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February 8, 2019
19-1037

Attention: **Len Ivison, A.Sc.T.**
Senior Project Manager

Re: **Stormwater Management Plan – Nation Rise Wind Farm**
Township of North Stormont, ON.

Dear Sir:

Please find enclosed our revised Stormwater Management Plan for the above noted project in The Township of North Stormont, Ontario.

This report presents the Stormwater Management Plan addressing the proposed construction of the substation, laydown area and maintenance access roads for the Nation Rise Wind Farm.

We trust the enclosed is adequate for your needs at this time. If there is anything further we can provide please contact us at your convenience.

Sincerely,

Josh Lelievre, P.Eng.
TULLOCH Engineering Inc.

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
1	1	EDP Renewables

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
0	JL	December 21, 2018	Issued for Review
1	JL	January 8, 2019	Issued for Permit
2	JL	January 30, 2019	Revised as per MECP Comments
3	JL	February 8, 2019	Revised per additional MECP Comments

TULLOCH Signatures

LICENSED PROFESSIONAL ENGINEER
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FEB.8/19
PROVINCE OF ONTARIO

Report Prepared By:

Josh Lelievre, P.Eng.
Project Manager

Date

LICENSED PROFESSIONAL ENGINEER
Feb. 8/19
C. L. KIRBY
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PROVINCE OF ONTARIO

Report Reviewed By:

Chris Kirby, P.Eng.
Project Manager

Date

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APPENDICES

1. INTRODUCTION

1.1 General

TULLOCH Engineering (TULLOCH) was retained by EDP Renewables to complete a Stormwater Management (SWM) Plan for the 99.76 MW Nation Rise Wind Farm (NRWF) located 40 kilometres southeast of Ottawa in The Township of North Stormont, Ontario, Canada. An overview of the NRWF development is indicated on the following Figure 1.1.

The overall development will consist of gravel access roads for the wind turbines, a substation and a temporary laydown area. This report will focus on the two (2) areas of development which would be expected to result in changes to stormwater runoff under proposed conditions. The two (2) areas are the substation and the laydown area.

It should be noted that the gravel access roads and turbine sites are not expected to have significant hydrologic impacts and are discussed further in Section 2.3.3 of this report.

1.2 Existing Conditions

1.2.1 Substation

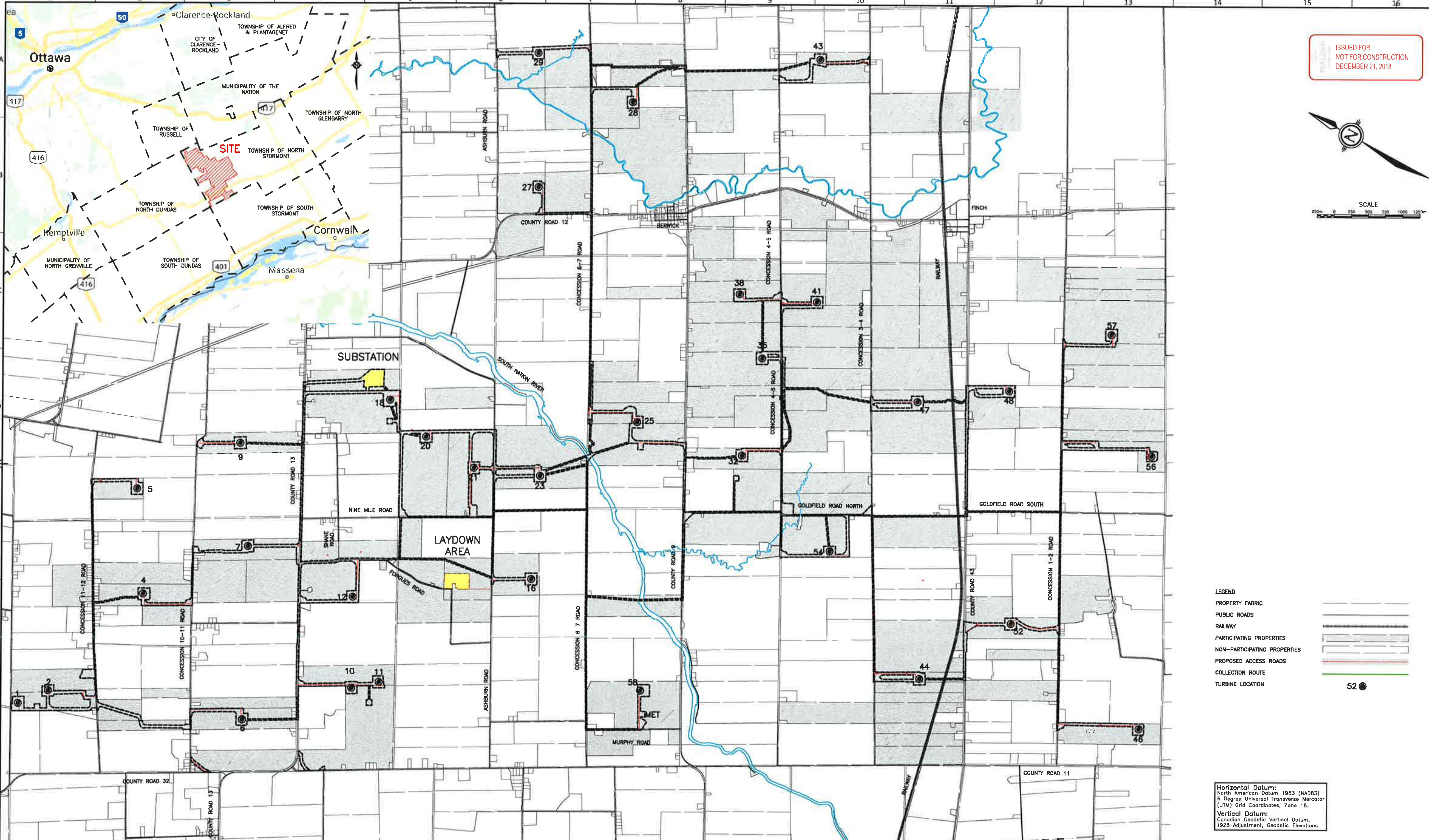
The proposed substation site is located approximately 1.0 kilometres southeast of County Road 13 and 400 metres southwest of Ashburn Road. The site consists of existing agricultural land (row crops) for its entirety. The site generally drains from the northwest to the southeast towards the existing Johnstone Municipal Drain and is generally flat at less than 0.5% grade. Refer to the following Figure 1.2.

Surficial native soils for the site generally consist of silty clay topsoil followed by silty clay. The Hydrologic Soil Group, according to the Soil Conservation Service Classification System, is “D”.

1.2.2 Laydown Area

The proposed laydown area site is located adjacent to Forgues Road and approximately 350 metre northwest of Ashburn Road. The laydown area consists of existing agricultural lands (row crops) and some farm buildings. Drainage is split with a portion draining to the west and the remainder to the east. There are currently no surface drainage features in proximity to this site and stormwater generally drains to lower elevations where it ponds until eventual evaporation and infiltration. Refer to the following Figure 1.3.

Surficial native soils for the laydown area generally consist of silty clay topsoil followed by silty clay. The Hydrologic Soil Group, according to the Soil Conservation Service Classification System, is “D”.



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NATION RISE WIND FARM
NORTH STORMONT, ONTARIO

KEY PLAN AND OVERALL SITE

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TULLOCH ENGINEERING

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Drawing Nº: FIG 1.1

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FLOW DIRECTION	1.0%
DRAINAGE AREA	
SUBSTATION FENCE LINE	
SOUTH NATION CONSERVATION WATERCOURSE	
PROPOSED ACCESS ROAD	
EXISTING TRANSMISSION LINE TOWER	

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NATION RISE WIND FARM
NORTH STORMONT, ONTARIO

SUBSTATION EXISTING CONDITIONS DRAINAGE PLAN

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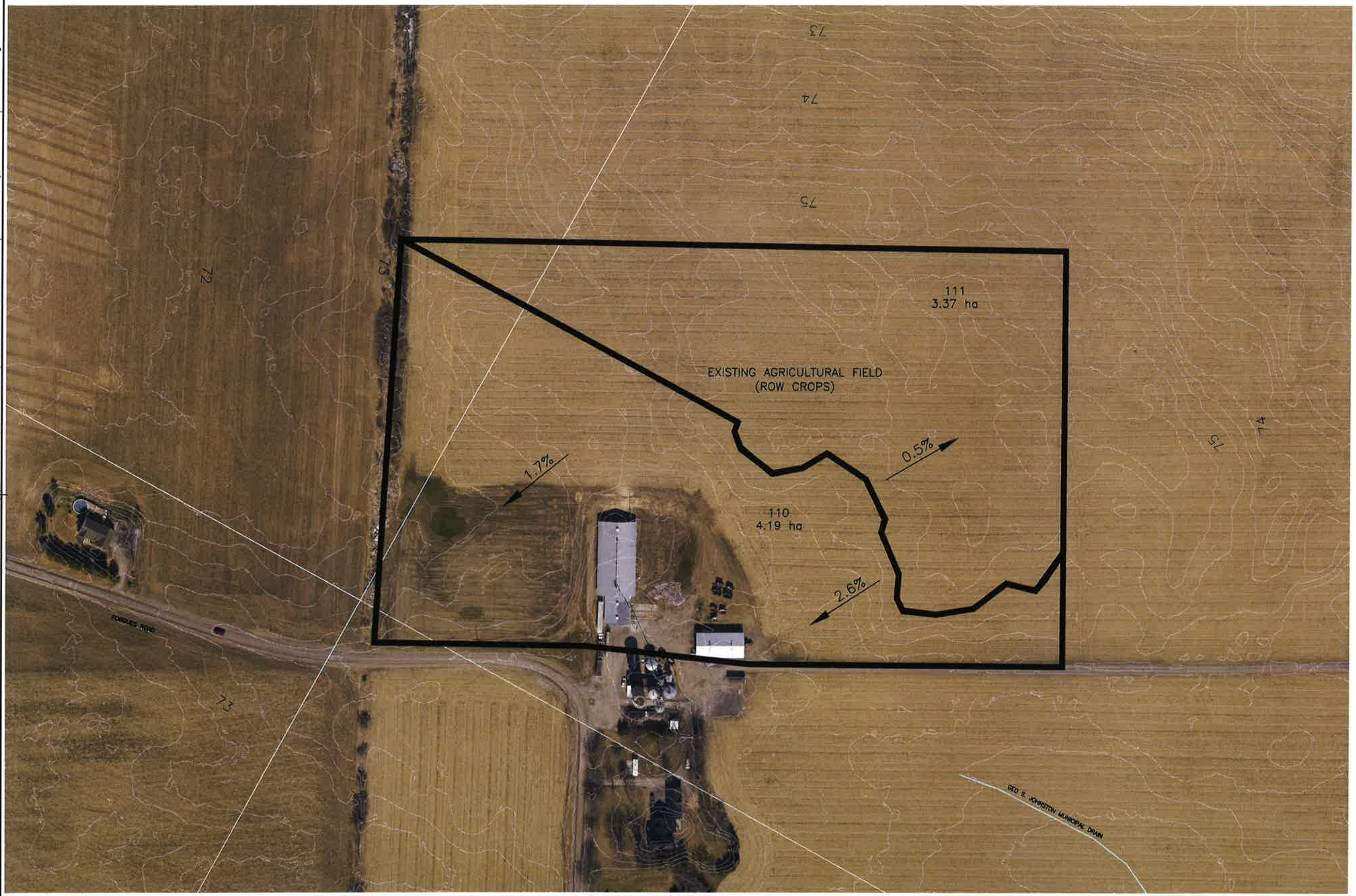

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NATION RISE WIND FARM
NORTH STORMONT, ONTARIO

LAYDOWN EXISTING CONDITIONS
DRAINAGE PLAN

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TULLOCH ENGINEERING

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Drawing Nº: FIG 1.3

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1.3 Proposed Conditions

1.3.1 Substation

The proposed substation site will consist of approximately 0.82 hectares of developed land out of the 20.63 hectare area that currently drains through the site. The developed area will be raised slightly above existing grades and consist of granular materials. Drainage will continue to flow overland similar to existing conditions and stormwater from the developed area will be graded towards the northeast. Refer to the following Figure 1.4. A hydrologic analysis is provided in the following sections of this report.

1.3.2 Laydown Area

The proposed laydown area site will consist of approximately 7.56 hectares of developed land. The developed area will be raised slightly above existing grades and consist of granular materials. Drainage will continue to flow overland similar to existing conditions and ponding areas will be modified as necessary to provide additional storage for increased post-development flows. Refer to the following Figure 1.5. A hydrologic analysis is provided in the following sections of this report.

1.4 Hydrologic Modelling

Hydrologic Modelling of the proposed development was conducted utilizing Visual OTTHYMO, version 3.0 software. The OTTHYMO model is an updated version of the original HYMO model developed by the United States Department of Agriculture in the early 1970's. HYMO and its updated versions, including OTTHYMO are in use throughout North America and the world for hydrologic modelling of rural and urban watersheds.

Rainfall inputs to the model consisted of a 1 hour Atmospheric Environment Service Type 2 rainfall distribution based on Intensity / Duration / Frequency (IDF) curves for The Township of North Stormont, Ontario. The IDF curves used in the analysis are shown as follows:

Table 1.1: MTO IDF Curves – Township of North Stormont – Rainfall Intensity (mm/hr)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	113.6	70.0	52.7	32.5	20.0	12.3	5.7	3.5	2.2
5-yr	151.1	93.1	70.1	43.2	26.6	16.4	7.6	4.7	2.9
10-yr	175.5	108.1	81.4	50.2	30.9	19.0	8.8	5.4	3.4
25-yr	206.2	127.0	95.7	58.9	36.3	22.4	10.4	6.4	3.9
50-yr	229.5	141.4	106.5	65.6	40.4	24.9	11.5	7.1	4.4
100-yr	252.2	155.3	117.0	72.1	44.4	27.4	12.7	7.8	4.8

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INDEX CONTOUR (1.0m INTERVAL)	70
FLOW DIRECTION	1.0%
DRAINAGE AREA	
SUBSTATION FENCE LINE	
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PROPOSED ACCESS ROAD	
EXISTING TRANSMISSION LINE TOWER	

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NATION RISE WIND FARM
NORTH STORMONT, ONTARIO

SUBSTATION FUTURE CONDITIONS
DRAINAGE PLAN

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TULLOCH ENGINEERING

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SOUTH NATION CONSERVATION WATERCOURSE	
PONDING AREA	
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NATION RISE WIND FARM
NORTH STORMONT, ONTARIO

LAYDOWN FUTURE CONDITIONS
DRAINAGE PLAN

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TULLOCH ENGINEERING

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Drawing Nº: FIG 1.5

The Soil Conservation Service Curve Number Method was utilized to model infiltration on pervious areas. Areas exhibiting minimal levels of imperviousness were modelled utilizing the NASH Unit Hydrograph Procedure to calculate storm run-off from rainfall excess.

2. STORMWATER MANAGEMENT

2.1 Pre-Development Conditions

2.1.1 Substation

Figure 1.2 indicates the pre-development conditions for the substation which was modelled as one (1) distinct catchment (100) as follows:

- Catchment 100 with a total drainage area of 20.63 hectares consisting of row crops;

The parameters utilized in the Visual OTTHYMO model for the drainage areas were as follows:

Table 2.1: Substation – Pre-Development Input Parameters

Parameter	Catchment 100
Drainage Area	20.63 ha
Design Rainfall	1 hr AES Type 2 Distribution
IDF Data	MTO Data for Twp of North Stormont
Soil Conservation Service Curve No. for Pervious Areas	CN = 89.0
Initial Abstraction	6.28 mm
Watershed Length	1000 m
Watershed Slope	0.75 %
Time to Peak	0.80 hr
NASH's Shape Parameter	3.0

The model of the pre-development conditions produced peak flow estimates for the areas as follows:

Table 2.2: Substation – Pre-Development Peak Flows

Return Period	Catchment 100
2 year	156 L/sec
5 year	299 L/sec
10 year	404 L/sec
25 year	548 L/sec
50 year	663 L/sec
100 year	781 L/sec

2.1.2 Laydown Area

Figure 1.3, in Appendix A, indicates the pre-development conditions for the laydown area which was modelled as two (2) distinct catchments (110 & 111) as follows:

- Catchment 110 with a total drainage area of 4.19 hectares consisting of row crops and some farm buildings; and
- Catchment 111 with a total drainage area of 3.37 hectares consisting of row crops.

The parameters utilized in the Visual OTTHYMO model for the drainage areas were as follows:

Table 2.3: Laydown Area – Pre-Development Input Parameters

Parameter	Catchment 110	Catchment 111
Drainage Area	4.19 ha	3.37 ha
Design Rainfall	1 hr AES Type 2 Distribution	1 hr AES Type 2 Distribution
IDF Data	MTO Data for Twp of North Stormont	MTO Data for Twp of North Stormont
Soil Conservation Service Curve No. for Pervious Areas	CN = 89.06	CN = 89
Initial Abstraction	6.27 mm	6.28 mm
Watershed Length	150 m	100 m
Watershed Slope	1.5 %	0.5 %

Time to Peak	0.31 hr	0.36 hr
NASH's Shape	3.0	3.0

The model of the pre-development conditions produced peak flow estimates for the areas as follows:

Table 2.4: Laydown Area – Pre-Development Peak Flows

Return Period	Catchment 110	Catchment 111	Combined
2 year	70 L/sec	50 L/sec	119 L/sec
5 year	133 L/sec	95 L/sec	228 L/sec
10 year	179 L/sec	129 L/sec	308 L/sec
25 year	242 L/sec	175 L/sec	418 L/sec
50 year	292 L/sec	212 L/sec	505 L/sec
100 year	344 L/sec	250 L/sec	593 L/sec

2.2 During Construction Conditions

Construction sequencing for the proposed development works at the substation, laydown, access roads and turbine sites will proceed in such a manner that aggregate will be placed immediately after stripping operations to minimize the amount of exposure to the underlying soils. As such, the during construction flows would be approximately equal to the post-development flows as the following section will outline. In addition to the construction sequencing, all site works will be in accordance with the Erosion and Sediment Control Plan (ESC) and the Civil Construction Plans, which will provide the contractor with measures to control runoff in the event of rainfall during construction activities.

2.3 Post-Development Conditions

For the post-development conditions it was assumed that there will be minimal alterations to the existing site grading in order to accommodate the proposed works.

2.3.1 Substation

Figure 1.4 indicates the post-development conditions for the substation which was modelled as two (2) distinct catchments (200 and 201) as follows:

- Catchment 200 with a total drainage area of 19.81 hectares will consist of the undeveloped portion (row crops) of the substation area. Run-off from this catchment will continue to flow overland in an easterly direction; and,

- Catchment 201 with a total drainage area of 0.82 hectares will consist of the substation site (gravel surface).

Table 2.5: Substation – Post-Development Input Parameters

Parameter	Catchment 200	Catchment 201
Drainage Area	19.81 ha	0.82 ha
Design Rainfall	1 hr AES Type 2 Distribution	1 hr AES Type 2 Distribution
IDF Data	MTO Data for Twp North Stormont	MTO Data for Twp of North Stormont
Soil Conservation Service Curve No. for Pervious Areas	CN = 89	CN = 91
Initial Abstraction	6.28 mm	5.02 mm
Watershed Length	900 m	100 m
Watershed Slope	0.75 %	0.2 %
Time to Peak	0.72 hr	0.14 hr
NASH's Shape Parameter	3.0	3.0

The following table shows the estimated peak, uncontrolled, post-development flows from the drainage area:

Table 2.6: Substation – Post-Development Unattenuated Peak Flows

Return Period	Catchment 200	Catchment 201	Combined
2 year	165 L/sec	27 L/sec	166 L/sec
5 year	316 L/sec	50 L/sec	318 L/sec
10 year	428 L/sec	66 L/sec	430 L/sec
25 year	579 L/sec	87 L/sec	583 L/sec
50 year	701 L/sec	104 L/sec	707 L/sec
100 year	825 L/sec	121 L/sec	832 L/sec

2.3.2 Laydown Area

Figure 1.5 indicates the post-development conditions for the laydown area which was modelled as three (3) distinct catchments (210, 211 and 212) as follows:

- Catchment 210 with a total drainage area of 4.07 hectares will consist of the northern portion of the site (gravel surface and some farm buildings). Run-off from this catchment will flow overland similar to existing conditions and be collected in a modified ponding area along the northwest boundary of the site;
- Catchment 211 with a total drainage area of 3.0 hectares will consist of the southern portion of the site (gravel surface and some farm buildings). Run-off from this catchment will flow overland similar to existing conditions and be collected in a modified ponding area along the southwest boundary of the site; and,
- Catchment 212 with a total drainage area of 0.49 hectares will consist of the eastern corner of the site (gravel surface). Run-off from this catchment will flow overland similar to existing conditions to the east.

Table 2.7: Laydown Area – Post-Development Input Parameters

Parameter	Catchment 210	Catchment 211	Catchment 212
Drainage Area	4.07 ha	3.00 ha	0.49 ha
Design Rainfall	1 hr AES Type 2 Distribution	1 hr AES Type 2 Distribution	1 hr AES Type 2 Distribution
IDF Data	MTO Data for Twp of North Stormont	MTO Data for Twp of North Stormont	MTO Data for Twp of North Stormont
Soil Conservation Service Curve No. for Pervious Areas	CN = 91.03	CN = 91.02	CN = 91
Initial Abstraction	5.02 mm	5.02 mm	5.02 mm
Watershed Length	250 m	150 m	30 m
Watershed Slope	2.0 %	1.2 %	2.0 %
Time to Peak	0.35 hr	0.27 hr	0.083 hr
NASH's Shape Parameter	3.0	3.0	3.0

The following table shows the estimated peak, unattenuated, post-development flows from the drainage area:

Table 2.8: Laydown Area – Post-Development Unattenuated Peak Flows

Return Period	Catchment 210	Catchment 211	Catchment 212	Combined
2 year	82 L/sec	73 L/sec	18 L/sec	160 L/sec
5 year	147 L/sec	130 L/sec	34 L/sec	285 L/sec
10 year	194 L/sec	171 L/sec	46 L/sec	376 L/sec
25 year	256 L/sec	226 L/sec	61 L/sec	498 L/sec
50 year	306 L/sec	269 L/sec	73 L/sec	594 L/sec
100 year	355 L/sec	313 L/sec	84 L/sec	691 L/sec

2.4 Results and Recommendations

2.4.1 Substation

The following Table 2.9, compares the pre-development peak flows to the post-development unattenuated peak flows for the substation site and indicates the percentage increase from pre-development conditions:

Table 2.9: Substation - Summary of Pre-Development and Post-Development Peak Flows

Return Period	Pre-Development Peak Flow	Post-Development Unattenuated Peak Flow	Percent Increase
Substation (All Catchments)			
2 year	156 L/sec	166 L/sec	6.4 %
5 year	299 L/sec	318 L/sec	6.4 %
10 year	404 L/sec	430 L/sec	6.4%
25 year	548 L/sec	583 L/sec	6.4 %
50 year	663 L/sec	707 L/sec	6.6 %
100 year	781 L/sec	832 L/sec	6.5 %

The results indicate a marginal increase in peak flows for all storm events ranging from 6.4 to 6.6%, as would be expected for a relatively small development within a large drainage area. The increase is considered to be minor and negligible as it isn't anticipated to have an adverse affect on any downstream properties.

2.4.2 Laydown Area

The following Table 2.10, compares the pre-development peak flows to the post-development unattenuated peak flows for the laydown area and indicates the percentage increase from pre-development conditions:

Table 2.10: Laydown Area - Summary of Pre-Development and Post-Development Peak Flows

Return Period	Pre-Development Peak Flow	Post-Development Unattenuated Peak Flow	Percent Increase
Laydown Area (All Catchments)			
2 year	119 L/sec	160 L/sec	34.5 %
5 year	228 L/sec	285 L/sec	25.0 %
10 year	308 L/sec	376 L/sec	22.1 %
25 year	418 L/sec	498 L/sec	19.1 %
50 year	505 L/sec	594 L/sec	17.6 %
100 year	593 L/sec	691 L/sec	16.5 %

The results indicate a moderate increase in peak flows for all storm events ranging from 16.5 to 34.5%, as would be expected by converting the entire drainage area from agricultural to gravel surface. As such it is recommended to construct ponding areas within the laydown area to temporarily store the additional stormwater generated from the development. These ponding areas are indicated on Figure 1.5

The design of the ponding areas was based on an iterative process in which different outlet conditions, ponding layouts, and quantity/storage relationships were analyzed.

Inflow hydrographs were generated in the Visual OTTHYMO model. A storage discharge relationship for the ponding areas was generated with the use of a spreadsheet and input into a reservoir routing function in Visual OTTHYMO. The inflow hydrographs were then connected to the reservoir in Visual OTTHYMO which performed a reservoir routing routine producing attenuated outflow hydrographs.

Outflow from the ponding areas will be controlled by overflow weirs for major storm events. Minor storm events will be controlled by infiltration and evaporation similar to pre-development conditions. Details of the ponding areas and weirs will be provided during the detailed design phase.

Inflow and outflow hydrographs for each area comparing pre-development peak flows to post-development attenuated peak flows are provided in Appendix A for the 5, 25 and 100-Year Return Period Rainfalls.

The analysis results of the ponding areas including estimated storage volumes required are detailed in the following table:

Table 2.11: Laydown Area – Ponding Area Analysis Results

Return Period	Maximum Ponding Depth		Storage Volume		Peak Outflow	
	Catchment 210	Catchment 211	Catchment 210	Catchment 211	Catchment 210	Catchment 211
2 year	0.24 m	0.25 m	225 m^3	166 m^3	*0.45 L/sec	*0.45 L/sec
5 year	0.32 m	0.32 m	301 m^3	215 m^3	72 L/sec	73 L/sec
10 year	0.34 m	0.34 m	320 m^3	229 m^3	134 L/sec	128 L/sec
25 year	0.36 m	0.36 m	342 m^3	244 m^3	207 L/sec	196 L/sec
50 year	0.38 m	0.37 m	357 m^3	254 m^3	264 L/sec	236 L/sec
100 year	0.40 m	0.39 m	374 m^3	263 m^3	317 L/sec	291 L/sec

*Infiltration only

The total, peak pre-development outflows from laydown area are compared to the peak post-development attenuated outflows in the following table:

Table 2.12: Laydown Area – Summary of Pre-Development and Post-Development Peak Flows

Return Period	Peak Pre-Development Flow	Peak Post-Development Attenuated Flow
	All Catchments	All Catchments
2 year	119 L/sec	18 L/sec
5 year	228 L/sec	122 L/sec
10 year	308 L/sec	239 L/sec

25 year	418 L/sec	382 L/sec
50 year	505 L/sec	477 L/sec
100 year	593 L/sec	592 L/sec

The above table indicates that post-development peak flows have been limited to pre-development levels for events up to the 100 year storm.

As mentioned previously, the increase in post-development flows for the substation property are considered negligible and therefore quantity control of the stormwater isn't considered warranted for this location.

It should be further noted that the "during construction" flows would be approximately equal to the post-development flows based on construction sequencing and the additional impervious area resulting from the temporary construction site trailers will be minimal (approx. 1.0% of the overall catchment area) and thus have a negligible effect on the post development CN values and corresponding flows. Therefore additional stormwater quantity and/or quality controls are not considered warranted for the "during construction" flows.

2.4.3 Access Roads & Turbine Sites

It is understood that access roads will be required for construction and maintenance purposes post-construction to access the wind turbine locations, substation, and laydown area. The access roads will consist of gravel surface and have a general width of approximately 6 metres. Further, localized disturbances and gravel surfacing at the turbine sites will be required for assembly areas and/or crane pads. Based on the hydrologic modeling for the substation site, the conversion of agricultural land to gravel surface for the access roads and turbine sites is considered to have a negligible increase in post-development flows. This is due mainly to the nominal areas involved. Detailed modeling of these areas is therefore not considered warranted.

2.4.4 Quality Control

It is understood that the NRWF development will not consist of any paved surfaces which are generally the primary concern for negative stormwater quality impacts. As such, contaminant loadings are expected to be more comparable to pre-development conditions than what would be expected for paved type surfaces. Packed gravel surfaces will still promote some infiltration and limit the buildup of surface contaminants. Further, run-off from the gravel surfaces will generally be directed towards grassed ditching and/or existing agricultural land where further infiltration/evaporation and settling of any generated sediment will take place.

All disturbed areas adjacent to the access roads, substation and laydown area should be restored to there original vegetated conditions post-construction.

Therefore, quality control is not expected to be a major concern based on the lack of paving and promotion of infiltration through gravel surfaces and vegetated areas. No further quality control is considered warranted for the proposed development.

3. OPERATIONS AND MAINTENANCE

The stormwater management features serving these developments are designed to require minimal maintenance. As a minimum, the following maintenance program is recommended:

- Twice per year inspections of the features to ensure that there are no problems with excess sedimentation buildup and/or drainage blocks and that the features are in good condition. Any materials collected within the features should be removed and disposed of in an appropriate manner. Any problems discovered should be repaired immediately; and,

- It is likely that, over time, some sediment will collect in the bottom of the ponding areas. This should be closely monitored and, if sediment deposits exceed a depth of approximately 0.05 metres it should be removed to re-establish the original storage/volume characteristics. This is particularly important during construction and prior to vegetation reestablishment in the Project area and the access road ditching system.

4. EROSION AND SEDIMENT CONTROL

Erosion and sediment control (ESC) measures will be implemented prior to commencement of any construction activities within the NRWF development including but not limited to vegetation clearing, topsoil stripping, grading and stockpiling of materials. Refer to the Erosion and Sediment Control Plan completed by TULLOCH Environmental under separate cover.

5. CONCLUSIONS

The following is a summary of the stormwater management plan for the proposed development.

- The substation area, access road and turbine site developments will have negligible impacts on post-development stormwater run-off and therefore quantity controls are not warranted;

- The laydown area will consist of ponding areas to limit post development flows to pre-development levels;

- The “during construction” flows will be approximately equal to the post construction flows;

- Quality controls are not deemed necessary due to the lack of pavement and promotion of infiltration through gravel surfaces and vegetated areas; and,

- Temporary erosion and sediment control measures will be installed, monitored and maintained during construction activities and shall remain in place until the sites are stabilized through vegetation reestablishment.

6. REPORT LIMITATIONS AND GUIDELINES FOR USE

We have prepared this report for the exclusive use of EDP Renewables and their authorized agents for the proposed development. The report is only applicable to the project described herein. Any changes to the project require a review by TULLOCH to ensure compatibility with the stormwater management system as described in this report.

7. CLOSURE

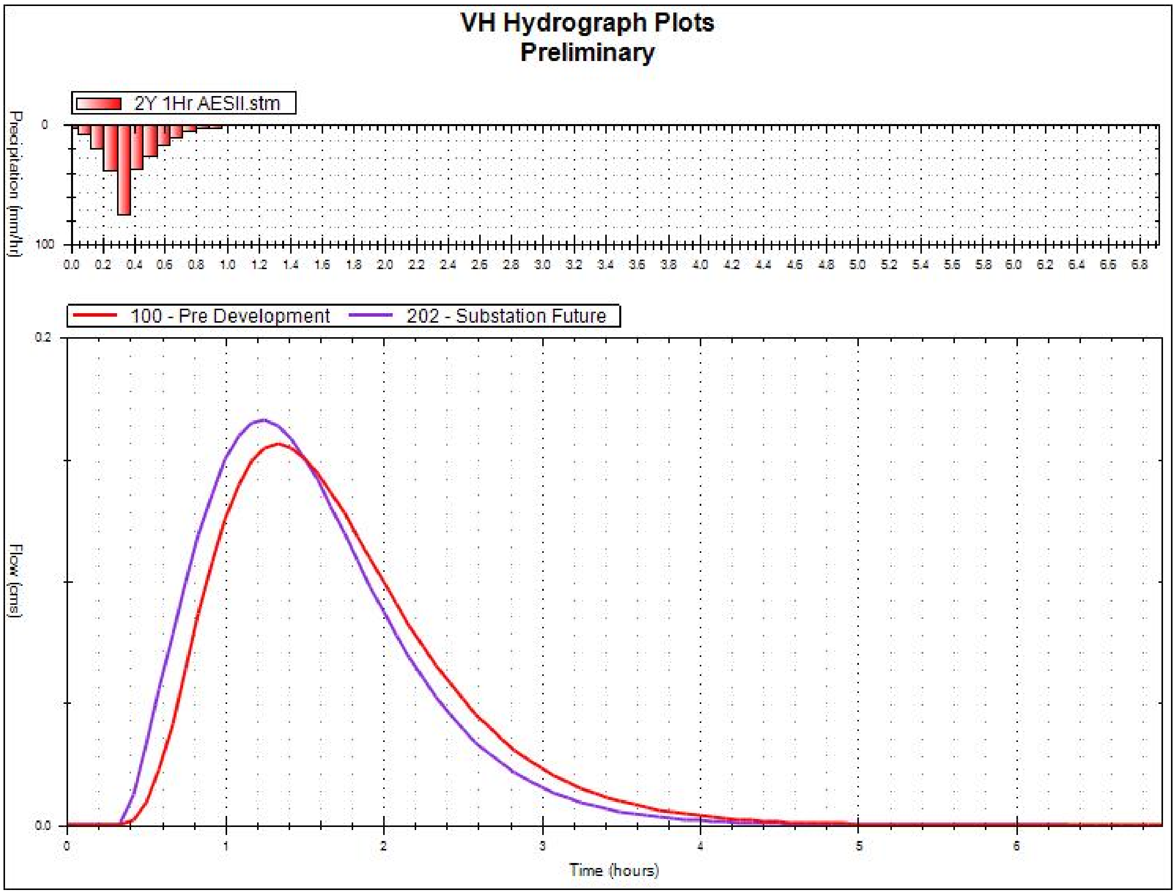
We trust that the information and recommendations in this report will be found to be complete and adequate for your consideration. Should further elaboration be required for any portion of this Stormwater Management Plan, we would be pleased to provide assistance.

APPENDIX A

Pre-Development and Post-Development Hydrographs

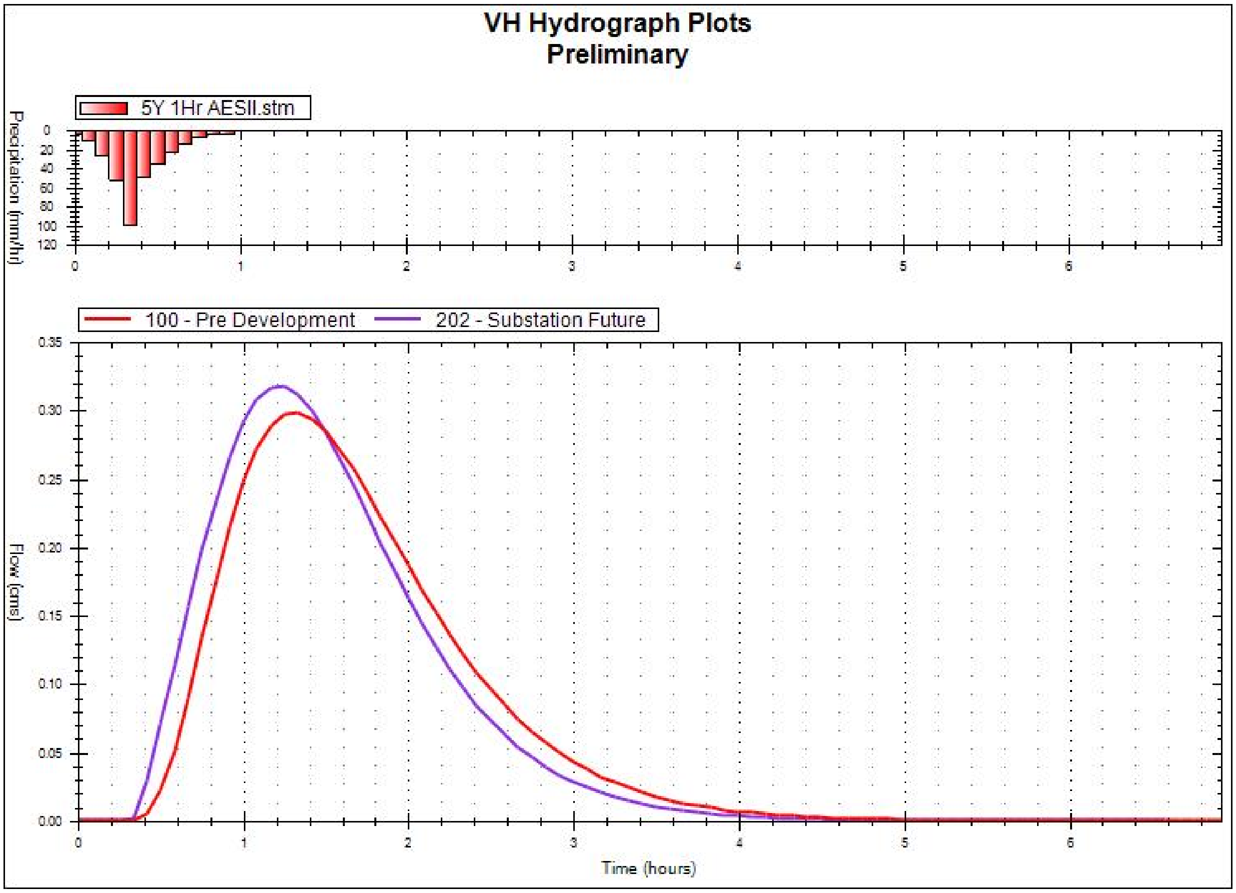
Substation - 2 Year Storm

Catchment 100 and Combined Catchment 200 & 201



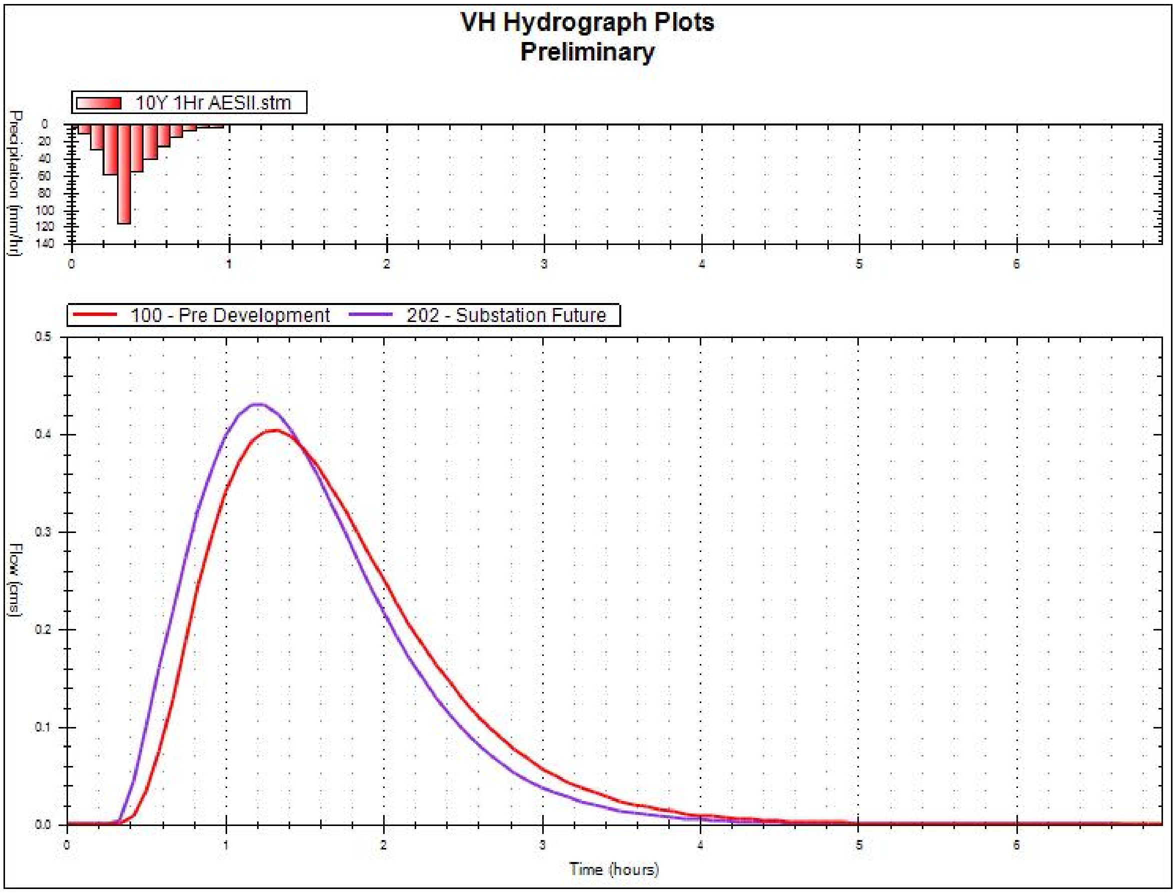
Substation - 5 Year Storm

Catchment 100 and Combined Catchment 200 & 201



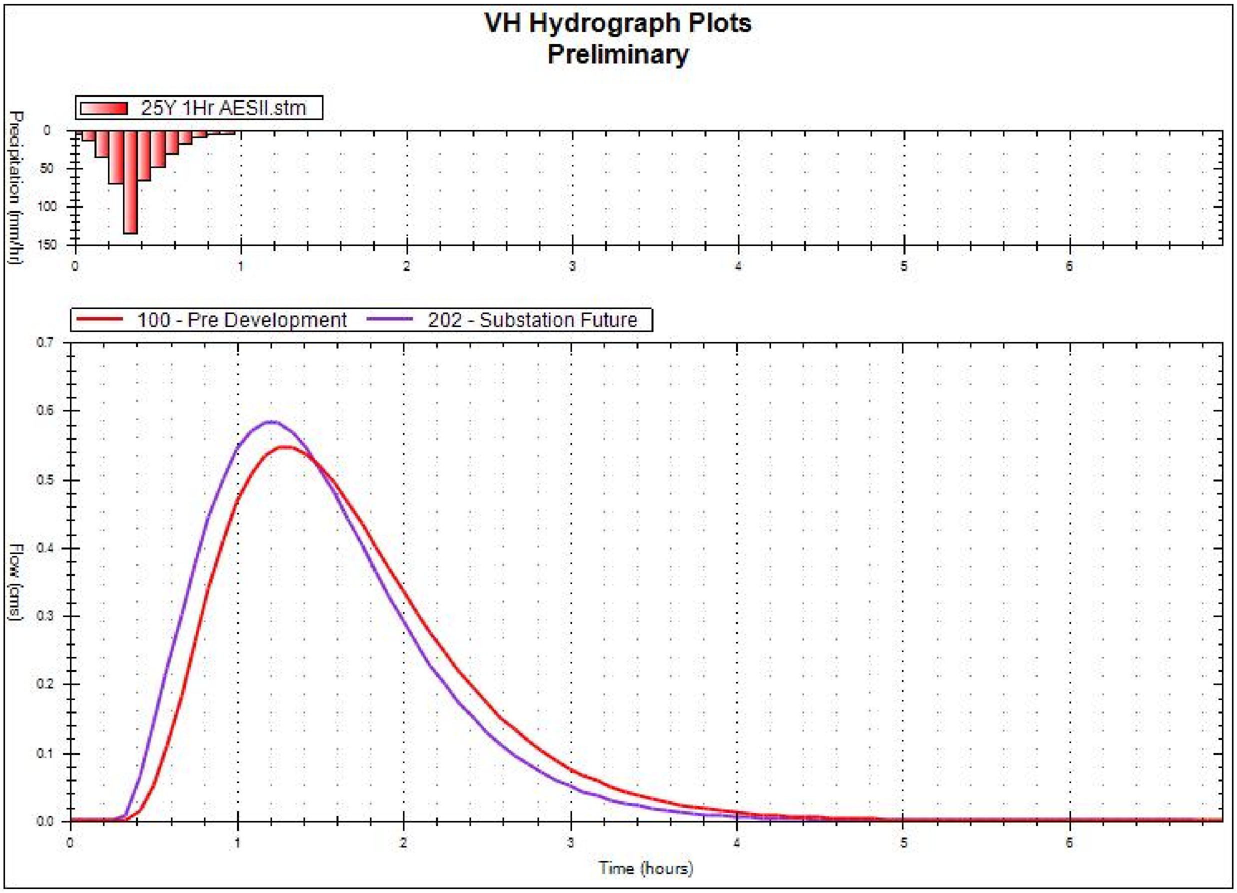
Substation - 10 Year Storm

Catchment 100 and Combined Catchment 200 & 201



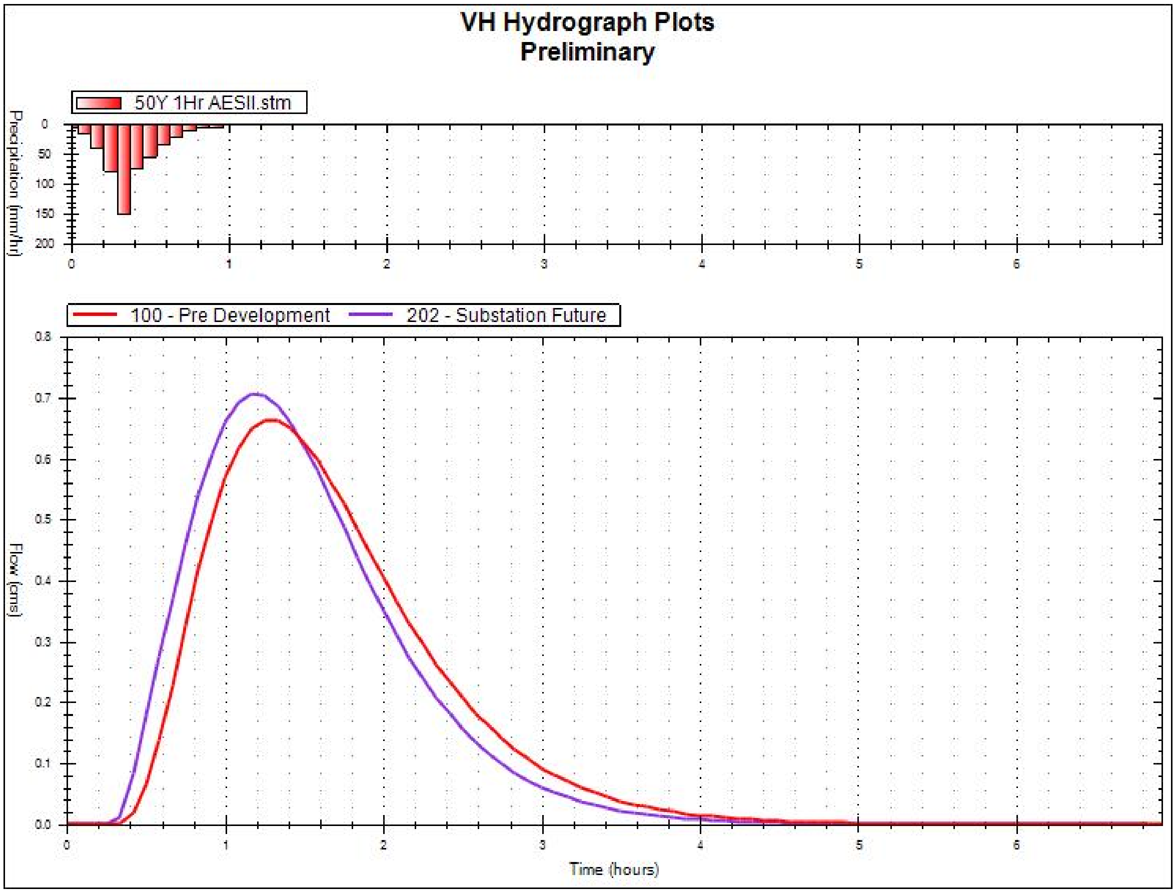
Substation - 25 Year Storm

Catchment 100 and Combined Catchment 200 & 201



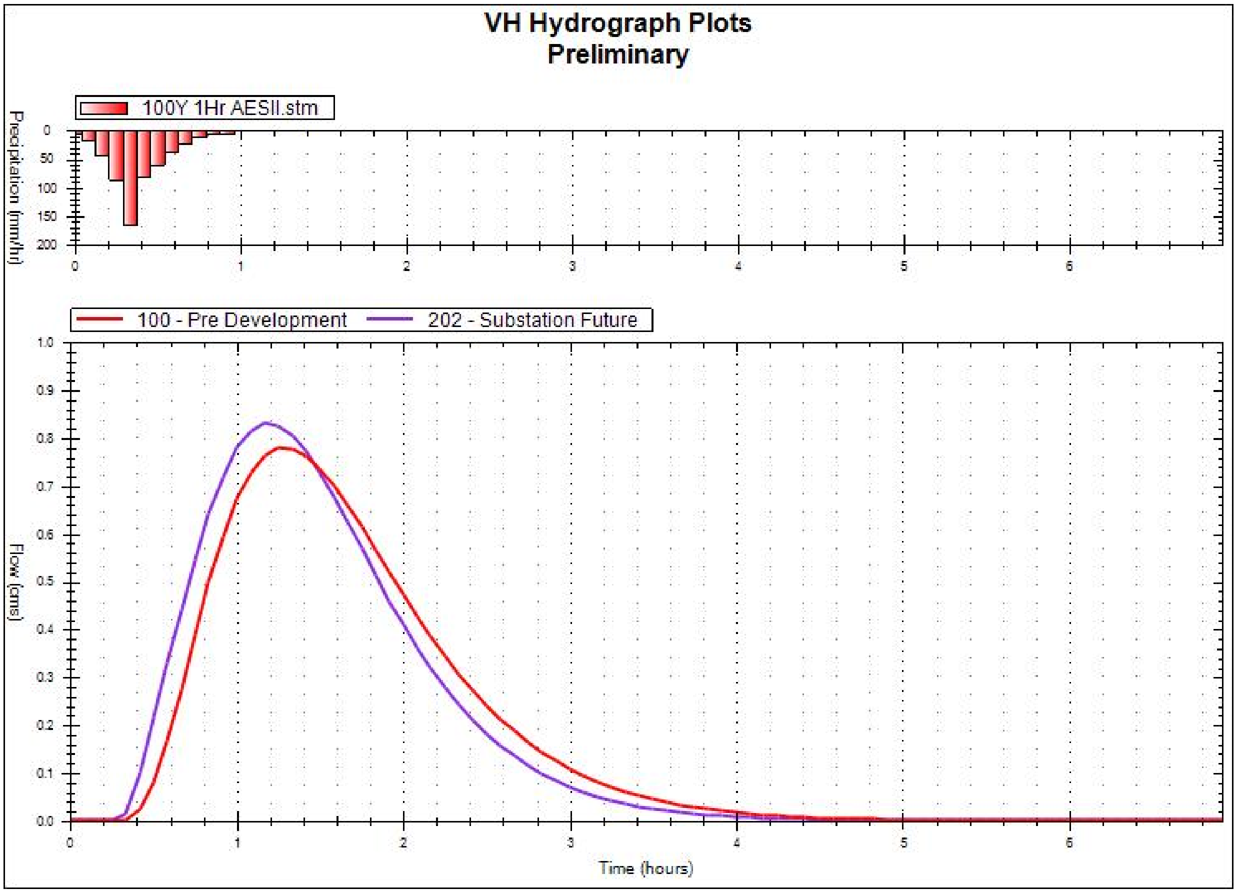
Substation - 50 Year Storm

Catchment 100 and Combined Catchment 200 & 201



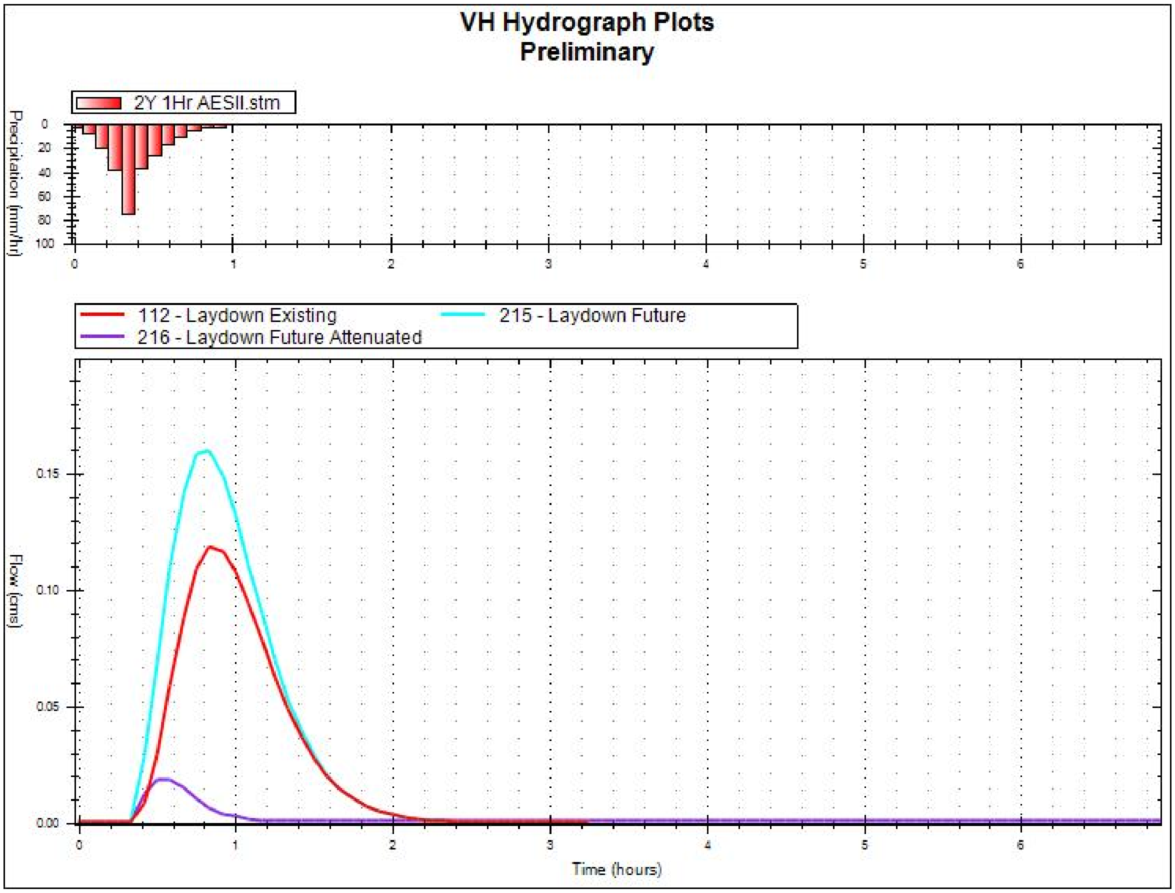
Substation - 100 Year Storm

Catchment 100 and Combined Catchment 200 & 201



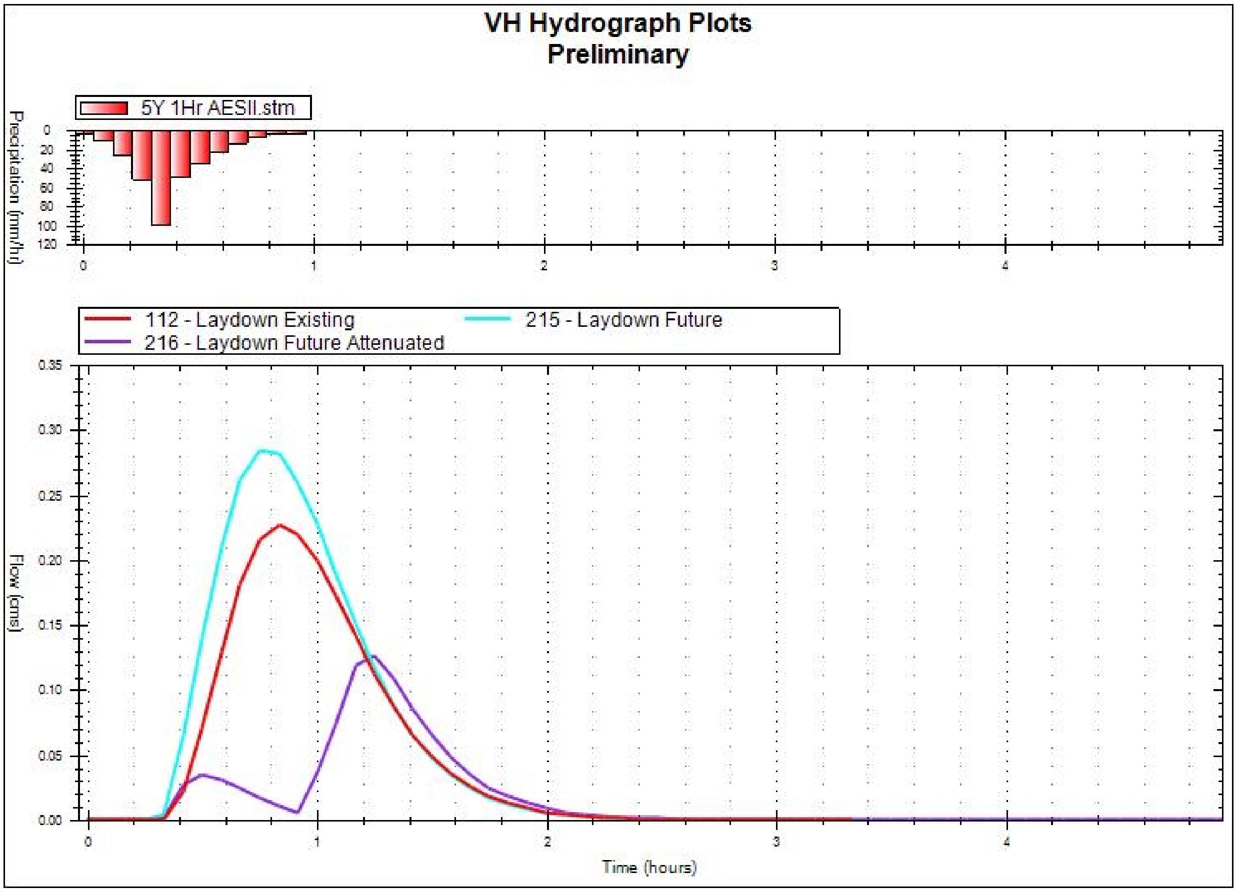
Laydown Area - 2 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



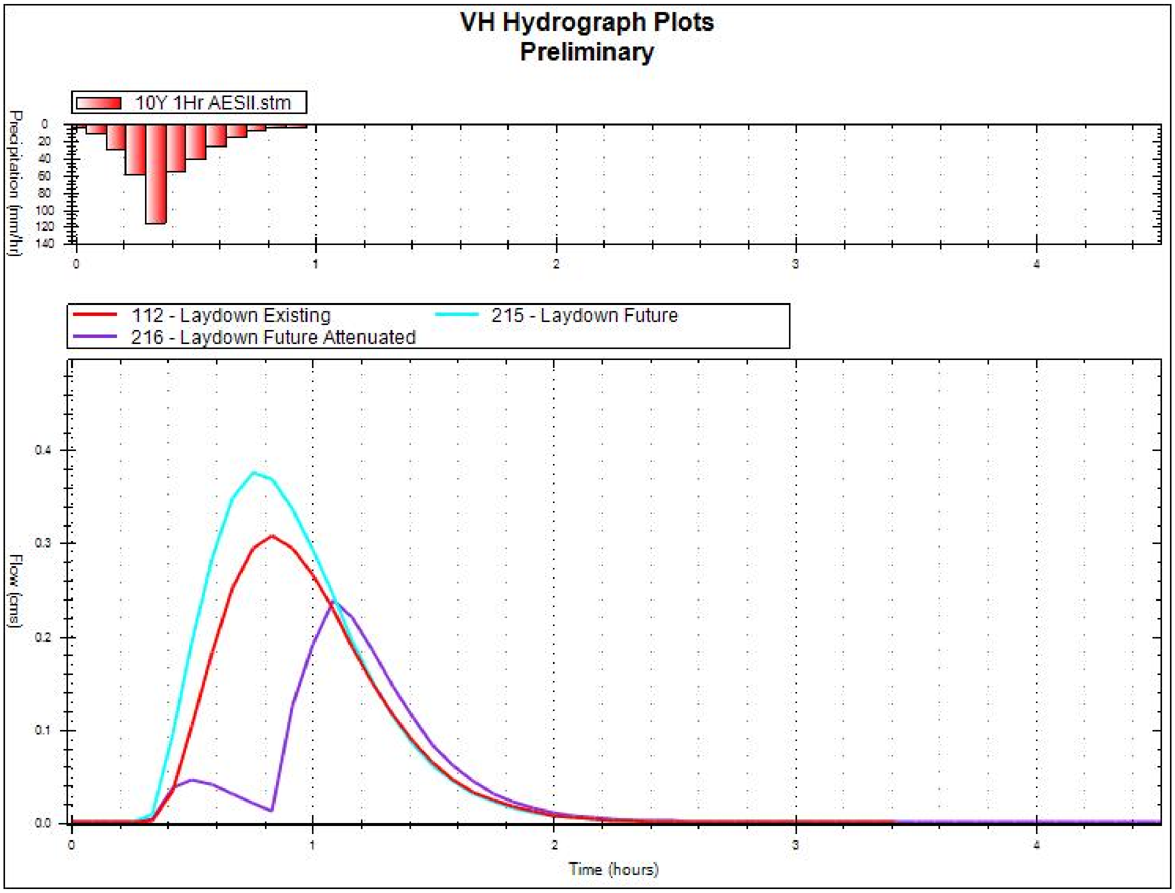
Laydown Area - 5 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



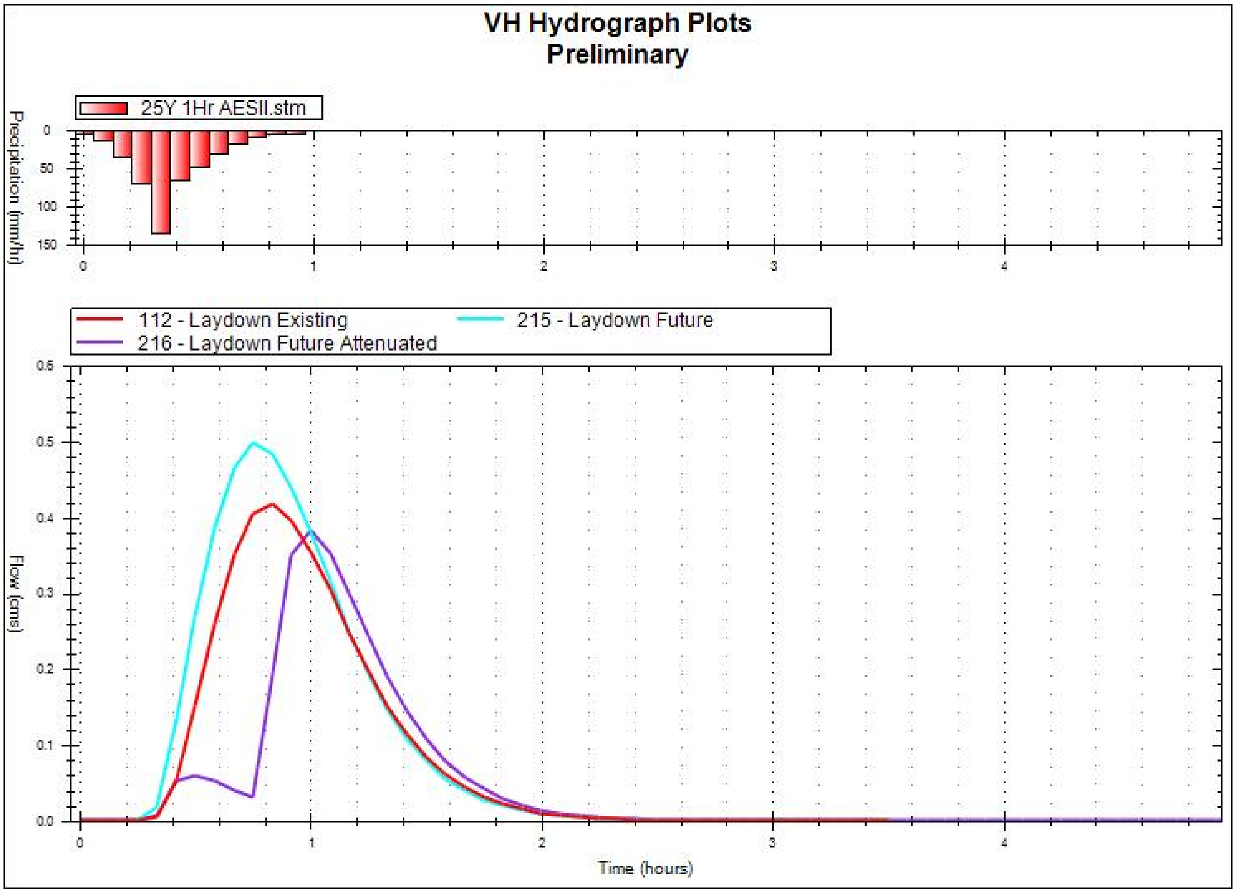
Laydown Area - 10 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



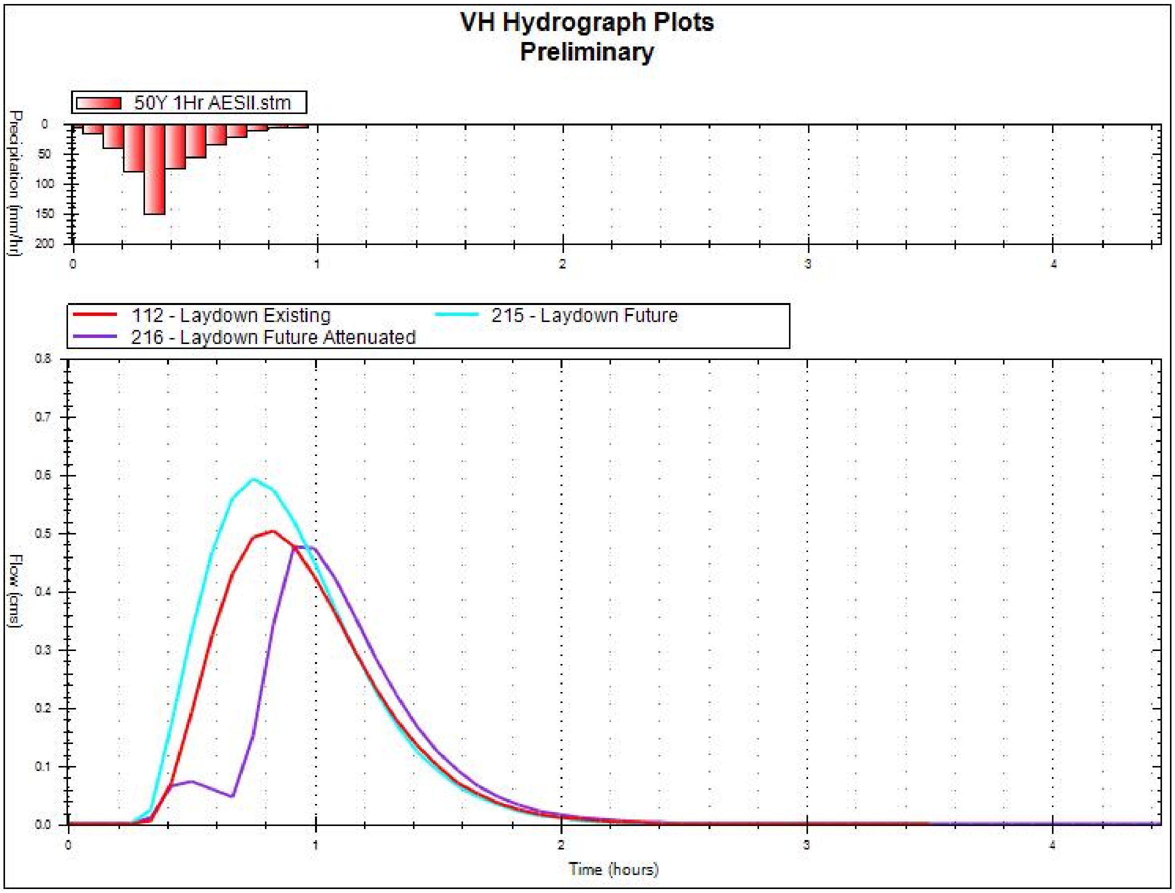
Laydown Area - 25 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



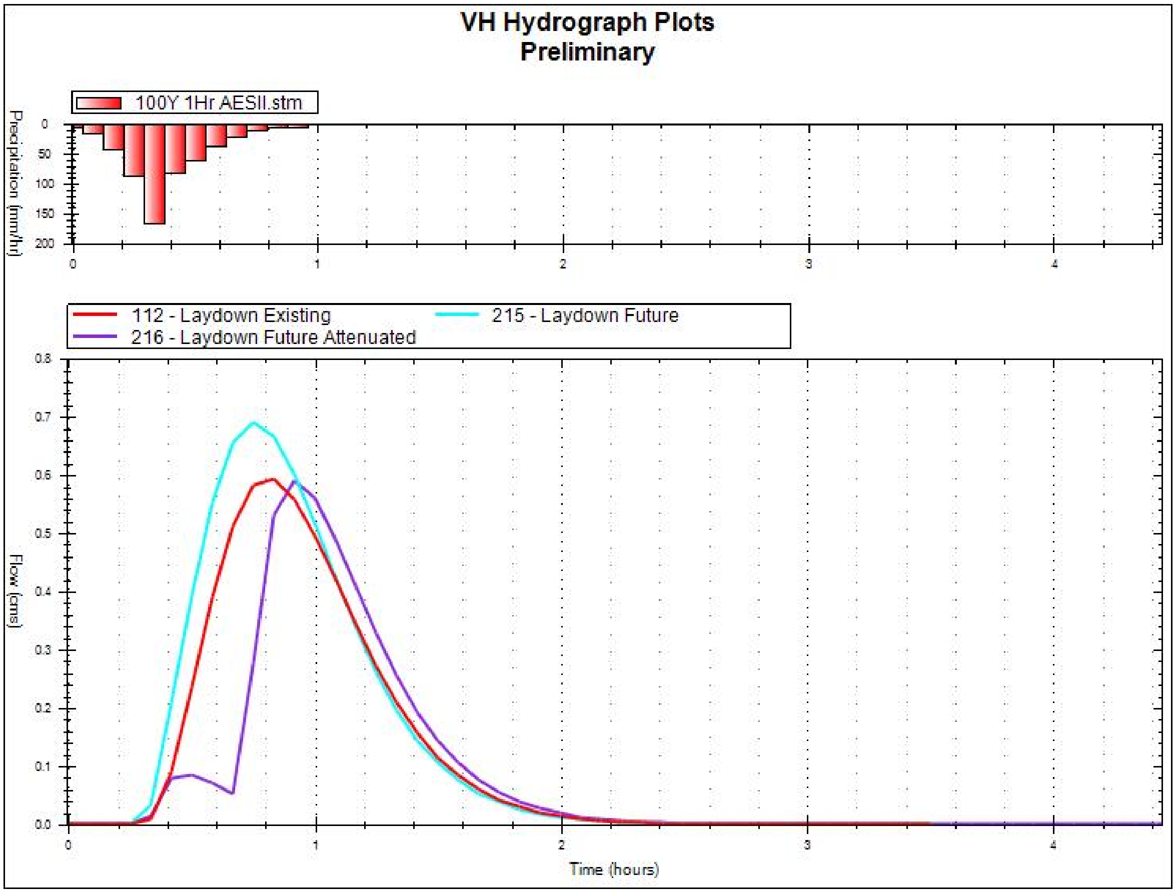
Laydown Area – 50 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



Laydown Area - 100 Year Storm

Combined Catchment 110 & 111 and Combined Catchment 210, 211 & 212



APPENDIX B

Time of Concentration Calculations

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration:	Substation Pre-Development Conditions
Airport Formula (mins.)	(3.26*(1.1-C)*(L^0.5))/(S^0.33) — * For C<0.4, Airport drainage
Bransby-Williams Formula (mins):	(0.057*L)/((S^0.2)*(A^0.1)) — * For C>0.4; Underestimates for permeable basins
Kirpich Formula (mins):	0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.500
L = Watershed Length (metres) =	1000.0
S = Watershed Slope (%) =	0.750
A = Watershed Area (hectares) =	20.63
H = Change in Height over Watershed (m) =	7.5
CN = SCS Curve Number =	89
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	68.0	44.6	26.3
Time to Peak = 0.67 * Tc (mins.)	45.6	29.9	17.6
Time to Peak (hours)	0.76	0.50	0.29

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.69 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.53 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.27 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.47 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7	1000	0.0075	0.23	71.28
Nearly bare soil, untilled	3.0			0.00	0.00
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**71.28**
Estimated Time to Peak (hours) =					**0.80**

Selected Time of Concentration (hours) = **0.8**

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration: Substation
Post-Development Conditions 200

Airport Formula (mins.) (3.26*(1.1-C)*(L^0.5))/(S^0.33) * For C<0.4, Airport drainage

Bransby-Williams Formula (mins): (0.057*L)/((S^0.2)*(A^0.1)) * For C>0.4; Underestimates for permeable basins

Kirpich Formula (mins): 0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.300
L = Watershed Length (metres) =	900.0
S = Watershed Slope (%) =	0.750
A = Watershed Area (hectares) =	19.81
H = Change in Height over Watershed (m) =	6.8
CN = SCS Curve Number =	84
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	86.0	40.3	24.3
Time to Peak = 0.67 * Tc (mins.)	57.6	27.0	16.3
Time to Peak (hours)	0.96	0.45	0.27

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.76 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.49 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.26 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.47 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7	900	0.0075	0.23	64.15
Nearly bare soil, untilled	3.0			0.00	0.00
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**64.15**
Estimated Time to Peak (hours) =					**0.72**

Selected Time of Concentration (hours) = 0.72

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration: Substation
Post-Development Conditions 201

Airport Formula (mins.)	(3.26*(1.1-C)*(L^0.5))/(S^0.33)	* For C<0.4, Airport drainage
Bransby-Williams Formula (mins):	(0.057*L)/((S^0.2)*(A^0.1))	* For C>0.4; Underestimates for permeable basins
Kirpich Formula (mins):	0.0196*((L/((S/100)^0.5))^).77)	

C = Rational Method Runoff Coefficient =	0.300
L = Watershed Length (metres) =	100.0
S = Watershed Slope (%) =	0.200
A = Watershed Area (hectares) =	0.82
H = Change in Height over Watershed (m) =	7.5
CN = SCS Curve Number =	91
L/W = Watershed Length to Width Ratio =	1

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	44.4	8.0	7.4
Time to Peak = 0.67 * Tc (mins.)	29.7	5.4	5.0
Time to Peak (hours)	0.50	0.09	0.08

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.20 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.14 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.14 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.34 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0	100	0.0020	0.13	12.42
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**12.42**
Estimated Time to Peak (hours) =					**0.14**

Selected Time of Concentration (hours) = 0.14

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration: Laydown
Pre-Development Conditions 110

Airport Formula (mins.)	(3.26*(1.1-C)*(L^0.5))/(S^0.33)	* For C<0.4, Airport drainage
Bransby-Williams Formula (mins):	(0.057*L)/((S^0.2)*(A^0.1))	* For C>0.4; Underestimates for permeable basins
Kirpich Formula (mins):	0.0196*((L/((S/100)^0.5))^).77)	

C = Rational Method Runoff Coefficient =	0.500
L = Watershed Length (metres) =	150.0
S = Watershed Slope (%) =	1.500
A = Watershed Area (hectares) =	4.19
H = Change in Height over Watershed (m) =	2.3
CN = SCS Curve Number =	89
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	21.0	6.8	4.7
Time to Peak = 0.67 * Tc (mins.)	14.0	4.6	3.1
Time to Peak (hours)	0.23	0.08	0.05

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.11 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.09 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.10 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.20 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3	150	0.0015	0.09	28.07
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0			0.00	0.00
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**28.07**
Estimated Time to Peak (hours) =					**0.31**

Selected Time of Concentration (hours) = 0.31

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration: Laydown
Pre-Development Conditions 111

Airport Formula (mins.) (3.26*(1.1-C)*(L^0.5))/(S^0.33) * For C<0.4, Airport drainage

Bransby-Williams Formula (mins): (0.057*L)/((S^0.2)*(A^0.1)) * For C>0.4; Underestimates for permeable basins

Kirpich Formula (mins): 0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.500
L = Watershed Length (metres) =	100.0
S = Watershed Slope (%) =	0.500
A = Watershed Area (hectares) =	3.37
H = Change in Height over Watershed (m) =	0.5
CN = SCS Curve Number =	89
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	24.6	5.8	5.2
Time to Peak = 0.67 * Tc (mins.)	16.5	3.9	3.5
Time to Peak (hours)	0.27	0.06	0.06

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.13 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.10 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.15 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.33 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3	100	0.0005	0.05	32.41
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0			0.00	0.00
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**32.41**
Estimated Time to Peak (hours) =					**0.36**

Selected Time of Concentration (hours) = **0.36**

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration: Laydown
Post-Development Conditions 210

Airport Formula (mins.) (3.26*(1.1-C)*(L^0.5))/(S^0.33) * For C<0.4, Airport drainage

Bransby-Williams Formula (mins): (0.057*L)/((S^0.2)*(A^0.1)) * For C>0.4; Underestimates for permeable basins

Kirpich Formula (mins): 0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.700
L = Watershed Length (metres) =	250.0
S = Watershed Slope (%) =	2.000
A = Watershed Area (hectares) =	4.07
H = Change in Height over Watershed (m) =	5.0
CN = SCS Curve Number =	91.03
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	16.4	10.8	6.2
Time to Peak = 0.67 * Tc (mins.)	11.0	7.2	4.2
Time to Peak (hours)	0.18	0.12	0.07

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.13 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.12 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.09 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.17 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0	250	0.0020	0.13	31.06
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**31.06**
Estimated Time to Peak (hours) =					**0.35**

Selected Time of Concentration (hours) = 0.35

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration:	Laydown Post-Development Conditions 211
Airport Formula (mins.)	(3.26*(1.1-C)*(L^0.5))/(S^0.33) — * For C<0.4, Airport drainage
Bransby-Williams Formula (mins):	(0.057*L)/((S^0.2)*(A^0.1)) — * For C>0.4; Underestimates for permeable basins
Kirpich Formula (mins):	0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.700
L = Watershed Length (metres) =	150.0
S = Watershed Slope (%) =	1.200
A = Watershed Area (hectares) =	3.00
H = Change in Height over Watershed (m) =	1.8
CN = SCS Curve Number =	91.02
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	15.0	7.4	5.1
Time to Peak = 0.67 * Tc (mins.)	10.1	4.9	3.4
Time to Peak (hours)	0.17	0.08	0.06

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.11 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.10 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.10 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.21 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0	150	0.0012	0.10	24.06
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**24.06**
Estimated Time to Peak (hours) =					**0.27**

Selected Time of Concentration (hours) = 0.27

Time of Concentration / Time to Peak Calculations

Required Inputs shown:

Area Under Consideration:	Laydown Post-Development Conditions 212
Airport Formula (mins.)	(3.26*(1.1-C)*(L^0.5))/(S^0.33) — * For C<0.4, Airport drainage
Bransby-Williams Formula (mins):	(0.057*L)/((S^0.2)*(A^0.1)) — * For C>0.4; Underestimates for permeable basins
Kirpich Formula (mins):	0.0196*((L/((S/100)^0.5))^).77)

C = Rational Method Runoff Coefficient =	0.700
L = Watershed Length (metres) =	30.0
S = Watershed Slope (%) =	2.000
A = Watershed Area (hectares) =	0.49
H = Change in Height over Watershed (m) =	0.6
CN = SCS Curve Number =	91
L/W = Watershed Length to Width Ratio =	0.5

	Airport	Bransby Williams	Kirpich
Time of Concentration (mins.)	5.7	1.6	1.2
Time to Peak = 0.67 * Tc (mins.)	3.8	1.1	0.8
Time to Peak (hours)	0.06	0.02	0.01

SCS Lag Time = (L^0.8)*(((990.6/CN)-8.906)^0.7)/(735*(S^0.5)) $T_c = 1.7*T_L$
= 0.02 hrs

Watt & Chow = 0.000326*((L/((S/100)^0.5))^0.79)
Time to Peak = 0.02 hrs

HYMO Time to Peak for Rural Areas with Slope < 2%
= 0.0086*(A^0.422)*(S^-0.46)*((L/W)^0.133)
= 0.04 hrs

HYMO Time to Peak for Rural Areas with Slope > 2%
= 0.016*(A^0.31)*((S/100)^-0.5)
= 0.09 hrs

Upland Method	K=V/(S^0.5) (m/s)	Length (m)	Slope (m/m)	Velocity (m/s)	Time (min.)
Forest with heavy ground litter, hay meadow	0.6			0.00	0.00
Trash fallow or minimum tillage cultivation	1.5			0.00	0.00
Short Grass Pasture	2.3			0.00	0.00
Cultivated, straight row	2.7			0.00	0.00
Nearly bare soil, untilled	3.0	30	0.0020	0.13	3.73
Grassed Waterway (ditch)	4.6			0.00	0.00
Paved Areas (sheet flow); small upland gullies	6.1			0.00	0.00
Total Time of Concentration (minutes) =					**3.73**
Estimated Time to Peak (hours) =					**0.04**

Selected Time of Concentration (hours) = 0.083