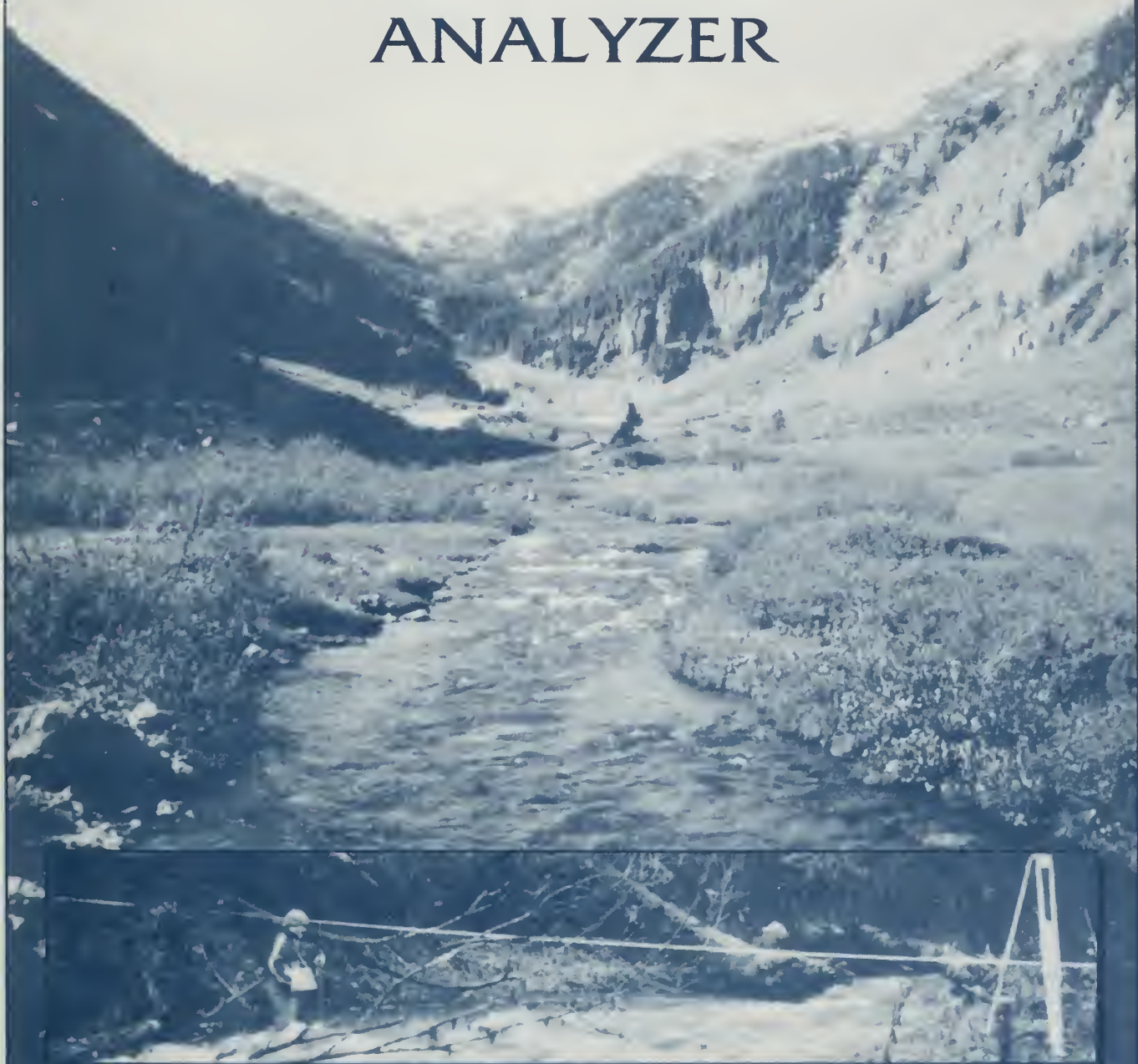


XSPRO:

A CHANNEL CROSS-SECTION ANALYZER



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XSPRO: A CHANNEL CROSS-SECTION ANALYZER

Technical Note 387
August 1992

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ABSTRACT

XSPRO is an interactive, menu-driven software package designed to assist watershed specialists in analyzing stream channel cross-section data. It has been specifically developed to handle channel geometry and hydraulic conditions for single transects in steep (gradient > 0.01) streams. Several resistance equations are supported, including those specifically designed for large roughness channels. Analysis options include

developing stage-to-discharge relationships and evaluating changes in channel cross-sectional area. Both graphical and tabular output can be generated. XSPRO can assist resource specialists in analyzing instream flow needs, performing hydraulic reconstructions, designing effective channel and riparian structures, and monitoring channel changes.

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Bureau of Land Management Technology Transfer Staff for their tireless efforts to complete this project and produce a usable program documentation reference.

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**PROGRAM
THEORY
AND
TECHNIQUES**

INTRODUCTION

Surveys of stream-channel cross sections provide important information for hydrologists, river engineers, geomorphologists, fishery biologists, and other professionals associated with river management issues. Data from cross-section surveys are useful for analyzing channel form and func-

tion, and the processes that influence a channel's hydrologic performance. Use of survey data to construct relationships between streamflow, channel geometry, and various hydraulic characteristics provides information that serves a variety of applications.

APPLICATIONS OF CROSS-SECTION DATA ANALYSIS

Information on stream-channel geometry and hydraulic characteristics is useful for channel design, restoration of riparian areas, and placement of instream structures. The analysis of cross-section hydraulics, along with an evaluation of flood frequency, is a primary consideration in channel design. Once a recurrence interval is defined for bank-full flow, the channel is designed to contain that flow, and higher flows are allowed to spread over the floodplain. Such periodic flooding is extremely important for the formation of channel macrofeatures (e.g., point bars and meander bends) and for establishment of certain kinds of riparian vegetation. A cross-section analysis may also help optimize placement of such items as culverts and fish habitat structures.

Additionally, knowledge of the relationships between discharge and channel geometry and hydraulics is useful for reconstructing the conditions associated with a particular flow situation. For example, in many channel-stability analyses, it is

customary to relate movement of substrate materials to some measure of stream power or average bed shear stress. If the relations between streamflow and certain hydraulic variables (e.g., mean depth and water-surface slope) are known, it is possible to estimate stream power and average bed shear at any given level of flow. Thus, a channel cross-section analysis makes it possible to estimate conditions of substrate movement at various levels of streamflow.

Finally, cross-section analyses provide important information for instream flow assessments. Various resource values may be altered by changes in hydraulic parameters associated with changes in streamflow. For example, the relation between low-water discharge and channel wetted perimeter may be an important consideration for macroinvertebrate production or the scenic enjoyment of a stream. Similarly, cross-section data may be used to define the depth-discharge relationship for analysis of fish habitat.

FEATURES OF XSPRO

Computer programs can be useful tools in channel cross-section analysis. One such program is XSPRO. The XSPRO program is designed for analyzing channel cross-section data in an interactive, user-friendly environment. The program is menu-driven with easy-to-read input and output screens, and an integrated graphics package to facilitate data entry. XSPRO uses a resistance-equation approach to single cross-section hydrau-

lic analysis (e.g., Manning's equation), and is capable of analyzing both the geometry and hydraulics of a given channel cross section. XSPRO was specifically developed for use in high-gradient streams and supports three alternative resistance equations for handling boundary roughness and resistance to flow. The program allows the user to subdivide the channel cross section so that overbank areas, mid-channel islands, and high-

water overflow channels may be analyzed separately. The program also allows input of variable

water-surface slopes so that slope may be varied with discharge to reflect natural conditions.

TECHNICAL BACKGROUND

The theoretical background for analyzing channel cross-section data is derived from the basic continuity, momentum, and energy equations of fluid mechanics. Specifically, streamflow at a cross section is computed using the simplified form of the continuity equation where discharge equals the product of velocity and cross-sectional area of flow. Computation of cross-sectional area is strictly a geometry problem; it is determined by inputting incremental depths of water (stage) to a channel cross section defined by surveyed distance-elevation pairs. In addition to cross-sectional area, the top width, wetted perimeter, mean depth, and hydraulic radius are computed for each increment of stage (Figure 1).

Once the channel geometry has been computed for a given stage, an estimate of mean cross-section velocity is needed to produce an estimate of streamflow. Analysis of the momentum and energy equations requires that, under certain conditions of streamflow, gravitational forces that cause water to move downhill are balanced by frictional forces at the channel boundary that tend to resist the downhill flow. Under these conditions it is possible to estimate resistance to flow and, hence, mean velocity at the channel cross section. Thus, various resistance equations have been developed for estimating mean velocity as a function of cross-section hydraulic parameters.

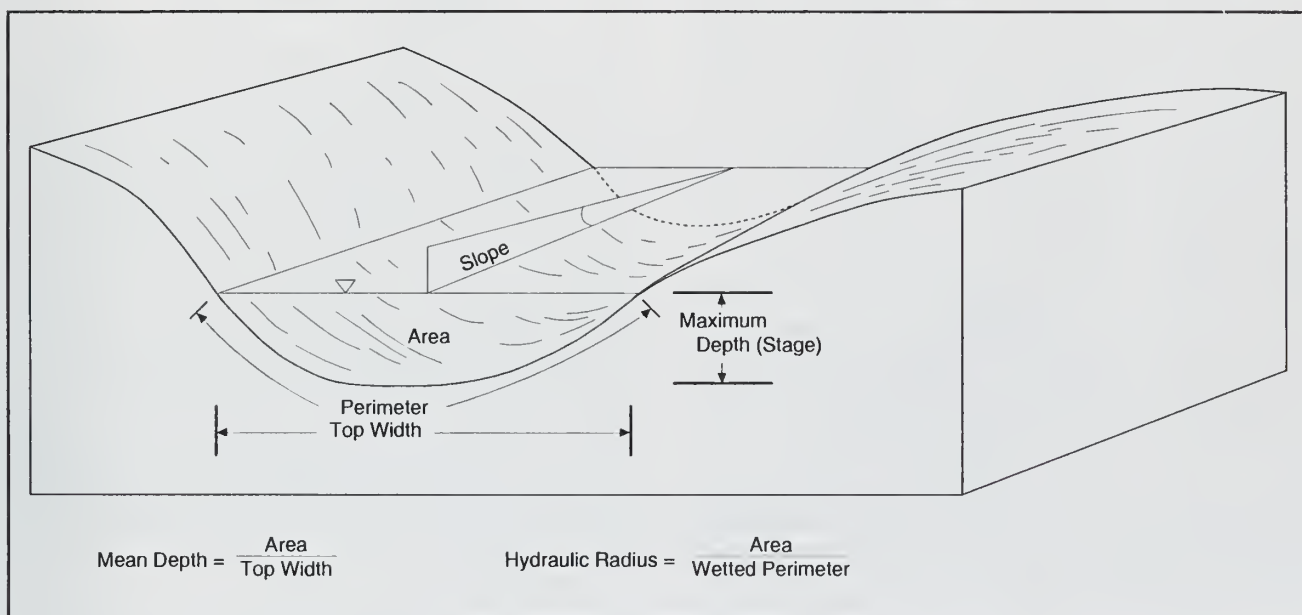


Figure 1. Definition diagram for hydraulic parameters.

GENERAL ASSUMPTIONS AND LIMITATIONS

As indicated, the mean velocity of streamflow in a cross section may be estimated when certain flow conditions are met. The main criteria for these flow conditions is that the bed slope, the water-surface slope, and the total energy grade line are parallel. The total energy of the stream is a function of the position of the streambed above some arbitrary datum (potential energy), the depth

of the water column (pressure energy), and the velocity of the water column (kinetic energy). The total energy grade line represents the rate at which energy is dissipated through turbulence and boundary friction. When the slope of the energy grade line is known, the various resistance formulas allow computation of mean cross-sectional velocity. When the water-surface slope and the energy

grade line parallel the streambed, the energy grade line is estimated with the water surface slope.

Under conditions of constant width, depth, area, and velocity, the water surface slope and energy grade line approach the slope of the streambed, producing a condition known as “uniform flow.” One feature of uniform flow is that the streamlines (the traces of the path that a particle of water would follow in the flow) are parallel and straight (Roberson and Crowe 1985). Perfectly uniform flow is rarely realized in natural channels, but the condition is approached in some reaches where the geometry of the channel cross section is relatively constant throughout the reach.

Conditions that tend to disrupt uniform flow include bends in the stream course; changes in cross-section geometry; obstructions to flow caused by large roughness elements, such as channel bars, large boulders, and woody debris; or other features that cause convergence, divergence, acceleration, or deceleration of flow (Figure 2). Resistance equations also may be used to evaluate these nonuniform flow conditions (gradually varied flow); however, energy-transition considerations (backwater calculations) must then be factored into the analysis. This requires the use of multiple transect models (e.g., HEC-2).

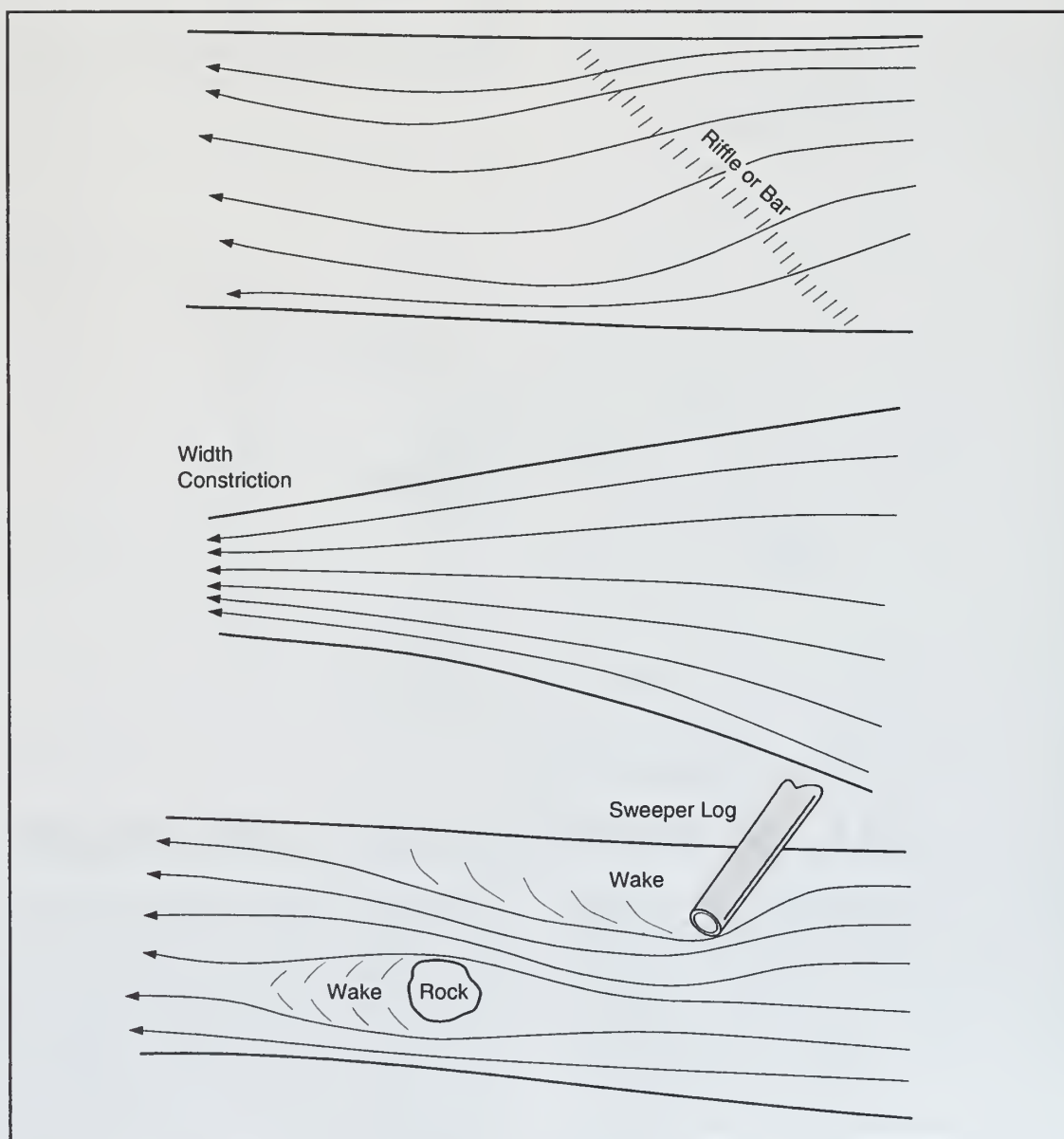


Figure 2. Some typical channel configurations that disrupt uniform flow.

RESISTANCE EQUATIONS

XSPRO supports three sets of resistance equations for estimating mean velocity at a cross section. Each equation or set of equations was developed from specific sets of data; therefore, use of a particular resistance formula to estimate velocity is subject to the limitations of the data used to develop that formula, as well as the assumptions of the formula itself. Also, because each resistance equation estimates channel resistance or roughness in a slightly different way, the different formulas may require different inputs from the user and likely will produce somewhat different results. Selection of the appropriate resistance equation requires understanding the assumptions and limitations in each approach.

Manning's Equation

XSPRO supports the use of Manning's equation for estimating mean cross-section velocity. Manning's equation was developed for conditions of uniform flow in which the water-surface profile and energy gradient are parallel to the streambed, and the area, hydraulic radius, and depth remain constant throughout the reach. Lacking a better solution, it is assumed that the equation is also valid for nonuniform reaches that are invariably encountered in natural channels, if the energy gradient is modified to reflect only the losses due to boundary friction (Dalrymple and Benson 1967). The Manning equation for mean velocity is given as:

$$V = \frac{k}{n} R^{2/3} S^{1/2} \quad (1)$$

where: k = 1 for metric units and 1.486 for English units,
 n = Manning's roughness coefficient,
 R = hydraulic radius, and
 S = energy slope (water-surface slope).

In Manning's equation, resistance to flow due to friction at the channel boundary is addressed through the use of a roughness coefficient supplied by the user of the equation. The roughness

coefficient may be thought of as an index of the features of channel roughness that contribute to the dissipation of stream energy.

There are three methods for estimating Manning's roughness coefficient for natural channels: direct solution of Manning's equation for n , comparison with computed n values for other channels, and formulas relating n to other hydraulic parameters. Each method has its own limitations and advantages.

The method of direct solution entails measuring stream discharge and dividing by the cross-sectional area of flow to obtain a mean velocity. The mean velocity, hydraulic radius (roughly equal to mean depth for wide channels), and water-surface slope may be entered into Manning's equation, and the equation solved directly for the roughness coefficient, n . This approach gives an estimate of n that is as accurate as the uncertainty associated with the measurement of discharge, cross-sectional area, and water-surface slope, but the n value obtained is only applicable to the particular stage at which the flow was measured.

Since the features of channel roughness that contribute to energy dissipation will vary with water level, n also will vary with water level; therefore, it is desirable to directly estimate n at more than one level of streamflow. Most authors cited have found that n values decrease with increasing stage, at least up to bank-full flow. If streamflow can be measured at several different stages, n may be calculated for a range of flows, and the relationship between n and stage determined.

The second method for estimating n values at a cross section involves comparing the reach to a similar, measured reach for which Manning's n has already been computed. This is probably the quickest and most commonly used procedure for estimating Manning's n and is usually done from either a table of values or by comparison with photographs of natural channels. Tables of Manning's n values for a variety of natural and artificial channels are common in the literature on hydrology (e.g., Chow 1959; Van Haveren 1986),

while photographs of stream reaches with computed n values have been compiled by Chow (1959) and Barnes (1967).

When the roughness coefficient is estimated from table values or by comparison with photographs of natural channels with known n , the chosen n value (n_b) is considered a base value that may need to be adjusted for local channel conditions. Several publications provide procedures for adjusting base values of n to account for channel irregularities, vegetation, obstructions, and sinuosity (Chow 1959; Benson and Dalrymple 1967; Arcement and Schneider 1984; Parsons and Hudson 1985). The most common procedure uses the formula proposed by Cowan (1956) to estimate the value of n :

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \quad (2)$$

where: n_b = base value of n for a straight, uniform, smooth channel in natural materials,

n_1 = correction for the effect of surface irregularities,

n_2 = correction for variations in cross-section size and shape,

n_3 = correction for obstructions,

n_4 = correction for vegetation and flow conditions, and

m = correction for degree of channel meandering.

Table 1 is taken from Aldridge and Garrett (1973) and may be used to estimate each of the above correction factors to produce a final estimated n .

While estimating Manning's roughness coefficient from a table of values or by comparison with photographs of channels with known n is the quickest and most commonly used method, most experienced hydrologists and river engineers simply estimate n from experience — often the tables and photographs are not even consulted. For that reason, this method is subject to the most variability between individuals, and is probably the least accurate method for arriving at Manning's n . Also, the method ordinarily is used to produce a single

value for roughness, which is then applied throughout the entire range of flow, often introducing large errors in the estimate of high or low flows.

The third method of determining Manning's roughness coefficient for a cross section uses empirical formulas relating n to other hydraulic parameters. Many of these formulas assume that the larger particles in the channel boundary dominate the hydraulic roughness; hence, the empirical relationships usually correlate n with some statistical index of bed-material size distribution. As such, these formulas are insensitive to changes in depth of flow at the cross section. To compensate for changes in roughness with changes in depth of flow, several formulas have been developed that use a relative roughness term relating some representative particle size (e.g., the 84th-percentile particle size) to the hydraulic radius or mean depth. Changes in depth of flow therefore change roughness and n values. Also, some empirical formulas, such as the Jarrett (1984) formula described below, do not use particle size at all, but relate the roughness coefficient n to other hydraulic parameters, such as slope and hydraulic radius.

Just as Manning's n may vary significantly with changes in stage (water level), channel irregularities, obstructions, vegetation, sinuosity, and bed-material size distribution, n may also vary with bed forms in the channel. The hydraulics of sand and mobile-bed channels produce changes in bed forms as the velocity, stream power, and Froude number increase with discharge. As velocity and stream power increase, bed forms evolve from ripples to dunes, to washed-out dunes, to plane bed, to antidunes, to chutes and pools. Ripples and dunes occur when the Froude number is less than 1 (subcritical flow); washed out dunes occur at a Froude number equal to 1 (critical flow); and plane bed, antidunes, and chutes and pools occur at a Froude number greater than 1 (supercritical flow). Manning's n attains maximum values when dune bed forms are present, and minimum values when ripples and plane bed forms are present (Parsons and Hudson 1985).

Because Manning's roughness coefficient varies with different flows and cross-section characteristics, it is important to define the vari-

ability of n over the entire range of flows when doing cross-section analysis. If possible, this is best accomplished by measuring discharge at several different water levels (stages), solving Manning's equation for the true value of n at each stage, and developing a relationship between stage and Manning's n . If Manning's n is estimated from a table of values or by comparison with

photographs, estimates should be made for several stages, and the relationship between n and stage defined for the range of flows of interest. If empirical formulas are used to estimate n , it is best to select a formula that is sensitive to mean depth or hydraulic radius, such as the formulas that use a relative roughness term.

Table 1. Factors that affect roughness of the channel (modified from Aldridge and Garrett, 1973, table 2).

	Channel conditions	n value adjustment ^{1/}	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
	Minor	0.001-0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
	Moderate	0.006-0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
	Severe	0.011-0.020	Badly sloughed or scalloped banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
Variation in channel cross section (n_2)	Gradual	0.000	Size and shape of channel cross sections change gradually.
	Alternating occasionally	0.001-0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
	Alternating frequently	0.010-0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.

^{1/} Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander.

Table 1. Factors that affect roughness of the channel — continued.

	Channel conditions	n value adjustment ^{1/}	Example
Effect of obstruction (n_3)	Negligible	0.000-0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross-sectional area.
	Minor	0.005-0.015	Obstructions occupy less than 15 percent of the cross-sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
	Appreciable	0.020-0.030	Obstructions occupy from 15 to 20 percent of the cross-sectional area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
	Severe	0.040-0.050	Obstructions occupy more than 50 percent of the cross-sectional area or the space between obstructions is small enough to cause turbulence across most of the cross section.
Amount of vegetation (n_4)	Small	0.002-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.

^{1/} Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander.

Table 1. Factors that affect roughness of the channel — continued.

	Channel conditions	n value adjustment ^{1/}	Example
Amount of vegetation (n_4) —(continued)	Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season, growing along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 feet.
	Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of vegetation; 8- to 10-year-old willow or cottonwood trees intergrown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 feet; bushy willows about 1 year old intergrown with some weeds along side slopes (all vegetation in full foliage) and no significant vegetation along channel bottoms where the hydraulic radius is greater than 2 feet.
	Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; bushy willow trees about 1 year old intergrown with weeds along side slopes (all vegetation in full foliage) or dense cattails growing along channel bottom; trees intergrown with weeds and brush (all vegetation in full foliage).

^{1/} Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander.

Table 1. Factors that affect roughness of the channel — continued.

	Channel conditions	n value adjustment ^{1/}	Example
Degree of meandering ^{1/} (Adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders.) (m)	Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
	Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
	Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

^{1/} Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander.

Resistance Equations Suggested by Thorne and Zevenbergen

Resistance equations that include a term for relative roughness have an inherent sensitivity to changes in depth because the ratio of mean depth (or hydraulic radius [R]) to large-element particle size is incorporated into the relative-roughness term. Thorne and Zevenbergen (1985), in a review of resistance equations developed for mountain streams, tested several formulas using relative-roughness terms for estimating mean velocity in steep, cobble/boulder-bed channels. For small relative-roughness values (i.e., R/d_{84} greater than 1), Thorne and Zevenbergen recommended an equation developed by Hey (1979) for estimating mean cross-section velocity:

$$\frac{\bar{U}}{(gRS)^{1/2}} = 5.62 \log \left(\frac{a'R}{3.5 d_{84}} \right) \quad (3)$$

$$a' = 11.1 \left(\frac{R}{D_{\max}} \right)^{-0.314} \quad (4)$$

where: $\bar{U}$ = mean cross-section velocity,
 g = acceleration due to gravity,
 R = hydraulic radius,

S = energy slope (water-surface slope in uniform flow),

d_{84} = intermediate diameter for the 84th-percentile particle size, and

$D_{\max}$ = maximum depth at section.

Similarly, for large relative-roughness values (i.e., R/d_{84} less than or equal to 1), Thorne and Zevenbergen recommended Bathurst's (1978) equation for estimating mean cross-section velocity:

$$\frac{\bar{U}}{(gRS)^{1/2}} = \left(\frac{R}{0.365 d_{84}} \right)^{2.34} \left(\frac{W}{\bar{D}} \right)^{7(\lambda_E - 0.08)} \quad (5)$$

$$\lambda_E = 0.039 - 0.139 \log \left(\frac{R}{d_{84}} \right) \quad (6)$$

where: $\bar{D}$ = mean depth,

W = water surface width, and
all other variables are as previously defined.

XSPRO supports these formulas as an option for calculating mean cross-section velocity. However, in applying these formulas to a cross-section analysis, the assumptions of the equations must be considered, i.e., that channel gradients generally

exceed 1 percent, channel beds are predominately cobble and boulder substrate, and relative roughness is large. Thorne and Zevenbergen (1985) reported average errors of only 6 percent when using the Hey equation for small values of relative roughness (i.e., $R/d_{84} \gg 1$), but even the best equations overpredicted mean velocity by as much as 30 percent for the highest values of relative roughness (i.e., $R/d_{84} < 1$), an error they attributed to difficulties in measuring bed-material sizes.

Jarrett's Equation for Manning's Roughness Coefficient

The previous discussion of Manning's equation alluded to the existence of empirical formulas for n that do not make use of particle-size data as an index of relative roughness. These formulas tend to relate the roughness coefficient to other hydraulic parameters. Jarrett (1984) developed the following equation for n , relating the roughness coefficient to water-surface slope and hydraulic radius at the section:

$$n = 0.39 S^{0.38} R^{-0.16} \quad (7)$$

Jarrett's equation for n has no explicit term for relative roughness; however, he reported a positive correlation between water-surface slope and coarse bed-material particle size. Thus, although particle size is not an explicit part of the equation, it is still implicit in the slope term. Jarrett also reported a slightly stronger correlation between Manning's n and slope than the correlation between n and d_{84} particle size.

Jarrett (1984) also compared n values calculated with the above equation to actual n values obtained from cross sections with measured hydraulic-geometry and flow data. The average standard error of the estimated n values was 28 percent, and ranged from -24 percent to +32 percent. Jarrett found the equation to slightly

overestimate n , with the greatest errors typically associated with low-flow measurements when the ratio of R/d_{50} is less than 7.

XSPRO supports the use of Jarrett's equation for estimating Manning's roughness coefficient and mean cross-section velocity. Again, the limitations of the data from which the equation was developed should be considered when doing a cross-section analysis. Specifically, the equation is limited to the following conditions:

1. Natural channels having stable bed and bank materials (gravels, cobbles, and boulders),
2. Water-surface slopes between 0.2 and 4.0 percent,
3. Hydraulic radii from 0.5 to 7.0 feet,
4. Cross sections unaffected by downstream obstructions (i.e., no backwater), and
5. Streams having relatively small amounts of suspended sediment.

Because Jarrett's equation includes hydraulic radius as a parameter for estimating Manning's n , it is inherently sensitive to changes in depth. The negative coefficient associated with the hydraulic-radius term indicates diminishing resistance with increasing depth. However, the relatively low value of this coefficient (n is only sensitive to the 1/6th power of hydraulic radius) means that n will change only slightly through the normal range of stage at a section. An independent evaluation of the equation on Idaho mountain streams confirmed this (Potyondy 1990). Jarrett's n appeared to fit the measured data best at flows at or above bank-full stage; the poorest fits occurred at low flow. Potyondy concluded that the equation was best applied to bank-full flow estimates, with low-water n values supplied from field measurements of hydraulic geometry and discharge.

SUBDIVIDING CROSS SECTIONS

Natural channel cross sections are rarely perfectly uniform, and it may be necessary to analyze hydraulics in a very irregular cross section. Frequently, high-gradient streams have overflow channels on one or both sides that carry water only during unusual high-flow events. Even in channels of fairly regular cross section, overbank areas transport water at discharges above bank-full. These areas usually have hydraulic properties significantly different from those of the main channel. Generally overflow channels and overbank areas are treated as separate subchannels, and the discharge computed for each of these subsections is added to the main channel to compute total discharge.

When subdividing a channel cross section into main channel, side channels, and overbank areas, XSPRO assumes frictionless vertical divisions ("smooth glass walls") between individual subsections. The assumption of negligible shear between subsections avoids the formidable task of estimating small energy losses due to friction between adjacent, moving bodies of water. XSPRO also assumes that flow can access each subsection as the stage reaches the lowest elevation of that subsection, that is, the overflow channel or overbank area is not blocked off from the flow at some upstream location.

FIELD PROCEDURES AND TECHNIQUES

A good cross-section analysis depends on good field data, which requires careful reach selection and proper field techniques. Whether a critical or representative reach is to be analyzed must be determined, and the uniform flow assumptions of

Manning's equation must be considered in reach selection. Proper field techniques must be followed in survey procedures, particle-size determinations, and streamflow measurements.

REACH SELECTION

The intended use of the cross-section analysis plays a large role in locating the reach and the cross section. The user must decide whether the section is to be located in a critical reach or in a reach that is considered representative of some larger area. The reach most sensitive to change or most likely to meet (or fail to meet) some important condition may be considered a critical reach. A representative reach will typify a definable portion of the channel system and will be used to describe that portion of the system (Parsons and Hudson 1985).

Once a reach has been selected, the channel cross section is sited in the location considered most suitable for meeting the uniform flow requirements of Manning's equation. The uniform flow requirement is approached where width, depth, and cross-sectional area of flow remain relatively constant, and the water-surface slope and energy grade line approach the slope of the streambed. For this reason, marked changes in channel geometry and discontinuities in the flow (steps, falls, and hydraulic jumps) should be avoided. Generally, the section should be located where it appears the streamlines are parallel to the bank and each other.

Straight channel reaches with perfectly uniform flow are rare in nature, and in most cases, uniform flow is only approached to varying degrees. If a reach with constant cross-sectional area and shape is not available, a slightly contracting reach is acceptable, provided that there is no significant backwater effect from the constriction. Backwater occurs where the stage-discharge relationship is controlled by the geometry of a single cross section or a break in bed slope a short distance downstream of the area of interest (section control). Manning's equation assumes the stage-discharge relationship is controlled by the geometry and roughness of a long reach of channel downstream of the section (channel control); thus, Manning's equation will not produce an accurate stage-discharge relationship in pools or other backwater areas. In addition, expanding reaches also should be avoided, as there are additional energy losses associated with channel expansions. When no channel reaches are available that meet or approach the condition of uniform flow, it may be necessary to use multitransect models (e.g., HEC-2) to analyze cross-section hydraulics.

FIELD PROCEDURES

The basic information to be collected in the reach selected for analysis is a survey of the channel cross section and water-surface slope, a

measurement of bed-material particle-size distribution, and a discharge measurement.

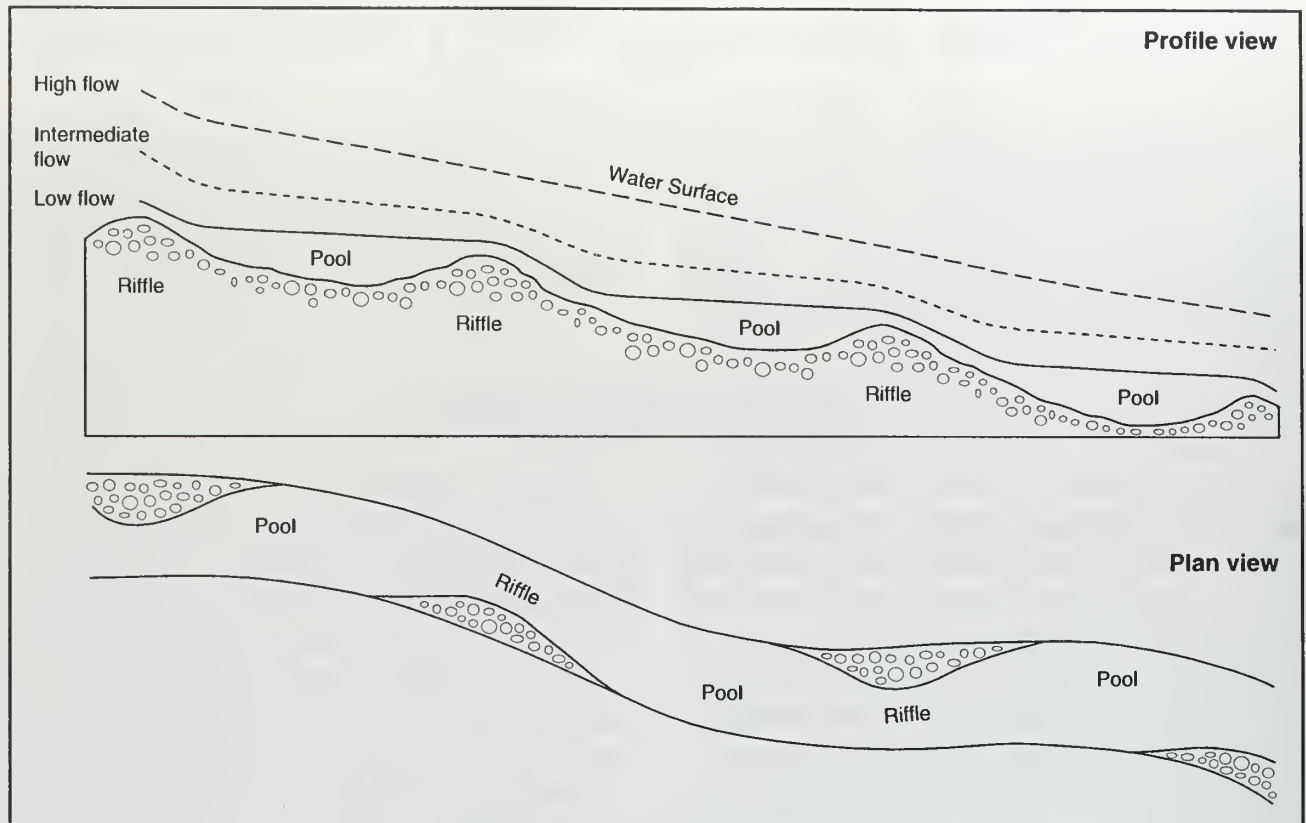


Figure 3. Diagram of longitudinal profile and plan view of a pool-riffle sequence. Water surface profiles in upper figure represent high, intermediate, and low flow conditions.

Survey of Cross Section and Water-Surface Slope

The basic data required for a channel cross-section analysis are a surveyed channel cross section and water-surface slope. The cross section is established perpendicular to the channel, and the points across the section are surveyed relative to a known or arbitrarily established benchmark elevation. The distance-elevation paired data associated with each point on the section may be obtained either by sag-tape or rod-and-level survey. The intricacies of correct survey procedures are beyond the scope of this document. For details of the sag-tape procedure, the reader is referred to Ray and Megahan (1979). Benson and Dalrymple (1967) present an excellent overview of rod-and-level surveying procedures, including guidance on equipment, field notes, and vertical and horizontal control.

Information on water-surface slope also is required input for a cross-section analysis. The survey of water-surface slope is somewhat more

complicated than the cross-section survey in that slope of the individual channel unit at the location of the section (e.g., pool, run, or riffle) must be distinguished from the more constant slope of the entire reach. (See Grant et al. 1990 for a detailed discussion on recognition and characteristics of channel units.) Water-surface slope in individual channel units may change significantly with changes in stage and discharge (Figure 3), while the slope of the entire reach will remain essentially unchanged. Thus, at low flow, the slope of the individual channel unit will have a strong influence on the stage-discharge relationship, while at high water, the average slope of the reach will control the stage-discharge rating. This is an important distinction for the XSPRO software, which allows the user to specify different slopes for high- and low-water stages. For this reason, when water-surface slopes are surveyed in the field, low-water slope may be approximated by the change in elevation over the individual channel unit where the cross section is located (approximately 1 to 5 channel widths in length), while

high-water slope is obtained by measuring the change in elevation over a much longer reach of channel (usually at least 15 to 20 channel widths in length).

Bed-Material Particle-Size Distribution

Computing mean velocity with resistance equations based on relative roughness, such as the ones suggested by Thorne and Zevenbergen (1985), requires an evaluation of the particle-size distribution of the bed material of the stream. For streams with no significant channel armor and bed material finer than medium gravel, bed-material samplers developed by the Federal Inter-agency Sedimentation Project (FISP 1986) may be used to obtain a representative sample of the streambed, which is then passed through a set of standard sieves to determine percent-by-weight of particles of various sizes. The cumulative percent of material finer than a given size may then be determined. Particle-size data are usually reported in terms of d_i , where i represents some nominal percentile of the distribution and d_i represents the particle size, usually expressed in millimeters, at which i percent of the total sample is finer. For example, 84 percent of the total sample would be finer than the d_{84} particle size. For additional guidance on bed-material sampling in sand-bed streams, the reader is referred to Ashmore et al. (1988).

XSPRO supports resistance equations for estimating velocity in steep mountain rivers with substrate much coarser than the medium-gravel limitation of FISP samplers. For these streams, the method used to measure substrate particle size is a pebble count (Wolman 1954), in which at least 100 bed-material particles are manually collected from the streambed and measured. A grid pattern of sampling points is paced or staked along the stream, and at each sample point, a particle is retrieved from the bed and the intermediate axis (not the longest or shortest axis) is measured. The measurements are tabulated as to number of particles occurring within predetermined size intervals, and the percentage of the total in each interval is then determined. Again, the percentage in each interval is accumulated to give a particle-size distribution, and the particle-size data are reported

as described above. Additional guidance for bed-material sampling in coarse-bed streams is provided in Yuzyk (1986) and Church et al. (1987).

Discharge Measurement

When analyzing channel cross-section data, it is desirable to have at least one good measurement of discharge at the section. Although a discharge estimate is not required to run XSPRO, the availability of streamflow data will greatly improve the quality of the input and provide a good check on the accuracy of the output (i.e., data on stage, discharge, and other hydraulic parameters). If only one discharge measurement is obtained, it likely will occur during low water and will be useful for defining the lower end of the rating table. If two measurements can be made, it is desirable to have a low-water measurement and a high-water measurement to define both ends of the rating table and to establish the relationship between Manning's n and stage. If high water cannot be measured directly, it may be necessary to estimate the high-water n using the Jarrett formula (Jarrett 1984) or the resistance equations recommended by Thorne and Zevenbergen (1985). If several discharge measurements can be made over a wide range of flows, relations between stage, discharge, and other hydraulic parameters may be developed directly without the use of XSPRO.

It is beyond the scope of this document to discuss all the intricacies of correct streamflow-measurement techniques. The reader is referred to Buchanan and Somers (1969), and Rantz and others (1982) for an in-depth treatment of this subject. Also, Smoot and Novak (1968) present procedures for calibration and maintenance of current meters to ensure accurate measurement of velocity and discharge. When equipment is functioning properly and standard procedures are followed correctly, it is possible to measure streamflow to within 5 percent of the true value. The data gathered from a standard discharge measurement also include information on top width and cross-sectional area, from which mean velocity and mean depth may be computed. This information is extremely useful for improving quality of output from any channel cross-section analysis program.

PROGRAM OPERATIONS

INTRODUCTION TO XSPRO

GETTING STARTED

XSPRO is a user friendly program for analyzing cross-sections of small mountain streams.

Requirements

XSPRO can be run on any 100 percent IBM^{1/} PC/XT/AT compatible computer with the following requirements:

- DOS 2.1 or higher
- 256K of RAM
- EGA, VGA, Hercules,
or AT&T 400 graphics
- One floppy drive

XSPRO can be run directly off of your distribution diskettes or you can copy the files to a directory on your hard disk. You will notice a significant increase in performance if the program is run from a hard disk.

Program Installation

You should first make a copy of the XSPRO distribution disk. The procedure will be different for one and two floppy systems.

One Floppy Systems

If you have only one floppy drive, place the distribution disk in drive A and type:

DISKCOPY A: B: <ENTER>

When the computer prompts you for the diskette for drive B, remove your distribution disk and place your backup disk in drive A. Your computer is now using your floppy drive as drive

B. When the copying is done, type:

A: <ENTER>

The computer will prompt you for the diskette for drive A, press ENTER and your system will be back to normal with your floppy acting as drive A.

Two Floppy and Hard Disk Systems

To install XSPRO on either a two floppy or hard drive system, you need to copy all of the files to either a second floppy or your hard drive. A batch file (INSTALL.BAT) has been included to make this easier. To use the batch file to install the program, insert the disk in the A drive and type:

**INSTALL <D1:> <D2:\DIRECTORY>
<ENTER>**

replacing <D1:> with the source drive and <D2:\DIRECTORY> with the drive name and directory of where you want to install the files. The install program will create the directory if it does not already exist and then copy all of the files to it. For example, to install XSPRO from floppy drive A to hard drive C in the directory XSPRO type:

INSTALL A: C:\XSPRO <ENTER>

More information can be found by typing:

TYPE README.1ST <ENTER>

^{1/} Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

RUNNING XSPRO: AN OVERVIEW

This section is meant to be an overview of the XSPRO program. All of the software elements described here are explained more completely in later chapters. This section is not meant to be a sample run or example. For more complete examples see the section on "Putting XSPRO to Work."

To run XSPRO, be sure you have a DOS command prompt and that the XSPRO files are in the current drive and directory. To start the program type:

XSPRO <ENTER>

Press ENTER after viewing the title screen, and you should see the XSPRO opening screen (Figure 4). The opening screen displays a menu window across the top supplemented by a second window displaying all of the current controlling parameters. The menu is active upon startup and

Cross-Section Professional Analyzer	
Modify	Exit
Run	
Print	
Controlling Parameters	
INPUT:	
Source of Data:	File
Filename:	SAMPLE.DAT
Data collection method:	other
Data Format:	Position-Elevation free form
Units:	Meters
OUTPUT:	
Filename:	SAMPLE.OUT
File output mode:	
Units:	Meters
ANALYSIS	
Analysis procedure:	Both Hydraulics and Regression
Resistance Equation	Jarrett

Figure 4. Main screen.

is controlled in the usual manner by using the ARROW keys to highlight a selection and pressing the ENTER key to activate that selection. Furthermore, you may activate a menu selection by pressing the key corresponding to the first letter of that selection (i.e., press R to activate the Run selection). The controls are the same for the submenus.

Context-sensitive help is available at any point in the program by pressing F1.

The first time XSPRO is run, it will bring up the default values for all of the controlling parameters. After the first time, the most recently selected controlling parameters will be remembered and used on the next run of the program. This will make it easy to compare formulas, data sets, or any parameter from one run to the next. If these data get corrupted for any reason, the program will start up with the hard coded defaults again and will warn you that it is doing so.

Input

The first step is to match the controlling parameters with the data being used and the output desired. Keep in mind that the program will start up with the parameters selected on the last run of the program or the hard coded defaults. An interactive input process is provided to edit all controlling parameters and input data. Selecting

Modify from the main menu brings up a submenu containing the *Parameters* and *Data* options.

Modify-Parameters

Selecting the *Parameters* submenu allows editing of the fields in the controlling parameters window.

The parameters are edited in two ways. The first method is to simply type the appropriate entry into the field. The other method is a menu selected input and is used when there are a finite set of responses. Highlight the field you wish to change and press SPACEBAR to see the selection menu. These menus work like all other menus in XSPRO.

Modify-Data

Selecting the *Data* submenu brings up an entry window for entering or editing cross-section data. You will specify the number of points to use and then enter the distance-elevation pairs. The manually entered data can be

saved to a file in position-elevation format. Figure 5 shows the keyboard data entry screen with a sample set of data.

Running the Analysis

The default values that will appear on the first run of XSPRO are enough to run an analysis of a sample data file that is included with your package. Selecting *Run* from the main menu starts the analysis process. This is the heart of the XSPRO program. Here the program brings together all of the information in the parameters window and analyzes the cross section you have defined. The first screen you see will be a graph of the cross section. This portion of the program is also interactive. You will be asked to input the low- and high-flow stages and corresponding slopes, and the increment to use to analyze the cross section. You will also be asked to select subsections along the cross section that should be analyzed separately. Furthermore, if you choose to supply your own Manning's n, you will enter that data here. The low- and high-flow stages and the section boundaries you select will be displayed on the screen.

(For a quick run of the sample data, enter 0.0 for the low stage, 2.3 for the low-stage slope, 7.0 for the high stage, 4.0 for the high-stage slope, and 0.1 for the increment. Leave the section boundary blank and the analysis will start. See the section on "Putting XSPRO to Work" for more complete examples.)

When you enter the last section boundary or Manning's n value, XSPRO will begin the analysis of the cross section. After the analysis is finished, the graph will be cleared and you will be shown the results of the analysis in the form of a table. This table can be scrolled through, back and forth, and you are provided with a highlight bar to ease viewing. An output file (named in parameters window) is filled with the same stage-to-discharge data seen on the screen. The format of this output file differs slightly from what was on the screen. The character identifiers for the different sections

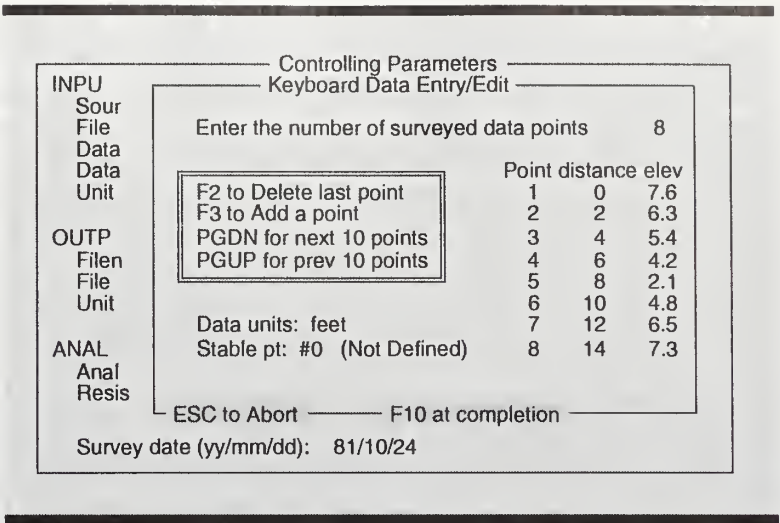


Figure 5. Keyboard entry screen.

are replaced with negative numbers (A becomes -1, B becomes -2, etc.), so that this output file can be used with your favorite spreadsheet program. Press SPACEBAR to continue.

Finally, the program will graph a log-log regression of discharge vs. radius. You are shown the regression formula used. If the regression analysis was not selected in the parameters window, XSPRO will move directly to the main screen from the table. Pressing SPACEBAR will return you to the main screen from the regression graph.

Printing Results

The output file generated is more suited toward inclusion in a spreadsheet and is not as easily viewed on a piece of paper, so a separate printing facility has been included with XSPRO. The output file you select to print will be printed in approximately the same format as the table you saw after the analysis was performed.

To print the data, select *Print* from the main menu. A new window will appear on your screen. Here you can select what, where, and how to print. There are defaults that will come up each time. The default file to print is the current analysis output file, the destination is LPT1, and a form feed will be inserted between each set of data. If any of these defaults vary from what you want to do, you may change them.

You may choose to send the output to a printer or to a file. If you print to a file, you must specify a file name. This file will contain exactly what would be sent to the printer.

Be sure your printer is connected and turned on. To start printing after you have made the appropriate changes, press F10. To abort printing at any time during the printing process, press ESC.

XSPRO BASIC PROCEDURES

XSPRO has many modern software conveniences, including consistent operation of function keys and use of windows. In addition, XSPRO

provides context-sensitive help, menu control, and simple error correction.

SPECIAL KEYS

The function keys and the ESC key have specific and more-or-less consistent operation throughout the program. The F1 key is always help, and the ESC key is always an abort key. F10, on the other hand, has two functions depending on where you are in the program. In an entry window, F10 will act as the completion key. When you are done entering, you press F10 to save the data and continue the program. The other function of the F10 key is as an undo key in the analysis part of the program. When you are entering the stage, section boundary, or Manning's n data, F10 will back you up a step or undo the last thing you did.

The SPACEBAR has a dual role as well. In the controlling parameters window, pressing the SPACEBAR will bring up a selection menu for the highlighted parameter. In the analysis phase, the SPACEBAR is used to continue to the next phase of the analysis. You press the SPACEBAR to clear the output table and move to the regression analysis, and to move from the regression analysis back to the main menu.

From the main menu, the F2 key will allow you to save data entered from the keyboard to a file.

HELP

Throughout the program, pressing the F1 key will bring up a context-sensitive help window. The help window will give you information about what is highlighted by the cursor and provide information for making decisions. The only way

to access help for a particular topic is to be at that specific point in the program and press F1. There is no help index facility in this version. To clear any help screen, press F1 again.

MENUS

XSPRO is a menu-driven program. All menus in XSPRO work identically and are consistent with the menus you are familiar with from other programs. For horizontal menus you use the LEFT/RIGHT ARROW keys, and for vertical menus you use the UP/DOWN ARROW keys to move between selections. Once the selection is highlighted, you may activate that selection by

pressing ENTER. To directly activate a menu selection, press the key corresponding to the first letter in the selection; you will not have to press ENTER. For example, to select *Run* from the main menu you just need to press *R* from anywhere in the main menu and the program will activate that selection. To abort any selection menu, press ESC.

ERROR CORRECTION

If you select the wrong option from a menu, pressing ESC will bring you back a level. This action is an abort; any changes made will be lost and the affected data will return to the values that were present before that selection was made. If the mistake was made in an input menu (from the controlling parameters window) you may, of course, go back and change your selection.

If you make a mistake in typing, the BACKSPACE, INSERT, and DELETE keys will work as expected.

Error in Stage/Slope/Interval Data

If you make a mistake during input of the stage data, you can press F10 to restart the stage specification procedure. All stage values will be cleared and you will be back to entering the low-flow stage value. After you enter the stage interval you must start over to make a change in the stage/slope/interval data. If you want to return to the main menu, press ESC.

Error in Section Boundary Data

You may clear any previous section boundary entered by pressing F10. If you keep pressing F10, you will step back through the sections that you've entered, clearing the previous one. After you enter a blank section to continue the program, you must start the analysis over to change any section boundary data. If you want to return to the main menu, press ESC.

Error in Manning's n Data

You may back up through the sections to clear the Manning's n values you entered by pressing F10. If you back up all the way to the first section, you may reenter the high-flow stage for the Manning's n values. After you enter the high-stage Manning's n for the last section, the program will proceed with the analysis. You must then restart the analysis to make any changes. If you want to return to the main menu, press ESC.

XSPRO INPUT

Input comes to XSPRO in three forms: 1) cross-section data from a file or the keyboard; 2) parameters to control the program, such as filenames, data format, resistance equations, etc.; and 3) specifics about how to analyze the cross

section, such as low- and high-flow stages, slope, boundaries for defining separate channels in the cross section, etc. These are explained in detail below.

DATA ENTRY

XSPRO can read in cross-section data from a file or directly from the keyboard.

Input From the Keyboard

Data can be entered from the keyboard by selecting *Modify-Parameters* from the main menu and selecting *Keyboard* as the source of data, pressing F10, and then selecting *Modify-Data* from the main menu. You are asked for the number of position-elevation points that occur on the cross section. This can be increased or decreased later; it is just used as a starting point. After entering this, you will see entry fields for the first ten points. Use the PGDN key to see the next ten points. To go back a full screen, use the PGUP key. You can move about through the entry fields with the ARROW keys, TAB key, or ENTER key.

Up to six digits will be retained for the position and elevation data.

F2 will delete the very last point. F3 will add a point to the end of the list. You may add points up to 200. You may delete all but one point.

When all input data are correct, press F10. If you want to save these data now (they can be saved later), answer *Y* to the question and give XSPRO a file name to save to. The data will be saved in position-elevation format. To save the data later, use the F2 key from the main menu.

Editing previously entered data is done through the *Modify-Data* menu selection. The only difference is that you won't be prompted for the number of points to be entered.

Input From a File

If *File* is selected for the source of data, you will need to specify a file name to use. When you select *Run* from the main menu, data will be read from the file and put through the analysis. The file may contain up to 200 data points. Be sure that the data file you are using is formatted correctly. Refer to Appendix A for information on input file formats. If you are using a file that was saved by XSPRO as data entered from the keyboard, the file will be in position-elevation format.

CONTROLLING PARAMETERS

XSPRO allows you to modify all of the important parameters that control the input, analysis, and output. All of the current values are displayed at once on the screen. You can adjust all of these parameters quickly and easily for comparisons of different formulas or different values. The first time the program is run, hard coded default values for the controlling parameters will be used. From then on, the most recent set of parameters will be the defaults when you start the program. XSPRO

saves these parameters in a file named "DEFAULTS.XSP." If this file is ever corrupted or missing, XSPRO will use the hard coded startup defaults again for the controlling parameters.

To modify any of the controlling parameters, select *Modify* from the main menu. Then select *Parameters* from the modify menu. The main menu will disappear and your cursor will be positioned on the input source field in the controlling parameters window. You can move from field to

field using the UP/DOWN ARROW keys. All of the fields and how to edit them are explained below.

Parameter Editing

There are two ways that parameter editing is done, depending on the field you are editing. The most basic way is to simply highlight the field you wish to edit and type in your response. The fields that allow this are: *filename*, d_{84} *diameter*, *date of cross section*, *cross-section number*, and all numerical entry fields. These fields do not have a finite number of responses, and therefore, anything within reason can be entered here.

The second method of editing involves fields that have a finite set of possible values; you will get a selection menu to choose from for these. See Figure 6 for an example of a field that uses menu selection. The *Data Collection Method* field has three possible responses: *Sag Tape*, *Rod and Level*, or *other*. To edit that field, just arrow down to highlight the field and press SPACEBAR. A menu box will appear with the possible selections for that field. This menu box is controlled exactly like the other menus. To select *other*, press *O*. The selection for the *Data Collection Method* will change to read *other* and the cursor will be on the next field. You could have just as easily highlighted *other* in the selection menu and pressed ENTER to select it. Most of the fields in this window work this way for ease of typing and for control of the input. *The fields that use the selection menu method are marked in this documentation with an asterisk.*

Another way that XSPRO controls what needs to be entered is by hiding particular fields when they won't affect a particular analysis. An example of this is the *Resistance Equation* field. If *Thorne and Zevenbergen* is selected as the resistance equation, the d_{84} fields will appear on the screen. For other resistance equations, these fields are not needed and you will not even see them.

There are some parameters that require additional information. Choosing *Sag Tape* instead of

other, as in the first example, triggers a different chain of events. A survey done with a sag tape will

Controlling Parameters		F1-Help
INPUT:		
Source of data:	File	Select Method Sag Tape Rod and Level other
Filename:	FPXS2.PRN	
Data collection method:	Sag Tape	
Data Format:	HJAndrews	
Units:	Feet	
OUTPUT:		
Filename:	FPXS2.OUT	
File output mode:	Overwrite	
Units:	Feet	
ANALYSIS		
Analysis procedure	Both Hydraulics and Regression	
Resistance Equation	Thorn & Zevenbergen	
d84 Units:	Feet	
d84 particle diameter:	0.003637	
Survey date (yy/mm/dd):	80/01/01	
Cross-section number:	101	
ESC to Abort		F10 at completion

Figure 6. Menu selection fields.

require other information about the conditions of the survey, and you will be prompted for these data. XSPRO first brings up an input window with fields for data that are specific to sag tape surveys. This is one way that additional information is entered. Here you must complete the inputs and press F10, or ESC to abort. You will return to the controlling parameters window and the cursor will be on the next field.

Input Parameters

Source of Data*

Data for a cross section can come from a previously created file, like a text dump from a spreadsheet, or you may input the position-elevation pairs from the keyboard. In this field, you select the source for the cross-section data. To modify the selection, highlight the field and press SPACEBAR. Then, select the data source from the menu.

Filename

The file name can be up to 40 characters long and can contain drive names and directory names. Furthermore, the wildcards '*' and '?' will work as

they do in DOS. Simply type in the name of the file you wish to use. You may use the wildcards to create a directory mask, and XSPRO will display a list of all the files in the specified directory that match that mask. The current directory is the default. For example, to obtain a listing of all of the files in the current directory that have a "PRN" extension, enter:

***.PRN <ENTER>**
 ("*.PRN" is a directory mask)

for the file name. A display window will appear on the screen with a listing of all the matching files. From here you can enter a file name or a new directory mask. Pressing ESC will return you to the parameters window without changing the mask you entered.

This file must contain some columnar form of data representing a distance measurement and an elevation measurement. Each line in the file will identify a particular point on the cross section. The specific formats available are described in Appendix A.

Data Collection Method*

XSPRO supports three selections of data survey methods: *Sag Tape*, *Rod and Level*, or *other*. *Other* is included for data that needs no correction. For the two specific survey types, some data correction must be made for uneven tape end elevations, tape physical characteristics, and tape sag. The sag tape forms a catenary curve, and if elevation data are measured from the streambed to the tape, these data will be incorrect. If the survey method was rod and level, the tape is assumed to be without sag. If the tape ends for either method are uneven, distance measurements using the tape will be incorrect.

If you select either of the two specific survey methods, you will be prompted with an input window to enter the data to be used for correction. For rod and level, just an elevation difference needs to be entered. For sag tape, an elevation difference, a tape

tension, and a tape weight need to be entered. You may move between the edit fields using the arrow keys. The other function keys work as before: F1 for help, F10 to complete, and ESC to abort.

Data Format*

Each selection corresponds to a different format for the input file. The files will normally contain two columns of numbers representing a position-elevation pair on each row that defines some point on a cross section. There are currently three formats available; they are outlined in Appendix A. Format selections are made from a menu.

The special case of selecting *User Defined* from the data format field involves specifying exactly which columns contain the two data values in your file and the length of each value. This is provided for an input file that may contain more than just the position and elevation data. For example, if you have four columns of data in a file and one of those columns contains a position value and another contains an elevation value, but they are not the first two columns or are not adjacent, you should select *User Defined* from the menu to extract the correct numbers. All you will need to tell XSPRO is which column numbers to search for the data and how wide those data columns are.

Figure 7 shows the screen after selecting *User Defined* as the data format. The values for position

The screen displays the following information:

- Controlling Parameters:**
 - F1-Help
 - Select Data Format
 - Position-Elevation free form
 - Elevation-Position free form
 - User Defined File Format
- INPUT:**
 - Source of data: File IN.DAT
 - Filename:
 - Data collection
 - Data Format:
 - Units:
- OUTPUT:**
 - Filename:
 - File output mo
 - Units:
- ANALYSIS**
 - Analysis proced
 - Resistance Equa
- Position data field: Elevation data field:**
 - column 12 column 21
 - length 4 length 3
- Navigation:**
 - ESC to Abort
 - F10 at completion

Figure 7. User defined data format screen.

data column and length and for elevation data column and length have been entered. When you select *User Defined*, an entry window appears and you are prompted for the column positions and lengths of the data. Figure 8 shows a portion of a sample input file where the data are not in a specific order. In this particular file the distance values start at column 12 and are 4 columns wide. The elevation values start at column 21 and are 3 values wide. As you can see, these values have been entered in Figure 7.

811024	101	0	139
811024	101	20	123
811024	101	100	88
811024	101	160	60
811024	101	170	168
811024	101	240	246
811024	101	300	271
811024	101	330	292
811024	101	340	334
811024	101	420	325
811024	101	450	340
811024	101	550	335
811024	101	730	324
811024	101	760	319
811024	101	800	348
811024	101	830	354
811024	101	860	323
811024	101	880	357
811024	101	940	315
811024	101	980	349
811024	101	1050	350

Figure 8. Sample input file.

Units*

The units of the input data can be either centimeters, meters, or feet. This is another menu selection field. The units you select will be used for all inputs. If centimeters are selected, the data read in from the input file will be converted to meters, and all inputs will be in meters. All of the internal computations will be done in English units.

Output Parameters

Filename

The output file will contain the stage-to-discharge relationship data. The format of the data

allows easy importing to your favorite spreadsheet. The file name can be up to 40 characters long and will accept drive and directory names. Like the input *Filename* field, you may enter a directory mask to get a listing of matching files.

File Output Mode*

If the file named in the *Filename* field exists, you will be prompted as to how you want the writing to that file to take place. You may select to *Overwrite* the file or *Append* to it. Overwriting will completely erase the file and then write the new data to the file. Appending will simply add the new output to the end of the file, preserving all previous data in the file. If you print an appended file, all of the data in that file will be printed. There is no limit on the size of the output file except for available disk space.

Units*

The units of the output data can be either in meters or feet. This is also a menu selection field. All output will use the units selected here. All of the internal computations will use English units regardless of the input and will be converted to meters for output if meters are selected as output units.

Analysis Parameters

Analysis Procedure*

You may choose how the program will perform the analysis. The selections are:

- *Geometry only*

The only values computed are perimeter, area, width, hydraulic radius, and average depth. This option is useful for comparing cross-section changes in geometry through time. The output data are reorganized to represent the depth of the stream and will go from the specified stable point to the lowest elevation on the cross section. This option is explained in detail under "Specific Uses" in the section on "Putting XSPRO to Work."

- *Hydraulics only*

Select this to skip the regression analysis. All the values computed for the geometric analysis are included in the output, along with slope, Manning's n , average velocity, and discharge. The data are organized from the low-stage value up to the high-stage value.

- *Both Hydraulics and Regression*

This selection gives you the hydraulic analysis and will also perform a regression on the discharge and hydraulic radius values.

Resistance Equation*

You may choose to use the equations suggested by Thorne & Zevenbergen (1985) or the Jarrett equation to compute a Manning's n , or you may choose to supply your own Manning's n values to use in the analysis (*User supplied Manning's n*). The Thorne & Zevenbergen model uses a user-supplied d_{84} diameter. If you choose *Thorne & Zevenbergen*, the fields for d_{84} diameter

and units will appear on the screen; the other two selections do not use these fields and so, for those selections, the fields will be invisible.

d_{84} Units*

The diameter of the d_{84} particle can be in feet or millimeters. Only if you select the *Thorne & Zevenbergen* equations will you see this parameter displayed on the screen or be able to select a value for it.

d_{84} Particle Diameter

This is a number representing the diameter of the 84th percentile size class in the bed material. Only if you select the *Thorne & Zevenbergen* equations will you see this parameter displayed on the screen or be able to enter a value for it.

Survey Date

Enter the date the survey was taken (optional). The date format is in year/month/day. This is provided to annotate the output.

RUNNING AN ANALYSIS

After modifying the controlling parameters, you may now run the analysis. Choose *Run* from the main menu. If you are entering the cross-section data from the keyboard and did not enter the data through the *Modify-Data* selection, the data entry window will pop up. Follow the direc-

tions for entering data. If you chose a file as the input source, XSPRO will read in the data from that file and move directly to graphing the cross section. F1 continues to provide context-sensitive help throughout this portion of the program.

CROSS-SECTION SPECIFICS

XSPRO will plot out the cross section on your screen after analyzing the position-elevation pairs and doing any data corrections. The lowest elevation point will be found and will be assigned as the zero elevation point in the graph. Remember that the sag tape and rod and level correction formulas

will have an effect on the appearance of the graph. You will be prompted for more information. An example of the graph of a cross section is shown in Figure 9. Your screen should look similar to this after you select *Run* and input any cross-section data that is needed.

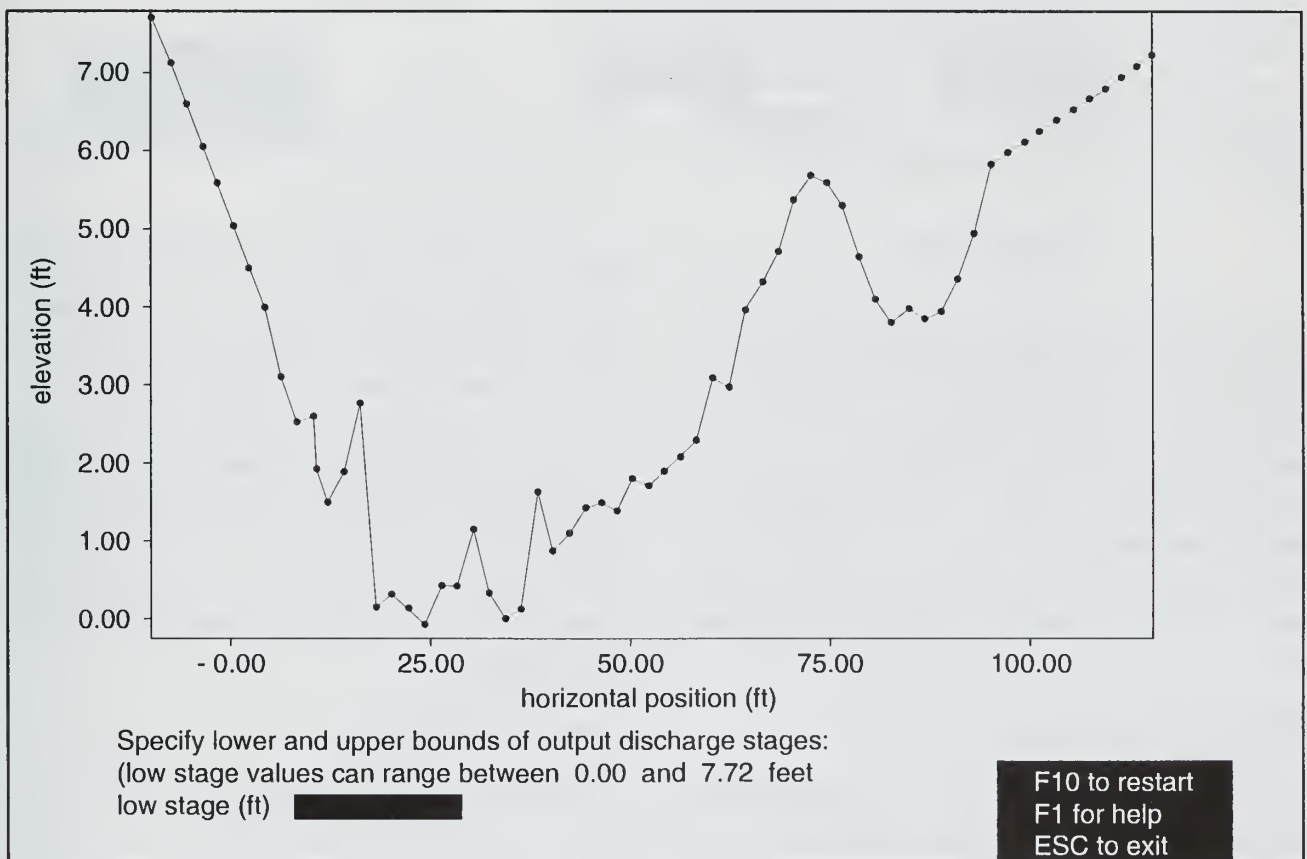


Figure 9. Sample cross-section graph.

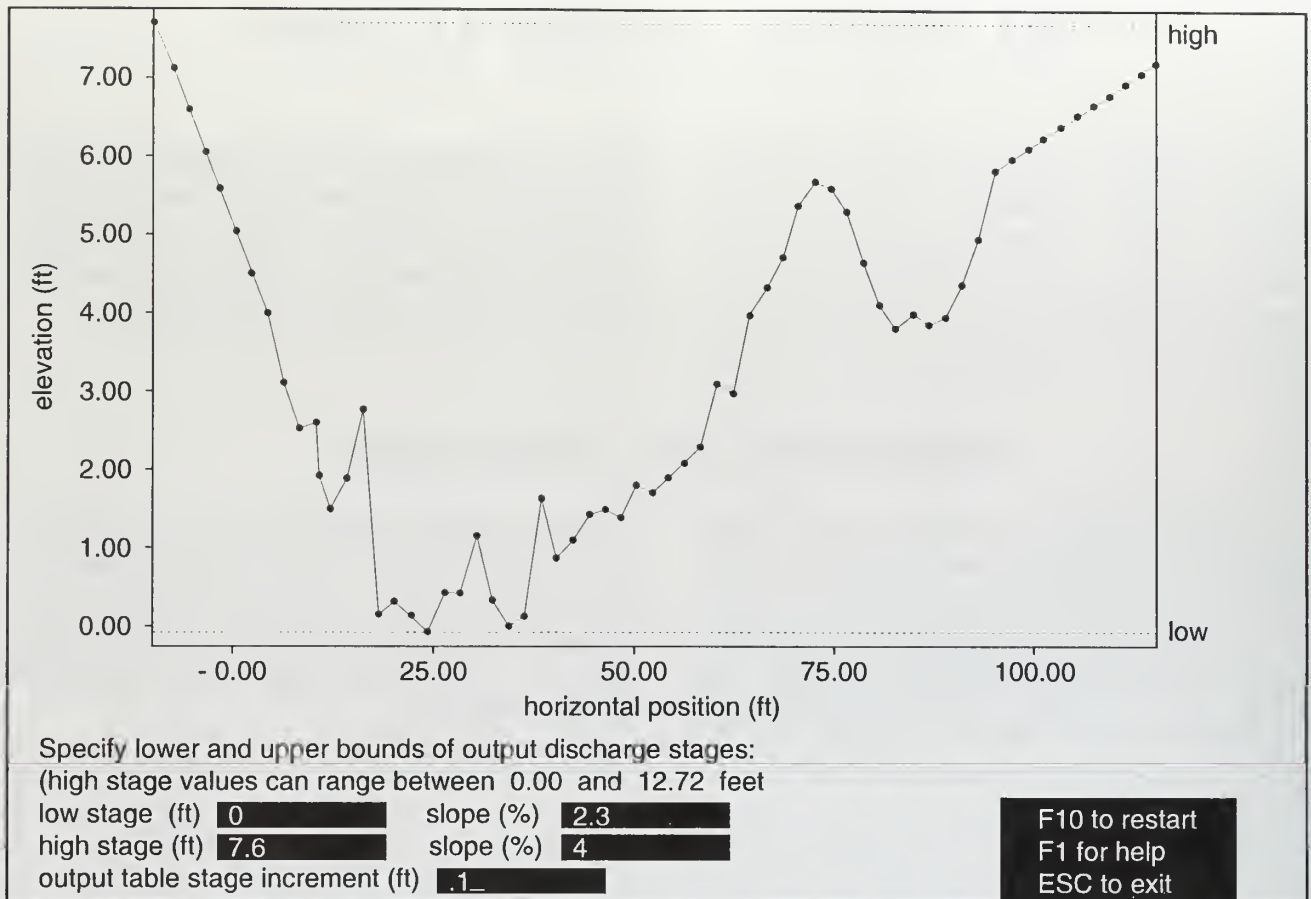


Figure 10. Stage, slope, increment entry.

Stage Data

In this section, the F10 key provides you a means to restart the stage specification portion of the program. At any point in this section, pressing F10 will back the program up to the point of redrawing the graph and prompting you for the low-stage value. There is no mechanism for moving around the various entry fields, so to change a value after entering it, you must restart this section and reenter the values. Refer to Figure 10.

High and Low Stage

If you selected to analyze just the geometry of the cross section, the high- and low-stage values will be computed from the highest and lowest elevation in the cross section. If XSPRO is being run in normal mode and you have selected to analyze the hydraulics of the cross section, you must enter the high- and low-flow stage values you will use.

As you enter the low- or high-stage values, they are graphically represented on the cross-section plot as dashed lines at the stage entered. The low- and high-flow values can be the same if you only want to analyze a single stage.

For the high stage, a number that is 1.5 m, or 5 ft, above the highest input elevation may be used. The program will assume vertical banks and extrapolate discharge for values above the highest input elevation. Data that are extrapolated are represented with an '*' after the discharge value on the output.

Percentage Slope

A slope value (in percent) is needed for both stage values. XSPRO will linearly interpolate a slope for each incremental stage. If you are just analyzing the geometry of the stream, no slope values are needed and you will not be prompted for them. The same low- and high-flow slope can be used if slope does not change.

Stage Increment

This is the increment that XSPRO will use to step through from the low- to high-flow stages. The analysis will start at the low-stage value and will increase by the value you input in the increment field, up to, but not past, the high-stage value. In the output you will see an evaluation of the cross section at every increment. For stages that contain more than one defined channel (see “Section Boundaries” section), the data for that stage will be split for each subchannel, and a sum of the values across the stream will be computed.

In Figure 10, all of the values for stage, slope, and increment have been entered.

XSPRO does not provide a mechanism to print this graph or the regression graph. However, you may use other software. See the “Printing” section for more information.

Section Boundaries

After you have entered the stage increment, XSPRO will clear those values from the screen

and prompt you for the section boundaries (Figure 11). The ability to break up a cross section into multiple channels that can be analyzed separately is one of XSPRO’s major features. To define a section boundary, enter the horizontal distance to that boundary. The boundary will appear as a vertical dashed line at the closest surveyed point. (The actual horizontal distance to this point is shown.) Up to five sections (four unique section boundaries) may be defined. The order in which the section boundaries are entered does not matter. In the output, each section will be analyzed separately, and a cross-sectionwide summary for the current stage will be the sum of all of the separate section numbers. Figure 11 is the same graph as Figure 10 after stage, slope, and increment values have been entered, and shows an example of where a section boundary should occur. A boundary at the 72 foot mark was entered.

If you make a mistake, the F10 key will clear the last entered section boundary. You may clear all of the boundaries that have been entered.

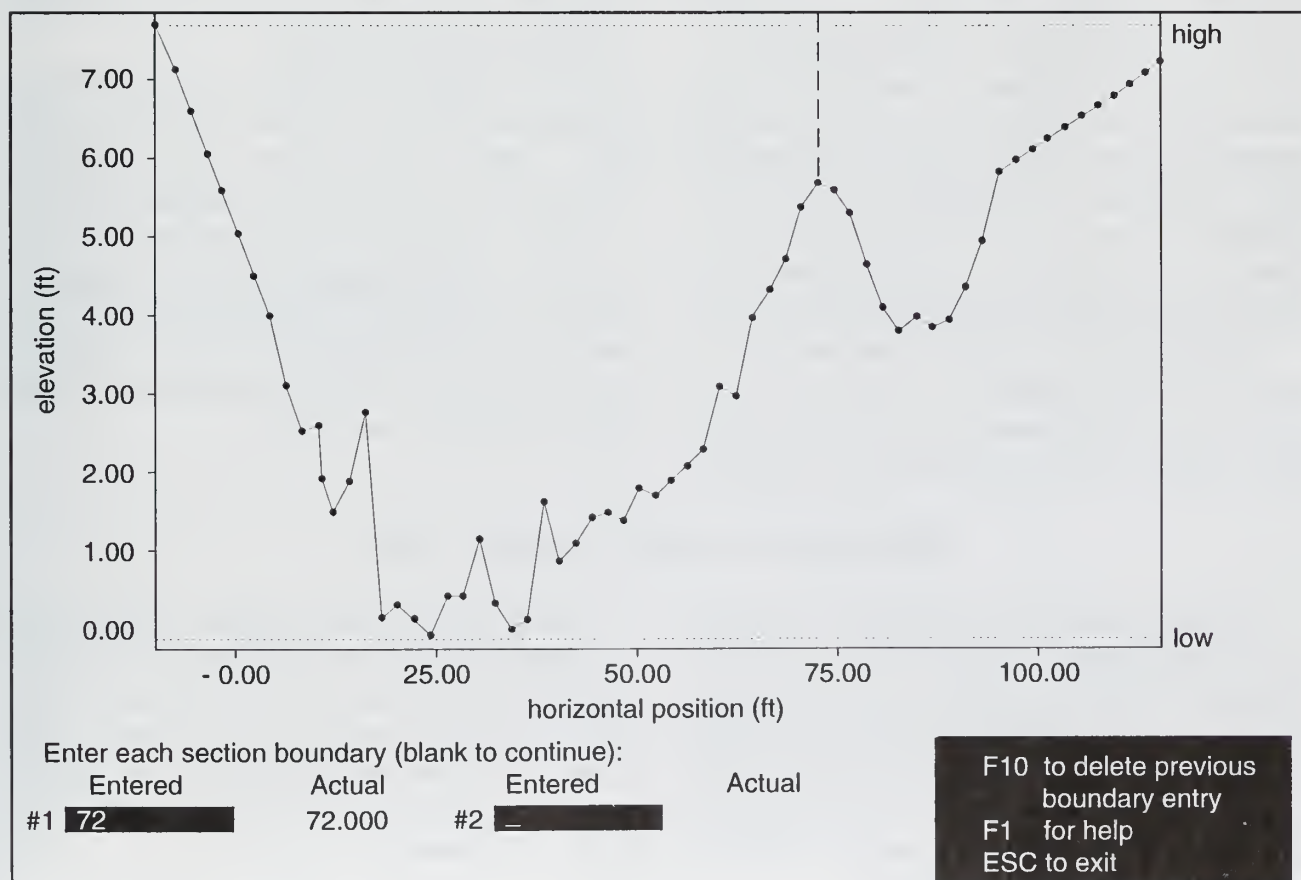


Figure 11. Section boundary selection.

To continue after you have entered all of the section boundaries, press ENTER. If you have no section boundaries, leave the field blank and press ENTER.

Manning's n Values

Finally, you will be prompted to enter your own Manning's n values if you selected *User supplied Manning's n* in the parameters window. Otherwise, XSPRO will calculate the resistance based on the equations specified. Because Manning's n varies with flow depth, you will be asked to specify both a low- and high-stage n value. These low and high stages can be different from the ones used to define the boundaries of the analysis in the previous screen. For example, n values calculated from field discharge measurements at low and high stages can be used. Both the

low- and high-stage n can vary from section to section, thereby accommodating different components of flow resistance over the cross section.

The previous stage lines will be cleared and you will be prompted to enter a low- and high-stage n for each section. A blue or solid (if you do not have a color monitor) vertical line will mark the right edge of the current section. XSPRO will calculate the low and high point of each section and not permit stage values outside this range. XSPRO will permit calculation of stages up to 5 feet above the highest surveyed point.

After the last high-flow n is entered, the program will start the hydraulic analysis. XSPRO will linearly interpolate a Manning's n for each incremental stage for each section, and will compute a flow-weighted average for the output summary. Manning's n will not interpolate to lower than 0.01.

TABULAR HYDRAULIC OUTPUT

After you finish entering the parameters for the analysis, XSPRO will produce a table showing stage-to-discharge data. The data start at the low-flow stage and increase at the increment you entered up to the high-stage value. You can scroll through the table using the UP/DOWN ARROW and PAGE keys. A highlight bar, current line number, and total lines of data information are provided to ease viewing. Pressing SPACEBAR clears the table and continues to the next screen.

If more than one section was defined, the sections will be assigned letters starting with the section that has the lowest elevation. So 'A' will be assigned to the section with the lowest eleva-

tion, then 'B' to the next, etc. In the summary for a specific stage, the section column will show the number of sections summed.

The data that were written to the output file are the same as the data in this table and may be printed later. However, the section boundaries in the output file are designated by negative numbers (-1 = A, -2 = B, etc.) and there is a stage value on each line. Both changes are to make the output file easier to import into a spreadsheet. If an '*' is present after the discharge for a given section or stage, that number was extrapolated beyond the range of the input survey data.

REGRESSION ANALYSIS

When the data table is cleared, you will see a graph representing a regression analysis of discharge to hydraulic radius for the current cross section. The graph will show a scatter plot of the actual radius:discharge pairs and then will plot the regression line. At the bottom of the graph, the regression formula used is shown. Figure 12 shows a sample regression graph.

There is the potential for failure of the program at this point if out-of-bounds data were used for the analysis. DATA MAY BE LOST if this occurs. XSPRO will stop analyzing the discharge values at the first sign of a value less than zero. This is to help keep the program from crashing. Still, some errors may occur.

XSPRO does not provide a printer utility for printing this or the cross-section graph. However, there are ways of getting this graphical output to print. See the “Printing Graphics Screens” section for more information.

Press SPACEBAR to clear this graph and return to the main menu. You have just executed a complete run of XSPRO’s main feature.

Note: If the error message “insufficient data for analysis” appears, decrease the stage increment in the cross-section window.

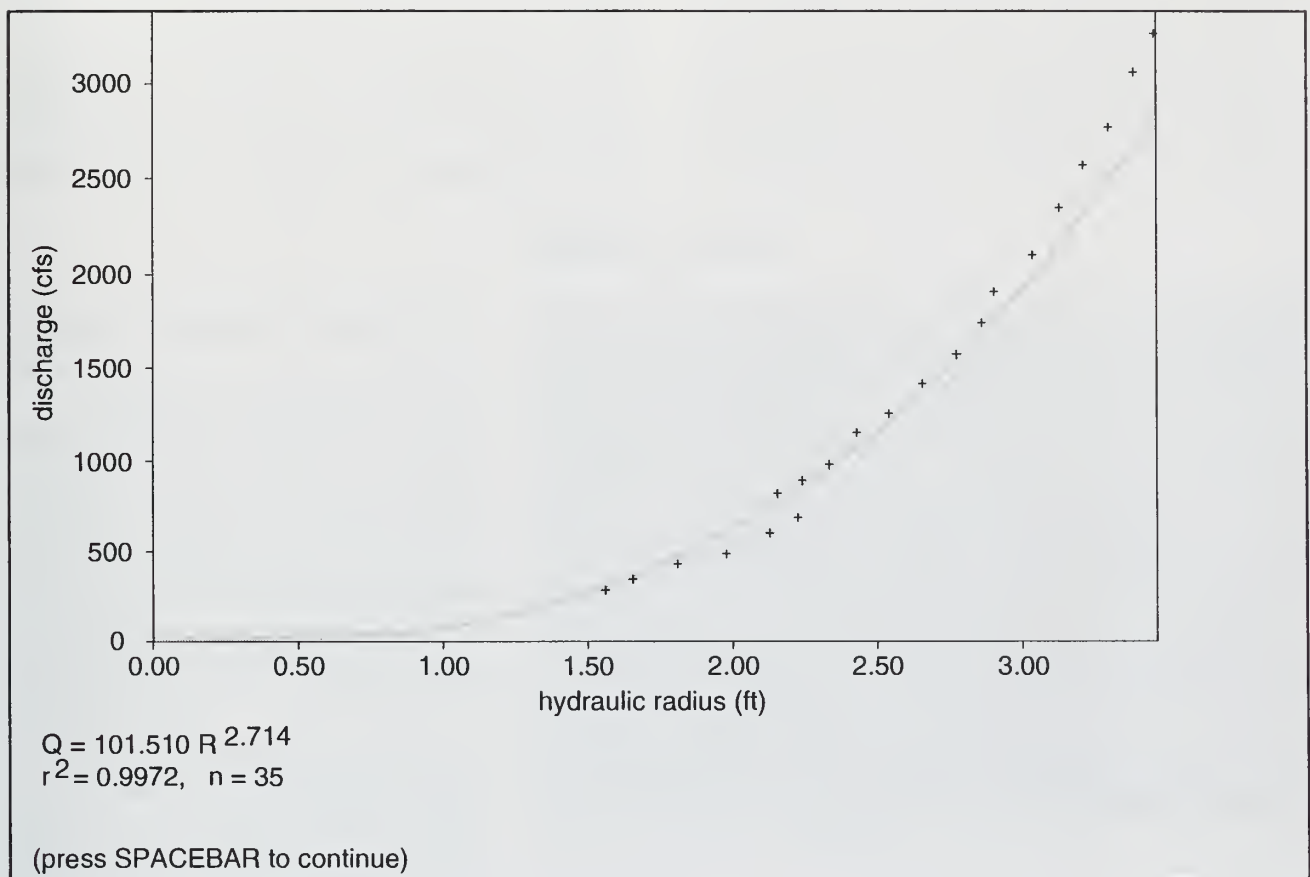


Figure 12. Sample regression graph.

XSPRO OUTPUT

OUTPUT FILE

A file named in the parameters window is filled with the analysis data while the analysis is taking place (see Appendix A for a more complete description of this file). At the beginning of the output file there will be some header information pertaining to the parameters used. This can be ignored and is only used by the printing program.

The real data in the output file are in column form with titles. This file is meant to be imported into a spreadsheet program. The section boundaries are renamed to negative numbers so conversion to numbers in a spreadsheet will be possible. For a less cryptic output, you can print the data from this file using the print facility of XSPRO.

PRINTING

Data From the Output File

The output from an analysis run is saved to the file specified in the controlling parameters window. This file becomes the input file for the printing facility. To print the output to a printer or file choose *Print* from the main menu. You will see a new window with the parameters that will be used for printing (Figure 13).

These fields work like the fields in the controlling parameters window. *Some are of the menu-selection variety and are marked with an asterisk after the field name.*

Controlling Parameters

INP
S
F
D
D
U
OU
F

Print data from file: FPXS2.OUT
Destination: LPT1

Insert form feed between cross sections (Y/N)? No

ESC to Abort F10 at completion

File output mode: Overwrite
Units: Feet

ANALYSIS
Analysis procedure: Both Hydraulics and Regression
Resistance Equation: Jarrett

Survey date (yy/mm/dd): 90/07/31
Cross-section number: 1

Figure 13. Print setup screen.

Source File

The source file to the printing facility is the file that contains the output from your run of an analysis. If the file contains data from more than one run of an analysis, all of the data in the file will be printed. The default value for this is the file named as the output file in the controlling parameters window. However, you can use any XSPRO output file.

The field works just like the *Filename* fields in the controlling parameters window. You may use drive names, directory names, and wildcards for a directory mask. The field is 40 characters long.

Destination*

You can direct the output to a printer or to a file; the text will be identical. The DOS device names for parallel and serial ports are used to direct output to a printer. Most likely your printer will be connected to LPT1, the first parallel port, and LPT1 will come up as a default each time you print. Your printer may be connected to a different port; if so, you will need to select that port from the selection menu. If you want to print to a file, select *File* from the menu and you will be prompted for the name of the file.

Filename

If you select *File* in the *Destination* field, you will be prompted for a file name. This file will be filled with exactly the same data as would be sent to the printer, including all form feeds. If the file exists, you will be asked how you want XSPRO to write to the file (appended or overwritten).

This field works just like the *Filename* fields in the controlling parameters window. You may use drive names, directory names, and wildcards for a directory mask. The field is 40 characters long.

File Output Mode*

If the file named in the *Filename* field exists, you will be prompted as to how you want the writing to that file to take place. Overwriting will completely erase the file and then write the new data to the file. Appending will simply add the new output to the end of the file, preserving all previous data in the file.

Form Feeds*

You can also select to have a form feed issued after each data set. This will only apply when the printed data contains data from more than one run. If you choose *No*, the separate sets of data will all run together. If you choose *Yes*, each data set will start on a new page. A form feed will be issued after the last page for all printouts.

Printing Graphics Screens

XSPRO does not provide you with an internal utility for printing graphics screens. However, a public domain software, "PRTSC.COM," is provided with XSPRO to enable use of the SHIFT-PRINT SCREEN key sequence to send graphics screens (i.e., cross-section plot, regression analysis) to either IBM, Epson, or Laserjet printers. The program can also detect which type of printer is being used.

To print graphics screens, PRTSC.COM must be loaded *before* loading XSPRO. At the DOS prompt, type:

PRTSC [PN] [RNNN]

where [PN] is the printer number (i.e., LPT1) and [RNNN] is the resolution. If you do not include anything on the command line, LPT1 and the Epson printer are assumed. You are given a choice of resolutions, but higher resolutions may affect printing speed. The resolution number must be three characters: "75," "150," or "300." Therefore, to configure for LPT2 and the Laserjet at 300 dots per inch, type:

PRTSC P2 R300

After this command, type "XSPRO" to begin the program as usual. Once inside XSPRO, pressing the SHIFT and PRINT SCREEN keys simultaneously will send the graph to the named printer.

Additional information about this program can be obtained by printing the file "PRTSC.DOC" supplied with XSPRO. This software is in the public domain; however, if you find yourself using the utility often, the author requests that you send a donation of \$5-\$10 to:

Jonathon Zuck
User Friendly, Inc.
P.O. Box 21164
Kalorama Station
Washington, DC 20009
(202) 387-1949

PUTTING XSPRO TO WORK

EXAMPLES USING SAMPLE DATA

Quick Run

To let you get the feel of using XSPRO, let us run through an example using data from a sample data file. Two sample data sets are provided with your distribution disk. They contain actual data collected from mountain streams in Oregon.

In the examples, only the mechanics of how XSPRO works will be explained. If you have any questions about the contents or purpose of any of the parameters discussed here, please refer to the complete explanations in the "Controlling Parameters" section.

Starting XSPRO

To run XSPRO, be sure you have a DOS command prompt and that the XSPRO files are in the current drive and directory.

Floppy Drive

If you are running XSPRO from a floppy drive, boot your machine as you normally do and then place the XSPRO disk in drive A. From the A drive type:

XSPRO <ENTER>

Hard Drive

If you installed XSPRO on your hard drive, you will need to know the drive and directory in which XSPRO was installed. Let us use the example of XSPRO being installed on drive C and in the subdirectory XSPRO (C:\XSPRO). In this case, to change to the XSPRO drive and directory, type:

C: <ENTER>

CD XSPRO <ENTER>

Then, to run XSPRO type:

XSPRO <ENTER>

If XSPRO was installed on any other drive or directory than shown here, just change the above instructions to match your case.

Analyzing the Sample Data

Following the title screen, your screen should look like Figure 14. If this is the first time XSPRO has been run on your machine, the default values for all of the parameters should be set to run with the data file "SAMPLE.DAT." You can verify this by matching what is in Figure 14 and what you see on your screen for the parameters window. If the parameters do not match up, you may need to go to the next example in the "Changing the Controlling Parameters" section where there are examples of changing the parameters so you can

Cross-Section Professional Analyzer			
Modify	Run	Print	Exit
Controlling Parameters			
INPUT:			
Source of data:	File		
Filename:	SAMPLE.DAT		
Data collection method:	other		
Data Format:	Position-Elevation free form		
Units:	Feet		
OUTPUT:			
Filename:	SAMPLE.OUT		
File output mode:			
Units:	Feet		
ANALYSIS			
Analysis procedure:	Both Hydraulics and Regression		
Resistance Equation	Jarrett		

Figure 14. Main screen.

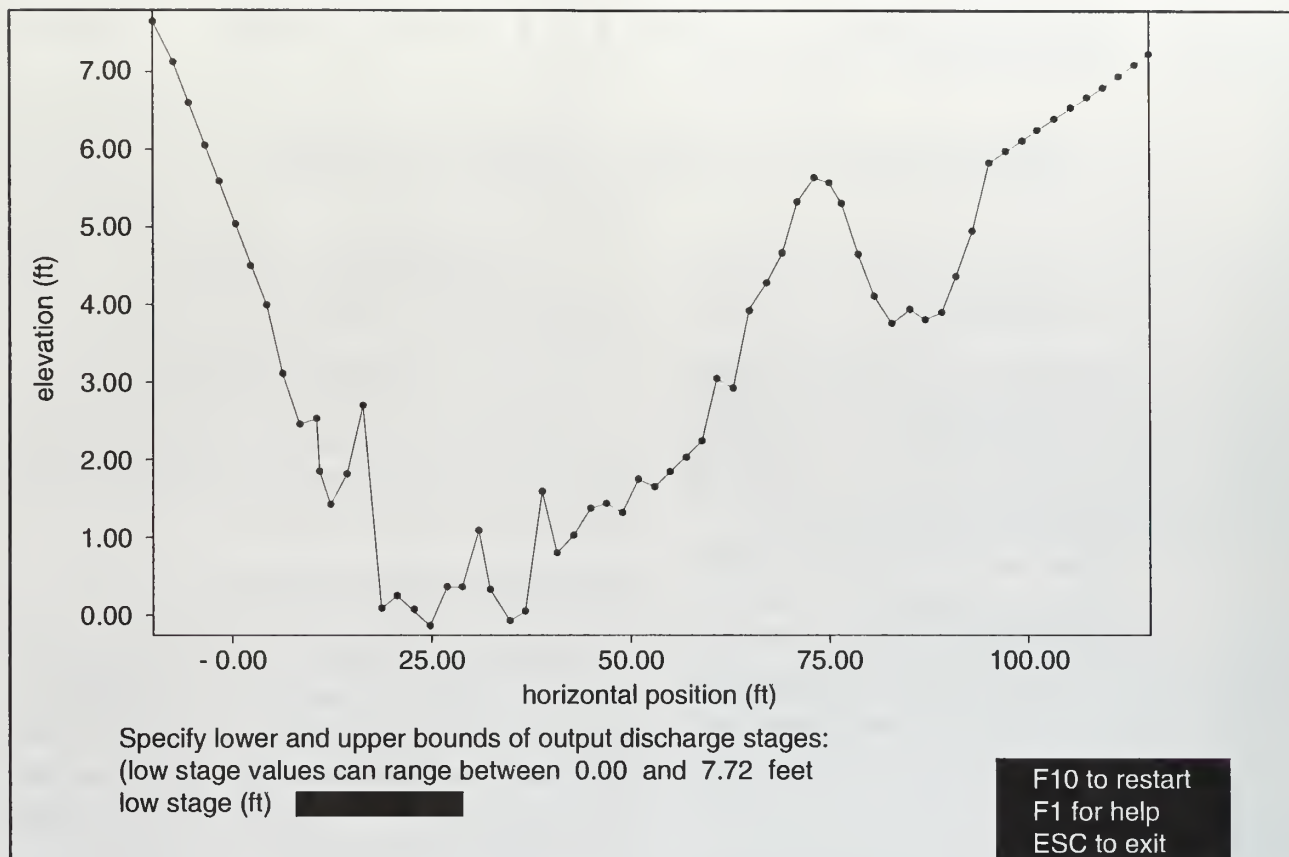


Figure 15. Sample data cross-section graph.

match up your screen and Figure 14.

Starting the Analysis

After the parameters are all set, you are ready to run the analysis. To run the analysis, highlight the *Run* selection from the main menu and press ENTER, or simply press *R* on the keyboard. XSPRO will read in the data from the file and graph it on your screen. Your screen should now look like Figure 15.

Stage/Slope Data Entry

In this section, you will be entering data that will control how the cross section will be analyzed. This section can be run over and over again until you get what you want out of XSPRO. The output file will be filled with the data from this analysis, so if you are going to run this over and over, it is suggested that you use the *Overwrite*

option for the output mode.

Your cursor should be in a highlighted box in the lower left corner of the screen. The prompt reads *Low stage (ft)*. Type:

0.0 <ENTER>

to use the lowest point on the graph as the low stage of the analysis. You will notice that the stages selected are represented as horizontal lines on the graph on your screen.

The cursor will move right, and now you are prompted for the slope (in percent) of the channel at that low stage. For this example type:

2.3 <ENTER>

The cursor will move down and left and now you are prompted for the high stage. Enter the high stage as:

7.0 <ENTER>

and the high-stage slope as:

4.0 <ENTER>

The last entry on this screen is the analysis increment between the selected stages. For this example, enter:

0.5 <ENTER>

Section Boundaries

The lower portion of your screen should clear and a new prompt for a section boundary distance value should appear. You should notice that at approximately the 70 foot mark (horizontal position), a small subchannel starts and continues to the right end of the cross section. You will isolate this subchannel from the rest of the cross section for this analysis. To tell XSPRO to create a section boundary here type:

70 <ENTER>

and you will see that XSPRO marked the point on the graph closest to the 70 foot mark. This is not where you wanted the section boundary to be, so you must clear this boundary and enter a new one. To clear the boundary, press F10. The line will disappear and XSPRO will be ready to accept a new entry. Try a few values if you like; you should find that 72 will work. To continue to the actual analysis, leave the *Section Boundary* field blank and press ENTER. A small status window will appear to show you that XSPRO is in fact working and has not crashed your machine.

Stage-Discharge Data Table

After a bit, the graph will disappear and an output table will appear on the screen. The data are sorted by stage and show the changes in hydraulic variables that occur as the stream “fills” up from the low stage to the high stage you specified. The

UP/DOWN ARROW keys and PAGE keys will work as expected to let you scroll through this data. The data shown here are the same data that get written to the output file. Press the SPACEBAR to continue to the regression.

Regression

XSPRO will plot a radius to discharge regression. The values used for the regression will be written to the output file. Press SPACEBAR to clear the graph and you will be back at the main screen.

Changing the Controlling Parameters

XSPRO lets you change all of the controlling parameters easily so you can see how they may affect your output, compare multiple sets of data, or correct a mistake. For this example, you will change the value in a menu selection field and use a straight keyboard entry field.

Start XSPRO. Select *Modify* from the main menu. You will get a submenu that allows you to branch off to *Modifying the Parameters* or *Keyboarded Data*. From here select *Parameters*. Your cursor should move to the *Controlling Parameters* window and the *Data Source* field should be highlighted. You may move between the fields with the ARROW keys. Details of the editing process are explained in the “Parameter Editing” section, so only an example of each will be provided here.

Selection Menu

Most all of the parameters have a finite set of possible values. For these parameters, we have made selecting a value just a matter of making a selection from a menu. Highlight the *Data Collection Method* field under the input section. Pressing SPACEBAR will bring up a selection menu for

that field. The menu shows all possible entries for that field (see Figure 16). In this case you can select from *Rod and Level*, *Sag Tape*, or *other*. Highlighting *other* and pressing ENTER, or just pressing *O* will select *other* for the *Data Collection Method* field.

Keyboard Entry

The other type of parameter is the one that you are probably most familiar with. It simply involves filling in the blank. All of the numerical fields and the *Filename* fields will work like this because there are an infinite number of responses. For an example, highlight either of the *Filename* fields and type in the name of a file. XSPRO will allow any character combination to be entered here.

Controlling Parameters		F1-Help
INPUT:		
Source of data:	File	Select Method Sag Tape Rod and Level other
Filename:	FPXS2.PRN	
Data collection method:	Sag Tape	
Data Format:	HJ Andrews	
Units:	Feet	
OUTPUT:		
Filename:	FPXS2.OUT	
File output mode:	Overwrite	
Units:	Feet	
ANALYSIS		
Analysis procedure	Both Hydraulics and Regression	
Resistance Equation	Thorn & Zevenbergen	
d84 Units:	Feet	
d84 particle diameter:	0.003637	
Survey date (yy/mm/dd):	80/01/01	
Cross-section number:	101	
ESC to Abort		F10 at completion

Figure 16. Menu selection fields.

SPECIFIC USES

Analyzing Geometry Changes from Year to Year

Suppose you have a set of cross sections for which you collect data annually and you wish to compare the annual changes in channel geometry. XSPRO makes it easy to do this kind of analysis. Setting the *Analysis Procedure* parameter to *Geometry Only* will reduce the output of XSPRO to only the geometric data: area, perimeter, topwidth, average depth, and hydraulic radius. The output will be ordered from the top of the cross section (default) or a specified stable point down (opposite of the ordering of a hydraulics analysis). This was designed specifically for analyzing changes in streambed geometry, since the upper part of the cross section is assumed stable and can serve as a reference point for changes in the lower part of the cross section. XSPRO will automatically select the high and low stages for the analysis, based on the highest and lowest points in the cross section, so all you have to do is enter the stage increment and the section boundaries. However, there are

several options for specifying stable points to which all elevations will be referenced. In this example, you will see how to analyze the geometry of a single cross section, and then have XSPRO append the output data of consecutive runs to a single file. You will then have a data file that spans some timeframe and can easily be imported into a spreadsheet program or printed out for further analysis.

Step 1: Set the Input and Output Parameters

For this example you will again use the file "SAMPLE.DAT" that came on your distribution disk. The data in the file "SAMPLE.DAT" uses the following input parameters (these will be the default settings when XSPRO is run for the first time):

Data Collection Method: Other
Data Format: Position-Elevation
Units: Feet

Our first step is to set the controlling parameters to match the data. Select *Modify* and then *Parameters* from the main menu. The cursor will now be positioned on the *Data Source* field. Follow the instructions in the previous section to match all of the input and output parameters with those in Figure 14. You should be aware of what output file and mode are selected so you don't overwrite any important data.

Step 2: Set the Analysis Parameters

Move down the window to the *Analysis Procedure* field. You want to analyze only the geometry of the stream so you must change the *Analysis Procedure* field to *Geometry Only*. To do this, press the SPACEBAR and select *Geometry Only* from the selection menu. Notice that the resistance equation information will disappear. None of that will matter in this analysis.

Press F10 to complete the parameter setup.

Step 3: Run the Analysis

Select *Run* from the main menu and XSPRO will graph the cross section. You will then be prompted to supply the upper boundary (stable point) for the analysis, along with the stage interval. A line indicating the upper boundary will be drawn on the cross section. The upper boundary represents the stable or reference level and will be indicated on the output as elevation 0. The channel geometry will be calculated from this point downward to the lowest elevation on the cross section at intervals indicated by the specified stage interval (Note: This may result in the first interval being less than the specified interval, depending on whether the specified interval divides evenly into the difference between the stable point and the lowest point on the cross section).

As with the hydraulic procedures, you can also subdivide the cross section into subchannels. Indicate where the section boundaries should be placed by typing a number corresponding to the horizontal distance; a vertical line will appear at the data point closest to this value. When all

section boundaries have been entered, hit ENTER to start the analysis.

The output will be ordered from the specified upper boundary down to the lowest elevation on the cross section, and identified in the left-most column as distance below datum. Pressing SPACEBAR will return you to the main menu, and complete the analysis of this set of data.

Step 4: Run the Analysis Again With Next Year's Data

From the main menu, select *Modify* and then *Parameters* and change the input file field so it contains the name of the file for the next set of data. Also change the *Output Mode* field to read *Append*. This will append the next year's data to the same output file. If you don't want to do this, you must choose a new output file name or the previous output data will be lost. Exit back to the main menu.

Select *Run* from the menu and hit ENTER two times to accept the same upper boundary and stage increment. Enter the same section boundaries as previously specified and hit ENTER to begin the analysis. The output table will be appended to the same file as the previous analysis. When the analysis finishes, you have a file with data in table form for 2 years of a cross section. This last step could be repeated with many more years of data.

To complete the analysis, follow the directions in Appendix B for importing files into Lotus 123. Year-to-year changes in channel geometry can be plotted on a single graph as long as the same reference level was used in each cross section.

There are two other ways of specifying stable or reference points for conducting *Geometry Only* analyses besides indicating them directly on the cross section as described above. One is by identifying a stable point when entering data from the keyboard (see next section). The other is by using a text editor program to add an uppercase letter *S* to the end of the line of data (no spaces) corresponding to the stable point in an ASCII data file. So, for example, if your cross-section data is in an ASCII file with each line consisting of a

single distance-elevation pair of numbers (separated by spaces), appending an *S* to any line will label the elevation of that point as the stable point. You will then see a line corresponding to that elevation in the graphics screen when the cross section is plotted. That point will also be identified as the stable point in the *Modify-Data* screen (see below). The advantage of either of these two ways of specifying stable points is that they are automatically written to the input data file. Identifying the stable point using the graphics screen alone does not alter the input file.

Entering Data With the Keyboard

Thus far, you have been using data from a file that already exists. XSPRO also allows you to enter the data for a cross section right from the keyboard, and it will save that data to a file that can be used some other time. You can also edit any entered data, as in the next example.

Start up XSPRO. This example uses made-up data; as always you may substitute any real data you have.

Step 1: Tell XSPRO You Want to Key In the Data

From the main menu, select *Modify* and then *Parameters*. Your cursor will be in the *Data Source* field, which is the one you want to change. Press SPACEBAR and select *Keyboard* as the source. Make sure all other parameters match what you want to do and press F10.

Step 2: Enter the Data

The *Modify* submenu should be active. Select *Data* and an entry window should appear on your screen. The first prompt is how many points you want to enter. This need only be a rough estimate as you can increase or delete points later. The maximum number of points per cross section is 200. For the number of points enter:

15 <ENTER>

XSPRO will now give you a table of distance and elevation points and your screen should look like Figure 17. The entry screen can only display ten points at a time. To move between sets of points, you must use the PGUP/PGDN keys. To move around within the set of points that are being displayed, you can use the UP/DOWN ARROW keys, TAB, and ENTER. If you need more points than you have, you may press F2 to add a point to the end of the list. If you have too many points, you may press F3 to delete a point from the end of the list. These functions are provided only to adjust the number of points; you cannot insert or delete points from anywhere but the end of the list.

--- Controlling Parameters ---

INPUT
Sour
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Data
Data
Unit

OUTP
File
File
Unit

ANAL
Anal
Resis

Keyboard Data Entry/Edit

Enter the number of surveyed data points 15

	Point	Distance	Elev
F2 to Delete last point	1	0	0
F3 to Add a point	2	0	0
PGDN for next 10 points	3	0	0
PGUP for prev 10 points	4	0	0
	5	0	0
	6	0	0
Data units: feet	7	0	.0
Stable pt: #0 (Not Defined)	8	0	0
	9	0	0
	10	0	0

ESC to Abort F10 at completion

Survey date (yy/mm/dd): 81/10/24

Figure 17. Keyboard input.

(Note: The data can be in any order as XSPRO will sort the entries by elevation.)

Type in the following list of distance-elevation pairs:

Distance	Elevation
0.0	4.6
1.5	3.2
3.0	1.8
4.5	0.6
6.0	0.1
7.5	0.0
9.0	0.3
10.5	1.0
12.0	1.9
13.5	1.7

Press PGDN to get the next set of entry fields. Then enter:

15.0	2.1
16.5	3.3
18.0	4.0
19.5	4.3
21.0	4.5

Press F10 to complete the entries. You will then be asked to specify which observation number corresponds to the stable point; this information is used in the *Geometry Only* analysis described above. The default value of 0 indicates that no stable point is to be specified. Press F10 again. You will be asked if you want to save the data to a file now. You can save the data to a file from the main menu by pressing F2, but to be safe, go ahead and save the data now. Press *Y* and then tell XSPRO what file name to use. After you type in the file name, press F10 to save the data.

Step 3: Analyzing the Data

The rest of the analysis works just like it does for data from a file. Select *Run* from the main menu and you will see a graph of the cross section. You enter all of the pertinent data and the analysis will continue.

Step 4: Editing Data From Keyboard Input

You can edit any mistakes made or make any changes needed to the data. When you get back to the main menu, select *Modify* and then *Data* again. You should get a filled editing screen with all of the values you used last time. You can now move to any cell and edit it. When you complete the editing, XSPRO will again ask if you want to save the data. If you have made changes, you should answer with a *Y* and tell XSPRO what file name to use.

Saving Keyed In Data From the Main Menu

When you complete either entering or editing data, XSPRO will ask if you want to save the data to a file. You can answer *Y* and save the data here, or you can save the data later from the main menu. From the main menu, press F2. You will be prompted for a file name and when you finish entering the name, press F10 to save the data. If no data have been entered, you will get an error.

LITERATURE CITED

- Aldridge, B.N., and J.M. Garrett. 1973. Roughness coefficients for stream channels in Arizona. U.S. Geological Survey Open-File Report.
- Arcement, G.J., Jr., and V.R. Schneider. 1984. Guide for selecting Manning's roughness coefficients for natural channels and flood plains. U.S. Dept. Trans., Federal Highway Administration Tech. Rept. No. FHWA-TS-84-204.
- Ashmore, P.E., T.R. Yuzyk, and R. Herrington. 1988. Bed-material sampling in sand-bed streams: Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, Report IWD-HQ-WRB-SS-88-4. 90 p.
- Barnes, Harry H., Jr. 1967. Roughness characteristics of natural channels. U.S. Geological Survey Water-Supply Paper 1849.
- Bathurst, J.C. 1978. Flow resistance of large-scale roughness. *Journal of the Hydraulics Division, Am. Soc. Civil Engr.*, Vol. 104, No. HY12, pp. 1587-1603.
- Benson, M.A., and Tate Dalrymple. 1967. General field and office procedures for indirect discharge measurements. *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A1.
- Buchanan, Thomas J., and William P. Somers. 1969. Discharge measurements at gaging stations. *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A8.
- Chow, Ven Te. 1959. Open-Channel Hydraulics. McGraw-Hill Book Company, New York. 680 p.
- Church, M.A., D.G. McLean, and J.F. Wolcott. 1987. River bed gravels: sampling and analysis. Department of Geography, University of British Columbia, Vancouver, British Columbia, Canada. pp. 43-88.
- Cowan, W.L. 1956. Estimating hydraulic roughness coefficients. *Agricultural Engineering*, Vol. 37, No. 7, pp. 473-475.
- Dalrymple, Tate, and M.A. Benson. 1967. Measurement of peak discharge by the slope-area method. *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 3, Chapter A2.
- Federal Inter-Agency Sedimentation Project. 1986. Catalog of instruments and reports for fluvial sediment investigations: Federal Inter-Agency Sedimentation Project, Minneapolis, Minnesota. 138 p.
- Grant, Gordon E., Frederick J. Swanson, and M. Gordon Wolman. 1990. Pattern and origin of stepped-bed morphology in high-gradient streams, Western Cascades, Oregon. *Geological Survey of America Bulletin*, Vol. 102, pp. 340-352.
- Hey, R.D. 1979. Flow resistance in gravel-bed rivers. *Journal of the Hydraulics Division, Am. Soc. Civil Engr.*, Vol. 105, No. HY4, pp. 365-379.
- Jarrett, Robert D. 1984. Hydraulics of high-gradient streams. *Journal of Hydraulic Engineering, Am. Soc. Civil Engr.*, Vol. 110, No. 11, pp. 1519-1539.
- Parsons, Stephen C., and Shirley Hudson. 1985. Stream channel cross section surveys and data analysis. U.S. Bureau of Land Management Tech. Rept. No. TR-4341-1.

- Potyondy, John P. 1990. An analysis of the use of roughness coefficients in the modeling of channel hydraulics: a comparison of flows calculated with Jarrett's equation to flows calculated using Manning's n-values. Unpublished report to the Boise National Forest.
- Rantz, S.E., and others. 1982. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge. U.S. Geological Survey Water-Supply Paper 2175.
- Ray, Gary A., and Walter F. Megahan. 1979. Measuring cross sections using a sag tape: a generalized procedure. USDA Forest Service General Technical Report INT-47.
- Roberson, John A., and Clayton T. Crowe. 1985. Fluid Mechanics. Houghton Mifflin Company, Boston. 712 p.
- Smoot, George F., and Charles E. Novak. 1968. Calibration and maintenance of vertical-axis type current meters. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 8, Chapter B2.
- Thorne, Colin R., and Lyle W. Zevenbergen. 1985. Estimating mean velocity in mountain rivers. *Journal of Hydraulic Engineering*, Am. Soc. Civil Engr., Vol. 111, No. 4, pp. 612-624.
- Van Haveren, Bruce P. 1986. Water Resource Measurements. American Water Works Association, Denver. 132 p.
- Wolman, M. Gordon. 1954. A method of sampling coarse river-bed material. *Transactions of the American Geophysical Union*, Vol. 35, No. 6, pp. 951-956.
- Yuzyk, T.R. 1986. Bed material sampling in gravel-bed streams: Sediment Survey Section, Water Resources Branch, Inland Waters Directorate, Environment Canada, Report IWD-HQ-WRB-SS-86-8. 74 p.

APPENDIX A — FILE FORMATS

INPUT FILES

Input files are ASCII text files that, in general, will contain two columns of data. One column will contain distance, the other elevation. Each line of the file will represent one point on the cross section. However, XSPRO can use several separate formats for the data files. Following is a list of the different formats and a description of how input files must be formatted for each.

Position-Elevation Free Form

This format requires a file that has at least two columns of data. The first column should have a position or horizontal distance, and the second column should have an elevation number. All other columns in the file will be ignored. The file will be read from top to bottom. Each line in the file will be processed, and the two values on that line will represent one pair of distance-elevation points on the cross section.

If you key in the data and save it to a file, the file will be saved in the position-elevation format.

Elevation-Position Free Form

This format requires a file that has at least two columns of data. The first column should have an elevation, and the second column should have a position or horizontal distance number. All other columns in the file will be ignored. The file will be read from top to bottom. Each line in the file will be processed, and the two values on that line will represent one point on the cross section.

User Defined

If none of the above formats match your needs, you can specify the column number and length of the position and elevation data in your file. If you have a file that was created by a spreadsheet program and it has the position and elevation data at columns other than the first two, you can specify those columns and the length. The program will search through the entire file for the data.

OUTPUT FILES

The output file that the program generates contains all of the hydraulic data as well as the regression numbers. The first five lines of the file will contain header information that is used by the printing facility. The next line has the column titles followed by the analysis data.

The letters you saw representing the section boundaries when the data was displayed on the screen are changed to numbers in the output file so a spreadsheet program won't have difficulty with text in a column of numbers. The relationship between the letters and numbers is simple; what used to be A is now -1, what used to be B is now -2, etc.

Another difference from the on-screen data is that the stage numbers are included on each line to further enable you to import the data into a spreadsheet. The asterisk at the end of the line for data that were extrapolated will usually not interfere with a spreadsheet. The final line of the output file is the numbers used in the regression analysis.

Of course, if you have the program append to the output file, there will be more than just one set of output data. Each set of data will start with a line of asterisks. The files can get as big as the disk space available.

APPENDIX B — IMPORTING XSPRO OUTPUT INTO LOTUS 1-2-3

XSPRO produces an output file that is easily imported into Lotus 1-2-3 for further analysis. Following are steps to import that data.

- Start Lotus 1-2-3 and select *File/Import/Text*. The file you want to use is the output file from XSPRO. Specify the correct file name and Lotus 1-2-3 should load the file.
- Remove the header information (everything but the column headers) for each data set. Leave a blank row between each set of data. You should now have all the data and the headers for each column.
- Now you have to convert the data to numbers. Move the cell pointer to the first row of data, not text (should be the first row

after the top column title row). Select *Data/Parse* from the menu. Select *Format-Line*. This will be the format used for all of the columns of data and will format the headers as well.

- Select *Input-Column* and mark all of the data.
- Select *Output-Range* and mark the upper-left cell.
- Select *Go*.

The data and column titles should all be in their own columns now. Don't forget to save the file before you finish.

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