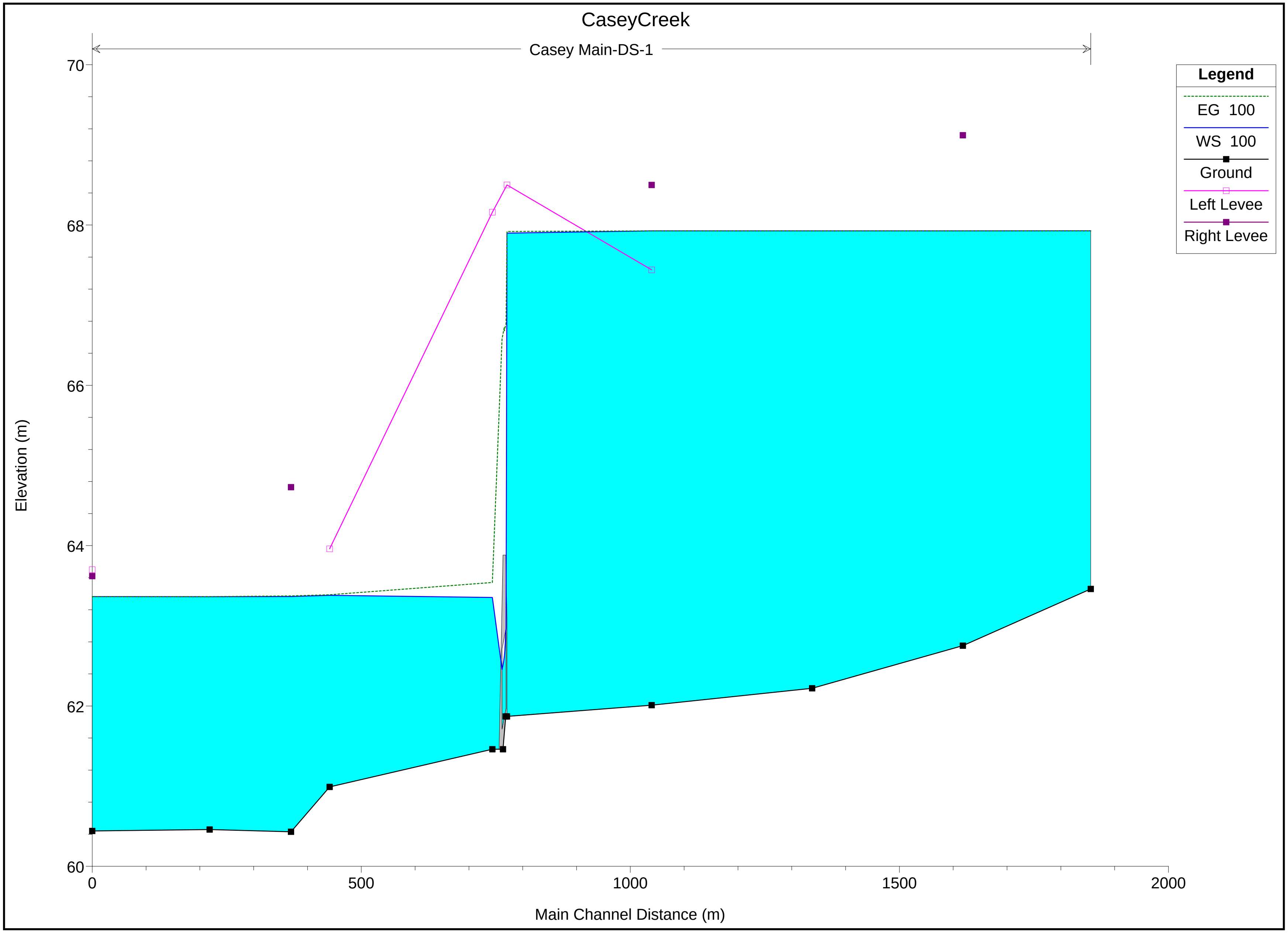

CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 164
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
64
63
62
61
60
59
400
600
800
1000
1200
1400

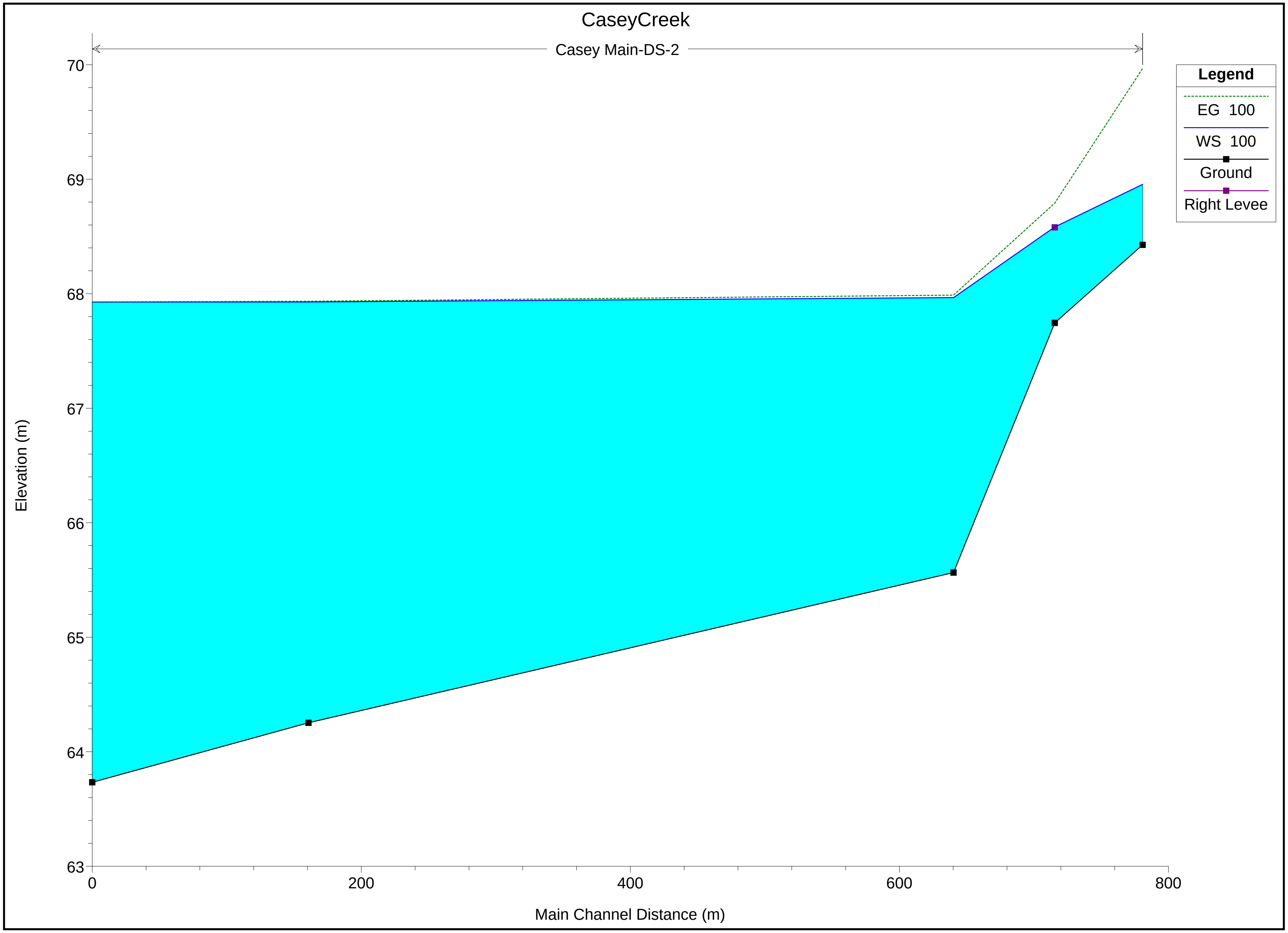

CaseyCreek
River = Casey Reach = Main-DS-1-DS-0 RS = 1
Legend
EG 100
WS 100
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
62.5
62.0
61.5
61.0
60.5
60.0
59.5
400
600
800
1000
1200
1400
1600
1800

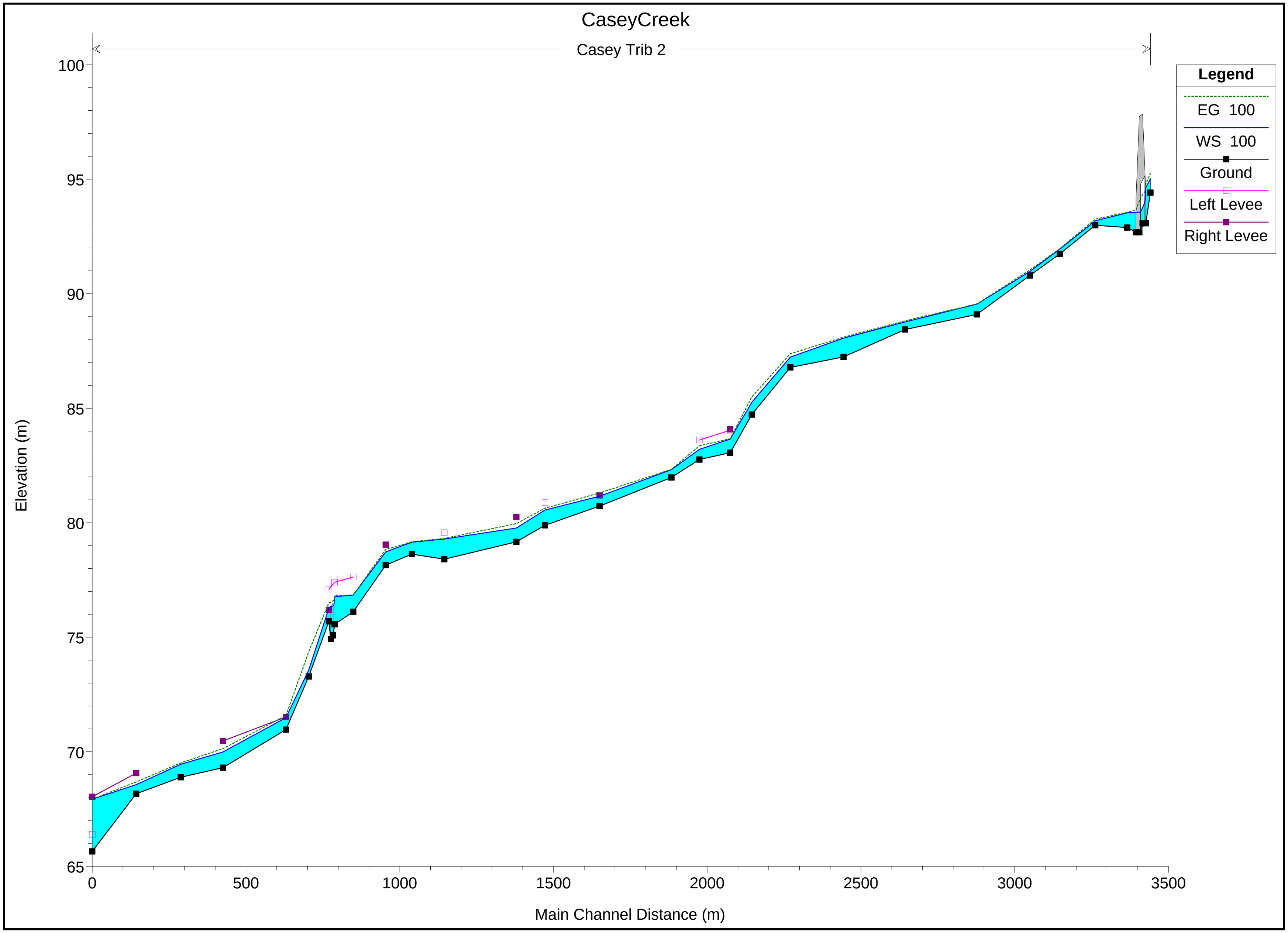


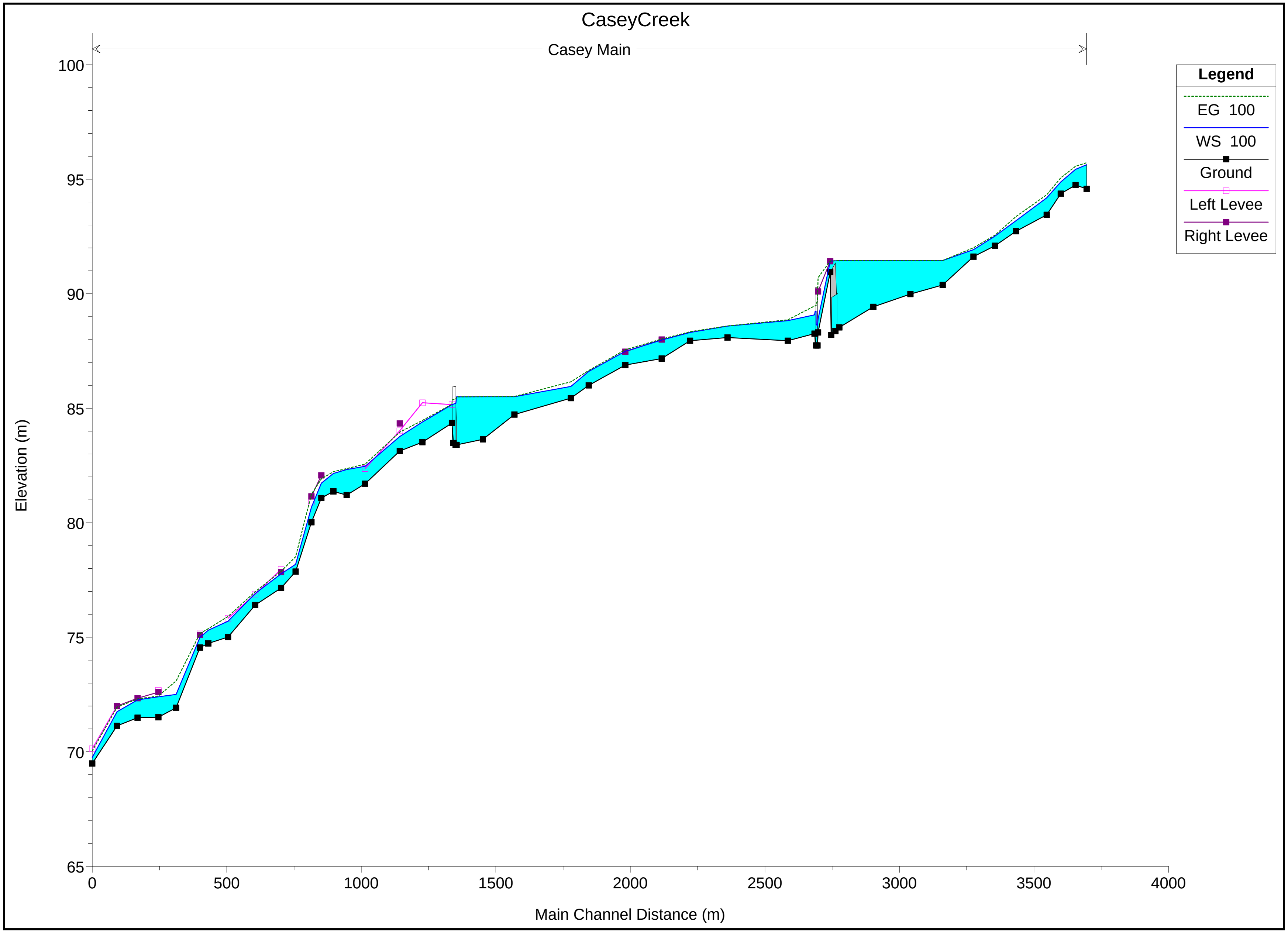
CaseyCreek
Casey Main-DS-1-DS-0
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
64
63
62
61
60
59
0
500
1000
1500
2000
2500

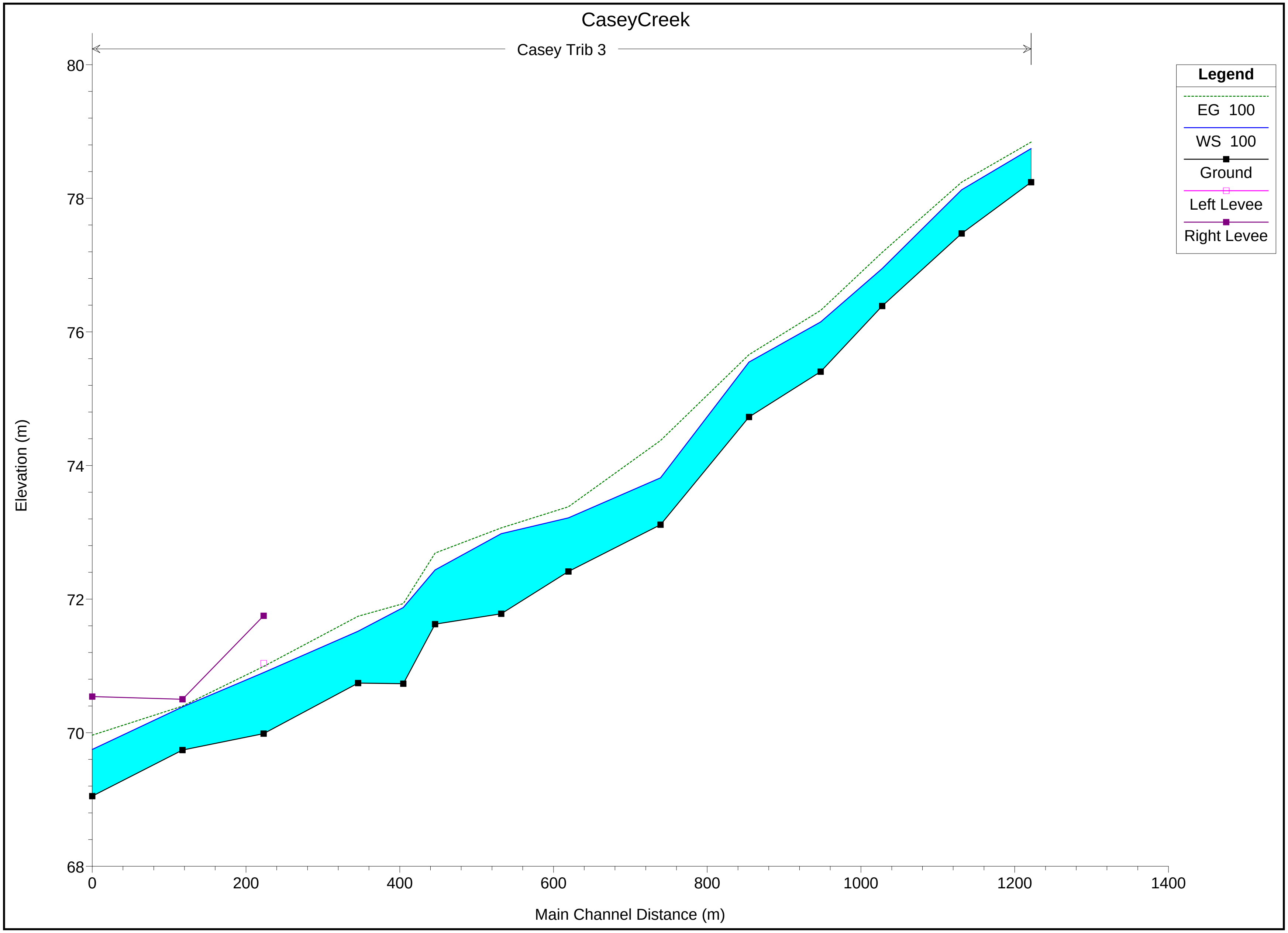

CaseyCreek
Casey Trib 1
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
70
68
66
64
62
60
0
500
1000
1500
2000
2500
3000
3500
4000


CaseyCreek
Casey Main-DS-1
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
70
68
66
64
62
60
0
500
1000
1500
2000


CaseyCreek
Casey Main-DS-2
Legend
EG 100
WS 100
Ground
Right Levee
Elevation (m)
Main Channel Distance (m)
70
69
68
67
66
65
64
63
0
200
400
600
800


CaseyCreek
Casey Trib 2
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
65
70
75
80
85
90
95
100
0
500
1000
1500
2000
2500
3000
3500


CaseyCreek
Casey Main
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
100
95
90
85
80
75
70
65
0
500
1000
1500
2000
2500
3000
3500
4000



CaseyCreek
Casey Trib 3
Legend
EG 100
WS 100
Ground
Left Levee
Right Levee
Elevation (m)
Main Channel Distance (m)
80
78
76
74
72
70
68
0
200
400
600
800
1000
1200
1400

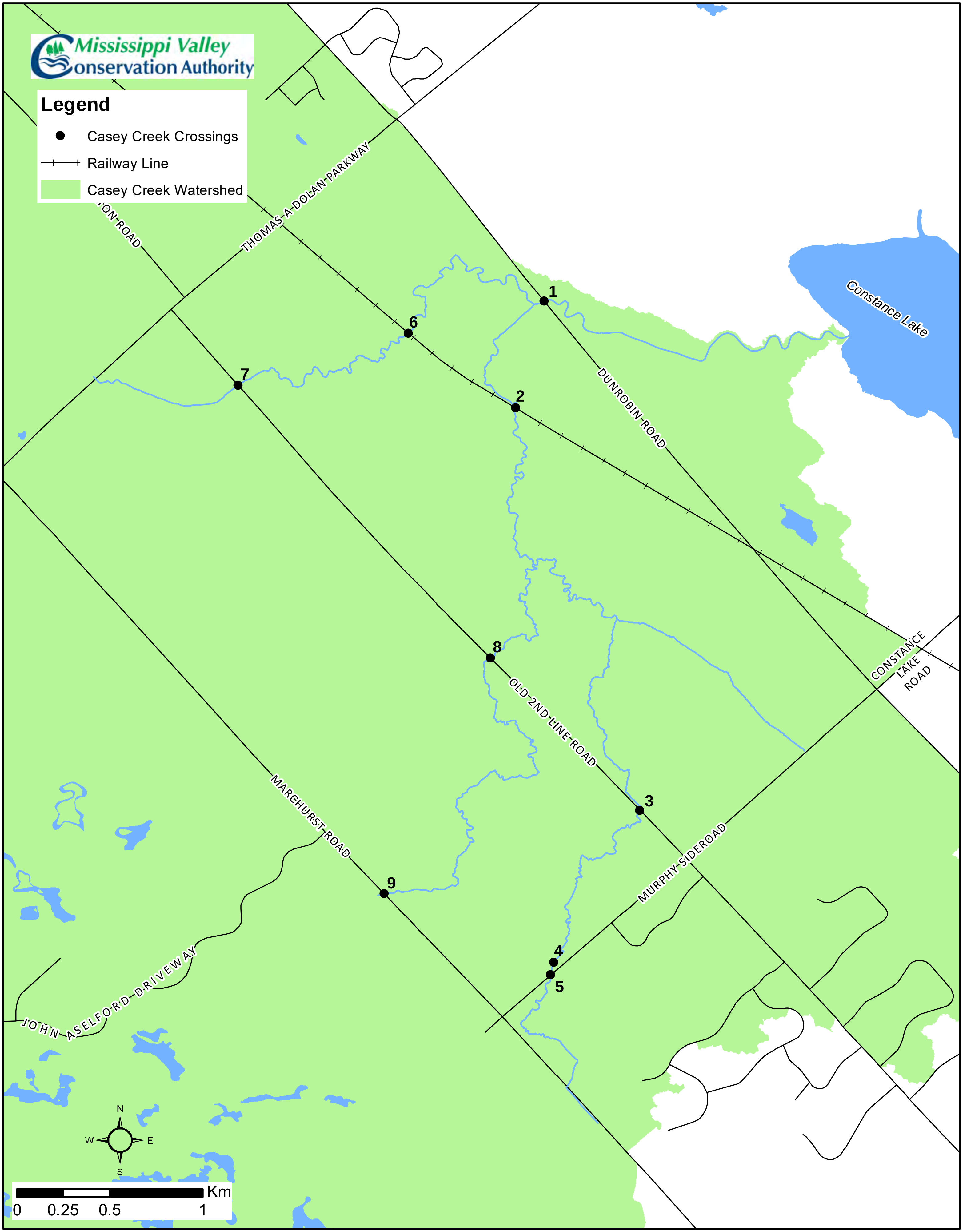
Appendix E

Structure Database

Table E-1 - Existing Structure Database											
Structure Location	Structure Number[1]	Cross-Section	Structure Type	Upstream Invert (m)	Downstream Invert (m)	Upstream Low Chord or Obvert (m)	Diameter or Height (m)	Width or Span (m)	Bridge Deck/Roadway Width[1] (m)	Culvert/Bridge Length (m)	Minimum Top of Road Elevation[2] (m)
Main Reach											
Dunrobin Road	1	2076	Concrete bridge, open bottom	60.33	60.33	61.9	1.55	15.4	12.1	21.3	62.8
Abandoned Railway Crossing	2	698	Concrete Box Culvert	61.97	61.71	62.97	1.0	3.0	4.6	7.9	67.7
Second Line Road	3	1303	Round Concrete Pipe	83.55	83.53	85.95	2.4	-	8.3	13.3	85.47
Farm crossing (50 m d/s of Murphy Side Road)	4	2659	Round Corrugated Metal Pipe	87.79	87.76	90.29	2.5	-	5.0	8.8	89.25
Murphy Side Road	5	2728	Concrete Box Culvert	88.46	88.29	90.01	1.55	3.05	15.8	32.9	91.35
Tributary 1 (Northwest Tributary Reach)											
Abandoned Railway Crossing	6	1319	Concrete Box Culvert	61.18	61.22	62.18	1.0	3.0	4.2	7.9	68.24
Second Line Road	7	2740	Concrete Box Culvert	62.9	62.8	65.55	2.65	5.4	10.6	24.6	67.58
Tributary 2 (Middle Tributary Reach)											
Second Line Road	8	760	Corrugated Metal Pipe Arch	75.11	74.94	76.51	1.4	1.8	7.0	12.2	77.0
Marchurst Road	9	3393	CSP Culvert	93.13	92.78	95.13	2.0	-	10.6	14.4	97.85

[1]: See Figure below

[2]: Road width (parallel to the flow) measured from aerial photographs and Minimum top of road obtained from the DEM



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Dunrobin Road on Main

Abandoned Railway Crossing Main

Second Line Road on Main

Farm crossing on Main

Murphy Road on Main

Abandoned Railway Crossing on Tributary1 (Northwest Tributary)

Second Line Road on Tributary 1- (Northwest Tributary)

Second Line Road on Tributary 2 (Middle Tributary)

Marchurst Road on Tributary 2 (Middle Tributary Tributary)

Appendix F

Calculated Water Surface Elevations for Casey Creek

Water Surface Elevations for Various Return periods

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 3	1228	2	0.18	78.33	78.34	0.15	0.52	
Trib 3	1228	5	0.9	78.46	78.5	0.37	0.9	0.15
Trib 3	1228	10	1.66	78.54	78.6	0.47	1.11	0.3
Trib 3	1228	25	2.89	78.65	78.73	0.37	1.31	0.41
Trib 3	1228	50	3.89	78.71	78.79	0.39	1.42	0.45
Trib 3	1228	100	5	78.74	78.84	0.45	1.56	0.5
Trib 3	1141	2	0.18	77.63	77.64	0.28	0.55	0.04
Trib 3	1141	5	0.9	77.77	77.82	0.55	1.06	0.37
Trib 3	1141	10	1.66	77.86	77.93	0.65	1.33	0.54
Trib 3	1141	25	2.89	77.97	78.08	0.57	1.64	0.67
Trib 3	1141	50	3.89	78.04	78.16	0.63	1.79	0.72
Trib 3	1141	100	5	78.13	78.24	0.59	1.82	0.42
Trib 3	1037	2	0.18	76.49	76.53	0.42	0.9	0.32
Trib 3	1037	5	0.9	76.63	76.72	0.71	1.46	0.61
Trib 3	1037	10	1.66	76.72	76.84	0.86	1.76	0.78
Trib 3	1037	25	2.89	76.83	76.99	1.02	2.11	0.9
Trib 3	1037	50	3.89	76.91	77.09	1.06	2.3	1
Trib 3	1037	100	5	76.95	77.19	1.15	2.69	1.18
Trib 3	957	2	0.18	75.61	75.62	0.16	0.54	0.19
Trib 3	957	5	0.9	75.82	75.86	0.39	1	0.45
Trib 3	957	10	1.66	75.94	76	0.49	1.26	0.58
Trib 3	957	25	2.89	76.06	76.15	0.61	1.62	0.76
Trib 3	957	50	3.89	76.08	76.23	0.77	2.06	0.97
Trib 3	957	100	5	76.15	76.32	0.77	2.28	1.07
Trib 3	864	2	0.18	74.91	74.96		1	
Trib 3	864	5	0.9	75.09	75.2	0.58	1.48	0.15
Trib 3	864	10	1.66	75.2	75.35	0.72	1.74	0.43
Trib 3	864	25	2.89	75.37	75.52	0.57	1.85	0.59
Trib 3	864	50	3.89	75.5	75.61	0.44	1.69	0.56
Trib 3	864	100	5	75.55	75.66	0.53	1.81	0.6
Trib 3	749	2	0.18	73.39	73.41		0.51	
Trib 3	749	5	0.9	73.63	73.68	0.3	0.98	0.28
Trib 3	749	10	1.66	73.77	73.85	0.44	1.26	0.42

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 3	749	25	2.89	73.92	74.04	0.59	1.62	0.61
Trib 3	749	50	3.89	73.71	74.27	1.13	3.38	1.07
Trib 3	749	100	5	73.82	74.37	1.22	3.44	1.19
Trib 3	625	2	0.18	72.54	72.59		0.95	
Trib 3	625	5	0.9	72.72	72.82		1.42	0.08
Trib 3	625	10	1.66	72.83	72.97		1.66	0.38
Trib 3	625	25	2.89	72.98	73.14		1.78	0.59
Trib 3	625	50	3.89	73.1	73.26	0.32	1.79	0.62
Trib 3	625	100	5	73.22	73.38	0.47	1.84	0.66
Trib 3	537	2	0.18	72.06	72.07	0.06	0.35	0.06
Trib 3	537	5	0.9	72.36	72.38	0.24	0.72	0.27
Trib 3	537	10	1.66	72.53	72.57	0.32	0.93	0.37
Trib 3	537	25	2.89	72.73	72.79	0.42	1.17	0.48
Trib 3	537	50	3.89	72.86	72.93	0.49	1.32	0.55
Trib 3	537	100	5	72.98	73.06	0.55	1.46	0.61
Trib 3	449	2	0.18	71.78	71.83		1.01	
Trib 3	449	5	0.9	71.97	72.09		1.49	
Trib 3	449	10	1.66	72.09	72.25		1.74	
Trib 3	449	25	2.89	72.24	72.44		1.99	
Trib 3	449	50	3.89	72.34	72.57		2.12	
Trib 3	449	100	5	72.44	72.69		2.23	
Trib 3	408	2	0.18	71.03	71.03	0.07	0.27	0.11
Trib 3	408	5	0.9	71.29	71.31	0.21	0.59	0.27
Trib 3	408	10	1.66	71.45	71.47	0.29	0.78	0.36
Trib 3	408	25	2.89	71.64	71.68	0.39	0.98	0.46
Trib 3	408	50	3.89	71.77	71.82	0.44	1.1	0.52
Trib 3	408	100	5	71.87	71.93	0.51	1.25	0.58
Trib 3	350	2	0.18	70.9	70.94		0.92	
Trib 3	350	5	0.9	71.09	71.17		1.25	0.13
Trib 3	350	10	1.66	71.24	71.33	0.17	1.33	0.35
Trib 3	350	25	2.89	71.44	71.54	0.35	1.42	0.45
Trib 3	350	50	3.89	71.58	71.69	0.43	1.49	0.47
Trib 3	350	100	5	71.52	71.74	0.58	2.14	0.68
Trib 3	227	2	0.18	70.26	70.27		0.45	0.01

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 3	227	5	0.9	70.52	70.55	0.12	0.8	0.22
Trib 3	227	10	1.66	70.62	70.68	0.26	1.12	0.35
Trib 3	227	25	2.89	70.68	70.82	0.45	1.71	0.59
Trib 3	227	50	3.89	70.71	70.93	0.59	2.16	0.77
Trib 3	227	100	5	70.9	70.99	0.5	1.57	0.32
Trib 3	122	2	0.18	69.98	69.99		0.47	0.16
Trib 3	122	5	0.9	70.18	70.22	0.08	0.89	0.37
Trib 3	122	10	1.66	70.26	70.29	0.16	0.98	0.39
Trib 3	122	25	2.89	70.31	70.33	0.22	0.95	0.31
Trib 3	122	50	3.89	70.35	70.36	0.24	0.91	0.31
Trib 3	122	100	5	70.38	70.4	0.25	0.85	0.31
Trib 3	5	2	0.18	69.18	69.22		0.92	0.23
Trib 3	5	5	0.9	69.34	69.44	0.37	1.44	0.52
Trib 3	5	10	1.66	69.45	69.58	0.55	1.72	0.69
Trib 3	5	25	2.89	69.58	69.75	0.69	1.98	0.81
Trib 3	5	50	3.89	69.67	69.86	0.79	2.15	0.9
Trib 3	5	100	5	69.75	69.96	0.89	2.32	1
Main	3689	2	0.07	94.93	94.93	0.02	0.14	
Main	3689	5	0.42	95.14	95.15	0.13	0.46	0.06
Main	3689	10	0.84	95.28	95.3	0.21	0.7	0.1
Main	3689	25	1.58	95.43	95.48	0.31	1	0.18
Main	3689	50	2.21	95.54	95.6	0.38	1.19	0.26
Main	3689	100	2.92	95.63	95.72	0.46	1.37	0.33
Main	3648	2	0.07	94.91	94.91		0.37	
Main	3648	5	0.42	95.07	95.09	0.15	0.73	0.09
Main	3648	10	0.84	95.16	95.21	0.28	0.98	0.24
Main	3648	25	1.58	95.28	95.36	0.43	1.3	0.39
Main	3648	50	2.21	95.36	95.47	0.53	1.51	0.49
Main	3648	100	2.92	95.43	95.56	0.61	1.7	0.58
Main	3593	2	0.07	94.46	94.48		0.73	
Main	3593	5	0.42	94.57	94.64		1.11	
Main	3593	10	0.84	94.65	94.74		1.33	
Main	3593	25	1.58	94.75	94.87	0.24	1.59	
Main	3593	50	2.21	94.81	94.97	0.4	1.74	
Main	3593	100	2.92	94.88	95.06	0.49	1.88	

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	3541	2	0.07	93.6	93.61	0.09	0.39	
Main	3541	5	0.42	93.78	93.81	0.31	0.8	0.1
Main	3541	10	0.84	93.89	93.95	0.44	1.08	0.25
Main	3541	25	1.58	94.03	94.12	0.5	1.4	0.41
Main	3541	50	2.21	94.11	94.22	0.61	1.63	0.51
Main	3541	100	2.92	94.19	94.32	0.72	1.79	0.59
Main	3427	2	0.07	92.78	92.8	0.17	0.64	0.18
Main	3427	5	0.42	92.87	92.94	0.47	1.14	0.44
Main	3427	10	0.84	92.95	93.05	0.6	1.41	0.56
Main	3427	25	1.58	93.05	93.19	0.75	1.74	0.7
Main	3427	50	2.21	93.13	93.28	0.84	1.86	0.72
Main	3427	100	2.92	93.19	93.38	0.95	2.05	0.83
Main	3349	2	0.07	92.19	92.2	0.12	0.29	0.06
Main	3349	5	0.42	92.29	92.31	0.25	0.54	0.22
Main	3349	10	0.84	92.36	92.37	0.34	0.68	0.29
Main	3349	25	1.58	92.43	92.45	0.46	0.85	0.39
Main	3349	50	2.21	92.47	92.5	0.55	0.97	0.46
Main	3349	100	2.92	92.52	92.56	0.62	1.09	0.53
Main	3268	2	0.07	91.67	91.69	0.4	0.62	
Main	3268	5	0.42	91.74	91.77	0.55	0.92	
Main	3268	10	0.84	91.78	91.83	0.69	1.17	0.2
Main	3268	25	1.58	91.84	91.91	0.76	1.4	0.39
Main	3268	50	2.21	91.89	91.96	0.72	1.49	0.5
Main	3268	100	2.92	91.93	92.01	0.78	1.59	0.57
Main	3154	2	0.07	91.02	91.02	0.01	0.03	0.01
Main	3154	5	0.42	91.24	91.24	0.03	0.08	0.03
Main	3154	10	0.84	91.42	91.42	0.05	0.1	0.04
Main	3154	25	1.58	91.65	91.65	0.06	0.12	0.05
Main	3154	50	2.21	91.44	91.44	0.12	0.25	0.1
Main	3154	100	2.92	91.45	91.45	0.16	0.33	0.13
Main	3034	2	0.07	91.02	91.02	0	0	0
Main	3034	5	0.42	91.24	91.24	0.01	0.02	0.01
Main	3034	10	0.84	91.42	91.42	0.01	0.03	0.01
Main	3034	25	1.58	91.65	91.65	0.02	0.04	0.02

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	3034	50	2.21	91.44	91.44	0.04	0.08	0.03
Main	3034	100	2.92	91.45	91.45	0.05	0.1	0.04
Main	2868	2	0.07	91.02	91.02	0	0	0
Main	2868	5	0.42	91.24	91.24	0	0.02	0
Main	2868	10	0.84	91.42	91.42	0	0.03	0
Main	2868	25	1.58	91.65	91.65	0	0.04	0
Main	2868	50	2.21	91.44	91.44	0	0.07	0
Main	2868	100	2.92	91.45	91.45	0.01	0.09	0
Main	2748	2	0.07	91.02	91.02		0.01	0
Main	2748	5	0.42	91.24	91.24		0.04	0
Main	2748	10	0.84	91.42	91.42		0.06	0
Main	2748	25	1.58	91.65	91.65	0	0.09	0
Main	2748	50	2.21	91.43	91.43	0.01	0.15	0
Main	2748	100	2.92	91.44	91.45	0.01	0.19	0.01
Main	2728		Culvert					
Main	2714	2	0.1	90.99	91.02	0.08	0.73	
Main	2714	5	0.84	91.14	91.24	0.15	1.41	
Main	2714	10	1.74	91.26	91.42	0.19	1.81	
Main	2714	25	3.39	91.42	91.65	0.19	2.24	0.06
Main	2714	50	4.83	91.42	91.42	0.04	0.48	0.05
Main	2714	100	6.47	91.42	91.42	0.05	0.65	0.07
Main	2665	2	0.1	88.41	88.49		1.3	
Main	2665	5	0.84	88.5	89.12		3.49	
Main	2665	10	1.74	88.58	89.52		4.29	0.07
Main	2665	25	3.39	88.71	89.95		4.93	0.13
Main	2665	50	4.83	88.75	90.72		6.23	0.18
Main	2665	100	6.47	88.89	90.7		5.97	0.19
Main	2659		Culvert					
Main	2652	2	0.1	88.33	88.36		0.72	
Main	2652	5	0.84	88.56	88.62		1.02	0.05
Main	2652	10	1.74	88.73	88.82		1.32	0.07
Main	2652	25	3.39	88.89	89.07		1.88	0.11
Main	2652	50	4.83	88.98	89.26		2.36	0.06

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	2652	100	6.47	89.08	89.46		2.76	0.05
Main	2545	2	0.1	88.24	88.24	0.06	0.11	0.04
Main	2545	5	0.84	88.45	88.46	0.25	0.45	0.17
Main	2545	10	1.74	88.57	88.58	0.4	0.71	0.19
Main	2545	25	3.39	88.68	88.71	0.54	0.96	0.27
Main	2545	50	4.83	88.76	88.79	0.61	1.1	0.31
Main	2545	100	6.47	88.83	88.86	0.64	1.19	0.37
Main	2321	2	0.1	88.21	88.21	0.07	0.11	
Main	2321	5	0.84	88.34	88.34	0.13	0.23	0.06
Main	2321	10	1.74	88.41	88.41	0.17	0.3	0.1
Main	2321	25	3.39	88.49	88.5	0.22	0.38	0.14
Main	2321	50	4.83	88.54	88.54	0.27	0.45	0.17
Main	2321	100	6.47	88.59	88.59	0.31	0.52	0.19
Main	2182	2	0.1	88	88.02	0.15	0.59	
Main	2182	5	0.84	88.1	88.13	0.35	0.92	0.26
Main	2182	10	1.74	88.15	88.19	0.46	1.07	0.34
Main	2182	25	3.39	88.19	88.24	0.59	1.32	0.48
Main	2182	50	4.83	88.25	88.29	0.55	1.19	0.48
Main	2182	100	6.47	88.31	88.34	0.57	1.15	0.51
Main	2076	2	0.1	87.3	87.3	0.02	0.22	
Main	2076	5	0.84	87.58	87.59	0.19	0.41	
Main	2076	10	1.74	87.72	87.73	0.24	0.57	0.1
Main	2076	25	3.39	87.85	87.88	0.21	0.8	0.21
Main	2076	50	4.83	87.9	87.94	0.29	0.97	0.27
Main	2076	100	6.47	87.98	88.02	0.35	1.06	0.29
Main	1940	2	0.1	87.07	87.08	0.19	0.42	0.04
Main	1940	5	0.84	87.22	87.3	0.63	1.41	0.48
Main	1940	10	1.74	87.34	87.43	0.47	1.63	0.61
Main	1940	25	3.39	87.45	87.52	0.53	1.65	0.49
Main	1940	50	4.83	87.47	87.52	0.55	1.67	0.49
Main	1940	100	6.47	87.49	87.56	0.67	1.93	0.61
Main	1805	2	0.1	86.04	86.07	0.67	0.66	
Main	1805	5	0.84	86.27	86.28	0.47	0.72	0.13
Main	1805	10	1.74	86.36	86.39	0.53	0.98	0.27

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	1805	25	3.39	86.46	86.5	0.68	1.2	0.26
Main	1805	50	4.83	86.52	86.57	0.75	1.34	0.33
Main	1805	100	6.47	86.61	86.65	0.72	1.32	0.42
Main	1738	2	0.1	85.57	85.57	0.12	0.23	
Main	1738	5	0.84	85.62	85.69	0.63	1.18	0.22
Main	1738	10	1.74	85.71	85.81	0.77	1.47	0.44
Main	1738	25	3.39	85.83	85.96	0.87	1.74	0.56
Main	1738	50	4.83	85.92	86.06	0.92	1.86	0.61
Main	1738	100	6.47	85.95	86.15	1.11	2.24	0.76
Main	1528	2	0.1	84.79	84.81	0.32	0.63	0.24
Main	1528	5	0.84	85.1	85.1	0.15	0.34	0.15
Main	1528	10	1.74	85.3	85.31	0.17	0.32	0.14
Main	1528	25	3.39	85.26	85.27	0.36	0.7	0.34
Main	1528	50	4.83	85.36	85.37	0.43	0.8	0.3
Main	1528	100	6.47	85.5	85.51	0.38	0.69	0.3
Main	1411	2	0.1	84.78	84.78	0.01	0.01	0
Main	1411	5	0.84	85.1	85.1	0.02	0.06	0.02
Main	1411	10	1.74	85.31	85.31	0.03	0.08	0.03
Main	1411	25	3.39	85.26	85.26	0.06	0.17	0.06
Main	1411	50	4.83	85.36	85.36	0.08	0.21	0.08
Main	1411	100	6.47	85.5	85.5	0.09	0.22	0.09
Main	1313	2	0.1	84.78	84.78	0	0.02	0.01
Main	1313	5	0.84	85.1	85.1	0.03	0.11	0.06
Main	1313	10	1.74	85.3	85.3	0.06	0.18	0.1
Main	1313	25	3.39	85.25	85.26	0.13	0.37	0.2
Main	1313	50	4.83	85.34	85.35	0.17	0.49	0.27
Main	1313	100	6.47	85.5	85.5	0.11	0.23	0.13
Main	1303		Culvert					
Main	1296	2	1.16	84.68	84.78		1.41	
Main	1296	5	2.91	84.87	85.09		2.11	
Main	1296	10	4.28	85	85.3		2.41	
Main	1296	25	6.24	85.16	85.17	0.27	0.6	
Main	1296	50	7.7	85.16	85.17	0.34	0.74	
Main	1296	100	9.21	85.16	85.18	0.4	0.89	

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	1206	2	1.16	83.92	83.97	0.31	1.06	0.41
Main	1206	5	2.91	84.09	84.16	0.49	1.39	0.46
Main	1206	10	4.28	84.17	84.25	0.6	1.51	0.47
Main	1206	25	6.24	84	84.76	1.3	4.26	1.44
Main	1206	50	7.7	84.06	84.72	1.36	4.14	1.41
Main	1206	100	9.21	84.4	84.47	0.74	1.59	0.63
Main	1122	2	1.16	83.41	83.46	0.34	1.08	0.46
Main	1122	5	2.91	83.54	83.61	0.56	1.49	0.75
Main	1122	10	4.28	83.61	83.71	0.64	1.71	0.88
Main	1122	25	6.24	83.71	83.83	0.74	1.96	0.96
Main	1122	50	7.7	83.72	83.89	0.9	2.35	1.16
Main	1122	100	9.21	83.77	83.96	0.96	2.48	1.22
Main	994	2	1.16	81.96	82.06	0.17	1.37	0.37
Main	994	5	2.91	82.13	82.29	0.53	1.8	0.62
Main	994	10	4.28	82.23	82.43	0.63	2.01	0.73
Main	994	25	6.24	82.35	82.59	0.65	2.25	0.77
Main	994	50	7.7	82.41	82.51	0.65	1.7	0.4
Main	994	100	9.21	82.47	82.57	0.66	1.77	0.31
Main	924	2	1.16	81.88	81.89	0.21	0.53	0.17
Main	924	5	2.91	82.09	82.11	0.21	0.73	0.24
Main	924	10	4.28	82.17	82.19	0.28	0.86	0.29
Main	924	25	6.24	82.24	82.27	0.37	1.04	0.29
Main	924	50	7.7	82.28	82.32	0.43	1.16	0.33
Main	924	100	9.21	82.32	82.36	0.45	1.27	0.36
Main	875	2	1.16	81.76	81.82	0.22	1.08	0.25
Main	875	5	2.91	81.9	82.01	0.4	1.59	0.38
Main	875	10	4.28	81.98	82.08	0.44	1.65	0.46
Main	875	25	6.24	82.06	82.15	0.48	1.72	0.58
Main	875	50	7.7	82.11	82.19	0.54	1.67	0.62
Main	875	100	9.21	82.15	82.23	0.59	1.72	0.67
Main	830	2	1.16	81.33	81.4	0.34	1.18	0.26
Main	830	5	2.91	81.45	81.57	0.55	1.54	0.56
Main	830	10	4.28	81.51	81.66	0.71	1.8	0.7
Main	830	25	6.24	81.61	81.77	0.83	1.95	0.8

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	830	50	7.7	81.65	81.85	0.88	2.11	0.9
Main	830	100	9.21	81.73	81.92	0.8	2.11	0.93
Main	793	2	1.16	80.35	80.46	0.52	1.55	0.57
Main	793	5	2.91	80.59	80.7	0.61	1.73	0.54
Main	793	10	4.28	80.54	80.93	1.08	3.08	0.83
Main	793	25	6.24	80.6	81.07	1.24	3.54	1.13
Main	793	50	7.7	80.65	81.14	1.32	3.72	1.25
Main	793	100	9.21	80.67	81.25	1.45	4.1	1.42
Main	756	2	1.16	77.99	78.32		2.54	
Main	756	5	2.91	78	79.19		4.82	
Main	756	10	4.28	78.1	78.35	0.54	2.2	0.42
Main	756	25	6.24	78.14	78.42	0.72	2.35	0.67
Main	756	50	7.7	78.16	78.49	0.83	2.55	0.78
Main	756	100	9.21	78.19	78.52	0.9	2.55	0.86
Main	700	2	1.16	77.46	77.5	0.18	0.89	0.31
Main	700	5	2.91	77.59	77.67	0.28	1.3	0.34
Main	700	10	4.28	77.68	77.74	0.35	1.32	0.38
Main	700	25	6.24	77.71	77.8	0.49	1.62	0.53
Main	700	50	7.7	77.74	77.84	0.57	1.76	0.61
Main	700	100	9.21	77.77	77.88	0.65	1.9	0.69
Main	604	2	1.16	76.67	76.74	0.45	1.33	0.63
Main	604	5	2.91	76.8	76.89	0.56	1.64	0.76
Main	604	10	4.28	76.84	76.98	0.57	2.04	0.87
Main	604	25	6.24	76.88	76.93	0.56	1.55	0.69
Main	604	50	7.7	76.89	76.96	0.67	1.8	0.8
Main	604	100	9.21	76.91	76.99	0.74	1.89	0.85
Main	503	2	1.16	75.28	75.33	0.55	1.07	0.41
Main	503	5	2.91	75.4	75.51	0.86	1.6	0.63
Main	503	10	4.28	75.47	75.62	1.03	1.92	0.77
Main	503	25	6.24	75.52	75.76	1.28	2.49	1
Main	503	50	7.7	75.63	75.83	1.21	2.34	0.86
Main	503	100	9.21	75.7	75.9	1.21	2.39	0.8
Main	430	2	1.16	74.95	74.96	0.19	0.52	0.23
Main	430	5	2.91	75.06	75.09	0.32	0.75	0.33

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	430	10	4.28	75.12	75.16	0.38	0.88	0.35
Main	430	25	6.24	75.21	75.26	0.43	1.01	0.39
Main	430	50	7.7	75.26	75.32	0.48	1.1	0.39
Main	430	100	9.21	75.31	75.37	0.49	1.18	0.44
Main	399	2	1.16	74.69	74.75	0.53	1.18	0.71
Main	399	5	2.91	74.79	74.88	0.77	1.56	0.9
Main	399	10	4.28	74.84	74.95	0.84	1.72	1
Main	399	25	6.24	74.91	75.05	0.95	1.97	1.19
Main	399	50	7.7	74.95	75.11	0.97	2.07	1.27
Main	399	100	9.21	74.99	75.17	1.04	2.2	1.37
Main	310	2	1.16	72.17	72.34	0.44	1.85	0.22
Main	310	5	2.91	72.29	72.64	0.61	2.67	0.69
Main	310	10	4.28	72.35	72.79	0.82	3.11	0.89
Main	310	25	6.24	72.43	72.92	1.11	3.42	1.1
Main	310	50	7.7	72.46	73.02	1.23	3.72	1.28
Main	310	100	9.21	72.5	73.09	1.33	3.9	1.3
Main	250	2	1.16	71.93	71.93	0.13	0.36	0.09
Main	250	5	2.91	72.14	72.16	0.18	0.52	0.17
Main	250	10	4.28	72.23	72.24	0.2	0.65	0.22
Main	250	25	6.24	72.31	72.34	0.27	0.78	0.27
Main	250	50	7.7	72.36	72.39	0.32	0.88	0.31
Main	250	100	9.21	72.4	72.44	0.36	0.96	0.33
Main	170	2	1.16	71.82	71.85	0.34	0.8	0.26
Main	170	5	2.91	72	72.06	0.2	1.14	0.43
Main	170	10	4.28	72.08	72.14	0.3	1.23	0.49
Main	170	25	6.24	72.17	72.22	0.33	1.24	0.47
Main	170	50	7.7	72.21	72.26	0.38	1.31	0.47
Main	170	100	9.21	72.27	72.31	0.4	1.29	0.38
Main	94	2	1.16	71.36	71.42	0.48	1.14	0.35
Main	94	5	2.91	71.47	71.59	0.74	1.62	0.59
Main	94	10	4.28	71.55	71.69	0.81	1.8	0.72
Main	94	25	6.24	71.62	71.81	0.93	2.14	0.85
Main	94	50	7.7	71.71	71.88	0.84	2.06	0.73
Main	94	100	9.21	71.75	71.95	0.89	2.24	0.76

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main	4	2	1.16	69.61	69.65	0.54	0.94	0.78
Main	4	5	2.91	69.68	69.75	0.68	1.29	0.97
Main	4	10	4.28	69.69	69.82	0.93	1.76	1.31
Main	4	25	6.24	69.74	69.89	0.95	1.95	1.4
Main	4	50	7.7	69.73	70	1.26	2.57	1.87
Main	4	100	9.21	69.76	70.04	1.31	2.65	1.89
Trib 2	3418	2	0	94.43	94.44		0.24	
Trib 2	3418	5	0.4	94.6	94.66	0.39	1.14	
Trib 2	3418	10	0.93	94.7	94.8	0.59	1.44	0.21
Trib 2	3418	25	1.96	94.83	94.99	0.76	1.81	0.49
Trib 2	3418	50	2.89	94.93	95.12	0.85	2.02	0.61
Trib 2	3418	100	3.98	95.02	95.26	0.93	2.28	0.72
Trib 2	3403	2	0	93.14	93.32		1.89	
Trib 2	3403	5	0.4	93.31	93.84		3.21	
Trib 2	3403	10	0.93	93.43	94.09		3.61	
Trib 2	3403	25	1.96	93.62	94.39		3.9	
Trib 2	3403	50	2.89	94.38	94.51		1.59	
Trib 2	3403	100	3.98	94.63	94.79		1.74	
Trib 2	3393		Culvert					
Trib 2	3371	2	0	92.98	92.98		0.01	
Trib 2	3371	5	0.4	93.17	93.18		0.42	
Trib 2	3371	10	0.93	93.28	93.3		0.69	
Trib 2	3371	25	1.96	93.4	93.45		0.97	
Trib 2	3371	50	2.89	93.49	93.55		1.15	
Trib 2	3371	100	3.98	93.56	93.65		1.34	
Trib 2	3343	2	0	92.98	92.98	0	0.01	
Trib 2	3343	5	0.4	93.16	93.16	0.09	0.2	0.06
Trib 2	3343	10	0.93	93.26	93.27	0.15	0.33	0.11
Trib 2	3343	25	1.96	93.38	93.39	0.24	0.51	0.18
Trib 2	3343	50	2.89	93.46	93.48	0.3	0.63	0.23
Trib 2	3343	100	3.98	93.53	93.56	0.35	0.76	0.28
Trib 2	3239	2	0	92.97	92.98	0.45		
Trib 2	3239	5	0.4	93.06	93.07	0.54	0.61	0.28
Trib 2	3239	10	0.93	93.08	93.12	0.73	0.8	0.47

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 2	3239	25	1.96	93.13	93.17	0.84	0.97	0.59
Trib 2	3239	50	2.89	93.15	93.21	0.92	1.13	0.66
Trib 2	3239	100	3.98	93.18	93.25	0.96	1.24	0.71
Trib 2	3124	2	0	91.7	91.7	0.08		
Trib 2	3124	5	0.4	91.81	91.81	0.25	0.23	
Trib 2	3124	10	0.93	91.84	91.85	0.34	0.36	
Trib 2	3124	25	1.96	91.89	91.9	0.43	0.51	
Trib 2	3124	50	2.89	91.92	91.93	0.49	0.6	
Trib 2	3124	100	3.98	91.95	91.97	0.56	0.7	
Trib 2	3027	2	0	90.8	90.81	0.4	0.1	
Trib 2	3027	5	0.4	90.87	90.89	0.62	0.52	
Trib 2	3027	10	0.93	90.9	90.92	0.59	0.67	
Trib 2	3027	25	1.96	90.93	90.97	0.68	0.91	
Trib 2	3027	50	2.89	90.95	91	0.73	1.04	
Trib 2	3027	100	3.98	90.97	91.04	0.76	1.15	
Trib 2	2854	2	0	89.13	89.13		0.06	
Trib 2	2854	5	0.4	89.3	89.3	0.13	0.29	0.09
Trib 2	2854	10	0.93	89.37	89.38	0.18	0.4	0.15
Trib 2	2854	25	1.96	89.46	89.47	0.19	0.52	0.22
Trib 2	2854	50	2.89	89.5	89.51	0.25	0.61	0.25
Trib 2	2854	100	3.98	89.54	89.56	0.31	0.68	0.3
Trib 2	2622	2	0	88.47	88.47		0.18	
Trib 2	2622	5	0.4	88.56	88.6		0.83	0.16
Trib 2	2622	10	0.93	88.62	88.66	0.15	0.89	0.31
Trib 2	2622	25	1.96	88.67	88.72	0.39	1.09	0.45
Trib 2	2622	50	2.89	88.72	88.77	0.47	1.06	0.5
Trib 2	2622	100	3.98	88.77	88.82	0.53	1.12	0.54
Trib 2	2421	2	0	87.28	87.28	0.02	0.09	
Trib 2	2421	5	0.4	87.54	87.55	0.22	0.5	0.21
Trib 2	2421	10	0.93	87.68	87.7	0.3	0.69	0.31
Trib 2	2421	25	1.96	87.86	87.89	0.4	0.92	0.42
Trib 2	2421	50	2.89	87.98	88.02	0.28	1.09	0.49
Trib 2	2421	100	3.98	88.06	88.1	0.32	1.18	0.52
Trib 2	2248	2	0	86.81	86.82		0.19	

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 2	2248	5	0.4	86.97	87	0.27	0.79	
Trib 2	2248	10	0.93	87.03	87.09	0.46	1.11	0.27
Trib 2	2248	25	1.96	87.11	87.21	0.64	1.46	0.48
Trib 2	2248	50	2.89	87.17	87.29	0.79	1.67	0.59
Trib 2	2248	100	3.98	87.23	87.38	0.92	1.84	0.69
Trib 2	2122	2	0	84.75	84.76		0.33	
Trib 2	2122	5	0.4	84.91	84.97		1.09	
Trib 2	2122	10	0.93	85	85.1	0.25	1.35	
Trib 2	2122	25	1.96	85.12	85.26	0.54	1.69	
Trib 2	2122	50	2.89	85.2	85.38	0.69	1.91	
Trib 2	2122	100	3.98	85.26	85.49	0.8	2.16	0.28
Trib 2	2052	2	0	83.09	83.09		0.07	
Trib 2	2052	5	0.4	83.27	83.28	0.07	0.34	0.17
Trib 2	2052	10	0.93	83.36	83.37	0.15	0.47	0.25
Trib 2	2052	25	1.96	83.49	83.5	0.17	0.62	0.32
Trib 2	2052	50	2.89	83.57	83.59	0.22	0.71	0.34
Trib 2	2052	100	3.98	83.65	83.67	0.28	0.78	0.37
Trib 2	1952	2	0	82.78	82.78		0.25	
Trib 2	1952	5	0.4	82.9	82.94	0.23	0.94	
Trib 2	1952	10	0.93	82.97	83.04	0.41	1.2	0.27
Trib 2	1952	25	1.96	83.06	83.17	0.58	1.51	0.49
Trib 2	1952	50	2.89	83.13	83.27	0.69	1.69	0.6
Trib 2	1952	100	3.98	83.2	83.36	0.78	1.84	0.69
Trib 2	1860	2	0	81.99	81.99	0.03	0.08	
Trib 2	1860	5	0.4	82.07	82.07	0.22	0.35	
Trib 2	1860	10	0.93	82.11	82.12	0.3	0.48	0.04
Trib 2	1860	25	1.96	82.17	82.19	0.38	0.64	0.18
Trib 2	1860	50	2.89	82.27	82.28	0.29	0.53	0.21
Trib 2	1860	100	3.98	82.32	82.33	0.3	0.6	0.25
Trib 2	1626	2	0	80.76	80.76		0.17	
Trib 2	1626	5	0.4	80.93	80.95		0.56	0.25
Trib 2	1626	10	0.93	81.02	81.05	0.04	0.73	0.32
Trib 2	1626	25	1.96	81.15	81.18	0.2	0.91	0.39
Trib 2	1626	50	2.89	81.1	81.22	0.33	1.62	0.69
Trib 2	1626	100	3.98	81.16	81.3	0.42	1.79	0.77

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 2	1449	2	0	79.91	79.91		0.13	
Trib 2	1449	5	0.4	80.13	80.15		0.63	0.17
Trib 2	1449	10	0.93	80.23	80.27		0.87	0.3
Trib 2	1449	25	1.96	80.37	80.43		1.11	0.49
Trib 2	1449	50	2.89	80.46	80.53		1.26	0.63
Trib 2	1449	100	3.98	80.55	80.64		1.38	0.73
Trib 2	1363	2	0	79.18	79.19		0.29	
Trib 2	1363	5	0.4	79.35	79.41		1.12	
Trib 2	1363	10	0.93	79.44	79.54	0.19	1.4	0.22
Trib 2	1363	25	1.96	79.58	79.72	0.5	1.7	0.44
Trib 2	1363	50	2.89	79.68	79.84	0.64	1.86	0.52
Trib 2	1363	100	3.98	79.77	79.96	0.74	2.03	0.68
Trib 2	1129	2	0	78.67	78.67		0	
Trib 2	1129	5	0.4	78.87	78.87	0.05	0.2	0.03
Trib 2	1129	10	0.93	78.99	78.99	0.1	0.33	0.09
Trib 2	1129	25	1.96	79.13	79.15	0.17	0.51	0.16
Trib 2	1129	50	2.89	79.21	79.23	0.23	0.65	0.18
Trib 2	1129	100	3.98	79.29	79.32	0.27	0.78	0.2
Trib 2	1021	2	0	78.67	78.67		0.13	
Trib 2	1021	5	0.4	78.82	78.83	0.13	0.41	0.26
Trib 2	1021	10	0.93	78.91	78.92	0.21	0.56	0.33
Trib 2	1021	25	1.96	79.03	79.04	0.22	0.74	0.37
Trib 2	1021	50	2.89	79.09	79.11	0.26	0.82	0.43
Trib 2	1021	100	3.98	79.15	79.17	0.26	0.91	0.47
Trib 2	935	2	0	78.19	78.19		0.23	
Trib 2	935	5	0.4	78.34	78.4		1.06	0.44
Trib 2	935	10	0.93	78.43	78.52	0.29	1.35	0.63
Trib 2	935	25	1.96	78.56	78.67	0.52	1.62	0.78
Trib 2	935	50	2.89	78.65	78.76	0.54	1.69	0.72
Trib 2	935	100	3.98	78.73	78.83	0.48	1.74	0.74
Trib 2	830	2	0	76.14	76.14		0.33	
Trib 2	830	5	0.4	76.34	76.36	0.18	0.6	0.3
Trib 2	830	10	0.93	76.43	76.44	0.23	0.64	0.29
Trib 2	830	25	1.96	76.56	76.56	0.24	0.59	0.18

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 2	830	50	2.89	76.66	76.66	0.21	0.52	0.16
Trib 2	830	100	3.98	76.84	76.85	0.15	0.32	0.13
Trib 2	770	2	0	75.73	75.73		0.06	
Trib 2	770	5	0.4	75.88	75.96		1.23	
Trib 2	770	10	0.93	76	76.12		1.53	
Trib 2	770	25	1.96	76.16	76.34		1.91	0.48
Trib 2	770	50	2.89	76.41	76.54	0.2	1.64	0.57
Trib 2	770	100	3.98	76.77	76.81	0.23	1.09	0.53
Trib 2	760		Culvert					
Trib 2	751	2	0	75.72	75.73		0.34	
Trib 2	751	5	0.4	75.87	75.93	0.64	1.11	0.38
Trib 2	751	10	0.93	75.96	76.06	0.91	1.44	0.55
Trib 2	751	25	1.96	76.09	76.24	1.2	1.8	0.87
Trib 2	751	50	2.89	76.18	76.38	1.39	2.06	1.1
Trib 2	751	100	3.98	76.27	76.52	1.57	2.3	1.3
Trib 2	688	2	0	73.31	73.31		0.27	
Trib 2	688	5	0.4	73.4	73.53		1.6	
Trib 2	688	10	0.93	73.44	73.72		2.37	
Trib 2	688	25	1.96	73.49	74.02		3.24	
Trib 2	688	50	2.89	73.53	74.2		3.63	
Trib 2	688	100	3.98	73.57	74.37		3.96	
Trib 2	613	2	0	70.98	70.99		0.3	
Trib 2	613	5	0.4	71.14	71.18	0.28	0.83	
Trib 2	613	10	0.93	71.24	71.29	0.42	1.03	
Trib 2	613	25	1.96	71.37	71.44	0.34	1.29	0.21
Trib 2	613	50	2.89	71.43	71.51	0.47	1.42	0.18
Trib 2	613	100	3.98	71.49	71.58	0.54	1.53	0.34
Trib 2	408	2	0	69.35	69.35		0.14	
Trib 2	408	5	0.4	69.56	69.59		0.77	0.29
Trib 2	408	10	0.93	69.67	69.73	0.25	1.11	0.44
Trib 2	408	25	1.96	69.8	69.91	0.41	1.49	0.59
Trib 2	408	50	2.89	69.9	70.03	0.52	1.69	0.7
Trib 2	408	100	3.98	69.99	70.14	0.61	1.85	0.79

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 2	271	2	0	68.91	68.91		0.13	
Trib 2	271	5	0.4	69.08	69.09	0.09	0.44	0.21
Trib 2	271	10	0.93	69.17	69.19	0.2	0.61	0.31
Trib 2	271	25	1.96	69.3	69.33	0.3	0.82	0.41
Trib 2	271	50	2.89	69.38	69.42	0.38	0.98	0.48
Trib 2	271	100	3.98	69.46	69.51	0.44	1.13	0.5
Trib 2	126	2	0	68.21	68.21		0.2	
Trib 2	126	5	0.4	68.36	68.38	0.21	0.67	0.05
Trib 2	126	10	0.93	68.4	68.45	0.39	0.94	0.22
Trib 2	126	25	1.96	68.46	68.54	0.56	1.26	0.41
Trib 2	126	50	2.89	68.51	68.61	0.65	1.41	0.48
Trib 2	126	100	3.98	68.56	68.68	0.74	1.57	0.56
Trib 2	6	2	0	65.67	65.68		0.33	
Trib 2	6	5	0.4	65.76	65.79		0.84	
Trib 2	6	10	0.93	65.81	65.87		1.1	0.31
Trib 2	6	25	1.96	65.89	65.99		1.43	0.59
Trib 2	6	50	2.89	66.11	66.16	0.21	0.94	0.43
Trib 2	6	100	3.98	67.93	67.93	0.04	0.08	0.03
Main-DS-2	784	2	1.28	68.54	69.55		4.45	
Main-DS-2	784	5	4.11	68.67	69.66	0.28	4.4	
Main-DS-2	784	10	6.63	68.77	69.73	1.01	4.37	0.92
Main-DS-2	784	25	10.43	69.35	69.37	0.32	0.86	0.36
Main-DS-2	784	50	13.44	69.64	69.65	0.24	0.63	0.29
Main-DS-2	784	100	16.63	68.96	69.97	1.57	5.01	1.3
Main-DS-2	719	2	1.28	68.05	68.16		1.55	0.88
Main-DS-2	719	5	4.11	68.3	68.51	0.41	2.19	1.18
Main-DS-2	719	10	6.63	68.45	68.72	0.65	2.57	1.13
Main-DS-2	719	25	10.43	68.45	69.12	1.03	4.05	1.78
Main-DS-2	719	50	13.44	68.49	69.47	1.31	4.94	1.72
Main-DS-2	719	100	16.63	68.58	68.79	0.78	2.81	1.25
Main-DS-2	643	2	1.28	65.99	66.02	0.35	0.81	0.4
Main-DS-2	643	5	4.11	66.34	66.4	0.49	1.17	0.54
Main-DS-2	643	10	6.63	66.55	66.62	0.56	1.36	0.6
Main-DS-2	643	25	10.43	66.8	66.89	0.63	1.55	0.65
Main-DS-2	643	50	13.44	66.91	67.02	0.73	1.74	0.72

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main-DS-2	643	100	16.63	67.97	67.99	0.42	0.86	0.35
Main-DS-2	164	2	1.28	64.88	64.91	0.13	0.86	0.41
Main-DS-2	164	5	4.11	65.27	65.33	0.38	1.35	0.63
Main-DS-2	164	10	6.63	65.48	65.57	0.49	1.6	0.78
Main-DS-2	164	25	10.43	65.73	65.85	0.6	1.88	0.95
Main-DS-2	164	50	13.44	66.16	66.25	0.55	1.62	0.84
Main-DS-2	164	100	16.63	67.93	67.93	0.2	0.56	0.19
Main-DS-2	3	2	1.28	64.09	64.21		1.57	0.64
Main-DS-2	3	5	4.11	64.36	64.56		2.13	1.08
Main-DS-2	3	10	6.63	64.52	64.78	0.16	2.43	1.26
Main-DS-2	3	25	10.43	64.71	65.04	0.54	2.8	1.37
Main-DS-2	3	50	13.44	66.13	66.15	0.29	0.83	0.32
Main-DS-2	3	100	16.63	67.93	67.93	0.07	0.27	0.13
Main-DS-1	1849	2	1.49	64.07	64.09	0.36	0.71	0.21
Main-DS-1	1849	5	4.88	64.36	64.39	0.36	1.01	0.35
Main-DS-1	1849	10	7.94	64.45	64.5	0.5	1.29	0.44
Main-DS-1	1849	25	12.56	64.92	64.94	0.39	0.84	0.32
Main-DS-1	1849	50	16.16	66.14	66.14	0.2	0.37	0.11
Main-DS-1	1849	100	20.1	67.93	67.93	0.1	0.18	0.07
Main-DS-1	1597	2	1.49	63.08	63.18		1.42	0.44
Main-DS-1	1597	5	4.88	63.33	63.53	0.54	2.03	0.77
Main-DS-1	1597	10	7.94	63.74	63.86	0.48	1.58	0.64
Main-DS-1	1597	25	12.56	64.85	64.87	0.29	0.7	0.29
Main-DS-1	1597	50	16.16	66.13	66.13	0.11	0.4	0.16
Main-DS-1	1597	100	20.1	67.93	67.93	0.07	0.19	0.07
Main-DS-1	1317	2	1.49	62.72	62.72	0.11	0.34	0.17
Main-DS-1	1317	5	4.88	63.27	63.27	0.14	0.43	0.22
Main-DS-1	1317	10	7.94	63.73	63.73	0.12	0.43	0.23
Main-DS-1	1317	25	12.56	64.84	64.85	0.11	0.3	0.16
Main-DS-1	1317	50	16.16	66.13	66.13	0.08	0.18	0.08
Main-DS-1	1317	100	20.1	67.93	67.93	0.03	0.11	0.04
Main-DS-1	978	2	1.49	62.61	62.62	0.14	0.38	0.18
Main-DS-1	978	5	4.88	63.2	63.21	0.22	0.53	0.27
Main-DS-1	978	10	7.94	63.68	63.69	0.22	0.57	0.3

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main-DS-1	978	25	12.56	64.83	64.84	0.09	0.38	0.18
Main-DS-1	978	50	16.16	66.13	66.13	0.07	0.17	0.06
Main-DS-1	978	100	20.1	67.93	67.93	0.03	0.08	0.02
Main-DS-1	704	2	1.49	62.47	62.48		0.55	0.34
Main-DS-1	704	5	4.88	63.07	63.1		0.82	0.53
Main-DS-1	704	10	7.94	63.57	63.61		0.92	0.6
Main-DS-1	704	25	12.56	64.77	64.81		0.83	0.54
Main-DS-1	704	50	16.16	66.09	66.12		0.72	0.48
Main-DS-1	704	100	20.1	67.9	67.92		0.63	0.12
Main-DS-1	698		Culvert					
Main-DS-1	694	2	1.49	61.99	62	0.38	0.6	0.26
Main-DS-1	694	5	4.88	62.12	62.23	0.98	1.51	0.74
Main-DS-1	694	10	7.94	62.23	62.44	1.35	2.03	1.05
Main-DS-1	694	25	12.56	62.5	62.76	1.56	2.31	1.27
Main-DS-1	694	50	16.16	62.81	63.06	1.54	2.24	1.29
Main-DS-1	694	100	20.1	63.35	63.54	1.35	1.94	1.15
Main-DS-1	677	2	1.49	61.23	61.25	0.7	0.75	0.26
Main-DS-1	677	5	4.88	61.66	61.67	0.38	0.6	0.27
Main-DS-1	677	10	7.94	61.97	61.98	0.35	0.61	0.28
Main-DS-1	677	25	12.56	62.4	62.41	0.32	0.62	0.28
Main-DS-1	677	50	16.16	62.79	62.8	0.28	0.57	0.26
Main-DS-1	677	100	20.1	63.38	63.39	0.25	0.47	0.2
Main-DS-1	383	2	1.49	61.12	61.13	0.16	0.4	0.19
Main-DS-1	383	5	4.88	61.57	61.59	0.3	0.72	0.33
Main-DS-1	383	10	7.94	61.89	61.91	0.37	0.84	0.39
Main-DS-1	383	25	12.56	62.34	62.36	0.26	0.86	0.39
Main-DS-1	383	50	16.16	62.75	62.77	0.25	0.74	0.33
Main-DS-1	383	100	20.1	63.37	63.37	0.23	0.55	0.11
Main-DS-1	225	2	1.49	61.06	61.07	0.22	0.5	0.15
Main-DS-1	225	5	4.88	61.46	61.49	0.34	0.87	0.32
Main-DS-1	225	10	7.94	61.79	61.83	0.28	0.97	0.39
Main-DS-1	225	25	12.56	62.27	62.3	0.33	0.91	0.38
Main-DS-1	225	50	16.16	62.71	62.73	0.33	0.8	0.16
Main-DS-1	225	100	20.1	63.36	63.36	0.09	0.33	0.09

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main-DS-1	2	2	1.49	61.06	61.06	0.01	0.04	0.02
Main-DS-1	2	5	4.88	61.48	61.48	0.02	0.04	0.02
Main-DS-1	2	10	7.94	61.82	61.82	0.02	0.03	0.02
Main-DS-1	2	25	12.56	62.29	62.29	0.02	0.03	0.02
Main-DS-1	2	50	16.16	62.73	62.73	0.02	0.03	0.02
Main-DS-1	2	100	20.1	63.36	63.36	0.02	0.03	0.01
Trib 1	3577	2	0.2	64.82	64.82	0.2	0.29	0.21
Trib 1	3577	5	1.26	65	65.01	0.32	0.55	0.3
Trib 1	3577	10	2.42	65.14	65.15	0.34	0.62	0.35
Trib 1	3577	25	4.4	65.34	65.36	0.31	0.68	0.4
Trib 1	3577	50	6.08	65.5	65.51	0.33	0.7	0.42
Trib 1	3577	100	7.96	66.41	66.41	0.17	0.34	0.18
Trib 1	3367	2	0.2	64	64.03		0.74	
Trib 1	3367	5	1.26	64.35	64.42	0.24	1.18	0.33
Trib 1	3367	10	2.42	64.55	64.66	0.43	1.52	0.44
Trib 1	3367	25	4.4	64.77	64.94	0.63	1.95	0.69
Trib 1	3367	50	6.08	64.79	65.1	0.84	2.61	0.94
Trib 1	3367	100	7.96	66.36	66.39	0.34	0.86	0.31
Trib 1	3097	2	0.2	63.51	63.52	0.15	0.29	0.16
Trib 1	3097	5	1.26	63.78	63.8	0.35	0.66	0.32
Trib 1	3097	10	2.42	63.96	63.99	0.44	0.86	0.38
Trib 1	3097	25	4.4	64.19	64.23	0.53	1.06	0.46
Trib 1	3097	50	6.08	64.66	64.68	0.39	0.8	0.36
Trib 1	3097	100	7.96	66.37	66.37	0.13	0.27	0.11
Trib 1	2762	2	0.2	63.05	63.06		0.36	0.06
Trib 1	2762	5	1.26	63.32	63.34	0.25	0.62	0.25
Trib 1	2762	10	2.42	63.51	63.53	0.39	0.76	0.34
Trib 1	2762	25	4.4	63.77	63.81	0.52	0.91	0.41
Trib 1	2762	50	6.08	64.57	64.59	0.37	0.58	0.31
Trib 1	2762	100	7.96	66.36	66.36	0.23	0.34	0.21
Trib 1	2740		Culvert					
Trib 1	2725	2	0.2	63.04	63.06		0.52	0.26
Trib 1	2725	5	1.26	63.29	63.33	0.25	0.93	0.45

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 1	2725	10	2.42	63.46	63.52	0.38	1.13	0.52
Trib 1	2725	25	4.4	63.72	63.78	0.57	1.22	0.57
Trib 1	2725	50	6.08	64.55	64.57	0.4	0.66	0.38
Trib 1	2725	100	7.96	66.34	66.34	0.24	0.37	0.24
Trib 1	2546	2	0.2	62.81	62.82	0.1	0.22	0.07
Trib 1	2546	5	1.26	63.1	63.1	0.19	0.43	0.2
Trib 1	2546	10	2.42	63.31	63.32	0.22	0.51	0.24
Trib 1	2546	25	4.4	63.62	63.63	0.26	0.55	0.26
Trib 1	2546	50	6.08	64.55	64.55	0.14	0.3	0.14
Trib 1	2546	100	7.96	66.34	66.34	0.05	0.1	0.04
Trib 1	2377	2	0.63	62.68	62.68	0.02	0.3	0.17
Trib 1	2377	5	3.18	63	63.01	0.18	0.48	0.31
Trib 1	2377	10	5.88	63.21	63.22	0.25	0.61	0.39
Trib 1	2377	25	10.35	63.54	63.56	0.3	0.71	0.45
Trib 1	2377	50	14.08	64.53	64.54	0.15	0.46	0.25
Trib 1	2377	100	18.23	66.34	66.34	0.08	0.24	0.13
Trib 1	1829	2	0.63	62.03	62.05	0.23	0.57	0.2
Trib 1	1829	5	3.18	62.45	62.5	0.33	1.01	0.4
Trib 1	1829	10	5.88	62.7	62.74	0.47	1.13	0.32
Trib 1	1829	25	10.35	63.35	63.36	0.25	0.72	0.25
Trib 1	1829	50	14.08	64.52	64.52	0.13	0.27	0.12
Trib 1	1829	100	18.23	66.34	66.34	0.07	0.13	0.06
Trib 1	1496	2	0.63	61.64	61.64	0.06	0.41	0.27
Trib 1	1496	5	3.18	62.1	62.12	0.18	0.73	0.44
Trib 1	1496	10	5.88	62.43	62.45	0.23	0.8	0.41
Trib 1	1496	25	10.35	63.33	63.33	0.11	0.27	0.12
Trib 1	1496	50	14.08	64.52	64.52	0.07	0.13	0.07
Trib 1	1496	100	18.23	66.34	66.34	0.04	0.08	0.04
Trib 1	1332	2	0.63	61.51	61.51	0.17	0.35	0.14
Trib 1	1332	5	3.18	62	62.01	0.36	0.58	0.29
Trib 1	1332	10	5.88	62.35	62.37	0.46	0.7	0.4
Trib 1	1332	25	10.35	63.3	63.32	0.43	0.63	0.4
Trib 1	1332	50	14.08	64.5	64.51	0.37	0.53	0.35
Trib 1	1332	100	18.23	66.32	66.33	0.3	0.44	0.29

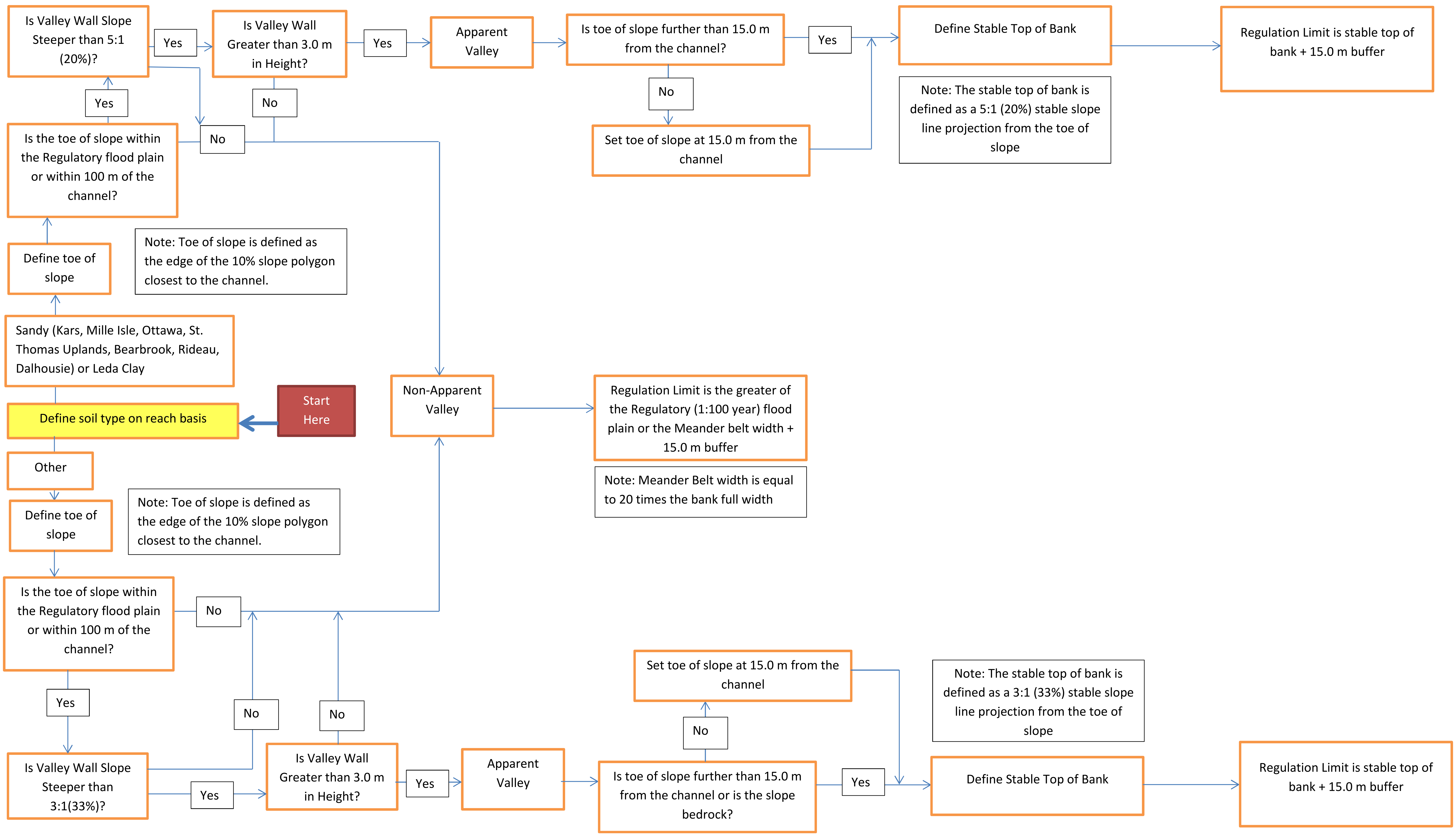
Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Trib 1	1319		Culvert					
Trib 1	1300	2	0.63	61.49	61.5	0.24	0.47	0.09
Trib 1	1300	5	3.18	61.83	61.87	0.6	0.98	0.35
Trib 1	1300	10	5.88	62.05	62.12	0.81	1.27	0.42
Trib 1	1300	25	10.35	62.36	62.45	0.98	1.5	0.67
Trib 1	1300	50	14.08	62.73	62.81	0.95	1.44	0.74
Trib 1	1300	100	18.23	63.35	63.41	0.84	1.24	0.71
Trib 1	1142	2	0.63	61.43	61.43	0.08	0.21	0.08
Trib 1	1142	5	3.18	61.62	61.64	0.25	0.67	0.28
Trib 1	1142	10	5.88	61.83	61.86	0.17	0.88	0.35
Trib 1	1142	25	10.35	62.29	62.31	0.22	0.64	0.23
Trib 1	1142	50	14.08	62.73	62.73	0.2	0.46	0.18
Trib 1	1142	100	18.23	63.36	63.37	0.17	0.33	0.15
Trib 1	806	2	0.63	61.37	61.37	0.06	0.13	
Trib 1	806	5	3.18	61.54	61.54	0.09	0.15	0.02
Trib 1	806	10	5.88	61.83	61.83	0.05	0.09	0.03
Trib 1	806	25	10.35	62.3	62.3	0.03	0.04	0.03
Trib 1	806	50	14.08	62.73	62.73	0.03	0.04	0.03
Trib 1	806	100	18.23	63.37	63.37	0.02	0.03	0.02
Trib 1	444	2	0.63	61.1	61.12	0.63	0.05	
Trib 1	444	5	3.18	61.49	61.49	0.1	0.15	0.07
Trib 1	444	10	5.88	61.82	61.82	0.08	0.13	0.06
Trib 1	444	25	10.35	62.3	62.3	0.07	0.12	0.06
Trib 1	444	50	14.08	62.73	62.73	0.07	0.11	0.05
Trib 1	444	100	18.23	63.36	63.36	0.06	0.09	0.05
Trib 1	7	2	0.63	61.06	61.06	0.04	0.09	0.03
Trib 1	7	5	3.18	61.48	61.48	0.06	0.12	0.04
Trib 1	7	10	5.88	61.82	61.82	0.06	0.12	0.05
Trib 1	7	25	10.35	62.29	62.29	0.06	0.12	0.06
Trib 1	7	50	14.08	62.73	62.73	0.06	0.11	0.06
Trib 1	7	100	18.23	63.36	63.36	0.05	0.1	0.06
Main-DS-1-DS-0	2091	2	3.58	61.06	61.06	0.08	0.38	0.11
Main-DS-1-DS-0	2091	5	9.72	61.46	61.48	0.13	0.64	0.19
Main-DS-1-DS-0	2091	10	16.71	61.78	61.81	0.19	0.84	0.25

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main-DS-1-DS-0	2091	25	27.85	62.24	62.29	0.26	1.04	0.32
Main-DS-1-DS-0	2091	50	36.89	62.67	62.72	0.29	1.11	0.33
Main-DS-1-DS-0	2091	100	46.81	63.36	63.36	0.08	0.28	0.07
Main-DS-1-DS-0	2076		Bridge					
Main-DS-1-DS-0	2062	2	3.58	61.01	61.03	0.09	0.6	0.09
Main-DS-1-DS-0	2062	5	9.72	61.35	61.4	0.17	1.01	0.16
Main-DS-1-DS-0	2062	10	16.71	61.59	61.67	0.27	1.33	0.22
Main-DS-1-DS-0	2062	25	27.85	61.87	62.01	0.39	1.73	0.34
Main-DS-1-DS-0	2062	50	36.89	62.05	62.23	0.48	2.01	0.43
Main-DS-1-DS-0	2062	100	46.81	62.22	62.45	0.56	2.29	0.51
Main-DS-1-DS-0	1509	2	3.58	60.83	60.83	0.08	0.3	0.05
Main-DS-1-DS-0	1509	5	9.72	61.07	61.07	0.13	0.48	0.09
Main-DS-1-DS-0	1509	10	16.71	61.24	61.25	0.18	0.62	0.13
Main-DS-1-DS-0	1509	25	27.85	61.42	61.43	0.23	0.81	0.17
Main-DS-1-DS-0	1509	50	36.89	61.54	61.55	0.26	0.92	0.2
Main-DS-1-DS-0	1509	100	46.81	61.65	61.67	0.3	1.04	0.24
Main-DS-1-DS-0	1160	2	3.94	60.51	60.57	0.45	1.51	0.23
Main-DS-1-DS-0	1160	5	10.45	60.61	60.68	0.54	1.91	0.36
Main-DS-1-DS-0	1160	10	17.76	60.68	60.77	0.63	2.27	0.45
Main-DS-1-DS-0	1160	25	29.48	60.85	60.9	0.52	1.88	0.41
Main-DS-1-DS-0	1160	50	38.98	60.95	61	0.52	1.86	0.43
Main-DS-1-DS-0	1160	100	49.38	61.04	61.09	0.53	1.9	0.46
Main-DS-1-DS-0	737	2	3.94	60.34	60.34	0.03	0.03	0.01
Main-DS-1-DS-0	737	5	10.45	60.43	60.43	0.06	0.09	0.02
Main-DS-1-DS-0	737	10	17.76	60.52	60.52	0.08	0.14	0.04
Main-DS-1-DS-0	737	25	29.48	60.64	60.64	0.1	0.21	0.06
Main-DS-1-DS-0	737	50	38.98	60.72	60.72	0.11	0.26	0.07
Main-DS-1-DS-0	737	100	49.38	60.79	60.79	0.13	0.3	0.08
Main-DS-1-DS-0	460	2	3.94	60.33	60.33	0.03	0.05	0.02
Main-DS-1-DS-0	460	5	10.45	60.39	60.39	0.07	0.12	0.04
Main-DS-1-DS-0	460	10	17.76	60.47	60.47	0.09	0.19	0.06
Main-DS-1-DS-0	460	25	29.48	60.57	60.57	0.11	0.26	0.08
Main-DS-1-DS-0	460	50	38.98	60.64	60.65	0.12	0.31	0.1
Main-DS-1-DS-0	460	100	49.38	60.71	60.72	0.14	0.35	0.11

Reach	River Sta	Profile	Q Total (m3/s)	W.S. Elev (m)	E.G. Elev (m)	Vel Left (m/s)	Vel Chnl (m/s)	Vel Right (m/s)
Main-DS-1-DS-0	164	2	3.94	60.31	60.31	0.05	0.09	0.03
Main-DS-1-DS-0	164	5	10.45	60.24	60.25	0.19	0.27	0.09
Main-DS-1-DS-0	164	10	17.76	60.27	60.27	0.29	0.43	0.15
Main-DS-1-DS-0	164	25	29.48	60.33	60.34	0.37	0.67	0.21
Main-DS-1-DS-0	164	50	38.98	60.39	60.39	0.39	0.81	0.24
Main-DS-1-DS-0	164	100	49.38	60.45	60.46	0.41	0.92	0.26
Main-DS-1-DS-0	1	2	3.94	60.2	60.23	0.2	0.99	0.18
Main-DS-1-DS-0	1	5	10.45	60.23	60.23	0.04	0.07	0.01
Main-DS-1-DS-0	1	10	17.76	60.23	60.23	0.06	0.12	0.02
Main-DS-1-DS-0	1	25	29.48	60.23	60.23	0.1	0.2	0.04
Main-DS-1-DS-0	1	50	38.98	60.23	60.23	0.13	0.26	0.05
Main-DS-1-DS-0	1	100	49.38	60.23	60.23	0.17	0.33	0.06

Appendix G

Regulation Limit Flow Chart



Start Here
Define soil type on reach basis
Sandy (Kars, Mille Isle, Ottawa, St. Thomas Uplands, Bearbrook, Rideau, Dalhousie) or Leda Clay
Define toe of slope
Note: Toe of slope is defined as the edge of the 10% slope polygon closest to the channel.
Is the toe of slope within the Regulatory flood plain or within 100 m of the channel?
Yes
No
Is Valley Wall Slope Steeper than 5:1 (20%)?
Yes
Is Valley Wall Greater than 3.0 m in Height?
No
Yes
Apparent Valley
Is toe of slope further than 15.0 m from the channel?
No
Set toe of slope at 15.0 m from the channel
Yes
Define Stable Top of Bank
Note: The stable top of bank is defined as a 5:1 (20%) stable slope line projection from the toe of slope
Regulation Limit is stable top of bank + 15.0 m buffer
Non-Apparent Valley
Regulation Limit is the greater of the Regulatory (1:100 year) flood plain or the Meander belt width + 15.0 m buffer
Note: Meander Belt width is equal to 20 times the bank full width
Other
Define toe of slope
Note: Toe of slope is defined as the edge of the 10% slope polygon closest to the channel.
Is the toe of slope within the Regulatory flood plain or within 100 m of the channel?
No
Yes
Is Valley Wall Slope Steeper than 3:1(33%)?
No
Yes
Is Valley Wall Greater than 3.0 m in Height?
No
Yes
Apparent Valley
Is toe of slope further than 15.0 m from the channel or is the slope bedrock?
No
Set toe of slope at 15.0 m from the channel
Yes
Define Stable Top of Bank
Note: The stable top of bank is defined as a 3:1 (33%) stable slope line projection from the toe of slope
Regulation Limit is stable top of bank + 15.0 m buffer

Appendix H

Technical Review Comments and Responses

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June 19, 2020 Project Number: P1747(06)-20

City of Ottawa
Infrastructure Services
110 Laurier Avenue West
Ottawa, Ontario
K1P 1J1

Attention: **Amanda Lynch, P.Eng, Project Manager**

Subject: **Technical Review of MVCA's Casey Creek Flood Plain Mapping Study**

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1. INTRODUCTION

J.F. Sabourin and Associates Inc. (JFSA) were retained by the City of Ottawa to complete technical reviews for flood plain mapping work by local Conservation Authorities between 2018 and 2020. These reviews will focus on reports, maps and supporting modelling prepared by Rideau Valley Conservation Authority (RVCA), Mississippi Valley Conservation Authority (MVCA) and South Nation Conservation (SNC). It is JFSA's understanding that the City of Ottawa, in conjunction with these three Conservation Authorities, has developed a multi-year program to update flood plain mapping within the City of Ottawa and to produce new flood plain mapping where it does not currently exist.

Casey Creek is located in the northwest end of the City of Ottawa and tributary to Constance Lake. According to the draft report, the creek has a total drainage area is approximately 55 km^2 and the main channel extends a length of approximately 6.5 km from Marchurst Road at the upstream end to its outlet at Constance Lake. There are three main tributary branches of Casey Creek that join the watercourse immediately upstream of Dunrobin Road. There is no existing flood plain mapping for Casey Creek.

MVCA provided JFSA with the flowing information for this technical review:

- Draft flood plain mapping study report and supporting appendices
- Draft flood hazard maps
- Draft flood plain GIS files
- Hydrologic (SWMHYMO) and hydraulic (HEC-RAS) models
- Completed flood plain mapping report checklist

The comments made in this technical review report are intended to be reviewed by MVCA for their consideration to increase confidence in the calculations and mapping completed for the Casey Creek study.

2. SCOPE OF TECHNICAL REVIEW

The scope of this technical review includes the following:

1. Complete a preliminary review and initial screening of the submitted documents to confirm the general report structure, level of detail and methodology and supporting information including models used and directly relevant reports are consistent with requirements for a flood plain mapping project.

2. Confirm the approach used in the draft report is consistent with the applicable technical guidelines and local standards.

3. Assess the descriptions and details in the draft report related to the hydrologic modelling and/or statistical analysis and hydraulic modelling. Confirm the report appropriately documents:
   a) The sources of information used to complete these analyses;
   b) Methodologies, parameters, and assumptions; and
   c) The information used is adequate in terms of accuracy, level of detail and representative of existing conditions for the purposes of flood risk mapping.

4. Confirm the report appropriately documents key information, both discussed and presented in summary tables and figures including:
   a) Selection of methodology and model(s) including commands/subroutines, used;
   b) Hydrologic analyses (models and/or statistical analyses used, input parameters, design storms and results);
   c) Hydraulic model parameters (cross-sections, bridges, culverts, boundary conditions, Manning's 'n', etc.);
   d) Methods of calibration/verification;
   e) Dam information, if applicable; and
   f) Wind, wave, ice analyses, if applicable

5. Confirm that the flood line delineation discussed in the report provides a clear presentation of the results with appropriate reference to the modelling results and that the results are reasonable and defendable.

3. FRAMEWORK FOR TECHNICAL REVIEW

The Ontario Ministry of Natural Resources and Forestry (MNRF), formally known as the Ontario Ministry of Natural Resources (MNR), produced a technical guide in 2002 titled "River & Stream Systems: Flooding Hazard Limit" (referred to as "the MNRF guide" in this letter report). This MNRF guide was prepared to assist in the understanding of the 1996 Provincial Policy Statement and updates to the original 1986 Flood Plain Management in Ontario, Technical Guideline Publications. This document provides a substantial level of technical guidance for flood plain mapping studies in Ontario and is currently being used as a guideline reference for other flood plain mapping projects in the Ottawa area.

Reference to the MNRF guide is provided periodically throughout the draft report. In the absence of an updated publication, the MNRF guide is considered a suitable reference document for the current MVCA flood plain mapping study.

As indicated in the MNRF guide "It [the technical guide] is not intended to be a list of mandatory instructions or technical methodologies to be rigidly applied in all circumstances, rather, it serves to assist technical staff experienced in water resources in the selection of the most appropriate computational method and flexible implementation measures, provided the decisions made are consistent with the latest Provincial Policy Statement". Although the technical guide is not a list of mandatory instructions, it does provide a means by which we can assess the draft MVCA report in terms of conformance to standard methodology in flood plain mapping studies in Ontario.

This technical review focuses specifically on the draft flood plain reporting prepared by MVCA. The following sections will use the MNRF guide as a framework to address all items detailed in **Section 2.0** of this letter report.

4. PRELIMINARY REVIEW

JFSA completed a preliminary review and initial screening of MVCAs' draft report titled Casey Creek Flood Plain Mapping Report (dated January 2020) and supporting documentation. JFSA formalized this preliminary review by providing comments to MVCA on March 13th, 2020 (see **Attachment 1**). MVCA responded to the preliminary review comments and subsequently provided JFSA with an updated draft report and additional hydrologic modelling files, as requested, on March 20th, 2020.

5. SELECTING FLOOD PLAIN STANDARD

According to Figure B-1 of the MNRF guide, the Mississippi Valley jurisdictional area (which includes the Casey Creek watershed) falls within Zone 2. In general, the 100-year flood is the governing flood plain standard for this zone. The exception to using the 1:100-year flood for Zone 2 is if there are recorded or documented flood levels found in the same watershed which exceeded the computed 1:100-year flood levels. The MNRF guide suggests that if the observed event is at least 0.1 m higher than the computed 100-year water level and the watershed characteristics have not changed since the historical observation, then the historical event should be considered for flood plain standard.

The 2020 Provincial Policy Statement identifies the flooding hazard limit as "the greater of:

1. the flood resulting from the rainfall actually experienced during a major storm such as the Hurricane Hazel storm (1954) or the Timmins storm (1961), [these specific storms are not applicable to MNRF Zone 2, where Casey Creek is located], transposed over a specific watershed and combined with local conditions, which evidence suggests that the storm event could have potentially occurred over watersheds in the general area;
2. the one hundred year flood; and
3. a flood which is greater than 1. or 2. which was actually experienced in a particular watershed or portion thereof as a result of ice jams and which has been approved as the standard for that specific area by the Minister of Natural Resources and Forestry"

MVCA has acknowledged that the 1:100-year flood is the flood plain standard to be used in preparing their flood risk maps for the Casey Creek. This is described in Section 1.1 on page 4 of the draft report.

In the absence of an observed water surface elevation (WSEL) in excess of 0.1 m above the 1:100-year and without knowledge of any regulation that would supersede the Provincial Policy Statement referenced above with respect to the flood plain standard, JFSA would agree MVCA has followed the applicable guidelines appropriately.

6. HYDROLOGIC ANALYSIS

6.1 Approach and Methodology

Section 2.1 on page 9 of the draft report indicates MVCA has completed hydrologic modelling to estimate peak flows for Casey Creek. It is noted SWMHMO version 4.02 was the chosen software used to simulate peak flows. This software is widely used for flood plain mapping studies in the City of Ottawa and surrounding areas and suitable for this study.

JFSA acknowledges there are no flow records currently available for Casey Creek and as such, using a hydrologic model is considered a reasonable alternative to a single station or regional frequency analysis.

- It is noted MVCA's draft report acknowledges the flow gauge located on the Carp River at Kinburn (HYDAT ID 02KF011). Suitable justification has been provided for not completing a statistical analysis on this gauge for use or comparison purposes in this particular flood plain mapping study considering the watershed characteristics of the Carp River are quite different from Casey Creek including a drainage area that is more than four times larger. As such, MVCA does not believe flow transpositions based on a frequency analysis of this gauge would result in representative flow values for Casey Creek. These are suitable justifications for MVCA's selected approach for hydrologic analysis.

6.2 Hydrologic Parameters

JFSA completed a cursory review of the hydrologic parameter selection and calculations to confirm general conformance with applicable guidelines. The following subsections provide a brief assessment of the parameters reviewed.

6.2.1 Drainage Area Delineation

It is noted that a SWMHYMO model was previously prepared by MVCA for Constance Creek which included the overall drainage area boundary of Casey Creek. As such, the model for Constance Creek was used as the basis for this study. It is also noted on page 12 of the draft report that sub-catchment areas were delineated from the Digital Elevation Model (DEM) developed by the City of Ottawa using LiDAR information. JFSA offers the following comments regarding the drainage area delineations:

- Page 10 of the draft report indicates that Casey Creek was represented in the Constance Creek SWMHYMO model by eight subcatchment areas. The current study areas are also discretized into eight subcatchment areas, however the report indicates these were redistributed. It is acknowledged that the overall drainage area has remained approximately the same (within 0.15%) and that in itself would have minimal impact on the hydrologic results.
- Figure 5 on page 12 and Table 1 on page 14 of the draft report includes drainage areas for the eight subcatchments delineated which range between 173.9 ha and 2847.4 ha. It is recommended MVCA complete more refined drainage area delineations (smaller subcatchments) to assess the potential impact on peak flows. For example, area A2 has a large drainage area of 2847.4 ha which appears to have variable hydrologic characteristics across the subcatchment. The north western portion is more predominantly wetland and wooded areas while the north eastern portion is more predominantly agricultural land (as shown on Figure 2). Considering each area could have a different hydrologic response it is warranted to check the associated impact to peak flows through further discretization.

6.2.2 Route Channel

- Page 14 of the draft report provides a brief description of the representation of the ROUTE CHANNEL commands in the SWMHYMO model and placement of flow notes. For flow node 3 it is noted that routing occurs through the center of subcatchment 6 and the peak flow from that subcatchment is added at the downstream end. It is assumed portions of subcatchment A6 will drain into the tributary prior to node 3. As such the model may underestimate peak flows along this routing segment. It is recommended MVCA review this route channel command and provide due consideration to adding additional inflow points accordingly.

- Similar to the above, subcatchment A3 is added directly downstream at flow node 8, however a portion of subcatchment A3 will drain to the tributary prior to node 8. It is recommended MVCA review and provide due consideration to adding additional inflow points accordingly.

6.2.3 Time of Concentration

As described on page 15 of the draft report, MVCA has reviewed the applicability of a number of methods to calculate the time of concentration for the sub-catchments including the Airport Formula, Bransby-Williams Formula, Kirpich Formula and SCS Lag Equations. JFSA offers the following comments:

- It is noted the calculation methods chosen by MVCA for the hydrologic model are the Airport Formula and the Bransby- Williams Formula as they are the most applicable to the individual subcatchments for Casey Creek. This is considered a reasonable approach for this study.
- It is recommended MVCA review the profiles of all flow paths and give due consideration to the MTO 85/10 method where applicable. This method avoids the distorting effects of a steep upper portion of a watershed or the effects of a highly irregular or convex or concave profile.
- It is noted, the time to peak values included in the SWMHYMO models for the SCS design storms do match those values provided on Table B2 in Appendix B, however, models for the Chicago storms and spring rainfall-snowmelt storms do not. It is recommended MVCA review this and update the models and/or report accordingly to ensure consistency. It is acknowledged time to peak values have been adjusted as described in Section 2.5, page 22 in the draft report. Refer to technical review comments in Section 6.3 of this memo for additional comments.

6.2.4 CN and Initial Abstraction (Ia) Calculations

It is noted MVCA has determined CN values for a variety of land uses and hydrologic soil types which are provided on Table B3 in Appendix B of the draft report. JFSA offers the following comments on the CN calculations:

- It is shown on Table 1 of the draft report that the CN values reflecting AMC III hydrologic conditions are smaller compared to AMCII. Considering this does not follow typical convention, it is recommended MVCA review and adjust these parameter values as required.
- It is noted CN values not shown on Table 4 are applied in the SWMHYMO model for the Chicago design storms. Those used appear to match the CN values calculated in Appendix B (unadjusted values). It is recommended MVCA update the modelling to suit or otherwise include descriptions in the report justifying the selection of CN values for each type of design storm.
- It is noted a list of CN values used for each land use and soil type is provided on Table B3 in Appendix B of the draft report. This table includes a CN value of 50 for water. Although it is acknowledged the 1997 MTO Drainage Management Manual provides a value of 50 for water, it is recommended MVCA use a higher CN value of given that all of the precipitation that falls on a water surface such as a lake will become runoff.

- It is acknowledged that MVCA has investigated an alternate procedure to the modified CN (or CN*) approach in which the value of Ia is reduced to 0.075*S ('S' is soil storage) and 0.01*S for soil groups A and B respectively. The draft report indicates the Ia values calculated using 0.075*S would be between 4 mm and 15 mm for the areas studied. Finally, on page 17, the draft report indicates Ia values were set to 2.5 mm for all subcatchments in the SWMHYMO model. It is noted that typically, using the modified SCS approach, the CN values would be reduced to CN* values in concert with a reduction in the Ia value (to less than 0.2*S). The combination of using a low Ia value with a standard CN value may overestimate peak flows, particularly for smaller CN values. Although the report indicates that the relatively low values of Ia were set to be conservative, it is recommended that MVCA include further detail on the difference in peak flows if selected CN values were replaced with CN* values. Reducing CN values to CN* is a more justifiable approach than simply reducing Ia values and arbitrary reductions in CN, as described in Section 2.5 of the draft report.

6.2.5 SWMHYMO Precipitation Input

It is noted MVCA has used the Ottawa Sewer Design guidelines as the source to derive summer design rainfall events for their hydrologic model which are presented on Table 2 of the draft report.

- It is noted on page 21 of the draft report that the data used to derive rainfall depths was from the IDF curves derived from rainfall records at the Ottawa International Airport between 1967 and 1997. This is considered a reasonable data source given the record length and proximity of Casey Creek to the Ottawa International Airport.
- It is noted MVCA has developed a procedure to derive spring rainfall-snowmelt synthetic design storms using data from the Meteorological Service of Canada. One, three and five day snowmelt events were considered, volumes distributed near the middle of the day and sine curve used to distribute the volume. Although JFSA is not aware of a standard procedure to follow to derive synthetic rainfall-snowmelt events, the procedure followed by MVCA appears reasonable.

6.3 Verification of Model Performance

Section 2.5 of the draft report provides details of the verification of modeled results and comparison. JFSA offers the following comments:

- It is acknowledged MVCA has completed an exercise using the Ontario Flow Assessment Tool (OFAT) produced by MNRF. It is also noted MVCA has completed a comparison of drainage areas generated using the OFAT tool and those determined for the current study and found them to compare reasonably well (within approximately 3% of each other).
- There are large differences noted between the peak flows generated using SWMHYMO and those estimated using the Index Flow and Multiple Regression Methods (approximately 200% to 300% higher at four comparison locations) for the current study during the initial model simulations as reported in Section 2.5 of the draft report. It is noted that the previous 2017 study of Constance Creek, also completed by MVCA, adjusted CN values (decreased by 10%) to bring OTTHYMO/SWMHYMO peak flows closer to the range determined by these other methods. In the current study, CN values are decreased by 15% in combination with doubling the Tp value. It is recommended MVCA rather modify hydrologic parameters based on what is most representative and justifiable. This may include revisiting the CN and time to peak calculations.

6.4 Comparison to Previous Studies

- It is noted MVCA has completed a comparison of peak flows between previous studies of Constance Creek as well as a compilation of watersheds with similar size and land use within MVCA and RVCA jurisdictions. This method of comparison helps to ensure simulated peak flows are within an appropriate range and a suitable method for this study.

- It is recommended MVCA add the drainage area of each individual creek/drain compared on Figure 7 of the draft report as the size of the watershed will have an impact on the unit peak flows.
- It is recommended MVCA revisit the comparisons shown on Figure 7 following changes to their modelling as a result of the enclosed technical review comments.

7. HYDRAULIC ANALYSIS

It is noted that HEC-RAS software (version 5.0.7) was used to study Casey Creek. This modeling software is widely used in Ontario, used for other flood plain mapping projects in the Ottawa area and considered sufficient for this flood plain study.

The HEC-RAS modelling files used for this technical review include:

(Summer Model Files – 12-Hour SCS)

- **Project:** HEC-RAS Model (*Casey Creek.prj*)
- **Plan:** Casey (*Casey Creek.p03*)
- **Geometry:** Casey (*Casey Creek.g03*)
- **Steady Flow:** Default Steady Flow (*Casey Creek.f01*)

7.1 Flow Inputs

A cursory review of the draft report sections 3.1 (Methodology) and 3.2 (Input Parameters) was completed. JFSA offers the following comments:

- Section 3.1 on page 38 of the draft report refers to the development of an estate residential subdivision and associated channel alterations works. Although detailed topographic data may not be available, if hydrologic characteristics of this development are available, it is recommended MVCA directly incorporate this information into the hydrologic model.
- It is noted modelled flows have been prorated to obtain peak flows at intermediate locations. It is recommended that MVCA rather complete more detailed drainage area discretization to obtain these peak flows. Refer to Section 6.2.1 of this memo for additional review comments.

7.2 Review of Cross Section Data

7.2.1 Cross-Sectional Geometry

A cursory review of the cross-sectional geometry and the descriptions provided in the draft report has been completed. JFSA offers the following comments:

- It is noted on page 40 of the draft report that a DEM derived from LiDAR was used to produce the cross-section data in the HEC-RAS model, which is representative of above water elevations. JFSA acknowledges this inherently adds some conservatism to the available cross section conveyance capacity. Supplementing the LiDAR derived cross-section geometry with field verified cross sections would further provide confidence to the model and worth consideration by MVCA.
- It is noted in Section 3.2 on page 40 of the draft report that the cross-sections are oriented left to right looking downstream. The cursory review has identified this is not the case for three cross sections including 809 (River: Casey, Reach: Trib 1-DS-0), 1 (River: Casey, Reach: Main-DS-1-DS-0) and 1293 (River: Casey, Reach: Main). It is recommended MVCA review cross section orientations and update the HEC-RAS model accordingly.

- It is noted cross section 827 (River: Casey, Reach: Main) extends into an adjacent spill area outside of the flood conveyance path. It is recommended MVCA update this cross section to only allow flow through the main channel.
- It is noted there are a number of cross sections in which the left and right bank stations are not correctly located. For example, cross section 622 (River: Casey, Reach: Trib 3) are both applied along the left bank geometry of the cross section. It is recommended MVCA review the placement of all left and right bank stations and update the model accordingly.

7.2.2 Overbank Lengths

As per the HEC-RAS Hydraulic Reference Manual, channel reach lengths should be measured along the thalweg. Overbank reach lengths should be measured along the anticipated path of the center of mass of the overbank flow. Although these lengths are of generally similar value, there are conditions where they differ significantly such as at river bends or where the channel meanders and overbanks are straight.

- Cursory checks of the reach lengths for the left and right overbanks indicate efforts have been made to adjust lengths and are in general conformance with the HEC-RAS methodology described above.

7.2.3 Manning's 'n' Coefficients

The methods used and selection of Manning's 'n' coefficients are provided on page 41 of the draft report. The range of values selected is between 0.045 and 0.1 for overbanks and 0.032 for the main channel as well as 0.013 and 0.024 for concrete and CSP culverts, respectively. These values generally fall within the applicable range of standard values.

- A cursory review of the Manning's 'n' coefficients selected, and aerial photos indicates there are locations where MVCA could consider higher values in the overbanks to represent forested/heavy brush areas more appropriately within the study area. It is recommended MVCA review these areas and give due consideration to updating the model accordingly.

7.2.4 Ineffective Flow Areas

It is noted that ineffective flow areas have been placed at the cross sections immediately upstream and downstream of all nine crossings included in the HEC-RAS model. This follows typical HEC-RAS convention to capture the contraction and expansion of flow and associated losses through these structures. JFSA offers the following comments regarding ineffective flow areas:

- The elevations specified for ineffective flow should generally correspond to elevations where significant flow passes over the crossing. For the upstream cross section, this is normally set at the lowest point of the top of road. At the downstream cross section, the elevation is normally set initially to an elevation below top of road (such as between low chord and lowest point of the top of road). It is recommended MVCA review the selection of ineffective flow elevations against these guiding principles and update the HEC-RAS model accordingly. For example, the ineffective flow areas applied at the upstream side of the Marchurst Road crossing (River: Casey, Reach: Trib 2, River Sta. 3483) are set at elevations above the road surface.
- It is noted the ineffective flow areas placed left and right of the culvert in cross section 2704 (River: Casey, Reach: Main) are not set at the appropriate location and blocking a portion of the culvert opening. This is also the case at cross section 840 (River: Casey, Reach: Trib 2) and cross section 2089 (River: Casey, Reach: Main-DS-1-DS-0). It is recommended MVCA review these cross sections and update the position of the ineffective flow areas accordingly.

7.2.5 Contraction and Expansion Coefficients

JFSA completed a comparison between the contraction/expansion coefficients and the draft flood plain geometry prepared by MVCA. JFSA offers the following comments:

- It is noted MVCA has applied contraction and expansion coefficients of 0.1 and 0.3 at most cross sections other than those adjacent to structures. This generally conforms to HEC-RAS modelling convention.
- It is noted there are inconsistencies in the HEC-RAS model regarding the increase in contraction and expansion coefficients in cross sections adjacent to structures. In general, the contraction and expansion coefficients should be increased at the first two cross sections upstream and first cross section downstream of structures in the HEC-RAS model. It is recommended MVCA review these cross sections and update the model accordingly.

7.2.6 Levees

It is noted MVCA has included levees at five select cross sections in their HEC-RAS model. JFSA offers the following comments regarding levees:

- Judgment should be made in the placement of levees with respect to which areas of the cross section are likely to convey flow if that elevation is overtopped. This judgment will include an investigation of looking at both upstream and downstream cross sections for similar conveyance features. If a conveyance channel appears to be present in one cross section but the adjacent ones do not contain these same features, then it is not likely the middle cross section will convey flow at that location. Levee locations in this case would be set to prevent bank overflow into what may only appear to be a conveyance channel. It is recommended MVCA provide due consideration of these principles in selecting the location of levees for use in their HEC-RAS modelling.

7.2.7 Junctions

- It is noted junctions Junc-DS02, Junc-DS03, and Junc-DS04 appear to include junction lengths which are not representative of the distance to adjacent cross sections. It is recommended MVCA review all junctions and confirm the junction lengths used are correct.

7.3 Boundary Conditions

The explanation provided by MVCA on pages 41, 42 and 43 of the draft report regarding boundary conditions are considered reasonable.

- It is noted Flood Hazard Map 10 shows a study limit line such that the closest cross section to Constance lake that is mapped in this study is 1160. At this cross section, the governing scenario is the 100-year flow on Casey Creek in combination with the 2-year water level on Constance Lake. The report and Flood Hazard Map are consistent at this location and respect the boundary condition as described in the report.

7.4 Review of Structures

A cursory review of the nine structures included in the HEC-RAS model was completed. JFSA offers the following comments:

- As noted in section 7.2.4 of this memo, the ineffective flow areas in the downstream cross section of the structure located at river station 2724 (River: Casey, Reach: Main) appear to be blocking a section of the culvert opening. There is also a warning message at this culvert location regarding the ineffective flow area being set in too far. It is recommended MVCA review this and update the model accordingly.

- It is noted there is structure missing from the hydraulic model which could potentially affect flood line delineations. The location between river station 2704 and 2541 (River: Casey, Reach: Main). It is recommended MVCA review this crossing and provide due consideration to adding it to the model.
- It is noted the entrance loss coefficient appears to be set to 0.5 for all culverts. It is recommended this value be selected based on the applicable inlet geometry. For example, the structure located at river station 1300 (River: Casey, Reach: Main) appears to be for a corrugated metal pipe that is projecting from fill. For this inlet configuration, the standard entrance loss coefficient should be set to 0.9, however a value of 0.5 has been selected. It is recommended MVCA review the entrance loss coefficients for all structures giving due consideration to inlet geometries in the selection of this coefficient.
- It is noted the simulated 100-year WSEL at the upstream side of the crossing located at river station 1326 (River: Casey, Reach: Trib 1-DS-0) is approximately 4 m higher than the WSEL on the downstream side. There is also a warning message indicating the flow in the culvert is entirely supercritical. The structure at river station 699 (River: Casey, Reach: Main-DS-1) shows similar results. It is recommended MVCA review these structures to ensure the simulated results are accurate.
- There are a number of warning messages noted in the HEC-RAS model associated to structures. It is recommended MVCA assess the reasons behind warning messages and update the model to eliminate these warning messages if possible.

7.5 Sensitivity Analysis

A cursory review of the sensitivity analysis was completed. JFSA offers the following comments:

- For the sensitivity analysis, it is recommended MVCA consider including the potential impact(s) of using the 100-year WSEL on Constance Lake in combination with a 100-year design storm on Casey Creek. This would be a test of the sensitivity of the boundary condition selected and of the MVCA conclusion that high water levels at the confluence of the two watercourses will be generated by two independent flood events.

8. FLOOD LINE DELINEATION

8.1 Flood Hazard Maps

JFSA has completed a cursory review of the draft flood hazard maps for Casey Creek which include map index numbers 1 through 10. JFSA offers the following comments:

- As indicated on page 48 of the draft report and Flood Hazard Map 9, there are five spills shown. Considering three of the spills are directed toward the same area, it is recommended MVCA give due consideration to delineating the flood plain in this area.
- As described on page 49 of the draft flood plain mapping report, it is acknowledged MVCA has not reduced flood flows as a result of spills. This is considered a conservative and reasonable approach for those areas from which the spills occur.

We trust the technical review comments enclosed will assist the City of Ottawa and MVCA toward the successful completion of this flood plain mapping project.

9 STATEMENT OF LIMITATIONS

Our technical review of MVCAs draft Casey Creek Flood Plain Mapping Study was limited to the specific scope of work for which we were retained and that is described in this report. Our review comments should be evaluated in light of this limited scope of work.

JFSA has relied in good faith on all information provided and does not accept responsibility for any deficiencies, misstatements, or inaccuracies contained in the report as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation and data.

JFSA is not a guarantor of the accuracy, completeness or adequacy of this information provided by others. JFSA assumes no responsibility or liability for errors or omissions resulting from inaccuracies in the data received from others. JFSA assumes no responsibility for any negligence by others related to the data provided for this technical review.

JFSA has provided technical review comments based on the information received. Final decisions regarding how these comments are addressed is not the responsibility of JFSA.

JFSA warrants only that its work was undertaken, and technical review comments prepared in a manner consistent with the level of skill and diligence normally exercised by competent engineering professionals practicing in the Province of Ontario.

Respectfully Submitted,

J.F Sabourin and Associates Inc.

Bryan Willcott

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Attachment 1 - Completed Pre-Screening Checklist for Casey Creek

JFSA
WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS

Project Ref #:P1747(06)
Client: City of Ottawa

Ottawa, ON
Paris, ON
Gatineau, QC
Montréal, QC
Québec, QC

Attachment 1

Pre-Screening Checklist

June 2020

Project Name: Casey Creek Flood Plian Mapping Study

Checklist Completed By: John Price **Date:** 28-Jan-20
JFSA Comments Provided By: Bryan Willcott **Date:** 13-Mar-20

Flood Hazard Mapping Study Checklist

	REQUIRED DOCUMENTATION	DOCUMENTATION INCLUDED? Y = Yes, N = No, NA = Not Applicable	FLOOD PLAIN MAPPING REPORT PAGE/APPENDIX REFERENCE	CA COMMENTS	JFSA PRELIMINARY TECHNICAL REVIEW (SCREENING) COMMENTS
1.0	***PROJECT INFORMATION***				
1.1	General description of the watercourse	☑ Y ☐ N ☐ NA	Section 1.2	-	OK
1.2	Description of study area and mapping limits *(including land use, overall imperviousness, etc.)*	☑ Y ☐ N ☐ NA	Section 2.2 and 2.3 Table 1	-	OK
1.3	Description of past flood plain studies and mapping for this watercourse *(list in comments)*	☑ Y ☐ N ☐ NA	Section 1.3	Constance Creek Flood Plian Mapping Study M. E. Andrews (1994) Constance Creek Flood Plain Mapping Study (April 2017), Mississippi Valley Conservation Authority	OK
1.4	Description of background drainage reports, SWM reports, etc. that were used to complete current study *(list in comments)*	☑ Y ☐ N ☐ NA	Section 2.3	Marchurst Estates Kanata,City of Ottawa - Revised Stormwater Management Report (Januray 2014), Stantec	OK
2.0	***HYDROLOGIC ANALYSIS***				
2.1	Floodplain standard selected *(ie: 1:100 year storm, historical storm, etc.)*	☑ Y ☐ N ☐ NA	Section 2.6	MVCA watershed is within Zone 2 and therefore the Regulatory flood hazard criterion is the 1:100 year flood. To employ a different flood stadard would require prior approval of the Minister of Natural Resources and revision to the MVCA regulation (Ontario Regulation 153/06)	OK
2.2	Clear identification of which hydrologic data has been measured and which data has been assumed	☑ Y ☐ N ☐ NA	Section 2.3 Appendix B and C	-	OK
2.3	The source of all hydrologic data used in the analysis is clearly documented and justified	☑ Y ☐ N ☐ NA	Section 2.3 Appendix B and C	-	OK
2.4	Tables, maps and/or graphs included to illustrate data such as stream flow records, historical storms, stage-discharge relationships, cross sections and profiles	☑ Y ☐ N ☐ NA	Appendix B and C.	-	OK
2.5	Flood Frequency Analysis used? If not, continue to 2.6.	☐ Y ☐ N ☑ NA	-	-	OK
2.5.1	Description of stream flow and rainfall records	☐ Y ☐ N ☑ NA	-	-	OK
2.5.2	Description of conversion of regulated stream flows to natural conditions (*if stream is subject to significant artificial regulation by dam, diversions, etc. that have significant effects on peak flows*)	☐ Y ☐ N ☑ NA	-	-	OK
2.5.3	Single Station Frequency analysis used? If so:	☐ Y ☐ N ☑ NA	-	-	OK
2.5.3.1	Data used, choice of probability distribution and method of parameter estimate documented	☐ Y ☐ N ☑ NA	-	-	OK

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	2.5.4	Regional Flood Frequency analysis used? If so:	☐ Y ☐ N ☑ NA	-	Index Flood Method and Multiple Regression Method , through the Ontario Flow Assessment Tool, used for compariosn as detailed in Section 2.4	OK
	2.5.4.1	The extent of the region and streams included are described along with the records used at each station	☐ Y ☐ N ☑ NA	-	-	OK
2.6		Rainfall/Runoff Modelling used? If not, continue to 2.7.	☑ Y ☐ N ☐ NA	-	-	OK
	2.6.1	Description of the basic methodology, assumptions and previous use	☑ Y ☐ N ☐ NA	Section 2.4.2	-	OK. Methodology is noted in Section 2.1.
	2.6.2	All hydrologic input parameters fully documented	☑ Y ☐ N ☐ NA	Tables 1, 2 and 4	-	OK. Descriptions provided in Section 2.3.
	2.6.3	Complete description of data extracted from background reports	☑ Y ☐ N ☐ NA	Section 2.3 and 2.6	-	OK
	2.6.4	SWM ponds included in the hydrologic modelling	☐ Y ☐ N ☑ NA	-	No SWM facilituies in watershed	OK
	2.6.4.1	Source of SWM pond data clearly identified	☐ Y ☐ N ☑ NA	-	-	OK
	2.6.4.2	Clear identification of the stage-storage-outflow relationship of the SWM ponds	☐ Y ☐ N ☑ NA	-	-	OK
	2.6.4.3	Clear identification of controlled and uncontrolled drainage areas	☐ Y ☐ N ☑ NA	-	-	OK
	2.6.5	Description and justification for rainfall data used	☑ Y ☐ N ☐ NA	Section 2.4.2	-	OK
	2.6.6	Description of method of calibration and validation, the records used and documentation of the comparison of simulated flows with flows obtained from other analysis (such as MTO Regional Frequency or Rational Method)	☑ Y ☐ N ☐ NA	Section 2.5	-	OK
2.7		Flows presented in tabular form for different events and locations	☑ Y ☐ N ☐ NA	Table 5A to 5J	-	OK
2.8		Comparison of flows with previous estimates and recorded events	☑ Y ☐ N ☐ NA	Section 2.6.1	-	OK
3.0		***HYDRAULIC ANALYSIS***				

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3.1	General description of the topography of the flood plain documented	☑ Y ☐ N ☐ NA	Section 1.2	-	OK
3.2	Method(s) for obtaining cross sections documented	☑ Y ☐ N ☐ NA	Section 3.2	-	OK
3.3	Summary of all structures and appurtenances (inlet and outlet configurations, headwalls, wing walls, piers, abutments, inverts, etc.)	☑ Y ☐ N ☐ NA	Appendix F	-	OK
3.4	Description / source of the roughness coefficients selected	☑ Y ☐ N ☐ NA	Section 3.2	-	OK
3.5	Description / source of the starting water level (downstream boundary condition)	☑ Y ☐ N ☐ NA	Section 3.2 and 3.3	-	OK
3.6	Description of extrapolation of stage-discharge curves of monitored data	☐ Y ☐ N ☑ NA	-	-	OK
3.7	Description of the backwater hydraulic software used	☑ Y ☐ N ☐ NA	Section 3.1	-	OK
3.8	Description of which coefficients used in the hydraulic software where obtained by direct or indirect measurement	☑ Y ☐ N ☐ NA	Section 3.2	-	OK
3.9	Description of the reasons behind water level differences as compared to previous studies	☐ Y ☐ N ☑ NA	-	No previous hydraulic studies	OK
3.10	Description of the techniques employed and calculations completed for ice or log jams	☐ Y ☐ N ☑ NA	-	-	OK
3.11	For lakes, wind setup and wave estimates are documented	☐ Y ☐ N ☑ NA	-	-	OK
3.12	Description of the effect of dams or dykes on hydraulic modelling	☐ Y ☐ N ☑ NA	-	-	OK
3.13	Tabular summary of backwater computations listing water levels for different flows and locations.	☑ Y ☐ N ☐ NA	Appendix G	-	OK
3.14	Summary of previous backwater analysis and observed past flood events documented	☐ Y ☐ N ☑ NA	-	No observed past flood events	OK
3.15	Description of calibration and validation of the backwater model	☐ Y ☐ N ☑ NA	-	-	OK
3.16	Summary of the sensitivity analysis documented	☑ Y ☐ N ☐ NA	Section 3.3.1	-	OK
3.17	Identification of spill areas in the hydraulic models and commentary on the effect of the spill	☑ Y ☐ N ☐ NA	Section 4.1	-	OK

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4.0	***FLOOD LINE DELINEATION***					
4.1	Description of flood line delineation		☑ Y ☐ N ☐ NA	Section 4.0	-	OK
	4.1.1	Date of aerial photos	☑ Y ☐ N ☐ NA	Section 4.0	-	OK
	4.1.2	Scale	☑ Y ☐ N ☐ NA	Section 4.0	-	OK
	4.1.3	Topographic contour intervals	☑ Y ☐ N ☐ NA	Section 4.0	-	OK
	4.1.4	Accuracy	☑ Y ☐ N ☐ NA	Section 4.0	-	OK
4.2	Explanation of the methodology used to plot flood lines		☑ Y ☐ N ☐ NA	Section 4.0	-	OK
4.3	Clear explanation of spill locations and study limits shown on maps		☑ Y ☐ N ☐ NA	Appendix D	See flood plain maps	OK
4.4	Description of floodway and flood fringe zones and the effect on encroachment on the flood plain		☐ Y ☐ N ☑ NA	-	-	OK
4.5	Description of the effect of dams or dykes on flood lines		☐ Y ☐ N ☑ NA	-	-	OK
5.0	***EXHIBITS***					
5.1	Location maps identifying study areas		☑ Y ☐ N ☐ NA	Appendix D	-	OK
5.2	Identification of historically flooded areas		☐ Y ☐ N ☑ NA	-	No information	OK
5.3	Identification of location of major structures, bridge data sheets		☑ Y ☐ N ☐ NA	Appendix F	-	OK
5.4	Historical photos		☐ Y ☐ N ☑ NA	-	-	OK
5.5	Tables and hydrographs to provide summary of discharges, elevation and mean velocities with cross section references		☑ Y ☐ N ☐ NA	Appendix G	-	OK
5.6	Flood frequency curves		☐ Y ☐ N ☑ NA	-	-	OK
5.7	Where a two zone application is used, computed width, depth and velocities across the flood fringe areas at both sides of the cross section		☐ Y ☐ N ☑ NA	-	-	OK

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5.8	Plot of flood profile	☑ Y ☐ N ☐ NA	Appendix E	-	OK
5.9	Plots of all cross sections as well as water surface profiles for each flood event considered	☑ Y ☐ N ☐ NA	Appendix E	-	OK

Casey Creek Flood Plain Mapping Report		
	JFSA Comment	**MVCA Response**
	Hydrologic Analysis	
1	It is recommended MVCA complete more refined drainage area delineations (smaller subcatchments) to assess the potential impact on peak flows.	A more detailed drainage area delineation was completed, the number of subcatchments was doubled in the revised hydrologic model.
2	Portions of subcatchment A6 will drain into the tributary prior to note 3. It is recommended MVCA review this route channel command and provide due consideration to adding additional inflow points accordingly	Subcatchment A6 was split into smaller subcatchments to provide additional inflow points.
3	A portion of subcatchment A3 will drain to the tributary prior to node 8. It is recommended MVCA review and provide due consideration to adding additional inflow points accordingly.	Subcatchment A3 was split into smaller subcatchments to provide additional inflow points.
4	It is recommended MVCA review the profiles of all flow paths and give due consideration to the MTO 85/10 method where applicable.	The MTO 85/10 method was utilized in the revised hydrologic model.
5	It is noted, the time to peak values included in the SWMHYMO models for the SCS design storms do match those values provided on Table B2 in Appendix B, however, models for the Chicago storms and spring rainfall-snowmelt storms do not. It is recommended MVCA review this and update the models and/or report accordingly to ensure consistency.	The time-to-peak values were updated in the report.
6	It is shown on Table 1 of the draft report that the CN values reflecting AMC III hydrologic conditions are smaller compared to AMCII. Considering this does not follow typical convention, It is recommended MVCA review and adjust these parameter values as required.	The CN values were updated in the report.
7	It is noted CN values not shown on Table 4 are applied in the SWMHYMO model for the Chicago design storms. Those used appear to match the CN values calculated in Appendix B (unadjusted values). It is recommended MVCA update the modelling to suit or otherwise include	The CN values were updated in the model and report.

	descriptions. It is recommended MVCA update the modelling to suit or otherwise include descriptions in the report justifying the selection of CN values for each type of design storm.	
8	It is noted a list of CN values used for each land use and soil type is provided on Table B3 in Appendix B of the draft report. This table includes a CN value of 50 for water. Although it is acknowledged the 1997 MTO Drainage Management Manual provides a value of 50 for water, It is recommended MVCA use a higher CN value of given that all of the precipitation that falls on a water surface such as a lake will become runoff.	A CN value of 50 was used for water and wetland land uses for all hydrologic soil types. Although all precipitation that falls on this lad use could initially produce runoff, depending on the outlet configuration/restriction this runoff will not necessarily be conveyed downstream (i.e. stored within the waterbody or wetland). Since the water depth or return period flood event at which conveyance downstream occurs is not specifically known a CN value of 50 was employed. Within the Casey Creek watershed, there is approximately 475 ha of wetland area (8.6% of the total watershed area) and only 35 ha of water (0.6% of the total watershed area). Since these two land uses comprise a relatively small percentage of total drainage area, using a higher CN value would have minimal impact on the calculated weighted CN value used in the analysis and hence an even smaller impact on the calculated flow values.
9	Although the report indicates that the relatively low values of Ia were set to be conservative, it is recommended that MVCA include further detail on the difference in peak flows if selected CN values were replaced with CN* values.	The CN values were not lowered and the CN* numbers were not used in the revised model.
10	There are large differences noted between the peak flows generated using SWMHYMO and those estimated using the Index Flow and Multiple Regression Methods (approximately 200% to 300% higher at four comparison locations) for the current study during the initial model simulations as reported in Section 2.5 of the draft report. It is noted that the previous 2017 study of Constance Creek, also completed by MVCA, adjusted CN values (decreased by 10%) to bring OTTHYMO/SWMHYMO peak flows closer to the range determined by these other methods. In the current study, CN values are decreased by 15% in combination with doubling the Tp value. It is	MVCA developed a new hydrologic model that did not require arbitrary reductions of model parameters.

	recommended MVCA rather modify hydrologic parameters based on what is most representative and justifiable. This may include revisiting the CN and time to peak calculations. It is recommended MCVA rather modify hydrologic parameters based on what is most representative and justifiable. This may include revisiting the CN and Time to peak calculations.	
11	It is recommended MVCA add the drainage area of each individual creek/drain compared on Figure 7 of the draft report as the size of the watershed will have an impact on the unit peak flows.	The drainage area is accounted for in the specific peak flows (L/s/Ha).
12	It is recommended MVCA revisit the comparisons shown on Figure 7 following changes to their modelling as a result of the enclosed technical review comments.	Figure 7 was updated with the revised modeling results.
	Hydraulic Analysis	
13	The report refers to the development of an estate residential subdivision and associated channel alterations works. Although detailed topographic data may not be available, if hydrologic characteristics of this development are available, it is recommended MVCA directly incorporate this information into the hydrologic model.	Detailed hydrologic information was not available; however, a slightly increased CN number was used in this subcatchment to reflect the proposed development.
14	It is recommended that MVCA rather complete more detailed drainage area discretization to obtain peak flows at intermediate locations rather than prorated.	Addressed in the revised version of the hydrologic model.
15	It is noted in Section 3.2 on page 40 of the draft report that the cross-sections are oriented left to right looking downstream. The cursory review has identified this is not the case for three cross sections including 809 (River: Casey, Reach: Trib 1-DS-0), 1 (River: Casey, Reach Main-DS-1-DS-0) and 1293 (River: Casey, Reach: Main). It is recommended MVCA review cross section orientations and update the HEC-RAS model accordingly.	Cross-sections were reviewed and the flow directions were corrected in the revised hydraulic model.
16	It is noted cross section 827 (River: Casey, Reach: Main) extends into an adjacent spill area outside of the flood	A levee was added on the right side to confine the flow within the conveyance path.

	conveyance path. It is recommended MVCA update this cross section to only allow flow through the main channel.	
17	It is noted there are a number of cross sections in which the left and right bank stations are not correctly located. For example, cross section 622 (River: Casey, Reach: Trib 3) are both applied along the left bank geometry of the cross section. It is recommended MVCA review the placement of all left and right bank stations and update the model accordingly.	Bank stations were corrected in the revised model as appropriate.
18	A cursory review of the Manning's 'n' coefficients selected, and aerial photos indicates there are locations where MVCA could consider higher values in the overbanks to represent forested/heavy brush areas more appropriately within the study area. It is recommended MVCA review these areas and give due consideration to updating the model accordingly.	As mentioned in the report, higher Manning's 'n values were used in the model on appropriate river reaches. 'For the flood plain (left and right overbanks), the flood plain vegetation is fairly uniform for most of the study reaches of Casey Creek consisting of pasture or crop field with some isolated areas of light brush. Therefore, a Manning's n value of 0.045 was used for most of the flood plain areas. In a few short reaches, this value was increased to 0.06 to represent more dense and mature vegetation. Downstream of Dunrobin Road, the vegetation becomes heavier. Therefore, a Manning's n value of 0.1, as noted in Table 5-6 (Ven Te Chow), corresponds to a flood plain with medium to dense brush, in summer was used for that reach in the HEC-RAS model'.
19	The elevations specified for ineffective flow should generally correspond to elevations where significant flow passes over the crossing. For the upstream cross section, this is normally set at the lowest point of the top of road. At the downstream cross section, the elevation is normally set initially to an elevation below top of road (such as between low chord and lowest point of the top of road). It is recommended MVCA review the selection of ineffective flow elevations against these guiding principles and update the HEC-RAS model accordingly. For example, the ineffective flow areas applied at the upstream side of	Placements of ineffective areas were reviewed and revised as appropriate.

	the Marchurst Road crossing (River: Casey, Reach: Trib 2, River Sta. 3483) are set at elevations above the road surface.	
20	It is noted the ineffective flow areas placed left and right of the culvert in cross section 2704 (River: Casey, Reach: Main) are not set at the appropriate location and blocking a portion of the culvert opening. This is also the case at cross section 840 (River: Casey, Reach: Trib 2) and cross section 2089 (River: Casey, Reach: Main-DS-1-DS-0). It is recommended MVCA review these cross sections and update the position of the ineffective flow areas accordingly.	Placements of ineffective areas were reviewed and revised as appropriate.
21	It is noted there are inconsistencies in the HEC-RAS model regarding the increase in contraction and expansion coefficients in cross sections adjacent to structures. In general, the contraction and expansion coefficients should be increased at the first two cross sections upstream and first cross section downstream of structures in the HEC-RAS model. It is recommended MVCA review these cross sections and update the model accordingly.	Contraction and expansion coefficients were reviewed and revised as appropriate
22	Judgment should be made in the placement of levees with respect to which areas of the cross section are likely to convey flow if that elevation is overtopped. This judgment will include an investigation of looking at both upstream and downstream cross sections for similar conveyance features. If a conveyance channel appears to be present in one cross section but the adjacent ones do not contain these same features, then it is not likely the middle cross section will convey flow at that location. Levee locations in this case would be set to prevent bank overflow into what may only appear to be a conveyance channel. It is recommended MVCA provide due consideration of these principles in selecting the location of levees for use in their HEC-RAS modelling.	All levees in the model were reviewed and placed following their upstream and downstream conveyance features as appropriate.

23	It is noted junctions Junc-DS02, Junc-DS03, and Junc-DS04 appear to include junction lengths which are not representative of the distance to adjacent cross sections. It is recommended MVCA review all junctions and confirm the junction lengths used are correct.	Junction lengths were reviewed and corrected as required.
24	As noted in section 7.2.4 of this memo, the ineffective flow areas in the downstream cross section of the structure located at river station 2724 (River: Casey, Reach: Main) appear to be blocking a section of the culvert opening. There is also a warning message at this culvert location regarding the ineffective flow area being set in too far. It is recommended MVCA review this and update the model accordingly.	Ineffective flow areas were reviewed and corrected as required.
25	It is noted there is structure missing from the hydraulic model which could potentially affect flood line delineations. The location between river station 2704 and 2541 (River: Casey, Reach: Main). It is recommended MVCA review this crossing and provide due consideration to adding it to the model.	The water crossing structure is included in the revised model.
26	It is noted the entrance loss coefficient appears to be set to 0.5 for all culverts. It is recommended this value be selected based on the applicable inlet geometry. For example, the structure located at river station 1300 (River: Casey, Reach: Main) appears to be for a corrugated metal pipe that is projecting from fill. For this inlet configuration, the standard entrance loss coefficient should be set to 0.9, however a value of 0.5 has been selected. It is recommended MVCA review the entrance loss coefficients for all structures giving due consideration to inlet geometries in the selection of this coefficient.	Entrance loss coefficients were reviewed and revised as appropriate. The structure located at river station 1300 of the original model (River: Casey, Reach: Main) is a Concrete pipe with a square-cut end and a value of 0.5 was used as entrance loss coefficient.
27	It is noted the simulated 100-year WSEL at the upstream side of the crossing located at river station 1326 (River: Casey, Reach: Trib 1-DS-0) is approximately 4 m higher than the WSEL on the downstream side. There is also a	Both these structures (at Tributary 1 and Main-DS-1) are upstream of the abandoned railway line crossing (now utilized as a trail). The crossing has a fairly small opening (3.0 m span by 1.0 m rise) and there is over 4.5 m of cover (fill) above the obvert of the culvert to the top of the

	warning message indicating the flow in the culvert is entirely supercritical. The structure at river station 699 (River: Casey, Reach: Main-DS-1) shows similar results. It is recommended MVCA review these structures to ensure the simulated results are accurate.	minimum top of the road/trail. This crossing orientation does cause a substantial increase in the upstream water elevation. These structures were reviewed and the revised hydraulic model run with a mixed flow regime also simulated similar results as the 1-D steady-state model.
28	There are a number of warning messages noted in the HEC-RAS model associated to structures. It is recommended MVCA assess the reasons behind warning messages and update the model to eliminate these warning messages if possible.	Messages were reviewed and eliminated as appropriate.
29	For the sensitivity analysis, it is recommended MVCA consider including the potential impact(s) of using the 100-year WSEL on Constance Lake in combination with a 100-year design storm on Casey Creek. This would be a test of the sensitivity of the boundary condition selected and of the MVCA conclusion that high-water levels at the confluence of the two watercourses will be generated by two independent flood events.	The scenario, 100-yr WSEL (60.9 m) at Constance Creek with 100-yr flows at Casey Creek did not produce any difference in the WSEL upstream of XS 1160 at the downstream end.
Flood Line Delineation		
30	As indicated on page 48 of the draft report and Flood Hazard Map 9, there are five spills shown. Considering three of the spills are directed toward the same area, it is recommended MVCA give due consideration to delineating the flood plain in this area.	A 2D model was developed and analyzed for this spill area and the results were consistent with the 1D model results.