Hydrology Report – July 2004

Jock River Flood Risk Mapping (within the City of Ottawa)

Prepared for: **Rideau Valley Conservation Authority**
Prepared by: **PSR Group Ltd.** in association with **JF Sabourin and Associates Inc**

Acknowledgements

This report was prepared by staff of JF Sabourin and Associates and PSR Group Ltd.

In particular:

- field data, statistical analysis and hydrologic modeling were completed by Josee Forget, Philippe Perron, P.Eng. and JF Sabourin, P.Eng. of JF Sabourin and Associates

- rainfall data and report preparation was provided by Paul Frigon, P.Eng. and Philippa Winters of PSR Group Ltd.

- appreciation is extended to the staff and students of the Calvary School, near Franktown, for use of their property for a temporary rainfall gauge site

- streamflow/snowpack data, subcatchment delineation and subwatershed location map were provided by Rideau Conservation Authority staff Patrick Larson and Ewan Hardie.

- historical rainfall data from relevant gauge locations was provided by Ron Rooke, City of Ottawa

- project review and co-ordination was provided by Bruce Reid, P.Eng. and Ferdous Ahmed, P.Eng. from the Rideau Valley Conservation Authority

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1.0 Introduction

The Rideau Valley Conservation Authority (RVCA) requires new flood risk mapping for the Jock River and its major tributaries within the City of Ottawa (Monahan Drain, Smith Creek, Leamy Creek, Flowing Creek and Van Gaal Drain).

The regulatory flood level, used for flood risk mapping within the Rideau River watershed, is defined as the 100 Year flood level: the water level associated with the river discharge that has a 1% probability of being equalled or exceeded each year, or occurs, on average, once every 100 years. Since flood risk mapping requires the development of hydraulic simulation models to define the 100 year water level, reliable flow estimates must be developed as major inputs to the hydraulic model. This report is one of two technical reports that will form the basis of the flood risk mapping; the other report is the hydraulics study that will determine flood levels based on the flows from this report.

The Jock River is a tributary of the Rideau River with the subwatershed having mainly rural land use; river slopes less than 0.5%; and no flow regulation. Its 556km2 drainage area is illustrated in Figure 1 and forms roughly 15% of the Rideau River watershed. The Jock River Watershed Plan – Background Report (JL Richards, 2000) delineated four distinct reaches of the watershed as summarized in Table 1. In this flood risk mapping study, reaches three and four are being addressed as the **lower reach**, between Richmond and the Rideau River, and reach two is being addresses as the **middle reach**, upstream of Richmond, between the Richmond Fen and Ashton.

Flow estimates can be provided by:

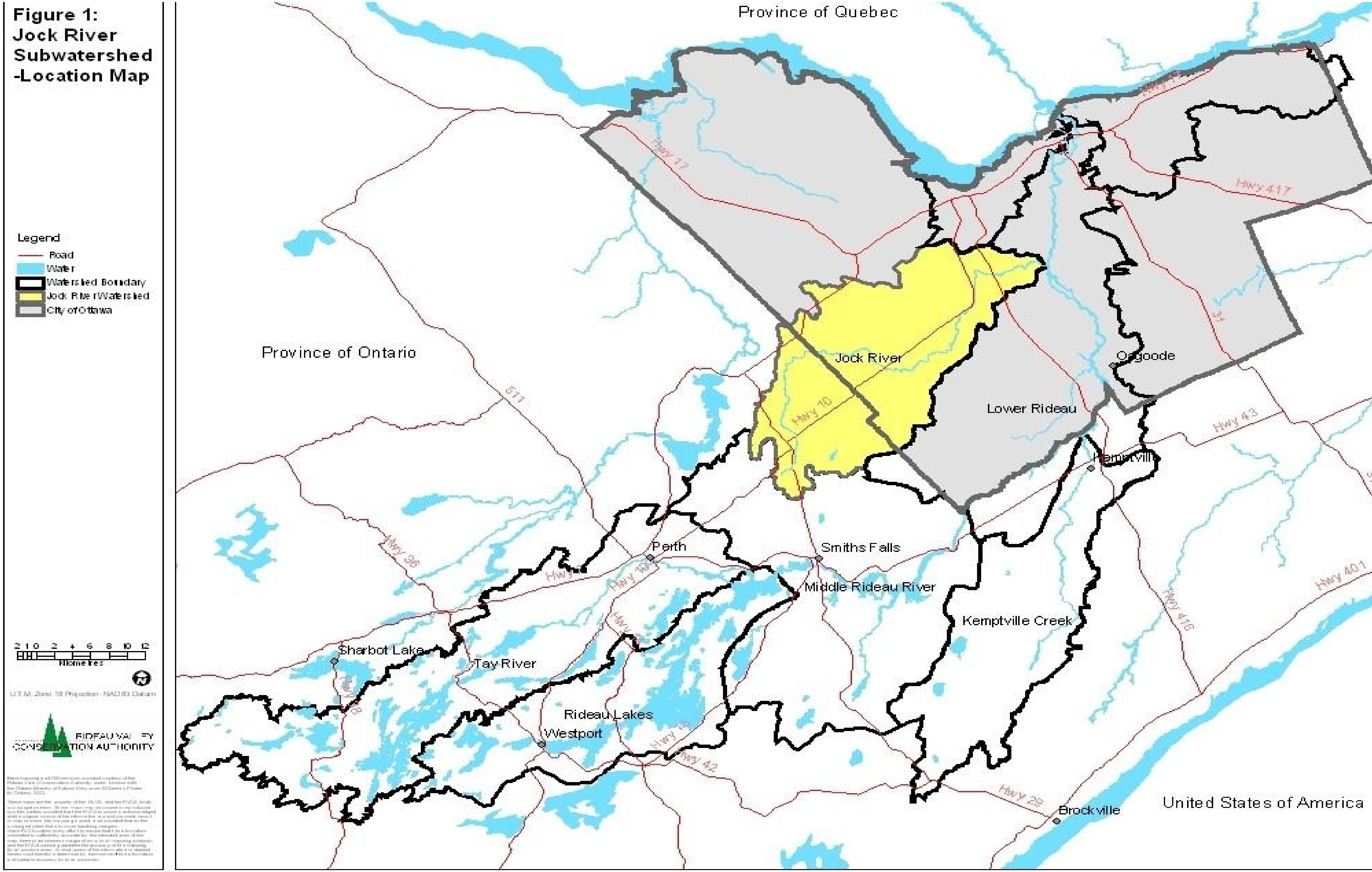
1. single station frequency analysis (SSFA) of observed or simulated peak flows. ie. a statistical analysis of maximum instantaneous peak flows
2. prorating SSFA flows, based on area, for points of interest other than the single station location
3. hydrologic modeling using simulated events as inputs: either snowmelt+rainfall (spring) or rainfall (summer).

In this study it is proposed to use flows derived from SSFA, where applicable, and hydrologic modeling where SSFA would not apply.

For the **lower reach**, the SSFA, derived from 34 years of record at the WSC gauge at Moodie Drive, can provide a good estimate of the 100 Year flow. All annual maximum peak flows have occurred during the Spring Runoff and proration techniques can be used to determine 100 year flow elsewhere in this reach.

Flows in the lower reach reflect the influence of the Richmond Fen while flows in the **middle reach** do not. Because of this influence, it cannot be assumed that the flows derived from SSFA can be prorated to the middle reach; they could provide a lower estimate of the 100 year flow than would actually occur. For the middle reach, a calibrated and validated

Figure 1: Jock River Subwatershed -Location Map



hydrologic model, with spring snowmelt+rainfall events as an input, should provide the best estimate of the 100 Year flow.

It is anticipated that maximum flood levels on **a tributary** will be influenced by flood levels on the Jock River: whether this occurs during a Spring or Summer event is not known. The maximum 100 Year flood level for a tributary would be based on hydraulic analysis that would consider flows on the Jock River and the tributary that, together, have a combined probability of once in 100 years. A calibrated and validated hydrologic model, for both Spring and Summer events, will assist in providing flows for the required hydraulic analysis in the hydraulics report.

It is important to note that the calibration/validation effort concentrated on the simulation of high flows for the purpose of flood risk mapping: the estimates of more frequent Return Period flows, such as the 2 year and 5 year, should be used with caution.

Table 1: Jock River - Watershed Characteristics
(from the "Jock River Watershed Plan –Surface Water Quantity Component - 1996"; with updated drainage areas - 2004)*

Characteristic⇒	**Area (km2)**		**Length (km)**	**Slope (m/m)**	**Landuse (%)**				**Predominant Soils**
Reach ⇓	**2000**	**2004**			**Forest**	**Farm**	**Wetland**	**Urban**	
1. Headwaters to Ashton	113	95	26	.001	62	21	17	0	sandy loam
2. Ashton to Richmond Fen	227	221	19	.002	35	48	16	1	sandy loam
3. Richmond Fen to Flowing Creek	126	138	10	.002	36	39	23	2	loam
4. Flowing Creek to Rideau River	88	102	17	.002	20.5	78	0.2	1.3	clay loam
Total	**554**	**556**							

* drainage areas were updated for the current study and may differ from those previously recorded; this includes differences in interpretation of Reach locations.

2.0 Single Station Frequency Analysis (SSFA)

Since 1970, flows from the Jock River subwatershed have been monitored at the Water Survey of Canada (WSC) streamflow gauge (02LA007) at Moodie Drive: the drainage area above this site is approximately 95% of the subwatershed. The RVCA has installed a similar streamflow gauge, in 2003, on the Jock River at Franktown Road that represents flow from approximately 32% of the subwatershed. 34 years of annual maximum instantaneous peak flows from the WSC gauge at Moodie Drive were used in the statistical analysis to determine the 100 Year flow. In 12 instances, maximum daily flows were converted to maximum instantaneous flows (see Appendix A).

Consolidated Frequency Analysis (CFA) software (version 3.1), developed by Environment Canada, was used to undertake the statistical analysis: the detailed results are provided in Appendix A.

Fundamental tests for independence, trend, homogeneity and randomness confirmed the quality and usefulness of the data. After a review of the SSFA results, including examination of data "fit" to four different probability distributions, and comparison with the results from other flow estimation techniques (including regional frequency analysis, index flood and watershed classification methods), the Log Pearson Type III (LP3) distribution was selected as the best distribution to provide an estimate of the 100 Year flow at Moodie Drive. The 100 year peak flow at Moodie Drive is estimated to be 196 m3/s. A summary of the results are provided in Appendix A, Table A4.

The SSFA results are presented in Table 3, along with other flow estimates for various Return Periods and prorated flows at other locations between Richmond and the Rideau River as well as between Richmond and Ashton for comparison purposes. Prorated flows were determined using the commonly employed relationship $Q1/Q2=(A1/A2)^{0.75}$ (MTO Drainage Manual: pg H4-7) where Q1 and Q2 are flows and A1 and A2 are their respective drainage areas.

Table 3: Spring and Summer Flows – Jock River and Tributaries

Location and Hydrologic Model Reference #	Flows (m^3/s) **(Spring – SSFA – observed/prorated)** *(Spring event – 10 day volume - modeled)*						(Summer – SSFA – continuous model - 38 years) ***(Summer event – SCS 24 hour - modeled)***					
Return Period=> (years)	**2**	**5**	**10**	**20**	**50**	**100**	**2**	**5**	**10**	**20**	**50**	**100**
Rideau River (N1)	95	129	148	167	189	205						
	86	*118*	*140*	*173*	*200*	*226*	*49*	*72*	*90*	*116*	*136*	*158*
Moodie Drive and d/s Monoghan Drain(N2)	91	123	142	160	181	196	37	60	78	95	119	139
	80	*109*	*128*	*158*	*182*	*206*	*46*	*66*	*82*	*105*	*122*	*141*
d/s Flowing Creek (N5)	82	110	127	144	162	176						
	63	*84*	*98*	*125*	*144*	*162*	*33*	*43*	*51*	*62*	*71*	*80*
d/s Richmond Fen (N7)	72	98	113	127	144	156						
	50	*67*	*86*	*111*	*127*	*145*	*23*	*28*	*31*	*41*	*51*	*61*
d/s King Creek (N10)	55	73	86	97	110	116						
(u/s Richmond Fen)	*46*	*70*	*86*	*107*	*125*	*141*	*29*	*44*	*54*	*69*	*80*	*93*
Franktown Road (N10-KC)	40	54	63	70	80	86						
	27	*42*	*51*	*64*	*74*	*83*	*19*	*28*	*35*	*44*	*51*	*60*
Ashton (N12)	25	34	39	44	50	54						
	8	*11*	*13*	*16*	*18*	*20*	*7*	*10*	*13*	*16*	*19*	*21*
Monoghan Drain	10	13	15	17	20	21						
	9	*13*	*16*	*20*	*24*	*27*	*11*	*18*	*22*	*29*	*34*	*40*
Flowing Creek	15	21	24	27	31	33						
	15	*22*	*28*	*35*	*40*	*46*	*15*	*22*	*28*	*37*	*44*	*51*
King Creek	23	31	36	40	46	49						
	19	*27*	*35*	*44*	*51*	*58*	*11*	*16*	*20*	*25*	*30*	*34*

3.0 Hydrologic Model

Two distinct hydrologic models have been developed for the Jock River subwatershed: one reflects Spring conditions and the other Summer conditions. They vary with regards to essential hydrologic parameters such as time to peak, soil infiltration rates and channel routing characteristics. Each model was calibrated based on observed runoff in 2003 at the Moodie Drive and Franktown streamflow gauges: the Spring model was validated using observed hydrographs from 1978, 1993, 1997 and 1998 at Moodie Drive.

Both models use Return Period design events to provide peak flow estimates at various points of interest in the subwatershed: for Spring, a snowmelt+rainfall event was developed; for Summer, the design event was a summer storm.

SSFA results from observed flows at Moodie Drive were used for additional validation of both the Spring and Summer models: design event peak flows, for various flood frequencies, were compared to SSFA of observed peak flows. As well, SSFA of peaks derived from continuous simulation of 38 years of record were compared to those observed. This additional validation provides a level of confidence that Return Period design events produce peak flows of reasonable magnitude.

3.1 Watershed Delineation

The watershed was divided into 14 major catchments and 11 minor catchments with points of interest at:

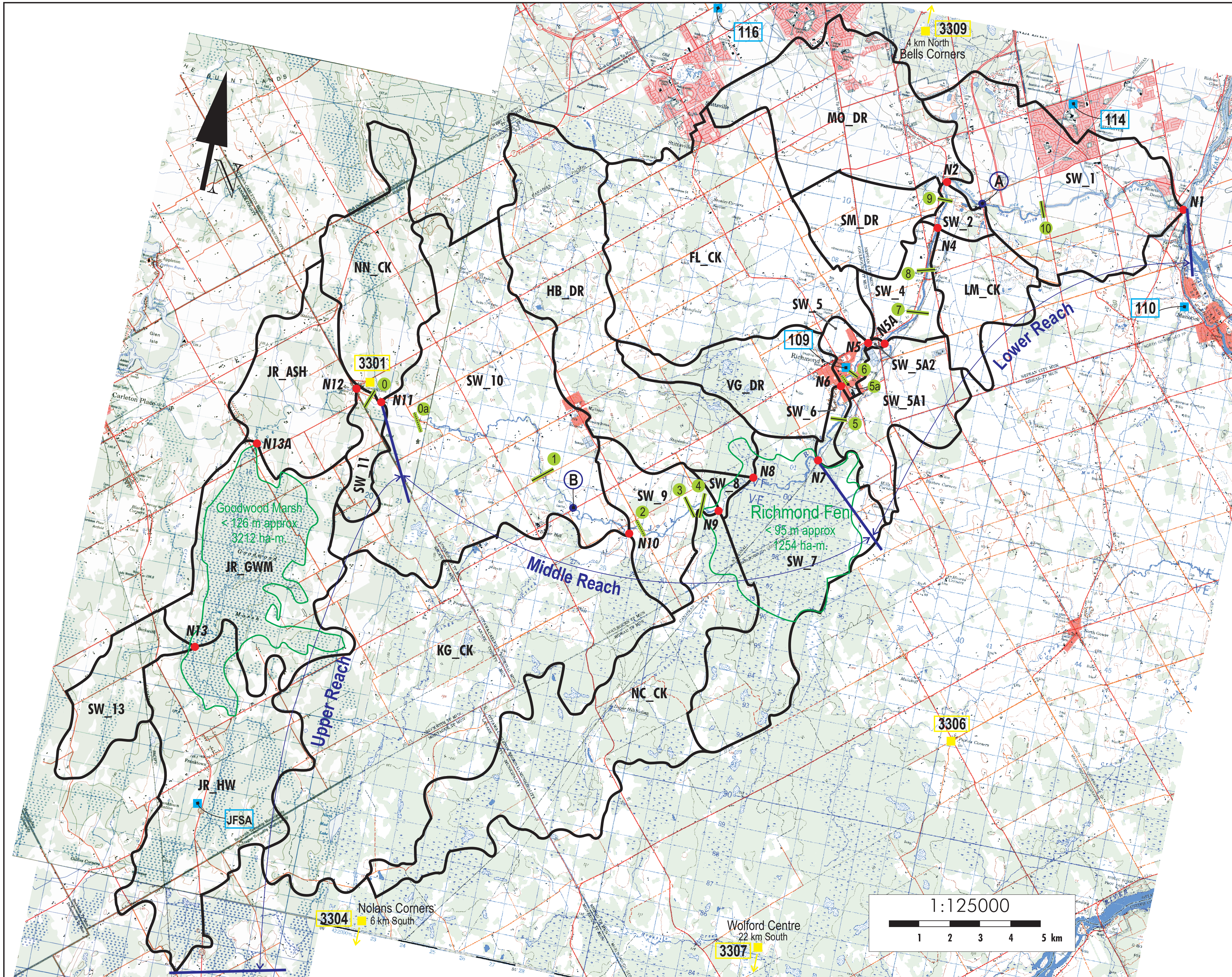
- Ashton
- Franktown Road,
- Kings Creek
- Nichols Creek
- Hobbs Drain
- Richmond Fen
- Richmond
- Van Gaal Drain,
- Flowing Creek,
- Leamy Creek,
- Monaghan Drain,
- Smiths Creek
- Rideau River.

Major sources of topographic data included 1:50,000 NTS and 1:10,000 OBM maps. Catchment identification was undertaken by visual assessment of the topographic data, field investigation, as well as automated delineation using GIS techniques as provided by the RVCA. For hydrologic analysis, the catchment delineation is appropriate and, on average, represents the best current information available.

A map of the hydrologic catchments is provided in Figure 2.

3.2 Hydrologic Characteristics

A hydrologic model of the watershed was developed using SWMHYMO (version 5.02) with CN values being determined from surficial geology maps provided by the Geologic Survey of



Legend:

- Watershed
- Bogs (Reservoir)
- Nodes
- Flow gauges
- Rain gauges
- Snow course stations
- River Cross-Sections (based on topo. maps)
- River Cross-Sections adjusted with field data
- Reaches limits

Flow gauges ID

- A 02LA007- Jock River near Richmond
- B Jock River at Franktown Rd

Rain gauges ID

- 109 Richmond
- 110 Manotick
- 114 Barrhaven
- 116 Maple Grove
- JFSA JFSA Inc, Temporary Rain Gauge 2003

Snow course stations ID

- 3301 Ashton
- 3304 Nolans Corners
- 3306 Pierces Corners
- 3307 Bells Corners
- 3309 Wolford Centre

Client:

RIDEAU VALLEY CONSERVATION AUTHORITY

Project:

Jock River Flood Plain Mapping Study

Title:

Watershed Delineation

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WATER RESOURCES AND ENVIRONMENTAL CONSULTANTS
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Figure 2

Ref. File: Base Map Jock River B.cdr

Canada and land use derived from 1:10,000 Ontario Base Maps provided by MNR. The time to peak (Tp) for each catchment was determined using the Bransby-Williams formula (summer Tp was augmented based on % of wetlands in catchment) . Appropriate channel sections were selected to allow channel routing as a component of the model. A summary of the hydrologic characteristics of the watershed are provided in Table 2 and the hydrologic model is shown, in schematic form, in Figures 3a and 3b.

The Richmond Fen and the reach, upstream of Ashton, that transects the Goodwood Marsh, were modeled as reservoirs to more accurately reflect their impacts on attenuating downstream peak flows. Stage-storage-discharge relationships were developed using channel hydraulics as a control for stage-discharge and best available mapping (1:10,000 OBM) for stage-storage: the results are provided in Figure B6 in Appendix B

As inputs to the model during its development and final output modes, the following data sources, as located in Figure 2, were utilised:

- a tipping bucket raingauge, installed from May through June near Franktown, supplemented the raingauge records at Richmond and Maple Grove (City of Ottawa), AES Ottawa CDA
- bi-weekly snowpack survey data, collected by RVCA, was used to correlate measured streamflow hydrograph volumes against snowmelt volumes computed with the degree-day type equations suggested by AES.
- daily temperature data from the AES Ottawa CDA was used in springmelt analyses.
- hourly rainfall data from 1960 to 1998 from the AES Ottawa CDA
- AES Ottawa CDA snowmelt+rainfall IDF curves were utilised in designing synthetic snowmelt+rainfall events
- rainfall IDF curves from the AES Ottawa CDA were used in developing design storms
- simple “averaging” was used to derive snowpack and rainfall inputs for the calibration effort

The following studies have been reviewed for consistency with the hydrologic model being currently developed and, with one exception noted below, no major discrepancies or ambiguities have been found:

- Rideau River watershed model - HSPF (1990).
- Stittsville MDP (1994)
- the Richmond MDP (1995)
- Monaghan Drain MDP (1998)
- Upper Poole Creek - Subwatershed Study (2000)
- Van Gaal Drain - Erosion Study (2001)
- Dwyer Hill Training - Centre SWM plan (2002)

Of note, however, are the headwaters of Poole Creek, where it has been determined that approximately 625ha drain to the Jock River via Hobbs Drain, rather than to Poole Creek.

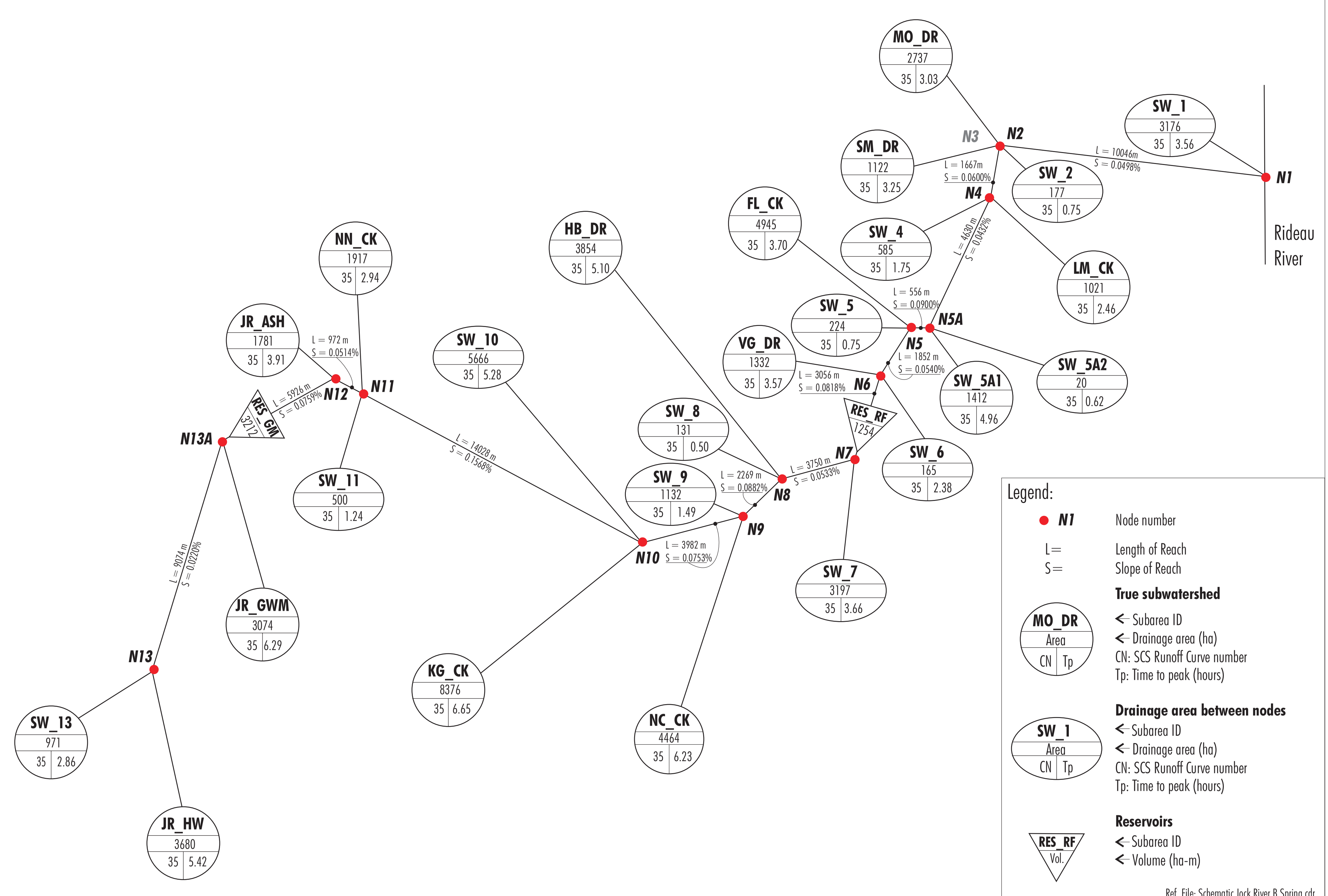

Figure 3A SWMHYMO Model Schematic of the Jock River Subwatersheds: Spring Model

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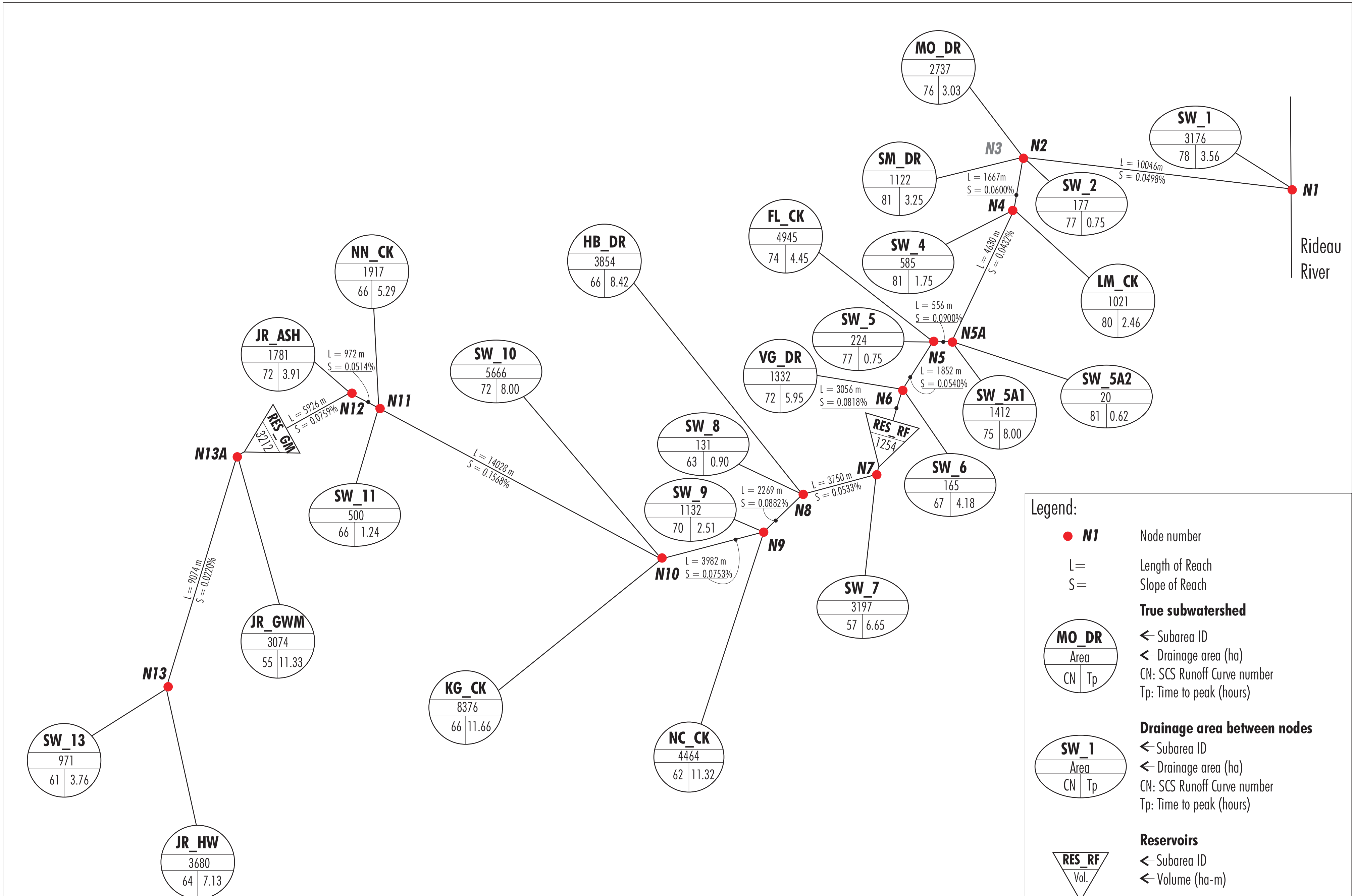

Ref. File: Schematic Jock River B Summer.cdr

Figure 3B SWMHYMO Model Schematic of the Jock River Subwatersheds: Summer Model

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Table 2: Summary - Hydrologic Parameters						
Parameter =>	**hydrologic**	**drainage**	**Spring**		**Summer**	
	model ID	**area (ha)**	**CN**	**Tp(hr)**	**CN**	**Tp(hr)**
subcatchment						
headwaters	JR_HW	3680	35	5.4	64	7.1
subcathcment 13	SW_13	971	35	2.9	61	3.8
Goodwood Marsh	JR_GWM	3074	35	6.3	55	11.3
Ashton	JR_ASH	1781	35	3.9	72	3.9
unnamed creek	NN_CK	1917	35	2.9	66	5.3
subcatchment 11	SW_11	500	35	1.2	66	1.2
Kings Creek	KG_CK	8376	35	6.7	66	11.7
subcatchment 10	SW_10	5666	35	5.3	72	8.0
Nicholls Creek	NC_CK	4464	35	6.2	62	11.3
subcatchment 9	SW_9	1132	35	1.5	70	2.5
subcatchment 8	SW_8	131	35	0.5	63	0.9
Hobbs Drain	HB_DR	3854	35	5.1	66	8.4
subcatchment 7	SW_7	3197	35	3.7	57	6.7
Van Gaal Drain	VG_DR	1332	35	3.6	72	6.0
subcatchment 6	SW_6	165	35	2.4	67	4.2
subcatchment 5	SW_5	224	35	0.8	77	0.8
Flowing Creek	FL_CK	4945	35	3.7	74	4.5
subcatchment 5A1	SW_5A1	1412	35	5.0	75	8.0
subcatchment 5A2	SW_5A2	20	35	0.6	81	0.6
subcatchment 4	SW_4	585	35	1.8	81	1.8
Leamy Creek	LM_CK	1021	35	2.5	80	2.5
subcatchment 2	SW_2	177	35	0.8	77	0.8
Smith Drain	SM_DR	1122	35	3.3	81	3.3
Monoghan Drain	MO_DR	2737	35	3.0	76	3.0
subcatchment 1	SW_1	3176	35	3.6	78	3.6
Total		**55659**				

3.3 Spring Model (December 1st to April 30th)

3.3.1 Calibration

Using snowpack and temperature data measured during Spring 2003, snowmelt+rainfall hyetographs were developed by converting the snowpack to daily runoff volumes based on snowmelt estimates provided by degree-day equations. These volumes were then appropriately distributed over the day (see Appendix B) and formed an input to the model. Hydrologic model parameters such as time to peak, antecedent moisture condition, subcatchment runoff coefficients and channel routing were modified to achieve model calibration so that simulated and observed hydrographs had a best fit for peak magnitude, runoff volume and time to peak: the final results are adequate in terms of peak time, magnitude and volume as illustrated in Figure B1 in Appendix B. Based on these results, it can be assumed that the model can be used to derive a reasonable estimate of the 100 year maximum instantaneous peak flow on the Jock River between Richmond and Ashton.

3.3.2 Validation

The calibrated spring model has been validated by comparing the simulated flows for peak Spring events in 1978, 1993, 1997 and 1998 with observed flows at the Moodie Drive gauge. Although there were variations in the timing of the peak between simulated and observed, the hydrologic model adequately reflects the magnitude and volume of the Spring event. The results are illustrated in Figure B2 in Appendix B.

Further validation of the model is provided by comparison of maximum instantaneous flows determined by the Spring design event with those determined by SSFA of maximum instantaneous observed flows. The results are illustrated in Table B3: there is good agreement and peak flows are within 5%, for the 50 year and 100 Year events.

3.3.3 Inputs/Results

The 100 year peak Spring flow was simulated using a synthetic 100 year snowmelt+rainfall event developed from AES snowmelt+rainfall IDF curves. These relationships have been developed for one through thirty day durations, with Return Periods from 2 through 100 years. Additional detail on the development of the synthetic snowmelt+rainfall hyetograph is provided in Appendix B.

The 10 day event was selected as being the appropriate duration for a synthetic Spring snowmelt+rainfall event – it correlated well with the 100 year SSFA results for the Moodie Drive gauge as shown in Table B3 in Appendix B. The volumes, for various Return Periods, were then distributed, hourly, over the 10 days, as described in Appendix B, and represent a best estimate of a simulated Spring snowmelt+rainfall event.

A summary of the modeled peak flows for the Spring event are provided in Table 3 and suggest a 100 year maximum instantaneous peak flow, upstream of the Richmond Fen, of 141 m3/s (versus 116 m3/s using SSFA proration). Modeled 100 year peak at Moodie Drive is 205 m3/s which agrees well with the SSFA estimate of 196m3/s. Summary model input and output is provided in Appendices D and E respectively.

3.4 Summer Model (May 1st to November 30th)

3.4.1 Calibration

Hourly streamflow data from the gauges at Moodie Drive and Franktown Road, in conjunction with hourly rainfall data from a temporary gauge at Franktown and the Richmond and Maple Grove gauges, were used in the calibration of the hydrologic model. Peak flow magnitude, timing and runoff volume, for rainfall-runoff during the late spring and early summer of 2003, are illustrated in Figure C1and C2 and show an adequate fit at Moodie Drive (estimated peak magnitudes within 20% of observed) and a less acceptable fit at Franktown Road (estimated peak magnitudes within 50% of observed). Additional effort could be expended, in future studies, to fine-tune the model.

3.4.2 Validation

The calibrated summer model could not be validated, by comparing the simulated flows for peak Summer events with observed flows at the Moodie Drive gauge, since observed hydrographs from past years are not readily available.

Validation of the model (and the design event) is provided by comparison of maximum instantaneous flows determined by the Summer design event with those determined by SSFA of continuous simulation results: peak flows are generally within 5% to 10% for the two modeling techniques. The results are illustrated in Table C4: there is good agreement and peak flows are within 5%, for the 50 year and 100 Year flows.

For additional validation, Summer peak flows, from the 34 years of daily record at Moodie Drive, were reviewed to identify the annual maximum daily peak summer flow (maximum instantaneous flows are not readily available). SSFA of these annual daily maximums were compared to SSFA of annual daily maximums derived from hourly continuous simulation over 38 years of record. The results are illustrated in Table C4: there is adequate agreement (within 15%) between the maximum daily observed flow and maximum daily simulated flow.

3.4.3 Inputs/Results

The 100 year peak Summer flow was estimated using a 100 year Design Storm. Ten different Design Storm distributions were assessed, along with various durations. They included:

1. Chicago 4 hour
2. Chicago 24 hour

3. SCS 6 hour
4. SCS 24 hour
5. AES 1 hour
6. AES 12 hour
7. Huff QI 3, 6 12 and 24 hour
8. Huff QII 3, 6 12 and 24 hour
9. Huff QIII 3, 6 12 and 24 hour
10. Huff QIV 3, 6 12 and 24 hour

The Return Period flows derived from the various design storms were compared with the SSFA Return Period flows derived from the series of annual Summer instantaneous peak flows developed from continuous simulation. Table C5 in Appendix C summarises the results of the comparison in which the ratio of the design storm peak to the SSFA peak, for any given Return Period, was identified: a ratio of 1.0 would suggest that the given design storm was the most appropriate event to model summer peak flows. The best agreement occurs using the SCS 24 hour distribution in which the average ratio, for the six Return Period flows (2, 5, 10, 25, 50 and 100 years), is 1.001.

Using the SCS 24 hour distribution as input, the 100 year peak summer flow at Moodie Drive is estimated to be 141m3/s. A summary of Return Period peak flows for various points of interest in the subwatershed is provided in Table 3. Summary model input and output is provided in Appendices D and E respectively.

4.0 Conclusions

Based on the previous sections, it is concluded that:

1. Maximum peak flows on the Jock River occur in the Spring.
2. Single Station Frequency Analysis (SSFA) is an appropriate method for determining maximum peak flows on the Jock River between Richmond and the Rideau River.
3. A reliable estimate of the 100 Year maximum peak flow on the Jock River, at Moodie Drive, is 196m3/s. This is based on SSFA of 34 years of peak flow record at the Water Survey of Canada Gauge at Moodie Drive and application of the Log Pearson 3 statistical distribution.
4. The prorated results of SSFA cannot be applied to estimate maximum peak flows on the Jock River between Richmond and Ashton due to the flow attenuation provided by the Richmond Fen.
5. Hydrologic modeling of Spring runoff, that uses synthetic snowmelt+rainfall volumes with a 10 day duration, is an appropriate method for determining maximum peak flows on the Jock River between Ashton and Richmond.
6. A reliable estimate of the 100 Year maximum peak flow on the Jock River at Franktown Road is 83m3/s.
7. Hydrologic modeling of Summer runoff, using a SCS 24 hour distribution rainfall distribution, is an appropriate method for determining peak summer flows on the Jock River and its major tributaries. It estimates the 100 Year peak summer flow, on the Jock River at Moodie Drive, to be 141m3/s.

5.0 Recommendations

Based on the conclusions it is recommended that:

1. 100 year flood level estimates on the Jock River, between Richmond Fen and the Rideau River, should use maximum peak flows determined by SSFA. The most appropriate statistical distribution is the Log Pearson 3 (LP3) which suggests a 100 year peak flow of 196m3/s for the Jock river at Moodie Drive
2. 100 year flood level estimates on the Jock River, between Richmond Fen and Ashton, should use maximum peak flows determined by a hydrologic model using a Spring design event based on 10 day AES snowmelt+rainfall IDF relationships.
3. for 100 year flood level estimates on Jock River tributaries, joint-probability analysis should be applied to flows on the Jock River and the tributary , for both Spring and Summer events , to determine which combination of flows produces maximum water levels in the tributary. The Summer design event is the SCS 24 hour.
4. The flows recommended for use in Flood Risk Mapping on the Jock River are provided in Table 4.

Table 4: Recommended Spring and Summer Flows – Jock River and Tributaries

Location and Hydrologic Model Reference #	**Flows (m3/s)** (Spring – SSFA – observed/prorated)* *(Spring event – 10 day volume - modeled)** *(Summer event – SCS 24 hour - modeled)**					
Return Period=> (years)	**2**	**5**	**10**	**20**	**50**	**100**
Rideau River (N1)	95	129	148	167	189	205
Moodie Drive and d/s Monoghan Drain(N2)	91	123	142	160	181	196
d/s Flowing Creek (N5)	82	110	127	144	162	176
d/s Richmond Fen (N7)	72	98	113	127	144	156
d/s King Creek (N10) (u/s Richmond Fen)	*46*	*70*	*86*	*107*	*125*	*141*
Franktown Road (N10-KC)	*27*	*42*	*51*	*64*	*74*	*83*
Ashton (N12)	*8*	*11*	*13*	*16*	*18*	*20*
Monaghan Drain	*11*	*18*	*22*	*29*	*34*	*40*
Flowing Creek	*15*	*22*	*28*	*37*	*44*	*51*
King Creek	*11*	*16*	*20*	*25*	*30*	*34*

* **font type and underlining indicate technique used in deriving flow**

References

1. Rideau River Watershed Model (1990). – RVCA – Marshall, Macklin, Monoghan
2. Stittsville MDP (1994) – Township of Goulbourn – AJ Robinson and Associates
3. Richmond MDP Update (1998) – Township of Goulbourn – Robinson Consultants
4. Monaghan Drain MDP (1993) – City of Kanata – Gore and Storrie
5. Upper Poole Creek - Subwatershed Plan (2000) – Township of Goulbourn – Marshall Macklin Monoghan
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