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Nils Roar Sælthun

THE "NORDIC" HBV MODEL

Description and documentation of the model version developed for the project Climate Change and Energy Production

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ABSTRACT

The model described in this report is a version of the HBV model developed for the project Climate Change and Energy Production, a Nordic project aimed at evaluating the impacts of climate change on the water resources of the Scandinavian countries (Finland, Sweden, Norway, Iceland and Denmark including Greenland), with emphasis on hydropower production.

The model incorporates many of the features found in individual versions of the HBV model in use in the Nordic countries, and some new ones. It has catchment subdivision in altitude intervals, a simple vegetation parametrization including interception, temperature based evapotranspiration calculations, lake evaporation, lake routing, glacier mass balance simulation, special functions for climate change simulations etc.

The user interface is very basic, and the model is primarily intended for research and educational purposes. Commercial versions of the model should be used for operational implementations.

SUBJECT TERMS
hydrological model
HBV
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Cover photo: Sluppefossen in Erdal
Photo by Nils Roar Sælthun

PREFACE

The model described in this report is a version of the HBV model developed for the project Climate Change and Energy Production, a Nordic project aimed at evaluating the impacts of climate change on the water resources of the Scandinavian countries, with emphasis on hydropower production. The project has been partly financed by the Nordic Council of Ministers, partly by national research funding, and partly by the participating institutions. An important part of the project was to establish a hydrological model suitable for simulating the effects of climate change on river runoff. An obvious choice is the HBV model, which has been used both in operational hydrology and research in the Nordic countries, and has been under continuous development for 25 years. The model has diverged into a number of different versions, and the present model incorporates many of the features found in these versions, and some new ones.

The user interface is very basic, and the model is primarily intended for research and educational purposes. Commercial HBV versions for operational applications are available from the Swedish Meteorological and Hydrological Institute and the Norwegian SINTEF group.

The model can be downloaded from several ftp servers, including the Orkustofnun (National Energy Authority of Iceland) server *ftp.os.is*, and the NVE internet server which will be operational in the second half of 1996.

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BIBLIOTEK

CONTENTS

1 INTRODUCTION

The HBV model, originally developed at the Swedish Meteorological and Hydrological Institute in the first half of the seventies (Bergström, 1976) has gained widespread use for a large range of applications both in Scandinavia and beyond. It can be classified as a semi-distributed conceptual model. It uses subbasins as primary hydrological units, and within these an area-elevation distribution and a crude classification of land use (forest, open, lakes) is implemented. The subbasin option is used in geographically or climatologically heterogeneous basins. The model consists of three main components:

- subroutines for snow accumulation and melt,
- subroutines for soil moisture accounting,
- response and river routing subroutines.

The model has a simple structure and the requirements on input data are moderate. It has been applied in some 30 countries in many different climatic regions and have developed in a plethora of versions (Bergström, 1992).

The version described in this report was developed for the Nordic project "Climate change and Energy Production" (Sælthun *et al.* 1996), as a synthesis of several versions used in the different Nordic countries. It incorporates:

- one or two zones per altitude interval
- "vegetation" description (interception, snow parameters, soil moisture parameters) per zone
- full HBV description on each zone
- lake distribution per altitude interval
- glacier distribution per altitude interval
- climatic change profiling (per month)
- variable temperature gradient (per month)
- full snow distribution (lognormal, described by coefficient of variation)
- temperature index evaporation modelling
- seasonal temperature index profile
- lake temperature simulation
- lake temperature-based lake evaporation
- adjustment factor for lake evaporation
- adjustment factor for glacier ice melt
- variable precipitation gradient
- lake module

The present version can handle 25 precipitation stations, four temperature stations and four runoff stations.

2 MODEL DESCRIPTION

This chapter contains a brief description of the model. For more background information on the HBV model the reader is referred to Bergström (1992). Details on the evapotranspiration part are found in Lindström *et al.* (1994). The concept of snow distribution was originally developed by Killingtveit and Aam (1978).

2.1 General structure

The main structure of the HBV model is a sequence of submodels:

- snow submodel
- soil moisture zone
- dynamic part
- routing

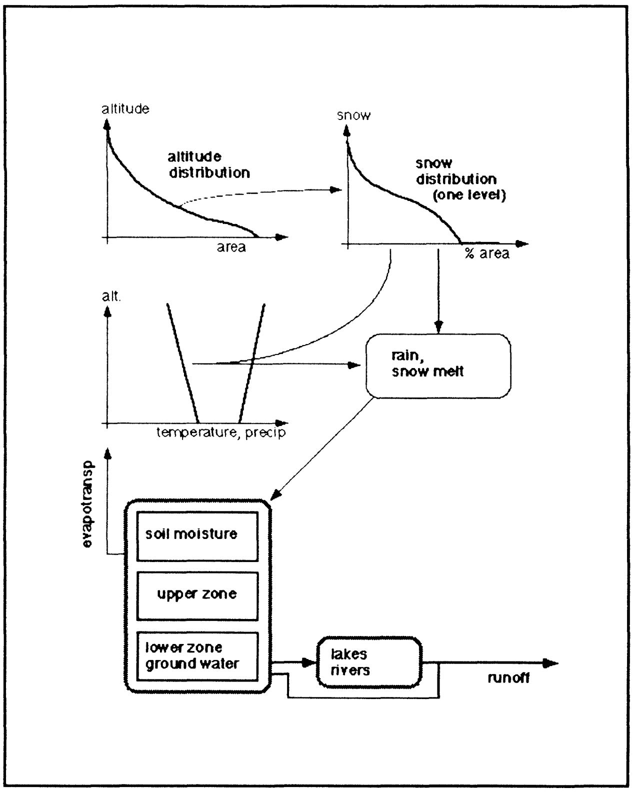

Figure 1 *General structure of the HBV model*

The model is further structured in altitude intervals. This subdivision can be applied only to the snow submodel, or to the whole model. In the latter case, the height intervals can further be subdivided in one or two vegetation zones and lakes.

Even when the model distributed on altitude intervals, the parameters are generally the same for all submodels. Interception, snow melt parameters and soil moisture capacity can however be varied according to vegetation type. The model can operate with up to 15 vegetation types, but usually not more than two or three would be activated.

A sketch of the model structure is given in Figure 1.

The distribution of the model in zones is controlled by index #27. Some of the model features described below do only apply to the distributed model.

2.2 Precipitation and temperature adjustments

2.2.1 Precipitation adjustment

All precipitation is adjusted by a fixed correction, PKORR, parameter # 45. This adjustment is partly due to gauge catch losses, partly due to nonrepresentative stations (disregarding altitude variations). When the temperature at the observation station indicates snow fall (at the station or at the weighted average altitude of the stations), the precipitation also adjusted with the snow fall correction factor SKORR, #46, to correct for the larger catch losses for snow.

2.2.2 Temperature and precipitation altitude gradients

The precipitation altitude gradient is assumed to be linear, i.e. a fixed proportional change of the observed precipitation per 100 m altitude change. The gradient is PGRAD, #65. An example: PGRAD = 0.03 indicates 3% precipitation increase, of observed precipitation, per 100 m. The gradient can be changed at a specified level, GRADALT, #47, where it changes to PGRAD1, #48. PGRAD1 specifies the change as a proportion of the precipitation at GRADALT. If GRADALT is zero, the change of gradient is not activated.

The temperature gradient is given as a lapse rate, deg C change per 100 m. The lapse rate on days without precipitation is specified by parameter TTGRAD, #63, and on days with precipitation by parameter TVGRAD, #64. Default values are -0.6 deg/100 m.

A seasonal profile of the temperature gradient can be specified by parameters 101 to 112, one per month from January to December. This profile is normalized against TTGRAD and TVGRAD, so that the annual mean value (average of the monthly values) equals these.

Table 1 *Snow fall redistribution functions for some typical coefficients of variation*

Area	Coefficient of variation				
	0.0	0.1	0.3	0.5	1.0
0.005	1.00	0.76	0.43	0.25	0.07
0.030	1.00	0.82	0.55	0.37	0.14
0.100	1.00	0.87	0.65	0.48	0.23
0.250	1.00	0.91	0.74	0.59	0.34
0.500	1.00	0.99	0.96	0.90	0.69
0.750	1.00	1.08	1.23	1.33	1.49
0.900	1.00	1.13	1.40	1.65	2.08
0.970	1.00	1.20	1.66	2.17	3.41
0.995	1.00	1.30	2.11	3.19	6.84

2.3 Snow submodel

2.3.1 Snow accumulation

Snow accumulation in an altitude level starts when precipitation falls at temperature lower than TX, #40. Up to an accumulated storage of SPDIST, #113, the accumulation is even. When the storage reaches this level, additional snow fall is distributed according to the specified snow distribution (see below).

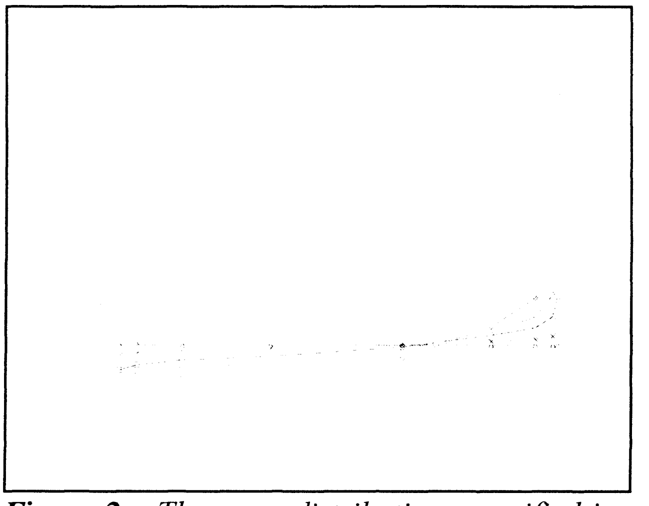

Figure 2 *The snow distributions specified in table 1*

2.3.2 Snow distribution

Snow distribution is given as a lognormal distribution, calculated for the quantile intervals 0.0-0.01, 0.01-0.05, 0.05-0.15, 0.15-0.35, 0.35-0.65, 0.65-0.85, 0.85-0.95, 0.95-0.99 and 0.99-1.0. In one altitude zone, this will give the following possibilities for snow cover percentage: 0, 1, 5, 15, 35, 65, 85, 95, 99, 100%. The actual form of the snow distribution is specified by its coefficient of variation, parameter CVMAX in the VEGTYPE file. Some examples of distributions for typical values of CVMAX are given in Table 1 and Figure 2.

2.3.3 Snow melt and refreeze

Basically the HBV model uses a temperature index (degree-day) method for snow melt calculation. The temperature index melt equation is

$$M = CX \cdot (T - TS) \qquad \text{for} \quad T > TS$$
$$M = 0 \qquad \text{"} \quad T < TS$$

where M is the melt (in mm), T is the altitude level temperature during the time step, TS the threshold temperature, parameter #41, and CX the temperature index, #40.

Meltwater is retained in the snow until the amount of liquid water reaches a fraction LV (parameter #44). Over this threshold meltwater leaves the snow pack. All nine subdivisions of the snow distribution in an altitude zone are treated individually.

When the temperature is below the melt threshold temperature, liquid water in the snow pack will refreeze, but at a lower efficiency than the melt. The refreeze equation is

$$F = CFR \cdot CX \cdot (TS - T) \qquad \text{for} \quad T < TS$$
$$F = 0 \qquad \text{"} \quad T > TS$$

CFR, #43, is a dimensionless constant less than 1.

2.3.4 Albedo simulation, varying temperature index

A simulation option allows varying temperature index, depending on whether it rains or not, and on albedo. This option is activated by setting index #29 to 1.

Albedo simulation. The albedo simulation is based on snow aging. The limiting values for the albedo are depending on the snow liquid water content - the maximum value is varying linearly from 0.5 for fully saturated snow to 0.8 for dry snow, and the minimum value from 0.2 for fully saturated to 0.6 for dry snow. More than 5 mm of snow fall will lift the albedo to the maximum value. Otherwise, the albedo will fall towards the limiting lower value by a temperature dependent exponential decay. The decay factor is specified by the parameter CALB, #49. The new albedo is calculated by the equation

$$A_{t+1} = A_{min} + (A_t - A_{min}) \cdot (1 - CALB \cdot T)$$

for days with temperature higher than 0.

For days with temperature between -10 °C and 0, the albedo is also reduced, but by a factor only 5 per cent of the decay for temperatures higher than zero.

Temperature index. For simulations with varying temperature index, the temperature index is split in three parts by the three parameters CRAD, CCONV and CCOND, #50, #51 and #52.

<u>"Radiation" part:</u> The "radiation" part is depending on albedo, potential short wave radiation at the earth surface, and precipitation. The short wave radiation is calculated by astronomical formulas, and is depending on the latitude, LAT, #100, and the day number. The actual radiation melt temperature index is calculated by the formula:

$$CX_{rad} = CRAD \cdot CX \cdot RVEKT \cdot e^{-0.1 \cdot P} (1-A)/0.5$$

RVEKT is the normalized potential incident radiation, set to 1 at May 15 at 60°N. RVEKT will vary from 0.05 at Jan 1 to 1.15 at midsummer. P is the precipitation. The component varies linearly with albedo and decreases exponentially with precipitation. At 10 mm it is reduced to 37% of the value at days without precipitation.

<u>"Convection" part:</u> The "convection" temperature index is always active, and equals

$$CX_{conv} = CCONV \cdot CX$$

<u>"Condensation" part:</u> The "condensation" temperature index is only active during precipitation days (more than 1 mm of rain), and equals

$$Cx_{cond} = CCOND \cdot CX$$

2.3.5 Glacier melt

On glaciers snow accumulates and melts at the same rate as on the non-glacierized areas in the same altitude level. For exposed glacier ice, the melt is increased by a factor CBRE, #66. If albedo-dependent snow melt is used, the albedo of the glacier ice is also set to the lowest value, 0.2.

2.3.6 Glacier snow storage zeroing

To avoid excessive snow storage build up in high areas, above the glaciation limit (the model has no other mechanism for converting "old" snow into glacier ice), any snow storage above the level SPDIST is set to SPDIST at the end of the snow melt season. The liquid water content is reduced accordingly. The day for snow storage reduction is given by the parameter NDAG, #39.

2.4 Evapotranspiration, interception

2.4.1 Potential evapotranspiration

Potential evapotranspiration can either be given as parameters to the model, or calculated by a temperature index method. In the first case, average potential evapotranspiration in mm/day is given for each month by parameters EP(1) to EP(12) - #67 to #78 (January to December). These are used as fixed values, and there is no differentiation between altitude levels, nor vegetation zones.

Bu the temperature index method, the potential evapotranspiration is calculated for each time step using a simple temperature index method:

$$\begin{array}{ll} PE = CE \cdot T & \quad for\ T > 0 \\ PE = 0 & \quad for\ T < 0 \end{array}$$

CE is specified by parameter #98. In addition, the potential evapotranspiration can be given a seasonal profile - the parameters #67 to #78 will in this mode act as monthly correction factors for CE. This seasonal profile can further be modified by the vegetation parameter EPVAR. The final temperature index formula is

$$PE = CE \cdot T (1+(EP(mnd)-1) \cdot EPVAR)$$

The mode for evapotranspiration calculations is controlled by index #25.

2.4.2 Snow evaporation

Generally, only snow free areas are assumed to evaporate. An exception is intercepted snow - see below.

2.4.3 Lake evaporation

Lakes are assumed to evaporate at potential rate. Parameter #60, CEVPL, is an adjustment on "land" evaporation as described above, to be applied on lakes. If preset potential evaporation is used, lakes are assumed to be ice covered to the same extent as the adjacent ground is snow covered. If temperature index methods are used, then the lake evapotranspiration is based on a simulated lake temperature. The lake temperature is calculated by a simple autoregressive model:

$$\boldsymbol{TLAKE_t = TLAKE_{t-1}(1 - 1/TLDAY) + T/TLDAY}$$

where TLAKE is lake surface temperature and T is air temperature. TLDAY is a parameter describing the temperature "memory" in days. If TLDAY (#62) is 0 or 1 then lake temperature is set equal to air temperature. Lake evaporation is calculated by the equation

$$\begin{aligned} &E_{lake} = CEVPL \cdot CE \cdot TLAKE && \textit{for } TLAKE > 0 \\ &E_{lake} = 0 && \textit{for } TLAKE < 0 \end{aligned}$$

This is a lake evapotranspiration method for shallow lakes developed at SMHI.

2.4.4 Interception

Interception storage is specified by the vegetation parameter ICMAX - given in mm. The interception storage will loose water at potential evapotranspiration rate, regardless of whether the intercepted precipitation is rain or snow. As long as water is present in interception storage, the actual evapotranspiration from the soil moisture zone is reduced by EP·ERED, where ERED is a dimensionless constant less than 1.0 specified by parameter #61.

2.5 Soil moisture zone

A central part of the HBV model is the soil moisture zone. Meltwater from snow, rain on snow free areas and glacier ice melt is input to this zone. In addition water can be drawn up from the ground water zone to the soil moisture zone. Actual evapotranspiration is calculated based on the water content in this zone, and the percolation to the dynamical parts of the model is a function of the water content. Water percolated "through" the zone is not delayed, and water is only removed from the zone by evapotranspiration.

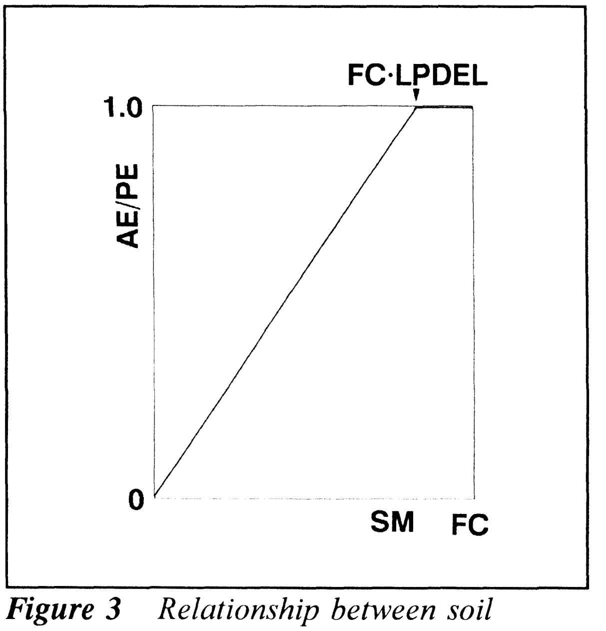

Figure 3 *Relationship between soil moisture content, potential evapotranspiration and actual evapotranspiration*

2.5.1 Actual evapotranspiration

Actual evapotranspiration is calculated by the equation

$$AE = PE \cdot SM/(FC \cdot LPDEL) \qquad \text{for } SM < FC \cdot LPDEL$$
$$AE = PE \qquad \text{for } SM > FC \cdot LPDEL$$

where SM is actual soil moisture content, FC (#79) is the maximum water content of the zone (in mm), and LPDEL (#80) a dimensionless parameter (< 1), indicating the level at which the evapotranspiration is potential. Figure 3 illustrates this relationship. FC as given in the main parameter file can be adjusted by the FCVEG parameter in the vegetation description file (VEGTYPE.DAT) - the actual maximum soil moisture content will be $FC \cdot FCVEG$. The LPDEL parameter in the main parameter file can be overridden by the LPDEL parameter in the VEGTYPE file.

2.5.2 Maximum infiltration

A maximum input rate to the upper zone can be specified by the parameter INFMAX, #82, in mm/d. The part of the input exceeding this goes directly to the upper zone.

2.5.3 Percolation

A fraction of the input water is percolated on to the dynamic parts of the model. The fraction percolated is given by the equation

$$CUZ = INSOIL \cdot (SM/FC)^{BETA} \qquad \text{for } SM < FC$$
$$CUZ = INSOIL \qquad \text{for } SM = FC$$

a nonlinear relationship controlled by the BETA exponent, parameter #81. Figure 4 illustrates the relationship.

2.5.4 Draw up

Water can be drawn from the ground water zone to the soil moisture zone. The amount drawn up is given by the equation

$$UP = 2.0 \cdot DRAW \cdot (LZ/LZMAX) \cdot (FC-SM)/FC$$

where DRAW is the parameter controlling the draw up. It is given in mm/d, and is the draw up when the soil moisture zone is at $0.5 \cdot FC$, and the ground water content (LZ) is at maximum (LZMAX).

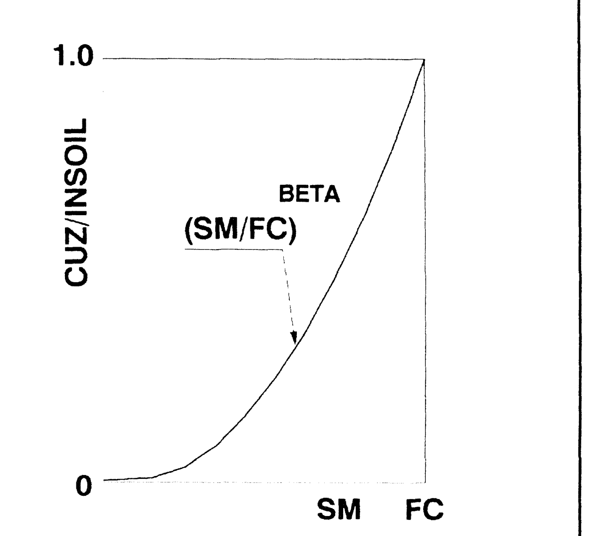

Figure 4 Relationship between soil moisture content and percolation

2.6 Upper zone

The upper zone is, together with the routing module, the main dynamical part of the model. It is essentially a piecewise linear reservoir, but with a constant deep percolation to the ground water zone - as long as there is water in the upper zone.

2.6.1 Deep percolation

The deep percolation to the lower zone is controlled by one parameter, PERC - #88 - given in mm/d.

2.6.2 Dynamic response

The zone has a two level dynamic response, controlled by three parameters, KUZ1 (#87), UZ1 (#86) and KUZ2 (#85). KUZ and KUZ1 are response coefficients in unit d^{-1}, and UZ1 is a threshold level between the two response regimes, given in mm. The response is essentially

$$QUZ = KUZ1 \cdot UZ \qquad \text{for } UZ < UZ1$$
$$QUZ = KUZ2 \cdot (UZ - UZ1) + KUZ1 \cdot UZ1 \qquad \text{for } UZ > UZ1$$

This is the momentary response - in the actual calculation these equations are integrated over the time step. Approximations of the following type are used:

$$QUZ = (UZ + 0.5(CUZ - PERC)) \cdot 2.0 \cdot KUZ/(2.0 + KUZ)$$

where UZ is the content of the upper zone at the start of the time step, and CUZ-PERC is the inflow to the zone.

2.7 Lower zone

The lower zone is a linear reservoir, describing ground water response. The runoff from the zone is given by

$$QLZ = KLZ \cdot LZ$$

where LZ is the lower zone content (mm), and KLZ (#89) the response coefficient. AS the inflow to the zone is limited to PERC (mm/d), the outflow will balance inflow at a content of

$$LZMAX = PERC/KLZ$$

A linear reservoir will never empty by runoff, but the draw up mechanism (3.5.4) can empty it, permitting periods with zero runoff from the model.

2.8 Lakes

Lake percentage is specified in each altitude interval. Precipitation on lakes and lake evaporation are calculated for each altitude interval, but the dynamic response of the lake area is calculated aggregated for the catchment. All precipitation on lakes, regardless whether it is rain or snowfall, is a direct contribution to the lake water balance. If there are reservoirs in the catchment, specified by MAGDEL, #4, the precipitation minus evaporation on this part of the lake area is added directly to runoff. The rest of the lake net precipitation is attenuated by the lake dynamics.

2.8.1 Lake dynamics

The lake dynamics are described as a single lake, through which the net lake precipitation and a part of the catchment runoff is routed. The parameters for the lake routing is:

KLAKE	#56	the rating curve coefficient of the lake
DELH	#57	the zero point of the rating curve
NLAKE	#58	the rating curve exponent
DELF	#59	the part of the catchment (runoff) that drains through the lake

2.9 Routing

Runoff from the dynamic part of the model (upper zone, lower zone, lake dynamics) can be attenuated/delayed through the routing module. Three methods of routing are available, specified by index #22. The three methods are:

0: no routing
1: lake routing
2: smoothing with fixed weights
3: smoothing with discharge dependent weights (triangular unit hydrograph)

The routing parameters are the five parameters ROUT(1) to ROUT(5), #90 to #94. The actual interpretation depends on the routing method chosen.

2.9.1 Lake routing

This routing corresponds to the lake dynamics described above. Lake dynamics and lake routing can be combined to simulate two lakes in series.

ROUT(1)	lake area (km^2)
ROUT(2)	lake rating curve coefficient
ROUT(3)	rating curve zero
ROUT(4)	rating curve exponent
ROUT(5)	part of catchment (runoff) draining through lake

2.9.2 Fixed weights routing

This is a moving average type routing with up to six weights:

$$Q_i = W1 \cdot QI_i + W2 \cdot QI_{i-1} + ... + W6 \cdot QI_{i-5}$$

where QI is the input to the routing. Parameter interpretation:

ROUT(1)	W1
ROUT(2)	W2
ROUT(3)	W3
ROUT(4)	W4
ROUT(5)	W5

W6 is calculated as 1 - W1-W2-W3-W4-W5.

2.9.3 Discharge dependent weights

This is routing by a triangular unit hydrograph, with discharge dependent base (the original HBV routing).

Parameter interpretation:

ROUT(1)	Q1
ROUT(2)	T1
ROUT(3)	Q2
ROUT(4)	T2

T1 is time base for discharge level Q1, while T2 is time base for discharge Q2. The actual time base is interpolated (or extrapolated) from (Q1,T1), (Q2,T2). The maximum time base is five time steps (days). If the extrapolation gives a higher value, it is set to five days.

2.10 Error functions

In single simulations, error topography and optimization run mode, error functions are presented to support interpretation of the results. It should be emphasized that the best judgment of the parameter fit very is often obtained by visual inspection of a graphical display of the simulations. The simulated water balance is also a very important guidance in model calibration, as are duration curves and frequency analysis of observed and simulated data. Duration curve and frequency analysis is not presented by the model software, but can easily be produced by for instance spreadsheet programming, using the data output produced by the model.

The error functions produced by the model are:

$$F2 = \sum (Q_m - Q_o)^2$$

F2 is simply the sum of squares of the errors (in mm/d). It is always nonnegative, and a perfect fit gives F2=0. The smaller the better.

A standardized modification of F2 is the R2 - the Nash efficiency criterion:

$$R2 = 1 - \frac{\frac{1}{n}F2}{Var(Q_o)}$$

where

$$Var(Q_o) = \frac{1}{n}\sum(Q_o - \overline{Q_o})^2$$

and where all sums are taken over all observations *n*.

R2 varies from minus infinity to 1. 1 indicates a perfect fit. An R2 value of zero is a model as good (or bad) as setting the simulated value constant to the mean runoff. An R2 value of 0.8 usually indicates what would be regarded a fairly good fit.

F2 and R2 are very sensitive to flood values - due to the second power involved, and timing errors in floods will affect these criteria strongly.

What is indicated in the output file as *rel.diff**2* is:

$$\sum \frac{Q_m - Q_o}{0.5\ (Q_m + Q_o)}$$

The *R2-log* error function corresponds to the R2 error function, but calculated on the logarithms of the observed and simulated runoff, to give more weight to the low flow data (this corresponds loosely to making the analysis on relative errors instead of absolute errors). The runoff data are given an offset of 0.001 mm to avoid problems in periods with zero runoff.

What is listed in the output as *Difference* is simply the difference between simulated and observed runoff over the whole period - in mm. It cannot be used for optimization - a good fit should give a low difference, but a low accumulated difference does not ensure a good fit.

3 FILES

3.1 Files distributed

The files in the model package are:

Executables:

hbv.exe	HBV model, compiled by Microsoft Fortran 5.1 for MS-DOS and OS/2
hbvplo.exe:	executable file, traditional screen plot
helvb.fon:	font file to be used together with hbvplo

Source files:

hbv.for:	main program and administrative routines
hbvsim.for:	outer simulation loop routines
hbvrut.for:	inner simulation loop routines (per time step)
hbvopt.for:	optimization routines
hbv_pc.for:	substitution routines for PC compilation

Data files:

default.dat:	default simulation options (some explanation on the file)
param.dat:	sample parameter file
groset.dat:	sample data file
climcha.dat:	sample climatic change profile
vegtype.dat:	sample vegetation type file
prtfil.res:	results - comma delimited file the content of the file is decided by index # 16

Supplementary files:

hbvres.exe:	produces a file with simulation statistics based on the prtfil.res file, produced with index # 16 set to 3. The file is in a format that is suitable for worksheet import
nve2hbv.exe:	utility to make input data files, based on NVE worksheet-type export files

3.2 File contents

3.2.1 DEFAULT.DAT

Sample file:

```
DEFAULT    0   0 1 1 7   0 1 1 7 0   1 0 1 1 0 3 0 1 0 0 0 0 0 0 1 0 1 0 0
1
no:        1                       11                   21
```

This is a fixed format file presetting simulation options. The option indexes can also be altered interactively in the program, but the DEFAULT.DAT file will not be rewritten.

Some important indexes:

13:	0:	no variation in parameters according to vegetation type
	1:	zone parameters according to vegetation type
16:	1:	snow water equivalent printout on PRTFIL.RES
	2:	water flows on PRTFIL.RES
	3:	states on PRTFIL.RES
	4:	snow cover on PRTFIL.RES
	5:	glacier mass balance on PRTFIL.RES
	6:	evaporation data etc on PRTFIL.RES
22:	0:	no routing
	1:	lake routing
	2:	smoothing with fixed weights
	3:	smoothing with discharge dependent weights (triangular unit hydrograph)
25:	0:	preset potential evapotranspiration (per month)
	1:	temperature dependent evapotranspiration
27:	0:	lumped main model
	1:	distributed model (altitude interval)
28:	0:	ordinary run
	1:	climatic change simulation run, data from CLIMCHA.DAT is used - snow correction is applied according to original data
29:	0:	standard temperature index snow melt calculations
	1:	albedo simulation - variable temperature index snow melt simulation

3.2.2 VEGTYPE.DAT

Sample data file:

```
Type        no    ICMAX    CXREL   TSDIFF    CVMAX    FCVEG    LPDEL    EPVAR
Mountain     1      0.0      1.0      0.0      0.5     0.75      0.8      0.5
Forest       2      2.0      0.7      0.0      0.3     1.00      0.6      1.0
Shrub        3      1.0      1.0      0.0      0.4      0.8      0.7      0.8
Rock         4      0.0      1.0      0.0      0.3      0.2      1.0      0.1
```

This is a fixed format file, describing vegetation zones, identified by number. Up to 15 vegetation types can be simultaneously defined on VEGTYPE.DAT

Parameter explanation:

ICMAX:	interception storage	[mm]
CXREL:	correction factor on temperature index	[1]
TSDIFF:	adjustment on zero melt temperature threshold	[deg C]
CVMAX:	coefficient of variation of snow distribution	[1]
FCVEG:	adjustment of maximum soil moisture content	[1]
LPDEL:	evapotranspiration eq. to pot. evapotranspiration at FC·LPDEL	[1]
EPVAR:	correction factor for deviations of potential evapotranspiration seasonal profile (epot = CE·T·(1+(EP(mnd)-1)·EPVAR)	[1]

NB! LPDEL will override LPDEL in main parameter file!

Default values:

ICMAX 0.0
CXREL 1.0

TSDIFF	0.0
CVMAX	0.5
FCVEG	1.0
LPDEL	LPDEL in parameter file
EPVAR	1.0

3.2.3 CLIMCHA.DAT

Sample data file:

```
      Temp    Prec
Jan    2.0     1.1
Feb    2.0     1.1
Mar    2.0     1.1
Apr    2.0     1.1
May    2.0     1.1
Jun    2.0     1.1
Jul    2.0     1.1
Aug    2.0     1.1
Sep    2.0     1.1
Oct    2.0     1.1
Nov    2.0     1.1
Dec    2.0     1.1
```

This file is used in climate change runs (see DEFAULT.DAT) to specify the climate change profile. The temperature change is given in deg C, the precipitation as a correction factor, i.e. the number of precipitation days is not changed. The corrections are applied **after** the observed precipitation data has been corrected for catch losses according to PKORR/SKORR in parameter file and the observed temperature. This is to avoid the areal precipitation to be artificially reduced due to reduced snow fall fraction (in the case of increased temperature).

3.2.4 PARAM.DAT

The parameter file can include several catchments, the catchments are identified by the first four letters in their name (case sensitive).

A full sample data file is shown in enclosure 1.

A partial sample is:

```
START  2GROSET
  2    0            1    PNO        Number of precipitation stations
  2    0  Møsstrand      PID1       Identification for precip station 1
  2    0         940.    PHOH1      Altitude precip station 1
  2    0         1.0     PWGT1      Weight precipitation station 1
  2    0            1    TNO        Number of temperature stations
  2    0  Møsstrand      TID1       Identification for temp station 1
  2    0         940.    THOH1      Altitude temp station 1
  2    0         1.0     TWGT1      Weight temp station 1
  2    0            1    QNO        Number of discharge stations
  2    0  Grosettjern    QID        Identification for discharge station
  2    0          1.     QWGT       Scaling factor for discharge
  2    0         6.51    AREAL      Catchment area                        [km2]
  2    4        0.050    MAGDEL     Regulation reservoirs                 [1]
  2    5      939.000    HYPSO ( 1,1), low point               [m]
  2    6      953.000    HYPSO ( 2,1)
  2    7      965.000    HYPSO ( 3,1)
  2    8      978.000    HYPSO ( 4,1)
  2    9      991.000    HYPSO ( 5,1)
  2   10     1004.000    HYPSO ( 6,1)
  2   11     1015.000    HYPSO ( 7,1)
  2   12     1025.000    HYPSO ( 8,1)
  2   13     1036.000    HYPSO ( 9,1)
  2   14     1056.000    HYPSO (10,1)
  2   15     1121.000    HYPSO (11,1), high point
  2   16        0.000    HYPSO ( 1,2), Part of total area below HYPSO (1,1) = 0
  2   17        0.100    HYPSO ( 2,2)
  2   18        0.200    HYPSO ( 3,2)
  2   19        0.300    HYPSO ( 4,2)
  2   20        0.400    HYPSO ( 5,2)
  2   21        0.500    HYPSO ( 6,2)
  2   22        0.600    HYPSO ( 7,2)
  2   23        0.700    HYPSO ( 8,2)
  2   24        0.800    HYPSO ( 9,2)
  2   25        0.900    HYPSO (10,2)
  2   26        1.000    HYPSO (11,2), Part of total area below HYPSO (11,1) = 1
  2   27        0.000    BREPRO( 1), Glacier area, part of total area, below HYPSO( 1,1)(=0.0)
  2   28        0.000
  2   29        0.000
  2   30        0.000
  2   31        0.000
  2   32        0.000
  2   33        0.000
  2   34        0.000
  2   35        0.000
  2   36        0.000
  2   37        0.000    BREPRO(11), Glacier area, part of total area, below HYPSO(11,1)
  2   38
  2   39      270.000    NDAG       Day no for conversion of glacier snow to ice
  2   40        0.000    TX         Threshold temperature for snow/ice          [C]
.......
  2  157            1     VEGT(1,10) Vegetation type 1, zone 10
  2  158            0     VEGT(2,10) Vegetation type 2, zone 10
  2  159          0.0     VEGA(10)   Vegetation 2 area, zone 10          [1]
  2  160          0.0     LAKE(10)   Lake area,         zone 10          [1]
FINIS
```

The file is fixed format, but only the parameter numbers (column 2) and parameter values (column 3) are read by the program. The other information is to be regarded as comments.

The first line marks the start of parameters for a new catchment. The catchment name is important, but only the first four characters identify the catchment. The file can contain any number of catchments between START/FINIS lines.

The second group of lines identifies the data series to be used in the simulation. The number and order must correspond with the columns of the input data file (see below). The precipitation series are listed first, then the temperature series and at last the runoff series. A maximum of 25 precipitation stations, four temperature stations and four runoff stations can be handled. Missing data for temperature and precipitation is accepted as long one series of each type has data. In the case of missing data, the other series are scaled up - the series weights are always normalized so that their sum is 1.

The hypsographic curve (altitude/area) is defined from parameter 5 on. In positions 5 to 15 the altitudes of up to 11 points on the curve are defined. The data has to start with the lowest point and end with the highest. Positions 16 to 27 are used for corresponding relative areas of the accumulated curve (area lower than indicated level). I.e. the first ordinate is 0 (low point) and the last 1.0 (high point). Internally in the model the areas are calculated as differences and the altitudes as mean values of the two points defining an interval. Observe that the interval areas do not need to be equally large. Positions 28 to 39 are used for defining glaciated areas. The number to register here is the accumulated glaciated area (lower than indicated level) as a fraction of the total catchment area.

The last part of the file, parameters 121 to 160, specifies information about the altitude intervals, with four parameters per interval. These are:

VEGT(..,1)	main vegetation type in this interval, referring to the vegetation type number in VEGTYPE.DAT
VEGT(..,2)	secondary vegetation type
VEGA()	relative area of **secondary vegetation type**
LAKE()	relative lake area in this interval

The last line, FINIS, defines the end of the catchment parameters.

The order of the numbered parameter lines is of no importance, and lines can be skipped (the parameter will be zero or another default value).

3.2.5 Input data file

Sample input data file:

```
1981    1    1   10.5    -4.6   0.048
1981    1    2    1.8    -7.1   0.048
1981    1    3    0.7    -9.7   0.048
1981    1    4    1.8   -10.5   0.048
1981    1    5    1.7   -13.7   0.043
1981    1    6      0   -18.4   0.043
1981    1    7      0   -12.9   0.039
1981    1    8    0.6   -14.6   0.039
```

The file can have any name (the user will be prompted for file name), and is read in Fortran list directed mode. The first three columns give the date, then the data is read, one line per time step, according to the parameter file header. The number of data columns must correspond with the number and order of data series specified in the header. Data series can be skipped by setting the weight to zero in the parameter file header, but the series must still be present in the file. Only daily values can be handled, and at present there is no option for handling missing data, except runoff data (missing = -10000).

Data units are mm for precipitation, °C for temperature and m^3/s for runoff. The input data file can usually easily be assembled from single data files by spreadsheets or Unix tools.

3.2.6 Output data files

Output is stored in two files, a plot file for use in HBVPLO, and a more general file, PRTFIL.RES. The plotfile is given a name xxxxyyy.plt, where xxxx is the first four characters in the catchment name and yyy is a number supply by the user at the initiation of the run. The file is an ASCII file with data organized in yearly data blocks.

PRTFIL.RES is structured to be easy to import to spreadsheets or data bases. The content is specified by index # 16 (set in DEFAULT.DAT or interactively during initiation). The implemented formats are:

1: snow water equivalent per altitude interval
2: water flows in model
3: internal states + input and output
4: snow cover per altitude interval
5: glacier mass balance per altitude interval
6: evaporation data etc.

Sample data file (index # 16 = 3):

```
       Simulation for GROSET         period:   1/ 9 1981 - 31/12 1983
       States
                     prec        temp       evap       snowres      snowcov    soilmoist  upper zn    lower zn      qsim          qobs
  1981,    9,    1,      .000,     7.608,     1.137,        .000,        .000,   118.707,       .000,     29.700,       .262,        .239,
  1981,    9,    2,      .000,     9.608,     1.440,        .000,        .000,   117.077,       .000,     29.403,       .256,        .239,
  1981,    9,    3,      .000,     8.008,     1.191,        .000,        .000,   115.738,       .000,     29.109,       .251,        .239,
  1981,    9,    4,      .000,     9.908,     1.461,        .000,        .000,   114.100,       .000,     28.818,       .245,        .239,
  1981,    9,    5,      .000,    10.908,     1.592,        .000,        .000,   112.322,       .000,     28.530,       .240,        .239,
  1981,    9,    6,      .000,     8.008,     1.163,        .000,        .000,   111.037,       .000,     28.244,       .235,        .212,
  1981,    9,    7,      .000,     5.508,      .804,        .000,        .000,   110.163,       .000,     27.962,       .231,        .186,
  1981,    9,    8,      .459,     6.808,     1.046,        .000,        .000,   109.345,       .000,     27.796,       .251,        .186,
  1981,    9,    9,      .826,     8.108,     1.274,        .000,        .000,   108.538,       .000,     27.720,       .267,        .186,
  1981,    9,   10,      .000,     7.908,     1.128,        .000,        .000,   107.311,       .000,     27.443,       .222,        .186,
........

  1983,   12,   25,     2.294,    -7.192,      .000,      43.885,     100.000,   158.214,       .000,     42.764,       .613,        .212,
  1983,   12,   26,    14.453,    -8.092,      .000,      58.337,     100.000,   158.214,       .000,     42.336,      1.217,        .212,
  1983,   12,   27,      .000,    -5.192,      .000,      58.337,     100.000,   158.214,       .000,     41.913,       .511,        .239,
  1983,   12,   28,     6.997,     -.492,      .000,      65.333,     100.000,   158.214,       .000,     41.494,       .853,        .239,
  1983,   12,   29,     3.212,    -3.592,      .000,      68.545,     100.000,   158.214,       .000,     41.079,       .668,        .239,
  1983,   12,   30,     5.965,    -2.092,      .000,      74.510,     100.000,   158.214,       .000,     40.669,       .803,        .239,
  1983,   12,   31,     3.556,    -4.792,      .000,      78.066,     100.000,   158.214,       .000,     40.262,       .685,        .319,


        SIMULATION RESULTS WITH THE HBV3-MODEL FOR CATCHMENT:GROSET       , RUN

        Accumulated volumes, mm :
        Precip.         2359.6  obs precip.: 2326.2 of this snow:   980.6
        Evapotr. :       473.8                          snowmelt:  1088.6
                                                    glacier melt:      .0
        sim runoff:    1766.8  obs runoff:  1523.0   difference:   243.8

        Initial states:     end states:    change:
             1/ 9 1981       31/12 1983
        ground+lake      132.0       186.6        54.6
        eff. snow           .0        68.7        68.7

    Snow distribution 31/12 1983
m asl.      946.    959.    972.    985.    998.   1010.   1020.   1031.   1046.   1089.
area         .10     .10     .10     .10     .10     .10     .10     .10     .10     .10
Tot snow     73.     73.     74.     75.     75.     75.     76.     78.     88.     94.
Liq. wat      2.      2.      1.      1.      1.      1.      0.      0.      0.      0.
Snow cov    100.    100.    100.    100.    100.    100.    100.    100.    100.    100.

        Comp err.         -4.35

        Precip.         2359.55
        Glac. melt          .00
        Evapotr.        -473.81
        Runoff         -1766.83
        Stor.ch.         -54.56
        Snow ch          -68.70
        Snow adj.           .00

       Error functions:
        rel.dif**2      284.11
        difference      243.79
        F2-value       1482.17
        R2-value           .87
        R2-log             .70
```

The tail of the file summarizes the run. Most of the information should be self-explanatory, but some of the entries may need some additional information:

Precip:	Computed areal precipitation
Obs. precip.:	Weighted, but not adjusted observed precipitation
of this snow:	Estimated snow fall at precipitation station(s) (basis for snow correction)
Liq. wat:	Liquid water content in snow
Comp. err:	Water balance error over the simulation period (should be caused by model or rounding errors)
Snow adj.:	For glacierized catchments, snow storage is zeroed at a fixed date each year. This entry gives the accumulated corrections

All accumulated values and states are given in mm over the total catchment area, or the altitude interval.

Error functions: *rel.dif**2*, *difference* and *F2-value* should be as small as possible, *R2-value* and *R2-log* as close to 1 as possible. For explanation of the error functions, see the model description below.

REFERENCES

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Bergström, S. (1992) *The HBV model - its structure and applications*. Report. RH 4,Swedish Meteorological and Hydrological Institute, Norrköping.

Killingtveit, Å. and Aam, S. (1978) En fordelt modell for snøakkumulering og -avsmelting *(A distributed model for snow accumulation and melt)*. Norwegian Institute of Technology, Divison of HydraulicEngineering, Trondheim (In Norwegian).

Lindström, G., Gardelin, M., Persson, M. and Bergström, S. (1994) Conceptual modelling of evapotranspiration for simulation of climate change effects. In: Kern-Hansen, C., Rosbjerg, D. and Thomsen, R. (Eds.) *Nordic Hydrological Conference 1994 - Tórshavn*, Danish Geological Survey, Copenhagen.

Sælthun, N.R., Aittoniemi, P., Bergström, S., Einarsson, K., Jóhannesson, T., Lindström, G., Ohlsson, P.-E., Thomsen, T., Vehviläinen, B. and Aamodt, K.O. (1996) *Climate change impacts on runoff and hydropower in the Nordic countries. Final report from of the project "Climate Change and Energy Production"*. Nordic Council of Ministers, Copenhagen.

ENCLOSURE 1

Sample parameter file

```
START   2GROSET
  2   0              1    PNO         Number of precipitation stations
  2   0   Møsstrand       PID1        Identification for precip station 1
  2   0          940.     PHOH1       Altitude precip station 1
  2   0          1.0      PWGT1       Weight precipitation station 1
  2   0              1    TNO         Number of temperature stations
  2   0   Møsstrand       TID1        Identification for temp station 1
  2   0          940.     THOH1       Altitude temp station 1
  2   0          1.0      TWGT1       Weight temp station 1
  2   0              1    QNO         Number of discharge stations
  2   0   Grosettjern     QID         Identification for discharge station
  2   0           1.      QWGT        Scaling factor for discharge
  2   0          6.51     AREAL       Catchment area                       [km2]
  2   4         0.050     MAGDEL      Regulation reservoirs                [1]
  2   5       939.000     HYPSO ( 1,1), low point           [m]
  2   6       953.000     HYPSO ( 2,1)
  2   7       965.000     HYPSO ( 3,1)
  2   8       978.000     HYPSO ( 4,1)
  2   9       991.000     HYPSO ( 5,1)
  2  10      1004.000     HYPSO ( 6,1)
  2  11      1015.000     HYPSO ( 7,1)
  2  12      1025.000     HYPSO ( 8,1)
  2  13      1036.000     HYPSO ( 9,1)
  2  14      1056.000     HYPSO (10,1)
  2  15      1121.000     HYPSO (11,1), high point
  2  16         0.000     HYPSO ( 1,2), Part of total area below HYPSO (1,1) = 0
  2  17         0.100     HYPSO ( 2,2)
  2  18         0.200     HYPSO ( 3,2)
  2  19         0.300     HYPSO ( 4,2)
  2  20         0.400     HYPSO ( 5,2)
  2  21         0.500     HYPSO ( 6,2)
  2  22         0.600     HYPSO ( 7,2)
  2  23         0.700     HYPSO ( 8,2)
  2  24         0.800     HYPSO ( 9,2)
  2  25         0.900     HYPSO (10,2)
  2  26         1.000     HYPSO (11,2), Part of total area below HYPSO (11,1) = 1
  2  27         0.000     BREPRO( 1), Glacier area, part of total area, below HYPSO( 1,1) (=0.0)
  2  28         0.000
  2  29         0.000
  2  30         0.000
  2  31         0.000
  2  32         0.000
  2  33         0.000
  2  34         0.000
  2  35         0.000
  2  36         0.000
  2  37         0.000     BREPRO(11), Glacier area, part of total area, below HYPSO(11,1)
  2  38
  2  39       270.000     NDAG        Day no for conversion of glacier snow to ice
  2  40         0.000     TX          Threshold temperature for snow/ice          [C]
  2  41        -1.000     TS          Threshold temperature fo no melt            [C]
  2  42         5.000     CX          Melt index                          [mm/deg/day]
  2  43         0.050     CFR         Refreeze efficiency                         [1]
  2  44         0.080     LV          Max rel. water content in snow              [1]
  2  45         0.900     PKORR       Precipitation correction for rain           [1]
  2  46         1.250     SKORR       Additional precipitation corection for snow at gauge [1]
  2  47                   GRADALT     Altitude for change in prec. grad.          [m]
  2  48                   PGRAD1      Precipitation gradient above GRADALT        [1]
  2  49         0.020     CALB        Ageing factor for albedo                [1/day]
  2  50         0.000     CRAD        Radiation melt component                    [1]
  2  51         1.000     CONV        Convection melt component                   [1]
  2  52         0.000     COND        Condensation melt component                 [1]
  2  56         100.0     KLAKE       Rating curve constant, lake         [m3/s]
  2  57           0.0     DELH        Rating curve saddlepoint, lake      [m]

  2  58           1.5     NLAKE       Rating curve exponent, lake
  2  59          0.75     DELF        Part of catchment controlled by lake  [1]
  2  60           1.1     CEVPL       lake evapotranspiration adjustment fact     [1]
  2  61           0.5     ERED        evapotranspiration red. during interception [1]
  2  62          30.0     TLDAY       Lake temperature time constant              [d]
  2  63        -0.600     TTGRAD      Temperature gradient for days without precip [deg/100 m]
  2  64        -0.600     TVGRAD      Temperature gradient for days with precip    [deg/100 m]
  2  65         0.030     PGRAD       Precipitation altitude gradient             [1/100 m]
  2  66         1.500     CBRE        Melt increase on glacier ice                [1]
  2  67         0.700     EP          EP( 1), Pot evapotranspiration, Jan   [mm/day] or [1]
  2  68         0.700     EP          EP( 2), Pot evapotranspiration, Feb   [mm/day] or [1]
  2  69         0.700     EP          EP( 3)
  2  70         1.000     EP          EP( 4)
  2  71         1.300     EP          EP( 5)
  2  72         1.400     EP          EP( 6)
  2  73         1.300     EP          EP( 7)
  2  74         1.100     EP          EP( 8)
  2  75         1.000     EP          EP( 9)
  2  76         0.900     EP          EP(10)
```

```
  2   77        0.700     EP         EP(11)
  2   78        0.700     EP         EP(12)), Pot evapotranspiration, Dec    [mm/day] or [1]
  2   79      170.00      FC         Maximum soil water content         [mm]
  2   80        0.70      LPDEL      Pot.evapotr when content = FC*LPDEL  [1]
  2   81        2.00      BETA       Non-linearity in soil water zone   [1]
  2   82       50.00      INFMAX     maximum infiltration capacity      [mm/day]
  2   83
  2   84
  2   85        0.40      KUZ2       Quick time constant upper zone     [1/day]
  2   86       30.00      UZ1        Threshold quick runoff             [mm]
  2   87        0.10      KUZ1       Slow time constant upper zone      [1/day]
  2   88        0.60      PERC       Percolation to lower zone          [mm/day]
  2   89        0.01      KLZ        Time constant lower zone           [1/day]
  2   90        0.00      ROUT       (1), Routing constant (lake area, km2)
  2   91        0.00      ROUT       (2), Routing constant (rating curve const)
  2   92        0.00      ROUT       (3), Routing constant (rating curve zero)
  2   93        0.00      ROUT       (4), Routing constant (rating curve exp)
  2   94        0.00      ROUT       (5), Routing constant (drained area ratio)
  2   95
  2   96
  2   97
  2   98        0.17      CE         Evapotranspiration constant        [mm/deg/day]
  2   99        0.0       DRAW       "draw up" constant                 [mm/day]
  2  100       60.0       LAT        Latitude                           [deg]
  2  101       -0.6       TGRAD(1)   Temperature gradient Jan           [deg/100m]
  2  102       -0.6       TGRAD(2)   Temperature gradient Feb           [deg/100m]
  2  103       -0.6       TGRAD(3)   Temperature gradient Mar           [deg/100m]
  2  104       -0.6       TGRAD(4)   Temperature gradient Apr           [deg/100m]
  2  105       -0.6       TGRAD(5)   Temperature gradient May           [deg/100m]
  2  106       -0.6       TGRAD(6)   Temperature gradient Jun           [deg/100m]
  2  107       -0.6       TGRAD(7)   Temperature gradient Jul           [deg/100m]
  2  108       -0.6       TGRAD(8)   Temperature gradient Aug           [deg/100m]
  2  109       -0.6       TGRAD(9)   Temperature gradient Sep           [deg/100m]
  2  110       -0.6       TGRAD(10)  Temperature gradient Oct           [deg/100m]
  2  111       -0.6       TGRAD(11)  Temperature gradient Nov           [deg/100m]
  2  112       -0.6       TGRAD(12)  Temperature gradient Dec           [deg/100m]
  2  113       20.0       SPDIST     Uniformly distributed snow acc     [mm]
  2  114      120.0       SMINI      Inital soil moisture content       [mm]
  2  115        0.0       UZINI      Initial upper zone content         [mm]
  2  116       30.0       LZINI      Initial lower zone content         [mm]
  2  121            2      VEGT(1,1) Vegetation type 1, zone 1
  2  122            0      VEGT(2,1) Vegetation type 2, zone 1
  2  123          0.0      VEGA(1)    Vegetation 2 area, zone 1          [1]
  2  124          0.9      LAKE(1)    Lake area,         zone 1          [1]
  2  125            2      VEGT(1,2) Vegetation type 1, zone 2
  2  126            0      VEGT(2,2) Vegetation type 2, zone 2
  2  127          0.0      VEGA(2)    Vegetation 2 area, zone 2          [1]
  2  128          0.3      LAKE(2)    Lake area,         zone 2          [1]
  2  129            2      VEGT(1,3) Vegetation type 1, zone 3
  2  130            0      VEGT(2,3) Vegetation type 2, zone 3
  2  131          0.0      VEGA(3)    Vegetation 2 area, zone 3          [1]
  2  132          0.0      LAKE(3)    Lake area,         zone 3          [1]
  2  133            2      VEGT(1,4) Vegetation type 1, zone 4
  2  134            0      VEGT(2,4) Vegetation type 2, zone 4
  2  135          0.0      VEGA(4)    Vegetation 2 area, zone 4          [1]
  2  136          0.0      LAKE(4)    Lake area,         zone 4          [1]
  2  137            1      VEGT(1,5) Vegetation type 1, zone 5
  2  138            0      VEGT(2,5) Vegetation type 2, zone 5
  2  139          0.0      VEGA(5)    Vegetation 2 area, zone 5          [1]
  2  140          0.0      LAKE(5)    Lake area,         zone 5          [1]
  2  141            1      VEGT(1,6) Vegetation type 1, zone 6
  2  142            0      VEGT(2,6) Vegetation type 2, zone 6
  2  143          0.0      VEGA(6)    Vegetation 2 area, zone 6          [1]
  2  144          0.0      LAKE(6)    Lake area,         zone 6          [1]
  2  145            1      VEGT(1,7) Vegetation type 1, zone 7
  2  146            0      VEGT(2,7) Vegetation type 2, zone 7
  2  147          0.0      VEGA(7)    Vegetation 2 area, zone 7          [1]
  2  148          0.0      LAKE(7)    Lake area,         zone 7          [1]
  2  149            1      VEGT(1,8) Vegetation type 1, zone 8
  2  150            0      VEGT(2,8) Vegetation type 2, zone 8
  2  151          0.0      VEGA(8)    Vegetation 2 area, zone 8          [1]
  2  152          0.0      LAKE(8)    Lake area,         zone 8          [1]
  2  153            1      VEGT(1,9) Vegetation type 1, zone 9
  2  154            0      VEGT(2,9) Vegetation type 2, zone 9
  2  155          0.0      VEGA(9)    Vegetation 2 area, zone 9          [1]
  2  156          0.0      LAKE(9)    Lake area,         zone 9          [1]
  2  157            1      VEGT(1,10) Vegetation type 1, zone 10
  2  158            0      VEGT(2,10) Vegetation type 2, zone 10
  2  159          0.0      VEGA(10)   Vegetation 2 area, zone 10         [1]
  2  160          0.0      LAKE(10)   Lake area,         zone 10         [1]
FINIS
```

ENCLOSURE 2

Recommended starting values and tentative range for parameters

2	39	270.000	NDAG	
2	40	1.000	TX	0 - 2
2	41	0.000	TS	-1 - 1
2	42	3.000	CX	2 - 5
2	43	0.050	CFR	0.01 - 0.10
2	44	0.080	LV	0.05 - 0.10
2	45	1.05	PKORR	
2	46	1.25	SKORR	
2	47		GRADALT	
2	48		PGRAD1	
2	49	0.020	CALB	
2	50	0.000	CRAD	
2	51	1.000	CONV	
2	52	0.000	COND	
2	56	n/a	KLAKE	
2	57	n/a	DELH	
2	58	n/a	NLAKE	
2	59	n/a	DELF	
2	60	1.2	CEVPL	1 - 1.4
2	61	0.5	ERED	0 - 1
2	62	30.0	TLDAY	
2	63	-0.600	TTGRAD	-1.0 - -0.6
2	64	-0.600	TVGRAD	-0.6 - -0.4
2	65	0.030	PGRAD	0 - 0.1
2	66	1.500	CBRE	1 - 2
2	67	0.700	EP(1)	
2	68	0.700	EP(2)	
2	69	0.700	EP(3)	
2	70	1.000	EP(4)	
2	71	1.300	EP(5)	
2	72	1.400	EP(6)	
2	73	1.300	EP(7)	
2	74	1.100	EP(8)	
2	75	1.000	EP(9)	
2	76	0.900	EP(10)	
2	77	0.700	EP(11)	
2	78	0.700	EP(12)	
2	79	150.00	FC	50 - 300
2	80	0.70	LPDEL	0.5 - 1
2	81	2.00	BETA	1 - 100
2	82	50.00	INFMAX	
2	83			
2	84			
2	85	0.30	KUZ2	
2	86	30.00	UZ1	
2	87	0.10	KUZ1	
2	88	0.60	PERC	
2	89	0.01	KLZ	
2	90	0.00	ROUT(1)	
2	91	0.00	ROUT(2)	
2	92	0.00	ROUT(3)	
2	93	0.00	ROUT(4)	
2	94	0.00	ROUT(5)	
2	95			
2	96			
2	97			
2	98	0.20	CE	0.15 - 0.25
2	99	0.5	DRAW	
2	100	n/a	LAT	
2	101	-0.6	TGRAD(1)	
2	102	-0.6	TGRAD(2)	
2	103	-0.6	TGRAD(3)	
2	104	-0.6	TGRAD(4)	
2	105	-0.6	TGRAD(5)	
2	106	-0.6	TGRAD(6)	
2	107	-0.6	TGRAD(7)	
2	108	-0.6	TGRAD(8)	
2	109	-0.6	TGRAD(9)	
2	110	-0.6	TGRAD(10)	
2	111	-0.6	TGRAD(11)	
2	112	-0.6	TGRAD(12)	
2	113	20.0	SPDIST	
2	114	120.0	SMINI	
2	115	0.0	UZINI	
2	116	30.0	LZINI	

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