HYSSR - THE MAIN REGULATOR PROGRAM

PROGRAM: HYSSR3.EXE

INTRODUCTION. The Hydro System Seasonal Regulation (HYSSR) model simulates the characteristics of a river system under varying streamflow conditions and electric energy requirements (load) over an extended time period. The model was originally developed in 1958, and has progressed from over-night executions using boxes of cards on an IBM computer to execution on a PC in less than five minutes.

HYSSR is a sequential streamflow routing model. For each project the program calculates what the outflow will be based on the continuity equation. (HYSSR assumes that water released from the uppermost project will reach the ocean during that time period.) The continuity equation states that the project outflow (**O**) during a time period equals the reservoir inflow (**I**) (which includes natural flow and releases from upstream projects) minus the change in storage at the project (ΔS) (which is positive when water is added to storage and negative when water is released from storage) minus losses (**L**) (from diversions, withdrawals, or evaporation). $\mathbf{O = I - \Delta S - L}$. The continuity equation is repeated for each project and period starting with the uppermost project and calculating streamflow and reservoir elevations sequentially downstream. Once the project outflows have been established, HYSSR computes the electric power generation based on each project's outflow (in cfs), head (difference between tailwater and forebay elevations in feet), and project efficiency.

Power (P) = Outflow (cfs) x Head (feet) x Efficiency x 1/11.8.

HYSSR's primary application is the Columbia River system, but it is flexible enough to be applied to other river systems. The Columbia River system is a mix of storage and run-of-river projects (see Glossary for project types) which are operated together to make the most efficient use of the available water and to meet the multiple uses of the system. These uses include flood control, electric power generation, irrigation, navigation, fish passage, fish and wildlife habitat, recreation, and water quality and supply. HYSSR simulates the characteristics of the hydro system under varying electric energy requirements (load) and streamflow conditions

over the historical record 1928 - 1989. From HYSSR's resulting output data, estimates can be made of the system's response to a variety of streamflow and operating conditions and their impacts.

INPUT. The HYSSR program executes in batch mode, so it requires a control file named **C:\HYSSR\CONFILES\HYSSR.CON.** This control file defines the names of the input data file, the Study Characteristics file, the Time Dependent Data (TDDATA) file, the Time Dependent Modifications (TDMODS) file, the TABOUT file (HYSSR's output file which can not be read by the user), the cyclical data file (which is written by HYSSR and then read later during program execution), an optional Gorge minimum fish flow file, and the three user readable output files. A sample control file follows:

```
*C:\HYSSR\CONFILES\HYSSR.CON
*
* Unit 5 is the input to the HYSSR regulator (record codes 01, 06, 10 & 20)
* Unit 6 is the printer output (Diagnostics)
* Unit 7 is the Study Characteristics file (STCHAR)
* Unit 8 is the cyclical data file (CYCFILE)
* Unit 9 is the time dependent data file (TDDATA)
* Unit 10 is the time dependent modifications file (TDMODS)
* Unit 12 is the output showing each project's regulation for each period
*     (REGOUT)
* Unit 13 is the output similar to the REGOUT output except that it fits on
a
*     single PC screen (SCREEN)
* Unit 14 is the output file written by HYSSR (TABOUT)
* Unit 19 is the Ross/Gorge minimum flow requirements input  (optional)
*
*     FORMAT  T4,I2,T7,A26,T34,A11,T46,A7,T54,A10,T65,I4
*_____________________________________________________________
*UNIT  FILE NAME                  FORMAT      STATUS  ACCESS  RECL
*_____________________________________________________________
   5  C:\HYSSR\DATA\HYSSR94.IN   FORMATTED   OLD
   6  C:\HYSSR\DATA\OUT61A.PRN   FORMATTED   UNKNOWN
   7  C:\HYSSR\DATA\STCHAR94.STY UNFORMATTED OLD
   8  C:\HYSSR\DATA\CYCFILE.61A  UNFORMATTED UNKNOWN
   9  C:\HYSSR\DATA\TDDATA.94    UNFORMATTED OLD
  10  C:\HYSSR\DATA\TDMODS.94    UNFORMATTED OLD
  12  C:\HYSSR\DATA\REGOUT.PRN   FORMATTED   UNKNOWN
  13  C:\HYSSR\DATA\SCREEN.PRN   FORMATTED   UNKNOWN
  14  C:\HYSSR\DATA\TABOUT.94    UNFORMATTED UNKNOWN DIRECT   104
  19  C:\HYSSR\DATA\GORGEMIN.DAT FORMATTED   OLD
*_____________________________________________________________
```

The input data file (Unit 5 called HYSSR94.IN in the sample control file) specifies the run options (record code 01), Grand Coulee's draft rate limits and elevation (record code 03), projects whose generation should not be included in the system total generation (record code 06), any changes to project characteristics from what is in the study characteristics file (record codes 10 and 20), lower limit variable energy content

curves for individual years (record code 48), and projects which will contribute to downstream target flows (record code 88). A sample input file follows the record descriptions below. These records use standard HYSSR record code format unless noted. Standard HYSSR format is:

STANDARD HYSSR RECORD FORMAT

COLS 1-2	Record code
COLS 8-10	Project number
COLS 19-20	Year
COLS 21-23	Period identifier or option
COLS 24-32	Data
COLS 33-35	Period identifier or option
COLS 36-44	Data
COLS 45-47	Period identifier or option
COLS 48-56	Data
COLS 57-59	Period identifier or option
COLS 60-68	Data
COLS 69-71	Period identifier or option
COLS 72-80	Data1

Record code 01: This record code defines the run options. These run options provide the program with the control information necessary to execute the HYSSR regulator. The options follow:

OPTION	DESCRIPTION	DEFAULT
NSY	Starting year for this study (e.g., 28)	none **
NSP	Starting period for this study (e.g., 09)	none **
NLY	Ending year for this study (e.g., 89)	none **
NLP	Ending period for this study (e.g., 08)	none **
BCP	Defines the beginning of the critical period by year and period (e.g., 2811)	none **
ECP	Defines the end of the critical period by year and period (e.g., 3202)	none **
CRC	Specifies the Critical Rule Curve (CRC) to be compared with the ARC in determining the Operating Rule Curve (ORC) **1** = CRC1, **2** = CRC2, **3** = CRC3, and **4** = CRC4	CRC1

OPTION	DESCRIPTION	DEFAULT
IRS	Type of study (see Glossary) = 0 continuous study = 2 refill study	none**
IRP	Option for special operation of Mica and Arrow. Allowable values: = 0 Option not used = 1 Operation at Mica and Arrow is balanced such that the resulting storage content of the two projects is at the same value as the system rule curve value. = 2, 3, 4, or 5 same as option 1 plus Mica's target flows are adjusted based on Arrow's content for the previous period as defined for a certain AOP. These values are changed for the current AOP.	0 (zero)
STN	This option must appear in columns 21-23 and must be the only option on that record. The study name must be in cols 24-32. This study name will be printed at the top of each page in the REGOUT (unit 12) output.	none
DP1	First depletion year for natural flows (e.g., 70 for 1970)	none **
DP2	Second depletion year for natural flows (e.g., 20 for 2020)	none **
TOL	Tolerance in Mw within which the load must be met (usual value = 10 Mw)	none **
OBJ	= 0 the system meets the load using the rule curves input in TDDATA and TDMODS. = 2 without record codes 72, 46, and 47 is the same as OBJ = 0. = 2 with record codes 72, 46, and 47 the system first meets the loads, then meets the target flows.	0 (zero)
PRN	Controls when output will be sent to printer files REGOUT, SCREEN, and DIAGNOSTICS. = 0 all three printer output files will be written to only if the study is less than six years in length. Only error messages are written to the DIAGNOSTICS file for longer studies. = 1 write output to the REGOUT file only. = 2 write output to the DIAGNOSTICS file only. = 3 write output to the SCREEN file only. = 4 write output to all three output files.	blank or zero
KEY	Units to be used for printed output to REGOUT, SCREEN, and DIAGNOSTICS. = 0 Content in KAF (English) Content in Mil. cubic meter (Metric) = 1 Content CFS-DAY = 2 Draft KAF = 3 Draft CFS-DAY = 4 Usable KAF = 5 Usable CFS-DAYS	0 (zero)

OPTION	DESCRIPTION	DEFAULT
MET	Units for printed output = 0 English units = 1 Metric units	0 (zero) **
MOK	Power computation conversion factor MW = QH/(MOK) MOK = (550 x 1000)/(62.4 x 0.76) English, power in Mw = 11,814 Metric, power in Mw = 101.934	11,814 **
GEN	Units for printed output for power = 0 Mw (megawatts) = 1 kW (kilowatts)	Mw **
ROC	= 0 Rockwood Amendment is not used to determine the ORC = 1 Rockwood Amendment is used to determine the ORC at all storage projects. Rockwood Amendment allows the ORC to be higher than flood control when the VRC controls.	not used
GCL	Draft rate limit at Grand Coulee in feet per day	1.5 ft/day

**** indicates that initial value was set when the Study Characteristics file was built and that value will be used unless over-ridden here.**

Record code 03: This record contains Grand Coulee's draft rate limits in feet per day and the reservoir elevations at which these draft rates change. For example, Grand Coulee's draft rate limit is 1.5 ft/day when the reservoir is above 1260 feet; the draft rate limit is 1.3 ft/day when the reservoir is at or below 1260 feet, but above 1240 feet; and the draft rate limit is 1.0 ft/day when the reservoir is at or below 1240 feet. Record code 03 for this example would be as follows:

```
03      19          GR1      1.5GR2      1.3GR3      1.0
03      19          GL1     1260GL2     1240
```

In this example, standard HYSSR format is used. Columns 8 – 10 contain the project number. **GR1**, **GR2**, and **GR3** indicate the three draft rate limit input values. **GL1** and **GL2** indicate the corresponding elevations where the draft rate limits change. A maximum of three draft rate limits and two elevations may be entered. If the draft rate limit is a constant for all reservoir elevations enter the draft rate limit using **GR1** on record code 03 without a **GL1** value or use the **GCL** option on record code 01. The default value for the draft rate limit is still 1.5 ft/day and will be used when no draft rate limit value is input.

Record code 06: This record indicates which project's generation should not be included in the total system generation. One record is required for each project to be excluded. Only the external project number is required in columns 8 - 10.

Record code 10: This record is used in conjunction with record code 20 for making changes to generating units for a project. This record defines the period, year, revision number, and corresponding number of units to be placed into service. This record can define several changes to generating units. The format for this record is:

COLS 1-2	Record code 10
COLS 8-10	Project number
COLS 16	Revision number
COLS 33-34	Period of first change (e.g., 08 for July)
COLS 35-36	Year of first change (e.g., 36 for 1936)
COLS 37-38	Number of generating units
COLS 39-40	Period of second revision
COLS 41-42	Year of second revision
COLS 43-44	Number of generating units

Period, year, and number of units can repeat to the end of the record.

Record code 20: This record may be used with or without record code 10, depending on the type of changes being made. All changes to a project's characteristics will over-ride the data in the Study Characteristics file beginning with the period specified on record code 10 (when available) and continuing to the end of the regulation. These changes do not change the Study Characteristics file. If no record code 10 is included, the changes input will apply to the entire regulation.

When changes are being made to a project's storage upper bounds (SUB), storage lower bounds (SLB), release upper bounds (RUB), or release lower bounds (RLB), no record code 10 is required. However, changes related to a project's generating characteristics require a record code 10. If the changes are to apply to the entire regulation, the year and period on record code 10 must match the starting period (NSP) and starting year (NSY) on record code 01. This is particularly important for studies of a short duration, such as one year studies and critical period studies.

When record codes 10 and 20 are paired to make changes to a project's generating characteristics all the necessary information must be provided in the correct format. On record code 10 the project number (cols.

8-10), revision number (col. 16), period of first change (cols. 33-34), year of first change (cols. 35-36), and number of generating units (cols. 37-38) must be input. Following record code 10 there must be one or more "20" records. The format for these "20" records is project number (cols. 8-10), number of generating units (cols. 11-12), the revision number (col. 16), and the identifiers and their data values beginning in column 21 and continuing to the end of the record. The data on record codes 10 and 20 for project number, revision number, and number of generating units must match. If they do not an error message will result and the run will stop.

The identifiers possible on record code 20 and their descriptions follow:

Identifier	Description
CL	Loss coefficient. Value is divided by 1,000,000.
EF	Full gate efficiency.
EN	Normal efficiency at critical head.
HC	Critical head in feet.
HL	Head loss in feet.
NAP	Adjacent project number for diversions or backwater flow restrictions.
PO	Plant overload in Mw.
QC7	Hydraulic capacity at 0.7 critical head. in CFS.
QL	Flow loss (seepage) in CFS.
QN	Normal operating flow in CFS.
RLB	Release lower bounds in CFS.
RUB	Release upper bounds in CFS.
SLB	Storage lower bounds in AF.
SUB	Storage upper bounds in AF.
Y1	Efficiency at 0.7 critical head.
Y2	Efficiency at 0.9 critical head.
Y3	Efficiency at 1.1 critical head.
Y4	Efficiency at 1.2 critical head.

A sample of record codes 10 and 20 follows:

```
10        3     1                0928 5
20        3 5   1    RLB     4000 EN     .950 EF    0.850 Y1    0.880
20        3 5   1     Y2    0.905 Y3    0.918 Y4    0.902 HL      3.5
10       31     1                0928 3
20       31 3   1     EN    0.927 EF    0.920 Y1    0.870 Y2    0.910
20       31 3   1     Y3    0.920 Y4    0.918 HL      3.5 QL        0
20       71  COM     RLB    36000
20      166  COM     RLB       10
```

Record code 48: This record code contains project lower limit variable energy content curve (LLVECC) values. These records normally are input to a HYSSR regulation through the TDDATA or TDMODS files as

cyclical data (data without a year in columns 19 - 20 which is applicable to all years in the study). When LLVECCs should be used in only certain years then record code 48 should have the specified year in columns 19-20. The LLVECCs input here will over-ride the values in TDDATA and TDMODS.

Record code 88: These records specify which projects may contribute water (in addition to the water required to meet the load) to a downstream target flow. Record code 88 is used in conjunction with record codes 72, 46, and 47 which are input into either the TDDATA or TDMODS files.

The project number where the target flow is to be met is in columns 8 - 10. No year is used. For each period that this project has a target flow (record code 72), that period needs to be in the Period Identifier columns and the project number for a contributing project (record codes 46 and 47) needs to in be the corresponding Data columns. One record code 88 is required for each target flow project and its contributing project. See sample below.

The input for target flows in the TDMODS file might be:

```
72    400        APR    15000MAY    22742JUN    35000JUL     8741
46      3        APR   4978.7MAY   4978.7JUN   4978.7JUL   4978.7
47      3        APR    889.9MAY    889.9JUN    889.9JUL    889.9
72     76      28AG1    50000AUG    50000
72     76      29APR    85000MAY    85000JUN    73333JUL    50000
46     31        APR   2238.0MAY   2238.0JUN   2238.0JUL   2238.0
47     31        APR   2238.0MAY   2238.0JUN   2238.0JUL   2238.0
46     31        AG1   2238.0AUG   2238.0
47     31        AG1   2238.0AUG   2238.0
```

Record codes 88 input to HYSSR (Unit 5):

```
88    400        APR        3MAY        3JUN        3JUL        3
88     76        APR       31MAY       31JUN       31JUL       31
88     76        AG1       31AUG       31
```

A sample input file (Unit 5) is shown below as an example of how this file might look:

```
01                  NSP        9NSY       28NLP        8NLY       88
01                  IRP        0IRS        0OBJ        2TOL       10
01                  BCP     3610ECP     3705STY       90TRC        0
01                  PRN        0
01                  STN REFILL04
06      21
06      72
06      84
06       1
06      41
06       6
06      46
06      49
06      50
06     169
06      59
88     400          APR        3MAY        3JUN        3JUL        3
88      76          APR       31MAY       31JUN       31JUL       31
88      76          AG1       31AUG       31
88      80          AG1       10AUG       10
88      80          JUN       19JUL       19AG1       19AUG       19
88      80          AG1        3AUG        3
48      10        29JAN   2364.2FEB   2258.7MAR   2169.6AP1   2176.9
48      10        30JAN   2614.7FEB   2510.2MAR   2411.4AP1   2469.7
48      10        33JAN   1191.8FEB   1110.0MAR   1055.7AP1   1137.0
48      10        34JAN   1950.6FEB   1989.1MAR   2057.7AP1   2151.2
48      19        29JAN   7669.2FEB   8151.4MAR   7743.6AP1   8341.6
48      19        30JAN   9107.4FEB   9007.4MAR   8496.7AP1   8439.6
48      19        31JAN   9107.4FEB   9107.4MAR   8555.0AP1   8442.5
```

The other required input files are the Study Characteristics file (STCHAR), the Time Dependent Data file (TDDATA), and the Time Dependent Modifications file (TDMODS). The TDDATA and TDMODS files must have each had as their input the same STCHAR file and this same STCHAR file must be input for the current regulation. If all the files are not consistent, an error may occur and program execution will stop.

The file associated with Unit 19 is the output from the Gorge Minimum Flow program (GORGEMIN.EXE). This is an **optional file**. This file contains the base minimum flow and minimum fish flow requirements for Gorge. If this file is not input, Ross and Gorge will not operate to meet minimum fish flow requirements at Gorge.

<u>OUTPUT.</u> The HYSSR program has four output files, three of which are formatted for a printer or PC screen. See sample output beginning on page 12. The DIAGNOSTICS (Unit 6 called OUT61A.PRN in the example confile) is the printer output file with any error messages plus other information that may be helpful in

understanding how a regulation was performed. REGOUT (Unit 12 called REGOUT.PRN in the example confile) is the printer output file of data for all projects for each period of the study. And SCREEN (Unit 13 called SCREEN.PRN in the example confile) is an output file with much of the same data as REGOUT except condensed to a selected number of projects and data items so that each period's output can fit onto a single PC screen.

The TABOUT output file contains the same data for each project as the REGOUT output plus additional data. This file is binary and is not readable by the user except through the use of programs. The file is organized by year, period, and internal project number (which is determined by project order and input through the STCHAR file). Each year, period, and project has a possible 24 data values associated with it which are contained on a single record. There are also records for each project's cyclical data with 00 (zero) as the year. These records contain the eight possible rule curves for that project. And finally for each year and period there are records for system information. These records have an internal project number of 0 (zero). The format for the TABOUT file is found on pages 10 and 11.

<u>PROGRAM EXECUTION ON THE PC:</u> To execute the HYSSR regulator program, have a copy of **HYSSR2.EXE** in the local **C:\HYSSR\PGM** subdirectory. Now type **HYSSR3** while in the **C:\HYSSR\PGM** subdirectory and the program will execute using the datasets named in HYSSR.CON. This control file must be in the local **C:\HYSSR\CONFILES** subdirectory and changed to meet the data file naming conventions being used. The existing format of the control file may not be altered.

TABOUT - HYSSR OUTPUT FILE FORMAT

There is one record for each project and the system for each period in the regulation. Records are in ascending order by year, by period, and by internal project number. System records have the highest internal project number equal to one greater than the number of projects in the river system. Also there is one record for every project for every period with a value of zero for the year (cyclical data).

Each record is 104 bytes in length. The format of each record is:

BYTE	DESCRIPTION
1-4	Year (alphanumeric)
5-6	Period (alphanumeric
7-8	Internal project number (binary)
9-104	24 - 4 byte data items as described below

FOR PROJECT DATA WITH YEARS

DATA ITEM	DESCRIPTION
1	Natural flow (CFS)
2	Spill (CFS)
3	Variable release lower bounds (CFS)
4	Regulated flows (CFS)
5	Project's generation (Mw)
6	KW/CFS
7	Change in storage (AF)
8	Storage upper bounds (AF)
9	Forebay elevation (FT)
10	Net head (FT)
11	Storage content (AF)
12	Spill (Mw)
13	KW/CFS @ Full Gate, Critical Head
14	Unregulated generation (Mw)
15	Plant capability (Mw)
16	Tailwater elevation (FT)
17	Initial change in storage (KAF)
18	Project limit indicator
19	Plant hydraulic capability (CFS)
20	Rule curve storage value (KAF)
21	Maximum discharge @ Critical Head (CFS)
22	Storage lower bounds (AF)
23	Mandatory Rule Curve (MRC) value (KAF)
24	Variable Refill Curve (VRC) value (KAF)

PROJECT DATA WITHOUT YEARS (00 in columns 1-4)

Data Item	Description
1	Assured Refill Curve (ARC) value (KAF)
2	1st Year Critical Rule Curve (CRC1) value (KAF)
3	2nd Year Critical Rule Curve (CRC2) value (KAF)
4	3rd Year Critical Rule Curve (CRC3) value (KAF)
5	4th Year Critical Rule Curve (CRC4) value (KAF)
6	Rule Curve 5 (KAF)
7	Rule Curve 6 (KAF)
8	Lower Limit Variable Energy Content Curve (LLVECC) value (KAF)
9-24	not used

SYSTEM DATA (External project number zero)

Data item	Description
1	Primary load (Mw)
2	Secondary load (Mw)
3	Thermal decrement (Mw)
4	Total plant capacity (Mw)
5	System generation (Mw)
6	Total number of days in Regulation
7	
8	Total generation - all periods (Mw)
9	Total Unregulated generation (Mw)
10	Total Usable Storage (KAF)
11	Thermal
12	Total number of days in Critical Period
13	Total number of periods in Regulation
14	Total System Spill in Critical Period (Mw)
15	Total System Spill (Mw x days) total from start
16	
17	
18	
19	
20	Rule Curve Number
21	
22	
23	
24	