**A PRIMER FOR CUSTOMIZING HL-RMS CONNECTIVITY FILES AND
ROUTING PARAMETER GRIDS**
**(Last Modified:  July 10, 2002)**

## 1.  INTRODUCTION

Several RFCs have expressed interest in testing the HL-RMS code.  Although the HL-RMS code and documentation continue to evolve, the HL-RMS code is now sufficiently mature to allow some testing by users outside of HL.  Test runs have been made at ABRFC, but initially on basins for which HL staff prepared the input files (e.g. routing parameter grids).  The process of preparing routing parameter grids for HL-RMS currently involves several steps for which there has been limited documented until now.  A visit to HL by ABRFC hydrologists has highlighted the steps that need more documentation.

This document is a primer describing how to get started with HL-RMS, the basic requirements, and how to customize the HL-RMS connectivity file and routing parameter grids.  In addition to the HL-RMS executable file, the input files required for a basic simulation run include:

(1)  A-priori SAC-SMA parameter grids (sac)
(2)  Default routing parameter grids (rutpix)
(3)  Cell connectivity file
(4)  Input deck
(5)  XMRG Files

These files are shown in green on the HL-RMS flow chart in Figure 1.  Note that the State grids are not required for a basic historical simulation run because states can be initialized using a constant uniform value in the Input Deck.  After an HL-RMS is run is completed, State grids are created that can be used to initialize subsequent simulations.

**HL will provide items 1 – 4** and RFCs will use their own XMRG files.  A more detailed listing of all the information provided by HL is given in Table 1.  The files provided by HL can be used to make base simulation runs (using the "Rating Curve Method" for channel routing parameters discussed in Section 2.2), but keep in mind that the default routing parameters provided, along with a priori SAC-SMA parameters are intended as a starting point and will not necessarily yield great results.  In order to make HL-RMS useful, RFCs will want to customize their routing parameter grids and connectivity file.

The cell connectivity file is the key to channel routing calculations.  The file stores an ordered list of all cells in the model domain.  The cells are ordered so that each time the next cell in the list is reached, computations for all upstream cells have already been completed.  In the header of the connectivity file, the user specifies basin outlet cells of interest for simulations.  The same outlet IDs used in the connectivity file are also used in the HL-RMS Input Deck (e.g. hlrms.card) to choose where hydrographs will be

generated.  Figure 2 shows a screenshot of the top of a connectivity file.  More details about the contents of connectivity files are provided in Section 2.2.

Thus, to allow custom setup for model runs on specific basins, the following three steps are described in Sections 2.1-2.3 of this document:

2.1 **Define Outlet Points in the Connectivity file**:  Select outlet points for modeling, determine the outlet HRAP coordinates, and add these outlets to the connectivity file.

2.2 **Analyze Flow Measurement Data to Determine Routing Parameters**:  For selected basins, analyze flow measurement data to determine routing parameters at basin outlets of interest.  This is perhaps the most difficult step because it requires subjective judgment by the hydrologist.  ArcView and (Excel) Spreadsheet analysis are used in this step.

2.3 **Generate Customized Routing Parameter Grids**:  Routing Run routine to customize routing parameter grids (gen_grid.exe).  This program is used to customize existing grids provided by HL.

**Notation and Organization:**  Within Sections 2.1 – 2.3 there are step by step procedures described, but there is also a good deal of explanatory material mixed in.  To clearly identify which portions of text actually describe user actions, the recommended steps are numbered S1 – S30.  Not all of the steps are required.  Some are optional and some require a choice.  For example, in Section 2.2, a user would perform steps S21 through S26 or step S27 but not both.
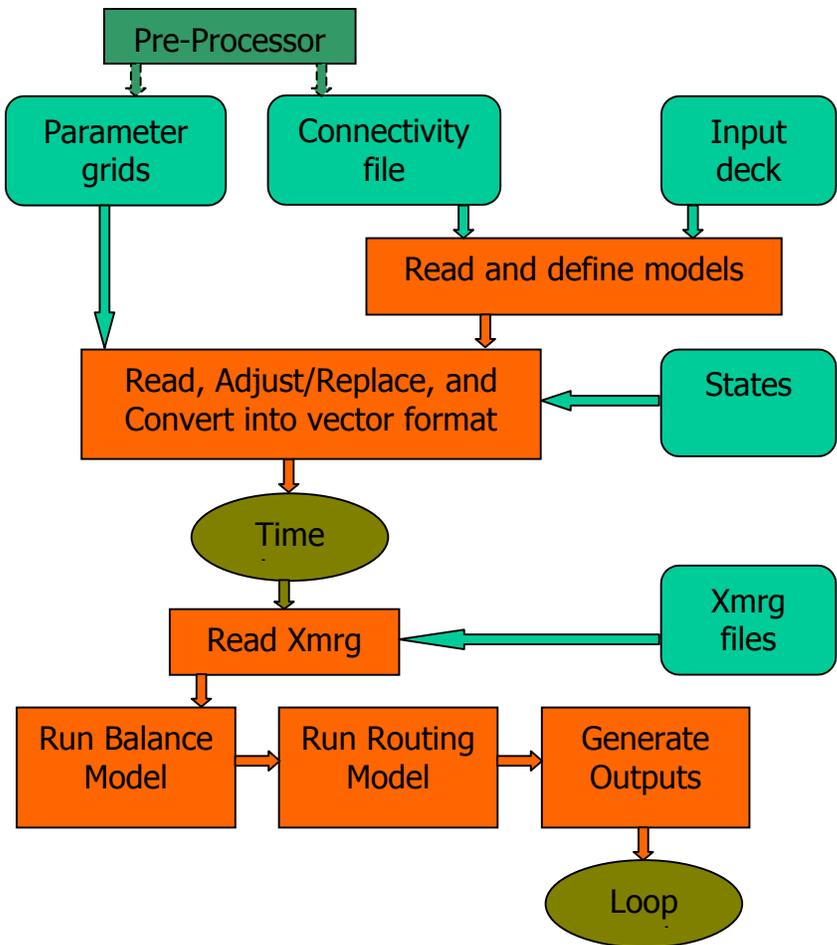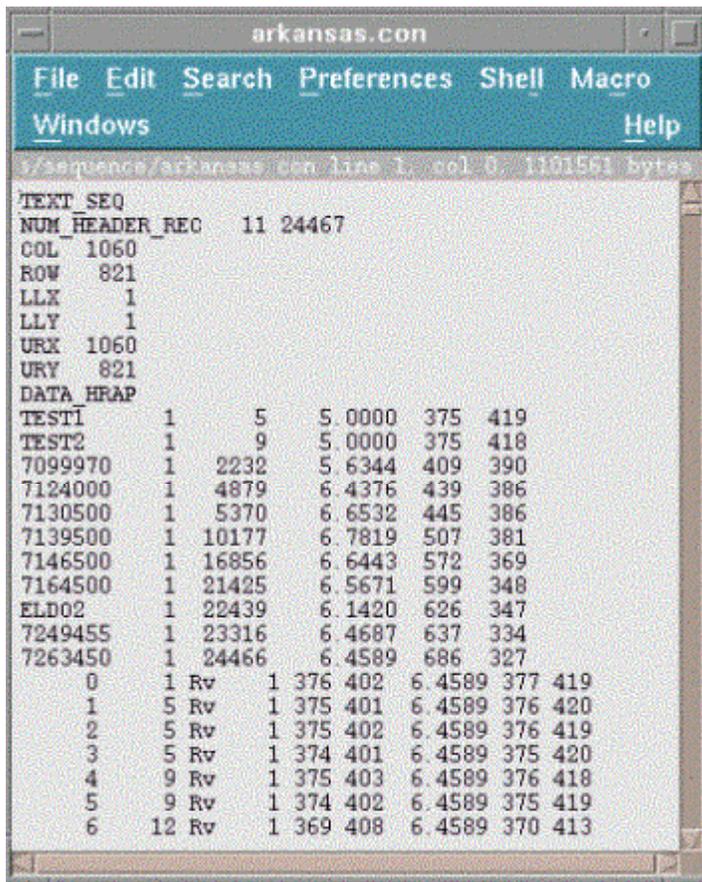
**Figure 1. HL-RMS Flow Chart**

```
TEXT_SEQ
NUM_HEADER_REC   11 24467
COL   1060
ROW    821
LLX      1
LLY      1
URX   1060
URY    821
DATA_HRAP
TEST1      1      5    5.0000  375  419
TEST2      1      9    5.0000  375  418
7099970    1   2232    5.6344  409  390
7124000    1   4879    6.4376  439  386
7130500    1   5370    6.6532  445  386
7139500    1  10177    6.7819  507  381
7146500    1  16856    6.6443  572  369
7164500    1  21425    6.5671  599  348
ELD02      1  22439    6.1420  626  347
7249455    1  23316    6.4687  637  334
7263450    1  24466    6.4589  686  327
     0     1 Rv    1 376 402  6.4589 377 419
     1     5 Rv    1 375 401  6.4589 376 420
     2     5 Rv    1 375 402  6.4589 376 419
     3     5 Rv    1 374 401  6.4589 375 420
     4     9 Rv    1 375 403  6.4589 376 418
     5     9 Rv    1 374 402  6.4589 375 419
     6    12 Rv    1 369 408  6.4589 370 413
```

**Figure 2.  Example Connectivity File**

**Table 1 List of files provided by HL**

**Programs**

| File Names | Description |
| --- | --- |
| ./bin/hlrms.exe | Main HL-RMS Program |
| ./bin/gengrid.exe* | Program to customize routing parameter grids |
| ./bin/stat_q.exe | Program that computes statistics comparing two time series in OH Data Card format (e.g. RMS output and observed flow data) |
| ./bin/check_1dxmrg.exe | Utility program to check the contents of the so-called "1D XMRG" binary files.  Just type "check_1dxmrg.exe <file_name>" |
| ./bin/date_to_hour.exe, hour_to_date.exe | Utility programs return either date corresponding to the hour number since Jan. 1, 1900 or the hour since Jan. 1, 1900 corresponding to a certain date.  Just type the program name for instructions. |
| ./bin/geotohrap* | Return HRAP coordinates given lon/lat for a point. |
| ./bin/rmsmaster.xls* | Excel spreadsheet used to help estimate routing parameters. |

| | |
|---|---|
| ./bin/rmsuser.avx*, coord.avx, threshr.avx (you should already have threshr.avx and you may have coord.avx) | ArcView Extension files. Copy these to the directory ./ext on your system below where you have installed ArcView. This extension helps to identify the correct basin outlet HRAP cell. |
| * Indicates program is discussed in detail in this document. | |

**Example Input Decks and Data Files**

| | |
|---|---|
| ./doc/Hlrms.card | Example input deck for hlrms.exe. |
| ./doc/gengrid.card | Example input deck for gengrid.exe. |
| ./doc/stat_q.cntl | Example input deck for stat_q.exe. |
| ./sequence/<two_letter_rfc_code>rfc.con | Basic connectivity file for an RFC. |
| ./parameters/rutpix_ALPHC rutpix_BETAC rutpix_DS rutpix_Q0CHN rutpix_QMCHN rutpix_ROUGC rutpix_ROUGH rutpix_SLOPC rutpix_SLOPH sac_LZFPM sac_LZFSM sac_LZPK sac_LZSK sac_LZTWM sac_PFREE sac_REXP sac_UZFWM sac_UZK sac_UZTWM sac_ZPERC | Parameter grids. Files with the "rutpix" prefix are routing parameter grids. Files with the "sac" prefix are a priori Sacramento model parameter grids. |
| ./gis/<reference_GIS_files> | Reference GIS files. See section 2.1 and Table 2 for a detailed description. |

**Documentation**

| | |
|---|---|
| ./doc/Hlrmsmanual.pdf | User Manual |
| ./doc/Gettingstarted.pdf | This document |
| ./doc/Stat_q.pdf | User Manual for the stat_q.exe program |
| ./doc/fihmcpaper.pdf | Paper submitted to the 2002 Federal Interagency Hydrologic Modeling Conference. Provides an overview of RMS and discusses some initial results. |

RFCs may also wish to customize SAC-SMA grids for their basins by using the HL-RMS scaling factor option. Scaling of SAC-SMA grids is a straightforward option specified in the HL-RMS Input Deck as explained in the User's Manual; therefore, this option not discussed in detail here.

## 2.1  DEFINING OUTLET POINTS IN THE CONNECTIVITY FILE

### 2.1.1  DETERMINING THE CORRECT HRAP COORDINATES FOR OUTLET POINTS

(Note:  This section assumes some basic ArcView knowledge.)

In most cases, simply converting the latitude and longitude coordinates for a gage of interest into HRAP coordinates will give the HRAP coordinates needed for the connectivity file header.

The simple utility program "geotohrap" will return HRAP coordinates given lat/lon coordinates at the command line:
$ geotohrap.exe <lon> <lat>
e.g.
$ geotohrap −100.0 35.0.

Note that West longitude coordinates are negative.

**However**, in some cases, the lat/lon coordinates recorded for a gage are not precisely consistent with digitized stream lines (RF1) and therefore the derived HRAP flow direction grids.  In these cases, an HRAP cell adjacent to the HRAP cell that actually contains the gage reported lat/lon may be the correct outlet cell for modeling purposes. For this reason, visual inspection of the HRAP flow directions in the vicinity of the USGS gaging station is recommended.  An ArcView GIS extension (rmsuser.avx) and data are provided to make this analysis easy.  The channel slope grid delivered with this extension can also be used to get an estimate of the outlet cell slope.

Figure 3 shows an example of a gage for which the reported lat/lon is not located precisely within the correct HRAP cell for RMS modeling.  Note that the green lines connect the center points of HRAP cells .  The Arkansas R. gage at Lamar, CO, is within cell (451, 387) and is close to the center of this cell, but the cell (451, 386) should be selected as the basin outlet for modeling purposes because this cell falls on the main channel of interest.
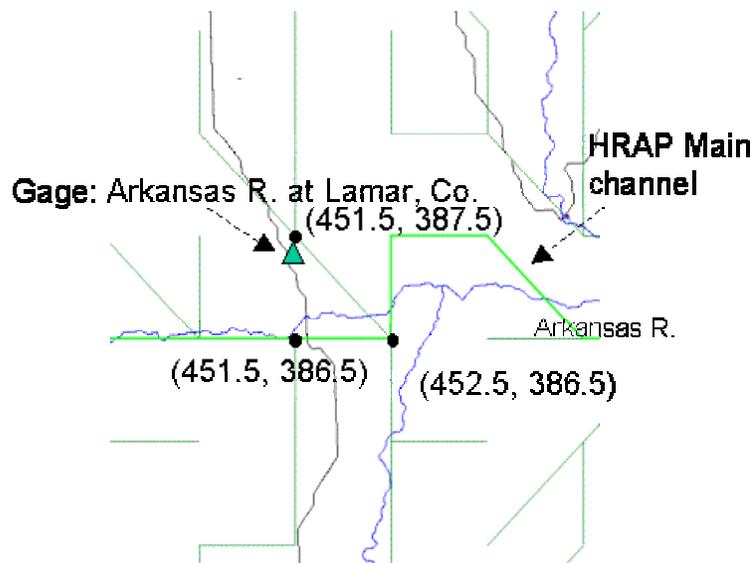
**Figure 3. Arkansas River at Lamar, CO, gage reported lat/lon falls within HRAP cell (451, 387), but cell (451, 386) should be selected as the outlet to model flows in the main channel with HL-RMS.**

Table 2 contains a list of GIS files that are provided. The files are provided in the polar Stereographic Map Projection used to define the HRAP coordinate system. Although this map projection is not typically used for GIS applications, data have been converted to this projection so that HRAP cells are square and viewing the HRAP cell-to-cell connectivity is easier. The Grid data sets listed in Table 2 contain a single value for each HRAP cell; therefore, the resolution is about 4-km. Note that these data are in a different projection than the data used by the CAP application. The CAP data are stored in an Albers Equal-Area projection. Although these polar Stereographic data sets and the CAP data sets cannot be overlaid in the same View, they can be displayed in the same ArcView project within separate View windows. CAP Data can be used to display the spatial variability of a-priori SAC-SMA parameters along with basin boundaries..

**Table 2. Useful GIS Files**

| File Name | Description |
|---|---|
| Usgsster.shp | USGS real time station locations |
| Rf1ster.shp | River Reach File 1 (edited at NOHRSC) |
| Fd10net.shp | Line network illustrating HRAP network connectivity |
| Rfcster.shp | RFC Boundary |
| Basster.shp | RFC Basin Boundaries Obtained from the NOHRSC Web Site |
| States.shp | State Boundaries |
| Hrapfd10 | Grid of HRAP flow directions |
| Hrapfa10 | Grid of HRAP flow accumulation (number of cells above a given cell) |
| Rut_sloph | Grid of hillslope slopes (m/m) (x 10000) |
| Rut_slopc | Grid of channel slopes (m/m) (x 10000) |

Steps to View Data and Identify Outlet Cell Info:

**S1:** Open ArcView and load the extensions: "RMS User" (rmsuser.avx), "ThreshR" (threshr.avx), and "Sp-coord" (coord.avx).

**S2**: Choose the menu option RMS User --> Load Data. You will be prompted for the location of the data files. Enter the full path name for the ./gis data files (see Table 2) on your system. Click OK to load data files and pre-selected legends.

**S3**: Initially, all loaded themes are not visible. Place a check mark next to Themes that you want visible by clicking with the mouse.

**S4**: Zoom in on a basin or basins of interest (basster.shp). (e.g. Draw a rectangle with the Zoom tool.)

**S5**: If the USGS gage that you are interested in is not in the "usgsster.shp" file, you can create your own point file using the following steps:

**S5.1**: Using a text editor, create a comma delimited ASCII file in the following format and name the file with a ".txt" extension.
*Id,lon,lat*
*1,-100.0,35.0*
*2,-101.0,35.1*
*etc.*

**S5.2**: Add the text file as a table to ArcView (Using the 'Add' button visible when the Project window is active and the Tables icon is selected. Under 'List Files of Type' choose *.txt)

**S5.3**: With a View active, choose the option View --> Add Event Theme. This creates a point Theme in geographic (lon,lat) coordinates.

**S5.4**:  To display the points with other data, they need to be projected into polar Stereographic coordinates.  Use the ![button] button to project your point file from Geographic to polar Stereographic coordinates.  This button is part of the "Sp-coord" extension (coord.avx).  <u>To use this button, the Theme that you wish to project should be the active Theme.</u>

**S6**:  Use the ![H] tool to click a point with the mouse and get the HRAP coordinates.  Note again that the Theme fd10net.shp shows lines that connect the centers of HRAP cells.  Clicking a point along this network will help identify the HRAP coordinates of interest.  Figure 4 shows an example of outlet point identification on the Chickaskia River.

**S7** (optional):  Although not required, other tools that are useful in identifying the main flow channels are the Tracing Tool (![icon]) (actually part of the ThreshR extension) and the Drainage Area Tool ![icon].  Use of the Tracing Tool requires that the flow direction Theme (hrapfd10) be active.  With the Tracing Tool selected, a click of the mouse on a cell will produce a bright green trace of the predicted path from that cell to the edge of the grid.  Use of the Drainage Area Tool requires that the flow accumulation grid (hrapfa10) is active.  With the Drainage Area Tool selected, a click of the mouse on a cell will report the number of upstream cells and the estimated drainage area in $km^2$ and $mi^2$.  Note that the program approximates the true drainage area by first computing the latitude of the point clicked, computing the scale factor for HRAP cells, and then assuming all cells in the basin have the same scale factor.  For large basins flowing north to south, this will result in an underestimated basin area.  The area estimates produced by this tool are only provided for reference.  In HL-RMS simulations, our strategy has been to scale the cell areas to reflect drainage areas reported by the USGS.

**S8** ("Channel Shape Method" only):  To use the Channel Shape routing parameterization method, it is necessary to get an estimate of the channel slope of the outlet cell.  To do this, simply make "rut_slopc" the active Theme and use the ![icon] Tool to click on the cell of interest to get the channel slope estimate.  The "Value" in the "Identify Results" box is your channel slope estimate.  Divide this number by 10000 to get channel slope in m/m.  Notes:  The channel slope estimates are computed using the 400-m resolution DEMs and flow directions and therefore accuracy may be suspect in some areas.  The minimum slope estimate allowed in processing was 1/10000.  This minimum value is assigned if the slope estimated from the DEM is zero.
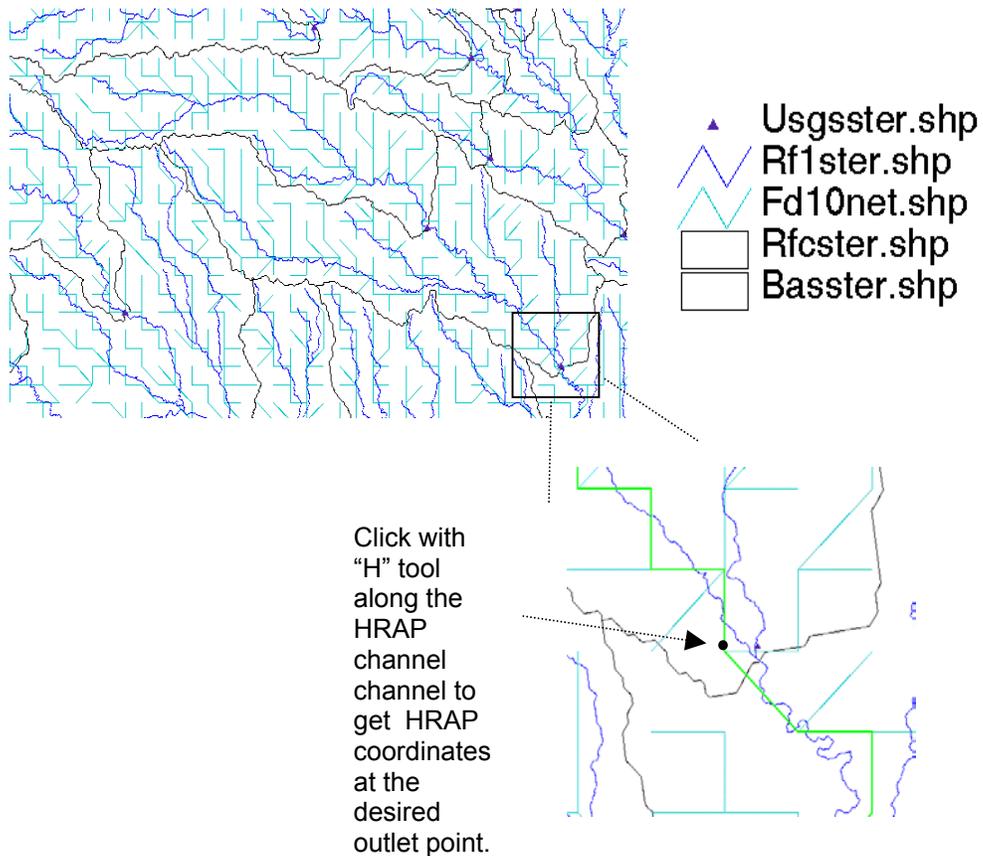
Click with "H" tool along the HRAP channel channel to get HRAP coordinates at the desired outlet point.

**Figure 4.  Example showing to forecast basins (CBNK1 and BLKO2) in the Chickaskia River basin.**

## 2.1.2  ADDING OUTLETS TO THE CONNECTIVITY FILE

The top portion of an RMS connectivity file is shown here.

> *TEXT_SEQ*
> *NUM_HEADER_REC   13 24467*
> *COL  1060*
> *ROW   821*
> *LLX    1*
> *LLY    1*
> *URX  1060*
> *URY   821*
> *DATA_HRAP*
> *TEST1    1    5    5.0000  375  419*
> *TEST2    1    9    5.0000  375  418*
> *7099970   1  2232   5.6344  409  390*

```
7124000   1   4879    6.4376 439 386
7130500   1   5370    6.6532 445 386
7139500   1  10177    6.7819 507 381
7146500   1  16856    6.6443 572 369
7164500   1  21425    6.5671 599 348
ELDO2     1  22439    6.1420 626 347
7249455   1  23316    6.4687 637 334
7263450   1  24466    6.4589 686 327
BLKO2     1  17407    6.2633 568 362
CBNK1     1  16559    6.2633 560 370
    0   1 Rv   1 376 402 6.4589 377 419
    1   5 Rv   1 375 401 6.4589 376 420
    2   5 Rv   1 375 402 6.4589 376 419
    3   5 Rv   1 374 401 6.4589 375 420
    4   9 Rv   1 375 403 6.4589 376 418
    5   9 Rv   1 374 402 6.4589 375 419
    6  12 Rv   1 369 408 6.4589 370 413
    7  12 Rv   1 369 406 6.4589 370 415
    8  13 Rv   1 375 404 6.4589 376 417
    .        .          .
    .        .          .
    .        .          .
```

Line 2:  Lists the number of outlets identified (13) and the total number of cells listed in the file (24467)

Lines 3, 4:  Number of columns and rows in the input grids.

Lines 4, 5:  Lower-left X and Y coordinates.

Lines 6, 7:  Upper-right X and Y coordinates.

Lines 10-22:  Basin outlet specifications.  Information included in each line:

    Col. 1:  ASCII identifier.  Must be the same as identifier used in HL-RMS control file on the @I card.

    Col. 2:  ignore

    Col. 3:  Cell line number of this outlet

    Col. 4:  Representative area ($mi^2$) of cells in this basin.  Computed as the USGS area divided by the number of HRAP cells in the basin.  (program does not currently use)

    Col. 5:  hrapx coordinate of outlet cell

    Col. 6:  hrapy coordinate of outlet cell

Lines 23-24489:  Cell List

    Col. 1:  Cell line number

    Col. 2:  Cell line number of the next downstream cell

    Col. 3:  ignore

    Col. 4:  ignore

    Cols. 5-6:  Locally referenced Hrapx and Hrapy

    Col. 7:  Area represented by the cell in $mi^2$

Cols. 8-9:  Globally referenced Hrapx and Hrapy (the true hrapx, hrapy coordinates)

**S9**:  To add a new outlet point to this file, a new Basin Outlet Specification line (e.g. line 23) should be added.  To provide the required information for this line, the user must determine the cell line number for this outlet (Col. 3).  To get the cell line number, do a text string search on the file for the hrapx and hrapy coordinates of the point you are adding (separated by a single space).  For example, search for "568 362" to identify the outlet line number for BLKO2 in the above example.  The search should find "568 362" in Columns 8-9 somewhere in the Cell List (lines 23-24489).  The value in Column 1 of the cell line number that is found should be placed in Column 3 of the Basin Outlet Specification (e.g. 17407 for BLKO2)

## 2.2  ANALYZE FLOW MEASUREMENT DATA TO DETERMINE ROUTING PARAMETERS

2.2.1  Overview and Excel Setup Requirements:

Analysis of flow measurement data to estimate channel parameters involves several steps.  For now, we offer a Spreadsheet to help estimate these parameters.  The Excel Spreadsheet includes Visual Basic for Applications (VBA) Macros.  The same analysis can be done manually in a Spreadsheet environment but would take much more time.  The VBA Macros were developed using Excel 2000 and use of Excel 2000 is recommended.  (If absolutely necessary, it might be possible to make the macros work under Excel 97.)

Although not required to get some benefit from the macros, to take full advantage of the RMSExcel macros, you should install the Excel Solver Add-In.  The **Tools --> Add-Ins** menu can be used to add the "Solver Add-in".  Even without the Solver Add-in, you may still find the other macro functions useful, so keep reading.

2.2.2  Downloading Raw Measurements

**S10:**  Go to http://water.usgs.gov/nwis

**S11:**  From the main page:  Click Surface Water.  Click Measurements.  At this point there are many search options to identify the stations you are interested in.  Choose whichever option you prefer and click "Submit."  In the "Choose Output Format" section, ask to see a table of selected sites in the "Display Summary of Selected Sites" section.  Click "Submit".  When the list of stations is displayed, click on a site number to get specific data for that station.  Save the flow measurement to your disk as a Text file in **Tab-Separated Data** format.  The top of the file that you obtain should look something like the following (Note:  Data lines are cut-off on this example.  Actual data lines contain many more columns.).  Although it is possible to download data for multiple stations to a single file, the VBA Macros will only work if a separate data file is downloaded for each station.

```
#
# Surface water measurements
#
# Further descriptions of the columns and codes used can be
found at:
#
http://waterdata.usgs.gov/nwis/help?output_formats_help#stre
amflow
#
# Stations in this file include:
#  USGS 07337000 Red River at Index, AR
#
#
site_no    agency_cd measurement_nu measurement_dt party_nm
15s  5s    5s   19d  12s  12s  12s  12s  12s  12s  12s
07337000   USGS 62   1952-07-11     k/m  5.40 1.03 0.43 1.68
07337000   USGS 63   1952-07-23     w    5.80 1.33 0.72 1.70
07337000   USGS 64   1952-08-06     w    35.0 38.5 0.79 2.07
07337000   USGS 65   1952-08-19     w    9.50 2.96 0.39 1.70
07337000   USGS 66   1952-09-03     g    7.60 2.14 0.34 1.69
```

If you download the data in a format that is not the same as the "Tab-delimited data" shown above, the Excel Spreadsheet macros will not work.

> **S12:** Determine the line number of the column labels (e.g. "site no", "agency", etc.). In this example, the line number is 11. This is the "# of Header Lines" required to run the VBA Macros correctly.

## 2.2.3 SpreadSheet Instructions

A significant amount of introductory material describing rmsmaster.xls is included here. The next action step in the instructions (S13) is on page 16. You may want to skip to S13 and refer back to the Worksheet descriptions for reference.

As currently written, the VBA macros rely on a specific Workbook organization. Sheets (Worksheets or Charts) with specific names must be present in order for some of the scripts to work. Additional Worksheets or Charts may be added and the order of these Sheets may be changed, but **do not change the Sheet names**. The Spreadsheet rmsmaster.xls contains default data when starting. Successful completion of the processing steps described below replaces default data stored in the Worksheet files and presented on the Charts.

The following Sheets are found in rmsmaster.xls and used by the VBA Macros:

Default Worksheet Names and Explanation:

*Raw Data*: Raw data are imported into Excel format and copied to this Worksheet.

*Select Data*: Selected columns of data are copied to this Sheet and sorted by Cross-section area. Columns with data in metric units are added for fields of interest.

*AvgdQAData*: Observed values of flow (Q) and cross-sectional area (A) are computed and stored in this Sheet. Some of the observed values in this sheet are actually averages of several sample observations with similar magnitudes. Typically, there are many more observations at low flows than at high flows. The averaging of observations with similar magnitudes prevents excessive weighting at the low end of the Q vs. A curve in regression calculations. This Sheet also contains numerous columns of predicted Q ("pred_Q") as a function of A for different parameter sets, and columns containing the differences between predicted and observed values. Each of the predicted Q columns is computed based on intercept and slope parameters specified in Column B. For Q = $a$A$^b$, $a$ = exp(intercept) and $b$ = slope. Several different types of regression fits are computed by default for consideration.

In the two ln[Q]cases, parameters ($a$, $b$) are derived by minimizing either the "squared error" differences or the "absolute error" differences between predicted and observed ln[Q]. Both intercept and slope are optimized in these cases. Several alternative parameter fits (still assuming Q = $a$A$^b$) are also automatically computed in which the

squared differences or the absolute differences in the Q values themselves (not ln[Q]) are minimized. In all cases, optimization is done using the Excel solver (see steps below). Four Q cases are computed by default: (1) fixed intercept, squared error, (2) fixed intercept, absolute error, (3) two parameter, squared error, and (4) two parameter, absolute error. In the fixed intercept cases, only the slope parameter is optimized (intercept is specified from the ln[Q] cases). In the two parameter case, both intercept and slope are optimized.

The macros compute several different types of regression fits because it is difficult to say that a single fitting procedures is the best to represent flow observations over all ranges, and for different gage sites. Note again that all of the cases are limited by the assumed Q = $a$A$^b$ relationship. In fact, so far, we have found that a manual option for specifying one parameter (say slope in log space) and then using the Excel Solver manually (explained more below) to optimize the other parameter produces the most satisfactory results based on visual inspection.

*AvgdAWData*: Same setup as the AvgdQAData Sheet except the variable relationship considered is cross-section area (A) as a function of width as opposed to Q vs. A. In this case, the parameters of interest ($\alpha$ and $\beta$) are both computed in Column D for various scenarios. $\alpha$ and $\beta$ in B=$\alpha$H$^\beta$ are computed as a function of the intercept and slope terms in Column B. Column B terms are optimized using the Solver.

*HB_Data*: Contains data for producing a graph of depth (H) vs. width (B).

*Control*: Contains user input describing the basin (Next to Red Text) or derived from other Sheets.

*PredictedQA*: Contains Q and A data computed using the channel shape method.

Default Chart Names and Explanations :

*Ln(Area-Width):* Plots of of Ln(A) vs. Ln(Width) using data from AvgdAWData

*Area-Width:* Plots of A vs Width using data from AvgdAWData

*N Graph:* Estimated Manning's n vs. Q

*H-B:* Elevation view of estimated outlet cross-section shape.

*Ln(QfA):* Plots of Ln(Q) vs. Ln(A); Data from AvgdQAData

QfA: Series of Q vs A; Data from AvgdQAData

Processing Steps:
    **S13:** Open the Spreadsheet rmsmaster.xls.

**S14:**  To make sure you don't overwrite the rmsmaster.xls sheet, save the sheet with a different name.  (e.g. basin1.xls).  This will create a copy.


**S15:**  Make the Control Sheet active and fill-in/edit the following cells:

Control!A1:  Default path to look for downloaded measurement files
Control!B6:  Drainage area of the basin in km$^2$
Control!B7:  Slope of the outlet cell (B6)  (Only required for Channel Shape Method).
Other cells next to Red text are filled in later steps.

**S16:**  With the Control Sheet active (actually any Sheet is o.k.), use **Ctl-Shift-L** to load the "RMS Parameters" menu.  (**Ctl-Shift-U** will unload this menu.).  This action also adds a menu ("Add/Subtract Series") that is seen only when a Chart is the active sheet.

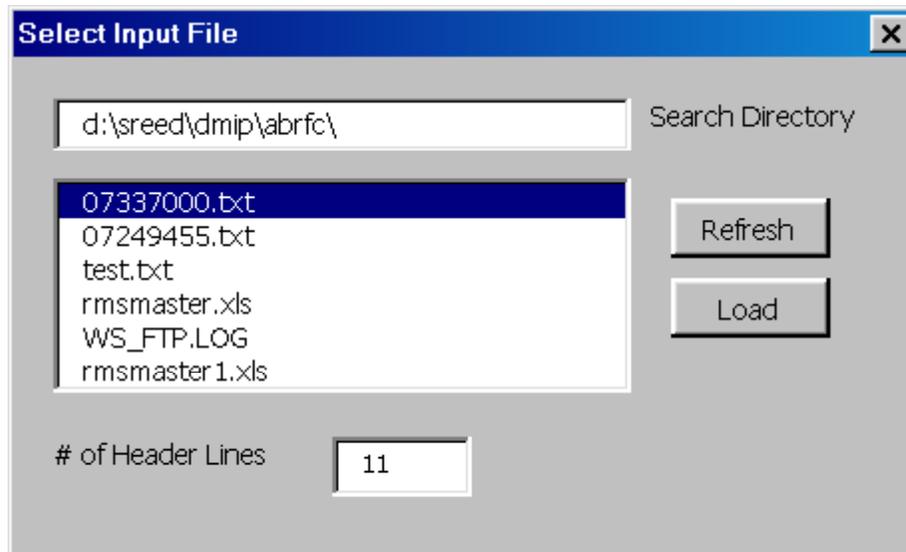**S17:**  Run RMS Parameters --> Load Data



**Figure 5.  Load Data Dialog**

The dialog above appears.  The default search directory is specified using the information in cell A1 of the Control worksheet.  Type a different path name if needed.  There must be a "\" at then end of the directory path.  Click "Refresh" to see a list of files in this directory.   # of Header Lines should be the number determined in Step **S12** of Section 2.2.2.  Click the file of choice and then hit the "Load" button.  This action replaces data in the RawData Worksheet.

**S18:**  Run RMS Parameters --> Process Data

Prepares data in SelectData, AvgdQAData and AvgdAWData sheets. The previous data in these sheets are cleared (Note: program assumes there are fewer than 10,000 measurements) Notes: The parameters navgs (number of averaged values) and mcount (number of measurements) get written to cells Control!A3 and Control!A4. Do not edit these cells.

**S19:** Run RMS Parameters --> Run Solver All
This should only take a few seconds to a minute; however, if the program appears to finish instantaneously there might be something wrong. Some messages like "Trial Solution" should flash by at the bottom of the Excel Window. The macro runs the Solver many times to get the optimal fits for parameters for the different regression cases on Sheets AvgdQAData and AvgdAWData.

Examine Results Using "Channel Shape Method" or "Rating Curve Method"

At this point you can examine results and identify model parameters. There are two methods currently available in RMS for defining channel parameters. One method is referred to as the "Channel Shape Method" for which estimates of $\alpha$ and $\beta$ in $B=\alpha H^{\wedge}\beta$ are required. H is depth and B is width. The second method is the "Rating Curve Method" for which estimates of $a$ and $b$ in $Q = aA^{\wedge}b$ are required. In general, it is easier to infer parameters for the Rating Curve Method than the Channel Shape Method. For the DMIP basins our simulation results have shown little difference in the hydrographs simulated with the two different methods. The expected advantage of the Channel Shape Method is in basins where there is significant variability in channel slopes. We have not really worked enough with basins of this type to find evidence of this advantage.

The menu "Add/Subtract Series" is available when a Chart Sheet is active. Items under this menu will add a specified series to the graph if it is not there or remove the graph if it is there (With the exception of the first item "Remove All Series"). Selecting an item under the "Add/Subtract Series" menu simultaneously updates the Charts *Ln(Area-Width)*, Area-Width, *N Graph*, *H-B, Ln(QfA)*, and *QfA*. Legends on the Charts are color-coded to correspond to cell colors in the Sheets "AvgdQAData" and "AvgdAWData". Note: DO NOT CHANGE ANY OF THE CELLS IN COLUMN D OF THESE SHEETS. COLUMN D VALUES ARE FUNCTION OF COLUMN B VALUES.

Channel Shape Method:

**S20:** Look at "n Graph" Chart and pick a Manning's n value. Enter the Manning's n value you select in the "Control" Sheet B8. You may want to adjust the y-axis scale when looking at this Chart (e.g. set the y-max value to 0.1). Manning's *n* values tend to approach a constant value as flows get bigger although the scatter in the data tends to be large. Pick a value representative of higher flows. Don't worry too much about getting an exact value as this parameter can be adjusted later.

**S21:** Examine the "Ln(Area-Width)" and "Area-Width" Charts. It is often wise to use the "Remove All Series" option at the beginning to start with a clean slate. Look at different regression fits in both log and arithmetic scales using the items in the "Add/Subtract Series" menu. The simple channel shape model cannot fit Area-Width data for all flow ranges. Since we are more interested in modeling high flows, it is not necessarily true that one of the best fit regression models that is automatically computed will yield the most satisfactory results.

**S22:** So far our most satisfactory results have been obtained by using a fairly subjective approach and only using the automatic regression lines for reference. For example, looking at the Ln(Area-Width) Chart, subjectively draw a straight line that seems to provide a good representation of high flows while not completely ignoring middle and low flows (Example for TALO2 shown in Figure 6). Estimate the slope of this line. Enter this slope value in AvgdAWData Cell B20(or B24-- there doesn't seem to be a big difference between solver results using absolute error vs. squared error.) Run Tools --> Solver to optimize the intercept corresponding to this slope (See Figure 7 for example Solver dialog). In this example, minimize AvgdAWData!B18 by changing Cell B19.
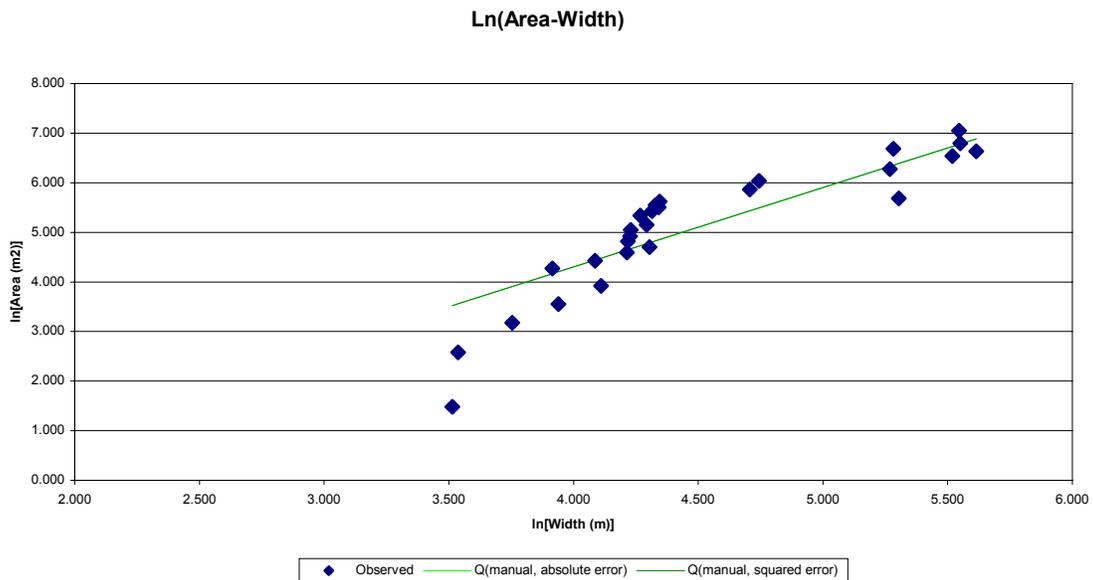


**Figure 6.  Example of a subjective fit to ln[A] vs. ln[Width(m)] for TALO2 in ABRFC ($\alpha = 6.46$ and $\beta = 1.66$)**
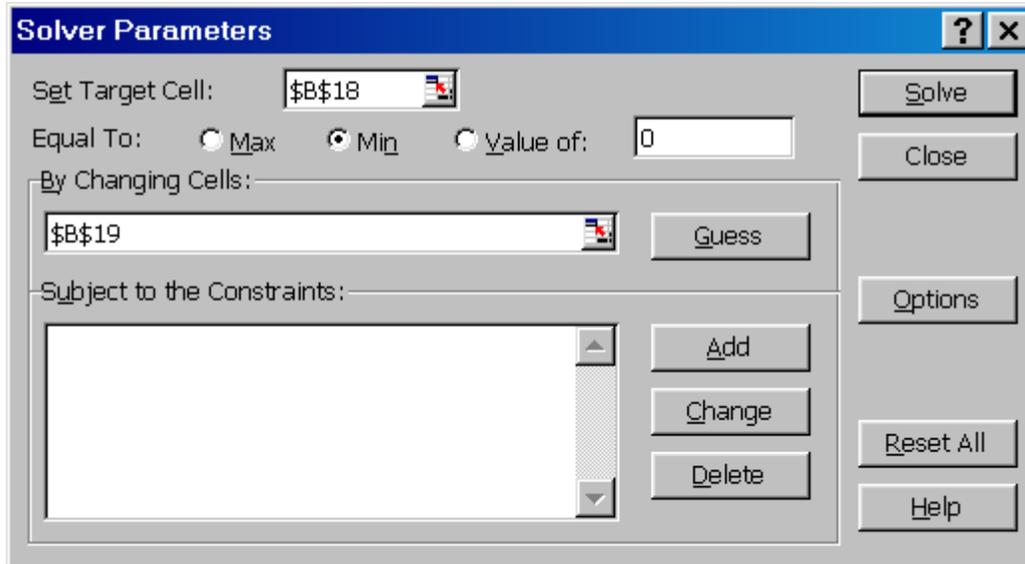
**Figure 7. Example Solver Dialog**

**S23:** Choose your best set of α and β parameters. For example, cells AvgdAWData D19 and D20 in this example. Enter the values in Sheet Control!B9 and Control!B10.

**S24:** Go to the "SelectData" Worksheet and pick a representative cross-section area (m$^2$) that corresponds roughly to the Manning's n value you selected. (One of the higher observed flows). Don't agonize too much over the choice of this value. Enter this value in Control!B12.

**S25:** Now take a look at the QfA Chart. You may want to clear all series with the Add/Subtract Series --> Remove All Series option. Select Add/Subtract Series --> Plot Channel Shape Method QA. The result will be a dashed line on the Q vs. A plot, which is the Q-A relationship predicted by your shape parameters and Manning's *n* value. You can now adjust your choice of Manning's *n* in cell B8 on the control sheet to try to get a better match to the Q-A curve.

You now have all of the information you need to generate custom parameter grids using the Channel Shape Method.

Rating Curve Method:

**S26:** Examine the "Ln(QfA)" and "QfA" Charts. It is often helpful to use the "Remove All Series" option at the beginning to start with a clean slate. Look at different regression fits in both log and arithmetic scales using the items in the "Add/Subtract Series" menu. The automatic regression fits tend to be more satisfactory for Q-A relationships than for Area-Width; however, it still seems sensible to use the same procedure described in Step 3 of the Channel Shape

Method procedure above. That is, subjectively estimate a slope from the ln[Q]-ln[A] curve, enter this slope value in AvgdQAData Cell B20, Run Tools --> Solver to optimize the intercept corresponding to this slope (See Figure 7). Figure 8 shows example results for the Q-A fitted relationship. In this case, Date information from the Sheet "SelectData" was also taken into consideration for subjective fitting.
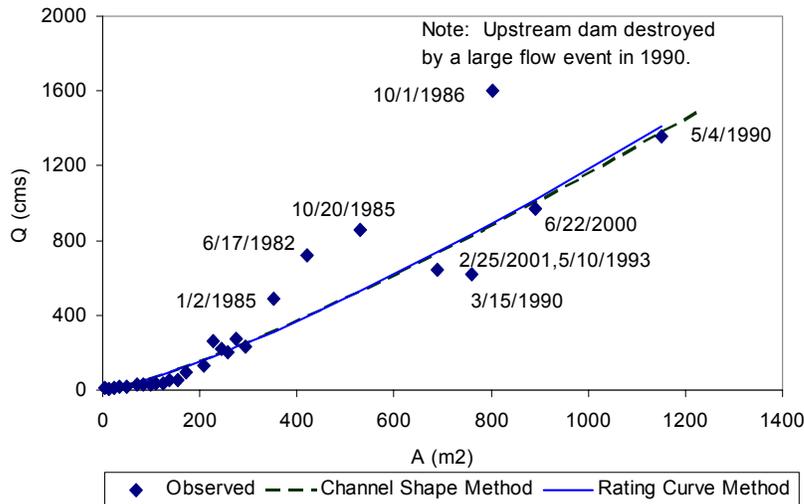


**Figure 8. Example of a subjective fit to Q vs. A for TALO2 in ABRFC (a = 0.16, b = 1.283)**

You can now use your *a* and *b* estimates to generate routing parameter grids. Values of *a* are shown in AvgdQAData Column D and b values are the "slopes" in Column B.

## 2.3. GENERATE CUSTOMIZED ROUTING PARAMETER GRIDS

Similar to Section 2.2, this section starts with a considerable amount of general explanation followed by example implementation steps (starting with **S27**). The file gengrid.card provided is an example input card used to generate routing parameter grids.

- The following 7 parameter grids are required for runs using the Channel Shape Method:

  rutpix_ALPHC: channel width parameter ($\alpha$)
  rutpix_BETAC: channel shape parameter ($\beta$)
  rutpix_DS: drainage density
  rutpix_ROUGC: channel roughness (Manning's n)
  rutpix_ROUGH: hillslope roughness
  rutpix_SLOPH: hillslope slope
  rutpix_SLOPC: channel slope

The DS and ROUGH grids are initially assigned default values of 2.5 and 0.15, but these grids can be filled with a different constant value using the gen_grid.exe program as described below. The SLOPH and SLOPC grids provided were computed at HL using DEM data.

- For the Rating Curve Method, only 2 grids are required:
      rutpix_Q0CHN: *a* in $Q = aA^b$
      rutpix_QMCHN: *b* in $Q = aA^b$

- To use the Channel Shape Method, an RFC user should generate the rutpix_ALPHC, rutpix_BETAC, and rutpix_ROUGC grids. To use the Rating Curve Method, the user should generate rutpix_Q0CHN and rutpix_QMCHN grids.
- Gen_grid.exe must be run once for each grid.
- ORDER IS IMPORTANT! The rutpix_ROUGC grid and rutpix_BETAC grids must be generated before the rutpix_ALPHC grid because the rutpix_ALPHC grid depends on ROUGC and BETAC. The rutpix_QMCHN grid should be created before the rutpix_Q0CHN grid.
- The @G card in gengrid.card should be:

      @G rutpix  7  3  2

      for the Channel Shape Method and

      @G rutpix  9  3  2

      for the Rating Curve Method

- In our initial implementations, the rutpix_ROUGC, rutpix_ALPHC, and rutpix_Q0CHN are spatially variable grids, while the rutpix_DS, rutpix_ROUGH, rutpix_BETAC, and rutpix_QMCHN grids are spatially constant within a basin. Gengrid.exe can be used to customize both spatially variable and spatially constant values for a basin.

- The **+IPRG** line is used in gengrid.card to specify parameter information. For a given run, only one **+IPRG** line is used per basin; however, parameter values for multiple basins can be specified in a single run. For example, BETAC values can be initialized for several basins at once, but both BETAC and ALPHC values cannot be initialized in the same run.

- The contents of the **+IPRG** line:

      **+IPRG** *<n_values> <parameter #> <variable_1, variable_2,..., variable_(n_value-2)>*

<n_values> is a number of entries in the input line including the <n_values> item.

is the number used to refer to a parameter based on its order in a list of parameters defined in HL-RMS. Routing parameters 1-7 are: *SLOPC(1), ROUGC(2), BETAC(3), ALPHC(4), SLOPH(5), DS(6), ROUGH(7)*. Q0CHN(8) and QMCHN(9) are parameters 8 and 9.

<variable_i> input variables required to generate grid of a selected parameter <parameter #>.

- To generate a constant value for rutpix_BETAC:

  **+IPRG**  3  *3*  *<value>*

  where <value> is the BETAC value

- Input variables to generate *ROUGC* parameter are a 'representative' roughness coefficient at outlet, and two parameters, *k1* (default value is 0.272) & *k2* (default value is -0.00011):

  **+IPRG**  5  2  $n_o$  *[ k1]*  *[ k2]*

  Input variables to generate the ALPHC grid are 'representative' discharge (Qo) (no longer used so really any value is o.k., but some value must be present), cross-section (Ao), and the $\alpha$ parameter at the outlet.

  **+IPRG**  5  4  $Q_o$  $A_o$  $\alpha_o$

  **+IPRG** entry should be provided for each basin ID. All other input deck entries can be same as described in an Appendix II of HLRMS User Manual.

- To generate rutpix_QMCHN values

  **+IPRG**  3  9  *<value>*

- To generate rutpix_Q0CHN

  **+IPRG**  4  8  *<q0chn_value>*  *<qmchn_value>*

- Each time gengrid.exe is executed for a basin, values for all cells upstream of the basin outlet are specified unless there are internal points specified during the same run. If you wish to assign one value to an inter-basin area between two gages and another value to the headwaters above the upstream gage, the values should be specified in the same gengrid.exe run –OR- If the values are specified in two separate runs, the values for the downstream outlet should be specified in the first run and the values for upstream points can be specified in subsequent runs. Specifying a downstream parameter value in subsequent run will overwrite values for previously specified internal points.

- Executing gengrid.exe is simply:

  $ gengrid.exe <input_card_name>

- Template files for all parameter grids are provided by HL.  Each time gen_grid.exe is run, the output is written to a file called TEMP.  For a given parameter, data from the template grid is first copied to TEMP and then pixels within the basin(s) specified in gengrid.card are updated.  If you are satisfied that gen_grid.exe has worked properly, you should overwrite the template parameter grid with the updated information in the file "TEMP" using the UNIX cp command, e.g. for ALPHC

  $ cp TEMP rutpix_ALPHC

  The UNIX cp should be done after each gengrid.exe because if you run gengrid.exe again for a different parameter, the TEMP file containing the output from the previous run is overwritten.

-

  **S27:**  Example steps for "Rating Curve Method"

    Specify the @G card appropriately
    @G rutpix  9  3  2

    Specify a rutpix_QMCHN value
    **+IPRG**   3  9 1.2333

    Run gengrid.exe
    $gengrid.exe gengrid.card

    Copy TEMP
    $ cp TEMP rutpix_QMCHN

    Comment the rutpix_QMCHN line and specify the rutpix_Q0CHN line:
    **+IPRG**   4  8 0.382  1.2333

    Run gengrid.exe
    $gengrid.exe gengrid.card

    Copy TEMP
    $ cp TEMP rutpix_Q0CHN

  **S28:**  Example steps for "Channel Shape Method"

    Specify the @G card appropriately
    @G rutpix  7  3  2

    Specify a rutpix_BETAC value
    **+IPRG**   3  3 2.12

Run gengrid.exe
$gengrid.exe gengrid.card

Copy TEMP
$ cp TEMP rutpix_BETAC

Comment the rutpix_BETAC line and specify the rutpix_ROUGC line:
**+IPRG**   5  2  0.051  0.272  -0.00011

Run gengrid.exe
$gengrid.exe gengrid.card

Copy TEMP
$ cp TEMP rutpix_ROUGC

Comment the rutpix_ROUGC line and specify the rutpix_ALPHC line:
**+IPRG**   5  4  665.  614.  0.43

Run gengrid.exe
$gengrid.exe gengrid.card

Copy TEMP
$ cp TEMP rutpix_ALPHC