# APPENDIX B – Hydrologic Model – Spring Event

## Snowmelt+Rainfall

- Calibration and Validation Results
- Design Events
- Explanation of AES rain+snowmelt extreme value analysis
- Stage-Storage-Discharge: Richmond Fen – Goodwood Marsh

# Calibration and Validation Results

For the Spring runoff in 2003, snowpack data provided by the RVCA and temperature/rainfall data from AES Ottawa CDA were used to synthesize an input hyetograph for the Spring hydrologic model of the Jock River. The synthesis process is discussed, in more detail, in the "Design Flows" section and requires the use of a snowpack melt-factor in developing the input hyetograph.

For the calibration and validation exercise, in which the elements of the hydrologic model are refined (API, infiltration, Tp, and CN), the melt-factor is a variable and is different for each year. It was determined by developing a "best fit" between observed snowpack behaviour and simulated snowpack behaviour. Figure B1(a) illustrates the impact of melt-factor on estimating snow pack melt behaviour by comparing observed water equivalent and estimated water equivalent (using melt-factor) during the Spring 2003 runoff: for this runoff event, a melt-factor of 1.99 was chosen as providing the best estimation of snowpack behaviour. While a melt-factor of 1.15 appears to provide a better fit with observed data, the tail-end of the snowpack depletion simulation using this factor, would significantly overestimate melt volume.

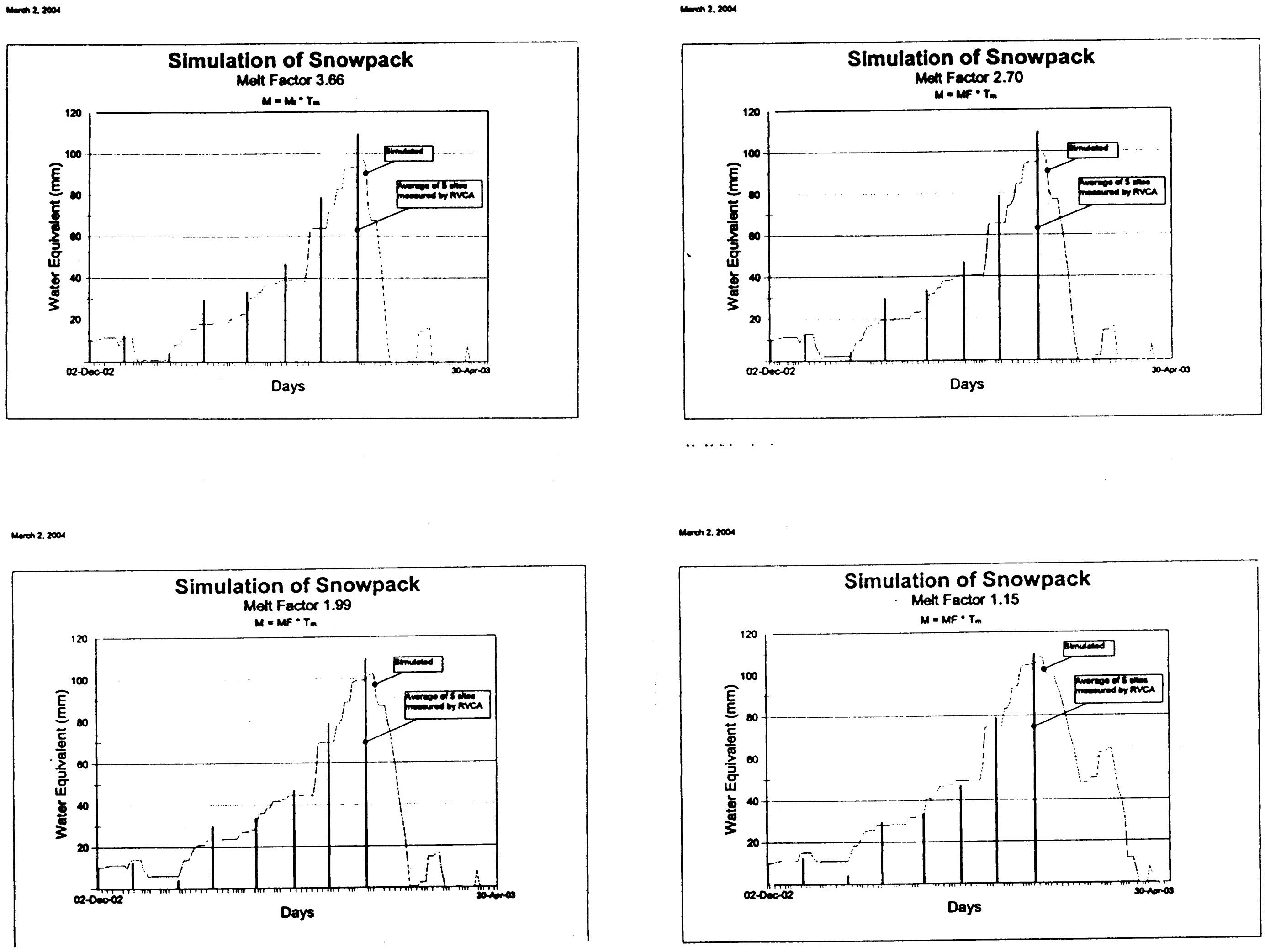
The resulting synthetic hydrograph at Moodie Drive and the observed hydrograph at Moodie Drive were compared and adjustments made in the hydrologic model (API, infiltration, Tp, CN) until there was a "best fit" between peak magnitude, volume of runoff and timing. The final calibration result is provided in Figure B1(b): the "best fit" is adequate and the peak and volume are overestimated by 30% and 15% respectively.

Spring runoff events in 1978, 1993, 1997 and 1998 were then simulated by the model and results were compared with observed flows. The comparison is illustrated in Figure B2 and shows a range of "fit" for peak, volume and timing. For two events the peak magnitudes are within 5% while for two others, they range between 15% and 30%. This suggests appropriate validation of the model.

Additional validation of the model is obtained by comparing the results of Return Period design event simulations with the results of SSFA of the observed record of maximum instantaneous peak flows at Moodie Drive. Table B3 compares the results of three different design event assumptions regarding CN value during Spring runoff:

- The first uses a fixed CN value of "35" and allows, in the SWMHYMO simulation, for snowmelt to be stored in the snowpack for release over a period of time; the acceptability of this approach was confirmed by a recent project completed for the City of Gatineau (JFSA).
- the second uses a fixed CN value of "90" to reflect frozen ground conditions and the high degree of imperviousness but no storage component.
- The third uses a CN that varies according to Antecedent Precipitation Index (API), Initial Abstraction (IA) and a storage factor (Sk) – similar to the CN* approach used in QUALHYMO.

# Figure B1(a) melt-factor impact on snowpack "water equivalent" simulation




M : Melt (mm/day)
$T_m$ : Mean Daily Temperature
$M_f$ : Melt Factor

Notes: * Climatic Data for the 1, 2 and 21 of March was taken from faxed data sheet of Ottawa MCI A station because the said days were not available in the online version of the Ottawa MCI A station.

Source: NRCC, Watt, W.E., et al: "Hydrology of Floods in Canada, A Guide to Planning and Design", 1990
M5 Model 5: (table 7.4)
$M_f$ Melt Factors for Québec city region (2.70) and Southern Ontario (3.66) (table 7.1)

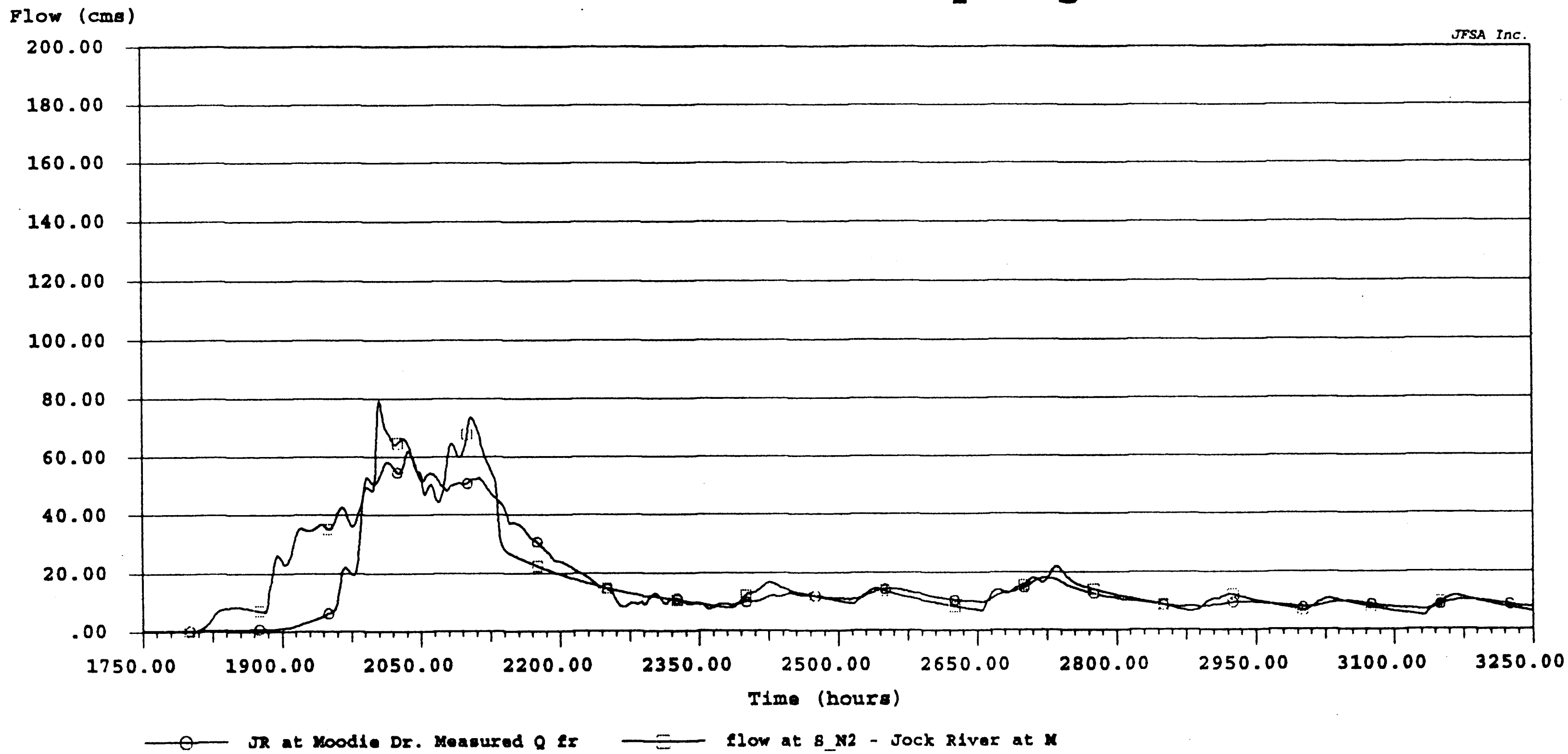
JFSA Report 294, "Étude de Calibration du Modèle Hydrologique des Bassins de Rétention du Ruisseau Moreau sous les Tours d'Hydro-Québec", May 2002.
$M_f$ Melt Factor for Gatineau (1.99)

Viessman, W Jr. et al, "Introduction to Hydrology", 2nd Ed., 1977, p. 362-3.
$M_d$ Adjusted snowmelt factor due to rainfall included in Mf computation

Snow water equivalent:
R.V.C.A Snow Survey
Average of Sites: Pierces Corners, Wolford Centre, Nolans Corners, Ashton, Bells Corners

Climatic Data:

# Model Calibration (Spring 2003)

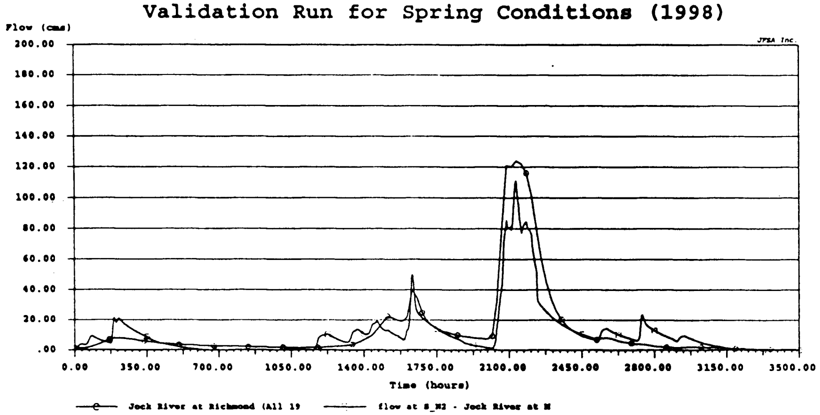



## Hydrograph Statistics:

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| ——o—— | H_JRATM.003 : JR at Moodie Dr. Measured Q from Jan-1-03 | 60.00 | 52483.00 | 62.000 | 2037.000 | 151.56 | 7.954E+07 | 1500.000 | 14.730 |
| ——□—— | H-S_N2.109 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 79.238 | 2006.000 | 175.81 | 9.227E+07 | 5000.000 | 5.126 |

Figure B1(b) Spring Hydrograph
Moodie Drive – 2003 – observed/simulated

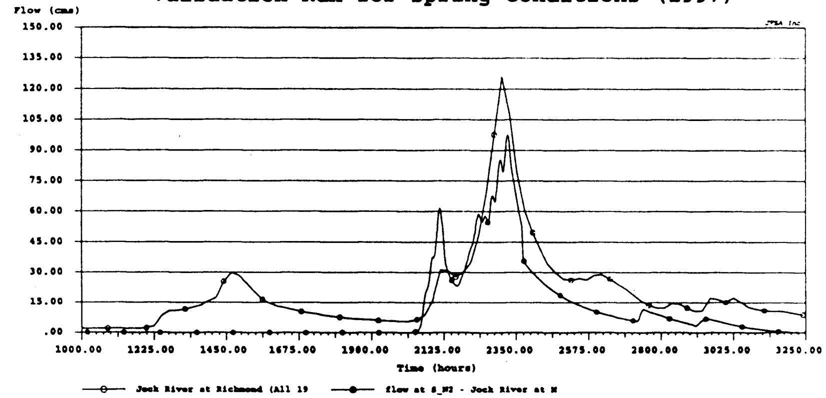
## Validation Run for Spring Conditions (1998)




**Hydrograph Statistics:**

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| —o— | 02LA007.998 : Jock River at Richmond (All 1998)-from HYDAT | 1440.00 | 55900.00 | 124.000 | 2136.000 | 287.71 | 1.608E+08 | 3480.000 | 12.838 |
| —— | flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 110.775 | 2134.000 | 263.80 | 1.385E+08 | 5000.000 | 7.692 |

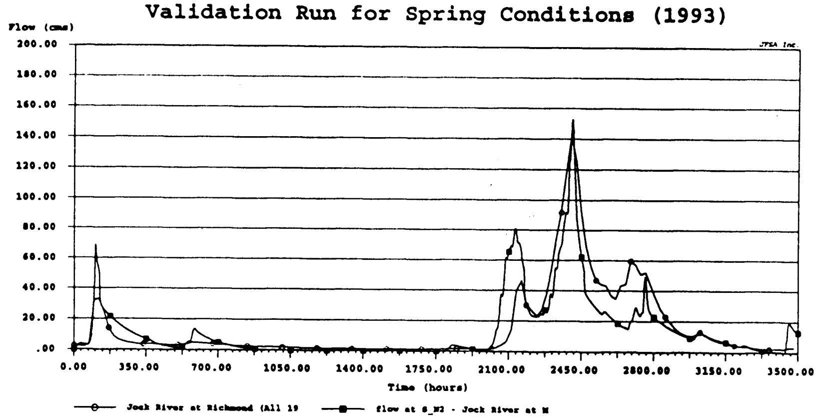
## Validation Run for Spring Conditions (1997)




**Hydrograph Statistics:**

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| —o— | 02LA007.997 : Jock River at Richmond (All 1997)-from HYDAT | 1440.00 | 55900.00 | 126.000 | 2304.000 | 292.40 | 1.635E+08 | 2232.000 | 20.342 |
| —●— | flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 97.455 | 2323.000 | 163.04 | 8.557E+07 | 5000.000 | 4.754 |

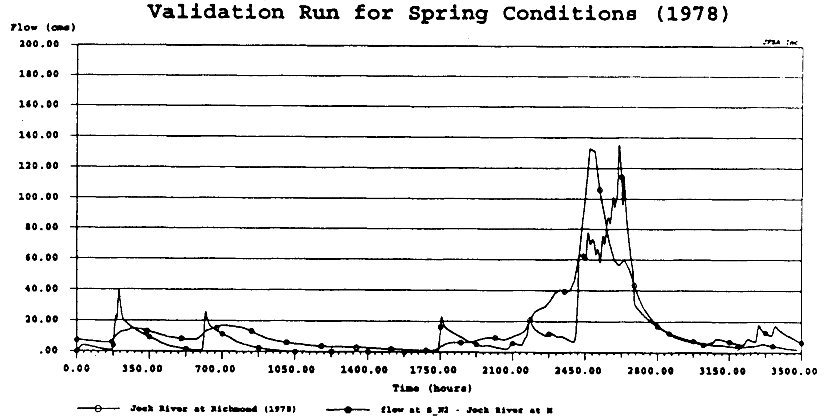
## Validation Run for Spring Conditions (1993)




**Hydrograph Statistics:**

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| —o— | 02LA007.993 : Jock River at Richmond (All 1993)-from HYDAT | 1440.00 | 55900.00 | 142.000 | 2400.000 | 340.68 | 1.904E+08 | 3480.000 | 15.201 |
| —■— | flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 152.884 | 2405.000 | 324.36 | 1.702E+08 | 5000.000 | 9.457 |

## Validation Run for Spring Conditions (1978)




**Hydrograph Statistics:**

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| —o— | 02LA007.978 : Jock River at Richmond (1978) | 1440.00 | 55900.00 | 133.000 | 2472.000 | 351.34 | 1.964E+08 | 3480.000 | 15.677 |
| —●— | flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 135.535 | 2613.000 | 301.60 | 1.583E+08 | 5000.000 | 8.794 |

Figure B2– Validation Events - Spring – Moodie Drive - observed/simulated

The comparison indicates that the CN=35 modeling assumptions provide peak flows that are within 5% of the SSFA results for observed Spring peaks at Moodie Drive, for the 25, 50 and 100 year events. This provides additional support for model validity in the Jock River watershed.

## Design Flows

The estimates of Spring flow, based on hydrologic model, were developed with several assumptions:

1. "Return Period" synthetic springmelt hyetographs (hourly precipitation inputs in terms of snowmelt and rainfall) could be based on "Return Period" snowmelt+rainfall volumes developed by AES.
    a. These volumes are provided in the form of intensity, duration, frequency relationships (see Table B2).
    b. They were derived from statistical analysis (Gumbel Extreme Value) of maximum annual snowmelt+rainfall volumes: the volumes were developed for 1 to 30 day periods based on observed precipitation (snow + rain) and temperature at the Ottawa CDA site from 1890 through to 1997 (see Table B1).
    c. annual volumes were estimated by Environment Canada using a snowpack accumulation/depletion algorithm as identified in Figure B5

2. a 10 day melt event, as illustrated in Figure B3, is a reasonable duration for a springmelt hyetograph: flow simulation results correlate well with the 100 year SSFA results for the Moodie Drive gauge as shown in Table B3.

3. these volumes have been distributed over the 10 day duration in the following manner: The "1 day" volume from Table B2 is assigned to day 5; the "2 day" volume minus the "1 day" volume is assigned to day 6; the "3 day" volume minus the "1 day" plus "2 day" volumes is assigned to day 4 (alternating volume placement about day 5) …. And so on until the 10 day event is constructed in terms of volume allocation on a daily basis.

4. A sine curve distribution could be used to allocate snowmelt+rainfall volume on an hourly basis for each day of the 10 day event.

The final simulated runoff hydrographs, for Spring events at Moodie Drive, with Return Periods ranging from 2 years to 100 years, are provided in Figure B4.

ATMOSPHERIC ENVIRONMENT SERVICE
RAIN+SNOWMELT INTENSITY, DURATION, FREQUENCY VALUES
PREPARED BY THE HYDROMETEOROLOGY DIVISION, CANADIAN CLIMATE CENTRE

STATION : Ottawa CDA, Ontario — STATION NUMBER 6105976

LATITUDE: 4523 LONGITUDE: 7543 ELEVATION(M): 79

SNOWMELT MODEL 5

CRITICAL PERIOD : 1ST OF MONTH 10 TO THE END OF MONTH 5 — NOTE : MODIFIED GUMBEL 12/82

| YR | TOTAL DAYS | % VALID | FLAG | START MAX | 1 DAY | 2 DAY | 3 DAY | 4 DAY | 5 DAY | 6 DAY | 7 DAY | 8 DAY | 9 DAY | 10 DAY | 15 DAY | 20 DAY | 25 DAY | 30 DAY | MAX SNPK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1890 | 242 | 88 | ** | D/M | 4/ 4 | 4/ 3 | 4/ 3 | 4/ 4 | 4/ 3 | 4/ 3 | 4/ 3 | 4/ 3 | 4/ 3 | 4/ 3 | 3/26 | 3/21 | 3/14 | 3/12 | |
| | | | | .1MM | 341 | 452 | 462 | 703 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 814 | 918 | 918 | |
| 1891 | 273 | 100 | | D/M | 3/ 9 | 4/10 | 4/ 9 | 4/ 9 | 4/ 9 | 3/29 | 3/28 | 3/28 | 3/21 | 3/21 | 3/28 | 3/23 | 3/21 | 3/13 | |
| | | | | .1MM | 316 | 601 | 752 | 783 | 783 | 867 | 907 | 907 | 987 | 1058 | 1284 | 1325 | 1498 | 1629 | 1870 |
| 1892 | 274 | 100 | | D/M | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 3 | 4/ 2 | 4/ 2 | 4/ 2 | 4/ 2 | 3/29 | 3/29 | 3/29 | 3/10 | |
| | | | | .1MM | 405 | 775 | 1069 | 1314 | 1568 | 1807 | 1878 | 1878 | 1878 | 1878 | 1949 | 1949 | 1949 | 1949 | 1750 |
| 1893 | 273 | 100 | | D/M | 4/13 | 4/12 | 4/11 | 4/10 | 4/10 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 8 | 3/31 | 3/31 | 3/24 | 3/21 | |
| | | | | .1MM | 442 | 736 | 948 | 1050 | 1075 | 1386 | 1411 | 1411 | 1411 | 1533 | 1552 | 1552 | 1625 | 1724 | 1832 |
| 1894 | 273 | 100 | | D/M | 4/ 4 | 3/ 5 | 3/ 5 | 3/ 4 | 3/ 3 | 3/ 2 | 3/ 2 | 4/ 4 | 4/ 4 | 3/31 | 3/ 5 | 3/ 2 | 3/18 | 3/ 6 | |
| | | | | .1MM | 285 | 478 | 663 | 672 | 681 | 792 | 792 | 834 | 834 | 906 | 1017 | 1111 | 1111 | 1120 | 2153 |
| 1895 | 273 | 100 | | D/M | 4/14 | 4/ 8 | 4/14 | 4/14 | 4/13 | 4/12 | 4/12 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 5 | 4/ 2 | 3/25 | 3/25 | |
| | | | | .1MM | 342 | 615 | 775 | 1060 | 1252 | 1406 | 1470 | 1513 | 1736 | 2021 | 2179 | 2243 | 2283 | 2343 | 1813 |
| 1896 | 274 | 100 | | D/M | 4/16 | 4/15 | 4/14 | 4/13 | 4/12 | 4/11 | 4/10 | 4/ 9 | 4/ 8 | 4/ 8 | 4/ 3 | 3/31 | 3/27 | 3/27 | |
| | | | | .1MM | 481 | 814 | 1199 | 1401 | 1572 | 1692 | 1743 | 1803 | 1823 | 1823 | 1823 | 1823 | 1823 | 1832 | 1921 |
| 1897 | 273 | 100 | | D/M | 3/10 | 4/ 4 | 4/ 4 | 4/ 2 | 4/ 1 | 3/31 | 3/30 | 3/29 | 3/29 | 3/27 | 3/22 | 3/19 | 3/19 | 3/ 9 | |
| | | | | .1MM | 264 | 471 | 471 | 653 | 764 | 875 | 997 | 1048 | 1048 | 1077 | 1077 | 1077 | 1108 | 1199 | 1163 |
| 1898 | 273 | 100 | | D/M | 12/11 | 3/12 | 3/11 | 3/10 | 3/ 9 | 3/ 9 | 3/11 | 3/10 | 3/11 | 3/11 | 3/ 9 | 3/ 9 | 3/ 9 | 3/ 9 | |
| | | | | .1MM | 369 | 619 | 864 | 986 | 1068 | 1068 | 1199 | 1321 | 1429 | 1596 | 1718 | 1800 | 1800 | 1800 | 1867 |
| 1899 | 242 | 88 | ** | D/M | 4/18 | 4/18 | 4/18 | 4/17 | 4/16 | 4/15 | 4/14 | 4/13 | 4/12 | 4/11 | 4/ 7 | 4/ 7 | 3/29 | 3/23 | |
| | | | | .1MM | 305 | 599 | 801 | 963 | 1034 | 1205 | 1400 | 1562 | 1718 | 1728 | 1728 | 1767 | 1969 | 2028 | |
| 1900 | 273 | 100 | | D/M | 2/13 | 4/ 6 | 4/ 5 | 4/12 | 4/11 | 4/11 | 4/ 2 | 4/ 6 | 4/ 5 | 4/ 6 | 4/ 1 | 3/29 | 3/29 | 3/20 | |
| | | | | .1MM | 334 | 425 | 556 | 673 | 844 | 879 | 921 | 1073 | 1204 | 1371 | 1502 | 1537 | 1674 | 1765 | 1703 |
| 1901 | 273 | 100 | | D/M | 11/21 | 4/13 | 4/12 | 4/11 | 4/10 | 4/ 9 | 4/ 8 | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 1 | 3/26 | 3/21 | 3/21 | |
| | | | | .1MM | 364 | 639 | 851 | 1044 | 1257 | 1450 | 1660 | 1760 | 1887 | 2046 | 2345 | 2520 | 2600 | 2640 | 2379 |
| 1902 | 273 | 100 | | D/M | 12/14 | 12/14 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/20 | 3/20 | 3/12 | 3/11 | 3/ 1 | 2/28 | |
| | | | | .1MM | 330 | 622 | 699 | 790 | 910 | 1072 | 1249 | 1366 | 1376 | 1376 | 1393 | 1510 | 1615 | 1615 | 1983 |
| 1903 | 273 | 100 | | D/M | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/18 | 3/17 | 3/17 | 3/17 | 3/11 | 3/ 7 | 2/28 | 2/28 | |
| | | | | .1MM | 330 | 653 | 891 | 1013 | 1265 | 1429 | 1521 | 1637 | 1728 | 1822 | 1822 | 1822 | 1862 | 1976 | 2178 |
| 1904 | 274 | 100 | | D/M | 4/10 | 4/10 | 4/ 9 | 4/ 8 | 4/ 8 | 4/ 7 | 4/ 7 | 4/ 6 | 4/ 6 | 4/ 2 | 3/31 | 4/ 6 | 4/ 1 | 3/27 | |
| | | | | .1MM | 436 | 776 | 938 | 1121 | 1263 | 1385 | 1484 | 1566 | 1566 | 1654 | 1796 | 1895 | 1946 | 2027 | 2725 |
| 1905 | 273 | 100 | | D/M | 3/29 | 3/29 | 3/28 | 3/28 | 3/27 | 3/25 | 3/25 | 3/29 | 3/29 | 3/28 | 3/27 | 3/24 | 3/18 | 3/18 | |
| | | | | .1MM | 263 | 486 | 628 | 739 | 838 | 902 | 1013 | 1161 | 1315 | 1457 | 1556 | 1618 | 1739 | 1858 | 2039 |
| 1906 | 273 | 100 | | D/M | 3/27 | 3/27 | 3/27 | 3/27 | 2/21 | 2/21 | 2/21 | 2/21 | 2/21 | 2/21 | 2/21 | 2/21 | 12/30 | 12/27 | |
| | | | | .1MM | 356 | 405 | 405 | 405 | 422 | 422 | 422 | 422 | 422 | 422 | 422 | 422 | 422 | 422 | 448 |
| 1907 | 273 | 100 | | D/M | 3/28 | 3/28 | 3/28 | 3/27 | 3/26 | 3/24 | 3/23 | 3/23 | 3/22 | 3/22 | 3/22 | 3/23 | 3/22 | 3/13 | |
| | | | | .1MM | 249 | 447 | 615 | 711 | 811 | 875 | 1057 | 1225 | 1327 | 1347 | 1347 | 1347 | 1398 | 1433 | 1239 |
| 1908 | 274 | 100 | | D/M | 4/26 | 4/25 | 4/24 | 4/23 | 4/23 | 4/22 | 4/21 | 4/20 | 4/19 | 4/18 | 4/14 | 4/ 8 | 4/ 3 | 3/29 | |
| | | | | .1MM | 359 | 684 | 978 | 1241 | 1456 | 1485 | 1516 | 1719 | 1870 | 1921 | 1957 | 2172 | 2232 | 2292 | 2590 |
| 1909 | 273 | 100 | | D/M | 4/14 | 4/13 | 4/13 | 4/13 | 4/12 | 4/12 | 4/12 | 4/ 7 | 4/ 6 | 4/ 6 | 4/ 3 | 3/30 | 3/25 | 4/ 3 | |
| | | | | .1MM | 490 | 917 | 1048 | 1250 | 1381 | 1409 | 1409 | 1430 | 1728 | 1859 | 2061 | 2143 | 2234 | 2283 | 2069 |
| 1910 | 273 | 100 | | D/M | 1/22 | 1/21 | 3/22 | 3/21 | 3/20 | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/13 | 3/ 5 | 2/28 | 2/27 | |
| | | | | .1MM | 289 | 391 | 541 | 562 | 765 | 785 | 785 | 785 | 785 | 785 | 785 | 820 | 820 | 820 | 1070 |
| 1911 | 273 | 100 | | D/M | 4/14 | 4/13 | 4/13 | 4/12 | 4/12 | 4/13 | 4/14 | 4/13 | 4/13 | 4/12 | 4/ 7 | 4/ 5 | 3/27 | 3/27 | |
| | | | | .1MM | 460 | 672 | 877 | 959 | 990 | 1061 | 1307 | 1519 | 1654 | 1736 | 1736 | 1836 | 1927 | 1927 | 1952 |
| 1912 | 274 | 100 | | D/M | 4/16 | 4/16 | 4/ 6 | 4/ 6 | 4/13 | 4/12 | 4/11 | 4/ 6 | 4/ 8 | 4/ 7 | 4/ 6 | 3/29 | 3/29 | 3/19 | |
| | | | | .1MM | 497 | 704 | 842 | 842 | 968 | 1099 | 1120 | 1125 | 1309 | 1572 | 1779 | 1962 | 1962 | 1962 | 1809 |
| 1913 | 273 | 100 | | D/M | 3/24 | 3/24 | 3/19 | 3/21 | 3/21 | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/19 | 3/13 | 3/13 | |
| | | | | .1MM | 383 | 569 | 730 | 749 | 935 | 1113 | 1299 | 1342 | 1342 | 1342 | 1532 | 1718 | 1780 | 1809 | 1787 |



Table B1 Snowmelt+ rainfall – Model 5 - Input Data

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1914 | 273 | 100 | D/M | 4/17 | 4/16 | 4/16 | 4/15 | 4/14 | 4/14 | 4/12 | 4/11 | 4/10 | 4/10 | 4/ 5 | 3/30 | 3/26 | 3/26 | |
| | | | .1MM | 285 | 491 | 696 | 798 | 857 | 857 | 898 | 989 | 999 | 999 | 1080 | 1080 | 1080 | 1093 | 1633 |
| 1915 | 273 | 100 | D/M | 11/16 | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 2 | 4/ 1 | 4/ 1 | 4/ 1 | 4/ 1 | 3/24 | 3/21 | 3/21 | 3/21 | |
| | | | .1MM | 402 | 479 | 619 | 710 | 801 | 872 | 974 | 999 | 999 | 999 | 999 | 999 | 1030 | 1100 | 1244 |
| 1916 | 274 | 100 | D/M | 4/17 | 4/13 | 4/12 | 4/11 | 4/13 | 4/12 | 4/12 | 4/10 | 4/10 | 4/11 | 4/11 | 3/29 | 3/27 | 3/28 | |
| | | | .1MM | 294 | 528 | 715 | 815 | 989 | 1176 | 1305 | 1407 | 1536 | 1627 | 1758 | 1827 | 1859 | 2046 | 3118 |
| 1917 | 273 | 100 | D/M | 4/19 | 4/18 | 4/17 | 4/17 | 4/16 | 4/15 | 4/14 | 4/13 | 4/12 | 4/11 | 3/24 | 4/ 1 | 3/27 | 3/23 | |
| | | | .1MM | 395 | 777 | 990 | 1188 | 1279 | 1390 | 1470 | 1490 | 1499 | 1508 | 1508 | 1530 | 1614 | 1654 | 2570 |
| 1918 | 273 | 100 | D/M | 4/ 2 | 4/ 1 | 4/ 6 | 3/30 | 3/29 | 3/29 | 4/ 2 | 4/ 1 | 3/31 | 3/30 | 3/30 | 3/29 | 3/21 | 3/17 | |
| | | | .1MM | 336 | 579 | 818 | 943 | 1014 | 1014 | 1214 | 1457 | 1659 | 1821 | 1892 | 1900 | 2045 | 2247 | 2664 |
| 1919 | 273 | 100 | D/M | 4/11 | 4/10 | 4/ 9 | 4/ 8 | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 5 | 4/ 3 | 4/ 3 | 4/ 3 | 3/23 | 3/18 | 3/16 | |
| | | | .1MM | 271 | 479 | 641 | 761 | 980 | 1081 | 1201 | 1201 | 1263 | 1263 | 1263 | 1263 | 1263 | 1263 | 1641 |
| 1920 | 274 | 100 | D/M | 3/27 | 3/26 | 3/25 | 3/24 | 3/23 | 3/23 | 3/23 | 3/21 | 3/21 | 3/18 | 3/13 | 3/12 | 3/ 6 | 3/ 6 | |
| | | | .1MM | 344 | 660 | 985 | 1259 | 1390 | 1442 | 1442 | 1452 | 1452 | 1496 | 1562 | 1614 | 1614 | 1614 | 1518 |
| 1921 | 273 | 100 | D/M | 3/21 | 3/20 | 3/19 | 3/19 | 3/20 | 3/16 | 3/15 | 3/15 | 3/16 | 3/12 | 3/ 8 | 3/ 2 | 2/28 | 2/23 | |
| | | | .1MM | 303 | 584 | 604 | 604 | 650 | 787 | 802 | 802 | 853 | 984 | 1055 | 1055 | 1319 | 1370 | 868 |
| 1922 | 273 | 100 | D/M | 11/19 | 4/ 6 | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 2 | 4/ 2 | 4/ 2 | 4/ 2 | 3/26 | 3/20 | 3/14 | 3/14 | |
| | | | .1MM | 341 | 549 | 743 | 905 | 984 | 1055 | 1117 | 1117 | 1117 | 1117 | 1125 | 1249 | 1309 | 1380 | 1191 |
| 1923 | 273 | 100 | D/M | 4/21 | 4/21 | 4/20 | 4/19 | 4/19 | 4/17 | 4/16 | 4/16 | 4/16 | 4/16 | 4/ 8 | 4/ 3 | 4/ 3 | 4/ 3 | |
| | | | .1MM | 619 | 1152 | 1568 | 1628 | 1628 | 1699 | 1759 | 1759 | 1759 | 1759 | 1759 | 1863 | 1863 | 1863 | 2248 |
| 1924 | 274 | 100 | D/M | 4/ 8 | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 5 | 4/ 5 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 3 | 3/28 | 3/22 | 3/22 | |
| | | | .1MM | 335 | 557 | 730 | 995 | 1086 | 1165 | 1352 | 1443 | 1474 | 1545 | 1698 | 1789 | 1809 | 1809 | 1935 |
| 1925 | 273 | 100 | D/M | 3/27 | 3/26 | 3/25 | 3/25 | 3/24 | 3/24 | 3/22 | 3/21 | 3/19 | 3/19 | 3/18 | 3/11 | 3/ 8 | 3/ 8 | |
| | | | .1MM | 331 | 585 | 798 | 964 | 1055 | 1055 | 1115 | 1190 | 1271 | 1437 | 1517 | 1517 | 1517 | 1517 | 1069 |
| 1926 | 273 | 100 | D/M | 4/22 | 4/22 | 4/22 | 4/22 | 4/21 | 4/21 | 4/22 | 4/21 | 4/21 | 4/22 | 4/21 | 4/13 | 4/ 8 | 4/ 8 | |
| | | | .1MM | 345 | 650 | 884 | 1180 | 1393 | 1413 | 1641 | 1854 | 2019 | 2304 | 2517 | 2569 | 2569 | 2569 | 2424 |
| 1927 | 273 | 100 | D/M | 11/16 | 4/ 5 | 4/ 4 | 4/ 4 | 4/ 3 | 3/13 | 3/12 | 3/12 | 3/30 | 3/29 | 3/27 | 3/12 | 3/13 | 3/12 | |
| | | | .1MM | 307 | 453 | 626 | 777 | 828 | 875 | 1006 | 1077 | 1107 | 1158 | 1258 | 1329 | 1329 | 1349 | 2186 |
| 1928 | 274 | 100 | D/M | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 5 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 4 | 3/25 | 3/22 | 3/15 | 3/13 | |
| | | | .1MM | 325 | 579 | 785 | 975 | 1077 | 1077 | 1077 | 1077 | 1077 | 1077 | 1077 | 1194 | 1309 | 1460 | 1363 |
| 1929 | 273 | 100 | D/M | 1/ 6 | 3/15 | 3/13 | 3/13 | 3/13 | 3/25 | 3/25 | 3/13 | 3/13 | 3/13 | 3/14 | 3/13 | 3/ 4 | 3/ 4 | |
| | | | .1MM | 274 | 340 | 442 | 546 | 546 | 621 | 621 | 670 | 739 | 820 | 857 | 928 | 967 | 1107 | 945 |
| 1930 | 273 | 100 | D/M | 1/ 8 | 1/ 7 | 1/ 7 | 1/ 7 | 2/20 | 2/19 | 1/ 2 | 1/ 2 | 1/ 2 | 1/ 2 | 1/ 2 | 2/19 | 2/19 | 2/13 | |
| | | | .1MM | 262 | 467 | 467 | 467 | 506 | 597 | 635 | 635 | 635 | 635 | 635 | 635 | 668 | 668 | 1055 |
| 1931 | 273 | 100 | D/M | 3/29 | 3/28 | 3/28 | 3/26 | 3/26 | 3/24 | 3/24 | 3/24 | 3/26 | 3/25 | 3/20 | 3/16 | 3/10 | 3/ 5 | |
| | | | .1MM | 248 | 390 | 501 | 634 | 745 | 857 | 968 | 1070 | 1175 | 1267 | 1398 | 1489 | 1518 | 1518 | 1486 |
| 1932 | 274 | 100 | D/M | 2/12 | 4/12 | 4/11 | 4/10 | 4/ 9 | 4/ 8 | 4/ 7 | 4/ 6 | 4/ 6 | 4/ 7 | 4/ 1 | 3/27 | 3/27 | 3/27 | |
| | | | .1MM | 317 | 399 | 581 | 743 | 946 | 997 | 1068 | 1076 | 1076 | 1077 | 1086 | 1131 | 1279 | 1279 | 853 |
| 1933 | 273 | 100 | D/M | 12/25 | 4/ 2 | 4/ 1 | 4/ 1 | 4/ 2 | 4/ 1 | 3/31 | 3/31 | 3/31 | 3/31 | 3/27 | 3/20 | 3/20 | 3/20 | |
| | | | .1MM | 214 | 320 | 482 | 573 | 708 | 870 | 941 | 941 | 941 | 941 | 983 | 983 | 983 | 983 | 688 |
| 1934 | 273 | 100 | D/M | 12/31 | 4/10 | 4/ 9 | 4/16 | 4/15 | 4/15 | 4/14 | 4/11 | 4/11 | 4/10 | 4/ 6 | 4/ 1 | 4/ 1 | 3/26 | |
| | | | .1MM | 732 | 792 | 894 | 1087 | 1310 | 1461 | 1585 | 1742 | 2087 | 2351 | 2502 | 2604 | 2666 | 2726 | 2207 |
| 1935 | 273 | 100 | D/M | 4/10 | 4/ 9 | 4/ 9 | 4/ 9 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 8 | 4/ 5 | 3/31 | 3/28 | 3/23 | 3/16 | |
| | | | .1MM | 283 | 537 | 790 | 972 | 1103 | 1214 | 1238 | 1238 | 1238 | 1258 | 1258 | 1324 | 1348 | 1348 | 1410 |
| 1936 | 274 | 100 | D/M | 3/12 | 3/28 | 3/28 | 3/25 | 3/26 | 3/25 | 3/25 | 3/25 | 3/22 | 3/22 | 3/17 | 3/12 | 3/11 | 3/12 | |
| | | | .1MM | 308 | 419 | 653 | 811 | 1008 | 1196 | 1335 | 1335 | 1475 | 1614 | 1689 | 1828 | 1998 | 2137 | 1484 |
| 1937 | 273 | 100 | D/M | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 5 | 12/27 | 12/26 | |
| | | | .1MM | 316 | 529 | 680 | 791 | 840 | 891 | 891 | 891 | 891 | 891 | 891 | 891 | 891 | 891 | 678 |
| 1938 | 273 | 100 | D/M | 3/23 | 3/23 | 3/21 | 3/23 | 3/20 | 3/21 | 3/20 | 3/19 | 3/23 | 3/17 | 3/17 | 3/13 | 3/13 | 3/ 5 | |
| | | | .1MM | 304 | 417 | 566 | 714 | 826 | 976 | 1123 | 1197 | 1245 | 1360 | 1507 | 1654 | 1728 | 1759 | 1397 |
| 1939 | 273 | 100 | D/M | 4/26 | 4/26 | 4/25 | 4/25 | 4/23 | 4/22 | 4/22 | 4/20 | 4/19 | 4/19 | 4/14 | 4/11 | 4/11 | 3/31 | |
| | | | .1MM | 345 | 587 | 789 | 925 | 1137 | 1319 | 1455 | 1584 | 1792 | 1928 | 1999 | 2050 | 2050 | 2090 | 1853 |
| 1940 | 274 | 100 | D/M | 4/19 | 4/18 | 4/18 | 4/17 | 4/18 | 4/18 | 4/18 | 4/18 | 4/17 | 4/16 | 4/12 | 4/ 9 | 4/ 1 | 3/31 | |
| | | | .1MM | 282 | 522 | 724 | 855 | 992 | 1125 | 1307 | 1460 | 1591 | 1677 | 1677 | 1677 | 1677 | 1808 | 1745 |
| 1941 | 273 | 100 | D/M | 12/29 | 4/10 | 4/ 9 | 4/ 8 | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 3 | 4/ 3 | 4/ 3 | 4/ 3 | 3/16 | |
| | | | .1MM | 416 | 628 | 893 | 1086 | 1228 | 1462 | 1564 | 1646 | 1717 | 1717 | 1717 | 1717 | 1717 | 1717 | 1764 |
| 1942 | 273 | 100 | D/M | 12/24 | 12/23 | 12/23 | 12/23 | 3/27 | 3/26 | 3/26 | 3/25 | 3/25 | 3/22 | 3/16 | 3/16 | 3/ 8 | 3/ 4 | |
| | | | .1MM | 325 | 490 | 490 | 490 | 500 | 611 | 685 | 745 | 745 | 751 | 858 | 932 | 932 | 998 | 1029 |
| 1943 | 272 | 99 | D/M | 4/25 | 4/24 | 4/23 | 4/23 | 4/22 | 4/22 | 4/22 | 4/21 | 4/20 | 4/19 | 4/17 | 4/ 9 | 4/ 9 | 3/31 | |
| | | | .1MM | 451 | 855 | 1189 | 1434 | 1677 | 1876 | 2107 | 2249 | 2324 | 2425 | 2505 | 2514 | 2514 | 2514 | 2427 |
| 1944 | 274 | 100 | D/M | 3/26 | 4/10 | 4/18 | 4/17 | 4/17 | 4/17 | 4/17 | 4/13 | 4/10 | 4/10 | 4/10 | 4/ 2 | 3/26 | 3/25 | |
| | | | .1MM | 223 | 415 | 471 | 540 | 540 | 540 | 540 | 580 | 757 | 888 | 1026 | 1026 | 1026 | 1026 | 909 |
| 1945 | 273 | 100 | D/M | 3/18 | 3/24 | 3/23 | 3/18 | 3/17 | 3/20 | 3/18 | 3/18 | 3/17 | 3/16 | 3/14 | 3/14 | 3/ 2 | 2/26 | |
| | | | .1MM | 265 | 508 | 710 | 859 | 1019 | 1141 | 1359 | 1613 | 1773 | 1878 | 2060 | 2131 | 2145 | 2145 | 1998 |
| 1946 | 273 | 100 | D/M | 3/13 | 3/13 | 3/13 | 3/13 | 3/13 | 3/13 | 3/ 8 | 3/ 7 | 3/ 6 | 3/ 6 | 3/ 2 | 3/ 2 | 3/ 2 | 2/13 | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | .1MM | 296 | 590 | 624 | 624 | 624 | 624 | 762 | 884 | 1002 | 1036 | 1036 | 1051 | 1102 | 1136 | 838 |
| 1947 | 273 | 100 | D/M | 4/11 | 4/23 | 4/10 | 4/11 | 4/10 | 4/10 | 4/ 9 | 4/ 5 | 4/ 6 | 4/ 5 | 4/10 | 4/ 5 | 4/ 5 | 4/ 2 | |
| | | | .1MM | 420 | 766 | 853 | 934 | 1064 | 1166 | 1246 | 1347 | 1447 | 1558 | 1660 | 1673 | 1726 | 2105 | 2334 |
| 1948 | 274 | 100 | D/M | 3/16 | 3/16 | 3/21 | 3/20 | 3/21 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | |
| | | | .1MM | 325 | 510 | 544 | 646 | 777 | 1031 | 1142 | 1283 | 1374 | 1516 | 1516 | 1758 | 1905 | 1905 | 1249 |
| 1949 | 273 | 100 | D/M | 3/27 | 4/ 3 | 4/ 3 | 4/ 2 | 4/ 1 | 3/31 | 3/22 | 3/22 | 3/27 | 3/27 | 3/22 | 3/22 | 3/22 | 3/22 | |
| | | | .1MM | 200 | 354 | 516 | 656 | 685 | 734 | 806 | 899 | 1049 | 1211 | 1353 | 1406 | 1406 | 1559 | 1443 |
| 1950 | 273 | 100 | D/M | 4/ 3 | 12/20 | 12/19 | 12/18 | 12/18 | 12/18 | 12/18 | 3/28 | 12/18 | 3/27 | 3/23 | 3/28 | 3/23 | 3/23 | |
| | | | .1MM | 322 | 581 | 666 | 821 | 821 | 821 | 821 | 840 | 943 | 1005 | 1041 | 1091 | 1173 | 1215 | 1327 |
| 1951 | 260 | 95 | D/M | 1/ 3 | 3/29 | 3/29 | 3/29 | 3/29 | 3/29 | 3/29 | 3/28 | 3/27 | 3/26 | 3/21 | 3/16 | 3/11 | 3/ 6 | |
| | | | .1MM | 334 | 544 | 664 | 795 | 891 | 1001 | 1151 | 1222 | 1222 | 1222 | 1222 | 1230 | 1245 | 1245 | 1200 |
| 1952 | 274 | 100 | D/M | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 2 | 4/ 5 | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 3 | 4/ 2 | 3/28 | 3/23 | 3/20 | 3/12 | |
| | | | .1MM | 328 | 488 | 640 | 761 | 951 | 1153 | 1313 | 1465 | 1595 | 1716 | 1821 | 1830 | 1830 | 1830 | 1686 |
| 1953 | 273 | 100 | D/M | 12/10 | 12/10 | 12/10 | 12/10 | 12/ 6 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | 12/ 5 | |
| | | | .1MM | 381 | 381 | 381 | 381 | 401 | 599 | 599 | 599 | 599 | 599 | 599 | 599 | 599 | 599 | 277 |
| 1954 | 271 | 99 | D/M | 4/11 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 7 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | 4/ 6 | |
| | | | .1MM | 354 | 651 | 813 | 813 | 1111 | 1438 | 1487 | 1487 | 1487 | 1487 | 1487 | 1487 | 1487 | 1487 | 1167 |
| 1955 | 273 | 100 | D/M | 4/10 | 4/10 | 4/10 | 4/ 9 | 4/ 9 | 4/ 9 | 4/ 6 | 4/ 5 | 4/ 4 | 4/ 3 | 3/30 | 3/30 | 3/21 | 3/15 | |
| | | | .1MM | 334 | 599 | 781 | 923 | 984 | 984 | 1144 | 1326 | 1457 | 1528 | 1648 | 1759 | 1881 | 1942 | 1957 |
| 1956 | 274 | 100 | D/M | 4/ 5 | 4/ 5 | 4/ 5 | 4/ 4 | 4/ 5 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 4 | 4/ 1 | 4/ 1 | 4/ 1 | 4/ 1 | 4/ 1 | |
| | | | .1MM | 290 | 524 | 716 | 807 | 978 | 1069 | 1133 | 1133 | 1133 | 1182 | 1182 | 1182 | 1182 | 1182 | 1148 |
| 1957 | 273 | 100 | D/M | 1/22 | 1/21 | 1/21 | 1/21 | 3/12 | 3/11 | 3/11 | 3/ 9 | 3/13 | 3/13 | 3/ 9 | 2/25 | 2/25 | 2/24 | |
| | | | .1MM | 402 | 515 | 515 | 515 | 519 | 537 | 537 | 577 | 626 | 678 | 698 | 716 | 716 | 756 | 730 |
| 1958 | 273 | 100 | D/M | 12/ 7 | 3/30 | 3/30 | 3/30 | 3/28 | 3/27 | 3/27 | 3/26 | 3/24 | 3/23 | 3/19 | 3/16 | 3/16 | 3/ 4 | |
| | | | .1MM | 218 | 313 | 455 | 550 | 648 | 768 | 863 | 934 | 1003 | 1136 | 1238 | 1333 | 1393 | 1393 | 1438 |
| 1959 | 273 | 100 | D/M | 4/15 | 4/14 | 4/14 | 4/ 8 | 4/ 8 | 4/10 | 4/ 9 | 4/ 8 | 4/ 8 | 4/ 6 | 4/ 1 | 3/30 | 3/30 | 3/20 | |
| | | | .1MM | 243 | 425 | 524 | 673 | 715 | 860 | 982 | 1220 | 1319 | 1392 | 1504 | 1603 | 1686 | 1837 | 2129 |
| 1960 | 274 | 100 | D/M | 4/17 | 4/17 | 4/16 | 4/15 | 4/14 | 4/13 | 4/12 | 4/12 | 4/10 | 4/ 9 | 4/ 4 | 3/30 | 3/28 | 3/28 | |
| | | | .1MM | 380 | 744 | 1098 | 1401 | 1617 | 1791 | 1884 | 1884 | 1917 | 1940 | 1940 | 1940 | 2034 | 2156 | 2233 |
| 1961 | 273 | 100 | D/M | 2/25 | 2/24 | 2/23 | 2/22 | 2/23 | 2/22 | 2/19 | 2/18 | 2/23 | 2/23 | 2/18 | 2/13 | 2/13 | 2/23 | |
| | | | .1MM | 241 | 284 | 408 | 417 | 418 | 427 | 437 | 528 | 580 | 618 | 627 | 627 | 627 | 700 | 747 |
| 1962 | 273 | 100 | D/M | 3/29 | 3/29 | 3/28 | 3/27 | 3/26 | 3/25 | 3/24 | 3/24 | 3/22 | 3/21 | 3/16 | 3/12 | 3/12 | 3/12 | |
| | | | .1MM | 274 | 516 | 663 | 754 | 925 | 1065 | 1116 | 1116 | 1258 | 1325 | 1325 | 1325 | 1325 | 1374 | 1407 |
| 1963 | 273 | 100 | D/M | 3/30 | 3/26 | 3/25 | 3/27 | 3/26 | 3/25 | 3/25 | 3/25 | 3/25 | 3/21 | 3/17 | 3/17 | 3/17 | 3/ 5 | |
| | | | .1MM | 285 | 309 | 423 | 459 | 607 | 721 | 741 | 741 | 741 | 781 | 801 | 801 | 801 | 804 | 1478 |
| 1964 | 274 | 100 | D/M | 3/ 6 | 3/ 5 | 3/ 4 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 2/ 5 | |
| | | | .1MM | 269 | 382 | 524 | 655 | 655 | 655 | 655 | 655 | 655 | 655 | 655 | 655 | 655 | 655 | 635 |
| 1965 | 273 | 100 | D/M | 4/ 7 | 4/ 6 | 4/ 5 | 4/ 5 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | 2/25 | 2/25 | 2/11 | 2/ 7 | |
| | | | .1MM | 233 | 375 | 486 | 486 | 546 | 546 | 546 | 546 | 546 | 546 | 610 | 610 | 610 | 610 | 734 |
| 1966 | 273 | 100 | D/M | 12/24 | 2/28 | 2/28 | 2/28 | 2/28 | 2/28 | 2/28 | 12/24 | 12/23 | 12/23 | 12/23 | 2/11 | 2/ 9 | 12/ 2 | |
| | | | .1MM | 208 | 313 | 404 | 404 | 404 | 404 | 404 | 460 | 506 | 506 | 506 | 506 | 506 | 506 | 676 |
| 1967 | 273 | 100 | D/M | 4/ 1 | 4/ 1 | 3/31 | 3/31 | 3/29 | 3/28 | 3/27 | 3/27 | 3/25 | 3/25 | 3/25 | 3/25 | 3/10 | 3/10 | |
| | | | .1MM | 376 | 693 | 804 | 804 | 886 | 1109 | 1283 | 1283 | 1314 | 1314 | 1314 | 1314 | 1314 | 1314 | 1630 |
| 1968 | 274 | 100 | D/M | 3/17 | 3/20 | 3/20 | 3/17 | 3/17 | 3/17 | 3/16 | 3/16 | 3/16 | 3/16 | 3/10 | 3/10 | 3/10 | 3/10 | |
| | | | .1MM | 219 | 375 | 538 | 650 | 818 | 981 | 994 | 994 | 994 | 994 | 994 | 1014 | 1166 | 1166 | 1027 |
| 1969 | 273 | 100 | D/M | 1/24 | 3/24 | 3/24 | 3/22 | 3/21 | 3/20 | 3/19 | 3/19 | 3/19 | 3/19 | 3/15 | 3/15 | 3/15 | 1/23 | |
| | | | .1MM | 232 | 332 | 332 | 412 | 514 | 562 | 572 | 572 | 572 | 572 | 603 | 603 | 603 | 603 | 929 |
| 1970 | 273 | 100 | D/M | 12/10 | 4/ 8 | 4/ 8 | 4/ 7 | 4/ 9 | 4/ 8 | 4/ 7 | 4/ 7 | 4/ 7 | 4/ 7 | 4/ 2 | 3/25 | 3/21 | 3/21 | |
| | | | .1MM | 284 | 425 | 456 | 466 | 641 | 812 | 822 | 822 | 822 | 822 | 822 | 837 | 837 | 837 | 1807 |
| 1971 | 273 | 100 | D/M | 4/13 | 4/12 | 4/11 | 4/10 | 4/12 | 4/12 | 4/11 | 4/10 | 4/10 | 4/10 | 4/ 3 | 3/30 | 3/30 | 3/30 | |
| | | | .1MM | 230 | 428 | 488 | 508 | 609 | 709 | 769 | 789 | 789 | 789 | 789 | 789 | 789 | 789 | 3370 |
| 1972 | 274 | 100 | D/M | 12/10 | 12/ 9 | 12/ 9 | 12/ 9 | 4/14 | 4/14 | 4/14 | 4/13 | 4/12 | 4/11 | 4/11 | 4/ 3 | 3/30 | 3/22 | |
| | | | .1MM | 257 | 397 | 517 | 628 | 725 | 879 | 1087 | 1168 | 1248 | 1288 | 1288 | 1288 | 1288 | 1288 | 2109 |
| 1973 | 273 | 100 | D/M | 3/17 | 3/16 | 3/15 | 3/15 | 3/13 | 3/12 | 3/11 | 3/10 | 3/10 | 3/ 8 | 3/ 3 | 3/ 3 | 3/ 3 | 3/ 3 | |
| | | | .1MM | 322 | 504 | 676 | 713 | 784 | 982 | 1159 | 1197 | 1234 | 1476 | 1638 | 1675 | 1701 | 1801 | 1298 |
| 1974 | 273 | 100 | D/M | 3/ 4 | 3/ 4 | 3/ 4 | 3/ 4 | 3/ 4 | 3/ 4 | 3/30 | 2/28 | 2/28 | 2/28 | 2/22 | 2/22 | 2/22 | 3/ 4 | |
| | | | .1MM | 446 | 568 | 719 | 1004 | 1004 | 1004 | 1025 | 1056 | 1056 | 1056 | 1056 | 1056 | 1056 | 1152 | 1040 |
| 1975 | 273 | 100 | D/M | 4/18 | 4/17 | 4/16 | 4/15 | 4/14 | 4/14 | 4/14 | 4/14 | 4/14 | 4/14 | 4/14 | 3/30 | 3/25 | 3/20 | |
| | | | .1MM | 363 | 668 | 900 | 1002 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1239 |
| 1976 | 274 | 100 | D/M | 4/ 1 | 4/ 1 | 4/ 1 | 3/25 | 3/31 | 3/28 | 3/26 | 3/25 | 3/25 | 3/25 | 3/21 | 3/20 | 3/13 | 3/ 5 | |
| | | | .1MM | 434 | 617 | 722 | 883 | 955 | 1115 | 1317 | 1530 | 1713 | 1818 | 1960 | 1960 | 2056 | 2198 | 1821 |
| 1977 | 273 | 100 | D/M | 3/13 | 3/13 | 3/12 | 3/10 | 3/10 | 3/10 | 3/ 9 | 3/ 9 | 3/ 9 | 3/ 7 | 3/ 4 | 2/24 | 2/24 | 2/24 | |
| | | | .1MM | 332 | 536 | 737 | 949 | 1153 | 1291 | 1402 | 1442 | 1442 | 1471 | 1511 | 1544 | 1572 | 1572 | 1299 |
| 1978 | 273 | 100 | D/M | 1/25 | 1/25 | 4/11 | 4/10 | 4/10 | 4/10 | 4/10 | 4/10 | 4/ 7 | 4/ 4 | 3/31 | 3/27 | 3/21 | 3/20 | |
| | | | .1MM | 332 | 384 | 536 | 724 | 842 | 924 | 924 | 924 | 959 | 998 | 1116 | 1198 | 1207 | 1325 | 1898 |



Table B1(cont'd) Snowmelt+ rainfall – Model 5 - Input Data

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | 273 | 100 | D/M | 3/23 | 3/22 | 3/21 | 3/21 | 3/20 | 3/20 | 3/20 | 3/20 | 3/20 | 3/20 | 3/10 | 3/ 5 | 3/ 3 | 2/23 | |
| | | | .1MM | 246 | 456 | 629 | 754 | 872 | 872 | 872 | 872 | 872 | 872 | 947 | 977 | 977 | 977 | 1500 |
| 1980 | 274 | 100 | D/M | 3/22 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/18 | 3/17 | 3/18 | 3/17 | 3/11 | 3/11 | 3/11 | |
| | | | .1MM | 509 | 685 | 813 | 950 | 1004 | 1004 | 1037 | 1040 | 1042 | 1073 | 1075 | 1075 | 1075 | 1075 | 537 |
| 1981 | 273 | 100 | D/M | 2/20 | 2/19 | 2/19 | 2/18 | 2/17 | 2/17 | 2/17 | 2/17 | 2/17 | 2/17 | 2/ 8 | 2/ 2 | 2/ 1 | 1/25 | |
| | | | .1MM | 236 | 460 | 656 | 811 | 957 | 957 | 957 | 957 | 957 | 957 | 1110 | 1176 | 1176 | 1203 | 1087 |
| 1982 | 273 | 100 | D/M | 3/31 | 3/31 | 3/30 | 3/31 | 3/30 | 3/30 | 3/30 | 3/25 | 3/25 | 3/25 | 3/19 | 3/13 | 3/11 | 3/12 | |
| | | | .1MM | 388 | 516 | 592 | 684 | 760 | 760 | 760 | 804 | 804 | 972 | 972 | 972 | 990 | 1013 | 1245 |
| 1983 | 273 | 100 | D/M | 1/10 | 2/ 2 | 2/ 2 | 1/31 | 1/31 | 1/31 | 1/31 | 1/31 | 1/31 | 12/15 | 12/15 | 12/23 | 1/10 | 12/15 | |
| | | | .1MM | 282 | 309 | 309 | 333 | 333 | 333 | 333 | 333 | 333 | 380 | 514 | 514 | 514 | 514 | 328 |
| 1984 | 274 | 100 | D/M | 2/14 | 2/13 | 2/13 | 2/13 | 3/31 | 3/30 | 2/13 | 2/13 | 2/13 | 2/14 | 2/11 | 2/11 | 2/ 3 | 2/ 3 | |
| | | | .1MM | 309 | 399 | 479 | 528 | 566 | 657 | 698 | 749 | 749 | 788 | 903 | 993 | 993 | 1002 | 936 |
| 1985 | 273 | 100 | D/M | 2/23 | 2/23 | 3/11 | 3/11 | 3/11 | 3/ 8 | 3/ 8 | 3/ 8 | 3/ 8 | 3/ 8 | 3/ 1 | 2/23 | 2/21 | 2/23 | |
| | | | .1MM | 276 | 334 | 429 | 482 | 482 | 528 | 581 | 581 | 581 | 581 | 581 | 581 | 634 | 679 | 1075 |
| 1986 | 273 | 100 | D/M | 3/19 | 1/19 | 1/18 | 1/18 | 3/15 | 3/15 | 3/13 | 3/13 | 3/13 | 3/10 | 3/ 9 | 3/ 2 | 3/ 2 | 2/18 | |
| | | | .1MM | 267 | 411 | 520 | 520 | 552 | 552 | 560 | 560 | 560 | 675 | 682 | 682 | 682 | 682 | 704 |
| 1987 | 273 | 100 | D/M | 3/ 8 | 3/ 7 | 3/20 | 3/19 | 3/18 | 3/17 | 3/17 | 3/17 | 3/17 | 3/17 | 3/ 8 | 3/ 7 | 2/28 | 2/28 | |
| | | | .1MM | 226 | 386 | 450 | 481 | 539 | 579 | 579 | 579 | 579 | 579 | 579 | 579 | 579 | 592 | 960 |
| 1988 | 274 | 100 | D/M | 3/26 | 3/25 | 3/25 | 3/25 | 3/25 | 3/25 | 3/25 | 3/25 | 3/25 | 3/25 | 3/14 | 3/ 8 | 3/ 8 | 3/ 8 | |
| | | | .1MM | 290 | 461 | 619 | 619 | 619 | 619 | 619 | 619 | 619 | 619 | 661 | 661 | 661 | 669 | 507 |
| 1989 | 273 | 100 | D/M | 3/28 | 3/27 | 3/26 | 3/25 | 3/24 | 3/24 | 3/24 | 3/24 | 3/24 | 3/24 | 3/14 | 3/14 | 3/ 4 | 3/ 4 | |
| | | | .1MM | 310 | 600 | 759 | 870 | 882 | 882 | 882 | 882 | 882 | 882 | 882 | 882 | 882 | 1121 | 838 |
| 1990 | 273 | 100 | D/M | 3/15 | 3/11 | 3/11 | 3/12 | 3/11 | 3/11 | 3/10 | 3/10 | 3/10 | 3/10 | 3/ 2 | 3/ 2 | 2/22 | 2/15 | |
| | | | .1MM | 192 | 354 | 502 | 617 | 781 | 842 | 854 | 854 | 854 | 854 | 854 | 854 | 854 | 864 | 906 |
| 1991 | 273 | 100 | D/M | 2/ 5 | 2/ 4 | 2/ 4 | 2/ 4 | 2/ 3 | 2/ 3 | 12/17 | 12/17 | 12/21 | 12/21 | 12/17 | 3/ 1 | 3/ 1 | 2/18 | |
| | | | .1MM | 204 | 368 | 446 | 528 | 540 | 540 | 553 | 553 | 633 | 662 | 662 | 722 | 774 | 803 | 855 |
| 1992 | 274 | 100 | D/M | 3/27 | 3/27 | 3/26 | 3/26 | 3/27 | 3/27 | 3/27 | 3/26 | 3/26 | 3/26 | 3/27 | 3/26 | 3/26 | 3/26 | |
| | | | .1MM | 472 | 638 | 646 | 646 | 709 | 835 | 889 | 897 | 897 | 897 | 958 | 1010 | 1178 | 1302 | 1300 |
| 1993 | 273 | 100 | D/M | 1/ 4 | 3/29 | 3/28 | 3/27 | 3/26 | 3/26 | 3/25 | 3/24 | 3/24 | 3/26 | 3/24 | 3/24 | 3/16 | 3/16 | |
| | | | .1MM | 361 | 559 | 756 | 966 | 1099 | 1197 | 1268 | 1319 | 1319 | 1338 | 1437 | 1570 | 1641 | 1699 | 1548 |
| 1994 | 273 | 100 | D/M | 2/20 | 3/22 | 3/22 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/21 | 3/31 | 3/22 | 3/21 | 3/21 | 3/15 | |
| | | | .1MM | 261 | 370 | 487 | 563 | 563 | 563 | 563 | 625 | 641 | 694 | 703 | 713 | 781 | 802 | 1448 |
| 1995 | 273 | 100 | D/M | 1/15 | 1/15 | 1/14 | 1/13 | 1/12 | 1/12 | 1/12 | 1/12 | 1/12 | 1/12 | 1/12 | 1/12 | 1/12 | 12/18 | |
| | | | .1MM | 583 | 689 | 739 | 829 | 889 | 889 | 889 | 927 | 981 | 981 | 981 | 981 | 981 | 981 | 335 |
| 1996 | 274 | 100 | D/M | 1/19 | 1/18 | 1/17 | 1/16 | 2/20 | 2/20 | 2/20 | 2/20 | 2/20 | 2/20 | 2/20 | 2/ 8 | 2/20 | 2/20 | |
| | | | .1MM | 381 | 580 | 582 | 618 | 758 | 800 | 800 | 822 | 822 | 822 | 822 | 822 | 822 | 822 | 1494 |
| 1997 | 273 | 100 | D/M | 2/21 | 4/ 5 | 4/ 4 | 4/ 3 | 4/ 2 | 4/ 1 | 4/ 1 | 3/29 | 3/29 | 3/28 | 3/25 | 3/25 | 3/14 | 3/14 | |
| | | | .1MM | 384 | 576 | 813 | 922 | 1059 | 1099 | 1099 | 1139 | 1376 | 1479 | 1680 | 1712 | 1746 | 1746 | 1450 |

**************************************************************************************************************************

| | 1 DAY | 2 DAY | 3 DAY | 4 DAY | 5 DAY | 6 DAY | 7 DAY | 8 DAY | 9 DAY | 10 DAY | 15 DAY | 20 DAY | 25 DAY | 30 DAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEAN EXTREME(MM) | 33.2 | 53.3 | 68.1 | 79.2 | 89.5 | 98.4 | 105.6 | 111.3 | 117.1 | 123.2 | 145.7 | 162.0 | 172.8 | 181.8 |
| STD. DEV.(MM) | 9.0 | 15.0 | 20.7 | 25.6 | 29.6 | 32.8 | 36.2 | 39.0 | 42.4 | 46.0 | 56.2 | 62.9 | 67.5 | 70.3 |
| YEARS ANALYSED | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 | 106.0 |

** NOTE ** MEAN AND STANDARD DEVIATION HAVE BEEN ADJUSTED TO ACCOUNT FOR ONE OBSERVATION PER DAY.

NOTE ** VALUE IN FLAG INDICATES YEAR NOT INCLUDED IN ANALYSIS BASED ON % DAYS OPERATIONAL ( <90.0% )

ATMOSPHERIC ENVIRONMENT SERVICE
RAIN+SNOWMELT INTENSITY, DURATION, FREQUENCY VALUES
PREPARED BY THE HYDROMETEOROLOGY DIVISION, CANADIAN CLIMATE CENTRE

STATION : Ottawa CDA, Ontario — STATION NUMBER 6105976

LATITUDE: 4523 LONGITUDE: 7543 ELEVATION(M): 79

SNOWMELT MODEL 5

CRITICAL PERIOD : 1ST OF MONTH 10 TO THE END OF MONTH 5 — NOTE : MODIFIED GUMBEL 12/82

RETURN PERIOD VALUES (MM) WITH 50% CONFIDENCE LIMITS

| RETURN PERIOD YEARS | 1 DAY | 2 DAY | 3 DAY | 4 DAY | 5 DAY |
|---|---|---|---|---|---|
| 2 | 31.71+/- .54 | 50.80+/- .90 | 64.73+/- 1.24 | 75.03+/- 1.54 | 84.63+/- 1.78 |
| 5 | 39.68+/- .91 | 64.06+/- 1.52 | 83.00+/- 2.09 | 97.66+/- 2.59 | 110.76+/- 2.99 |
| 10 | 44.97+/- 1.23 | 72.86+/- 2.05 | 95.12+/- 2.83 | 112.68+/- 3.50 | 128.10+/- 4.05 |
| 25 | 51.63+/- 1.66 | 83.96+/- 2.77 | 110.41+/- 3.81 | 131.62+/- 4.72 | 149.96+/- 5.45 |
| 50 | 56.58+/- 1.99 | 92.19+/- 3.31 | 121.74+/- 4.56 | 145.66+/- 5.65 | 166.18+/- 6.52 |
| 100 | 61.50+/- 2.32 | 100.38+/- 3.86 | 133.02+/- 5.31 | 159.63+/- 6.58 | 182.31+/- 7.60 |

| RETURN PERIOD YEARS | 6 DAY | 7 DAY | 8 DAY | 9 DAY | 10 DAY |
|---|---|---|---|---|---|
| 2 | 93.07+/- 1.97 | 99.69+/- 2.18 | 104.90+/- 2.34 | 110.16+/- 2.55 | 115.69+/- 2.76 |
| 5 | 121.99+/- 3.31 | 131.69+/- 3.67 | 139.32+/- 3.94 | 147.64+/- 4.29 | 156.28+/- 4.65 |
| 10 | 141.19+/- 4.48 | 152.92+/- 4.95 | 162.16+/- 5.33 | 172.52+/- 5.80 | 183.21+/- 6.28 |
| 25 | 165.40+/- 6.04 | 179.70+/- 6.68 | 190.96+/- 7.18 | 203.89+/- 7.82 | 217.18+/- 8.47 |
| 50 | 183.35+/- 7.22 | 199.55+/- 7.99 | 212.32+/- 8.59 | 227.15+/- 9.36 | 242.37+/-10.14 |
| 100 | 201.21+/- 8.42 | 219.30+/- 9.31 | 233.56+/-10.01 | 250.29+/-10.91 | 267.43+/-11.81 |

| RETURN PERIOD YEARS | 15 DAY | 20 DAY | 25 DAY | 30 DAY |
|---|---|---|---|---|
| 2 | 136.51+/- 3.37 | 151.72+/- 3.78 | 161.74+/- 4.05 | 170.24+/- 4.22 |
| 5 | 186.10+/- 5.68 | 207.22+/- 6.36 | 221.30+/- 6.82 | 232.30+/- 7.11 |
| 10 | 219.01+/- 7.68 | 244.05+/- 8.59 | 260.82+/- 9.22 | 273.49+/- 9.61 |
| 25 | 260.51+/-10.35 | 290.50+/-11.58 | 310.67+/-12.43 | 325.43+/-12.95 |
| 50 | 291.28+/-12.38 | 324.94+/-13.86 | 347.63+/-14.87 | 363.94+/-15.50 |
| 100 | 321.89+/-14.43 | 359.20+/-16.15 | 384.39+/-17.33 | 402.25+/-18.06 |

** WARNING ** : THE 1-DAY 100-YEAR RETURN PERIOD EVENT IS EXCEEDED BY THE 1-DAY EVENT IN 1923
** WARNING ** : THE 1-DAY 100-YEAR RETURN PERIOD EVENT IS EXCEEDED BY THE 1-DAY EVENT IN 1934
** WARNING ** : THE 2-DAY 100-YEAR RETURN PERIOD EVENT IS EXCEEDED BY THE 2-DAY EVENT IN 1923
** WARNING ** : THE 3-DAY 100-YEAR RETURN PERIOD EVENT IS EXCEEDED BY THE 3-DAY EVENT IN 1923
** WARNING ** : THE 4-DAY 100-YEAR RETURN PERIOD EVENT IS EXCEEDED BY THE 4-DAY EVENT IN 1923

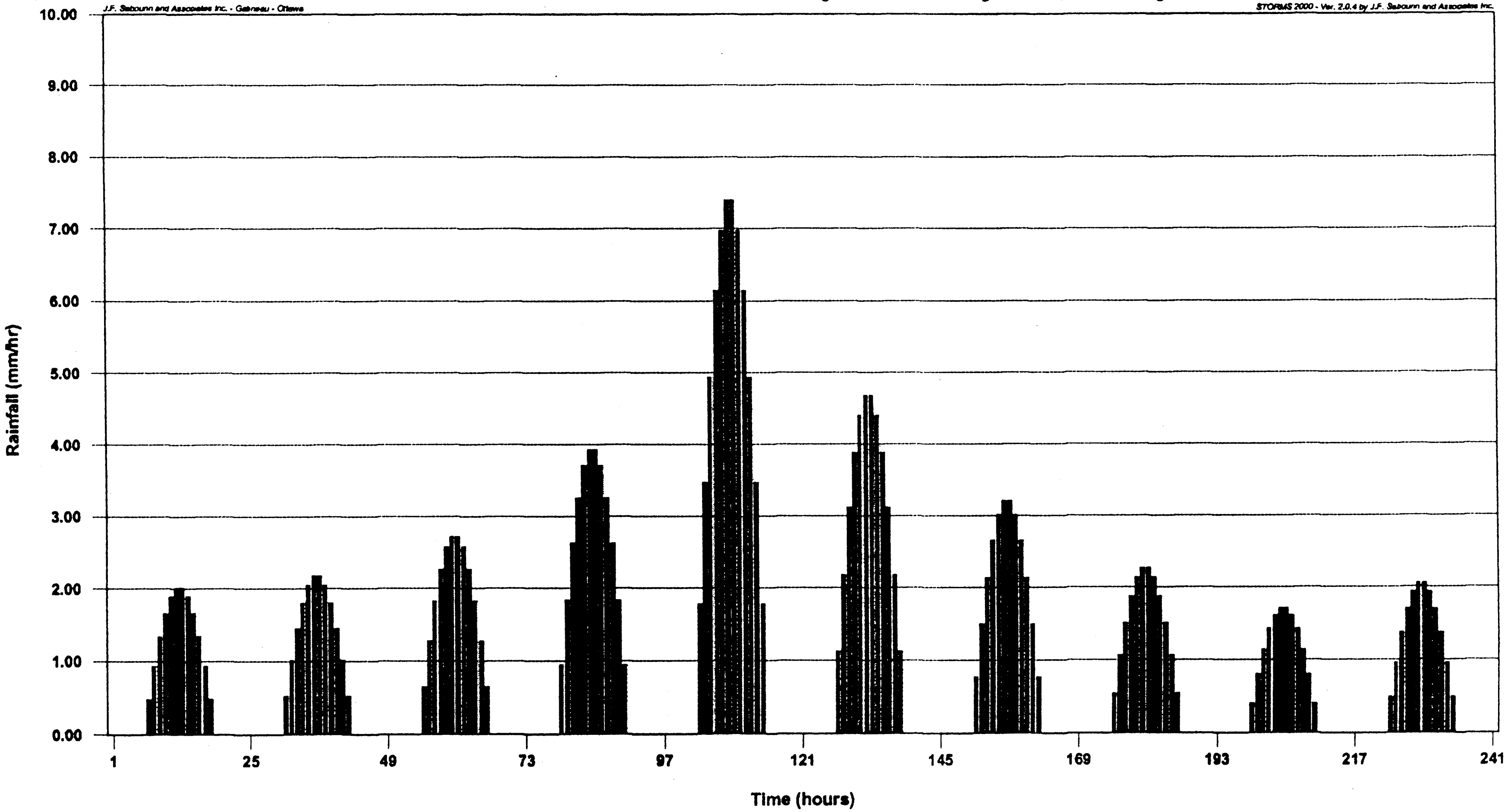


**Table B2 – Snowmelt+rainfall – Model 5 - IDF relationships 1 through 30 day durations; 2 through 100 year Return Periods**

Table B3 – Validation – At Moodie Drive - SSFA/observed vs. Design Event

| **SPRING (Dec-Apr)** | | Flows (m3/s) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Return Period (years)** | | | | | |
| **Flow Estimation Technique** | **Flow Type** | **2** | **5** | **10** | **25** | **50** | **100** |
| Design Event (10 day return period rainfall+snowmellt) (CN=35) | Qmax inst | 80 | 109 | 128 | 158 | 182 | 206 |
| Design Event (10 day return period rainfall+snowmellt) (CN=90) | Qmax inst | 83 | 123 | 150 | 183 | 208 | 233 |
| Design Event (10 day return period rainfall+snowmellt) (CN=variable) | Qmax inst | 64 | 95 | 119 | 152 | 177 | 200 |
| SSFA – LP3 (observed) | Qmax inst | 91 | 123 | 142 | 160 | 181 | 196 |

## Model 5 CDA - S+Rain 12hr/day, RTP 100 years, 10 Days.




## Storm Statistics:

*Storm Filename: D:\Proj\411-02\SWMHYMO\Snowmelt and Rain\51001012.stm*
*Storm File Comment: Model 5 CDA - S+Rain 12hr/day, RTP 100 years, 10 Days.*

| | | |
|---|---|---|
| Total Rain | = | 267.52 (mm) |
| Storm Duration (hrs): | = | 240:00:00 |
| Ave. Intensity | = | 1.11 (mm/hr) |
| Max. Intensity | = | 7.41 (mm/hr) at 660.00 (minutes) |

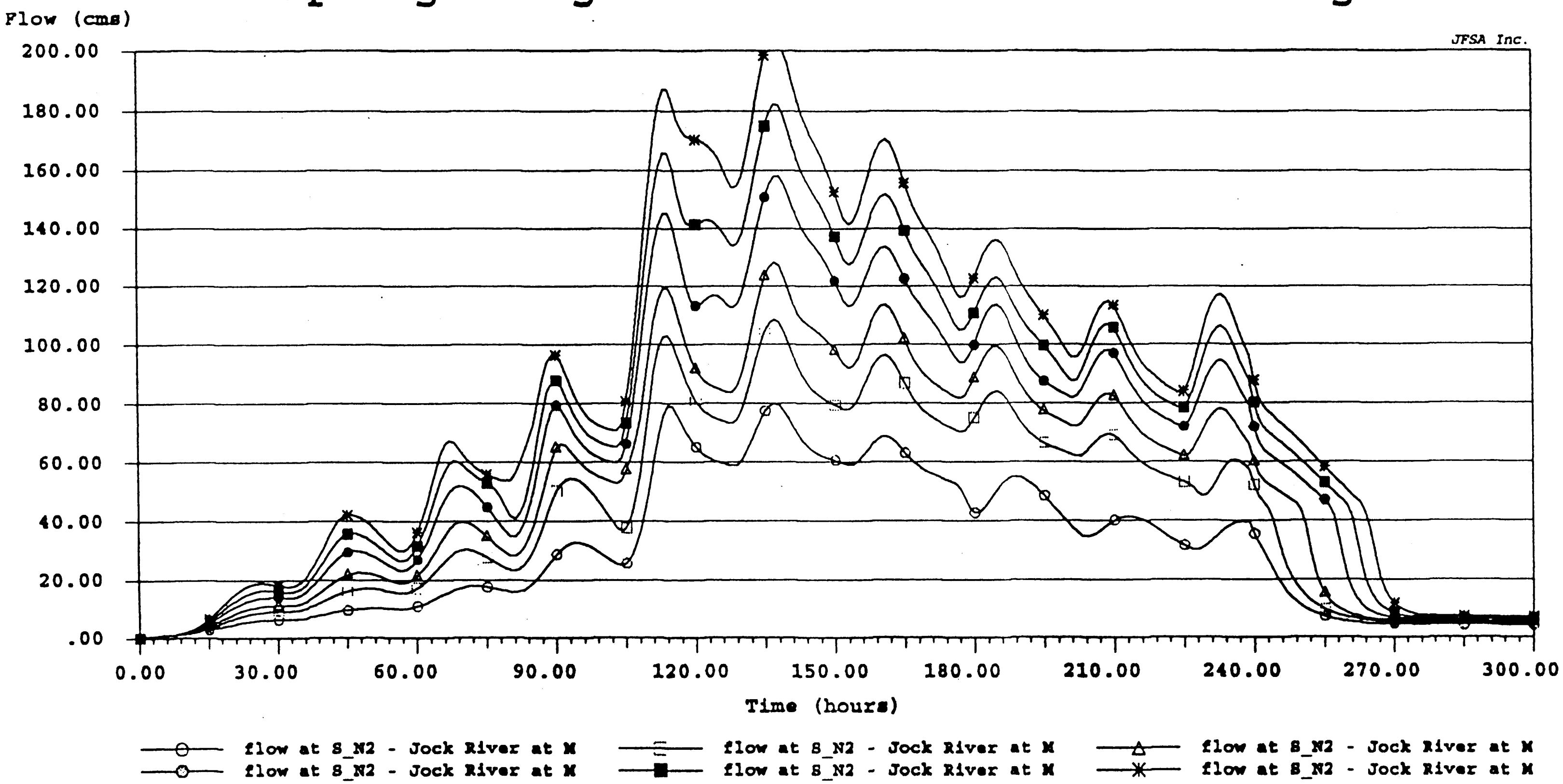
**Maximum Average Intensities: (mm/hr)**

| Time Window | 5 min | 10 min | 15 min | 30 min | 1 hr | 2 hrs | 3 hrs | 6 hrs | 12 hrs | 24 hrs |
|---|---|---|---|---|---|---|---|---|---|---|
| Ave. Intensity (mm/hr) | 7.41 | 7.41 | 7.41 | 7.41 | 7.41 | 7.41 | 7.27 | 6.85 | 5.12 | 2.56 |

Figure B3 – Synthetic Hyetograph

- snowmelt+rainfall– 100 Year

## Spring Design Events ar Moodie Drive Gauge




### Hydrograph Statistics:

| Legend | Filename & Comment | Time Step (min) | Drainage Area (ha) | Peak Flow (cms) | Time to Peak (hrs) | Runoff Volume (mm) | Runoff Volume (cu.m) | Duration of flow (hrs) | Average flow (cms) |
|---|---|---|---|---|---|---|---|---|---|
| ○ | H-S_N2.002 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 80.085 | 137.000 | 64.83 | 3.402E+07 | 569.000 | 16.610 |
| □ | H-S_N2.005 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 108.490 | 137.000 | 93.86 | 4.926E+07 | 684.000 | 20.005 |
| △ | H-S_N2.010 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 128.249 | 137.000 | 113.26 | 5.944E+07 | 756.000 | 21.841 |
| ⊗ | H-S_N2.025 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 158.038 | 138.000 | 138.43 | 7.265E+07 | 1002.000 | 20.141 |
| ■ | H-S_N2.050 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 182.229 | 137.000 | 157.36 | 8.259E+07 | 1021.000 | 22.469 |
| ✳ | H-S_N2.100 : flow at S_N2 - Jock River at Moodie | 60.00 | 52483.00 | 206.358 | 137.000 | 176.55 | 9.266E+07 | 1040.000 | 24.749 |

Figure B4 – 2 Year through 100 Year simulated runoff – Moodie Drive – Spring

# Explanation of AES rain+snowmelt extreme value analysis

**Prepared by:**
**Hydrometeorology Division, Canadian Climate Centre, Atmospheric Environment Service**

Daily rainfall and snowmelt estimates for the noted stations are analysed assuming a Gumbel extreme value distribution. Data are for the period of record shown on the attached computer printout. The results provide annual extreme values for durations from 1 to 30 days and estimated amounts for return periods up to 100 years. The snowmelt estimates were based on degree-day type equations. Five different snowmelt equations were used giving five different sets of snowmelt values.

**Data**

The input data used in this analysis and in the calculation of the snowmelt estimates were daily maximum and minimum temperatures, daily rainfall total and daily depth of fresh snow measurements by ruler. A snow density of 0.1 was assumed to convert snow depth into its water equivalent. Such snow measurements may not be spatially representative. The snowmelt estimates should therefore be considered with the same precaution in mind.

**Snowmelt Calculation**

Daily snowmelt estimates were calculated using degree-day type equations. Five different equations were used and a description of each is given below. The units of measure indicated below are the units used in the original presentation of the model. All models and resulting output have been converted to metric (SI) units in the computer software. The algorithm for accumulating and depleting the snow pack is given in Figure B5.

**Method of Analysis**

The algorithm is based upon synthetic snowpacks which are accumulated according to the daily snowfall measurements and depleted according to the snowmelt as determined by each of the snowmelt models. The algorithm ceases to operate when the synthetic snowpack is reduced to zero. Daily rainfall is added to the daily snowmelt as calculated by each model and the maxima of the combined rain plus snowmelt values are used to determine the annual maximum series for the different durations.

Maximum annual values for rainfall plus snowmelt for each of the five snowmelt estimate data sets were determined for 1 to 30 day periods. These annual maximum value series were then analyzed assuming a Gumbel extreme value (EV1) distribution and using a method of moments fit (see Hogg and Carr, 1985) to derive extreme value estimates for return periods up to 100 years. The annual maximum values for each duration period have been tabulated together with the starting date of each maximum event.

No attempt was made to estimate missing data. Periods with missing data were not analyzed for maximum values but an annual maximum was still deter mined provided 90% of the data were available for the critical period of the year as specified on the printout. Such annual maxima based on an incomplete data year are flagged; (**).

Rigorous testing of the annual maximum series for goodness of fit to the Gumbel distribution has not been done. However, plots of several randomly chosen series on Gumbel graph paper have shown reasonably good fits. (See Louie and Hogg, 1980)

**References**

Hogg, W.D. and D.A. Carr, 1985. Rainfall Frequency Atlas for Canada. 90 pp., Supply & Services Canada, ISBN 0-660-52992-0, Ottawa.

Louie, P.Y.T. and W.D. Hogg, 1980. Extreme Value Estimates of Snowmelt, Proc. CDN. Hydrol. Symp.: 80. PP 64-78. NRC Ottawa

1) **Model 1 - <u>Eastern Canada Forested Basin</u>**
   SM1 = 0.0397 (Ta - 27.6) (inches/day)
   Ta = mean daily air temperatures F
   Ref: Pysklywec, D.W., K.S. Davar and D.I. Bray (1968): Snowmelt at an Index Plot, Water Resour. Res., 4(5), 937-946.

2) **Model 2 - <u>Western North America Mountain Basin</u>**
   SM2 = (0.074 + 0.007 R) (Ta - 32) + 0.05 (inches/day)
   R = daily rainfall in inches
   Ta = mean daily air temperature F
   Ref: United States Army Corps of Engineers (1956): Snow Hydrology, North Pacific Division, Portland, Oregon

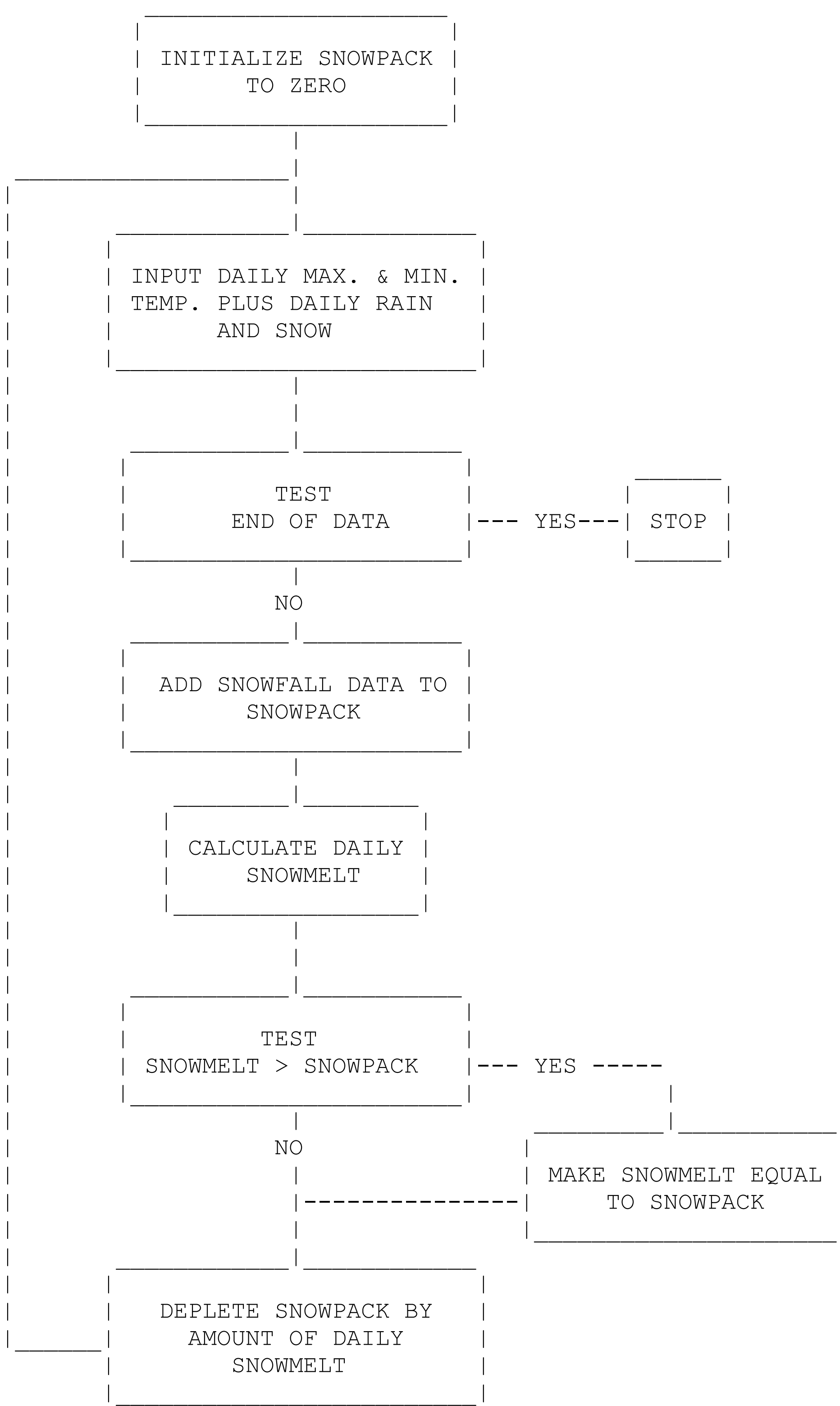
3) **Model 3 - <u>Western Canada Mountain Basin</u>**
   SM3 = 3.0 (Ta + TCA) (((Tx - TN)/8) + TN) (mm/day)
   Ta = mean daily air temperatures C
   Tx = maximum daily temperature C
   TN = minimum daily temperature C
   TCA = (TN/4.4) but must be IN THE RANGE OF 0 TO 1.5
   Ref: Quick, M.C. and A. Pipes (1975): The UBC Watershed Model, Proceedings of Symposium in Bratislava, Application of Mathematical Models in Hydrology and Water Resource Systems, IAHS Pub. No. 115

4) **Model 4 - <u>Southern Ontario</u>**
   SM4 = 0.02 (Tx - 32) (inches/day)
   Tx = maximum daily air temperature F
   Ref: Bruce, J.P. and R.H. Clark (1966): Introduction to Hydro meteorology, p. 257, Pergamon Press, Toronto

5) **Model 5 - <u>Modification of Model 4</u>**
   SM5 = 0.08 (Ta - 32) (inches/day)
   Ta = mean daily air temperature F

**FIGURE B5**

ALGORITHM FOR ACCUMULATING AND DEPLETING THE SNOWPACK



## Characteristics of on-line natural reservoirs on the Jock River

### Richmond Fen
**(Node 7 in SWMHYMO model)**

| Elev.* (m) | Depth (m) | Storage Adjusted (ha-m) | Outflow Spring** ($m^3/s$) | Outflow Summer** ($m^3/s$) |
|---|---|---|---|---|
| 94.500 | 0.000 | 0.00 | 0.000 | 0.000 |
| 94.625 | 0.125 | 2.40 | 2.076 | 0.905 |
| 94.750 | 0.250 | 4.13 | 6.224 | 2.907 |
| 95.000 | 0.500 | 9.18 | 20.393 | 9.744 |
| 95.250 | 0.750 | 14.96 | 42.929 | 20.304 |
| 95.500 | 1.000 | 310.21 | 72.880 | 34.167 |
| 96.000 | 1.500 | 605.46 | 161.510 | 74.993 |
| 96.250 | 1.750 | 900.71 | 226.870 | 104.876 |
| 96.500 | 2.000 | 2892.00 | 306.850 | 140.560 |
| 97.000 | 2.500 | 3616.00 | N/A | 225.000 |

* Approximate elevations obtained from available maps.
** Outflow from reservoir assumed to be controlled by capacity of downstream channel section. The difference between the Spring and Summer conditions result from the use of different roughness coefficients.

### Goodwood Marsh
**(Node 12 in SWMHYMO model)**

| Elev.* (m) | Depth (m) | Storage Adjusted** (ha-m) | Outflow*** ($m^3/s$) |
|---|---|---|---|
| 123.750 | 0.000 | 0.00 | 0.000 |
| 123.875 | 0.125 | 0.00 | 0.033 |
| 124.000 | 0.250 | 0.00 | 0.065 |
| 124.125 | 0.375 | 0.00 | 0.179 |
| 124.250 | 0.500 | 0.00 | 0.354 |
| 124.375 | 0.625 | 0.00 | 0.564 |
| 124.500 | 0.750 | 0.00 | 0.967 |
| 124.625 | 0.875 | 0.00 | 1.369 |
| 124.750 | 1.000 | 2.14 | 1.991 |
| 124.875 | 1.125 | 39.83 | 2.693 |
| 125.000 | 1.250 | 81.70 | 3.509 |
| 125.125 | 1.375 | 318.77 | 4.578 |
| 125.250 | 1.500 | 594.95 | 5.647 |
| 125.375 | 1.625 | 910.22 | 7.109 |
| 125.500 | 1.750 | 1264.59 | 8.616 |
| 125.625 | 1.875 | 1658.06 | 10.371 |
| 125.750 | 2.000 | 2090.62 | 12.402 |
| 125.875 | 2.125 | 2562.29 | 14.455 |
| 126.000 | 2.250 | 3073.05 | 16.888 |
| 126.250 | 2.500 | 3462.49 | 22.056 |
| 126.500 | 2.750 | 3965.96 | 27.280 |
| 126.750 | 3.000 | 4495.50 | 34.965 |
| 127.000 | 3.250 | 5008.75 | 43.093 |

* Approximate elevations obtained from available maps.
** For flow depths of 1.0 m or less, the storage in the Goodwood Marsh is assumed to be minimal.
** Outflow from reservoir assumed to be controlled by capacity of downstream channel section.

Project 411-02
Prep for: JFSA Inc

Date: Sept/29/2003
Updated: July 15, 2004
Prep by: JoF

Figure B6 – Stage-Storage-Discharge: Richmond Fen – Goodwood Marsh