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Preliminary Analysis System for Water Surface Profile Computations (PAS) User's Manual

Hydraulic Computer Program HY-11

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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FOREWORD

This Implementation Package contains user instructions for PAS, a microcomputer program that is designed to assist in stream geometry data development for water surface profile computations. PAS enables the user to study the relationship between the desired accuracy for a water surface profile and the cost of acquiring the data. PAS has been designated HY-11 in the Federal Highway Administration Hydraulics Computer Program series.

Copies of the manual are being distributed to Federal Highway Administration Regional and Division offices and to each State highway agency. Additional copies of the manual and program are available from McTrans, the Center for Microcomputers in Transportation, Gainesville, Florida 32611, and the National Technical Information Service, 5280 Port Royal Road, Springfield, Virginia 22161.

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NOTICE

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16. Abstract

The Preliminary Analysis System for Water Surface Profile Computations (PAS) - User's Manual describes and illustrates the use of a microcomputer program to assist in stream geometry data development for water surface profile computations. The program implements the findings of the research project "Accuracy of Computed Water Surface Profiles," (Hydrologic Engineering Center, 1986) and incorporates features for preliminary hydraulic computations based on limited data.

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**PRELIMINARY ANALYSIS SYSTEM FOR
WATER SURFACE PROFILE COMPUTATIONS
(PAS)**

USER'S MANUAL

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INTRODUCTION

1. **Background and Overview.** The Preliminary Analysis System for Water Surface Profile Computations (PAS) computer program is designed to assist in data development for profile computations. It makes use of the findings of a research project on computed water surface profile accuracy and incorporates features for preliminary hydraulic computations based on limited data. The program enables study of the relationship between desired accuracy for a water surface profile; the technology and accuracy of survey and map data for defining stream geometry; the areal extent of needed data collection; and the cost of acquiring the data. The preliminary hydraulic computations estimate normal, critical, and hydraulic depths and flow area, top width, and similar parameters. The accuracy analysis, data collection needs, and hydraulic computations are based on user-provided preliminary stream geometry and roughness such as would be developed in a field reconnaissance.

PAS is a microcomputer program designed specifically for the interactive PC environment. Options are selected and data entry is provided via the keyboard. Graphic displays and hard copy output are selected by pressing function keys. A data base of input data and output results is created and retained for use in subsequent analysis sessions.

This user's manual provides installation and operating instructions, program capability description, and an illustrated example. Appendices contain listings of error messages and valid data ranges.

The PAS program is maintained and distributed by the Hydrologic Engineering Center, Water Resources Support Center, U.S. Army Corps of Engineers, 609 Second Street, Davis, California 95616. This agency should be contacted for any questions regarding its use or availability.

2. **Acknowledgements.** PAS was developed by the Hydrologic Engineering Center under contract to the Federal Highway Administration as a follow-on activity to the research study that is documented in *Accuracy of Computed Water Surface Profiles* (Hydrologic Engineering Center 1986). The research report and supplement *Commercial Survey Guidelines for Water Surface Profiles - Supplement*, (Hydrologic Engineering Center 1987) provide additional detailed documentation relative to computed profile accuracy.

3. **Hardware and Software Requirements.** The PAS program code is FORTRAN 77 with supplementary proprietary machine language routines used for keyboard and screen interactions and graphic displays to the monitor. The keyboard/screen routines are the product of Spindrift Library, Spindrift Laboratories, 116 South Harvard Avenue, Arlington Heights, IL 60005. The graphic routines are the product of GRAFMATICS by MICROCOMPATIBLES, Inc.,

301 Prelude Drive, Silver Spring, MD 20901. The program is provided in executable code form that includes the proprietary routines. The HEC has been granted permission to provide the code in this form to all requesters.

Program Language: FORTRAN 77

Operating System: MS DOS 3.1 or higher

Minimum Hardware Requirements:

- IBM Personal Computer or 100 percent compatible
- 640K random access memory (RAM)
- 20 Mb hard disk
- 5-1/4 internal flexible disk drive, capacity 360K or 1.2Mb
- 25 line, 80 character/line color/monochrome monitor with graphics adapter.
- (optional for hard copy graphics output) IBM-compatible graphics printer

Files provided on Installation Diskette:

- PAS.ARC - compressed archive file containing the following:
  - PAS.EXE - PAS executable program file,
  - STRMFILE - data base file for PAS containing test example BEAR CREEK,
  - PAS.INI - definition file for user's graphics monitor and program color settings,
  - PAS.HLP - help file for PAS program,
  - PAS.SCR - screen file for PAS program,
- PKXARC.EXE - executable program needed to un-archive PAS.ARC, and
- PKXARC.DOC - documentation for program PKXARC.EXE.

4. **Installation Instructions.**

   a. Create subdirectory on hard disk,

      e.g. type **MD PROFILE** and press <Enter>

   b. Change to subdirectory,

      e.g. type **CD C:\PROFILE** and press <Enter>

   c. Insert diskette in drive A (or B), close door and type:

      A:PKXARC A:PAS and press <Enter>

   d. Answer questions if requested.

5. **Quick Start.** Initiate program session:

      type **PAS** and press <Enter>

An opening screen and message will appear that contains credits and disclaimer information. Press any key and the PAS program opening menu will appear. The cursor will be located at the CROSS SECTION DATA ENTRY option location. Press the F1 function key. Read the resulting general opening help message through to completion - all four pages. Instructions on program usage, cursor movement convention, function key usage, and program help message features are included.

The program operating environment default is white foreground color on black background color and Color Graphics (CGA) monitor. To change to your own color preference and hardware configuration, select the SYSTEM ENVIRONMENT option by pressing the letter corresponding to the option or moving the cursor to the option and pressing the enter key. Follow the instructions and return to the main menu when completed by pressing the F10 key. Subsequent program sessions will use the color and monitor selections specified in this session.

Now move the cursor to each option on the opening menu in turn and call up the general help messages (with the <Alt> F1 key). This should be done before continuing with program operations. A test data set is included in the data base and may be accessed by entering the stream ID of BEAR CREEK where requested. The practice example (DRY CREEK), contained later in this document, can be used for a complete data entry and analysis session to acquaint the user with the PAS program.

DATA ACQUISITION FOR PROFILE ANALYSIS

6. **General.** Several important decisions are required early when conducting water surface profile studies to ensure complete and efficient acquisition of basic data. The range of flows to be studied is required to determine the potential areal extent of flooding. The geometric representation of the stream reach of interest is essential. The lateral bounds and upstream and downstream study limits are needed to delimit mapping extent. Roughness estimates are important to the reliability of the computed profile accuracy. Some idea of the acceptable level of accuracy of the computed profile is required. It is essential to understand that the accuracy of a computed profile is dependent on the accuracy of the geometric representation of the stream and degree of reliability of roughness coefficient estimates.

The PAS program is specifically designed to assist in determining the lateral and longitudinal extent of stream geometry data acquisition and roughness estimation. It also provides specific estimates of subsequent computed profile accuracy as a function of geometric data acquisition technology, accuracy of geometric data, and reliability of estimates of hydraulic roughness. Finally, the program provides the capability for comparing the cost of alternative geometric data acquisition methods for the specific stream reach and hydraulic characteristics under study.

7. **Stream Reach Determination.** Figure 1 is a sketch depicting stream reach determination. Calculations, and thus data collection, must be initiated sufficiently far downstream to assure accurate results at the beginning of the study area. Calculations must also be continued a sufficient distance upstream to accurately determine the impact of stream modifications or structures on upstream water surface profiles.

The downstream study length is governed by the effect of errors in the starting water surface elevation on the computed water surface elevations at the beginning of the study area. Two commonly applied starting water surface elevation criteria are critical depth and normal depth. The starting location should be far enough downstream so that the computed profile converges to the base profile prior to the beginning of the study area.

The upstream study length is the distance where the profile resulting from the upstream-most locally created headloss converges with the profile for the undisturbed condition. This distance is a function of headloss, stream hydraulic properties, and discharge.

The profile accuracy research study derived study reach prediction equations through extensive analysis of a large number of natural stream data sets. The PAS program uses these

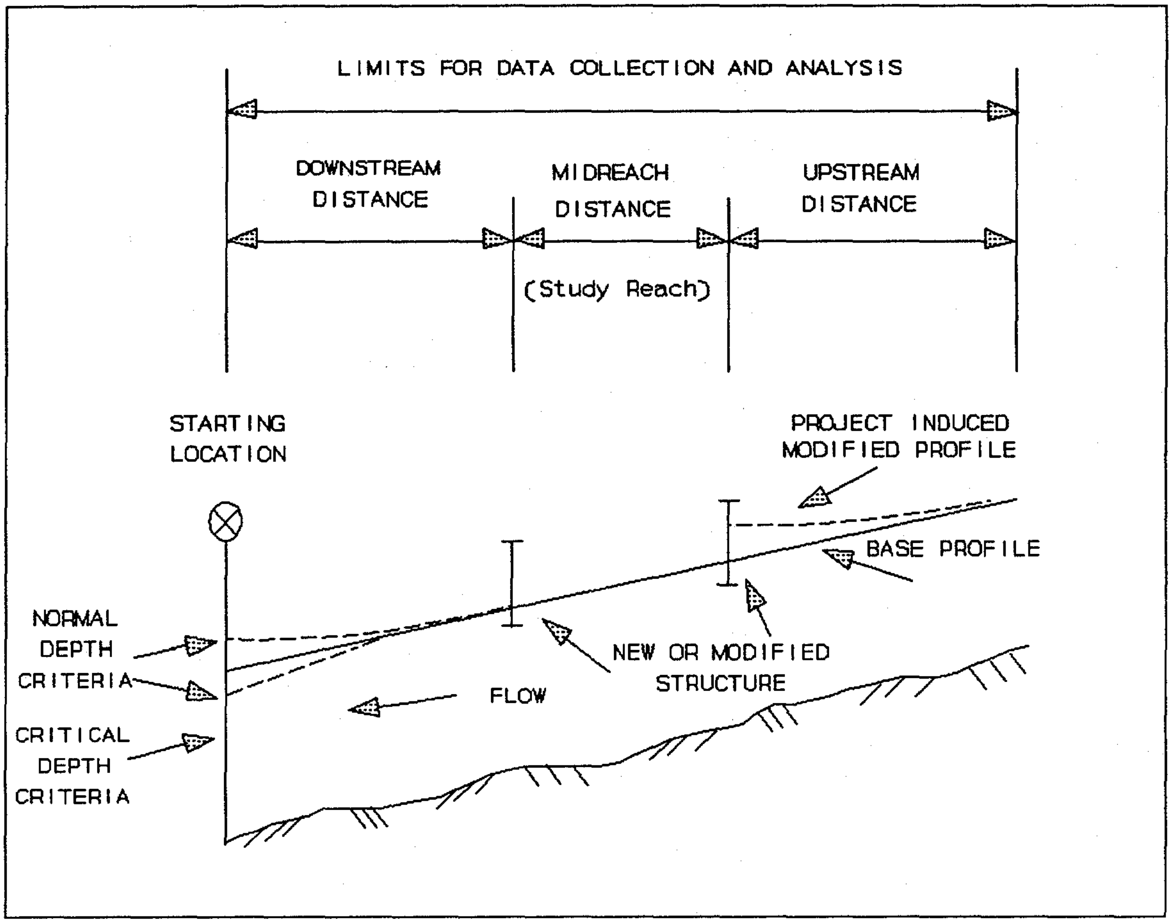


Figure 1 - Stream Reach Determination

equations to estimate study reach lengths based on preliminary stream hydraulic information provided by the user.

8. **Computed Profile Accuracy.** The accuracy of a computed profile depends on a number of complex factors. Several important ones are: applicability of profile calculation theory, numerical solution methodology for the computation theory, and basic data defining the profile calculation system. It is assumed that professional engineering judgment will govern selection and application of appropriate theory; and that the methodology employed by the analyst in his work uses reliable numerical solution methods. It is further assumed that the flow system is correctly represented by appropriate placement of cross sections, specification of effective flow areas, and accurate representation of flow lengths. The remaining item then is the basic data used for defining the profile computation system. Focus herein is on data defining stream geometry and hydraulic roughness for one-dimensional, subcritical, steady-flow conditions.

Figure 2 is a sketch of the relationship between the natural cross section and the surveyed representation of the geometry used for computations. The survey method employed to define the coordinate points will have an impact on the accuracy of the cross-sectional representation (and thus the accuracy of the computed water surface profile).

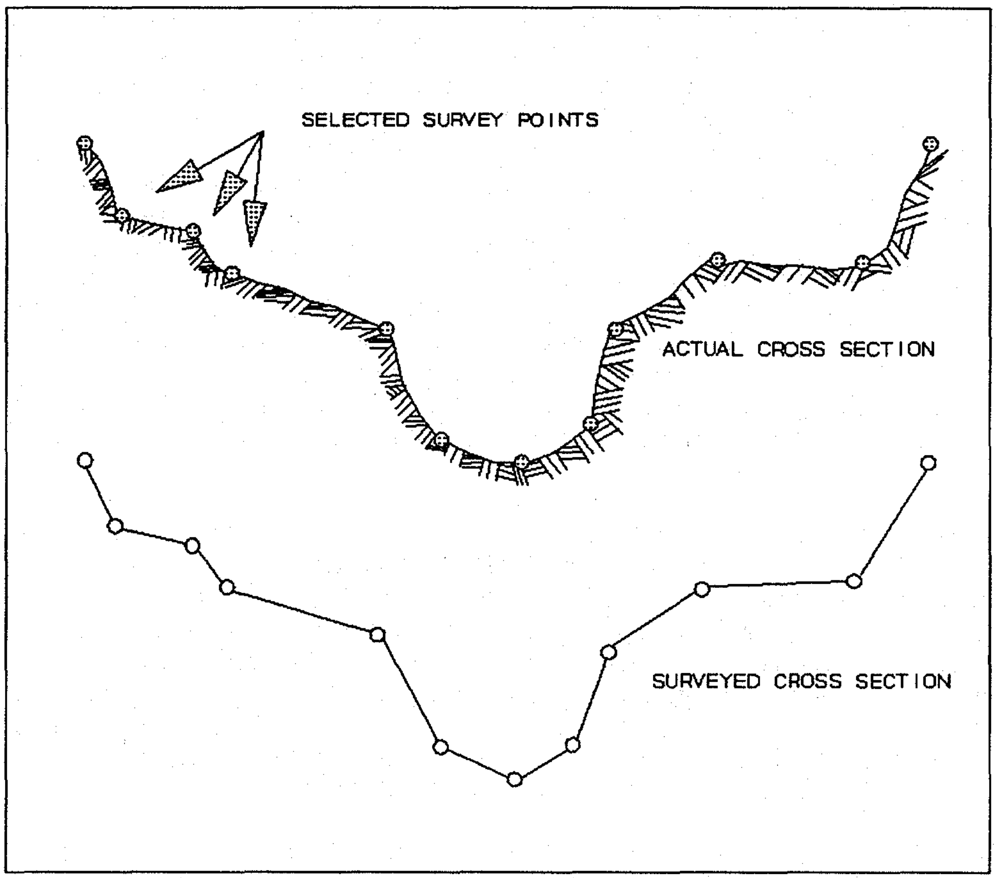


Figure 2 - Cross-sectional Concepts

The profile accuracy research project investigated the relationship between the survey method, specified accuracy of the method, and accuracy of the computed profile. The research project also investigated the influence of the reliability of estimating the channel hydraulic roughness on the computed profile accuracy. The research resulted in development of prediction equations in which computed profile accuracy is a function of survey (map) technology, survey (map) accuracy, and reliability index of hydraulic roughness. The study was performed using 98 natural stream data sets used in computing the 1% chance exceedance water surface profile. A Monte Carlo simulation strategy was employed in which stream geometry was stochastically adjusted for alternative survey methods and accuracy, hydraulic roughness stochastically adjusted for alternative reliability of estimates, and subsequent changes on computed water surface profiles studied. The result is the family of prediction equations that are incorporated in the PAS program. The details of the analysis and derivation of the prediction equations are contained in the final research report (Hydrologic Engineering Center, 1986). The prediction equations are documented in the equations appendix (Appendix D).

9. **Survey/Mapping Cost.** The survey/mapping methods, suitable for stream geometry determination, investigated in the profile accuracy research project are the following: conventional field surveys, aerial spot elevations, topographic maps derived from aerial photogrammetry methods, and hydrographic surveys. The accuracy levels considered are the following: no error (the assumption for field surveys), and 2-ft., 5-ft., and 10-ft. contour intervals. Table 1 defines the accuracy specifications for aerial spot elevations and topographic maps. The accuracy level for hydrographic surveys for within channel geometry is assumed to be the same accuracy as that of the survey method selected for the overbank areas. The cost of stream geometry data acquisition is a function of the survey method employed, survey difficulty due to terrain and land cover, data reduction from survey method to computation input format, and regional cost differences.

The reference for the profile accuracy research project (Hydrologic Engineering Center 1987) documents the details of the survey methods investigated, the cost of cross-sectional data acquisition for the methods, and the general guidelines for cross-sectional geometry determination. A supplemental investigation was performed to develop the survey cost data table in the format to be used by the PAS program. Appendix E contains the table developed in that investigation that forms the basis for the default survey cost data contained in PAS.

10. **Hydraulic Computations.** PAS computes a number of hydraulic parameters needed for the technical analysis of stream reach length estimation, computed profile accuracy, and survey cost analysis. The parameters are also useful as preliminary estimates of important hydraulic characteristics of the stream to be studied in detail later. The stream reach is characterized by up to 5 representative cross sections each defined by eight coordinate points, a discharge, and hydraulic roughness values. The discharge is assumed to be a preliminary estimate of the 1 percent chance exceedance flow so that the hydraulic parameters computed are consistent with the prediction equations used to estimate stream reach lengths and computed profile errors. PAS then computes the normal depth and critical depth for each of the cross sections.

The computational algorithms used in PAS were developed by Robert G. Traver, Ph.D. candidate, and Professor Arthur C. Miller, faculty advisor, Pennsylvania State University, State College Pennsylvania. The solution method will be published as a component of Mr. Traver's Ph.D. thesis. The algorithms solve the non-prismatic channel forms of Manning's open channel flow

Table 1
<u>Accuracy Specifications for Mapping</u>*

Aerial survey map accuracy for spot elevations and topographic maps is defined by the mapping industry standard. Standard Map Accuracy is described by the following criteria:

1. The plotted position of all coordinate grid ticks and monuments, except benchmarks, will be within 0.01 inch from their calculated positions.

2. At least 90 percent of all well-defined planimetric features shall be within 0.033 inch of their true positions, and all shall be within 0.066 inch of their true positions.

3. At least 90 percent of all contours shall be within one-half contour of true elevations, and all contours shall be within one contour interval of true elevation, except as follows:

   For mapping at scales of 1" = 100' or larger in areas where the ground is completely obscured by dense brush or timber, 90 percent of all contours shall be within one contour interval or one-half the average height of the ground cover, whichever is the greater, of true elevation. All contours shall be within two contour intervals or the average height of the groundcover, whichever is the greater, of true elevation. Contours in such areas shall be indicated by dashed lines.

   Any contour which can be brought within the specified vertical tolerance by shifting its plotter position .033 inch shall be accepted as correctly plotted.

   At least 90 percent of all spot elevations shall be within one-fourth the specified contour interval of their true elevation, and all spot elevations shall be within one-half the contour interval of their true elevation, except that for 5-foot contours 90 percent shall be within 1.0 foot and all shall be within 2.0 feet.

*Source: Brochure from Cartwright Aerial Surveys Inc., Sacramento, California.

equation for normal depth and the general Froude Number equation for critical depth. A spline interpolation routine is used with a search algorithm that has proven to be efficient and accurate. The general form of the Manning's equation for natural channels is documented in the HEC-2 User's Manual (Hydrologic Engineering Center 1982).

Hydraulic parameters associated with normal depth are computed and stored for subsequent usage. A normal depth rating curve is also computed at the user's choice.

PAS PROGRAM CAPABILITIES

11. **Philosophy of Use.** The PAS program is built around the idea that an analyst wishes to plan surveys for stream geometry and other necessary data collection to be efficient and consistent with the computed profile accuracy that is appropriate for the study. Preliminary information about the stream reach is either available or can be developed with limited effort. The analyst is aware that a trade-off exists between the survey method and accuracy to be specified, the cost of the surveys, and the accuracy of the resultant computed profiles. The analyst knows that no computed profile is completely accurate (nor do they need to be). The analyst also recognizes that the reliability of the estimate of the hydraulic roughness has a great bearing on the computed profile accuracy that is achievable, regardless of the stream geometry accuracy.

The preliminary work begins with locating a suitable topographic map. The 7-1/2 minute U.S. Geological Survey quadrangle map is suitable for most studies. The preliminary estimate of the study bounds, both laterally and longitudinally are marked on the map and several (up to 5) locations are identified as representative for the study reach. Files are searched for previous studies that would provide information on the magnitude of the 1 percent chance exceedance discharge and observed flood profiles. The U.S. Geological Survey or other water resources data agencies often have developed regional regression equations that can be used to estimate the 1 percent flow. The upstream and downstream limits of the study area of interest are identified and any special structures or information needs therein are noted.

A field trip is then taken to gather preliminary stream geometry and hydraulic roughness data. Other special characteristics of the study area are noted such as the number and location of bridges, active construction activities, and occurring natural processes that might effect the study area. Several photographs of the stream channel and overbank areas are taken for later reference. The cross-sectional geometry for the selected (up to 5) locations is measured and recorded. A hand level (or instrument for taking rough stadia), and cloth tape should be sufficient for taking measurements if the stream channel is easily accessible. Otherwise more elaborate plans may be necessary. A field estimate of the stream hydraulic roughness may be made if an experienced engineer is present. These estimates are later confirmed by comparing the photographs of stream characteristics with published data or through coordination with other experienced individuals.

The PAS program may now be used to assist in developing information that will form the basis for survey acquisition specifications and planning further field work to improve estimates of hydraulic roughness. The field derived preliminary geometric data is entered into PAS and verified with online plots at the time of data entry. Hydraulic parameters are computed and examined through study of graphic plots and/or reports available online. Changes are made to the geometry or data as appropriate through editing of stream geometry data files. Cross sections are selected to represent upstream and downstream study bounds for use in subsequent study limit estimates. Had the analyst already developed or had hydraulic parameter estimates for the stream reach of interest, or decided that computation of the values were not necessary, the preferred values could be entered directly, overriding the computed values.

The study limit analysis is performed next. Additional information to be provided by the analyst are estimated maximum headloss at the upstream-most location and degree of confidence desired for the study length estimate. Information on the latter can be obtained through the online program help. For most cases the default of an average estimate is appropriate. For special case streams where the upstream limit is critical and additional data collection later would prove unwise, the more stringent confidence might be specified. The analyst may wish to study the sensitivity by successively specifying different confidence values and recomputing the corresponding reach lengths. PAS is designed to perform this in an interactive mode.

The error analysis may now be performed. Additional information to be provided by the analyst includes an index of confidence in error prediction and an estimated reliability of Manning's roughness. Guidelines are provided in the help messages regarding selection of values. For most cases the default of an average estimate is appropriate. For special case situations in which conservative estimates of potential errors is justified, the more stringent confidence might be specified. The confidence in Manning's roughness refers to the expected case when the detailed profile analysis is performed. It would be unusual if observed high water marks would enable calibration of roughness values so accurately that a confidence index of 0 could be specified. For streams with no observed high water marks and little previous study experience, a reliability index of 1.0 should be specified. The default (0.5) is an average reliability. The computed errors are displayed after computation. The errors are studied to better select the appropriate survey method. Several alternative confidence and reliability indexes can be selected and the error results computed.

The survey method cost analysis is usually performed last. The user must specify a number of factors and criteria for cross-sectional spacing. Data previously computed in the work session is retained in the data base and used in the analysis. A cost comparison is then displayed for the several survey methods and survey accuracy criterion. Many of the data items may be overridden if desired and alternative cost comparisons computed and displayed. The cost comparison together with the computed profile error analysis previously performed provide the basis for an informed decision about survey method and accuracy, and the ranges of computed profile accuracy possible.

Other typical uses of the PAS program include assessing the accuracy of previously computed profiles should disputes arise as to the validity of a published profile. Another use could be to perform preliminary hydraulic analysis for use early in the reconnaissance phase of feasibility studies, or for use in other studies needing approximate water surface elevations. The rating curves and plots would be used in this instance.

12. **Program Options and Operations.** Selection of program options is via the main menu. This menu appears following the banner screen display upon initiation of a program session.

```
              Computed Water Surface Profile Accuracy System

  FILE MANAGEMENT AND SYSTEM UTILITIES          STUDY REACH DELINEATION
    A. File Management                            J. Study Limit Report
    B. System Environment

  CROSS SECTION PROPERTIES                      PROFILE ERROR ANALYSIS
    C. Cross Section Data Entry                   K. Error Report
    D. Hydraulic Variables Data Entry
    E. Cross Section Plot
    F. Cross Section Report                     COST COMPARISON
    G. Hydraulic Variable Report                  L. Cost Report
    H. Rating Table                               M. Optional Costs
    I. Rating Curve

          Use arrow keys to highlight selection.  Press <ENTER>
1Help  2Prtscr 3Index  4      5      6      7      8      9      10Quit
```

The menu provides the opportunity to select options from any of five different major functions: FILE MANAGEMENT AND SYSTEM UTILITIES; CROSS SECTION PROPERTIES; STUDY REACH DELINEATION; PROFILE ERROR ANALYSIS; and COST COMPARISON. To access a particular option, press the letter key next to the function. You may also move the cursor to highlight any item and press the <Enter> key.

The F1 (Help) function key may be used (alone or with the Alt key) at any time for help information and instructions. Pressing F1 alone will provide general help and information related to a screen or function. Pressing <Alt> F1 simultaneously will provide detailed definitions and instructions for the item defined by the cursor location. The help message is cleared from the screen by pressing any key.

The F2 (Prtscr) function key may be used at any time to generate a hard copy of the screen except when a plot is on the screen.

The F3 (Index) function key will display an index of the Stream Ids stored in the current program data base file (STRMFILE).

The F10 (Quit) function key is used to exit the program or to return to the main menu from any data entry form, report, or plot.

The ESCape key backs up one level in menus or operations, providing an escape from any function currently in progress. The F10 key must be used from the main menu screen to exit the program and return to DOS.

Data values are entered and edited on a series of input screens in an easy to use manner. On each screen, you enter values in highlighted fields. For example, the stream identification code is typed on the Cross Section Data Entry screen in a 12-character field that looks like this:

Stream Id

Each character that you type appears on the screen as you type it. The blinking cursor indicates where the next value you type will appear. If the cursor is represented by a large blinking square, the keyboard is in insert mode (an indicator will appear on the bottom row of the screen). If the cursor is represented by a blinking underline, the keyboard is in typeover mode. Insert mode is the default. In insert mode, for numeric fields, numbers are inserted immediately following the cursor (i.e., right-justified in the field); for character fields, the characters are inserted at the cursor location. In typeover mode, the characters or numbers that are typed always replace the character at the cursor location and the cursor is advanced to the next location. If a field is filled, no number or character may be inserted in insert mode and a bell is sounded. The program will not accept invalid characters or spaces in numeric fields. The cursor is located at the left-most position of a new field if characters are expected or at the right-most position of the new field if numbers are expected.

The keys that control the location of the cursor are referred to as the DIRECTION keys. These keys are located on the numeric keypad of the PC keyboard. Each DIRECTION key is referred to by the orientation of the arrow label on the key (Left, Right, Up, Down).

The Up DIRECTION key moves the cursor to the field immediately above the current field to the best of the programmer's discretion. The Down DIRECTION key moves the cursor to the field immediately below the current field, if such a field exists.

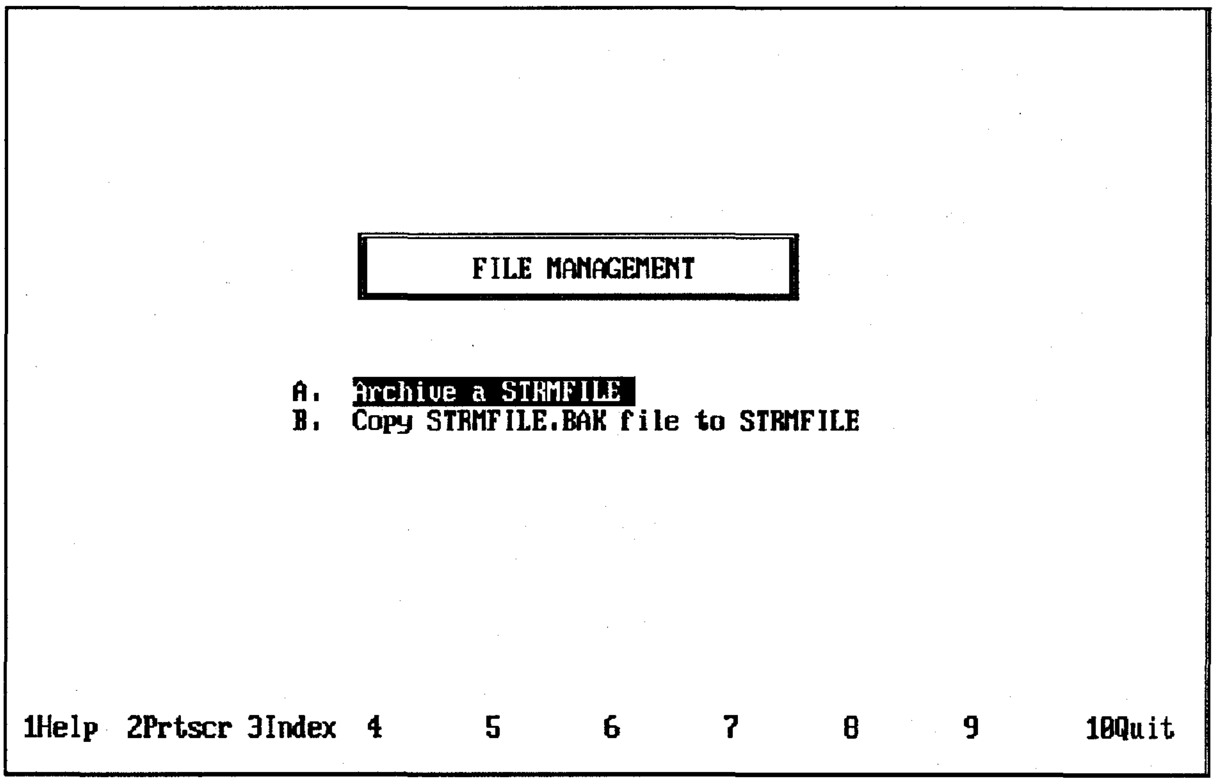
The Right DIRECTION key moves the cursor one character or number to the right, if possible. If the cursor is at the right-most position of the field, it is moved to the field immediately to the right of the current field, if such a field exists. The Left DIRECTION key performs similarly, moving the cursor to the left.

The carriage return/line feed key is denoted <Enter> on the keyboard. This key moves the cursor to the next field on the screen, if such a field exists. The cursor is located in the left-most position (character field) or right-most position (numeric field) of the new field. The Tab key is equivalent to the <Enter> key. <Shift-Tab> moves the cursor to the previous field on the screen and locates it similarly. Pressing <Enter> or <Tab> when located at the last field does not move the cursor. The same is true for the <Shift-Tab> when in the first field.

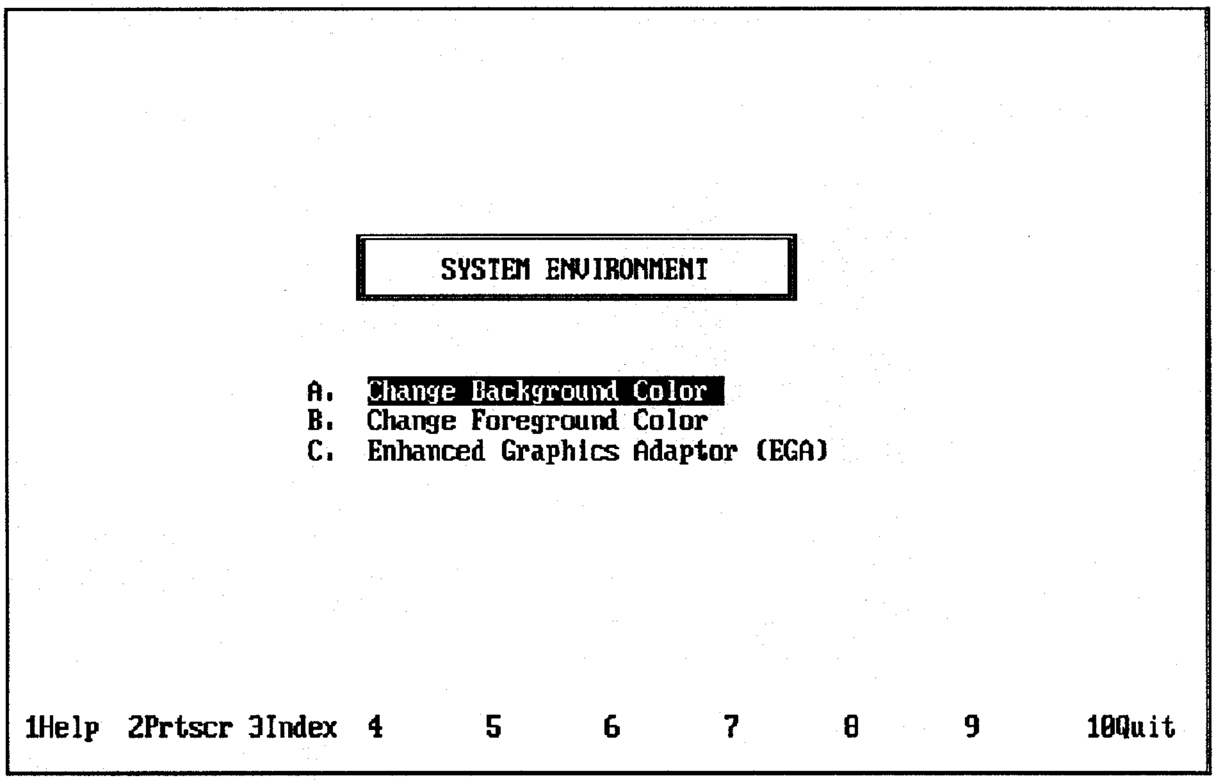
The keys located on the numeric keypad labelled <Home> and <End> move the cursor to the first field of the screen and the last field of the screen, respectively. The cursor is located in the appropriate position of the field depending on whether the field is a character field or a numeric field.

The delete key, denoted <Del>, deletes the character or number at the current cursor location. <Backspace> deletes the character or number to the left of the current cursor position. If the cursor is at the left-most position of the field, the <Backspace> key does not move the cursor. In character fields, the string is left-justified; in numeric fields, the string is right-justified. All numeric fields are checked for valid data ranges following pressing the <Enter> or <Tab> keys. Appendix C contains valid data ranges for each input field.

13. **File Management.** The File Management menu has two components (see below): (A) Archive a STRMFILE; and (B) Copy STRMFILE.BAK file to STRMFILE. Option A is used to copy the current data base file called STRMFILE to another file for archival purposes. This should be done whenever the STRMFILE contains 20 or more Stream IDs. It may be done at any time to archive the STRMFILE. As your STRMFILE grows, you will be informed by the program when you reach the 20 stream mark. Option B can be used to recover a backup file if the current STRMFILE is accidentally destroyed.



14. **System Environment.** The System Environment menu has three components: (A) Change Background Color; (B) Change Foreground Color; and (C) Enhanced Graphics Adapter (EGA). Option A allows permanent changes to be made in the background color used during program execution. Option B permanently changes the foreground color. Option C is a toggle used to inform the program whether or not you have an enhanced graphics adapter and monitor. If you have a color graphics adapter (CGA) or a monochrome display, do not use this option. The options set here are stored in a file called PAS.INI and used in subsequent program sessions or until changed.



15. **Cross Section Data Entry.** This option is used to enter or edit cross-sectional data. A cross section data entry form will appear on the screen which permits entry of up to five cross sections for each stream. Each cross section is defined by 8 coordinate points and all are required. If this is the first operation being performed, the Stream Id must be the first data entered. Otherwise, the program will remember the Stream Id entered previously. If the cross-sectional data for that stream already exists in the current data base file, pressing the <Enter> key will cause the data to appear on the screen for the first cross section. This allows you to edit the previously entered data. When entering a new stream, the default data will appear on the screen. Data will be checked for validity before cursor movement to the next field.

Cross Section Data Entry

Stream Id BEAR CREEK — Cross Section No. 1

	Distance (feet)	Elevation (feet)
1	0	1767
2	220	1755.7
*3	767	1754.7
4	775	1747.4
5	789	1749.7
*6	815	1756.9
7	936	1763.2
8	1006	1766.7

Manning's n Values

- .100 Left Overbank
- .040 Channel
- .1 Right Overbank

* Represents high banks of channel

Discharge (cfs) 7000
Slope (ft/mi) 10
Percent of Study Reach 10

Upper Elevation Limit (ft)
Represents Upstream Reach (N/Y) N
Represents Downstream Reach (N/Y) Y

1Help 2Prtscr 3Index 4 5 6 7Plot 8Calc 9Cont 10Quit
INSERT

The F7 (Plot) function key will generate a screen plot of the cross-sectional data that is currently on the screen. If the hydraulic data variables have been computed, then the normal depth will be plotted on the graph.

The F8 (Calc) function key causes the program to compute the hydraulic data variables for the cross-sectional data. A WAIT signal will flash in the lower left corner until the operation is completed. The representative hydraulic data variables will be computed and if they already exist in the current data base file, you will be asked if you want to overwrite them. This prevents hydraulic data variables that were entered directly by you from being overwritten. This key should be pressed when the analyst wishes to be certain new values are being computed for the data base. Exiting this option with the F10 key, the normal operation, will result in automatic recalculation of the hydraulic data variables.

The F9 (Cont, for continue) function key causes the program to write the data on the screen to the current data base file and allows the user to continue to enter or edit the data for the next cross section. At the end of the fifth cross section, the F9 key will return to the first cross section. It also causes the cursor to be repositioned in the Cross Section No. field and thus ready for data entry for the next cross section. No data entered on the screen will be saved prior to pressing this key.

The F10 (Quit) function key returns the user to the main menu after computing and storing the hydraulic data variables. The WAIT message will flash in the lower left corner of the screen while computations are being performed. The weighted parameters for the overall reach, downstream section, and upstream section are computed based on the percent of study reach. If more than one cross section is selected to represent the upstream or downstream section, the cross section with the highest number will be used.

16. **Hydraulic Variables Data Entry.** The user can bypass or override the cross-sectional data entry and program computations by selecting the Hydraulic Variables Data Entry option. You may enter the weighted values for the overall reach, the downstream section, and the upstream section directly using this data entry form. If a Stream Id already exists in the current data base file, the hydraulic variables values will appear on the screen allowing editing of the previously entered or computed values. The F10 (Quit) function key returns you to the main menu after writing the data to the current data base file. The ESCape key returns you to the main menu without writing the data to the data base file.

Hydraulic Variable Data Entry

Stream Id BEAR CREEK	Overall	Representative Downstream Cross Section	Representative Upstream Cross Section
Discharge (cfs)	7800.	7800	7800
Slope (ft/mi)	10.0	10	10
Manning's n	.08	.08	.08
Normal Depth (ft)	11.4	12.7	12.1
Critical Depth	9.2	10.4	10.4
Hydraulic Depth	4.1	4.6	3.7
Survey Width (ft)	1010.		
Top Width (ft)	814.	740.	785.

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit
INSERT

17. **Cross Section Plot.** This option allows the user to cycle through the plots for all the cross sections stored in the current data base for a particular stream. After entering a Stream Id, you may enter a cross-sectional number and press the F9 (Cont) function key to plot that particular cross section, or you may use the F9 (Cont) function key alone to plot each cross section in sequence. When a plot is on the screen and you have an IBM-compatible printer, you may use the keyboard <Print Scrn> key to get a hard copy of the plot. The DOS GRAPHICS command must be executed prior to this program session for <Print Scrn> to produce a graphic plot. Otherwise, pressing any key will return you to the plot entry form. The ESCape key or F10 (Quit) function key will return you to the main menu.

```
                              Cross Section Plot
Stream Id DEAR CREEK                                   Cross Section No. 1







1Help  2Prtscr 3Index  4      5      6      7      8      9Cont   10Quit
                                                     INSERT
```

18. **Cross Section Report.** This report summarizes the computed cross-sectional properties for each cross section. The only field that can be changed is the Stream Id. If you select a Stream Id that is not in the current data base file, an index of valid Stream Ids will appear on the screen. Most data items are defined concurrent with input screens. The remaining items are the following: minimum elevation - the minimum elevation for the cross section; top width - linear distance across the cross section for elevation equal to normal depth; and proportion - same as percent of study reach. Pressing <Enter> with a valid Stream Id will produce a report.

Cross Section Report

Stream Id BEAR CREEK

	No. 1	No. 2	No. 3	No. 4	No. 5
Discharge (cfs)	7800	7800	7800	7800	7800
Slope (ft/mi)	10	10	10	10	10
Area (sq ft)	3376.	3196.	3520.	3731.	2887.
Manning's n					
Left Bank	.100	.1	.1	.1	.1
Channel	.040	.04	.04	.04	.04
Right Bank	.1	.1	.1	.1	.1
Upper Elev. (ft)	1765.1	1769.1	1776.5	1781.0	1785.9
Minimum Elev. (ft)	1747.4	1753.6	1761.3	1763.0	1768.8
Normal Depth (ft)	12.7	10.5	10.2	13.0	12.1
Critical Depth (ft)	10.4	7.2	8.4	10.9	10.4
Hydraulic Depth (ft)	4.6	5.2	3.6	4.3	3.7
Top Width (ft)	740.	620.	975.	875.	785.
Proportion (%)	10	20	30	10	30

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

INSERT

19. **Hydraulic Variable Report.** This report displays the weighted hydraulic data variables that are stored in the current data base file. This report looks identical to the Hydraulic Variables Data Entry screen except for the title. You may NOT use this screen to modify the values in the current data base file. The values stored in the data base are used in subsequent analysis. Pressing <Enter> with a valid Stream Id will produce a report.

Hydraulic Variable Report

Stream Id BEAR CREEK	Overall	Downstream Cross Section No. 1	Upstream Cross Section No. 3
Discharge (cfs)	7800.	7800	7800
Slope (ft/mi)	10.0	10	10
Manning's n	.08	.08	.08
Normal Depth (ft)	11.4	12.7	12.1
Critical Depth	9.2	10.4	10.4
Hydraulic Depth	4.1	4.6	3.7
Survey Width (ft)	1010.		
Top Width (ft)	814.	740.	785.

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit
INSERT

20. **Rating Table.** This table displays discharge-elevation values computed from Manning's equation for normal depth conditions. Discharge values, ranging from 10 percent to 200 percent of the input discharge, are selected by the program and water surface elevations are determined for those values for each cross section. The WAIT message will flash in the lower left corner of the screen while computations are being performed.

Rating Table

Stream Id DEAR CREEK

	No. 1	No. 2	No. 3	No. 4	No. 5
Discharge (cfs)	**Elevation (ft)**	**Elevation (ft)**	**Elevation (ft)**	**Elevation (ft)**	**Elevation (ft)**
780.	1755.3	1758.6	1765.9	1771.0	1774.6
1170.	1756.0	1759.3	1766.7	1771.7	1775.6
1560.	1756.4	1759.8	1767.3	1772.3	1776.3
2340.	1757.1	1760.6	1768.2	1773.1	1777.4
3900.	1758.2	1761.8	1769.5	1774.2	1778.9
4680.	1758.6	1762.3	1770.0	1774.6	1779.4
6240.	1759.4	1763.3	1770.8	1775.4	1780.4
7800.	1760.1	1764.1	1771.5	1776.0	1780.9
10900.	1761.3	1765.4	1772.6	1777.1	1780.9
15600.	1762.9	1767.2	1774.0	1778.6	1780.9

1Help 2Prtscr 3Index 4 5 6 7 8Calc 9 10Quit
INSERT

21. **Rating Curve.** The rating curve is a graphic representation of the rating table. It may be plotted for each cross section stored in the data base, one at a time. After entering a Stream Id, you may enter a cross-sectional number and press <Enter> to plot the rating curve for that particular cross section. You may use the F9 (Cont) function key to plot the rating curve for each cross section in sequence. When a plot is on the screen and you have an IBM-compatible printer, you may use the keyboard <Print Scrn> key to generate a hard copy of the plot. The DOS GRAPHICS command must have been issued prior to the current program session in which a hard copy graphic plot is desired. Otherwise, pressing the <Enter> key will return you to the plot entry form. The ESCape key or F10 (Quit) function key will return you to the main menu. The WAIT message will flash in the lower left corner of the screen while computations are being performed.

```
                              Rating Curve
Stream Id DEAR CREEK                               Cross Section No. 3








1Help  2Prtscr 3Index  4     5     6     7     8Calc   9Cont   10Quit
                                                   INSERT
```

22. **Study Limit Report.** This report enables determination of the upstream and downstream limits for stream geometry and roughness data collection. The limits are determined from stream hydraulic properties, selected standard error index, and structure headloss. Default values for input items will be used if not specified. Regression equations 7.1, 7.2, and 7.3 from *Accuracy of Computed Water Surface Profiles* (Hydrologic Engineering Center 1986) are used for the computations. See Appendix D Equations. The estimated downstream distance is computed for both conditions of starting at normal depth and starting at critical depth (bottom left of screen). The estimated upstream distance (lower right) is computed based on the input structure headloss and stream parameters shown for the upstream representative cross section (or parameters). The F8 (Calc) function key will cause the program to calculate the distances. Repeated alteration of input data and F8 (Calc) key operations is expected. The values on the screen are saved for subsequent analysis by pressing the F10 (Quit) key to exit the screen.

Study Limit Report

Stream Id BEAR CREEK | Standard Error 3

Maximum Headloss at Upstream Most Structure (ft) 0.5

Downstream Cross Section No. 1		Upstream Cross Section No. 3	
Weighted n Value	.08	Weighted n Value	.08
Wtd. Hydraulic Depth (ft)	4.6	Wtd. Hydraulic Depth (ft)	4.6
Top Width (ft)	740.	Top Width (ft)	740.
Discharge (cfs)	7800	Discharge (cfs)	7800.
Slope (ft/mi)	10	Slope (ft/mi)	10.0
ESTIMATED DISTANCES (ft)			
Start Critical Depth	3000.		
Start Normal Depth	2700.	ESTIMATED DISTANCE (ft)	1700.

1Help 2Prtscr 3Index 4 5 6 7 8Calc 9 10Quit
INSERT

23. **Error Report.** This report enables study of the relationship between estimated computed profile error and technology and accuracy of survey method, reliability of Manning's n, and stream hydraulic properties. Input values are standard error index and reliability of Manning's n. Stream hydraulic properties are retrieved from the program data base. Estimated computed profile errors are calculated from regression equations 6.3 through 6.10 from *Accuracy of Computed Water Surface Profiles* (Hydrologic Engineering Center 1986). See Appendix D Equations. Emean is the mean reach absolute profile error and Emax is the reach maximum absolute profile error.

Error Report

Stream Id BEAR CREEK

Standard Error 3
Reliability of Manning's n 0.5

Slope (ft/mi)	10.0	Weighted n Value	.08
Discharge (cfs)	7800.	Weighted Hydraulic Depth (ft)	4.1

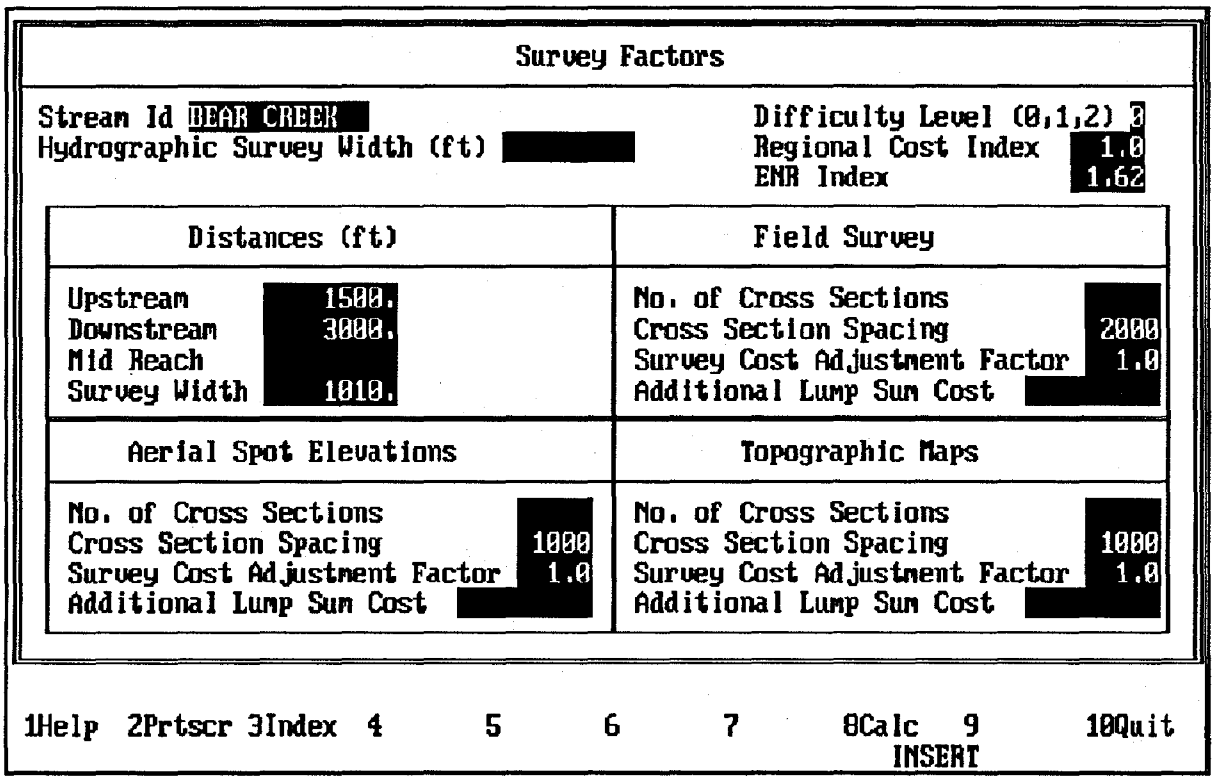
	Emean (ft)	Emax (ft)
Field Survey	.41	1.04
Aerial Spot Elevations		
2-ft.	.44	1.08
5-ft.	.47	1.14
10-ft.	.52	1.24
Topographic Maps		
2-ft.	.70	1.95
5-ft.	.99	2.59
10-ft.	1.49	3.58

1Help 2Prtscr 3Index 4 5 6 7 8Calc 9 10Quit
INSERT

Field surveys are performed by crews using conventional survey instruments and are presumed to be without error. Aerial spot elevations are developed by photogrammetry methods in which elevations are determined from a stereo model developed from the aerial photographs. Topographic maps are map products with inscribed contour lines from which elevations may be manually read. The contour intervals characterize the accuracy standard of the survey methods.

The F8 (Calc) function key will cause the program to calculate the errors. Repeated alteration of input data and F8 (Calc) key operations is expected.

24. **Cost Report.** This report enables comparison of survey costs among the survey methods. Data are required to define distances, survey difficulty, and numbers of cross sections needed by survey method. Several data items are supplied from the program data base (distances and survey width). Others are provided with default values. The remainder are optional inputs. All data fields may be overridden by providing alternative input in each field. There are two screens. The opening screen (Survey Factors) defines the survey factors as described above; the Cost Report screen will appear when the F8 (Calc) function key is pressed. Costs are computed and written to this second screen.



25. **Cost Comparison Report.** This report screen displays a summary of data from the Survey Factors and provides computed survey costs for the 3 survey methods and 4 accuracy specifications. Costs are the total for each survey method for developing complete stream geometry data and preparing and verifying the necessary HEC-2 data sets. Pressing any key, other than F2 (Prtscr) will cause return to the Survey Factors screen. Repeated data entry on the Survey Factors screen and calculations are possible.

Cost Comparison Report

Stream Id DEAR CREEK

Level of Difficulty 3

Total Distance (ft) 4500.

Survey Width (ft) 1010.

Hydrographic Survey Width (ft)

Regional Cost Factor 1.0

ENR Index 1.62

Total Survey Costs in Dollars

	No Error	2-ft.	5-ft.	10-ft.
Field Survey (3. cross sections)	6401.	NA	NA	NA
Aerial Spot Elevations (6. cross sections)	NA	6454.	6454.	6454.
Topographic Maps (6. cross sections)	NA	11926.	11091.	9774.

Press any key to continue.

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

26. **Optional Cost.** This option enables program data base survey costs to be replaced with user-supplied survey cost data. The values stored in the program are taken from the *Commercial Survey Guidelines for Water Surface Profiles* supplement to *Accuracy of Computed Water Surface Profiles* (Hydrologic Engineering Center 1987). The cost data contained in the supplement was expanded and the results are documented in Appendix E Survey Cost Data.

The Survey Cost Per Cross Section consists of nine (9) screens for each Stream Id, representing three (3) different indexes of cross-sectional numbers and (3) difficulty levels for each index. You may change the index and the costs for any of the nine screens. You may not change the difficulty level.

Survey Cost Per Cross Section (Dollars)

Stream Id BEAR CREEK   Difficulty Level (0,1,2) 0
Index Number of Cross Sections 11

Floodplain Width (ft)

	200	500	1000	3000	5000
Field Survey	440	490	560	640	740
Aerial Spot Elevations	562	562	565	573	933
Topographic Maps					
2-ft.	835	907	1043	1253	2307
5-ft.	795	857	970	1155	2104
10-ft.	726	772	855	987	1767
Hydrographic Surveys	490	520	590	600	650

1Help 2Prtscr 3Index 4 5 6 7 8 9Cont 10Quit
INSERT

The F9 (Cont) function key is used to cycle through the nine screens.

The F10 (Quit) function key will store the costs in the current data base file for the selected stream and return to the main menu. The modified costs will then be used in cost calculations.

The ESCape key will return to the main menu without storing the costs in the current data base file.

EXAMPLE APPLICATION

27. **Background Information.** A water surface profile study is to be performed for Dry Creek in the vicinity of Jonesburg. Flood profiles are required for several purposes including on-going feasibility studies of flood damage reduction projects and design studies for highway crossing upgrades. There are four bridges across Dry Creek within the study area. See Figure 3.

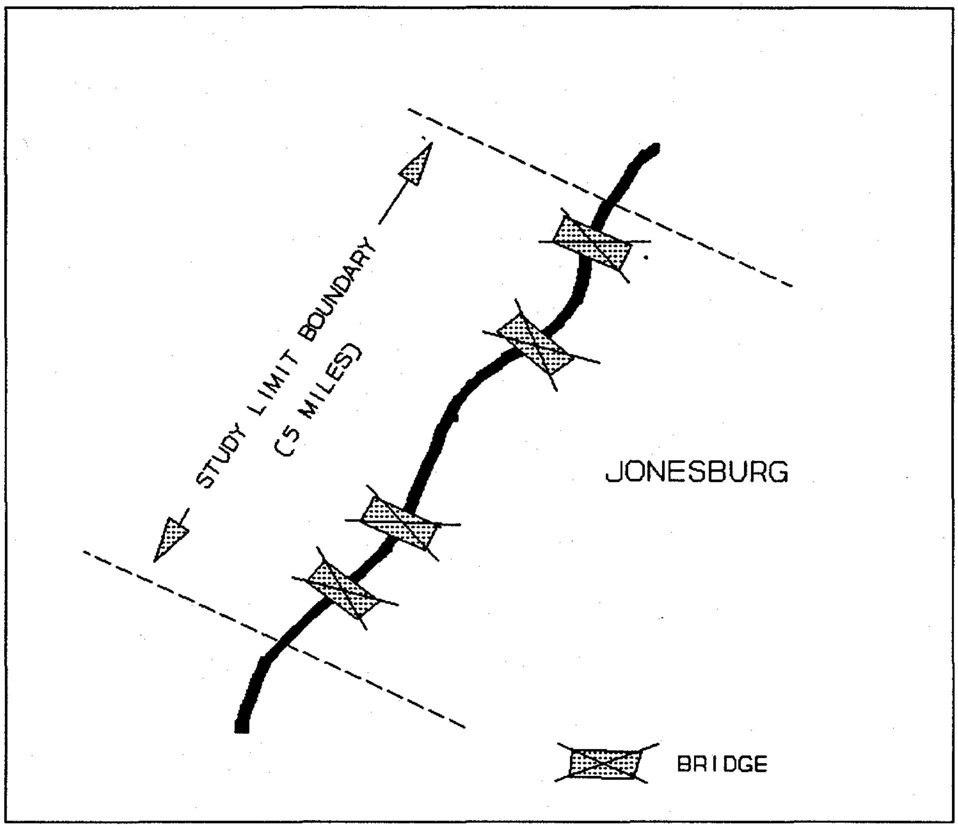


Figure 3 - Dry Creek Study Reach

28. **Water Surface Profile Analysis.** An immediate task is to obtain surveyed cross-sectional coordinate data for detailed water surface profile computations needed early in the studies. The water surface profile analysis, and thus cross-sectional data assembly, must begin sufficiently far downstream of the study area to negate any starting elevation errors associated with the profile computations. The upstream distance must be sufficient to cover any headloss effects of the upper-most bridge or potential project such as a levee.

The surveys will be conducted in the winter when there is minimal vegetation cover and flow in the stream is low. The Dry Creek flood plain is moderately sloped and is about 15 percent wooded, 65 percent in crops, and 20 percent in pasture. The Dry Creek drainage area taken from U.S.G.S. quadrangle maps at the upper study limit is 200 sq. mi., and at the lower study limit is 250 sq. mi..

The Profile Accuracy Program (PAS) will be used to compare the cost of field surveys, aerial spot elevations, and topographic maps to obtain cross-sectional data for the water surface profile computations. A field reconnaissance was conducted to gather preliminary cross-sectional data and Manning's n-values for the PAS program. The elevations were obtained using hand levels. Station distances were estimated from pacing the flood plain areas and by use of a cloth tape in the channels. Manning's n-values were estimated from field inspection and reference to Open-Channel Hydraulics (Chow 1959). Table 2 lists the 8-point cross-sectional data. Table 3 lists the estimated Manning's roughness values. Table 4 shows pertinent reach data obtained from the hand level surveys (channel slope) and U.S.G.S. quadrangle maps (percent of reach of each cross section).

Table 2
Cross-sectional Data

Downstream Section No.1		Section No.2		Section No.3		Upstream Section No.4	
Distance	Elev	Distance	Elev	Distance	Elev	Distance	Elev
0	1770	0	1774	0	1783	0	1788
220	1756	360	1760	390	1771	315	1780
765	1755	765	1758	1015	1766	880	1774
790	1750	775	1754	1035	1760	910	1768
815	1757	795	1755	1060	1761	925	1769
935	1763	815	1762	1070	1764	930	1776
1005	1766	1035	1769	1330	1771	945	1780
1100	1769	1100	1774	1465	1782	965	1790

Table 3
Manning's Roughness Coefficient n

Cross Section Number	Left Overbank	Channel	Right Overbank
1	.06	.05	.07
2	.06	.06	.06
3	.08	.07	.08
4	.07	.06	.08

Table 4 Cross Section Reach Data		
Cross Section No.	Slope Ft./Mi.	Percent of Study Reach
1	4.5	15
2	4.5	20
3	5.0	35
4	6.0	30

The discharge values for the 1-percent chance exceedance frequency event may be estimated using the following regional equation developed by the U.S.G.S. for the Jonesburg region.

$$Q_{100} = 170\ A^{.7}S^{.5}$$

where: Q_{100} = the discharge for the 1-percent chance exceedance frequency event,
A = drainage area in square miles, and
S = average channel slope in feet per mile

29. **Questions/Tasks.** The following questions/tasks are typical of what might be required to determine appropriate survey methods for obtaining cross-sectional coordinate data for water surface profile computations. The PAS program can assist in developing the information.

* Determine the 1-percent chance exceedance frequency discharge values for each of the preliminary cross sections.

* Input the cross-sectional data obtained from the field reconnaissance into the PAS program. Review the cross-sectional coordinate data by plotting each cross section after the data are input.

* What are the normal, critical, and hydraulic depths computed for each cross section? What is the estimated average flow velocity through each cross section?

* Using the normal depth rating tables or curves, what is the water surface elevation for the flow of 25,000 cfs?

* How far downstream of the lower study limit must the water surface profile start to have an 84 percent chance that the possible error in starting water surface elevations used in profile computations will be negated at the study limits?

* How far upstream above the upper study limits will the backwater effect from the upper-most bridge extend if the headloss is 5 feet and we wish to ensure an 84 percent chance of the distance being less than estimated?

* What survey technologies and contour interval accuracy are applicable if the accuracy of the profile is desired to within 1 foot with only a 16 percent chance that the estimate might be exceeded? Manning's n reliability index is judged to be 0.5. What would the survey technologies and accuracy be if Manning's n reliability index were 0 and then 1.0?

* Determine the most cost effective survey procedure for gathering cross-sectional coordinate data for the Dry Creek study. The profile mean reach error must be within 1 foot with no more than a 16percent chance that the error estimates will be greater than those calculated. Other relevant data are:

a. the Regional Cost Index is 1.15,

b. the survey difficulty level is 1,

c. there is a 16 percent chance the upstream and downstream distances will be greater than those estimated,

d. the additional cost for detailed surveys of the four bridges is $2,000,

e. the desired number of field survey cross sections is 20, and

f. the cross-sectional spacing for aerial spot elevations and topographic maps survey methods is 1000 feet.

30. **One-percent Chance Exceedance Frequency Discharge.** The Q_{100} for cross section 1 (DA = 250 sq. mi.) from the regional regression equation is 18,100 cfs. The Q_{100} for cross section 4 (DA = 200 sq. mi.) is 15,500 cfs. The Q_{100} for cross sections 2 and 3 are interpolated between these values as about 17,500 and 16,500 cfs, respectively.

31. **Input Cross-sectional Data.** The Cross Section Data Entry screen appears by selecting option C on the opening menu. Pressing the F1 key retrieves the general help message for this option. Data entry begins by specifying a stream id (the cursor is initially positioned in the Stream Id field). Specific instructions for an acceptable id is obtained by pressing <Alt> F1. The context sensitive help message, shown below in Figure 4, provides the necessary instructions. Similar help messages can be retrieved for all data entry fields on the screen by positioning the cursor in the appropriate field and pressing <Alt> F1.

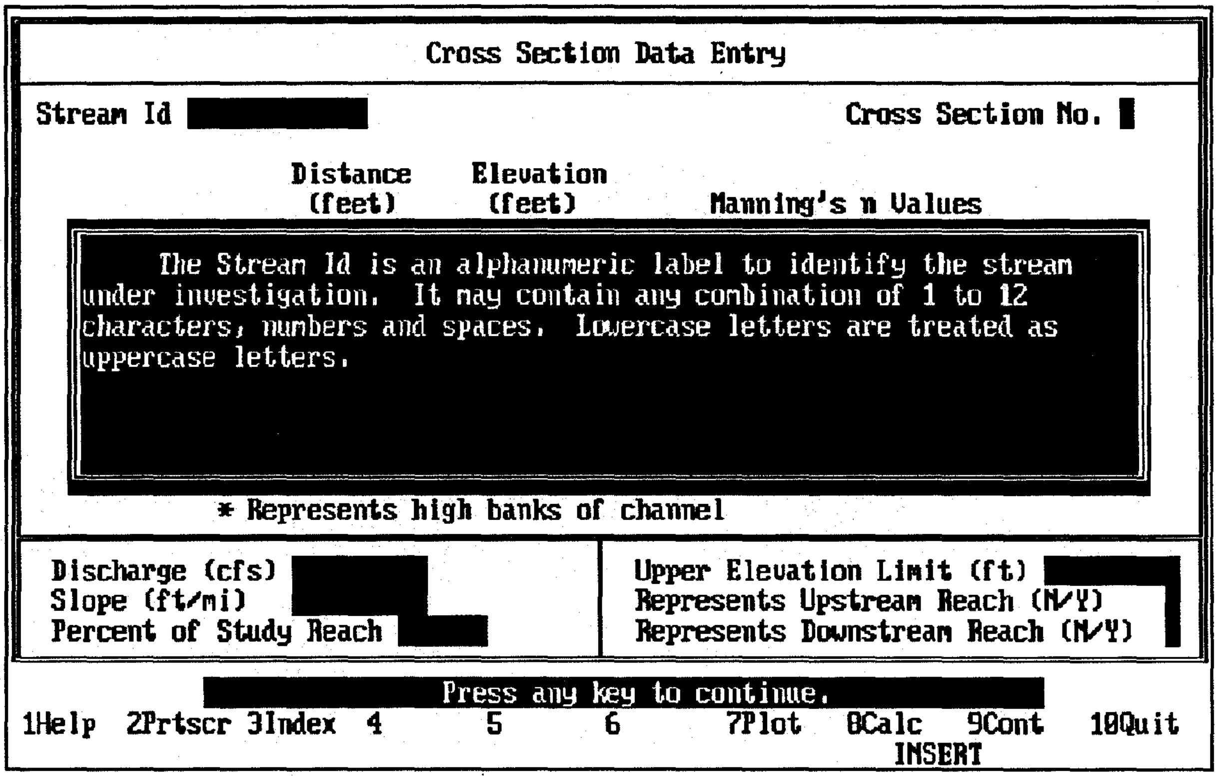


Figure 4 - Cross Section Data Entry Help Message

Data entry proceeds as the user wishes. A convenient mode of entry is to press the NumLock key and use the number entry keypad. The cursor will proceed logically through the form upon pressing <Enter> or <Tab>. Refer to Section 12 for the cursor movement convention used by PAS. The cursor will not move from a field until a valid data entry is made. Entries are verified by the program when <Enter> is pressed. Should the entered value be outside the allowable range, the cursor will not move to the next field and the message "Value Must Be In Range ### to ###" will appear at the bottom of the screen. The message will disappear upon valid data entry. The acceptable value ranges for each respective field is defined in the field context sensitive help messages.

Figure 5 is a copy of the completed data entry screen for cross-sectional number 1. A hard copy of the screen may be obtained by pressing the F2 key. Figure 6 is a copy of the plot of cross section 1. This plot may be viewed on the screen by pressing the F7 key following cross-sectional data input. Cross-sectional plots may also be viewed by selecting the cross section plot option from the main menu. Figures 7, 8, and 9 display completed data entry screens for the remaining cross sections. When satisfied with all cross section data entries, press the F10 key and the program will store the data and perform hydraulic parameter computations. A WAIT message will flash in the lower left corner as computations are performed.

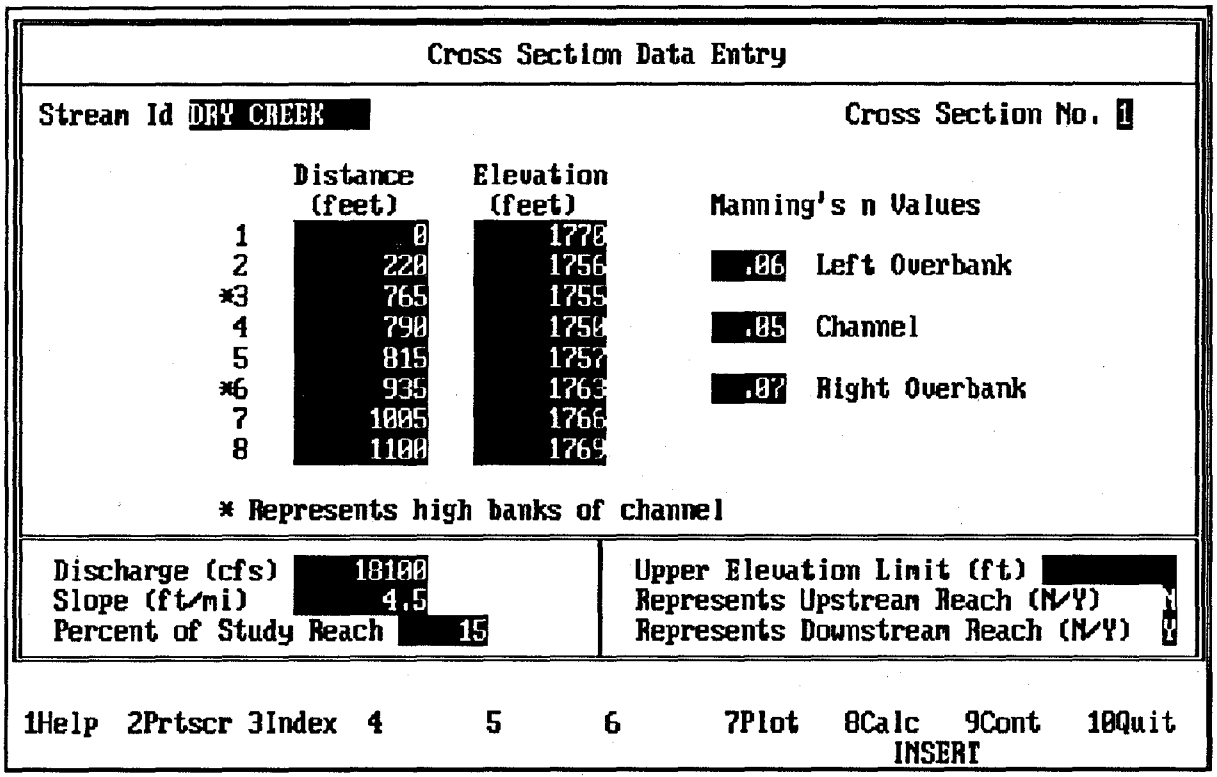


Figure 5 - Cross Section 1 Data Entry Screen

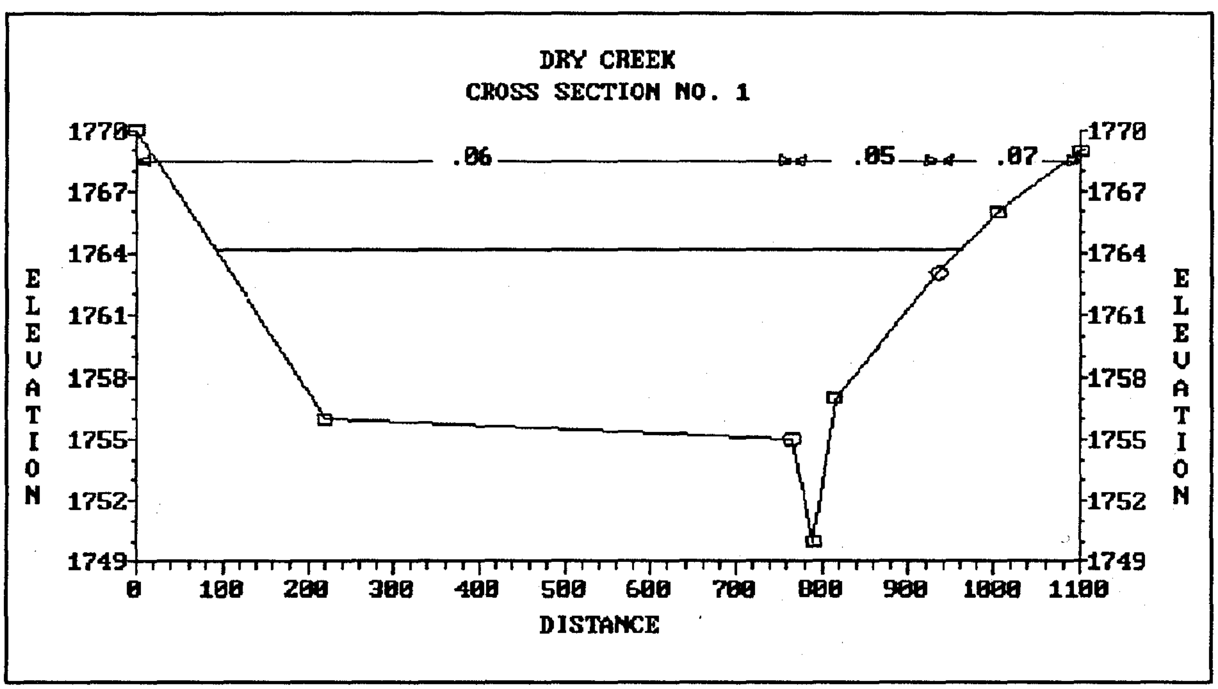


Figure 6 - Cross Section 1 Plot

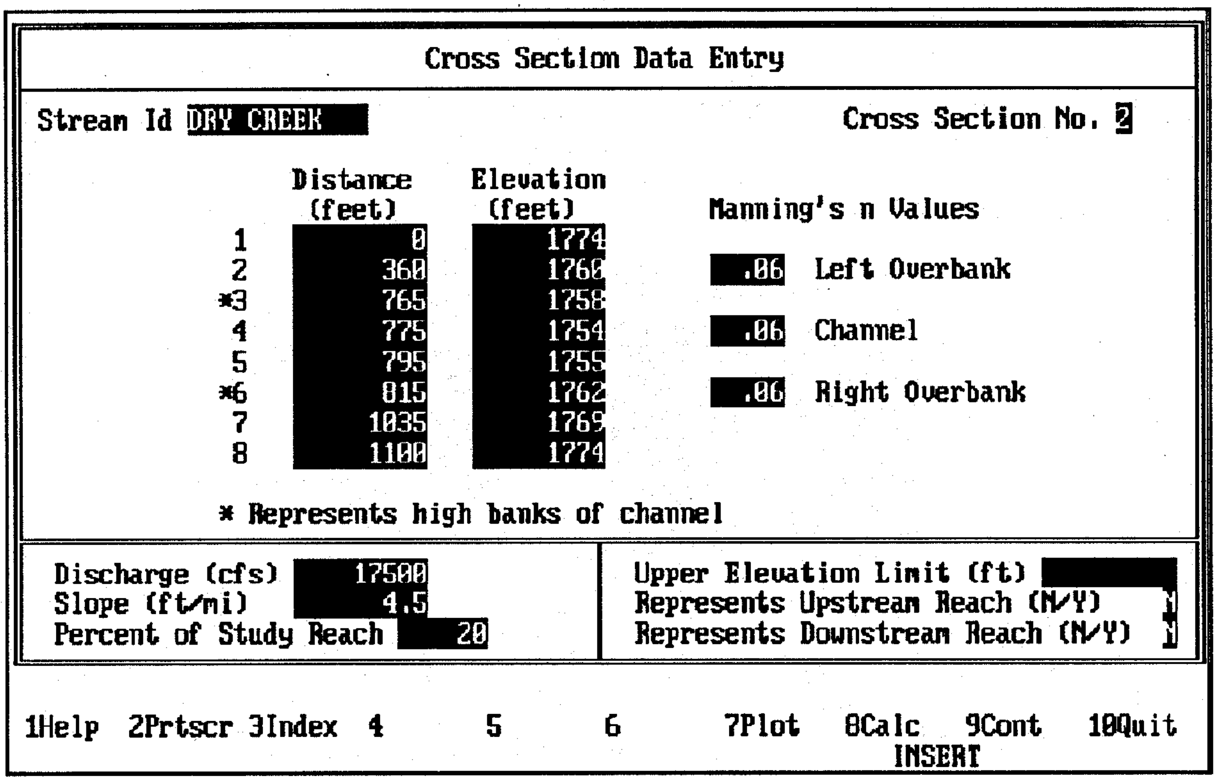


Figure 7 - Cross Section 2 Data Entry Screen

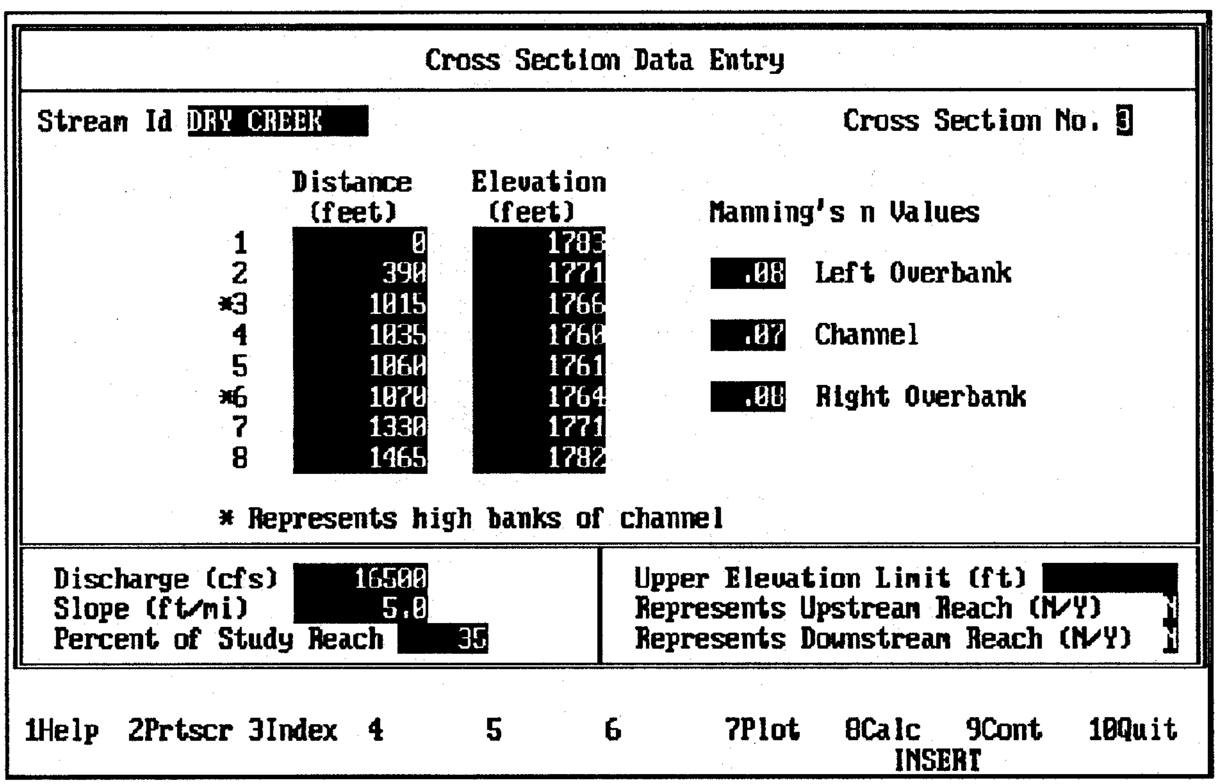


Figure 8 - Cross Section 3 Data Entry Screen

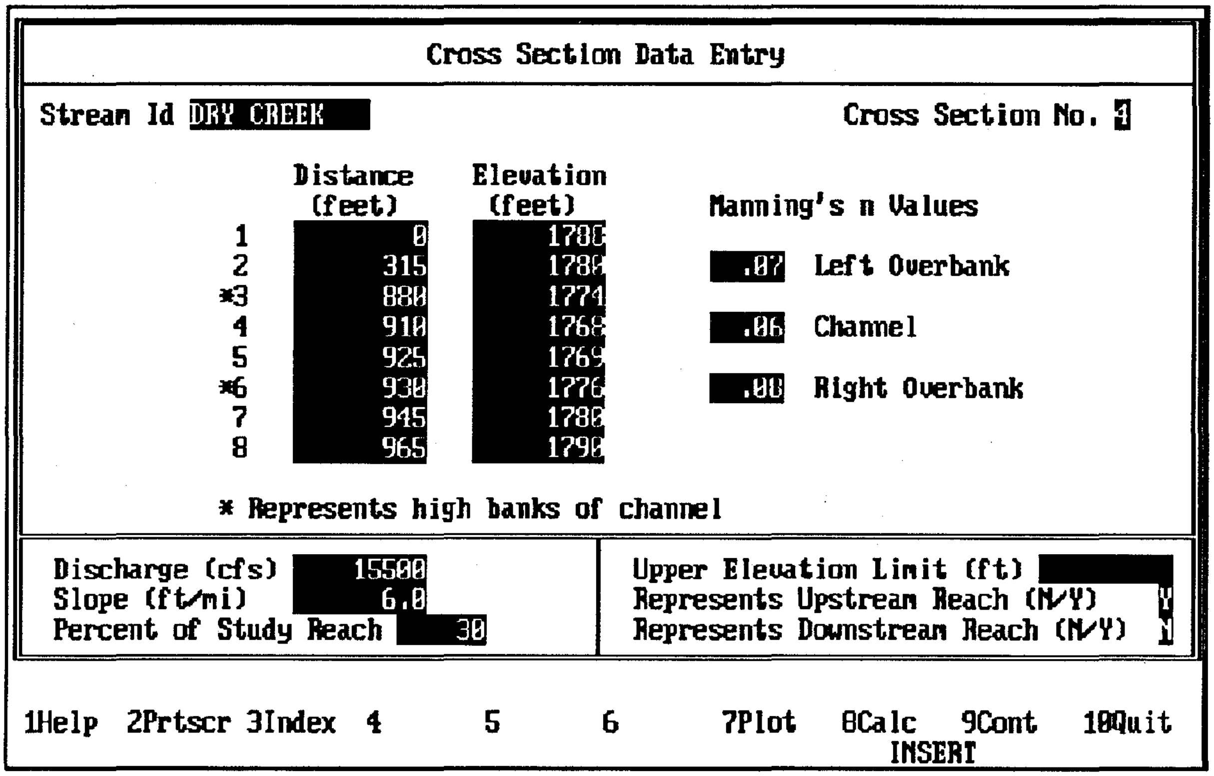


Figure 9 - Cross Section 4 Data Entry Screen

32. **Normal, Critical, and Hydraulic Depths and Velocity.** The values in Table 5 were obtained from the Cross Section and Hydraulic Variable Reports shown in Figure 10. These reports are selected from the main menu and displayed to the screen. Hard copies may be obtained by pressing the F2 key. The average velocity of the flow through the cross section for the 1-percent chance discharge is obtained by dividing the discharge by the flow area.

Table 5
Hydraulic Parameters

Cross Section No. (ft.)	Normal Depth (ft.)	Critical Depth (ft.)	Average Velocity (ft./sec.)
1	14.2	8.6	2.9
2	15.0	8.6	2.7
3	15.5	10.5	2.1
4	16.8	11.9	2.7

Cross Section Report

Stream Id DRY CREEK

	No. 1	No. 2	No. 3	No. 4	No.
Discharge (cfs)	18100	17500	16500	15500	
Slope (ft/mi)	4.5	4.5	5.0	6.0	
Area (sq ft)	6343.	6515.	7707.	5669.	
Manning's n					
Left Bank	.06	.06	.08	.07	
Channel	.05	.06	.07	.06	
Right Bank	.07	.06	.08	.08	
Upper Elev. (ft)	1769.2	1774.0	1780.5	1789.8	
Minimum Elev. (ft)	1750.0	1754.0	1760.0	1768.0	
Normal Depth (ft)	14.2	15.0	15.5	16.8	
Critical Depth (ft)	8.6	8.6	10.5	11.9	
Hydraulic Depth (ft)	7.2	7.2	6.7	6.9	
Top Width (ft)	875.	910.	1150.	820.	
Proportion (%)	15	20	35	30	

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

INSERT

Hydraulic Variable Report

Stream Id DRY CREEK

	Overall	Downstream Cross Section No. 1	Upstream Cross Section No. 4
Discharge (cfs)	16640.	18100	15500
Slope (ft/mi)	5.1	4.5	6.0
Manning's n	.07	.06	.07
Normal Depth (ft)	15.6	14.2	16.8
Critical Depth	10.3	8.6	11.9
Hydraulic Depth	6.9	7.2	6.9
Survey Width (ft)	1150.		
Top Width (ft)	962.	875.	820.

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

INSERT

Figure 10 - Cross Section and Hydraulic Variable Reports

33. **Water Surface Elevations for 25,000 cfs.** A table of flow vs. water surface elevation may be obtained by selecting the Rating Table option (H) from the main menu. Upon selection of this option, the WAIT light will flash in the lower left corner for a time. The computations needed to develop the table are substantial. Upon completion of computations, the table will appear on the screen. The water surface elevations for 25,000 cfs are interpolated from the Rating Table Report shown in Figure 11. Table 6 summarizes the water surface elevation for each cross section for 25,000 cfs. Graphic plots of the rating table values are obtained by selecting the Rating Curve option in the main menu. Figure 11 also shows a plot of the rating curve for cross section 1.

Table 6
Water Surface Elevations

Cross Section No.	Water Surface Elevation
1	1765.9
2	1770.8
3	1777.7
4	1787.1

Rating Table

Stream Id DRY CREEK

Discharge (cfs)	No. 1 Elevation (ft)	No. 2 Elevation (ft)	No. 3 Elevation (ft)	No. 4 Elevation (ft)	No. Elevation (ft)
1664.	1757.4	1761.4	1768.8	1777.5	.0
2496.	1758.1	1762.1	1769.7	1778.5	.0
3328.	1758.7	1762.8	1770.3	1779.3	.0
4992.	1759.6	1763.9	1771.4	1780.4	.0
8320.	1761.1	1765.7	1772.8	1782.1	.0
9984.	1761.7	1766.4	1773.5	1782.8	.0
13300.	1762.8	1767.7	1774.6	1784.0	.0
16600.	1763.8	1768.8	1775.6	1785.1	.0
23200.	1765.5	1770.5	1777.3	1787.0	.0
33200.	1767.6	1772.7	1779.5	1788.0	.0

1Help 2Prtscr 3Index 4 5 6 7 8Calc 9 10Quit
INSERT

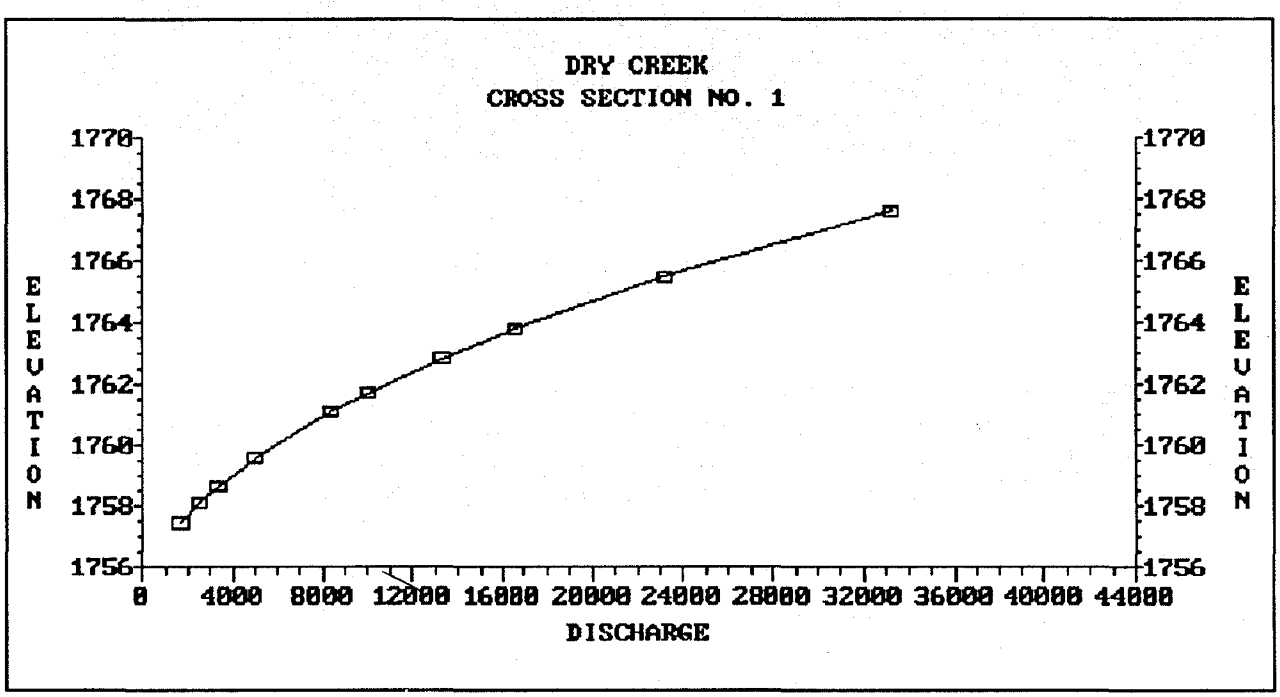


Figure 11 - Rating Table and Curve for Cross Section 1

34. **Downstream Distance.** Selection of the Study Limit Report option (J) from the main menu enables study of the upstream and downstream distances. The key data entry item is the Standard Error. With the cursor positioned in this field, pressing <Alt> and F1 simultaneously retrieves the message reproduced in Figure 12. According to the instructions, we select a standard error of 1 as appropriate for our analysis. Upon completing data entry, pressing the F8 key will result in the distance computations being performed.

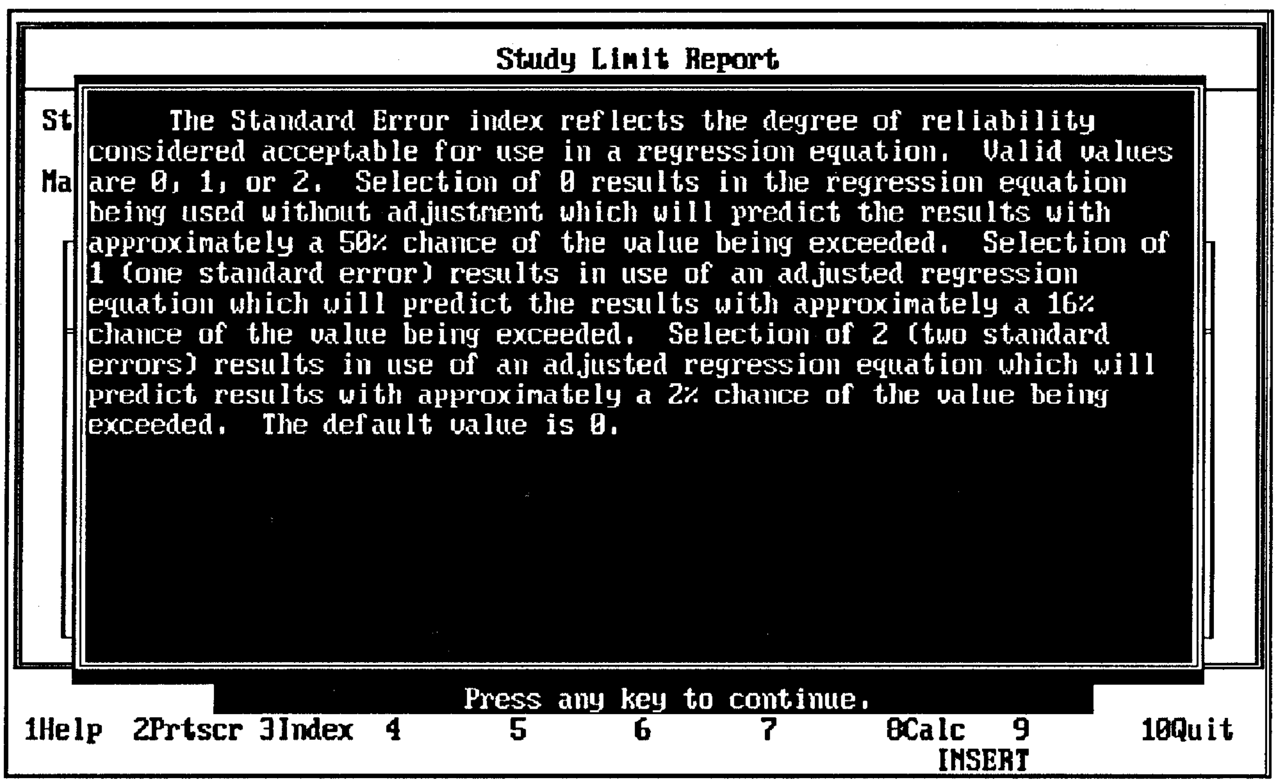


Figure 12 - Standard Error Help Message

Starting at critical depth, the downstream distance is 17,500 feet. For normal depth, the distance is 15,600 feet. See Figure 13. The program will store both values for subsequent recall and use. The larger value will be used in survey cost computations.

35. **Upstream Distance.** The upstream distance for a 5 foot headloss with a 16 percent chance that the estimate may be exceeded is 17,900 feet. This value can be read from the lower right corner of the screen shown in Figure 13. With a 2 percent chance that the estimate might be exceeded, the distance increases to 27,200 feet. The more reasonable value to use in our study is the 17,900 feet.

Study Limit Report

Stream Id DRY CREEK Standard Error 1

Maximum Headloss at Upstream Most Structure (ft) 5

Downstream Cross Section No. 1		Upstream Cross Section No. 4	
Weighted n Value	.06	Weighted n Value	.07
Wtd. Hydraulic Depth (ft)	7.2	Wtd. Hydraulic Depth (ft)	6.9
Top Width (ft)	875.	Top Width (ft)	820.
Discharge (cfs)	10100	Discharge (cfs)	15500
Slope (ft/mi)	4.5	Slope (ft/mi)	6.0
ESTIMATED DISTANCES (ft)			
Start Critical Depth	17500.		
Start Normal Depth	15600.	ESTIMATED DISTANCE (ft)	17900.

1Help 2Prtscr 3Index 4 5 6 7 8Calc 9 10Quit
INSERT

Figure 13 - Study Limit Report

36. **Survey Technology and Accuracy.** The relationship between survey technology and accuracy is analyzed by use of the Error Report, selected from the main menu. The Error Report shown in Figure 14 was developed from the study specifications described in Section 29. It indicates that only field surveys and aerial spot elevation surveys for 2 and 5 foot contour intervals provide mean profile accuracy within 1 foot for a Manning's n value reliability index of 0.5. If the index is 0, all but the 10 foot contour interval topographic map would provide a 1 foot accuracy. For an index of 1.0 no survey method would enable the calculations to be within a foot. See Figure 14.

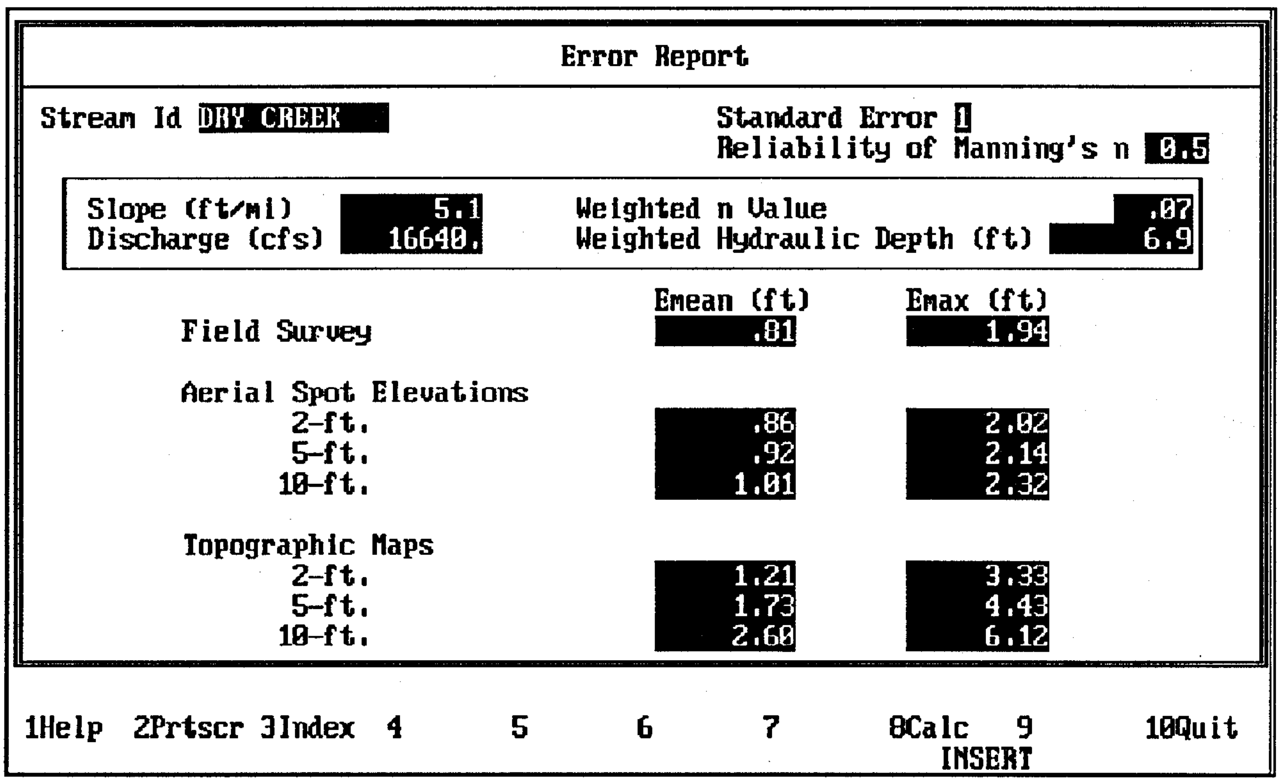


Figure 14 - Error Report

37. **Survey Method for Cross-sectional Data.** Selection of the Cost Report at the main menu permits analysis of the survey factors and costs relevant to survey methods selection. Data entry is required for several items and optional data entry is permitted for others. The top of Figure 15 shows the Survey Factors display as it is retrieved. Input is required for Difficulty Level, Regional Cost Index, Mid Reach Distance, and Additional Lump Sum Costs for bridges. The completed Survey Factors display is also shown in Figure 15 (bottom). Notice the $2,000 additional costs for the four bridges required for all methods.

```
                              Survey Factors
Stream Id DRY CREEK                          Difficulty Level (0,1,2) 0
Hydrographic Survey Width (ft)               Regional Cost Index    1.0
                                             ENR Index             1.62

        Distances (ft)                         Field Survey
Upstream          17900.          No. of Cross Sections
Downstream        17500.          Cross Section Spacing          2000
Mid Reach                         Survey Cost Adjustment Factor   1.0
Survey Width       1150.          Additional Lump Sum Cost

     Aerial Spot Elevations                  Topographic Maps
No. of Cross Sections             No. of Cross Sections
Cross Section Spacing        1000 Cross Section Spacing          1000
Survey Cost Adjustment Factor 1.0 Survey Cost Adjustment Factor   1.0
Additional Lump Sum Cost          Additional Lump Sum Cost

1Help  2Prtscr 3Index  4     5     6     7      8Calc   9     10Quit
                                                  INSERT
```

```
                              Survey Factors
Stream Id DRY CREEK                          Difficulty Level (0,1,2) 1
Hydrographic Survey Width (ft)               Regional Cost Index    1.5
                                             ENR Index             1.62

        Distances (ft)                         Field Survey
Upstream          17900.          No. of Cross Sections            20
Downstream        17500.          Cross Section Spacing          2000
Mid Reach                         Survey Cost Adjustment Factor   1.0
Survey Width       1150.          Additional Lump Sum Cost       2000

     Aerial Spot Elevations                  Topographic Maps
No. of Cross Sections             No. of Cross Sections
Cross Section Spacing        1000 Cross Section Spacing          1000
Survey Cost Adjustment Factor 1.0 Survey Cost Adjustment Factor   1.0
Additional Lump Sum Cost     2000 Additional Lump Sum Cost       2000

1Help  2Prtscr 3Index  4     5     6     7      8Calc   9     10Quit
                                                  INSERT
```

Figure 15 - Survey Factors

The Cost Comparison Report is shown in Figure 16. The field survey cost for 20 cross sections is about $3,300 more than the cost for 36 cross sections obtained by aerial spot elevations. Both methods would generate similar profile accuracy (refer back to Figure 14). The topographic map method cannot provide sufficient survey accuracy for the calculated profile to be determined within 1 foot. The cost is also $6-10,000 more than the other methods. The increased cost is due principally to developing the contour maps. However, other uses of topographic map data may require its development.

Cost Comparison Report

Stream Id DRY CREEK — Level of Difficulty 1

Total Distance (ft) 35400. — Regional Cost Factor 1.15

Survey Width (ft) 1150. — ENR Index 1.62

Hydrographic Survey Width (ft)

Total Survey Costs in Dollars	No Error	2-ft.	5-ft.	10-ft.
Field Survey (20. cross sections)	14424.	NA	NA	NA
Aerial Spot Elevations (36. cross sections)	NA	11099.	11099.	11099.
Topographic Maps (36. cross sections)	NA	21368.	19683.	17097.

Press any key to continue.

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

Figure 16 - Cost Comparison Report

38. **Conclusions.** The recommended survey method is aerial spot elevations for 5-foot contour interval accuracy. Later use of the aerial products to develop topographic maps would be possible if desired for other purposes. This would not be possible for field survey data. The preliminary ratings and water surface elevations are also usable products until such time as the more detailed water surface profile computations are performed.

REFERENCES

Chow, Ven Te, 1959. Open-Channel Hydraulics, McGraw-Hill, Inc., New York.

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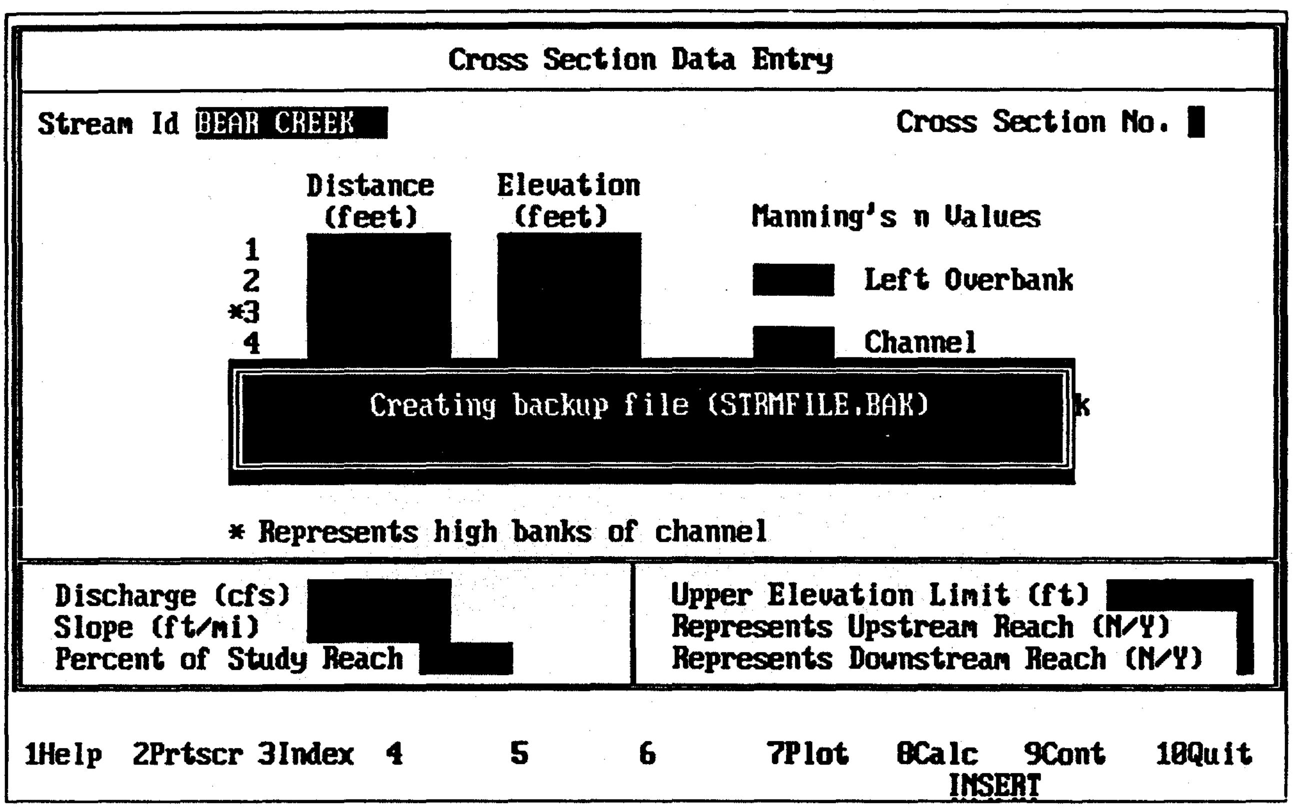
Hydrologic Engineering Center, 1987. *Accuracy of Computed Water Surface Profiles - Commercial Survey Guidelines For Later Surface Profiles Supplement*, U.S. Army Corps of Engineers.

APPENDIX A

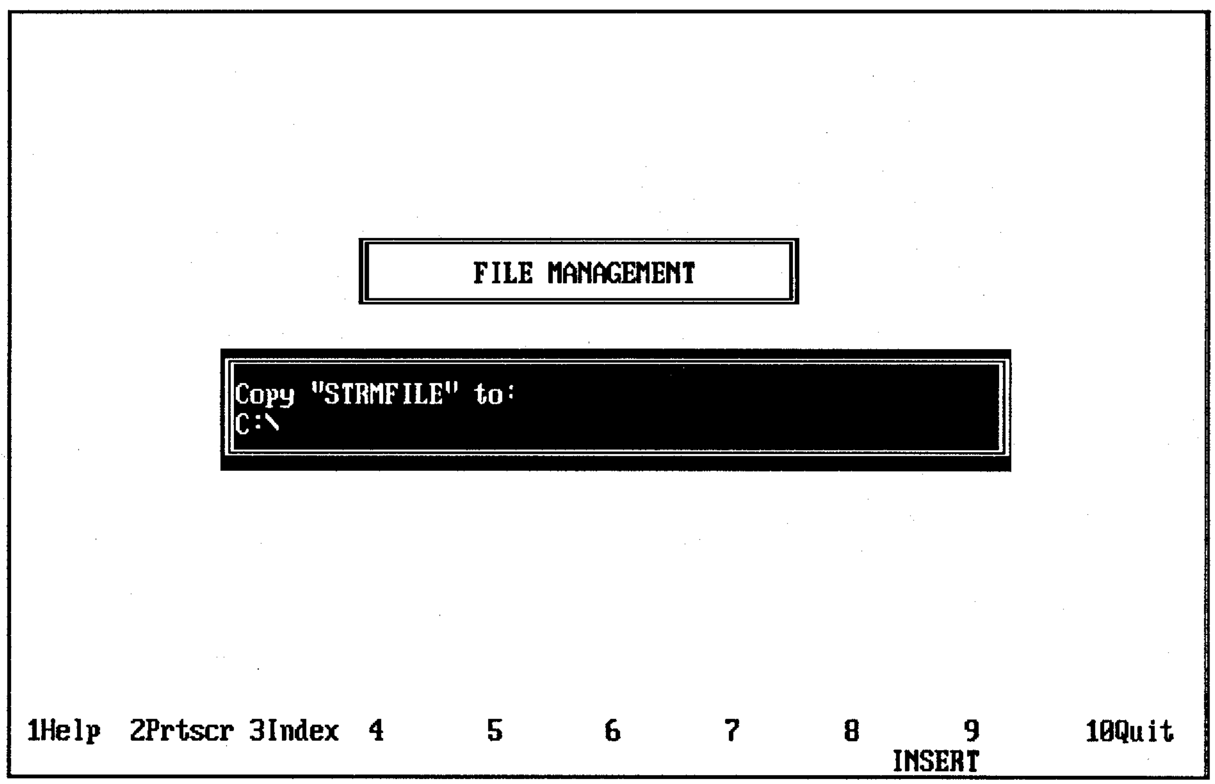
PAS Program Messages

The PAS program may generate the following messages. The action needed to clear the messages is described.

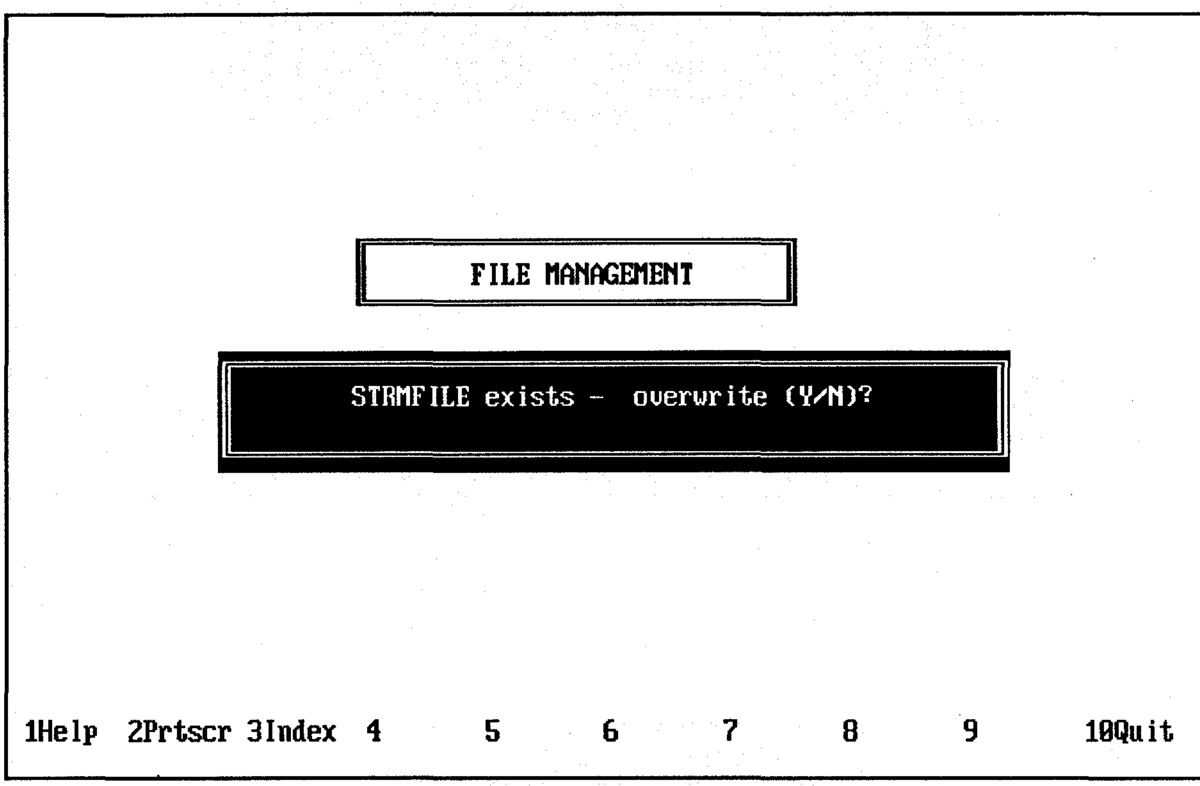
A.1 When the PAS program first reads an existing STRMFILE, it creates a backup file in case of hardware failure during program execution. The name of backup file is STRMFILE.BAK. When this action takes place, the following message is displayed on the screen.



A.2 When a STRMFILE contains more than 20 stream ids, you will be reminded to archive the current STRMFILE and create a new one for future studies. The file management option of the PAS program automates the archive process. After selecting option A from the file management menu, the following message appears on the screen. You may enter any valid DOS pathname and filename, including a file extension. The STRMFILE will be copied to the specified location on the C drive. If you would like to change the drive specifier, you must backspace to the beginning of the line and type in the new drive specifier and filename. The same function can be accomplished outside of the PAS program using the DOS Copy command.



A.3 Selecting the B option from the file management menu will copy the latest backup file, STRMFILE.BAK, to the current STRMFILE. If a current STRMFILE already exists, you will be asked the following question. You may respond by typing either a Y or an N. If you type any letter other than Y, the copy will <u>not</u> take place.



A.4 The System Environment menu allows you to set up the PAS program to use the greater resolution of an enhanced graphics adaptor. Choosing the C option from this menu will display one of the following two messages.

SYSTEM ENVIRONMENT

Enhanced Graphics Adaptor (EGA) Set

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

SYSTEM ENVIRONMENT

Enhanced Graphics Adaptor (EGA) NOT Set

1Help 2Prtscr 3Index 4 5 6 7 8 9 10Quit

A.5 Pressing the F10 key from the Cross Section Data Entry form will initiate the hydraulic parameter computations. If the hydraulic data variables for a particular stream are already stored in the STRMFILE, you will be asked whether or not you would like to replace the stored values. This option prevents you from inadvertently overwriting data. You may respond to the following question by typing either a Y or an N. If you type any letter other than Y, the copy will <u>not</u> take place.

```
                        Cross Section Data Entry

 Stream Id BEAR CREEK                              Cross Section No. 1

                 Distance    Elevation
                  (feet)      (feet)        Manning's n Values
            1          0        1767
            2        220      1755.7        .100  Left Overbank
           *3        767      1754.7
            4        775      1747.4        .040  Channel
              Hydraulic data variables exist - overwrite (Y/N)?      k

            * Represents high banks of channel

  Discharge (cfs)         7800      Upper Elevation Limit (ft)
  Slope (ft/mi)             10      Represents Upstream Reach (N/Y)    N
  Percent of Study Reach    10      Represents Downstream Reach (N/Y)  Y

 1Help  2Prtscr 3Index  4      5      6      7Plot   8Calc   9Cont   10Quit
WAIT                                            INSERT
```

APPENDIX B

PAS Help Messages

On-line help messages are available to the user. They are called up by pressing the F1 key (for general information) and by pressing <Alt> F1 for context sensitive information. Each option, and therefore each screen, is described as well as all available input fields. The following is a listing of all help messages contained in the PAS help files. The tagging label identifies the screens/data fields for which the messages apply.

#TAG PASMENU

The Profile Accuracy System (PAS) computer program is an implementation of the findings of the research investigation sponsored by the Federal Highway Administration documented in the Hydrologic Engineering Center (HEC) report *Accuracy of Computed Water Surface Profiles*, HEC, December 1986. The program provides the capability to study the relationships between desired accuracy for a computed water surface profile, technology and accuracy of map data for defining channel geometry, the areal extent of needed data collection, and the cost of acquiring the needed data. Other capabilities include computation of typical hydraulic parameters such as normal, critical, and hydraulic depths and top width.

Eight coordinate points define the geometry of the cross sections. Channel roughness and flow define the stream conditions. Graphical outputs are provided for efficient viewing of input data and evaluation of analysis results.

The Main Menu of the Profile Accuracy System (PAS) provides the opportunity to perform any of five different major functions: (1) FILE MANAGEMENT AND SYSTEM UTILITIES; (2) CROSS SECTION PROPERTIES; (2) STUDY REACH DELINEATION; (4) PROFILE ERROR ANALYSIS; and (5) COST COMPARISON. To access a particular function, press the letter key next to the function. You may also move the cursor to highlight any item and press the <ENTER> key.

The F1 (Help) function key may be used (alone or with the Alt key) at any time for help information and instructions. Pressing F1 alone will provide general help and information related to a screen or function. Pressing <Alt> F1 simultaneously will provide detailed definitions and instructions for the item defined by the cursor location. The help message is cleared from the screen by pressing any key.

The F2 (Prtscr) function key may be used at any time, except when a plot is on the screen, to get a hard copy of the screen.

The F3 (Index) function key will display an index of the Stream Ids stored in the current program data base file (STRMFILE).

The F10 (Quit) function key is used to exit the program or to return to the main menu from any data entry form, report, or plot.

The ESCape key backs up one level in menus or operations. The F10 key must be used to exit the program.

See next page for key pad functions.

PAS Key Pad Functions

Home: Move to Stream Id field
End: Move to last input field on screen
Tab: Move to next field
Shift Tab: Move to prior field
Backspace: Delete character before the cursor
Del: Delete character at the cursor
←→ : Move cursor left/right a character or field
↑↓: Move cursor up/down a field
Ins: Insert character mode (toggle)
Insert mode on - insert character at the cursor
Insert mode off (typeover) - replace character at cursor

<table>
<tr><td>7
Home</td><td>8
↑</td><td>9</td><td>-</td></tr>
<tr><td>4
←</td><td>5</td><td>6
→</td><td rowspan="3">+</td></tr>
<tr><td>1
End</td><td>2
↑</td><td>3</td></tr>
<tr><td colspan="2">0
Ins</td><td>.
Del</td></tr>
</table>

#TAG FILEMGT
#TAG MAINMA

The File Management menu has two components: (A) Archive a STRMFILE; and (B) Copy STRMFILE.BAK file to STRMFILE. Option A should be used to copy the current data base file called STRMFILE to another file for archival purposes. This should be done whenever the STRMFILE contains 20 or more Stream IDs. It may be done at any time to archive the STRMFILE. As your STRMFILE grows, you will be informed by the program when you reach the 20 stream mark. Option B can be used to recover a backup file if the current STRMFILE is accidently destroyed.

#TAG SYSTENV
#TAG MAINMB

The System Environment menu has three components: (A) Change Background Color; (B) Change Foreground Color; and (C) Enhanced Graphics Adaptor (EGA). Option A allows you to permanently change the background color used during program execution; Option B permanently changes the foreground color. Option C is a toggle used to inform the program whether or not you have an enhanced graphics adaptor. If you have a color graphics adaptor (CGA) or a monochrome display, do not use this option. The options set here are stored in a file called PAS.INI.

#TAG XSECIP
#TAG MAINMC

The Cross Section Data Entry selection is used to enter or edit cross section data. A cross section data entry form will appear on the screen to allow you to enter up to five cross sections for each stream. Each cross section is defined by 8 coordinate points; all are required. If this is the first operation being performed, the Stream Id must be the first data entered; otherwise, the program will remember the Stream Id entered previously. If the cross section data for that stream already exists in the current data base file, pressing the <Enter> key will cause the data to appear on the screen for the first cross section. This allows you to edit the previously entered data. When entering a new stream, the default data will appear on the screen. Data will be checked for validity before going on to the next field.

The F7 (Plot) function key will plot the cross section that is currently on the screen. If the hydraulic data variables have been computed, then the normal depth will be plotted on the graph.

The F8 (Calc) function key causes the program to compute the hydraulic data variables for the cross section data. A WAIT signal will flash in the lower left corner until the operation is completed. The representative hydraulic data variables will be computed and if they already exist in the current data base file, you will be asked if you want to overwrite them. This prevents hydraulic data variables that were entered directly by you from being overwritten.

The F9 (Cont) function key causes the program to write the data on the screen to the current data base file and allows you to enter or edit the data for the next cross section. At the end of the fifth cross section, the F9 key will return to the first cross section.

The F10 (Quit) function key returns you to the Main Menu after computing the hydraulic data variables. The WAIT message will flash in the lower left corner of the screen while computations are being performed. The weighted parameters for the overall reach, downstream section, and upstream section are computed based on the percent of study reach. If more than one cross section is selected to represent the upstream or downstream section, the cross section with the highest number will be used.

#TAG HYDVARIN
#TAG MAINMD

The user can bypass or override the cross section data entry and program computations by selecting the Hydraulic Variables Data Entry option. You may enter the weighted values for the overall reach, the downstream section, and the upstream section directly using this data entry form. If a Stream Id already exists in the current data base file, the hydraulic variables values will appear on the screen allowing you to edit the previously entered or computed values. The F10 (Quit) function key returns you to the main menu after writing the data to the current data base file. The ESCape key returns you to the main menu without writing the data to the data base file.

#TAG XSECPLOT
#TAG MAINME

The Cross Section Plot option allows you to cycle through the plots for all the cross sections stored in the current data base for a particular stream. After entering a Stream Id, you may enter a cross section number to plot that particular cross section, or you may use the F9 (Cont) function key to plot each cross section in sequence. When a plot is on the screen, if you have an IBM-compatible printer, you may use the keyboard <Print Scrn> key to get a hard copy of the plot. The DOS GRAPHICS command must be executed prior to this program session for <Print Scrn> to produce a graphic plot. Otherwise, pressing any key will return you to the plot entry form. The ESCape key or F10 function key will return you to the main menu.

#TAG XSECREPT
#TAG MAINMF
The Cross Section Report summarizes the computed cross section properties for each cross section. The only field you may change is the Stream Id. If you select a Stream Id that is not in the current data base file, an index of valid Stream Ids will appear on the screen. Most data items are defined concurrent with input screens. The remaining items are: minimum elevation - the minimum elevation for the cross section; top width - linear distance across cross section for elevation equal to normal depth; and proportion - same as percent of study reach.

#TAG HYDVREPT
#TAG MAINMG
The Hydraulic Variable Report displays the weighted hydraulic data variables that are stored in the current data base file. This report looks identical to the Hydraulic Data Entry screen except for the title. You may NOT use this screen to modify the values in the current data base file. The values stored in the data base are used in subsequent analysis.

#TAG RATNGTAB
#TAG MAINMH
The Rating Table is a table of discharge-elevation values computed from Manning's equation for normal depth conditions. Discharge values ranging from 10 percent to 200 percent of the input Q are selected by the program and water surface elevations are determined for those values for each cross section. The WAIT message will flash in the lower left corner of the screen while computations are being performed.

#TAG RATNGCRV
#TAG MAINMI
The Rating Curve, a graphic representation of the Rating Table, may be plotted for each cross section stored in the data base, one at a time. After entering a Stream Id, you may enter a cross section number to plot the rating curve for that particular cross section, or you may use the F9 (Cont) function key to plot the rating curve for each cross section in sequence. When a plot is on the screen, if you have an IBM-compatible printer, you may use the keyboard <Print Scrn> key to get a hard copy of the plot. The DOS GRAPHICS command must have been issued prior to the current program session in which a hard copy graphic plot is desired. Otherwise, pressing the <Enter> key will return you to the plot entry form. The ESCape key or F10 (Quit) function key will return you to the main menu. The WAIT message will flash in the lower left corner of the screen while computations are being performed.

#TAG STDYREPT
#TAG MAINMJ
The Study Limit Report enables determination of the upstream and downstream limits for stream geometry and roughness data

collection. The limits are determined from stream hydraulic properties, selected standard error index, and structure headloss. Default values for input items will be used if not specified. Regression equations 7.1, 7.2, and 7.3 from *Accuracy of Computed Water Surface Profiles* (HEC) are used for the computations. The estimated downstream distance is computed for both conditions of starting at normal depth and starting at critical depth (bottom left of screen). The estimated upstream distance (lower right) is computed based on the input structure headloss and stream parameters shown for the upstream representative cross section (or parameters).

The F8 (Calc) function key will cause the program to calculate the distances. Repeated alteration of input data and F8 (Calc) key operations is expected. The values on the screen are saved for subsequent analysis by pressing the F10 (Quit) key to exit the screen.

#TAG ERROREPT
#TAG MAINMK

The Error Report enables study of the relationship between estimated computed profile error and technology and accuracy of survey method, reliability of Manning's n, and stream hydraulic properties. Input values are standard error index and reliability of Manning's n. Stream hydraulic properties are retrieved from the program data base. Estimated computed profile errors are calculated from regression equations 6.3 through 6.10 from *Accuracy of Computed Water Surface Profiles* (HEC). Emean is the mean reach absolute profile error and Emax is the absolute reach maximum profile error.

Field Surveys are performed by crews using conventional survey instruments and are presumed to be without error. Aerial Spot Elevations are developed by photogrammetry methods in which elevations are determined from a stereo model. Topographic Maps are paper products with inscribed contour lines from which elevations may be manually read. The contour intervals characterize the accuracy standard of the survey methods.

The F8 (Calc) function key will cause the program to calculate the errors. Repeated alteration of input data and F8 (Calc) key operations is expected.

#TAG SURVFACT
#TAG MAINML

The Cost Report enables comparison of survey costs among the survey methods. Data are required to define distances, survey difficulty, and numbers of cross sections needed by survey method. Several data items are supplied from the program data base (distances and survey width). Others are provided with default values. The remainder are optional inputs. All may be overridden by providing alternative input in each field. There are two screens: (1) the opening screen (Survey Factors) defines the survey factors as described above and (2) the Cost Report screen will appear when the F8 (Calc) function key is pressed. Costs are computed and written to this second screen.

#TAG COSTREPT

The Cost Comparison Report screen displays a summary of data from the Survey Factors and provides computed survey costs for the 3 survey methods and 4 accuracy specifications. Costs are the total for each survey method for developing complete stream geometry data and preparing and verifying the necessary HEC-2 data sets. Pressing any key will cause return to the Survey Factors screen. Repeated data entry on the Survey Factors screen and calculations are possible.

#TAG SURVCOST
#TAG MAINMM
The Optional Cost selection enables program data base survey costs to be replaced with user-supplied survey cost data. The values stored in the program are taken from the *Commercial Survey Guidelines for Water Surface Profiles* supplement to *Accuracy of Computed Water Surface Profiles* (HEC). The cost data contained in the supplement was expanded and the results are documented in the User's Manual.

The Survey Cost Per Cross Section consists of nine (9) screens for each Stream Id, representing three (3) different indexes of cross section numbers and (3) difficulty levels for each index. You may change the index and the costs for any of the nine screens. You may not change the difficulty level.

The F9 (Cont) function key is used to cycle through the nine screens.

The F10 (Quit) function key will store the costs in the current data base file for the selected stream and return to the main menu. The modified costs will then be used in cost calculations.

The ESCape key will return to the main menu without storing the costs in the current data base file.

#TAG STRMID
The Stream Id is an alphanumeric label to identify the stream under investigation. It may contain any combination of 1 to 12 characters, numbers and spaces. Lowercase letters are treated as uppercase letters.

#TAG SECTNO
The Cross Section No. is an integer from 1 to 5 representing the sequence number of the cross section.

#TAG DIST2
#TAG DIST3
#TAG DIST4
#TAG DIST5
#TAG DIST6
#TAG DIST7
#TAG DIST8
#TAG DIST1
Distance is the distance (in feet) representing the x-coordinate of a cross section coordinate point. There must be 8 coordinate points defining each cross section. The third distance value represents the left overbank station. The sixth distance value represent the right overbank station. Valid values range from 0 to 10,000 to the nearest .1 foot.

#TAG ELEV2

#TAG ELEV3
#TAG ELEV4
#TAG ELEV5
#TAG ELEV6
#TAG ELEV7
#TAG ELEV8
#TAG ELEV1

Elevation is the elevation (in feet) representing the y-coordinate of a cross section coordinate point. The elevation values must decrease to the bottom of the river bed before increasing (eg., islands may not be included). There must be 8 coordinate points defining each cross section. Valid values range from 0 to 10,000 to the nearest .1 foot.

#TAG XNVALL

Manning's n Value is the roughness coefficient for the left overbank portion of the cross section. Valid values range from .010 to 1.0 to the nearest .001.

#TAG XNVALC

Manning's n Value is the roughness coefficient for the channel portion of the cross section. Valid values range from .010 to 1.0 to the nearest .001.

#TAG XNVALR

Manning's n Value is the roughness coefficient for the right overbank portion of the cross section. Valid values range from .010 to 1.0 to the nearest .001.

#TAG XSECQ

Discharge is the discharge or flow in cubic feet per second (cfs) for a flood event that has a 1 percent chance of being exceeded in any given year. Valid values range from 10 to 999,999 to the nearest 10 cfs.

#TAG XSLOPE

Slope is the stream slope in feet per mile representative for this cross section. Valid values range from 1.0 to 30.0 to the nearest .1 foot.

#TAG XPCTDY

Percent of Study Reach is the percent of the study reach that is represented by a cross section. The default is equal percentage for each cross section. Percentages are entered as whole numbers greater than 1. A value of 50 appears as the default value for all cross sections. Valid values range from 10 to 90 to the nearest 1 percent. Output reports use the label "proportion."

#TAG ELVLIM

Upper Elevation Limit is the upper elevation (in feet) within a cross section that will be used to compute the survey width. If not specified, an elevation will be computed for the specified flow plus 5 vertical feet. Valid values range from 0 to 10,000 to the nearest foot.

#TAG REPUP

Represents Upstream Reach specifies whether or not this cross section is intended to represent the upstream portion of the study reach. Valid values are N or Y.

#TAG REPDWN

Represents Downstream Reach specifies whether or not this cross section is intended to represent the downstream portion of the study reach. Valid values are N or Y.

#TAG OFLOW

Discharge is the discharge or flow in cubic feet per second (cfs) for a flood event that has a 1 percent chance of being exceeded in any given year. A weighted value is computed for the overall reach. This value may also be input directly. Valid values range from 10 to 999,999 to the nearest 10 cfs.

#TAG UFLOW
#TAG DFLOW

Discharge is the discharge or flow in cubic feet per second (cfs) for a flood event that has a 1 percent chance of being exceeded in any given year. The value is taken as the discharge for the selected representative cross section or as the overall weighted value if no representative cross section is specified. This value may also be input directly. Valid values range from 10 to 999,999 to the nearest 10 cfs.

#TAG OSLOPE

Slope is the slope in feet per mile for the overall portion of the study reach. A weighted value is computed for the overall reach based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from 1.0 to 30.0 to the nearest .1 foot.

#TAG USLOPE
#TAG DSLOPE

Slope is the slope in feet per mile for the selected representative cross section or as the overall weighted value if no representative cross section is specified. This value may also be input directly. Valid values range from 1.0 to 30.0 to the nearest .1 foot.

#TAG ONVAL

Manning's n Value is the roughness coefficient for the overall reach. A weighted value is computed for the overall reach based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from .010 to .999 to the nearest .001

#TAG UNVAL
#TAG DNVAL

Manning's n Value is the roughness coefficient for the selected representative cross section or as the overall weighted value if no representative cross section is specified. This value may also be input directly. Valid values range from .010 to .999 to the nearest

.001

#TAG ONDPTH

Normal Depth for the overall study reach is the computed flow depth that represents where the rate of energy loss equals the channel slope. A weighted value is computed based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG DNDPTH

Normal Depth for the downstream portion of the study reach is the computed flow depth that represents where the rate of energy loss equals the channel slope. If no downstream cross section is selected, the downstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG UNDPTH

Normal Depth for the upstream portion of the study reach is the computed flow depth that represents where the rate of energy loss equals the channel slope. If no upstream cross section is selected, the upstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG OCDPTH

Critical Depth for the overall study reach is the flow depth for minimum specific energy. A weighted value is computed based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG DCDPTH

Critical Depth for the downstream portion of the study reach is the flow depth for minimum specific energy. If no downstream cross section is selected, the downstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG UCDPTH

Critical Depth for the upstream portion of the study reach is the flow depth for minimum specific energy. If no upstream cross section is selected, the upstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG OHDPTH

Hydraulic Depth for the overall study reach is the flow area divided by the top width. A weighted value is computed based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG DHDPTH

Hydraulic Depth for the downstream portion of the study reach is the flow area divided by the top width. If no downstream cross section is selected, the downstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG UHDPTH
Hydraulic Depth for the upstream portion of the study reach is the flow area divided by the top width. If no upstream cross section is selected, the upstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 1 to 50 to the nearest .1 foot.

#TAG SWIDTH
The Survey Width is the computed top width for the upper elevation limit either computed by the program or input directly by the user. Valid values range from 100 to 10,000 to the nearest .1 foot.

#TAG OTWDTH
The Top Width for the overall study reach is the linear distance between two equal elevations along a cross section for computed normal depth for the overall study reach. A weighted value is computed based on the percent of study reach for each cross section. This value may also be input directly. Valid values range from 100 to 10,000 to the nearest .1 foot.

#TAG DTWDTH
The Top Width for the downstream portion of the study reach is the linear distance between two equal elevations along a cross section for a computed normal depth. If no downstream cross section is selected, the downstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 100 to 10,000 to the nearest .1 foot.

#TAG UTWDTH
The Top Width for the upstream portion of the study reach is the linear distance between two equal elevations along a cross section for a computed normal depth. If no upstream cross section is selected, the upstream parameters are set equal to the overall parameters. This value may also be input directly. Valid values range from 100 to 10,000 to the nearest .1 foot.

#TAG HSWDTH
The Hydrographic Survey Width is the distance of the cross section that must be surveyed by hydrographic methods. The costs for this width will be added to the survey costs for each survey method. Valid values range from 0 to 10,000 feet but should not exceed the survey width. The default value is 0.

#TAG LEVELD
#TAG DIFLVL
The Difficulty Level represents the level of difficulty in obtaining the survey data. Level 0 = flat, light cover. Level 1 = moderate cover and steepness. Level 2 = steep, heavy cover. The program default is 0.

#TAG RCOSTF
#TAG RCINDX

The Regional Cost Index is a multiplier adjustment to the program cost algorithms to reflect regional cost differences. The program default value is 1.0 reflecting conditions in Sacramento, CA, 1985. Valid values range from .5 to 3.0 to the nearest .1. Appendix D of *Commercial Survey Guidelines for Water Surface Profiles - Supplement*, HEC, January, 1987, provides suggested labor adjustment indices.

#TAG ENRNDX

The Engineering News Record (ENR) Index is a composite US Bureau of Reclamation value published in the ENR quarterly cost round-up. The program default value of 1.62 brings the base value Jan 1985 costs to the current Oct 1987 costs. Valid values range from 1.00 to 3.00 to the nearest .01.

#TAG UDIST

The Upstream Distance represents the distance where the profile resulting from the structure-created-headloss converges with the profile for the undisturbed condition. The distance is computed by the program using regression equations as described for the Study Limit Report or may be input directly. Valid values are greater than 0 to the nearest 100 feet.

#TAG DDIST

The Downstream Distance represents the distance downstream from point of interest at which data collection should begin. The distance is computed by the program using regression equations as described for the Study Limit Report. The larger of the two computed values (start normal depth and start critical depth) is used. The value may also be input directly. Valid values are greater than 0 to the nearest 100 feet.

#TAG MRDIST

The Mid Reach Distance represents any additional distance to be added to the upstream and downstream distances that is needed to define the overall study limits. Valid values are greater than 0 to the nearest 100 feet.

#TAG FSNSEC
#TAG FNXSEC

The No. of Cross Sections for field survey is the number of cross sections to be surveyed and thus used to compute the survey costs. The number of cross sections may be computed as the total distance (upstream distance + mid reach distance + downstream distance) divided by the default value of 2,000 feet per cross section or may be input directly. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are integers from 1 to 1,000.

#TAG FSPACE

The Cross Section Spacing for field survey represents the distance between cross sections. It is used to calculate the number of cross sections used to compute the survey costs. (The number of cross sections = the total distance (upstream + mid reach + downstream) divided by the cross section spacing + 1). The default spacing equals 2,000 feet. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are greater than 99 to the nearest 100 feet.

#TAG FCFACT
#TAG ACFACT
#TAG TCFACT
The Survey Cost Adjustment Factor for each survey method is a multiplier to apply to the cost equation to reflect possible location variation in costs among survey methods. The default value is 1.0. Valid values range from .5 to 3.0 to the nearest .1.

#TAG FACOST
#TAG AACOST
#TAG TACOST
The Additional Lump Sum Cost for each survey method represents a lump sum cost over and above the program-computed cost to be added to program costs to reflect special items such as setting monuments, development of special maps, etc.. The default value is 0. Valid values are greater than 0 to the nearest $100.

#TAG ASNSEC
#TAG ANXSEC
The No. of Cross Sections for aerial spot elevations is the number of cross sections used to compute the survey costs. The number of cross sections may be computed as the total distance (upstream distance + mid reach distance + downstream distance) divided by the default value of 1,000 feet per cross section or may be input directly. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are integers from 1 to 1,000.

#TAG ASPACE
The Cross Section Spacing for aerial spot elevations represents the distance between cross sections. It is used to calculate the number of cross sections used to compute the survey costs. (The number of cross sections = the total distance (upstream + mid reach + downstream) divided by the cross section spacing + 1). The default spacing equals 1,000 feet. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are greater than 99 to the nearest 100 feet.

#TAG TMNSEC
#TAG TNXSEC
The No. of Cross Sections for topographic maps is the number of

cross sections used to compute the survey costs. The number of cross sections may be computed as the total distance (upstream distance + mid reach distance + downstream distance) divided by the default value of 1,000 feet per cross section or may be input directly. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are integers from 1 to 1,000.

#TAG TSPACE

The Cross Section Spacing for topographic maps represents the distance between cross sections. It is used to calculate the number of cross sections used to compute the survey costs. (The number of cross sections = the total distance (upstream + mid reach + downstream) divided by the cross section spacing + 1). The default spacing equals 1,000 feet. The user may override the default number of cross sections or spacing. If computation of the number of cross sections from the spacing is desired, the field for the No. of Cross Sections must be blank. Valid values are greater than 99 to the nearest 100 feet.

#TAG INDEX

The Index Number of Cross Sections represents the number of cross sections for the survey costs per cross section table. There may only be three (3) different indexes. These indexes are used for all the levels of difficulty. The default values are 11, 51, and 81. Valid values are successively increasing integers from 1 to 100.

#TAG F200
#TAG F500
#TAG F1000
#TAG F3000
#TAG F5000

The Field Survey cost per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG A200
#TAG A500
#TAG A1000
#TAG A3000
#TAG A5000

The Aerial Spot Elevations cost per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG T2200
#TAG T2500
#TAG T21000
#TAG T23000
#TAG T25000

The Topographic Maps cost per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for the 2-foot.

contour interval for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG T5200
#TAG T5500
#TAG T51000
#TAG T53000
#TAG T55000
The Topographic Maps cost per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for the 5-foot. contour interval for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG T0200
#TAG T0500
#TAG T01000
#TAG T03000
#TAG T05000
The Topographic Maps cost per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for the 10-foot. contour interval for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG H200
#TAG H500
#TAG H1000
#TAG H3000
#TAG H5000
The Hydrographic Surveys costs per cross section for the flood plain widths of 200, 500, 1,000, 3,000, and 5,000 feet for each index number of cross sections and difficulty level. Valid values are greater than 0 to the nearest $1.

#TAG STDERR
The Standard Error index reflects the degree of reliability considered acceptable for use in a regression equation. Valid values are 0, 1, or 2. Selection of 0 results in the regression equation being used without adjustment which will predict the results with approximately a 50 percent chance of the value being exceeded. Selection of 1 (one standard error) results in use of an adjusted regression equation which will predict the results with approximately a 16 percent chance of the value being exceeded. Selection of 2 (two standard errors) results in use of an adjusted regression equation which will predict results with approximately a 2 percent chance of the value being exceeded. The default value is 0.

#TAG HLOSS
The Maximum Headloss at Upstream Most Structure represents the induced increase in water surface elevation resulting from placement of a bridge or other structure in the waterway. The default value is 0.5. Valid values range from 0.5 to 5.0 to the nearest .1 foot. A value of 0 may be input if no structure or headloss is desired.

#TAG RELMN
The Reliability of Manning's n reflects the confidence in the

estimated value of Manning's n coefficient. A value of 0.0 represents perfect confidence (or perfect knowledge of Manning's n); a value of 1.0 represents modest confidence reflected by professional engineering judgment. The default value equals 0.5 or moderate confidence. Valid values range from 0.0 to 1.0 to the nearest .1.

#TAG TOTDIS
Total Distance is the sum of the upstream, mid reach, and downstream distances. This number is used to determine the number of cross sections used in the cost comparison report.

#TAG AS2
#TAG AS5
#TAG AS10
#TAG TM2
#TAG TM5
#TAG TM10
#TAG FSNOER
The Cost Comparison for each survey technology.

#TAG FILEMA
Archive a STRMFILE will copy an existing STRMFILE to a new file. This function should be performed whenever a STRMFILE contains 20 or more Stream Ids. You will be asked for a new file name before the copy is performed.

#TAG FILEMB
Copy STRMFILE.BAK file to STRMFILE will restore a previously created backup STRMFILE in the event that the current STRMFILE is damaged. If a current STRMFILE exists, you will be asked if you want to overwrite it.

#TAG SYSEMA
If you are using a color monitor, you may change the background color by selecting this item. Pressing the <A> key or the <Enter> key when this option is highlighted will cycle through the different colors. Any changes you make will be stored in the file PAS.INI for future reference.

#TAG SYSEMB
If you are using a color monitor, you may change the foreground color by selecting this item. Pressing the <B> key or the <Enter> key when this option is highlighted will cycle through the different colors. Any changes you make will be stored in the file PAS.INI for future reference.

#TAG SYSEMC
If you are using an enhanced color monitor, you may inform the program by selecting this option. Repeated selection of this option will turn the option on and off. Any changes you make will be stored in the file PAS.INI for future reference.

#TAG ENDHLP
END OF HELP FILE

APPENDIX C

Data Entry Field Range Checks

PAS checks the values of data items entered by the user for validity. The values are compared with a set of ranges at the time of data entry. Values outside the acceptable range are rejected and a valid range message written to the monitor. Tabulated below by option/screen are the input fields and data ranges.

C.1 Cross Section Data Entry

The Cross Section No. is an integer from 1 to 5.

Distance valid values range from 0 to 10,000 to the nearest .1 foot.

Elevation valid values range from 0 to 10,000 to the nearest .1 foot.

Manning's n Value valid values range from .010 to 1.0 to the nearest .001.

Discharge valid values range from 10 to 999,999 to the nearest 10 cfs.

Slope valid values range from 1.0 to 30.0 to the nearest .1 foot.

Percent of Study Reach valid values range from 10 to 90 to the nearest 1 percent.

Upper Elevation Limit valid values range from 0 to 10,000 to the nearest foot.

Represents Upstream Reach valid values are N or Y.

Represents Downstream Reach valid values are N or Y.

C.2 Hydraulic Variables Data Entry

Discharge valid values range from 10 to 999,999 to the nearest 10 cfs.

Slope valid values range from 1.0 to 30.0 to the nearest .1 foot.

Manning's n Value valid values range from .010 to .999 to the nearest .001

Normal Depth valid values range from 1 to 50 to the nearest .1 foot.

Critical Depth valid values range from 1 to 50 to the nearest .1 foot.

Hydraulic Depth valid values range from 1 to 50 to the nearest .1 foot.

The Survey Width valid values range from 100 to 10,000 to the nearest .1 foot.

The Top Width valid values range from 100 to 10,000 to the nearest .1 foot.

C.3 Study Limit Report Screen

The Standard Error index valid values range from 0 to 2.

The Maximum Headloss at Upstream Most Structure valid values range from 0.5 to 5.0 to the nearest .1 foot. A value of 0 may be input if no structure or headloss is desired.

C.4 Error Report

The Reliability of Manning's n valid values range from 0.0 to 1.0 to the nearest .1.

C.5 Survey Factors

The Hydrographic Survey Width valid values range from 0 to 10,000 feet but should not exceed the survey width.

The Difficulty Level valid values range from 0 to 2.

The Regional Cost Index valid values range from .5 to 3.0 to the nearest .1.

The Engineering News Record (ENR) Index valid values range from 1.00 to 3.00 to the nearest .01.

The Upstream Distance valid values are greater than 0 to the nearest 100 feet.

The Downstream Distance valid values are greater than 0 to the nearest 100 feet.

The Mid Reach Distance valid values are greater than 0 to the nearest 100 feet.

The No. of Cross Sections valid values are integers from 1 to 1,000.

The Cross Section Spacing valid values are greater than 99 to the nearest 100 feet.

The Survey Cost Adjustment Factor valid values range from .5 to 3.0 to the nearest .1.

The Additional Lump Sum Cost valid values are greater than 0 to the nearest $100.

C.6 Other Costs (Survey Costs Per Cross Section) Screen

The Index Number of Cross Sections valid values are successively increasing integers from 1 to 100.

The Field Survey cost per cross section valid values are greater than 0 to the nearest $1.

The Aerial Spot Elevations cost per cross section valid values are greater than 0 to the nearest $1.

The Topographic Maps cost per cross section valid values are greater than 0 to the nearest $1.

The Hydrographic Surveys costs per cross section valid values are greater than 0 to the nearest $1.

APPENDIX D

Equations

The regression equations used in PAS to compute upstream and downstream distances and profile errors are published in Accuracy of *Computed Water Surface Profiles* (Hydrologic Engineering Center 1986). The equations are presented below, identified with the equation numbers of the original publication.

Downstream Reach Length.

$$Ldc = 6600*HD/S \qquad \text{(Equation 7.1)}$$

and,

$$Ldn = 8000*HD^{.8}/S \qquad \text{(Equation 7.2)}$$

where: Ldc = downstream study length (along main channel) in feet for critical depth starting conditions,
Ldn = downstream study length (along main channel) in feet for normal depth starting conditions,
HD = average reach hydraulic depth (1-percent chance flow area divided by cross section top width) in feet, and
S = average reach slope in feet per mile.

Upstream Reach Length.

$$Lu = 10{,}000*HD^{.6}*HL^{.5}/S \qquad \text{(Equation 7.3)}$$

where: Lu = The estimated upstream study length (along main channel) in feet required for convergence of the modified profile to within .1 feet of the base profile,
HL = headloss ranging between .5 and 5.0 feet at the channel crossing structure for the 1-percent chance flow.

Errors - Field Survey.

$$Emean = .076*HD^{.6}*S^{.11}*(5*Nr)^{.65} \qquad \text{(Equation 6.3)}$$

and $$Emax = 2.1*(Emean)^{.8} \qquad \text{(Equation 6.4)}$$

where: Emean = mean reach absolute profile error in feet,
Emax = absolute reach maximum profile error in feet,
Nr = reliability of estimation of Manning's coefficient on a scale of 0 to 1.0

Errors - Aerial Spot Elevations.

$$Emean = .076*HD^{.60}*S^{.11}*(5*Nr + Sn)^{.65} \qquad \text{(Equation 6.5)}$$

and $$Emax = 2.1*(Emean)^{.8} \quad \text{(Equation 6.6)}$$

For the special case of Nr = 0, when Manning's coefficient is precisely known, a better equation is

$$Emean = .0731*S^{.49}*Sn^{.83} \quad \text{(Equation 6.7)}$$

where: Sn = the standardized survey accuracy being analyzed - the contour interval 2-, 5-, 10-feet divided by 10; and other variables are as previously defined.

Errors - Topographic Maps.

$$Emean = .45*HD^{.35}*S^{.13}*(Nr + Sn) \quad \text{(Equation 6.8)}$$

and $$Emax = 2.6*(Emean)^{.8} \quad \text{(Equation 6.9)}$$

For the special case when Manning's coefficient is precisely known (Nr = 0), the profile error can be found with greater accuracy with the equation

$$Emean = .632*S^{.23}*Sn^{1.18} \quad \text{(Equation 6.10)}$$

APPENDIX E

Survey Cost Data

The survey cost data for PAS was developed from a special study performed as an addendum to *Accuracy of Computed Water Surface Profiles - Commercial Survey Guidelines For Water Surface Profiles Supplement* (Hydrologic Engineering Center 1987). The basic data developed in that reference were extended to cover the full range of flood plain widths, map accuracy, and survey factors adopted for PAS. Table 7 is a copy of data from the addendum. The values from the table are used as follows: category A - aerial spot elevations; category B - topographic maps; category C - field surveys; and category D - hydrographic surveys. Category E is not used. The values in the table should match the values displayed when the Optional Costs option is selected from the main menu of PAS.

Table 7
<u>Survey Costs Summary</u>

Costs Per Section
(Dollars)

Category	Cost Table No.	Survey Description	Contour Interval (feet)	Spacing @ 2000 Feet (11 Sections) Section Width, feet					Spacing @ 400 Feet (51 Sections) Section Width, feet					Spacing @ 250 Feet (81 Sections) Section Width, feet				
				200	500	1000	2000	5000	200	500	1000	2000	5000	200	500	1000	2000	5000
				(dollars)														
A		Aerial Surveys, Cross Sections Only																
	3	Flat, Light Cover	-	562	562	565	573	933	142	142	144	146	229	97	97	97	104	157
	*	Moderate Slope, Moderate Cover	-	621	621	625	632	1,051	155	156	158	159	255	105	105	109	112	173
	4	Steep, Heavy Cover	-	680	680	684	690	1,169	168	169	171	171	280	113	113	120	120	189
B		Aerial Surveys, Topography and Cross Sections																
	5	Flat Light Cover	2	835	907	1,043	1,253	2,307	201	216	247	292	526	134	144	162	196	343
	*	Moderate Slope, Moderate Cover	2	1,078	1,182	1,383	1,687	3,207	254	277	322	387	720	167	182	212	256	466
	6	Steep, Heavy Cover	2	1,320	1,456	1,722	2,120	4,107	306	337	396	481	914	200	219	261	315	588
	7	Flat, Light Cover	5	795	857	970	1,155	2,104	193	206	231	272	482	128	137	152	183	316
	*	Moderate Slope, Moderate Cover	5	1,016	1,100	1,260	1,511	2,839	241	259	295	349	641	159	170	195	231	416
	8	Steep, Heavy Cover	5	1,237	1,342	1,549	1,866	3,573	288	312	358	425	799	189	203	238	279	515
	9	Flat, Light Cover	10	726	772	855	987	1,767	178	188	206	235	409	119	125	137	160	270
	*	Moderate Slope, Moderate Cover	10	916	970	1,071	1,228	2,267	219	232	254	287	517	145	153	170	193	338
	10	Steep, Heavy Cover	10	1,105	1,167	1,286	1,469	2,767	259	275	301	339	625	170	180	202	226	406
C		Field Surveys																
	11	Flat, Light Cover	-	440	490	560	640	740	260	300	350	430	520	230	270	320	400	480
	*	Moderate Slope, Moderate Cover	-	505	560	645	740	865	305	355	415	510	620	270	325	380	475	575
	12	Steep, Heavy Cover	-	570	630	730	840	990	350	410	480	590	720	310	380	440	550	670
D	13	Hydrographic Surveys	-	490	520	590	600	650	180	200	230	260	290	140	150	160	180	210
E	14	Cross Sections Only Using Existing Topography	-	56	56	61	61	64	31	31	38	38	41	28	28	34	34	37

* Interpolated between Flat, Light Cover and Steep, Heavy Cover.

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