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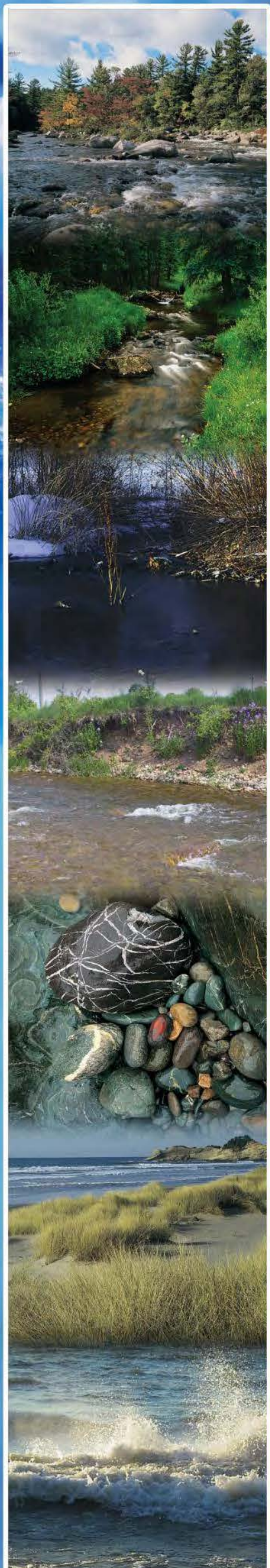

water's edge
ENVIRONMENTAL SOLUTIONS TEAM LTD.

14 Mile Creek Tributaries

Fluvial Geomorphological and Erosion Threshold Assessment

October 21, 2013

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WE 10032

Steve van Haren, P.Eng., P.E.
Project Manager, Water Resources
Associate
MMM Group Limited
100 Commerce Valley Drive West
Thornhill, Ontario L3T 0A1

Dear Mr. van Haren:

RE: Bentall Development, Town of Oakville
North Oakville EIR/FSS - 14 Mile Creek Tributaries
Fluvial Geomorphological and Erosion Threshold Assessment

MMM Group Ltd (MMM) was engaged by Bentall to undertake an Environmental Implementation Report and Functional Servicing Study for the lands located within the Town of Oakville. As part of this study, Water's Edge was requested to complete a fluvial geomorphological and erosion threshold assessment of the 14 Mile Creek tributaries immediately north and south of Dundas Street, the direct receiving water bodies for existing and future stormwater runoff.

The proposed Development Lands will contribute runoff to these tributaries and an assessment of the tributaries is required in order to ensure that changes upstream as a result of development will not cause adverse impacts. Water's Edge has completed a fluvial assessment of the East and West Tributaries south of Dundas Street, and the tributary north of Dundas Street. Appropriate erosion thresholds have been determined for the studied tributaries. Our assessment included an examination of the general geomorphic characteristics and an assessment of erosion threshold values.

Site inspections of the Study Area were completed by Water's Edge staff on various occasions (November 25 and December 3, 2010, and June 7, 2013). The tributaries south of Dundas were surveyed in 2010 and the West Tributary to the north of Dundas was surveyed in 2013. The site inspections were undertaken after a review of the mapping and available literature was completed in order to confirm site and general system characteristics.

Data sources for the analysis include:

- Air photograph mosaic of the Study Area (Google, 2010);
- Historic Air Photos – 1934, 1960, 1961, 1969, 1979 and 1988 (from MMM);
- Hydrological Modelling (MMM, 2011);
- Geomorphic Field Assessments and Surveys (Water's Edge); and
- Discussions with MMM staff.

1.0 EXISTING GEOMORPHIC CONDITIONS

The Study Area is located within the Town of Oakville, generally bounded by Bronte Road to the east and Tremaine Road to the west, immediately north and south of Dundas Street. The tributaries of interest are likely 2^{nd} order tributaries of 14 Mile Creek. The source of the tributary is agricultural lands north of Dundas Street. In each tributary, overland runoff and possible tile drainage flows south to the Dundas Street culverts. From the Dundas Street culverts, the tributaries continue to flow southerly through riparian zones between residential developments to their confluence approximately 800 metres south of Dundas Street. The confluence of the combined tributaries with 14 Mile Creek is approximately 1 kilometre further downstream. Figure 1 presents an aerial photograph of the site based on Google imagery.

Figure 1: Site Location

The watersheds to the Dundas Street culverts consist of rural agricultural with inclusions of low-lying areas. At the West and East Tributaries south of Dundas Street, existing and proposed residential development flanks the riparian zone. The existing watersheds are approximately 359 ha and 388 ha for the East and West Tributaries at the Dundas Street culverts respectively.

Geological mapping shows that the watershed is characterized as till moraine and till plain. sandy loams with few stones. The majority of the upstream watersheds consist of well drained Oneida clay loam on the table lands with poorly drained Jeddo clay loams in the riverine valleys. The West Tributary has significant exposures of shale bedrock within the reach.

The valley walls of both reaches are generally forested while the valley floors are generally graminoid with shrub thicket and occasional tree species.

Channel morphology and substrate characteristics can change along a watercourse. Hence, it becomes imperative to account for these changes by delineating lengths of a watercourse that exhibit similar planform, sediment substrate, land use, local geology, valley confinement, hydrology and slope. In this study, five different reaches were delineated to account for change landuse, physical constraints (including hydraulic controls), sediment substrates, hydrology and local slopes. Other characteristics remained very comparable along the entire length of the tributaries that were studied. The East and West Tributaries south of Dundas have been named Reach A and B, respectively. Due to site conditions, each tributary south of Dundas Street can be considered as distinct reaches based on macro-scale properties of slope, stream order, geology and land use/vegetation. The west tributary north of Dundas Street can be divided into three reaches (Reaches C, D and E). See Figure 2 and Figure 3 for the location of each reach and the location of the various cross sections north and south of Dundas Street, respectively.

Bankfull characteristics were generally noted along each profile. A bankfull zone can be seen in the various photographs by the change in vegetation in the channel but also due to an obvious change in the bank slope. Appendix C shows the longitudinal profile of each creek reach.

Cross sections were surveyed within each reach as well. Five cross sections were surveyed for each reach south of Dundas Street. Seven cross sections were surveyed in the west branch of the tributary north of Dundas Street. The system consists of relatively disturbed reaches; however, there are obvious geomorphic features (i.e. riffles and pools). The surveyed cross sections are detailed in Appendix C. Chainages are noted on each figure.

Figure 2: Location of Reaches and Cross Sections: Reaches A and B

Figure 3: Location of Reaches and Cross Sections: Reaches C, D and E

Substrate sampling was also completed at each of the seventeen cross sections. Channel substrates ranged from sands to cobbles in all surveyed reaches. Our observations also note that the substrates are likely sourced from the till overburden and can be platey in nature in the west tributary given the extensive presence of local shale bedrock. The riffle substrate sizes are noted in Table 1.

It is also noted that all reaches are relatively stable due to the vegetation present on the banks with minimal channel obstructions. Reaches north of Dundas Street also have access to wide floodplains. Occasional large woody debris and channel accumulations have lead to localized channel instabilities in each of the tributaries.

Based on this, our field reconnaissance and geomorphic survey included the determination of various geomorphic parameters as well as sampling of the existing substrates for each of the four reaches present within the study area. The five distinct reaches are discussed as follows:

East Tributary:
The East Tributary (Reach A) is located south of Dundas Street, west of Valley Ridge Drive. Five cross sections have been surveyed in this reach. The channel was once straightened through this reach (as per historic air photos) but has been naturalizing over time. The channel is a single thread, low sinuosity, naturalizing channel. The substrate within this reach ranges from fine sands to platey cobbles given the nature of the overburden. The channel is only slightly entrenched within the floodplain (Entrenchment Ratio > 2.4) and has an overall moderate to high Width/Depth ratio (average >12). The bankfull slope in the reach is approximately 0.006 m/m. The general bankfull width is approximately 3 to 6 metres (based on our evaluation of bankfull conditions).

West Tributary (south of Dundas):
The West Tributary (Reach B) is located south of Dundas Street to Colonel William Parkway. Five cross sections have been surveyed in this reach as well. The channel is a single thread, sinuous, pool/riffle system. The substrate within this reach ranges from fine sands to platey cobbles given the nature of the overburden. The channel is slightly to moderately entrenched within the floodplain (Entrenchment Ratio > 1.4) and has an overall moderate to high Width/Depth ratio (average >12). The bankfull slope in the reach is approximately 0.0068 m/m. The general bankfull width is approximately 4 to 9 metres (based on our evaluation of bankfull conditions).

West Tributary (north of Dundas):
The West Tributary (Reaches C, D and E) is located north of Dundas Street. The section of this tributary studied extends from the Dundas Street at the downstream end to its confluence with an outlet channel running from a pond. The tributary is sub-divided into Reaches C and D. Also included is Reach E which extends from the outlet of the pond to its confluence with the tributary. Historically, the pond outlet was located at its south end. The old outlet channel has been cut off and the new outlet is hydraulically connected to the West Tributary at the north end with the aid of an artificial outlet channel (Reach E). Reaches C, D and E are described as follows:

a) **Downstream Reach (Reach C):** Two cross sections (XSC1 and XSC2) were surveyed in this reach. This reach is distinctly steeper (0.0196 m/m) than the upstream reach (Reach D). The substrate within this reach ranges from fine sands to platey cobbles given the nature of the overburden. This reach has a few localized erosion spots. The reach is single threaded, sinuous channel that shows pool/riffle morphology. The last 50 m of this reach is channelized by vertical concrete walls that lead to a box culvert at the downstream end at Dundas Street. The channel has a bankfull width of approximately 4 m. The Width/Depth ratio and the Entrenchment Ratio of the channel are moderate which is indicative of a B4 channel.
b) **Upstream Reach (Reach D):** Four cross sections (XSD1 to XSD4) have been surveyed in this reach. This reach is bounded by the confluence of the pond outlet

channel with the West Tributary at the upstream end and by Reach C at the downstream end. The substrate within this reach ranges from fine sands to platey cobbles given the nature of the overburden. At the upstream end, the channel shows both multiple threaded and single threaded morphology. The channel is predominantly single threaded downstream of XSD4. The channel morphology is a disturbed pool/riffle system, particularly at the upstream end possibly due to anthropogenic effects due to the contribution of flows from the outlet channel. The channel generally shows moderate Entrenchment (1.4 < ER < 2.2) and Width/Depth (W/D > 12) ratios as shown in Table 1C. However, the channel does show high Entrenchment Ratio at least one location. The bankfull slope in the reach is approximately 0.007 m/m. The general bankfull width is approximately 3.8 to 11.5 metres (based on our evaluation of bankfull conditions). The channel is generally of the Rosgen B4 type with some characteristics of a C4 channel.

c) **Outlet Channel (Reach E):** The creek banks immediately downstream of the pond outlet are most likely artificial as evidenced by the trapezoidal nature of the channel cross sections. Based on our observations and available mapping information, it is evident that the outlet of the pond at the north-west end was created through artificial means. A channel was dug from the north-west end of the pond to its confluence with the West Tributary. As this reach approaches the confluence with the tributary in the north, the creek develops into multiple channels, converges into a single channel, and diverges into multiple-threaded channels intermittently. However, not all channels in the multi-threaded portion seem active. Some channels appear to be abandoned under low flow conditions. This reach can be classified as Rosgen C4 channel.

In summary, and for the purposes of communicating the characteristics of the channel, the tributaries south of Dundas Street can be considered to be Rosgen C4 systems. The tributary north of Dundas Street is generally a B4 system showing some characteristics of a C4 system. However, any classification should be taken with caution as it is based on field work conducted on a slightly disturbed system. Tables 1A, 1B, and 1C present a summary of the field work results and our analyses for the East, West Tributaries south of Dundas and West Tributary north of Dundas Street, respectively. Photographs and survey results (profiles and cross sections) detailing site conditions are presented in Appendices A and C, respectively.

Table 1A: Summary of Geomorphic Parameters – East Branch (Reach A)

Parameter	XSA1	XSA2	XSA3	XSA4	XSA5
Bankfull Width (m)	6.09	2.88	5.26	6.28	2.87
Bankfull Mean Depth (m)	0.29	0.42	0.21	0.48	0.66
Bankfull Max Depth (m)	0.49	0.57	0.56	0.33	0.49
Bankfull Area (m^2)	1.77	1.20	1.09	3.02	1.91
Wetted Perimeter (m)	6.68	3.71	5.67	7.24	4.19
Hydraulic Radius (m)	0.26	0.32	0.19	0.42	0.45
Width-Depth Ratio	21.1	7.0	25.4	13.0	4.3
Entrenchment Ratio	10.4	21.3	10.7	10.5	7.5
Sinuosity	1.19	1.19	1.19	1.19	1.19
Bankfull Slope	0.006	0.006	0.006	0.006	0.006
Channel Substrate D_{50} (mm)	17.7	6.3	3.8	24.8	9.7
Channel Substrate D_{84} (mm)	30.7	48.1	47.9	51.8	36.6
Rosgen Classification	C4	C4	C4	C4	C4

Table 1B: Summary of Geomorphic Parameters – West Branch south of Dundas (Reach B)

Parameter	XSB1	XSB2	XSB3	XSB4	XSB5
Bankfull Width (m)	4.12	5.28	9.11	7.63	4.43
Bankfull Mean Depth (m)	0.29	0.13	0.19	0.24	0.47
Bankfull Max Depth (m)	0.43	0.28	0.48	0.52	0.71
Bankfull Area (m^2)	1.20	0.69	1.74	1.85	2.07
Wetted Perimeter (m)	4.71	5.54	9.50	8.11	5.36
Hydraulic Radius (m)	0.26	0.12	0.18	0.23	0.39
Width-Depth Ratio	14.1	40.3	47.4	31.7	9.5
Entrenchment Ratio	10.4	1.5	1.4	3.3	4.6
Sinuosity	1.19	1.19	1.19	1.19	1.19
Bankfull Slope	0.0068	0.0068	0.0068	0.0068	0.0068
Channel Substrate D_{50} (mm)	38.5	48.6	11.8	11.7	41.8
Channel Substrate D_{84} (mm)	169.2	122.4	59.2	49.8	179.0
Rosgen Classification	C4	C4	C4	C4	C4

Table 1C: Summary of Geomorphic Parameters – West Branch north of Dundas (Reaches C and D)

Parameter	XSC1	XSC2	XSD1	XSD2	XSD3	XSD4	XSE1
Bankfull Width (m)	4.42	4.2	7.66	7.95	3.77	11.48	1.78
Bankfull Mean Depth (m)	0.14	0.19	0.17	0.62	0.23	0.54	0.14
Bankfull Max Depth (m)	0.29	0.37	0.4	0.94	0.41	0.8	0.31
Bankfull Area (m^2)	0.62	0.79	1.34	4.91	0.88	6.24	0.89
Wetted Perimeter (m)	4.49	4.29	8.43	8.87	3.89	12.21	3.47
Hydraulic Radius (m)	0.14	0.18	0.16	0.55	0.23	0.51	0.26
Width-Depth Ratio	21.57	22.11	45.06	12.82	16.39	21.26	12.71
Entrenchment Ratio	1.88	2.2	1.45	4.34	1.61	2.12	3.11
Sinuosity	1.24	1.24	1.64	1.64	1.64	1.64	1.64
Bankfull Slope	0.0196	0.0196	0.0071	0.0071	0.0071	0.0071	0.0071
Channel Substrate D_{50} (mm)	24.95	17.61	21.72	14.4	14.82	15.13	25.47
Channel Substrate D_{84} (mm)	54.5	70.24	54.99	39.24	85.16	24.95	69.35
Rosgen Classification	B4	B4	B4	C4	B4	B4	C4

2.0 RAPID FIELD ASSESSMENTS

2.1 Rapid Stream Assessment Technique

One of the most complete multi-parameter measures of stream conditions and field-tested is the Rapid Stream Assessment Technique, developed by John Galli and other staff of the Metropolitan Washington (DC) Council of Governments (Galli and others, 1996). The RSAT systematically focuses on conditions reflecting aquatic-system response to watershed urbanization. It groups those responses into six categories, presumed to adequately evaluate the conditions of the stream system at the time of measurement on a reach-by-reach basis. The six categories are:

1. Channel stability;
2. Channel scouring and sediment deposition;
3. Physical in-stream habitat;
4. Water quality;
5. Riparian habitat conditions; and
6. Biological conditions.

Stream channel stability and cross-sectional characterization is a critical component of RSAT. A 30 metre long channel reach is surveyed at each transect. Signs of instability (such as bank sloughing, recently exposed non-woody tree roots, general absence of vegetation within bottom 1/3 of the bank, recent tree falls, etc.) and channel degradation or downcutting (such as high banks in small headwater streams and erosion around man-made structures) are noted and cross-section measurements are made.

An assessment of soil conditions along the stream banks is also conducted to determine soil texture and potential erodibility of the stream bank. Qualitative water quality measurements are also made (temperature, turbidity, colour and odour) along with an indication of substrate fouling. The RSAT stream work also typically involves a qualitative sampling and evaluation of benthic organisms.

Each category is assigned a value which is then summed to provide an overall score and ranking. Within these broad categories, our assessment technique evaluated the stream reach. Table 2 details the range of scores and rankings with a higher score suggesting a healthier system. The results of the RSAT evaluation are presented in Table 4.

Table 2: RSAT Scores with Associated Rankings

RSAT Score	Ranking
41-50	Excellent
31-40	Good
21-30	Fair
11-20	Poor
0-10	Degraded

2.2 Rapid Geomorphic Assessment

Stream stability has also been assessed using a Rapid Geomorphic Assessment (MOE, 2004). The RGA assessment focuses entirely on the geomorphic component of a stream system. The RGA method consists of four factors that summarize various components of channel adjustment, specifically: aggradation, degradation, channel widening and plan form adjustment. Each factor is assessed separately and the total score indicates the overall stability of the system. This methodology has been applied to numerous streams and the following table details the ranking criteria (see Table 3). The results of the Rapid Geomorphic Assessment have been presented in Table 4.

Figure 4 and Figure 5 show the results of the Rapid Geomorphic Assessment for the reaches south and north of Dundas Street, respectively.

Table 3: Interpretation of RGA Scores

Stability Index (SI) Value	Classification	Interpretation
SI $\leq$ 0.20	In Regime	The channel morphology is within a range of variance for streams of similar hydrographic characteristics and evidence of instability is isolated or associated with normal river meander processes
0.21 $\leq$ SI $\leq$ 0.40	Transitional or Stressed	Channel morphology is within a range of variance for streams of similar hydrographic characteristics but the evidence of instability is frequent.
SI $\geq$ 0.40	In Adjustment	Channel morphology is not within the range of variance and evidence of instability is wide spread/

2.3 Qualitative Habitat Evaluation Index

The Ohio Qualitative Habitat Evaluation Index (QHEI) was designed to provide a quantitative evaluation of the physical characteristics which are qualitative within a given stream reach. The QHEI was developed to measure physical factors that influence fish communities and other aquatic life such as invertebrates. This index may be used to summarize non-biological variables relating biological variables measured to physical, chemical and habitat factors. A QHEI measurement can have a maximum score of 100. QHEI is comprised of the following metrics:

1. **Substrate** - measuring substrate type and substrate quality (Max. 20 points)
2. **Instream Cover** - measures instream cover type and amount (Max. 20 points)
3. **Channel Morphology** - includes channel sinuosity, development, stability and channelization (Max. 20 points)
4. **Riparian Zone and Bank Erosion** - measures floodplain quality, extent of bank erosion and the width of the riparian zone (Max. 10 points)
5. **Pool and Riffle Quality** - component measures include overall diversity of current velocities, pool depth and morphology and riffle-run depth, substrate and substrate quality (Max. 20 points).
6. **Map Gradient** - elevation drop through sampling area (Max. 10 points).

QHEI ranges for Exceptional, Good and Marginal/Poor habitats are >67.5, 52.5 to 67.5 and <52.5 respectively using a statistical analysis of QHEI scores associated to HBI scores, recognizing that there will be some overlap for each of these zones.

Table 4: Summary of Rapid Assessments and General Reach Characteristics

Reach	Characteristics
Reach A	Historically straightened channel (as per historic air photographs) Channel has been naturalizing over time Moderate sinuosity, single thread channel with some braiding Some eroding banks at outside bends Valley floodplain consists primarily of graminoids and shrub material Slightly entrenched due to moderately wide floodplain Well vegetated, treed valley walls Pool-riffle pattern present RSAT Score: 29.4 (Fair) RGA Score: 0.34 (Stressed/Transitional) – Aggradation and widening QHEI Score: 71 (Exceptional)
Reach B	Natural channel though more pronounced valley section Sinuous, single thread channel Valley floodplain consists primarily of graminoids and shrub material Some woody debris Large extent of exposed, eroding shale bedrock Substrate generally comprised of platey shale substrate Slightly to moderately entrenched due to moderately wide floodplain Pool-riffle pattern is generally present RSAT Score: 27.4 (Fair) RGA Score: 0.44 (In Adjustment) – Aggradation, planform adjustment and widening QHEI Score: 64 (Good)
Reach C	Artificial channel through the downstream end Single thread channel pool/riffle channel Localized obstruction caused by woody debris Exposed shale bed in mid-section of the reach RSAT Score: 35.0 (Good) RGA Score: 0.44 (In Adjustment) – Aggradation and widening

Reach D	Multiple threaded to single thread channel Grassed trapezoidal section with no easy access to floodplain at upstream end, transitions to a channel with easier floodplain access as it moves downstream Good riparian zone through entire reach Disturbed pool-riffle pattern RSAT Score: 32.0 (Good) RGA Score: 0.49 (In Adjustment) – Aggradation, planform adjustment and widening
Reach E	Dug out outlet from pond Grassed trapezoidal artificial channel from the outlet to confluence with tributary proceeding from culvert FM2 Some multiple threaded channels within the trapezoidal sections RSAT Score: 32.0 (Good) RGA Score: 0.29 (Stressed/Transitional) – Aggradation and planform adjustment

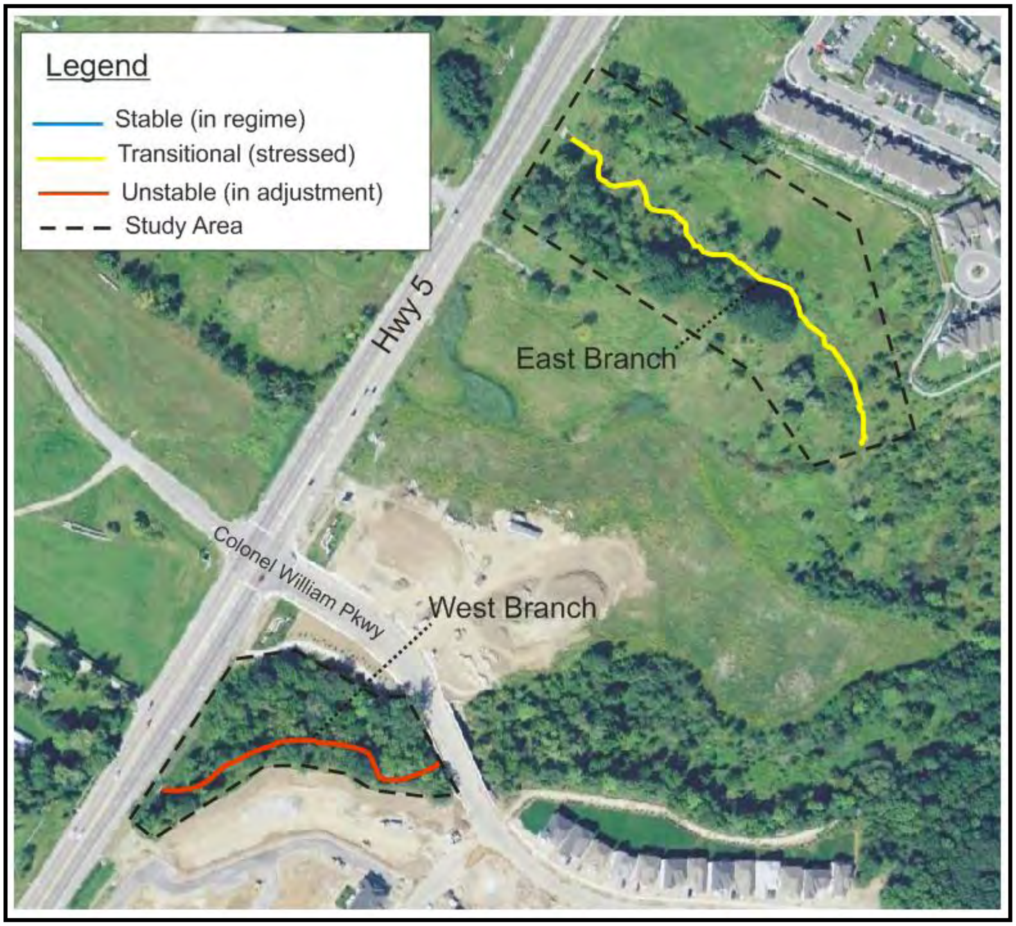


Figure 4: RGA Results for Reaches A and B

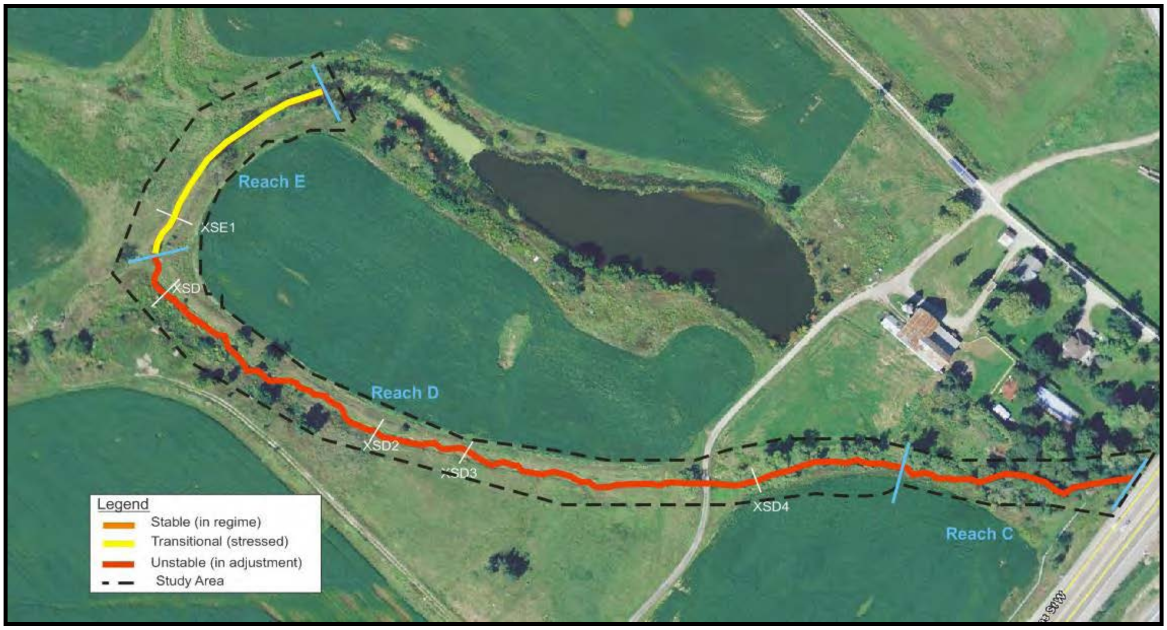


Figure 5: RGA Results for Reaches C, D and E

3.0 EROSION THRESHOLDS

3.1 General

The geomorphic assessments included measurements of channel, bank and bankfull flow characteristics. The survey provided a measure of the local energy gradient. Detailed information was collected in order to determine erosion thresholds, shear stress and critical discharge values. Erosion thresholds indicate the point at which sustained flows will tend to entrain and transport sediment, specifically the D_{50} and D_{84} of the substrate materials.

Calculations of bankfull discharge were based on measurements of channel cross-sectional dimensions, bankfull gradient and stream bed roughness. Additionally, a variety of geomorphic threshold predictors were used in combination with measurements of substrate and bank material to determine the appropriate erosion threshold.

Given the nature of the substrate and bank composition, the calculations performed to determine the threshold discharge for bed materials were based two types of approaches. The first approach utilizes tractive forces while the other is based on permissible velocities. For the first approach, the Critical Particle Shear Stress is examined against the mean Boundary Shear Stress at the channel. To determine the Critical Particle Shear Stress the formulae presented by Komar (1987) and Fischenich (2001) were used, both of which are based on the original Shields work. Based on the critical shear stress determined by this method, a critical depth is back-calculated and a critical discharge is determined. The permissible velocity approach utilizes Hjulstrom’s chart to plot the particle mean velocity and the median particle size to determine if the material represented by the median grain size is likely to erode, deposit or be transported. The mean velocity plotted is the permissible velocity determined from a table presented by Fortier and Scobey (1926) for various materials types. The channel materials chosen at each cross section for the permissible velocity method is presented in Table 6. A critical shear stress is associated with each of the permissible velocity values. This information is used to determine the critical discharge. Table 7 provides the summary of the results from the various methods. Additionally, Figures 6 to 8 in show the Hjulstrom Charts for the surveyed reaches.

3.2 Channel Flows

Return period peak flows for the Study Area were acquired from MMM. These peak flows were estimated using unit flow rates at Dundas Street culverts provided in the North Oakville Creeks Subwatersheds Study (NOCSS). Flows at the Study Area are noted in Table 5. Figures for the regression analyses are presented in Appendix C.

Table 5: Study Area Return Period Peak Flows (in m^3/s - from MMM, 2011)

	Storm Event Return Period						Area (ha)
	2 yr	**5 yr**	**10 yr**	**25yr**	**50 yr**	**100 yr**	
East Tributary	2.15	3.58	4.66	6.09	6.81	7.89	359 ha
West Tributary	2.33	3.88	4.65	5.82	6.98	7.75	388 ha

Based on the return period flows, bankfull channel flow has been calculated to be approximately 1.82 and 2.05 m^3/s for the East and West Tributaries respectively (using the regression formulae). Using data from the geomorphic field work, and using a friction factor/relative roughness methodology, bankfull flows were determined to be in the range of 2.82 and 1.52 m^3/s for the East and West Tributaries, respectively (based on surveyed cross sections that best presented the site conditions). The correlation between these two represents a reasonable confirmation of the field results.

3.3 Erosion Threshold Considerations

Using the data collected during the field investigations, related hydraulic parameters were determined including stream power, unit stream power, bed shear stress and critical shear stress were determined at each cross section. Boundary shear stresses ranged from 11.3 to 26.7 Pa for East Tributary, 8.3 to 22.7 Pa for West Tributary south of Dundas, and 8.4 to 33.5 Pa for West Tributary north of Dundas. Critical particle shear stresses where determined to be in the range of 22.4 to 37.7 Pa for East Tributary, 36.3 to 123.2 Pa for West Tributary south of Dundas, and 32.4 to 51.2 Pa for West Tributary north of Dundas. Reach B critical shear stress values are higher due to the presence of bedrock material. Tables 6, 7A, 7B, 7C and 7D present a summary of the threshold analyses.

Table 6: Permissible Velocity Bed Materials Used

Cross Section	Bed Material used
XSA1	Graded silts to cobbles when non-colloidal
XSA2	Coarse gravel, non-colloidal
XSA3	Graded silts to cobbles when non-colloidal
XSA4	Coarse gravel, non-colloidal
XSA5	Graded silts to cobbles when non-colloidal
XSB1	Coarse gravel, non-colloidal
XSB2	Graded silts to cobbles when non-colloidal
XSB3	Graded silts to cobbles when non-colloidal
XSB4	Graded silts to cobbles when non-colloidal
XSB5	Cobbles and shingles
XSC1	Coarse gravel, non-colloidal
XSC2	Coarse gravel, non-colloidal
XSD1	Coarse gravel, non-colloidal
XSD2	Coarse gravel, non-colloidal
XSD3	Graded silts to cobbles when non-colloidal
XSD4	Graded silts to cobbles when non-colloidal
XSE1	Coarse gravel, non-colloidal

- Descriptions of bed materials are based on Chang (1988)

Table 7A: Summary of Geomorphic Analyses – East Tributary Reach A

Method	Parameter	XSA1	XSA2	XSA3	XSA4	XSA5
SUMMARY PARAMETERS	Relative Roughness (m/m)	8.6	6.7	4.1	8.1	12.4
	Shear Velocity (m/s)	0.12	0.14	0.11	0.16	0.16
	Velocity based on FF/RR (m/s)	1.01	1.03	0.67	1.25	1.47
	Bankfull Q (cms)	1.79	1.23	0.73	3.77	2.81
	Froude #	0.60	0.51	0.47	0.57	0.58
	Stream Power (W/m)	105.3	72.7	42.9	222.0	165.3
	Unit Stream Power (W/m^2)	17.3	25.2	8.2	35.4	57.7
	BED SHEAR τ_o (N/m^2)	15.6	19.0	11.3	24.6	26.7
KOMAR 1987	CRITICAL τ_{cr} (N/m^2)	22.36	35.03	34.15	37.70	26.62
	RATIO τ_{cr} / τ_o	0.70	0.54	0.33	0.65	**1.00**
FISCHENICH 2001	CRITICAL τ_{cr} (N/m^2)	23.29	32.70	29.57	39.27	25.79
	RATIO τ_{cr} / τ_o	0.67	0.58	0.38	0.63	**1.04**
PERMISSIBLE VELOCITY (COLLOIDAL WATER)	CRITICAL τ_{cr} (N/m^2)	38.32	32.09	38.32	32.09	38.32
	RATIO τ_{cr} / τ_o	0.41	0.59	0.30	0.77	0.70
	Permissible Velocity (m/s)	1.68	1.83	1.68	1.83	1.68

Table 7B: Summary of Geomorphic Analyses – West Tributary Reach B

Method	Parameter	XSB1	XSB2	XSB3	XSB4	XSB5
SUMMARY PARAMETERS	Relative Roughness (m/m)	1.5	1.0	3.1	4.6	2.2
	Shear Velocity (m/s)	0.13	0.09	0.11	0.12	0.15
	Velocity based on FF/RR (m/s)	0.50	0.26	0.62	1.48	0.71
	Bankfull Q (cms)	0.61	0.18	1.09	1.48	1.47
	Froude #	0.30	0.23	0.45	0.52	0.33
	Stream Power (W/m)	40.6	12.2	72.9	99.0	86.3
	Unit Stream Power (W/m^2)	9.8	2.3	8.0	13.0	19.5
	BED SHEAR τ_o (N/m^2)	17.1	8.3	12.3	15.1	22.7
KOMAR 1987	CRITICAL τ_{cr} (N/m^2)	123.24	89.17	43.10	36.25	130.35
	RATIO τ_{cr} / τ_o	0.14	0.09	0.29	0.42	0.17
FISCHENICH 2001	CRITICAL τ_{cr} (N/m^2)	94.87	92.89	41.75	35.12	135.79
	RATIO τ_{cr} / τ_o	0.18	0.09	0.29	0.43	0.17
PERMISSIBLE VELOCITY (COLLOIDAL WATER)	CRITICAL τ_{cr} (N/m^2)	32.09	38.32	38.32	38.32	52.69
	RATIO τ_{cr} / τ_o	0.53	0.22	0.32	0.39	0.43
	Permissible Velocity (m/s)	1.83	1.68	1.68	1.68	1.68

Table 7C: Summary of Geomorphic Analyses – West Tributary Reach C

Method	Parameter	XSC1	XSC2
SUMMARY PARAMETERS	Relative Roughness (m/m)	5.3	9.9
	Shear Velocity (m/s)	0.16	0.18
	Velocity based on FF/RR (m/s)	1.10	1.55
	Bankfull Q (cms)	0.68	1.24
	Froude #	0.94	1.14
	Stream Power (W/m)	131.1	237.9
	Unit Stream Power (W/m^2)	29.7	56.6
	BED SHEAR τ_o (N/m^2)	25.3	33.5
KOMAR 1987	CRITICAL τ_{cr} (N/m^2)	39.70	51.16
	RATIO τ_{cr} / τ_o	0.64	0.66
FISCHENICH 2001	CRITICAL τ_{cr} (N/m^2)	41.35	53.30
	RATIO τ_{cr} / τ_o	0.61	0.63
PERMISSIBLE VELOCITY (COLLOIDAL WATER)	CRITICAL τ_{cr} (N/m^2)	32.09	32.09
	RATIO τ_{cr} / τ_o	0.79	**1.04**
	Permissible Velocity (m/s)	1.83	1.83

Table 7D: Summary of Geomorphic Analyses – West Tributary Reaches D and E

Method	Parameter	XSE1	XSD1	XSD2	XSD3	XSD4
SUMMARY PARAMETERS	Relative Roughness (m/m)	4.7	7.5	37.2	13.8	32.6
	Shear Velocity (m/s)	0.09	0.11	0.19	0.12	0.18
	Velocity based on FF/RR (m/s)	0.61	0.83	2.26	1.11	2.11
	Bankfull Q (cms)	0.15	1.08	11.13	0.96	13.05
	Froude #	0.52	0.64	0.92	0.74	0.91
	Stream Power (W/m)	10.5	74.4	769.6	66.3	902.8
	Unit Stream Power (W/m^2)	5.9	9.7	96.8	17.6	78.6
	BED SHEAR τ_o (N/m^2)	8.4	11.3	37.1	14.2	34.1
KOMAR 1987	CRITICAL τ_{cr} (N/m^2)	50.51	40.05	28.58	62.03	32.41
	RATIO τ_{cr} / τ_o	0.17	0.28	**1.30**	0.23	**1.05**
FISCHENICH 2001	CRITICAL τ_{cr} (N/m^2)	52.62	41.73	27.69	64.62	24.95
	RATIO τ_{cr} / τ_o	0.16	0.27	**1.34**	0.22	**1.37**
PERMISSIBLE VELOCITY (COLLOIDAL WATER)	CRITICAL τ_{cr} (N/m^2)	32.09	32.09	32.09	38.32	38.32
	RATIO τ_{cr} / τ_o	0.26	0.35	1.16	0.37	0.89
	Permissible Velocity (m/s)	1.83	1.83	1.83	1.68	1.68

Of the two Shields formula based methods reported in tables (Komar and Fischenich), the erosion threshold values based on Komar were chosen to determine the critical flows. The Fischenich formula applies a correction to the Shields formula to account for the angle of repose of the median grain size. The Komar formula was developed empirically using various experimental data sets of varying grain sizes. Both Fischenich and Komar formulae provide similar results. On the other hand, the permissible velocity methods commonly used to provide a general idea of erosion threshold parameters are overly conservative and do not provide accurate values.

In order to determine the critical flows through the East and West Tributaries of 14 Mile Creek, the identification of sections through the tributaries where the critical/limiting conditions exist is essential; however, it is also essential for the average channel conditions to be considered. Therefore, the following scenarios were taken into account:

- **Scenario 1:** Average critical flows at all cross sections within a reach;
- **Scenario 2:** Average critical flow at all cross sections within a reach which show the ratio τ_{cr} / τ_o to be greater than 1;
- **Scenario 3:** Critical flow computed using average shear stress at all cross sections within a reach (using the channel geometry of the limiting cross section);
- **Scenario 4:** Critical flow computed using average shear stress at all cross sections within a reach which show the ratio τ_{cr} / τ_o to be greater than 1 (using the channel geometry of the limiting cross section);and,
- **Scenario 5:** Critical flow at the most limiting cross section.

Of these scenarios, the third one was chosen at it represents all cross sections within the reach while taking the limiting cross section into consideration. However, it was noted that a "limiting cross section" could be defined in two ways and depending on the chosen method the critical flow values obtained are drastically different. The two methods are noted below:

- **Method A:** Cross section with the largest value of the ratio τ_{cr} / τ_o; and,
- **Method B:** Cross section that produces the least critical flow when its channel geometry is used in Scenario 3.

Since the choice of Method B yielded more consistent and conservative results, it was used to compute the critical flows. The critical flow results from both methods and the corresponding critical cross section chosen is listed in Table 8.

Table 8: Summary of Critical Flows

Reach	Method A			Method B		
	Limiting XS	Average (τ_{cr} / τ_o)	Critical Flow (cms)	Limiting XS	Average (τ_{cr} / τ_o)	Critical Flow (cms)
A	A5	0.86	1.27	A2	0.61	**0.56**
B	B4	0.18	1.48	B2	0.10	0.18
C	C2	0.74	0.25	C2	0.74	**0.25**
D	D2	0.91	3.24	D3	0.35	0.96
E	E1	0.17	0.15	E1	0.17	0.15

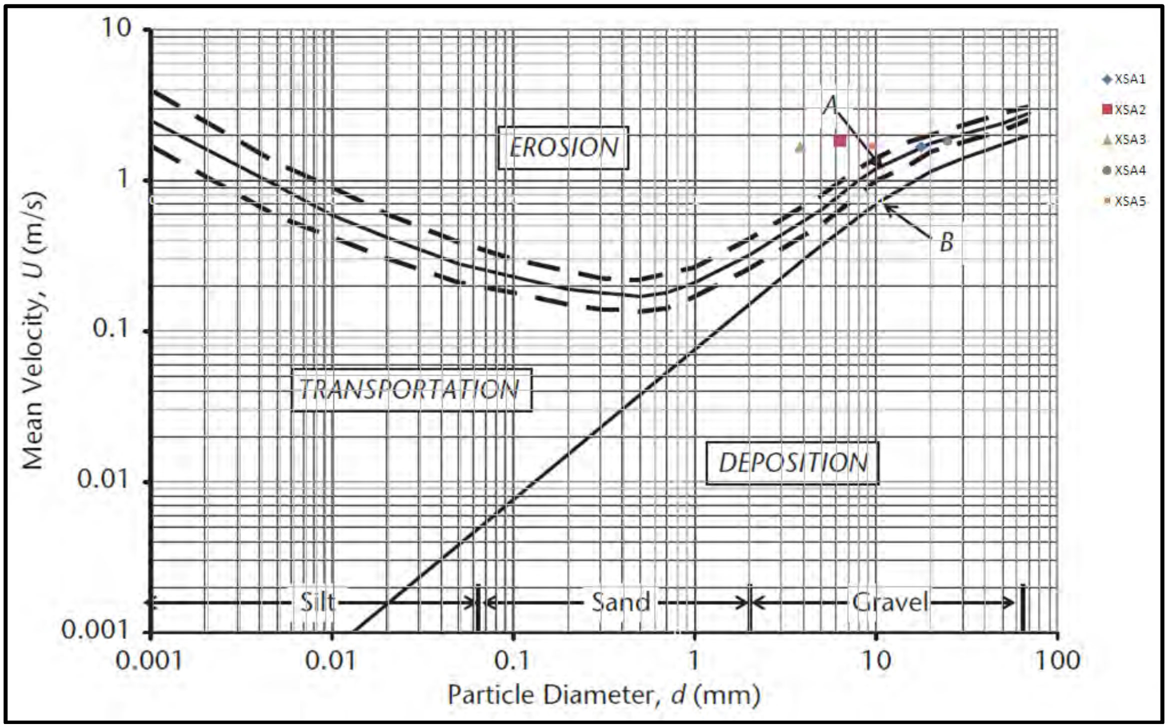


Figure 6: Hjulstrom's Chart for Reach A (modified from Dingman, 2009)

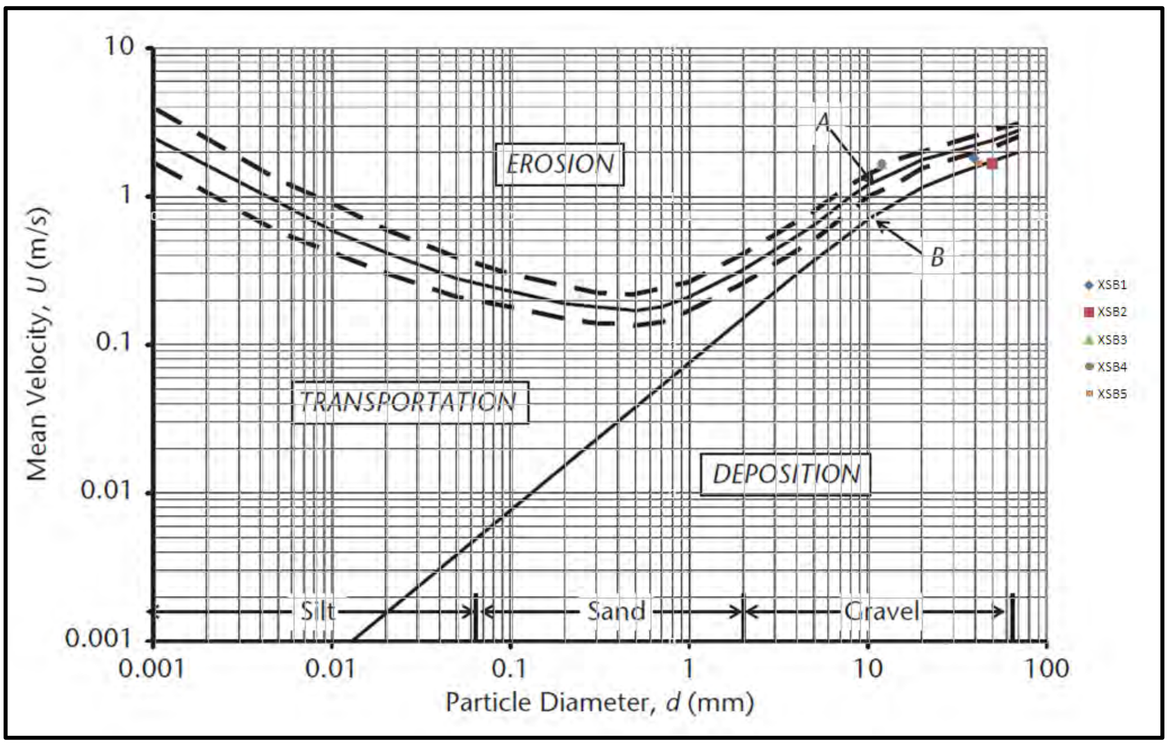


Figure 7: Hjulstrom's Chart for Reach B (modified from Dingman, 2009)

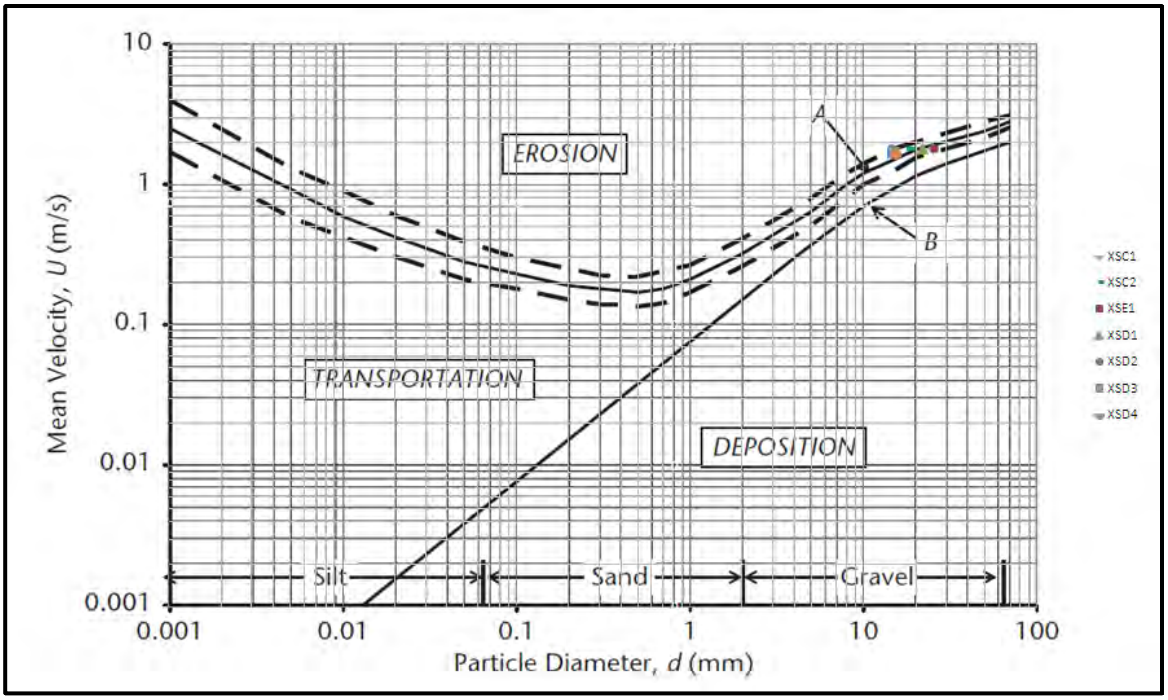


Figure 8: Hjulstrom's Chart for Reaches C, D and E (modified from Dingman, 2009)

3.4 Discussion

The tractive force approach formulae used (Komar and Fischenich) provide converging values for critical shear stresses with Fischenich approach usually being the most conservative approach. The permissible velocities approach is based on general channel substrate material without taking other channel conditions into account. It is a less conservative approach but may be used to confirm the upper bound critical stress values obtained through other approaches. In our Hjulstrom diagrams, we have used the permissible velocities based on "colloidal water". This approach assumes that there will be suspended solids in the stream at flows at which critical stresses occur on the bed. Permissible velocities based on "clear water" provide lower critical shear stress values and may be used as worst case scenarios. However, since we do not anticipate clear water conditions in cases of bankfull flows, the analyses based on this approach is not included in this report.

From Figure 6, it is evident that within Reach A, the cross sections where erosion of the median particle size occurs are cross sections XSA2, XSA3, and XSA5. Tractive force analyses confirm these results. Similarly, in Reach B, the highest ratios obtained were at cross sections XSB3 and XSB4 where according to Figure 7, erosion is likely to occur. Within Reach C, cross sections XSC1 and XSC2 show average bed stresses that do not exceed the critical shear stress.

Based on the critical cross sections (as determined by the worst case scenarios presented by average bed shear to critical shear stress ratios (τ_{cr}/τ_o)) as discussed in the previous section, the corresponding critical flow values were determined (Table 8). The tractive force methods were used to determine the corresponding flow estimates since they presented more conservative flow estimates as opposed to the permissible velocity method.

Based on the results shown in tables 7 and 8, it is evident that 0.56 m^3/s is the critical flow through the East Tributary (Reach A). Similarly, among the natural reaches within the West Tributary, Reach B yeilds the lowest critical flow value of 0.18 m^3/s (using Scenario 3 and Method B). However, this value is unusually low since an evaluation of the procedure used reveals that the use of cross section B2 is not suitable as it is unlike other cross sections in the reach. Its cross sectional area is at least about half of that of the other cross sections. The use of other cross sections yeild a range of flow values from 0.61 m^3/s to 1.48 m^3/s. Therefore, Reach B is not the limiting reach in the West Tributary. Reach C shows critical flow of 0.25 m^3/s. This flow forms the critical flow for the West Tributary.

4.0 SUMMARY

As part of the Bentall Development EIR/FSS, a geomorphic analysis was completed for the East and West Tributaries of 14 Mile Creek. Distinct reaches were established for each tributary and geomorphic field work, including a longitudinal profile for each reach and a total of seventeen cross sections were completed.

While hydrological modeling suggests that bankfull flows are reasonably similar (as confirmed by the geomorphic field work), the East Tributary is slightly more sensitive than the West Tributary. This is largely due to the presence of eroding shale bedrock sediment in the West Tributary and the presence of fine substrate material within the East Tributary.

To assist in the development of stormwater management targets, a summary of erosion threshold parameters have been provided.

Based on our site investigations, analyses and assessments, we can conclude that:

1. East and West Tributaries south of Dundas (Reaches A and B) have typical characteristics generally representative of a C4 system while the West Tributary north of Dundas (Reaches C and D) is largely representative of a B4 system;
2. The RSAT scores for Reaches A, B, C, D, and E are 29.4, 27.4, 35 32, and 32, respectively. The RGA scores for Reaches A, B, C, D, and E are 0.34, 0.44, 0.44, 0.49 and 0.29, respectively.
3. Based on the RGA scores, Reaches A and E are “Stressed/Transitional” with aggradation and widening processes present while Reach B and D in the West Tributary are “In Transition” with aggradation, planform adjustment and widening processes present, Reach C is “In Transition” with aggradation, and widening processes present;
4. Hjusltrom’s diagrams provided show the cross-sections at which erosions can be expected;
5. The critical flows for the East Tributary and West Tributary of the 14 Mile Creek are 0.56 and 0.25 m^3/s, respectively, and;
6. Monitoring of the cross sections, particularly the limiting cross sections, is recommended.

Respectfully submitted,

Ed Gazendam, M. Eng., P. Eng.,
Water’s Edge

Appendix A: Photographs
Appendix B: Aerial Photographs
Appendix C: Profiles, Cross Sections and Regression Analyses

References:

Chang, H.H. (1988). Fluvial Processes in River Engineering, John Wiley and Sons, New York and other cities, citing Fortier, S., and Scobey, F.C. (1926). “Permissible canal velocities,” Transactions of the ASCE, 89:940-984.

Dingman, S. L. (2009). Fluvial Hydraulics, Oxford University Press, Inc., New York.

Fischenich. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, M.S. www.wes.army.mil/e/emrrp

Komar, Paul D. 1987. Selective grain entrainment and the empirical evaluation of flow competence. Sedimentology, 34: 1165-1176.

APPENDIX A:

Photographs

14 Mile Creek Tributaries Oakville, Ontario

PHOTOGRAPH NO.: 1
FROM:
LOOKING: AT CROSS SECTION 1
COMMENT: EAST TRIBUTARY REACH A

PHOTOGRAPH NO.: 2
FROM:
LOOKING: AT CROSS SECTION 2
COMMENT: EAST TRIBUTARY REACH A

PHOTOGRAPH NO.: 3
FROM:
LOOKING: AT CROSS SECTION 3
COMMENT: EAST TRIBUTARY REACH A

PHOTOGRAPH NO.: 4
FROM:
LOOKING: AT CROSS SECTION 4
COMMENT: EAST TRIBUTARY REACH A

PHOTOGRAPH NO.: 5
FROM:
LOOKING: AT CROSS SECTION 5
COMMENT: EAST TRIBUTARY REACH A

PHOTOGRAPH NO.: 6
FROM:
LOOKING: AT CROSS SECTION 1
COMMENT: WEST TRIBUTARY REACH B

PHOTOGRAPH NO.: 7
FROM:
LOOKING: AT CROSS SECTION 2
COMMENT: WEST TRIBUTARY REACH B

PHOTOGRAPH NO.: 8
FROM:
LOOKING: AT CROSS SECTION 3
COMMENT: WEST TRIBUTARY REACH B

PHOTOGRAPH NO.: 9
FROM:
LOOKING: AT CROSS SECTION 4
COMMENT: WEST TRIBUTARY REACH B

PHOTOGRAPH NO.: 10
FROM:
LOOKING: AT CROSS SECTION 5
COMMENT: WEST TRIBUTARY REACH B

PHOTOGRAPH NO.: 11
FROM:
LOOKING: AT CROSS SECTION 1
COMMENT: WEST TRIBUTARY REACH E

PHOTOGRAPH NO.: 12
FROM:
LOOKING: AT CROSS SECTION 1
COMMENT: WEST TRIBUTARY REACH D

PHOTOGRAPH NO.: 13
FROM:
LOOKING: AT CROSS SECTION 2
COMMENT: WEST TRIBUTARY REACH D

PHOTOGRAPH NO.: 14
FROM:
LOOKING: AT CROSS SECTION 3
COMMENT: WEST TRIBUTARY REACH D

PHOTOGRAPH NO.: 15
FROM:
LOOKING: AT CROSS SECTION 4
COMMENT: WEST TRIBUTARY REACH D

PHOTOGRAPH NO.: 16
FROM:
LOOKING: AT CROSS SECTION 1
COMMENT: WEST TRIBUTARY REACH C

PHOTOGRAPH NO.: 17
FROM:
LOOKING: AT CROSS SECTION 2
COMMENT: WEST TRIBUTARY REACH C

PHOTOGRAPH NO.: 18
FROM:
LOOKING: AT DOWNSTREAM END OF REACH C
COMMENT: NOTE THE CHANNELIZATION

PHOTOGRAPH NO.: 19
FROM:
LOOKING: DRY BED SUBSTRATE (INDICATIVE OF ACTIVE BED AS WELL) in XSD1 and XSD2
COMMENT: WEST TRIBUTARY REACH D

APPENDIX B:

Aerial Photographs

14 Mile Creek Tributaries Oakville, Ontario


1934


1960


1961


1969


1979


1988

APPENDIX C:

Profile, Cross Sections and Regression Analyses

14 Mile Creek Tributaries Oakville, Ontario

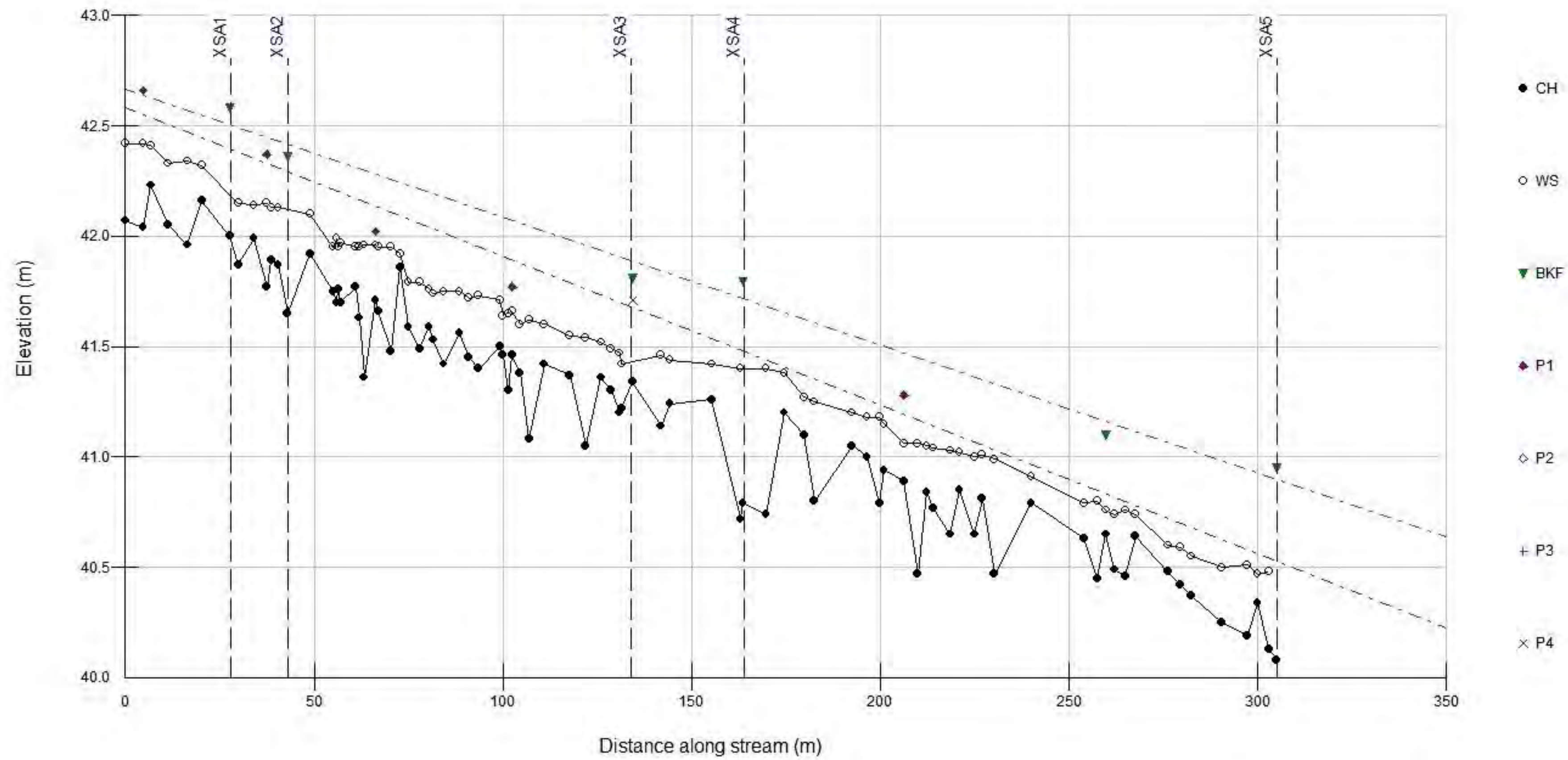


Figure 1: **East Tributary (Reach A) Channel Profile (Note: Elevation and Distance in feet – from a rod level survey in 2010)**

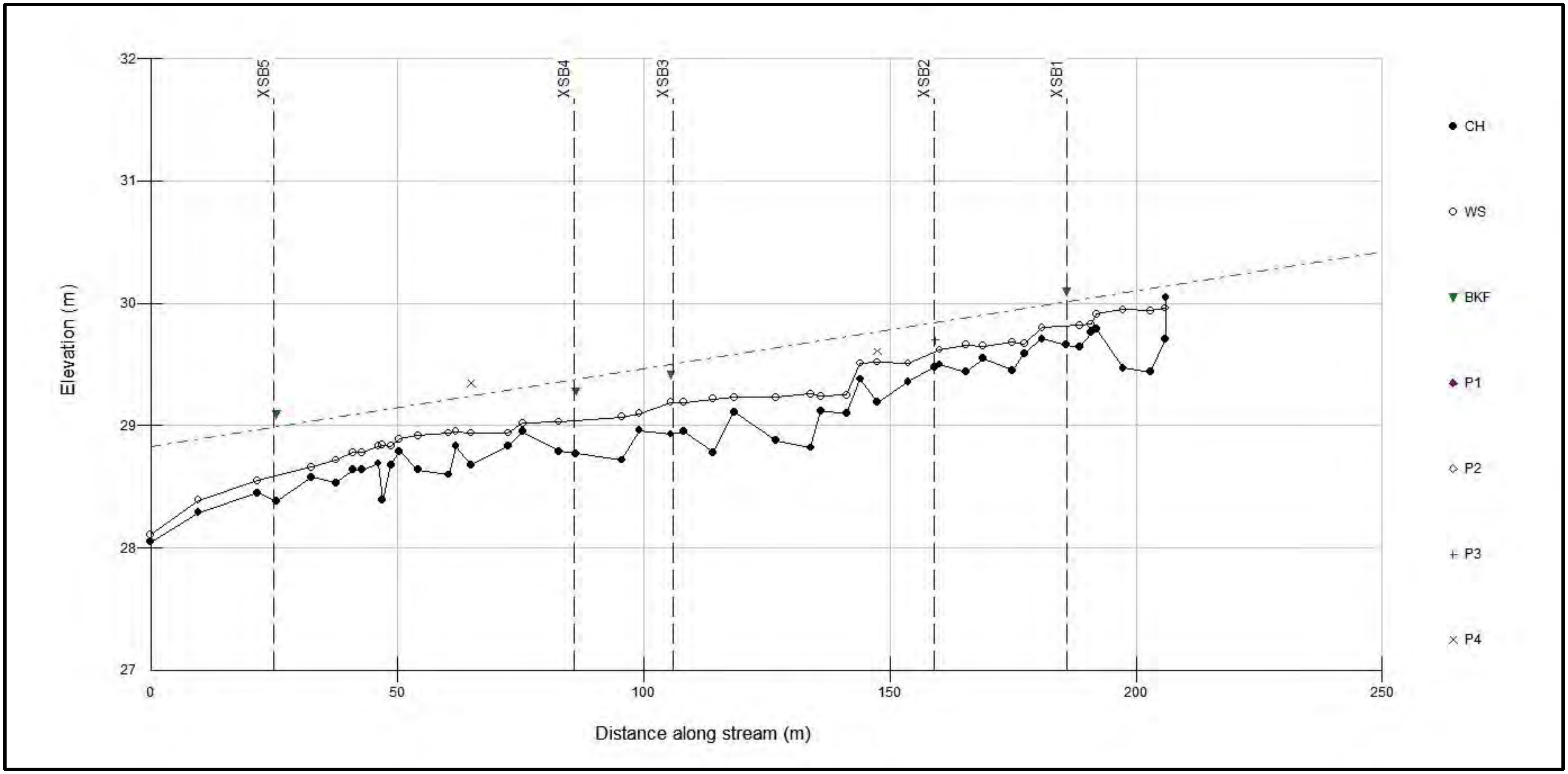


Figure 2: West Tributary (south of Dundas Street – Reach B) Channel Profile (Note: data from a rod and level survey in 2010)

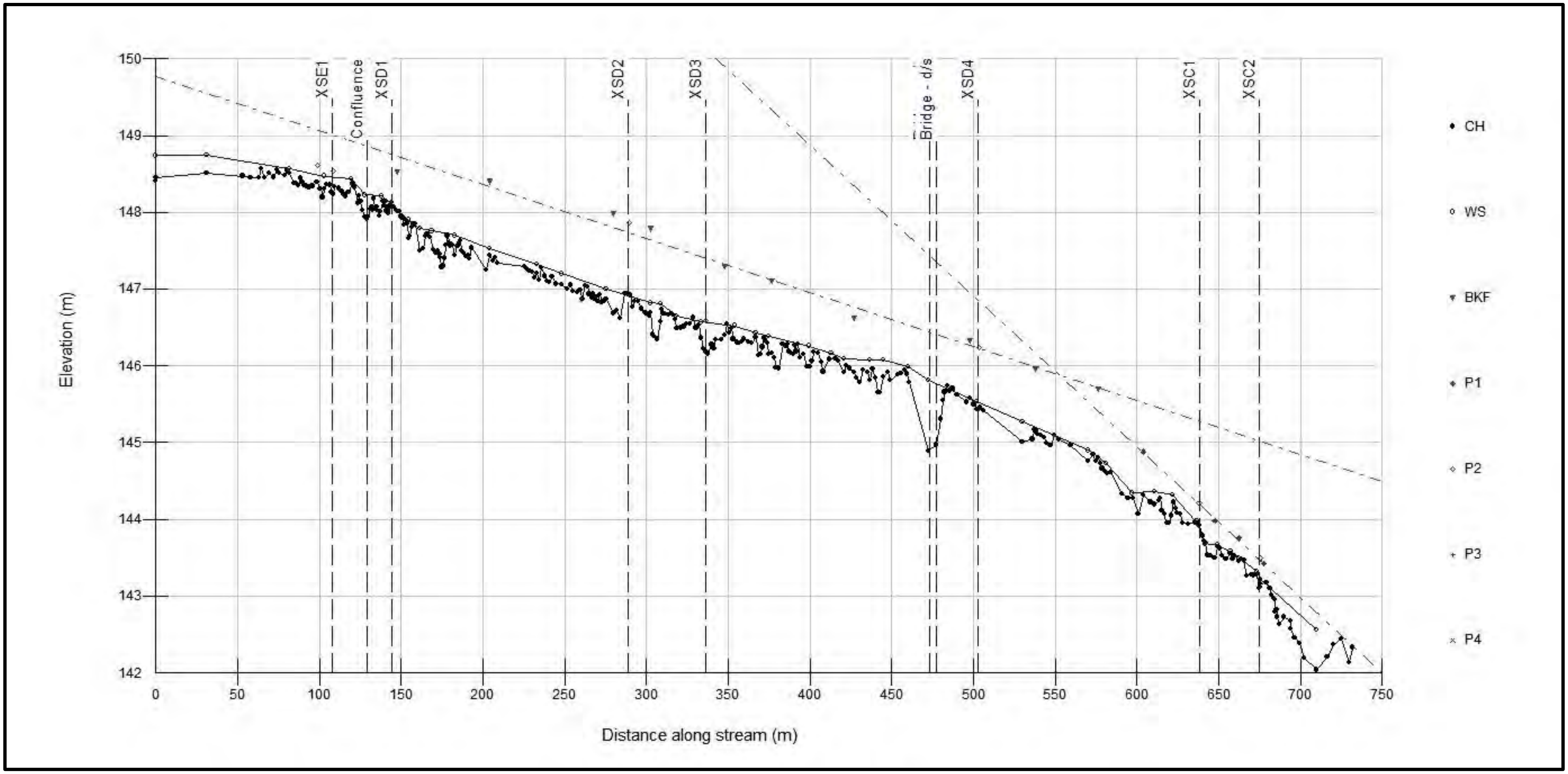


Figure 3: **West Tributary (south of Dundas Street – Reaches C, D and E) Channel Profile (data from 2013 GPS/Total Station survey)**

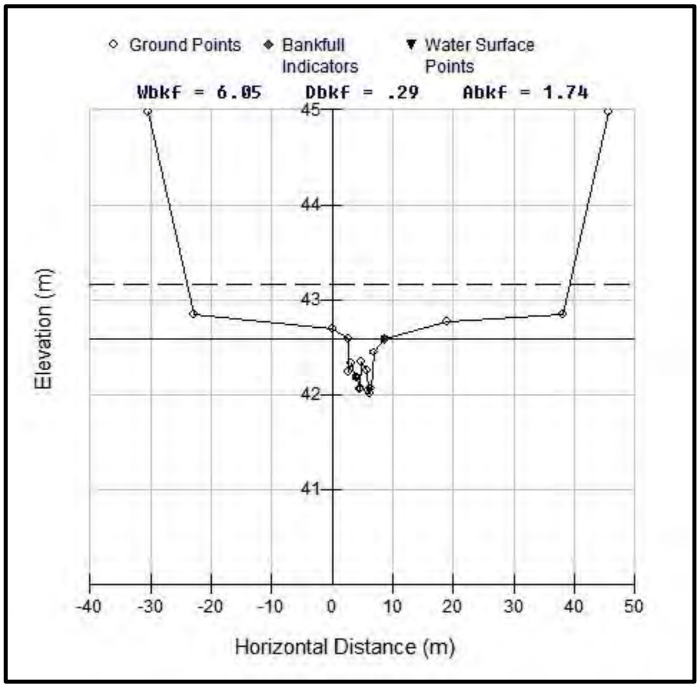


Figure 4: Cross Section A1

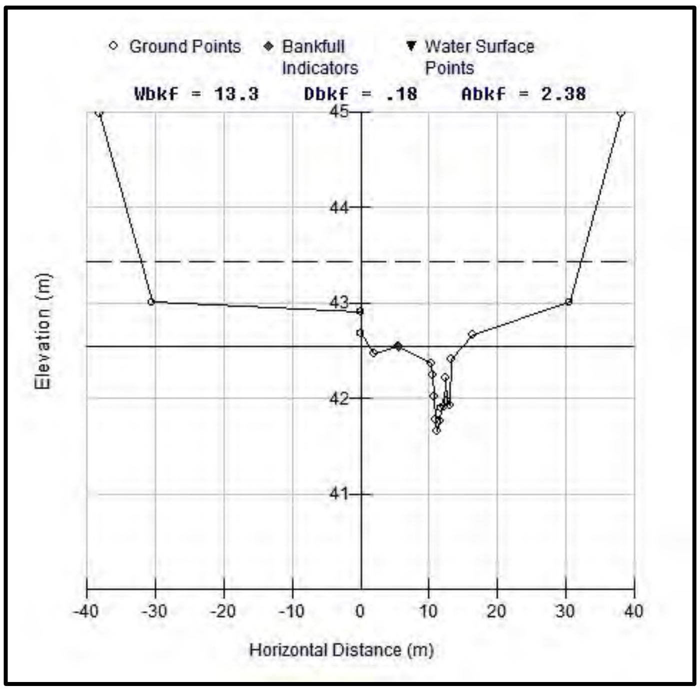


Figure 5: Cross Section A2

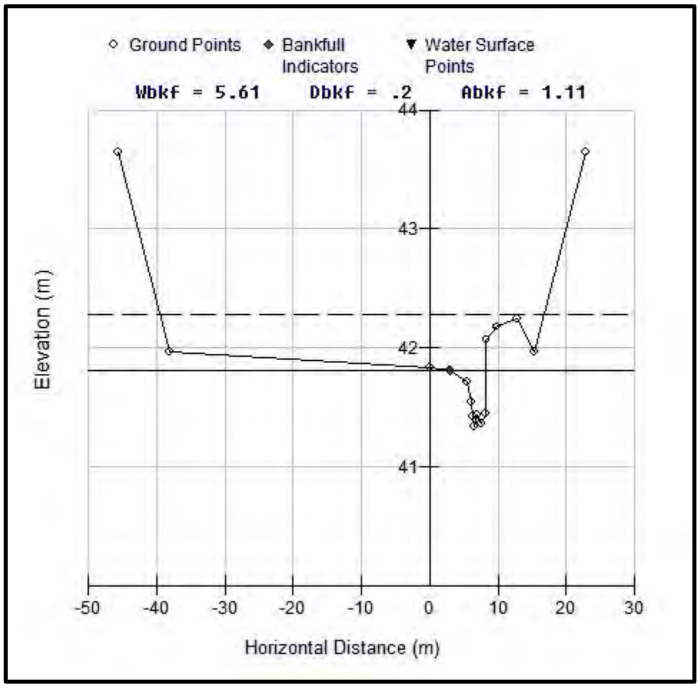


Figure 6: Cross Section A3

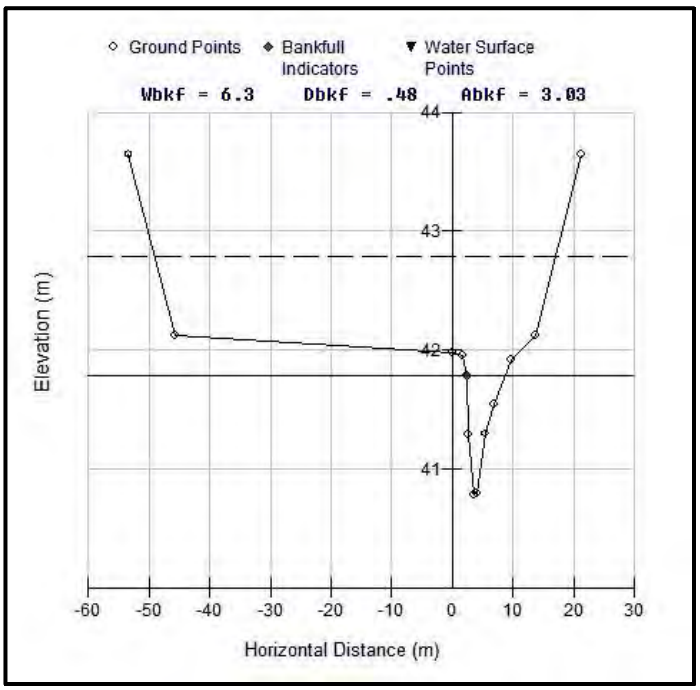


Figure 7: Cross Section A4

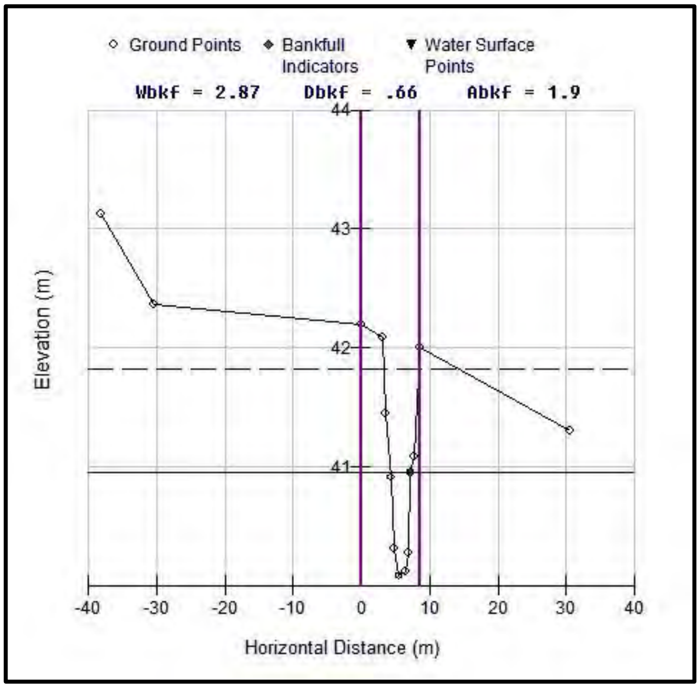


Figure 8: Cross Section A5

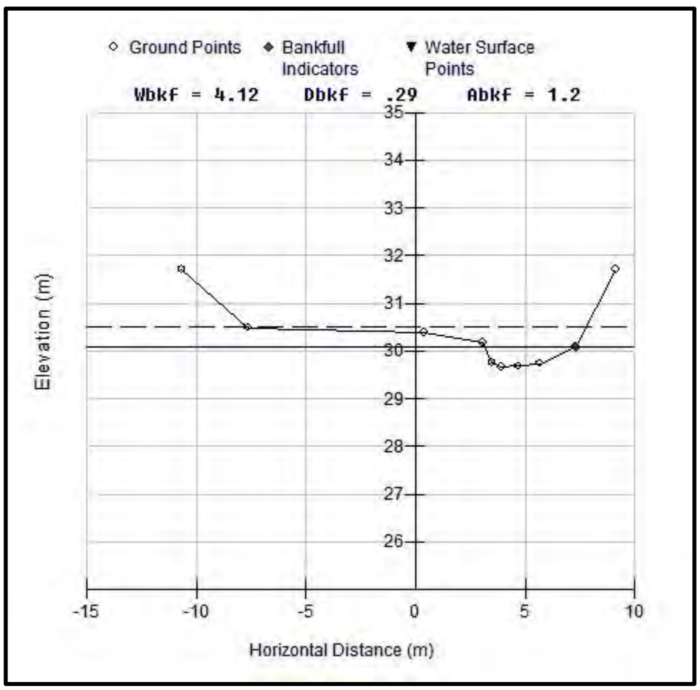


Figure 9: Cross Section B1

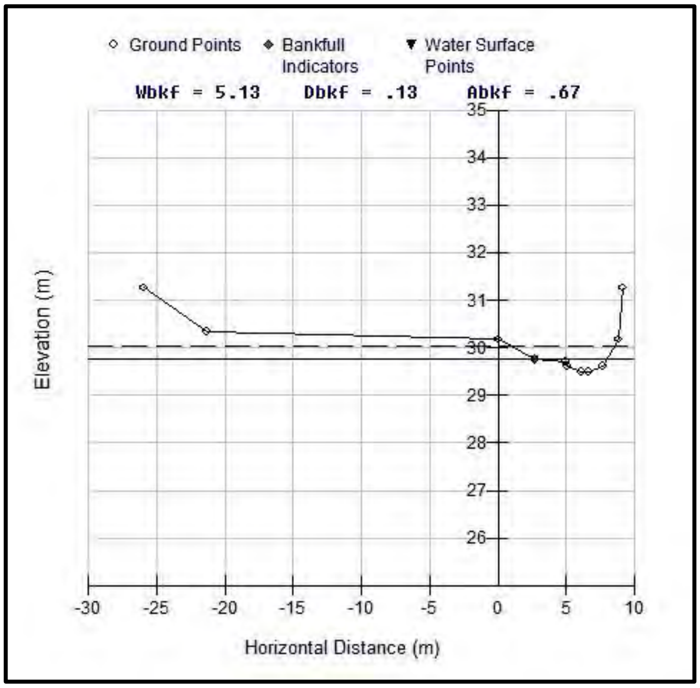


Figure 10: Cross Section B2

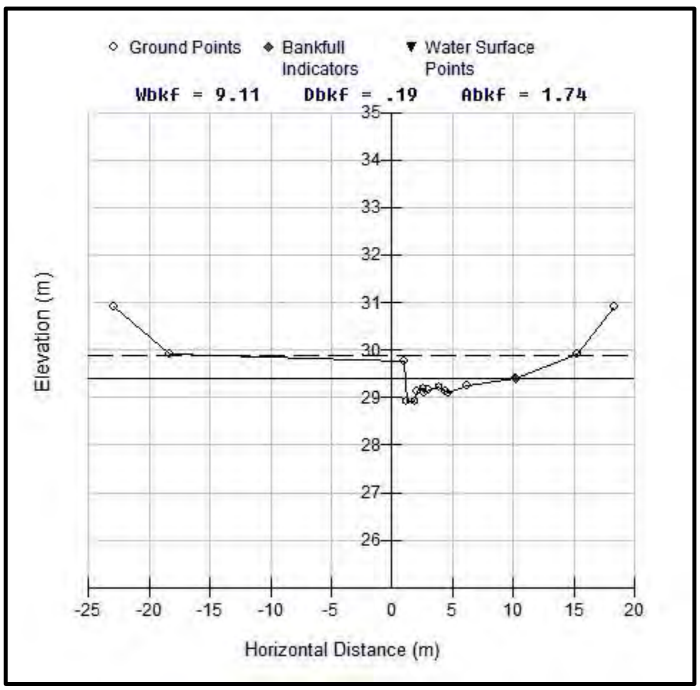


Figure 11: Cross Section B3

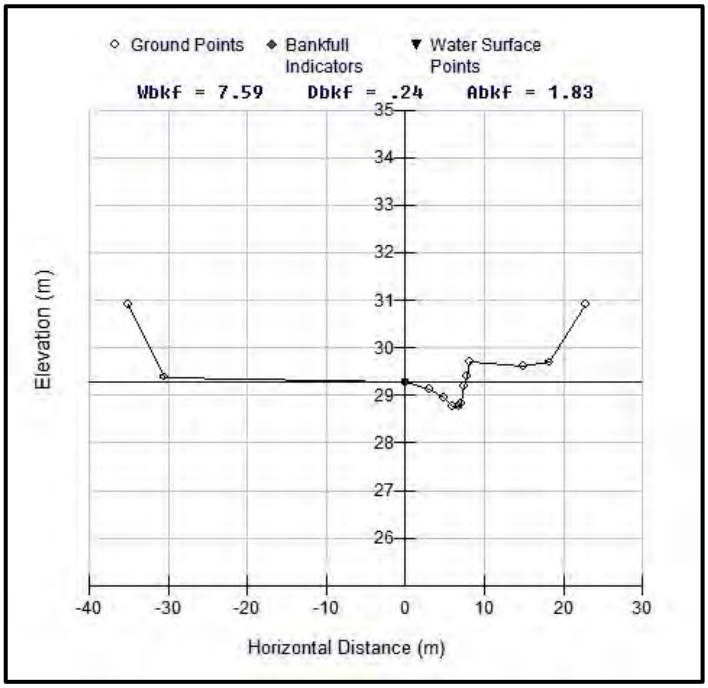


Figure 12: Cross Section B4

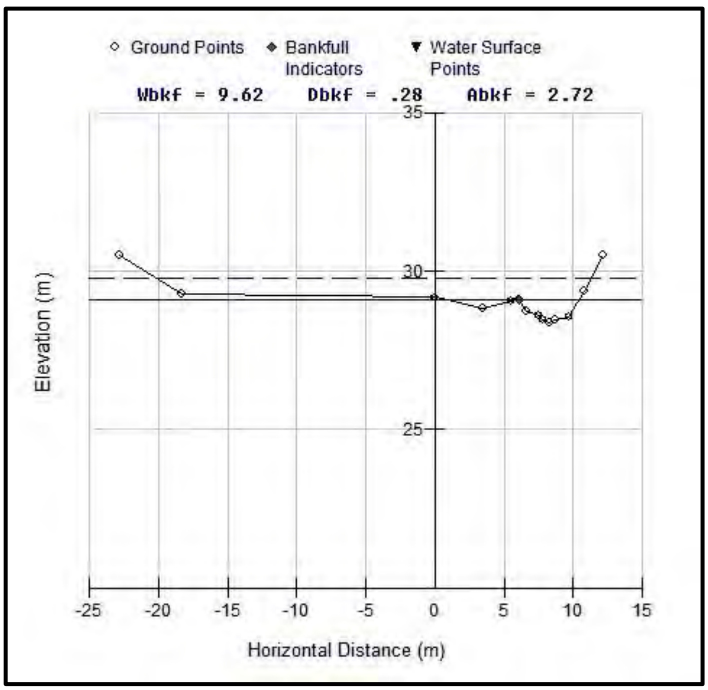
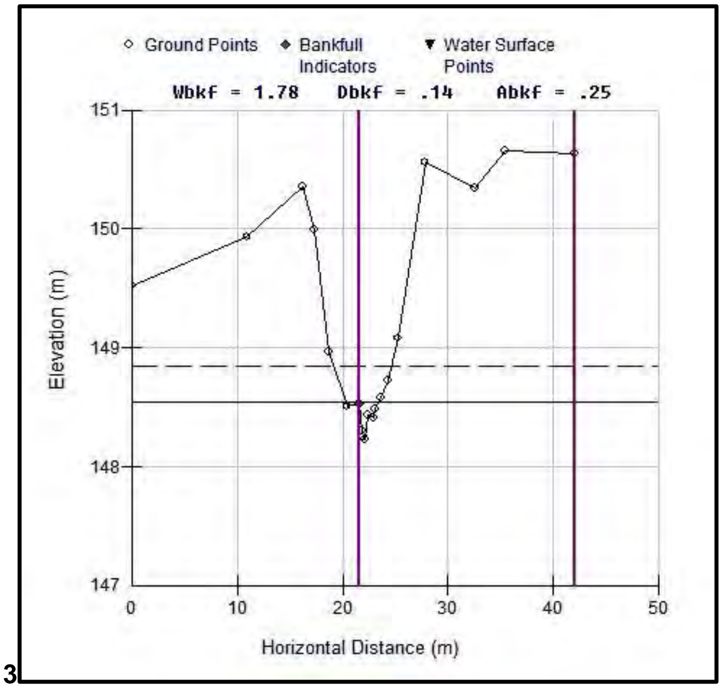


Figure 13: Cross Section B5



3

Figure 14: Cross Section E1

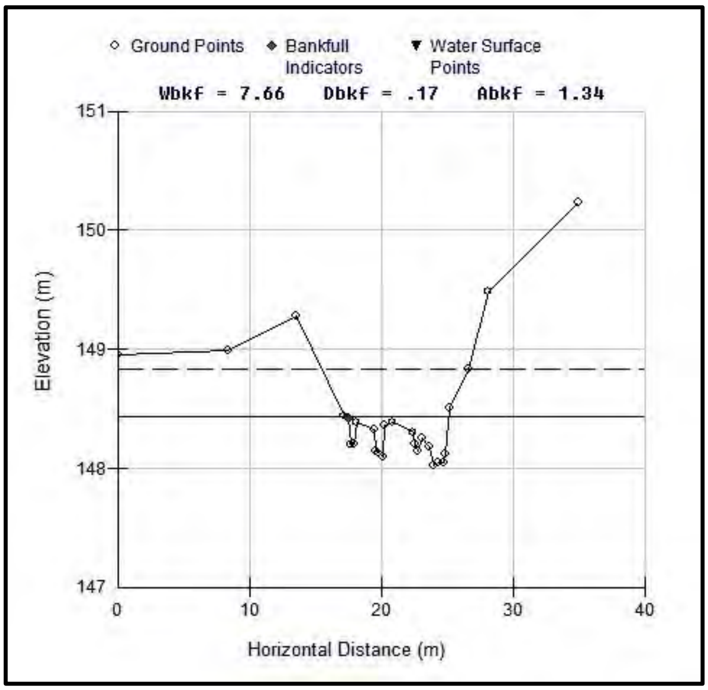


Figure 15: Cross Section D1

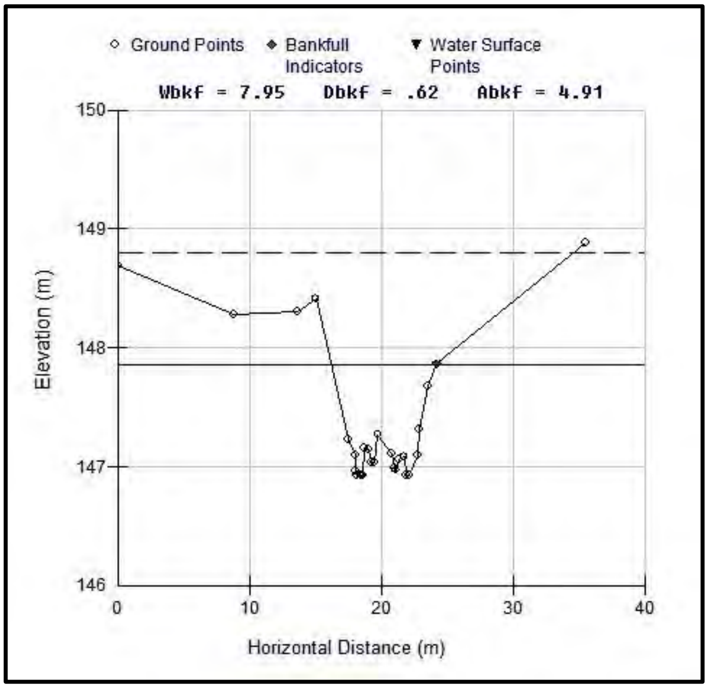


Figure 16: Cross Section D2

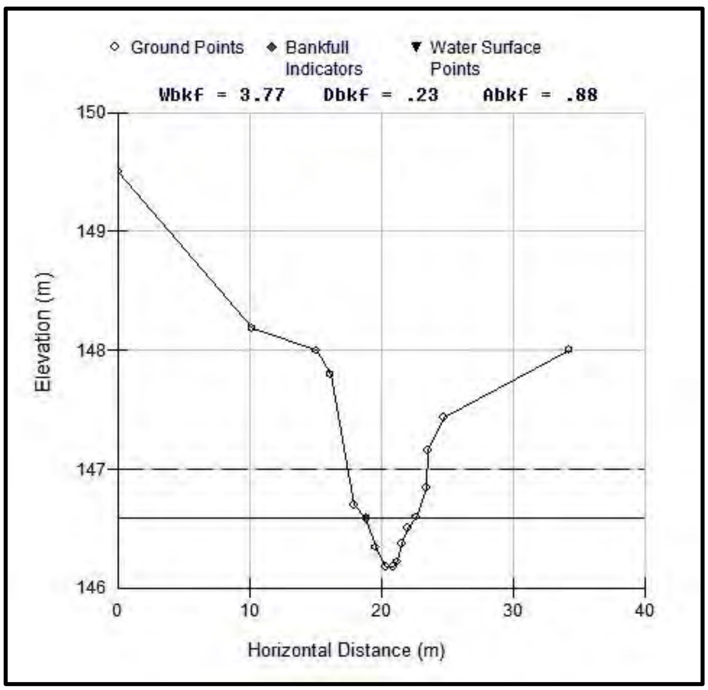


Figure 17: Cross Section D3

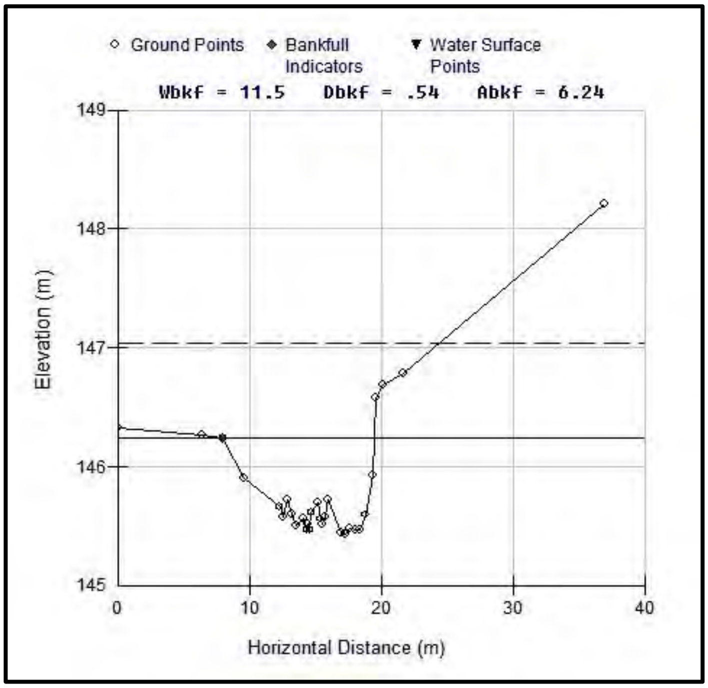


Figure 18: Cross Section D4

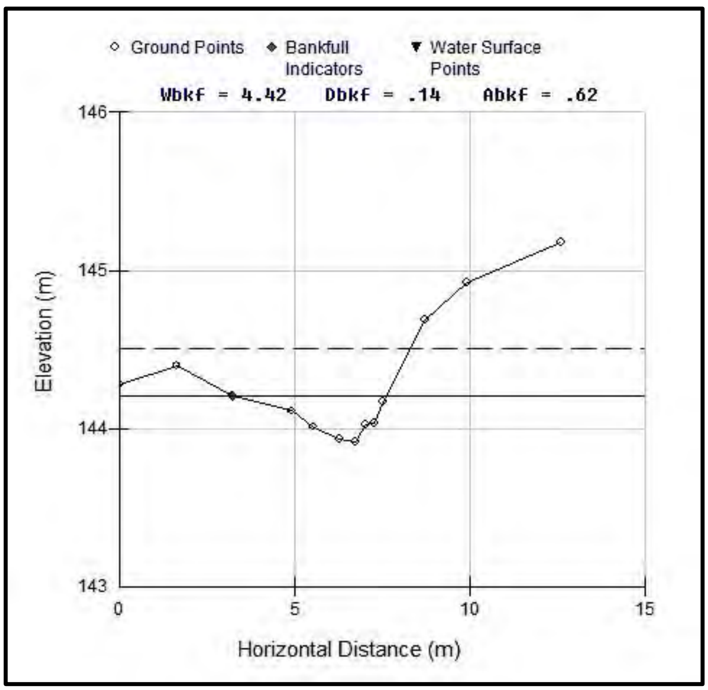


Figure 19: Cross Section C1

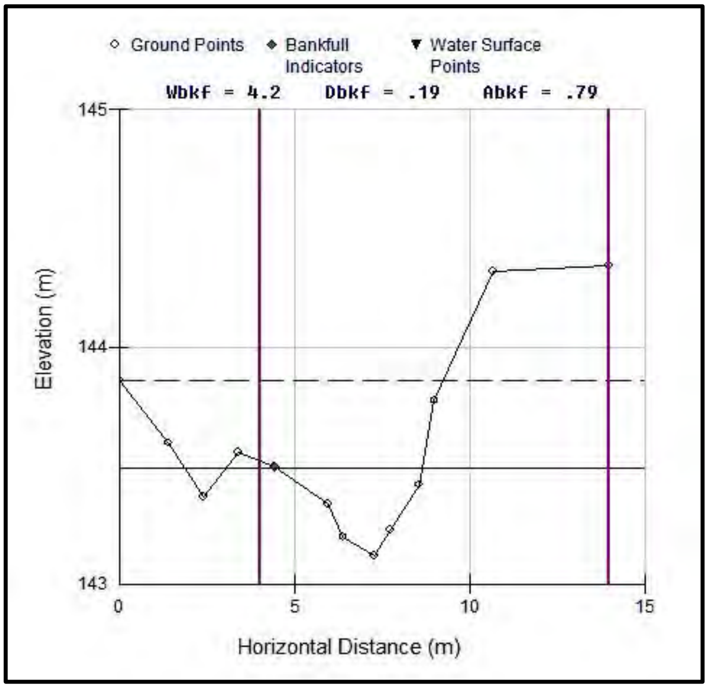


Figure 20: Cross Section C2

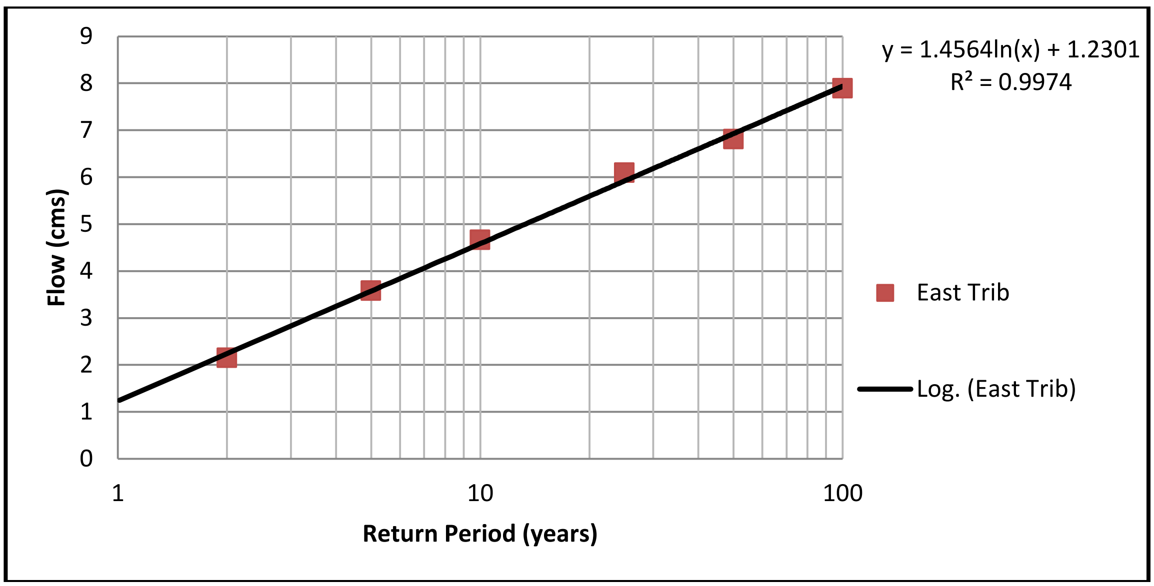


Figure 21: Regression Analysis – East Tributary

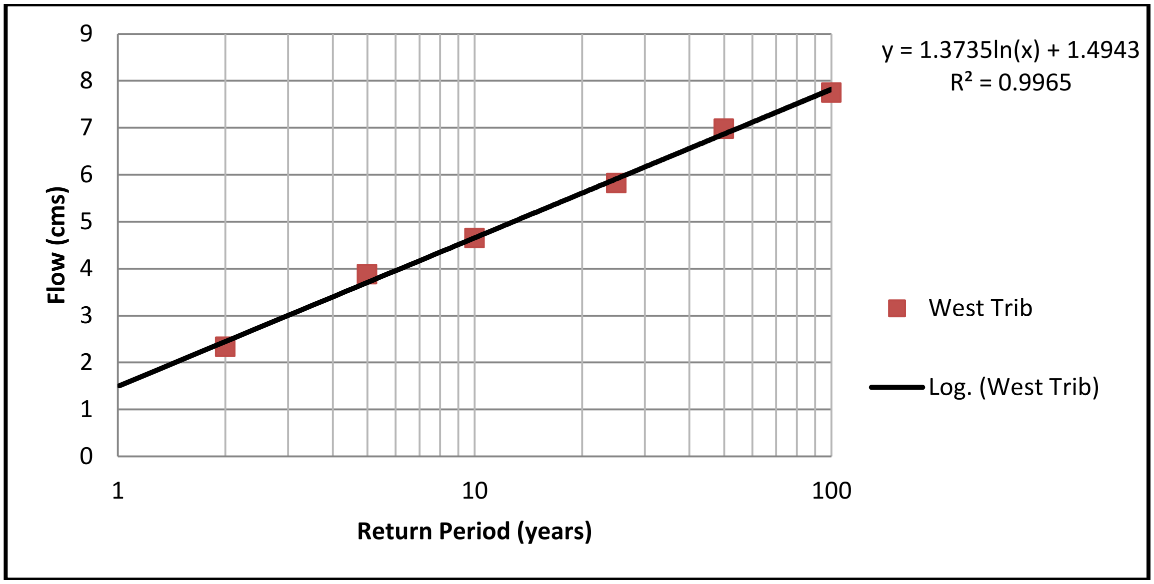


Figure 22: Regression Analysis – West Tributary

March 10, 2016
WE 10032

Steve van Haren, P.Eng., P.E.
Project Manager, Water Resources
Associate
MMM Group Limited
100 Commerce Valley Drive West
Thornhill, Ontario L3T 0A1

Dear Mr. van Haren:

RE: Bentall Development, Town of Oakville
North Oakville EIR/FSS - 14 Mile Creek Tributaries
Response to Peer Review on Erosion Threshold Assessment

A peer review letter was submitted to the Town of Oakville on February 10, 2016 based on the 2013 Water's Edge Fluvial Geomorphological and Erosion Threshold Assessment. This memorandum addresses the comments in the peer-review letter and is organized in three sections analogous to the letter.

Erosion Threshold Determination
To determine the erosion threshold through the two 14 Mile Creek tributaries, Water's Edge delineated five reaches. Reach A is the east tributary and located south of Dundas Street. The remaining reaches B through E are located on the west tributary. Reach B is located south of Dundas Street whereas the rest of the reaches are located upstream of Dundas Street. The number of cross sections for each of the reaches was based on the length of the reach and the site conditions. In the case of Reach C, it was determined that two riffle cross-sections adequately represented the geomorphic conditions in the creek. It is our opinion that additional field work will not be required to confirm field characteristics. As a point of clarification, we note that only riffles were used of determine thresholds, as is standard practice.

Erosion threshold flows are determined for a representative grain size. Often, D_{50}, the median grain size is used based on the understanding that a single grain size can predict the erosional response of a watercourse due to changes in flow. However, depending on the geomorphological characteristics of the stream, other grain sizes such as D_{16} and D_{84} may also be chosen to determine critical shear stresses and threshold flows. As noted by the reviewer, D_{84} was used as opposed to the commonly used D_{50} in the determination of the erosion threshold in this study.

Particle mobility is affected by various factors such as particle pivoting angle, degree of grain exposure and sediment fabric properties such as imbrication and cluster bed forms. These properties vary with the heterogeneity of the channel bed. That is to say that the channel critical shear stress does not only depend on an absolute size of a particle but also on its size relative to the rest of the bed material. (Knighton, 1998). Size selective transport takes place in coarse-grained alluvial streams. Specifically particles that show less exposure, increased imbrication, embeddedness clustering and sheltering of bed particles have a higher erosion threshold and are not transported as easily as they would if the particle bed structures were to be loosely arranged. Photographs 1 to 4 show the armored bed, i.e., granular material in the channel bed. From the photographs, it is clear that the bed structures are not loosely arranged. The larger substrate, particularly those in the D_{84} range show embeddedness. The substrate smaller than the D_{84} are not likely to be entrained easily because of the "sheltering" offered by the larger substrate. Therefore, it was determined that if the D_{84} particle size was to move, it would result in substantial channel adjustment. Hence, this grain size was chosen to determine the critical shear stress and erosion threshold flow.


Photograph 1: Bed substrate in Reach C


Photograph 2: Bed substrate in Reach C


Photograph 3: Bed substrate in Reach D


Photograph 4: Bed substrate in Reach D

In order to validate our understanding of this channel system, erosion threshold flows were also calculated using D_{50} and compared to D_{84} results. The critical flow calculated using the median grain size in the previously determined limiting cross sections in Reaches C and D are 0.007m^3/s and 0.067 m^3/s, respectively. However, during our field visit, when the flow in the watercourse was greater than 0.007 m^3/s, the D_{50} particles were not entrained. This observation also lead credence to the methodology used. Therefore, we deem the use of D_{84} to be appropriate in the calculation of erosion threshold flows.

As part of our analysis to characterize the watercourses and to determine the limiting reach for the west tributary, the reach characteristics were assessed using RSAT and RGA. In both these field assessments Reaches C and D performed similarly with Reach D showing slightly more worse and degraded characteristics. Further, Reach D shows bed shear to critical shear stress ratios of greater than 1 which typically indicates a stressed channel. Despite these characteristics, Reach C was chosen as the limiting reach since it yielded smaller threshold flows – 0.25 m^3/s as compared to 0.96 m^3/s of Reach D. However, on re-examining the data presented and as recommended by the peer review letter, we do support the use of Reach D instead of Reach C as the limiting reach for reasons listed below:

- RGA score for Reach D (0.49) is poorer than that of Reach C (0.44);
- Reach D shows higher bed shear to critical shear stress ratio than Reach C, thus indicating a greater likelihood of movement; and,

- Reach D has a shallower slope (0.7%) than Reach C (2.0%). Therefore, Reach D needs a higher flushing flow than Reach C to prevent sediment aggradation. A higher threshold flow would help with channel maintenance.

Based on Reach D as the limiting reach, a critical threshold flow recommended is 0.96 m^3/s.

Erosion Threshold Analysis and Results

The critical threshold value to be used in the SWM analysis is recommended to be 0.96 m^3/s. Flows below this threshold are determined to be required to maintain the channel without causing aggradation through the currently aggrading tributary as evidenced by the RGA results.

Erosion Control Analyses

We do not recommend critical flow exceedance of 30% yielded by the use of 0.25 m^3/s for critical threshold flow. The exceedance is much larger compared to the 5% which is generally considered acceptable. The large percent exceedance suggests that the flows exceeding the threshold would dominate channel forming processes and possibly lead to channel widening.

Summary

In summary, we conclude and recommend the following:

- No additional field work is required to confirm erosion thresholds;
- The D_{84} particle size was used to determine the erosion threshold flow;
- The limiting reach for this study, as recommended by the peer review, is Reach D;
- The critical flow at the limiting cross section of Reach D is 0.96 m^3/s; and,
- Erosion exceedance analysis should take the newly proposed critical flow of 0.96 m^3/s into account.

Respectfully submitted,

Ed Gazendam, M. Eng., P. Eng.,
President
Water's Edge

Christina Bright, M. A. Sc.
River Scientist

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May 3, 2017
WE 10032

Ashraf Zaghal, Ph.D., P.Eng.
Project Manager, Water Resources
Associate
MMM Group Limited
100 Commerce Valley Drive West
Thornhill, Ontario L3T 0A1

Dear Dr. Zaghal:

RE: Bentall Development, Town of Oakville
North Oakville EIR/FSS - 14 Mile Creek Tributaries
Clarification of Memorandum dated March 10, 2016

A peer review letter was submitted to the Town of Oakville on February 10, 2016 based on the 2013 Water's Edge Fluvial Geomorphological and Erosion Threshold Assessment. Following the peer review, a memorandum dated March 10, 2016 addressing the comments in the peer-review letter was submitted by Water's Edge. The previous memorandum generated further discussions through email and a teleconference. This letter provides CH staff with clarification requested in their email dated August 22, 2016 and during the subsequent teleconference.

As mentioned in the previous memorandum, Reach D was chosen as the limiting reach. As per the geomorphic assessment undertaken, this reach shows a greater sensitivity than the previously chosen Reach C. The change in the choice of sensitive reach Reach D (instead of Reach C) was based on the re-examination of the data and was also based on following through with the line of reasoning suggested by the Peer Review Letter. The erosion threshold flow at this reach, and hence the critical flow was determined to be $0.96 m^3/s$ based on a D_{84} particle size. The rationale for the choice of the index particle size was based on field observations.

Movement of fines and D_{84} particles

CH staff are concerned that the D_{84} particle would be destabilized if finer particles are first moved under lower flows, particularly considering the low sediment load present in SWM discharge. To allay this concern, we note that the method used in the determination of the erosion threshold are based on tractive force analysis which assume that the particle rests on a plane surface without interference from other particles. No hiding factor is taken into account. Therefore, particle stability is solely based on the particle and not on the surrounding matrix. This method is quite conservative. Any resistive force provided by other particles due to imbrication or partial burial does provide additional stability which are not accounted for in the erosion threshold calculations. Therefore, regardless of the movement of other particles, the D_{84} particle would be at incipient motion only at the critical flow of $0.96 m^3/s$. That said, we acknowledge that the question of sediment supply in SWM channels is a larger issue relevant for all erosion threshold projects.

Bank Erosion Threshold

CH staff has also requested information on the bank erosion thresholds. Our previous assessment did not take bank erosion thresholds into consideration. Therefore, this memorandum provides the requested supplemental assessment of bank erosion and bank shear stresses.

This assessment on bank erosion is based on a modified Chow (1959) approach. The modification was required to account for the varying substrate materials in the bed and the banks. This method provides the value for a ratio (K) of the bed and bank shear stress. The ratio is based on bed and bank materials and the cross-section geometry (approximated to be a trapezoid). The ratio can be applied to both Komar (1987) and Fischenich (2001) approaches previously used to determine the critical bed shear stress. The geomorphic and hydraulic summary parameters are provided in the tables below (Tables 1a, 1b for reaches upstream of Dundas St, Tables 2a and 2b for Reach B and Tables 3a and 3b for Reach A). Furthermore, a summary of critical flows based on the limiting cross-sections for each reach established previously (2013 report) is also provided.

Table 1a: Geomorphic & Hydraulic Parameters (for reaches upstream of Dundas St)

Parameter	XSE1	XSD1	XSD2	XSD3	XSD4	XSC1	XSC2
Depth (m)	0.14	0.17	0.62	0.23	0.54	0.14	0.19
Width (m)	1.78	7.66	7.95	3.77	11.48	4.42	4.20
Z (Left Bank)	1.18	0.56	0.48	0.28	0.14	0.13	0.30
Z (Right Bank)	0.95	1.30	0.45	0.37	0.48	0.44	0.24
Left Bank Angle	49.72	29.38	25.43	15.86	8.16	7.37	16.82
Right Bank Angle	43.67	52.36	24.30	20.38	25.46	23.98	13.38
Bottom Width (m)	0.30	0.90	4.00	0.90	5.80	1.00	0.90
Angle of Repose for Bed Particles	38.00	38.00	36.00	36.00	36.00	38.00	38.00
Angle of Repose for Bank Particles	31.00	31.00	31.00	31.00	31.00	31.00	31.00
Critical Bed Particle Size (mm)	0.40	69.35	54.99	39.24	85.16	44.50	54.50
Slope (m/m)	0.007	0.007	0.007	0.007	0.007	0.02	0.020
Hydraulic Radius (m)	0.12	0.16	0.54	0.20	0.49	0.13	0.17
Relative Roughness (m/m)	4.75	7.49	37.25	13.83	32.62	5.28	9.89
Shear Velocity (m/s)	0.09	0.11	0.19	0.12	0.18	0.16	0.18
Velocity based on FF/RR (m/s)	0.61	0.83	2.26	1.11	2.11	1.10	1.55
Bankfull Q (m^3/s)	0.15	1.08	11.13	0.96	13.05	0.68	1.24
Froude #	0.52	0.64	0.92	0.74	0.91	0.94	1.14
Stream Power (W/m)	10.50	74.35	769.6	66.32	902.75	131.07	237.88
Unit Stream Power (W/m2)	5.90	9.71	96.81	17.59	78.64	29.65	56.64
Mean Boundary SHEAR τ_o (N/m^2)	8.37	11.26	37.09	14.18	34.14	25.33	33.52
max BED SHEAR τ_L (N/m^2)	11.02	13.92	30.20	13.26	22.54	24.42	27.62
max BANK SHEAR τ_s (N/m^2)	8.95	12.26	27.81	9.78	25.50	18.66	21.40
K = Bed/Left Bank	-	0.23	0.46	0.70	0.79	0.74	0.64
K = Bed/Right Bank	-	-	0.50	0.61	0.46	0.47	0.69

Table 1b: Shear Stress Parameters (reaches upstream of Dundas St)

Method	Parameter	XSE1	XSD1	XSD2	XSD3	XSD4	XSC1	XSC2
KOMAR (1987)	CRITICAL BED τcr (N/m^2)	50.51	40.05	28.58	62.03	32.41	39.70	51.16
	CRITICAL BANK τcr (N/m^2)	-	-	14.22	43.49	25.77	29.57	35.15
FISCHENICH (2001)	CRITICAL BED τcr (N/m^2)	52.62	41.73	27.69	60.09	31.40	41.35	53.30
	CRITICAL BANK τcr (N/m^2)	-	-	13.77	42.13	24.96	30.80	36.62

Critical bank shear stress could not always be calculated at some of the cross-sections where the bank angle was steeper than the angle of repose of the bank substrate. This is a limitation of the Chow approach in estimation of shear stress.

Table 2a: Geomorphic & Hydraulic Parameters (Reach B)

Parameter	XSB1	XSB2	XSB3	XSB4	XSB5
Depth (m)	0.29	0.13	0.19	0.24	0.47
Width (m)	4.12	5.28	9.11	7.63	4.43
Z (Left Bank)	0.24	1.13	4.24	0.17	0.22
Z (Right Bank)	0.22	0.50	0.06	0.23	0.10
Left Bank Angle	13.72	48.44	76.7	9.75	12.33
Right Bank Angle	12.37	26.52	3.33	13.16	5.75
Bottom Width (m)	2.20	2.60	3.50	0.90	0.90
Angle of Repose for Bed Particles	40.00	40.00	36.0	36.00	40.00
Angle of Repose for Bank Particles	31.00	31.00	31.0	31.00	31.00
Critical Bed Particle Size (mm)	70.24	169.2	122	59.17	49.77
Slope (m/m)	0.007	0.007	0.07	0.007	0.006
Hydraulic Radius (m)	0.26	0.12	0.18	0.23	0.38
Relative Roughness (m/m)			15.5		
	6.66	2.57	9	19.42	9.22
Shear Velocity (m/s)	0.13	0.09	0.11	0.12	0.15
Velocity based on FF/RR (m/s)	0.99	0.48	1.08	1.26	1.25
Bankfull Q (m^3/s)	1.20	0.33	1.88	2.32	2.58
Froude #	0.59	0.42	0.79	0.82	0.58
Stream Power (W/m)	82.45	22.64	129	159.51	151.61
Unit Stream Power (W/m2)	20.01	4.29	14.2	20.90	34.23
Mean Boundary SHEAR τ_o (N/m^2)	17.62	8.57	12.6	15.57	22.66
max BED SHEAR τ_L (N/m^2)	13.00	10.68	19.8	7.09	15.00
max BANK SHEAR τ_s (N/m^2)	10.39	8.90	21.4	8.97	12.82
K = Bed/Left Bank	0.64	-	-	0.78	0.65
K = Bed/Right Bank	0.65	0.36	0.82	0.74	0.70

Table 2b: Shear Stress Parameters (Reach B)

Method	Parameter	XSB1	XSB2	XSB3	XSB4	XSB5
KOMAR (1987)	CRITICAL BED τcr (N/m^2)	123.24	89.17	43.10	36.25	130.35
	CRITICAL BANK τcr (N/m^2)	80.26	-	-	28.31	91.56
SHEILDS (modified as per Julien, 1995)	CRITICAL BED τcr (N/m^2)	147.89	103.04	47.89	40.28	156.42
	CRITICAL BANK τcr (N/m^2)	96.31	-	-	31.46	109.87
FISCHENICH (2001)	CRITICAL BED τcr (N/m^2)	137.89	99.76	41.75	35.12	145.84
	CRITICAL BANK τcr (N/m^2)	89.80	-	-	27.43	102.44

Table 3a: Geomorphic & Hydraulic Parameters (Reach A)

Parameter	XSA1	XSA2	XSA3	XSA4	XSA5
Depth (m)	0.29	0.42	0.21	0.48	0.66
Width (m)	6.10	2.88	5.26	6.28	2.87
Z (Left Bank)	3.50	0.99	0.32	0.56	1.50
Z (Right Bank)	0.76	0.23	6.22	0.38	2.24
Left Bank Angle	74.08	44.60	17.83	29.06	56.34
Right Bank Angle	37.31	12.75	80.86	21.04	65.90
Bottom Width (m)	3.80	0.60	1.90	0.60	2.10
Angle of Repose for Bed Particles	38.00	35.00	33.00	38.00	36.00
Angle of Repose for Bank Particles	31.00	31.00	31.00	31.00	31.00
Critical Bed Particle Size (mm)	178.96	30.70	48.09	46.89	51.76
Slope (m/m)	0.006	0.006	0.006	0.006	0.006
Hydraulic Radius (m)	0.26	0.32	0.19	0.42	0.45
Relative Roughness (m/m)	15.00	51.31	51.17	16.87	47.02
Shear Velocity (m/s)	0.12	0.14	0.11	0.16	0.16
Velocity based on FF/RR (m/s)	1.18	1.72	1.33	1.53	2.01
Bankfull Q (m^3/s)	2.09	2.06	1.45	4.64	3.82
Froude #	0.70	0.85	0.93	0.71	0.79
Stream Power (W/m)	123.31	121.33	85.13	272.98	224.97
Unit Stream Power (W/m2)	20.22	42.08	16.19	43.50	78.52
Mean Boundary SHEAR τ_o (N/m^2)	15.59	18.97	11.29	24.59	26.70
max BED SHEAR τ_L (N/m^2)	23.89	23.99	18.80	23.62	38.51
max BANK SHEAR τ_s (N/m^2)	24.64	18.88	22.13	19.60	36.03
K = Bed/Left Bank	-	-	0.74	0.26	-
K = Bed/Right Bank	-	0.78	-	0.55	-

Table 3b: Shear Stress Parameters (Reach A)

Method	Parameter	XSA1	XSA2	XSA3	XSA4	XSA5
KOMAR (1987)	CRITICAL BED τcr (N/m^2)	22.36	35.03	34.15	37.70	26.62
	CRITICAL BANK τcr (N/m^2)	-	-	-	20.79	-
SHEILDS (modified as per Julien, 1995)	CRITICAL BED τcr (N/m^2)	23.36	38.92	37.95	41.89	29.58
	CRITICAL BANK τcr (N/m^2)	-	-	-	23.10	-
FISCHENICH (2001)	CRITICAL BED τcr (N/m^2)	23.29	32.70	29.57	39.27	25.79
	CRITICAL BANK τcr (N/m^2)	-	-	-	21.66	-

Table 4: Critical Flow Summary for Limiting Cross-Sections

Method	Parameter	XSE1	XSD3	XSC2	XSB2	XSA2
KOMAR (1987)	Average BED τo/τcr	0.17	0.35	0.74	0.10	0.61
	Average BANK τo/τcr	-	0.51	1.04	-	-
	BED Threshold Flow (m^3/s)	0.15	0.96	0.25	0.33	0.56
	BANK Threshold Flow (m^3/s)	-	0.59	0.11	-	-
FISCHENICH (2001)	Average BED τo/τcr	0.16	0.35	0.71	0.09	0.63
	Average BANK τo/τcr	-	0.53	0.99	-	-
	BED Threshold Flow (m^3/s)	0.15	0.96	0.27	0.33	0.51
	BANK Threshold Flow (m^3/s)	-	0.55	0.13	-	-

Based on Table 4, it is evident that the bank threshold is lower than the bed threshold for almost all scenarios where bank threshold could be calculated. However, it must be noted that the bank thresholds do not account for the cohesive fines that were found in the bank. Additionally, the bank is also strengthened by the vegetation which would further reduce the threshold of motion for bank particles. The effect of vegetation has not been accounted for in the analysis. These additional factors that contribute to the stability of the bank particles allow for the use of bed threshold flow as opposed to the bank threshold flow.

Deposition Threshold

The question of the potential requirement of a deposition threshold was brought up in addition to the erosion threshold to address the concern of aggradation. At present, there is no "industry standard" for the determination of deposition threshold. However, in this specific case, the issue of deposition threshold can be dealt with by the use of an appropriate erosion threshold. It is important to note that while excessive transport results in erosion, insufficient transport results in aggradation and thus thwarts the development of geomorphic features. Therefore, a high enough flushing flow would prevent sediment aggradation through Reach D and allow for the dynamic system that tends towards the condition of quasi-equilibrium.

Summary

In summary, we conclude and recommend the following:

- The erosion threshold analysis performed assumes that the D_{84} particle is independent of the surrounding substrate matrix and therefore will remain stable under critical flow regardless of the potential movement of the finer particles;
- Bank erosion thresholds were established and noted to be lower than bed erosion threshold. However, owing to stability provided by the cohesive soils and vegetation, the use of bed erosion threshold has therefore been determined to be more appropriate; and,
- A deposition threshold was not established. The concern of aggradation can be sufficiently addressed through the use of the recommended critical flow.

Respectfully submitted,

Ed Gazendam, M. Eng., P. Eng.,
President
Water's Edge

Christina Bright, M. A. Sc.
River Scientist

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MMM GROUP

INTER OFFICE MEMO

To:	Ashraf Zaghal, Ph.D., P.Eng.	Date:	September 18, 2015
From:	Scott Cowan, GIT, CTech. Mark Hartley, B.Sc.(Fisheries), M.Sc., P.Eng.	Job No.:	1409222-001
Subject:	Fluvial Geomorphological Field Assessment of Reach 14W-12A	CC:	Steve van Haren, P.Eng., P.E.

1.0 INTRODUCTION

MMM Group Limited (MMM Group) was retained by Bentall Kennedy (Canada) LP – Lazy Pat Farms to develop an Environmental Implementation Report / Functional Servicing Study (EIR/FSS) for 14 Mile Creek West and the Lazy Pat Farms Property, North Oakville West. The EIR/FSS proposed a drainage plan developed, which included creek work developed based on the principles of Natural Channel Design and the North Oakville Creeks Subwatershed Study (NOCSS) requirements, which alters the flow regime of Reach 14W-12A (the Reach). Upon review of the EIR/FSS, Conservation Halton (CH) provided comments, with a specific request for additional assessment to determine whether the alterations to the Reach's flow regime will negatively impact the existing geomorphic form and function of the Reach (item 1(d) from the August 11, 2015 meeting minutes).

This memorandum summarizes the existing background information in the EIR/FSS relevant to the Reach, and outlines the results of a geomorphological field assessment undertaken to determine the contribution the existing flow regime has on maintaining the existing form and function of the Reach.

2.0 BACKGROUND

2.1 SITE LOCATION

The Reach is located within the western portion of North Oakville West Secondary Plan (NOWSP) area, which has been defined as the 407 West Employment Area. The Reach is located on the north side of Dundas Street West, generally mid-way between Tremaine road and Zenon Drive, in the Town of Oakville (see Figure 1 below).

Figure 1 – Location of Reach 14W-12A

2.2 REVIEW OF EIR/FSS

An EIR/FSS for 14 Mile Creek West and the Lazy Pat Farms Property, North Oakville West was prepared by MMM Group and submitted to Bentall Kennedy in November 2014. The EIR/FSS identifies the Reach as a 125 m long watercourse with a trapezoidal cross-section that appears in the historic record between 1934 and 1960 (see Figure 6.2 from the EIR/FSS). The EIR/FSS determined that the Reach was constructed to allow outflows from pond 14W-14A (which was constructed at the same time) to flow back out into Reach 14W-12. The Reach contains a narrow incised channel which receives diffuse flow through cattails which extend downstream of the pond inlet/outlet for approximately 75 m. As a component of the EIR/FSS, a Fluvial Geomorphological and Erosion Threshold Assessment of the 14 Mile Creek tributaries immediately north and south of Dundas Street was completed by Water's Edge in October 2013.This assessment included a high-level inventory of existing geomorphic conditions, including the completion of a Rapid Stream Assessment Technique (RSAT) and Rapid Geomorphic Assessment (RGA). The EIR/FSS defines a meander belt width, erosion allowance, and overall corridor width for the Reach. The report does not assess the contribution the existing flow regime has on maintaining the existing form and function of the Reach.

2.3 PHYSIOGRAPHY AND GEOLOGY

The Reach and surrounding area are situated in the South Slope physiographic region as defined by Chapman and Putman, (1984). Surficial geology of the reach consists of the reddish coloured clay-silt

Halton Till which is locally derived from the underlying bedrock. The underlying bedrock in the area is Upper Ordovician Red Shale and interbedded Limestone of the Queenston Formation.

3.0 GEOMORPHOLOGICAL FIELD ASSESSMENT

a site visit was completed by MMM Group on September 11, 2015 to determine the contribution the existing flow regime has on maintaining the existing form and function of the Reach. For the purposes of the site visit the following were undertaken:

1. Overview of reach characteristics,
2. typical cross-section survey and long profile, and
3. photographic record of the site.

At the time of the site visit the weather was warm and dry, with no precipitation during, or 24 hours prior to the assessment. There was no observed flow during the site visit.

3.1 OVERVIEW OF REACH CHARACTERISTICS

The Reach is approximately 125 m in length originating upstream at the inlet/outlet to pond 14W-14A (the Pond) and terminating downstream at its confluence with reach 14W-12. The cross-section of the Reach is typified by a trapezoidal geometry with a flat bottom, typical of a constructed channel. The Reach is heavily vegetated with shrubs and tall grasses along its entire length and throughout the entire cross-section. The watercourse bottom is dominated by cattails for the majority of the reach length (extending approximately 75 m downstream from the upstream limit and 20 m upstream from the downstream limit). There is no channel definition within the cattails. Where cattails are not present, the watercourse bottom is dominated by well-established shrubs and tall grasses. A small poorly-defined incised channel was observed in this section. There was no significant alluvium deposits found within the incised channel or within the cattails. Banks along the entire length of the Reach are dominated by shrubs and tall grasses. Soils within the Reach consist of silts and clays with some organics. Bank slopes (sta. 2 – 5 m and sta. 11 – 14 m) appear to be stable along the entire length with no indications of toe erosion, slumping, or other failure. No indicators of aggradation, degradation, widening, planimetric form adjustment, or instability were identified within the cattails, adjacent to the low flow channel, or along the banks of the creek.

3.2 CROSS SECTION SURVEY & LONG PROFILE

A typical cross-section was surveyed, approximately 90 m downstream from the Pond outlet and 35 m upstream of the Reach outlet into 14W-12 (Figure 2). The cross-section survey confirms the general trapezoidal form of the reach. The left bank and right bank are approximately 2.0 m and 1.6 m high, respectively, with a bank slope of approximately 2:1. Reach bottom width and top width are 5.0 m and 12.0 m, respectively. A small poorly-defined incised channel (0.20 m deep and 0.35 m wide) is located at sta. 8.0 m. This incised channel does not exist within regions vegetated by cattails although overall cross-sectional geometry is similar. Photo 6 was taken of the poorly-defined incised channel in the surveyed cross-section. Photos 3, 4, and 5 represent the typical cross-section and capture the thick vegetation, cross-sectional geometry, and lack of low flow channel definition within the Reach.

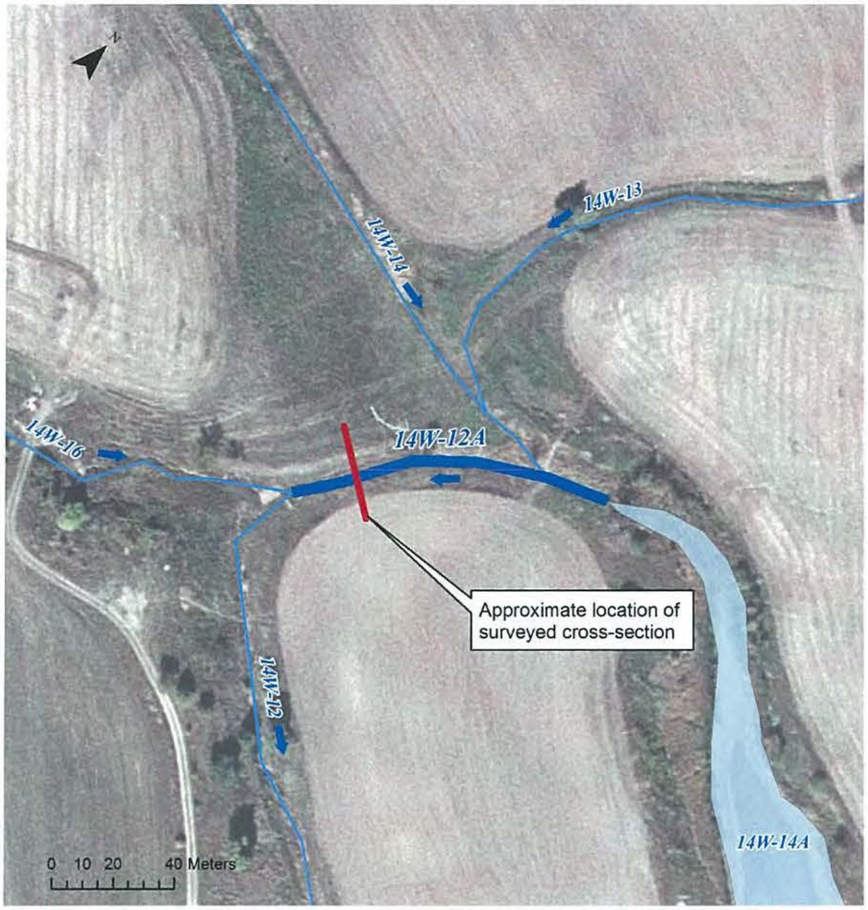

Figure 2 – Location of surveyed typical cross-section on Reach 14W-12A

The results of the cross-section survey are presented in Figure 3 below. Please note that the elevations indicated are relative only, and were developed assuming a datum on the left top of bank of 100 m.

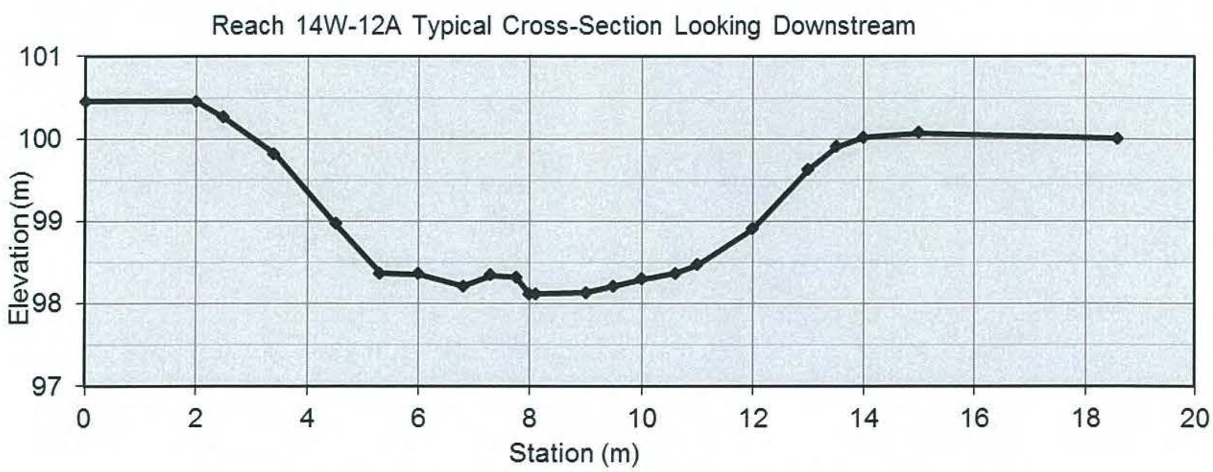

Figure 3 – Survey of typical cross-section of 14W-12A, looking downstream

A long profile survey of the channel bottom was completed extending approximately 30 m upstream and 15 m downstream of the surveyed cross-section to determine the approximate slope of the Reach invert. The results of the long profile survey indicate that the reach slope is approximately 0.85 %, draining towards 14W-12.

3.3 GEOMORPHIC PROCESSES

Clearly the origins of this open channel are anthropogenic; it was excavated between 1935 and 1960 for the purpose of conveying excess water from Reach 14W-14/14W-14A/14W-13 westwards towards Reach 14W-2. Recent topographic observations support this conclusion. The horizontal alignment of the Reach is east-west which is nearly perpendicular to the flow direction of the adjoining tributaries. The flow regime (time series and flow direction) is highly dependent upon the response of the upstream catchments and the water level in the on-line pond (Reach 14W-14A). The preferred flow path appears to be from north to south and only includes the Reach under high flow conditions; the magnitude of the flow split is difficult to determine.

4.0 SUMMARY AND CONCLUSION

The presence of thick vegetation, the absence of a continuous well-defined low flow channel, and the absence of geomorphic indicators (i.e. aggradation, degradation, widening, planimetric form adjustment, or instability) indicates that fluvial geomorphic processes are not occurring within the Reach. This also indicates that the Reach is not actively working to maintain or recover a natural form and function. Because geomorphic processes are not ongoing under the current flow regime, it can be concluded that the existing flow regime does not contribute to the maintenance of the existing form and function. Subsequently, modifications to the existing flow regime will not negatively impact the existing form and function of the Reach.

5.0 CLOSURE

We have based the foregoing assessment on our understanding of your present needs. Please contact the undersigned should you have any question about this work.

Yours truly,

MMM GROUP LTD.

Prepared by:

Scott Cowan, GIT, CTech.
Fluvial Geomorphologist
Water Resources

Reviewed by:

Mark Hartley, B.Sc.(Fisheries), M.Sc., P.Eng.
Senior Project Manager
Water Resources

Photo Appendix

	
Photo 1 – Outlet of Pond and upstream limit of Reach 14W-12A	**Photo 2** – Upstream limit of Reach 14W-12A looking upstream to Pond. Heavy Cattail growth and no defined channel.
	
Photo 3 – Surveyed cross-section looking upstream at cattail growth, and eventual outlet from the pond.	**Photo 4 –** Surveyed cross-section looking downstream at cattail growth, and eventual outlet to reach 14W-12

	
Photo 5 – Surveyed cross-section looking downstream through heavily vegetated oversized trapezoidal channel bottom	**Photo 6** – Incised low flow channel within surveyed cross-section

Appendix 7.2 – Hydrological Modelling Results

Revised Oct 2016
CATCHMENT PARAMETERS

Existing

Catchment #	Area (ha)			Imp %	Direction to		Note
	Total	Imper.	Per.		Culvert at HWY 407	Culverts at Dundas Street	
1001	118.47	0.94	117.53	1	FM-1	FM-D4	
1002	27.31	0.26	27.05	1	FM-2	FM-D4	
1003A	91.72	1.11	90.61	1	FM-3	FM-D4	
1003B	27.37	0.6	26.77	2	FM-3	FM-D4	
1004	6.76	0.26	6.5	4	FM-4	FM-D4	
1005	35.6	0.19	35.41	1	FM-5	FM-D5	
1006	33.58	0.13	33.45	0	FM-6	FM-D5	
1007A	52.76	0.07	52.69	0	FM-7	FM-D5	
1007B	18.98	0.07	18.91	0	FM-7	FM-D5	
1007C	71.39	0.13	71.26	0	FM-7	FM-D5	
1007D	27.66	0.13	27.53	0	FM-7	FM-D5	
1008	5.93	0.01	5.92	0	FM-8	FM-D5	
1102	30.19	1.21	28.98	4		FM-D2	
1103	14.36	0.6	13.76	4		FM-D3	
1105	37.44	1.87	35.57	5		FM-D4	
1201	15.43	0.93	14.50	6		FM-D4	
1202	38.18	2.29	35.89	6		FM-D4	
1203	15.86	0.95	14.91	6		FM-D4	
1210	1.95	0.12	1.83	6		FM-D4	
1211	7.17	0.36	6.81	5		FM-D4	
1301	1.73	1.56	0.17	90		FM-D4	
1302	2.38	2.14	0.24	90		FM-D4	
1303	3.64	3.28	0.36	90		FM-D4	
1106	15.19	0.39	14.8	3		FM-D4A	
1107	13.2	1.06	12.14	8		FM-D5	
1510	7.95	0.64	7.31	8		FM-D5	
1108	48.74	4.26	44.48	9		FM-D5	
1109	27.51	0.16	27.35	1		FM-D5	
1304	0.95	0.86	0.10	90		FM-D5	
1305	5.69	5.12	0.57	90		FM-D5	
1110	17.63	0.70	16.93	4		FM-D6	
1501	1.23	0.49	0.74	40		FM-D2	Dundas Expansion Catchments
1502	2.24	0.69	1.55	31		FM-D3	Dundas Expansion Catchments
1503	1.82	0.69	1.13	38		FM-D4	Dundas Expansion Catchments
1504	1.33	0.68	0.65	51		FM-D4A	Dundas Expansion Catchments
1505	0.56	0.22	0.34	39		FM-D5	Dundas Expansion Catchments
1506	1.17	0.49	0.68	42		FM-D6	Dundas Expansion Catchments

Interm - Phase 1A

Catchment #	Area (ha)			Imp %	Direction to		Note
	Total	Imper.	Per.		Culvert at HWY 407	Culverts at Dundas Street	
1001	118.47	0.94	117.53	1	FM-1	FM-D4	
1002	27.31	0.26	27.05	1	FM-2	FM-D4	
1004	6.76	0.26	6.5	4	FM-4	FM-D4	
1005	35.6	0.19	35.41	1	FM-5	FM-D5	
1006	33.58	0.13	33.45	0	FM-6	FM-D5	
1008	5.93	0.01	5.92	0	FM-8	FM-D5	
1102	30.06	1.20	28.86	4		FM-D2	
1105	37.44	1.87	35.57	5		FM-D4	
1106	15.19	0.39	14.8	3		FM-D4A	
1107	13.2	1.06	12.14	8		FM-D5	
1510	7.95	0.64	7.31	8		FM-D5	
1108	48.74	4.26	44.48	9		FM-D5	
1109	27.51	0.16	27.35	1		FM-D5	
1110	17.63	0.7	16.93	4		FM-D6	
1201	15.43	0.93	14.50	6		FM-D4	
1202	36.29	2.18	34.11	6		FM-D4	
1203	6.84	0.41	6.43	6		FM-D4	
1210	2.13	0.13	2.00	6		FM-D4	
1211	7.17	0.36	6.81	5		FM-D4	
1301	1.73	1.56	0.17	90		FM-D4	
1302	2.38	2.14	0.24	90		FM-D4	
1303	3.64	3.28	0.36	90		FM-D4	
1304	0.95	0.86	0.10	90		FM-D5	
1305	5.69	5.12	0.57	90		FM-D5	
3000	7.82	0.39	7.43	5		FM-D4	
3051	1.37	0.07	1.30	5		FM-D4	
3090	15.58	14.02	1.56	90		FM-D4	Proposed SWM Pond 2
1003A	91.72	1.11	90.61	1	FM-3	FM-D4	
1003B	27.37	0.6	26.77	2	FM-3	FM-D4	
1007A	52.76	0.07	52.69	0	FM-7	FM-D5	
1007B	18.98	0.07	18.91	0	FM-7	FM-D5	
1007C	71.39	0.13	71.26	0	FM-7	FM-D5	

1007D	27.66	0.13	27.53	0	FM-7	FM-D5	
1501	1.23	1.05	0.18	85		FM-D2	Dundas Expansion Catchments - On-site Control
1502	2.24	1.84	0.40	82		FM-D3	Dundas Expansion Catchments - Controlled by Proposed Pond 2
1503	1.82	1.46	0.36	80		FM-D4	Dundas Expansion Catchments - On-site Control
1504	1.33	1.18	0.15	89		FM-D4A	Dundas Expansion Catchments - On-site Control
1505	0.56	0.45	0.11	80		FM-D5	Dundas Expansion Catchments - On-site Control
1506	1.17	0.90	0.27	77		FM-D6	Dundas Expansion Catchments - On-site Control

Interm - Phase 1B

Catchment #	Area (ha)			Imp %	Direction to		Note
	Total	Imper.	Per.		Culvert at HWY 407	Culverts at Dundas Street	
1001	118.47	0.94	117.53	1	FM-1	FM-D4	
1002	27.31	0.26	27.05	1	FM-2	FM-D4	
1004	6.76	0.26	6.50	4	FM-4	FM-D4	
1005	35.6	0.19	35.41	1	FM-5	FM-D5	
1006	33.58	0.13	33.45	0	FM-6	FM-D5	
1008	5.93	0.01	5.92	0	FM-8	FM-D5	
1106	15.35	0.46	14.89	3		FM-D4A	
1107	13.2	1.06	12.14	8		FM-D5	
1510	7.95	0.64	7.31	8		FM-D5	
1108	48.74	4.26	44.48	9		FM-D5	
1109	27.51	0.16	27.35	1		FM-D5	
1110	17.63	0.7	16.93	4		FM-D6	
1301	1.73	1.56	0.17	90		FM-D4	
1302	2.38	2.14	0.24	90		FM-D4	
1303	3.64	3.28	0.36	90		FM-D4	
1304	0.95	0.86	0.10	90		FM-D5	
1305	5.69	5.12	0.57	90		FM-D5	
2309	2.56	2.56	0.00	100		FM-D4	Rooftop Storage on Proposed Buildings G6-1, G6-2 & G6-3
2399	**7.68**	**0.38**	**7.30**	**5**		**FM-D4**	**Revised Existing Catchment Draining to 14W-12A - Mar 17 2016**
3000	7.82	0.39	7.43	5		FM-D4	
3050	36.29	1.81	34.48	5		FM-D4	
3051	1.37	0.07	1.30	5		FM-D4	
3080	3.39	0.17	3.22	5		FM-D4	
3090	15.57	14.01	1.56	90		FM-D4	Proposed SWM Pond 2
3100	**10.82**	**0.54**	**10.28**	**5**		**FM-D4**	**Proposed SWM Pond 3 - Revised with portion of catchment to 14W-12A**
3200	12.99	11.69	1.30	90		FM-D4	Proposed SWM Pond 3
3201	0.76	0.04	0.72	5		FM-D4	
3300	30.06	1.20	28.86	4		FM-D2	
4001	8.85	0.18	8.67	2		FM-D4	
4002	13.41	0.27	13.14	2		FM-D4	
4003	6.11	0.12	5.99	2		FM-D4	
4010	0.56	0.01	0.55	2		FM-D4	
4011	0.57	0.01	0.56	2		FM-D4	OCT 12 2016 REV
4012	0.26	0.01	0.25	2		FM-D4	OCT 12 2016 REV
4013	0.65	0.01	0.64	2		FM-D4	
4016	0.10	0.002	0.10	2		FM-D4	OCT 12 2016 REV
1003A	91.72	1.11	90.61	1	FM-3	FM-D4	
1003B	27.37	0.60	26.77	2	FM-3	FM-D4	
1007A	52.76	0.07	52.69	0	FM-7	FM-D5	
1007B	18.98	0.07	18.91	0	FM-7	FM-D5	
1007C	71.39	0.13	71.26	0	FM-7	FM-D5	
1007D	27.66	0.13	27.53	0	FM-7	FM-D5	
1501	1.23	1.05	0.18	85	0	FM-D2	Dundas Expansion Catchments - On-site Control
1502	2.24	1.84	0.40	82	0	FM-D3	Dundas Expansion Catchments - Controlled by Proposed Pond 2
1503	1.82	1.46	0.36	80	0	FM-D4	Dundas Expansion Catchments - On-site Control
1504	1.33	1.18	0.15	89	0	FM-D4A	Dundas Expansion Catchments - On-site Control
1505	0.56	0.45	0.11	80	0	FM-D5	Dundas Expansion Catchments - On-site Control
1506	1.17	0.90	0.27	77	0	FM-D6	Dundas Expansion Catchments - On-site Control

Interm - Phase 2

Catchment #	Area (ha)			Imp %	Direction to		Controlled by Proposed SWM Facilities
	Total	Imper.	Per.		Culvert at HWY 407	Culverts at Dundas Street	
1001	118.47	0.94	117.53	1	FM-1	FM-D4	
1002	27.31	0.26	27.05	1	FM-2	FM-D4	
1004	6.76	0.26	6.50	4	FM-4	FM-D4	
1005	35.6	0.19	35.41	1	FM-5	FM-D5	
1006	33.58	0.13	33.45	0	FM-6	FM-D5	
1008	5.93	0.01	5.92	0	FM-8	FM-D5	
1106	12.97	0.39	12.58	3		FM-D4A	
1107	9.17	0.73	8.44	8		FM-D5	
1510	7.57	0.61	6.96	8		FM-D5	
1108	48.74	4.26	44.48	9		FM-D5	
1109	27.51	0.16	27.35	1		FM-D5	
1110	17.63	0.7	16.93	4		FM-D6	
1301	1.73	1.56	0.17	90		FM-D4	
1302	2.38	2.14	0.24	90		FM-D4	
1304	0.95	0.86	0.10	90		FM-D5	
1305	5.69	5.12	0.57	90		FM-D5	

1306	2.19	1.97	0.22	90		FM-D4	
1307	1.45	1.31	0.15	90		FM-D4	
2309	**5.12**	**5.12**	**0.00**	**100**		**FM-D4**	**Revised Rooftop Storage on Proposed Buildings - Mar 17 2016**
3000	7.82	0.39	7.43	5		FM-D4	
3050	36.19	1.81	34.38	5		FM-D4	
3051	1.37	0.07	1.30	5		FM-D4	
3080	3.39	0.17	3.22	5		FM-D4	
3090	15.57	14.01	1.56	90		FM-D4	Proposed SWM Pond 2
3100	**20.92**	**18.83**	**2.09**	**90**		**FM-D4**	**Proposed SWM Pond 3 - with Revised Rooftop Control - Mar 17 2016**
3200	16.07	14.46	1.61	90		FM-D4	Proposed SWM Pond 3
3300	30.06	1.20	28.86	4		FM-D2	
4001	2.43	0.05	2.38	2		FM-D4	
4002	10.02	0.20	9.82	2		FM-D4	
4003	6.11	0.12	5.99	2		FM-D4	
4010	0.56	0.01	0.55	2		FM-D4	
4011	0.57	0.01	0.56	2		FM-D4	OCT 12 2016 REV
4012	0.26	0.01	0.25	2		FM-D4	OCT 12 2016 REV
4013	0.65	0.01	0.64	2		FM-D4	
4014	2.89	0.06	2.83	2		FM-D4	
4015	3.10	0.06	3.04	2		FM-D4	
4016	0.10	0.002	0.10	2		FM-D4	OCT 12 2016 REV
4021	3.39	0.07	3.32	2		FM-D4	
1003A	91.72	1.11	90.61	1	FM-3	FM-D4	
1003B	27.37	0.60	26.77	2	FM-3	FM-D4	
1007A	52.76	0.07	52.69	0	FM-7	FM-D5	
1007B	18.98	0.07	18.91	0	FM-7	FM-D5	
1007C	71.39	0.13	71.26	0	FM-7	FM-D5	
1007D	27.66	0.13	27.53	0	FM-7	FM-D5	
1501	1.23	1.05	0.18	85	0	FM-D2	Dundas Expansion Catchments - On-site Control
1502	2.24	1.84	0.40	82	0	FM-D3	Dundas Expansion Catchments - Controlled by Proposed Pond 2
1503	1.82	1.46	0.36	80	0	FM-D4	Dundas Expansion Catchments - On-site Control
1504	1.33	1.18	0.15	89	0	FM-D4A	Dundas Expansion Catchments - On-site Control
1505	0.56	0.45	0.11	80	0	FM-D5	Dundas Expansion Catchments - On-site Control
1506	1.17	0.90	0.27	77	0	FM-D6	Dundas Expansion Catchments - On-site Control

ULTIMATE

Catchment #	Area (ha)			Imp %	Direction to		Controlled by Proposed SWM Facilities
	Total	Imper.	Per.		Culvert at HWY 407	Culverts at Dundas Street	
1001	118.47	0.94	117.53	1	FM-1	FM-D4	
1002	27.31	0.26	27.05	1	FM-2	FM-D4	
1004	6.76	0.26	6.50	4	FM-4	FM-D4	
1005	35.6	0.19	35.41	1	FM-5	FM-D5	
1006	33.58	0.13	33.45	0	FM-6	FM-D5	
1008	5.93	0.01	5.92	0	FM-8	FM-D5	
1106	12.97	0.39	12.58	3		FM-D4A	
1107	9.17	0.73	8.44	8		FM-D5	
1510	7.57	0.61	6.96	8		FM-D5	
1108	48.74	4.26	44.48	9		FM-D5	
1109	27.51	0.16	27.35	1		FM-D5	
1110	17.63	0.7	16.93	4		FM-D6	
1301	1.73	1.56	0.17	90		FM-D4	
1302	2.38	2.14	0.24	90		FM-D4	
1304	0.95	0.86	0.10	90		FM-D5	
1305	5.69	5.12	0.57	90		FM-D5	
1306	2.19	1.97	0.22	90		FM-D4	
1307	1.45	1.31	0.15	90		FM-D4	
2309	**5.12**	**5.12**	**0.00**	**100**		**FM-D4**	**Revised Rooftop Storage on Proposed Buildings - Mar 17 2016**
3000	23.55	20.72	2.83	88		FM-D2	Proposed Future SWM Pond 1
3050	21.05	4.21	16.84	20		FM-D4	Proposed Future SWM Pond as per Tremaine & Dundas 2nd Plan
3051	1.37	0.07	1.30	5		FM-D4	
3060	14.40	12.67	1.73	88		FM-D4	Proposed Future SWM Pond 5
3080	2.89	2.60	0.29	90		FM-D4	Proposed SWM Pond 3
3090	18.51	16.66	1.85	90		FM-D4	Proposed SWM Pond 2
3100	**36.96**	**33.26**	**3.70**	**90**		**FM-D4**	**Proposed SWM Pond 3 - with Revised Rooftop Control - Mar 17 2016**
3300	15.34	0.61	14.73	4		FM-D2	
4001	2.43	0.05	2.38	2		FM-D4	
4002	8.46	0.17	8.29	2		FM-D4	
4003	6.11	0.12	5.99	2		FM-D4	
4010	0.56	0.01	0.55	2		FM-D4	
4011	0.57	0.01	0.56	2		FM-D4	OCT 12 2016 REV
4012	0.26	0.01	0.25	2		FM-D4	OCT 12 2016 REV
4013	0.65	0.01	0.64	2		FM-D4	
4014	2.89	0.06	2.83	2		FM-D4	
4015	2.96	0.06	2.90	2		FM-D4	
4016	0.10	0.002	0.10	2		FM-D4	OCT 12 2016 REV
4021	3.39	0.07	3.32	2		FM-D4	
1003A	91.72	1.11	90.61	1	FM-3	FM-D4	
1003B	27.37	0.60	26.77	2	FM-3	FM-D4	
1007A	52.76	0.07	52.69	0	FM-7	FM-D5	
1007B	18.98	0.07	18.91	0	FM-7	FM-D5	
1007C	71.39	0.13	71.26	0	FM-7	FM-D5	

1007D	27.66	0.13	27.53	0	FM-7	FM-D5	
1501	1.23	1.05	0.18	85	0	FM-D2	Dundas Expansion Catchments - On-site Control
1502	2.24	1.84	0.40	82	0	FM-D3	Dundas Expansion Catchments - Controlled by Proposed Pond 2
1503	1.82	1.46	0.36	80	0	FM-D4	Dundas Expansion Catchments - On-site Control
1504	1.33	1.18	0.15	89	0	FM-D4A	Dundas Expansion Catchments - On-site Control
1505	0.56	0.45	0.11	80	0	FM-D5	Dundas Expansion Catchments - On-site Control
1506	1.17	0.90	0.27	77	0	FM-D6	Dundas Expansion Catchments - On-site Control

To EIR Nodes		Existing Drainage Area (ha)		Difference (%)	EIR Subcatchment
		NOCSS	MMM *		
Culverts at HWY 407	FM-1	149.4	118.5	-21%	FM 1001
	FM-2	29.4	27.3	-7%	FM 1002
	FM-3	125.7	119.1	-5%	FM 1003A, FM 1003B
	FM-4	7.3	6.8	-7%	FM 1004
	FM-5	30.3	35.6	17%	FM 1005
	FM-6	33.5	33.6	0%	FM 1006
	FM-7	162.8	170.8	5%	FM 1007A, FM1007B, FM1007C, FM1007D
	FM-8	5.3	5.9	12%	FM 1008
Culverts at Dundas Street	FM-D2	46.6	31.4	-33%	FM1102
	FM-D3	11.7	14.4	23%	FM 1103
	FM-D4	424.0	397.2	-6%	FM1001, FM1002, FM1104, FM1003A, FM1003B, FM1004, FM 1105
	FM-D4a	15.2	16.5	9%	FM1106
	FM-D5	340.0	350.5	3%	FM1005, FM1006, FM1007A, FM1007B, FM1007C, FM1007D, FM1008, FM1108, FM1107, FM1109
Total		1381.2	1327.6	-4%	

* MMM updated drainage areas based on 2002 Town of Oakville topographic mapping.

To EIR Nodes		Existing Drainage Area (ha) *	Phase 1A		Phase 1B		Phase 2		Ultimate Condition	
			Drainage Area (ha)	Difference (ha) from Existing	Drainage Area (ha)	Difference (ha) from Existing	Drainage Area (ha)	Difference (ha) from Existing	Drainage Area (ha)	Difference (ha) from Existing
Culverts at Dundas Street	FM-D2	31.4	31.3	-0.1	31.3	-0.1	31.3	-0.1	40.1	8.7
	FM-D3	14.4	0.0	-14.4	0.0	-14.4	0.0	-14.4	0.0	-14.4
	FM-D4	397.2	413.5	16.3	413.2	16.0	420.0	22.7	410.8	13.5
	FM-D4a	16.5	16.5	0.0	16.7	0.2	14.3	-2.2	14.3	-2.2
	FM-D5	350.5	350.5	0.0	350.5	0.0	346.1	-4.4	346.1	-4.4
Total		810.0	811.8	1.8	811.7	1.7	811.7	1.6	811.3	1.2

* MMM updated drainage areas based on 2002 Town of Oakville topographic mapping.

Peak Flows Rates with Original NOCSS UFR and Original NOCSS Drainage Area

EIR Node		Original NOCSS Drainage Area (ha)	Flow Type[1]	Return Period (Year)						
				2	5	10	25	50	100	Regional
Culverts at HWY 407	FM-1	149.4	UFR (m3/s/ha)	0.006	0.010	0.012	0.015	0.017	0.020	0.049
			PFR (m^3/s)	0.94	1.48	1.79	2.27	2.59	2.93	7.32
	FM-2	29.4	UFR (m3/s/ha)	0.008	0.012	0.015	0.019	0.021	0.024	0.056
			PFR (m^3/s)	0.23	0.36	0.43	0.55	0.63	0.71	1.65
	FM-3	125.7	UFR (m3/s/ha)	0.006	0.009	0.011	0.014	0.016	0.018	0.047
			PFR (m^3/s)	0.71	1.14	1.40	1.79	2.05	2.32	5.95
	FM-4	7.3	UFR (m3/s/ha)	0.001	0.004	0.006	0.008	0.010	0.012	0.041
			PFR (m^3/s)	0.01	0.03	0.04	0.06	0.08	0.09	0.30
	FM-5	30.3	UFR (m3/s/ha)	0.004	0.008	0.011	0.014	0.017	0.020	0.052
			PFR (m^3/s)	0.13	0.25	0.33	0.44	0.51	0.59	1.57
	FM-6	33.5	UFR (m3/s/ha)	0.005	0.009	0.011	0.015	0.018	0.021	0.055
			PFR (m^3/s)	0.15	0.29	0.38	0.51	0.60	0.69	1.83
	FM-7	162.8	UFR (m3/s/ha)	0.006	0.010	0.013	0.016	0.019	0.021	0.053
			PFR (m^3/s)	0.99	1.64	2.05	2.65	3.05	3.48	8.68
	FM-8	5.3	UFR (m3/s/ha)	0.001	0.008	0.013	0.019	0.024	0.029	0.073
			PFR (m^3/s)	0.01	0.04	0.07	0.10	0.13	0.15	0.39
Culverts at Dundas Street	FM-D2	46.6	UFR (m3/s/ha)	0.007	0.011	0.013	0.017	0.020	0.022	0.054
			PFR (m^3/s)	0.31	0.51	0.62	0.80	0.92	1.04	2.50
	FM-D3	11.7	UFR (m3/s/ha)	0.010	0.016	0.019	0.024	0.028	0.031	0.065
			PFR (m^3/s)	0.12	0.19	0.23	0.28	0.32	0.36	0.76
	FM-D4	424.0	UFR (m3/s/ha)	0.006	0.010	0.012	0.015	0.017	0.020	0.049
			PFR (m^3/s)	2.62	4.17	5.09	6.49	7.42	8.39	20.96
	FM-D4a[2]	15.2	UFR (m3/s/ha)	0.013	0.020	0.024	0.030	0.035	0.039	0.073
			PFR (m^3/s)	0.20	0.31	0.37	0.46	0.53	0.59	1.11
	FM-D5	340.0	UFR (m3/s/ha)	0.006	0.010	0.013	0.017	0.019	0.022	0.055
			PFR (m^3/s)	2.01	3.43	4.35	5.68	6.60	7.56	18.73

1) UFR = Unit Flow Rate, PFR = Peak Flow Rate
2) Since UFR at culvert FM-D4A is not specified in NOCSS, the UFR based on Existing Flow from Original NOCSS Model Catchment FM-1106 is used

Peak Flows Rates with Original NOCSS UFR and MMM Revised Drainage Area

EIR Node		MMM Revised Drainage Area (ha)	Flow Type[1]	Return Period (Year)						
				2	5	10	25	50	100	Regional
Culverts at HWY 407	FM-1	118.5	UFR (m3/s/ha)	0.006	0.010	0.012	0.015	0.017	0.020	0.049
			PFR (m^3/s)	0.75	1.17	1.42	1.80	2.05	2.32	5.80
	FM-2	27.3	UFR (m3/s/ha)	0.008	0.012	0.015	0.019	0.021	0.024	0.056
			PFR (m^3/s)	0.21	0.33	0.40	0.51	0.58	0.66	1.53
	FM-3	119.1	UFR (m3/s/ha)	0.006	0.009	0.011	0.014	0.016	0.018	0.047
			PFR (m^3/s)	0.68	1.08	1.32	1.69	1.94	2.20	5.64
	FM-4	6.8	UFR (m3/s/ha)	0.001	0.004	0.006	0.008	0.010	0.012	0.041
			PFR (m^3/s)	0.01	0.03	0.04	0.06	0.07	0.08	0.28
	FM-5	35.6	UFR (m3/s/ha)	0.004	0.008	0.011	0.014	0.017	0.020	0.052
			PFR (m^3/s)	0.16	0.29	0.38	0.51	0.60	0.70	1.84
	FM-6	33.6	UFR (m3/s/ha)	0.005	0.009	0.011	0.015	0.018	0.021	0.055
			PFR (m^3/s)	0.15	0.29	0.38	0.51	0.60	0.69	1.83
	FM-7	170.8	UFR (m3/s/ha)	0.006	0.010	0.013	0.016	0.019	0.021	0.053
			PFR (m^3/s)	1.04	1.73	2.15	2.78	3.20	3.65	9.11
	FM-8	5.9	UFR (m3/s/ha)	0.001	0.008	0.013	0.019	0.024	0.029	0.073
			PFR (m^3/s)	0.01	0.05	0.08	0.11	0.14	0.17	0.44
Culverts at Dundas Street	FM-D2	31.4	UFR (m3/s/ha)	0.007	0.011	0.013	0.017	0.020	0.022	0.054
			PFR (m^3/s)	0.21	0.34	0.42	0.54	0.62	0.70	1.69
	FM-D3	14.4	UFR (m3/s/ha)	0.010	0.016	0.019	0.024	0.028	0.031	0.065
			PFR (m^3/s)	0.15	0.23	0.28	0.35	0.40	0.44	0.93
	FM-D4	397.2	UFR (m3/s/ha)	0.006	0.010	0.012	0.015	0.017	0.020	0.049
			PFR (m^3/s)	2.46	3.90	4.77	6.08	6.95	7.86	19.63
	FM-D4a[2]	16.5	UFR (m3/s/ha)	0.013	0.020	0.024	0.030	0.035	0.039	0.073
			PFR (m^3/s)	0.21	0.33	0.40	0.50	0.57	0.64	1.20
	FM-D5	350.5	UFR (m3/s/ha)	0.006	0.010	0.013	0.017	0.019	0.022	0.055
			PFR (m^3/s)	2.07	3.54	4.48	5.85	6.80	7.80	19.31

1) UFR = Unit Flow Rate, PFR = Peak Flow Rate
2) Since UFR at culvert FM-D4A is not specified in NOCSS, the UFR based on Existing Flow from Original NOCSS Model Catchment FM-1106 is used

TABLE APP-7.2

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EIR Nodes **FM-D2**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2701**	**2701**	**2701**	**2701**	**2701**	**2701**	**2701**	**2050**	**2050**
Drainage Area (ha)	**31.42**	**31.42**	**31.29**	**31.29**	**31.29**	**31.29**	**31.29**	**31.29**	**40.12**	**40.12**
2-Yr	0.21	0.22	0.24	0.21	0.24	0.21	0.24	0.21	0.91	0.18
5-Yr	0.34	0.36	0.38	0.34	0.38	0.34	0.38	0.34	1.29	0.27
10-Yr	0.42	0.44	0.47	0.43	0.47	0.43	0.47	0.43	1.52	0.36
25-Yr	0.54	0.57	0.59	0.56	0.59	0.56	0.59	0.56	1.83	0.49
50-Yr	0.62	0.65	0.68	0.65	0.68	0.65	0.68	0.65	2.06	0.57
100-Yr	0.70	0.74	0.76	0.74	0.76	0.74	0.76	0.74	2.28	0.65
Regional	1.69	1.73	1.73	1.73	1.73	1.73	1.73	1.73	3.19	1.40
	Area from Model ->	31.42	31.29	31.29	31.29	31.29	31.29	31.29	40.12	40.12

EIR Nodes **FM-D3**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**1103**								
Drainage Area (ha)	**14.36**	**14.36**								
2-Yr	0.14	0.15								
5-Yr	0.23	0.23								
10-Yr	0.29	0.27								
25-Yr	0.34	0.34								
50-Yr	0.39	0.39								
100-Yr	0.45	0.44								
Regional	0.93	0.93								
	Area from Model ->	14.36								

EIR Nodes **FM-D4**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2703**	**2444**	**2444**	**2444**	**2444**	**2444**	**2444**	**2703**	**2703**
Drainage Area (ha)	**397.23**	**397.23**	**413.51**	**413.51**	**413.21**	**413.21**	**419.98**	**419.98**	**413.31**	**410.75**
2-Yr	2.46	2.47	2.84	2.45	2.82	2.37	3.57	2.32	4.03	2.25
5-Yr	3.90	3.87	4.38	3.85	4.33	3.72	5.32	3.62	5.94	3.52
10-Yr	4.77	4.70	5.30	4.67	5.24	4.52	6.40	4.38	7.12	4.37
25-Yr	6.08	5.98	6.69	5.99	6.60	5.79	7.99	5.64	8.85	5.49
50-Yr	6.95	6.82	7.61	6.81	7.50	6.58	9.04	6.43	9.99	6.24
100-Yr	7.86	7.70	8.57	7.68	8.45	7.42	10.14	7.27	11.19	7.04
Regional	19.63	19.34	20.61	19.14	20.46	18.50	22.15	18.16	23.20	17.41
	Area from Model ->	397.23	413.51	413.510	413.21	413.210	419.98	419.98	413.31	410.75

EIR Nodes **FM-D4A (Since UFR at culvert FM-D4A is not specified in NOCSS, the UFR based on Existing Flow from Original NOCSS Model Catchment FM-1106 is used)**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2704**	**2704**	**2704**	**2704**	**2704**	**2704**	**2704**	**2704**	**2704**
Drainage Area (ha)	**16.52**	**16.52**	**16.52**	**16.52**	**16.68**	**16.68**	**14.30**	**14.30**	**14.30**	**14.30**
2-Yr	0.21	0.22	0.24	0.20	0.24	0.20	0.21	0.17	0.21	0.17
5-Yr	0.33	0.34	0.37	0.31	0.37	0.31	0.32	0.26	0.32	0.26
10-Yr	0.40	0.42	0.44	0.37	0.45	0.38	0.39	0.32	0.39	0.32
25-Yr	0.50	0.53	0.55	0.48	0.56	0.48	0.48	0.41	0.48	0.41
50-Yr	0.57	0.60	0.62	0.55	0.63	0.56	0.55	0.48	0.55	0.48
100-Yr	0.64	0.67	0.70	0.63	0.71	0.64	0.61	0.55	0.61	0.55
Regional	1.20	1.23	1.24	1.23	1.25	1.25	1.08	1.07	1.08	1.07
	Area from Model ->	16.52	16.52	16.520	16.68	16.680	14.30	14.30	14.30	14.30

EIR Nodes **FM-D5**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2061**	**2061**	**2061**	**2061**	**2061**	**2061**	**2061**	**2061**	**2061**
Drainage Area (ha)	**350.50**	**350.50**	**350.50**	**350.50**	**350.50**	**350.50**	**346.09**	**346.09**	**346.09**	**346.09**
2-Yr	2.07	2.30	2.30	2.29	2.30	2.29	2.22	2.21	2.22	2.21
5-Yr	3.54	3.86	3.87	3.85	3.87	3.85	3.74	3.73	3.74	3.73
10-Yr	4.48	4.86	4.87	4.85	4.87	4.85	4.71	4.70	4.71	4.70
25-Yr	5.85	6.31	6.32	6.31	6.32	6.31	6.12	6.11	6.12	6.11
50-Yr	6.80	7.30	7.31	7.30	7.31	7.30	7.09	7.08	7.09	7.08
100-Yr	7.80	8.36	8.37	8.36	8.37	8.36	8.11	8.11	8.11	8.11
Regional	19.31	19.71	19.71	19.71	19.71	19.71	19.33	19.33	19.33	19.33
	Area from Model ->	350.50	350.50	350.500	350.50	350.500	346.09	346.09	346.09	346.09

Reference Nodes **1**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2503**	**2503**	**2503**	**3999**	**3999**	**3999**	**3999**	**3999**	**3999**
Drainage Area (ha)	**205.45**	**205.45**	**203.74**	**203.74**	**200.80**	**200.80**	**200.41**	**200.41**	**197.97**	**197.97**
2-Yr	1.23	1.37	1.36	1.36	1.33	1.33	1.33	1.33	1.83	1.24
5-Yr	2.05	2.13	2.11	2.11	2.08	2.08	2.08	2.08	2.77	1.96
10-Yr	2.47	2.57	2.55	2.55	2.51	2.51	2.51	2.51	3.35	2.41
25-Yr	3.08	3.26	3.23	3.23	3.18	3.18	3.17	3.17	4.18	3.05
50-Yr	3.70	3.71	3.68	3.68	3.62	3.62	3.61	3.61	4.75	3.47
100-Yr	4.11	4.18	4.15	4.15	4.09	4.09	4.08	4.08	5.36	3.91
Regional	10.07	10.29	10.21	10.21	10.06	10.06	10.04	10.04	11.06	9.44
	Area from Model ->	205.45	203.74	203.740	200.80	200.800	200.41	200.41	197.97	197.97

Reference Nodes **1A**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**3002**	**3002**	**3002**	**2999**	**2999**	**2999**	**2999**	**2999**	**2999**
Drainage Area (ha)	**203.50**	**203.50**	**201.61**	**201.61**	**199.59**	**199.59**	**199.20**	**199.20**	**196.76**	**196.76**
2-Yr	1.22	1.35	1.34	1.34	1.32	1.32	1.32	1.32	1.82	1.24
5-Yr	2.04	2.11	2.09	2.09	2.07	2.07	2.06	2.06	2.76	1.95
10-Yr	2.44	2.55	2.52	2.52	2.50	2.50	2.49	2.49	3.34	2.39
25-Yr	3.05	3.23	3.20	3.20	3.16	3.16	3.15	3.15	4.17	3.04
50-Yr	3.66	3.67	3.64	3.64	3.60	3.60	3.59	3.59	4.73	3.45
100-Yr	4.07	4.14	4.11	4.11	4.06	4.06	4.05	4.05	5.34	3.88
Regional	9.97	10.20	10.10	10.10	10.00	10.00	9.98	9.98	11.00	9.38
	Area from Model ->	203.50	201.61	201.610	199.59	199.590	199.20	199.20	196.76	196.76

Reference Nodes **1B**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**3001**	**3001**	**3001**	**1999**	**1999**	**2520**	**2520**	**2520**	**2520**
Drainage Area (ha)	**163.59**	**163.59**	**163.59**	**163.59**	**161.57**	**161.57**	**161.28**	**161.28**	**159.58**	**159.58**
2-Yr	0.98	1.08	1.08	1.08	1.06	1.06	1.06	1.06	1.05	1.05
5-Yr	1.64	1.69	1.69	1.69	1.67	1.67	1.67	1.67	1.65	1.65
10-Yr	1.96	2.04	2.04	2.04	2.02	2.02	2.01	2.01	1.99	1.99
25-Yr	2.45	2.59	2.59	2.59	2.56	2.56	2.55	2.55	2.53	2.53
50-Yr	2.94	2.95	2.95	2.95	2.92	2.92	2.91	2.91	2.88	2.88
100-Yr	3.27	3.34	3.34	3.34	3.29	3.29	3.29	3.29	3.25	3.25
Regional	8.02	8.22	8.22	8.22	8.11	8.11	8.10	8.10	8.02	8.02
	Area from Model ->	163.59	163.59	163.590	161.57	161.570	161.28	161.28	159.58	159.58

Reference Nodes **2**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2505**	**2505**	**2505**	**2516**	**2516**	**2516**	**2516**	**2516**	**2516**
Drainage Area (ha)	**174.10**	**174.10**	**174.10**	**174.10**	**10.81**	**10.81**	**5.69**	**5.69**	**5.69**	**5.69**
2-Yr	1.04	1.00	1.00	1.00	0.30	0.21	0.18	0.04	0.18	0.04
5-Yr	1.74	1.59	1.59	1.59	0.45	0.33	0.25	0.05	0.25	0.05
10-Yr	2.09	1.94	1.94	1.94	0.54	0.40	0.29	0.06	0.29	0.06
25-Yr	2.61	2.48	2.48	2.48	0.66	0.50	0.35	0.07	0.35	0.07
50-Yr	3.13	2.83	2.83	2.83	0.75	0.57	0.39	0.08	0.39	0.08
100-Yr	3.48	3.20	3.20	3.20	0.84	0.64	0.43	0.09	0.43	0.09
Regional	8.53	8.23	8.23	8.23	1.03	0.86	0.52	0.22	0.52	0.22
	Area from Model ->	174.10	174.10	174.100	10.81	10.810	5.69	5.69	5.69	5.69

Reference Nodes **2C**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)						
Gawser ID	**Original UFR with MMM Revised Catchment**	**2033**	**2033**	**2033**						
Drainage Area (ha)	**166.93**	**166.93**	**166.93**	**166.93**						
2-Yr	1.04	0.95	0.95	0.95						
5-Yr	1.74	1.52	1.52	1.52						
10-Yr	2.09	1.85	1.85	1.85						
25-Yr	2.61	2.37	2.37	2.37						
50-Yr	3.13	2.71	2.71	2.71						
100-Yr	3.48	3.06	3.06	3.06						
Regional	8.53	7.88	7.88	7.88						
	Area from Model ->	166.93	166.93	166.930						

Reference Nodes **2B**

Return Period					Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID					**2505.00**	**2505**	**2505**	**2505**	**2505**	**2505**
Drainage Area (ha)					**141.99**	**141.99**	**141.85**	**141.85**	**138.46**	**138.46**
2-Yr					0.79	0.79	0.79	0.79	0.77	0.77
5-Yr					1.27	1.27	1.27	1.27	1.23	1.23
10-Yr					1.55	1.55	1.55	1.55	1.51	1.51
25-Yr					1.99	1.99	1.98	1.98	1.93	1.93
50-Yr					2.27	2.27	2.27	2.27	2.21	2.21
100-Yr					2.58	2.58	2.58	2.58	2.51	2.51
Regional					6.68	6.68	6.67	6.67	6.50	6.50
	Area from Model ->				141.99	141.990	141.85	141.85	138.46	138.46

Reference Nodes **2A**

Return Period					Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID					**2515**	**2515**	**2515**	**2515**	**2515**	**2515**
Drainage Area (ha)					**152.90**	**152.90**	**147.64**	**147.64**	**144.25**	**144.25**
2-Yr					0.93	0.90	0.89	0.83	0.87	0.80
5-Yr					1.48	1.43	1.40	1.31	1.36	1.28
10-Yr					1.81	1.75	1.71	1.61	1.67	1.56
25-Yr					2.31	2.24	2.18	2.05	2.12	2.00
50-Yr					2.64	2.56	2.48	2.34	2.43	2.29
100-Yr					2.99	2.90	2.81	2.66	2.74	2.59
Regional					7.38	7.29	7.03	6.89	6.86	6.72
	Area from Model ->				152.90	152.900	147.64	147.64	144.25	144.25

Reference Nodes **3A**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**1999**	**2034**	**2034**	**1087**	**1087**	**1087**	**1087**	**1087**	**1087**
Drainage Area (ha)	**379.55**	**379.55**	**377.84**	**377.84**	**353.70**	**353.70**	**348.05**	**348.05**	**342.22**	**342.22**
2-Yr	2.28	2.35	2.34	2.34	2.26	2.22	2.20	2.13	2.57	2.04
5-Yr	3.80	3.69	3.67	3.67	3.54	3.48	3.45	3.35	3.95	3.23
10-Yr	4.55	4.48	4.46	4.46	4.31	4.24	4.19	4.07	4.79	3.97
25-Yr	5.69	5.69	5.66	5.66	5.47	5.39	5.32	5.17	6.04	5.04
50-Yr	6.83	6.49	6.46	6.46	6.24	6.15	6.06	5.90	6.87	5.74
100-Yr	7.59	7.32	7.29	7.29	7.04	6.94	6.84	6.66	7.73	6.48
Regional	18.60	18.45	18.36	18.36	17.39	17.29	17.01	16.83	17.63	16.10
	Area from Model ->	379.55	377.84	377.840	353.70	353.700	348.05	348.05	342.22	342.22

Reference Nodes **3B**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2034**	**90**	**90**	**2040**	**2040**	**2040**	**2040**	**2040**	**2040**
Drainage Area (ha)	**395.41**	**395.41**	**384.68**	**384.68**	**384.38**	**384.38**	**391.15**	**391.15**	**390.74**	**388.18**
2-Yr	2.37	2.45	2.38	2.38	2.34	2.30	3.04	2.25	3.46	2.17
5-Yr	3.95	3.85	3.74	3.74	3.67	3.61	4.60	3.51	5.17	3.40
10-Yr	4.74	4.67	4.54	4.54	4.46	4.39	5.54	4.25	6.21	4.17
25-Yr	5.93	5.94	5.77	5.77	5.65	5.57	6.95	5.42	7.76	5.27
50-Yr	7.12	6.77	6.58	6.58	6.44	6.35	7.87	6.20	8.78	6.00
100-Yr	7.91	7.64	7.43	7.43	7.27	7.16	8.85	7.02	9.85	6.78
Regional	19.38	19.22	18.70	18.70	18.51	18.06	20.11	17.72	21.19	16.97
	Area from Model ->	395.41	384.68	384.680	384.38	384.380	391.15	391.15	390.74	388.18

Reference Nodes **3**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2034**	**1098**	**1098**	**1098**	**1098**	**1098**	**1098**	**1098**	**1098**
Drainage Area (ha)	**395.41**	**395.41**	**411.69**	**411.69**	**411.39**	**411.39**	**418.16**	**418.16**	**411.49**	**408.93**
2-Yr	2.37	2.45	2.80	2.44	2.78	2.36	3.52	2.31	3.98	2.23
5-Yr	3.95	3.85	4.33	3.81	4.27	3.68	5.26	3.58	5.88	3.48
10-Yr	4.74	4.67	5.24	4.62	5.18	4.47	6.33	4.33	7.04	4.31
25-Yr	5.93	5.94	6.62	5.92	6.53	5.72	7.91	5.57	8.77	5.43
50-Yr	7.12	6.77	7.52	6.73	7.41	6.50	8.94	6.35	9.90	6.16
100-Yr	7.91	7.64	8.47	7.59	8.35	7.32	10.03	7.18	11.08	6.95
Regional	19.38	19.22	20.47	18.99	20.32	18.35	22.00	18.01	23.03	17.26
	Area from Model ->	395.41	411.69	411.690	411.39	411.390	418.16	418.16	411.49	408.93

Reference Nodes **4**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2444**	**2444**	**2444**	**2444**	**2444**	**2444**	**2444**	**2703**	**2703**
Drainage Area (ha)	**413.83**	**413.83**	**413.51**	**413.51**	**413.21**	**413.21**	**419.98**	**419.98**	**413.31**	**410.75**
2-Yr	2.48	2.61	2.84	2.45	2.82	2.37	3.57	2.32	4.03	2.25
5-Yr	4.14	4.10	4.38	3.85	4.33	3.72	5.32	3.62	5.94	3.52
10-Yr	4.97	4.99	5.30	4.67	5.24	4.52	6.40	4.38	7.12	4.37
25-Yr	6.21	6.34	6.69	5.99	6.60	5.79	7.99	5.64	8.85	5.49
50-Yr	7.45	7.22	7.61	6.81	7.50	6.58	9.04	6.43	9.99	6.24
100-Yr	8.28	8.16	8.57	7.68	8.45	7.42	10.14	7.27	11.19	7.04
Regional	20.28	20.34	20.61	19.14	20.46	18.50	22.15	18.16	23.20	17.41
	Area from Model ->	413.83	413.51	413.510	413.21	413.210	419.98	419.98	413.31	410.75

Reference Nodes **5 (Since UFR at NODE 5 is not specified in NOCSS, the UFR based on Existing Flow from Original NOCSS Model Catchment FM-1107 is used)**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2106**	**2106**	**2106**	**2106**	**2106**	**2106**	**2106**	**2106**	**2106**
Drainage Area (ha)	**57.70**	**57.70**	**57.70**	**57.70**	**57.70**	**57.70**	**53.29**	**53.29**	**53.29**	**53.29**
2-Yr	0.46	0.59	0.59	0.59	0.59	0.59	0.50	0.50	0.50	0.50
5-Yr	0.76	1.01	1.01	1.01	1.01	1.01	0.86	0.86	0.86	0.86
10-Yr	0.95	1.24	1.24	1.24	1.24	1.24	1.06	1.06	1.06	1.06
25-Yr	1.22	1.58	1.58	1.58	1.58	1.58	1.35	1.35	1.35	1.35
50-Yr	1.42	1.82	1.82	1.82	1.82	1.82	1.56	1.56	1.56	1.56
100-Yr	1.61	2.06	2.06	2.06	2.06	2.06	1.77	1.77	1.77	1.77
Regional	3.54	3.79	3.79	3.79	3.79	3.79	3.38	3.38	3.38	3.38
	Area from Model ->	57.70	57.70	57.70	57.70	57.70	53.29	53.29	53.29	53.29

Reference Nodes **6**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID							**2026**	**2026**	**2026**	**2026**
Drainage Area (ha)							**138.70**	**138.70**	**135.31**	**135.31**
2-Yr							0.77	0.77	0.75	0.75
5-Yr							1.23	1.23	1.20	1.20
10-Yr							1.51	1.51	1.47	1.47
25-Yr							1.94	1.94	1.89	1.89
50-Yr							2.22	2.22	2.16	2.16
100-Yr							2.51	2.51	2.45	2.45
Regional							6.52	6.52	6.35	6.35
	Area from Model ->						138.70	138.70	135.31	135.31

Reference Nodes **7**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID							**1999**	**1999**	**1999**	**1999**
Drainage Area (ha)							**158.18**	**158.18**	**156.62**	**156.62**
2-Yr							1.04	1.04	1.03	1.03
5-Yr							1.63	1.63	1.62	1.62
10-Yr							1.98	1.98	1.96	1.96
25-Yr							2.51	2.51	2.48	2.48
50-Yr							2.86	2.86	2.83	2.83
100-Yr							3.23	3.23	3.19	3.19
Regional							7.95	7.95	7.87	7.87
	Area from Model ->						158.18	158.18	156.62	156.62

Reference Nodes **8**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID							**2651**	**2651**	**2651**	**2651**
Drainage Area (ha)							**11.60**	**11.60**	**11.60**	**11.60**
2-Yr							0.04	0.04	0.04	0.04
5-Yr							0.08	0.08	0.08	0.08
10-Yr							0.10	0.10	0.10	0.10
25-Yr							0.14	0.14	0.14	0.14
50-Yr							0.16	0.16	0.16	0.16
100-Yr							0.18	0.18	0.18	0.18
Regional							0.52	0.52	0.52	0.52
	Area from Model ->						11.60	11.60	11.60	11.60

Reference Nodes **9 (Since UFR at NODE 9 is not specified in NOCSS, the UFR based on Existing Flow from Original NOCSS Model Catchment FM-1107 is used)**

Return Period	Existing Peak Flows (cms)	Existing Peak Flow (cms)	Interim P1A - Uncontrolled Peak Flow (cms)	Interim P1A - Controlled Peak Flow (cms)	Interim P1B - Uncontrolled Peak Flow (cms)	Interim P1B - Controlled Peak Flow (cms)	Interim P2 - Uncontrolled Peak Flow (cms)	Interim P2 - Controlled Peak Flow (cms)	Ultimate Uncontrolled Flow (cms)	Ultimate Controlled Flow (cms)
Gawser ID	**Original UFR with MMM Revised Catchment**	**2710**	**2710**	**2710**	**2710**	**2710**	**2710**	**2710**	**2710**	**2710**
Drainage Area (ha)	**49.75**	**49.75**	**49.75**	**49.75**	**49.75**	**49.75**	**45.72**	**45.72**	**45.72**	**45.72**
2-Yr	0.40	0.42	0.42	0.42	0.42	0.42	0.34	0.34	0.34	0.34
5-Yr	0.66	0.73	0.73	0.73	0.73	0.73	0.60	0.60	0.60	0.60
10-Yr	0.82	0.91	0.91	0.91	0.91	0.91	0.75	0.75	0.75	0.75
25-Yr	1.06	1.17	1.17	1.17	1.17	1.17	0.97	0.97	0.97	0.97
50-Yr	1.22	1.35	1.35	1.35	1.35	1.35	1.12	1.12	1.12	1.12
100-Yr	1.39	1.53	1.53	1.53	1.53	1.53	1.27	1.27	1.27	1.27
Regional	3.05	3.06	3.06	3.06	3.06	3.06	2.69	2.69	2.69	2.69
	Area from Model ->	49.75	49.75	49.75	49.75	49.75	45.72	45.72	45.72	45.72

Comparison of Flows at HWY 407 Culverts

Flows at HWY 407 Culverts (Upstream Inlet) - NOCSS EXI Model

EIR Nodes	FM-1	FM-2	FM-3	FM-4	FM-5	FM-6	FM-7	FM-8
Gawser ID	**1001**	**1002**	**2019**	**1004**	**1005**	**1006**	**2048**	**1008**
Drainage Area (ha)	**149.44**	**29.38**	**125.70**	**7.28**	**30.30**	**33.52**	**162.80**	**5.31**
2-Yr	0.94	0.23	0.71	0.01	0.13	0.15	0.99	0.01
5-Yr	1.48	0.36	1.14	0.03	0.25	0.29	1.64	0.04
10-Yr	1.79	0.43	1.40	0.04	0.33	0.38	2.05	0.07
25-Yr	2.27	0.55	1.79	0.06	0.44	0.51	2.65	0.10
50-Yr	2.59	0.63	2.05	0.08	0.51	0.60	3.05	0.13
100-Yr	2.93	0.71	2.32	0.09	0.59	0.69	3.48	0.15
Regional	7.32	1.65	5.95	0.30	1.57	1.83	8.68	0.39
Area from Model ->	149.44	29.38	125.70	7.28	30.30	33.52	162.80	5.31

Flows at HWY 407 Culverts (Upstream Inlet) - MMM EXI Model

EIR Nodes	FM-1	FM-2	FM-3	FM-4	FM-5	FM-6	FM-7	FM-8
Gawser ID	**1001**	**1002**	**2019**	**1004**	**1005**	**1006**	**2048**	**1008**
Drainage Area (ha)	**118.47**	**27.31**	**119.09**	**6.76**	**35.60**	**33.58**	**170.79**	**5.93**
2-Yr	0.75	0.21	0.68	0.01	0.16	0.15	1.03	0.01
5-Yr	1.18	0.33	1.09	0.03	0.29	0.29	1.71	0.05
10-Yr	1.42	0.40	1.33	0.04	0.38	0.38	2.13	0.08
25-Yr	1.80	0.51	1.70	0.06	0.51	0.51	2.76	0.11
50-Yr	2.06	0.58	1.95	0.07	0.60	0.60	3.18	0.14
100-Yr	2.32	0.66	2.20	0.08	0.69	0.69	3.63	0.17
Regional	5.81	1.53	5.63	0.28	1.84	1.84	9.10	0.43
Area from Model ->	118.47	27.31	119.09	6.76	35.60	33.58	170.79	5.93

Flows at HWY 407 Culverts (Upstream Inlet) - NOCSS EXI Model (UFR) with MMM Revised Catchment Areas

EIR Nodes	FM-1	FM-2	FM-3	FM-4	FM-5	FM-6	FM-7	FM-8
Gawser ID	**1001**	**1002**	**2019**	**1004**	**1005**	**1006**	**2048**	**1008**
Drainage Area (ha)	**118.47**	**27.31**	**119.09**	**6.76**	**35.60**	**33.58**	**170.79**	**5.93**
2-Yr	0.75	0.21	0.68	0.01	0.16	0.15	1.04	0.01
5-Yr	1.17	0.33	1.08	0.03	0.29	0.29	1.73	0.05
10-Yr	1.42	0.40	1.32	0.04	0.38	0.38	2.15	0.08
25-Yr	1.80	0.51	1.69	0.06	0.51	0.51	2.78	0.11
50-Yr	2.05	0.58	1.94	0.07	0.60	0.60	3.20	0.14
100-Yr	2.32	0.66	2.20	0.08	0.70	0.69	3.65	0.17
Regional	5.80	1.53	5.64	0.28	1.84	1.83	9.11	0.44

‘

Appendix 7.3 – Erosion Control Analysis Calculations

Fourteen Mile Creek Watershed
Threshold Flow Exceedance Summaries
FINAL APRIL 5, 2017, MMM

PROPOSED SWM REGIONAL CONTROL
WITH DUNDAS EXPANSION AND 407 CORRIDOR

Notes:

for Phase 2 and Ultimate Conditions	5.12	ha	Rooftop to 14W-12A
for Phase 1B	7.68	ha	Existing Undeveloped Land to 14W-12A , and
	2.56	ha	Rooftop to 14W-12A

POND #	Detention Time (HR) - P1A, P1B, P2	Detention Time (HR) - ULT
POND 2	47.4	47.4
POND 3	53.4	41.3
POND 5	N/A	46.9
POND 1	N/A	42.4

FLOW NODE #3

Threshold 0.96 (m^3/s)

SC	GAWSER ID #	Drainage Area (ha)	Mean Flow	Flow Highest	Extremes Lowest	Total Hours	EXCEEDANCE				DIFFERENCE % WITH EXISTING			
			(m^3/s)	(m^3/s)	(m^3/s)	hr	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
EXI	2034	395.41	0.016	4.299	0	262968	719	0.30	99	7.3	N/A	N/A	N/A	N/A
P1A	1098	400.26	0.018	4.326	0	262968	755	0.30	102	7.4	5.01%	0.00%	3.03%	1.37%
P1B	1098	399.96	0.020	4.156	0	262968	731	0.30	97	7.5	1.67%	0.00%	-2.02%	2.74%
P2	1098	406.73	0.023	4.145	0	262968	752	0.30	97	7.8	4.59%	0.00%	-2.02%	6.85%
ULT	1098	406.7	0.025	4.089	0	262968	754	0.30	94	8.0	4.87%	0.00%	-5.05%	9.59%

Appendix 7.4 – Hydrologic Flow Regimes Analysis Calculations

Introduction

The purpose of this memorandum is to provide an updated flow regime analysis for the Lazy Pat study, and address Conservation Halton's (CH) comments on the Hydrologic Model Interim report submitted in May 2016 (Section 6.7) and the Flow Regime Memorandum submitted in December 2016. In the interim report, a hybrid assessment tool was used in order to strive to address a flow analysis for watercourses that were intermittent or ephemeral in nature as standard assessment tools are typically applied to permanent watercourses and thus not entirely applicable. In this memorandum, we have selected what we feel is a more appropriate hybrid approach that better represents the functionality of these watercourses and their pre-, during and post-development flow regimes. The proposed approach for this assessment is presented in Figure 1.

In general, the main comments from CH and the Town of Oakville included a presentation of results in a clear manner, greater ecological input into the assessment and the maintenance of "Excellent Conditions" at all flow nodes with specific focus on Flow Nodes 2, 2B and 9 during all phases. For specific item on the comment list, refer to Table 8.

Our report addresses CH's most recent comments including their desire to maintain "Excellent Conditions" as emphasized in their list of comment, including monthly and seasonal functionality. Specifically, in this revised memorandum, accompanying the Comprehensive Report, we are presenting:

- General pattern analysis:
  - Monthly flow regime during a Wet Year
  - Monthly flow regime during a Dry Year
  - Monthly flow regime during an Average Year
- Specific analysis for highest period for ecological functionality:
  - April and May

The approach selected to address these comments includes the presentation of the following in order to better defining the seasonal flow regimes in relation to the key ecological functions:

- **Existing condition characterization** through the assessment of the ecological functionality of the aquatic community and habitat;
- **Impact assessment through preliminary eco-hydrologic analysis** using Tenant Method, Tessman Method and Flow Duration Curves; and
- **Impact assessment detail hydrologic analysis** through the linkage of ecological functions to the flow regime criteria:
  - Timing – same timing of flow under all phases;
  - Magnitude – sufficient to sustain ecological functions under all phases;
  - Duration – maintain same duration of flow under all phases; and
  - Frequency - maintain same frequency of flow under all phases.

Flow Regime Analysis Approach

Overview

In regard to ecological flows management, numerous methodologies have been suggested to determine streamflows required to protect aquatic ecosystems in streams and rivers. Tharme (2003) categorized environmental flow methodologies into four types: hydrological, habitat rating, habitat simulation, and holistic methodologies.

Ecological principles and tools used in the articulation of ecological objectives within these methodologies vary according to assumed linkages between ecology and stream physical processes. Accordingly, the Flow Regime Analysis approach we utilize is a holistic approach that is based on our understanding of the unique nature of the habitats and flows within the Subject Property. As such, this memorandum is primarily dependent on:

1. Ecological input that is informed with scientific tools and techniques, in addition to local field experience; and
2. Hydrological input that is founded on different desktop analysis tools that have been used globally in identifying and quantifying streamflows.

Both inputs have two main streams of focus to include:

1. **Existing Conditions**: an examination of the existing conditions as documented in Reach 14W-11A, the confluence of Reach 14W-13 and 14W-14, and Reach 14W-12A; and
2. **Proposed Conditions and Impact Assessment**: undertake a comparison of the existing to the anticipated post-development condition (under all development phases). Specifically:
    a. Impact of re-aligning Rach 14W-13 and Reach 14W-14 into Reach 14W-22
    b. Impact of re-aligning Reach 14W-11A into Reach 14W-23
    c. Impact of losing surface runoff input from Reach 14W-13 and Reach 14W-14 into Reach 14W-12A

Ecological Input
The Flow Regime Analysis approach we utilize in this memorandum is primarily dependent on ecological input that is based on the following aspects of aquatic ecology:

1. Flow regime;
2. Aquatic habitat;
3. Review of Redside Dace (*Clinostomus elongatus*) ecology;
4. Benthic microinvertebrate community present and drift; and
5. Natural flow regime criteria (Timing, Duration, Magnitude, and Frequency of flows).

Hydrological Input
The hydrologic input is primarily based on the following hydrologic tools:

1. Hydrologic annual and seasonal flow metrics (Tennant and Tessman);
2. Overall hydrologic regime (flow duration curves); and
3. Functional streamflows and natural flow regime criteria.
4. Monthly flows during Wet, Dry, and Average Years.

Integrated Eco-hydrologic Analysis
Both the ecological input and the hydrologic input are combined to form an integrated eco-hydrologic analysis (Figure 1). Specifically, two levels of analysis are proposed:

1. Preliminary analysis, using Tennant and Tessman methods, in addition to flow duration curves; and
2. Detailed analysis using functional streamflows and natural flow regime criteria.

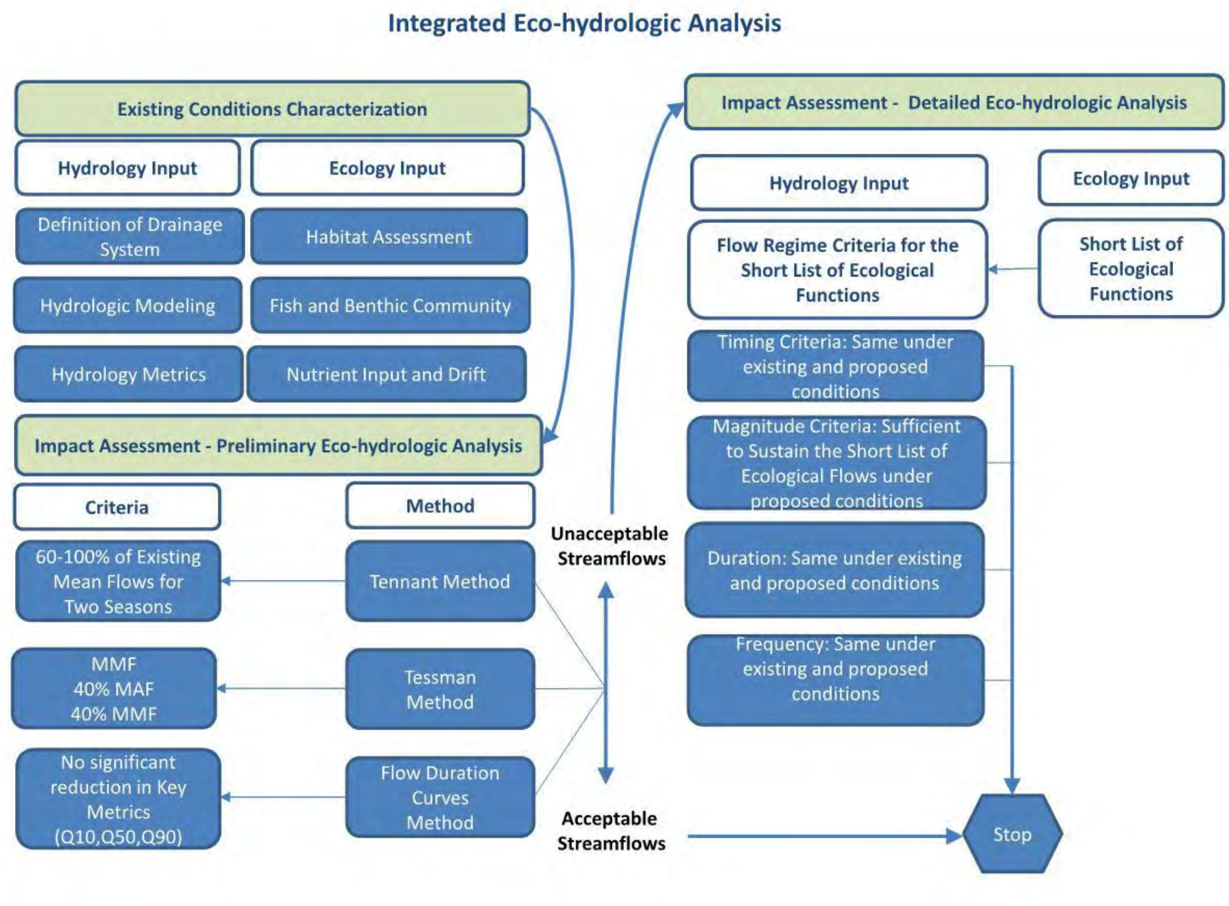


Figure 1. Integrated Eco-hydrologic Analysis Tool

Ecological Input – Existing Conditions

The proposed development of the Subject Property will result in the alteration of the existing drainage boundaries and in some instances reduce the quantity of flow in a number of watercourses (subject reaches). This alteration in flow has the potential to change ecological functions (Linnansaari et. al., 2013) within these reaches. As such, CH has requested that further review be undertaken including the assessment of ecological function associated with the anticipated change in flow, specifically within three reaches: Reach 14W-11A (Node 9), Reach 14W-12A (Node 2) and Reach 14W-22 (Node 2B).

In order to understand the anticipated impacts to the ecological function of Reach 14W-11A and Reach 14W-12A, the examination of the existing conditions will utilize two ecological components consisting of:

- Redside Dace ecology; and
- Benthic macroinvertebrate community.

The examination of each reach related to the above two components will provide an assessment of the form and function of the Reach 14W-11A (Node 9) and Reach 14W-12A (Node 2). Once this baseline assessment of function is determined, an evaluation of the potential impacts associated with the proposed alteration of flow post-development will be assessed to forecast the functional changes of these reaches (if any).

As Node 2B is located in Reach 14W-22, the new realigned channel replacing Reach 14W-13 and Reach 14W-14, there are no existing conditions at this node.

Existing Conditions Characterization – Ecology Input

The existing aquatic communities (fish and benthic), as well as, the habitat conditions have been documented based on the descriptions provided in the Environmental Implementation Report / Functional Servicing Study – Main Report (3rd Submission) (EIR) (2014), as well as, a site reconnaissance field investigation undertaken on November 18, 2016.

Flow Regime

Based on field observations, the flow regimes for all watercourses and reaches has be assessed and classified according to the information collected during field investigations related to surface flows and groundwater inputs. The results displayed in Table 1 taken from the EIR (2014) which indicates that all of the watercourses on site are part of a system that is surface water dependent.

Table 1: Flow Regime Assessment by Reach.

Reach	Node	Surface Water Influence	Groundwater Influence	Flow Regime	Comments
14W-11A	9	Completely surface water	none	Intermittent	Flow is surface water dependant with the reach considered to be losing water into the ground during most of the year.
14W-12	3A	Majority of flow	Minor inputs through-out the majority of the year	Intermittent	Insufficient groundwater to maintain baseflow during the summer months – isolated pools.

Reach	Node	Surface Water Influence	Groundwater Influence	Flow Regime	Comments
14W-12A	2	Majority of flow	Low (November to May)	Intermittent	Insufficient groundwater to maintain baseflow during the summer months – dry channel.
14W-13	2C	Completely surface water	none	Intermittent	Dry channel during the summer months.
14W-14	2C	Majority of flow	Minor inputs thought-out the majority of the year	Intermittent	Insufficient groundwater to maintain baseflow during the summer months – dry channel.

In summary, all of the watercourses on the Subject Property are considered to have an intermittent flow regime which are heavily reliant on surface water (i.e. spring freshet and precipitation events). Although groundwater inputs are present in some locations, these inputs are minimal and are insufficient in volume to maintain baseflow during periods of reduced precipitation. Reach 14W-11A (Node 9) and Reach 14W-13 do not receive any groundwater inputs and rely solely on surface water for flows. Reach 14W-12, Reach 14W-12A (Node 2), Reach 14W-14 and Reach 14W-16 all receive minor amounts of groundwater input in varying quantities, but not enough to maintain base flow during the summer months.

Aquatic Habitat Assessment

The purpose of the habitat assessment is to determine the function of the aquatic habitat, specifically related to critical lifecycle requirements of the associated fish community. As such, a brief description of the habitat present in Reach 14W-11A, Reach 14W-12A, Reach 14W-13 and Reach 14W-14 is provided below followed by a habitat summary table below (Table 2). For a more detail description of the habitat, refer to the EIR (2014).

Reach 14W-11A

Within the Subject Property, south of Highway 407, Reach 14W-11A which is considered a Medium Constraint Stream Corridor (EIR, 2014) with the Ministry of Natural Resources and Forestry (MNRF) indicating that this reach functions as Contributing Habitat to Redside Dace downstream of the Subject Property (EIR, 2014). The aquatic habitat in Reach 14W-11A is heavily influenced by its intermittent flow regime. When water is present, the aquatic habitat consists of diffuse flow through dense vegetation and a short defined channel approximately 10 m long. During the most recent field reconnaissance in 2016, no flow was observed however, there was an area of pooled water (wetted width 1.5 m, depth 0.2 m) at the upstream limit prior to transitioning to a densely vegetated swale with narrow riparian habitat. A culvert farm crossings of the swale is also present in the reach that has a shallow (~0.05 m deep) water ponded in it that extended a few metres upstream and downstream of the crossing. The habitat appears to be fairly uniform and devoid of any specialized habitat features. No fish were observed within the ponded areas during 2016. The intermittent flow regime, lack of specialized habitat features and limited refuge habitat (ponded areas) suggests that the reach provides limited opportunities for fish. However, given that fish were captured within this swale, Reach 14W-11A is assessed as functioning as seasonal direct fish habitat. It should be noted that the short section of defined channel at the upstream limit is proposed to be affected/removed during future widening of the 407 Transitway.

Reach 14W-12A

Within the Subject Property, Reach 14W-12A is considered a High Constraint Stream Corridor (EIR, 2014) with the MNRF indicating that Reach 14W-12A functions as Contributing Habitat to Redside Dace. The aquatic habitat in Reach 14W-12A is heavily influenced by its intermittent flow regime, and conveys flows from Reaches 14W-13 and 14W-14 as well as the Farm Pond (Reach 14W-14A) before discharging into Reach 14W-12. The channel associated with Reach 14W-12A was constructed as part of the Farm Pond works to convey water from the pond to Reach 14W-12. The narrow incised constructed channel is approximately 125 m long and is located in a trapezoidal valley. The aquatic habitat present in the channel consists of sections with dense Cattail vegetation with diffuse flow at the Farm Pond outlet and at the connection to Reach 14W-12 with and a semi-defined channel consisting entirely of run habitat between. The semi-defined channel has a narrow flow path approximately 0.3 m wide with a bank depth ranging from 0.2 m to 0.3 m and a substrate consisting of a mixture of silt and clay. Grasses were observed in the semi-defined channel with abundant overhanging herbaceous vegetation to provide cover. No fish were observed due to the intermittent flow regime. It is anticipated that when water is present in this reach, the absence of specialized habitat features to attract fish, uniform morphology and substrate as well as potentially limited connectivity due to the dense cattail vegetation suggests that the reach provides limited opportunities for fish. However, given that fish are present in connecting reaches and a clear physical barrier (e.g. dam, vertical drop, etc.) is not present there is some potential that Reach 14W-12A functions as seasonal direct fish habitat, even though, the function as indirect fish habitat is likely more accurate through flow and allochthonous conveyance.

Reach 14W-13

Within the Subject Property, Reach 14W-13 is considered a Low Constraint Stream Corridor and is classified by the MNRF to function as Contributing Habitat the Redside Dace (EIR, 2014). The aquatic habitat in Reach 14W-13, is heavily influenced by its intermittent flow regime with no present flow during the site investigation in 2016. Within the Subject Property, 14W-13 flows between two active agricultural fields with a defined flow path characterized as an excavated straight swale with gently sloped defined banks. The riparian vegetation buffer varies widely from an upstream width of approximately 60 m to a narrow width between the fields of approximately 6 m. Within the swale, the vegetation is dense consisting of Reed Canary Grass, Cattail and Teasel. Sporadic trees are present along the swale to offer minimal shading and allochthonous inputs. No flow was observed; however, when present, it would travel as diffuse flow through the dense vegetation. The substrate consisting of silt, clay, sand and organic material was dry when pressed. A formal (i.e. culvert) and informal farm crossings of the swale were present. Within 14W-13, the aquatic habitat appears to be fairly uniform and devoid of any specialized habitat features, consisting of diffuse flow. Field investigations confirm that due to the intermittent flow regime and a lack of specialized habitat features, Reach 14W-13 functions as indirect fish habitat by providing flow contribution to downstream fish habitat.

Reach 14W-14

Within the Subject Property, Reach 14W-14 is considered a Medium Constraint Stream Corridor that discharges into a High Constraint Corridor (reach 14W-12A) and is classified by the MNRF as functioning as Contributing Habitat to Redside Dace (EIR, 2014). The aquatic habitat in Reach 14W-14, is heavily influenced by its intermittent flow regime as no flow was observed during the 2016 site investigation. Within the Subject Property, the aquatic habitat south of Highway 407 consists of area of open water that transitions into wide dense meadow marsh habitat (Reed Canary Grass) with a number of small pockets of standing water and damp soils between two active agricultural fields. The meadow marsh lacked any sort of banks and ranged in width from 100 to 25 m. The substrate in the meadow marsh consisted of silt, clay and organic material. Approximately 150 m upstream of the confluence with Reach 14W-13 to the confluence with Reach 14W-12A, a narrow (approximately 0.3 m wide) and shallow (approximately 0.2 m deep) semi-defined channel through a dense and narrow meadow marsh and cultural meadow vegetation was observed. There is no canopy cover along the entire reach between Highway 407 and the confluence with Reach 14W-12A which likely limits the quantity of allochthonous inputs. A number of informal farm crossings were present through the meadow marsh. Within Reach 14W-14, the aquatic habitat appears to be fairly uniform and devoid of any specialized habitat features. Reach 14W-14 functions as direct fish habitat as fish were captured in the upstream pool south of Highway 407. This Reach will be removed as part of the proposed development with flows being redirected to the new realigned channel referred to as Reach 14W-22.

Table 2: Habitat Summary Table.

Reach ID	Flow (Permanent/ Intermittent / Ephemeral)	Thermal Regime (Warm / Cool / Cold)	Channel Form / Flow Pattern	Substrate Type	Vegetation (Riparian & In-Water)	Supports a Fishery (Direct, Indirect or None)	Fish Species Present
Reach 14W-11a	Intermittent	Coolwater to warmwater	Short defined channel with isolated ponding that transitions to a densely vegetated, excavated swale. This reach to be affected/removed by future 407 Transitway. Flow pattern mainly as diffuse flow through dense vegetation with a short defined channel section.	Silt, Clay	Riparian: Grasses, Teasel In-water: Reed Canary Grass, Teasel, Cattails	Seasonal direct fish habitat Contributing Habitat to Redside Dace	Bluntnose Minnow Brook Stickleback Creek Chub Fathead Minnow
Reach 14W-12a	Intermittent	Coolwater to warmwater	Semi-defined channel with a narrow flow path in the bottom of a excavated trapezoidal channel • Width 0.3 m • Bank depth 0.2 m to 0.3 m Flow pattern mainly as diffuse flow through dense Cattails with a short section of a semi-defined channel.	Silt, Clay	Riparian: Herbaceous vegetation (grasses, meadow spp.) In-water: Grasses, Cattails	Seasonal direct fish habitat Contributing Habitat to Redside Dace	None
Reach 14W-13	Intermittent	Coolwater to warmwater	Defined flow path characterized as an excavated straight swale with gently sloped defined banks. Flow pattern as diffuse flow through dense vegetation	Silt, Clay, Sand, Organic Material	Riparian: Trees In-water: Reed Canary Grass, Cattail, Teasel	Indirect fish habitat Contributing Habitat to Redside Dace	None
Reach 14W-14	Intermittent	Coolwater to warmwater	Pooled open water habitat transitioning to diffuse flow through dense meadow marsh habitat that transitions into a defined channel • Width 0.3 m • Bank depth 0.2 m. Flow pattern mainly as diffuse flow through dense vegetation with a short section of a semi-defined channel.	Silt, Clay, Organic Material	Riparian: Herbaceous vegetation (grasses, meadow species) In-water: Meadow Marsh spp.	Direct fish habitat Contributing Habitat to Redside Dace	Brook Stickleback Fathead Minnow

Benthic Macroinvertebrate Community and Drift

Benthic macroinvertebrates are small, aquatic organisms that exist in the substrate of a watercourse or waterbody and are excellent indicators of environmental conditions including habitat diversity and water quality (i.e. organic pollutants). They form a crucial component of the aquatic ecosystem by breaking up leaves and other organic debris, feeding on algae and other plants in the watercourse, and are food for many fish species. For the purpose of this assessment, the benthic macroinvertebrate community will be reviewed based on the function as a forage source for fish both as direct use (i.e. foraged within the same reach) or downstream drift (i.e. originating from a separate reach).

The assessment of the productivity will be guided by the following principles:

- **Aquatic Habitat** – Aquatic habitat (e.g., morphology and substrate) is a strong influence on the composition of the benthic macroinvertebrate community in terms of diversity. Benke and Huryn (2010) indicate that (in a general sense) the relationship between aquatic macroinvertebrate diversity and productivity has a positive relationship, in other words the more diverse a population the greater the productivity. It is important to note that Benke and Huryn (2010) also indicated that this relationship is not a governing standard as there are other factors, namely flow regime and human activity that can also influence a community.

  It is also important to note that benthic macroinvertebrates will generally occur in greater abundance within certain types of habitats (i.e. riffles) versus others (i.e. pool) and thus will have a bearing on productivity. In other words, reaches with a greater number of riffles (e.g. Reach 14W-16) will likely have a greater abundance of organisms versus a reach that does not (e.g. Reach 12W-12A)

- **Flow Regime** – This factor has a substantial influence on the productivity of a habitat in terms of benthic macroinvertebrate production, as the presence of water is required to allow for the establishment and population growth and will dictate the number of generations that may occur. The benthic macroinvertebrate production in intermittent / ephemeral streams would occur on an irregular and sporadic basis as opposed to a permanent stream that would permit production permanently with limitations set by the species life cycle. Thus there is a direct relationship to the amount of forage and drift available to a fish within a particular reach and fish in downstream reaches (drift)

  Flow regime also has an influence on diversity as the longer the flow duration, species with greater generation time as well as those with short generation times can coexist while an intermittent and ephemeral flow regime would be limited to species with shorter generation times. This is supported by the Xerces Society for Invertebrate Conservation (http://www.xerces.org/macroinvertebrate-streamflow-indicators/ Accessed November 30, 2016), which indicates that taxa diversity and/or richness tends to be higher in permanent watercourses rather than intermittent ones with diversity and abundance the lowest in ephemeral watercourses.

- **Human Activity** – Human interaction with a watercourse can have a strong influence on the productivity and diversity of the benthic macroinvertebrate community regardless of the two factors above, with the degree of influence related to the type of activity. Activities that physically alter habitat and/or affects water quantity or quality can at times override the other factors, namely habitat and flow regime and impair diversity and productivity.

Existing Benthic Macroinvertebrate Community

As indicated in the EIR (2014), benthic macroinvertebrate sampling was only undertaken at one location in Reach 14W-11A and two locations in Reach 14W-16 in 2009 due to flow conditions.

According to the Ontario Benthos Biomonitoring Network (OBBN) protocol, sample collection during the cooler months increases the potential to maximize benthos richness as the benthos tend to expand their range due to higher oxygen contents in lower water temperatures (Jones, et. al., 2007). Based on the desire to obtain the greatest abundance and diversity for the analysis, sampling was scheduled for Fall 2016. During this period, multiple attempts were made to undertake sampling within Reach 14W-12A however, Reach 14W-12A lacked flow during this period. As a means to determine whether precipitation events were perhaps missed, a review of recent hydrographs of the Subject Property indicated that heavy precipitation events in the fall that would typically provide flow to Reach 14W-12A did not occur in advance of freezing temperatures. In the absence of data directly from Reach 14W-12A, the results of the benthic sampling from Reaches 14W-11A and 14W-16 will be combined for the assessment. The rationale for this approach is that although Reach 14W-16 has very different habitat conditions (i.e. morphology, substrate, flow regime) to Reach 14W12A, there is a potential sharing of similar populations due to connectivity while Reach 14W-11A shares a more similar habitat characteristics and flow regime which is in line with Belmar (2012) that states sites with similar hydrological characteristic share a similarity in invertebrate compositions

The results of the benthic sampling by Family are below in Table 3.

Table 3: Benthic Macroinvertebrate Sampling Results.

Family	Common Name	Reach 14W-11A No. of Individuals	Reach 14W-16A (downstream) No. of Individuals	Reach 14W-16A (upstream) No. of Individuals
Amphipoda	Amphipods	4	6	
Ceratopogonidae	Biting Midges	13	2	12
Chironomidae	Non-Biting Midges	53	9	78
Coleoptera	Beetles and Weevils	8	4	2
Decapoda	Crayfish	1		
Ephemeroptera	Mayflies	2		
Gastropod	Snails & Slugs	3		5
Isopoda	Woodlice, Pillbugs	4	297	89
Oligochaeta	Freshwater Worms	14	3	17
Simuliidae	Black Flies		2	1
Tabanidae	Horseflies	1		
Tipulidae	Crane Fly	1		4
Zygoptera	Damselflies			1
	Total	**104**	**323**	**209**

Reach 14W-11A

The benthic sampling undertaken in Reach 14W-11A resulted in the identification of eleven different Families for a moderate diversity rate based on the representation of individuals within the families. An examination of the distribution of the population within these families identified that the majority of individuals are represented by one tolerant taxa with very few intolerant taxa. If fact, more than half of the individuals captured were from one Family, Chironomidae, which are common with impacted habitats.

Although the diversity is moderate and Benke and Huryn (2010) indicate the diversity may be a measure of productivity, the dominance by single tolerant taxa suggests that human influence (i.e. Highway 407 and agriculture) likely overrides the previously stated diversity relationship to productivity. This in association with the minimal habitat diversity and intermittent flows indicates that this reach is considered to provide a low productivity function in relation to the benthic macroinvertebrate community.

Reach 14W-12A

Benthic sampling was undertaken at two sites in Reach 14W-16 upstream of Reach 14W-12A; a downstream site in closest proximity to the confluence and an upstream site. The downstream site resulted in the identification of seven different Families with a low diversity rate while nine Families were identified from the upstream site with a moderate diversity rate. A review of the Families present, indicates that all Families from both sites are represented by tolerant taxa with zero intolerant taxa. The upstream site consisted mostly of two Families, Isopoda and Chironomidae, while the downstream site was dominated by a single Family, Isopoda. Samples represented by Families that make up 20% or more of the sample, are consider to be under environmental stress, which appears to be occurring at both sample sites in Reach 14W-16.

Notwithstanding the general similarities of the benthic communities in both watercourse reaches, an assessment of the community and habitat in Reach 14W-16 suggests that the variability in habitat and flows within this reach is makes using this data as a partial surrogate for Reach 14W-12A unsuitable. As a result, it is (conservatively) assumed that the community in Reach 14W-11A is more reflective of the habitat that would be present within Reach 14W-12A due to habitat similarities (both within the reach and upstream of Reach 14W-12A) and flow regimes.

As a result the assessment of function and productivity would be similar to that of Reach 14W-11A presented above that generally states there is moderate diversity with the dominance by tolerant taxa due to human influence (i.e. Highway 407 and agriculture). Again this is anticipated to override the previously stated diversity relationship to productivity and in association with minimal habitat diversity and intermittent flows, this reach is considered to provide a low productivity function in relation to the benthic macroinvertebrate community.

<u>Summary</u>

As previously stated, the benthic community is largely influenced by the habitat, flow regime and human activity. In the absence of human influences, the productivity is tied largely to the flow regime as water has to be present in order to permit the establishment and successful propagation of organisms, as well as, habitat given that certain habitat features (i.e. riffles, coarse substrates) are more productive than others. The flow regime and habitat in Reach 14W-11A and Reach 14W-12A consisting of a combination of diffuse flow through vegetation and short defined sections with isolated pool or run habitat are considered to have relatively low functionality as it related to benthic macroinvertebrate production. hat is not to say that these reaches do not serve a function just that the existing conditions (i.e. flow regime and habitat) results in low productive capacity for benthic macroinvertebrates.

Furthermore, the same factors that limit benthic macroinvertebrate communities (i.e. habitat and flow regime) also limit the use of these reaches as direct fish habitat. As a result, these reaches are considered to principally provide benthic drift as a food source for fish in downstream communities when flows are present rather than in the reaches themselves.

Redside Dace Ecology

The main fish species that was examined in relation to the potential changes to flow was Redside Dace. The rationale for the use of this single species is that it was specifically identified in CH comments and is the most sensitive species present within the Subject Property as the majority of the remaining species are tolerant to a wide range of conditions or are stocked populations. It is anticipated that the analysis of effects to this particular species would cover potential adverse effects to the tolerant species.

Redside Dace are classified as Endangered (END) and protected along with their habitat under the provincial Endangered Species Act (ESA, 2007). Within the Subject Property, the MNRF has classified Reach 14W-12 and Reach 14W-16 as Occupied Redside Dace Habitat and Reach 14W-14, Reach 14W-13, Reach 14W-14A, Reach 14W-12A and Reach 14W-11A as Contributing Habitat to Redside Dace (EIR, 2014). The habitat in these reaches was further classified in the EIR (2014) as High Constraint Stream Corridor (Reach 14W-12A) and Moderate Constraint Stream Corridor (Reach 14W-11A) connected to a High Constraint Stream Corridor – Requiring Rehabilitation (Reach 14W-11). Within the Subject Property, Redside Dace were captured in Reach 14W-12 immediately upstream of the Dundas Road culvert. A description of the habitat requirements and foraging strategy utilized by Redside Dace is provided below in order to provide context to the assessment. This is followed by a functional assessment of the existing conditions in Reach 14W-11A and Reach 14W-12A as it relates to this species.

Habitat Requirements and Assessment

Redside Dace generally inhabit the mid-water column of quiet pools of clear creeks and streams with a sand or gravel substrate and overhanging riparian vegetation. This species is a coolwater sight feeder that generally leaps out of the water to capture flying insect hovering above the surface. They are also know to feed at the terrestrial insects that have fallen onto the water surface. It is intolerant of turbidity and the removal of riparian vegetation for which it depends on for feeding. Spawning occurs in the spring from May to June with water temperatures ranging from 16^{o}C to 19^{o}C with eggs being laid in gravelly riffles in the nest of other minnow species, typically Creek Chub. As such, Creek Chub are a very important companion species for Redside Dace, such that, hybrids between the two species are known to occur (Redside Dace Recovery Team, 2010, Holm, et al., 2009, Scott and Crossman, 1998, Eakins, 1999-2016).

The habitat in Reach 14W-12A lacks the preferred habitat features for this species including pools for foraging, refuge and over wintering habitat and suitable gravelly riffles for spawning. The MNRF has previously indicated (in other projects) that without the presences of pool habitat, the species would not be present. As such, it would be highly unlikely that this species would use the habitat in Reach 14W-12A, even in an opportunistic manner if flows were present. Potential contributing function of this reach to Redside Dace located downstream in Reach 14W-12 would consists of providing flow contributions and allochthonous inputs to downstream habitats with limited input related to benthic macroinvertebrate drift given the feeding strategy of Redside Dace at the surface rather than within the water column or along the substrate. Given the intermittent nature of the flow regime at Reach 14W-12A, this contribution is further limited to seasonally flows and precipitation events.

There was no evidence of Redside Dace in Reach 14W-11A; however, it is connected to Occupied Redside Dace further downstream. Currently, the potential for the species to access the Reach 14W-11A is being prevented by a previously observed vertical drop barrier located downstream of the Subject Property, and as such, will be assessed as Contributing Habitat to Redside Dace. Similar to Reach 14W-12A, Reach 14W-11A would provide flow contributions, allochthonous inputs and limited input related to aquatic benthic macroinvertebrate drift on a seasonally basis and associated with precipitation events.

In addition, a summary habitat functional assessment related to the remaining fish species recorded on site has been undertaken to provide context to the overall functionality of these reaches to the fish community. The habitat potential for the remaining fish species located downstream (i.e. Reach 14W-11 and Reach 14W-12) ranges from none to marginal for these remaining species. During the spawning period, the use would be marginal at best and potential limited to a single species given the absence of suitable habitat (i.e. morphology, substrate, structure). During the remainder of the year, these reaches may be used opportunistically (inconsistently) if/when sufficient flows are present to provide passage from downstream populations and flow to maintain habitat. Refer to Table 4 below for an assessment of habitat use by specific species as context to the overall ecological functionality of these reaches.

Table 4: Fish Community Habitat Assessment.

Fish Species		Existing Habitat Conditions		General Morphology	General Substrate	Spawning Morphology	Spawning Substrate	Source Population	Connectivity	Likelihood to Occur & Habitat Function	
Common Name	**Scientific Name**	**Reach 14W-11A**	**Reach 14W-12A**							**Reach 14W-11A**	**Reach 14W-12A**
Blacknose Dace	*Rhinichthys obtusus*	Intermittent flow Coolwater to warmwater Small watercourse with an open channel and excavated swale sections Low gradient Mostly diffuse flow through dense vegetation	Intermittent flow Coolwater to warmwater Small watercourse with dense Cattails and a small semi-defined channel sections Low gradient Mostly diffuse flow through dense vegetation	Coolwater Riffles and runs Small to medium-sized watercourses Moderate to steep gradients	Gravel	Riffles	Gravel	Reach 14W-12	Seasonally to Reach 14W-12A	N/A	Opportunistic only if conditions permit, general requirements
Bluntnose Minnow	*Pimephales notatus*			Warmwater Tolerant of turbidity, siltation and organic enrichment Shallow lakes, creek, rivers and ponds	Sand to gravel, occasionally coarser rocks	Same as general habitat	Rocks and logs	Reach 14W-12 & Reach 14W-11A	Seasonally to Reach 14W-12A & Reach 14W-11A	Opportunistic only if conditions permit, general requirements	Opportunistic only if conditions permit, general requirements
Brook Stickleback	*Culaea inconstans*			Coolwater Tolerant of degraded conditions Vegetated margins of lakes, ponds and flowing pools and backwaters	Generalist	Same as general habitat	Stems of aquatic vegetation	Reach 14W-14, Reach 14W-12, Reach 14W-11A & Farm Pond	Seasonally to Reach 14W-12A & Reach 14W-11A	Opportunistic only if conditions permit, potential spawning habitat	Opportunistic only if conditions permit, general requirements
Brown Bullhead	*Ictalurus nebulosus*			Warmwater Tolerant of degraded conditions Shallow lakes and pools / runs of slow moving streams with abundant cover	Sand to mud	Same as general habitat	In the vicinity of cover such as logs, stumps or rocks	Reach 14W-12	Seasonally to Reach 14W-12A	N/A	None
Creek Chub	*Semotilus atromaculatus*			Coolwater Tolerant of degraded conditions Pools of clear creeks and small rivers Occasionally found at the shores of small lakes	Generalist	Same as general habitat	Gravel	Reach 14W-12, Reach 14W-11A & Farm Pond	Seasonally to Reach 14W-12A & Reach 14W-11A	Opportunistic only if conditions permit, general requirements	Opportunistic only if conditions permit, general requirements
Fathead Minnow	*Pimephales promelas*			Warmwater Tolerant of turbidity, high water temperatures and degraded conditions Still water ponds, lakes, creeks and small rivers	Soft substrate	Same as general habitat	Rocks and logs	Reach 14W-14, Reach 14W-12 & Reach 14W-11A	Seasonally to Reach 14W-12A & Reach 14W-11A	Opportunistic only if conditions permit, general requirements	Opportunistic only if conditions permit, general requirements
Largemouth Bass	*Micropterus salmoides*			Warmwater Tolerant of high water conditions Intolerant of low dissolved oxygen conditions Prefers clear, warm water of shallow lakes, bays, ponds, marshes, backwater areas, and pools of creeks and small rivers	Soft substrate and abundant cover	Same as general habitat, 1 m to 4 m of water	Sand and soft substrate	Farm Pond (Stocked)	Seasonally to Reach 14W-12A	N/A	None
Redside Dace	*Clinostomus elongatus*			Coolwater Intolerant of turbidity and removal of riparian vegetation Quiet pools of clear creeks and streams with overhanging riparian vegetation	sand or gravel	Riffles	Gravel	Reach 14W-12	Seasonally to Reach 14W-12A	N/A	None
White Sucker	*Catostomus commersoni*			Coolwater Tolerant of degraded conditions Prefer pools and riffles in creeks, rivers, warm shallow lakes and embayments of larger lakes	Generalist	Shallow streams, lake margins and quiet river mouths. Can spawn in rapids.	Gravel	Reach 14W-12	Seasonally to Reach 14W-12A	N/A	Opportunistic only if conditions permit, general requirements

Benthic Macroinvertebrate Foraging

Aquatic benthic macroinvertebrates provide numerous benefits to an aquatic system including the breaking down of organic debris, as well as, providing forage for fish. As such, a further review of the potential benthic macroinvertebrate species that are essential for Redside Dace foraging has been undertaken. Studies have indicated that Redside Dace are primarily surface or aerial feeders based on the examination of gut contents with adult Dipterans being the most common species and mid-water and benthic foraging secondary (McKee and Parker, 1981). Furthermore, terrestrial insects, including those that hover and swim at the water's surface (Diptera), as well as, those that fall into the water (Hymenoptera – bees, ants, wasps and Coleoptera – beetles) are the main part of their diet indicating that they appear to be opportunistic feeders (Savanta, 2008). Of the Dipterans consumed, the genus *Hilara* was most common (Savanta, 2008). Dipterans, including *Hilara,* are mobile and will inhabit various habitats during their lifecycle and with the swarming above the watercourse the most directly relevant to Redside Dace.

Although these reaches do provide some degree of drift to downstream reaches, Redside Dace feed predominantly on terrestrial insects flying above the water surface or that have fallen onto the water surface,. This suggests that they do not rely immediately on the benthic macroinvertebrate community present in the substrate of the pools they inhabit and thus, they are not reliant on aquatic benthic macroinvertebrate drift from upstream habitats for foraging. As such, the relationship between Redside Dace and the habitats in Reach 14W-11A and Reach 14W-12A to support their foraging is reduced to the function to support the aquatic larva of Diptera species, which molt into adults and disperse to potentially become prey. Redside Dace reliance on Reach 14W-11A and Reach 14W-12A is further reduced as their preferred Dipteran species for foraging is the highly mobile *Hilara* species. Since this species in known to uses a variety of habitats throughout its lifecycle and flying to seek out suitable habitat (Cummings, 2006; Delettre, 1997; SWCSMH, 2013), if this food source is using Reach 14W-11A and Reach 14W-12A and conditions become unsuitable, the adults have the options of utilizing other reaches within the Subject Property. So, although Redside Dace have a very specific habitat requirement for foraging, their preferred prey species can use a variety of habitats and as a result these reaches should not be considered limiting factors.

Summary

In summary, the habitat in Reach 14W-11A and Reach 14W-12A is not suitable to support Redside Dace directly due to the lack of pools which are essential for the species (e.g. foraging) or gravel riffles for spawning.

In an indirect capacity, both reaches provide flow contributions, although function is limited to seasonally flows and precipitation events. With respect to Redside Dace foraging and benthic macroinvertebrate community, Redside Dace likely undertake limited foraging on drifting aquatic benthic macroinvertebrates from upstream habitats instead focusing feeding opportunities at the water's surface or above.

Hydrologic Input – Existing Conditions

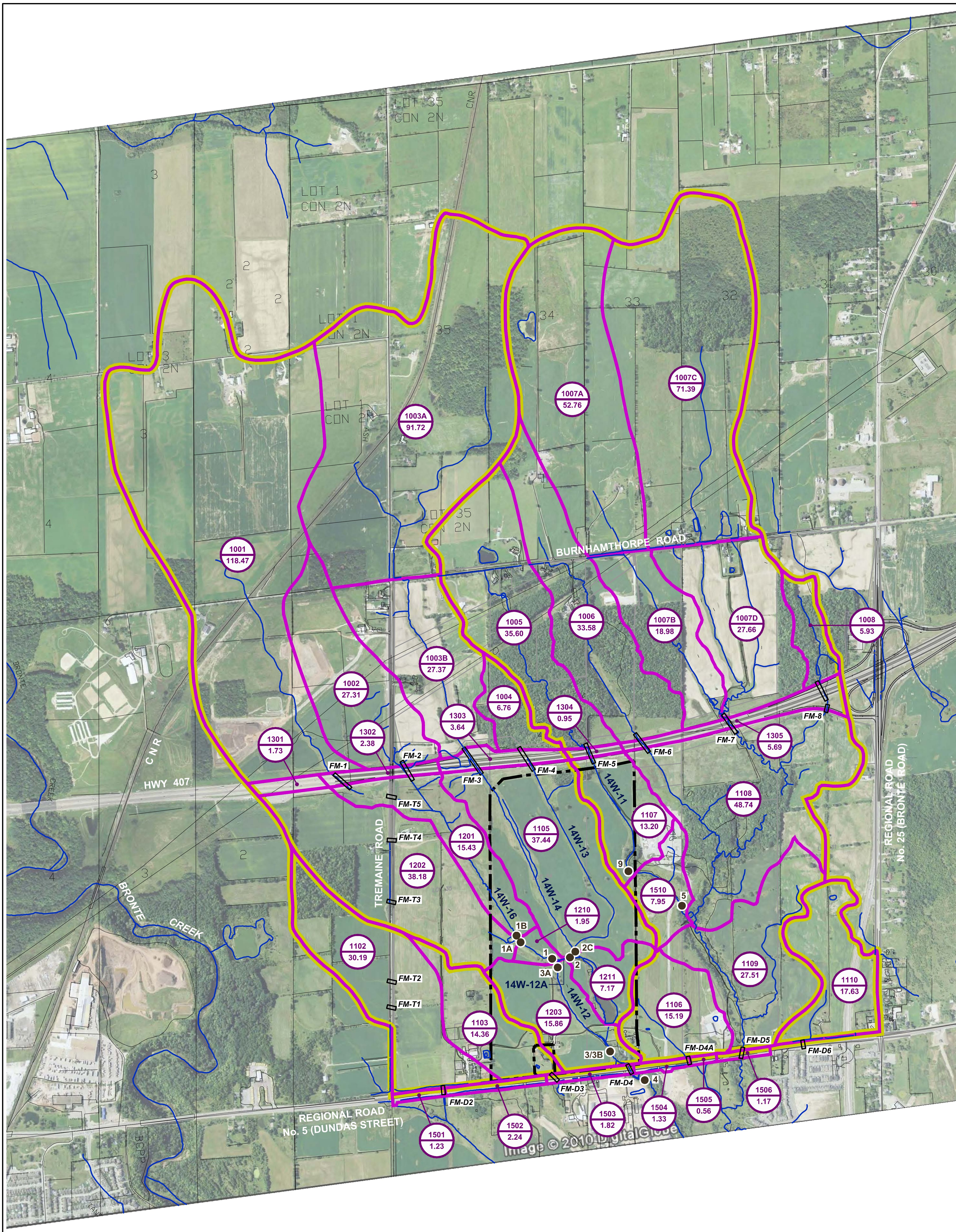
The GAWSER modeling platform was used in the hydrologic analysis and interpretation of hydrologic features and functions. Drainage boundaries and flow nodes have been delineated and drainage schematics have been developed to clearly illustrate drainage pathways under existing conditions (Section 7: **Figure 7.4.1**).

A long-term continuous flow model run (1962-1992) was performed for the purpose of flow regime analysis. Flow Duration Curves (FDCs) for flow nodes 2, 2B (2C under existing conditions), and 9 are shown in **Figures 7.4.2, 7.4.3, 7.4.4 and 7.4.5.**

The hydrologic metrics extracted from the FDCs for the three flow nodes (Table 4) represent high flow regime (10% Exceedance), median flows (50% Exceedance), and low flows (90% Exceedance). The results show the low magnitudes of streamflows even under the high flow regime, which is in agreement with the field observations undertaken by our aquatic ecology team. More specifically, the metrics obtained from the three flow duration curves show that the majority of the flows occur as peak flows resulting from freshets or snowmelt-based events.

Table 4: Hydrologic Metrics for the three Flow Nodes under Existing Conditions

% Exceedance	Node 2 Existing Conditions (m^3/s)	Node 2C Existing Conditions (m^3/s)	Node 9 Existing Conditions (m^3/s)
10.0	0.0062	0.0060	0.0022
50.0	0.0002	0.0001	0.0000
90.0	0.0000	0.0000	0.0000



Environmental Implementation Report / Functional Servicing Study for 14 Mile Creek West and the Lazy Pat Farm Property

Existing Drainage Boundaries and Reference Nodes (Revised from NOCSS by MMM)

LEGEND

- SUBJECT PROPERTY
- SUB-CATCHMENT BOUNDARY
- EIR SUB-CATCHMENT BOUNDARY
- EXISTING CREEK
- CULVERTS (EIR NODES)
- 1001 — SUB-CATCHMENT No.
- 118.47 — AREA (ha)
- 1 — REFERENCE NODE

Scale

1 : 15000   0 0.1 0.25 0.5 0.75km

Client: Bentall Kennedy

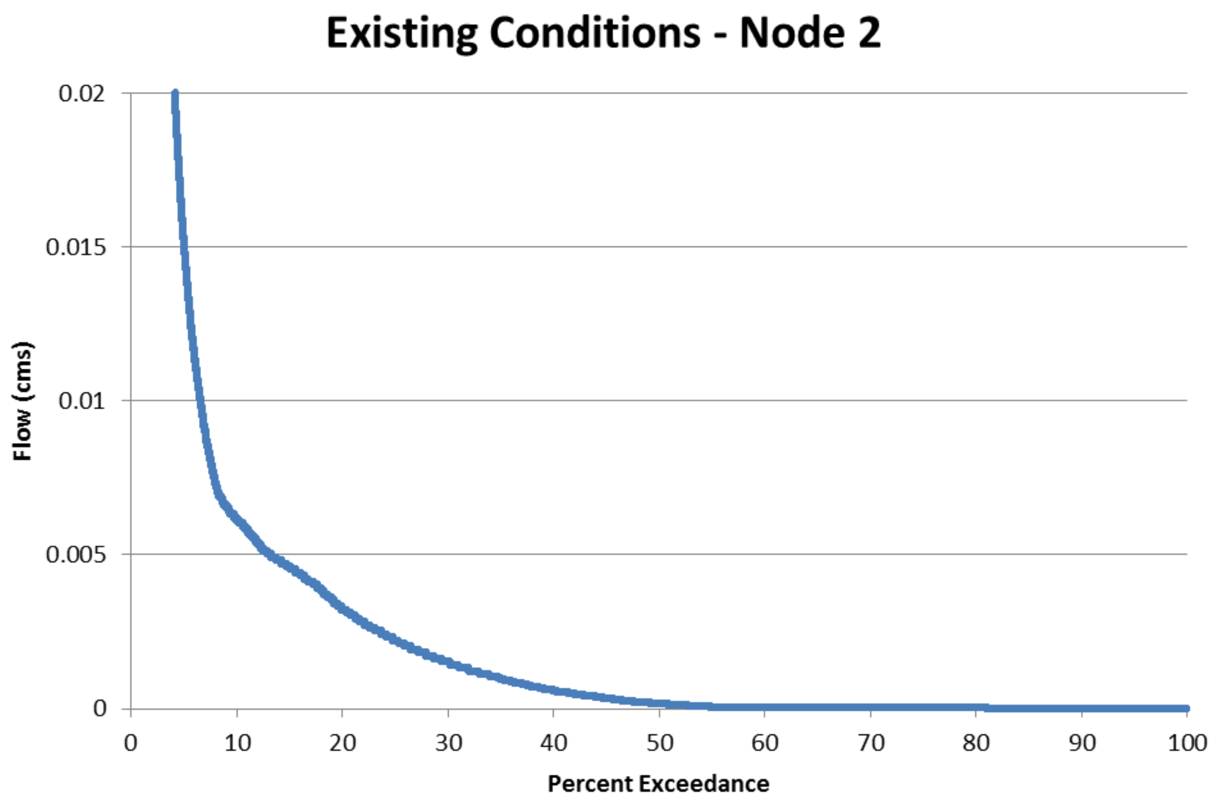
Prepared by: wsp

Date: June 2017

Project No.: 09M-00013-01-WR1

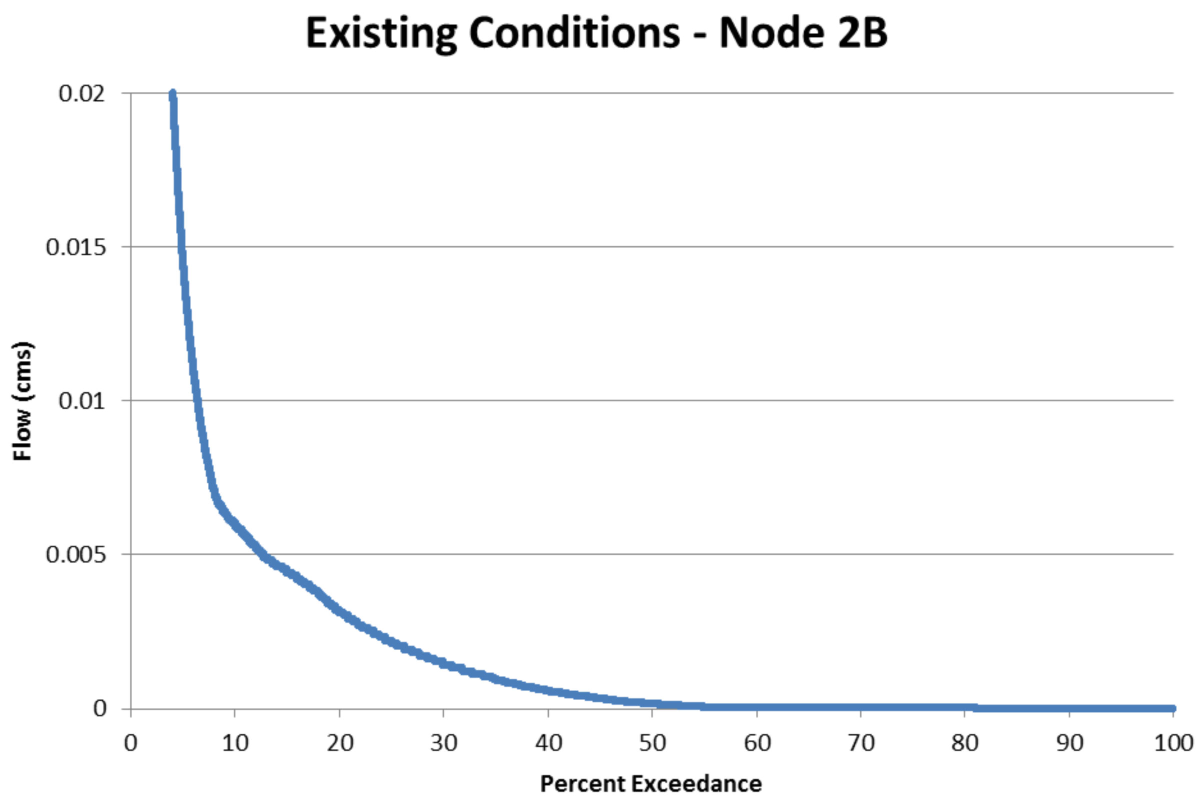
Aerial Photo: © DigitalGlobe 2010, Google 2009

Figure 7.4.1



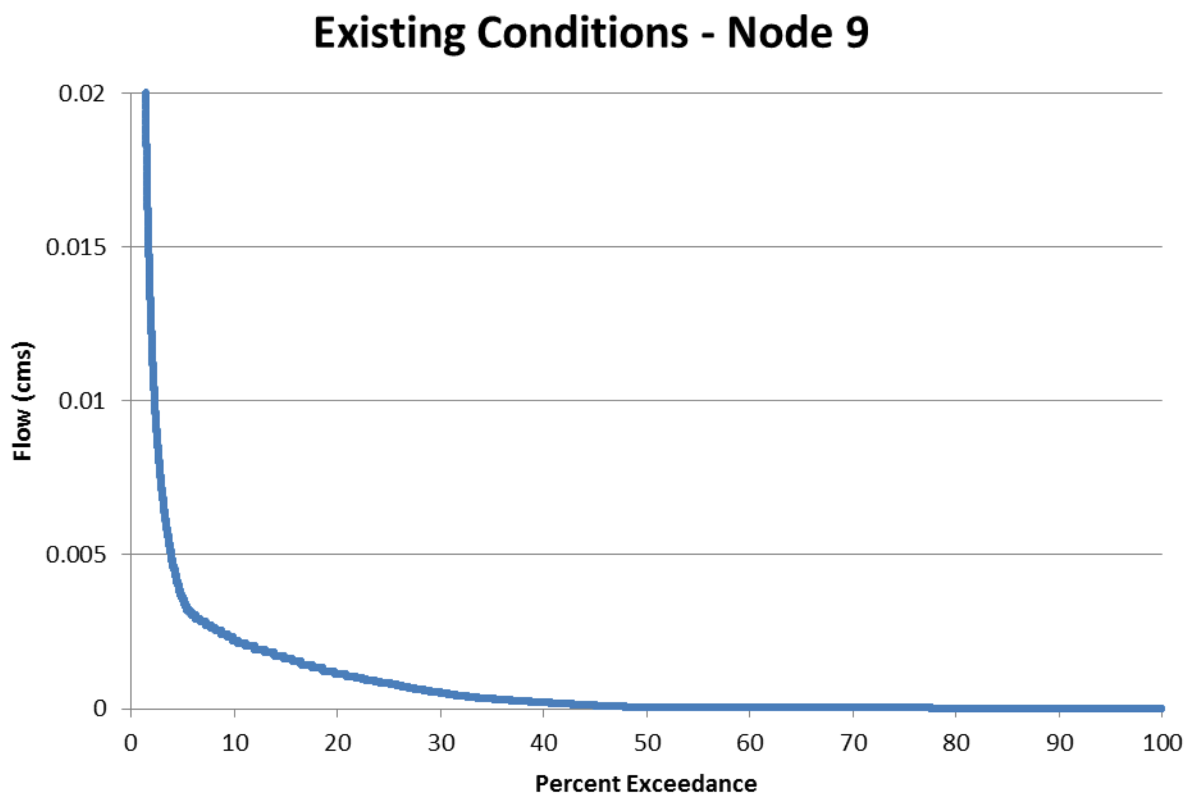
Flow Duration Curve for Node 2 - Existing Conditions

% Exceedance	Existing Conditions (m^3/s)
10.0	0.0062
50.0	0.0002
90.0	0.0000



Flow Duration Curve for Node 2B - Existing Conditions

% Exceedance	Existing Conditions (m^3/s)
10	0.0060
50	0.0001
90	0.0000



Flow Duration Curve for Node 9 - Existing Conditions

% Exceedance	Existing Conditions (m^3/s)
10	0.0022
50	0.0000
90	0.0000

Integrated Eco-hydrologic Analysis – Proposed Conditions

As previously indicated, the approach taken is a holistic approach that incorporates a number of annalysis tools integrated with the ecological function of the habitats in question. The Instream Flow methods were selected on the principle of startinng from a coarse level of detail (i.e. Tennant Method) to a level of greater specifitivity (i.e Flow Duration Curve) given the dynamic nature of the flow regimes and our understaning of the watercoourse characteristics. These analysis tools include:

- **Tennnant Method** – High level analysis solely based on two seasons.
- **Tessman Method** - Moderate level analysis solely based on a fraction of mean annual flow or mean monthly flow.
- **Flow Duration Curve** – Relatively detailed analysis based on exceedance probability of the full hydrologic record.

As indicated in Figure 1, detailed analysis may be required in the event that stream flows were considered unacceptable by these tools.

Proposed development is planned to be undertaken under four (4) interim phases. Accordingly, the following development phases have been analyzed:

- Existing (i.e. pre-development) (**Figure 7.4.1**)
- Interim Conditions Phase 1A (**Figure 7.4.2**)
- Interim Conditions Phase 1B (**Figure 7.4.3**)
- Interim Conditions Phase 2 (**Figure 7.4.4**)
- Ultimate Conditions (**Figure 7.4.5**)

Preliminary Analysis Results and Discussion

The results of the application of the three hydrologic tools are presented below. All development scenarios were considered.

Tennant Method

The Tennant method (also known as the Montana method) recommends minimum flows based on a percentage of mean annual flows (MAF) derived from historical records or results from deterministic hydrologic models. The method proposes the following ranges for habitat conditions vs. percentages of mean annual flows:

Table 5: Instream Flow Regimes based on Tennant Method (1976)

Description of flow or habitat	October to March	April to September
Flushing or maximum flow	200% of the average flow	
Optimum range of flow	60 – 100%	
Outstanding habitat	40%	60%
Excellent habitat	30%	50%
Good habitat	20%	40%
Fair or degrading habitat	10%	30%
Poor or minimum habitat	10%	10%
Severe degradation	< 10%	< 10%

For the Tennant method, the analysis of the full hydrologic record (1962 – 1992) was carried out. The two seasons represent average conditions over the full record, which is a common practice in the implementation of this method.

- Node 2: The implementation of the Tennant method resulted in unacceptable results during the two seasons (October to March and April to September) under all development phases, except for Phase 1A where there will be no impact to this node.
- Node 2B: The implementation of the Tennant method resulted in acceptable results during the two seasons (October to March and April to September) under all development phases, except for Phase 1A where there will be no impact to this node.
- Node 9: The implementation of the Tennant method resulted in acceptable results during the two seasons (October to March and April to September) under all development phases, except for Phase 1A where there will be no impact to this node.

Tessman Method

The Tessman method (1980) proposes the following flow conditions as criteria for minimum monthly flows within a stream:

Table 6. Tessman Method Criteria

Flow Condition	Recommended Minimum Monthly Flow (MMF)
MMF < 40% MAF	MMF
MMF > 40% MAF and 40% MMF < 40% MAF	40% MAF
40% MMF > 40% MAF	40% MMF

For the Tessman method, the analysis of the full hydrologic record (1962 – 1992) was carried out. The Mean Annual Flows (MAFs) and Mean Monthly Flows (MMFs) represent average conditions over the full record, which is a common practice in the implementation of this method.

- Node 2: The implementation of the Tessman method resulted in unacceptable results during the whole year, except for Phase 1A where there will be no impact to this node.
- Node 2B: The implementation of the Tessman method resulted in acceptable results during some of the months, namely November to May, August, and September under all development phases, except for Phase 1A where there will be no impact to this node. Unacceptable results were obtained for the months of June, July, and October under all development phases, except for Phase 1A where there will be no impact to this node.
- Node 9: The implementation of the Tessman method resulted in acceptable results during the whole year under development phases 1A and 1B. Under development phases 2 and Ultimate, July and October have unacceptable results.

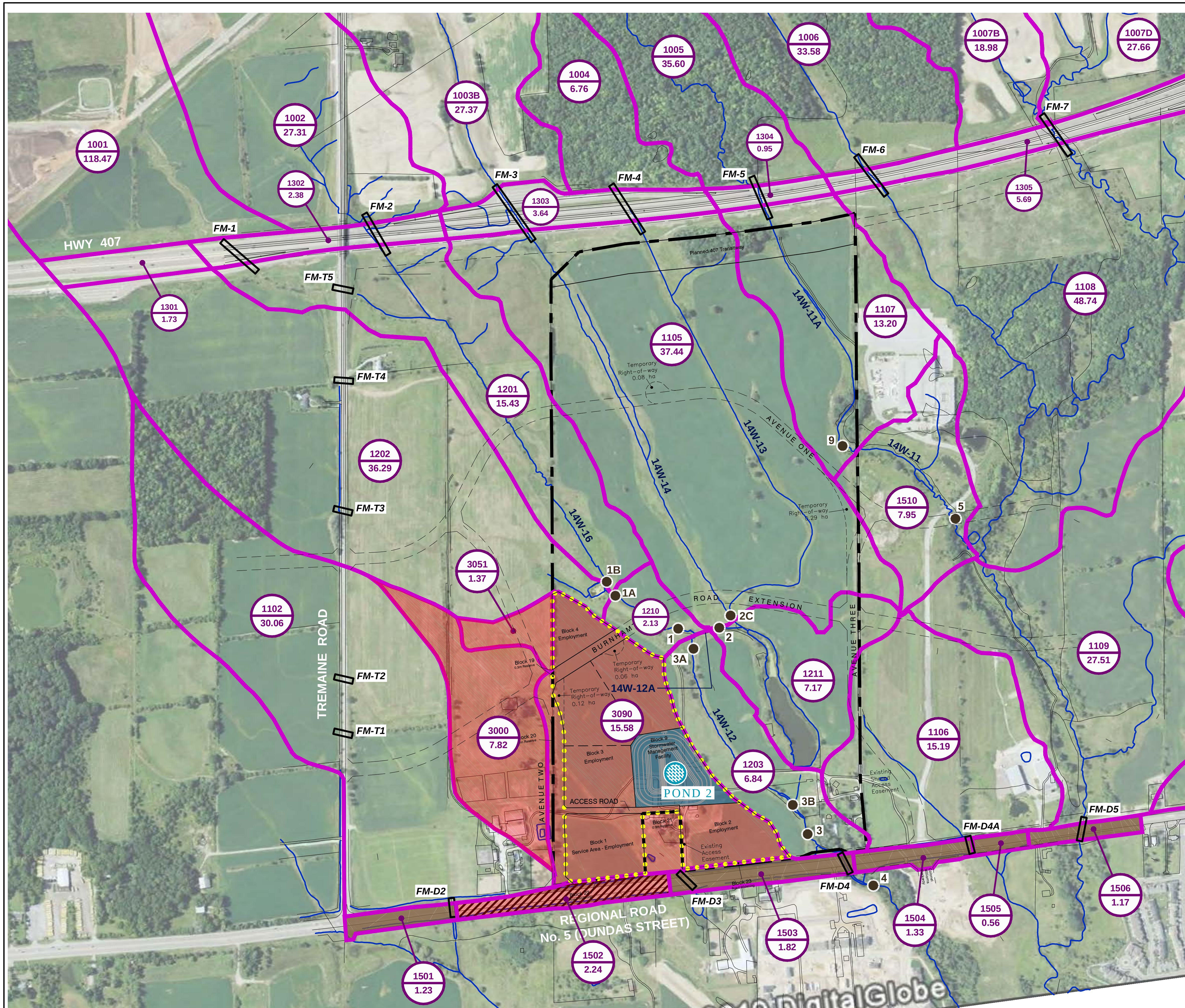
Flow Duration Curves Method

Flow Duration Curves (FDCs) are excellent hydrologic tools to identify hydrologic metrics such as Q10 (high flow range), Q50 (median flow), and Q90 (low flow range). The comparison between two FDCs representing specific scenarios such as pre-development vs. post-development or pre-regulation vs. postregulation may provide great opportunity to assess changes in flow regime expected under future conditions.

- Node 2: The flow duration curves under all development phases show a significant reduction in streamflows (except for Phase 1 where there is no impact to this node), especially for flows in the medium and high flow ranges (10% - 50% exceedance).
- Node 2B: The flow duration curves under development phases show a slight reduction in streamflows (except for Phase 1 where there is no impact to this node), especially for flows in the high flow range (10% exceedance).
- Node 9: The flow duration curves under development phases show a negligible reduction in streamflows (except for Phase 1 where there is no impact to this node).

The application of the preliminary analysis provided very useful information in terms of changes to annual and seasonal flow regime under all development phases. After using three hydrologic tools, it is apparent that the impact of development on Node 2 is unacceptable under all development phases. Besides, the results of Nodes 2B and 9 show unacceptable ecological flows for certain months. Consequently, the need to run further analysis was deemed appropriate.

Insert **Figures 7.4.1 to 5**



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Interim Phase 1A Drainage Boundaries and Reference Nodes

LEGEND

- SUBJECT PROPERTY
- SUB-CATCHMENT BOUNDARY
- EXISTING CREEK
- CULVERTS (EIR NODES)
- 3000 — SUB-CATCHMENT No.
- 7.82 — AREA (ha)
- PROPOSED SWM POND (INTERIM)
- 1 — REFERENCE NODE
- DEVELOPMENT BOUNDARY
- POND 2 DRAINAGE AREA
- SWM BLOCKS
- DUNDAS ST. CONTROLS BY ON-SITE STORAGE AND DRAINS TO DOWNSTREAM
- DUNDAS ST. DRAINS TO POND 2

Scale 1 : 7500 — 0, 100, 200, 300, 400m

Client: Bentall Kennedy

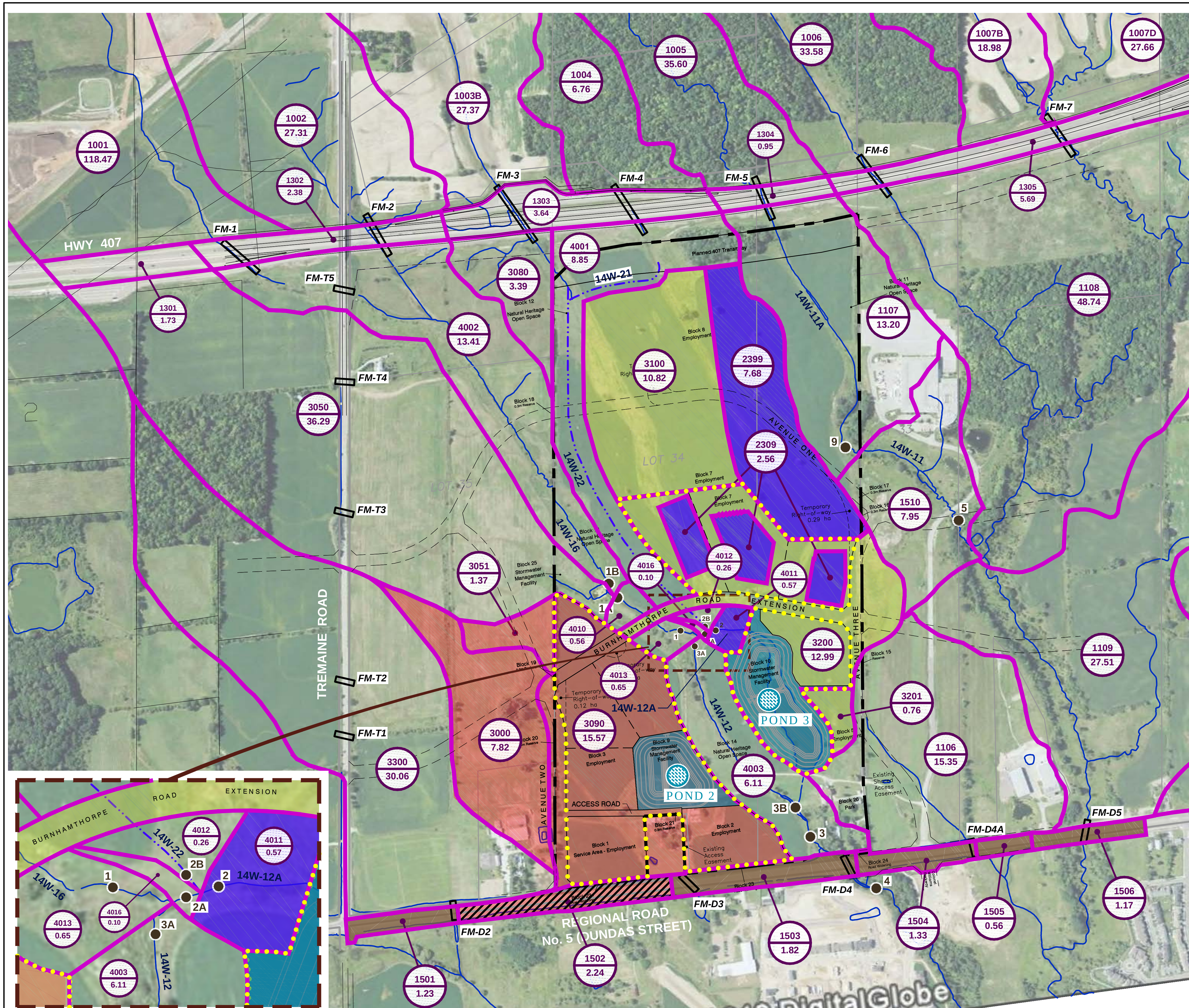
Prepared by: WSP

Date: June 2017

Project No.: 09M-00013-01-WR1

Aerial Photo: © DigitalGlobe 2010, Google 2009

Figure 7.4.2



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Interim Phase 1B Drainage Boundaries and Reference Nodes

LEGEND

- SUBJECT PROPERTY
- SUB-CATCHMENT BOUNDARY
- EXISTING CREEK
- PROPOSED REALIGNED CREEK
- CULVERTS (EIR NODES)
- SUB-CATCHMENT No. (3000) / AREA (ha) (7.82)
- PROPOSED SWM POND (INTERIM)
- REFERENCE NODE (1)
- DEVELOPMENT BOUNDARY
- POND 2 DRAINAGE AREA
- SWM BLOCKS
- DUNDAS ST. CONTROLS BY ON-SITE STORAGE AND DRAINS TO DOWNSTREAM
- DUNDAS ST. DRAINS TO POND 2
- POND 3 DRAINAGE AREA
- AREA DRAINS TO 14W-12A (REF. NODE 2)

Scale 1 : 7500 — 0 100 200 300 400m

Client: Bentall Kennedy

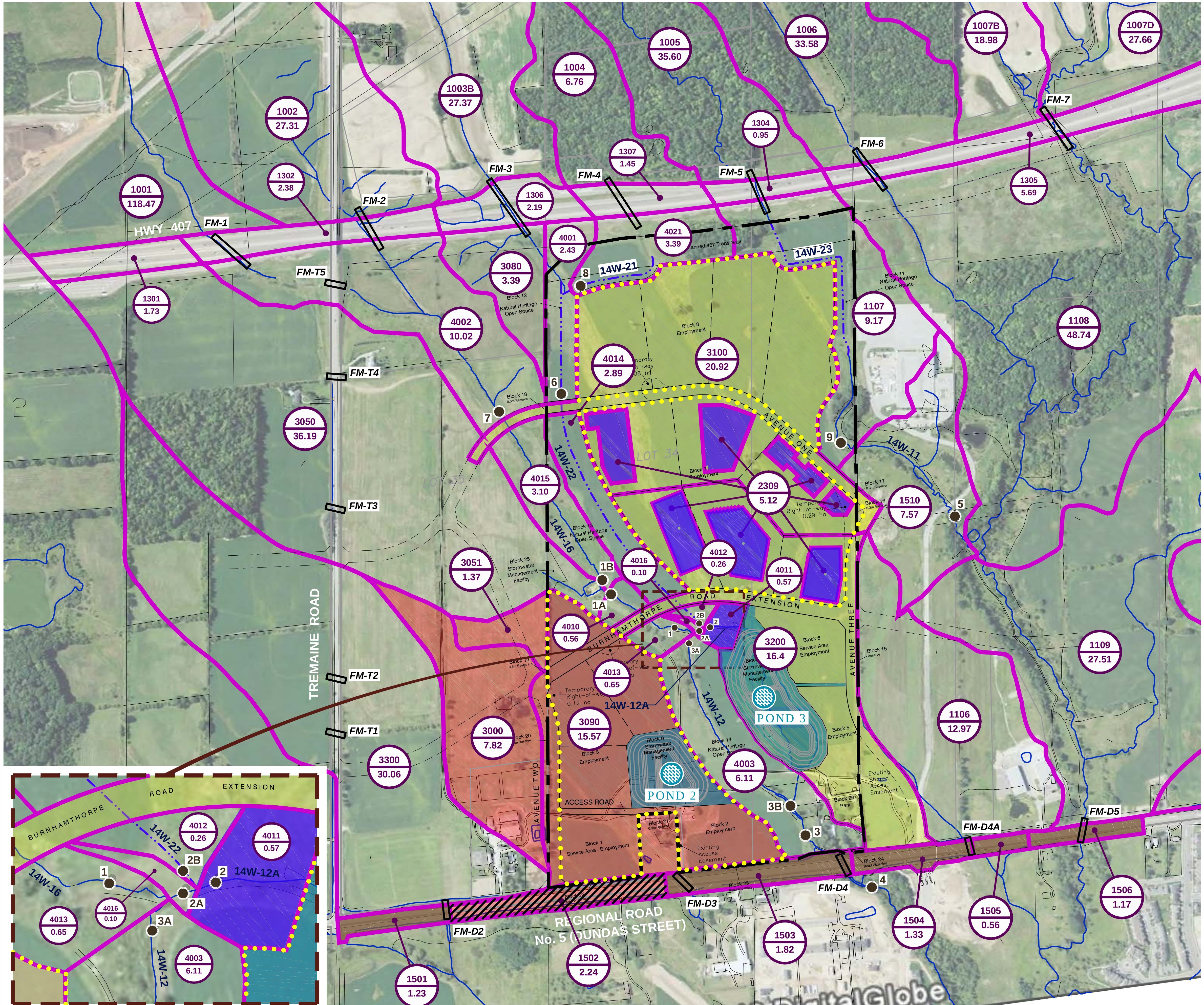
Prepared by: wsp

Date: June 2017

Project No.: 09M-00013-01-WR1

Aerial Photo: © DigitalGlobe 2010, Google 2009

Figure 7.4.3



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Interim Phase 2 Drainage Boundaries and Reference Nodes

LEGEND

- SUBJECT PROPERTY
- SUB-CATCHMENT BOUNDARY
- EXISTING CREEK
- PROPOSED REALIGNED CREEK
- CULVERTS (EIR NODES)
- SUB-CATCHMENT No. / AREA (ha) (3000 / 7.82)
- PROPOSED SWM POND (INTERIM)
- REFERENCE NODE
- DEVELOPMENT BOUNDARY
- POND 2 DRAINAGE AREA
- SWM BLOCKS
- DUNDAS ST. CONTROLS BY ON-SITE STORAGE AND DRAINS TO DOWNSTREAM
- DUNDAS ST. DRAINS TO POND 2
- POND 3 DRAINAGE AREA
- AREA DRAINS TO 14W-12A (REF. NODE 2)

Scale 1 : 7500 (0, 100, 200, 300, 400m)

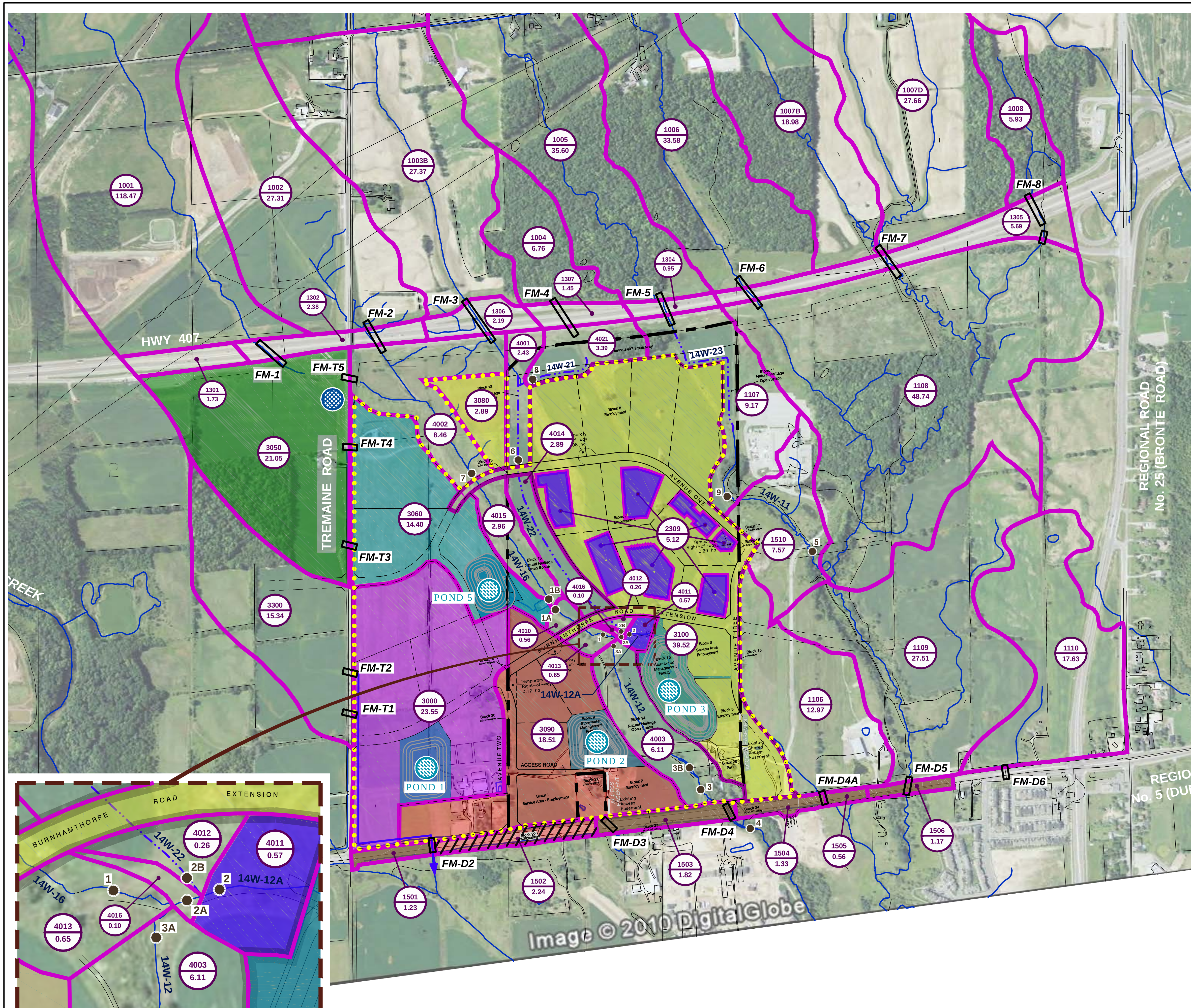
Client: Bentall Kennedy

Prepared by: WSP

Date: June 2017

Project No.: 09M-00013-01-WR1

Figure 7.4.4



Environmental Implementation Report / Functional Servicing Study for 14 Mile Creek West and the Lazy Pat Farm Property

Ultimate Drainage Boundaries and Reference Nodes

LEGEND

- SUBJECT PROPERTY
- SUB-CATCHMENT BOUNDARY
- EXISTING CREEK
- PROPOSED REALIGNED CREEK
- CULVERTS (EIR NODES)
- SUB-CATCHMENT No. (3000) / AREA (ha) (7.82)
- PROPOSED SWM POND (INTERIM)
- REFERENCE NODE
- DEVELOPMENT BOUNDARY
- POND 2 DRAINAGE AREA
- SWM BLOCKS
- DUNDAS ST. CONTROLS BY ON-SITE STORAGE AND DRAINS TO DOWNSTREAM
- DUNDAS ST. DRAINS TO POND 2
- POND 3 DRAINAGE AREA
- AREA DRAINS TO 14W-12A (REF. NODE 2)
- TREMAINE POND DRAINAGE AREA
- POND 5 DRAINAGE AREA
- POND 1 DRAINAGE AREA

Scale 1 : 10000 (0, 0.1, 0.2, 0.3, 0.4, 0.5km)

Client: Bentall Kennedy

Prepared by: wsp

Date: June 2017

Project No.: 09M-00013-01-WR1

Aerial Photo: © DigitalGlobe 2010, Google 2009

Figure 7.4.5

Node 2

Tennant Method

Total Scenario Average Flows Node 2 (CMS)										
Span	EXI	Criteria (Min)	PH1A	Situation	PH1B	Situation	PH2	Situation	ULT	Situation
Oct:March	0.007718	0.00463	0.007718	Acceptable	0.000763	Unnaceptable	0.000756	Unnaceptable	0.000756	Unnaceptable
Apr:Sept	0.005547	0.00333	0.005547	Acceptable	0.000746	Unnaceptable	0.000973	Unnaceptable	0.000973	Unnaceptable

Tessman Method

Scenario	EXI	PH1A	PH1B	PH2	ULT
Flow Node	2	2	2	2	2
GAWSER ID#	2505	2505	2516	2516	2516
AVERAGE FLOW	0.0068	0.0068	0.0008	0.0008	0.0008

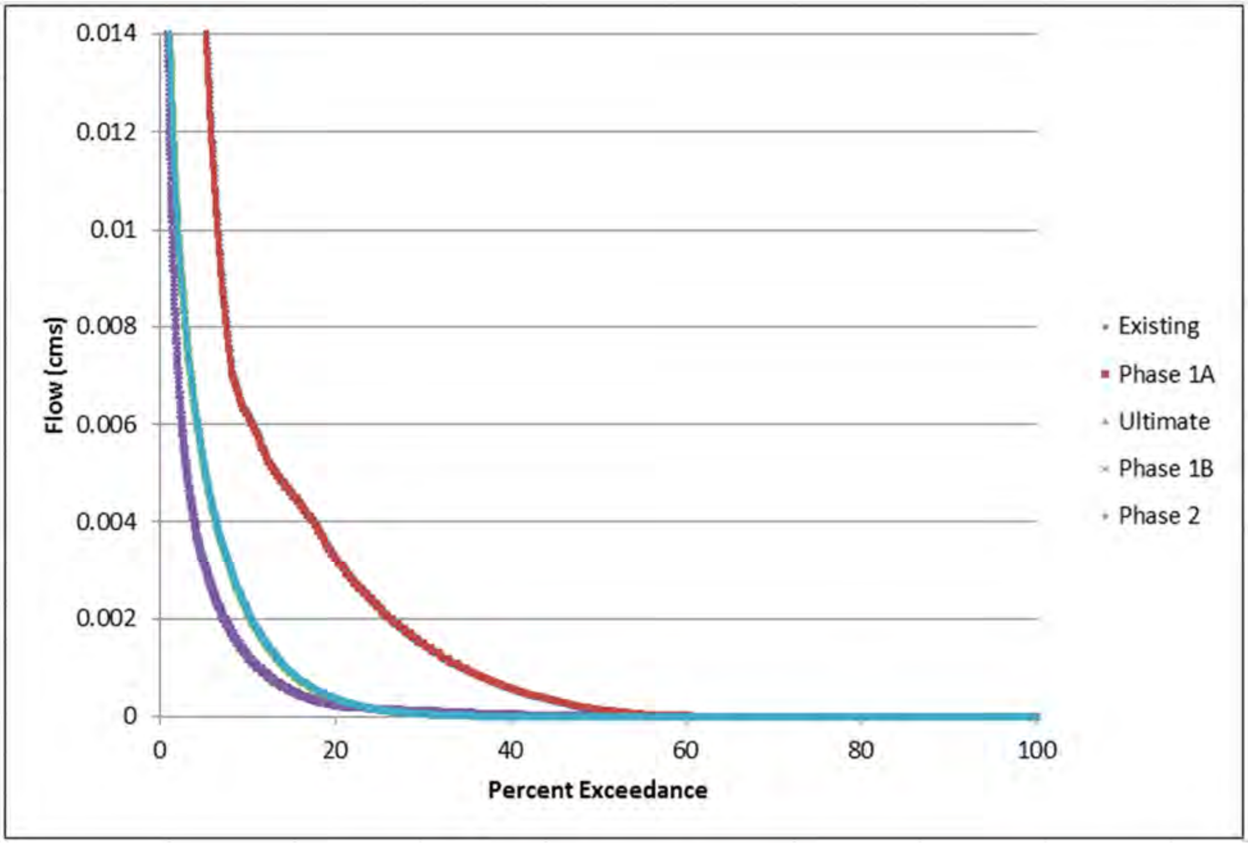
Node 2 Total Scenario Average Flows (CMS)												
			Criteria									
Span	Ex. MMF	40% MMF	Situation	Min.MF	PH1A MMF	Status	PH1B MMF	Status	PH2 MMF	Status	ULT MMF	Status
January	0.0058	0.0023	40% MAF	0.0027	0.0058	Acceptable	0.0005	Unacceptable	0.0004	Unacceptable	0.0004	Unacceptable
February	0.0087	0.0035	40% MMF	0.0035	0.0087	Acceptable	0.0007	Unacceptable	0.0005	Unacceptable	0.0005	Unacceptable
March	0.0165	0.0066	40% MMF	0.0066	0.0165	Acceptable	0.0012	Unacceptable	0.0008	Unacceptable	0.0008	Unacceptable
April	0.0115	0.0046	40% MMF	0.0046	0.0115	Acceptable	0.0010	Unacceptable	0.0009	Unacceptable	0.0009	Unacceptable
May	0.0063	0.0025	40% MAF	0.0027	0.0063	Acceptable	0.0007	Unacceptable	0.0009	Unacceptable	0.0009	Unacceptable
June	0.0028	0.0011	40% MAF	0.0027	0.0028	Acceptable	0.0006	Unacceptable	0.0008	Unacceptable	0.0008	Unacceptable
July	0.0028	0.0011	40% MAF	0.0027	0.0028	Acceptable	0.0006	Unacceptable	0.0010	Unacceptable	0.0010	Unacceptable
August	0.0045	0.0018	40% MAF	0.0027	0.0045	Acceptable	0.0008	Unacceptable	0.0012	Unacceptable	0.0012	Unacceptable
Septemeber	0.0036	0.0014	40% MAF	0.0027	0.0036	Acceptable	0.0007	Unacceptable	0.0010	Unacceptable	0.0010	Unacceptable
October	0.0025	0.0010	MMF	0.0025	0.0025	Acceptable	0.0005	Unacceptable	0.0008	Unacceptable	0.0008	Unacceptable
November	0.0062	0.0025	40% MAF	0.0027	0.0062	Acceptable	0.0008	Unacceptable	0.0009	Unacceptable	0.0009	Unacceptable
December	0.0099	0.0039	40% MMF	0.0039	0.0099	Acceptable	0.0009	Unacceptable	0.0008	Unacceptable	0.0008	Unacceptable
MAF	**0.0068**				**0.0068**		**0.0008**		**0.0008**		**0.0008**	
40% MAF	**0.0027**											
Flushing Flow	**0.0137**				**0.0137**		**0.0015**		**0.0017**		**0.0017**	

MMF= Mean Monthly Flow

MAF= Mean Annual Flow

Node 2

Flow Duration Curve Node 2



Exceedance Probability (flows in cms)					
% Exceedance	Existing	Phase 1A	Phase1B	Phase 2	Ultimate
10.0	0.0062	0.0062	0.0012	0.0021	0.0021
50.0	0.0002	0.0002	0.0000	0.0000	0.0000
90.0	0.0000	0.0000	0.0000	0.0000	0.0000

Node 2B

Tennant Method

Total Scenario Average Flows Node 2B (CMS)										
Span	EXI	Criteria (Min)	PH1A	Situation	PH1B	Situation	PH2	Situation	ULT	Situation
Oct:March	0.007376	0.00443	0.007376	Acceptable	0.006119	Acceptable	0.006098	Acceptable	0.00594	Acceptable
Apr:Sept	0.005313	0.00319	0.005313	Acceptable	0.004419	Acceptable	0.004396	Acceptable	0.00429	Acceptable

Tessman Method

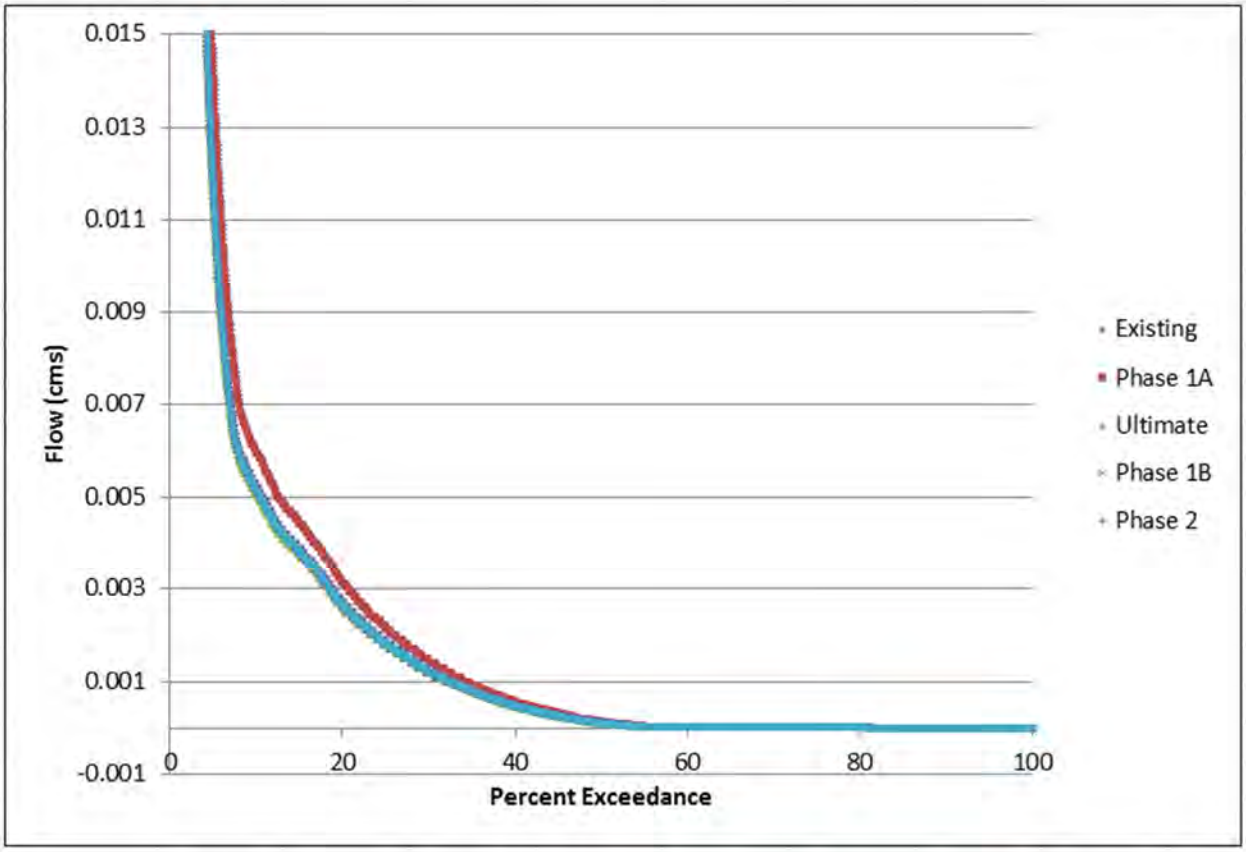
Scenario	EXI	PH1A	PH1B	PH2	ULT
Flow Node	2C	2C	2B	2B	2B
GAWSER ID#	2033	2033	2505	2505	2505
AVERAGE FLOW	0.0065	0.0065	0.0054	0.0054	0.0053

Node 2B Total Scenario Average Flows (CMS)												
			Criteria									
Span	Ex. MMF	40% MMF	Situation	Min.MF	PH1A MMF	Status	PH1B MMF	Status	PH2 MMF	Status	ULT MMF	Status
January	0.0055	0.0022	40% MAF	0.0026	0.0055	Acceptable	0.0046	Acceptable	0.0046	Acceptable	0.0045	Acceptable
February	0.0084	0.0033	40% MMF	0.0033	0.0084	Acceptable	0.0070	Acceptable	0.0070	Acceptable	0.0068	Acceptable
March	0.0158	0.0063	40% MMF	0.0063	0.0158	Acceptable	0.0132	Acceptable	0.0132	Acceptable	0.0129	Acceptable
April	0.0110	0.0044	40% MMF	0.0044	0.0110	Acceptable	0.0093	Acceptable	0.0092	Acceptable	0.0090	Acceptable
May	0.0060	0.0024	40% MAF	0.0026	0.0060	Acceptable	0.0051	Acceptable	0.0051	Acceptable	0.0050	Acceptable
June	0.0027	0.0011	40% MAF	0.0026	0.0027	Acceptable	0.0022	Unacceptable	0.0022	Unacceptable	0.0021	Unacceptable
July	0.0026	0.0011	40% MAF	0.0026	0.0026	Acceptable	0.0021	Unacceptable	0.0021	Unacceptable	0.0021	Unacceptable
August	0.0043	0.0017	40% MAF	0.0026	0.0043	Acceptable	0.0035	Acceptable	0.0035	Acceptable	0.0034	Acceptable
Septemeber	0.0034	0.0014	40% MAF	0.0026	0.0034	Acceptable	0.0027	Acceptable	0.0027	Acceptable	0.0026	Acceptable
October	0.0024	0.0009	MMF	0.0024	0.0024	Acceptable	0.0019	Unacceptable	0.0019	Unacceptable	0.0018	Unacceptable
November	0.0059	0.0024	40% MAF	0.0026	0.0059	Acceptable	0.0048	Acceptable	0.0048	Acceptable	0.0047	Acceptable
December	0.0094	0.0038	40% MMF	0.0038	0.0094	Acceptable	0.0078	Acceptable	0.0078	Acceptable	0.0076	Acceptable
MAF	**0.0065**				**0.0065**		**0.0054**		**0.0054**		**0.0053**	
40% MAF	**0.0026**											
Flushing Flow	**0.0131**				**0.0131**		**0.0109**		**0.0108**		**0.0105**	

MMF= Mean Monthly Flow
MAF= Mean Annual Flow

Node 2B

Flow Duration Curve Node 2B



% Exceedance	Existing	Phase 1A	Phase1B	Phase 2	Ultimate
10	0.0060	0.0060	0.0052	0.0052	0.0051
50	0.0001	0.0001	0.0001	0.0001	0.0001
90	0.0000	0.0000	0.0000	0.0000	0.0000

Node 9

Tennant Method

Total Scenario Average Flows Node 9 (CMS)										
Span	EXI	Criteria (Min)	PH1A	Situation	PH1B	Situation	PH2	Situation	ULT	Situation
Oct:March	0.001928	0.00116	0.001928	Acceptable	0.001928	Acceptable	0.001718	Acceptable	0.001718	Acceptable
Apr:Sept	0.001545	0.00093	0.001545	Acceptable	0.001545	Acceptable	0.001392	Acceptable	0.001392	Acceptable

Tessman Method

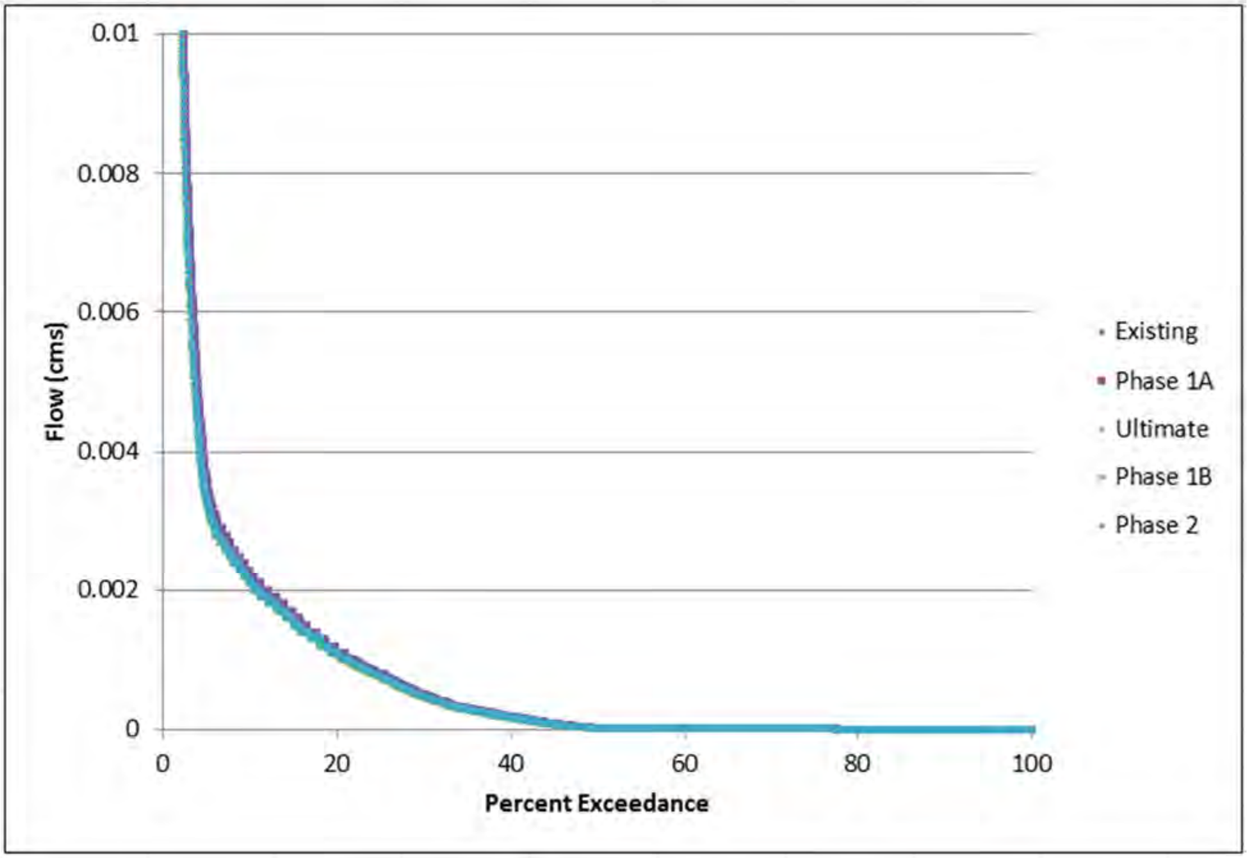
Scenario	EXI	PH1A	PH1B	PH2	ULT
Flow Node	9	9	9	9	9
GAWSER ID#	2710	2710	2710	2710	2710
AVERAGE FLOW	0.0018	0.0018	0.0018	0.0016	0.0016

Node 9 Total Scenario Average Flows (CMS)												
			Criteria									
Span	Ex. MMF	40% MMF	Situation	Min.MF	PH1A MMF	Status	PH1B MMF	Status	PH2 MMF	Status	ULT MMF	Status
January	0.0014	0.0006	40% MAF	0.0007	0.0014	Acceptable	0.0014	Acceptable	0.0013	Acceptable	0.0013	Acceptable
February	0.0022	0.0009	40% MMF	0.0009	0.0022	Acceptable	0.0022	Acceptable	0.0020	Acceptable	0.0020	Acceptable
March	0.0043	0.0017	40% MMF	0.0017	0.0043	Acceptable	0.0043	Acceptable	0.0039	Acceptable	0.0039	Acceptable
April	0.0032	0.0013	40% MMF	0.0013	0.0032	Acceptable	0.0032	Acceptable	0.0029	Acceptable	0.0029	Acceptable
May	0.0020	0.0008	40% MMF	0.0008	0.0020	Acceptable	0.0020	Acceptable	0.0018	Acceptable	0.0018	Acceptable
June	0.0008	0.0003	40% MAF	0.0007	0.0008	Acceptable	0.0008	Acceptable	0.0007	Acceptable	0.0007	Acceptable
July	0.0007	0.0003	40% MAF	0.0007	0.0007	Acceptable	0.0007	Acceptable	0.0006	Unacceptable	0.0006	Unacceptable
August	0.0011	0.0004	40% MAF	0.0007	0.0011	Acceptable	0.0011	Acceptable	0.0010	Acceptable	0.0010	Acceptable
Septemeber	0.0009	0.0003	40% MAF	0.0007	0.0009	Acceptable	0.0009	Acceptable	0.0007	Acceptable	0.0007	Acceptable
October	0.0006	0.0002	MMF	0.0006	0.0006	Acceptable	0.0006	Acceptable	0.0005	Unacceptable	0.0005	Unacceptable
November	0.0015	0.0006	40% MAF	0.0007	0.0015	Acceptable	0.0015	Acceptable	0.0013	Acceptable	0.0013	Acceptable
December	0.0024	0.0009	40% MMF	0.0009	0.0024	Acceptable	0.0024	Acceptable	0.0021	Acceptable	0.0021	Acceptable
MAF	0.0018				0.0018		0.0018		0.0016		0.0016	
40% MAF	0.0007											
Flushing Flow	0.0036				0.0036		0.0036		0.0032		0.0032	

MMF= Mean Monthly Flow
MAF= Mean Annual Flow

Node 9

Flow Duration Curve Node 9



Exceedance Probability (flows in cms)					
% Exceedance	Existing	Phase 1A	Phase1B	Phase 2	Ultimate
10	0.0022	0.0022	0.0022	0.0021	0.0021
50	0.0000	0.0000	0.0000	0.0000	0.0000
90	0.0000	0.0000	0.0000	0.0000	0.0000

Detailed Analysis Results and Discussion

Following the application of the preliminary analysis, we found that further analysis was needed to evaluate the acceptability of streamflows within Nodes 2, 2B, and 9. This detailed assessment is related to the anticipated changes to flow associated with each flow node (Reach) is discussed below. Although the hydrologic assessment was done on monthly basis for three typical years, the discussion below centers on the specific period of April and May related to Redside Dace. This period was presumably selected as it is typically the period of greatest potential functionality for these intermittent / ephemeral habitats for this period. This period is within a typical period of "sensitivity" due this species spawning period, however; it should be noted that if flow is present, these reaches are unlikely to provide spawning habitat for Redside Dace given the absence of required habitat (i.e. morphology, substrate, structure) and thus the function is limited to contributions to downstream conveyance. The remainder of the year these reaches are unlikely to be inhabited by Redside Dace and only opportunistically (inconsistently) used by other species if/when sufficient flows are present to provide passage from downstream populations and flow to maintain habitat.

As part of analyzing monthly flows during typical hydrologic years, the following flow regime criteria were used:

1. Timing – refers to the seasonal cycle as to when flows will be present in the reach and will potential changes in flow occur in relation to existing conditions.

2. Frequency – Refers to the number of peaks associated with a storm event that occurs within a given period of time. Specifically, will the change in flow resulting from the proposed development exhibit fewer peaks thus have an effect on the ecological function?

3. Duration – Refers to the period of time associated with a specific flow condition. Specifically, will a reduced duration of flow from the proposed development occur and thus have an effect on the ecological function.

4. Magnitude – Refers to peak flow rates and volumes. Specifically, will a reduction in the magnitude of flow from the proposed development occur and thus have an effect on the ecological function?

In order to analyze the four criteria of the flow regime, three years representative of dry, wet and average years within the full record were investigated, namely,

- Dry Year: The year 1963: 370 mm
- Wet Year: The year 1992: 956 mm
- Average Year: The year 1972: 687 mm

The monthly hydrographs for each typical year are shown at the end of this memorandum, with summary tables including magnitude, frequency, timing, and duration for each month, under all development phases.

Node 9 (Reach 14W-23)

Timing
Timing of the flows is considered "Acceptable" according to the Tennant Method, Tessman Method and Flow Duration Curve assessments for all development phases throughout the year, including April to May. Thus the function of this reach in relation to this criterion is anticipated to be maintained.

Frequency and Duration
The frequency and duration of flow will remain largely unchanged from the existing condition during all months, including April and May. As such, the ecological function of the proposed reach is not anticipated to be impacted by duration or frequency.

Magnitude
The magnitude of flow indicates a reduction in the flow rate (ranging from 15%-20%) under all phases of the development, which is an acceptable range of change, since the wetted perimeter and continuity of flow downstream will be covered in all cases (refer to cross sections conveying 2-year and 5-year flows, extracted from the HEC RAS model covering the Subject Property). As such, anticipated water depth in the new channel for the 2-year and the 5-year flows will be 25 cm and 30 cm under compared to 15 cm and 20 cm under existing conditions, with the advantage of having natural channel design characteristics (i.e. riffles, pools, low flow channel) under proposed conditions.

Summary
The ecological assessment of the reduced flow rate has indicted that only a reduction in magnitude will occur. Although there is a reduction in the flow rate impacting magnitude, the 2-year and the 5-year flows under all development phases will be suitable for fish and for benthic macroinvertebrates, and the reach will continue to function in a similar manner to the existing conditions. In addition, the realignment of a section of Reach 14W-11A to create a new channel based on natural channel design principles will result in a variety of morphological features, which will provide greater habitat diversity for fish and benthic macroinvertebrates while providing contributions to downstream habitat during the "Sensitive Period" to Redside Dace.

Node 2 (Reach 14-12A)

Node 2 is located within Reach 14W-12A upstream of the confluence with Reach 14W-22 (Realigned Reaches 14W-13 and 14W-14). The exact location of the confluence of Reach 14W-12A and Reach 14W-22 has not been determined at this time given the scope of the EIR/FSS and will be determined at the detail design stage of the project. Instead it has been deemed feasible that the confluence be located within a range of the 5 to 20 m upstream from the confluence with Reach 14W-12 resulting in the assessment of approximately 100 m of Reach 14W-12A (Node 2) due to reduced flows.

Timing
Timing of the flows is considered "Acceptable" according to the Tennant Method, Tessman Method and Flow Duration Curve assessments for all development phases during April to May. Thus the function of this reach in relation to this criterion is anticipated to be maintained during this period.

Duration and Frequency

The results of the flow assessment indicate that the frequency of the flow present will remain largely unchanged from the existing condition. However, the duration of monthly flows is expected to increase (as shown in the enclosed hydrographs).

Magnitude

With the exception of Phase 1A, the magnitude of flow is significantly reduced under all phases. Even though there is significant reduction in flow rates, we found that the range of peak flows during sensitive months such as April and May, in addition to the 2-year and 5-year return period flows, under all development phases are capable of inundating the channel and maintaining flow continuity through the reach. The enclosed figures of HEC RAS cross sections show that flows such as 0.005 cms (approximately mean annual flow) and 0.015 cms occupy flow depth from four to 8 cm of channel bottom width under proposed conditions.

In order to confirm, the findings from the fluvial geomorphic investigation of Reach 14W-12A (submitted as part of the Hydrologic Model Interim Report, May 2016) were used in a hydraulic assessment (HEC RAS model) of the reach.

The following peak flows were incorporated in the HEC RAS model: 0.005 m^3/s, 0.025 m^3/s, 2-year flow, and 5-year flow under all proposed development phases. Based on the results shown in the HEC RAS summary table (**Appendix 6.1**), flow continuity is maintained under proposed development conditions. Specifically, under lower flows such as 0.005 cms and 0.015, we found that flow depths are very similar under existing and proposed conditions (all phases). Under 2-year and 5-year flows, it is noticed that there is reduced capacity, however flow continuity and flushing flows are maintained. More specifically water surface elevations and flow velocities are sufficient to maintain flow through the reach and capable of eroding fine sands according to the enclosed Hjulstrom Curve, which satisfies flushing flow criteria for this reach. More specifically, since flows that would flush superficial sediment may be needed for ecological purposes, we applied Hjulstrom curve to determine if the velocities identified under each peak flow could erode surficial sediment and provide for suitable feeding habitat and living space. The Hjulstrom curve shows that the velocities determined under the proposed conditions peak flows are all capable of flushing fine to medium sand (velocities > 0.24 m/s).

Although there is a significant decrease in flow within this reach, there will be a continued maintenance of limited ecological function. That being said, the function of this reach in general is limited in the existing condition due to its modified nature, intermittent flows and lack of habitat diversity for aquatic species that may opportunistically use this section of the Reach 14W-12A.

Summary

The ecological assessment of the reduced flow rate has indicted that only a reduction in magnitude will occur. Although this decrease is significant from the existing conditions, the amount of flow present will still ensure a wetted channel to maintain ecological functions of Reach 14W-12A on monthly basis.

Given that the primary function of this approximately 100 m section of the reach that will be altered is as downstream conveyance and contribution, the potential effect associated with the reduced flow rate to downstream habitat and communities are anticipated to be addressed through the design of the realigned channel (Reach 14W-22). This constructed feature on its own has limited productivity and function and, as such, the effect is anticipated to be addressed by the benefits that will be created by the natural channel design principles, specifically the variety of morphological features and substrates, which will provide greater habitat diversity for fish and benthic macroinvertebrates. Furthermore, the flow associated with this new channel, will convey a similar amount as associated with Reach 14W-13 and Reach 14W-14 to Reach 14W-12 continuing to contribute flow to Redside Dace during the “Sensitive Period”. Details of the realigned channel as discussed in greater detail below.

Node 2B (Reach 14W-22)

This flow node is associated with the realigned and redirected Reach 14W-13 and Reach 14W-14 thus there are no existing condition for Node 2B, instead the existing condition is represented by the flows for Node 2C (confluence of Reach 14W-13 and Reach 14W-14).

Timing
Timing of the flows is considered “Acceptable” according to the Tennant Method, Tessman Method and Flow Duration Curve assessments for all development phases during April to May. Thus the function of this reach in relation to this criterion is anticipated to be maintained during this period.

Frequency and Duration
The frequency and duration of flow will remain largely unchanged from the existing condition. As such, the ecological function of Reach 14W-22 is not anticipated to be impacted by duration or frequency.

Magnitude
The magnitude of flow indicates a reduction in the flow rate (ranging from 15%-20%) under all phases of the development. Although the rate of flow will be reduced, the wetted perimeter and continuity of flow downstream are not anticipated to change substantially, and thus the amount of wetted habitat will likely remain similar and the reach continue to function in a similar fashion to the existing conditions (refer to cross sections conveying 2-year and 5-year flows, extracted from the HEC RAS model covering the Subject Property). As such, anticipated water depth in the new channel for the 2-year and the 5-year flows will be in the range of 20 to 30 cm under existing and proposed conditions, with additional advantage of having natural channel design characteristics (i.e. riffles, pools and low flow channel) under proposed conditions.

Fluvial Geomorphic Considerations

In order to examine the impact of development on erosion processes at Nodes 2, 2B, and 9, we chose to apply the Flow Duration Curves rather than Tennant and/or Tessman. The main reason is primarily based on the stronger foundation of Flow Duration Curves since they represent a full hydrologic record (30 years in this case) and could easily show the impact of development on hydrologic metrics such as Q_{10}, Q_{50}, and Q_{90}. In that regard, previous subwatershed and monitoring studies (e.g. The Humber River Watershed Scenario Modelling and Analysis Report, TRCA and the Eastern Subwatersheds SWM Retrofit Study, City of Ottawa) dealing with the impact of urban development on channel morphology and stream erosion cited the 10% exceedance flow significant increases or decreases (> 20%) as an indicator of changes to sediment entrainment, transport, and deposition regimes within a channel.

Table 7. 10% Exceedance Flows as Geomorphic Condition Criteria

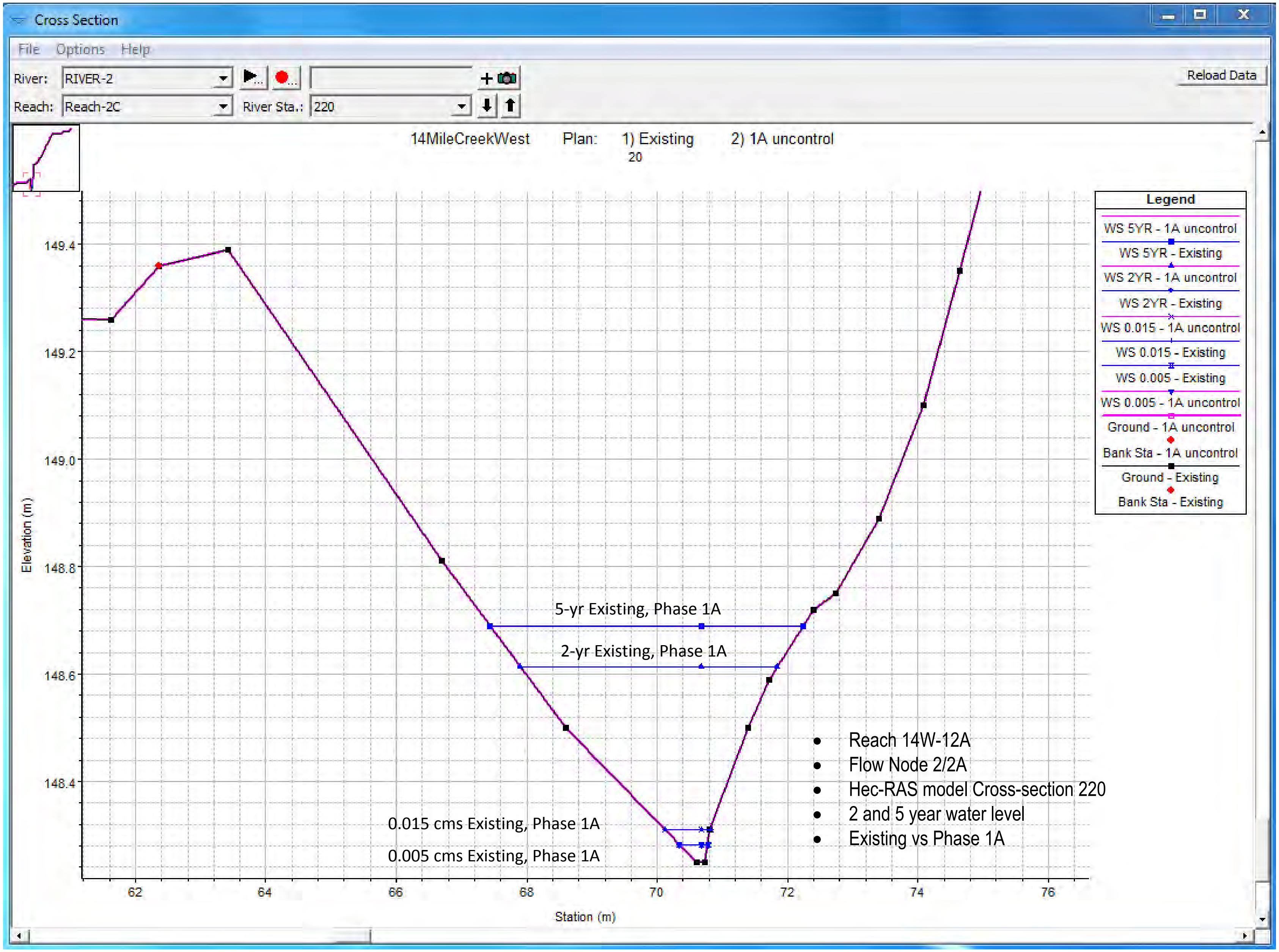
% Exceedance	Node 2	Node 2B	Node 9
Existing	0.0062	0.0060	0.0022
Phase 1A	0.0062	0.0052	0.0022
Phase 1B	0.0012	0.0052	0.0022
Phase 2	0.0021	0.0052	0.0021
Ultimate	0.0021	0.0051	0.0021

For Nodes 2B and Node 9, the impact of the proposed development ranges between 5% (Node 9) and 15% (Node 2B) of the 10% exceedance flows under existing conditions, which is not significant to alter the fluvial geomorphic regime within the two channels. However, the changes at Node 2 seem considerable. This variation in flows is addressed as part of the Erosion Threshold Analysis and Erosion Control Analysis at Node 3 located on 14W-12 (Chapter 7 in the EIR/FSS report).

Flushing Flows Considerations

Within the Subject Property, the analysis of fluvial geomorphic functions in terms of erosion and deposition is primarily discussed as part of the analysis of Reach 14W-12, including erosion control analysis (Section 7), in addition to the discussion above concerning 10% exceedance flows.

It should be noted that fluvial geomorphic functions in terms of erosion and deposition should not be confused with flushing flows proposed as part of the Tennant and/or Tessman methods. Specifically, erosion and deposition processes discussed in this section and under the erosion control analysis for 14W-12 are concerned with high flows in the range of Bankfull Flows and above. Flushing flows proposed as part of Tennant and/or Tessman methods are primarily concerned with low and medium flows in the range of 2 x Mean Annual Flows (Table 5), and this Tessman definition is the one used to assess flows for 14W-12A since it is relevant for allochthonous conveyance. Therefore, flows between 0.005 and 0.015 cms were used for this purpose on Node 2, Node 2B, and Node 9.



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Reach: Reach-2C
River Sta.: 220
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20
Legend
WS 5YR - 1A uncontrol
WS 5YR - Existing
WS 2YR - 1A uncontrol
WS 2YR - Existing
WS 0.015 - 1A uncontrol
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 1A uncontrol
Ground - 1A uncontrol
Bank Sta - 1A uncontrol
Ground - Existing
Bank Sta - Existing
5-yr Existing, Phase 1A
2-yr Existing, Phase 1A
0.015 cms Existing, Phase 1A
0.005 cms Existing, Phase 1A
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 220
2 and 5 year water level
Existing vs Phase 1A
Elevation (m)
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149.0
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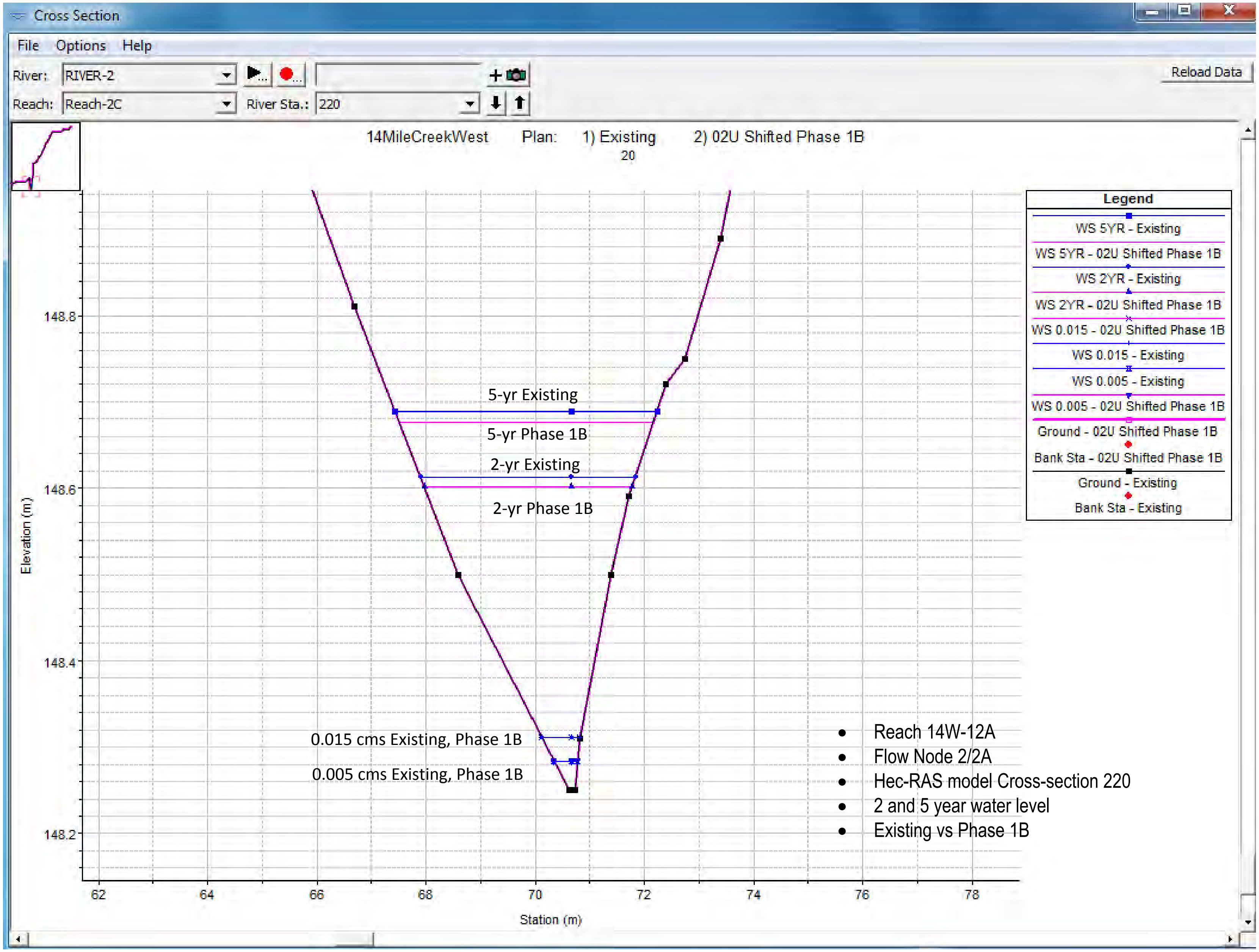
148.6
148.4
Station (m)
62
64
66
68
70
72
74
76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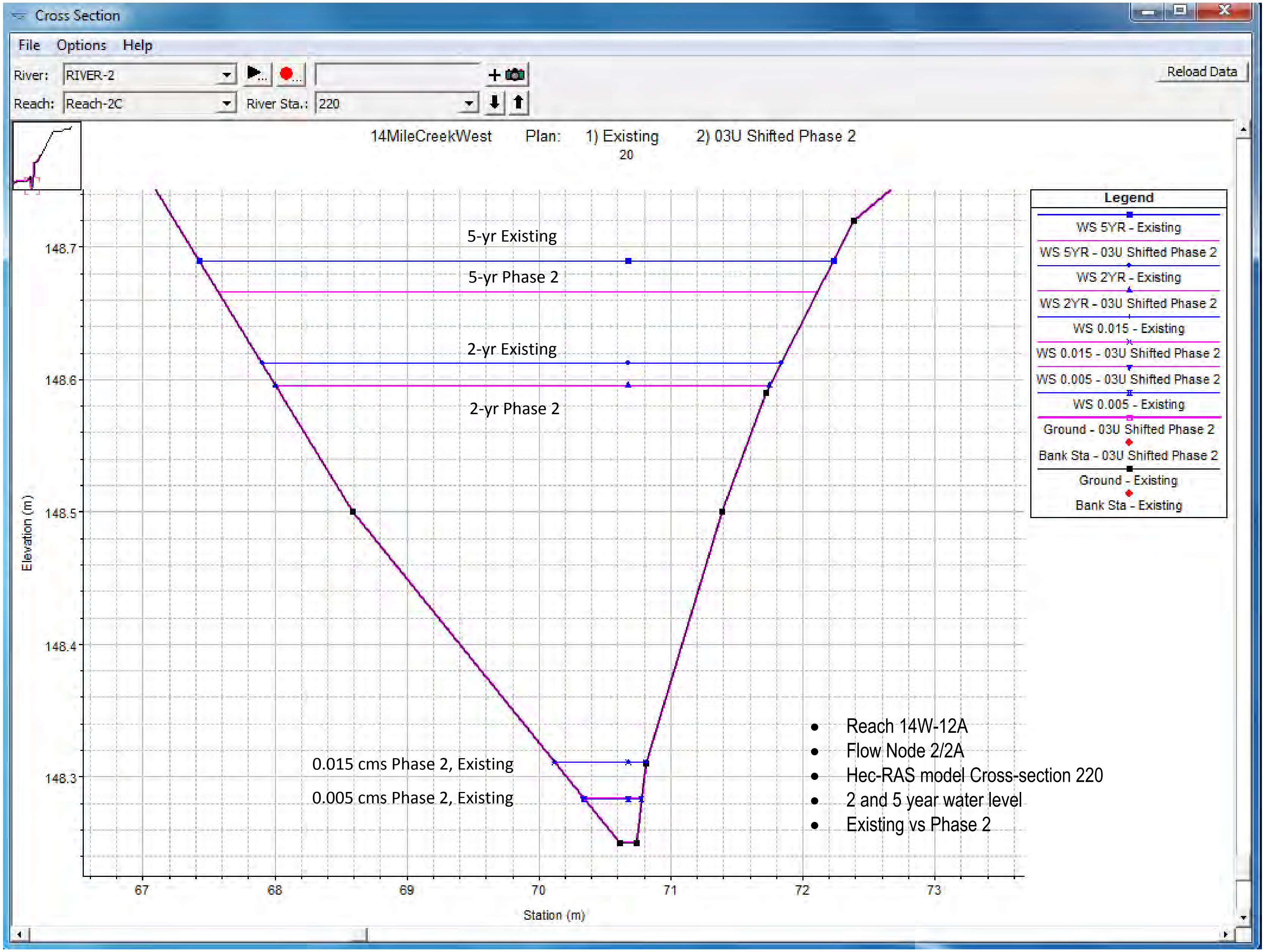
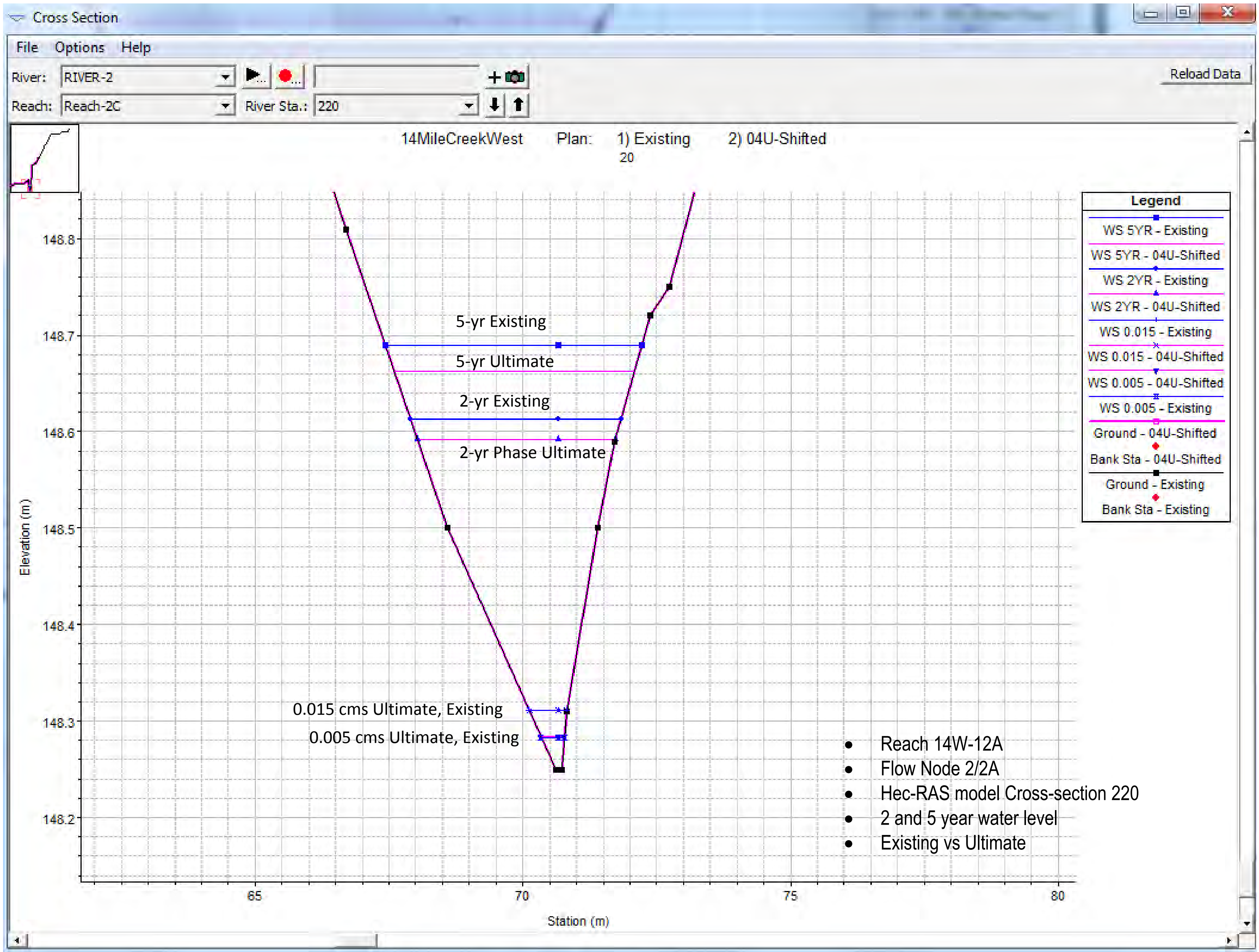
20
Legend
WS 5YR - Existing
WS 5YR - 02U Shifted Phase 1B
WS 2YR - Existing
WS 2YR - 02U Shifted Phase 1B
WS 0.015 - 02U Shifted Phase 1B
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 02U Shifted Phase 1B
Ground - 02U Shifted Phase 1B
Bank Sta - 02U Shifted Phase 1B
Ground - Existing
Bank Sta - Existing
5-yr Existing
5-yr Phase 1B
2-yr Existing
2-yr Phase 1B
0.015 cms Existing, Phase 1B
0.005 cms Existing, Phase 1B
Elevation (m)
148.8
148.6
148.4
148.2
Station (m)
62
64
66
68
70
72
74
76
78
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 220
2 and 5 year water level
Existing vs Phase 1B



- Reach 14W-12A
- Flow Node 2/2A
- Hec-RAS model Cross-section 220
- 2 and 5 year water level
- Existing vs Phase 2



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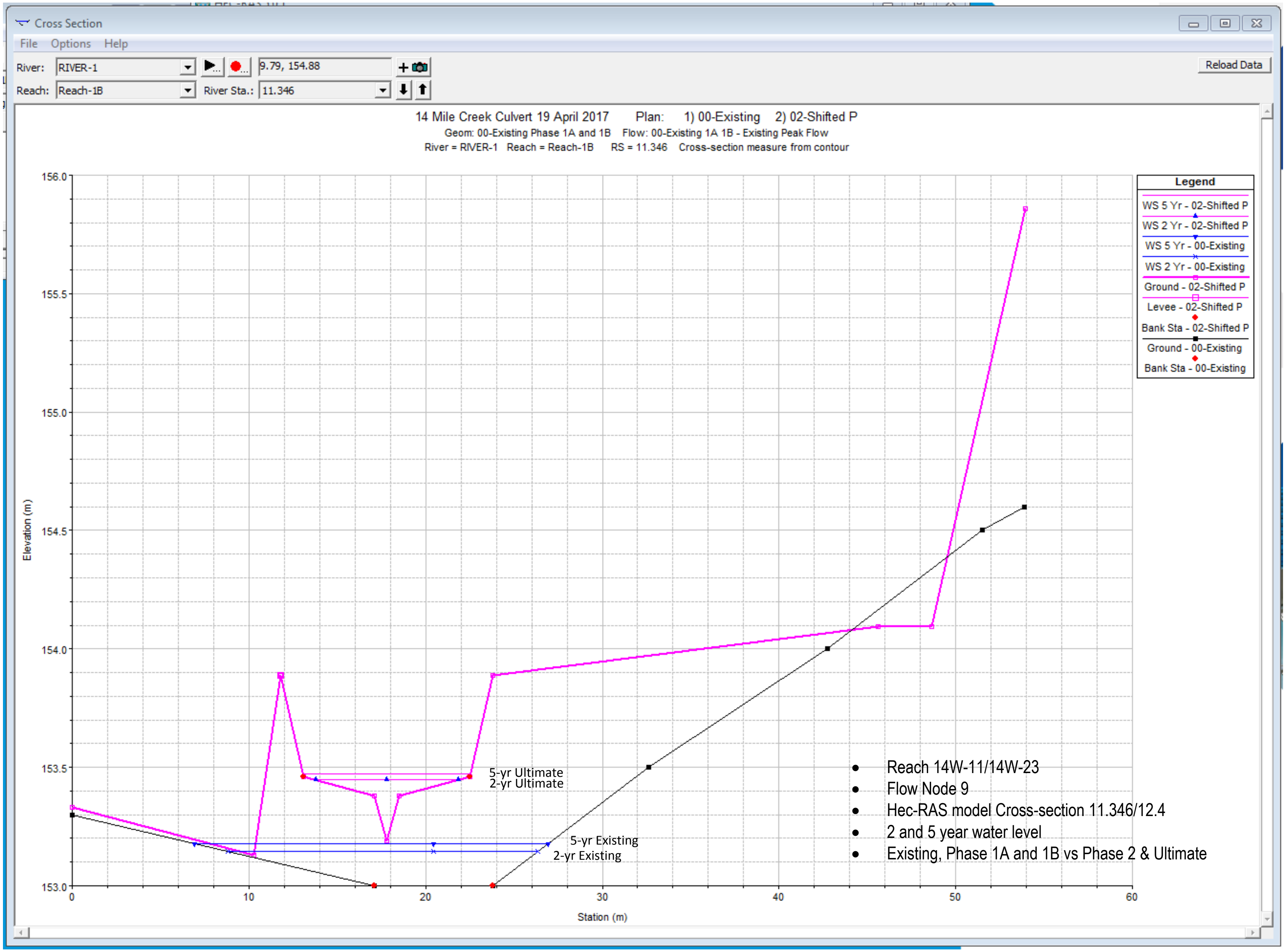

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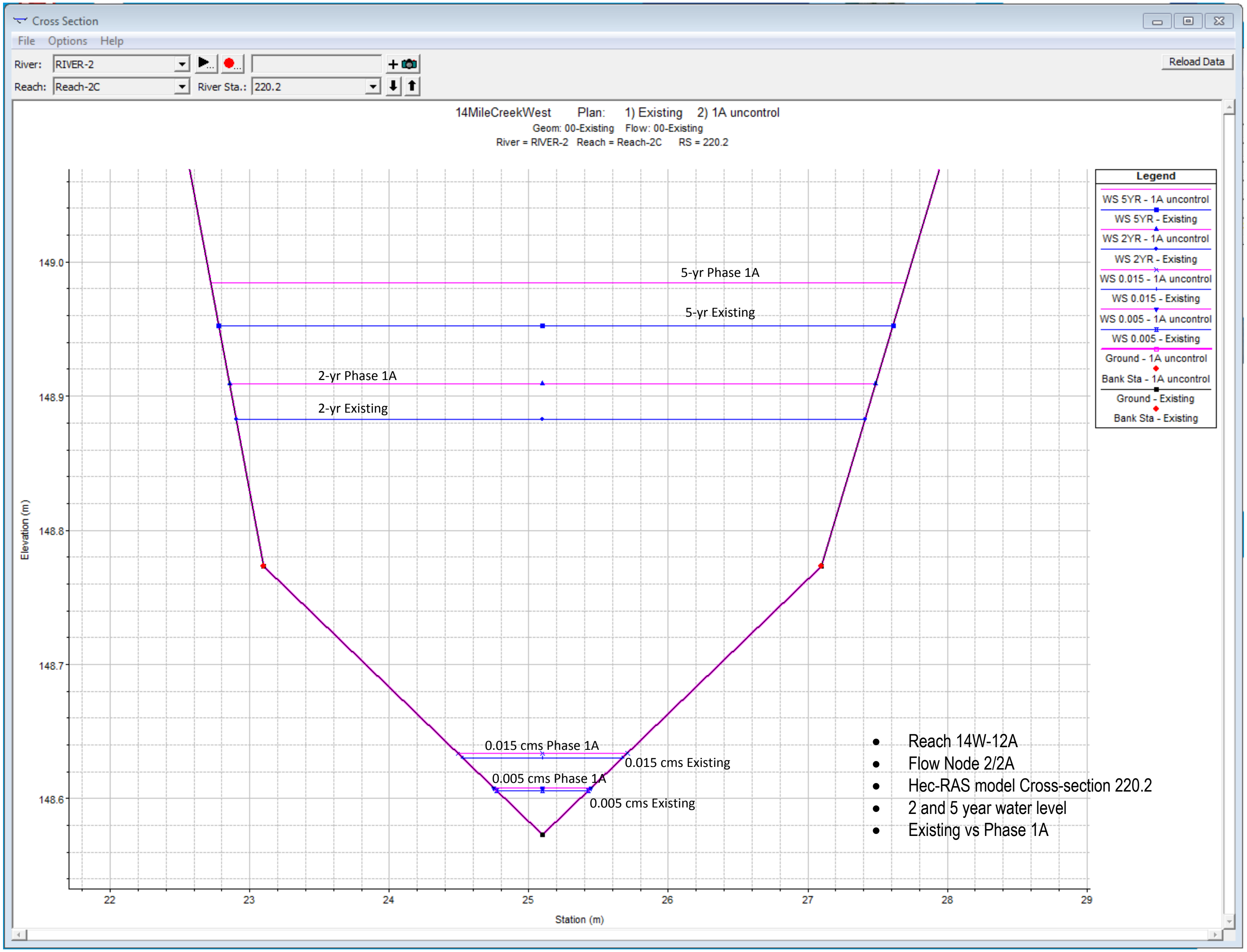
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Legend
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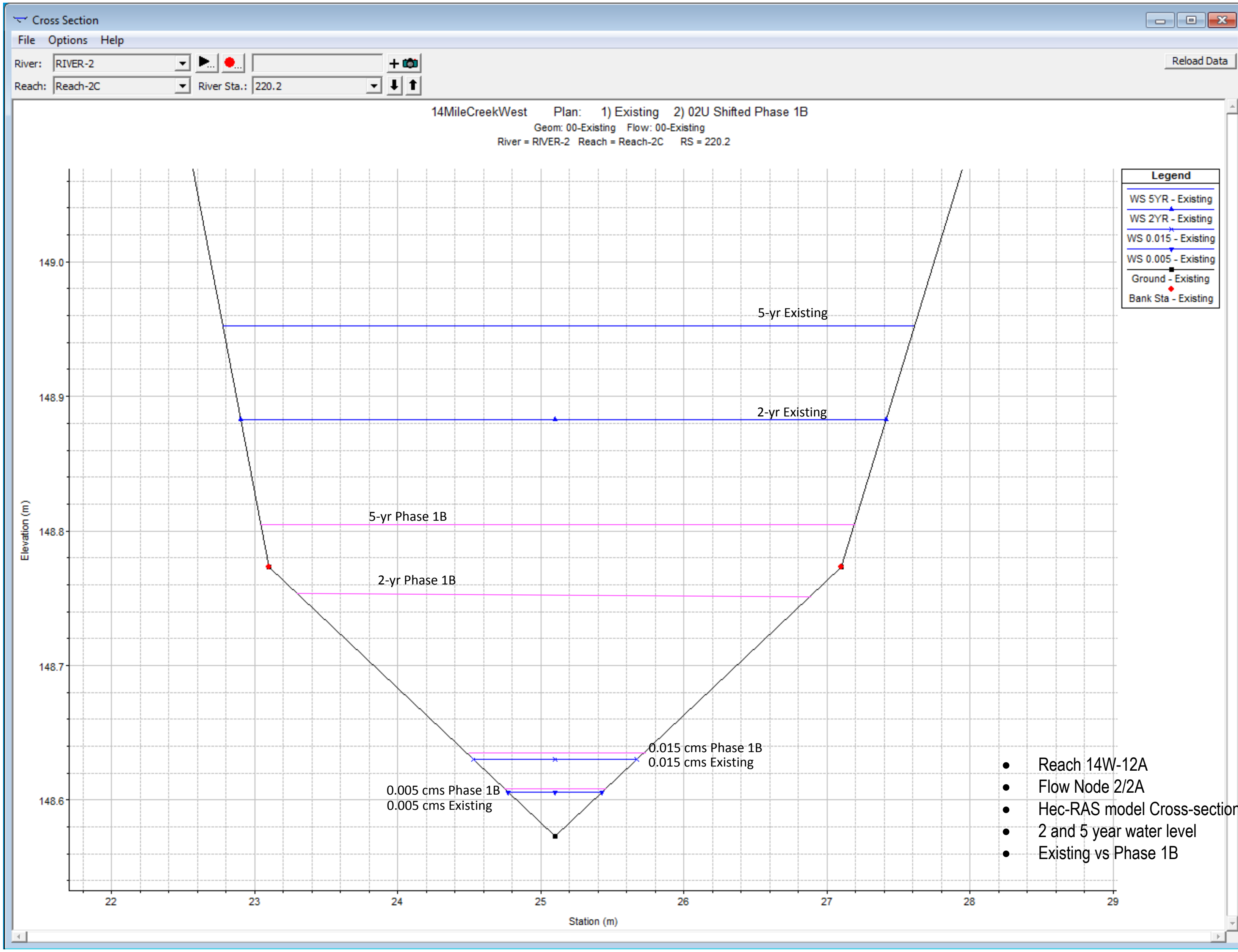
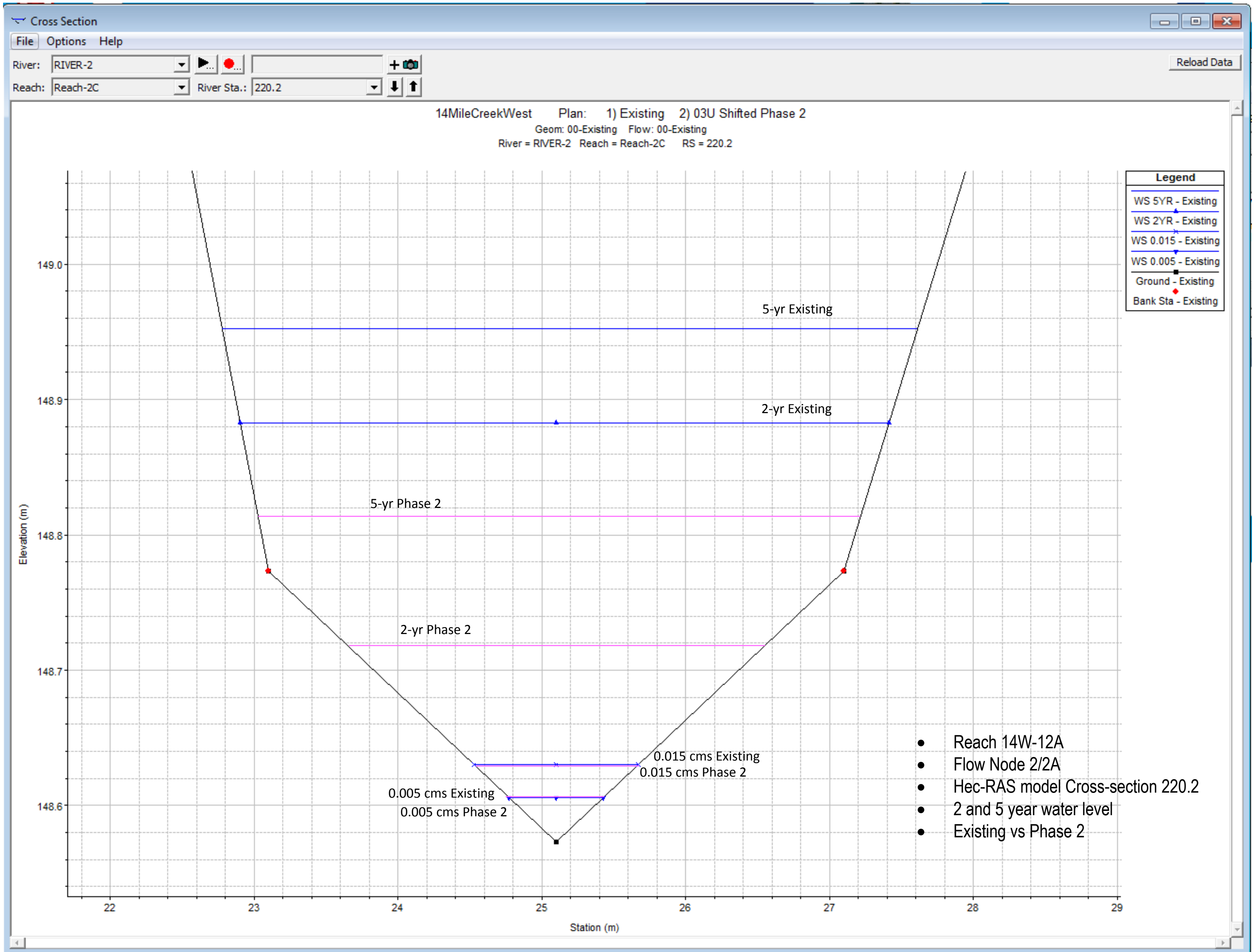
WS 5YR - Existing
WS 2YR - 1A uncontrol
WS 2YR - Existing
WS 0.015 - 1A uncontrol
WS 0.015 - Existing
WS 0.005 - 1A uncontrol
WS 0.005 - Existing
Ground - 1A uncontrol
Bank Sta - 1A uncontrol
Ground - Existing
Bank Sta - Existing
5-yr Phase 1A
5-yr Existing
2-yr Phase 1A
2-yr Existing
0.015 cms Phase 1A
0.015 cms Existing
0.005 cms Phase 1A
0.005 cms Existing
Elevation (m)
Station (m)
149.0
148.9
148.8
148.7
148.6
22
23
24
25
26
27
28
29
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 220.2
2 and 5 year water level
Existing vs Phase 1A



- Reach 14W-12A
- Flow Node 2/2A
- Hec-RAS model Cross-section 220.2
- 2 and 5 year water level
- Existing vs Phase 1B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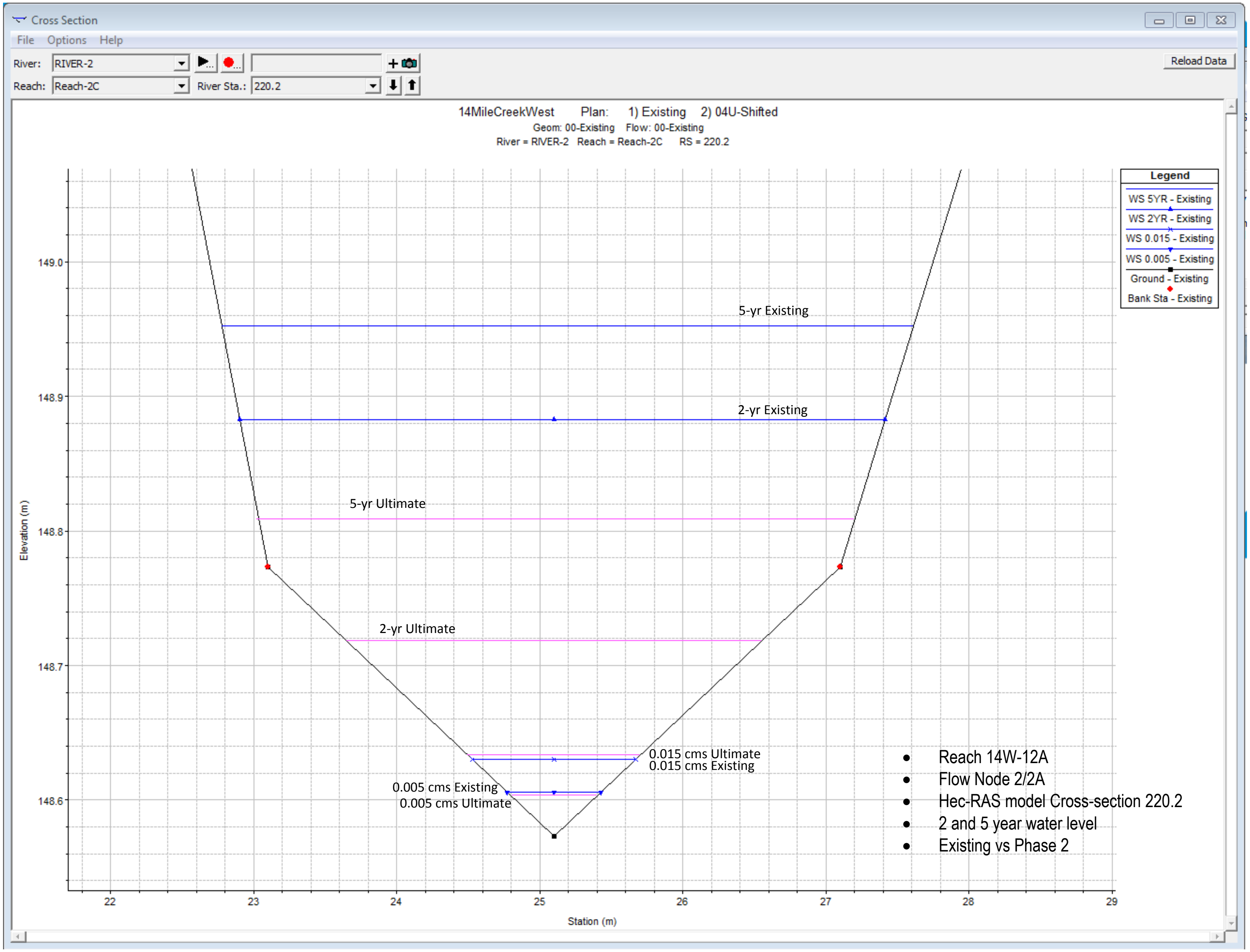
WS 2YR - Existing
WS 0.015 - Existing
WS 0.005 - Existing
Ground - Existing
Bank Sta - Existing
5-yr Existing
2-yr Existing
5-yr Phase 2
2-yr Phase 2
0.015 cms Existing
0.015 cms Phase 2
0.005 cms Existing
0.005 cms Phase 2
Elevation (m)
149.0
148.9
148.8
148.7
148.6
Station (m)
22
23
24
25
26
27
28
29
• Reach 14W-12A
• Flow Node 2/2A
• Hec-RAS model Cross-section 220.2
• 2 and 5 year water level
• Existing vs Phase 2



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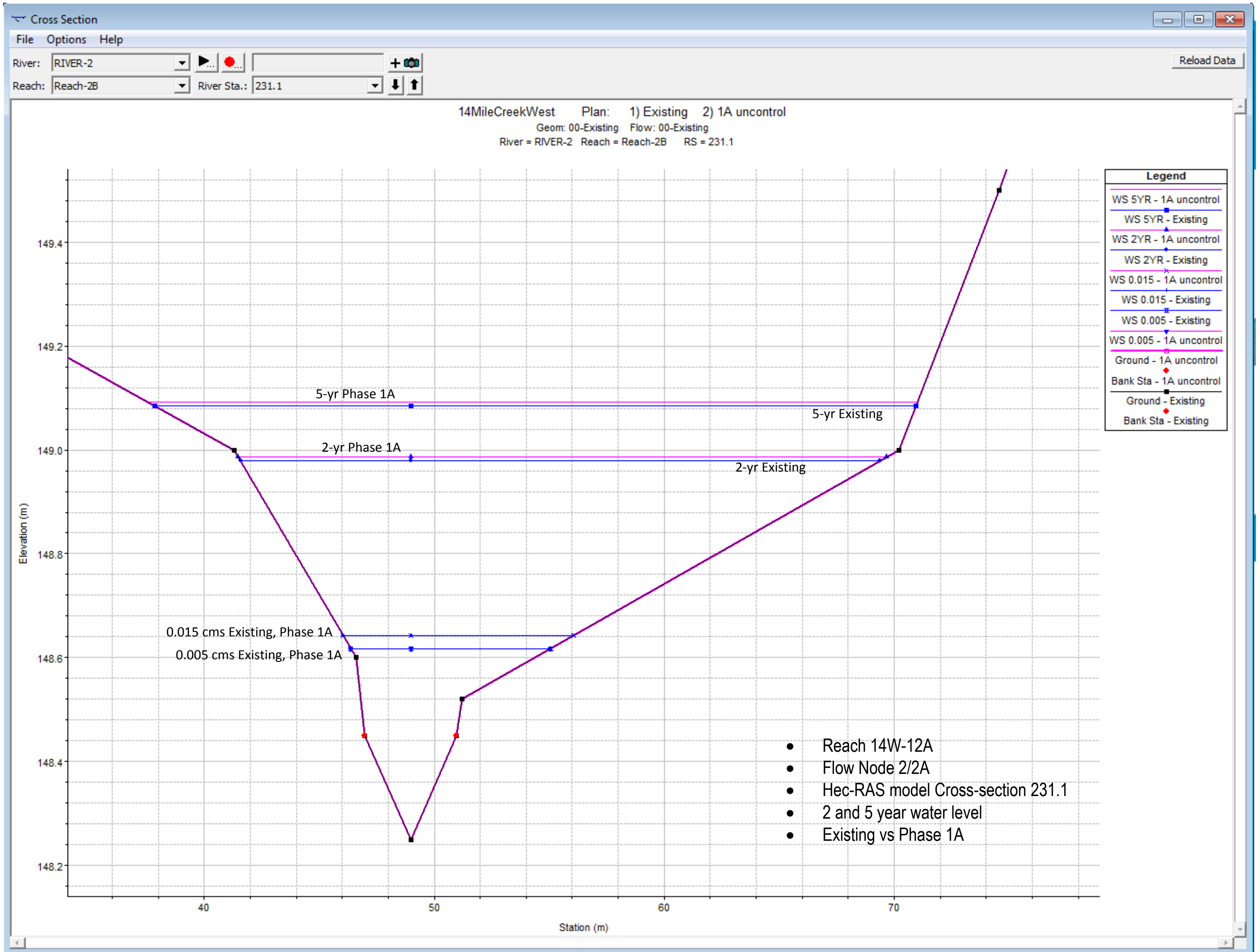
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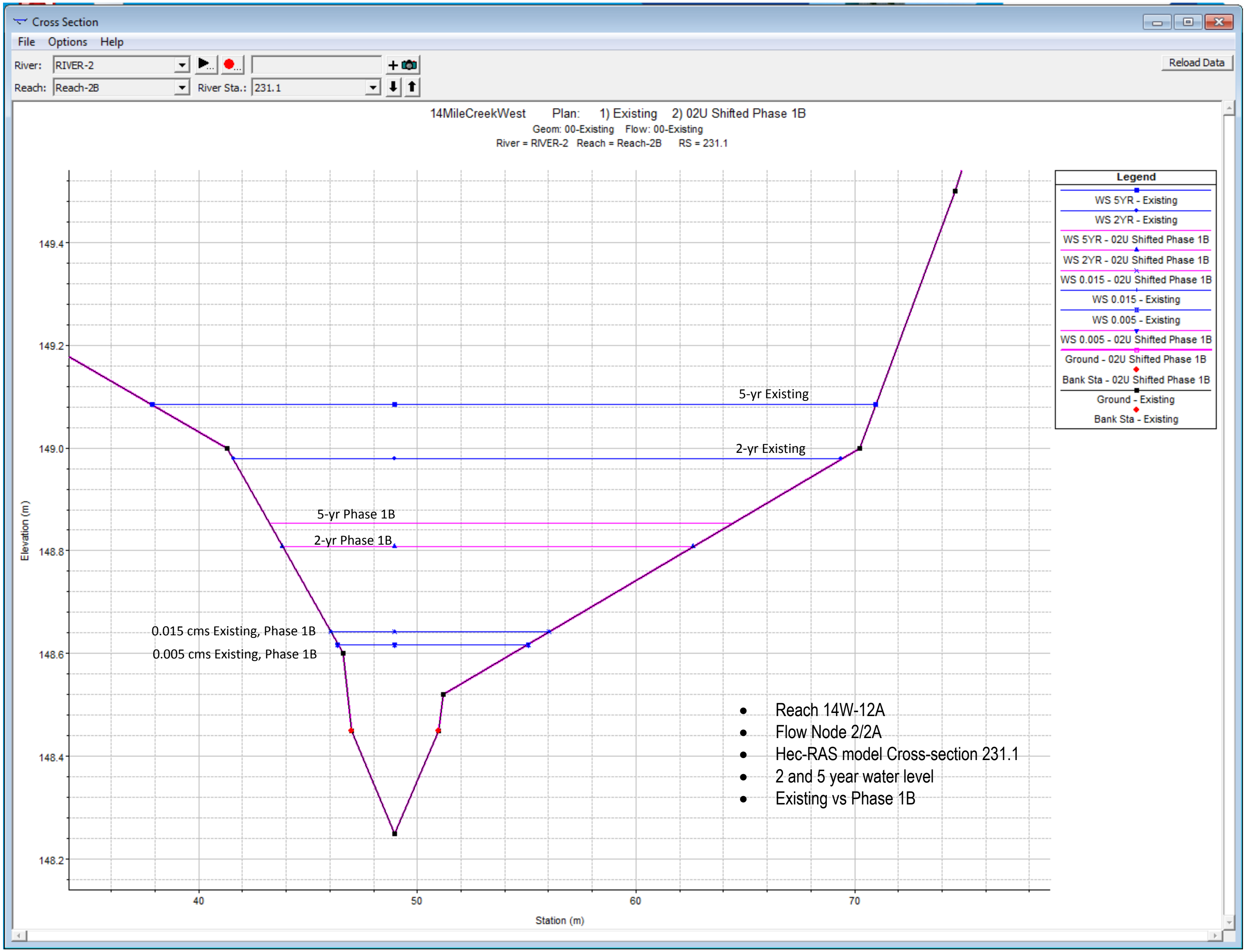
WS 5YR - Existing
WS 2YR - 1A uncontrol
WS 2YR - Existing
WS 0.015 - 1A uncontrol
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 1A uncontrol
Ground - 1A uncontrol
Bank Sta - 1A uncontrol
Ground - Existing
Bank Sta - Existing
5-yr Phase 1A
5-yr Existing
2-yr Phase 1A
2-yr Existing
0.015 cms Existing, Phase 1A
0.005 cms Existing, Phase 1A
Elevation (m)
149.4
149.2
149.0
148.8
148.6
148.4
148.2
Station (m)
40
50
60
70
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 231.1
2 and 5 year water level
Existing vs Phase 1A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Legend
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WS 2YR - Existing
WS 5YR - 02U Shifted Phase 1B
WS 2YR - 02U Shifted Phase 1B
WS 0.015 - 02U Shifted Phase 1B
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 02U Shifted Phase 1B
Ground - 02U Shifted Phase 1B
Bank Sta - 02U Shifted Phase 1B
Ground - Existing
Bank Sta - Existing
5-yr Existing
2-yr Existing
5-yr Phase 1B
2-yr Phase 1B
0.015 cms Existing, Phase 1B
0.005 cms Existing, Phase 1B
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 231.1
2 and 5 year water level
Existing vs Phase 1B
Elevation (m)
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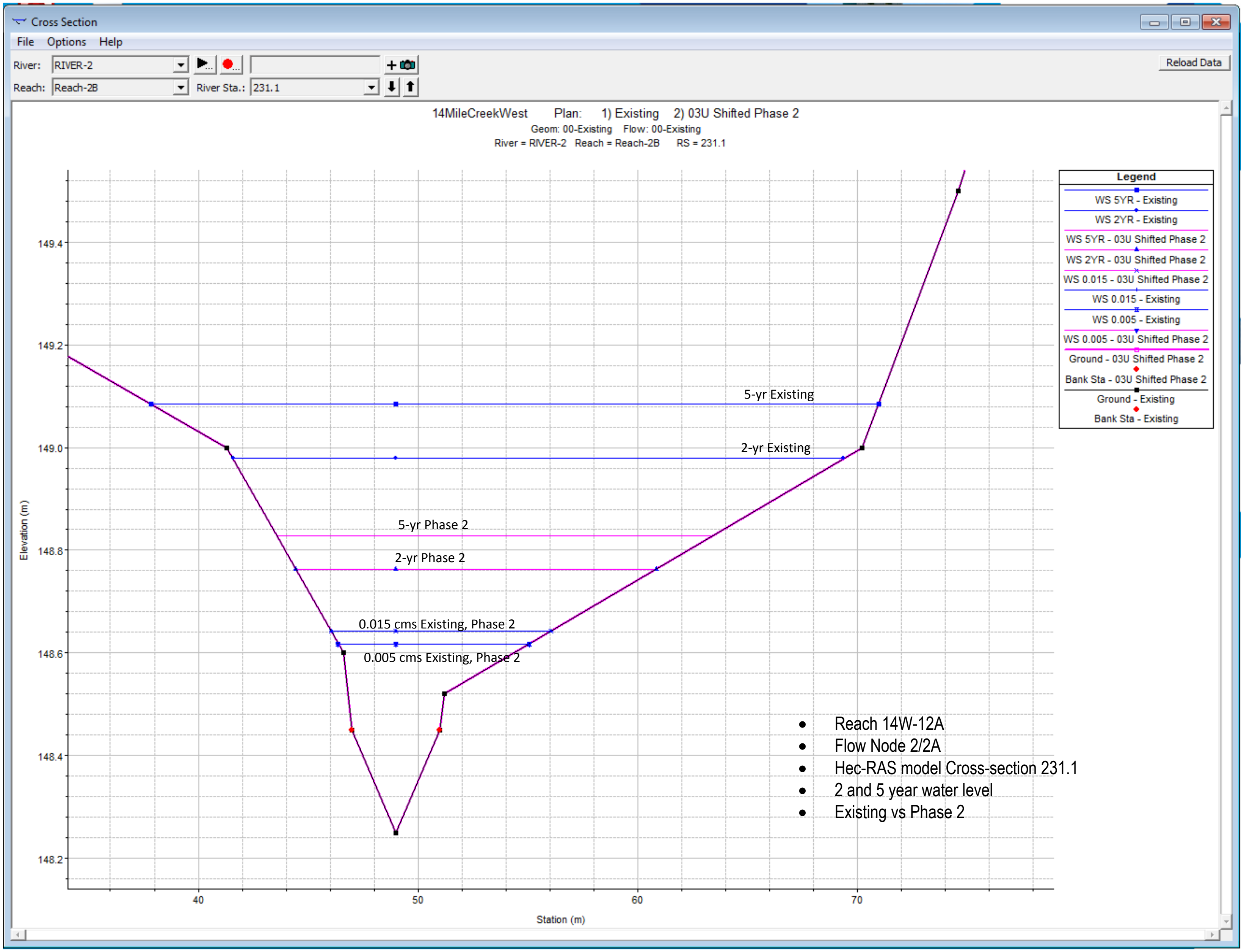
149.2
149.0
148.8
148.6
148.4
148.2
Station (m)
40
50
60
70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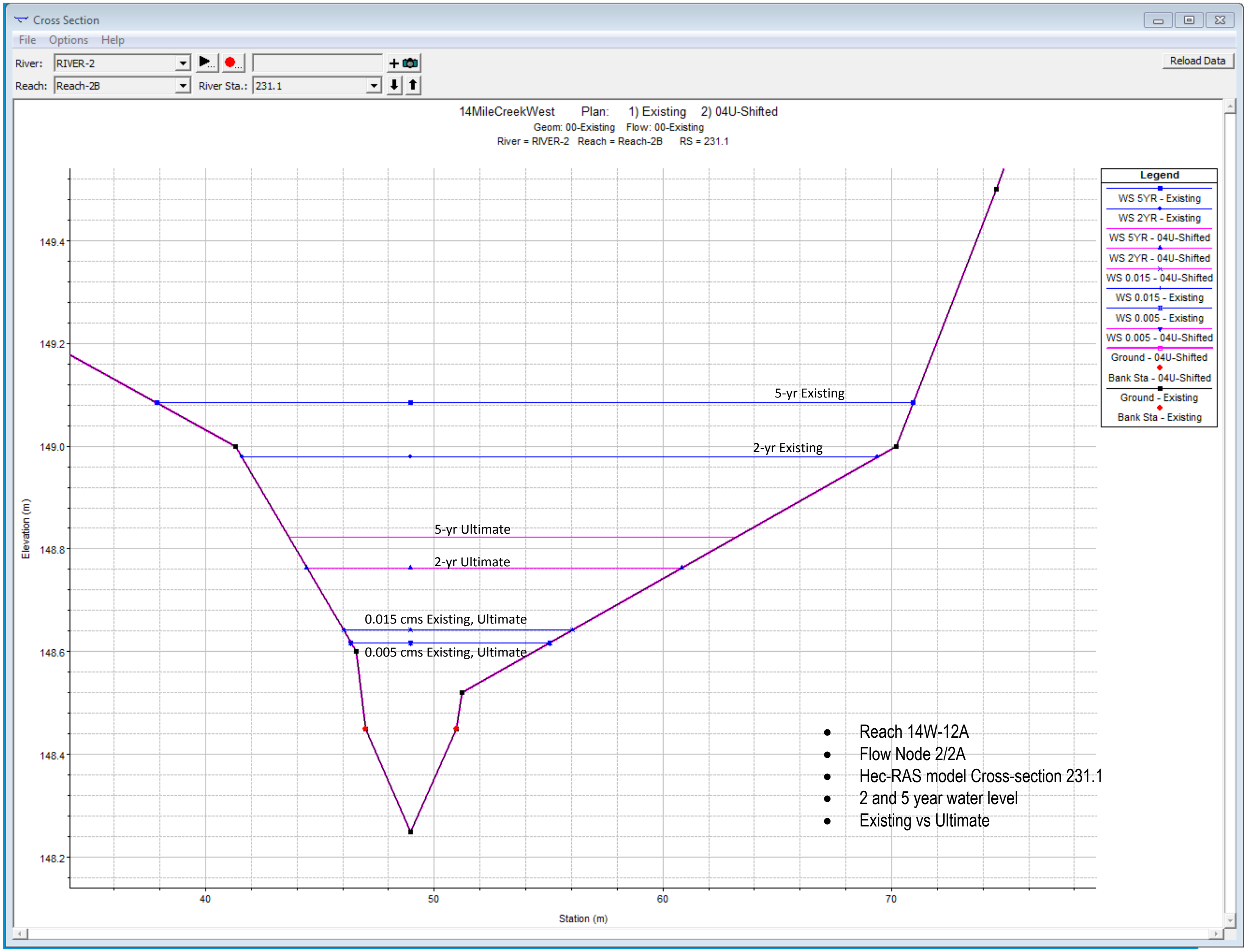
Geom: 00-Existing Flow: 00-Existing
River = RIVER-2 Reach = Reach-2B RS = 231.1
Legend
WS 5YR - Existing
WS 2YR - Existing
WS 5YR - 03U Shifted Phase 2
WS 2YR - 03U Shifted Phase 2
WS 0.015 - 03U Shifted Phase 2
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 03U Shifted Phase 2
Ground - 03U Shifted Phase 2
Bank Sta - 03U Shifted Phase 2
Ground - Existing
Bank Sta - Existing
5-yr Existing
2-yr Existing
5-yr Phase 2
2-yr Phase 2
0.015 cms Existing, Phase 2
0.005 cms Existing, Phase 2
Elevation (m)
Station (m)
149.4
149.2
149.0
148.8
148.6
148.4
148.2
40
50
60
70
Reach 14W-12A
Flow Node 2/2A
Hec-RAS model Cross-section 231.1
2 and 5 year water level
Existing vs Phase 2



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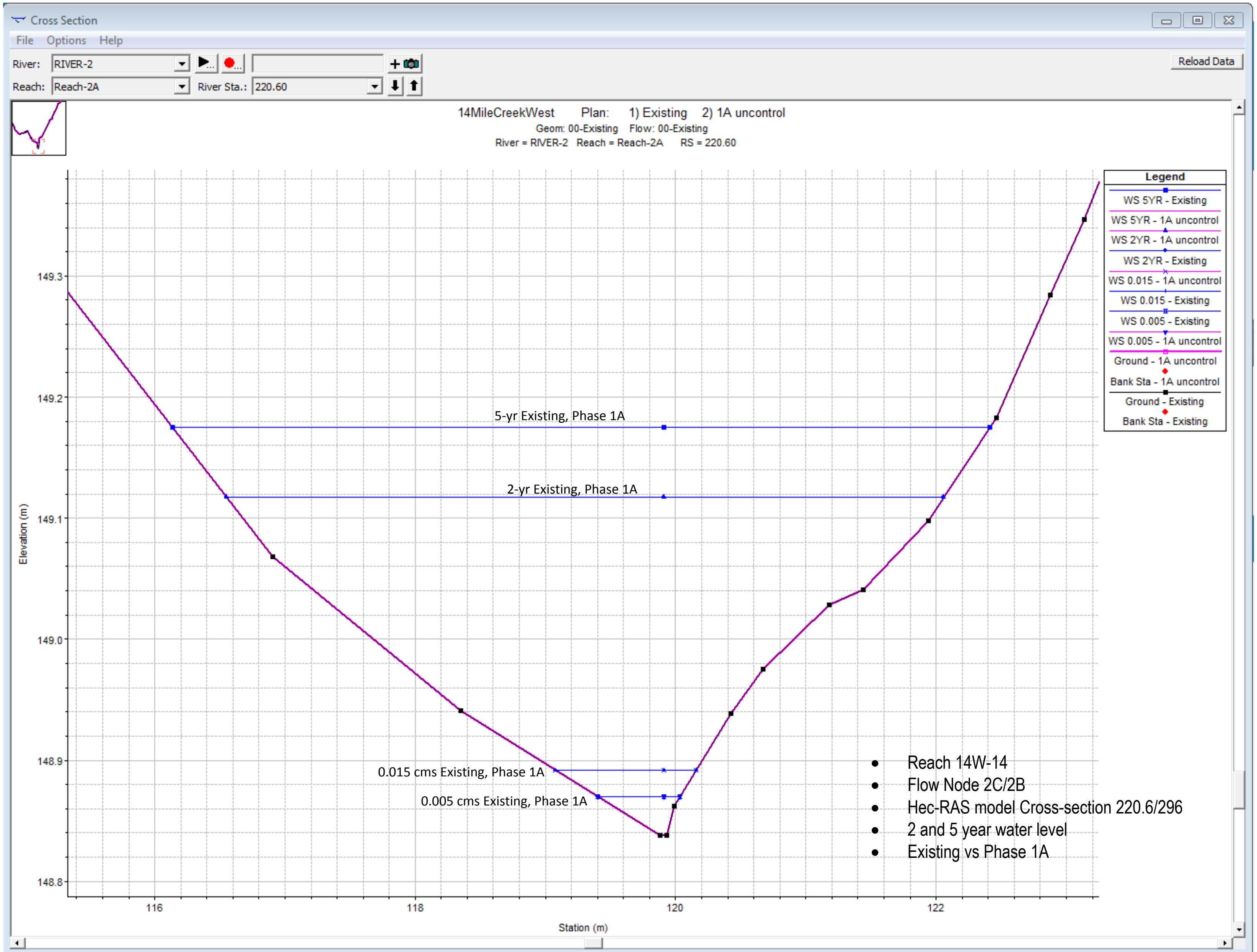
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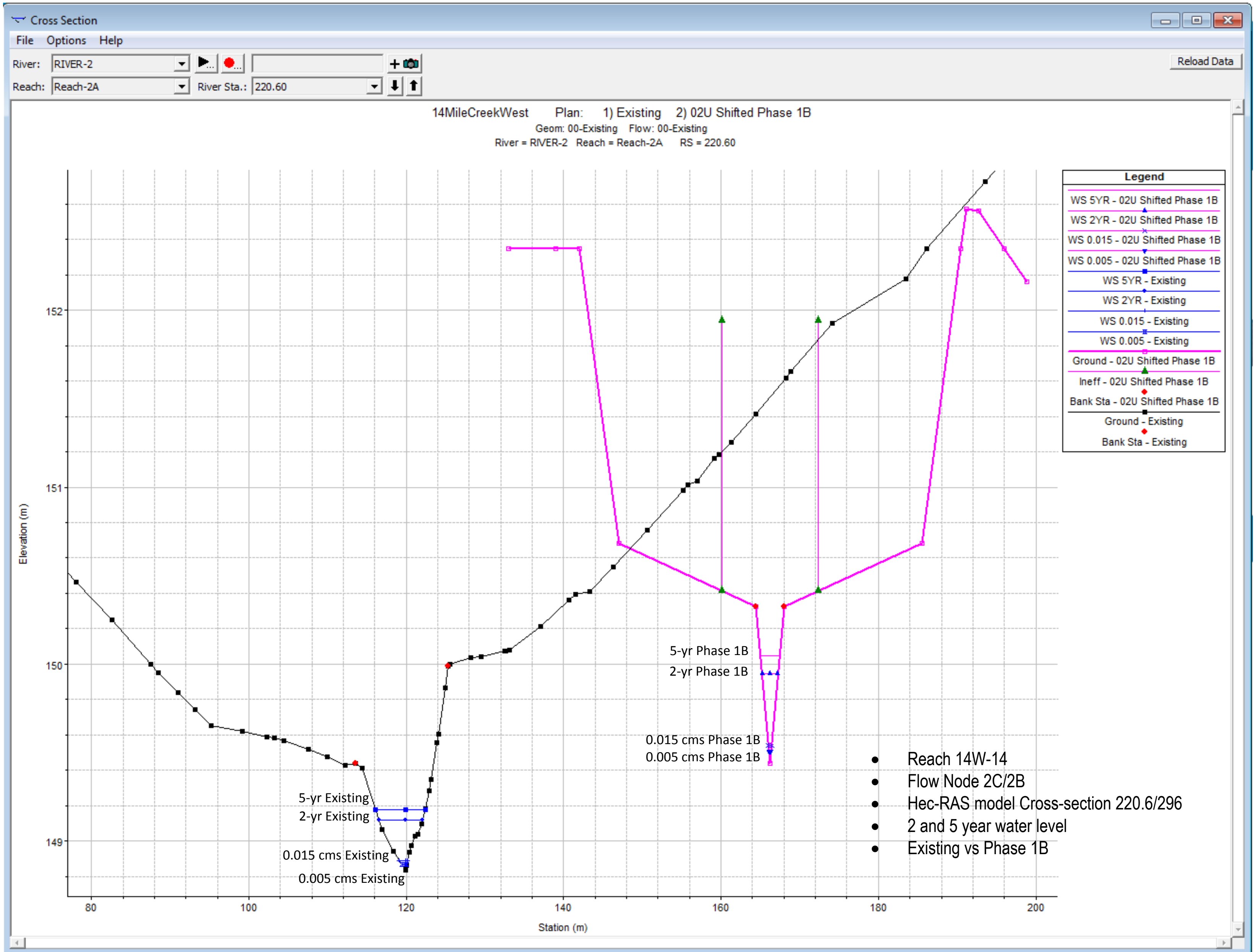
Geom: 00-Existing Flow: 00-Existing
River = RIVER-2 Reach = Reach-2A RS = 220.60
Legend
WS 5YR - Existing
WS 5YR - 1A uncontrol
WS 2YR - 1A uncontrol
WS 2YR - Existing
WS 0.015 - 1A uncontrol
WS 0.015 - Existing
WS 0.005 - Existing
WS 0.005 - 1A uncontrol
Ground - 1A uncontrol
Bank Sta - 1A uncontrol
Ground - Existing
Bank Sta - Existing
5-yr Existing, Phase 1A
2-yr Existing, Phase 1A
0.015 cms Existing, Phase 1A
0.005 cms Existing, Phase 1A
Elevation (m)
149.3
149.2
149.1
149.0
148.9
148.8
Station (m)
116
118
120
122
Reach 14W-14
Flow Node 2C/2B
Hec-RAS model Cross-section 220.6/296
2 and 5 year water level
Existing vs Phase 1A


Cross Section
File Options Help
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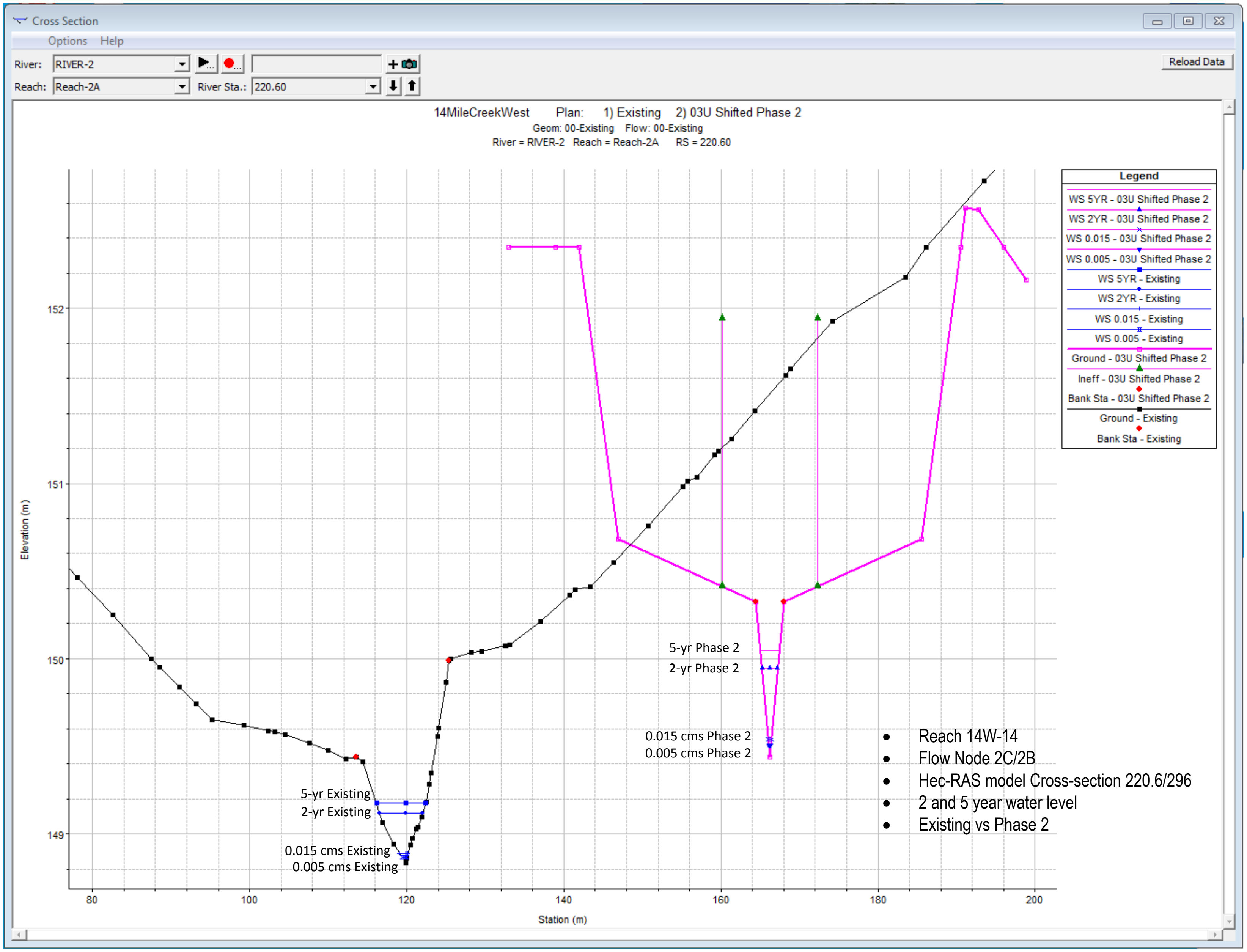
Reach: Reach-2A
River Sta.: 220.60
Reload Data
14MileCreekWest Plan: 1) Existing 2) 02U Shifted Phase 1B
Geom: 00-Existing Flow: 00-Existing
River = RIVER-2 Reach = Reach-2A RS = 220.60
Legend
WS 5YR - 02U Shifted Phase 1B
WS 2YR - 02U Shifted Phase 1B
WS 0.015 - 02U Shifted Phase 1B
WS 0.005 - 02U Shifted Phase 1B
WS 5YR - Existing
WS 2YR - Existing
WS 0.015 - Existing
WS 0.005 - Existing
Ground - 02U Shifted Phase 1B
Ineff - 02U Shifted Phase 1B
Bank Sta - 02U Shifted Phase 1B
Ground - Existing
Bank Sta - Existing
Elevation (m)
Station (m)
152
151
150
149
80
100
120
140
160
180
200
5-yr Phase 1B
2-yr Phase 1B
0.015 cms Phase 1B
0.005 cms Phase 1B
5-yr Existing
2-yr Existing
0.015 cms Existing
0.005 cms Existing
Reach 14W-14
Flow Node 2C/2B
Hec-RAS model Cross-section 220.6/296
2 and 5 year water level
Existing vs Phase 1B



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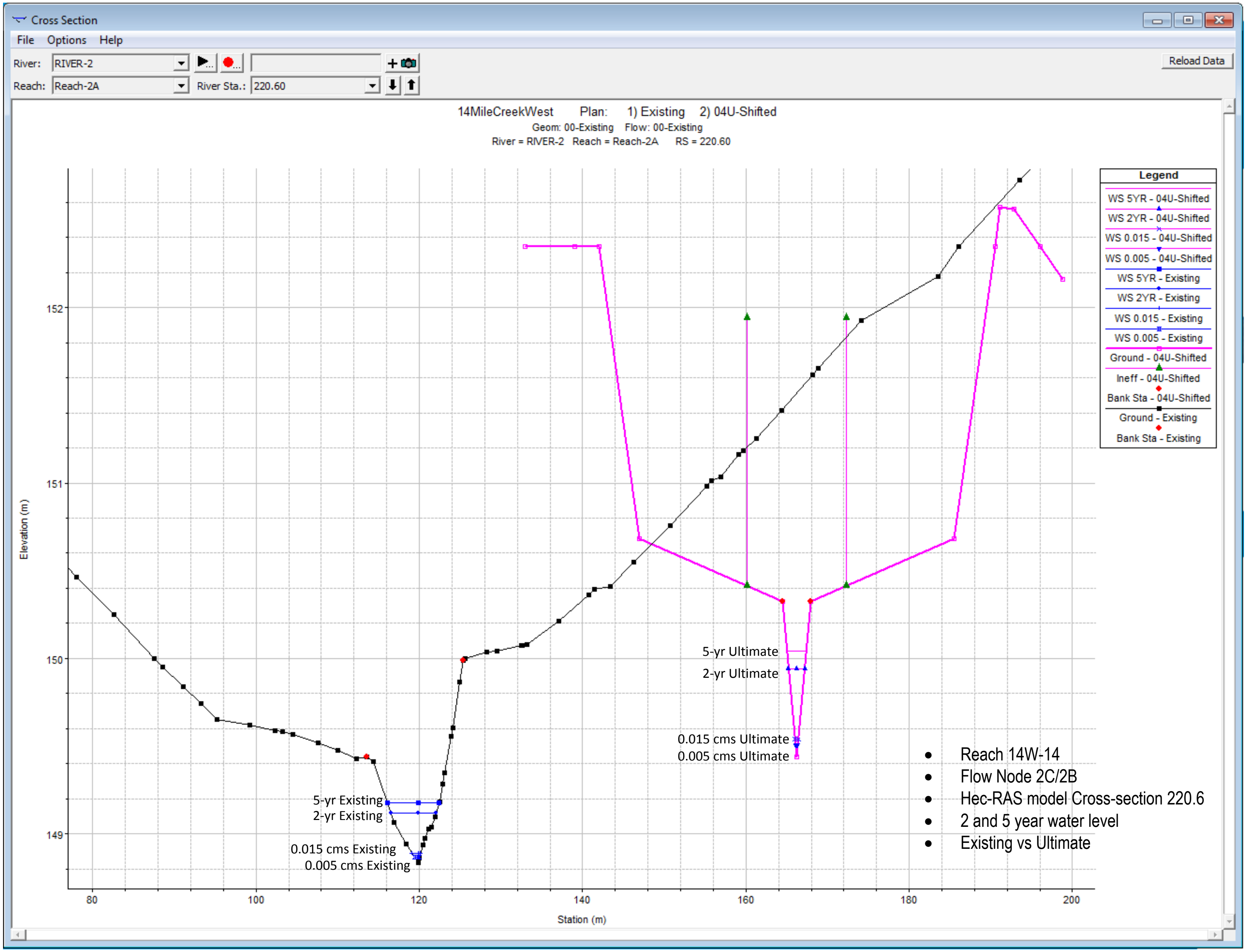
River = RIVER-2 Reach = Reach-2A RS = 220.60
Legend
WS 5YR - 03U Shifted Phase 2
WS 2YR - 03U Shifted Phase 2
WS 0.015 - 03U Shifted Phase 2
WS 0.005 - 03U Shifted Phase 2
WS 5YR - Existing
WS 2YR - Existing
WS 0.015 - Existing
WS 0.005 - Existing
Ground - 03U Shifted Phase 2
Ineff - 03U Shifted Phase 2
Bank Sta - 03U Shifted Phase 2
Ground - Existing
Bank Sta - Existing
Elevation (m)
Station (m)
5-yr Phase 2
2-yr Phase 2
0.015 cms Phase 2
0.005 cms Phase 2
5-yr Existing
2-yr Existing
0.015 cms Existing
0.005 cms Existing
Reach 14W-14
Flow Node 2C/2B
Hec-RAS model Cross-section 220.6/296
2 and 5 year water level
Existing vs Phase 2



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Final Assessment

A review of the existing conditions associated with Reach 14W-11A and Reach 14W-12A with respect to aquatic habitat, Redside Dace and benthic macroinvertebrate community including benthic drift was undertaken. Once the function of each reach related to those criteria, the changes expected during all phases of development related to a reduction in flow, specifically related to the "Sensitive Period" for Redside Dace (April to May) was undertaken. The assessment has confirmed that although the magnitude of flow at all three Nodes reviewed will be slightly reduced; noticeable changes to the existing conditions in terms of flow continuity and wetted habitat during the "Sensitive Period" are not anticipated for Reach 14W-11A.

Based on the enclosed monthly hydrographs and the flow depths under different flows (0.005 cms, 0.015 cms, 2-year flow, and 5-year flow), the anticipated flows will provide partial maintenance of existing functions (i.e. flow conveyance and nutrients to Reach 14W-12) on a monthly basis, and during the "Sensitive period" of April and May.

Furthermore, with respect to flows in the downstream Reach 14W-12 Occupied Redside Dace habitat, there will be no reduction of flow as the reduced flow from 14W-12A will be compensated with the flows from Reach 14W-22 and the stormwater management facilities outflows. Monthly flows are presented at the end of this memorandum, and they show marginal changes in peak flows, and no changes in frequency and duration. In addition, Erosion Control Analysis has been completed as part of the assessment of impact of development at Node 3.

Although the main purpose of this document is to assess the impacts of flow modification on these particular nodes as it relates to ecological function, there is a factor that must be considered as well; the benefits of the proposed channel realignments (Reach 14W-22 and Reach 14W-23). The use of natural channel design principles (i.e., riffle/pool sequences with a connecting low flow channel) will result in greater habitat diversity, specifically the introduction of morphological variation and coarse substrate (i.e., gravel and cobble) not present or present in limited amount in Reach 14W-11A, Reach 14W-13 and Reach 14W-14, as well as, substantial expansion of the riparian stream corridor widths. These features will potentially improve the function of these reaches for the aquatic community including:

- Expansion of fish ranges (refuge pools);
- Spawning habitat (morphology and substrate);
- Redside Dace spawning (riffles and substrate);
- Redside Dace range expansion into Reach 14W-22 and Reach 14W-23 when the rehabilitation of Reach 14W-11 occurs (pools, riffles);
- Improved benthic macroinvertebrate production and diversity (riffle);
- Improved drift as active agricultural operations has a lower number of drifting macroinvertebrates than urban settings (Hennigar, 2012); and
- Improved fish productivity as the density of macroinvertebrate and their drift can influence fish growth and population size (Wills et. al., 2006).

As a result, this final assessment takes into account the ecological function of these reaches, the potential effects of the flow changes during the period when the reaches Has the greater ecological function (i.e., April and May) and the anticipated benefits of the realigned channels.

Node 9 (Reach 14W-11A)

- Function of this reach in general is limited in the existing condition due to its modified nature, intermittent flows and lack of habitat diversity for aquatic species providing limited direct use.
- Realigned channel (Reach 14W-23) will introduce habitat diversity including riffles, pools and coarse substrates.
- Reach 14W-23 potential to provide spawning and refuge habitat for fish, potential increase to benthic macroinvertebrate community diversity and productivity.
- The associated wider riparian stream corridor width will provide additional allochthonous inputs during runoff events.

Node 2 (Reach 14W-12A)

- Function of this reach in general is limited in the existing condition due to its modified nature, intermittent flows and lack of habitat diversity for aquatic species providing limited direct use.
- Exhibit the greatest reduction in flow due to the removal of the headwaters.
- Reduced flows will be lessen by directing rooftop drainage into this reach.
- Peak flows during the "Sensitive Period" to Redside Dace (April to May) have shown to be able to provide sufficient flow to maintain partial ecological function.
- Contributions of flow and benthic macroinvertebrates will be addressed since mean annual flow and flushing flow (2 x mean annual flow according to Tessman) will provide flow continuity and fine sand entrainment.

Node 2B (Reach 14W-22)

- No existing condition as located in the realigned Reach 14W-22.
- Realigned channel (Reach 14W-22) will introduce habitat diversity including riffles, pools, coarse substrates beyond what is provided by Reaches 14W-13 and 14W-14.
- Reach 14W-22 potential to provide spawning and refuge habitat for fish, potential increase to benthic macroinvertebrate community diversity and productivity.
- The associated wider riparian stream corridor width will provide additional allochthonous inputs during runoff events.

Responses to Comments

The comments received on July 15th, 2016 are as follows:

- b) Discussion of Tessman Method Results
- c) Appendix A, Flow Duration Curves
- d) Discussion of the Flow Duration Method Results
- e) Table 6.3, Summary of Impacts on Ecology and Sediment Transport, All Nodes
- f) Table 6.3, Summary of Impacts on Ecology and Sediment Transport, Node 2

The table below provides brief responses. Responses to comments received in January 2017 are presented in another table.

Table 8. Comment and Responses

Comment	Response
b) Discussion of Tessman Method Results	
i) The hybrid tool	The hybrid tool was removed. For clarity purposes, the Tennant and Tessman methods results are now included separately.
ii) Tessman Method recommendations	Tessman method results are now compatible with the table
iii) Applicability of Tennant Method	The application of the Tennant was based on 30 years of hydrologic record, with average values estimated for two seasons. Instantaneous flows were evaluated under the detailed analysis portion of this report.
iv) use of MMF under Tennant	We used two seasons. MMF and MAF were only used under the Tessman method.
v) The hybrid tool	The hybrid tool was removed. For clarity purposes, the Tennant and Tessman methods results are now included separately.
vi) Using standard Tennant and Tessman methods for nodes 2, 2B, and 9	The two methods are now used separately.
vii) Redside Dace sensitive months	The detailed analysis discusses the timing and other natural flow regime considerations.
c) Appendix A, Flow Duration Curves	Noted. 2 is compared to 2A, 2C to 2B, and 9 to 9.
d) Discussion of the Flow Duration Method Results	Noted. Discussion revised.
e) Table 6.3, Summary of Impacts on Ecology and Sediment Transport, All Nodes	Flushing flows for Nodes 2, 2B, and 9 are discussed in this report.
f) Table 6.3, Summary of Impacts on Ecology and Sediment Transport, Node 2	Flushing flows “in a fashion similar to existing or baseline conditions” have been identified for sensitive months for nodes 2, 2B, and 9.

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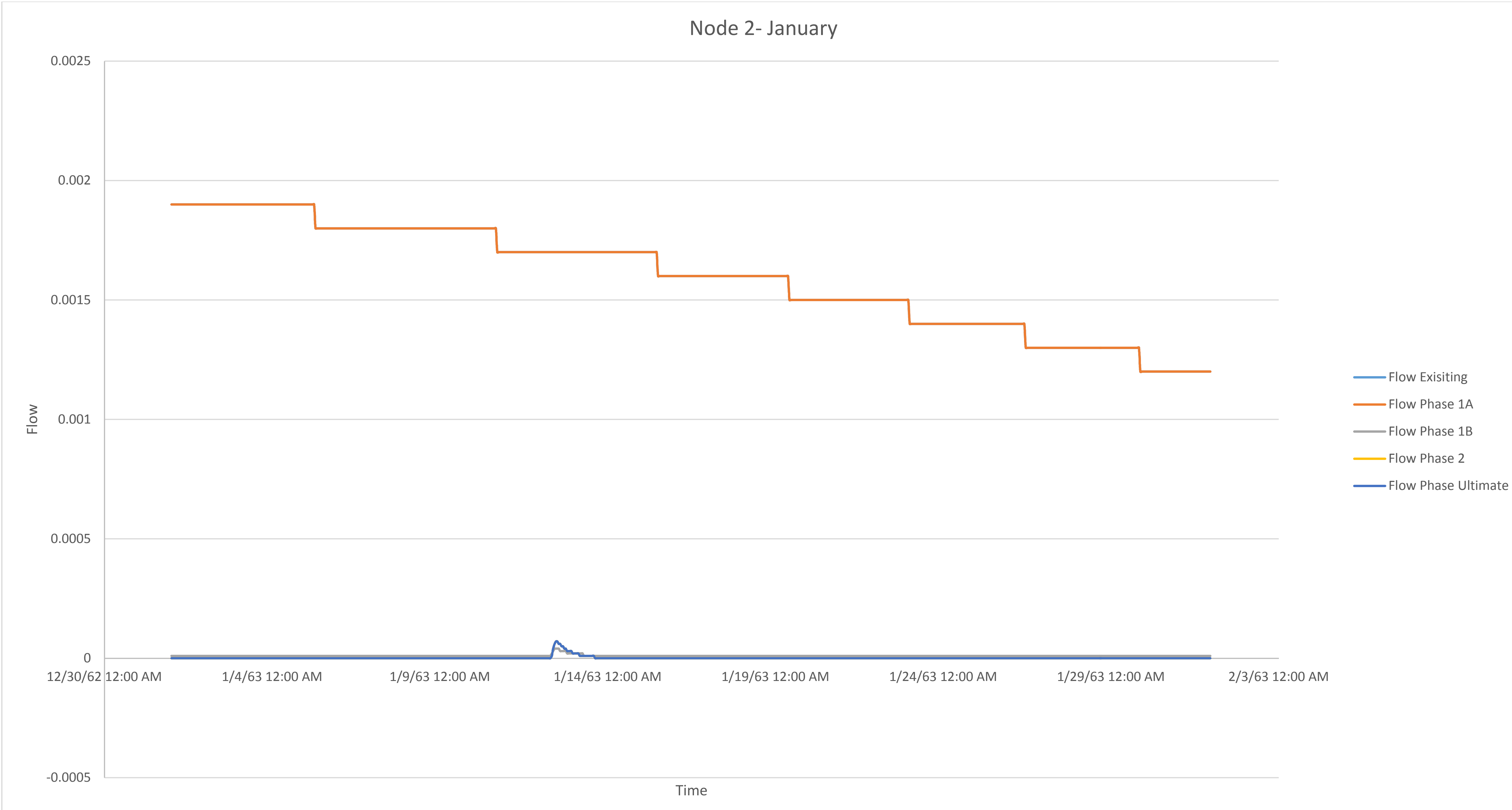
Monthly Comparative (phase-based) Hydro-Graphs for 3 years (wet, average, and dry) at 3 nodes (2, 2B/2C, and 9).

Table of Contents

Note:

1) All graphs have cms as unit of flow.
2) The wet year-1992, has data only till October.
3) Page attributes-size is 11x17 (tabloid) and orientation is landscape.

Dry Year-1963



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<tr><td rowspan="2">Magnitudes (cm/s)</td><td>Max.</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">0.00004</td><td rowspan="2">0.00007</td><td rowspan="2">0.00007</td></tr>
<tr><td>Min.</td></tr>
<tr><td rowspan="2">Duration (h)</td><td>Max.</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">23</td><td rowspan="2">20</td><td rowspan="2">20</td></tr>
<tr><td>Min.</td></tr>
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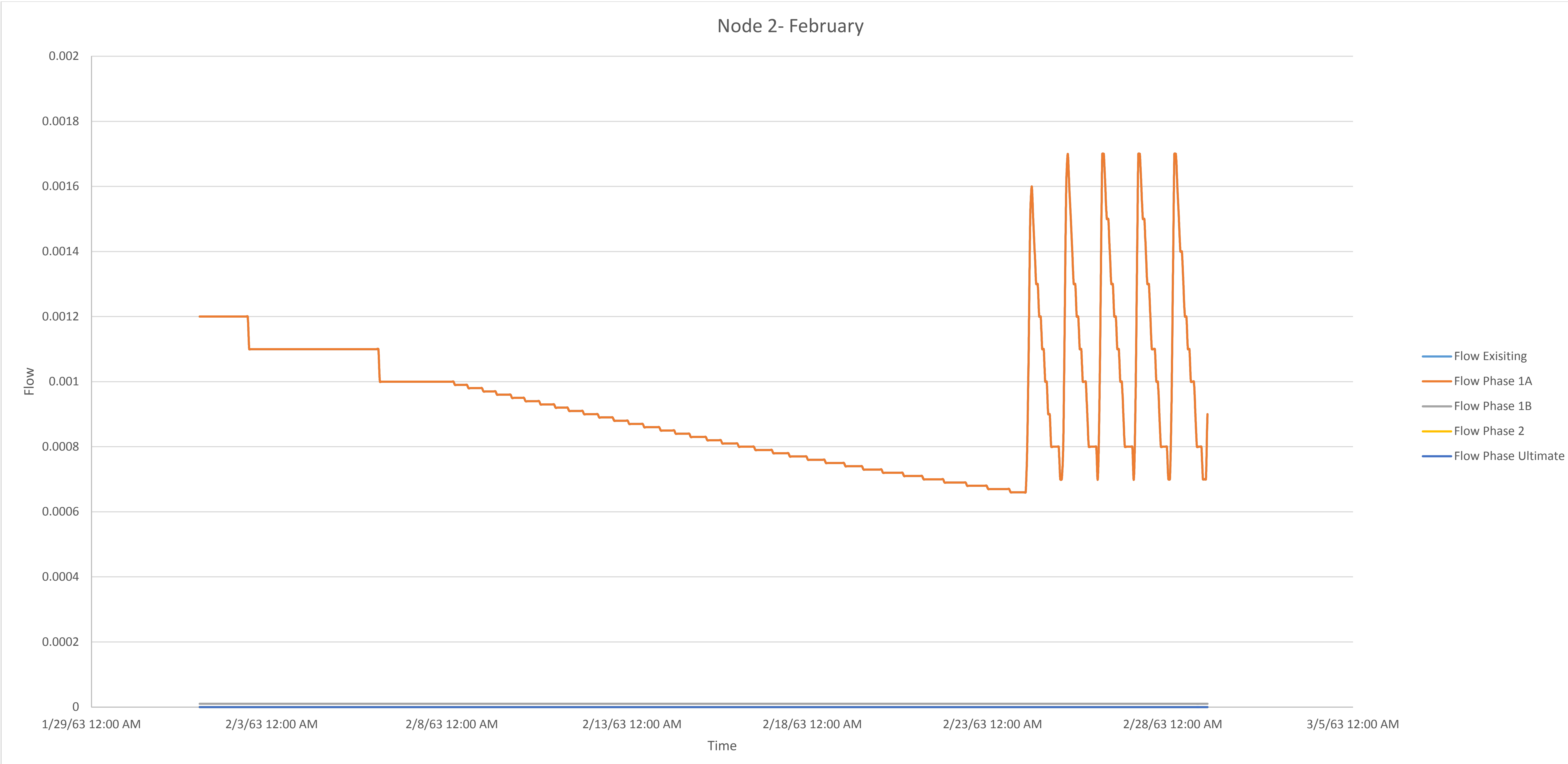
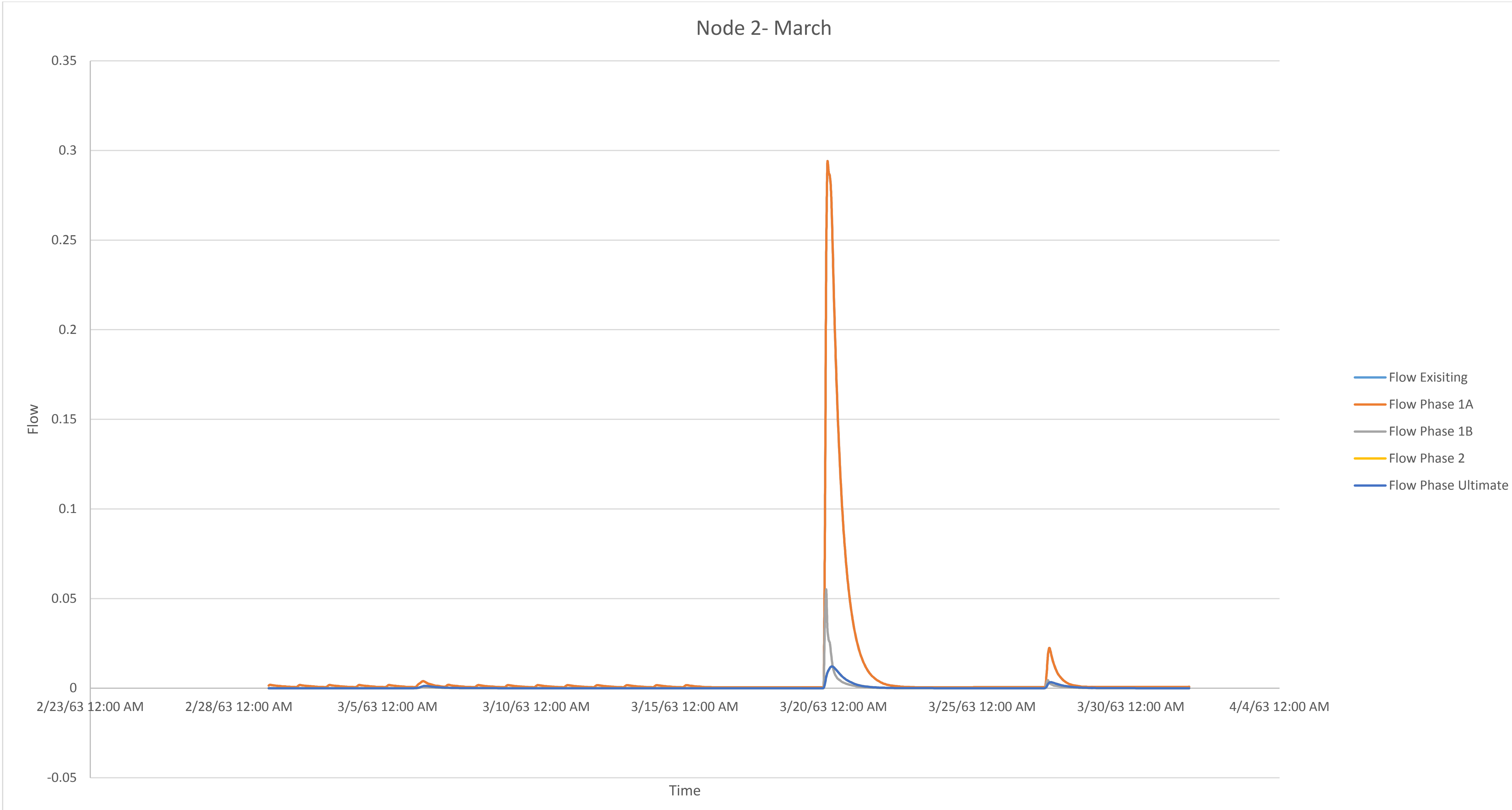
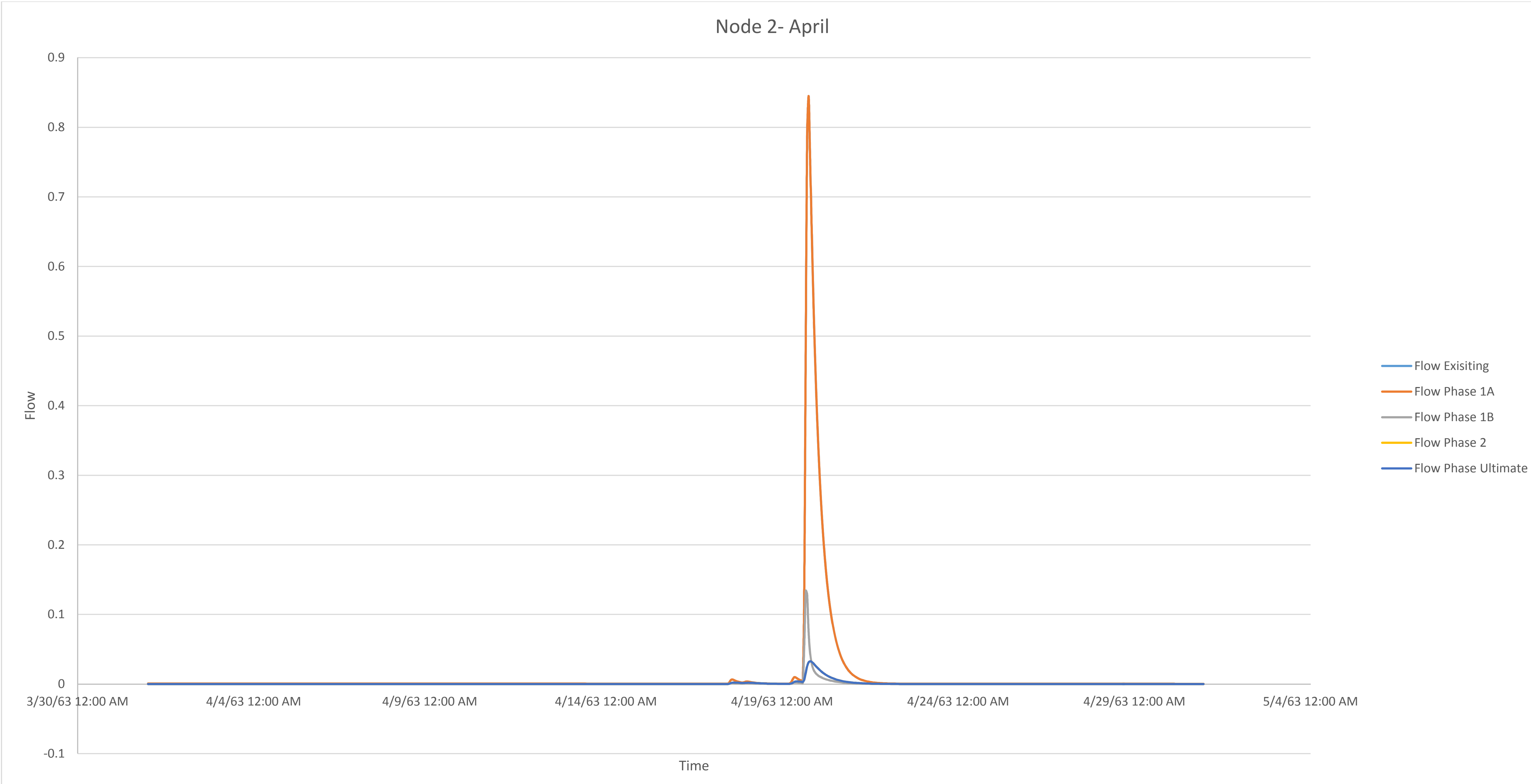


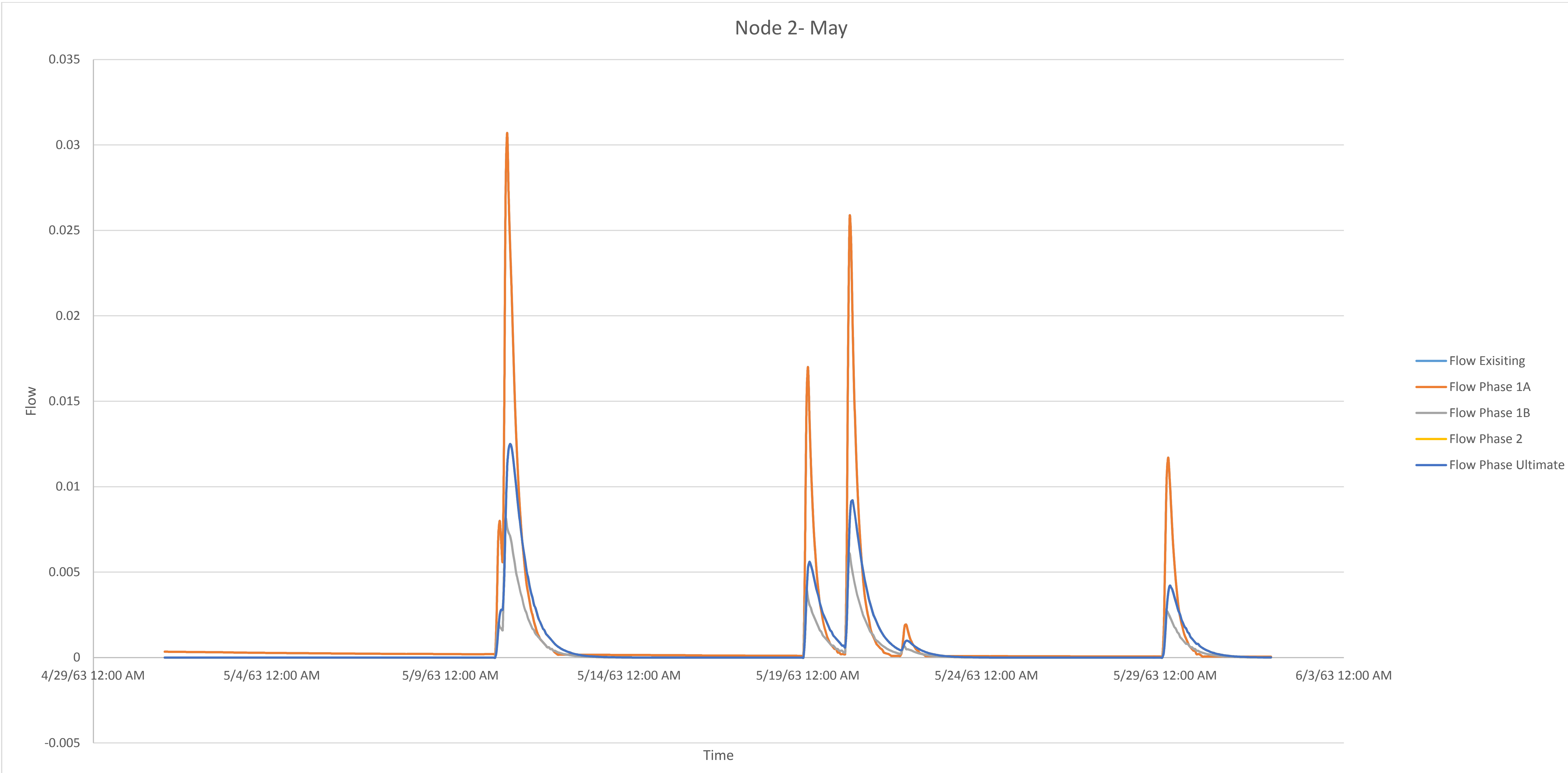
February						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	0	0	0
Magnitudes (cm/s)	Max.	0.0017	0.0017			
	Min.	0.0016	0.0016			
Duration (h)	Max.	24	24			
	Min.	22	22			



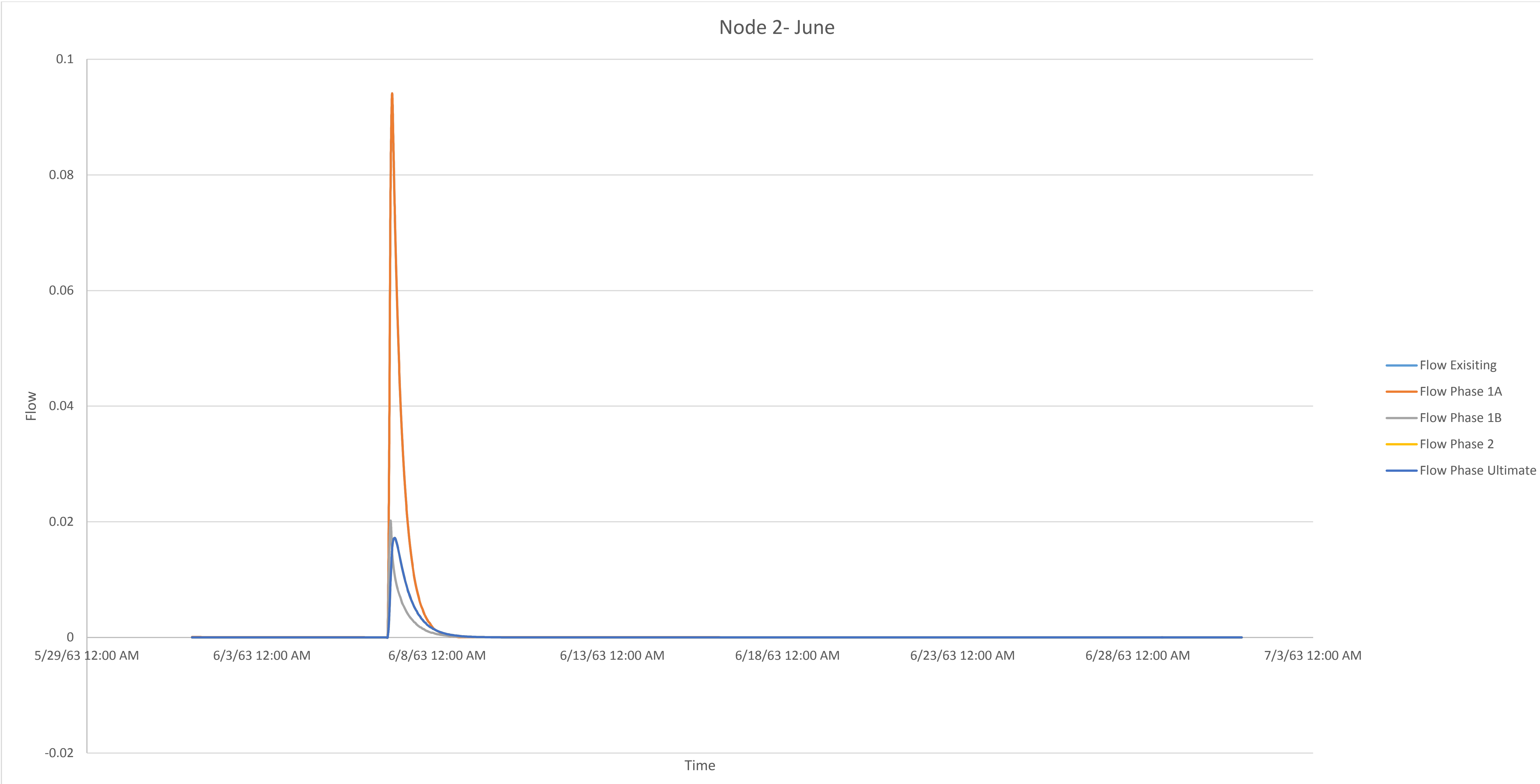
March						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		17	17	3	3	3
Magnitudes (cm/s)	Max.	0.2935	0.2935	0.0551	0.012	0.012
	Min.	0.00168	0.00168	0.00076	0.00125	0.00073
Duration (h)	Max.	75	75	80	77	77
	Min.	24	24	57	56	56



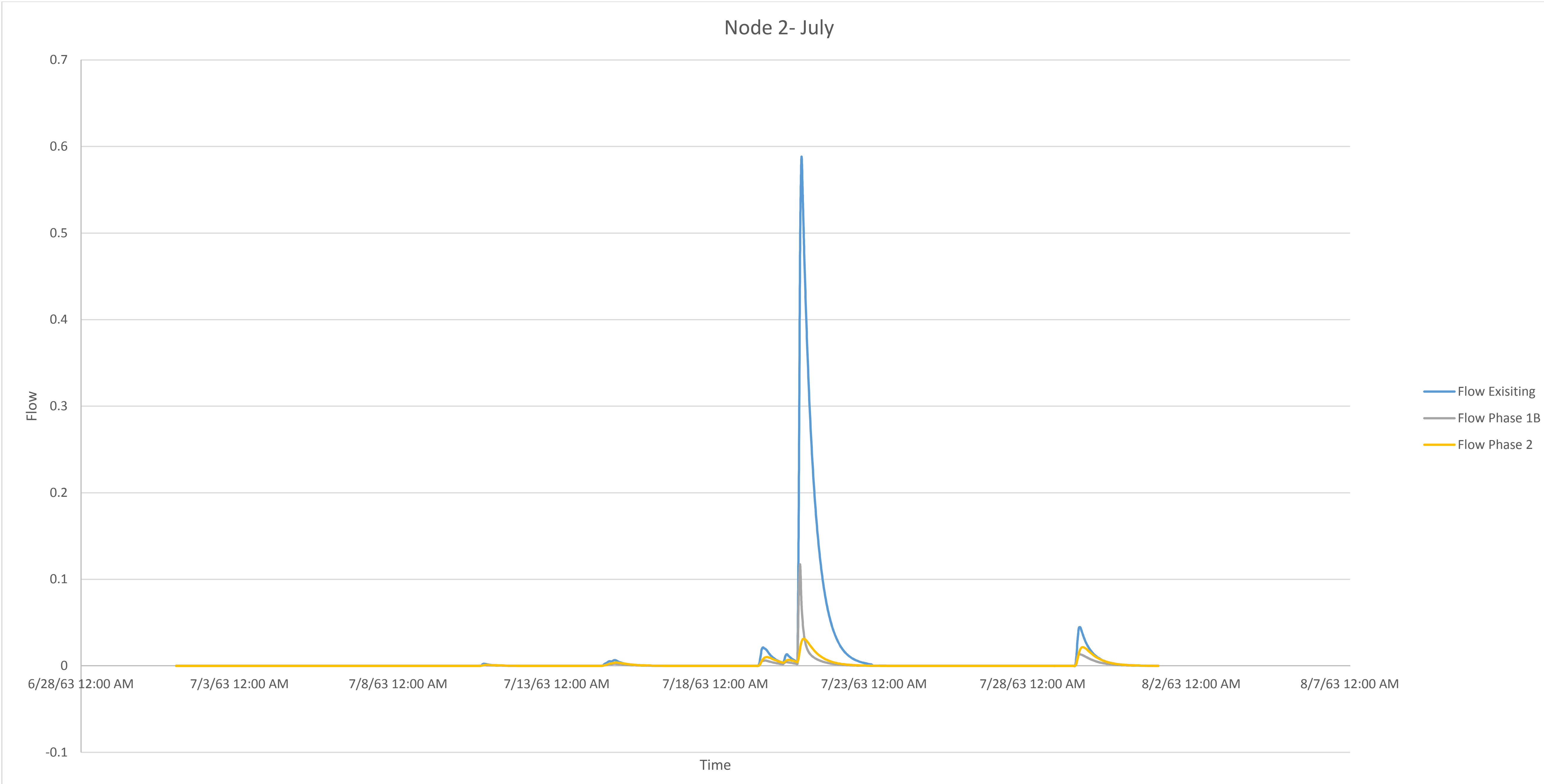
April						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitudes (cm/s)	Max.	0.8448	0.8448	0.1337	0.0327	0.0327
	Min.	0.0066	0.0066	0.0014	0.00218	0.00218
Duration (h)	Max.	79	79	77	88	88
	Min.	32	32	35	36	36



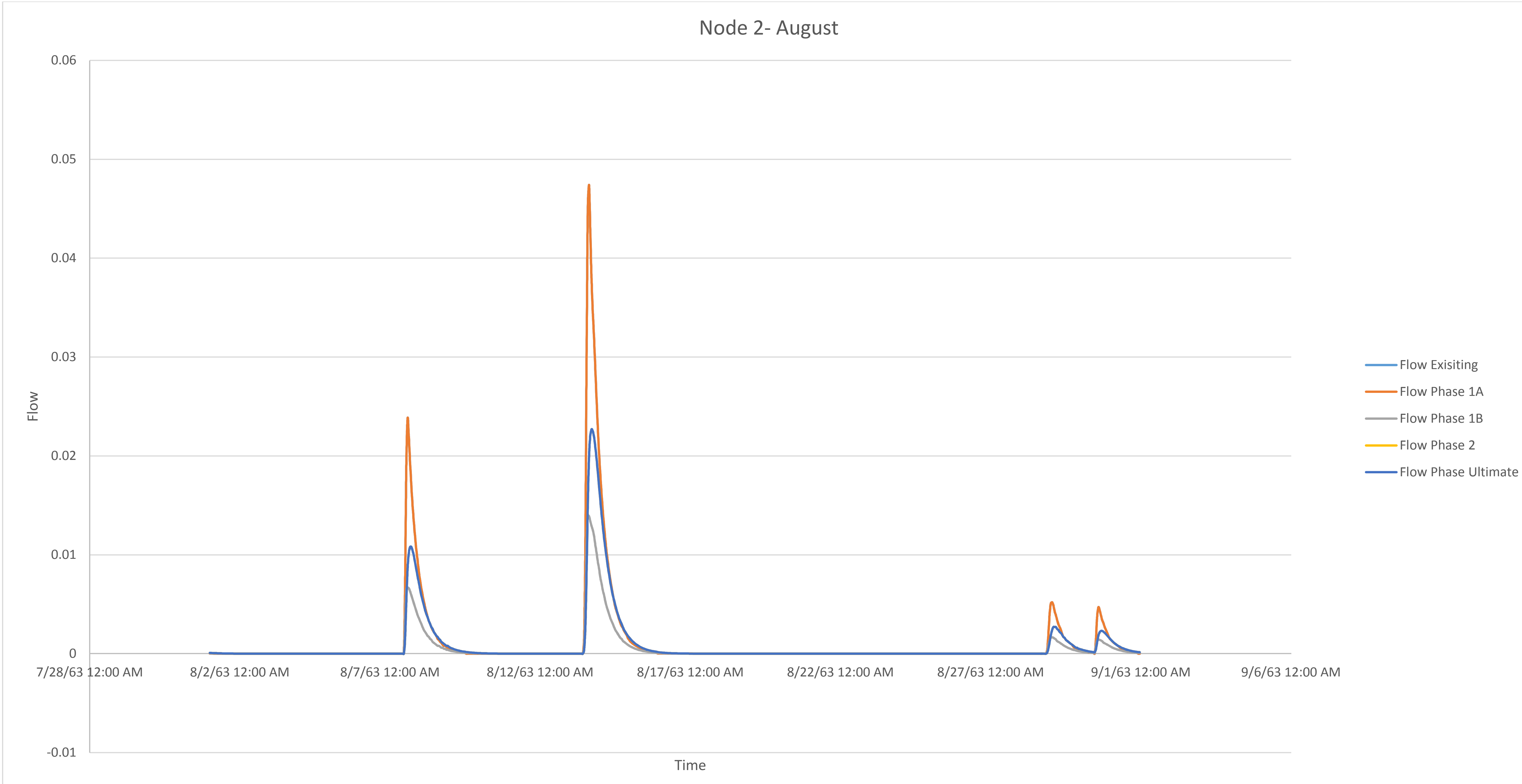
May						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitudes (cm/s)	Max.	0.9027	0.9027	0.1589	0.038	0.038
	Min.	0.0051	0.0051	0.00027	0.00021	0.00021
Duration (h)	Max.	60	60	77	66	66
	Min.	7	7	22	21	21



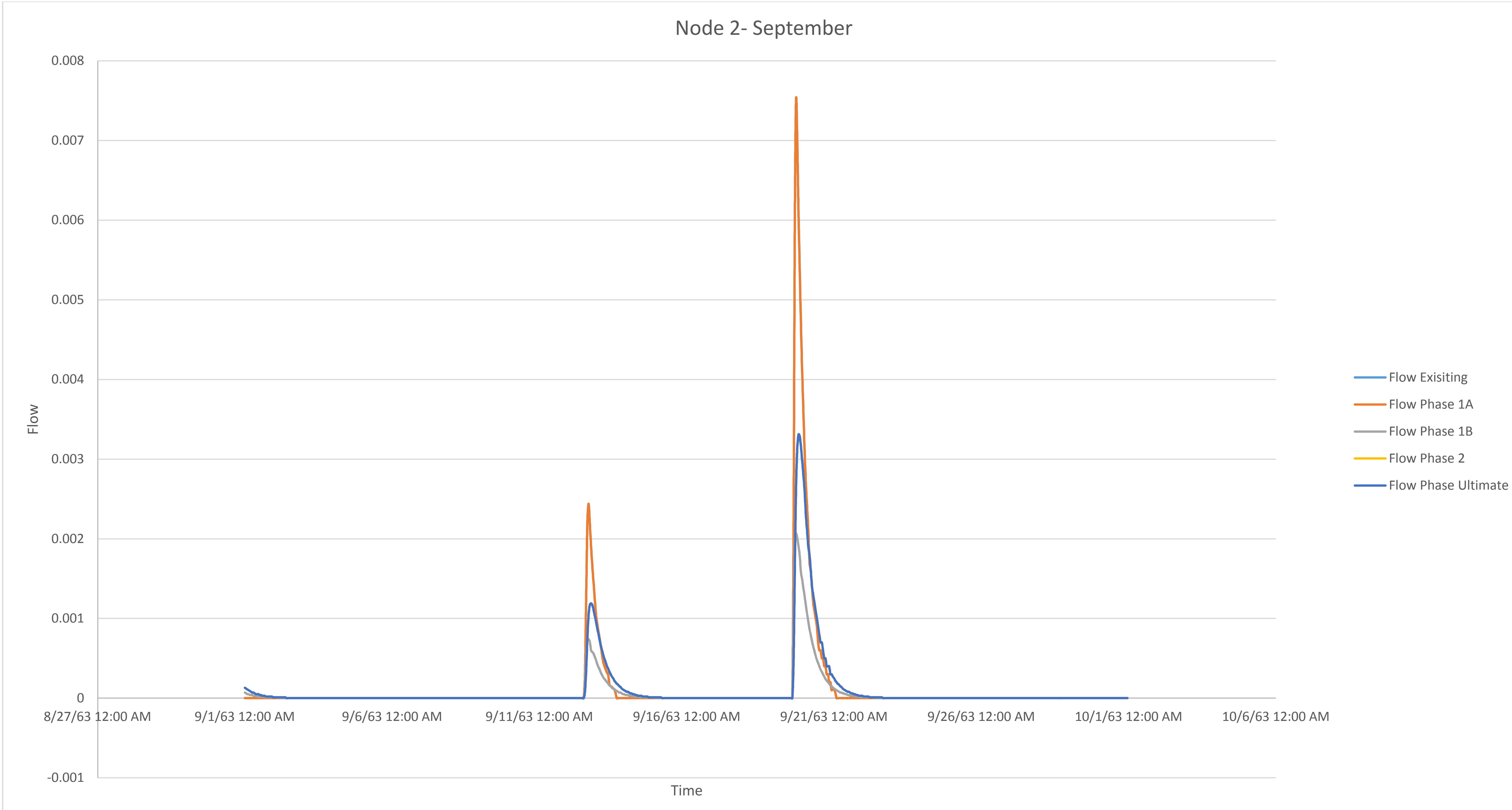
June						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitudes (cm/s)	Max.	0.094	0.094	0.0151	0.0172	0.0172
	Min.					
Duration (h)	Max.	63	63	65	72	72
	Min.					



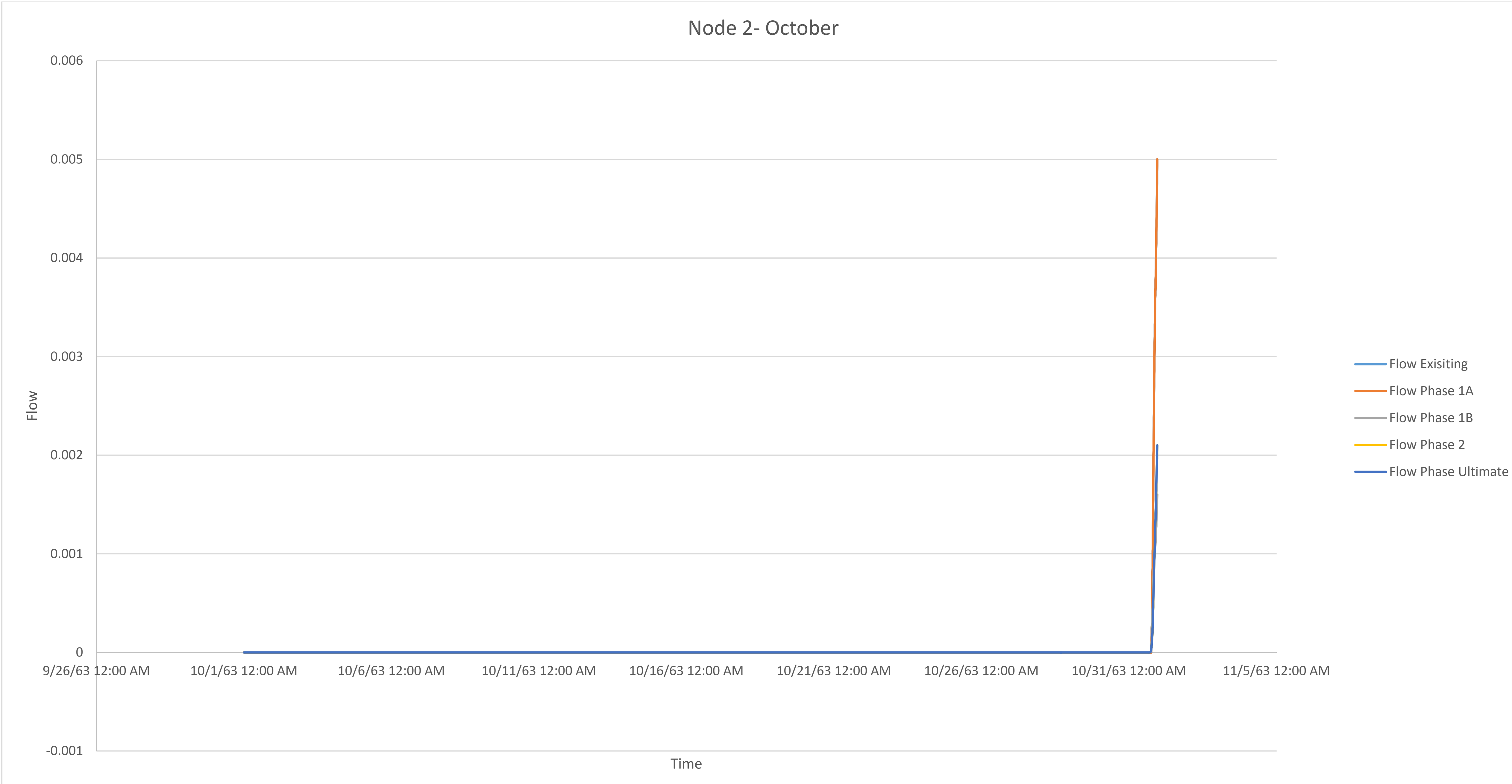
July						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		6	6	6	6	6
Magnitudes (cm/s)	Max.	0.5865	0.5865	0.1173	0.0313	0.0313
	Min.	0.00246	0.00246	0.0007	0.00112	0.00112
Duration (h)	Max.	100	100	101	109	109
	Min.	24	24	54	61	61



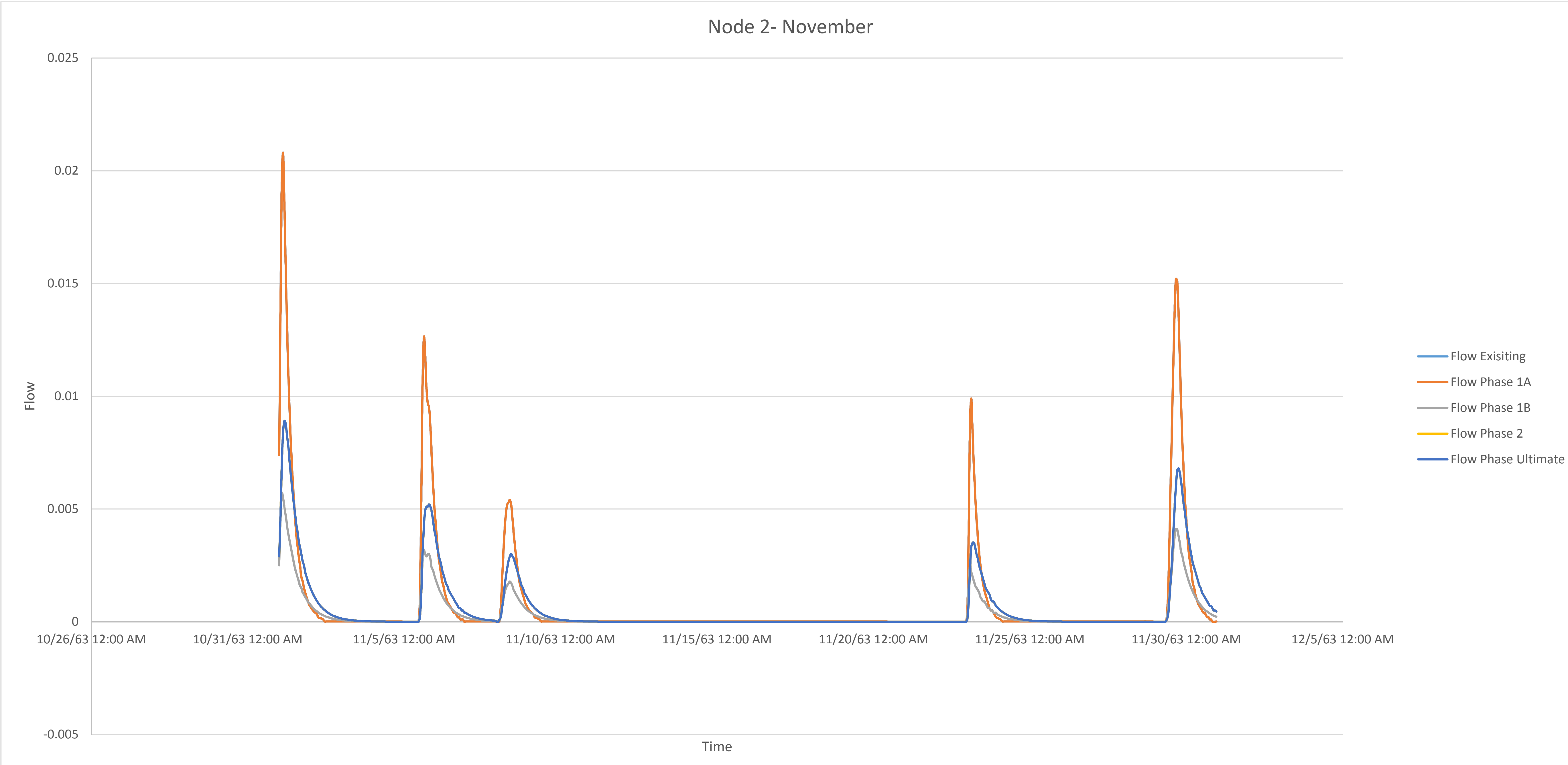
August						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitudes (cm/s)	Max.	0.0474	0.0474	0.0139	0.0227	0.0227
	Min.	0.0052	0.0052	0.00166	0.0027	0.0027
Duration (h)	Max.	83	89	83	91	91
	Min.	38	38	38	38	38



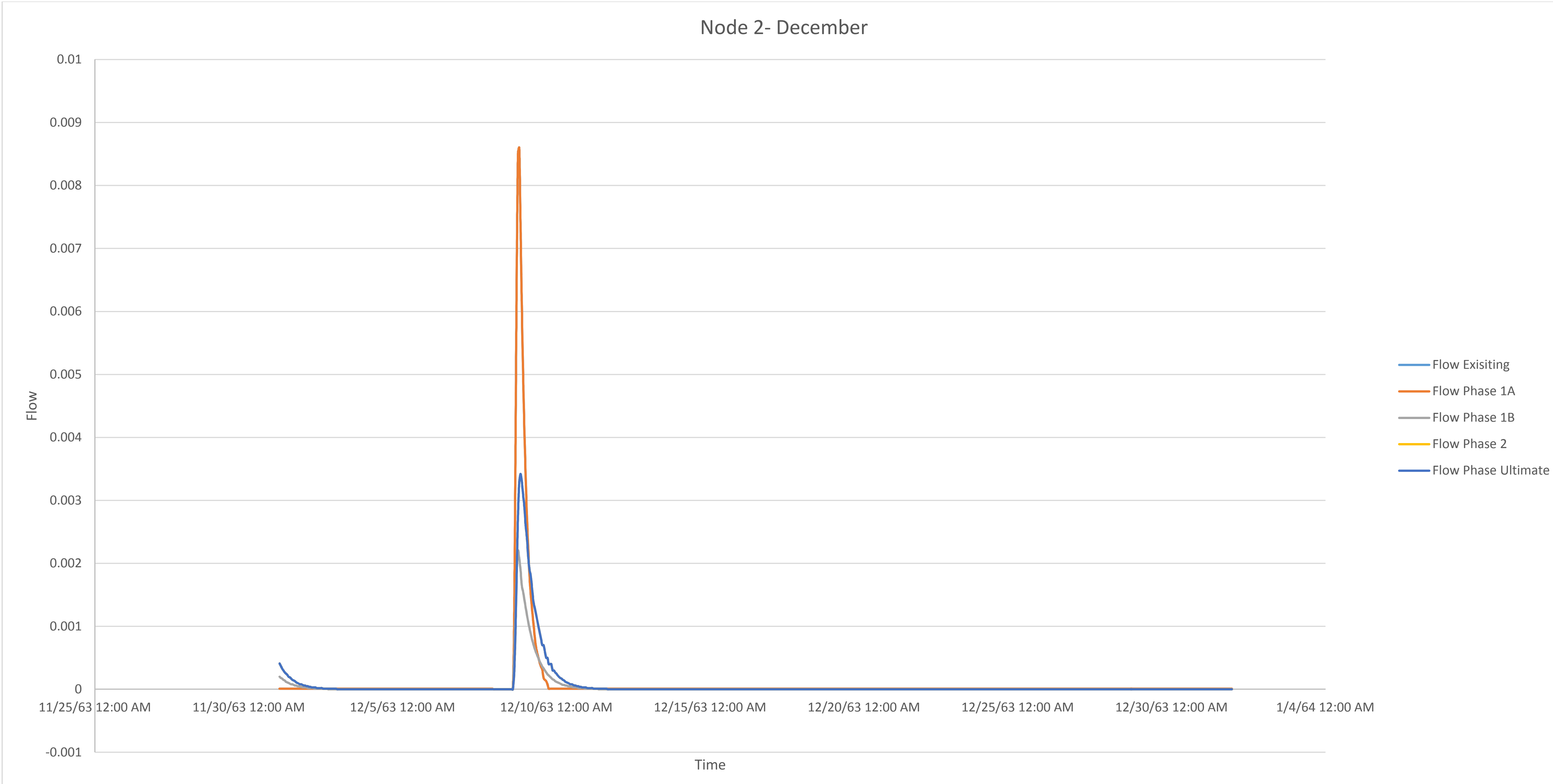
September						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		2	2	2	2	2
Magnitudes (cm/s)	Max.	0.0075	0.0075	0.00207	0.00331	0.00331
	Min.	0.00244	0.00244	0.00075	0.00119	0.00119
Duration (h)	Max.	35	35	66	73	73
	Min.	26	26	55	63	63



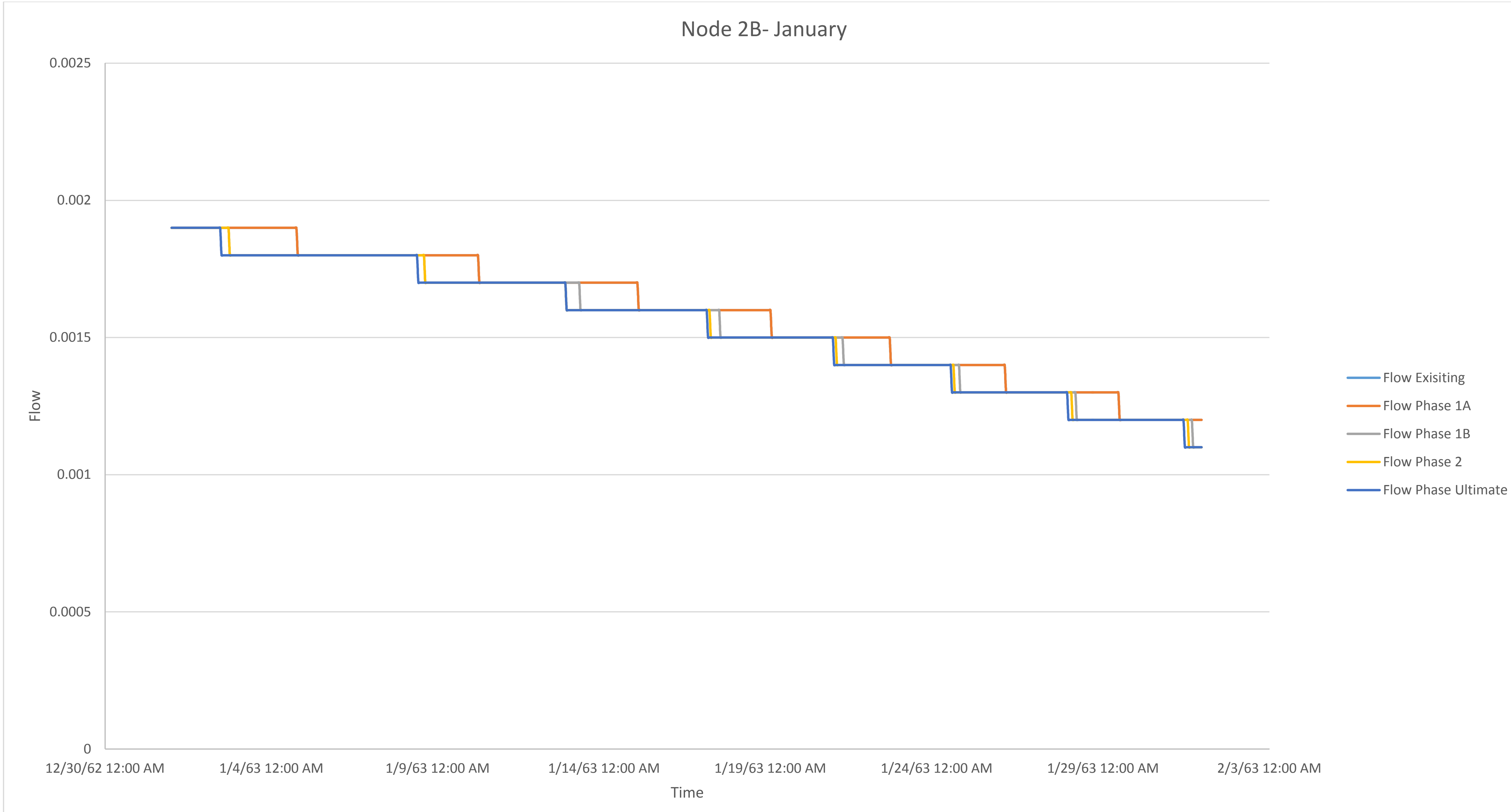
October						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency						
Magnitudes (cm/s)	Max.					
	Min.					
Duration (h)	Max.					
	Min.					



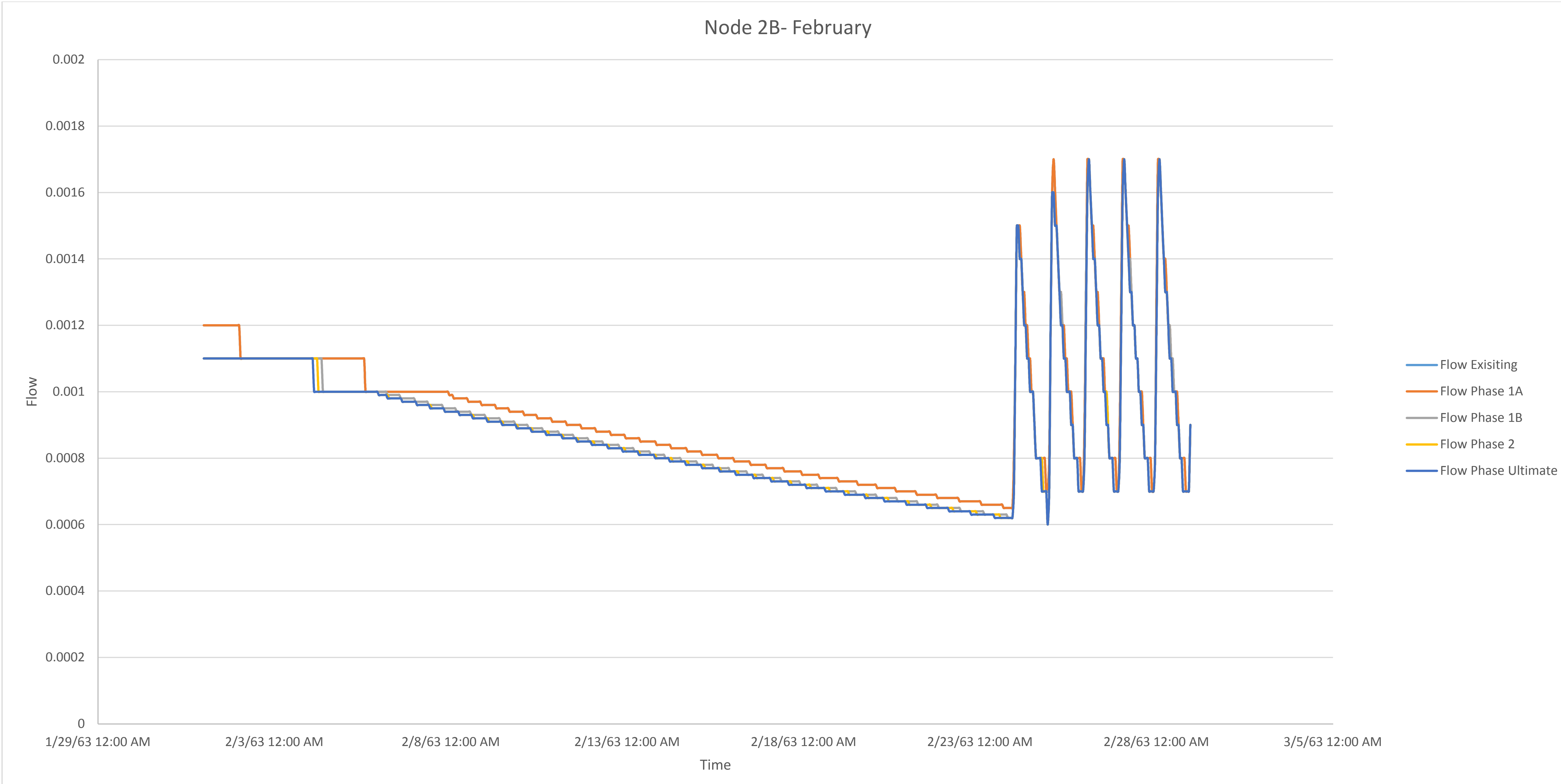
November						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	5	5	5
Magnitudes (cm/s)	Max.	0.0126	0.0126	0.0032	0.0052	0.0052
	Min.	0.0052	0.0052	0.00178	0.0029	0.0029
Duration (h)	Max.	41	41	80	87	87
	Min.	22	22	44	47	47



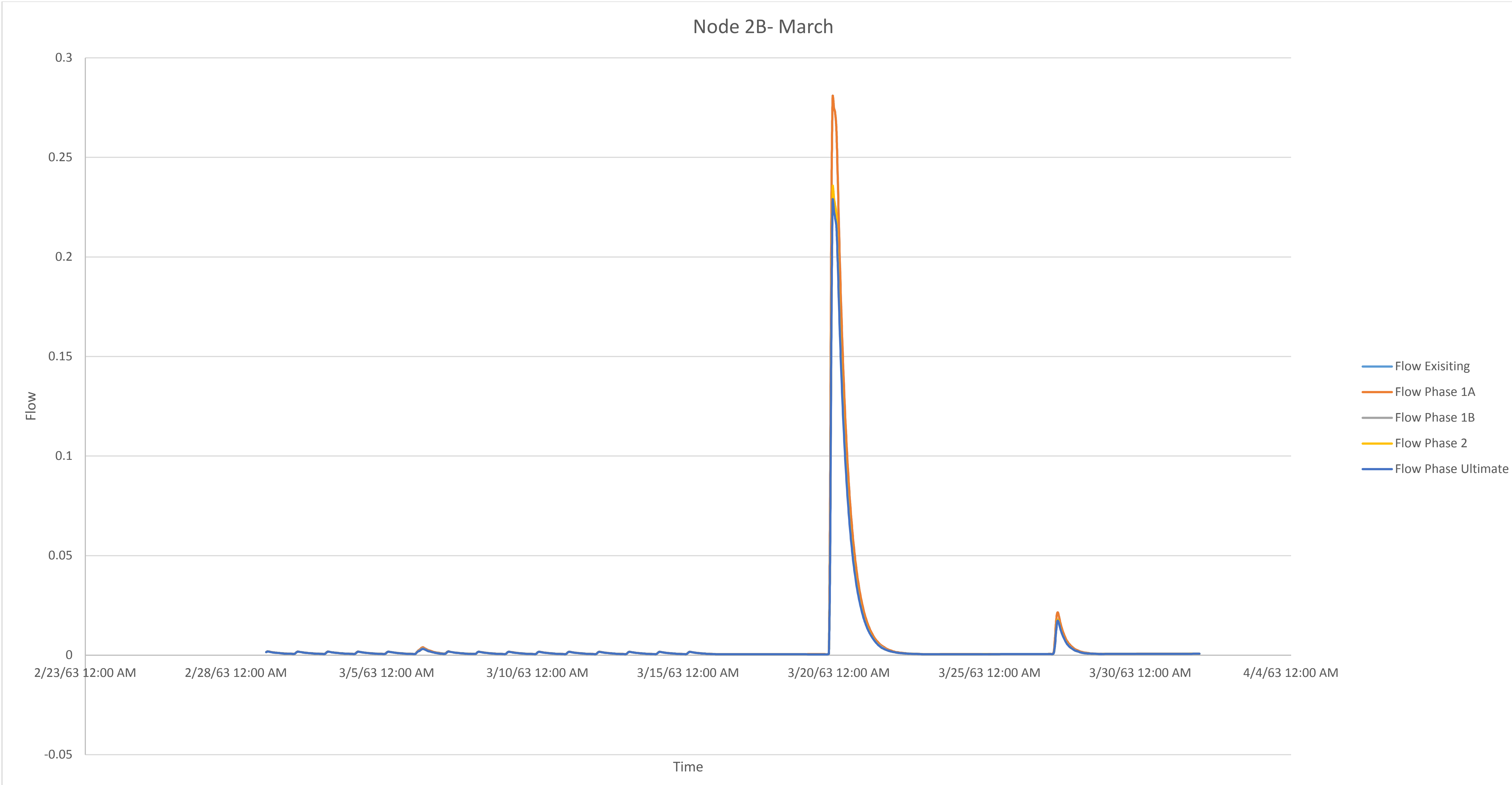
December						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitudes (cm/s)	Max.	0.0086	0.0086	0.0022	0.00342	0.00342
	Min.					
Duration (h)	Max.	27	27	66	72	72
	Min.					



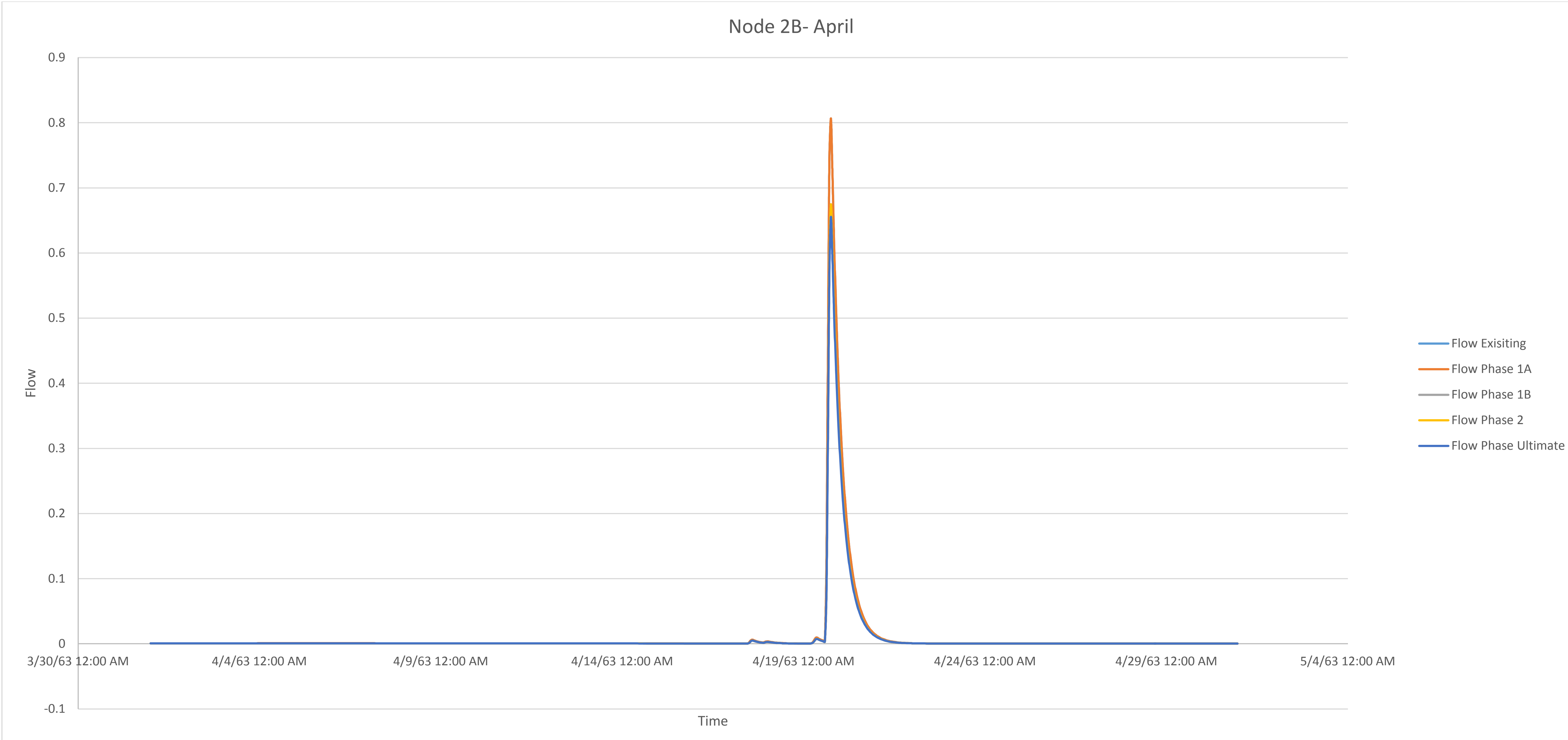
January						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		0	0	0	0	0
Magnitude (cm/s)	Max.					
	Min.					
Duration (h)	Max.					
	Min.					



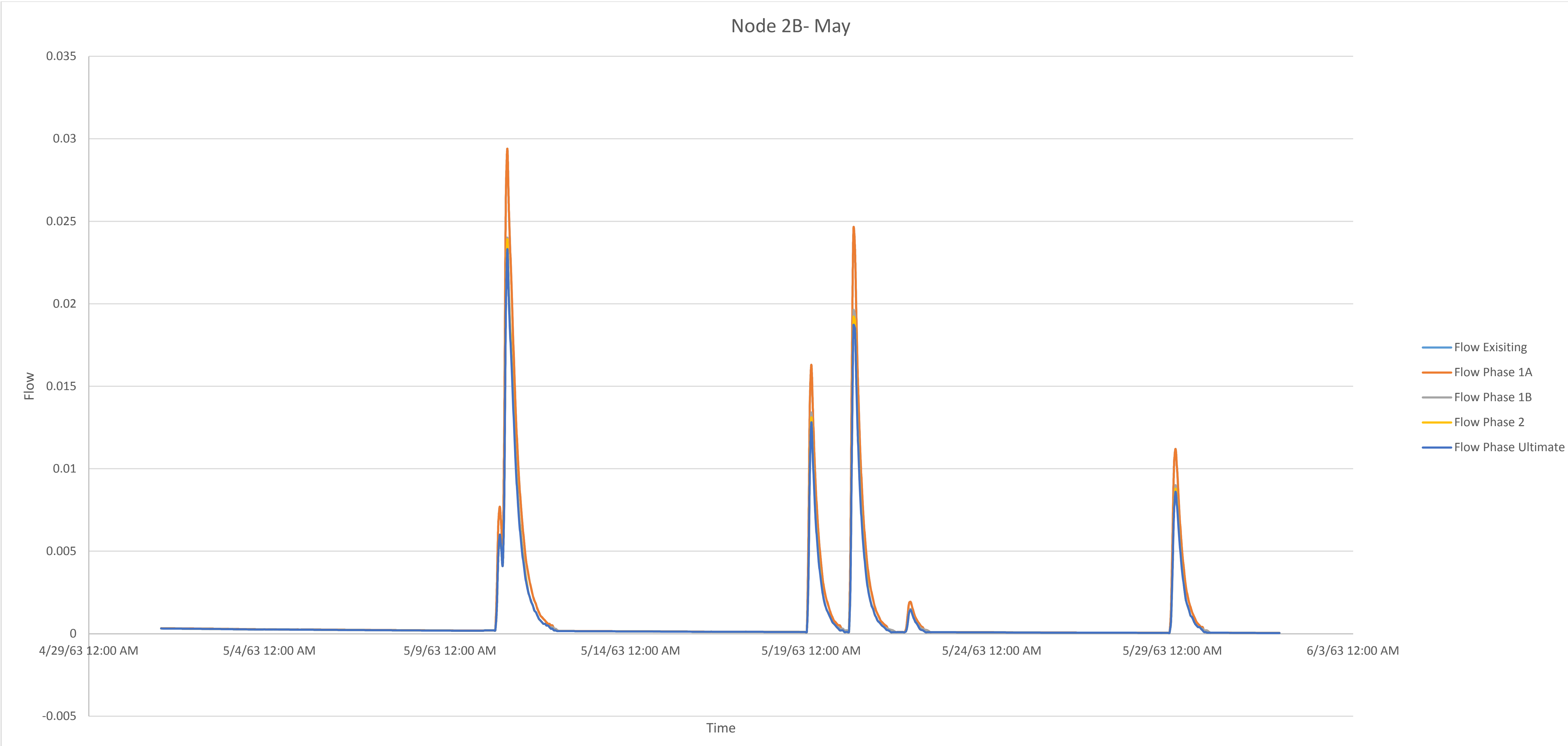
February						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	5	5	5
Magnitude (cm/s)	Max.	0.0017	0.0017	0.0017	0.0017	0.0017
	Min.	0.0015	0.0015	0.0015	0.0015	0.0015
Duration (h)	Max.	21	21	19	19	19
	Min.	22	22	20	20	19



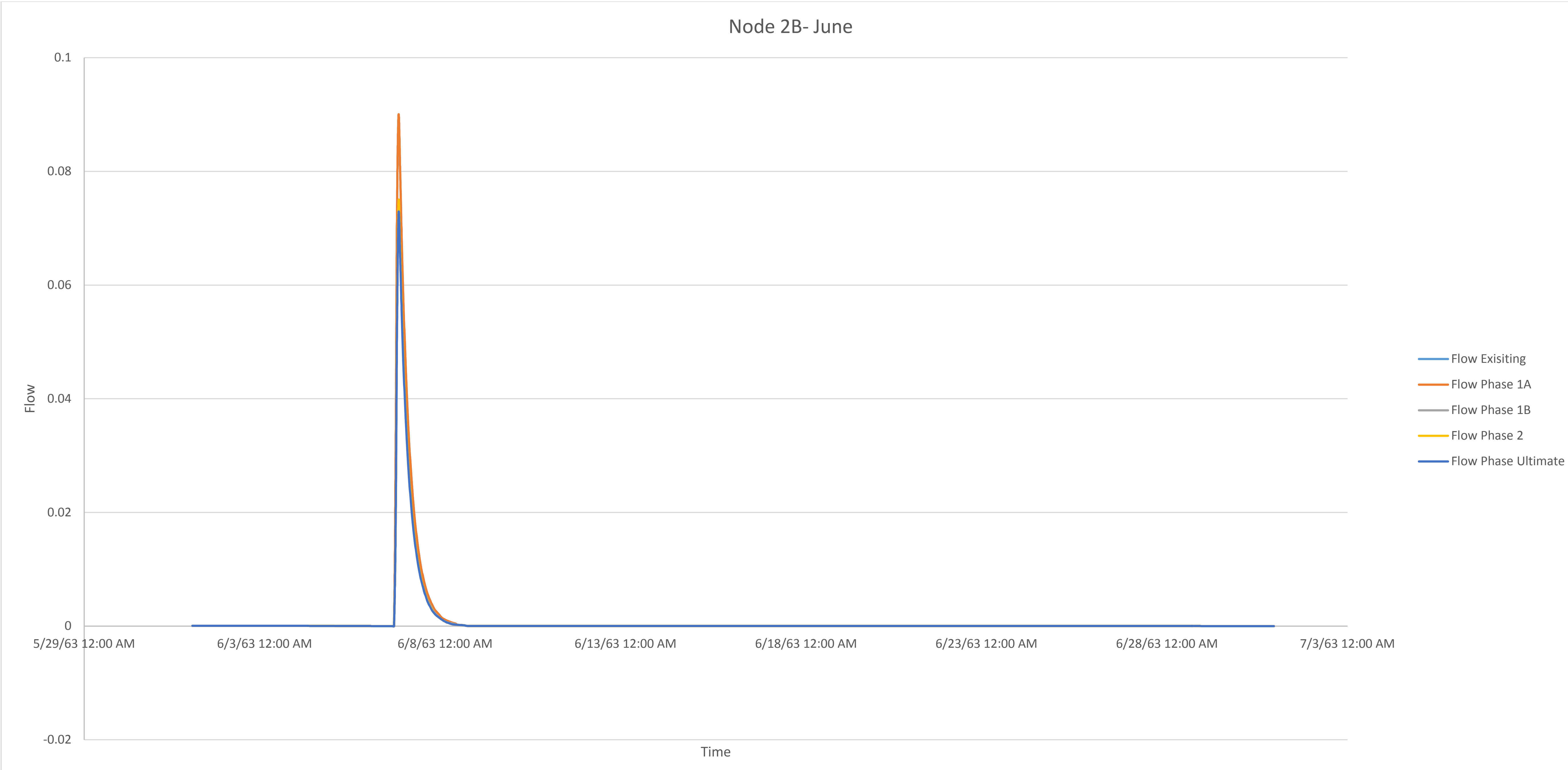
March						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		16	16	16	16	16
Magnitude (cm/s)	Max.	0.2804	0.2804	0.2349	0.2352	0.2285
	Min.	0.00168	0.00168	0.00166	0.00165	0.00165
Duration (h)	Max.	75	75	75	75	75
	Min.	23	23	23	23	23



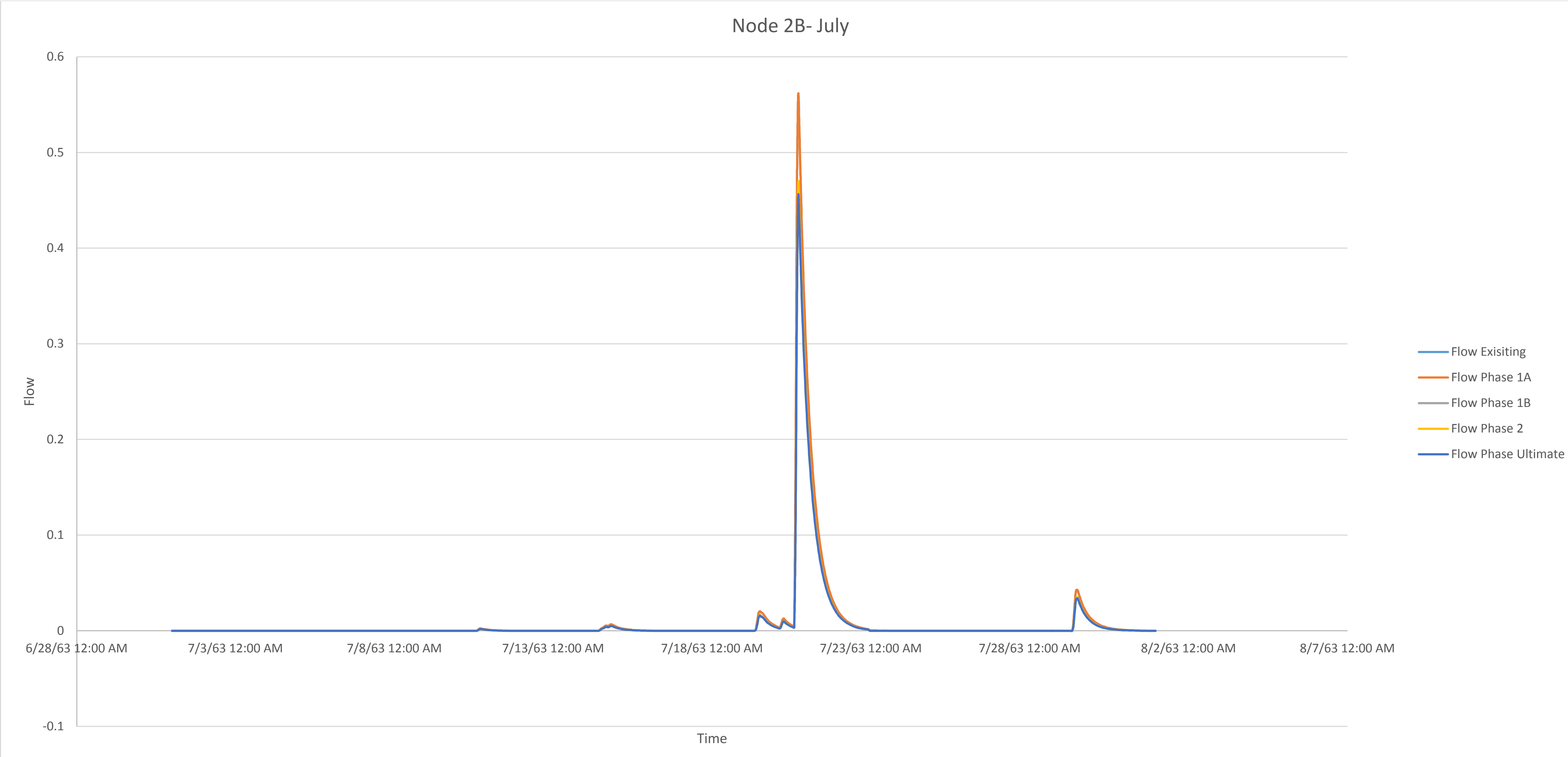
April						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitude (cm/s)	Max.	0.8066	0.8066	0.6739	0.6746	0.6553
	Min.	0.0037	0.0037	0.0028	0.0028	0.0028
Duration (h)	Max.	79	79	79	78	78
	Min.	23	23	23	19	19



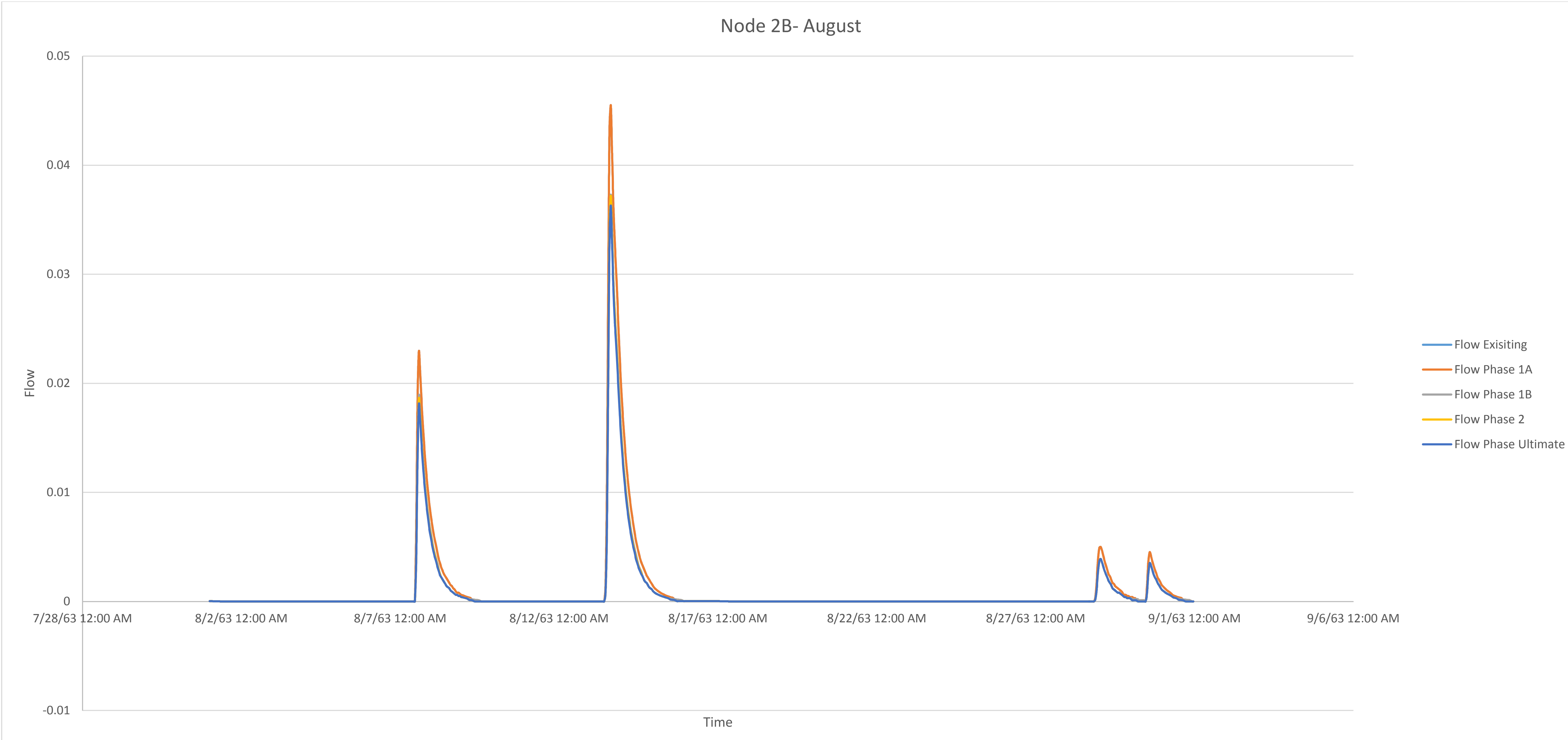
May						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		6	6	6	6	6
Magnitude (cm/s)	Max.	0.0294	0.0294	0.024	0.0239	0.0233
	Min.	0.00193	0.00193	0.0015	0.00144	0.00144
Duration (h)	Max.	41	41	41	40	40
	Min.	16	16	16	13	13



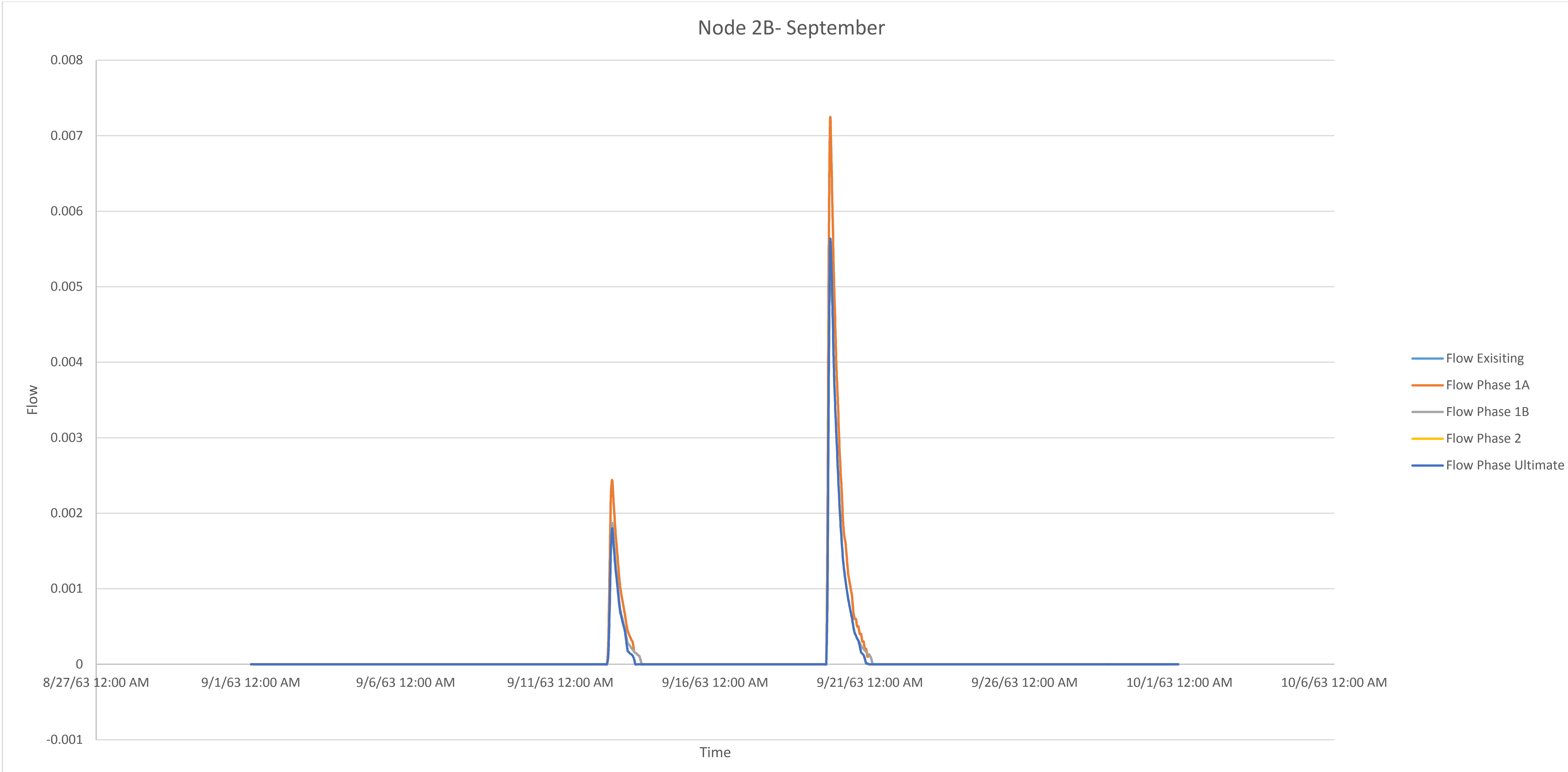
June						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitude (cm/s)	Max.	0.0899	0.0899	0.0745	0.0746	0.0725
	Min.					
Duration (h)	Max.	47	47	47	47	47
	Min.					



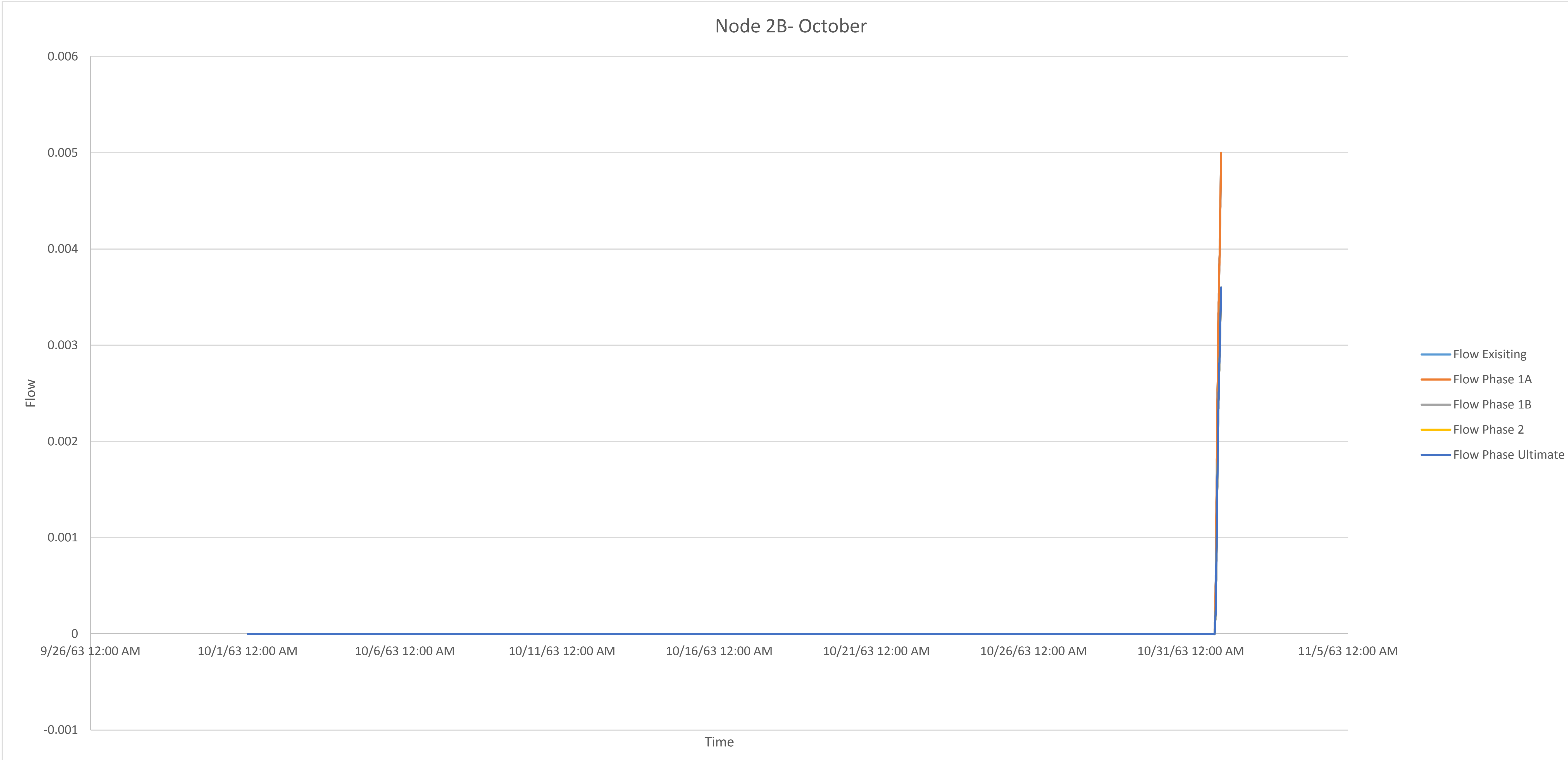
July						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		6	6	6	6	6
Magnitude (cm/s)	Max.	0.5596	0.5596	0.4657	0.4662	0.4527
	Min.	0.00246	0.00246	0.0019	0.0019	0.0019
Duration (h)	Max.	70	70	56	56	56
	Min.	24	24	24	19	19



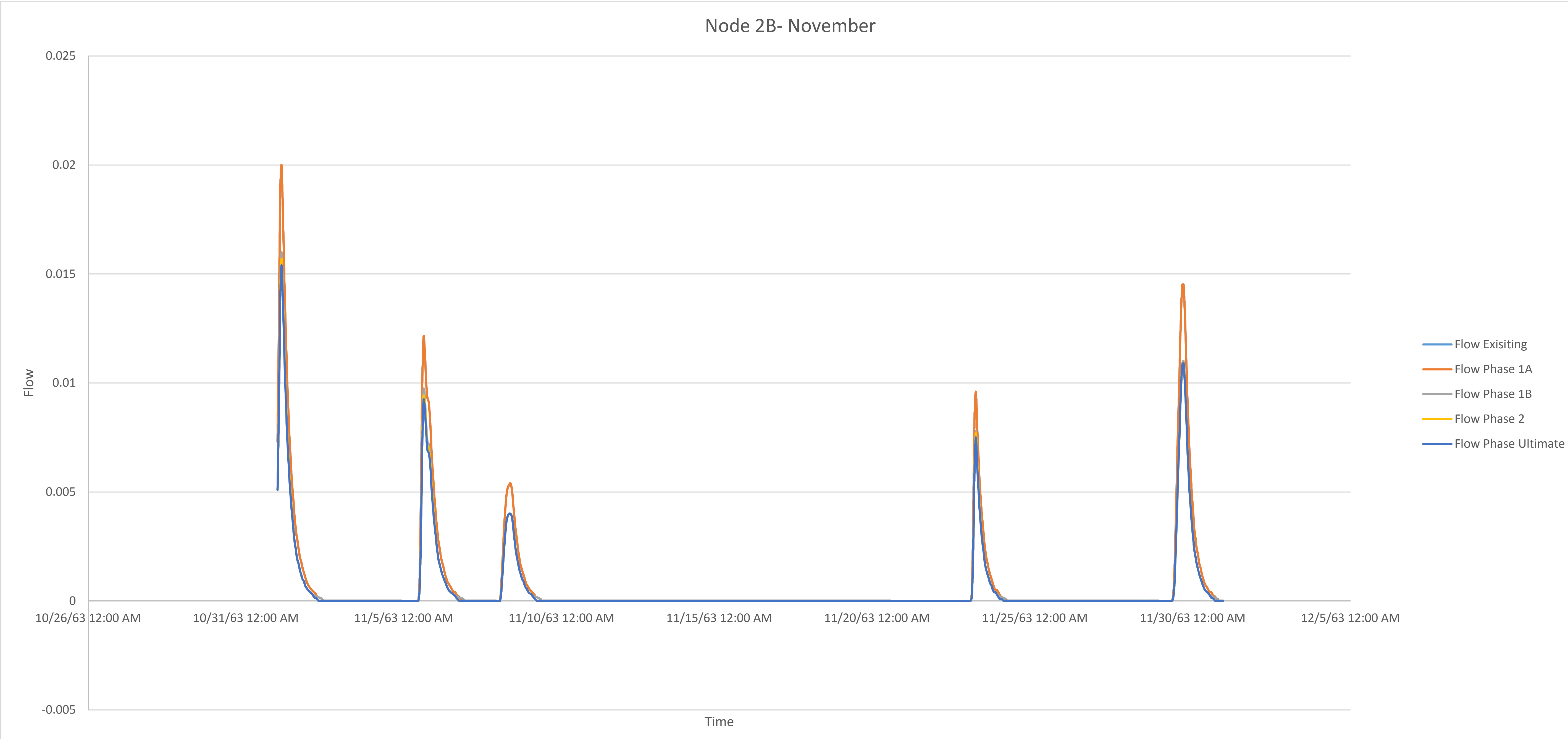
August						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitude (cm/s)	Max.	0.0455	0.0455	0.0373	0.0372	0.0363
	Min.	0.0045	0.0045	0.0035	0.0035	0.0035
Duration (h)	Max.	59	59	59	54	54
	Min.	34	34	34	29	29



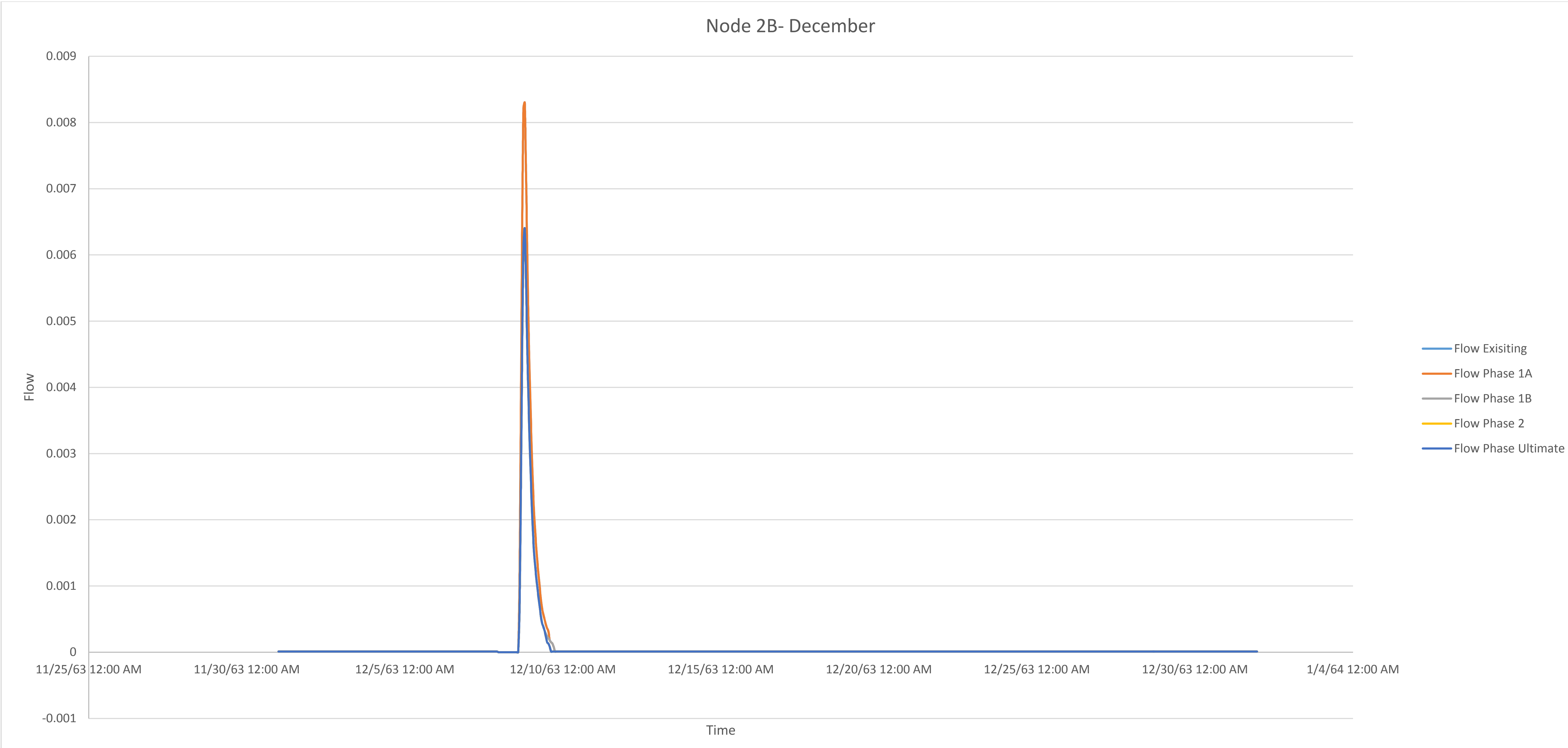
September						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		2	2	2	2	2
Magnitude (cm/s)	Max.	0.0072	0.0072	0.0056	0.0056	0.0056
	Min.	0.00244	0.00244	0.00187	0.0018	0.0018
Duration (h)	Max.	35	35	35	32	32
	Min.	26	26	26	21	21



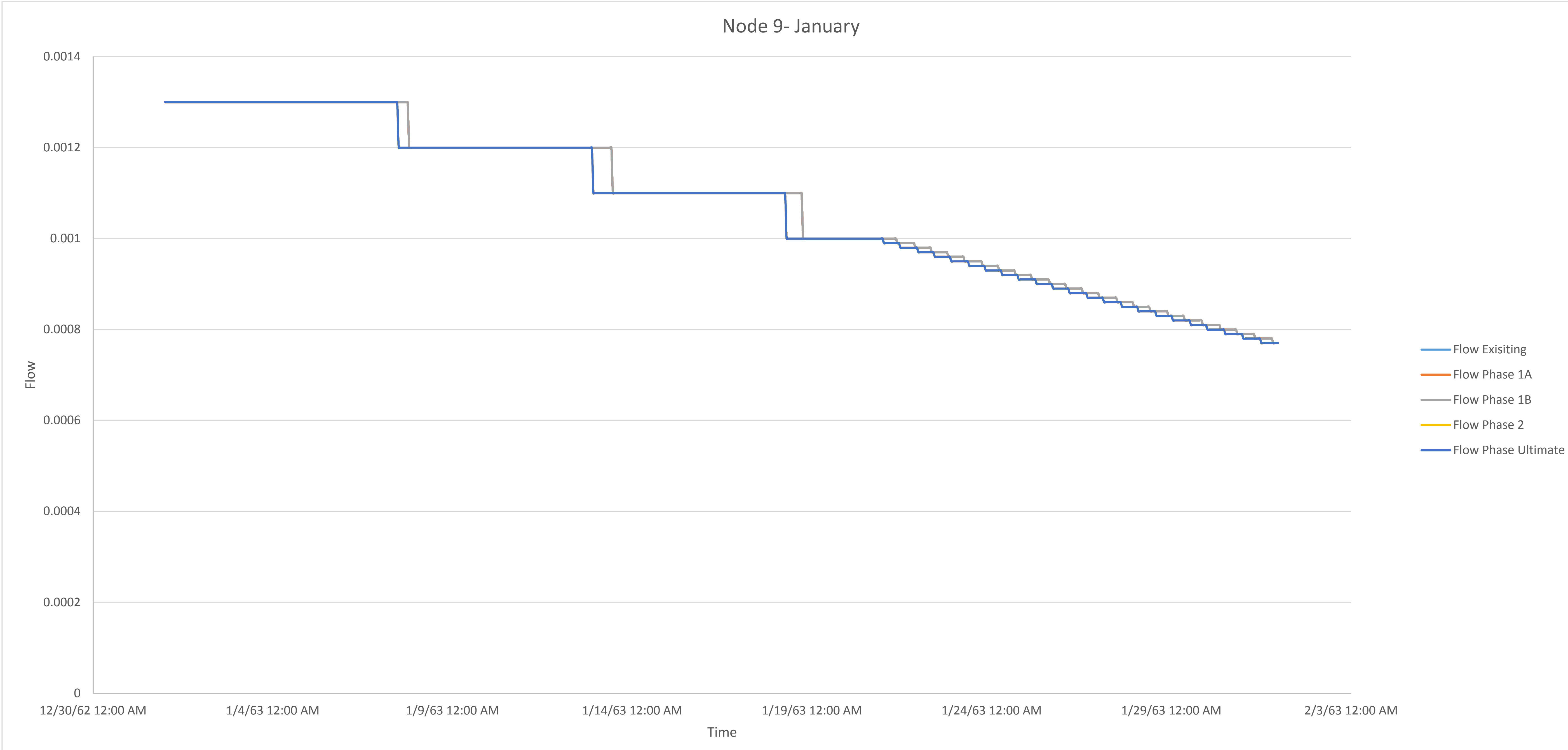
October						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		0	0	0	0	0
Magnitude (cm/s)	Max.					
	Min.					
Duration (h)	Max.					
	Min.					



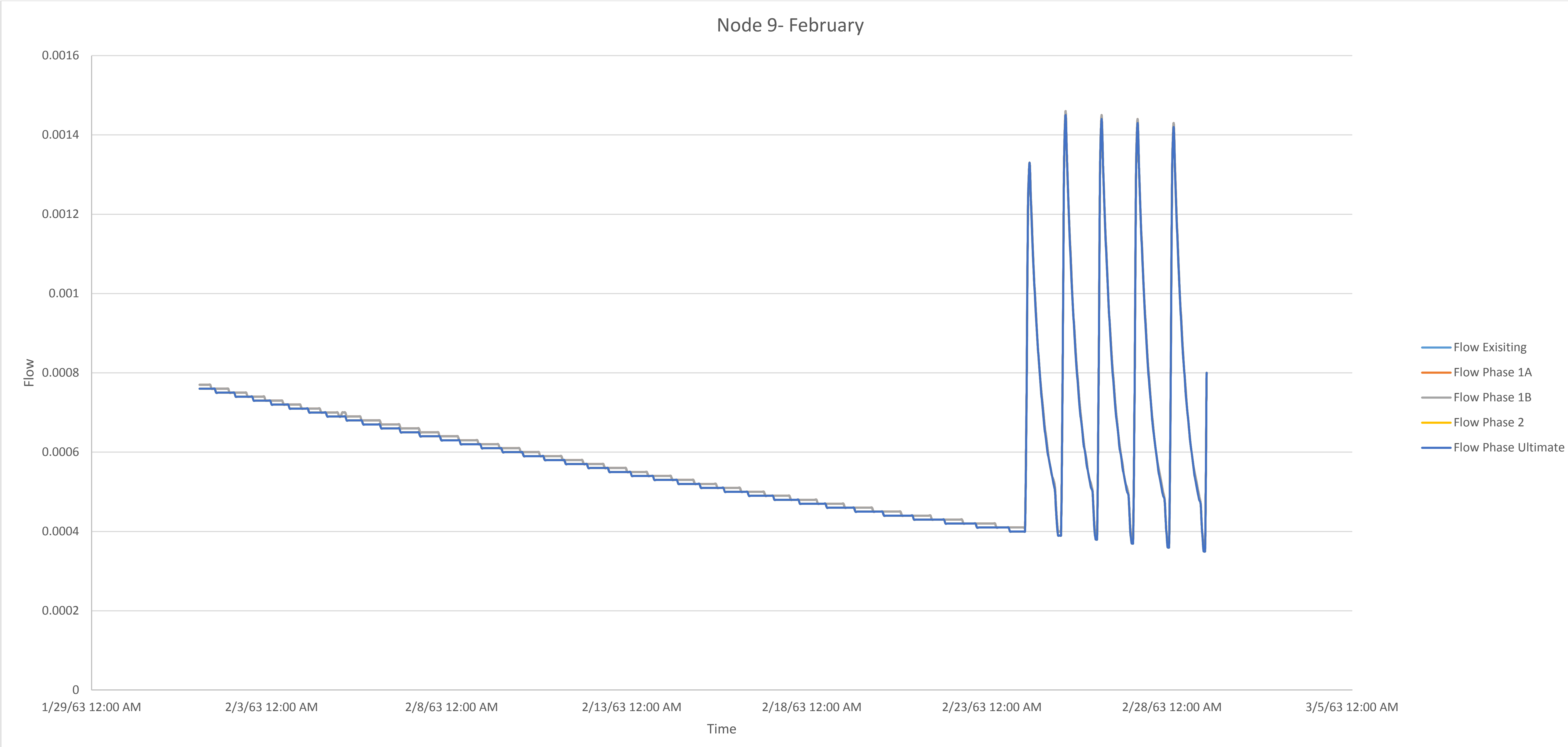
November						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	5	5	5
Magnitude (cm/s)	Max.	0.0145	0.0145	0.011	0.0109	0.0109
	Min.	0.0054	0.0054	0.004	0.004	0.004
Duration (h)	Max.	35	35	35	32	32
	Min.	31	31	31	27	27



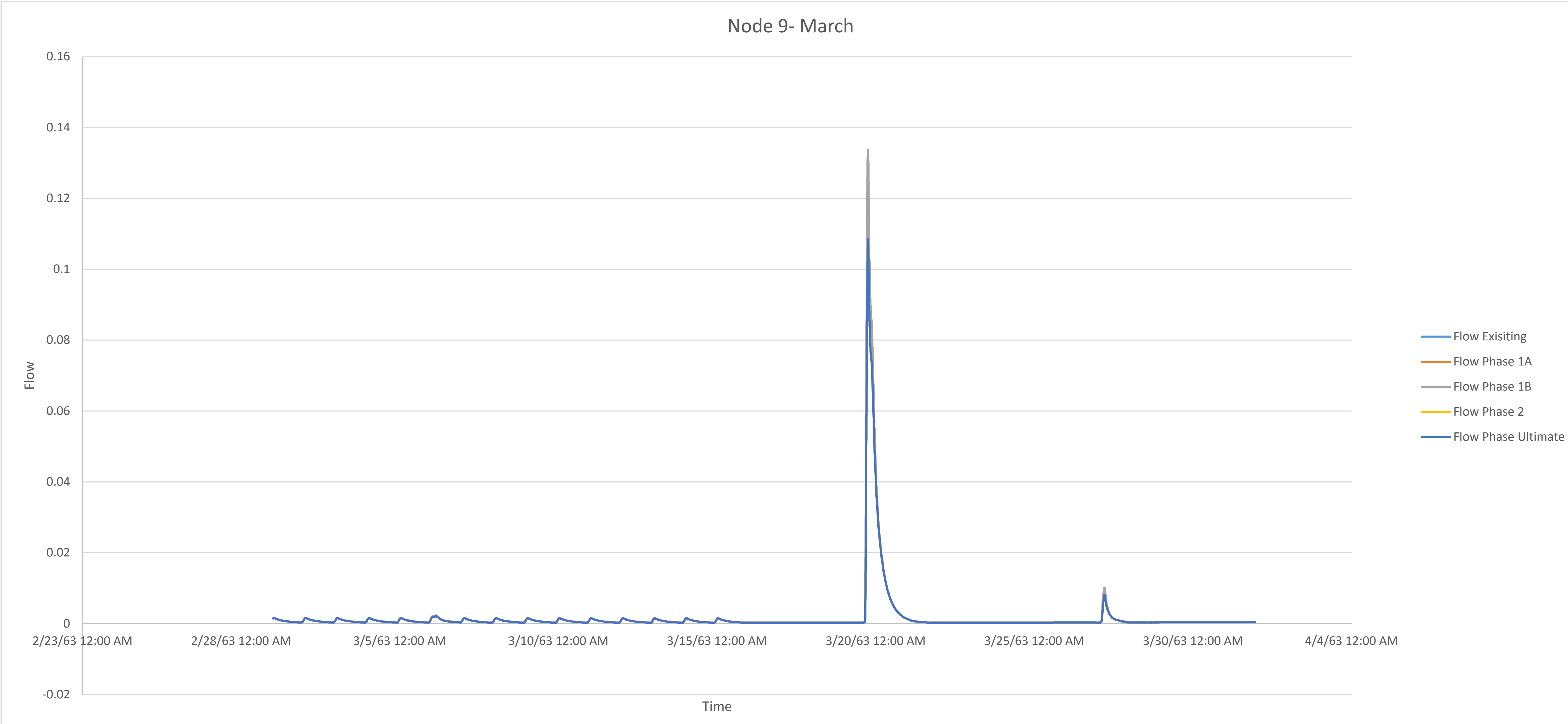
December						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitude (cm/s)	Max.	0.0083	0.0083	0.0064	0.0064	0.0064
	Min.					
Duration (h)	Max.	27	27	27	24	24
	Min.					



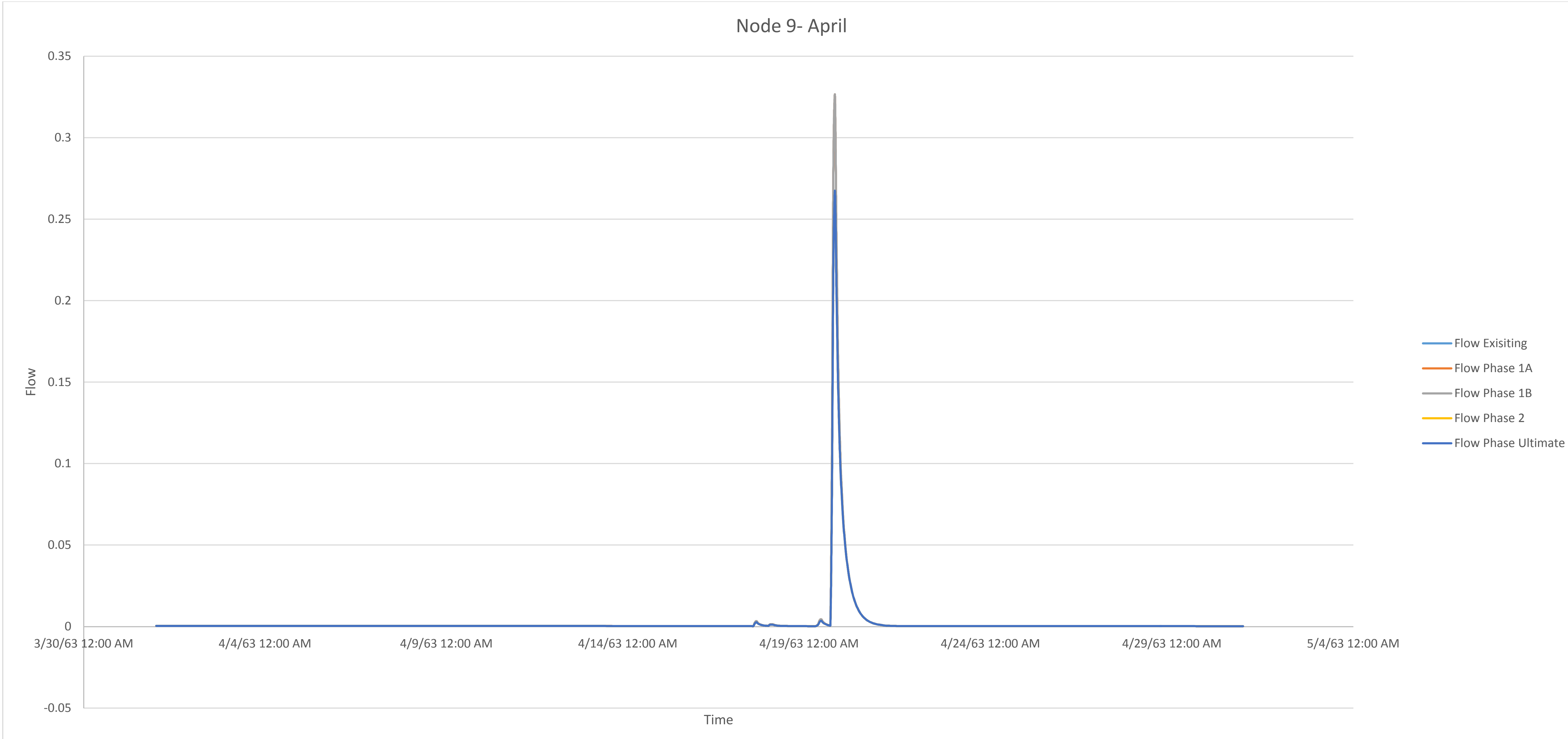
January						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		0	0	0	0	0
Magnitude (cm/s)	Max.					
	Min.					
Duration (h)	Max.					
	Min.					



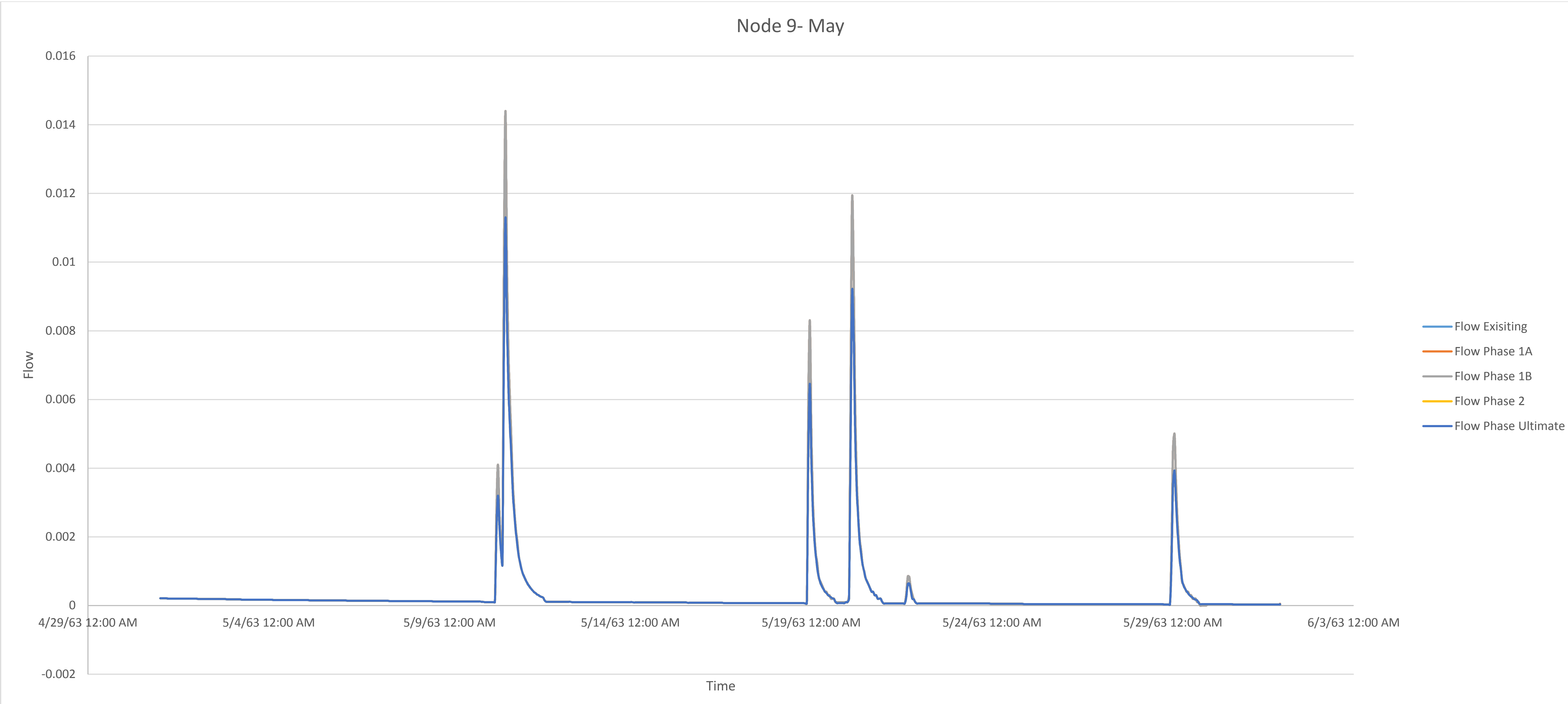
February						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	5	5	5
Magnitude (cm/s)	Max.	0.00146	0.00146	0.00146	0.00145	0.00145
	Min.	0.00133	0.00133	0.00133	0.00133	0.00133
Duration (h)	Max.	22	553629	553629	553629	553629
	Min.	21	21	21	21	21



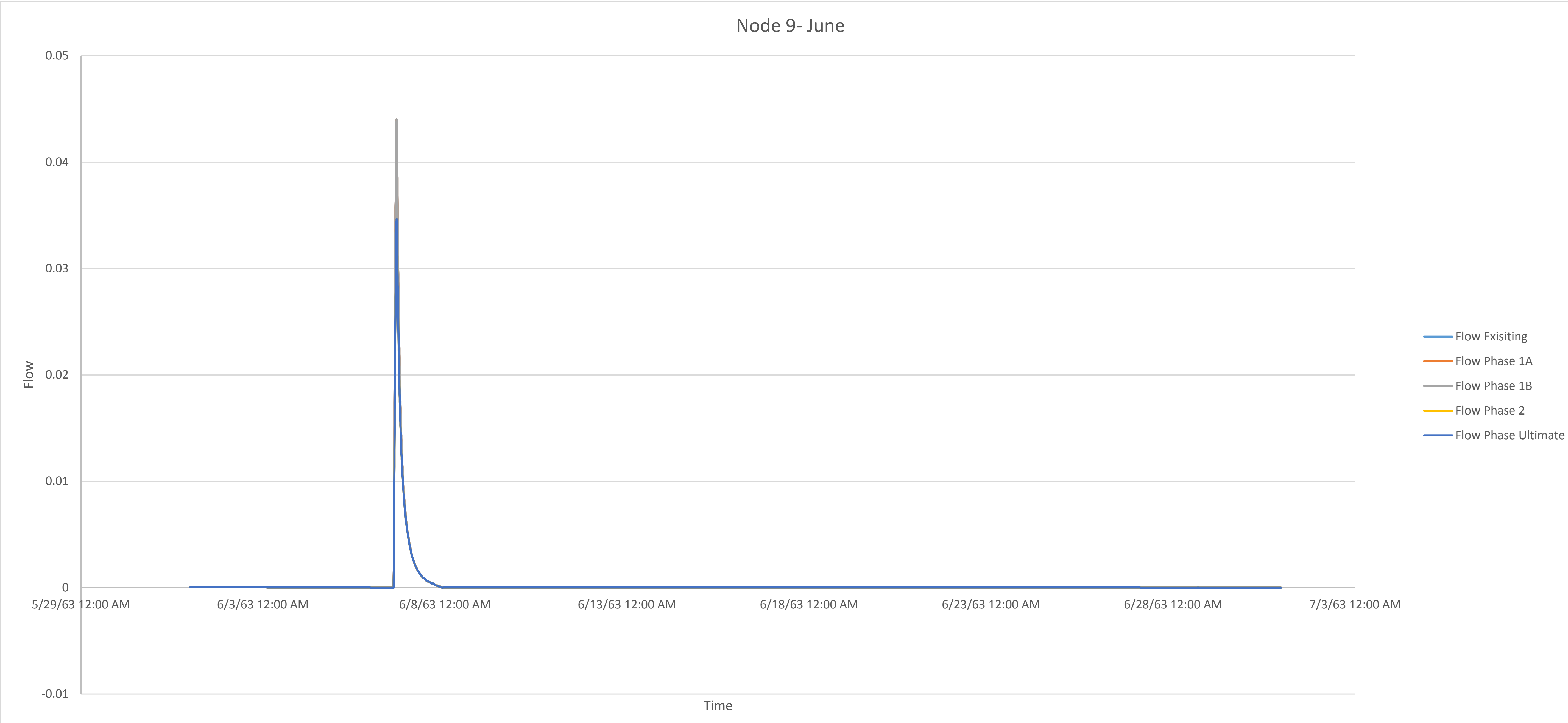
March						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		16	16	16	16	16
Magnitude (cm/s)	Max.	0.1333	0.1333	0.1333	0.1078	0.1078
	Min.	0.0015	0.0015	0.0015	0.0015	0.0015
Duration (h)	Max.	48	48	48	48	48
	Min.	20	20	20	20	20



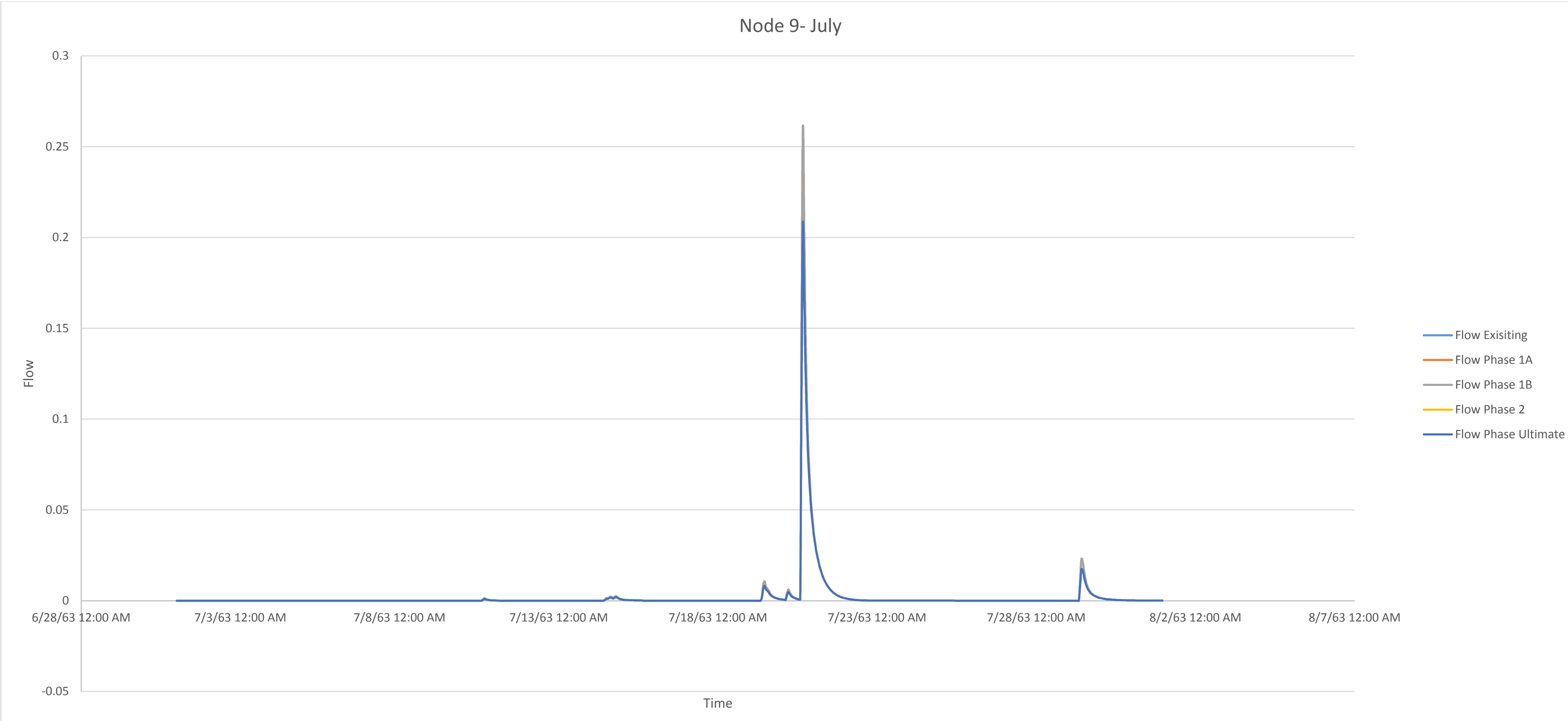
April						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitude (cm/s)	Max.	0.3262	0.3262	0.3262	0.2674	0.2674
	Min.	0.00138	0.00138	0.00138	0.0011	0.0011
Duration (h)	Max.	44	44	44	44	44
	Min.	13	13	13	13	13



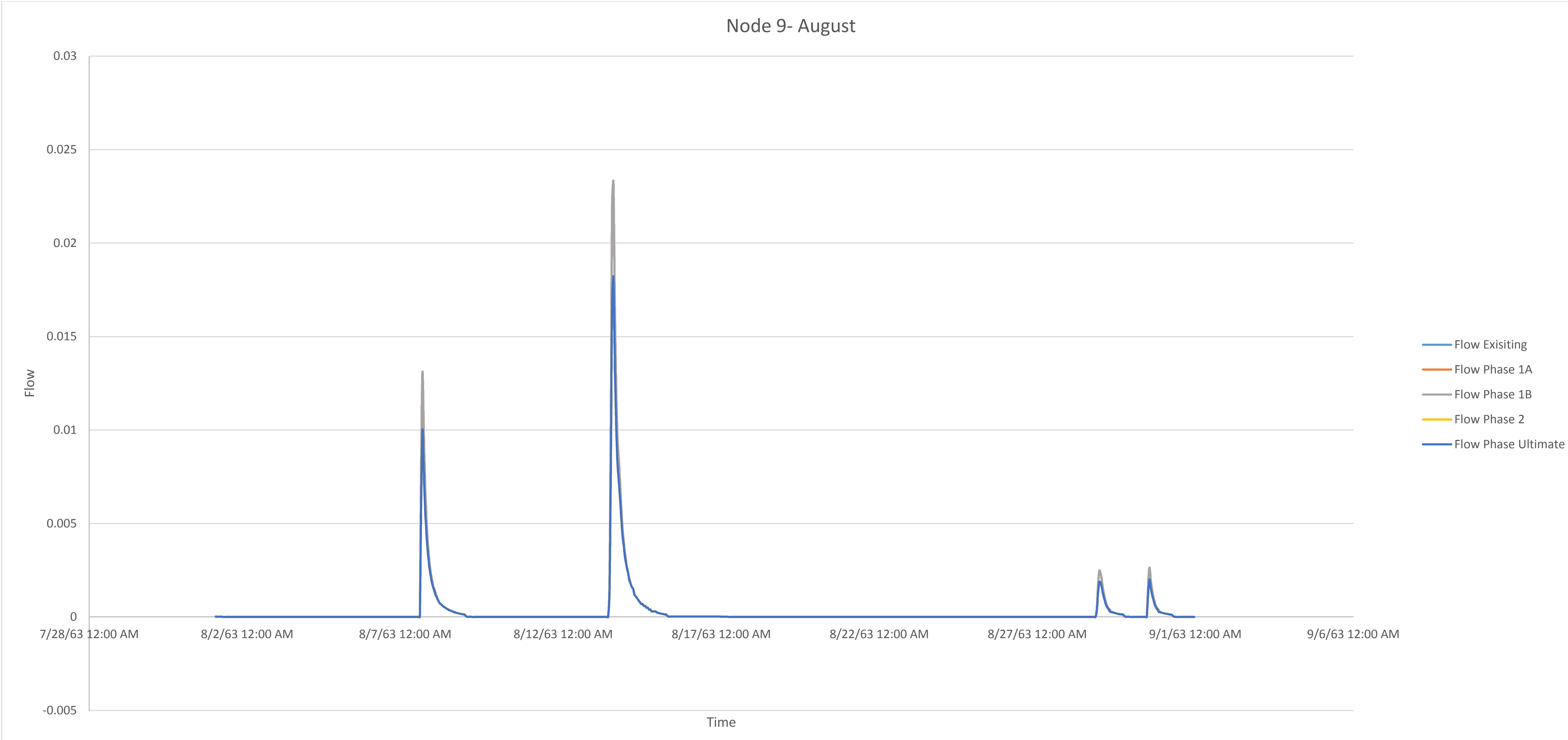
May						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		6	6	6	6	6
Magnitude (cm/s)	Max.	0.0144	0.0144	0.0144	0.0113	0.0113
	Min.	0.00085	0.00085	0.00085	0.00064	0.00064
Duration (h)	Max.	33	33	33	33	33
	Min.	7	7	7	7	7



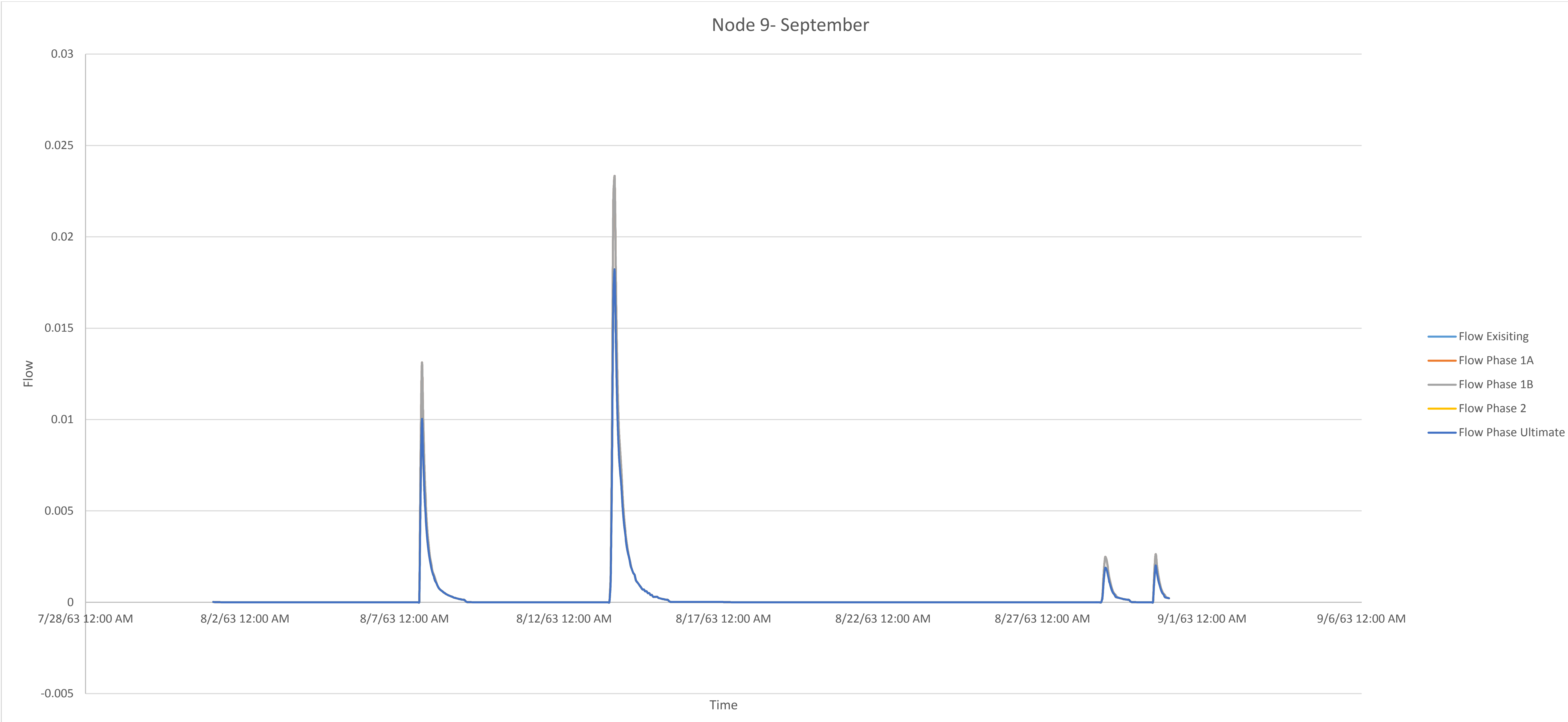
June						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitude (cm/s)	Max.	0.044	0.044	0.044	0.0346	0.0346
	Min.					
Duration (h)	Max.	31	31	31	31	31
	Min.					



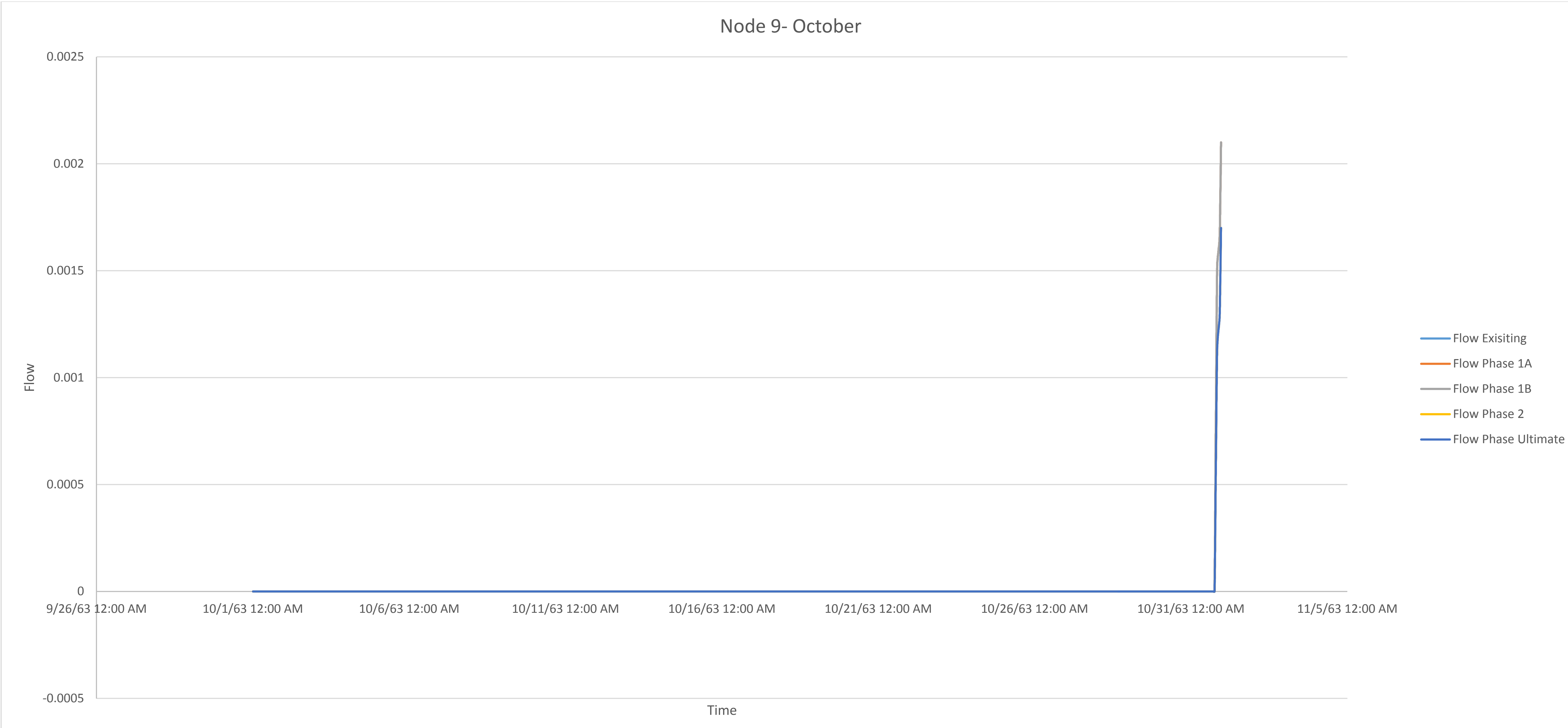
July						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		6	6	6	6	6
Magnitude (cm/s)	Max.	0.2609	0.2609	0.2609	0.2074	0.2074
	Min.	0.00133	0.00133	0.00133	0.00099	0.00099
Duration (h)	Max.	39	39	39	39	39
	Min.	12	12	12	12	12



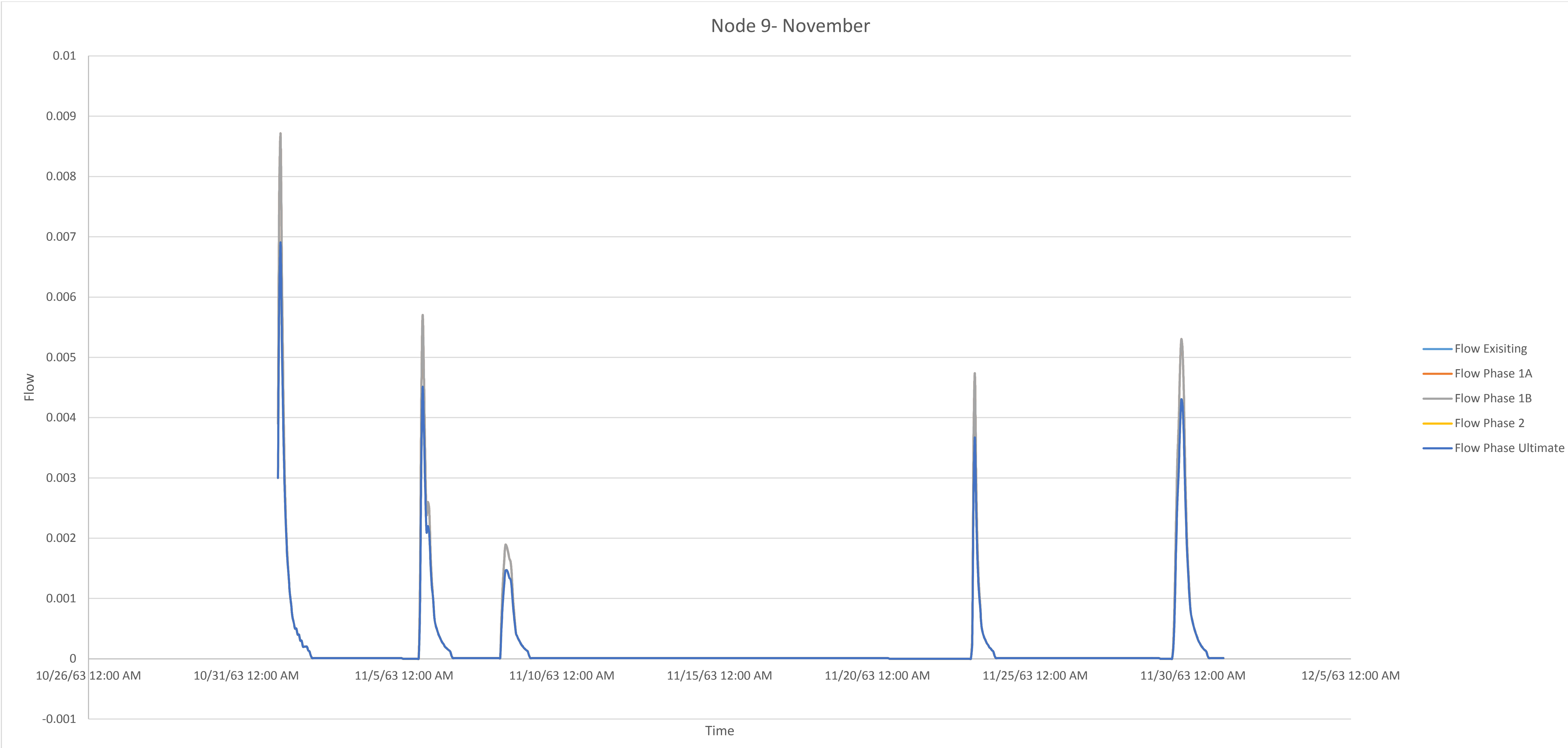
August						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		4	4	4	4	4
Magnitude (cm/s)	Max.	0.0233	0.0233	0.0233	0.0182	0.0182
	Min.	0.00247	0.00247	0.00247	0.00188	0.00188
Duration (h)	Max.	45	45	45	45	45
	Min.	26	26	26	26	26



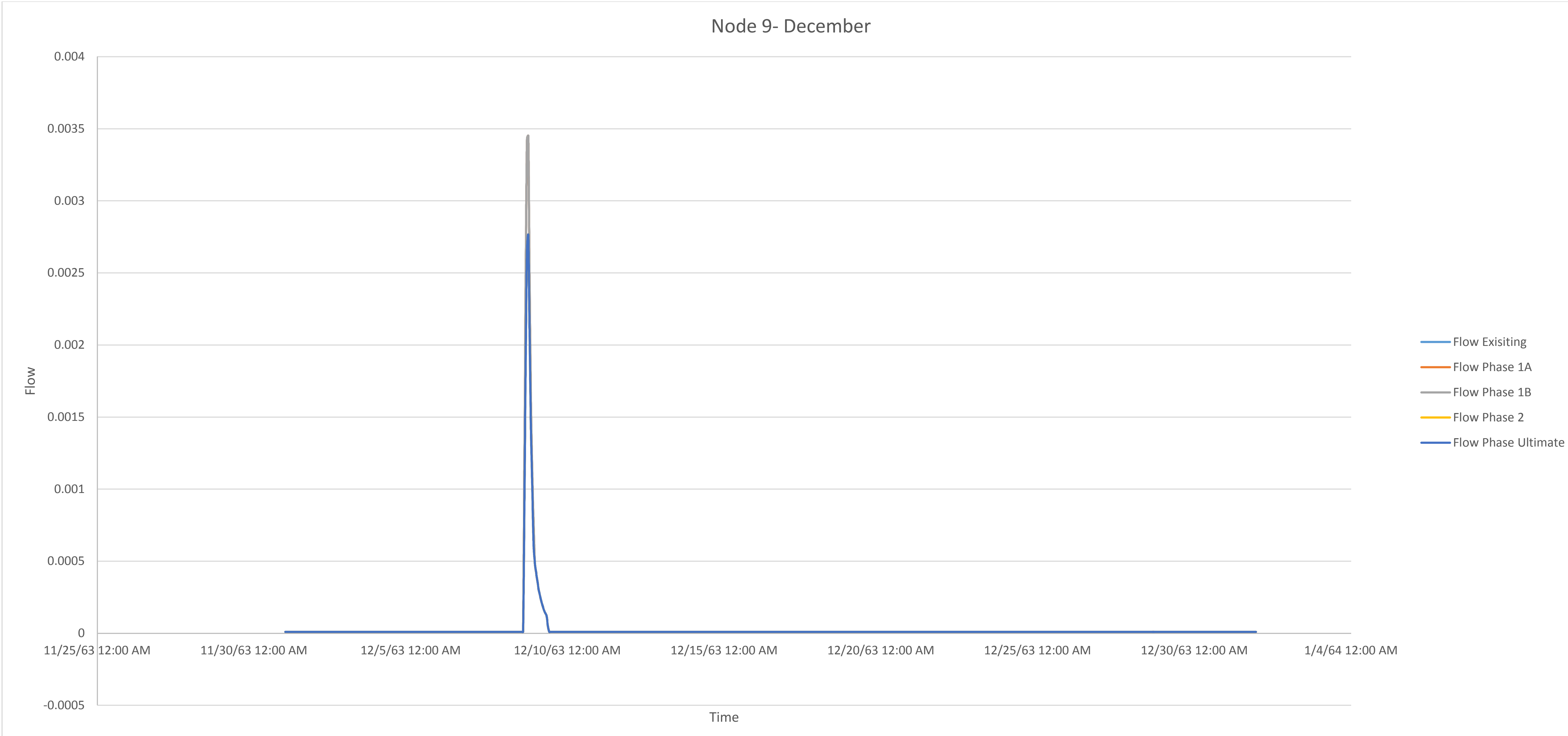
September						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		2	2	4	2	2
Magnitude (cm/s)	Max.	0.00402	0.00402	0.00402	0.00307	0.00307
	Min.	0.00119	0.00119	0.00119	0.00089	0.00089
Duration (h)	Max.	30	30	30	30	30
	Min.	12	12	12	12	12



October						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		0	0	0	0	0
Magnitude (cm/s)	Max.					
	Min.					
Duration (h)	Max.					
	Min.					



November						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		5	5	5	5	5
Magnitude (cm/s)	Max.	0.00570	0.00570	0.00570	0.00450	0.00450
	Min.	0.00189	0.00189	0.00189	0.00147	0.00147
Duration (h)	Max.	25	25	25	25	25
	Min.	22	22	22	22	22



December						
Conditions		Existing	Phase 1A	Phase 1B	Phase 2	Ultimate
Frequency		1	1	1	1	1
Magnitude (cm/s)	Max.	0.00345	0.00345	0.00345	0.00276	0.00276
	Min.					
Duration (h)	Max.	19	19	19	19	19
	Min.					