Detailed Stream Channel and Riparian Cross-Sections: SHIM field methods and the Cross-Sectional Diagram Tool

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I) Detailed Stream Channel Cross-Sections

The standard SHIM procedure involves collection of stream channel wetted, bankfull and floodplain widths and depths. In terms of providing a general description of stream conditions at different points along the stream channel this is considered sufficient. However, more detailed SHIM field procedures and accompanying mapping software tools have also been developed to capture greater details of stream channel complexity if required. More precise measurement of channel shape in conjunction with descriptions of upland slope and condition can aid in development of hydraulic models used for regional flood planning. This information is becoming of ever-greater importance as urban development of headwater areas in British Columbia continues to increase. Outlined below are the specific field procedures and measurement points for undertaking detailed channel cross-sections, as well as description of the accompanying ArcView Cross-Sectional tool designed to graphically display the collected data.

A) Cross-sectional measurement points:

Channel measurements are taken using a folding ruler and a flexible tape measure stretched perpendicular to the direction of stream flow. A handheld clinometer and a flexible tape measure are used for determinations of upland slope. Required cross-sectional measurements of stream channel widths, depths and elevations as well as upland riparian features are based on the following survey points defined in Figure 1 below:

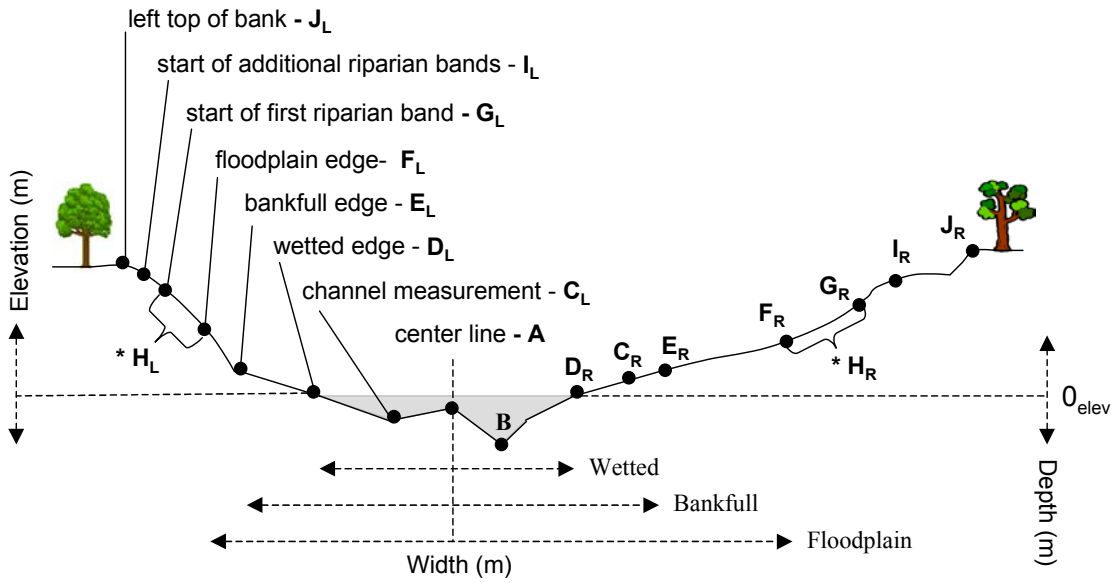


Figure 1. Cross-sectional measurement points for SHIM stream surveys.

A – channel center line (midpoint of bankfull width)
B – thalweg (deepest channel measurement, may be left or right of center line)
C_L – left channel measurements (CL1 to CL3) – may be taken below or above water line
C_R – right channel measurements (CR1 to CR3) – may be taken below or above water line
D_L – left wetted channel edge
D_R – right wetted channel edge
E_L – left bankfull edge
E_R – right bankfull edge
F_L – left floodplain edge
F_R – right floodplain edge
G_L – beginning of first left bank riparian band
G_R – beginning of first right bank riparian band
*** H_L** and/or **H_R**: measured when a strip of vegetation is too narrow to include as a distinct riparian band, yet is considered to represent a significant change in bank slope.
I_L - beginning of additional riparian band(s) for left bank
I_R – beginning of additional riparian band(s) for right bank
J_L – top of bank location for left bank
J_R – top of bank location for right bank

***Note**: left and right banks are determined by facing downstream.*

B) General field protocol for detailed cross-sectional measurements:

1) Stretch out tape measure between two partners and measure/record bankfull width
2) Go to defined stream center line (midpoint of bankfull width)
3) Measure/record stream center line depth/elevation
4) One partner (who will be the operator of the GPS unit) stays at stream center line for the duration of the channel measurements and holds the spool of the tape measure. The second partner (who will actively take channel measurements) then moves towards the right bank stretching out the end of the tape measure and using the folding vertical ruler to take multiple measurements of right channel widths and depths/elevations and wetted right channel width. After each channel measurement this partner calls out the associated values to the GPS operator, who will repeat the numbers (to ensure that the measurement has been heard correctly in potentially noisy conditions) and record them in the GPS unit. Upon reaching right bankfull edge, measure/record right bankfull elevation.
5) Measure/record right floodplain width and elevation.
6) Return to stream center line point and move towards left bank repeating procedural steps 4 to 6 for all left channel points.
7) Upon completion of channel measurements the GPS operator joins their partner at the edge of the left floodplain. Begin measurements of any extra bands (if needed) or left riparian bands from this point.
8) The GPS operator again holds the spool of the tape measure while their partner stretches out the tape to the end of the extra band or to the beginning of the next riparian band. This partner calls out the associated width to the GPS operator who records the measurement.

9) The GPS operator then uses a clinometer to measure the slope of the left band (in conjunction with their partner providing an adjustment for ground-to-eye height as described in the following methods section) and also takes a compass bearing of the transect direction. Both these measurements are recorded in the GPS data logger.
10) Both partners advance up the left slope taking measurements of widths and slopes (and associated vegetation information) for each of the left riparian bands defined. Continue up left bank until all measured riparian band widths total 50 meters, or (in steeply sloped areas) extend the riparian measurements to 10m beyond the "top of bank", if not included in the 50m measurement.
11) Upon encountering "top of bank", end the current riparian band at this point and record a "Yes" in the appropriate data field in the GPS unit.
12) Both partners then walk across the stream channel to the right floodplain edge and repeat procedural steps 7 to 12 for the right bank upland measurements from this point.

- **Note:** as an alternative or supplement to tape measurements, "top of bank" and riparian band breaks may be collected directly as GPS point features

- **Note:**

a) in the standard SHIM procedures wetted, bankfull and floodplain heights were measured as depths (+) relative to the stream bottom at channel center line, whereas
b) in the detailed SHIM cross-sectional procedures channel, wetted, bankfull and floodplain heights are measured as depths (-) or elevations (+) relative to the stream water surface level or deepest point in stream channel (if dry).

C) Measurement methods:

All measurements of cross-sectional channel widths are determined relative to the stream center line, while measurements of depth (-) and elevation (+) are determined relative to zero elevation at the level of the water surface or, if the stream channel is completely dry, at the level of the deepest point in the stream channel.

Depths: measured by an individual holding a folding ruler vertically upright from the wetted stream bottom. Markings from the ruler are read off at the water surface for associated depth measurements taken at multiple points within the wetted stream channel (CLs and/or CRs). (Figure 2). All depth measurements (below the water surface) are recorded as negative values (-).

Elevations: measured by an individual holding a folding ruler vertically upright from the edge of the water surface (D) while simultaneously holding one end of a tape measure. For stream channels that are dry the ruler is held vertically upright from the bottom substrate. A partner stretches the other end of the tape measure to the appropriate channel measurement point (i.e., CL, CR, E or F). The first individual then holds their end of the tape measure horizontal to the folding ruler and reads off from the ruler the associated elevation measurement for the surveyed point (Figure 2). Elevation measurements are recorded as positive values (+). For sections of the stream channel that are dry, channel measurements (including CLs, CRs or center line) are measured as elevations (+) relative to the surface level of the existing water flow. If the entire stream channel is dry (no flowing water), then measurements for all channel features are recorded as elevations (+) relative to the deepest point of the channel (B).

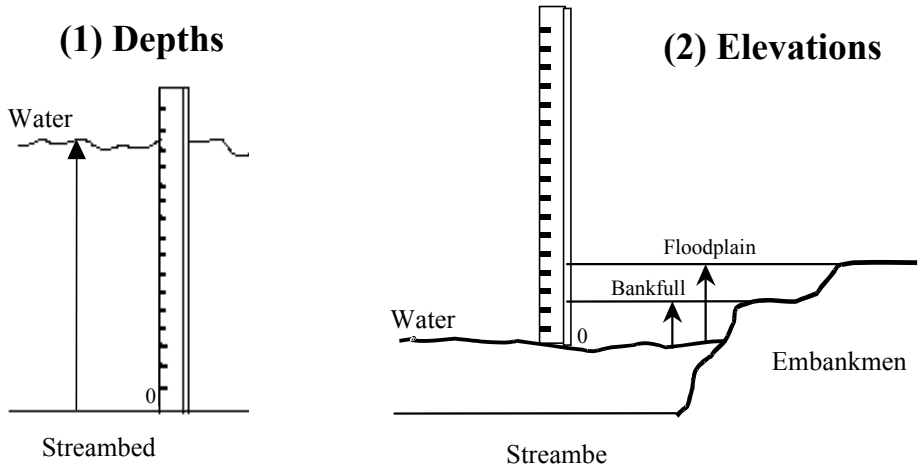


Figure 2. Depth and elevation measurements used in the detailed channel methods**.**

Widths: determined by anchoring one end of a flexible tape measure (either by one partner holding a tape end or else securing it with a rock or stick) while stretching the other end across to a desired survey point. The measured distance is then read off from the markings indicated on the tape.

Slope: determined in degrees with a clinometer, a sighting device used to measure the angle of a line of sight above or below horizontal. To use a clinometer, you look through the eyepiece with one eye to see the angle measuring scale and a horizontal line. With the other eye, you sight on the point of land you want to measure. When the horizontal line is aligned with your survey point, you simply read the scale to find the gradient (Figure 3).

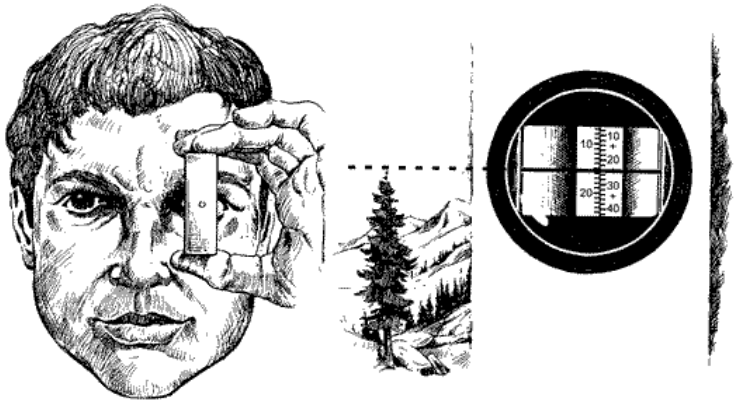


Figure 3. Slope measurements with a handheld clinometer.

Gradient is a measure of how quickly the land falls (or rises) over a measured horizontal distance. The higher the gradient, the steeper the slope. Steep, high gradient slopes lose height quickly over short distances, whereas gentle, low gradient slopes lose very little height over comparable distances. To use the clinometer in the field, first determine the height from the ground to the eyes of the person holding the instrument. This height can be flagged on a pole or stick as an adjustable siting marker, which will be held vertical from the base of the survey point by a second team member. All clinometer readings should then be taken in line with this marker to adjust for individual variations in observer height (Figure 4). Before commencing measurements of the slope, determine the aspect (direction that the slope is facing) with a magnetic compass (correctly adjusted for declination).

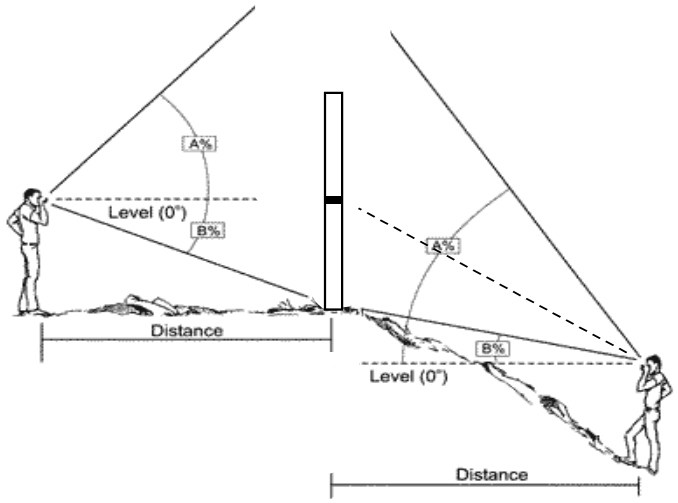


Figure 4. Adjusting for ground to eye height when taking clinometer measurements.

D) Channel measurements:

Center line: no width is taken here (only depth or elevation), as the channel center line (A) provides the zero reference point for all cross-sectional width measurements. Accurate spatial co-ordinates for this point are captured with a Trimble Pathfinder GPS unit.

Left channel widths (CL1, CL2 and CL3): measured for each by stretching a tape measure from the stream center line (A) and determining incremental widths across the channel (Figure 5). One to three channel widths may be taken in conjunction with depths or elevations to provide a good representation of the channel bottom. A separate left channel width (D_L) is taken at the wetted edge of the stream.

Right channel widths (CR1, CR2 and CR3) measured by stretching a tape measure from the channel center line (A) and determining incremental widths across the channel (Figure 5). One to three channel widths may be taken in conjunction with depths or elevations to provide a good representation of the channel bottom. A separate right channel width (D_R) is taken at the wetted edge of the stream.

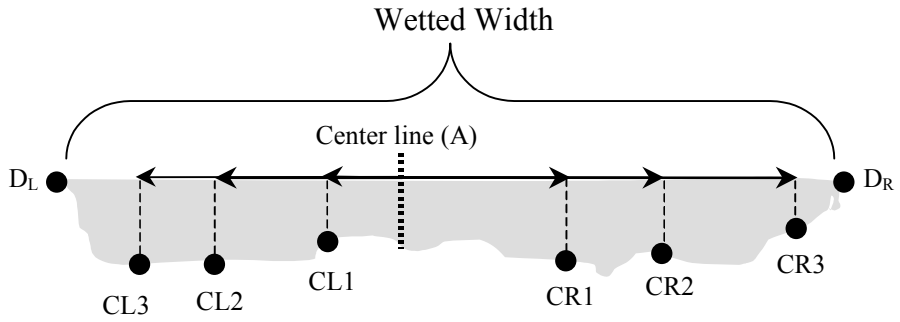


Figure 5. Incremental channel width measurements taken from the channel center line.

Thalweg (B): the deepest point captured in the stream cross-sectional depth/elevation measurements. Thalweg may be left or right of the channel center line.

Wetted channel width: the total distance from D_L to D_R. Left and right wetted channel widths are measured separately from the channel center line. No depth is taken at the wetted edges, as the water surface represents the zero reference point for measured depths and elevations.

Bankfull width: measured by stretching a tape measure from left bankfull edge (E_L) to right bankfull edge (E_R). Alternatively, this can be measured as the combined separate distances of center line to left bankfull edge (E_L) and center line to right bankfull edge (E_R).

Left floodplain width: measured by stretching a tape measure from left bankfull edge (E_L) to left floodplain edge (F_L).

Right floodplain width: measured by stretching a tape measure from right bankfull edge (E_R) to right floodplain edge (F_R).

Right and left extra bands (H_L and H_R): measured by stretching a tape measure from edge of floodplain (F_L or F_R) to end of first extra band. Only the slope and width of these bands are recorded. As many as two strips may be measured for each bank.

E) Riparian measurements:

Left riparian bands: measured by stretching a tape measure from start of first riparian band (G_L) to beginning of next riparian band (I_L). Repeated in a continuing sequence for each distinct riparian band identified (e.g., I_L to J_L, etc. for a possible total of 1 to 4 left riparian bands). Gradient of each riparian band is also determined from G_L to I_L, I_L to J_L, etc. using a handheld

clinometer. Widths are determined along the slope of the embankment, providing a measure of slope-distance for each of the left bank riparian bands. A compass bearing for the left slope is taken at the commencement of the first riparian band.

Right riparian bands: measured by stretching a tape measure from start of first riparian band (G_R) to beginning of next riparian band (I_R). Repeated in a continuing sequence for each distinct riparian band identified (e.g., I_R to J_R, etc. for a possible total of 1 to 4 right riparian bands). Gradient of each riparian band is also determined from G_R to I_R, I_R to J_R, etc. using a handheld clinometer. Widths are determined along the slope of the embankment, providing a measure of slope-distance for each of the right bank riparian bands. A compass bearing for the right slope is taken at the commencement of the first riparian band.

Left top of bank (J_L): no additional measurement for this point is required in the field. Simply enter a coding of (Yes) in the SHIM field data logger if the end of an identified riparian band represents the left top of bank. An algorithm calculating the distance from the stream center line to the designated left top of bank point will be activated automatically in the SHIM cross sectional tool extension.

Right top of bank (J_R): no additional measurement for this point is required in the field. Simply enter a coding of (Yes) in the SHIM field data logger if the end of an identified riparian band represents the right top of bank. An algorithm calculating the distance from the stream center line to the designated right top of bank point will be activated automatically in the SHIM cross sectional tool extension.

F) Definition of terms:

"active floodplain":

a level area adjacent to a stream channel, having its lower elevational extent defined by the bankfull discharge level, that is occupied by standing or flowing water on average once in five years[1]. The active floodplain can be identified by:

a) flood channels free of terrestrial vegetation
b) rafted debris or fluvial sediments newly deposited on the surface of the forest floor or suspended on trees or vegetation
c) recent scarring of trees by material moved by flood waters.

"bankfull width":

the width of the wetted stream channel at the normal high water level attained during mean annual flow events. A number of criteria can be used to determine bankfull edge in the field. The following should be considered:

a) a change in vegetation (>2 years old) from bare ground, with no trees, to vegetated ground with trees, from no moss to moss covered ground, or from bare ground to grass-

covered ground, particularly in range lands (i.e., where rooted, terrestrial vegetation begins);

b) the highest elevation below which no fine woody debris (needles, leaves, cones or seeds) occurs; and

c) a change in texture of deposited sediment (e.g., from clay to sand, or sand to pebbles, or boulders to pebbles).

"riparian bands":

distinct associations of hydrophilic vegetation (plants adapted to continuous high moisture content) occurring next to the banks of surveyed streams, lakes, and wetlands, as well as adjoining upland vegetation influenced by the adjacent stream or ponded water. Each riparian band represents uniform slope and vegetation, and a change in either of these requires delineation of a new band.

"slope-distance":

measurement of distance (width) along a gradient (as opposed to horizontal distance)

"thalweg":

the lowest point along the length of a measured stream or river bed.

"top of bank":

(a) the point closest to the boundary of the active floodplain of a stream where a break in the slope of the land occurs such that the grade beyond the break is flatter than 3:1 at any point for a minimum distance of 15 metres measured perpendicularly from the break; and,

(b) for a floodplain area not contained within a ravine, the edge of the active floodplain of a stream where the slope of the land beyond the edge is flatter than 3:1 at any point for a minimum distance of 15 metres measured perpendicularly from the edge[1].

- top of bank is a necessary prerequisite for establishing the boundaries of Fisheries Sensitive Zones (FSZ). FSZs are an important planning component in determining minimum setbacks required for development adjacent to a stream.

[1] Millar, J.N., N.Page, M. Farrell, B. Chilibeck, and M. Child. 1997. Establishing Fisheries Management and Reserve Zones in Settlement Areas of Coastal British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences N0. 2351.

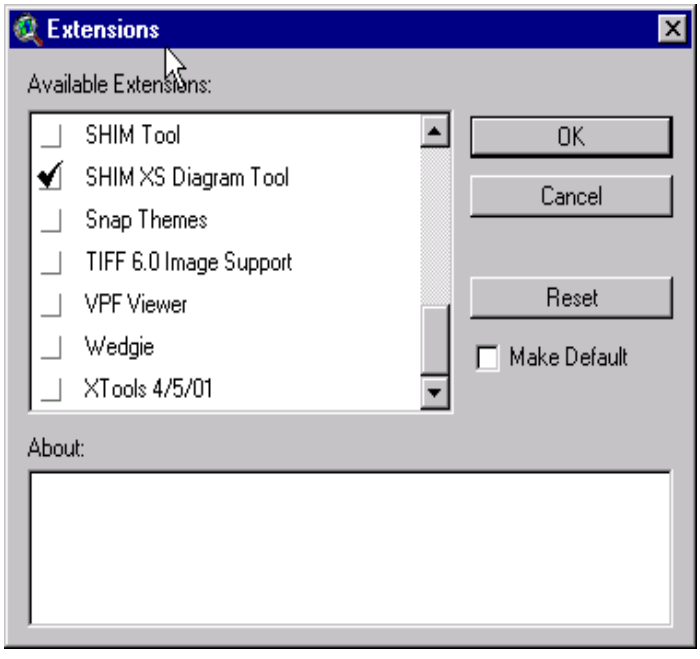
[2] Taken from the Streamside Protection Regulations pursuant to Section 12 of the BC *Fish Protection Act* (2001).

II) Arcview Cross-Sectional Diagram Tool Extension:

The Cross-Sectional Diagram Tool extension was developed to generate diagrams of spatially accurate stream cross-sectional profiles based on GPS collected point data for stream widths and depths. This information can be used in hydraulic analyses that help determine stream water-surface elevations at periods of high flood and can assist planners in defining floodway limits. This guide will provide step-by-step instructions in the application of the Cross-Sectional Diagram Tool and is designed for the basic ArcView user. Although the extension has been developed to allow display of channel cross-sections using ArcView, the generated datasets are easily transferable for cross-sectional analyses in other software packages such as Microstation and ArcInfo. The Cross-Sectional tool will create profiles of stream cross-sections using information collected with either the standard SHIM cross-sectional procedures (i.e., simple measurements of wetted, bankfull and floodplain widths/depths) or the more detailed SHIM cross-sectional procedures (i.e., measurements of channel, wetted, bankfull and floodplain widths and depths/elevations).

(A) Loading the extension in ArcView:

1. Copy the shimxsv1_5.avx file provided into the Ext32 subfolder on your computer hard drive (C:\Esri\Av_gis30\Arcview\Ext32)
2. Open ArcView with a new project and in the project file menu go to File > Extensions, select the SHIM XS Diagram Tool extension and click OK.



3. Loading the extension will add the XS Diagram Tool icon  to the view window.

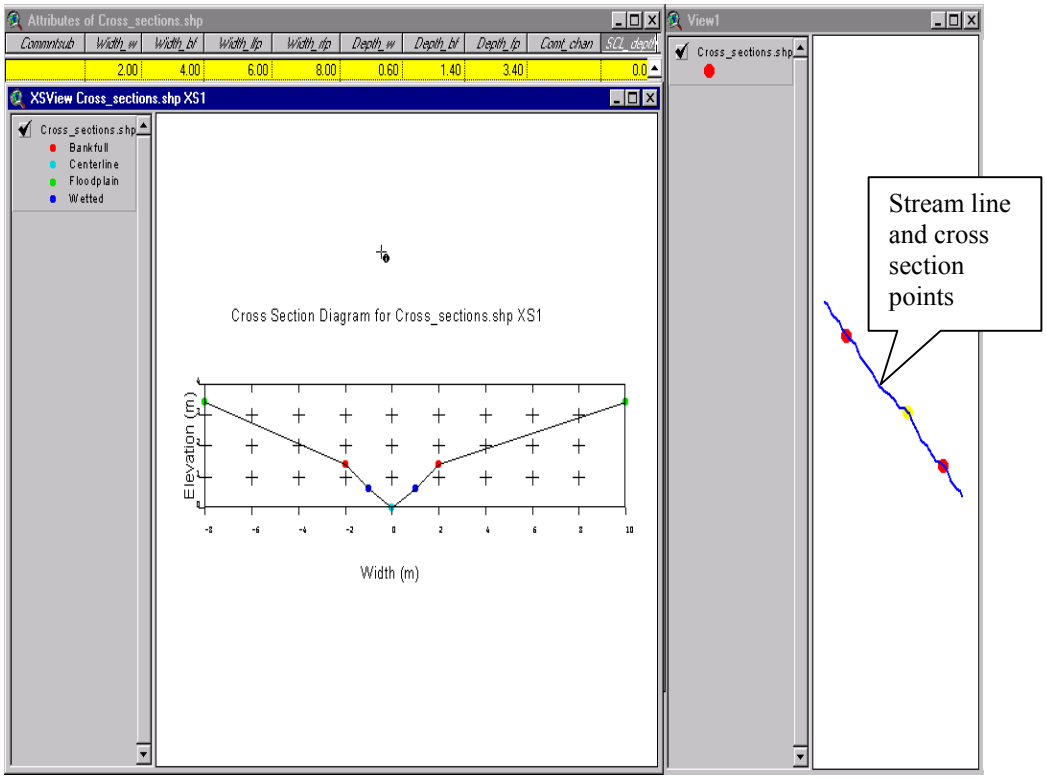
(B) Displaying stream cross-sections:

1. In the Edit View window's button menu click on the Add Theme tool  and add a SHIM Cross-Section points theme to the view.

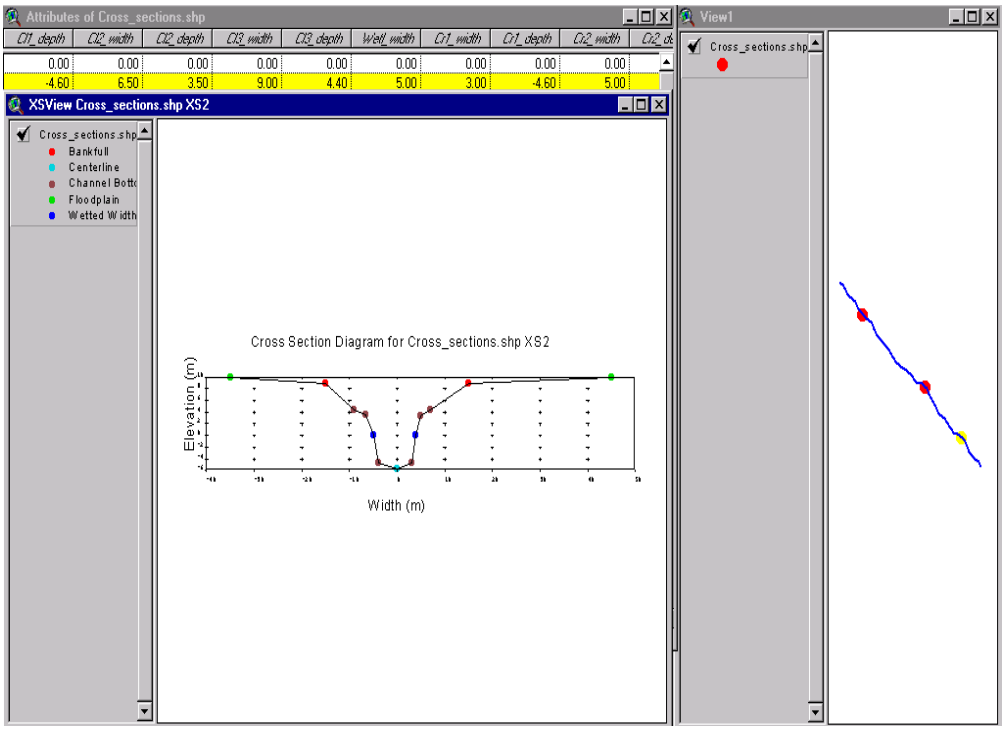
2. Next click on the XS Diagram Tool icon  and then click on any selected cross-sectional point within the Cross-Section theme.

3. A diagram of the stream channel's cross-sectional profile at this location will be generated automatically based on the entered stream data points and internal algorithms for trigonometry coded within the extension. Three different levels of cross-sectional complexity are possible given the extent of point data collected in regard to channel widths/depths and whether information on riparian bands and top of bank has been recorded:

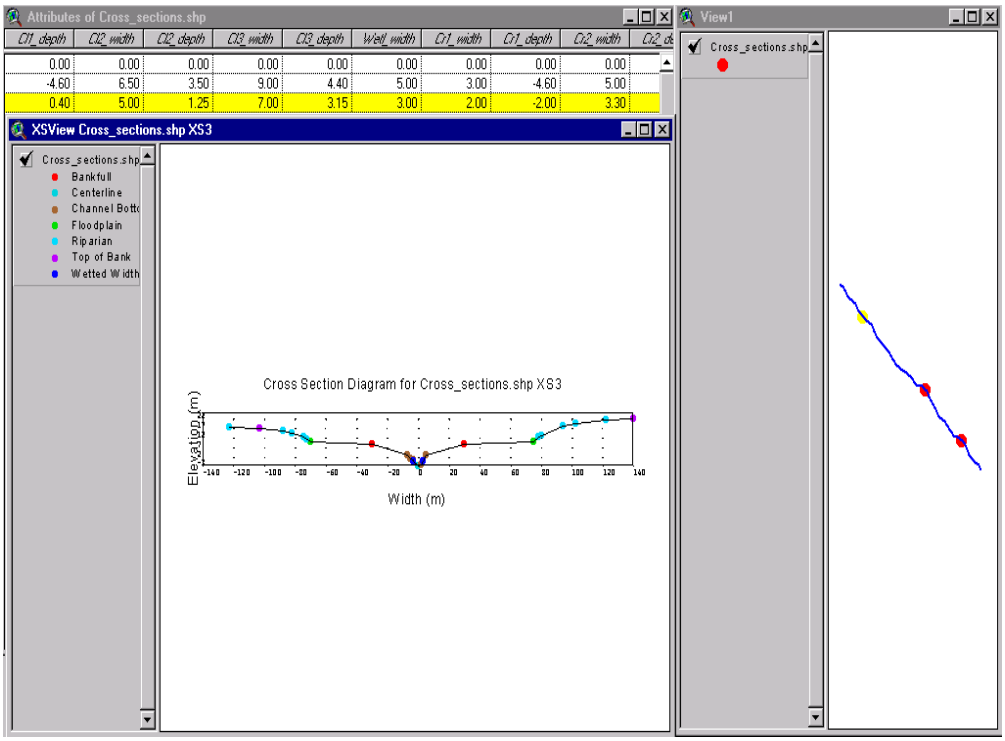
i) A cross-sectional diagram of a simplified stream channel profile will be created when collected information is limited to point data on wetted, bankfull and floodplain widths and depths (i.e., standard SHIM stream survey protocol)



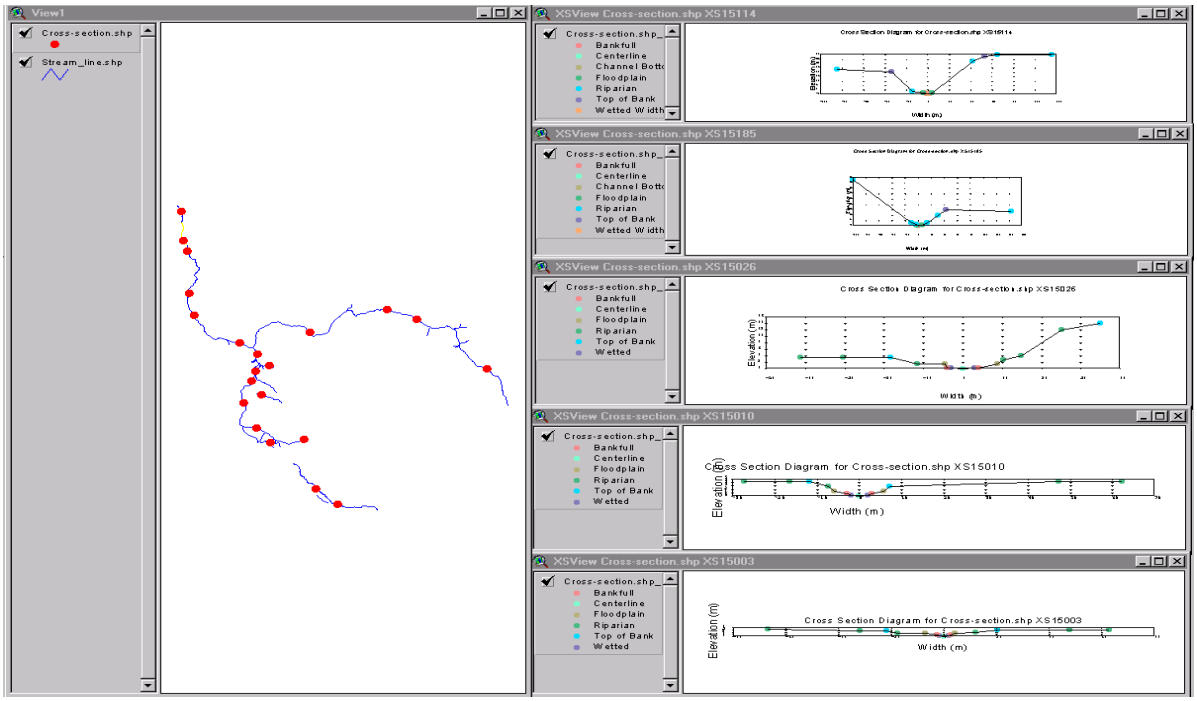
ii) A more complete representation of the stream channel profile will be generated automatically if collected data includes detailed information on wetted channel bottom heterogeneity (i.e., multiple channel depth/elevation and width measurements), in addition to measurements of bankfull and floodplain widths/depths.



iii) The most complex cross-sectional profile illustrating details of both channel structure and the adjacent upland slope will be generated automatically if data collected includes information outlined for (ii) and additional accompanying information on riparian bands (i.e., widths and slopes) and top of bank location (i.e., detailed SHIM cross-sectional protocol).



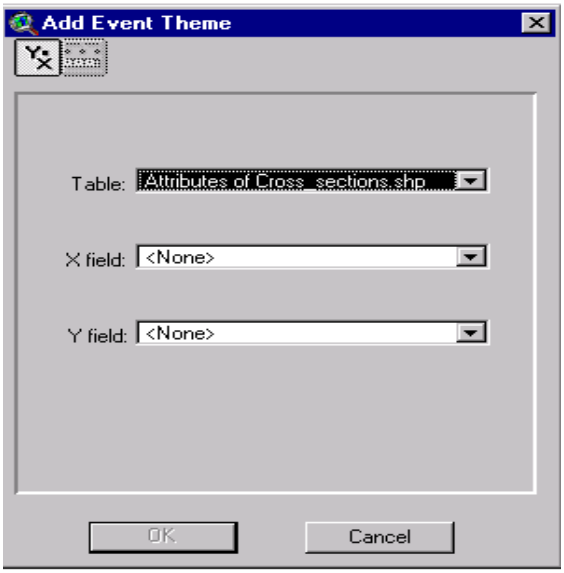
Selecting multiple cross-section points simultaneously will allow you to visually examine the change in hydraulic profile along the length of the stream.



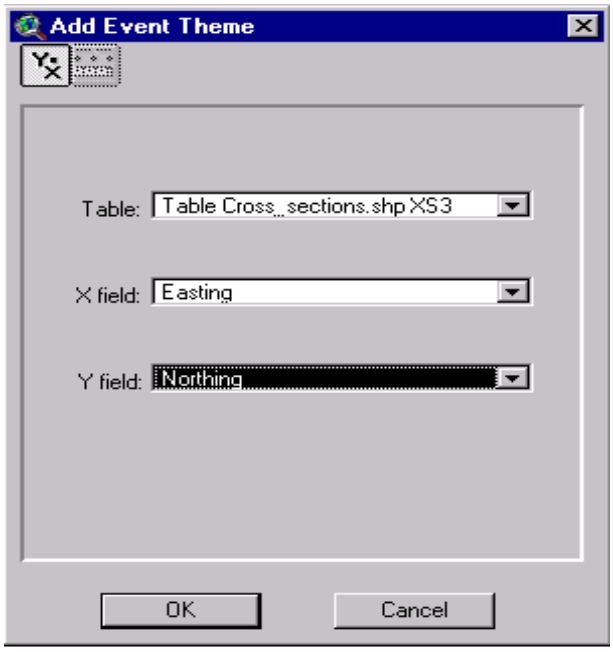
(C) Displaying cross-sectional attribute tables:

The Cross-Sectional Tool Extension can be used to examine the stream channel attributes within a database (dbf) format. The dbf tables created can be exported to other software packages (e.g., Arc Info, Microstation, etc.) for GIS users who prefer to work outside the ArcView environment.

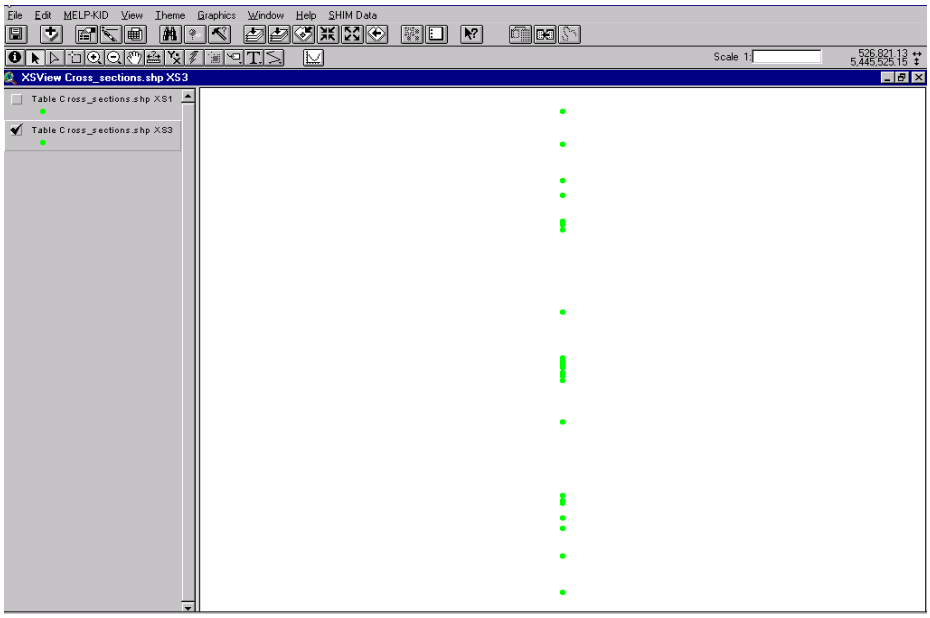
1) In the Edit View window select the "Add Event Theme" option which and bring up the associated menu box.



2) Scroll through the Table options within the menu to select a desired cross-section point. In the X and Y fields select Easting and Northing respectively; these last 2 fields will orient your cross-sectional features within a UTM coordinate system.



3) Clicking on "OK" will then bring up a shape file of the detailed cross-section attributes within the Edit View window.



4) In the Edit View window's button menu click on the Open Theme Table tool  to bring up the detailed attribute table for the selected cross section.

Attributes of Cross-se.shp_xs0.dbf

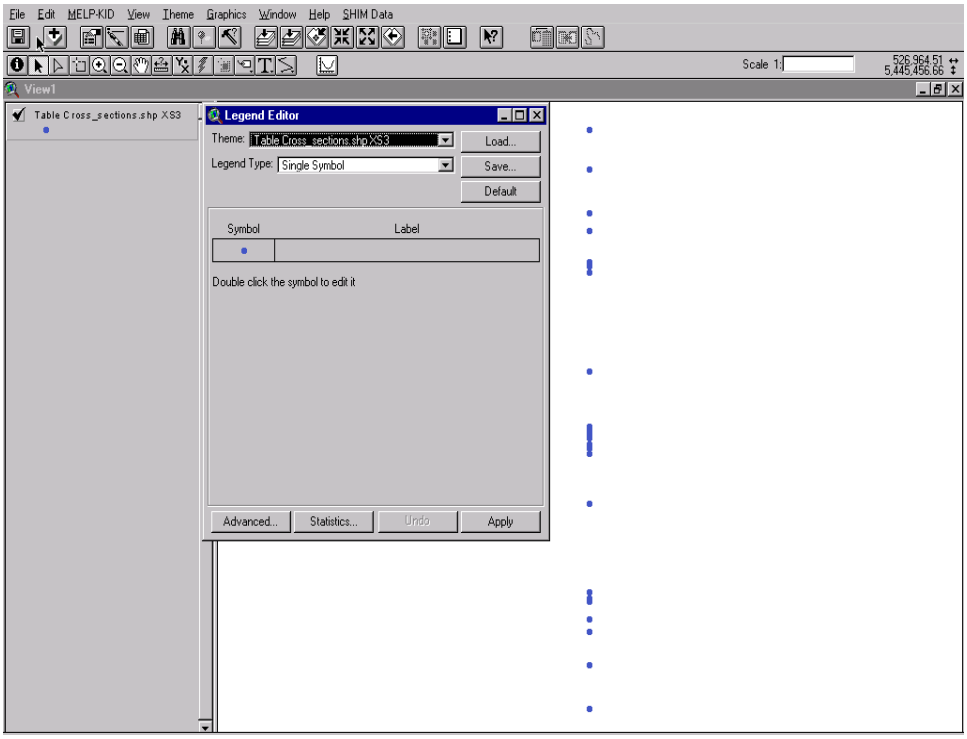
Shape	Station	Elevation	Label	RipClass	Easting	Northing
Point	0.00	-0.28	Centerline		585334.72	5443481.51
Point	-0.50	-0.24	Channel Bottom		585334.55	5443481.04
Point	-1.60	0.05	Channel Bottom		585334.19	5443480.00
Point	-2.30	0.10	Channel Bottom		585333.97	5443479.34
Point	-1.20	0.00	Wetted Width		585334.32	5443480.38
Point	0.50	-0.34	Channel Bottom		585334.88	5443481.99
Point	1.15	-0.24	Channel Bottom		585335.09	5443482.60
Point	2.50	0.23	Channel Bottom		585335.53	5443483.88
Point	1.93	0.00	Wetted Width		585335.34	5443483.34
Point	-2.95	0.22	Bankfull		585333.75	5443478.72
Point	2.95	0.22	Bankfull		585335.68	5443484.30
Point	-4.75	0.30	Floodplain		585333.17	5443477.02
Point	4.15	0.30	Floodplain		585336.07	5443485.44
Point	-63.26	54.86	Riparian	Mixed forest	585314.12	5443421.70
Point	-138.43	82.22	Top of Bank	Mixed forest	585289.65	5443350.62
Point	-188.37	84.84	Riparian	Mixed Forest	585273.39	5443303.41
Point	65.43	51.72	Top of Bank	Mixed forest	585356.02	5443543.38
Point	122.00	-4.85	Riparian	Mixed forest	585374.44	5443596.87

The station field within this table represents channel feature widths (m) relative to the stream center line [negative values (-) representing widths on the left streambank, whereas positive values (+) represent widths on the right bank]. The elevation field (m) represents depths (-) or elevations (+) relative to the wetted surface level or, in the case of totally dry channels, the deepest point of the streambed. Easting and Northing fields define accurate geographic locations for surveyed channel points, based on the trigonometry of field measured slope-distances relative to the original GPS captured stream center line.

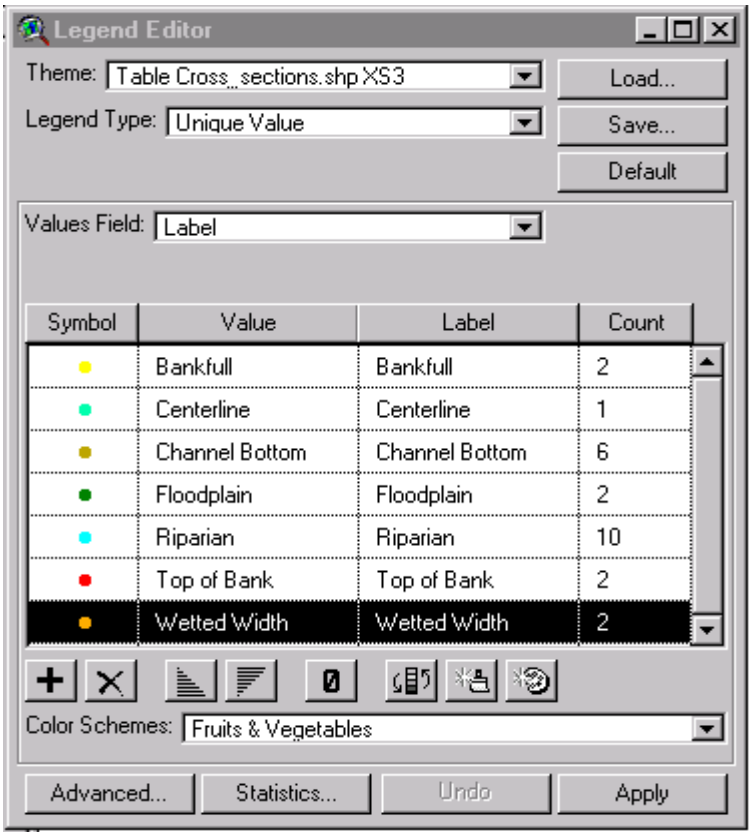
(D) Spatial display of cross-sectional features:

Cross-sectional attributes collected using the SHIM methods are spatially linked to a GPS referenced stream center line (accurate to $\pm$ 5m). Consequently, all channel cross-section points have associated UTM coordinate locations that can be used to display the points on any underlying map or orthophoto backdrop. This mapping feature greatly enhances the ability to examine the layout of the stream corridor within the spatial context of the surrounding landscape.

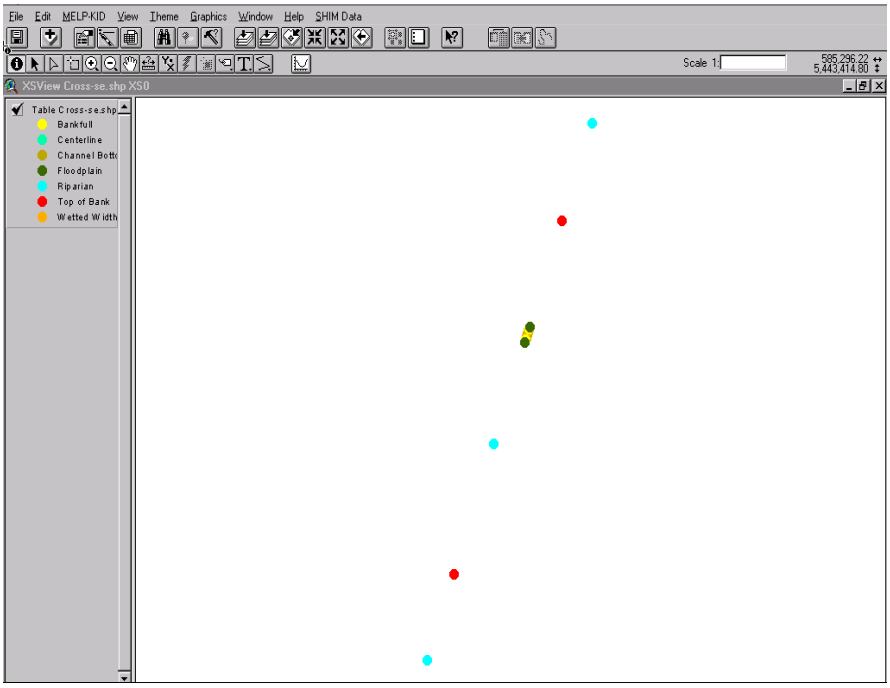
1) In the Edit View window double click on the selected Table_Cross sections.shp file that you added earlier as an event theme. This will bring up the Legend Editor for the event theme.



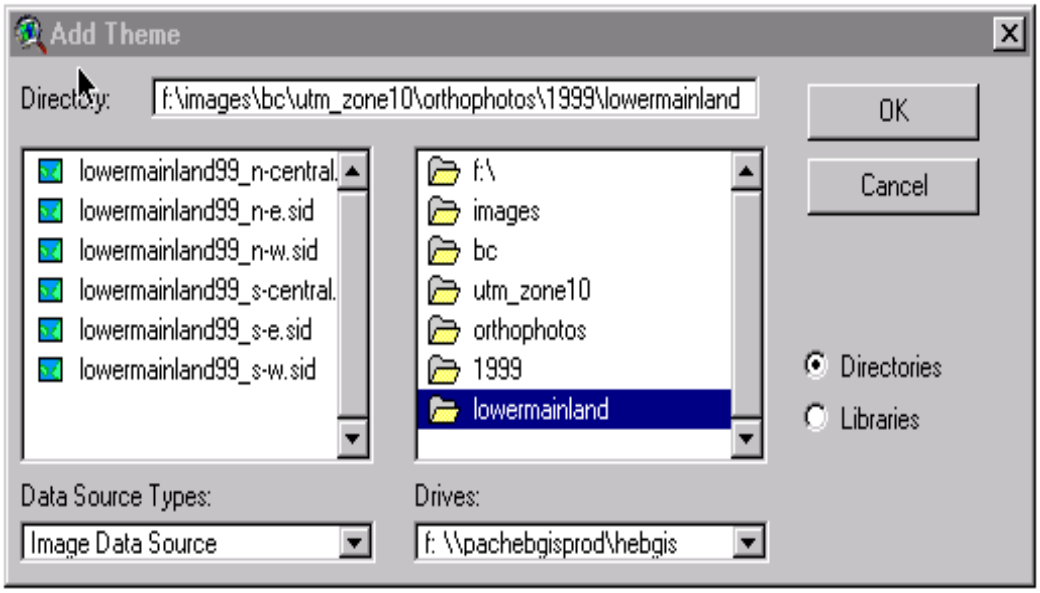
2) Within the Legend Editor menu select “Unique Value’ for the Legend Type and “Label” for the Values field.



Click on Apply and unique colour identifiers will be created for each channel feature in the view.



3. In the Edit View window click on the Add Theme tool , select Image Data Source and scroll through your directories to select an appropriate orthophoto coverage to provide a visual backdrop to your surveyed stream channel.



Acquistion of current orthophoto coverages is the responsibility of the user, and can be obtained through various regulatory agencies (e.g., DFO, GDBC, municipal governments).

4. Displaying underlying orthophotos will improve the ability to resolve stream channel features in relation to the surrounding landscape.