APPENDIX C

HECPRM OUTPUT

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INTRODUCTION

HECPRM output is stored in the Hydrologic Engineering Center's Data Storage System (HEC-DSS). HEC-DSS data is classified into two generic data types - time series data, in which one value is given for each time step, and paired data, in which two variables are related to each other by a piece-wise linear function. HEC-DSS data files are identified with pathnames consisting of 6 parts, labeled A through F. The 6 pathname parts and the information they contain can be seen in Table C-1.

Table C-1. HEC-DSS Pathname Parts (USACE 1999)

Pathname Part	Description
A	Study Designation
B	Node identifier name*
C	Data type
D	Starting date of data block (if time series data)
E	Time step (if time series data) or month (if penalty function)
F	Node or link description

*For diversion links only part B consist of the "from" node identifier, followed by "-", followed by the "to" node identifier (e.g. SOURCE-SINK)

The information contained in part C is critical for identifying what output is contained in each HEC-DSS data file. In the ensuing sections, the various formats used by HEC-DSS for part C will be outlined both for time series and for paired data. Note that the information in this appendix is taken primarily from USACE (1999). Not all of the output available from HECPRM will be covered. Only the output specified in the CALVIN model runs will be discussed.

TIME SERIES DATA

Flow Data

As specified in the CAVLIN input files, HECPRM produces up to 4 time series of flows for each node as well as an additional flow time series for every link specified as a diversion. The part C specifications and descriptions of each of these output types are shown in Table C-2.

Of the output types listed in the table, FLOW_IN, FLOW_LOC, and FLOW appear for every node on the schematic. FLOW does not contain meaningful data unless the node has been specified as the origin of either a channel or reservoir release link. If a link is specified as a channel or reservoir release its time series of flows is stored in the FLOW designation of the upstream node. FLOW_DIV may appear in Part C when either a link or a node is specified in

Part B. FLOW_DIV appears for all links that are specified as diversions and represents the flow in the diversion link. FLOW_DIV also appears for a node if the node has been specified as the origin of 2 or more diversion links, in which case it stores the sum of all diversions emanating from the node.

Table C-2. Pathname Part C for Flow Data (USACE, 1999)

Part C	Description
FLOW_IN(KAF)	Total inflow into the node (in KAF), including upstream releases, diversions, and local inflow
FLOW_LOC(KAF)	Local inflow into the node (in KAF)
FLOW(KAF)	Total release from the node into the channel or reservoir release link specified downstream (in KAF)
FLOW_DIV(KAF)	The flow in a diversion link, or the total flow in all diversion links that originate from a node (in KAF)

The proper specification of diversion links is important for understanding the flow output. Only one channel or reservoir release link can emanate from each node. If a node is the origin of two or more links that are specified as either channel or reservoir release, HEC-PRM will only produce a time series for one of them. This makes necessary the use of diversion links when 2 or more links emanate from the same node. In addition, the output for diversion links is clearer than for channel or reservoir release links because both the origin and terminal nodes are specified in part B of the pathname. For this reason, the most recent CALVIN model run has replaced all channel and reservoir release links with diversion links.

Reservoir Data

For reservoirs, HECPRM produces all of the flow data described for nodes above. In addition, time series of monthly end-of-period storage and evaporation volumes are produced for each reservoir. Table C-3 shows the part C specifications used for storage and evaporation. To produce this information, the initial reservoir storage must be greater than zero. If the initial storage equals zero, HECPRM will not recognize the node as a reservoir.

Table C-3. Pathname Part C for Reservoir Data (USACE 1999)

Part C	Description
STOR	Reservoir end-of-period storage (in KAF)
EVAP(KAF)	Reservoir evaporation (in KAF)

Economic Information

HECPRM outputs two types of economic information at every time step:

- A shadow value on each arc and reservoir link
- A marginal value at every node

In the raw HECPRM output, a shadow value is defined as the cost of increasing the lower or upper bound of a constraint by one unit. Thus, the shadow values on upper bound constraints are negative and those on lower bound constraints positive. In reporting these CALVIN results, these numbers are usually inverted to report the benefit, rather than the cost, of increasing a constraint. A marginal value is defined as the benefit of increasing a node's fixed external flow by one unit. The part C designations for shadow and marginal values appear in Table C-4.

MARG_COST, DUAL_ORIG, and DUAL_TERM appear for every diversion link and for every node. If a link is specified as a channel or reservoir release the dual information is stored in the MARG_COST, DUAL_ORIG, and DUAL_TERM designations of the upstream node. MARG_COST_S, DUAL_ORIG_S, and DUAL_TERM_S appear for every storage node.

It should be noted that there is an inconsistency in the HECPRM output data if neither a channel nor a reservoir release link is specified as leaving a particular node. In such cases, MARG_COST, DUAL_ORIG, and DUAL_TERM are still specified for the node, but the meaning of the data is unclear. For example, DUAL_ORIG for the node does not equal the DUAL_ORIG values for the diversion links leaving the node, which are all equal. In these cases, the marginal and shadow values are contained in the MARG_COST, DUAL_ORIG, and DUAL_TERM outputs for the diversion links. The significance of the economic outputs for nodes is unknown. Further investigation is required to clarify the meaning of this information.

Table C-4. Pathname Part C for Dual Information (USACE 1999)

Part C	Description
MARG_COST	Shadow value on an upper or lower-bound flow constraint (in $/af)
MARG_COST_S	Shadow value on an upper or lower-bound storage constraint (in $/af)
DUAL_ORIG	Marginal value of additional water at the origin node of a link (in $/af)
DUAL_ORIG_S	Marginal value of additional water added to a reservoir at the beginning of the period (in $/af)
DUAL_TERM	Marginal value of additional water at the terminal node of a link (in $/af)
DUAL_TERM_S	Marginal value of additional water added to a reservoir at the end of the period (in $/af)

The definitions of the dual information terms differ somewhat from those found in the HECPRM User's Manual. To clarify the meaning of the output, a simple test model has been developed and run in HECPRM.

<u>Dual Information Test Model</u>

The test model consists of a simple system with one reservoir and three demands. Two of the demands have constant per unit flow benefit functions (entered as negative constant costs). The third demand is a constant minimum flow requirement. The model ran for two monthly time periods. A schematic representation of the system can be seen in Figure C-1. The reservoir has a maximum capacity of 4 kaf, an initial storage of 1 kaf, and no evaporation. The inflow into the reservoir was equal to 10 kaf in the first time step and 0 kaf in the second time step. All of the links were specified as diversion links. The amplitude was equal to 1.0 for every link. The constraints and costs on the links are shown in Table C-5.

Table C-5. Test Model Input Data

Link	Min Flow Constraint (TAF)	Max Flow Constraint (TAF)	Constant Cost ($/af)
TR1-T1	0	INF	0
T1-D1	0	INF	-1
T1-D2	0	2	-3
T1-D3	3	INF	0

Figure C-1. Schematic Representation of Test Model

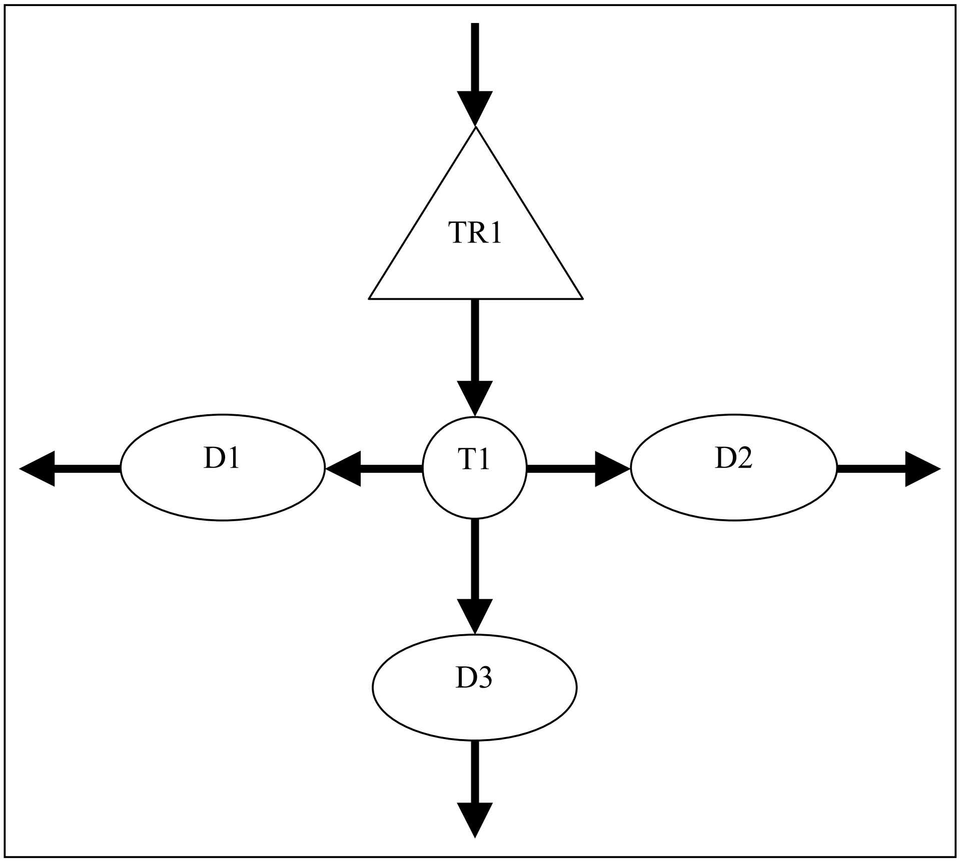


Table C-6. Test Model Results

Link or Node (Part B)	Part C	Time Period	
		1	2
TR1	STOR	4 kaf	0 kaf
	MARG_COST_S	-2 $/af	3 $/af
	DUAL_ORIG_S	1 $/af	3 $/af
	DUAL_TERM_S	3 $/af	0 $/af
TR1-T1	FLOW_DIV(KAF)	7 kaf	4 kaf
	MARG_COST	0 $/af	0 $/af
	DUAL_ORIG	1 $/af	3 $/af
	DUAL_TERM	1 $/af	3 $/af
T1-D1	FLOW_DIV(KAF)	2 kaf	0 kaf
	MARG_COST	0 $/af	0 $/af
	DUAL_ORIG	1 $/af	3 $/af
	DUAL_TERM	0 $/af	2 $/af
T1-D2	FLOW_DIV(KAF)	2 kaf	1 kaf
	MARG_COST	-2 $/af	0 $/af
	DUAL_ORIG	1 $/af	3 $/af
	DUAL_TERM	0 $/af	0 $/af
T1-D3	FLOW_DIV(KAF)	3 kaf	3 kaf
	MARG_COST	1 $/af	3 $/af
	DUAL_ORIG	1 $/af	3 $/af
	DUAL_TERM	0 $/af	0 $/af

The HECPRM output for this model can be seen in Table C-6. The storage and flow results are the same as they would be if the model were run in Excel Solver. The MARG_COST and MARG_COST_S values are identical to the shadow prices that would result if this model were run in Excel Solver. HEC-PRM does not produce reduced costs. The DUAL_ORIG and DUAL_TERM values appear to indicate the marginal value of adding additional water to the system at a particular node.

PAIRED DATA

Penalty Functions

The penalty functions produced by HECPRM are essentially the same as those entered as input into the model. Each function is defined by a set of points that describe a relationship between economic value and either flow or storage according to a decreasing piece-wise linear function. The points contained in the output are the same as those in the input except that an additional point is added with zero economic and flow or storage equal to 10,000,000 kaf. Thus, all flow or storage values from zero to 10,000,000 kaf are assigned a penalty when solving the model. The Part C designations for penalty functions contained in the output can be seen in Table C-7.

Table C-7. Pathname Part C for Penalty Functions (USACE 1999)

Part C	Description
Q(KAF)-P_EDT	Penalty functions on a flow link (in $/af)
S-P_EDT	Penalty function on a storage link (in $/af)

The flow and storage penalty functions appear on every link or storage node for which penalties were defined in the input file. The penalty functions are defined for every month and for the last time step. Part E of the filenames contain either a three-character month abbreviation or "LAST" to specify when the function applies. Storage penalties and diversion links flow penalties are specified according to the appropriate storage node or diversion link. For channel and reservoir release links, Q(KAF)-P_EDT appears in the Part C designation of the upstream node.

Exceedance Functions

HECPRM produces piece-wise linear relationships of the percentage of monthly exceedance for the flow in every channel or reservoir release link and for the storage in every storage node. Exceedance relationships are developed separately for every month and also as a composite of all months. The Part C designations for the exceedance outputs can be seen in Table C-8. The exceedance functions for channel and reservoir release links are contained in the PCT_EXCEED_MON_FLOW(KAF) and PCT_EXCEED_TOT_FLOW(KAF) Part C designations of the upstream node. Exceedance functions of storage are specified according to the appropriate storage node.

Table C-8. Pathname Part C for Exceedance Functions (USACE 1999)

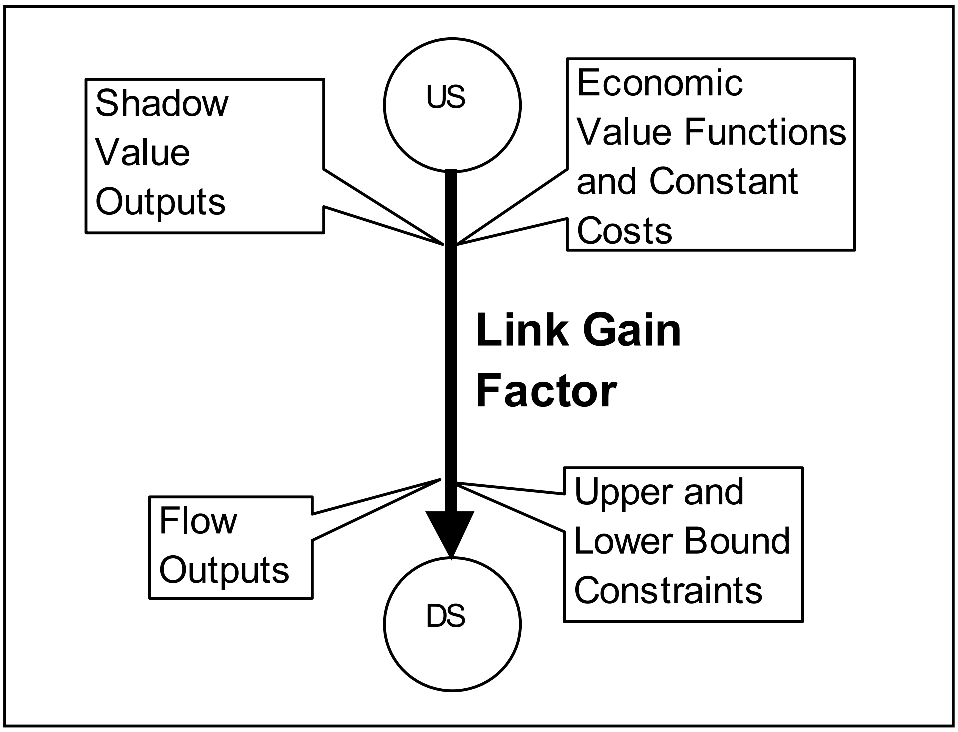
Part C	Description
PCT_EXCEED_MON_FLOW(KAF)	Exceedance relationship of flow in a particular month (in kaf)
PCT_EXCEED_TOT_FLOW(KAF)	Exceedance relationship of flow in all months (in kaf)
PCT_EXCEED_MON_STOR	Exceedance relationship of storage in a particular month (in kaf)
PCT_EXCEED_TOT_STOR	Exceedance relationship of storage in all months (in kaf)

HECPRM does not provide exceedance output for diversion links. A tool has been developed in conjunction with CALVIN, however, which can generate exceedance plots and tables for all time series data using MS Excel 97.

GAIN FACTORS AND THE LOCATIONS OF MODEL INPUTS AND OUTPUTS

In the CALVIN input, a gain factor, or amplitude, is entered for every flow and storage link. This gain factor is a multiplier that determines the percent of the flow that leaving the upstream node that arrives at the downstream node. The default value is 1.00, for which 100% of the flow will arrive at the downstream node.

Figure C-2. Location of Inputs and Outputs Relative to Gain Factor



An important consideration when creating the input data or when interpreting the output data is where the information described in this appendix is located on the link relative to the gain factor. Constant costs and economic value functions are applied at the upstream end of the link, before the gain factor is applied. Upper and lower bound constraints are applied at the downstream end of the link, after the gain factor. Similarly, MARG_COST values are reported upstream and flow and storage values are reported downstream of the gain factor. Thus, if the gain factor is greater than 1.00, the economic outputs will be calculated for a flow less than the flow reported in the output and, for a gain factor less than 1.00, the economic outputs will be calculated for a flow greater than the reported flow. The relative locations of application for economic value functions, gain factors, and constraints, and of reporting for MARG_COST and flow are shown on Figure 2.

REFERENCES

US Army Corps of Engineers (1999), *HEC-PRM Package (Draft),* Hydrologic Engineering Center, Davis, CA