MODELLING SNOWMELT INFILTRATION TO FROZEN PRAIRIE SOILS

by

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FINAL REPORT

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1. INTRODUCTION

A number of models have been developed for synthesizing streamflow from snowmelt. For example: the U.S. National Weather Service River Forecasting System, NWSRFS (U.S. Department of Commerce, 1972; Anderson, 1973; Peck, 1976); the Streamflow Simulation and Reservoir Regulation Model, SSARR (U.S. Army Corps of Engineers, 1972); the Hydrological Engineering Centre HEC-1 Flood Hydrograph Package (U.S. Army Corps of Engineers, 1973); the U.S. Department of Agriculture Hydrograph Laboratory Model USDAHL-74 (Holtan et al., 1975); the HBV of the Swedish Meteorological and Hydrological Institute (Bergström, 1978) and the UBC Watershed and Flow Model (Quick and Pipes, 1972). Of the systems which have been developed no model has been adopted for universal use. Similarly, in Canada the water management agencies of different Provinces responsible for streamflow forecasting are not unanimous in their choice of a model that best satisfies their requirements and produces the most reliable and accurate results. For example, recently the Ministry of Natural Resources, Province of Ontario tendered a study of the suitability of eighteen snowmelt subroutines used in existing, established models for interfacing with their streamflow forecasting system (Maclaren Plansearch, 1984). Ongoing tests are being conducted by the World Meteorological Organization and other bodies on the performance of a number of the "better-known" models in different physiographic and climatic regions of the world.

Each model differs from another, either as it calculates hydrological components or simulates the processes of snowcover accumulation and ablation, evaporation, infiltration, changes in soil moisture storages and flood routing. A main factor contributing to the differences is that most models were developed under a specific set of physiographical conditions, e.g. climate, topography, vegetation and soil types. Consequently, a model developed in a mountainous area will not usually give reliable streamflow simulations for a prairie watershed; nor should it be expected. Even when a model is applied to an area with similar characteristics to those where it was developed, extensive calibration and testing of its performance is usually necessary.

The simulation of snowmelt runoff has been most successful where there is abundant, uniformly-distributed snow and pronounced topographical relief. The opposite situation exists on the Prairies. The snowcover is shallow and large estimation errors in snowcover depth and water equivalent frequently occur, there is little relief and evaporation, infiltration and depressional storage are often comparable in magnitude with the total water content of the snowcover. Definition of a basin's snow resource is complicated by the interaction of wind with both topography and snowcover. This biases measurements and obscures the runoff potential. Continued strong winds erode friable snowcovers and transport both falling and erodible snow downwind. A comparison between measurements of snowcover at climatological stations and adjacent windswept fields showed that only about two-thirds of the snowfall recorded at the stations was retained on the fields (McKay, 1963). Much of the "lost" snow sublimates during wind transport or accumulates in shelterbelts, ditches and gullies. For that reason snow surveys taken in exposed sites can be very poor predictors of the runoff potential.

The performance of a model in simulating streamflow from natural catchments is directly related to the accuracy with which infiltration is evaluated. In most operational systems infiltration is estimated by empirical equations such as those reported by Horton (1940) and Holtan (1961), soil moisture accounting routines, or from relationships that index antecedent groundwater storage conditions and the soil moisture storage potential to the base flow recession characteristics of the streamflow hydrograph. Two main problems arise in applying these procedures to watersheds in northern and west-central Canada namely; (1) no attempt is made to distinguish differences in the infiltration process to unfrozen and frozen soils and (2) many streams are ephemeral, i.e. flow only occurs following a rainfall or snowmelt event and therefore the recession properties of the hydrograph do not properly index the soil moisture storage of a basin at the time of runoff.

Runoff from a Prairie watershed is not generated uniformly from the area enclosed by the topographical divide of the basin.

Prairie lands are relatively-flat and their natural drainage systems are often poorly developed and unconnected. At times there may be no contribution of runoff from large areas of the watershed because of the lack of snowcover and the large amounts of depressional storage. Yet even under these conditions significant runoff can occur, the source being snow in the less visible channels and depressions that feed the main drainageway. A 1966 survey of in-channel snow near Regina showed 12,322 m^3 of water/1000 m of channel when the snow had virtually disappeared from adjacent fields and before significant streamflow. In 1984, surveys near Melfort, Saskatchewan showed an average snowcover of 540 mm in ditches adjacent to fields having an average depth of 70 mm. Snow in the ditches was denser than in the fields; an average density of 340 kg/m^3 compared with 190 kg/m^3 and contained more ice layers. Rough calculations suggested the water equivalent of the snow in the ditches of about 16,430 m^3/1000 m. In-channel snow, although an important source of water in low snow years, is an impediment to flow and the nature of its water storage, transmission and melt characteristics can be critical to hydrograph synthesis, particularly on small and medium-sized watersheds. As storage is filled overflow enters the channels. The result is that a Prairie basin has a variable "contributing" area whose magnitude varies with such factors as the amount of snowfall and antecedent soil moisture and surface storage conditions. In this regard hydrologists have made use of the concept of "Effective" and "Gross" drainage areas. The "Effective" area is that portion of a basin which might be expected to entirely contribute runoff to the main stream during a flood with a return of two years; the "Gross" area is the plane area enclosed by the drainage divide which might be expected to contribute runoff to the outlet under extremely wet conditions (Godwin and Martin, 1975). The "Effective" area includes the major channels and land immediately adjacent to defined drainageways. It is the snowcover in these areas that needs to be surveyed in low snow years; this component of the average basin snowcover becomes less important in snowier winters because of the larger area contributing to runoff. Further research is needed into the interaction of snowfall, snowcover and topographical aspects, and contributing area.

2. OBJECTIVES

The project reported herein is a continuation of the project "Snowmelt infiltration into frozen Prairie soils" which was undertaken for the Research Management Division, Alberta Environment under contract AE No. 84-0472 and reported in 31 March 1984. The work focusses on the problem of infiltration to frozen soils with the major aim directed to evaluating and testing an algorithm of the process that can be used in computer-based, operational forecasting systems for simulating streamflow from snowmelt on watersheds in Alberta and Saskatchewan. Specifically, the project objectives/terms of reference were:

1. To generate a computer program (based on previous work) describing the snowmelt-infiltration-runoff interactions.
2. To debug, test and evaluate the algorithm (item 1) when used in the United States National Weather Service River forecasting System - Sacramento Model (NWSRFS) for synthesizing streamflow from snowmelt on watersheds in Saskatchewan.
3. To incorporate the program (item 1) into the Streamflow Synthesis and Reservoir Regulation System (SSARR).
4. To test and evaluate the performance of the "modified SSARR model" in synthesizing streamflow from snowmelt on selected watershed(s) of interest to the Hydrology Branch, Environment Alberta, e.g. Vermilion River at Vegreville, Alberta.

3. DEVELOPMENT OF AN INFILTRATION ALGORITHM

Based on approximately fifteen years of study of the snow hydrology of the Prairie region, the results of infiltration studies in similar climatic regions of the USSR reported in the literature (Motovilov, 1978, 1979; Popov, 1973) and the findings of a comprehensive study of infiltration to frozen soils in the Dark Brown and Brown soil zones of Saskatchewan (Granger et al., 1984), it is suggested that frozen soils may be grouped into three broad categories with regard to their infiltration potential, namely; Restricted, Limited and Unlimited (see Fig. 1).

Restricted - infiltration is impeded by an impermeable layer, such as an ice lense on the soil surface or at a shallow depth in the soil. For practical purposes the amount of meltwater infiltration can be assumed to be negligible and most of the snow water goes to evaporation or direct runoff.

Limited - infiltration is governed primarily by the snowcover water equivalent and the frozen water (ice) content of the soil layer, 0-300 mm.

Unlimited - a soil containing a high percentage of large, air-filled, non-capillary pores or macropores at the time of melt and most or all the snow water infiltrates. Examples of these soils are dry, heavily-cracked clays and coarse, dry sands.

In the classification it is evident that when evaporation and surface storage losses are neglected the runoff coefficients to be assigned to soils of Restricted and Unlimited infiltration potential in a practical modelling scheme would be 1.0 and 0 respectively. Thus, the problem remaining is one of defining the relationship between infiltration, snowcover water equivalent and a frozen soil moisture content for the Limited case. This can be done using the results reported by Granger et al. (1984). They found in medium to fine-textured, uncracked frozen Prairie soils in which the entry of meltwater was not impeded by an impermeable layer that: (a) the average depth water penetrated a soil during snowcover ablation was 260 mm (standard deviation = 100 mm) and (b) the amount of snowmelt infiltration was inversely related to the average moisture (ice) content of the soil layer, 0-300 mm, at the time of melt. Based on these findings, they derived a set of equations defining the interrelationships between snowmelt infiltration (INF), snowcover water equivalent (SWE) and the premelt moisture content (θ_p). For practical purposes, these results can be approximated by the equation:

$$INF = 5(1-\theta_p)SWE^{0.584} \qquad (1)$$

in which INF and SWE are in mm and θ_p is the degree of pore saturation cm^3/cm^3.

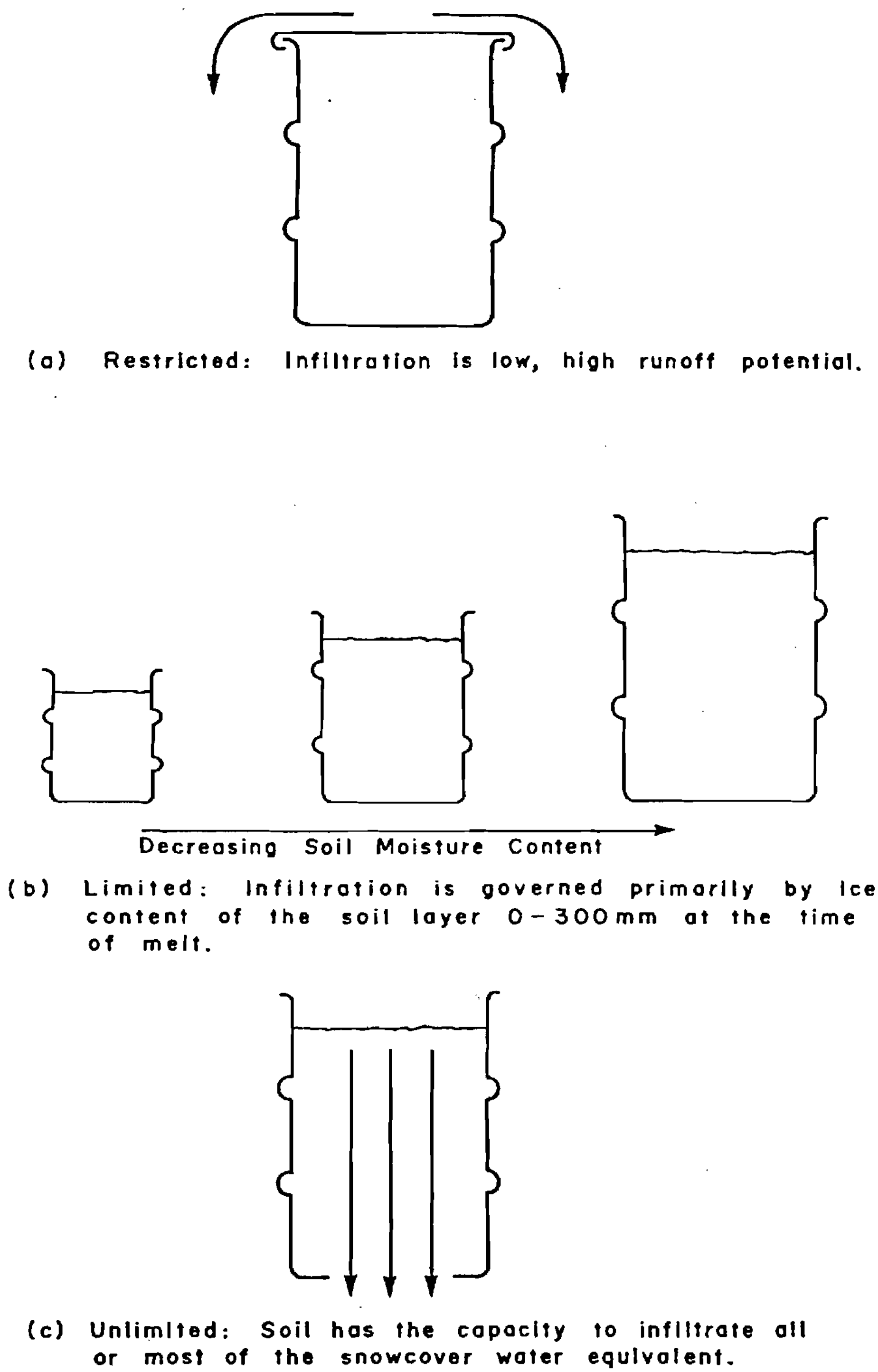


Figure 1. Conceptual model for classifying the infiltration potential of frozen Prairie soils: (a) Restricted, (b) Limited and (c) Unlimited (after Gray et al., 1984).

3.1 SEQUENCING INFILTRATION QUANTITIES - THE LIMITED CASE

In order to apply the model in operational practice the variation in infiltration rate with time over the melt period must be assumed. The infiltration pattern depends on many factors: the rates of snowmelt and snowcover runoff; the depth, temperature regime and water transmission characteristics of the snowcover; the content and distribution of ice in the frozen soil, the soil temperature regime and others. Figure 2 (Granger et al., 1984) illustrates the effects of premelt soil moisture, snowcover depth and melt conditions on snowmelt infiltration.

Curve 1 - infiltration to a relatively dry soil (∿14% moisture content by volume) resulting from the slow melt of a relatively-deep, Prairie snowcover (∿500 mm). Infiltration is delayed by the movement and storage of meltwater in the snowcover. After the snow ripens, water is released almost continuously throughout the melt period. Infiltration occurs at variable

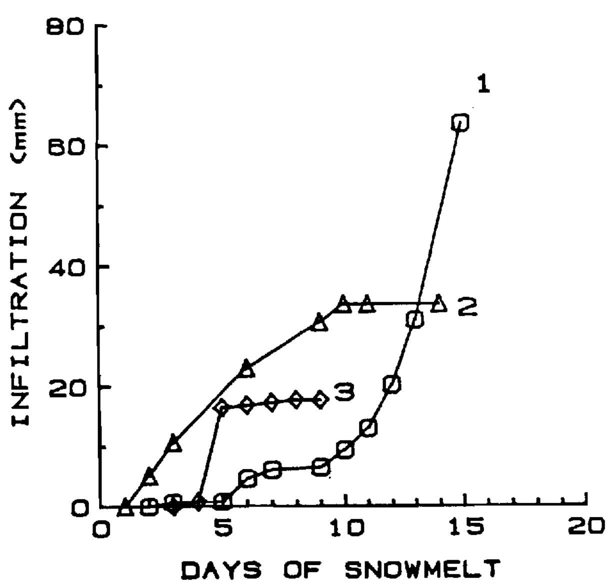


Figure 2. Mass snowcover infiltration curves. Curve 1: dry soil (∿14% moisture by volume), deep snowcover and variable rates of snowmelt; Curve 2: (∿18% moisture by volume), rapid melt of snowcover, and water ponds on the surface; and Curve 3: (∿35% moisture by volume), rapid melt and ice layer forms at the surface early in the melt period (after Granger et al., 1984).

rates with a trend for the rate to increase with time because of an increase in the rate of release of meltwater and thawing of the soil.

Curve 2 - infiltration to a relatively dry soil (∿18% moisture content by volume) caused by the rapid melt of a ripe snowcover and water ponds on the soil surface providing a reasonably constant supply. The maximum infiltration rate occurs early in melt and the soil moisture storage, which is limited because of refreezing of meltwater in the soil and reduced downward percolation, is satisfied after approximately nine days of melt.

Curve 3 - infiltration to a relatively wet soil (∿35% moisture content by volume) resulting from the rapid melt of a shallow snowcover; an ice layer formed at the soil surface and prevented infiltration until it thawed on the fifth day of melt. The amount of infiltration is low.

In view of the strong dependency of infiltration on the melt process it would seem logical to allow the output of meltwater from the snowcover generated by the ablation subroutine of a model to be a dominant factor in sequencing the infiltration amount. Four approaches to the problem were considered:

1. Assume that up to the time the snowmelt infiltration potential of a frozen soil (Eq. 1) is satisfied all meltwater released by the snowcover enters the soil. That is the infiltration rate is taken equal to the rate of meltwater release and no snowcover runoff occurs to a stream channel. This procedure has the advantages that it is direct, simple and easy to program. However, it has the disadvantages that it considers a frozen soil has an unlimited capability of absorbing water during the early part of melt, that the infiltration process does not continue throughout the entire ablation period and the time of snowcover runoff is set directly by the ablation subroutine of the system. It is expected that this procedure would provide better results in the case of a slow melt as compared to a rapid melt.
2. Assume infiltration to be a constant percentage of the amount of

meltwater released by the snowcover. This approach has the same advantages as the above (item 1). In addition it allows infiltration to continue throughout the period of ablation and can be used for both advanced and delayed melt patterns. The major limitation to the method is that it ties the infiltration process directly to the snowcover ablation sequence both in timing and magnitude, trends which can not be rationalized on a physical basis.

3. Assume the infiltration rate of a frozen soil during a period of continuous melt is a constant, i.e., the shape of the cumulative infiltration - time curve is linear or uniform. This approach is similar to the "index method" commonly used in calculating rainfall-runoff relations for unfrozen soils (Linsley et al., 1949). Whereas the assumption leads to a more complicated simulation routine than those required with the others (items 1 and 2) an advantage is that to a limited extent it decouples the processes of infiltration and snowmelt. However, output from the snowcover melt subroutine will remain a controlling factor governing the infiltration pattern. The effects of a discontinuous, interrupted melt on the snowcover water equivalent, the infiltration potential of a frozen soil and the timing and magnitude of snowcover runoff can be built into the infiltration algorithm.

   A major problem in applying the procedure (item 3) is one of deciding the "snowmelt infiltration index". It was found for continuous, uninterrupted melt sequences that the period of infiltration usually fell in the range from 5-9 days. The smaller values were usually associated with the rapid melt of a relatively shallow snowcover. Based on these findings it is suggested that a period of infiltration of 6 d be used to establish the index, i.e., snowmelt infiltration index (mm/d) = infiltration potential (mm) ÷ 6 d. This recommendation is also based on two other major considerations: (a) it is highly unlikely that a design snowcover, one capable of producing maximum flow rates and volumes, would completely ablate in a period less than 6 d following the initiation of melt and (b) for delayed, interrupted melt patterns the period of infiltration can easily be extended to a longer duration by the algorithm.

4. Assume that when the rate of meltwater release from the snowcover is less than the snowmelt infiltration index all meltwater infiltrates the frozen ground and when the meltwater rate exceeds the index, infiltration is a percentage of the amount of meltwater produced. The infiltration ratio or the percentage of the amount of meltwater that infiltrates is taken as the ratio of the amount of infiltration potential to the amount of snowcover water equivalent remaining at the time the infiltration index is exceeded. In effect, this procedure of sequencing infiltration combines those described by items 1, 2 and 3. It has the advantage over the method described as item 2 in that it eliminates the contribution to streamflow by small melt events, such as those frequently encountered early in the ablation period when there is strong diurnal cycling of melt, and thereby delays the occurrence of runoff. However it has the disadvantage, because of the decrease in the infiltration ratio caused by the infiltration contributions from these small events, to cause the infiltration sequence to follow an "advanced" pattern.

4. EVALUATION AND VERIFICATION TESTS OF INFILTRATION MODEL

4.1 GENERAL

The performance of the infiltration model was evaluated by comparing "predicted" and "measured" volumes of runoff and "simulated" and "observed" streamflow hydrographs on two watersheds in Saskatchewan; the Creighton Tributary, a small sub basin (11.4 km^3) of the Bad Lake Watershed which is located near Bickleigh, approximately 165 km southwest of Saskatoon in the semi-arid part of the Province; and the Wascana Creek Watershed at Sedley, a watershed having a "gross" drainage area of approximately 350 km^2 located approximately 50 km southeast of Regina.

The general topography of the Creighton Tributary may be classed as rolling and gently undulating with approximately 85% of the area under cultivation of cereal grains by dryland farming. It falls within a "transitional" soil zone dividing glacial and lacustrine soils which include the two principle soil series: Haverhill silty clay and clay loams and Sceptre clay. An important feature of the watershed is that it does not contain large elements of depressional storage and therefore the "gross" area can be assumed a close approximation of area of the watershed contributing to flow. Runoff calculations were completed on the watershed for the two winters, 1973/74 and 1974/75. In these years comprehensive snow surveys were conducted on the watershed to establish the average areal snowcover water equivalent by procedures outlined by Steppuhn and Dyck (1974); measurements of the "fall" soil moisture content were made with a neutron gauge at 23 sites in fields located adjacent to the watershed of the same soil type and cropping patterns (Banga, 1981) and streamflow from snowmelt was carefully monitored. Other data needed for the simulations, namely daily precipitation and air temperature, were obtained from the Bad Lake Climatological Station located approximately 5 km from the watershed.

The two years, 1973/74 and 1974/75, provided contrasting snowcover and premelt soil moisture conditions. The winter of 1973/74 was a year of near record snowfall which produced an average depth of snowcover on the watershed of 556 mm having a water equivalent of 143 mm. It was preceded by a warm, dry fall in which the average moisture content of the surface layer of soil (0-300 mm) was very low, especially in those soils having crops the preceding summer ($\sim$15% by volume). In contrast, snow conditions during the winter of 1974/75 would be likened more closely to "normal". The average depth and water equivalent of the snowcover were 299 mm and 71 mm respectively and the average "fall" soil moisture content was 27.4% by volume.

The Wascana Creek watershed at Sedley falls in the Dark Brown soil zone of the Province. Approximately 85% of the basin is under cultivation of cereal grains; the remaining area is in pasture, woody vegetation, roads, farmyards and townsites. The topography is flat to gently rolling and because of the poor relief the percentage of the "gross" drainage area that contributes to the annual streamflow from snowmelt can vary widely. Although the natural "effective" and "gross" areas of the basin are listed as 236.7 km^2 and 1634.3 km^2 respectively (PFRA, 1985); a storage reservoir located upstream of the gauging station has the effect of reducing the effective area to $\sim$125 km^2 and the gross area to $\sim$350 km^2.

Data on soil moisture, snowcover depth and water equivalent and streamflow for the watershed were obtained from Federal and Provincial Agencies namely: the Water Management Service and Atmospheric Environment Service, Environment Canada; the Hydrology Branch Saskatchewan Water Corporation, and the Swift Current Research Station, Agriculture Canada (Davin Watershed). In 1981/82 these data were supplemented by snowcover and soil moisture measurements made on the area as part of a joint Canada-United States investigation of the application of airborne gamma techniques for estimating the areal snowcover water equivalent (Carroll et al., 1983; Goodison et al., 1984).

Temperature data for the snowmelt calculations and precipitation data used to update snow survey measurements after March 1 were from the Regina Airport.

4.2 WATER BALANCE CALCULATIONS: CREIGHTON TRIBUTARY

A simple, direct test of the performance of the infiltration model in calculating streamflow from snowmelt is to compare the total potential volume of runoff, calculated as the difference between the snowcover water equivalent and infiltration, with the measured amount obtained from the streamflow hydrograph. Reasonable agreement in the values would be expected under the assumption that losses to depressional storage, evaporation and other factors are small compared to the volume of direct runoff.

The results of the water budget calculations for 1973/74 and 1974/75 are given in Table 1. From these data it can be shown that the values of the unit runoff potential, calculated as the difference (areally-weighted snowcover water equivalent (SWE) - snowmelt infiltration (INF)) are in reasonably-close agreement with the "measured" volumes obtained from the streamflow hydrographs. The ratio of

Table 1. Snowcover (SWE), soil moisture (θ_p), infiltration (INF) and runoff statistics for the Creighton Tributary for the winters of 1973/74 and 1974/75 and a comparison of the volumes of runoff calculated by the infiltration model with those obtained from recorded hydrographs. SWE, INF and runoff volume are expressed as an equivalent depth of water (mm) on the "gross" area of the watershed, i.e. 11.4 km^2.

Winter	Land Use	Area (km^2)	SWE (mm)	Infiltration[a] Class	θ_p	INF (mm)	Measured Runoff (mm)	Residual[b] (mm)
1973/74	Fallow	4.67	54.2	Limited	0.31	24.2		
	Stubble	5.04	65.4	Unlimited	0.25	65.4		
	Grass	1.68	23.6	Limited	0.25	10.6		
		Total	143.2			100.2	42.2	1.0
1974/75	Fallow	3.58	23.0	Limited	0.46	8.9		
	Stubble	6.13	30.9	Limited	0.54	14.8		
	Grass	1.68	16.6	Limited	0.44	6.5		
		Total	70.5			30.2	34.5	5.8

[a] All land in stubble assumed to fall in the "Unlimited" class in 1974. Decision based on:
(a) extremely dry fall resulted in soil moisture condition near or below wilting point and,
(b) field observations of melt and runoff sequences showed only small amounts of runoff from many fields of stubble.

[b] Residual = SWE - INF - measured runoff; i.e. the unaccounted volume presumably lost to storage and evaporation.

"calculated" to "measured" volume was 1.02 in 1973/74 and 1.17 in 1974/75. The residual ((SWE - INF) - measured runoff) expressed as an equivalent average depth of water over the area, was 1.0 mm in 1973/74 and 5.8 mm in 1974/75. It is considered that the agreement in "calculated or potential" and "measured" volumes is acceptable considering the level of accuracy with which the different terms used in the calculations could be evaluated and the fact that evaporation and storage losses have been neglected.

The assumption of classifying the infiltration potential of the total area in stubble in 1973/74 as "Unlimited" (see Table 1) is subject to question because the extent of soil cracking was not recorded. It is known however, from field experience of the interaction of soil moisture and soil cracking of the lacustrine clay of the area and field observations of snowmelt runoff during the melt sequence in 1974, that it would be incorrect in describing the infiltration potential of the watershed in 1973/74 as "Limited". Soil cracking was assumed to be extensive because the phenomenon has been observed in other years in fields of the same soil type (Sceptre clay) at higher moisture levels than those measured in the fall of 1973. In addition, field observations during snowmelt in the spring of 1974 showed runoff from stubble land to be highly variable. On some fields, small but measurable surface flows were observed; on others the volumes of runoff were insignificant with respect to the snowcover water equivalent. Also, the results of snowmelt runoff studies conducted on small areas (micro-watersheds) located in the Bad Lake watershed close to the Creighton Tributary reported by Erickson et al. (1978) showed significantly lower amounts of surface runoff from stubble in 1974 compared with the quantities generated in other years at the same energy index of melt. One can however, only postulate the exact division of the total area of the watershed to "Unlimited" and "Limited" classes.

4.3 INTERACTION BETWEEN RUNOFF POTENTIAL, RUNOFF VOLUME AND "APPARENT" CONTRIBUTING AREA - WASCANA CREEK AT SEDLEY

Table 2 lists some general statistics on snowcover, soil moisture, infiltration, runoff and contributing area for Wascana Creek near Sedley, Saskatchewan for seven years in the period 1972-1982 inclusive. In view of the narrow range in values of the premelt soil moisture content given in Table 2 (θ_p; 0.41-0.53) one is tempted to assume that the antecedent "moisture" conditions on the watershed, in terms of soil moisture and depressional storages, did not differ significantly between years. Under these conditions a strong association between the volume of observed streamflow and the unit runoff potential, the sum of the snowcover water equivalent (SWE) plus precipitation occurring during the melt period (PPT) less the volume of infiltration (INF) i.e., (SWE + PPT - INF) would be expected. Note: for additional discussion of the reasonableness of the assumption of a close association between surface and soil moisture storage elements the reader is referred to the work by Gray et al., (1985).

Figure 3 is a plot of the observed streamflow volume with the unit runoff potential for the seven years of data given in Table 2. The numbers opposite the plotted points represent the "apparent" contributing area, the area of the basin that produced the observed runoff volume with the unit runoff potential. The data in the figure show a trend for the volume of runoff to increase linearly with the unit runoff potential which is relatively-independent of the "apparent" contributing area; a trend that was unexpected considering the storage elements between years may have differed appreciably. Note, a trend for the runoff volume to increase with snowcover water equivalent (SWE) could also be shown. However the scatter in the data is extremely large.

In the figure three line segments have been plotted and numbered. The primary division of the data (Curves 1 and 3) is rationalized on the basis that the runoff response characteristics of poorly-defined drainage areas of the watershed adjacent to the channels differ significantly from those of the snow-filled channels. That is:

Curve 1 - runoff from the "gross" area of the basin assuming the surface storage elements of the watershed for runoff are satisfied and evaporation losses are negligible. The line has a slope equal to the "gross" area of the basin or 350 km^2, and represents the upper "envelope" curve of runoff for the basin.

Curve 3 - runoff from snow-filled channels. The runoff relationship

Table 2. Annual statistics on soil moisture, snowcover infiltration runoff and contributing area for seven years of record on Wascana Creek near Sedley, Saskatchewan, 1972-1982.

Year	Premelt Moisture Content[a] (θ_p) mm	Snow Water Equivalent (SWE) mm	Ppt During Melt (PPT) mm	Infiltration Potential (INF) mm	Unit Runoff Potential (SWE+PPT-INF) mm	Observed Streamflow Volume $10^{-6}m^3$	"Apparent" Contributing Area[b] km^2
1972	0.47	45	4.4	24.5	25.1	3.63	144
1974	0.44	137	0.0	49.5	90.0	24.00	267
1976	0.48	100	1.6	38.5	63	21.50	341
1978	0.41	42	0.4	26.4	16.8	3.00	188
	0.41	60[c]	0.4	32.4	28.3	3.00	106
1979	0.47	83	0.0	36.0	47	12.75	271
1980	0.49	51	0.0	25.4	26	4.25	163
1982	0.53	99	0.0	34.4	64.6	19.13	296

a) θ_p = average premelt soil moisture (ice) content of the soil layer, 0-300 mm.

b) "Apparent" Contributing Area = drainage area of the watershed used in the simulations to produce the observed volume of flow.

c) SWE estimate biased to snow survey measurements in channels and depressions.

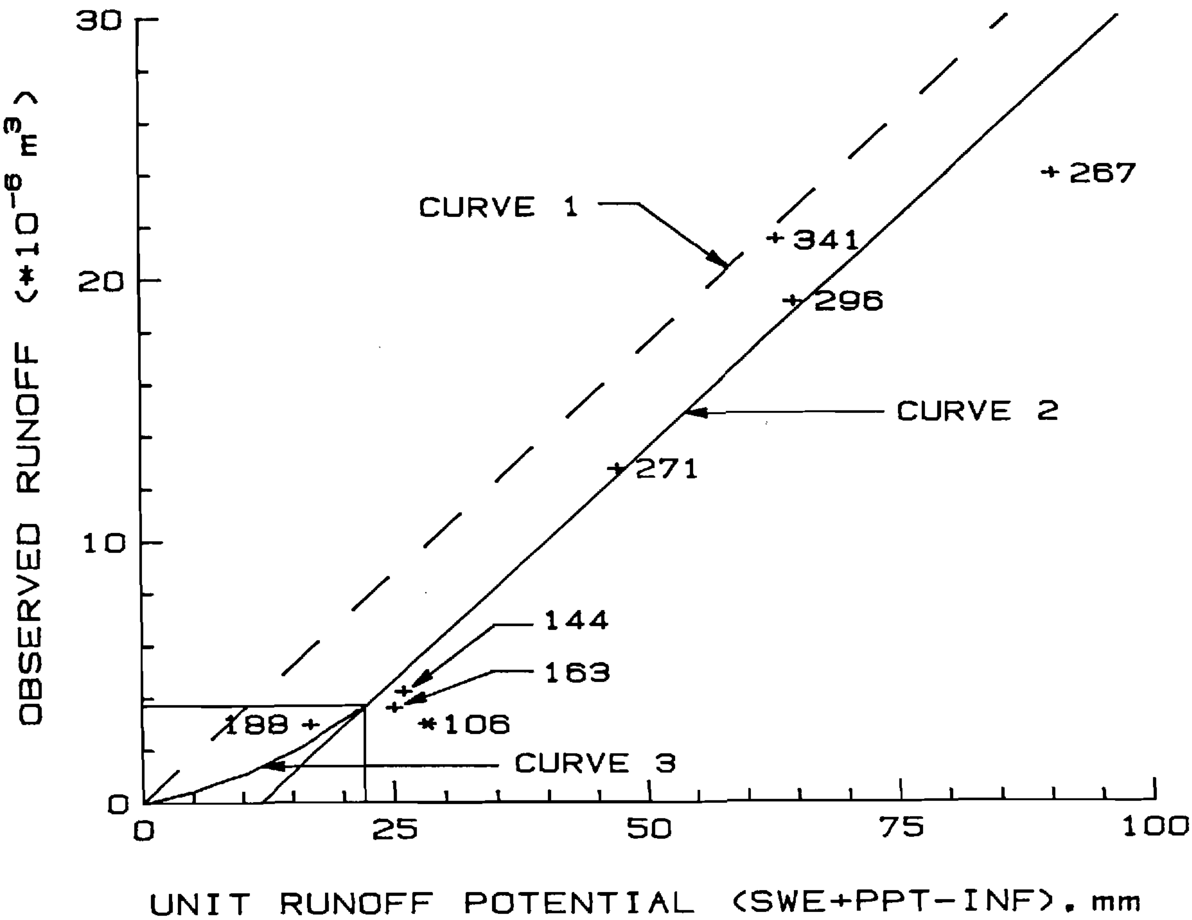


Figure 3. Relationship between observed runoff, unit runoff potential and "apparent" contributing area for Wascana Creek at Sedley, Saskatchewan.

is approximated by a curve having a concave shape showing an increase in runoff per unit runoff potential with increasing potential. Although the shape can not be verified it is rationalized on the basis that as the amount of snow water collected in the channels increases the rate of runoff released per unit of snow water equivalent also increases, until such time when direct runoff contributions from areas of the watershed adjacent to the channels become the major source of supply.

Curve 2 can be likened to a transition zone in which the "apparent" area contributing to streamflow enlarges in size according to the magnitude of the runoff potential and reaches a maximum value equal to the "gross" area. The association between observed streamflow and runoff potential is assumed linear because the relationship defined the trend of the data within acceptable, practical limits and there was no obvious physical reason for describing the relation with a different geometric form. Also, no attempt was made to determine the best-fit regression for the data because of the small number of data points and the values of the unit runoff potential were calculated from measurements which were routinely-collected as part of an operational field survey program. That is, the measurement program was not specifically designed to warrant a rigorous, statistical approach. An important property of the line is that the slope is equal to 350 km^2, the "gross area".

Two other characteristics of Curve 2 (Fig. 3) having hydrological implications are the intercepts with the "x" and "y" axes and the point of intersection or tangency of the line with Curve 3. The "x" intercept represents the unit runoff potential above which the volume of runoff can be assumed a linear function of the "gross" area. Thus, it can likened to a displacement value, similar to a roughness height used to define wind velocity and other profiles. The "y" intercept (vertical displacement from Curve 1) represents the average volume of storage (primarily depressional) that must be satisfied before runoff from the watershed can be directly related to the "gross" area. For Wascana Creek this value was approximately $3.9 * 10^6 m^3$. Note, like Curve 1 which represents the "upper" envelope curve of maximum runoff for a given potential, a line positioned some distance vertically-below and paralleling Curve 2 would describe the runoff characteristics under maximum surface and depressional storage characteristics, i.e. the case of very dry antecedent moisture conditions.

It is assumed the point of tangency of Curves 2 and 3 represent the "apparent" contributing area when the runoff release and response characteristics change from "channel" to "watershed" patterns. The area was calculated in the range of 150-160 km^2, a size slightly larger than the "effective" area of 125 km^2.

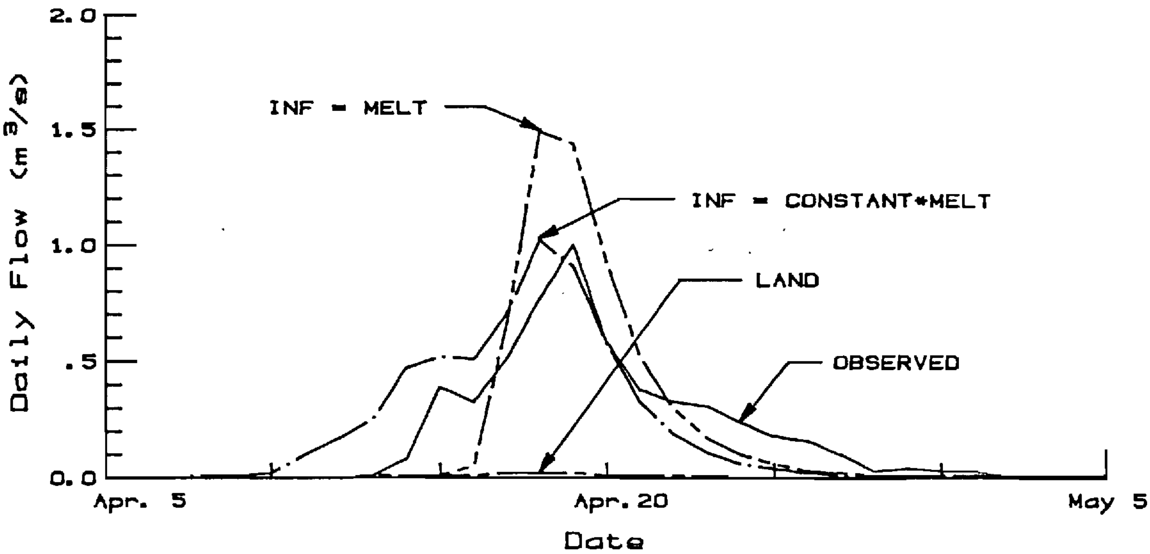
The findings suggest procedures for estimating: (1) the runoff volume from snowmelt from the runoff potential and the "gross" area of the basin; (2) an initial value of the "apparent" contributing area for use in model simulations and (3) the size of a watershed when its runoff response changes from "channel" to "watershed" characteristics. Also, the fact that runoff analysis lends itself to a rational physical interpretation is taken as evidence in support of the validity of the approach to modelling infiltration to frozen soils.

4.4 COMPARISONS OF OBSERVED AND SIMULATED HYDROGRAPHS

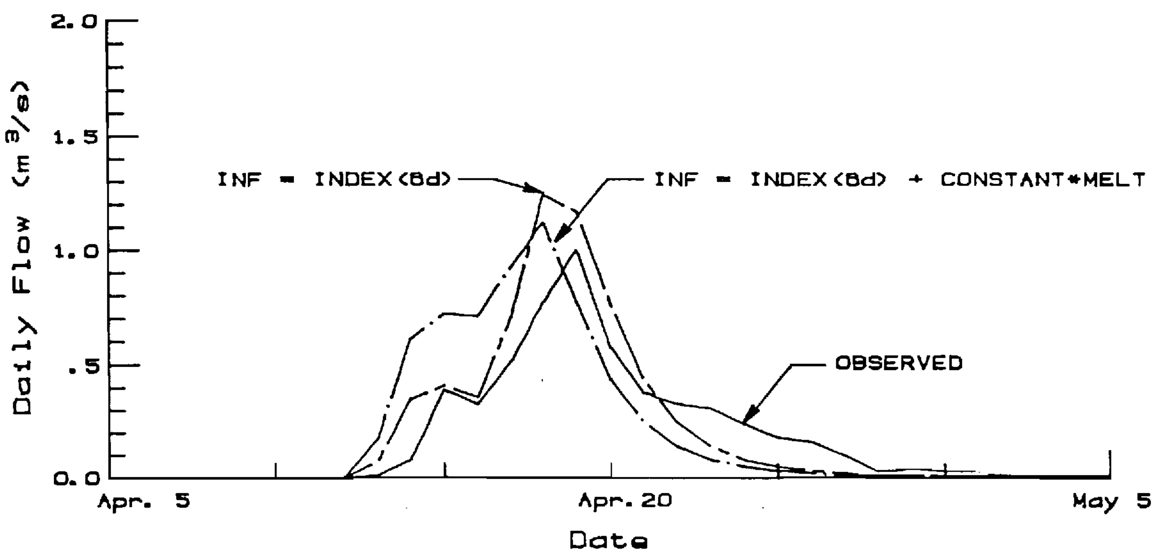
Algorithms were written to describe the four approaches to sequencing the infiltration potential (Eq. 1) discussed in Section 3.1 and interfaced with the National Weather Service River Forecasting System - Sacramento Model (NWSRFS). The system was then used to synthesize streamflow from snowmelt on the Creighton Tributary and Wascana Creek in different years and the simulations compared with observed hydrographs.

4.4.1 Creighton Tributary

Figures 4 and 5 show the simulated and observed hydrographs for the Creighton Tributary for 1974 and 1975 respectively. Note, all simulated hydrographs were generated using the same input data (for example time-area histogram, air temperature, snow water equivalent and others) and routing coefficients. In the figures the simulated hydrographs are identified as: LAND - the NWSRFS with its LAND soil moisture accounting subroutine; INF = MELT - the LAND subroutine of the NWSRFS was replaced by the infiltration algorithm in which the amount of snowmelt infiltration was taken equal to the amount of meltwater released by the snowcover up to the time the infiltration potential was satisfied; INF = CONSTANT * MELT - the NWSRFS with the algorithm in which infiltration is assumed a constant times the amount of meltwater produced; INF = INDEX(6d) - the NWSRFS assuming a constant daily snowmelt infiltration rate (snowmelt infiltration index) equal to the snowmelt infiltration potential (Eq. 1) divided by 6d; and INF = INDEX(6d) + CONSTANT * MELT - the NWSRFS and an algorithm that assumes INF = MELT on days when the amount of melt is less than (INDEX(6d)) and INF = CONSTANT * MELT on days when INDEX(6d) is exceeded.



(a)



(b)

Figure 4. Observed and simulated hydrographs from snowmelt for Creighton Tributary, 1974. (a) OBSERVED - measured streamflow; LAND - the NWSRFS operated with its LAND soil moisture accounting routine; INF = CONSTANT * MELT - the NWSRFS with the infiltration algorithm assuming infiltration is a constant percentage of the amount of meltwater released from the snowcover; INF = MELT - the NWSRFS with infiltration equal to the amount of meltwater released by the snowcover up to the time infiltration potential is satisfied and (b) INF = INDEX(6d) - the NWSRFS assuming a constant daily infiltration rate equal to the snowmelt infiltration potential (Eq. 1) divided by 6d and INF = INDEX + CONSTANT * MELT - the NWSRFS and an infiltration algorithm that assumes INF = MELT on days when the amount of melt is less than the snowmelt index based on 6d of continuous melt (i.e. INDEX(6d) and INF = CONSTANT * MELT on days when melt exceeds INDEX(6d)).

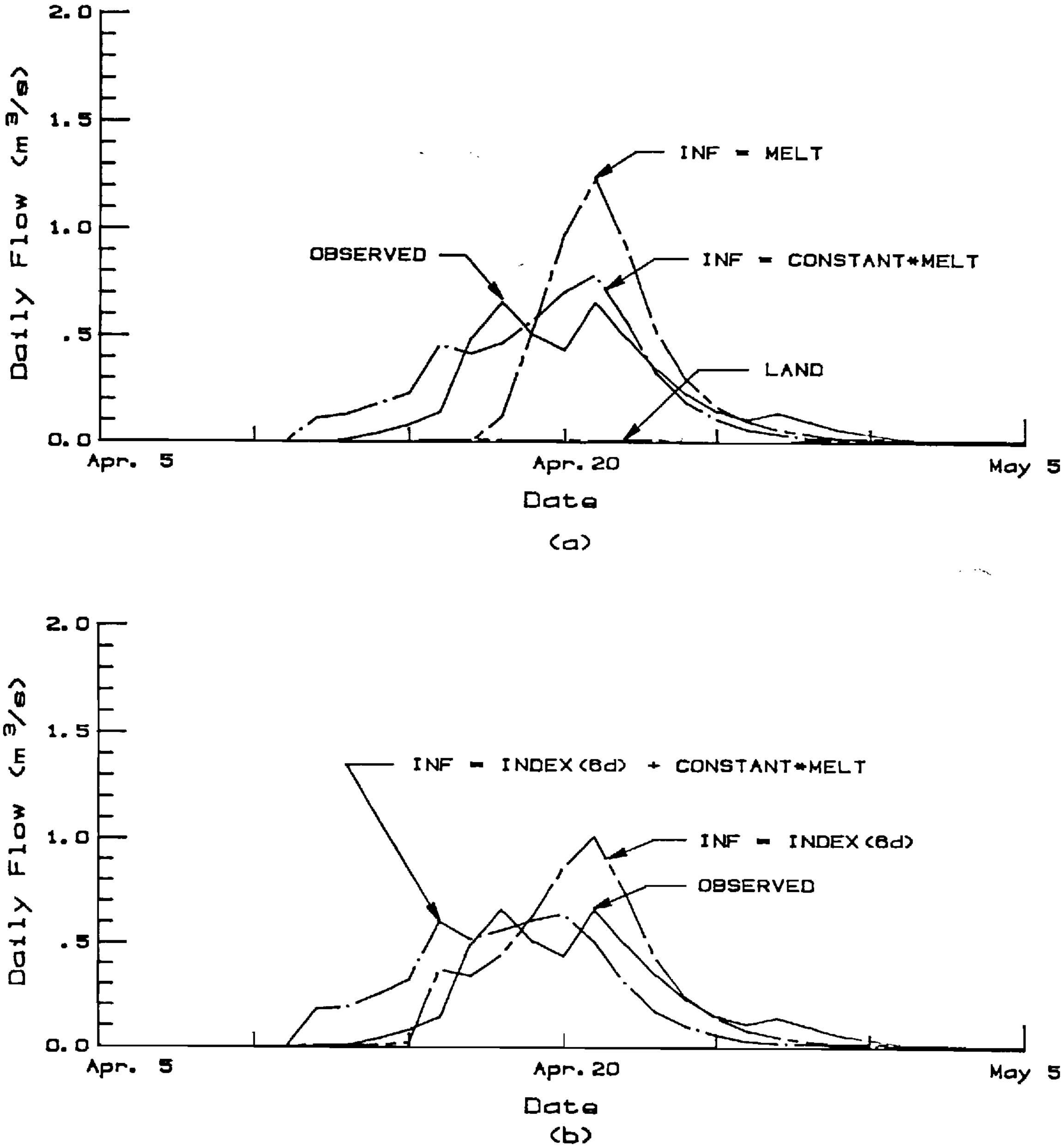


Figure 5. Observed and simulated hydrographs from snowmelt for Creighton Tributary, 1975. (a) OBSERVED - measured streamflow; LAND - the NWSRFS operated with its LAND soil moisture accounting routine; INF = CONSTANT * MELT - the NWSRFS with the infiltration algorithm assuming infiltration is a constant percentage of the amount of meltwater released from the snowcover; INF = MELT - the NWSRFS with infiltration equal to the amount of meltwater released by the snowcover up to the time infiltration potential is satisfied and (b) INF = INDEX(6d) - the NWSRFS assuming a constant daily infiltration rate equal to the snowmelt infiltration potential (Eq. 1) divided by 6d and INF = INDEX + CONSTANT * MELT - the NWSRFS and an infiltration algorithm that assumes INF = MELT on days when the amount of melt is less than the snowmelt index based on 6d of continuous melt (i.e. INDEX(6d) and INF = CONSTANT * MELT on days when melt exceeds INDEX(6d)).

Before discussing the results in Figs. 4 and 5 it is important to point out that no attempt was made to align the simulated hydrographs with the observed hydrographs to a position of best fit. Poor agreement between hydrographs could be the result of numerous factors other than infiltration, for example incorrect simulations of the ablation process and water storage and transmission characteristics of the snowcover and soil and poor selection of the time-area distribution pattern and routing constants. It is also worthy to point out the NWSRFS is a highly flexible system in the extent that the simulated hydrographs could be "forced" to fit the observed hydrograph by changing the magnitude of different input parameters. However, except for changes that could be suggested in the soil moisture accounting subroutine, most could not be physically rationalized (see Gray et al., 1984). An in-depth study of the system is however beyond the scope of this report. Thus, in reviewing the data the reader is asked to concentrate on the relative improvement the different infiltration algorithms produce between the simulated and observed hydrographs. It should also be recognized that because the input volume of snow water to the system is constant in a given year, an algorithm that causes the time base of the simulated hydrograph to be less than the time of observed flow will give discharge rates higher than the observed rates, and vice versa.

The major features to be noted in Figs. 4 and 5 are:

(1) The NWSRFS system operated with an unmodified LAND subroutine grossly underestimates the volume of runoff (Figs. 4a and 5a). The calculated and observed volumes in 1974, expressed as an equivalent depth of water on the basin, were 1.5 mm and 42.2 mm respectively; in 1975 they were 0.9 mm and 34.5 mm. Gray et al. (1984) have shown these results can be expected unless the LAND subroutine is adjusted to account for the differences between the infiltration characteristics of unfrozen and frozen soils. These adjustments involve limiting the water storage capacity of the Upper zone of the soil moisture accounting system and restricting percolation from the Upper zone to the Lower zone. Both of these changes

can be physically rationalized and Gray et al. (1984) show they significantly improve the performance of the NWSRFS in simulating observed data.

(2) The improvement in hydrograph simulation obtained with the infiltration algorithm. An accepted measure of agreement between observed (q_{oi}) and simulated flow (q_{si}) is the nondimensional parameter R^2 defined by the equation (Nash and Sutcliffe, 1970):

$$R^2 = 1 - \left(\sum_{i=1}^{n} (q_{oi} - q_{si})^2 / \sum_{i=1}^{n} (q_{oi} - \bar{q}_o)^2\right)$$

in which n = number of values at evenly spaced time intervals, and $\bar{q}_o$ = mean of the observed flows.
R^2, termed "efficiency", is analgous to the coefficient of determination in statistics, and the closer its' positive value is to unity the closer the agreement between observed and simulated hydrographs. The values obtained with the LAND subroutine and the infiltration algorithm INF = CONSTANT * MELT in 1974 were -0.35 and 0.70 respectively.
Table 3 lists the R^2-values for the hydrographs simulated on the Creighton watershed with the different infiltration algorithms in 1974 and 1975. As shown, each of the algorithms improves the efficiency of the NWSRFS in describing the observed streamflow over that obtained when the system was operated with its LAND subroutine unchanged. This result was expected and could be deduced from the gross underestimation of runoff volume by LAND. Interestingly, the highest R^2-value of each year of 0.70 was given by infiltration model that assumed INF = CONSTANT * MELT.

(3) In comparing the simulations produced by the different algorithms the following trends are evident:
(a) INF = MELT - This model causes the simulated hydrograph to lag the occurrence of observed streamflow. Table 3 shows the difference was 3d in 1974 and 5d in 1975. The effect of the delay is to produce a simulated hydrograph with a short

Table 3. Effect of different infiltration model on the Efficiency, R^2 and the start of streamflow, Creighton Tributary 1974 and 1975.

Year	Algorithm	R^2	Day Streamflow Begins
1974	Observed		April 13
	LAND	-0.35	" 10
	INF = MELT	0.26	" 16
	INF = CONSTANT * MELT	0.70	" 10
	INF = INDEX(6d)	0.68	" 13
	INF = INDEX(6d) + CONST * MELT	0.30	" 13
1975	Observed		April 13
	LAND		" 14
	INF = MELT	-0.30	" 18
	INF = CONSTANT * MELT	0.70	" 12
	INF = INDEX(6d)	0.54	" 12
	INF = INDEX(6d) + CONST * MELT	0.60	" 12

time base, hence a much higher peak discharge rate than the observed (Figs. 4a and 5a).

(b) INF = CONSTANT * MELT - This model tended to cause the opposite effect on the time of beginning of simulated streamflow than obtained with INF = MELT; that is, simulated flow started in advance of observed runoff by 3d in 1974 and by 1d in 1975. This result can be explained by the fact that in both years the snowmelt sequence followed a delayed pattern. For this condition, since snowmelt infiltration is taken as a percentage of the meltwater produced, even small melt events produce runoff. On natural watersheds it is unlikely that these melt events early in the albation period would result in measurable streamflow.

(c) INF = INDEX(6d) - This model gave R^2-values of 0.68 in 1974 and 0.54 in 1975, which are of comparable magnitude of R^2 = 0.70 obtained in both years with INF = CONSTANT * MELT. It had the advantage over the latter in that the start of simulated flow agreed within 1d of the observed flow in both 1974 and 1975.

(d) INF = INDEX(6d) + CONSTANT * MELT - The performance of this model in simulating the observed hydrograph can be generally classed as falling intermediary between the results obtained with the algorithms, INF = CONSTANT * MELT and INF = INDEX x (6d). That is it produced closer agreement in the time of start of streamflow than the former but lower R^2-values and the same times of beginning of streamflow as the latter and in 1975 a higher R^2-value.

From the above results it is difficult to make a decision, one that can be supported by strong quantitative evidence, which of the three methods of sequencing the infiltration (items 3b, 3c, 3d) will consistently produce the better results. Each method has its advantages and disadvantages. Nevertheless, it is suggested the procedure involving the use of an infiltration index and assuming infiltration equal to a percentage of the amount of melt be adopted. This opinion is based on the rationale that the algorithm eliminates runoff from those small melt events occurring in the early part of the melt sequence and it ties infiltration in both magnitude and timing to the melt sequence.

4.4.2 Wascana Creek at Sedley

As discussed earlier in the report the Creighton Tributary is a relatively-small watershed (11.4 km^2) on which the depression storage elements were reasonably small and the "gross" drainage area could be assumed to be a reasonable approximation of the Prairies. The hydrophysical properties would not be considered typical of most larger watersheds in the region which are characterized by poorly-defined drainageways and large surface depressions. In order to test the performance of the infiltration algorithm in synthesizing streamflow from snowmelt on poorly-drained watersheds and to demonstrate the impact of "contributing area" on the agreement between simulated and observed flows the system was applied to Wascana Creek at Sedley.

Figure 6 shows the observed streamflow hydrographs for a low flow year, 1972 (Fig. 6a) and a high flow year, 1982 (Fig. 6b) plotted with three hydrographs generated with the NWSRFS: LAND - the system was operated with its LAND subroutine and a contributing area of 125

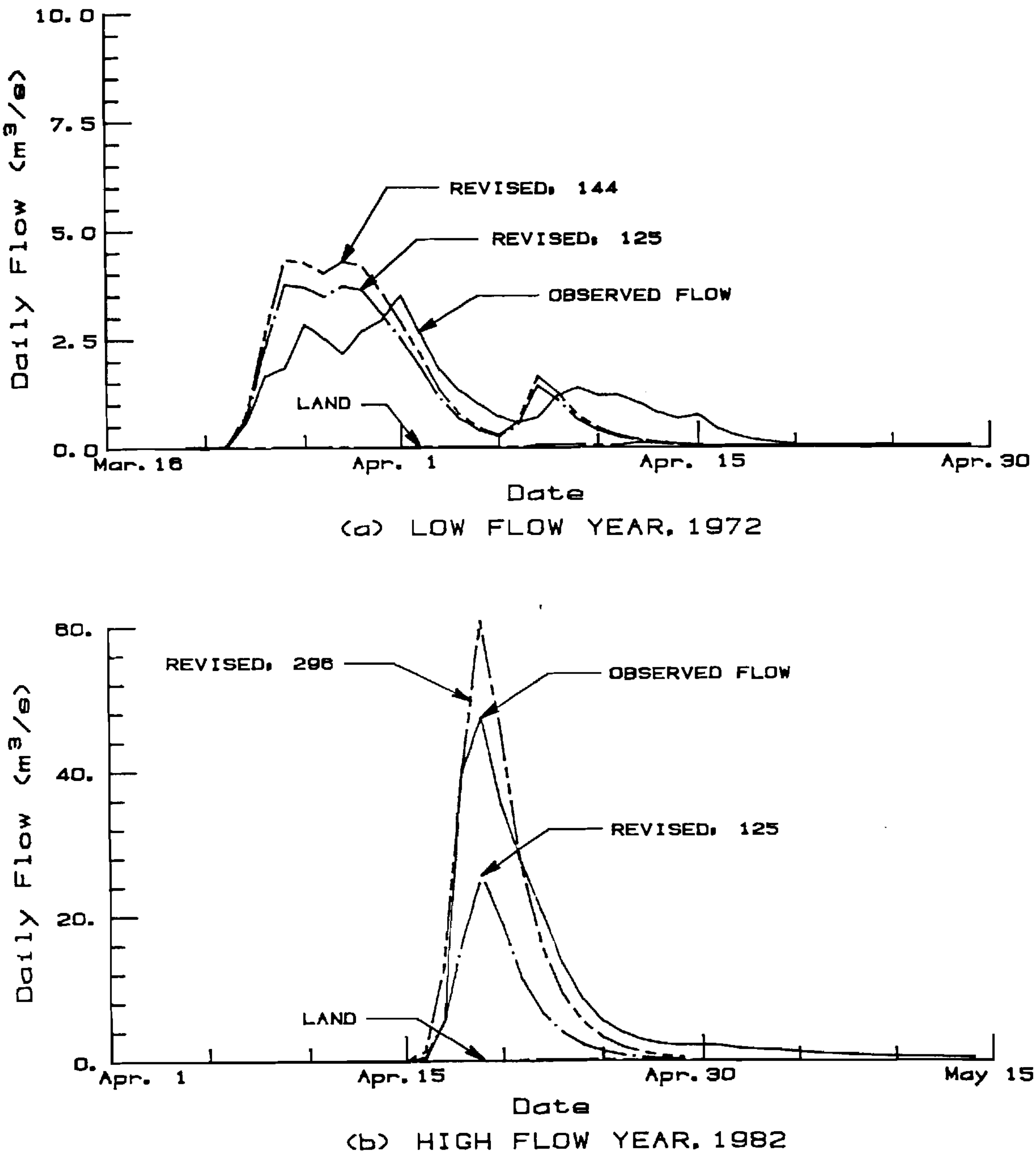


Figure 6. Observed and simulated hydrographs for Wascana Creek at Sedley, Saskatchewan: (a) low flow year, 1972, and (b) high flow year, 1982. LAND - the NWSRFS was operated with its "LAND" subroutine and a contributing area of 125 km^2, the "effective" drainage area; REVISED 125 - the NWSRFS with the LAND subroutine replaced by the infiltration algorithm and a drainage area of 125 km^2; and REVISED 144 (Fig. 6a) and REVISED 296 (Fig. 6b) - the NWSRFS with the infiltration algorithm and a drainage area (144 km^2 or 296 km^2) which produced the observed volume of runoff.

km^2, the "effective" drainage area; Revised 125 - the NWSRFS with the LAND subroutine replaced by the infiltration algorithm (INDEX(6d) + CONSTANT * MELT) and a drainage area of 125 km^2 and Revised 144 (Fig. 6a) or 296 (Fig. 6b) - the NWSRFS with the infiltration algorithm and a drainage area (144 km^2 or 296 km^2) which produced the observed volume of runoff. The respective return - period volumes and peaks correspond to approximately 3y and < 2y events in 1972 and the 10y and 50y values in 1982. All simulated hydrographs shown in Fig. 6 used the same model parameters; only the size of the drainage area was changed. Also, for the comparisons the simulated hydrographs were positioned so that the start of runoff agreed with the time of beginning of observed flow. From the data in Figs. 6a and 6b it can be observed:

(1) The NWSRFS with its LAND subroutine grossly underestimates the observed volume of runoff. For example, in 1982 the observed runoff, expressed as an equivalent depth of water on a drainage area of 125 km^2, was 153 mm compared with a depth of 2 mm simulated by the LAND subroutine. The result is the same as that reported for the Creighton watershed.

(2) In years of low flow the "effective" area (125 km^2) of the watershed is the better estimator of the "apparent" area of the watershed contributing to the peak discharge; in years of high flow a contributing area equal to or less than the "gross" area (350 km^2) gives the better simulation. A dependency in the degree of association between hydrographs on basin size is expected because the volume of snow water used as input to the system is directly related to area. The R^2-values of the simulated hydrographs using a contributing area of 125 km^2 were 0.70 in 1972 (low flow year) and 0.48 in 1982 (high flow year) respectively. When the size of the contributing area is assumed to be 296 km^2 R^2 increases in value to 0.89 for 1982.

(3) The agreement between the shapes and time elements of the simulated hydrographs using the infiltration algorithm and observed hydrographs vary in the two years. For 1972 the

agreement would be classed as fair to poor; in 1982 it would be considered satisfactory.

Another finding, observed in comparisons of simulated and observed hydrographs for ten years of record, was that the time of simulated flow consistently lagged the beginning of observed flow. The delays ranged from 2-5 d with the larger values associated with years of low snowcover. It is suspected that this trend reflects a problem in accurately simulating the meltwater release and water transmission properties of snow-filled channels.

4.5 SUMMARY

The material presented in this Section demonstrates methods of interfacing the infiltration model with an operational forecasting system, in the examples presented the U.S. National Weather Service River Forecasting System (NWSRFS), and the results obtained with the revised system in synthesizing streamflow from snowmelt from Prairie watersheds. Comparisons between the potential volume of runoff and observed streamflow showed that the model will provide estimates of runoff within acceptable practical limits and because of the improved estimate of the volume of flow a modeller can expect better simulations of streamflow discharge rates. Procedures are also described for estimating the size of the contributing area of a watershed, based on the snowcover water equivalent, infiltration potential and surface storage characteristics, to be used in streamflow simulations.

In summary, it is considered that the improvement in performance demonstrated by the NWSRFS with the infiltration model in simulating streamflow from watersheds in Saskatchewan is sufficient to warrant implementing the model in the Streamflow Synthesis and Reservoir Regulation Model (SSARR).

5. IMPLEMENTATION OF THE SSARR MODEL ON THE HP1000 COMPUTER

The implementation of the SSARR model on the HP1000 computer required attention to four distinct problems, namely: the incompatibility with IBM FORTRAN; the question of program size; the difficulties associated with an archaic and poorly-structured code and the need for support programs. A list of these problems and the manner in which they were solved is presented below.

5.1 IBM INCOMPATIBILITY

(1) IBM uses a '32 bit' integer while HP uses a '16 bit' integer, this meant it was necessary to declare all integer variables to be double for compatibility. This involved a trivial change to the compiler "job" line at the start of each subroutine.

(2) In IBM FORTRAN, integers can be inputted using real format and then through an equivalence statement thay can be treated as real variables. This kind of type conversion is not possible on the HP1000. The problem was solved by searching for all input statements where integers were read using real format, changing the variables to real and equivalencing them back to the integer variable. Most of these problems were found in subroutine INCARD, a revised listing is included in Appendix A.

(3) Output routine CPRINT required changes in order to print real and integer variables correctly (a listing of the modified version of CPRINT is included in Appendix B). As per item (2) above, the problem stems from the fact that IBM does type conversion on input/output based on the type of the format statement.

(4) On output IBM treats blank columns as zeroes, HP treats them as blanks. HP does have an IBM compatibility feature (BZ) that allows blanks to be read as zeroes. Solving the problem was a simple matter of inserting BZ in every input format statement in the program.

(5) The SSARR model makes use of an IBM non-standard subroutine called CORE for internal data (or core) transfers. An attempt was made to emulate the function of this routine with a FORTRAN subroutine, but this proved to be impossible due to the internal data type conversions mentioned previously. It became necessary to change over completely and use FORTRAN 77 standard Internal Read statements. This involved a radical change in the way input data was passed between the various input routines. A new common block called DOH was created (see Appendix A). This block uses character strings to pass input data from module to module, the data is then retrieved using Internal Read statements.

5.2 PROGRAM SIZE

The common block size requirements of SSARR were too large to be handled as ordinary named common on the HP1000. It was necessary therefore to place common block 'C1' in EMA (Extended Memory Area) common, this is memory that is outside of the normal address space of the program. This technique is normally very easy to apply, however, in this case, special care was required due to the fact that 'C1' is the storage area for all of the process control variables.

Direct access disk files presented another obstacle because these files can not be handled as external devices from the FORTRAN program. The size penalty for including the file handling package in the program is very large. The only solution was to write a separate FORTRAN program, callable from the model, to do Direct Access Memory transfers. Sequential access files are handled as external devices by the program.

In an effort to reduce program size for greater ease of loading, several unused subroutines were replaced by dummy routines. Those replaced were BASINM, BASMET, BASMC and CPRINM.

5.3 PROGRAM STRUCTURE

The majority of the SSARR subroutines are difficult to read and understand, this is due to several factors including, sparse comments, poor structure, and overuse of "GO TO" and "ARITHMETIC IF" statements.

The first 100 lines of INCARD were restructured using "BLOCK IFS" wherever possible. The main purpose for doing this was to facilitate the change from IBM "Call CORE" to FORTRAN 77 standard internal read statements, and the use of character variables for logic control - A listing of the revised subroutine is included in Appendix A. A beneficial effect of the restructuring is that "Block If" logic is much easier to understand.

In preparation for modification of modules BASEC and BASINE, they were re-organized and updated. It was necessary to review both routines line by line and change to "Block If" logic in order to be able to identify areas of the code that would have to be modified to incorporate the DOH infiltration algorithm. Subroutine BASEC was split into two parts, the new routine SCA_DEPLETE is the snowcover depletion part of BASEC. Subroutine BAS_PRINT was split away from BASINE and modified slightly so that the output format for basin results is consistent for all watershed options (ie. Split Watershed, Elevation Band). Listings of the revised versions of BASINE and BASEC are included in Appendices C and D respectively.

The first "bug" found in the program was within subroutine BASEC. This "bug" was introduced when subroutine BASEC was split away from BASINE by the ARMY CORPS OF ENGINEERS. When the new subroutine was created, communication between BASEC and BASINE was accomplished by means of a new common block BASIN, which contained all but two of the local variables common to both modules. This problem is not a problem if a large computer is used, since the entire program is memory resident at all times. However, with a segmented program on the HP1000, this is not the case, each call to a subroutine brings in a fresh copy of that routine. Local variables are initialized to zero with each fresh copy. The end result in this case was that variable SSA was initialized correctly only once each "day" (every fourth call) which resulted in only one quarter of each day's precipitation being processed. The solution was to put SSA and SFA in common block BASIN. A search was conducted for other variables in this category, none were found.

5.4 SUPPORT PROGRAMS

The plotting routine in the SSARR model is a rather crude line printer plot and it would have required considerable effort to get it running. The simplest solution was to write a separate FORTRAN program to read the SSARR output and re-write it in a form suitable for a generalized plotting package. This system provides quick, accurate plots of one or several data sets on any given graph. For instance it is now possible to compare the hydrograph produced by the revised model to the original model and to the observed flow. This plot program would not likely be of any value to Alberta Environment.

Two other support programs were also required. The first, to convert meteorological data from NWS (National Weather Service) format to SSARR format, and the second to convert AES (Atmospheric Environment Service) format to SSARR format.

6. IMPLEMENTATION OF DOH INFILTRATION ALGORITHM

The process of getting the SSARR model up and running took much longer than expected. One benefit of this work was the familiarity gained with the various SSARR subroutines their inputs and communication between them. This familiarity made it obvious that implementation of the DOH infiltration algorithm was not possible simply by making changes to the input tables.

Experience gained in modifying the NWSRFS Model was applied to the alteration of the SSARR Model. Infiltration sequencing based on the combination INDEX(6d) and CONSTANT/MELT (sec. 3.1, p. 10) was chosen to implement in the SSARR based on its performance in the NWSRFS. The Soil Moisture Index (SMI) of the SSARR was treated in a fashion similar to the Upper Zone soil moisture storage of the NWSRFS.

Four distinct areas of the SSARR program required revision in order to implement the DOH Infiltration Algorithm. These were: the input routine INCARD; the overall watershed control subroutine BASINE; the watershed processing routine BASEC and the output routine CPRINT. All modified lines in the various modules are flagged with the following: "! PAT LANDINE (date)".

6.1 INCARD

Modification of INCARD was simply a matter of changing the appropriate read statement to input a Prairies-Option. The read statement in question is at line 268 of the listing in Appendix A. Transferring that value to the processing routine was more difficult. The best way to pass the option appeared to be through the "basin characteristic record" on direct access file "IODC". However, all available space on this record was used. The only way to get around this was to change the size of the space allotted for the station name and description from 11 words (44 characters) to 10 words. The extra word made available is now used for the Prairies-Option. It is entered on the "CB01" card at column 17, and the value is stored in word 13 of the "basin characteristic record" on direct access file "IODC". (See Appendix F for changes to the SSARR Users Manual.) There are four defined values for the Prairies-Option; 0 - Default value, DOH algorithm bypassed; 1 - Limited infiltration case; 2 - Unlimited infiltration case; 3 - Restricted infiltration case.

6.2 BASINE

Modification of BASINE consisted of the insertion of two "If-Then-Endif" blocks. The first is located at line 367 (Appendix C) in the initialization section to ensure that variables pertaining to the Prairies-Option are defined. The second is in the processing section at line 576 immediately after the call to BAS_PRINT. If the current snow water equivalent (SWE = XS(48)) exceeds the previous maximum SWE, the "block if" is executed. The total potential infiltration (TOTINF) for the "Limited" case is calculated (see Eq. 1, p. 5) and the infiltration threshold is calculated based on a spring snowmelt infiltration period of 6 days (sec. 3.1, p. 9).

6.3 BASEC

Alterations to BASEC were more extensive. New "If-Then-Else-Endif" blocks were put in at lines 430, 755 and 781. If the snow-covered area (SCA) is greater than 1.0 and if the Prairies-Option (PR_OPTN) is greater than zero (0) then a new section of code is executed otherwise the old code is used. At line 755, the new code simply sets BaseFlow Percent (BFP) to zero. Similarly, at line 781, Sub-Surface flow Percent (SSP) is set to zero. At line 430, the new code is simply a call to a subroutine called PRAIRIES, this routine is included as part of the BASEC listing, beginning at line 1017 in Appendix D. Two variables, Watershed Precipitation (WP) and Period Snowmelt (PSN) are passed to the routine, which returns the Runoff Percent (ROP) for the period.

If the Prairies-Option (PR_OPTN) equals one (Limited Infiltration Case), Subroutine PRAIRIES compares the sum of RAIN + PSN to THRESHOLD, if THRESHOLD is exceeded, Spring is declared. The infiltration ratio (INFR) is calculated as: INFR = (TOTINF - SUMINF)/(MAXSWE - SUMINF) where SUMINF is the sum of infiltration that has occurred. INFR represents the fraction of each day's melt that will infiltrate. If it is spring then ROP is 1.0 minus INFR, otherwise ROP is zero, which means that any minor melt occurring before spring will infiltrate completely. If PR_OPTN is 2 then ROP is set to zero (no runoff). If PR_OPTN is greater than 2 then ROP equals one (no infiltration).

The changes outlined above resulted in a program that produced good hydrograph simulation in terms of peak flow and total volume. However, when the printed results showing moisture input/output for the basin were studied a new problem surfaced. The melt plus rain for each period should be divided between infiltration and runoff according to the value of ROP. Instead, the melt plus rain was being added directly to the Soil Moisture Index (SMI) as well as sending the correct portion to runoff. This caused the SMI to be too high, which resulted in extra runoff (Runoff depends on SMI) and of course the water input/ output for the basin did not balance.

A search was conducted to locate the code that was causing the imbalance. It was traced to a section of code beginning at line 919 in subroutine BAS_PRINT (part of BASINE listing in Appendix C). This section is a soil moisture feedback loop introduced by Alberta Environment. The code was detoured by putting an "If-Then-Endif" block around it. If the Prairies-Option is greater than zero, this section is bypassed. This means that the feedback loop can still be used by Alberta Environment simply by setting the option to zero (default).

The above change produced some improvement. Certain individual periods in the printout showed a water balance; however there was no overall balance from the beginning to the end of melt. Water was being created in the switch from a snow-covered to a snow-free watershed. The method used to transfer water from the Snow Covered Area (SCA) to the Snow Free Area (SFA) was at the root of this error. A simple solution was found by writing a new variable DELTA_SMI, which is equal to the Moisture Input (MI) multiplied by one minus ROP, into a temporary data file for each computation period. When the SFA basin is processed, this file is rewound, read a line at a time and the value of DELTA_SMI for the corresponding period is added to the current SMI. This solved the problem of transferring soil moisture from the SCA to the SFA.

There was one other minor factor affecting the water balance. The model allows the user to set a maximum value for the Soil Moisture Index (SMIMAX). If this maximum was exceeded, the SMI was simply reset to SMIMAX and the excess water was "wasted". This could amount to an appreciable sum of water in a basin that was always near saturation. Changes were made so that SMI excess is now converted to runoff. There are two locations in BASEC where this was done, line 691 and 736; and one in SCA_DEPLETE at line 948.

In the course of checking water balances it was noticed that the column headed ETI (EvapoTranspiration Index) in the basin results file was not the computed ETI for the period, but rather the maximum that could have occurred. A change was made at line 961 of BAS_PRINT so that computed ETI would be written.

Other minor changes were made to BASEC to cause the SCA and the percent Snow Volume (SNVOL) to be reduced to 0.05 rather than 1.0 at the end of melt. This eliminated the trickle of water discharged by the SCA after melt was over and at the same time improved the appearance of the SCA and SNVOL columns because they print as 0.0 instead of 1.0 when melt is over.

6.4 CPRINT

A minor change was made at line 207 of CPRINT to cause it to print the Prairies-Option that had been selected for that run.

7. STREAMFLOW SIMULATION

7.1 WASCANA WATERSHED

All initial trials and debugging of the REVISED SSARR Model were conducted on the Wascana Creek watershed at Sedley, Saskatchewan (For details concerning the watershed refer to page 10). Data for the years 1972, 1974, 1979, 1980 and 1982 were used in the "break-in" process.

The starting point for the input parameter set was taken from a sample data set used by Alberta Environment for the Red Deer River at Sundre. This data set required several modifications, including obvious changes such as watershed elevation and area. Other changes were made to such things as SMIMAX, base and rain-freeze temperatures and surface routing parameters.

The value of SMIMAX was changed from 127 to 178 mm. The value of 178 mm was arrived at by equating the SMI in SSARR to the upper soil zone, defined as that depth to which meltwater will penetrate. This soil zone is approximately 300 mm in depth (Granger et al., 1984) and if a saturation moisture content of $\sim$55% by volume is used, then the maximum storage capacity of this zone is 165 mm. For the NWSRFS Model, this was rounded up to 170 mm, which produced a good streamflow simulation. In the case of the SSARR Model 165 mm was converted to inches then rounded up to 7.0 (178 mm). In the operation of the model the user needs to know the degree of saturation of the soil layer, 0-300 mm, prior to melt, this value multiplied by SMIMAX should be entered as the starting point for SMI prior to melt.

The base temperature and the rain-freeze temperature were set to 1.1^{o}C (34^{o}F); other values were tested but 34^{o}F produced the best agreement in the time elements of the simultated and observed hydrographs. Setting the base temperature above freezing is actually a round-about way of accounting for the negative internal energy content and storing liquid water in the snowpack, thereby preventing any of the pre-spring "trickle" from showing up on the simulated hydrograph.

Hydrograph timing and shape were further improved by adjusting the surface flow routing parameters. The number of surface routing phases was set at 7 and the surface time of storage to 12 hours.

Melt rates for the March-April period were also adjusted to correspond more closely with data from Bad Lake, Sask. and minor changes were also made in the monthly ETI (EvapoTranspiration Index) table and the SMI-RI-ROP table.

The contributing area for the basin was different for each year studied. In the simlations reported below the values for the contributing areas were those reported by Gray et al. (1985b) as a result of their work on Wascana Creek with the NWSRFS. For a more complete discussion of the determination of contributing area, refer to section 4.3 of the report and Gray et al. (1985b).

7.1.1 Simulations

Figure 7 shows the observed streamflow hydrographs plotted with the simulated hydrographs generated by the SSARR and Revised SSARR models for a low flow year, 1972 (Fig. 7a) and a high flow year, 1982 (Fig. 7b). For comparable results using the NWSRFS refer to Fig. 6, p. 26. The input data sets used for the simulations were the same except in the Revised SSARR the Prairies option was set to one (Limited Case). In the low flow year (1972) up to April 18, the streamflow volume simulated with the Revised system was only 4% less than the observed; with the SSARR it was 48% less. The agreement in shapes of observed and simulated hydrographs for the year is less than ideal and may be attributed to a host of factors, for example, poor choice of the melt factor (this was the only year studied with melt occurring in March), an incorrect base temperature, incorrect simulation of other factors affecting snowcover ablation and melt, runoff generated principally from in-channel accumulations and others. Conversely, as shown in Fig. 7b, the agreement of the hydrographs in both shape and timing in the high flow year is markedly improved from the results obtained in 1972. Further, it is obvious the simulation with the Revised SSARR is better than that obtained with the original system. The R-squared value for the Revised SSARR was 0.792 compared with 0.632 with the SSARR and the volume of runoff simulated with the Revised SSARR was 12% less than the observed whereas SSARR underestimated the observed flow by 34%.

Simulations of streamflow were also conducted on the watershed for three other years 1974, 1979 and 1980. A comparison between observed and simulated volumes for all five years is given in Table 4. From these data it can be observed that in all years except 1980 the relative error in predicting the runoff volume was substantially smaller with the Revised SSARR compared with the SSARR. Also it can

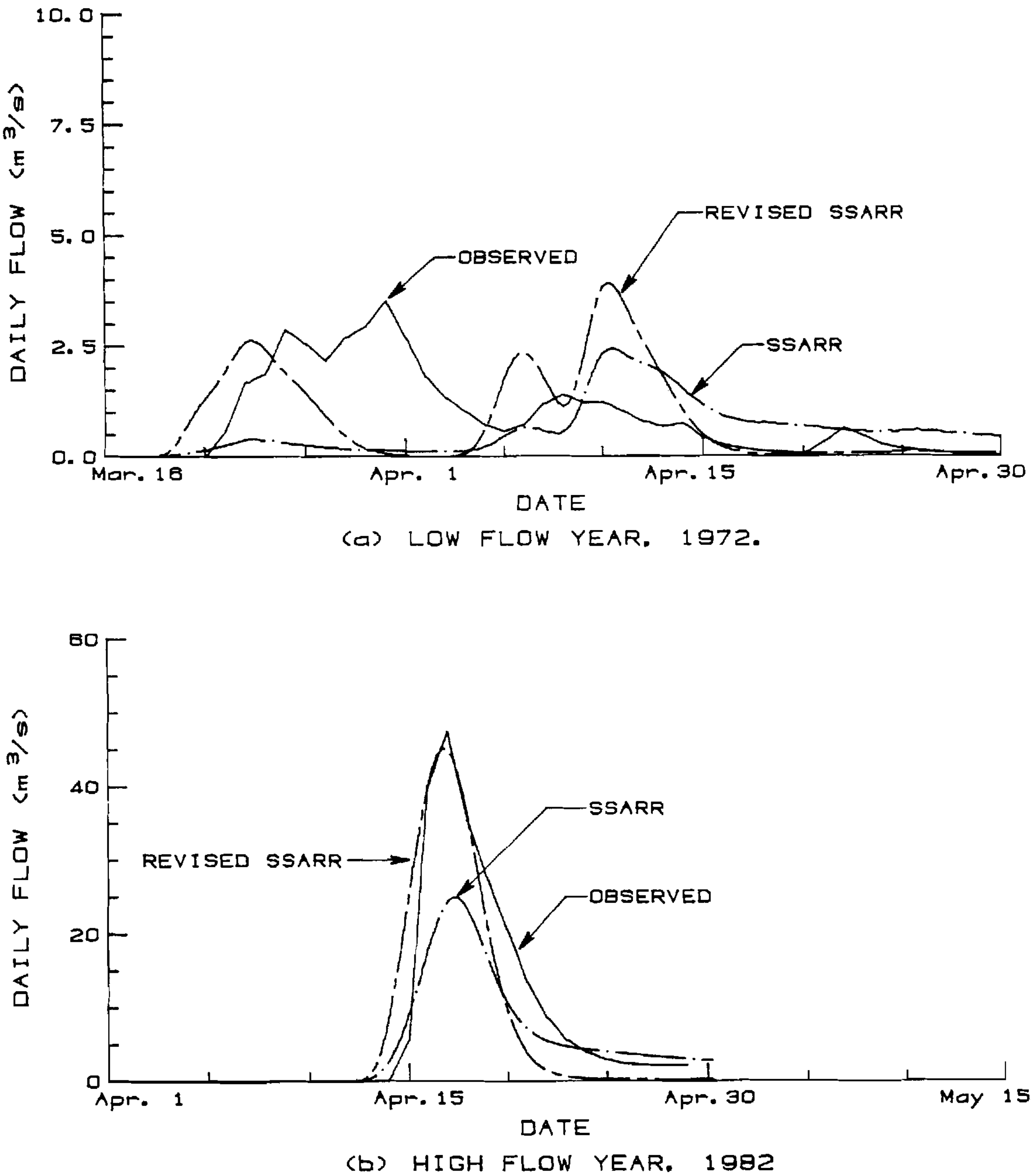


Figure 7. Observed and simulated streamflow hydrographs from snowmelt for Wascana Creek at Sedley, Saskatchewan: (a) low flow year, 1972 and (b) high flow year, 1982. Revised SSARR - the SSARR model with the DOH infiltration algorithm and SSARR - the model operated in its original mode.

Table 4. Comparison of observed flow volume and volumes simulated with Revised SSARR and SSARR models for five years of snowmelt runoff on Wascana Creek near Sedley, Saskatchewan.

Year	Date Flow Ends	Observed Flow (cmsd)	Revised SSARR		SSARR	
			Flow (csmd)	Error %	Flow (csmd)	Error %
1972	Apr.18	38.9	37.4	4	20.2	48
1974	May 10	327.5	254.2	22	231.7	29
1979	May 1	152.7	127.5	17	85.7	44
1980	Apr.20	47.9	58.1	21	40.4	16
1982	Apr.30	219.7	193.3	12	145.9	34
Mean				15.2		34.2
Std. Deviation				7.4		12.7

be observed that the simulated volumes, except that volume simulated by the Revised SSARR, in 1980, are less than the observed flow. This result was surprising inasmuch as the values for the contributing area used in the simulations were those values which produced the observed flow almost exactly with the NWSRFS and the same infiltration algorithm, meteorological inputs, initial soil moisture contents and initial snow water equivalents. The reason for the difference in volumes produced by the NWSRFS and the SSARR and the underprediction of the observed flow by SSARR can be attributed to the fact that the two models treat snow accumulations and ablation differently. For example, SSARR uses a low-level cut-off to eliminate very small or insignificant snowfalls. Hence in many years, the maximum snow water equivalent (MAXSWE) used in the SSARR will be less than the value used in the NWSRFS. Table 5 compares values of MAXSWE given by the two systems. Only in 1980 was the MAXSWE with SSARR greater than for the NWSRFS; this was due to the fact that SSARR predicted a later date of spring break-up and as a consequence an additional (late-occurring) precipitation event was added to the snowpack. The net result, as shown in Table 4 was to cause the runoff volume simulated by the Revised SSARR in 1980 to be larger than the observed.

The results above suffice to demonstrate that the infiltration algorithm significantly improves the simulation of streamflow

Table 5. Comparison of MAXSWE for the NWSRFS and SSARR.

Year	NWSRFS mm	SSARR mm
1972	45	41
1974	137	129
1979	83	77
1980	51	57
1982	99	94

from snowmelt by the SSARR model on a Prairie watershed. On average, the algorithm reduced the relative error in predicting volumes by a factor of ∿2, from 34 to 15%. At the same time however, the data point out the high degree of dependency of the agreement between simulated and observed hydrographs on MAXSWE and contributing area. Reasonable agreement can only be expected when these parameters, or their product have been accurately evaluated.

7.2 VERMILION RIVER AT VEGREVILLE

The general topography of the Vermilion River basin above Vegreville is flat to gently rolling, with significant amounts of depressional storage throughout the central and upper parts. The gross drainage area of the watershed is 1589 km^2, and the effective area is 613 km^2 (PFRA, 1985). Land use maps provided by Alberta Environment were not complete, but did indicate that significant areas of the southern and eastern parts of the watershed were unimproved pastureland (40%), the remainder of the basin is used principally for dryland production of cereal crops and oilseeds.

There are two major soil orders in the basin. Solonetzic soils make up approximately 60% of the area, while Chernozemic soils account for the remaining 40% (Bowser et al., 1962). Solonetzic soils are dominant in the south and east and in areas falling immediately adjacent to stream channels. The most common soil series in the Solonetzic area is Camrose Loam, which is rated as having a moderate drainage capacity. This means that water is removed slowly from the soil surface and a temporary water table often develops (Bowser et al., 1962). In the Chernozemic soil area, Angus Ridge loam is very common. This is a very fertile eluviated black soil which is well-drained (Bowser et al., 1962).

The water storage capability of the loam soils is rated as "medium", which means they are capable of holding from 50 mm to 125 mm of water per 300 mm of soil at field capacity (Bowser et al., 1962). This would suggest saturation capacities in the range of 33 to 83% by volume. Data obtained from the Canada Agriculture Research Substation at Vegreville (Personal communication) showed an average saturation moisture content of the Solonetzic soil to be ∿50% by volume (i.e. 150 mm of water per 300 mm of soil) and this value was used as the maximum soil moisture index (SMIMAX) of the SSARR model in the simulation trials conducted on the basin.

The pre-melt data available for the Vermilion basin was for the most part scanty and in some cases unreliable. The only soil moisture measurements available were from the Canada Agriculture Research Substation at Vegreville. These data were assumed to be of good quality, but they are only representative of that area of the watershed immediately adjacent to the research station. There were also several "key" years in which no data were collected, notably the fall of 1978 and 1979. The lack of soil moisture data made it necessary to use monthly rainfall data collected prior to freeze-up (Sept. and Oct.) to estimate the premelt soil moisture status. In this calculation it was assumed that the soil moisture content was near the wilting point (∿15%) at the end of August. The amount of precipitation occurring after Sept. 1 and before Nov. 1 was used to classify the soil moisture content into three broad categories: (a) above field capacity (33% by volume); (b) field capacity (25% by volume); and (c) below field capacity (17% by volume).

The only snow survey data available which had been collected directly on the basin was from the Bruce snow pillow course which is located near the main stream channel approximately 25 km south of Vegreville. Based on an "on-site" visit to the Bruce station it was considered that the exposure conditions at the site were sufficiently different from those of the surrounding area to put in question the reliability of the snow survey data as representing snow conditions on the watershed. Other comparisons of hydrometeorological data verified this conclusion. For example, the snow water equivalent (SWE) at the pillow on Mar. 1, 1979 was 61 mm and on Mar. 15 it was 81 mm. A review of the precipitation records for Vegreville reported by the Atmospheric Environment Service showed only 8 mm of snowfall in the period; Camrose showed no precipitation. Again on March 1, 1978, SWE was 74 mm; on March 15, SWE was 94 mm; no precipitation was reported during the period at Vegreville and only 1 mm at Camrose. The second highest SWE recorded at the Bruce pillow during the years 1975 to 1984 was 94 mm on March 15, 1978; the lowest recorded streamflow was in 1978.

In view of the quality of the snow pillow data it was discarded and the snow depth measurements reported by the Atmospheric Environment Service for the Canada Agriculture Research Substation at Vegreville were used for the simulation. These data appeared to be more consistent with the recorded streamflow than the snow pillow data. The initial value of snowcover water equivalent was taken as the product of the snowcover depth (Vegreville) and the snow density (Bruce snow pillow) on March 1 of a given year. Updating this variable to account for late-occurring snowfalls was accomplished using measurements from a Nipher snow gauge at Vegreville.

7.2.1 Simulations

Figures 8 and 9 show the simulated and observed hydrographs from snowmelt for the Vermilion River at Vegreville for high, medium and low flow years. In the figures the Revised SSARR is output from the model containing the DOH infiltration algorithm; SSARR is output from the system when operated in its original mode. Identical input parameters were used in each system. Runoff in 1974 (Fig. 8a), the high flow year, was the result of very high antecedent soil moisture conditions caused by above normal rainfall in the fall (78 mm occurring between September 1 and October 31, 1973) and a very heavy, deep snowpack. The hydrographs described as the medium flow year, 1979 (Fig. 8b) represent discharge produced under very high antecedent

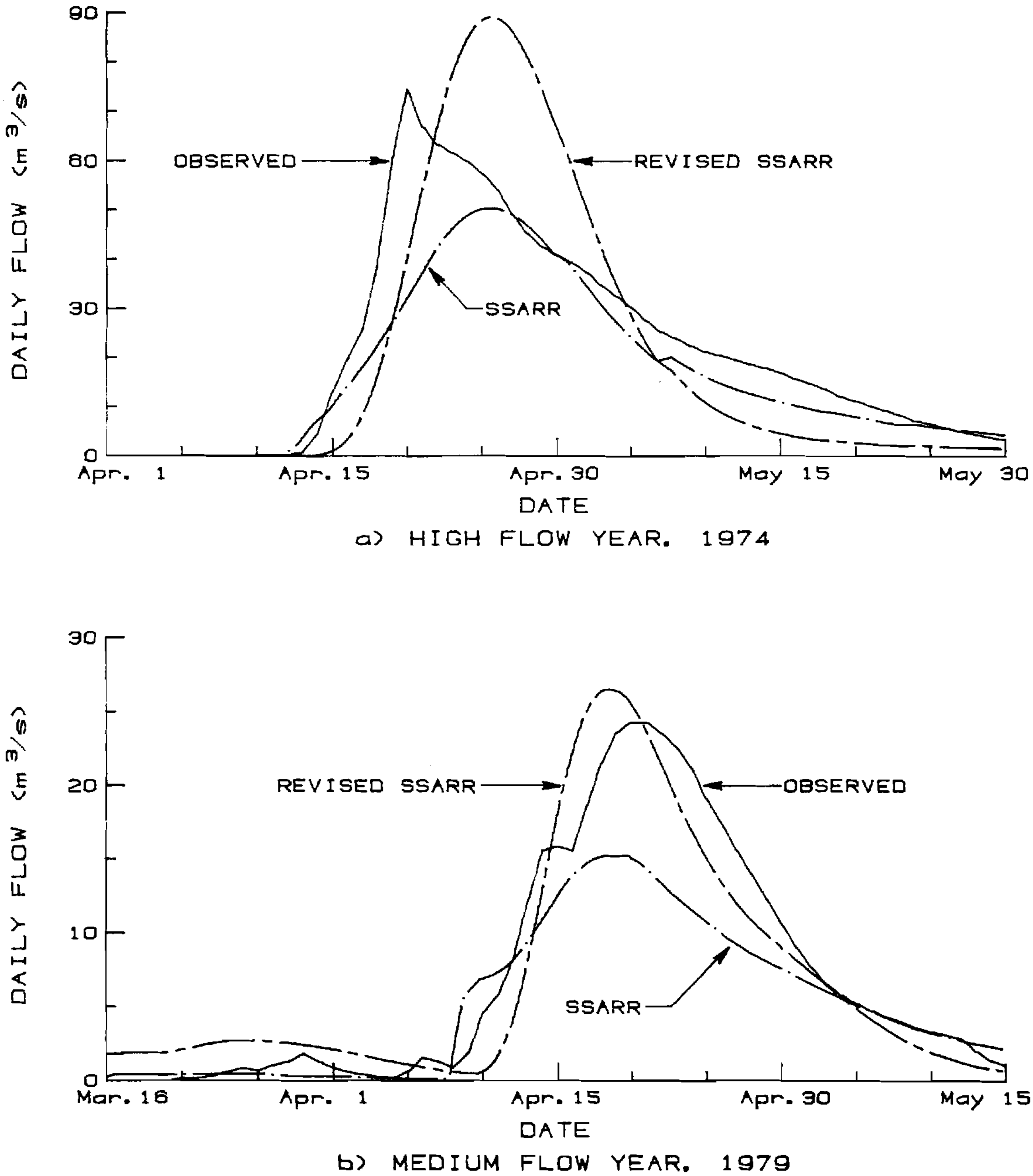


Figure 8. Observed and simulated streamflow hydrographs from snowmelt for Vermilion River at Vegreville, Alberta: (a) high flow year, 1974 and (b) medium flow year, 1979. Revised SSARR - the SSARR model with the DOH infiltration algorithm and SSARR - the model operated in its original mode.

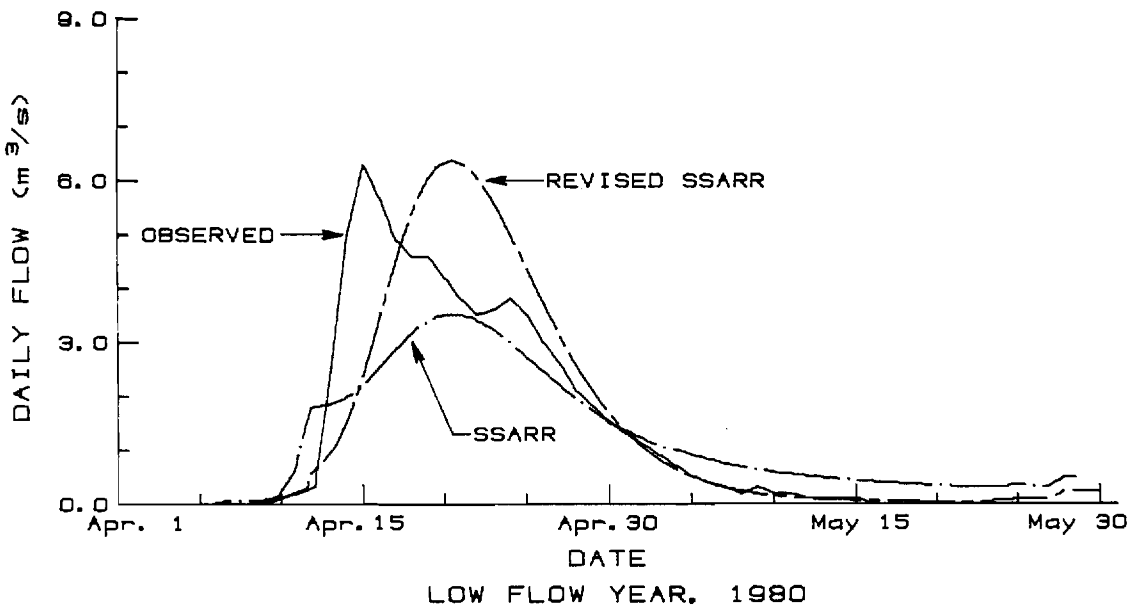


Figure 9. Observed and simulated streamflow hydrographs from snowmelt for the Vermilion River at Vegreville, Alberta for a low flow year, 1980. Revised SSARR - the SSARR model with the DOH infiltration algorithm and SSARR - the model operated in its original mode.

moisture conditions (110 mm of rain occurred between September 1 and October 31, 1978) and an average snowcover. Figure 9, the low flow year, 1980, can be taken as representing streamflow runoff under conditions where the fall and winter precipitation amounts were near normal.

Table 6 summarizes the data inputs and the results of the simulations given in Figs. 8 and 9. It should be noted that 1979 was used as a calibration year in which the size of the contributing area was adjusted in increments of 70 km^2 (25 mi) until the volume of runoff produced by the Revised SSARR agreed within 2% of the observed flow. Experience gained in this process was used to estimate the size of the contributing area for 1974 and 1980. As mentioned previously, pre-melt SMI was put into one of three categories based on the rainfall received the previous fall. 1974 and 1979 were considered wet (above field capacity); fall moisture conditions in 1980 were taken as average (field capacity). The maximum SWE listed in Table 6 is the value for March 1.

In comparing the observed and simulated flows given in Table 6 it is obvious that the Revised SSARR provided better approximations of the observed flow volumes than obtained with SSARR. These findings are consistent with the results obtained with the two systems on Wascana Creek.

Table 6. Summary of input parameters and output for simulation with the SSARR and Revised SSARR models on the Vermilion River.

Year	Cont. Area	Fall Rain	Pre-Melt SMI	MAX SWE	Flow				
					Observed	Revised SSARR	Error	SSARR	Error
	km^2	mm	mm	mm	cmsd	cmsd	%	cmsd	%
1974	972	78	100	137	1297	1232	5	1010	22
1979	764	110	100	50	432	425	2	323	25
1980	278	64	75	50	74	78	5	62	17

7.3 GENERAL OBSERVATIONS

In the investigations conducted with the SSARR and Revised SSARR models for simulating "observed" streamflow from snowmelt on the Wascana and Vermilion watersheds no attempt was made to maximize the agreement between the "simulated" and "observed" hydrographs. It is known that SSARR offers sufficient flexibility that by changing different parameters such as; the melt factors, the base temperatures used for melt or distinguishing precipitation as rain or snow, the number of reservoirs used for routing, the size of the contributing area or other variables, much closer agreement between the hydrographs could have been achieved. This objective was not pursued because of the limitations imposed by the data sets used in the calculations; e.g. with respect to quality, reliability, representativeness and completeness, and most changes would lack a physical base, hence put in question the value and integrity of the exercise. As a consequence, the evaluations have been based on the agreement between the flow volumes simulated by the two systems with the same set of input parameters and the observed flow. Even the findings from this simple analysis may be subject to question, particularly for the Vermilion River, because the gauging station is a natural control and the errors in measurement of discharge unknown.

It is also pointed out that the infiltration model used in the Revised SSARR was developed from field data that did not include Solonetzic soils. The manner in which the snowmelt infiltration characteristics of frozen, Solonetzic soils should be best-represented in the infiltration model requires further study. For example, should they be treated as areas having a small constant, but limited water storage capacity or can they be assumed to have characteristics analagous to wet, non-solonetzic soils of Limited infiltration potential?

Despite the above remarks, it is believed that the Revised SSARR will lead to "improved" simulations of streamflow from snowmelt on the Vermilion River from those obtainable with SSARR; the degree of improvement largely depending on proper evaluation of several model parameters.

8. SUMMARY

This report presents the results of an investigation directed to interfacing a snowmelt infiltration model for frozen soils with the U.S. Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation model (SSARR) and testing the performance of the revised system (Revised SSARR) in simulating streamflow from snowmelt on Prairie watersheds.

The infiltration model used is that developed by the Division of Hydrology, University of Saskatchewan which suggests that for practical purposes frozen soils may be grouped into three general classes with respect to their snowmelt infiltration potential: Restricted -all snow water goes to runoff; Unlimited - all snow water infiltrates; and Limited - infiltration (INF) is related to the snowcover water equivalent (SWE) and soil water/ice content of the soil layer, 0-300 mm, at the time of melt (θ_p). An empirical expression describing the interrelationship between INF, SWE and θ_p for the Limited case is presented.

The procedures and methodologies of implementing and incorporating the infiltration model into operational streamflow forecasting systems are discussed. Specific details with respect to such aspects as: revisions to the existing subroutines and the development of a subroutine for defining the infiltration algorithm required to interface the model with the U.S. Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation model (SSARR) are presented and described.

Tests were conducted with the Revised SSARR, the model with the infiltration algorithm, and the SSARR in simulating streamflow from snowmelt on the Wascana Creek watershed near Sedley, Saskatchewan and the Vermilion River at Vegreville, Alberta for several years of record. Comparisons between the flow volumes showed that the Revised SSARR substantially reduced the relative error in estimating the observed flow from that obtained with SSARR. Reductions in the relative error ranging from 7-44% of observed were found.

The discussions emphasize the need for accurate estimates of model input parameters, such as snowcover water equivalent, size of contributing area and soil moisture/ice content at the time of melt for reliable simulation of streamflow from snowmelt on a Prairie watershed and proper evaluation of model performance.

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10. APPENDICES

10.1 Appendix A

Common Block DOH

```
C
C     INCLUDE FILE FOR COMMON BLOCK 'DOH'      SSARR
C
      CHARACTER TEXT*80
C
      COMMON /DOH/TEXT
C
c     TEXT is a character variable used in reading the input
c          file line by line and  then transferring the
c          data to the appropriate real or integer variable
c          via Internal Read Statements.
```

Subroutine INCRD

```
FTN7X,J,E
$EMA /C1/
      SUBROUTINE INCARD (ICC, ICN, ISTA, IR)
     +, 1:43 PM  WED., 24  APR., 1985 (851126.0941)
C        INPUT A CARD IMAGE AND IDENTIFY AND FORMAT IT. RETURN AN
C         INTERNAL CARD CODE NUMBER (ICC) WITH VALUES 2 THROUGH 100
C         IF IDENTIFIED. ICC =1 IF CARD CANNOT BE IDENTIFIED, AND IR(1)
C         AND IR(2) WILL CONTAIN COL. 1 AND 2 RESP., IN A1 FORMAT.
C         IR(3) - IR(19) WILL CONTAIN COL. 14-80 IN A4 FORMAT.
C
C         RETURN COL. 3-4 IN I2 FORMAT (ICN), AND COL. 5-13 IN I9
C         FORMAT (ISTA).
C            RETURNED CONTENTS OF IR ARRAY ARE DESCRIBED AT EACH
C         CARD READ INSTRUCTION.
C             UNIT  IOR IS CARD READER.
C
C     Re-organized to use character variables and Block If logic
C     June 1985 by:
c                 Pat Landine
c                 Division of Hydrology
c                 University of Saskatchewan
C
$INCLUDE [C1    :PL:121,NOLIST
$INCLUDE [DOH   :PL:121,NOLIST
C
      INTEGER NPA (1), IR(1), IRT(35)
      REAL XIR(35)
      CHARACTER*1 CC1,CC2,XT*4
      EQUIVALENCE (NP, NPA(1))
```

```
      EQUIVALENCE (IRT(1),XIR(1))
C
C     Read a Line into Character Variable
c
    1 READ (IOR,'(A)', END=390 ) TEXT
      WRITE (IOB,'(A)') TEXT
C
      IF(TEXT(1:1).EQ.' ') GO TO 1            ! Test for comment card
      IF(TEXT(1:2).EQ.'XX') THEN
         WRITE (IOW,'(A)') TEXT(3:)           ! "XX CARD Comment
         GO TO 1                              ! Written to Unit IOW
      ENDIF
C
C     Identify Input Data Line By Line
C
      READ (TEXT,10) CC1,CC2,ICNO,ISTA
   10 FORMAT (BZ,2A1, 1X, I1, I9)
C
      IF (CC1.EQ.'E') GO TO 1                  ! Test for End Card (ignore)
C
      IF (CC1.EQ.'P'.AND.CC2.EQ.'T') THEN      ! Test for PT card
         ISTA = 0
         ICCT = 100
         GO TO 420
      ENDIF
      IF(CC1.EQ.'X') GO TO 1412
C
      DO 6 I=1,27
    6 IRT(I) = 0
C
C        TEST CARD CODES
C
      IF(CC1.EQ.'P') THEN               !
         IF(CC2.EQ.'L') GO TO 1410      !
         IF(CC2.EQ.'E') GO TO 1410      !
         IF(CC2.EQ.'Q') GO TO 1410      !
         IF(CC2.EQ.'S') GO TO 1410      ! Plot Control
         IF(CC2.EQ.'H') GO TO 1410      !
         IF(CC2.EQ.'R') GO TO 1410      !
         IF(CC2.EQ.'U') GO TO 1410      !
         IF(CC2.EQ.'M') GO TO 1410      !
         GO TO 450                      !
      ENDIF
C
      IF(CC1.EQ.'C') THEN                    ! Characteristic
C
         IF(CC2.EQ.'R') GO TO 140               ! Reach
C
         IF(CC2.EQ.'L') GO TO 150              ! Lake
C
         IF(CC2.EQ.'C') GO TO 160              ! Transfer Point
c
```

```
             IF(CC2.EQ.'1') GO TO 470          ! Flow/Elev Table
      C
             IF(CC2.EQ.'2') GO TO 510          ! Backwater Table
      C
             IF(CC2.EQ.'3') GO TO 530          ! Basin Elev/Pct Area Table
      C
             IF(CC2.EQ.'P') GO TO 550          ! Temp/Precip Station
      C
             IF(CC2.EQ.'T') GO TO 570          ! General Table
      C
             IF(CC2.EQ.'F') GO TO 572          ! CF Table (Family of Curves)
      C
             IF(CC2.NE.'B') GO TO 400          ! Basin
      c
       120   IF(ICNO - 1) 400, 590, 130        ! Basin Char.  First Card
      C
       130   IF(ICNO - 3) 650, 665, 670      ! Basin  Second card or TP-STA list
      C
       140   IF(ICNO - 2) 600, 690, 400      ! Reach Char. 1st or 2nd Card
      C
       150   IF(ICNO - 2) 610, 710, 400      ! Lake Char. 1st or 2nd card
      C
       160   IF(ICNO - 2) 620, 730, 400      ! Transfer point 1st or 2nd card
          ENDIF
      c
       170  IF(CC1.EQ.'T') GO TO 750        ! Time Control
      C
          IF(CC1.EQ.'1') GO TO 780        ! File Call
      C
          IF(CC1.EQ.'2') GO TO 240        ! Initial Condition
      C      INITIAL CONDITION ADJUSTMENT OR
      C        DAILY PRECIP IN USGS FORMAT
          IF(CC1.EQ.'3') THEN
             IF(CC2.EQ.'R') GO TO 920
      C        CC 3B BASIN IC ADJUST
             IF(CC2.EQ.'B') GO TO 1365
             IF(CC2.EQ.'L') GO TO 900
             GO TO 1300
          ENDIF
      C
          IF(CC1.EQ.'4') GO TO 280       ! Temp/Precip Readings
      C
          IF(CC1.EQ.'5') GO TO 1170      ! Daily Distibution
      C
          IF(CC1.EQ.'6') GO TO 320       ! Lake/Res. Regulation or Control Pt.
          GO TO 350
      C
      C
       240  IF(CC2.EQ.'B') THEN                 ! Basin Initial Conditions
      C
             IF(ICNO - 1)1370, 400, 840      ! 1st or 2nd Basin Card
          ENDIF
```

```
C
C
       IF(CC2.EQ.'R') GO TO 870         ! Reach Initial Conditions
C
       IF(CC2.EQ.'L') GO TO 900         ! Lake Initial Conditions
       GO TO 400
C
C          TEMP/PRECIP DATA
C
  280  IF(CC2.EQ.'P') GO TO 930      ! Periodic Data
C
       IF(CC2.EQ.'E') GO TO 1060     ! Daily Elevations
C
       IF(CC2.EQ.'D') GO TO 1100     ! Daily Melt, Rain, or Temp.
       GO TO 1060
c
C          RESERVOIR REGULATION
C        PERIODIC CONTROL
  320  IF(CC2.EQ.'P') GO TO 1050
       IF(CC2.EQ.'S') GO TO 1420
       GO TO 1090
C
  350  IF(CC1.EQ.'J') GO TO 1350              ! Job Card
C
       IF(CC1.EQ.'H') GO TO 1340              ! Heading Card
       GO TO 400
C         END OF FILE ON CARD READER.
  390  WRITE (IOB, 392)
  392  FORMAT ('0    END OF FILE ON INPUT DECK',/)
       ICCT = 99
       GO TO 435
C         CARD CANNOT BE IDENTIFIED
  400  READ (CC1,*) IRT(1)
       READ (CC2,*) IRT(2)
       READ (TEXT, 413)  IRT(35)
       WRITE (IOB,410) TEXT
  410  FORMAT (BZ,21H UNIDENTIFIED CARD***, A80)
       ICCT = 1
       GO TO 420
  412  READ (TEXT,413) XIR(35)
  413  FORMAT (BZ,A1)
       GO TO 420
C         SETUP T/P STA - MAKE ISTA NEGATIVE
  415  ISTA = ISTA *(-1)
C****  SETUP TO RETURN AND RETURN ****
  420  ICN = ICNO
       DO 430 J = 1, 28
  430  IR(J) = IRT(J)
  435  ICC = ICCT
C
       IF(IRTRC) 437, 440, 437
  437  WRITE(IOW, 438) CC1, CC2, ICNO, ISTA, ICCT
```

```
  438 FORMAT (BZ,13H INCARD TRACE, 2X, 2A1, I2,2I9 )
  440 CONTINUE
      RETURN
C
C         CONFIGURATION CARD
C     IR(1) - IR(6) DOWNSTREAM STATION NUMBERS
  450 READ (TEXT, 460) (IRT(J), J=1,6)
  460 FORMAT (BZ,13X, 6(1X,I9))
      ICCT = 2
      GO TO 420
C         FLOW/ELEVATION TABLE
C     XIR(1) ELEVATION - METER OR 10 FEET
C     XIR(2) OUTFLOW - CUMEC OR 10-CFS
C     XIR(3) TIME OF STORAGE - HOUR IN TENTHS
C     IR(4)  STORAGE - 10**3 CUMET OR AF.
C     IR(5)-IR(8) SAME AS 1-4, NEXT ELEMENT
  470 READ (TEXT, 480) M, (XIR(J), J=1,3), IRT(4), (XIR(L),L=5,7),IRT(8)
  480 FORMAT (BZ,14X, I1,1X, 2(F7.3, F7.1, F6.1, I9))
      ICCT = 3
      GO TO 420
C         BACKWATER TABLE
C     XIR(1) OUTFLOW - CUMEC OR 10 CFS
C     XIR(2) ELEVATION - METER OR 10 FEET
C     XIR(3) TIME OF STORAGE - HOURS
C     XIR(4) ELEV. OR OUTFLOW UNCONVERTED IN F9.3 FORMAT
C     XIR(5) - XIR(8) SAME AS 1-4, 2ND ELEMENT
  510 READ (TEXT, 520)        (XIR(J), J = 1,8)
  520 FORMAT (BZ,16X,         2(F7.1, F7.3, F6.1, F9.3))
      ICCT = 4
      GO TO 420
C         ELEVATION VS PERCENT AREA BASIN TABLE
C     XIR(1) ELEVATION METERS OR 10-FEET (F7.3)
C     XIR(2) PERCENT AREA
C     3-4, 5-6, 7-8, 9-10, 11-12 ADDITIONAL ELEMENTS
  530 READ (TEXT, 540) (XIR(J), J=1,12)
  540 FORMAT (BZ,14X,  6(F7.3, F3.1))
      ICCT = 5
      GO TO 420
C         TEMPERATURE/PRECIP. STATION CHARACTERISTIC
C     XIR(1) BASE TEMPERATURE
C     XIR(2) STATION ELEVATION
C     XIR(3) AIR TEMP. LAPSE RATE-DEGREES F. PER 1000 FT.
  550 READ (TEXT, 560) XIR(1), XIR(2), XIR(3)
  560 FORMAT (BZ,14X, F4.1, F7.3, F4.2)
      ICCT = 6
      GO TO 415
C         GENERAL CHARACTERISTIC TABLE
C           OR CF CARD FOR FAMILY OF CURVES (ICCT=18)
C     XIR(1) - XIR(7) ELEMENTS IN F8.0 FORMAT
  570 ICCT = 7
      GO TO 574
C        CF CARD
```

```
 572  ICCT = 18
 574  READ (TEXT,580) (XIR(J),J=1,7)
 580  FORMAT (BZ,18X, 7F8.0)
      GO TO 415
C         CARD NO. 1 OF CHARACTERISTICS
C      BASIN
 590  IRT(1) = 1
      GO TO 630
C      REACH
 600  IRT(1) = 2
      GO TO 630
C      LAKE/RESERVOIR
 610  IRT(1) = 3
      GO TO 630
C      TRANSFER POINT
 620  IRT(1) = 4
C
C         FORMAT CARD 1
C       IR(1) STATION TYPE
C       IR(3) SPECIAL EXIT
C       IR(4)  FLOW/ELEV CODE
C       IR(5) FLOW OUTPUT CODE
C       IR(6) IC OUTPUT-START
C       IR(7) IC       -1ST PERIOD
C       IR(8) IC       -1ST DAY
C       IR(9) IC       -END OF TIME
C       IR(10)IC       -ALL PERIODS
C       IR(11) IC      -ALL DAYS
C      XIR(12)-XIR(21) STATION DESCRIPTION    ! 22 CHNGD TO 21 PAT
C       IR(23) PRAIRIES OPTION               !   PAT LANDINE
 630  READ (TEXT,640) IRT(23),(IRT(J), J=3,11), (XIR(L),L=12,22)
 640  FORMAT (BZ,16X,I1,1X, 3I1, 1X, 6I1, 2X, 11A4)
      ICCT = 8
      GO TO 420
C         BASIN 2ND CHARACTERISTIC CARD
C     XIR(1) DRAINAGE AREA - SQ. MILES OR SQ. KM
C      IR(2) SURFACE PHASES
C     XIR(3) SURFACE TIME OF STORAGE
C      IR(4) SUBSURFACE PHASES
C     XIR(5)  TS
C      IR(6) BASEFLOW PHASES
C     XIR(7)  TS
C     XIR(8) BASEFLOW INFILTRATION INDEX TIME OF STORAGE
C      IR(9) PR VS. KE TABLE ID, ETI LOSS FUNCTION.
C      IR(10) SNOW COVER DEPLETION TABLE ID
C      IR(11) SNOW COVER OUTPUT TABLE ID
C      IR(12) ETI TABLE ID
C      IR(13) SMI VS RUNOFF
C     XIR(14) BII TIME OF STORAGE (FOR FALLING FLOW)
C650  READ (TEXT,660) (XIR(J), J=1,14)
 650  READ (TEXT,660) XIR(1), IRT(2), XIR(3), IRT(4), XIR(5),
     1      IRT(6), XIR(7), XIR(8), (IRT(J),J=9,13), XIR(14)
```

```
 660  FORMAT (BZ,14X,F6.0,I1,F4.1,2(I1,F5.1),1X,F5.1,5I4,F5.1)
      ICCT = 9
      GO TO 420
C        BASIN 3RD CHARACTERISTIC CARD
C      IR(1) ID-SURFACE TS VS.OUTPUT RATE RELATION.
C     IR(2) ID-BII VS. BASEFLOW PERCENT OF RUNOFF RELATION.
C     XIR(3) BII MAXIMUM
C     IR(4) ID-SURFACE/SUBSURFACE INPUT SPLIT RELATION
C     XIR(5) RADIATION EXPOSURE RATIO. (RK) AS X.XXX
C     XIR(6) WIND EXPOSURE RATIO. (WK)  X.XXX
C     XIR(7) EFFECTIVE FOREST COVER RATIO.  (F) X.XXX
C     XIR(8) CONSTANT WIND SPEED IN MPH. (WIND) XXX.X
C      IR(9) TABLE ID-AIR TEMPERATURE VS. DEW POINT
C     IR(10) MELT RATE VS. PERCENT SEASONAL RUNOFF
C     XIR(11) PERCENT ALLOWABLE ERROR IN BASIN IC ADJUSTMENT
C     XIR(12) MAXIMUM ERROR IN DISCHARGE IN IC ADJUSTMENT
C     XIR(13) RAIN FREEZE TEMPERATURE. DEFAULT IS 35 DEGR.
C     XIR(14) BASE TEMPERATURE FOR SNOWMELT. DEFAULT IS 40 DEGR.
C     XIR(15) AIR TEMP. LAPSE RATE. NORMAL=3.3/1000FEET
C665  READ (TEXT, 667) (XIR(J), J= 1,15)
 665  READ (TEXT, 667) IRT(1),IRT(2),XIR(3),IRT(4),(XIR(J),J=5,8),
     1     IRT(9),IRT(10),(XIR(J),J=11,15)
 667  FORMAT (BZ,14X,2I4,F5.2,I4,3F4.3,F4.1,2I4,F3.1,F7.1,2F3.1,F3.2)
      ICCT = 16
      GO TO 420
C         BASIN TEMP/PRECIP STATION AND TABLE LIST
C     IR(1) DATA CODE
C     IR(2) TP STA. ID
C     XIR(3) WEIGHT PERCENT
C     4-6,7-9,10-12,13-15,16-18,19-21 SAME AS 1-3.
 670  READ (TEXT, 680) (IRT(J), IRT(J+1), XIR(J+2), J= 1, 19, 3)
 680  FORMAT (BZ,18X, 7(I1, I4, F3.0))
      ICCT = 10
      GO TO 420
C        REACH 2ND CHARACTERISTIC CARD
C      IR(1) BACKWATER CODE
C      IR(2) BACKWATER STATION
C      IR(3) NUMBER OF PHASES
C     XIR(4) N FOR Q**(-N)
C     XIR(5) KTS
 690  READ (TEXT, 700) (IRT(J), J=1,3), XIR(4), XIR(5)
 700  FORMAT (BZ,14X, I1, I9,1X, I2, F4.3, F6.2)
      ICCT = 11
      GO TO 420
C         LAKE/RESERVOIR 2ND CHARACTERISTIC
C     IR(1) BACKWATER CODE
C     IR(2) BACKWATER STATION
C     XIR(3) ELEVATION UPPER BOUND - METERS OR 10-FEET
C     XIR(4) ELEVATION LOWER BOUND
C     XIR(5) SPILLWAY CREST ELEVATION
C710  READ (TEXT, 720) (IRT(J),J=1,5)
 710  READ (TEXT, 720) IRT(1),IRT(2),(XIR(J),J=3,5)
```

```
  720 FORMAT (BZ,14X, I1, I9, 13X, 3F7.3)
      ICCT = 12
      GO TO 420
C         TRANSFER POINT 2ND CHARACTERISTIC
C     IR(1) DOWNSTREAM STATION FOR LOCAL CALCULATION
C     IR(2) ADJACENT STATION NUMBER
C     IR(3) ADJACENT RELATION ID
C    XIR(4) WEIGHT - PERCENT
C     IR(5) OUTFLOW SIGN CONTROL, 1 MEANS REVERSE SIGN.
C730  READ (TEXT, 740) IRT(5), (IRT(J),J=1,4)
  730 READ (TEXT, 740) IRT(5), (IRT(J),J=1,3),XIR(4)
  740 FORMAT (BZ,14X,I1,I9,1X,I9, 1X, I4, F4.1)
      ICCT = 13
      GO TO 420
C          TIME CONTROL
C     IR(1) START TIME - HOURS IN TENTHS FROM YEAR 1900
C     IR(2) HOURS IN TENTHS PER PERIOD
C     3-4, 5-6, 7-8              SAME AS 1-2
C     IR(9) LAST TIME FIELD, RUN END TIME IF ALL PERIOD CONTROLS USED.
C     IR(10)-IR(13) INSTANTANEOUS CONDITION OUTPUT TIMES, IN BASE TIME.
C     IR(14) INSTANTANEOUS CONDITION OUTPUT CODE FOR OUTPUTTING ALL PERI
C     IR(15) RIVER ROUTING DELETE CODE
C750  READ (TEXT, 760) (IRT(J), J=2, 31)
  750 READ (TEXT, 760) (IRT(J),J=2,25),(XIR(J),J=26,29),IRT(30),IRT(31)
  760 FORMAT (BZ,4X, 4(I3, 3I2, I3), I3, 3I2,4F4.0,I1, 1X, I1)
      I = 1
      DO 770 J= 2, 22, 5
C        MONTH MUST BE NON-ZERO
      IF(IRT(J+2)) 764, 762, 764
  762 IRT(I)=0
      GO TO 772
  764 CONTINUE
      CALL BTIME (IRT(J),IRT(J+1),IRT(J+2),IRT(J+3), IRT(I))
      IRT(I+1) = IRT(J+4)
  770 I = I + 2
C
  772 I = 10
      DO 775 J = 26, 29
      K = (XIR(J)*10.) +0.5
      IF( K    ) 773, 774, 773
  773 IRT(I) = IRT(I) + K
      GO TO 775
  774 IRT(I) = 0
  775 I = I + 1
      IRT(14) = IRT(30)
      IRT(15) = IRT(31)
      ICCT = 54
      GO TO 420
C        FILE IODD CALL CARD - CODE 1 IN COL.1
C     IR(1) TYPICAL RUN TIME (IN BASETIME) FOR DATE TRANSLATION FROM FIL
C     IR(2) TYPICAL FILE TIME
C     IR(3) STATION NO. OF RECORD IN FILE IODD
```

```
C      IR(4) START TIME OF EXTRACTED RECORD. IF ZERO, USE T-CARD TIMES.
C      IR(5) END TIME OF EXTRACTION.
C      IR(6) FORTRAN UNIT NO. OF FILE IODD. IF ZERO, 31 ASSUMED.
C          FILED OUTPUT CALL (TO IOT4) CARD - CARD CODE IF, ICC = 74
C      IR(3) STATION NO. ON FILE IOT4. IF ZERO, ISTA ASSUMMED.
C      IR(6) UNIT NUMBER OF INPUT FILE - IF ZERO, IOT4 ASSUMMED.
  780 READ (TEXT, 790) (IRT(J), J=10,17),IRT(3), IRT(18), IRT(19),
     1 IRT(20), IRT(21), IRT(6)
  790 FORMAT (BZ,13X, 2(1X, I3, 3I2), 1X, I9 , 1X, 5I2)
      IF(CC2.EQ.'F') GO TO 815
  791 CALL BTIME (IRT(10),IRT(11),IRT(12),IRT(13), IRT(1))
      CALL BTIME (IRT(14),IRT(15),IRT(16),IRT(17), IRT(2))
      IF (IRT(18) + IRT(19))  793,792,793
  792 IRT(4) = ITME(1)
      GO TO 795
  793 CALL BTIME (0, 1, IRT(18), IRT(19), IRT(4))
  795 IF(IRT(20) + IRT(21)) 805, 800, 805
  800 IRT(5) = 0
      GO TO 810
  805 CALL BTIME(240,31,IRT(20), IRT(21), IRT(5))
  810 ICCT = 55
      GO TO 420
  815 ICCT = 74
      GO TO 420
C          GENERAL TIME CONVERSION STATEMENT
  820 CALL BTIME (IRT(20), IRT(21), IRT(22), IRT(23), IRT(1))
      GO TO (400, 860, 890, 420, 420, 1130, 420), MA
C          BASIN INITIAL CONDITION 2ND CARD
C      IR(1) TIME
C      IR(2) RECESSION CODE
C     XIR(3)-XIR(10)PHASE VALUES - CUMEC OR 10-CFS
  840 READ (TEXT, 850) (IRT(J), J=20, 23), IRT(2),(XIR(L), L=3, 10)
  850 FORMAT (BZ,14X, I3,3I2, I1, 8F7.1)
      MA = 2
      GO TO 820
  860 IF(ICNO - 3) 863, 864, 865
  863 ICCT = 57
      GO TO 420
  864 ICCT = 68
      GO TO 420
  865 ICCT = 69
      GO TO 420
C          REACH INITIAL CONDITION
C      IR(1) TIME
C      IR(2) FLOW/ELEVATION CODE 0=FLOW, 1= ELEVATION
C      XIR(3)-XIR(10) FLOWS ( KCFS) OR ELEVATION (METERS)
  870 READ (TEXT, 880) (IRT(J), J=20,23), IRT(2), (XIR(L), L=3,10)
  880 FORMAT (BZ,14X, I3, 3I2, I1, 8F7.1)
      MA= 3
      GO TO 820
  890 ICCT = 58
      GO TO 420
```

```
C          LAKE/RESERVOIR INITIAL CONDITION
C       IR(1) TIME
C     XIR(2) OUTFLOW - CUMEC
C     XIR(3) ELEVATION - METERS
C      IR(4) STORAGE - 10**3 CUMET, AF
  900  ICCT = 59
C ***ALSO USED FOR REACH IC ADJUSTMENT***
  905  READ (TEXT, 910) (IRT(J), J=20, 23), XIR(2), XIR(3), IRT(4)
  910  FORMAT (BZ,14X, I3,3I2,1X, F7.1, F7.3, I9)
       MA = 4
       GO TO 820
C          REACH INIT. CONDITION ADJUSTMENT
C      IR(1) TIME
C     XIR(2) OUTFLOW CUMEC/10-CFS
C     XIR(3) ELEVATION METERS/10-FEET
  920  ICCT = 60
       GO TO 905
C          PERIODIC TEMP/PRECIP STATION DATA
C      IR(1) DATA CODE - POSITIVE=INTERPOLATE, NEGATIVE=NO INTERPOLATE
C      IR(2) TIME OF READING - .1 HOURS
C     XIR(3) DATA IN F7.3 FORMAT
C      4-5, 6-7, 8-9, 10-11 SAME AS 2-3
  930  ICCT = 61
  935  ISTA = ISTA*(-1)
C *** ALSO USED BY PERIODIC FLOW CARD FORMAT ***
  940  READ (TEXT, 950) (IRT(J), J=12,15), XIR(1), XIR(16),(IRT(L),
     1 IRT(L+1), XIR(L+2), L = 17, 26, 3)
  950  FORMAT (BZ,14X, I3, 3I2, A1,1X, F7.3, 4(I3, I2, F7.3))
       MB = 1
C
C         TEST DATA CODE FOR X OVERPUNCH (Method Changed by LANDINE)
C
  955  WRITE (XT,'(A4)') XIR(1)        ! Use Text variable for Comparison
       DO  I = 1,9
          IF(XT(1:1).EQ.CHAR(I+48)) GO TO 1000
       ENDDO
       DO I = 74,82                          ! Decimal Equiv. of J to R
          IF(XT(1:1).EQ.CHAR(I)) GO TO 1010
       ENDDO
       IF(XT(1:1).EQ.'0') GO TO 990
       IF(XT(1:1).NE.' ') GO TO 1022
  990  IRT(1) = 0
       GO TO 1020
 1000  IRT(1) = I
       GO TO 1020
 1010  IRT(1) = -I + 20
 1020  GO TO (1025, 1080, 1120), MB
C         DATA CODE ERROR
 1022  WRITE (IOB, 1023)
 1023  FORMAT (BZ,16H0DATA CODE ERROR)
       ICCT = 1
       GO TO 420
```

```
C        CONVERT TIMES TO BASE HOURS
1025  I = 2
      J = 14
1030  CALL BTIME (IRT(12), IRT(13), IRT(14), IRT(15), IRT(I))
      IRT(I+1) = IRT(J+2)
      IF(I - 10) 1040, 420, 420
1045  I = I + 2
      J = J + 3
      IRT(12) = IRT(J)
      IRT(13) = IRT(J+1)
      GO TO 1030
1040  IF(IRT(J+4)) 1047, 1047, 1045
1047  IRT(I+2) = 0
      GO TO 420
C         PERIODIC FLOW OR ELEVATION DATA
C     IR(1) DATA CODE
C     IR(2) TIME OF DATA ELEMENT
C    XIR(3) FLOW OR ELEVATION ELEMENT - SCALED F7.3
C     4-5, 6-7, 8-9, 10-11 SAME AS 2-3.
1050  ICCT = 66
      GO TO 940
C         DAILY TEMP/PRECIP STATION ELEVATIONS
C     IR(1) TIME
C     IR(2) DATA CODE - NEGATIVE= NO INTERPOLATE
C    XIR(3) -XIR(10) ELEVATIONS - METERS OR 10-FEET
1060  ICCT = 62
      ISTA = ISTA * (-1)
C *** ALSO USED BY DAILY FLOW CARD ***
1065  READ (TEXT, 1070) CC2, IRT(17),
     1                    (IRT(J), J=19, 23), IRT(1),(XIR(L), L= 3,10)
1070  FORMAT (BZ,1X, A1, I2,9X,I1,I3, 3I2, A1, 8F7.3)
      IF(CC2 .EQ.'D') GO TO 1076
      IF(CC2 .EQ.' ') GO TO 1079
      IF(CC2 .EQ.'0') GO TO 1079
      IF(CC2 .EQ.'E') GO TO 1076
      DO    1074 J = 1,9
      IF(CC2 .EQ.CHAR(J+48)) GO TO 1078
1074  CONTINUE
1076  IRT(17) = 240
      GO TO 1079
1078  IRT(17) = IRT(17) + J*100
1079  MB = 2
C        CONVERT DATA CODE TO NUMERIC
      GO TO 955
1080  IRT(2) = IRT(1)
      MA = 5
C         CONVERT TO BASE TIME
      GO TO 820
C         DAILY FLOW/ELEVATION SPECIFIED DATA
C     IR(1) TIME
C     IR(2) DATA CODE
C    XIR(3) -XIR(10)FLOWS OR ELEVATION SCALED F7.3 (1000CFS OR METERS)
```

```
C      IR(17) HOURS PER READING (SPACING)
C      IR(19) NUMBER OF READINGS ON CARD
 1090  ICCT = 67
       GO TO 1065
C          DAILY TP-STA TEMP./PRECIP/MELT RATE READINGS
C      IR(1) TIME
C      IR(2) DATA CODE - NEGATIVE=NO INTERPOLATE
C     XIR(3)-XIR(16)READINGS SCALED F4.3
C      IR(17) HOURS SPACING OF READINGS, IN TENTHS OF HOURS.
C      IR(19) NUMBER OF READINGS ON CARD
 1100  READ (TEXT,1110) IRT(17), ISTA, (IRT(J),J=19,23),IRT(1),
      1 (XIR(J), J=3,16)
 1110  FORMAT (BZ,4X, I3, 2X, I4, I1, I3, 3I2, A1, 14F4.3)
       MB = 3
C         CONVERT DATA CODE
       GO TO 955
 1120  MA = 6
C         CONVERT TIME
       IRT(2) = IRT(1)
       GO TO 820
 1130  ICCT = 63
       GO TO 415
C         DAILY DISTRIBUTION
C      IR(1) 1ST TIME
C     XIR(2) - XIR(9) 3-HR PERIOD PERCENTS
C      IR(10) 2ND TIME
C     XIR(11) - XIR(18) DIST.
C      IR(19) 3RD TIME
C     XIR(20) - XIR(27) DIST.
 1170  READ (TEXT, 1180) (IRT(J),J=28,31),ITSWT, (XIR(K),K=2,9),IRT(32),
      1 IRT(33), (XIR(L), L=11,18),IRT(34), IRT(35), (XIR(M),M=20,27)
 1180  FORMAT (BZ,14X,I3,3I2,I1,8F2.0,2(2I2,8F2.0))
       CALL BTIME (IRT(28), IRT(29),IRT(30),IRT(31), IRT(1))
       IF(IRT(32)) 1200, 1190, 1200
 1190  IRT(10) = 0
       GO TO 1230
 1200  CALL BTIME (IRT(28), IRT(32), IRT(33), IRT(31), IRT(10))
       IF(IRT(34)) 1220, 1210, 1220
 1210  IRT(19) = 0
       GO TO 1230
 1220  CALL BTIME (IRT(28), IRT(34), IRT(35), IRT(31), IRT(19))
 1230  ICCT = 65
       IRT(28) = ITSWT
       GO TO 415
C         DAILY PRECIP IN USGS FORMAT- CC 3
C      IR(1) TIME
C      IR(2) DATA CODE = 3
C      XIR(3) - XIR(19) PRECIP READINGS.
 1300  READ (TEXT, 1310) (IRT(J), J=21, 23), ISTA, (XIR(L), L = 3, 19)
 1310  FORMAT (BZ,3X, 3I2, I3, 17F4.3)
C         ASSUME DAILY READINGS AT 6 A.M.
       IRT(20) = 60
```

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      CALL BTIME (IRT(20), IRT(21), IRT(22), IRT(23), IRT(1))
      IRT(2) = 3
      IF(IRT(21) - 18) 1330, 1320, 1330
1320  XIR(17) = 0.
      XIR(18) = 0.
      XIR(19) = 0.
1330  ICCT = 70
      ISTA = ISTA*10
      GO TO 415
C        JOB CARD,CC-JSR, OR HEADING CARD, CC-4
C     IR(1) JOB NUMBER
C     IR(2) DATE IN I6 FORMAT
C     IR(3) IRTRC - TRACE CODE
C     IR(4)  COL 22 OF JOB CD
C     IR(5)  ICPRT- INIT. COND. PRINT CONTROL.
C     IR(6) IRJOB- RUN UPDATE AND CONFIG CONTROL.
C     IR(7) MEAS - UNITS OF MEASURE.
C     IR(8)  IPRINT - HOURS PER OUTPUT PRINT LINE
C     IR(9) -IR(14) COLS 30 - 35 OF JOB CARD IN A1 FORMAT
C    IR(15)-IR(24) JID - JOB DESCRIPTION
C        HEADING CARD
1340  ICCT = 72
      GO TO 1355
C        JSR CARD (JOB)
1350  ICCT = 98
1355  READ (TEXT, 1360) (IRT(J), J=1,24)
 1360 FORMAT (BZ,4X,I9,I6,1X,5I1,I4,2I1,2A1,2I1,5X,10A4)
      GO TO 420
C        BASIN INITIAL CONDITION FIRST CARD-REVISED FOR SNOW
C          OR CC-3B BASIN IC ADJUST
C     IR(1) TIME IN BASE TIME
C     IR(2) ID-RAIN DAILY DISTRIBUTION.
C     XIR(3) SOIL MOISTURE INDEX (SMI) F5.2
C     XIR(4) BASEFLOW INFILTRATION INDEX (BII) F5.2
C     IR(5) ID-SNOW MELT DAILY DISTRIBUTION.
C     XIR(6) INITIAL SNOW COVERED AREA IN PERCENT (SCA) F4.1
C     XIR(7) RAIN ACCUMULATED RUNOFF F5.2 INCHES.
C     XIR(8) SNOW ACCUMULATED RUNOFF F5.2 INCHES.
C     XIR(9) SNOW TOTAL SEASONAL RUNOFF IN INCHES, F5.2.
C     IR(10) ID-ACTUAL RAIN PATTERN FOR INITIAL CONDITION ADJUSTMENT.
C     IR(11) CODE FOR IR(12), 0 OR 1 = OUTFLOW IN IR(12), 2=ELEVATION
C     XIR(12) OBSERVED OUTFLOW (10-CFS, F7.1) OR ELEVATION(10-FEET, F7.3
C     XIR(13) INIT. MELT RATE-INCHES PER DEGREE-DAY.
C     IR(14) UNADJUSTED PRINT CODE
C        BASIN IC ADJ, CC 3B00
 1365 ICCT = 73
      GO TO 1375
C        BASIN IC, CC 2B00
1370  ICCT = 71
C1375 READ (TEXT, 1380)(IRT(J), J=20,23), (IRT(L), L= 2,6), XIR(13),
C    1 IRT(14), (XIR(J),J=7,12)
 1375 READ (TEXT, 1380)(IRT(J), J=20,23),IRT(2),XIR(3),XIR(4),IRT(5),
```

```
     1      XIR(6),XIR(13), IRT(14), (XIR(J),J=7,9),IRT(10),IRT(11),
     2      XIR(12)
1380  FORMAT(BZ,14X,I3,3I2,I4,2F5.2,I4,F4.1,F4.3,3X,I1,3F5.2,I4,I1,F7.1)
      XIR(13) = XIR(13) * .1
      IF(IRT(11) - 1) 1390, 1390, 1385
1385  XIR(12) = XIR(12)/100.
1390  MA = 7
      GO TO 820
C        PLOT CONTROL - READ BY PLOTLK
1410  ICCT = 100
      GO TO 412
C        CARD CODE X - TTYPRT CONTROL CARD
 1412 ICCT=102
      GO TO 435
C        CC-6S PERIODIC REGULATION DATA
C     IR(1) BASE TIME OF 1ST READING
C     IR(2) DATA CODE OF 1ST READING
C    XIR(3) 1ST VALUE
C     IR(4)-IR(6) TIME, DATA CODE, AND VALUE OF 2ND READING
C     IR(7)-IR(9) TIME,DC,VALUE OF 3RD
C     IR(10)-IR(12) TIME,DC,VALUE OF 4TH READING
C1420 READ (TEXT, 1430) IRT(15),IRT(16),IRT(17),IRT(14),(IRT(I),I=18,34)
 1420 READ (TEXT, 1430) IRT(15),IRT(16),IRT(17),IRT(14),IRT(18),XIR(19),
     1       (IRT(I),IRT(I+1),IRT(I+2),IRT(I+3),XIR(I+4),I=20,34,5)
1430  FORMAT (BZ,14X,I3,3I2,I1, F7.3, 3(I3,2I2,I1, F7.3))
      J = 1
      DO 1440 I = 15, 30, 5
      CALL BTIME(IRT(I),IRT(I+1),IRT(I+2),IRT(14), IRT(J))
      IRT(J+1) = IRT(I+3)
      IRT(J+2) = IRT(I+4)
1440  J = J+3
C
      ICCT = 64
      GO TO 420
      END
```

10.2 Appendix B

Subroutine CPRINT

```
FTN7X,J,E
$EMA /C1/
      SUBROUTINE CPRINT (I, IW , ISTA, JUPD, IR, XIR)
     +, 3:32 PM  WED., 19  JUNE, 1985 <851113.1157>
C         SUBROUTINE TO PRINT CHARACTERISTICS. INPUTS ARE-
C         I - INPUT AS ZERO FOR INITIALIZATION. USED AS LINE COUNTER
C              BY SUBR.
C         IOW - PRINT FILE NUMBER
C         ISTA - STATION ID - (POS=RIVER STA, NEG= TPSTA OR TABLE)
C         JUPD - DATE LAST UPDATED,AS DDMMYY. (TAPE UPDATE PRINT ONLY)
C         IR - Characteristic Record (Disc Format ) INTEGER
C         XIR - Characteristic Record (Disc Format ) REAL
C
$INCLUDE [C1   :PL:121,NOLIST
C
      REAL XIR(1),XPR(5,6)
      INTEGER NPA (1),  IPR(5,6), IR(1)
      INTEGER*2 ELEVEN,ITIME(5),IYEAR,DAY
C
      CHARACTER*24 NAME(9),MONTH*4
C
      EQUIVALENCE (NP, NPA(1))
      EQUIVALENCE (IPR(1),XPR(1))
C
      DATA ELEVEN/11/                               ! DATA FOR EXEC 11
      DATA NAME/'SNOW LINE   ELEV. (10FT)',
     1         'SNOW CVRD    AREA (%)  ',
     2         'PRECIP.     (INCHES)   ',
     3         'AIR TEMP.      (F)     ',
     4         'DEW POINT   TEMP. (F)  ',
     5         'ALBEDO         (%)     ',
     6         'INSOLATION  (LANGLEYS) ',
     7         'WIND SPEED     (MpH)   ',
     8         'MELT RATE    (IN.-DD)  '/
C
      MH = 1
      JD = JUPD
      IP = I
      IS = ISTA
C        TEST FOR INITIALIZATION
      IF(IP) 5, 10, 5
    5 IF(IS) 40, 120, 35
   10 IF(IS) 20, 100, 15
   15 IF(IR(4) - 1) 100, 20, 16
   16 IF(IR(4)- 2) 100, 520, 100
C        TP-STA OR TABLE
```

```
   20 IP = 1
      WRITE(IW,30)
   30 FORMAT (1H1,19X,56HTEMPERATURE/PRECIP STATION CHARACTERISTIC CHECK
     1 PRINTOUT)
      WRITE(IW,31)
   31 FORMAT(26X,50HFLOW(10CFS)  ELEVATION(10FEET)  STORAGE(ACRE-FEET))
      WRITE(IW,32)
   32 FORMAT (26X,  33HCF TABLE--FLOW(CFS) ELEV(.01FEET))
      GO TO 50
C
   35 IF(IR(4)-1) 120, 40, 37
   37 IF(IR(4) - 2) 120, 520, 120
C        TEST-PAGE FULL
   40 IF(IP-46) 50, 50, 20
C        TEST - T/P STA OR TABLE
   50 IF(IR(4)) 55, 70, 90
C        TEST FOR DISTRIBUTION RECORD
   55 IF(IR(4)+2) 800, 800, 60
C
C        PRINT TABLE
   60 J = IR(1)
      WRITE(IW,65) IS, (XIR(L), L=5,J)
   65 FORMAT (1H0, I9, 6H TABLE, 30X, 5F15.5/
     1 (1X,8F15.5))
      IP = IP + (J-9)/8 + 3
      GO TO 520
C
C        TEMP/PRECIP STATION
   70 WRITE(IW,80) IS,XIR(5),XIR(6)
   80 FORMAT (1H0, I9, 12H T/P STATION,17X, 12H BASE TEMP.=,
     1 F6.1,  12H  ELEVATION=, F10.3)
      IP = IP + 2
      GO TO 520
C        TIME-DEPENDENT DATA RECORD
   90 J = IR(1)
      IF (IR(9).EQ.0) THEN
         ISTAP1 = IS/10
         ISTAP2 = IS - ISTAP1 * 10
         WRITE(IW,'("$",I9,".",I1, " TIME DEPENDENT DATA-HOUR,DAY,"
     1        "MONTH,YEAR,DATA CODE,DATA," 20X, " LENGTH=", I4)')
     2         ISTAP1, ISTAP2, J
         WRITE(IW,'("     DATA CODES - 0-FREEFLOW,1-OUTFLOW,2-ELEV,"
     1        "3-STOR LEVEL,4-STOR CHANGE IN TERMS OF FLOW RATE,"
     2        " 5-ELEV CHANGE/DAY,6-STOR CHANGE/DAY")')
         IP = IP + 1
      ELSE
         II = IR(9)
         WRITE(IW,'("$",I9, "   TIME DEPENDENT DATA-HOUR,DAY,MONTH,"
     1        "YEAR,DATA,"3X "DATA CODE=", I3, 2X,A24,
     2        "     LENGTH=",I4)') IS, IR(9), NAME(II), J
      ENDIF
C
```

```
         IP = IP + 1
         IF(J - 11) 520, 520, 92
   92    IF(IR(2)) 93, 94, 94
C        T  TIME-DEPENDENT DATA RECORD, PRECIP FORM.
   93    K = 2
         GO TO 95
C           REGULATION
   94    K = 3
   95    K1 = 5*K
         DO 105 L = 11, J, K1
         DO 96 K2 = 1,5
         DO 96 K3 = 1,6
   96    IPR(K2,K3) = 0
C
         K3 = L
         DO 99  K2 = 1, 5
         IF(J-K3) 101,101, 97
   97    CALL CTIME (IR(K3), IPR(K2,1), IPR(K2,2),IPR(K2,3),IPR(K2,4))
         IPR(K2,6) = IR(K3+1)
         IF(K - 3) 99, 98, 99
   98    IPR(K2,5) = IR(K3+2)
   99    K3 = K3 + K
C
C 100 STMT FOLLOWS 105
  101    IF(IP - 46) 104, 104, 102
  102    IP = 0
  104    IP = IP+1
         IF (IR(9).NE.0) GO TO 107
         WRITE (IW, 106)((IPR(K2,K3), K3=1,5),(XPR(K2,6)), K2=1,5)
  106    FORMAT (1X,5(I4,1H-,4I2,1X,F11.2))
         GO TO 105
  107    WRITE(IW,108)((IPR(K2,K3),K3=1,4),(XPR(K2,6)),K2=1,5)
  108    FORMAT(1X,5(I4,1H-, 3I2, 3X, F11.2))
  105    CONTINUE
         GO TO 520
C
C
  100    IP = 51
         WRITE(IW,'(32X,"RIVER STATION CHARACTERISTIC CHECK PRINTOUT")')
C
C Time Stamp by Pat Landine July22/1985
c
         CALL EXEC (ELEVEN,ITIME,IYEAR)
         CALL ETAD (ITIME(5),IYEAR,MONTH,DAY)
         WRITE (IW,'("****Time of This Run****"/A4,1X,I2","I4,","I2,I2/)')
       1      MONTH,DAY,IYEAR,ITIME(4),ITIME(3)
C
         WRITE(IW,31)
         GO TO (140, 290, 370, 420, 620, 710), MH
C
C           TEST - FIRST OF RIVER STA PRINT
  120    IF(IP - 51) 100, 130, 130
```

```
C        TEST - PAGE FULL
 130  IF(IP - 96) 140, 140, 100
C
C        PRINT FIRST LINE OF RIVER STATION
 140  WRITE(IW,150)
 150  FORMAT(13H0     STATION)
      MA = IR(2)
      IF(MA - 1) 170, 200, 160
 160  IF(MA - 4) 200, 200, 170
C        STATION TYPE CODE NOT RECOGNIZABLE
 170  J = IR(1)
      WRITE (IW, 180) IS, (IR(L), L= 1, J)
 180  FORMAT (1X, I9,33H TYPE CODE CAN NOT BE IDENTIFIED./(8X,10I11))
      IP = IP + J/10 + 1
      GO TO 520
C
C        TYPE CODE OK, FINISH 1ST LINE
 200  CALL CTIME (IR(27), I1, I2, I3, I4)
      ISTAP1 = IS/10
      ISTAP2 = IS - ISTAP1*10
      WRITE(IW,210) ISTAP1, ISTAP2,(XIR(L),L=3,13)
 210  FORMAT(I9,1H.,I1,1X,11A4)
C
C        SETUP TABLE LENGTHS AND PRINT PHASES AND FIXED DATA
      NWR= IR(1)
      NLF = IR(28)
      NWT = 0
      NWE = 0
      NWF = 0
      NWB = 0
      IF(MA - 1) 600, 220, 600
C        BASIN
 220  NLE = IR(39)
      NLT = IR(40)
      IF(NLT) 230, 240, 230
 230  NWT = NWR - NLT + 1
      NWR = NWR - NWT
 240  IF(NLE) 250, 260, 250
 250  NWE = NWR - NLE + 1
      NWR = NWR - NWE
 260  IF(NLF) 265, 267, 265
 265  NWF = NWR - NLF + 1
C        PRINT BASIN FIXED DATA
 267  WRITE (IW, 270) XIR(30),IR(31),XIR(32),IR(33),XIR(34),IR(35),
     1       XIR(36),XIR(37),IR(38),IR(43),IR(44), IR(41), IR(42),
     2       IR(45),IR(46),IR(52),IR(53),IR(63),IR(64),XIR(69),
     3       XIR(48),XIR(49),IR(51),XIR(68), XIR(47), XIR(66), XIR(61),
     4       (XIR(L), L= 55, 58), XIR(22),XIR(23),XIR(54),XIR(59),
     5       XIR(62),XIR(67), XIR(65), XIR(60)
 270  FORMAT ( 10X,"AREA   SURFACE SUBSURF  BASEFLOW BII-TS P/KE M-D"
     1"S R-DS SCDF  SCA  ETI  SMI S/SS  DEW S-TS  BII  RN-AR  ML-AR  "
     2"SRO  MR-F"/ F15.0,I3,F6.1,2(I2,F7.1),F7.1,11I5,3F7.2,I5/
```

```
     3"   K-RAD K-WIND FOREST WIND  IC-ADJ-%,QMAX  FREEZ BASE LAPSE,"
     4 F14.1, F10.2, F20.2, F19.3/ F8.3, 2F7.3, F6.1, F7.1, F9.0, 3F5.1,
     5"     SCR=", F6.3, 15X,"MAX BII=", F7.2, 9X,"MRR=", F6.3)
C
      WRITE (IW,'(/"Prairies Option = "i2/)') IR(13)  ! LANDINE NOV 8 85
      IP = IP+6
      NL = 2 + NWT/8
      IF(IP + NL - 96) 290, 290, 280
C        HEAD NEW SHEET
  280 MH = 2
      GO TO 100
  290 J = NLT + NWT - 1
      WRITE (IW, 300) (IR(L),IR(L+1),XIR(L+2), L=NLT, J,3)
  300 FORMAT ( 16X, 8(13H  DC HSTA WGT)/ 17H    HYDROMET STAS,
     1 8( I3, I5, F5.0))
  330 IP = IP + NL
C
C        PRINT BASIN PHASE VALUES
      NS = 69 + IR(31)
      NSS = NS + 1
      NSSE = NS + IR(33)
      NB = NSSE+1
      NBE = NSSE + IR(35)
      WRITE (IW, 340) (XIR(L), L= 70, NS)
  340 FORMAT (22H     SURFACE PHASES    , 11F9.1)
      WRITE (IW, 350) (XIR(L), L= NSS, NSSE)
  350 FORMAT (22H     SUBSURFACE PHASES, 11F9.1)
      WRITE (IW, 360) (XIR(L), L = NB, NBE)
  360 FORMAT (22H     BASEFLOW PHASES   , 11F9.1)
      IP = IP + 3
C
C        PRINT ELEVATION VS. PERCENT AREA ARRAY
      IF(NWE) 362, 400, 362
  362 NL = NWE / 8
      IF( IP + NL - 96) 370, 370, 365
  365 MH = 3
      GO TO 100
  370 NWE = NLE + NWE - 1
      WRITE (IW, 380) NLE, (XIR(L), XIR(L+1),L=NLE,NWE, 2)
  380 FORMAT (23H     ELEVATION/PCT AREA, I5, 3X, 6(F10.3, F5.1)/
     1  (1X,F10.3,F5.1,F10.3,F5.1,F10.3,F5.1,F10.3,F5.1,F10.3, F5.1,
     2 F10.3, F5.1, F10.3, F5.1, F10.3, F5.1))
      IP = IP + NL
C
C
C        COMMON ROUTINE TO PRINT FLOW VS ELEVATION TABLE AND RETURN
  400 IF( NWF ) 401, 520, 401
  401 NW = IR(29)
      IF(NW) 405, 402, 405
  402 NW = 4
  405 NL =(NWF/ NW) / 3
      IF(IP + NL - 96) 420, 420, 410
```

```
  410 MH = 4
      GO TO 100
  420 IF(NW - 4) 440, 440, 430
  430 NW = 4
  440 WRITE (IW, 450)
  450 FORMAT(70H0    ELEVATION/FLOW TABLE-E(10FEET), Q(10CFS), TS(HOURS)
     1, S(ACRE-FEET))
      WRITE (IW,451)
  451 FORMAT(3X,3(1HE,12X,1HQ,9X,2HTS,6X,1HS,8X))
      NWF = NLF + NWF - 1
      IF(NW - 3) 460, 480, 500
  460 WRITE(IW,470) (XIR(L+1),XIR(L),L=NLF,NWF,2)
  470 FORMAT(3(F9.3,F13.1,18X))
      GO TO 515
  480 WRITE(IW,490) (XIR(L+1),XIR(L),XIR(L+2),L=NLF,NWF,3)
  490 FORMAT(3(F9.3,F13.1,F8.1,10X))
      GO TO 515
  500 WRITE(IW,510) (XIR(L+1),XIR(L),XIR(L+2),IR(L+3),L=NLF,NWF,4)
  510 FORMAT(3(F9.3,F13.1,F8.1,I10))
  515 IP = IP + NL + 1
C
C        RETURN
  520 CONTINUE
      I = IP
      RETURN
C
C        REACH - PRINT FIXED DATA AND PHASES
  600 NWT = IR(42)
      NL=2*NWT/13 + 3
      IF(IP + NL - 96) 620, 620, 610
  610 MH = 5
      GO TO 100
  620 J = NWT + 69
      K = IR(42) - 1
      WRITE (IW, 630) XIR(40), XIR(41), K    ,(XIR(L),L= 70, J)
  630 FORMAT ( 7H     N=, F6.3, 5H KTS=, F8.2, 8H PHASES=, I3, 2X,
     1 9F9.1/(3X, 13F9.1))
C        PRINT PHASE ELEVATIONS
      NWT = J + NWT
      J= J + 1
      WRITE (IW, 635) (XIR(L), L = J, NWT)
  635 FORMAT (3X, 13F9.3)
      IP = IP + NL
      GO TO 730
C
C        SETUP TO PRINT BACKWATER AND FLOW/ELEV TABLES - REACH OR LAKE
  640 NLB = IR(32)
      IF(NLB) 650, 660, 650
  650 NWB = NWR - NLB + 1
      NWR = NWR - NWB
  660 IF(NLF) 670, 680, 670
  670 NWF = NWR - NLF + 1
```

```
C
C        PRINT BACKWATER - REACH OR LAKE
  680 IF(NWB) 690, 400, 690
  690 NL = NWB/12 + 1
      IF(IP+ NL - 96) 710, 710, 700
  700 MH = 6
      GO TO 100
  710 NWB = NWB + NLB - 1
      WRITE (IW, 720) NLB, IR(31), IR(30), (XIR(L), L= NLB, NWB)
  720 FORMAT (14H     BACKWATER, I6, 11HCONTRL STA=, I10, 6H PARA=, I2,
     1 15H     Q, E1, E2=     , F14.1,
     1 F9.3,        F9.3, F14.1,F9.3,       F9.3/(F14.1,F9.3,     F9.3,
     2 F14.1,F9.3,      F9.3, F14.1, F9.3,       F9.3,F14.1,2F9.3))
      IP = IP + NL
      GO TO 400
C
C        LAKE/RESERVOIR
  730 WRITE (IW, 740) XIR(33), XIR(34), XIR(53)
  740 FORMAT (16H     UPPER ELEV=, F9.3,13H  LOWER ELEV=, F9.3,
     1 29H   SPILLWAY CREST ELEVATION =, F9.3)
      IP = IP + 3
C
C        TRANSFER POINT (GAGE)
  750 IF(NLF) 760, 770, 760
  760 NWF = NWR - NLF + 1
  770 WRITE (IW, 780) (IR(L),L=43,46),XIR(47)
  780 FORMAT (43H     TRANSFER POINT, DOWNSTREAM STATION IS , I1, I9,
     114H ADJACENT STA-, I9,10H RELATION-, I4, 8H WEIGHT=, F5.1)
      IP = IP + 3
      GO TO 640
C
C         DISTRIBUTION RECORD
  800 J = IR(1)
      K = 5
      WRITE (IW, 810) IS, J
  810 FORMAT (1H0, I9, 63H DAILY DISTRIBUTION-PERIOD 1    2    3    4
     1 5    6    7    8, 10X, 7HLENGTH=,I4)
  815 CALL CTIME (IR(K), IPR(1,1),IPR(2,1),IPR(3,1),IPR(4,1))
      L = K+8
      K = K+1
      WRITE(IW,820)   (IPR(K1,1), K1=1,4), (XIR(K1), K1=K,L)
  820 FORMAT (    I5, 1H , I3, 1H/, I2, 1H/, I2,18X, 8F5.0)
      K = K + 8
      IF(K - J) 815, 830, 830
  830 IP = IP + (J-4)/9 + 2
      GO TO 520
C         RETURN IS AT STATEMENT 520
      END
C
C***************************************************
C
C     Subroutine to provide Meaningful date stamp for output
```

```
c
      SUBROUTINE ETAD (DOYEAR,YEAR,MONTH,DAY)
C
C     Convert Day of Year to Date
C
      IMPLICIT NONE
C
      INTEGER*2 YEAR,DAY,MON(12),K,DOYEAR
C
      CHARACTER*4 MO(12),MONTH*4
C
      DATA MON/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA MO/'Jan.','Feb.','Mar.','Apr.','May ','June',
     1        'July','Aug.','Sep.','Oct.','Nov.','Dec.'/
C
      IF(MOD(YEAR,4).EQ.0) MON(2) = 29
C
      DAY = 0
      DO 30 K=1,12
         DOYEAR = DOYEAR - MON(K)
         IF(DOYEAR.LT.1) GO TO 40
   30 CONTINUE
C
   40 DAY = DOYEAR + MON(K)
      MONTH = MO(K)
      MON(2) = 28
      RETURN
      END
```

10.3 Appendix C

Subroutine BASINE

```
FTN7X,J,E
$EMA /C1/
      SUBROUTINE BASINE
     +,11:17 AM  WED., 27  FEB., 1985 (851126.0950)
C BASIN    MAIN PROGRAM TO PROCESS BASIN STATIONS IN ENGLISH UNITS OF ME
C           1. DIGESTS TIME-DEPENDENT METEOROLOGICAL DATA.
C           2. ROUTES INPUTS THRU BASEFLOW, SUBSURFACE, AND SURFACE
C              PHASES.
C           3. PRINTS (ON FILE IOW) THE RESULTING VALUES.
C
c      Re-organized to use Block If logic
c                  by:
c                      Pat Landine
c                      Division of Hydrology
c                      University of Saskatchewan
c
      IMPLICIT NONE        ! Pat Landine   July 29 1985
c
C
$INCLUDE [C1   :PL:121,NOLIST
$INCLUDE [INF  :PL:121,NOLIST       ! Pat Landine Aug. 1985
$INCLUDE [BASIN:PL:121,NOLIST
$INCLUDE [AREA1:PL:121,NOLIST
$INCLUDE [AREA2:PL:121,NOLIST
C
      REAL TEMP(5),TELEV(5),XS(1),XNPA(1),ERRTS(3), TSMSG(3),
     1     OPTION(20),OPTSCA(13),
     2     EFAREA,PARA,RATIO,RDTSMI,SCAL,SLOPE,SSSRO,SWEL,SWEQ,
     3     TEMPA,TEMPB,TPAR,THETAP
C
      INTEGER NPA (1) ,IHEAD, IOPTA,IOPTDC,IOPTMI,IOPTMO,IOPTMR,
     1       IOPTSB,IOPTTB,JT,K1
C
C        DCA(I,J) ARRAY- I IS DATA CODE
C                             J=1 SUM OF WEIGHTED VALUES FROM ALL HYDROMET
C                                 STATIONS FOR THIS PERIOD.
C                             J=2 COUNT OF CONTRIBUTING STATIONS.
C
      EQUIVALENCE (NPA(1), XNPA(1), NP)
      EQUIVALENCE (IS(1), XS(1))
C
      DATA OPTION/'MELT INDEX, THERMAL BDG,SNOW',
     1          ' BAND,  DEPL. CURVE,MELT AND RAIN,  MELT ONLY,      '/
      DATA OPTSCA/', RUNOFF FROM SNOW COVERED A',
     1             'REA ONLY(SPLIT BASIN)   '/
      DATA IOPTMI, IOPTTB, IOPTSB, IOPTDC/1, 4, 7, 10/
```

```
      DATA IOPTMO, IOPTMR/17,13/
      DATA TSMSG/'  -  NO   + '/
C
      IHEAD = ICL22   ! Correct for Common Block Inconsistency
      MIXSW=0
      IF(MEAS.EQ. 3) MIXSW=3
      IF(MIXSW.EQ.3) MEAS=0
C
C        SETUP RUN TIME HEADING
      DAT(1) = ABL
      DAT(2) = ABL
      CALL CTIME (ITME(1), JHR, JDA, JMO, JYR)
      JYR = 1900 + JYR
      CALL ALMTH (JMO, AMO(1))
C                                  RESET TO 1ST STATION
      IP = 1
      SWF = 0.
C                         TEST FOR BASIN
c
 100  K = 2*NP + IP
      IF(ICS(K) .NE. 1) GO TO 110
C                  TEST - OUTFLOWS SPECIFIED FOR THIS STATION.
      CALL DICTG (ICS(IP), 1, K, IS(1))
      IF(K .NE. 0) GO TO 110
      CALL DICTG (ICS(IP), 0, IAD, IS(1))
      GO TO 200
C        BASIN COMPLETED
 105  SWF = 1.
C
      WRITE (IOW,'("&")')                 !! BASIN DELIMITER
C
 110  IF(IP .GE. NP) GO TO 130
      IP = IP + 1
      GO TO 100
C
 125  IERROR = 60 + IERROR
      WRITE (IOW, 126) ICS(IP), NTD, (IS(J), J = 1,70), (ITP(J),J=1,60)
 126  FORMAT ( 7H1 BASIN, I10,12H ERROR, NTD=, I5/13H CHAR. RECORD/
     1 7( 10I11/),
     2 10H ITP ARRAY/ 6(10I11/)/"REAL XS ARRAY ")
      WRITE (IOW, *)  (XS(J), J = 1,70)
C
C        RUN COMPLETE - ALL BASINS DONE.
 130  CONTINUE
 136  WRITE(IOW, 140)
 140  FORMAT (1H1)
      RETURN
C
C
C        BASIN FOUND - SETUP FOR PROCESSING
 200  NTD = LODE + 2
      REWIND 61                           !! Unit 15 changed to 61
```

```
C         RESET INITIAL COND. ADJUSTMENT PROCEDURE
C
       SWIC = 0.          ! Adjustment Iteration Control Switch
C
       ICATS = 0          ! Time Shift Adjustment
C
       SWICC = 0.         ! Unadjusted Flow Print Switch
c
       PR_OPTN = IS(13)   ! Prairies Option  (Pat Landine)
C
       ISWU = IS(14)      ! Unadjusted Basin Results Print Switch
C
       PICA = 1.          ! Rain and Snow Volume Adjustment
C
       ITOSHF = 0         ! Rain Time Shift
C
       SWI =0.            ! Reset Input Switch, No Input-No Process
C
       SWS = 1.           ! Set Switch SWS to Rain-Basin
       ISTAP1 = ICS(IP)/10
       ISTAP2 = ICS(IP) - ISTAP1*10
C             RESET TO INPUT TIME-DEPENDENT DATA AND RELATIONS FROM IODT.
C             DATA FOR THIS STATION IS STORED IN COMMON BEHIND DICTIONARY.
       I = IS(40)
       J = 1
       IE = IS(1) - 3
c
       IF( I .EQ. 0)  THEN     ! No Precip Stations Listed
          SWI = 1.             ! Process Basin With no Input
       ELSE
C                          THERE ARE T/P STATIONS LISTED.
 210      ISTA =-IS(I+1)
C             ITP ARRAY-THREE WORDS PER HYDROMET STATION,
C             ITP(J) SCAN INDEX
C             ITP(J+1) INDEX TO NPA OF LOCATION OF HYDROMET RECORD.
C             ITP(J+2) INDEX TO NPA OF LOCATION OF TEMPERATURE STATION
C             CHARACTERISTIC RECORD WHICH CONTAINS STATION ELEVATION.
C
          ITP(J) = 11
          IDC = IS(I)
          CALL DICTG (ISTA, IDC, IA, NPA(NTD))
          IF(IA .EQ. 0) THEN
C                          (I) IS ADDR IN RECORD OF T/P ENTRY.(J) IS ADDR
C                          IN ITP-ARRAY CORRESPONDING TO I.
             ITP(J+1) = 0
          ELSE
C
             ITP(J+2) = 0
             ITP(J+1) = NTD
C             SET CUT-IN ARRAY CODE TO ZERO. PROBABLY REDUNDANT INSTRUCTION.
             NPA(NTD+4)=0
             SWI=1.
```

```
                 IF(IDC.NE.3) THEN
C                                    SNOW DATA, SET SNOW SWITCH ON.
                    SWS=0.
C                              LOOK FOR HYDROMET STATION CHARACTERISTIC RECORD
                    IDC=0
                    NTD=NTD+NPA(NTD)
                    CALL DICTG (ISTA,IDC,IA,NPA(NTD))
                    IF(IA.EQ.0) GO TO 258
                    ITP(J+2)=NTD
                 ENDIF
                 NTD = NTD + NPA(NTD)
  258            IF(NTD.GT.ICLGT) THEN
                    IERROR = 1
                    GO TO 125
                 ENDIF
              ENDIF
C                              TEST - LAST OF T/P STA
              IF(I .LT. IE) THEN
                 I = I + 3
                 J = J + 3
                 GO TO 210
              ELSE
C                                TEST - ANY INPUT.
                 IF(SWI.EQ.0) GO TO 110
              ENDIF
           ENDIF
C
C                   TIME-DEP. DATA FOR T/P STA LOADED.
C                   NOW LOAD RELATIONS
           IDC = -1
           MA = 0
C
           J = IS(38)          !
           GO TO 330           ! PR vs KE, ETI Loss
  290      IRKE = J            !
C
           J = IS(41)          !
           GO TO 330           ! Snow Cover Depletion
  300      IRSD = J            !
C
           J = IS(43)          !
           IDC = -2            !
           GO TO 330           ! Daily Snow Melt Distibution
  302      IRSDI = J           !
C
           J = IS(44)        !
           GO TO 330         ! Daily Rain Distribution
  304      IRRDI = J         !
C
           J = IS(45)        !
           IDC = -1          !
           GO TO 330         ! ETI
```

```
 306  IRETI = J         !
C
      J = IS(46)        !
      GO TO 330         ! SMI vs Runoff
 308  IRSMI = J         !
C
      J = IS(52)        !
      GO TO 330         ! Surface/Subsurface split relation
 310  IRSPS = J         !
C
      J = IS(53)        !
      GO TO 330         ! Air Temp. vs Dew Point
 312  IRDEW = J         !
C
      J = IS(63)        !
      GO TO 330         ! Outflow vs Surface Time of Storage
 314  IRTS = J          !
C
      J = IS(64)        !
      GO TO 330         ! Baseflow vs BII
 316  IRBF = J          !
C
      J = IS(51)        !
      GO TO 330         ! Season Runoff vs Snow Melt Rate
 318  IRMLT = J         !
      GO TO 390
C                    COMMON ROUTINE TO EXTRACT RELATIONS FROM FILE IODT.
c
 330  IF( J .NE. 0) THEN
          J = -IABS(J)
          CALL DICTG ( J, IDC, IA, NPA(NTD))
          IF(IA.EQ.0) THEN
              J = 0          ! Relation Can't be found , or not required
          ELSE
              J = NTD        ! Relation Loaded
              NTD = NTD + NPA(NTD)
              IF(NTD.GT.ICLGT) THEN
                  IERROR = 2
                  GO TO 125
              ENDIF
          ENDIF
      ENDIF
C       RETURN FOR NEXT SEARCH
      MA = MA + 1
      GO TO (290, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318), MA
C       END OF COMMON EXTRACT ROUTINE
C       SET TIME SHIFT SWITCH
 390  IF (IRRDI.NE.0) THEN
          ITSWT = NPA(IRRDI+2)
      ELSE
          ITSWT = 0
      ENDIF
```

```
C                     INITIALIZE BASIN PROCESS
C
      IF (XS(20).NE.0.) THEN
         IF (ISWU.EQ.0) THEN
C                 SETUP IC ADJUSTMENT AND TOLERANCE (TEST, IN 10CFS)
            SWIC = 1.
         ENDIF
         NICA = 4
C                 PRESET PREVIOUS ITERATION RESULT TO OBSERVED VALUE.
         QPREV = XS(20)
         TEST = XS(23)
         IF(XS(22) .EQ. 0.) THEN
            IF(XS(23) .EQ. 0.) THEN
               TEST = XS(20) * .1
            ENDIF
         ELSE
            IF(XS(23) .EQ. 0.) TEST = 999999.
            IF(XS(20)*(XS(22)/100.).LE. TEST) THEN
               TEST = XS(20)*XS(22)/100.
            ENDIF
         ENDIF
      ELSE
C                     NO IC ADJ
         SWIC = 0.
      ENDIF
C                     RESET 1ST PERIOD SWITCH (1ST PER OF STATION PROCESS)
  410 SWPF = 0.
C                     RESET 1ST DAY SW.
      SWDF= 0.
C                     SET DAY-START TIME,AND MONTH
      IDAY = ITME(1)
      ITO = ITME(1)
      NRTME = 1
C                     CALC. INITIAL BASIN DISCHARGE.
      J = IS(31) + 69
      QSR = XS(J)
      QIN = XS(70) + XS(J+1)
      J = J + IS(33)
      QSSR = XS(J)
      QIN = QIN+XS(J+1)
      J = J + IS(35)
      QBR = XS(J)
      QO = QSR + QSSR + QBR
      QOUT = QO
C
C            SETUP BII CONTROLS
C        SWBII = 1 FOR RISING Q,=-1 FOR FALLING Q, =0 IF NO FALL BIITS
C        BIITS IS TS RELATED TO SWBII (XS(37) OR XS(50))
C        RISE OR FALL IS DETERMINED FROM ROUTING PHASE VALUES.
C
      IF(XS(50) .EQ. 0) THEN
         SWBII = 0.
```

```
            BIITS = XS(37)
         ELSE
C                      SET SWITCH TO RISING FOR 1ST PERIOD.
            SWBII = 1.
C                      IF FALLING Q, REVERSE SWITCH
            IF(QIN.LT.QOUT) SWBII=-1.
         ENDIF
C                        SETUP BASIN OUTFLOW RECORD.
C
         IRBOF = NTD
         NPA(IRBOF) =  5 +   NTI
         NTD = NTD + NPA(IRBOF)
         IF(NTD .GT. ICLGT) THEN
            IERROR = 3
            GO TO 125
         ENDIF
         NPA(IRBOF+1) = ICS(IP)
         NPA(IRBOF+2) = JDATE
         NPA(IRBOF+3) = 2
         XNPA(IRBOF+4) = QOUT
         NRBOF = IRBOF + 5
C
C                 RESET TABLE-SCAN INDEXES FOR TIME-DEP DATA
C
         NRTS  = 0    $  NRRDI = 0   $  NRETI = 0      $  NRSMI = 0
         NRSPS = 0    $  NRBF = 0    $  IRSCA=0        $  WP = 0.
         NRKE = 0     $  ROP = 0.    $  BII   = XS(66) $  BFP = 0.
         RGP = 0.     $  XKE = 0.    $  PSN = 0.       $  SNOW = 0.
         SNRAD = 0.   $  SNCC = 0.   $  SNF = 0.       $  PAR = 0.
         SCA = XS(68)
         IF (SCA.LT.0.) SCA = 0.
         IF (SCA.GT.100.0) SCA = 99.9
         SMLT = XS(61)
         RAIAR=XS(69)
         SMA = 0.  $   SRA = 0.  $   E = 0.   $   DD = 0.  $  AREAM = 0.
c
C
C         INITILIZE OTHERS VARIABLES
C
         EFAREA=100.  $  ISETS=0     $  TM0=0.01    $  TM1=0.01
         TM2=0.01       $  ITDST=0     $  IWTF=0.     $  TCOUNT=0
         ZETI=0.        $  AETI=0.     $  RSFA=1.     $  XHR=24.
C
C           SET I.C. DSMI   DMMY BASIN/SMIMAX CONCEPT
C            SMIMAX NO INPUT ASSUME NO LIMIT
C
         SUBLT=0.0
         DSMI=XS(47)
         IF(XS(61).GT.0.)DSMI=XS(61)*100.
         XS(61)=0.
         SMLT=0.
         IF(XS(58).GT. 0) SMIMAX=XS(58)
```

```
      IF(XS(58) .LE. 0.)SMIMAX=999.9
      SSSI=0.0
      SSSO=0.0
      AETI=0.
      ZETI=0.
C
C     If Prairies option Initialize INF. Variables
C
      IF(PR_OPTN.EQ.1) THEN                    ! Pat Landine Sep. 20 85
         MAXSWE = XS(48)
         THETAP = XS(47)/SMIMAX                ! SMI = XS(47)
         TOTINF = (5.*(1.-THETAP)*(MAXSWE*25.4)**0.584)/25.4
         IF(TOTINF.GT.MAXSWE) TOTINF = MAXSWE
         THRESHOLD = TOTINF/(240./ITME(NRTME+1) *6.)  ! Inf. Threshold
C                                                     !  = 6 days
         SPRING = .FALSE.                      ! Not Spring Yet
         SUMINF = 0.0                          ! Accumulated Inf.
      ENDIF
c
C              PLUS IS THE SURPLUS OF SMI OVER SMIMAX
      PLUS=0.0
C               RESET TEMP STATION DATA FOR LAPSE RATE COMPUTATION
C               FOR NEW WATERSHED
C
      TEMP(1)=0.    $  TEMP(2)=0.    $   TEMPA=0.
      TEMPB=0.      $  TELEV(1)=0.   $   TELEV(2)=0.
C
C              RESET SWITCH TO HEAD 1ST PAGE.
C
      SWA = 0.   $   I = JHR     $   K = JDA      $   K2 = JMO
      K3 = JYR   $   IPAGE = 0   $   MNTHN = JMO   $   N = 1
C
C        DETERMINE IF SNOW, OR RAIN BASIN. INITIALIZE SNOW.
C        AVOID ERROR ON DEVIDE CHECK IF SNOW BASIN
C
      IF(XS(49) .GT. 0.  .AND.  XS(48) .LE. 0.)XS(48)=0.001
C
      IF(SWS .EQ. 0) THEN
C                        TEST FOR AREA VS. ELEVATION CURVE.
C                             AND  SEASON RUNOFF SPECIFIED
         IF(IS(39).NE.0 .AND. IRSD.NE.0 .AND. XS(49).NE.0) THEN
            ARO=XS(48)
C                        IF J CARD HAS 1 IN COL.35, USE RAIN+MELT FOR ARO.
            IF(ICL30(6).EQ.1) ARO=ARO+XS(69)
C
C        INSURE THAT ARO DOES NOT EXCEED SEASONAL RUNOFF.
C        CODE 2 ON CB01 CARD =   SNVOL OPTION FOR PLAIN AREA
C        SI OR XS(49) FOR MIN W.E. FOR 100% SNOW COVER CALLED NORMAL W.E
C        SI OR XS(49) CAN NOT BE UPDATED W/ NEW SNOW
C
            SI=XS(49)
            SWSI=0.0
```

```
            IF(IS(15) .EQ. 2)SWSI=1.
            IF(ARO .LE. XS(49) .OR. SWSI.NE. 0) THEN
               PAR=(ARO/XS(49)) * 100.
               IF(PAR .GT. 99.9)PAR=99.9
            ELSE
               WRITE (IOB,'("***ERROR-ARO ",F7.2," GREATER"
     1               " THAN SRO ",F7.2," FOR STATION ",I10,".",I1,
     2               "--PAR SET TO 99,  EXECUTION CONTINUING")')
     3               XS(48), XS(49), ISTAP1, ISTAP2
               PAR = 99.9
            ENDIF
C                      TEST WHAT OPTION OF SCD RELATIONSHIPS
            J = XNPA(IRSD+4)
            NRSD = 0
            PARA=0
            CALL TLU2 (1,PARA,J ,NRSD,  NPA(IRSD+5),RSL(1) ,KE)
            TSCT=RSL(2)
C                            THERETICAL SNOW COVER AREA IS EXTRACTED
            CALL TLU2 (1, PAR, J, NRSD, NPA(IRSD+5), RSL(1), KE)
            EAV = 0.
            NRDEW = 0
            NREAV = 0
            NRMLT = 0
            NRSDI = 0
            EHM = 0.
            EHMN = 0.
            SWE = 0.
            IF(IS(42) .NE. 0) THEN
C                         SETUP OUTPUT AREA FOR SNOW COVERED AREA RECORD
               IRSCA = NTD
               NTD = NTD + 10 + 2*NTI
               IF(NTD .GT. ICLGT) THEN
                  IERROR = 4
                  GO TO 125
               ENDIF
               NPA(IRSCA+1) = -IS(42)
               NPA(IRSCA+2) = JDATE
               NPA(IRSCA+3) = 1
               NPA(IRSCA+4) = 0
               NPA(IRSCA+8) = 2
               NPA(IRSCA) = NTD - IRSCA
               NRSCA = IRSCA + 10
            ENDIF
C                    COMPUTE RATIO OF ACTUAL SNOW COVER TO THEORETICAL SCA
C
            IF(SCA .NE. 0 .AND. RSL(2).NE.0.) THEN
C
               RATIO  =   SCA /RSL(2)
C                    INITIALIZE SCAT,SWET CO-ORDINATES OF DEVIATION POINT
               SCAT=0
               SWET=0
C                    BYPASS DEVIATION POINT SEARCH IF ACC R.O. OPTION
```

```
                IF(TSCT.LE.1) THEN
C                       IF AREAL SNOWPACK OPTION GO AHEAD TO
C                       CALCULATE DEVIATION POINT ON SCD CURVE
                   SWEL=XS(48)
                   SCAL=SCA
                   PARA=PAR
                   SLOPE=XS(67)
C                               DEFAULT SLOPE OF DEVIATION CURVE FOR
C                      ASSURING CONVERGENCE IN THE DEVIATION POINT SEARCH
                   IF(RATIO.GT.1 .AND. SLOPE.LE.2  )SLOPE=2
                   IF(RATIO.LT.1 .AND. SLOPE.GE.0.5)SLOPE=0.5
                   IF(SLOPE.LE.0)SLOPE=0
C
C                             SEARCH DIVIATION POINT AT 5% ACCURACY
 4393              PARA=PARA-5
                   IF(PARA.LE.0)PARA=0
                   SWEQ=XS(49)*PARA/100.
                   CALL TLU2(1,PARA,J,NRSD,NPA(IRSD+5),RSL(1),KE)
                   SCT=RSL(2)
                   SCA=100*SLOPE*(SWEQ-SWEL)/XS(49) + SCAL
                   IF(PARA.NE.0) THEN
C                     CONVERGE ON 1ST TRIAL IF INITIAL SCA,SWEQ ON CURVE
                      IF(RATIO.NE.1) THEN
                         IF(RATIO.GE.1) THEN
C                                       INITIAL SCA ABOVE SCD CURVE
                            IF(SCA.GT.SCT) GO TO 4393
                         ELSE
C                                        INITIAL SCA BELOW SCD CURVE
                            IF(SCA.LT.SCT) GO TO 4393
                         ENDIF
                      ENDIF
                   ENDIF
C                                DEVIATION POINT FOUND ON SCD CURVE
                   SWET=SWEQ
                   SCAT=SCT
                   SCA=SCAL
                   SWEQ=SWEL
C                                RE-CALCULATE SLOPE OF DEVIATION LINE
                   IF(SWET.NE.SWEL)
     1                XS(67)=((SCAT-SCAL)/100.) /
     2                       ((SWET-SWEL)/XS(49))
                   IF(SWET.EQ.SWEL)XS(67)=0
C                                 SET SWITCH FOR SCA DEPLETION
                   SWSCD=0
                   IF(RATIO.GT.1)SWSCD=1
                   IF(RATIO.LT.1)SWSCD=-1
                ELSE
C                        ACC R.O. OPTION XS(67)=SCA/SCT
                   XS(67)=RATIO
                ENDIF
C
C
```

```
                 ELSE
                     XS(67) = 1.
                     SCA = RSL(2)
                     IF (SCA.LT.0.) SCA = 0.
                     IF (SCA.GT.99.9) SCA=99.9
                 ENDIF
C                         COMPUTE RATIO OF ACTUAL MELT-RATE TO THEORETICAL MR.
C
                 IF(IRMLT .NE. 0) THEN
                     J = XNPA(IRMLT+4)
                     CALL TLU2 (1,PAR,J,NRMLT,NPA(IRMLT+5),RSL(1),KE)
                     IF(SMLT .NE. 0) THEN
                         XS(60) = SMLT/RSL(2)
                     ELSE
                         SMLT = RSL(2)
                         XS(60) = 1.
                     ENDIF
                 ELSE
C                                  COMPUTE SNOW MELT CONSTANTS
C                                            RADIATION-NON FOREST AREA
                     RNFK = XS(55) * (1.- XS(57)) * .00004
C                                            CONVECTION-CONDENSATION
                     CCK  = XS(56) *.0084
C                                            LONGWAVE RADIATION IN FOREST.
                     CFK = .029* XS(57)
                 ENDIF
             ELSE
C                              RAIN ONLY BASIN
                 SWS = 1.
                 IRSCA = 0
             ENDIF
         ENDIF
C
C        Reset for Month ; Print Heading By Entering BAS_PRINT at 1215
c
         IF(SWA.EQ.0) THEN
             CALL TWELVE_FIFTEEN (EFAREA,RDTSMI,SSSRO,JT,TPAR,IHEAD)
             SWA = 1.
         ENDIF
C
C           RESET FOR DAY - INCREMENT TO END OF DAY, RESET SWP - 1ST PER
C             OF DAY.
   510   IF(IDAY .LE. ITO) THEN
             IDAY = ITO  + 240
C                            RESET SWP, THIS IS START OF NEW 24 HOUR DAY.
             SWPR = 0.
             SWPS = 0.
         ELSE
             SWPR = 1.
             SWPS = 1.
         ENDIF
C
```

```
C                 PROCESS A PERIOD  Setup Period Hours
C
      CALL BASEC
c                      Print Basin Results
c
      CALL BAS_PRINT (EFAREA,RDTSMI,SSSRO,JT,TPAR,IHEAD)
C
c     Do Potential Infiltration Calcuations
c
      IF(XS(48).GT.MAXSWE) THEN    ! Pat Landine Aug. 1985
         MAXSWE = XS(48)
         THETAP = SMI/SMIMAX
         TOTINF = (5.*(1.-THETAP)*(MAXSWE*25.4)**0.584)/25.4
         IF(TOTINF.GT.MAXSWE) TOTINF = MAXSWE
         THRESHOLD = TOTINF/(240./ITME(NRTME+1) *6.)  ! Inf. Threshold
C                                                     ! 6 DAYS
         SPRING = .FALSE.                             ! Not Spring Yet
      ENDIF
c
      MNTHN = K2
C                 SETUP INITIAL CONDITIONS AT END OF COMPUTE PERIOD
      XS(47) = SMI
      XS(66) = BII
      XS(68) = SCA
      IS(27) = ITE
      XS(61) = SMLT
      XS(69)=RAIAR
C                       STORE OUTFLOW TO OUTPUT RECORD.
      XNPA(NRBOF) = QOUT
      NRBOF = NRBOF + 1
      N = N + 1
      QO = QOUT
      IF(SWIC .NE. 0.) GO TO 1396
C                      TEST - SNOW COVER RECORD TO BE WRITTEN.
      IF(IRSCA.NE.0) THEN
         IF(SWS.EQ.0) THEN
            NPA(NRSCA) = ITO + IHR
            XNPA(NRSCA+1) = SRANS
            NRSCA = NRSCA + 2
         ENDIF
      ENDIF
C
      IF(IS(19).NE.0) THEN
C                            OUTPUT INSTANTANEOUS CONDITIONS
         IF(N.GT. NTI) GO TO 1430
         CALL ICOUT (IP, IS(1))
      ENDIF
C                 TEST - LAST PERIOD
C
 1396 IF(N.GT. NTI) GO TO 1430
      ITO = ITE
      IF(ITME(NRTME+3).EQ.0) GO TO 510
```

```
      IF(ITO.LT. ITME(NRTME+2)) GO TO 510
      NRTME = NRTME + 2
      GO TO 510
C                TEST FOR INITIAL CONDITION ADJUSTMENT
C
1430  IF(SWIC) 1455, 1440, 1455
1440  IF(XS(20)) 1470, 1520, 1470
1455  ERR = XS(20) - QOUT
      IF (SWICC.NE.1.) THEN
         SWICC = 1.
         QOUTU = QOUT
      ENDIF
      IF (TEST.LT.ABS(ERR)) THEN
         IF (ITSWT.NE.1) THEN
C                  IF PREVIOUS ITERATION RESULTS IN SAME QOUT, QUIT.
            IF (QPREV.EQ.QOUT) GO TO 1465
            QPREV = QOUT
            IF(NICA .EQ. 0) GO TO 1465
            NICA = NICA - 1
            IF(SWIC .GE. 0.) THEN
C                              CALC ADJUSTMENT TO PICA
               APICA = 0.5
               IF (ERR .LT. 0.) APICA = -0.25
               SWIC = -1.
            ELSE
               IF(APICA .LE. 0.) THEN
                  IF(ERR .GE. 0.) THEN
                     APICA = -APICA/2.       ! Reversal
                  ELSE
                     APICA = APICA/2.
                  ENDIF
               ELSE
                  IF(ERR.LT.0) THEN
                     APICA = -APICA/2.       ! Reversal
                  ELSE
                     APICA = APICA/2.
                  ENDIF
               ENDIF
            ENDIF
            PICA = PICA + APICA
C                              RETURN TO TRY AGAIN
            GO TO 1467
C                              PERFORM TIME SHIFT
         ENDIF
         ICATS = ICATS + 1
         IF (ICATS.EQ.2)  GO TO 14643
         IF (ICATS.EQ.3)  GO TO 14644
         ITOSHF = ITME(2)/2
         IF (SWBII.EQ.1..AND.ERR.LT.0.)    GO TO 14649
         IF (SWBII.EQ.-1..AND.ERR.GT.0.)   GO TO 14649
14643    ITOSHF = - ITOSHF
         GO TO 14649
```

```
14644    ITSWT = 0
         IF (ABS(ERR).LE.ERRTS(1).AND.ABS(ERR).LE.ERRTS(2)) GO TO 1467
         IF (ERRTS(2).LE.ABS(ERR).AND.ERRTS(2).LE.ERRTS(1)) GO TO 14645
         ITOSHF = 0
         GO TO 1467
14645    ITOSHF = - ITOSHF
         GO TO 1467
14649    ERRTS(ICATS)  = ABS(ERR)
         GO TO 1467
      ENDIF
C            TOLERANCE MET OR 10 TRYS TAKEN. RECOMPUTE FOR PRINTOUT
C
1465  SWIC = 0.
1467  CALL DGET (IAD, IS(1))
      GO TO 410
1470  IF (ISWU.NE.0) THEN
         ISWU = 0
         SWIC = 1.
         GO TO 1455
      ENDIF
C           ADJUSTMENT WITHIN ALLOWED ERROR COMPLETE. ADD REMAINDER TO
C             PHASES.
      J = IS(31)
      XI = J
      ERR = XS(20) - QOUT
      X = ERR * QSR / QOUT
      K = 70
C        ADJUST SURFACE PHASES
      MA = 1
1475  DO  I = 1, J
         QO =XS(K)+X
         IF(QO.LT.0 ) QO = 0.
         XS(K)=QO
         K=K+1
      ENDDO
C
      GO TO (1482, 1484, 1486), MA
C
1482  MA = 2                     !
      X = ERR * QSSR / QOUT      ! Adjust Subsurface Phases
      J = IS(33)                 !
      GO TO 1475                 !
C
1484  MA = 3                     !
      X = ERR * QBR / QOUT       ! Adjust Baseflow Phases
      J = IS(35)                 !
      GO TO 1475                 !
C
1486  NICA = 4 - NICA            !
      XNPA(NRBOF-1) = XS(20)     ! Print Adjustment Result
      IF (ITOSHF.LT.0) IMSG = 3
      IF (ITOSHF.EQ.0) IMSG = 2
```

```
      IF (ITOSHF.GT.0) IMSG = 1
C
      WRITE (IOW,1488) PICA, QOUT, NICA, QOUTU, TSMSG(IMSG), XS(20)
 1488 FORMAT (73H0BASIN INITIAL CONDITION ADJUSTMENT RESULTS. RAIN-MELT
     1CORRECTION RATIO =, F6.3, 20H  COMPUTED OUTFLOW =, F10.1 /
     2 20H  ITERATIONS TAKEN =, I3, 22H  UNADJUSTED OUTFLOW =, F10.1,
     3 6X, A4, 10HTIME SHIFT, 10X, 18HOBSERVED OUTFLOW =, F10.1)
      XS(20) = 0.
C
C        TIME ALL DONE FOR THIS STATION
C
 1520 IF(IS(19).NE.0) CALL ICOUT (IP, IS(1))
      IF(IRSCA.NE.0) THEN
         IF(SWS.EQ.0) THEN
C                            WRITE OFF SCA RECORD FOR RAIN BASIN.
            IA = 0
            CALL DICTP (NPA(IRSCA+1), IA, NPA(IRSCA))
         ENDIF
      ENDIF
C              STORE BASIN OUTFLOW RECORD
C
      IA = 0
      CALL DICTP (NPA(IRBOF+1), IA, NPA(IRBOF))
C
      IS(16) = IS(17)
      CALL DPUT (IAD, IS(1))
C
C        CONSTRUCT SNOW MELT CALC. OPTION LINE
C
      IF(SWS .NE. 0.) GO TO 105          ! Transfer control to Start
C
C        MELTRATE OR THERMAL BUDGET
      IOPTM = IOPTMI
      IF(IRMLT .EQ. 0) IOPTM=IOPTTB
C                                       SNOW BAND OR DEPL. CURVE
      IOPTB = IOPTDC
      IF(IS(15) .EQ. 1) IOPTB=IOPTSB
C                                        LAPSE TEMPERATURES
      OPTL = AY
      IF(SWE .EQ. 0.) OPTL = AN
      I = IOPTM+2
      J = IOPTB+2
C                                ACCUM. RUNOFF FUNCTION OF MELT OR MELT+RAIN.
      IOPTA=IOPTMO
      IF(ICL30(6).EQ.1) IOPTA=IOPTMR
      K=IOPTA+3
C                                              SPLIT BASIN
      IF(IRSCA.NE.0) THEN
         WRITE (IOW,1580)(OPTION(N),N=IOPTM,I),(OPTION(K1),K1=IOPTA,K),
     1                   (OPTION(K2),K2=IOPTB,J), OPTL,OPTSCA
         WRITE (IOW,'("*** SMIMAX=",F10.2)') SMIMAX
         IF(SWSI.EQ. 1 ) WRITE (IOW,'("*** PLAIN AREA MELT OPTION"
```

```
     1                                "   SI=",F10.2)') SI
            IF(MIXSW.EQ.3) WRITE (IOW,'("*** MIXED UNIT MODE FOR"
     1                                  " METRIC T,P,ETI,MR")')
            GO TO 105
         ENDIF
C
         WRITE (IOW,1580)(OPTION(N),N=IOPTM,I),(OPTION(K1),K1=IOPTA,K),
     1                  (OPTION(K2),K2=IOPTB,J),OPTL
 1580 FORMAT ("*MELT OPTIONS ARE ",3A4,"%AR FUNCTION OF ",7A4,
     1          "LAPSE= ",A1,13A4)
C
         WRITE (IOW,'("*** SMIMAX= ",F10.2)') SMIMAX
         IF(SWSI.EQ. 1 ) WRITE (IOW,'("*** PLAIN AREA MELT OPTION"
     1                                "  SI= ",F10.2)') SI
         IF(MIXSW.EQ.3) WRITE (IOW,'("*** MIXED UNIT MODE FOR"
     1                               " METRIC T,P,ETI,MR")')
C           TEST - END OF STATIONS
         GO TO 105
C
         END
C
C*************************************************************
C
$EMA /C1/
         SUBROUTINE BAS_PRINT (EFAREA,RDTSMI,SSSRO,JT,TPAR,IHEAD)
C
C        This section Separated from BASINE by Pat Landine July 30 1985
C
         IMPLICIT NONE
$INCLUDE [C1    :PL:121,NOLIST
$INCLUDE [INF   :PL:121,NOLIST
$INCLUDE [BASIN:PL:121,NOLIST
$INCLUDE [AREA1:PL:121,NOLIST
C
         REAL XS(1),XNPA(1),
     1        EFAREA,RDTSMI,SSSRO,TPAR
C
         INTEGER NPA (1),
     1           JT,IHEAD
C
C
         EQUIVALENCE (NPA(1), XNPA(1), NP)
         EQUIVALENCE (IS(1), XS(1))
C
C           PRINT RESULTS OF SUBROUTINE BASINE
C
         CALL CTIME ( ITE , I, K, K2, K3)
         K3 = 1900 + K3
         IF(MNTHN.EQ.K2) THEN
            IF(IS(17) .GE. 8 .OR. SWIC.NE.0) THEN
               ILINE = ILINE + 1
               RETURN
```

```
              ENDIF
              IF(ILINE.LE. 44) GO TO 1245
              GO TO 1232
          ENDIF
C*****
          ENTRY TWELVE_FIFTEEN (EFAREA,RDTSMI,SSSRO,JT,TPAR,IHEAD)
 1215     CALL ALMTH (K2, DMO(1))
          CALL EXETI (IRETI, NRETI, K2, ETI)
          IF(SWIC .NE. 0. .OR. IS(17).GE. 8) THEN
              ILINE = ILINE + 1
              RETURN
          ENDIF
          IF(SWA .NE. 0.) THEN
C                                   TEST - OVERFLOW AT MONTHEND.
              IF(ICL30(2) .NE. 0) THEN
                  IF(ILINE.LE. 42) GO TO 1240
              ENDIF
          ENDIF
 1232     IPAGE = IPAGE + 1
          WRITE (IOW,'("1" 20X,"BASIN RESULTS - STATION",I10,
         1        ".",I1,1X,11A4,/"      1 RUN DATE  RUN NO."
         2        "  INITIAL DATE, HOUR          JOB DESCRIPTION")')
         3         ISTAP1, ISTAP2, (IS(J),J=3,13)
          IF(IHEAD.EQ.0) THEN
              WRITE(IOW,'(4X,2A4,I8,I6,1X,3A1,2I5,1H0,I11,2X,10A4,7X,
         1                 " ALBERTA ENVIRONMENT NOV/84")')
         2                 DAT, JDATE,JDA, AMO, JYR, JHR, JOB, JID
          ELSE
              WRITE(IOW,'(4X,2A4,I8,I6,1X,3A1,2I5,1H0,I11,2X,10A4,3X,
         1                 " U. of S. Division of Hydrology")')
         2                 DAT, JDATE,JDA, AMO, JYR, JHR, JOB, JID
          ENDIF
          IF(IS(15).EQ.1) THEN
              WRITE(IOW,'(28X,"ETI =",F5.2," IN./DAY" 35X," AREA =",F7.1,
         1         " SQ. MI.")') ETI, XS(30)
              WRITE(IOW,'(" DY HOUR  PCPN ZRA  RAIN"
         1         "  SNOW  AC-SN  D-DY  ZMA M-RATE  MELT  ETI"
         2         "  SMI  ROP  RGP   BII  BFP  BASEF  SUBSF"
         3         "   SURF   DISCH HOUR DAY"/"*")')
          ELSEIF(SWS.GE. 1.0) THEN
              WRITE(IOW,'(28X,"ETI =",F5.2," IN./DAY, MELT RATE ="
         1         ,F6.3," IN./DEGREE-DAY, AREA =",F7.1," SQ. MI.")')
         2         ETI, SMLT, XS(30)
              WRITE(IOW,'(" DY HOUR  PCPN ZRA RN-AR ML-AR ZAR ELEV SCA"
         1        " D-DY ZMA  MELT  MI  ETI  SMI  ROP  RGP  "
         2        "BII  BFP  BASEF  SUBSF   SURF   DISCH HOUR DAY"/"*")')
          ELSE
              TPAR=0.0
              JT=XNPA(IRSD+4)
              CALL TLU2(1,TPAR,JT,NRSD,NPA(IRSD+5),RSL(1),KE)
              TSCT=RSL(2)
              IF(TSCT.LE. 1.0) THEN
```

```
                WRITE(IOW,'(28X,"ETI ="F5.2," IN./DAY, MELT RATE ="
     1             ,F6.3," IN./DEGREE-DAY, AREA =", F7.1,
     2             " SQ. MI.")') ETI,SMLT,XS(30)
                WRITE(IOW,'(" DY HOUR  PCPN %RA RN-AR"
     1             " SNVOL %VL ELEV SCA D-DY %MA  MELT  MI  ETI"
     2             "  SMI  ROP  RGP  BII  BFP  BASEF  SUBSF   SURF"
     3             "   DISCH HOUR DAY"/"+")')
           ENDIF
         ENDIF
C
         ILINE = 0
 1240    WRITE (IOW,'(1X, 3A1, I5, 115X, 3A1, I5)') DMO, K3, DMO, K3
         ILINE = ILINE + 1
 1245    IQP =(QOUT*10.) + .5
         IQS = QSR *10.
         IQSS = QSSR * 10.
         IQB = QBR * 10.
         IELEV = (E*10.) + .5
         RRAA=WP*SRA/100.
         SSNN=WP-RRAA
         RRMI=(WP*SRA/100.+PSN*SMA/100.)
         RRRG=RRMI*ROP
         ISCA = SCA + .5
         IROP =(ROP*100.) +.5
         IBFP =(BFP*100.) + .5
         ISMA = SMA + .5
         ISRA = SRA + .5
         IPAR = PAR + .5
         IF(IROP.GT. 100)WRITE(IOW,'(10X,"*****  WARNING:"
     1                        " ROP GREATER THAN 100%  ("F7.2") ***** ")')
     2                         ROP
C
C           TEMPORARY SMI DUE TO RESIDUAL RUNOFF MOISTURE
C           IN SOIL....BASIN STORAGE
C           SSSI = ACC.  S/SS MOISTURE INPUT TO WATERSHED  - INCHES
C           SSSO = ACC.  S/SS MOISTURE OUTPUT FROM WATERSHED  - INCHES
C           RRRG, SSSRO ,SSSI, SSSO  ALL BASED 100% CATCHMENT
C           DTSMI FOR SPLIT OPTION  BASED ON EFFECTIVE CATCHMENT  ONLY
C
         IF (PR_OPTN.LT.1) THEN
            SSSRO = RRRG*(1.0-BFP)
            SSSI = SSSI + SSSRO
            SSSO = SSSO + 12.0*((IQS + IQSS)*3600.0*XHR)/
     1                     (XS(30)*5280.0*5280.0)
            IF(EFAREA.GT.10.)
     1                 DTSMI = SSSRO*(100./EFAREA) -12.0*((IQS +IQSS)
     2                  *3600.*XHR) / (0.01*EFAREA *XS(30)*5280.*5280.)
            IF(EFAREA.LE. 20) DTSMI=0.
            IF(SSSI.LT.SSSO) DTSMI=0.0
C                                      UPDATE EFAREA IF DRAINING PERIOD ENDS
C                                      SPLIT BASINS ONLY
            RDTSMI=DTSMI/XHR
```

```
            IF(RDTSMI.GE. (-0.005)) THEN
C                         EFAREA = EFFECTIVE DRAINAGE FOR SMI ADJUSTEMENT
              EFAREA=100.
              IF(SWS.EQ. 0 .AND. IRSCA .NE. 0) EFAREA = SCA
              IF(SWS.NE. 0 .AND. DCA(2,2).NE.0 ) EFAREA = DCA(2,1)
            ENDIF
C            PLUS IS THE SMI SURPLUS OVER SMIMAX
            SMI = SMI + PLUS + DTSMI
            IF(SMI.LE.SMIMAX) PLUS = 0.
            IF(SMI.GT.SMIMAX) PLUS = SMI-SMIMAX
            IF(SMI.GT.SMIMAX) SMI = SMIMAX
            IF(SMI.LT. 0) SMI = 0.0
            IF(PLUS.LT.0.) PLUS = 0.0
C                                     RESET PLUS  FOR SMALL EFFECTIVE AREA
            IF(EFAREA.LT.20.) PLUS = 0.
C                           DTSMI = CHANGE IN  TEMPORARY BASIN STORAGE
C                         LIMIT ACCUMULATED S/SS MOISTURE OUTPUT TO TOTAL INPUT
            IF(SSSI.LT. SSSO)SSSO=SSSI
         ENDIF
C                                    AETI ( ETI FROM LAST PERIOD)
         AETI=ZETI
C
C           PRINT DETAILS OF IMPORTANT PARAMETERS
C
         IF(IRSCA.EQ.0) DSMI = 0.
         IF(IRSCA.EQ.0) JDSMI = 0
         IF(IS(15).NE.1) THEN
           WRITE (IOW,'(I3,I4,1H0,F6.2,I4,2F6.2,I4,I5,I4,F5.1,I4,
     1          F6.2,F5.2,1X,F4.3,F6.3,I3,F6.3,F5.2,I4,3I7,I8,I5,1H0,I3
     2          )') K,I,WP,ISRA,RAIAR,XS(48),IPAR,IELEV,ISCA,DD,ISMA,
     3          PSN,RRMI,ZETI*XKE,XS(47),IROP,RRRG,BII,IBFP,IQB,IQSS,
     4          IQS,IQP,I,K
         ELSE
           WRITE (IOW,'(I3,I4,1H0,F6.2,I4,2F6.2,F7.2,F6.1,I5,F7.3,
     1          F6.3,F5.4,F6.3,I4,F6.3,F6.2,I4,3I7,I8,I5,1H0,I3)')
     2          K, I,WP,ISRA,RRAA,SSNN,XS(48) , DD ,ISMA , SMLT,
     3          PSN,ZETI*XKE,XS(47),IROP,RRRG,BII,IBFP,IQB,IQSS,
     4          IQS,IQP,I,K
         ENDIF
         ILINE = ILINE + 1
         RETURN
         END
```

10.4 Appendix D

Common Block INF

```
C
C     INCLUDE FILE FOR COMMON BLOCK 'INF'     SSARR
C
C      This Common Block Contains Variables for The Prairies Option
c           Written By: Pat Landine
c                       Division of Hydrology
c                       University of Saskatchewan
C
      INTEGER  PR_OPTN
C
      REAL MAXSWE,TOTINF,INFR,THRESHOLD,SUMINF
C
      LOGICAL SPRING
C
      COMMON /INF/ MAXSWE,TOTINF,INFR,PR_OPTN,THRESHOLD,SUMINF,SPRING
C
c     Maxswe    - The maximum Snow Water Equivalent that occurred
c                 prior to spring melt
c
c     Totinf    - The total predicted infiltration for snow melt period
c
c     Infr      - The Infiltration Ratio
c
c     Pr_Optn   - The Prairies Option selected
c
c     Threshold - The amount of snow melt that must occur in one
c                 period before spring is declared.
c
c     Suminf    - The amount of infiltration that has already occurred
c
c     Spring    - Logical variable; True if spring has been declared
c
```

10.4.1 Subroutine BASEC

```
FTN7X,J,E
$EMA /C1/
      SUBROUTINE BASEC
     +,11:15 AM  WED., 27  FEB., 1985 (851126.1013)
C PART OF SUBROUTINE BASINE. THIS SECTION OF CODE WAS PUT INTO A
C  SEPARATE SUBROUTINE TO REDUCE THE COMPILER REQUIREMENTS FOR BASINE.
C
C      BLOCK IF'S put in July 17 1985    Pat Landine
C
      IMPLICIT NONE           ! PAT LANDINE  JULY 17 85
C
$INCLUDE [C1    :PL:121,NOLIST
$INCLUDE [INF   :PL:121,NOLIST
$INCLUDE [BASIN:PL:121,NOLIST
$INCLUDE [AREA1:PL:121,NOLIST
$INCLUDE [AREA2:PL:121,NOLIST
C
      REAL TEMP(5),TELEV(5),XS(1),XNPA(1),
     1      DELTA,DELVT,DRGP,DROP,DRYNES,DSMIR,DSMIS,DXKE,RATIO,SFAC,
     2      SFAP,SND,TEMPA,TEMPB,TPAR,TXKE,WPRATE,XLAPSE,
     3      SMI_EXCES,DELTA_SMI
C
      INTEGER NPA (1) ,JE,JT
C
C         DCA(I,J) ARRAY- I IS DATA CODE
C                           J=1 SUM OF WEIGHTED VALUES FROM ALL HYDROMET
C                                STATIONS FOR THIS PERIOD.
C                           J=2 COUNT OF CONTRIBUTING STATIONS.
      EQUIVALENCE (NPA(1), XNPA(1), NP)
      EQUIVALENCE (IS(1), XS(1))
C
C         PROCESS A PERIOD
C         SETUP PERIOD HOURS
C           JE COUNTER FOR TEMP NUMBER
      JE=0
C
C
C
      IHR = ITME(NRTME+1)
      DAYS = IHR
      DAYS = DAYS/240.
      ITE = ITO + IHR
      I = IS(40)
      SDISP = 100.*DAYS
      DISP = 100.
      IHRR= IHR
      IHRS = IHR
      IF(IHR .GE. 240) THEN
         SWPR = 0.
```

```
            SWPS = 0.
        ELSE
C
            IF(IRRDI .NE. 0) THEN    ! Test for Rain Distibution
                ITA = ITO + ITOSHF
                CALL DEXTR (ITA,IHR, NPA(IRRDI), NRRDI, DISP)
                IF(NRRDI .GT. 0) GO TO 605
                IF (ITOSHF.LT.0) THEN
                    DISP = 0.
                    GO TO 605
                ENDIF
            ENDIF
            DISP = 100.
            SWPR= 0.
            GO TO 610
C          RAIN DISTRIBUTION IN EFFECT.
  605       IF (DISP.LT..001)  DISP = 0.
            IHRR = 240
C
  610       IF(IRSDI .NE. 0) THEN            ! Test for Snow Distribution
                CALL DEXTR (ITO, IHR, NPA(IRSDI), NRSDI, SDISP)
                IF(NRSDI .GT. 0) IHRS = 240
            ELSE
                SDISP = DAYS*100.
                SWPS= 0.
            ENDIF
        ENDIF
C          SNOW DISTRIBUTION IN EFFECT
C          SETUP TO EXTRACT READINGS FOR DAY FROM HYDROMET STATIONS
C
  620   DO K = 1, 10         ! Clear Summing Array
            DCA(K,1) = 0.
            DCA(K,2) = 0.
        ENDDO
C
        J = 1
        IE = IS(1)
        DO 650 K = I, IE, 3
            M = ITP(J+1)
            IF(M .EQ. 0) GO TO 650
            IDC = IS(K)
            IF(IDC .EQ. 3) GO TO 630
C                                            SNOW DATA
            IHST = IHRS
C               IF SNOWLINE ELEV OR SNOW COVERED AREA DATA, EXTRACT REGARDLESS
            IF(IDC .LE. 2) GO TO 633
            IF(SWPS)650, 633, 650
C                                             RAIN
  630       IF(SWPR .NE. 0.) GO TO 650
            IHST = IHRR
  633       CALL TEXTR (ITO, IHST, NPA(M), ITP(J), V, NV)
            IF(NV .EQ. 0) GO TO 650
```

```
        IF(IDC .EQ. 4) GO TO 643
        IF(IDC .NE. 5) GO TO 644
C                                               TEMPERATURE READING
 643    IF(SWE .EQ. 0.) THEN
C                                             ACCUM FOR AVERAGE HM-STA ELEVATION
           IF(ITP(J+2) .NE. 0) THEN
              M = ITP(J+2)
              EHM = EHM +(XNPA(M+5) * XS(K+2))
              EHMN = EHMN + XS(K+2)
C                                                SUM READING TO WEIGHTED TOTAL
              JE=JE+1
              IF(JE .LE. 2)TELEV(JE)=XNPA(M+5)*10.
           ENDIF
        ENDIF
C
C                           DATA WEIGHING FACTOR    NOT  LARGER THAN 999.0
C                 IF W % LARGER THAN 999 FOR TEMP,SWITCH IWTF FOR TEMP DISTRIB
  644   IF( XS(K+2).GE. 999.) THEN
           DCA(IDC,1)=DCA(IDC,1)+V*100
           IF(IDC.EQ.4) IWTF=1
        ELSE
           DCA(IDC,1)=DCA(IDC,1)+V* XS(K+2)
        ENDIF
C
        DCA(IDC,2) = DCA(IDC,2) + 1.
c
C                           STORE TEMP READINGS FOR LAPSE RATE COMPUTATION
C
        IF(IDC.EQ. 4 .AND. DCA(IDC,2) .EQ. 1) TEMP(1) = V
        IF(IDC.EQ. 4 .AND. DCA(IDC,2) .EQ. 2) TEMP(2) = V
C
C
        IF(IDC.EQ.4 .AND.DCA(4,2).EQ. 1) TM0 = TM2
        IF(IDC.EQ.4 .AND.DCA(4,2).EQ. 1) TM1 = V
        IF(IDC.EQ.4 .AND.DCA(4,2).EQ.2 ) TM2 = V
C
 650  J = J + 3               ! End of DO Statment
C
      IF(SWE.EQ.0) THEN
        IF(EHMN.NE.0) THEN
           EHM = EHM/EHMN
           SWE = 1.
        ENDIF
      ENDIF
C
      DO J = 1, 9                          ! Compute Averages
        DCA(J,1) = DCA(J,1)/100.
        IF(DCA(J,2).GT. 1.1) THEN
           DCA(J,1) =(DCA(J,1)/DCA(J,2))
        ENDIF
      ENDDO
c
```

```
C          TEMPERATURE DISTRIBUTION OPTION :TWO TEMP STATIONS
C          WEIGHING FACTOR LARGER THAN 999.0 AND
C          NO MELT DISTRIBUTION AND SIX HRS INTERVAL OPTION
C
      IF(DCA(4,2).EQ. 2 .AND. XHR.EQ. 6. .AND. NRSDI.EQ. 0
     1 .AND.SWS.EQ.0. .AND. IWTF.EQ. 1)  ITDST=1
      IF(ITDST.EQ.1) DCA(4,1) = 0.5*(TM0+TM1)
      IF(ITDST.EQ.2) DCA(4,1) = TM1
      IF(ITDST.EQ.3) DCA(4,1) = 0.5*(TM1+TM2)
      IF(ITDST.EQ.4) DCA(4,1) = TM2
      IF(ITDST.GE.1 .AND. ITDST.LE.4 .AND. DCA(4,2).EQ.0 )
     1   DCA(4,2)=1
C
C                                                          METRIC MIXED MODE
      IF(MIXSW.EQ. 3) THEN
          DCA(3,1)=DCA(3,1)*100./25.4
          DCA(4,1)=  (9./5.)*DCA(4,1)+ 32.0
          IF(IRMLT.NE.0) THEN
              DCA(5,1) = DCA(5,1)*100./25.4
          ELSEIF(SWS.NE.0) THEN
              DCA(5,1) = DCA(5,1)*100./25.4
          ENDIF
          IF(DCA(9,2) .GT. 0) THEN
              DCA(9,1)=DCA(9,1)*21.87
          ENDIF
       ENDIF
C
C          COMPUTE PERIOD LAPSE RATE FOR SNOW BASIN
C          DELVT DIFFERENCE OF TEMP ELV
C
      IF(SWS.EQ.0) THEN
          TEMPA  =TEMP(1)
          TEMPB  =TEMP(2)
          IF(MIXSW.EQ. 3) THEN
             TEMPA = (9./5.)*TEMP(1)+32.
             TEMPB = (9./5.)*TEMP(2)+32.
          ENDIF
          XLAPSE=3.2
          XS(62)=3.2
          DELVT=ABS(TELEV(1)-TELEV(2))
          IF(DELVT.GE. 500  .AND. DCA(4,2) .GT. 1 .AND. XHR.LE. 6) THEN
             XLAPSE = (-1000.)*(TEMPB  -TEMPA  )/(TELEV(2)-TELEV(1))
             XS(62) = XLAPSE
          ENDIF
          IF(XS(62).GT.   5.)XS(62)=5.0
          IF(XS(62).LT.   0.5)XS(62)=1.0
      ENDIF
C
      TEMPA=0.
      TEMPB=0.
C
      IF(DCA(3,1).LT. 0.0)SUBLT=-DCA(3,1)   ! Neg. Prec. Means Sublimation
```

```
      IF(DCA(3,1).GE. 0.)SUBLT=0.0
      IF(DCA(3,1).LT. 0.0)DCA(3,1)=0.0
c
      IF (SWPS.EQ.0.) THEN
          DETI = DCA(5,1)
          SWETI = DCA(5,2)
      ENDIF
      IF(SWPR .EQ. 0.) THEN
          WP = DCA(3,1)* PICA
          P = WP
      ENDIF
C
C
      IF(SWS .NE. 0.) GO TO 1000      ! Test for Snow Basin
C
      IF(SWPS .NE. 0.) GO TO 850      ! Test , Compute Snow for this period
C
C        SNOW MELT COMPUTATIONS
C
C        DCA(IDC,1) CONTAINS DAYS READINGS FOR DATA CODES IDC. SEE STMT.
C        TLU(SCA) FOR SNOWLINE ELEV.
      J = IS(39)
      SAV = 100. - SCA
C
      SFA = SAV     ! SFA = snow free area at beginning of period
C
      IF(SAV .GT. 99.9) SAV = 99.9
      CALL TLU2 (2, SAV, 2, NREAV, IS(J), RSL(1), KE)
      E = RSL(1)
c
C        TEST - MELT RATE OR THERMAL BUDGET.
c
      IF((IS(15) .NE. 1).AND.(IRMLT.EQ.0 )) GO TO 768
C                        MELT RATE COMPUTATION
c
      IF(SWE.EQ.0) THEN                   ! No HM-STA Elevation
          T = DCA(4,1)
          SMA = SCA
          SRA = 100.
          GO TO 764
      ENDIF
C
      IF(DCA(4,2).EQ.0) THEN              ! No Temp. Reading
         SMA = 0.
         SRA = 100.
         SNOW = 0
         DD = 0
         GO TO 850
      ENDIF
c
C                        COMPUTE SNOW NO-MELT LEVEL
C                        MELT-ELEV = HM-ELEV + (TEMP-BASETEMP)/LAPSERATE
```

```
c
      Ei= EHM +(100.*(DCA(4,i) - XS(59)) / XS(62))
C
      IF(Ei.GT. 99999) Ei = 99999.  ! Limit Max,Min Elev. for No-melt Area
      IF(Ei.LT.     0) Ei = 0.
C
      CALL TLU2 (i, Ei,2, NREAV, IS(J), RSL(i), KE)
      SMA = RSL(2)          ! SMA = % area Below No-Melt level, From Table
c
      IF (SMA.LT.0.) SMA=0.
      IF (SMA.GT.99.9) SMA=99.9
c
C         RAIN FREEZE LEVEL = EHM + (TEMP - RAIN-FREEZE-TEMP)/LAPSE RATE
      Ei= EHM + (100.*(DCA(4,i) - XS(54))/XS(62))
C
      IF(Ei.GT. 99999)Ei=99999.  ! Limit Max,Min Elev. For Rain Freeze Level
      IF(Ei.LT.     0)Ei=0.
C
      CALL TLU2 (i, Ei,2, NREAV, IS(J), RSL(i), KE)
      SRA = RSL(2)      ! SRA % area Below Rain-Freeze Elev., From Table
c
      IF (SRA.LT.0.) SRA=0.
      IF (SRA.GT.99.9) SRA=99.9
C
      SSA=100.-SRA      ! SSA = % area above Rain-Freeze Elev.
      IF(SAV.GE. SMA) THEN
          SMA = 0.
          SNOW = 0.
          DD = 0.
          GO TO 850
      ENDIF
C                         LAPSE TEMP TO AVERAGE ELEV OF MELTING SNOW.
      SAV    =(SAV + SMA)/2.
      CALL TLU2 (2, SAV, 2, NREAV, IS(J), RSL(i), KE)
      T = DCA(4,i) - ((RSL(i) - EHM)*XS(62) / 100.)
      SMA = SMA - (100. - SCA)
C                                                      CALC. DEGREE-DAYS
  764 IF(IRMLT .NE. 0) THEN
          DD = T - XS(59)
          IF(SCA.LT.  0.10 .AND. XS(48).LT.0.01)DD=0.00
          IF(DD.LT.0) THEN
              SNOW = 0.
              DD = 0.
              GO TO 850
          ENDIF
C                                           COMPUTE DAYS SNOW MELT
          SNOW = DD * SMLT
          GO TO 850
      ENDIF
c
C        COMPUTE SNOW = RNFK(1-ALBEDO)*INSOLATION+
C                        CCK*WIND*(.22*(AIRTEMP)+.78(DEWPOINT))+
```

```
C                          CFK*(AIRTEMP)
C
C                                                  COMPUTE FIRST TERM, RADIATION
  768 SNOW= RNFK*(100. - DCA(6,1)) * DCA(7,1)
      SNRAD = SNOW
      SNF = 0.
      SNCC = 0.
      DD = 0.
      SMA = SCA
      SRA = 100.
c
C        COMPUTE CONVECTION AND CONDENSATION TERM. TEMPERATURES ARE FROM
C          32 DEGREES. CONSTANT .22
C
      IF(DCA(8,2).NE.0) THEN       ! Test for Wind
         WIND = DCA(8,1)
      ELSE
         WIND=0.
      ENDIF
C        TEST FOR AIR TEMPERATURE - NO AIR TEMP READINGS, SNOW= 1ST TERM
      IF(DCA(4,2).NE.0) THEN
C                                LAPSE AIR TEMP TO AVERAGE ELEVATION OF SNOW.
         SLAPSE = 0.
         IF(SWE .NE. 0.) THEN
C                                 IF NO TEMP-STA ELEVATION, DO NOT LAPSE
            SAV = 99.9 - SCA/2.
            CALL TLU2 (2, SAV, 2, NREAV, IS(J), RSL(1), KE)
            SLAPSE = XS(62) * (RSL(1) - EHM)/100.
            DCA(4,1) = DCA(4,1) - SLAPSE
         ENDIF
C                         COMPUTE LONGWAVE MELT ON FOREST AREA, THIRD TERM.
         SNF =  CFK*(DCA(4,1)-32.)
         SNOW = SNOW + SNF
C
         IF(DCA(5,2).EQ.0) THEN    ! Test for Dew Point Reading
C
            IF(IRDEW.EQ.0)  THEN   ! No Dew Point Reading
               DCA(5,1)= 32.
            ELSE                   ! Get Dew Point From Table
               J =XNPA(IRDEW+4)
               CALL TLU2 (1, DCA(4,1), J, NRDEW,NPA(IRDEW+5),
     1                   RSL(1), KE)
               DCA(5,1) = RSL(2)
            ENDIF
         ENDIF
C                           CONDENSATION AND CONVECTION TERM, 2ND TERM.
c
         DCA(5,1) = DCA(5,1) - SLAPSE
         SNCC = CCK * WIND * (0.22  *(DCA(4,1)-32.) + 0.78*
     1   (DCA(5,1) - 32.))
         SNOW = SNOW + SNCC
         IF(SNOW.LT.0) SNOW = 0.
```

```
          ENDIF
C
 850      PSN =(SNOW * SDISP/100.) * PICA     ! Compute Period Snow Melt
C
          SND=0.0                             ! Limit PSN to Snow Water Depth
          IF(SCA .LT. 0.5)SND = 0.0
          IF(TSCT .LE. 1.0 .AND. SCA .GT. 0.5) SND = XS(48)*100./SCA
          IF(TSCT .LE. 1.  .AND. PSN .GT. SND)PSN = SND
C
C            COMPUTE BASIN RUNOFF
C
1000      WP = P*DISP/100.       ! Calc. WP as Portion (DISP) Of Days Precip(P)
          IF(IS(15) .EQ. 1) THEN
C                     UPDATE ARO AS SNOW PACK VOLUME FOR SNOW-BAND COMPUTATION
              XS(48) = XS(48) + WP*(99.9-SRA)/100.0
              IF(SMA .GT. 0.) THEN
                  XS(48) = XS(48) - PSN*SMA/100.
                  IF(XS(48) .LT. 0.) THEN
                      PSN = PSN + (XS(48)*100./SMA)
                      XS(48) = 0.
                      IF(PSN .LT. 0.) PSN = 0.
                  ENDIF
              ENDIF
          ENDIF
          XHR = IHR
          XHR = XHR/10.
          XH2R = XHR/2.
C
          IF(IRKE .NE. 0) THEN              ! Test For KE Relation
C                                             LOOKUP KE VALUE FOR ETI LOSS.
              IF (SWS.NE.0.) GO TO 10051
              IF (IRMLT.EQ.0) GO TO 1006
10051         IF (SWETI.NE.0.) THEN
C                                    KE FUNCTION OF SMI WHEN DAILY ETI USED
                  XKE=XS(47)
                  DXKE=DSMI
                  GO TO 10061
              ENDIF
C                                CHECK KE OR DKE CURVE
1006          TXKE=0.0
              K=1
              K2=XNPA(IRKE+4)
              CALL TLU2(K,TXKE,K2,NRKE,NPA(IRKE+5),RSL(1),KE)
              TXKE=RSL(2)/100.
              IF(TXKE.LT. 0.10) THEN
                  XKE = XS(47)
                  DXKE = DSMI
                  GO TO 10061
              ENDIF
C                                    KE FUNCTION OF WP
C                                    DXKE FOR DUMMY BASIN
              XKE=WP*12./XH2R
```

```
              DXKE=XKE
      10061   K = 1
              K2 = XNPA(IRKE+4)
              CALL TLU2 (K,XKE,K2, NRKE, NPA(IRKE+5), RSL(1), KE)
              XKE = RSL(2)/100.
              K=1
              K2=XNPA(IRKE+4)
              CALL TLU2(K,DXKE,K2,NRKE,NPA(IRKE+5),RSL(1),KE)
              DXKE=RSL(2)/100.
          ELSE
              XKE = 1.
          ENDIF
      C
      C   GET PERIOD INPUT OR RUNOFF (RG) FROM SMI AND PRECIP
      c
          IF(IRSMI.NE.0) THEN
              IF(SCA.GT.1.0.AND.PR_OPTN.GT.0) THEN        !! Pat Landine
                  CALL PRAIRIES (WP,SRA,PSN,ROP)          !! Aug.14/85
      c
                  DROP = ROP        ! ROP For Dummy Rain Basin
      C
              ELSE
                  K = 1
                  K2  = XNPA(IRSMI+4)
                  IF(K2.GT. 6) THEN
      C                  TABLE IS FAMILY OF CURVES FROM CF CARD, ROP VS.SMI,INPUT
                      RGP =(WP+PSN)/XHR
                      CALL TLU3F(XS(47), RGP, NPA(IRSMI+4), ROP)
                      ROP = ROP/100.
      C                                  COMPUTE ROP FOR DUMMY RAIN BASIN
                      K=1
                      K2=XNPA(IRSMI+4)
                      DRGP=WP/XHR
                      CALL TLU3F(DSMI,DRGP,NPA(IRSMI+4),DROP )
                      DROP=DROP/100.
                  ELSE
      C                                  TABLE IS SMI VS. ROP FROM CT CARD.
      C
                      CALL TLU2 (K,XS(47),K2,NRSMI,NPA(IRSMI+5),RSL(1),KE)
                      ROP = RSL(2)/100.
      C                                  COMPUTE ROP FOR DUMMY RAIN BASIN
                      K=1
                      K2=XNPA(IRSMI+4)
                      CALL TLU2(K,DSMI,K2,NRSMI,NPA(IRSMI+5),RSL(1),KE)
                      DROP=RSL(2)/100.
                  ENDIF
              ENDIF
          ELSE
              ROP = 1.0
          ENDIF
          RGP= ROP * (WP + PSN)
      C
```

```
      RG = RGP/XHR            ! CALC. RUNOFF RATE PER HOUR
C
C        UPDATE ACC. RUNOFF OR SNOW W.E. LEFT IN BASIN
C        TEST SCD CURVE,INDEPENDENT VARIABLE=0 GIVES SCA=0 IMPLIES
C        AREAL MEAN SNOWPACK W.E. INSTEAD OF ACC.RUNOFF OPTION
C        SNOWPACK W.E.IS REQUIRED IN MELT RATE TABLE FOR THIS OPTION
c
      IF(SWS.EQ.0) THEN
          TPAR=0.0
          JT=XNPA(IRSD+4)
          CALL TLU2(1,TPAR,JT,NRSD,NPA(IRSD+5),RSL(1),KE)
          TSCT=RSL(2)
          IF(TSCT.GT.1.0) THEN
C                                                XS(48) IS ACC. RUNOFF
              IF(IS(15).NE.1)XS(48)=XS(48)+(SMA/100.)*ROP*PSN
              ARO=XS(48)
              IF(ICL30(6).EQ.1) ARO=ARO+RAIAR
              IF(ARO.LE.XS(49)) THEN
                  PAR = (ARO/XS(49))*100.
                  IF(PAR.GE.99.9) PAR = 99.9
              ELSE
                  PAR=99.9
              ENDIF
          ELSE
C                                          XS(48) IS MEAN AREAL S.W.E.
              XS(48)=XS(48)-(SMA/100.)*PSN
              ARO=XS(48)
              IF(ARO.GT.  0.0 ) THEN
                  PAR = (ARO/XS(49))*100.
                  IF(PAR.GE.99.9) PAR = 99.9
              ELSE
                  XS(48)=0.0
                  ARO=0.0
                  PAR=0.0
              ENDIF
          ENDIF
C
      SFAP = 100. - SCA      ! Snow Free Area of Previous period
C
C                             COMPUTE SNOW COVERED AREA AT PERIOD END
c
          J = XNPA(IRSD+4)
          CALL TLU2 (1, PAR, J, NRSD, NPA(IRSD+5), RSL(1), KE)
          SCT = RSL(2)
C
          IF(DCA(2,2).EQ.0) THEN   ! Test-SCA Specified for Basin
c
C                                       TEST-SNOWLINE ELEVATION SPECIFIED
              IF(DCA(1,2).EQ.0) CALL SCA_DEPLETE (RATIO,DELTA,*1070)
c
C                                       IGNORE SNOW LINE ELEV IF SL=0
              IF(DCA(1,1).LE.0) CALL SCA_DEPLETE (RATIO,DELTA,*1070)
```

```
              J = IS(39)
              CALL TLU2 (1, DCA(1,1), 2, NREAV, IS(J), RSL(1), KE)
              SCA = 100. - RSL(2)
          ELSE
              SCA = DCA(2,1)
              IF(SCA.GT.99.9)SCA=99.9
              IF(SCA.LT.   0)SCA=0.
          ENDIF
c
C         UPDATE SNOWPACK VOLUME OR SEASONAL R.O. IF SCA ADJ. MANUALLY
          IF(WP .GT. 0.04) THEN
              IF(TSCT.LE. 1.0) THEN
                  XS(48) = XS(48)+(SSA/100.)*WP
                  XS(49) = XS(49)+(SSA/100.)*WP
              ENDIF
              IF(SWSI.EQ. 1 ) XS(49)=SI
              IF(TSCT.GT. 1.0) XS(49)=XS(49)+(SSA/100.)*ROP*WP
              ARO=XS(48)
              PAR=(ARO/XS(49))*100.
              IF(PAR.GE. 99.9)PAR=99.9
              J=XNPA(IRSD+4)
              CALL TLU2(1,PAR,J,NRSD,NPA(IRSD+5),RSL(1),KE)
              SCT=RSL(2)
c
C                            UPDATE XS(67) FOR DIFFERENT OPTIONS
C
              IF(TSCT.GT.1) THEN
C                        XS(67)= RATIO OF SCA & SCT FOR ACC Runoff OPT.
                  IF(SCT.GT.1) XS(67)=SCA/SCT
                  IF(SCT.LE.1) XS(67)=1
                  GOTO 1070
              ENDIF
C                               UPDATE XS(67)=SLOPE OF DEVIATION LINE
C                               FOR  SNOWPACK OPTION
              IF(XS(48).NE.SWET)
     &           XS(67)=((SCA-SCAT)/100) / ((XS(48)-SWET)/XS(49))
              IF(XS(48).EQ.SWET) XS(67)=0
              IF(XS(67).LT.0 ) WRITE(IOW,'(" WARNING: NEGATIVE"
     1              " SLOPE FOR NEW SNOW SCD LINE; ZERO SLOPE"
     2              " IS ASSUMED")')
              IF(XS(67).LT.0) XS(67)=0
C                              FOR LOWER END OF SCA CURVE ASSUME SLOPE=1
              IF(SCT.LE.1)XS(67)=1.0
          ENDIF
c
C                                COMPUTE CONTRIBUTING SNOW COVERED AREA
 1070     AREAM= XS(30) * SMA /100.
C                                        CALC. NEW MELT RATE
          IF(IRMLT .EQ. 0) GO TO 1085
          J = XNPA(IRMLT+4)
          CALL TLU2 (1, PAR, J, NRMLT, NPA(IRMLT+5), RSL(1), KE)
          IF(DCA(9,2).NE.0) THEN
```

```
                SMLT = DCA(9,1)
                IF (RSL(2).NE.0.) THEN
                    XS(60) = SMLT/RSL(2)
                    GO TO 1085
                ENDIF
            ENDIF
C                 MELT RATE RETURNS TO THEORETICAL VALUE (TABLE) IN 72 HOURS.
            IF(IS(15) .EQ. 1) GO TO 1085
            XS(60) = (1. - XS(60))*(XHR / 72.) + XS(60)
            SMLT = RSL(2) * XS(60)
            GO TO 1085
        ENDIF
C*****                         NOT A SNOW BASIN
c
1080    IF(DCA(2,2).NE.0) THEN
            SRA = DCA(2,1)
C           READ(61,'(3F6.3)') DSMIS,SMISCA,RSFA ! Unit 15 chngd to 61 PAT
            READ(61,*) DELTA_SMI       ! Landine Oct. 9 85
c
C                    READ ADDITIONAL SMI COME FROM NEWLY SNOW FREED AREA
            IF(SRA.LT.0) THEN
                SRA=0.
            ENDIF
            SCA=0.
            AREAR = XS(30) * SRA/100.
            SRAIN = SRA
        ELSE
            AREAR= XS(30)
            SRA = 100.
            SRAIN = SRA
        ENDIF
        GO TO 1088
c
C          COMPUTE SMA AND SRA FOR SNOW COVERED BASIN.
C           AT STMT 1085, SRA IS % OF BASIN BELOW RAIN-FREEZE TEMP.
C          SRA IS COMPUTED HERE AS % OF BASIN RAIN IS RUNNING OFF OF.
C          SRAIN IS TOTAL % OF BASIN ON WHICH PRECIP FELL, EITHER SCA OR 1
C          SRANS IS % OF BASIN BELOW RAIN-FREEZE TEMP, OR SNOWLINE,WHICHEV
1085    SRAIN = SRA
        IF(SWS .EQ.0.) SRAIN = 100.
        IF(IRSCA .NE. 0.) THEN
            SRAIN = SCA
            IF(SWPS .EQ. 0.) THEN
                SRANS = SRA
                SRA = SCA - (100.- SRA)
                IF(SRANS .GT. (100.-SCA)) SRANS = 100.-SCA
                IF(SRA .LT. 0.) SRA = 0.
C                       SNOW BAND TYPE BASIN, TEST FOR ZERO SNOW COVER.
                IF(IS(15).EQ.1 .AND. XS(48).LE. 0.) THEN
                    SRA = 0.
                    SRANS = 100.
                    SRAIN = 0.
```

```
                  ENDIF
               ENDIF
            ENDIF
            AREAR = XS(30) * SRA/100.
      1088  RAIAR = RAIAR + SRA*WP*ROP/100.
c
C                     NEW SMI = (OLD SMI)+WP+PSN-RG-   ((XHR/24.)*ETI - WP*KE)
            SMIRF = 0.
            IF(SRAIN .GT. 0) SMIRF =(SRA/SRAIN) * WP
C                                  ADDITION TO SMI ALWAYS LESS THAN 100% OF WP
            IF(SRA .GT. SRAIN  .AND. SRAIN .GT. 1.) SMIRF=WP
            IF( SWS .NE. 0  .AND. SRAIN .LT.  1.) SMIRF=0.0
            SMISF = 0.
            IF(SCA .GT. 0.05) SMISF =(SMA/SCA) * PSN      ! LANDINE SEP 16 1985
C
C              ADDITION TO SMI ALWAYS LESS THAN 100% OF PSN
C              NOTE THAT IN ABOVE EQUATION SMA IS BASED ON DATA AT
C              THE BEGINING WHILE SCA IS AT PERIOD END
C              LIMIT MOISTURE INPUT TO SNOW BASIN BASED ON THE DEPLETION
C              OF SNOW AREA/ SPLIT OPTION ONLY
C              SCD SINGLE BASIN OPTION SMISF BASED ON 100 PERCENT AREA
C
            IF(SWS .EQ. 0)SFAC=100. -SCA
            IF(SWS .EQ. 0 .AND. IRSCA .NE. 0 .AND. SFAC .GT. SFA  .AND.
           1  SCA .GT. 0.05) SMISF=(SMA-(SFAC-SFA))/SCA*PSN  ! LANDINE SEP 16 1985
            IF(SMISF .LT. 0.)SMISF=0.
            IF(SMA .GE. SCA)SMISF=PSN
C           IF(SCA .LE. 0.05)SMISF=0.0                         ! LANDINE  SEP16 1985
            IF(SFAP.GT.99.9) SMISF = 0.0         ! LANDINE OCT 8 85
C
            IF(IRSCA .EQ. 0  .AND. IS(15) .NE. 1)SMISF=(SMA/100.)*PSN
C
C                                   IF HEAVY RAIN ZETI =0.0
            WPRATE=WP/XHR
            IF(WPRATE.GT. 0.02) ZETI=0.
            IF(WPRATE.LE. 0.02) THEN
C                                   RAIN OPTION ETI DISTR TABLE REQUIRED
C                             SNOW OPTION ALWAYS ETI UNIFORM DISTRIBUTION
               IF(SWETI.GT. 0.) TCOUNT=0.0
               XETI=ETI
               ZETI=XETI*XHR/24.0
C                                 SNOWMELT G.E.S.OPTION NO DAILY ETI OPTION
               IF(SWS.NE.0. .OR. IRMLT.NE.0.) THEN
                  IF(SWS.EQ.0.) THEN
C                                            SNOW OPTION
c
                     IF(SWETI.EQ.0. .AND. TCOUNT.LE.0.) ZETI=ETI*XHR/24.0
                     IF(SWETI.EQ.0. .AND. TCOUNT.GT.0.) ZETI=AETI
                     IF(SWETI.NE.0. .AND. DETI.LE.0) ZETI=ETI*XHR/24.0
                     IF(SWETI.NE.0. .AND. DETI.GT.0) ZETI=DETI*XHR/240.
c
C                                                          RAIN OPTION
```

```
                ELSEIF(SWETI.NE.0.) THEN
                   XETI=(DETI*SDISP/1000.)
                   IF(XETI.EQ.0.)XETI=ETI*XHR/24.0
                   ZETI=XETI
                ENDIF
             ENDIF
          ENDIF
C
          SMI = XS(47) + (1.-ROP) * (SMIRF+SMISF) - ZETI*XKE
C                             ZERO ETI FOR SNOW SPLIT BASIN IN ANY CASE
          IF( SWS.EQ. 0 .AND. IRSCA .NE. 0)
     1      SMI=XS(47)+(1. -ROP)*(SMIRF+SMISF)
C
C            Soil Moisture Carried over from SCA   ! PAT LANDINE OCT 85
C
          IF(SWS .NE. 0.  .AND. DCA(2,2) .NE. 0.) SMI = SMI + DELTA_SMI
c
          IF(SMI .GT. SMIMAX) THEN                        ! Pat Landine Sep. 16/85
             SMI_EXCES = SMI - SMIMAX
             ROP = ROP + SMI_EXCES/(WP + PSN)
             IF(ROP.GT.1.) ROP = 1.0
             SMI = SMIMAX
          ENDIF
          IF(SMI .LT.0.) SMI = 0.
C               NO ADJUSTMENT ON SMI OF DUMMY BASIN IF 100 PERCENT SNOW
C               COVER OR NO RAIN AREA OR NOT SPLIT OPTION
C
          IF(SWS.EQ.0) THEN
             IF(IRSCA .NE. 0) THEN
C                                   SFAC(SNOW FREE AREA AT THE PERIOD END)
                SFAC=100.-SCA
c
C                IF RAIN DOES NOT COVER 100% SNOW FREE AREA OR NO RAIN
C                 FREE AREA
C               DSMIR,DSMIS MOIST. INPUT TO DUMMY RAIN BASIN FROM RAIN&MELT
c
                DSMIR=0.0
                IF(SCA .LT. 99.0 .AND. SRANS .GT. 1.)DSMIR=WP
                IF(SRANS .LT. SFAC .AND. SFAC .GT. 0.5)
     1              DSMIR=(SRANS/SFAC)*WP
C                    IF SNOW FREE AREA EXPANDS ADJUST THE INCREMENT ON DSMI
                DSMIS=0.0
                IF(SFAC .GT. SFA  .AND. SFAC .GT. 1.)
     1              DSMIS=(SFAC-SFA)*PSN/SFAC
                IF(SFAC.LE. 0)RSFA=1
                IF(SFAC.GT. 0)RSFA=SFA /SFAC
                IF(RSFA .GT. 1)RSFA=1.
                IF(RSFA .LE. 0)RSFA=0.
c
c               Transfer Soil Moisture To SFA via DELTA_SMI  Landine Oct 9 85
c
                DELTA_SMI = (WP*SRA/100.+ PSN*SMA/100.) * (1.- ROP)
```

```
                WRITE (61,*) DELTA_SMI
c               WRITE(61,'(3F6.3)') DSMIS,SMI,RSFA   ! Unit 15 chngd to 61 PAT
                IF(IRMLT .NE. 0 ) THEN
                   IF(SWETI .NE. 0. ) THEN
C                         RECOMPUTE SMI FOR SNOW BASIN IF BOTH DAILY
C                         AND AVE.  ETI ARE INPUT ,  USE ZERO  ETI
C                         FOR SNOW WATERSHED ANY CASE AND DETI FOR DUMMY
C                         BASIN FOR SPLIT BASIN OPTION ONLY
C
                      SMI=XS(47)  +(1.0 -ROP )*(SMIRF +SMISF)
                      IF(SMI .GT. SMIMAX) THEN        ! Pat Landine Sep. 16/85
                         SMI_EXCES = SMI - SMIMAX
                         ROP = ROP+SMI_EXCES/(WP + PSN)
                         IF(ROP.GT.1.) ROP = 1.0
                         SMI = SMIMAX
                      ENDIF
                      IF(SMI .LE. 0.)SMI=0.0
                   ENDIF
                ENDIF
C                  ADJUST DSMI BASED ON MOISTURE INPUT FOR SPLIT BASIN ONLY
                DSMI=DSMI + (1.0-DROP)*(DSMIR+DSMIS) -DXKE*ZETI
                IF(DSMI .GT. SMIMAX)DSMI=SMIMAX
                IF(DSMI .LE. 0.)DSMI=0.0
             ENDIF
          ENDIF
C                GET BFP AS FUNCTION OF BII AT START OF PERIOD.
C
          IF(ABS(XS(66)) .LT. 0.00001) XS(66) = 0.
          IF(IRBF.NE.0) THEN
             IF(SCA.GT.1.0.AND.PR_OPTN.GT.0) THEN      !! Pat Landine
                BFP = 0.0                               !! Aug.14 85
             ELSE
C                  BASEFLOW PERCENTAGE OF INPUT - BII ARG. IN IN. OR CM.
                K = 1
                K2 =XNPA(IRBF+4)
C                         THREE DIMENSIONAL CURVE FOR BII FUNCTION
                IF(XS(47).LE. 0.01)DRYNES =99.99
                IF(XS(47).GT. 0.01)DRYNES =1.0/XS(47)
                IF(K2.GT.6) THEN
                   CALL TLU3F(XS(66),DRYNES ,  XNPA(IRBF+4)  ,BFP)
                   BFP=BFP/100.
                ELSE
                   CALL TLU2(K,XS(66),K2,NRBF,XNPA(IRBF+5),RSL(1),KE)
                   BFP = RSL(2)/100.
                   IF(K2 .GE. 3) THEN
C                        BASEFLOW LIMIT SPECIFIED IN TABLE IN INCHES/HOUT
                      IF((RG*BFP) .GT. RSL(3)) BFP = RSL(3)/RG
                   ENDIF
                ENDIF
             ENDIF
          ELSE
             BFP = 0.
```

```
      ENDIF
C                            RESIDUAL RUNOFF - NOT BASEFLOW
      IF(RG.NE.0) THEN
          IF(SCA.GT.1.0.AND.PR_OPTN.GT.0) THEN    !! Pat Landine
              SSP = 0.0                           !! AUG.14/85
          ELSE
              RGS = RG* (1. - BFP)
C                            SURFACE INPUT AS FUNCTION OF RGS.
C                            SUBSURFACE PERCENT OF RGS
              IF(IRSPS.NE.0) THEN
                  K = 1
                  K2 = XNPA (IRSPS + 4)
C                                THREE - D FUNCTION FOR S-SS RELATIONSHIP
                  IF(K2.GT.6)  THEN
                      CALL TLU3F(RGS,XS(47),XNPA(IRSPS+4) ,RSL(2))
                      IF(RSL(2) .LT. 0)RSL(2)=0.0
                  ELSE           ! Two - D Function for S-SS Relationship
c
                      CALL TLU2 (K,RGS,K2,NRSPS,XNPA(IRSPS+5),RSL(1),KE)
                      IF(RSL(2).LT.0) RSL(2) = 0.
                  ENDIF
                  SSP = (RGS - RSL(2))/RGS
              ELSE
                  SSP = .5
              ENDIF
          ENDIF
      ELSE
          SSP = .5
      ENDIF
      IF(IRTS.NE.0) THEN
          K = 1
          K2 = XNPA(IRTS+4)
          CALL TLU2 (K, QO, K2, NRTS, XNPA(IRTS+5), RSL(1), KE)
          TSR    = RSL(2)
      ELSE
          TSR = XS(32)
      ENDIF
C
C     CONVERT INPUT RATE TO FLOW.
C     ENGLISH SYSTEM - RUNOFF IS IN     INCH/HR. CONVERSION IS 1-UNIT
C         OF RUNOFF = 64.53333 10S-OF-CFS
C
      QRG = ROP*64.53333*(AREAM*PSN + AREAR*WP) / XHR   ! Runoff
C
      QBG = QRG * BFP                                   ! Baseflow Input
C
      QSSG = (QRG - QBG) * SSP                          ! Subsurface Input
C
      QSG = QRG - QBG - QSSG                            ! Surface Input
C
      CALL ROUTE (IS(31), QSG, XHR, TSR, XS(70))     ! Route Surface
      K = 70 + IS(31)                                ! Calc Time Storage
```

```
      QSR  = XS(K - 1)                              ! Ratio
C
      CALL ROUTE (IS(33), QSSG, XHR, XS(34), XS(K)) ! Route Subsurface
      QIN = XS(70) + XS(K)
      K = K + IS(33)
      QSSR = XS(K-1)
C
      CALL ROUTE (IS(35),QBG, XHR, XS(36), XS(K))   ! Route Baseflow
      QIN = QIN + XS(K)
      K = K + IS(35) - 1
      QBR = XS(K)
      QOUT = QSR + QSSR + QBR
C                                 CALC. BII AT PERIOD END
      IF(SWBII .NE. 0.) THEN
          IF(QIN.LT.QOUT) THEN   ! Falling Q
              SWBII = -1.
              BIITS = XS(50)
          ELSE                   ! Rising Q
              SWBII = 1.
              BIITS = XS(37)
          ENDIF
      ENDIF
      BII =XS(66)+((ROP*(SMIRF+SMISF)/DAYS)-XS(66))*
     1 (XHR/(BIITS+XH2R))
C
      IF(BII .GT. XS(65)) BII = XS(65)       ! Test BII Maximum
C
      TCOUNT=TCOUNT+XHR                      ! Reset Tcount=0.0 After 24 hrs
      IF(TCOUNT.GE. 24.) TCOUNT=0.0
      IF(ITDST.GT.0) ITDST=ITDST+1
      IF(ITDST.GT.4) ITDST=0
C         END OF THE DAY FOR TEMP DISTRIBUTION
C          TEMP DITRIBUTION APPLIED ONLY FOR 6 HR INTERVAL,2 TEMP STATION
      RETURN
      end
C
C*****
C
$EMA /C1/
      SUBROUTINE SCA_DEPLETE (RATIO,DELTA,*)
     +,11:15 AM  FRI., 26  JULY, 1985 (851126.1013)
c
c     SnowCover Depletion Routine
C
C     This Section Separated By Pat Landine July 26 1985
C
      IMPLICIT NONE
C
$INCLUDE [C1    :PL:121,NOLIST
$INCLUDE [BASIN:PL:121,NOLIST
$INCLUDE [AREA1:PL:121,NOLIST
$INCLUDE [AREA2:PL:121,NOLIST
```

```
C
      REAL XS(1),XNPA(1),DELTA,RATIO,SMI_EXCES
C
      INTEGER NPA (1)
C
      EQUIVALENCE (NPA(1), XNPA(1), NP)
      EQUIVALENCE (IS(1), XS(1))
C
      IF(TSCT.LE.1) THEN  ! No New Snow , Deplete SCA Accordingly
c
          IF(SWSCD.EQ.0) THEN   ! Depletion Using Theoretical curve
              SCA=SCT
c
          ELSE                  ! Depletion Using Deviation Line
              IF(XS(49).GT.0)SCA=100*XS(67)*(XS(48)-SWET)/XS(49)+SCAT
              IF(XS(49).LE.0)SCA=0
C                                        CHECK END OF DEVIATION LINE
              IF(XS(48).LE.SWET) THEN  ! Return to Theoretical Relation
                  SCA=SCT
              ENDIF
          ENDIF
c
      ELSE                     ! If ACC. Runoff option
          SCA=XS(67)*SCT   ! Deplete SCA Using Ratio Factor XS(67)
      ENDIF
c
      IF(SCA.LT.0)SCA=0
      IF(SCA.GT. 100)SCA=100
      IF(IS(15).EQ. 1.0)XS(48)=XS(48)-SUBLT
      IF(IS(15).NE. 1.0 .AND. SWS.EQ. 0.0 .AND. TSCT.LE. 1.0)
     1     XS(48)=XS(48)-SUBLT*SCA/100.
      IF(XS(48).LT. 0)XS(48)=0.0
      IF(XS(48).LE. 0.001)SUBLT=0.0
c
C         RESET    XS48  XS49 FOR A NEW SNOWPACK
C          APPLICABLE FOR SNOW VOL DEPLETION ONLY NOT ACC R.O. OPTION
c
      IF(SWS .EQ. 0) THEN
          IF(IS(15).NE. 1) THEN
              IF(TSCT.LE. 1.0) THEN
                  IF(XS(48).LE. 0.05) THEN
C                              IF PLAIN AREA SNOWPACK DO NOT RESET XS(49)
                      IF(SWSI.NE. 1)XS(49)=0.10
                      XS(48)=0.001
                      SCA = 0.05          ! PAT LANDINE SEP 16 1985
                      SCT = 0.05          ! PAT LANDINE SEP 16 1985
                      XS(67)=1.0
                  ENDIF
              ENDIF
          ENDIF
      ENDIF
c
```

```
C        NEW-SNOW ROUTINE , ADJUST SMI AFTER ACCUMULATION OF NEW SNOW
c
C     IF(IRSCA .NE. 0  .AND. SCA .LE.  0.5)XS(47)=DSMI  ! LANDINE OCT 7 85
      IF(SSA.GE. 1.0 ) THEN
         IF(WP.GT. 0.01)  THEN
            IF(SCA.LT.SSA) THEN
C                SSA PERCENT AREA ABOVE RAIN FREEZE ELEVATION
C                BASIN SMI IS TO BE ADJUSTED BASED ON THE EXTEND OF SCA
              DELTA =SSA-SCA
              IF(WP.GE. 0.10) THEN  ! Adjust SMI ,SCA only for Significant e
C                   SMI IS ADJUSTED ONLY WHEN SPLIT WATERSHED OPTION USED
                 IF(SWS.EQ. 0. .AND. IRSCA .NE. 0 .AND.
     1           IS(15) .NE. 1)
     1           XS(47)=(XS(47)*SCA/SSA) + (DSMI*DELTA/SSA)
                 IF(XS(47) .GT. SMIMAX) THEN   ! Pat Landine Sep. 16/85
                    SMI_EXCES = XS(47) - SMIMAX
                    ROP = ROP + SMI_EXCES/(WP + PSN)
                    IF(ROP.GT.1.) ROP = 1.0
                    XS(47) = SMIMAX
                 ENDIF
                 IF(XS(47) .LE.  0.)XS(47)=0.0
                 SCA=SSA
              ENDIF
           ENDIF
           IF(TSCT.LE.1.0) THEN
C                XS(49) MAX SNOWPACK VOL   /XS(48) PRESENT SNOWPACK VOLUME
C                IF SWSI=1  MELT IN PLAINS AREA  XS(49)NOT UPDATED
              XS(49)=XS(49)+(SSA/100.)*WP
              IF(SWSI.EQ. 1 )XS(49)=SI
              XS(48)=XS(48)+(SSA/100.)*WP
              ARO=XS(48)
              PAR=(ARO/XS(49))*100.
              IF(PAR.GE. 99.9)PAR=99.99
              J=XNPA(IRSD+4)
              CALL TLU2(1,PAR,J,NRSD,NPA(IRSD+5),RSL(1),KE)
              SCT=RSL(2)
C                  UPDATE SLOPE OF SCA DEVIATION LINE AFTER NEW SNOW
              IF(XS(48).NE.SWET)
     1           XS(67) = ((SCA-SCAT) /100) /
     2                    ((XS(48)-SWET) /XS(49))
              IF(XS(48).EQ.SWET)XS(67)=0
              IF(XS(67).LT.0    )XS(67)=0
              IF(SCT.LE.1)      XS(67)=1
           ELSE
C                XS(49) TOTAL SEASONAL R.O. OPTION
C                XS(67) IN SEASONAL R.O. OPTION IS RATIO SCA/SCT
              XS(49)=XS(49)+(SSA/100.)*ROP*WP
              ARO=XS(48)
              PAR=(ARO/XS(49))*100.
              IF(PAR.GE. 99.9)PAR=99.9
              J=XNPA(IRSD+4)
              CALL TLU2(1,PAR,J,NRSD,NPA(IRSD+5),RSL(1),KE)
```

```
                  SCT=RSL(2)
                  IF(SCT .GT. 1.)XS(67)=SCA/SCT
                  IF(SCT.LE. 1.)XS(67)=1.0
              ENDIF
          ENDIF
      ENDIF
C                 UPDATE SWITCH FOR NEW SNOW DEPLETION
C                 SWSCD=0  ON THEORETICAL CURVE
C                      =+1 ABOVE THEORETICAL CURVE
C                      =-1 BELOW THEORETICAL CURVE
      IF(SCA.GT. SCT) SWSCD= 1
      IF(SCA.LT. SCT) SWSCD=-1
      IF(SCA.EQ. SCT) SWSCD=0
      IF(SCA.LT.SCAT) SWSCD=0
      IF(XS(48).LT.SWET) SWSCD=0
      RATIO=SCA/SCT
C          IF RATIO CLOSE TO 1 ASSUME THEORETICAL DEPLETION
      IF(RATIO.GE.0.95 .AND. RATIO.LE.1.05) THEN
          SWSCD=0
          XS(67)=0
      ENDIF
C                        UPDATE SCAT & SWET USING SCD CURVE VALUES
C                         FOR FUTURE DEVIATION CALCULATIONS
      IF(SWSCD.EQ.0) THEN
          SCAT=SCA
          SWET=XS(48)
      ENDIF
      RETURN 1      ! Return To 1070 in Sub. BASEC
      END
C
C
      SUBROUTINE PRAIRIES (WP,SRA,PSN,ROP)
     +, 1:30 PM  THU., 29  AUG., 1985 (851126.1013)
C
C     Return ROP (Runoff Percent) for Prairie Watersheds
C
C                    Written by: Pat Landine
C                                Division of Hydrology
C                                University of Saskatchewan
C                                Aug. 29/1985
C
      IMPLICIT NONE
C
$INCLUDE [INF  :PL:121,NOLIST
C
      REAL WP,PSN,ROP,RAIN,SRA
C
C     Limited Infiltration Potential  (PR_OPTN = 1)
C
      RAIN = WP * SRA/100.
      IF(PR_OPTN.EQ.1) THEN
C
```

```
C                 If Spring Has Just Begun , Calculate INFR
C
            IF((RAIN+PSN.GT.THRESHOLD).AND.(.NOT.SPRING)) THEN
               SPRING = .TRUE.
               INFR = (TOTINF - SUMINF)/(MAXSWE - SUMINF)
            ENDIF
C
            IF(SPRING) THEN                        ! SPRING - Runoff according
               ROP = 1.0 - INFR                    ! To Division of Hydrology
               IF(PSN.GT.0.) SUMINF = SUMINF + (RAIN+PSN)*INFR
            ELSE
               ROP = 0.0                           ! Not Spring NO Runoff
               IF(PSN.GT.0.) SUMINF = SUMINF + RAIN + PSN
            ENDIF
            RETURN
         ENDIF
C
C        Unlimited Infiltration Potential    (PR_OPTN = 2)
C
         IF(PR_OPTN.EQ.2) THEN
            ROP = 0.0
            RETURN
         ENDIF
C
C        Restricted Infiltration Potential   (PR_OPTN >= 3)
C
         ROP = 1.0
         RETURN
         END
```

10.5 APPENDIX E

Revisions to the SSARR User's Manual (Batch Model Version), 1983 Edition. This section contains material to be inserted into the SSARR User's Manual in order to bring it up to date with the changes outlined in this report.

Page 1a - Additional modifications were carried out in 1985 by the Division of Hydrology at the University of Saskatchewan under contract with the RMD of Alberta Environment. The purpose of these changes was to improve the simulation of streamflow from snowmelt for prairie watersheds. This was accomplished by the incorporation of an infiltration algorithm developed by the Division of Hydrology. This algorithm can be selected by setting the "Prairies Option" to any one of 3 defined values. (See Sec. 2.3.4.1 for definitions.) Modifications were made in such a way that they do not interfere with the original program or changes made by Alberta Environment.

Page 11, insert after paragraph 3 - When the Prairies Option is used, the SMI range is determined on a physical basis, it is taken to represent the physical storage capacity of the upper soil layer (upper 30 cm). The maximum SMI should be set by multiplying the thickness of the upper layer (30 cm) by the average saturation moisture content for the watershed. For example, if the saturation moisture content is 50%, then SMIMAX is 15 cm. The starting value of SMI for a given simulation is arrived at by taking the product of SMIMAX and the current watershed average degree of saturation. A soil moisture survey of the watershed is required, with particular attention to areas near the stream channel and other areas that might be expected to contribute to streamflow.

Page 12, insert after paragraph 3 - As part of the modifications made to introduce the Prairies Option, a change was made in the way SMI excess is handled. Previously, the excess SMI was simply "wasted", meaning that it was not added to SMI or runoff. This has been changed so that SMI excess is now converted to runoff.

Page 13, insert after paragraph 1 - When the Prairies Option is selected the runoff delay feedback loop is bypassed.

Page 16, insert after last paragraph - If the Prairies Option is selected, Baseflow percent is set equal to zero for the spring snowmelt period. When spring melt is complete, the table value is used.

Page 19, at the end of section 1.4.4.3 - If the Prairies Option is selected the subsurface runoff (RSS) is set to zero. When spring snowmelt is complete, the surface-subsurface flow separation table is used.

Page 60a - 2.3.4.1 CB01,CR01,CL01 and CC01 Card Formats continued: COLUMN 17 Prairies Option

This option applies to the spring snowmelt period only. For a detailed description of this option and its use refer to: Modelling Snowmelt Infiltration to Frozen Prairie Soils, by D.M. Gray and P.G. Landine.

0 - Default; Prairies Option bypassed.

1 - Limited Infiltration

2 - Unlimited Infiltration (no runoff)

3 - Restricted Infiltration (no infiltration)

Page 62, second line from bottom - "31-74" becomes "31-70" Station name and description; printed on all reports for this station. The space allocated for this description was shortened by the Division of Hydrology to make space available for the Prairies Option.

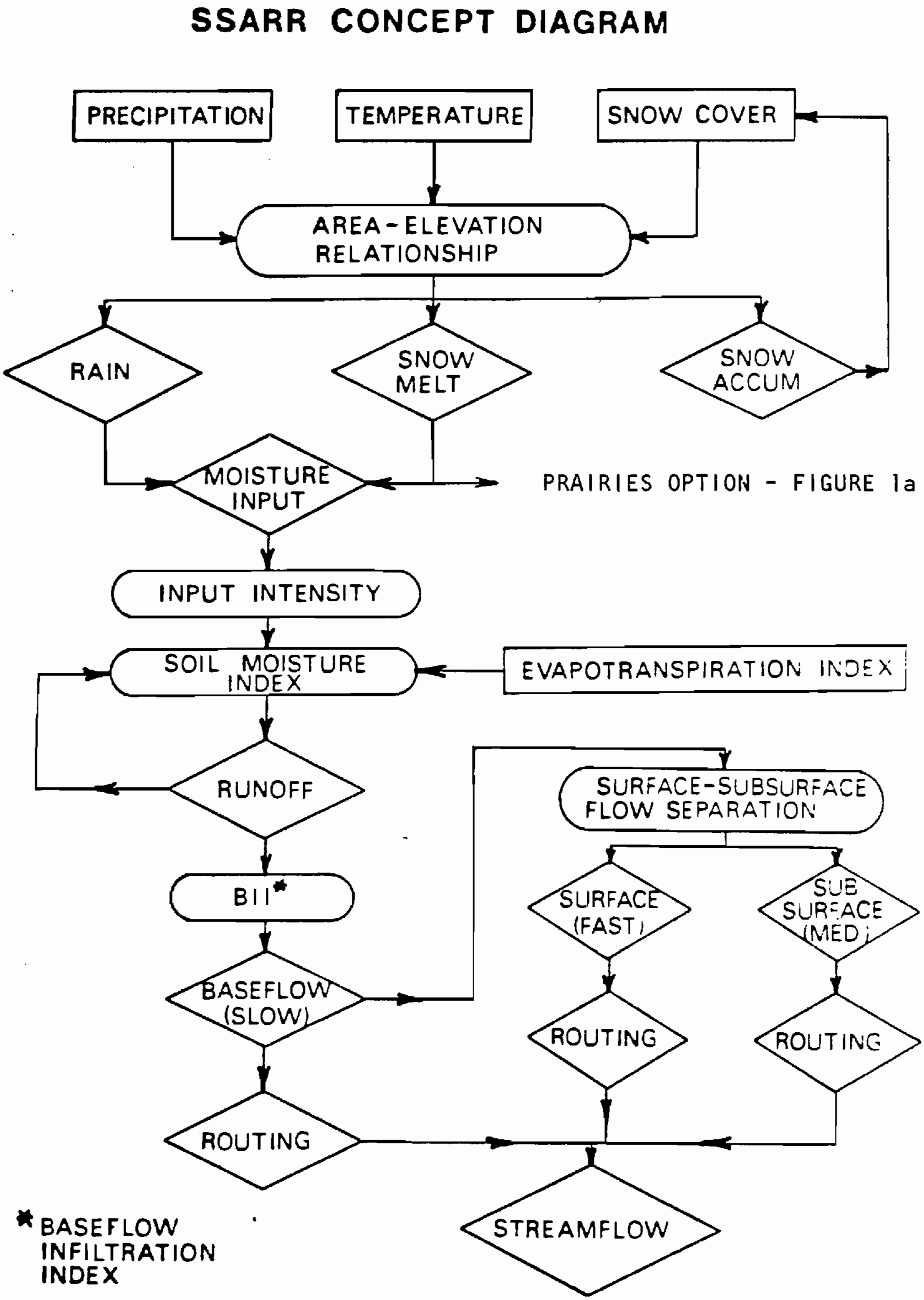
SSARR CONCEPT DIAGRAM
PRECIPITATION
TEMPERATURE
SNOW COVER
AREA-ELEVATION RELATIONSHIP
RAIN
SNOW MELT
SNOW ACCUM
MOISTURE INPUT
PRAIRIES OPTION - FIGURE 1a
INPUT INTENSITY
SOIL MOISTURE INDEX
EVAPOTRANSPIRATION INDEX
RUNOFF
SURFACE-SUBSURFACE FLOW SEPARATION
BII*
SURFACE (FAST)
SUB SURFACE (MED)
BASEFLOW (SLOW)
ROUTING
ROUTING
ROUTING
STREAMFLOW
* BASEFLOW INFILTRATION INDEX

Figure 1.

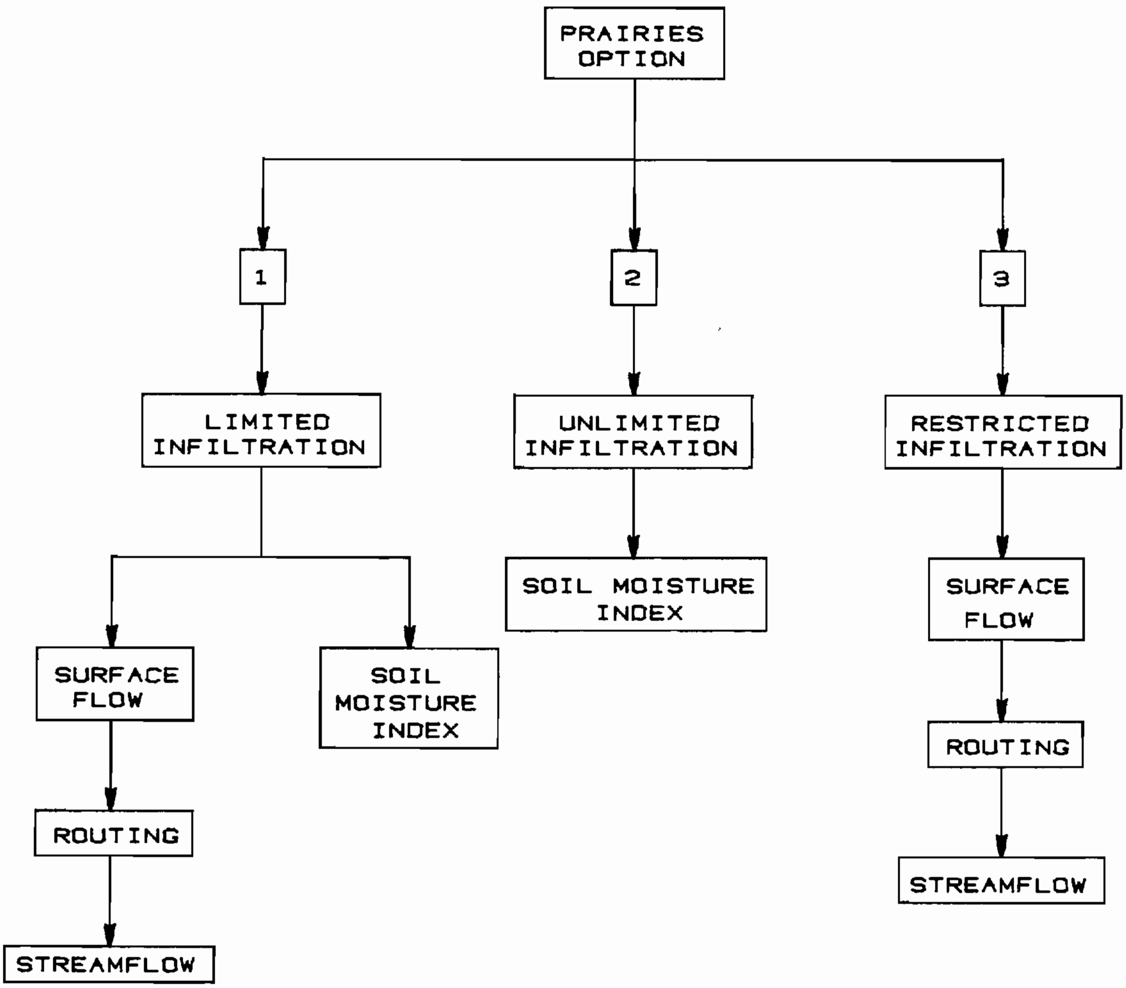
PRAIRIES OPTION
1
2
3
LIMITED INFILTRATION
UNLIMITED INFILTRATION
RESTRICTED INFILTRATION
SURFACE FLOW
SOIL MOISTURE INDEX
ROUTING
STREAMFLOW
SOIL MOISTURE INDEX
SURFACE FLOW
ROUTING
STREAMFLOW

Figure 1a.