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Interactive Calibration Program
Suggested Changes and Enhancements

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Introduction

This report gives the author's suggestions regarding changes to the existing Interactive Calibration Program (ICP) and the highest priority enhancements that should be added to the program. The baseline version of ICP for this report is that which was in use at the time of the death of Hillel Sukenik (i.e. the features that were included in ICP at that time are assumed to remain in any new version unless noted in this report). The status of ICP at that time is documented in "ICP Status - February 2000" by Eric Anderson (see Appendix B to this report). That document indicates bugs that existed in the last official version of ICP that was released prior to Hillel's death (NWSRFS release 14.1). It also lists some suggestions for minor changes to the program. Also included are changes that Hillel made to his working version after the last official release and bugs that were found in these updates (the code for these changes has never been recovered). All of the features that existed at that time, plus fixes for the existing bugs and suggested changes noted in the February 2000 document, are recommended to be included in future versions of ICP unless specifically indicated in this report.

This report doesn't assume how the suggested changes and enhancements will be incorporated into ICP. The suggestions could be incorporated into the existing code or the entire program could be rewritten (possibly with some code from the existing program reused). This report includes a proposal for one major addition to ICP and lists several other possible enhancements. Undoubtedly other features may need to be added to the program over time based on user suggestions.

The suggestions in this report are based on the author's extensive experience with the development and use of ICP. This includes personal use of the program over many years as well as feedback from River Forecast Center (RFC) personnel while assisting various offices with calibration problems and training workshops.

Background

Manual (trial and error) calibration of conceptual hydrologic models was accomplished by running simulation programs in batch mode for many years. The models were run with a given set of parameter values, printer plots were generated and analyzed (in many cases by using color pencils to connect daily hydrograph values), parameter values were modified, and another run was made. Even with the best turn-around, typically only a few trials could be made in a day. The volume of output in many cases limited the information that could be displayed for the user to analyze. It was also quite difficult to visualize how the models were functioning with only

text output. This continued from when conceptual models were first developed in the early 1960's into the 90's. Early simulation programs were designed around a single model of each part of the hydrologic cycle (i.e. one snow model, one soil moisture model, one watershed response model, etc.) that could only be applied in a specified manner. In the late 1970's the Hydrologic Research Laboratory (HRL) of the National Weather Service (NWS) began development of simulation programs that could accommodate a wide variety of hydrologic models and procedures and allow the sequence of computations to vary depending on the application. These programs were referred to as MCP (Manual Calibration Program) followed by a version number. This effort culminated with MCP3 in which each model and procedure was coded as a separate module referred to as an operation. The operations could then be sequenced in whatever order was needed for a particular application in what was referred to as the operations table. Data were passed from one operation to another by time series. However, MCP3 was still run in batch mode. The idea of interactive calibration was discussed for a number of years and was on many hydrologist's wish list. Somewhere around 1990 an interactive calibration program was developed by a contractor based on HRL specifications as part of the PROTEUS project. This program was run on a PR1ME computer, but the displays and functionality didn't really meet the demands of the users and the program was never used for more than demonstrations.

In the early 1990's HRL developed the Interactive Forecast Program (IFP) using UNIX/X windows technology. IFP provided interactive control and graphical output for operational river forecasting. The actual modeling computations, as specified in the operations table for each forecast location, used the same code as the batch operational forecast program. IFP allowed the forecasters to select which locations were to be run, apply adjustments to input data and model computations based on the graphical displays, and rerun the simulation until they were satisfied with the comparison between simulated and observed values up to the current time and the forecast out into the future. In looking at the features built into IFP it was apparent that the same technology could be used to finally create an interactive calibration program that would meet user needs.

In about 1993 a programmer, Hillel Sukenik, was hired and assigned to work on coding ICP. This author provided the requirements for the features to be included and specified the form of the graphical displays. George Smith, the lead developer of IFP, provided guidance as how to use the UNIX/X windows technology and the feasibility of the proposed features. ICP was first introduced to the RFCs at a calibration workshop at the West Gulf RFC in June 1995 just before this author retired from HRL. Improvements and enhancements continued to be made to ICP up until the time of Hillel's death in the late summer of 1999. This author provided most of the guidance for changes to ICP during this period and was the primary person to test new versions. In May of 1999 a significant enhancement was added to ICP with the inclusion of the Time Series Plot (PLOT-TS) display which allowed the users to graphically display all types of time series data. Previously only mean daily discharges could be displayed graphically. There were a number of bugs in the initial version of the PLOT-TS display. Many of these were fixed by Hillel in a test version of the program in the succeeding months, but never made it into an official release.

The overall response of the users (mainly RFC personnel) to ICP has been overwhelmingly positive. ICP has greatly improved the time required to perform a calibration. It has allowed the users to make many runs and analyze the results within a relatively short period of time with graphical displays that contain much more information than previously available. It has not only greatly improved the calibration process, but has allowed the RFC forecasters to gain a much better understanding of the models they use every day to produce operational river forecasts. Calibration of conceptual models has always been important to producing accurate river forecasts with the longest possible lead time. With the advent of extended probabilistic predictions, the need for good calibrations is absolutely essential. Many of the benefits of the Advanced Hydrologic Prediction System (AHPS) are based on such extended predictions and thus require properly calibrated models. The number of complaints and requests for changes to ICP have been amazingly small over the years especially considering how much the program is used by the RFCs. Most of the suggestions for changes have come from this author. One of the main reasons that HRL didn't allocate the resources needed to support ICP after Hillel's death was because there were so few requests from the field offices to fix bugs or make changes to the program, though as time passes the RFCs are expressing more concerns about support for ICP. With the expansion of AHPS it is now imperative that ICP be properly maintained and enhanced.

Structure and Organization of ICP

ICP provides interactive control and graphical displays for MCP3. ICP allows the user to select the watershed and the MCP Control (input) File to use (this file specifies the run period, display units, the time series and operations used, and the parametric information for each operation). ICP then allows the user to run MCP3 to perform the hydrologic computations for the entire run period. When ICP is being used to run MCP3, variables stored in common blocks tell various routines in MCP3 to write data values and other information to temporary files. These files are then read by ICP when the user selects the graphical displays to be generated. Graphical output is only provided for certain operations (currently SNOW-17, SAC-SMA, WY-PLOT, and PLOT-TS). The two main graphical displays in ICP are linked to the WY-PLOT and PLOT-TS operations. Model states and computed values from the SNOW-17 and SAC-SMA operations can be inserted in the WY-PLOT display above the daily discharge plot. Output from operations for which graphical displays are not included can be viewed through the ICP interface in text format.

Once MCP3 is run with a given set of model parameters and the results displayed, the user can analyze the output and decide manually which parameters should be changed. Special interfaces are provided to alter parameter values for the models whose parameters are most frequently modified during a calibration (SNOW-17, SAC-SMA, and UNIT-HG). The parameters and variables for other operations are changed if needed by editing the control file directly. ICP can save certain time series from a run prior to rerunning MCP3. After rerunning MCP3, the new results can be displayed along with selected time series that were saved from a prior run for comparison. This cycle continues until the user determines that the calibration is complete.

It should be noted that although MCP3, and thus ICP, are primarily used for generating a

watershed simulation that is compared to observations in order to calibrate the models being used, the operations table can be used for other purposes. This includes such applications as comparing observed daily discharges for a number of watersheds within a given river basin and computing local area contributions and reservoir inflows. These are important applications and the graphical displays produced by ICP are of great benefit in analyzing the results. In these cases there is no comparison made between computed and observed values at a given location.

In designing ICP it was decided to use a system suggested by the Colorado Basin RFC (CBRFC) to organize the control files for each watershed within an RFC area. CBRFC decided on this system when developing a program to generate the input needed for the control files for each location. The system uses a region, basin, and watershed to store and locate the control files. Multiple regions are used when the RFC wants to divide their area up into several large sections (e.g. the CBRFC might want to divide their area into regions representing the Colorado River above Hoover Dam, the Salt and Gila basins, and the Great Basin streams). Basins typically correspond to the Forecast Groups that the RFCs use for operational forecasting. Watersheds are the individual locations where simulations are to be performed. The region, basin, watershed organization was used to create the calibration directory structure used by NWSRFS for storing control files for use by ICP, MCP3, and OPT (batch automatic parameter optimization program). It is recommended that the region, basin, watershed organization be retained within ICP in the future and that the resulting directory structure be maintained.

In order to manage MCP Control Files, ICP was designed to recognize three control files in the directory for a given watershed. The name of these files consisted of the watershed directory name followed by .curr, .prev, and .best. The idea was that .curr would contain the current parameter values, .prev would contain a set from a prior run (up to the user to determine when to move .curr to .prev), and .best would contain the best or final set of values. It has turned out that the users have seldom used the ICP feature to copy (relabel) control files and any existing temporary files from one suffix to another. Typically if the users want to save a given control file, they use UNIX commands to copy the .curr file to another file within the watershed directory. The use of the 3 suffixes for file names results in the need for the users to make a number of mouse clicks to select the file to use and to specify what happens when a file is altered. A number of users have complained that the number of mouse clicks were excessive. For these reasons it is recommended that the .curr, .prev, and .best file naming convention be abandon in the future. It is recommended that ICP will always use the control file with the watershed directory name and a .curr suffix (i.e. this is the only control file that ICP will recognize). The user can save various versions of the control files for a given watershed by using UNIX commands to copy and rename files, but in order for ICP to use the control file it must first be copied to the watershedname.curr file. The effect of this labeling change will be reflected in the subsequent description of changes to menus and option selections for ICP.

Suggested Changes to ICP

This section will be organized around the 3 main windows that are currently used to select the ICP features. These are the main program window (i.e. the small window that first appears when

ICP is initiated), the main WY-PLOT display window, and a primary PLOT-TS display window.

I. Interactive Calibration Program Window (initial window) - This window has 3 pull down menus that are used to determine the watershed being run, edits to the control deck and parameter values, when MCP3 is run, and the displays to be generated. These are the CONTROL, EDIT, and DISPLAY menus. The order that these menus are shown in the ICP window should be changed to CONTROL, DISPLAY, and then EDIT. This is the typical sequence of initial use when running the program.

A. CONTROL menu - currently contains 4 options: Select Watershed, Relabel, Run MCP, and Exit. In the future only the Select Watershed, Run MCP, and Exit options should remain.

1. Select Watershed - When select watershed is chosen, the user clicks on the region and basin in which the watershed is located and then on the watershed to be run. Currently the program then lists the control files available for that watershed (i.e. .curr, .prev, and/or .best). This last column should be eliminated since only the .curr file will now be used. Instead 2 new items should be added below the region, basin, and watershed selection panels. The first will indicate whether a watershedname.curr file exists in the watershed directory (i.e. YES or NO - if NO, then a message will indicate that such a file must be created before continuing). The second item will allow the user to specify if text output will be generated for all operations or just for those without graphic displays. This selection is currently made in the Deck Selection window when Run MCP is specified. The default should be to only produce text output for the operations that can't be displayed graphically (same as current default).

The New Region, New Basin, and New Watershed buttons should be removed. These currently can be used to create new directories. Most, if not all, users currently create these directories with UNIX commands and don't use the Select Watershed window for that purpose.

The Accept (accepts selection and closes window), Close (just closes the window without accepting the selection), and Cancel (cancels current selection) buttons should be maintained.

Currently ICP has problems when trying to switch from one watershed to another without exiting the program (item 20 under EXISTING BUGS IN VERSION 14.1 in Appendix B). It is not critical to have this functionality since a user typically works on one watershed for some time before switching to another watershed and thus it is not a big deal to exit the program before starting a new watershed. Unless the switch can be made from one watershed to another without causing any problems or a significant programming effort, the user should not be allowed to use the Select Watershed window to change watersheds once MCP3 has been run for the first

watershed.

Currently the Select Watershed window can't be chosen when a WY-PLOT or PLOT-TS display exists (program indicates that the user must first Quit the displays). This could be changed so that the user could change the text output selection while working on a given watershed, but this is not an important feature as the users seldom want to make this change.

2. Relabel - This feature should be removed since only a .curr control file will now be used by ICP. This should reduce the complexity of the program, the number of mouse clicks that the user must make, and the chance for core dumps during subsequent steps.

3. Run MCP - Currently the user must select which of the available control files is to be run and then click on Okay. Without the use of .curr, .prev, and .best control files, there is no need to make this selection. When Run MCP is chosen, MCP should be run using the .curr control file. A pop-up window should probably appear indicating that MCP is running and then followed by another window that indicates that the MCP run has finished and show the STOP code (0 = no warnings or errors, 4 = one or more warnings, 8 = one or more errors, and 16 = fatal error - currently shown in the Return Value from MCP3 window - wording could be improved).

4. Exit - This selection is made when the user is ready to exit the ICP program. Exiting the program causes all temporary files that were produced during the session to be deleted so that such files don't clutter up the disk space. No change is needed.

B. DISPLAY menu - currently contains two options: Water Year Plot and Plot Time Series. In the future it should contain 4 options: Water Year Plot, Plot Time Series, Statistics, and Text Output.

1. Water Year Plot - Currently when the Water Year Plot display is selected, the user must choose whether plots from .curr, .prev, or .best are produced. In the future no such selection will be needed. The user will just choose Water Year Plot and then the display for the first WY-PLOT operation in the control file will appear. The form of the water year plot display and the features that are linked to this display have been readily accepted by the users of ICP and do not require any significant changes. Thus, the Water Year Plot display should remain exactly as in the current version of the program except for the following:

a. Bug fixes and minor changes specified in Appendix B should be made. These are items 1,3,4,5,6,7,8,14,16,17, and 18 under EXISTING BUGS IN VERSION 14.1, items 4,8,9, and 11 under CHANGES SUGGESTED FOR VERSION 14.1, and items 1 and 2 under CHANGES MADE IN ICP.update.

b. Currently the first SQME time series in the WY-PLOT currently being displayed can be saved for display on a subsequent run (implemented using the Control menu on the Water Year Plot display). The last SQME saved can be plotted on the current WY-PLOT display as a dashed orange line by selecting Load SQME under the Select menu. When there are multiple WY-PLOT operations in a control file, only the first SQME from one of the operations can be saved. When Load SQME is selected, this time series will be displayed for the current WY-PLOT operation being displayed even if it is not for the operation that included the Saved SQME time series. This feature should be changed to be similar to the feature designed in the Plot Time Series display. For each WY-PLOT operation the user should be able to save any one time series (not just a SQME) and then reload this time series at any time after it has been saved (reloaded time series will be plotted as a dashed orange line as in the current ICP). Thus, if there are 3 WY-PLOT operations in the control file, up to 3 time series (one from each operation) can be saved and subsequently reloaded. The Save a Time Series and Reload a Time Series selections should both be under the Control menu for the Water Year Plot display (currently Save SQME is under the Control menu and Load Last SQME is under the Select menu). This item is mentioned in Appendix B as item 7 under CHANGES SUGGESTED FOR VERSION 14.1, but is more clearly defined here.

c. For the Percolation Analysis feature, the Solve option under the Points item of the Select menu of the Percolation Analysis Curve PD vs LZDEFR window should be removed. This feature doesn't work correctly in some cases and in most cases can lead to improper suggested parameter adjustments.

2. Plot Time Series - The Plot Time Series display was a new feature added to version 14.1 of ICP. This display allows the user to plot any of the time series defined in the control file rather than just the mean daily flow time series used by the WY-PLOT operation. Any one Plot Time Series display can have up to 6 plots of different time series using the same time scale. All the time series on each plot must have the same units, but the data units can vary from one plot to another. The time intervals of the time series on a given plot, as well as from plot to plot, can vary. As with WY-PLOT, multiple PLOT-TS operations can exist in the MCP Control File and thus there can be multiple Plot Time Series displays within ICP. Since this was a new feature in the last official release of ICP before Hillel's death, a number of bugs existed. These problems have limited how much the users have relied on this display. Several of the problems were fixed by Hillel in the months after the version14.1 release, but never were incorporated into an official version of ICP. These fixes make it much easier to use the Plot Time Series display. This author exclusively uses the version of ICP that includes these fixes and has used this version for training at a number of RFCs (thus some RFCs have copies of this version and may be using it for calibration even though it is now over 3 years old).

Currently when Plot Time Series is chosen under the ICP Display menu, the user must select between displays for the .curr, .prev, and .best control files. In the future no such selection will be needed. In the current version once the control file is selected the Plot Time Series window appears. The user must then use the Select menu to choose which of the PLOT-TS operations is displayed (the features under the Control menu have no function for this window). This should be changed so that the Plot Time Series display is just like the Water Year Plot display, i.e. when Plot Time Series is selected under the ICP Display menu, the first PLOT-TS operation in the control file should be displayed. This intermediate window should not appear. This change is noted as item 5 under CHANGES SUGGESTED FOR VERSION 14.1 in Appendix B, but is more clearly defined here.

The general form of the Plot Time Series display has been readily accepted by the users. Thus, the Plot Time Series display should remain exactly as in the current version of the program except for the following:

a. Fixes for existing bugs and suggested changes noted in Appendix B should be made unless overridden by subsequent items in this list. This includes items 9,10,11,12,13,15, and 19 under EXISTING BUGS IN VERSION 14.1 and items 4 and 10 under CHANGES SUGGESTED FOR VERSION 14.1.

b. The display for each PLOT-TS operation should include a title after the words Time Series Plot in the panel at the top of the display as for Water Year Plot displays.

c. For the Change Analysis option under the Control menu of the Plot Time Series display, the Control menu should be removed from the PLOT-TS Display Adjustment window (currently only contains a Close option which is already included as a button at the bottom of the window). Only the Select menu would remain - allows the user to choose for which plot the scales are to be changed (note that changes to the duration affect all plots since only one time scale is used). At the bottom of the window an Okay button (apply and close) should be added like on the change analysis feature for the Water Year Plot display.

d. For the Show Legend option under the Control menu of the Plot Time Series display, the information for each time series on each plot should be color coded to match the plotted line for that time series (like the legend for the Water Year Plot display). This is also noted as item 12 under SUGGESTED CHANGES FOR VERSION 14.1 in Appendix B.

e. The items under the Select menu of the Plot Time Series display are the identifiers of each PLOT-TS operation that is included in the control file. This could be a tear-off just like for the Water Year, SAC-SMA, and Snow-17 operations under the Select menu for the Water Year Plot display. This would

reduce the number of mouse clicks when switching from one Plot Time Series display to another. This is not a critical feature and shouldn't be done until the program can successfully switch from the display for one PLOT-TS operation to the display for another. Currently the program coredumps or doesn't function correctly when such a switch is attempted (included as item 19 under EXISTING BUGS IN VERSION 14.1 in Appendix B).

f. The Help menu on the main Plot Time Series display should be moved over to the right side so it is consistent with the Water Year Plot display. Currently there are no Help items for either display.

g. The capability needs to be added to the Plot Time Series display to edit time series. This is mentioned as item 6 under CHANGES SUGGESTED FOR VERSION 14.1 in Appendix B, but is defined differently and with more detail in this report. This feature is primarily needed for MAT time series in order to get the form of precipitation correct. The MAT time series for the watershed (more than one if multiple subareas used) would be shown on one of the plots for the Plot Time Series display. Other plots would show information such as precipitation, observed snowfall, simulated water equivalent, and simulated and observed discharges needed to decide whether the temperature values should be altered. Based on the information shown, MAT values could be changed as needed. There may be other data types that also could be edited using this capability, however, editing should only be allowed for MCP INPUT time series.. The proposed features and rules to follow to edit time series using the Plot Time Series display are as follows:

- Add an Edit menu to the Plot Time Series display with two options. The first option would be Select Time Series and the second would be Save Values.

- When Select Time Series is chosen, the user would be asked first to choose the plot that contains the time series to be edited. Time series on only one plot on only one of the Plot Time Series displays could be undergoing editing at any given time. Next, all the time series on the selected plot that are eligible for editing (i.e. MCP INPUT series) would be shown and the user would indicate which should be changed (note that all the time series for a given plot will have the same units). If the plot doesn't contain any INPUT time series, none would be shown and the user would have to select another plot. A copy of the chosen time series should then be stored for use during the editing process.

- When the user right mouse clicks on the plot selected for editing, rather than the x-y window that currently appears (window containing date and value of time series closest to the pointer) two new windows would appear for use in

making the edits. Both of these windows would contain values for all time series to be changed for a three day period; the day associated with the pointer location and the days before and after. The first window would graphically show the data values for the 3 day period for all the time series selected for editing (each time series in a different color). The second window would show the actual data values in a table (first column would be time and subsequent columns would contain the values for each time series). This second window would contain a button below each data value column labeled Restore Original and three buttons at the bottom of the window labeled Save & Close, Cancel & Close, and Reset Last Value. These windows would be somewhat analogous to the windows currently used to edit ET-Demand values for the Sacramento model and unit hydrograph ordinates. An example of what these windows should look like is shown in Figure 1. The windows should be large enough for the user to clearly see what is being done, but not so large as to hide much of the Plot Time Series display.

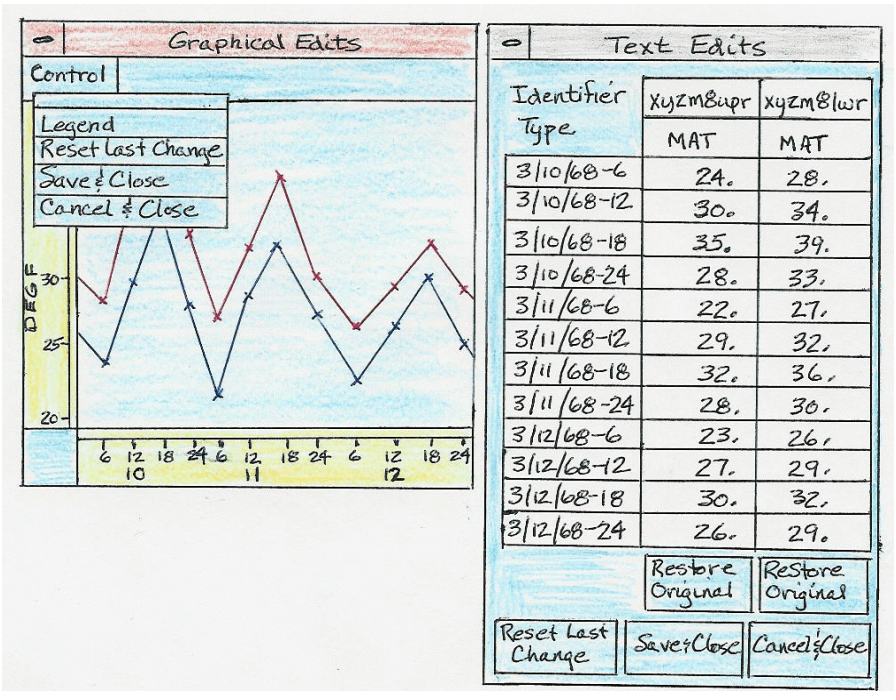

Figure 1. Example Windows for Editing Time Series.

• The user could specify changes to the time series values by clicking on a plotted value and dragging it to a new value in the first window or by changing a text value in the second window. Changes made in one window should be reflected in the other. Changes would be made one value at a time. When all the changes were made, the user would click on Save & Close and the new values would replace the previous values in the copy of the time series. If Cancel & Close were selected, no changes would be made to the time series. Restore Original would set the values back to those that existed prior to the two windows appearing. Reset Last Change would merely reset the last value changed without resetting any other values.

• The user would go through the Plot Time Series display making edits to as many periods as needed. The user would get a chance to replace the original time series with the edited versions when the following occurred:

◦ When the Save Values option is selected under the Edit menu,

◦ When Run MCP is selected under the Control menu of ICP,

◦ When the user Quits the Plot Time Series display or switches from the display for one PLOT-TS operation to another, or

◦ When the Exit option is selected under the Control menu of ICP.

When any of these situations occur after edits have been made to a copy of the time series, a window will pop up asking the user what to do. The choices at this point would be: overwrite original time series with the edited copy or cancel the editing process. If Cancel is selected, a window should appear asking the user if they are sure that they want to ignore the edits that have been made. If the user clicks on OK, no changes are made to the original time series and the temporary copies are deleted. If Overwrite is selected, the edited copy of the time series would replace the original internally in ICP and the Datacard image files containing the time series would be overwritten.

• If the user wants to save the original time series, the Datacard image file for those time series should be copied to a new file using UNIX commands prior to overwriting the files. By using the Save A Time Series and Reload A Time Series options under the Control menu for the Plot Time Series display, the user could display the unedited version of one of the altered time series after MCP was rerun and the Plot Time Series display was refreshed. Since currently only one time series per plot can be saved and reloaded, prior versions of multiple edited time series could not be displayed.

3. Statistics - a graphical statistics display will be a new major enhancement to ICP.

This proposed features for this display are described under the Major Enhancement for ICP section of this report.

4. Text Output - this option will result in the text output from all operations that don't have graphical output to be shown in a new window. Text output from all operations will be included if this feature was chosen under the Select Watershed option of the ICP Control menu. The text output is currently displayed using the Edit Wide Listing option under the ICP Edit menu (misnomer since no editing involved). It was proposed to be changed to View MCP Listing in item 2 of the CHANGES SUGGESTED FOR VERSION 14.1 in Appendix B, however, it would be better to use the term Text Output and put it under the ICP Display menu rather than the Edit menu. The output can be just like it is in the current version of ICP.

C. EDIT menu - this menu currently contains 3 options: Edit Deck, Edit Wide Listing, and Selected Parameters. In the future there will also be 3 options which will be: Edit Control File, Save Control File, and Selected Parameters.

1. Edit Control File - this option will allow the user to edit the watershedname.curr control file using an editor just like in the current version of ICP. Since only a .curr file will be used by future versions of ICP, the file selection and override warning windows will no longer be needed (reduces the number of mouse clicks). When choosing Edit Control File, the .curr version of this file will immediately be made available for editing. Since much of an MCP control file is in fixed format, it would be better to use an editor that showed columns (like nedit) than the current editor used by ICP.

2. Save Control File - Even though the user can use UNIX commands to make a copy of an MCP control file at any time, it would probably be helpful to allow this to be done via ICP. By making this option a part of the Edit menu, the user would be reminded that there is the option to save a version of the control file prior to making changes. This option would bring up a window showing the current files in the watershedname directory and then let the user choose an existing file (not .curr) or a new file suffix into which the existing .curr file would be copied.

3. Selected Parameters - this option would function like it does in the current version of ICP. Special features would be available for changing the parameters for those operations that are most frequently modified during a calibration. As with the current ICP, this should include the SAC-SMA, SNOW-17, and UNIT-HG operations (the API-CONT operation should be removed from the list until code is actually added to ICP to change parameters for this operation). Since ICP will only use the .curr control file in the future, the file selection and override warning windows will no longer be needed. The program will go directly to the window for the chosen operation. The features currently in ICP for changing selected parameters should be kept, thus this option should remain exactly as in the current version of the program

except for the following:

a. Bug fixes and minor changes specified in Appendix B should be made. These are item 2 under EXISTING BUGS IN VERSION 14.1 and item 1 under the CHANGES SUGGESTED FOR VERSION 14.1.

b. The selected parameter editing feature for the SAC-SMA operation should be expanded to allow the user to change the initial state variables. These frequently need to be altered when parameter values are changed. Currently the initial values must be changed via the Edit Deck option (result is that users seldom make the changes that should be made). The initial state variables (UZTWC, UZFWC, LZTWC, LZFSC, LZFPC, and ADIMC) should be added below the parameters for each SAC-SMA operation. An On/Off option should be provided to automatically adjust the initial state variables based on parameter changes. Manual changes could be made at any time. If the automatic change option is On (initial default value), the following rules should be used for adjusting the initial state variables when parameter values are changed:

• Tension water deficits should be preserved unless this causes the initial contents to be less than 0.0. In that case the value is set to 0.0. Also if initial tension water states are greater than the capacities, the contents should be set to the capacity. This affects UZTWC, LZTWC, and ADIMC.

• The value of UZFWC is maintained unless it is greater than UZFWM, in which case UZFWC is set equal to UZFWM.

• The values of the initial supplemental and primary storages are adjusted to maintain the same initial outflow from each groundwater component unless this causes the contents to exceed the capacity (if contents exceed the capacities initially, the contents should be set equal to the capacity). The equations to use in this case are:

$$LZFPC_2 = LZFPC_1 \bullet \frac{LZPK_1 \bullet (1 - ADIMP_1 - PCTIM_1) \bullet (1/(1+SIDE_1))}{LZPK_2 \bullet (1 - ADIMP_2 - PCTIM_2) \bullet (1/(1+SIDE_2))}$$

$$LZFSC_2 = LZFSC_1 \bullet \frac{LZSK_1 \bullet (1 - ADIMP_1 - PCTIM_1) \bullet (1/(1+SIDE_1))}{LZSK_2 \bullet (1 - ADIMP_2 - PCTIM_2) \bullet (1/(1+SIDE_2))}$$

if $LZFPC_2 \rangle LZFPM$, then $LZFPC_2 = LZFPM$, and
if $LZFSC_2 \rangle LZFSM$, then $LZFSC_2 = LZFSM$

c. The UNIT-HG operation changes are currently limited to modifying the shape of the unit hydrograph. The sum of the ordinates are automatically maintained as the shape is changed. The following additional changes should be allowed in the future (all changes would be implemented by clicking on Curve in the initial UNIT-HG editing window and then making the change either via the plotted unit hydrograph or the text listing of the ordinates):

- The number of ordinates by adding or removing ordinates with a value of zero. Non-zero ordinates cannot be removed. A number of ordinates text box would be added to the text listing of the ordinates. This value could then be changed by the user and the result shown by regenerating the plot and text listing (note that the control file is not changed at this point). If non-zero ordinates were attempted to be removed, a message would indicate that the change is not allowed.

- An option to change the area associated with the unit hydrograph (item 3 under the CHANGES SUGGESTED FOR VERSION 14.1 in Appendix B) should be implemented by adding a drainage area text box to the text listing of the ordinates. This should be the drainage area computed from the unit hydrograph ordinates and not the user specified area. The user could then change this area and all the ordinates would be multiplied by the ratio of the new area to the old area.

- The time interval associated with the unit hydrograph. The new time interval must be a multiple of the old interval or divide evenly into the old interval. The number of ordinates will change as the time interval is changed. If the time interval is increased, the new time interval must not be greater than the old interval multiplied by the old number of ordinates. This would be implemented by adding a time interval text box to the text listing of the ordinates. The user could then change this value. If the time interval is decreased, the new ordinates are determined by linear interpolation between the initial ordinates. If the time interval is increased, the new ordinates are determined by using the ordinates of the initial unit hydrograph that occur at the new interval spacing. After new ordinates are generated, they should be adjusted to match the drainage area associated with the initial unit hydrograph.

- The shape of the unit hydrograph should be done as it is now except that when a point is dragged to the bottom of the plot, the ordinate value should go to zero (currently it can't be set to zero by this manner, instead the text listing must be edited to set values to zero).

The equation that is used to compute the drainage area from the unit hydrograph ordinates is:

$$A = \frac{\sum_{i=1}^{N} ord_i}{C \bullet (24/\Delta t)}$$

where: A = drainage area (English units - mi^2, Metric - km^2),
C = conversion factor (English - 26.9 cfsd/in/mi^2 and
Metric - 0.011574 cmsd/mm/km^2),
Δt = time interval (hours),
N = number of ordinates, and
ord_i = ordinate values.

The buttons at the bottom of the text listing window will remain the same. Save & Close will save the changes and close the plot and text listing windows. Restore Original will restore everything to the initial values when Curve was selected in the Edit UNIT-HG window. Reset Last Change will merely reset the last change made. Cancel & Close will close the windows but leave the unit hydrograph unchanged.

Major Enhancement for ICP

The highest priority enhancement that is needed for the ICP program is a more versatile way of statistically analyzing and comparing time series using graphical output. The only statistical information currently available during calibration is text output from the STAT-QME operation. This operation is limited to computing mostly numerical statistics between observed and simulated mean daily flow time series. Any other statistical information must be generated by saving time series to a file and then analyzing the data with a separate program. What is needed is the ability to generate a variety of statistical information from any of the time series used for calibration and have much of the output be in graphical form so that the user can more easily interpret the results.

The proposal offered in this report is to add a new operation to MCP that will be referred to as the STAT-ICP operation and then use ICP to graphically display the information generated by the operation. This is analogous to how the ICP Water Year Plot and Plot Time Series displays are currently produced. By using a new operation to define the statistics available for display, the time series involved, and any options or parametric information needed, it would be very easy to make all the checks that are required. The Parameter Input (PIN) routine for an operation can quickly check to make sure that the time series have been defined and contain data values. Also an STAT-ICP operation could be inserted at any point within the operations table where the time series contain the values that the user wants to analyze. This is important since in many cases time series are modified several times throughout the sequence of operations. The parametric information for the statistical display will be stored in the .curr MCP Control File just like for any other operation. The Execution (EX) routine for the operation could compute numerical quantities for each statistic, if appropriate, and then write these and the other data

needed, such as the time series values themselves, to a temporary file for use by ICP. This is exactly how the current ICP displays function. There would be no text output from the STAT-ICP operation other than a summary of the definition information from the Print Parameter (PRP) routine. A single STAT-ICP operation could be used to define all of the statistics to be displayed by ICP or multiple STAT-ICP operations could be included as needed.

An alternative that was considered was to allow the user to interactively define which statistics to display and the time series, options, and parametric information needed. The statistics control information specified in this manner would need to be stored somewhere for use in generating the displays (the other option would be for the user to make this selection every time a display was needed which would be time consuming and unreasonable). The control information could be stored in another file in the watershedname directory such as a .stat file. This alternative would require that all of the time series be written to a temporary file as MCP was being executed so that the data to generate any specified statistic would be available to ICP. This alternative was rejected for several reasons. First, it would be more difficult to check the definition information. The MCP Control Deck would have to be read to determine which time series were available and if the time series contained data values. The code needed to determine whether a time series contains data values would be significant whereas, MCP already has routines to make this check for an operation. Second, the time series values written to the temporary file (most likely those that exist at the end of the operations table) may not be the ones that the user wants to analyze since time series can be modified multiple times in the sequence of operations. Third, since in this alternative the MCP Control File could be changed independent of the statistical controls, incompatibilities could result. The net result would be that the checks at definition time couldn't guarantee that the displays will contain the proper information or can even be produced. This would require that additional checks are made when the statistical display is requested from ICP. Overall this alternative would shift much of the responsibility for insuring that the definition information was correct and the desired results would be produced from the computer code to the user. Thus, this alternative was rejected.

Rather than manually preparing the MCP Control File, the input could be generated interactively. This could be done for the entire control file or only for selected operations such as STAT-ICP. The results would then be checked when the MCP was run. This has been considered in the past, but rejected primarily because the benefit gained didn't seem to match the effort required. It is not very difficult to generate a MCP Control File. The major requirement from the RFCs is to be able to visually analyze model results in an interactive manner, not the preparation of model input control files. Operationally this is why the effort was focused on the Interactive Forecast Program (IFP) and not on interactively producing segment definitions.

The statistical display for ICP could contain a wide variety of different statistical information. Appendix A contains a list of some of the possible statistics to include and some sample descriptions of the input needed and graphical output that could be provided. The initial release of ICP with a graphical statistics package might only include a few of the statistics with others added as they are requested and resources are available. Most of the statistics needed for calibration will involve the comparison of two time series though the statistical analysis of single

or even multiple time series could also be helpful in some cases. Detailed descriptions of all the statistics to be added to ICP are not needed until there is a definite commitment to add this feature to the program.

I. STAT-ICP Operation - this operation would require Parameter Input (PIN), Print Parameter (PRP), Operations Table Entry (TAB), and Execution (EX) routines as described in section VIII.4 of the NWSRFS User's Manual. Even though carryover space may be used for certain numerical computations, Print Carryover (PRC) and Carryover Transfer (COX) routines are not needed since carryover would not be input by the user and this operation would only be for calibration use. It is not the intention of this report to include a design for the STAT-ICP operation, but some description of the function of the PIN and EX routines is warranted.

A. Parameter Input (PIN) routine - this routine reads the control information for the operation and makes the necessary checks to insure that there will be no problems during execution. The input will primarily consist of a specification of each statistic that the user might want to display with ICP. An 8 character statistic type identifier could be used to indicate the statistics needed. For each statistic the user would need to specify the time series involved. The PIN routine would then make the necessary checks on the time series. Also for each statistic there could be various options or parametric information that need to be specified and checked. Any required carryover or scratch file space required would be initialized.

B. Execution (EX) routine - this routine is called by MCP on a monthly basis. The time series values for the month and the carryover at the beginning of the month are provided to the routine. Numerical computations would be performed, if needed, on the time series values to obtain the information that would be required for the ICP statistical displays. These values, as well as the time series themselves in the case of many of the statistics, would be written to a temporary file for use by ICP when a graphical display is requested by the user. Carryover values would be updated. There would be no text output other than for debugging purposes.

II. ICP Statistical Display - as mentioned previously, Statistics will be one of the options on the Display menu for ICP along with Water Year Plot, Plot Time Series, and Text Output. When Statistics is chosen, it is proposed that a window appear listing the statistics that can be displayed for the first STAT-ICP operation in the MCP Control File. This window will have a Control and Select menu. The Control menu will contain a Quit option like for the Water Year Plot and Plot Time Series displays. The Select menu will be a tear off that allows the user to switch from one STAT-ICP operation to another and to refresh the displays (again the same as for the Water Year Plot and Plot Time Series displays). For each statistic listed for a given STAT-ICP operation, the time series involved (identifier, type, time interval, and keyword (only for multiple value series)) will be shown along with a Display button. The user will decide which of the statistics are to be shown at any given time for a given STAT-ICP operation. When the user clicks on the Display button for a given statistic, a window will appear containing the main graphical output for that statistic (samples of the displays for

some of the proposed statistics are shown in Appendix A). If the user switches to display statistics for another STAT-ICP operation or Quits the Statistics display, all of the windows showing statistical output will be closed. Whenever MCP is rerun, the user will need to click on the currently displayed STAT-ICP operation on the Select menu in order to refresh the output (similar to the other displays). If the user selects a different STAT-ICP operation after MCP is run, the existing statistical output windows will be closed and the user must then choose which statistics are to be displayed for the newly selected operation.

The main graphical output window for each statistic will typically contain two menus. The Control menu will include a Legend option to indicate the colors used for each time series and a Close option. Options could also be included so that the user could save selected output and then reload those values after MCP was rerun so that the effect of the model parameter changes on certain statistics could be seen. The Select menu will be used to choose addition plots to be generated in addition to the main graphical display for the given statistic.

Other Possible Future Enhancements

While a versatile, graphical statistical display is the most important feature that needs to be added to ICP, there are several other enhancements that should be considered as resources are available. Detailed descriptions of these enhancements are not needed until there is a commitment to add these features to ICP. Other Enhancements to consider include:

I. Snow Areal Depletion Curve Analysis - this enhancement would be added to the Water Year Plot display under the Analysis menu (currently Percolation is the only option on this menu). This feature is needed in order to assist the user in deciding how to change the SNOW-17 model areal depletion curve. The user would be able to see what the depletion curve looked like (including snow on bare ground variation) and where the model was on the curve at any selected point in time. The user could then make a mark to indicate how the curve should be changed to improve that case (like with the percolation analysis). After going through a number of years of data, the user could see if a pattern emerged indicating how the curve should be adjusted.

II. Sacramento Model Time Lapse - the Water Year Plot display currently contains graphical output showing the model states and the relative magnitude of each component of runoff on a daily basis. In many cases it would be helpful to see what is happening internally within the model from one time interval to another. A bucket display like those used in part 4 of the NOAA video "Calibration of the Sacramento Soil Moisture Accounting Model" could be generated for this purpose. The user could start the display at any point in time and increment from one time interval to another either manually or in a time lapse mode. This feature would be linked to the Water Year Plot display. Such a feature would not only assist the user to understand what was taking place during an event, but would also be very valuable as a training tool.

III. SNOW-17 Model Time Lapse - would show how the snow cover states and energy exchange varies from one time interval to another similar to the proposed Sacramento Model time lapse display. The form of the output is uncertain at this point. Such a display would assist the user to understand how the model is functioning during various events and again would be valuable as a training tool. The feature would also be linked to the Water Year Plot display.

Summary

Properly calibrated models are critical to producing accurate short term river and flood forecasts with a maximum lead time and are essential for providing extended streamflow predictions. The Interactive Calibration Program (ICP) is undoubtedly the most important tool available for model calibration. ICP not only allows users to calibrate models in an efficient manner, but it gives the forecasters necessary insights into how the models operate in order to effectively make real time adjustments and properly use the models to generate operational forecasts. The graphical displays produced by ICP allow the users to visualize how the models work and what is taking place during each segment of the historical record. The interactive features allow the users to quickly change model parameters and options and evaluate the results. ICP is used extensively as the RFCs calibrate and recalibrate watersheds for operational applications. The Advanced Hydrologic Prediction System (AHPS) is predicated on properly calibrated watersheds. Thus, in the AHPS era it is even more important that ICP be the most effective calibration tool possible. Very little has been done to maintain and enhance ICP in recent years. Fortunately the current version has been widely accepted by the RFCs and contains most of the features they need in order to meet their calibration objectives. However, there are a number of bugs that limit the effectiveness of the current version and several enhancements needed to improve the usefulness of the program. It is critical that a tool like ICP that is so important to the NWS Hydrology Program be maintained and enhanced. This report proposes a number of changes and enhancements that would improve the efficiency and usefulness of ICP.