Vermont Stream Geomorphic Assessment

Appendix B



Phase 3 Data Management System Instructions

Vermont Agency of Natural Resources April, 2004

Phase 3 Data Management System (DMS)

The Phase 3 data management system (DMS) consists of a spreadsheet workbook and a database. The spreadsheet workbook pre-processes the data before the data is entered into the database where analysis, queries and report development is conducted. Responsibility for entering raw field data into the spreadsheet workbook will fall upon the assessor. Once data is entered into the workbook it can be sent to the River Management Program (RMP). River management staff will be responsible for transferring the data to the Phase 3 database. A set of standard reports will be generated and made available to the assessor. People interested in custom reports will have the opportunity to work with the RMP to have such reports generated.

Phase 3 Spreadsheet Workbook

Overview

The spreadsheet workbook is designed to perform the following functions:

- Accept field data collected using Vermont's Geomorphic Assessment Phase 3 field protocols;
- Perform a number of calculations using these data;
- Organize calculated data into summary tables for review and printing; and
- Format the information for export to a permanent Access database.

The Phase 3 Workbook has seven individual worksheets (the "tabs" that show up at the bottom of the screen). They are:

- Rch Loc. And Desc.
- QAQC (Quality Assurance Sheet)
- Long. Profile and Pattern
- Pebble Count
- Cross-Section
- Bank Erodibility
- Meander Geometry

These worksheets accept field data. To increase efficiency of the data entry process, they have been designed to look similar to the field forms used during Phase 3 assessment. There are other hidden worksheets in the workbook that are used solely to format and store data for transfer to the database. As these worksheets are critical to the data transfer process they have been locked to prevent accidental changes from being made.

The phase 3 workbook is color coded for ease of use. The key to the color-coding scheme is as follows:

- **Blue:** Data entry cells,
- White: Calculation results,
- **Grey:** Titles, headings, and background.

Drop down menus and check boxes are data entry mechanisms on several of the worksheets that do not follow the color coding scheme (as they are colored white).

Most of the blue data entry cells have detailed instructions in the form of cell comments. They're marked by red triangles in the upper right corner of the cell. To bring up the instructions simply place the cursor over the cell of interest.

Opening and Saving the Workbook

It is highly recommended that the Phase 3 workbook be saved as a Microsoft Excel Template. This will ensure that a blank copy or template is always available for receipt of new data. Follow these steps to open a clean copy that is ready to accept field data:

1. Put a copy of the template (or a Shortcut pointing to it) in the folder MS Excel looks to for templates. Usually it's is one of these folders:

C:\Program Files\Microsoft Office\Templates\Spreadsheet Solutions

C:\Windows\Application Data\Microsoft\Templates

C:\Windows\Profiles\user_name\Application Data\Microsoft\Templates

- C:\Windows\Profiles\user_name\Application Data\Microsoft\Excel\XLStart
- 2. With MS Excel open, select File>New... and double-click on the DMS template.
- 3. Click "Enable Macros" if asked.
- 4. Click "NO" if asked whether to update any linked files. (A clean version of the template will open.)
- 5. Save the workbook (when you're finished entering data) as you would any other workbook.

For more information on creating and using Excel templates go to the help library in the Excel program.

Worksheet Layout

The following pages show pictures of the worksheets and briefly describes the layout of each. More detailed instructions can be found in the cell comments.

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h Location and Description			
Stream Name Assessor Assigned Ske (D Location Observers Locationsination UGSIS Map Name/No. Latitude (dd mm ss.ss) Longtitude (dd mm ss.ss) Notes: Valley Type Nearec Clage &		Vatershed 4 Digi SR-Number Date Established Toom Vaterbody D Elevation (It) Benchmark Elevation (It) Drainage Area (sgmk) Assessment Type Surficial Geology Upgstream Corridon	Phase 1 Reach # Phase 2 Segment # Other Phases Completed Devel size Phase 3 Data Collected Inst Pratic Inst Pratic
Location of Nearest Gage 📃 👱		Paved Roads, Buildings	Pant Bendin Piender Genediq
tream Geomorphic Assessment eference Stream Type	Reference Stream Type	Validation Comments	
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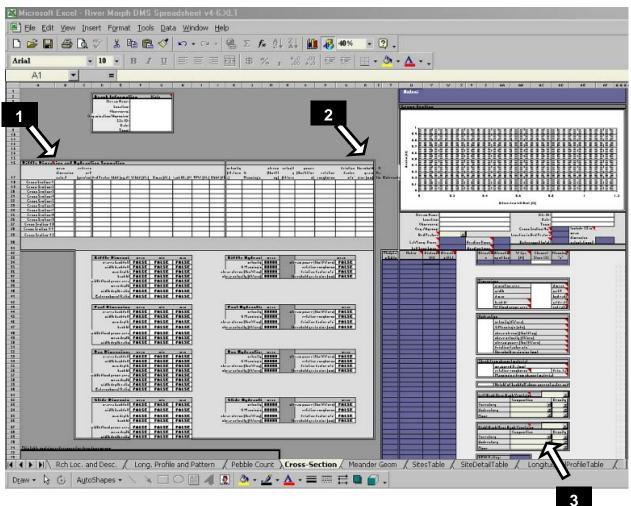
Reach Location and Description Worksheet

- 1. **Reach Location and description.** Enter general information about the study site in this sheet. You may find you want to fill in some of this information after you have entered and analyzed some of the field data. For instance, it may be easier to determine the stream type after you have looked at the cross section data.
- 2. **Geomorphic Assessment.** This data will help you to decide: how your study reach has departed from its reference condition; how the channel may be adjusting to achieve equilibrium; through what channel evolution process are these adjustments occurring; and the stream's sensitivity to further disturbance.

)A				M			
QA Team Leader.		_			Phase 2 Rapid Asso	sment completed on the	Phase 3 Survey site
NR Team Leader:					_		
							et, and Database used exclusively
heck one or more bo		8.14	d Survey		Phase One Assessm	ent Utilized in Interpreta	ion of Phase Three Results?
ypes of ANR spons received by one or m			a Analysis	Oth	er protocols used:		
our assessment tean		🗆 Q.A		011	or protocom and.		
D 1 D 1	Confidence	Date		Date of QA	Date of State		1
Phase 3 Step Number	Level	Completed	Date Updated	Officer Review	QA Review	Comments	
Step 1		· · ·					
Sep 2							
otep 3	-						
Step 4							
Step 5 Step 6							
Step 6 Step 7	-						
							IJ
				Equipment			
				Calibration			
Phase 3 Step	Number	Tool Used to	Collect Data	Date			
Step 1.3			-	•	I		
Step 1.4			•				
Step 1.6			•	r			
Step 2.1 Elevation Step 2.1 Distance				·			
Sten 2.2 Elevation		-					
Step 2.2 Elevation Step 2.2 Distance							
Step 2.2 Elevation Step 2.2 Distance Step 2.3							

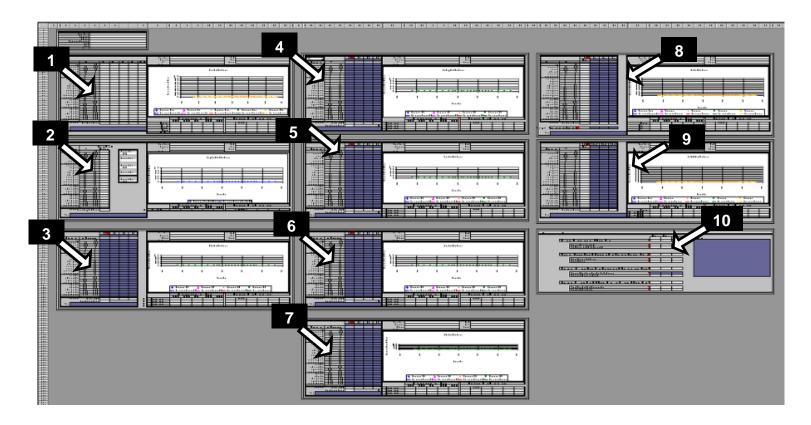
- 1. Training and Protocols. QA information on the training of the assessment team.
- 2. Confidence Level and Completion Dates. Documents the level of confidence the assessment team has in the results of each step. Also documents the assessment and QA review dates.
- 3. Equipment Used. Type and calibration information for the equipment used on each step.

Cross-Section Worksheet



- 1. **Dimension and Hydraulics Summary.** Summarizes cross sectional dimensions and a number of calculated hydraulic parameters for the cross sections.
- 2. Cross Section 1. This portion of the worksheet accepts data for the first cross section, plots the data, and performs a number of calculations. Enter field data into the BLUE cells. There's room for eleven more cross sections to the right.
- 3. Bank Vegetation. Use these drop-down menus to describing near-bank vegetation.

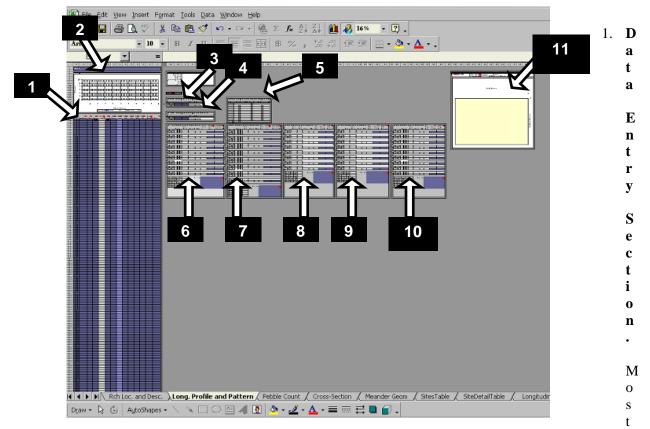
Pebble Count Worksheet



- 1. **Total Pebble Count.** Summarizes and plots the pebble count data for each feature type and for the reach as a whole.
- 2. Weighted Pebble Count. Provides a particle size distribution that weights the distribution of each bed feature by the linear extent of that feature. The extent of each feature must be calculated on the "Long. Profile and Pattern" worksheet in order for the weighted pebble count to work.
- 3. **Other Pebble Count.** Accepts pebble count data for "Other" bed types and computes and graphs the distribution.
- 4. **Riffle/Step Pebble Count.** Accepts pebble count data for Riffles, Steps, or Plane Beds and computes and graphs the distribution.
- 5. **Run Pebble Count.** Accepts pebble count data for Runs and computes and graphs the distribution.
- 6. **Pool Pebble Count.** Accepts pebble count data for Pools and computes and graphs the distribution.
- 7. **Glide Pebble Count.** Accepts pebble count data for Glides and computes and graphs the distribution.
- 8. **Bar Pebble Count.** Accepts pebble count data for Bars and computes and graphs the distribution.
- 9. **Riffle BED Pebble Count.** Accepts pebble count data for Riffle BEDS and computes and graphs the distribution.
- 10. Entrainment Calculations. Uses riffle bed and bar data to calculate the critical dimensionless shear stress and the depth required to entrain specific particle sizes.

Stream Geomorphic Assessment Handbooks

Longitudinal Profile and Pattern Worksheet



of the data from the longitudinal field survey gets entered in these blue cells. Read the cell comments at the top of each column for detailed instructions.

- 2. **Longitudinal Profile Plot.** Plots the elevation of the streambed, banks, bankfull, and water surface from upstream to down.
- 3. Valley Length and Slope Calculator. Calculates the length and slope of the valley using distances and elevations that you specify. Read the cell comments for detailed instructions.
- 4. **Stream Length and Slope Calculator.** Calculates the length and slope of the stream using distances and elevations that you specify. Read the cell comments for detailed instructions.
- 5. **Bendlength and Wavelength Calculator.** Calculates the along-channel bendlengths straight-line wavelength for each apex you identify in Section 1.
- 6. **Riffle Length and Slope Calculator.** Calculates the length and slope of riffles (both individually and as an average) and determines the percentage of the reach that is classified as riffle.
- 7. **Pool Length and Slope Calculator.** Same as #6, above, but for Pools.
- 8. **Run Length and Slope Calculator.** Same as #6, above, but for Runs.
- 9. Glide Length and Slope Calculator. Same as #6, above, but for Glides.
- 10. Step Length and Slope Calculator. Same as #6, above, but for Steps.
- 11. **Meander Pattern Plot.** Plots the meander pattern of the stream using the distance and azimuth values you entered in Section 1. When adjusted so the X and Y axes are scaled equally (see the cell comment for detailed instructions), circles can be drawn on the plot to determine radii of curvature for the reach.

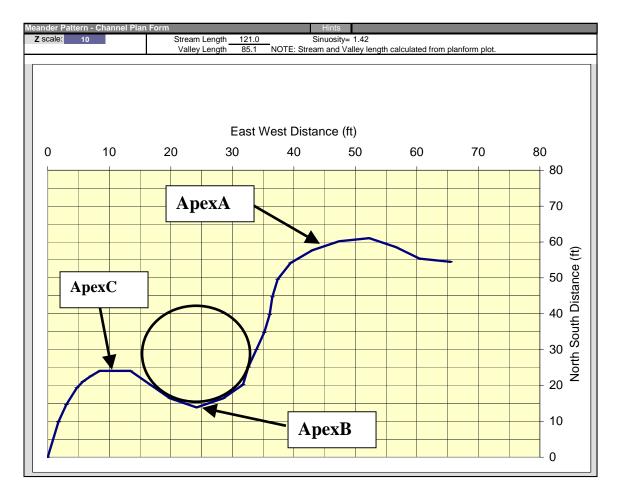
Using the longitudinal profile worksheet to measure planform geometry where azimuth readings have been collected as part of the longitudinal survey.

- 6. Use the Long. Profile and Pattern worksheets to determine Bendlengths and Wavelengths.
- 7. Enter longitudinal survey data in the Long. Profile and Pattern worksheet.
- 8. Identify the meander apexes in the second column (as the instructions at the top of the column indicate) by typing "Apex1", "Apex2", and so forth.
- 9. If you did not identify the apexes while in the field, look at the planform plot to help choose the apexes. You may need to count data points to determine, for instance, that the fifth surveyed point is an apex.
- 10. You need to identify three apexes for each curve you're analyzing:
- 11. the apex of the preceding curve (A),
- 12. the apex of the curve of interest (B), and
- 13. the apex of the next curve (C).
- 14. The program will calculate and display in the Bendlength and Wavelength Calculator section:
- 15. the along-channel distance from A to B (Bendlength1, Lb1),
- 16. the along-channel distance for B to C (Bendlength2, Lb2),
- 17. the straight-line distance from A to C (Wavelength, Lm).

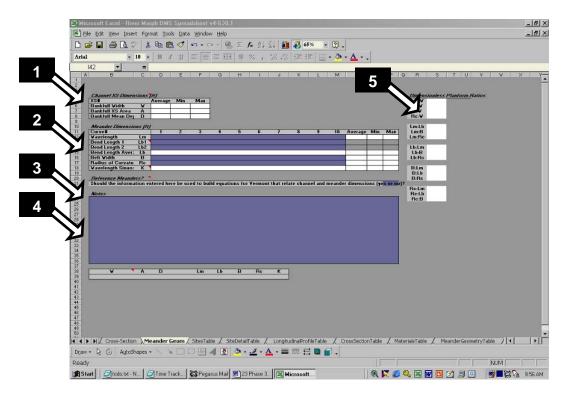
18.

- 19. Use the Planform plot to Determine the Radius of Curvature.
- 20. As the instruction in the worksheet indicate, drag the axis of the graph so that the scale on the X and Y axis are the same.
- 21. For instance, you might have 50ft by 50ft square grids on the plot.
- 22. It's very important that the grids are square.
- 23. Turn on the drawing toolbar (if it's not already available) by selecting View>Toolbars...>Drawing.
- 24. Click on the Oval icon and use it to draw an oval on the plot.
- 25. Click and drag somewhere near the curve you're interested int.
- 26. Don't worry about locating and sizing the oval correctly on the first try.
- 27. Format the oval
- 28. Right-click on it and select Format Autoshape...
- 29. On the Colors and Lines tab, check the Semi-Transparent box.
- 30. On the Size tab, make the height and width the same and click OK.
- 31. Right click again on the circle and Select Format Autoshape...
- 32. Check the Lock Aspect Ratio box and click OK.
- 33. Resize the circle to fit your curve by dragging the corners (not the sides or it might turn back into an oval.
- 34. Move the circle into position with the mouse.
- 35. Print the plot and measure the on paper distance of the axis intervals and calculate the scale of the plot. For example you might set the axis intervals to 50ft. print out the plot and measure the on paper interval distance as 1 inch. You now know that the scale of the plot is 1 inch = 50 feet.
- 36. Measure the diameter of the circle and divide by two, or use a compass to measure the radius.
- 37. Use the Planform Plot to Determine the Beltwidth
- 38. Click on the line tool and draw a line connecting the apex proceeding your curve to the apex following your curve (e.g., a line connecting ApexA to ApexC which is the wavelength of the curve at ApexB).
- 39. Draw a second line that runs perpendicular to the one you just drew and connects that line to the apex of your curve (ApexB).
- 40. Print the plot, establish the scale as in step 2G above and measure the two lines created in steps a and b.

41. Recognize that the beltwidth is measured from outside of channel to outside of channel (rather than centerline). The line you just measured is probably (depending on where you drew your lines) based on the centerline of the channel and thus represents the *amplitude* of the curve and not the *beltwidth*. If necessary, adjust the measurement to get your final measurement of beltwidth.



Planform Worksheet



- 1. **Channels XS Dimensions.** Enter the dimensions (bankfull width and area) of cross sections that will be used in the analysis of the streams meander patterns. The instruction cells provide further guidance on selecting appropriate cross sections. If you previously entered cross-section data on the "Cross-Section" sheet, you may choose to use some or all of those cross sections. The spreadsheet does not automatically retrieve those data, however, because some of those cross sections may not be suitable for meander geometry analysis.
- 2. **Planform Dimensions.** Enter the dimensions for up to ten curves that will be used in the analysis of meander patterns. The instruction cells provide guidance for selecting appropriate curves. The worksheet calculates an average for each parameter, and this average is taken to represent the reach.
- 3. **Reference Meanders?** Specify whether the data you've entered should be used to develop equations relating stream channel dimensions to meander patterns. See the cell comment for further instructions.
- 4. **Notes Section.** Enter notes here explaining the source of the data, choices to include of exclude channel and meander dimension data, and any other information.
- 5. **Dimensionless Planform Ratios.** This section calculates ratios relating meander geometry variables to each other and to bankfull width.

The following figures show the layout of several of the reports that have been developed as part of the phase 3 Geomorphic Assessment Database.

Database Reports

The following figures represent two of the standardized Phase 3 reports that have been developed thus far. As more data is entered into the State Geomorphic Database other reports will become available.

			Depart	ure fro	m Re	ference		
			SitelD: StreamType:	07000000		Location: Ga	ge	
				Dime	nsion			
	Existing	V	Γ Reference	Reach Da	ta	Publ	ished Data	Design
	Channel	Mean	Range	Sample Size	Power	Mean	Range	
Entrenchment Ratio	1.27	1.70	1.20 - 2.35	4		*		
Width to Depth Ratio	24.33	29.94	22.06 - 41.95	4	26.74	*		
Bank Height Ratio		1.47	1.37 - 1.60	3				
Bankfull Width	123.13	99.38	74.10 - 132.50	4	104.38			
Bankfull Mean Depth	5.10	3.45	2.78 - 4.90	4	3.90			
Riffle X Sec Area	625.57	356.55	248.90 - 650.30	4	420.71			
Max Depth Ratio								
Riffle	1.40	1.43	1.25 1.72	3				
Run		1.56	1.42 - 1.69	3				
Pool	1.46	2.11	2.11 - 2.11	1				
Glide			-					
Area to Area Ratio								
Run		1.07	0.93 - 1.35	3				
Pool	0.80	1.18	1.18 * 1.18	1				
Glide			-					
Width to Width Ratio								
Run		0.97	0.78 - 1.21	3				
Pool	0.64	0.95	0.95 - 0.95	1				
Glide			-					

Profile								
	Existing					Pul	blished Data	Design
	Channel	Mean	Range	Sample Size	Power	Mean	Range	
Riffle Slope Ratio		2.83	2.39 - 3.27	2				
Riffle Spacing Ratio			1. A.				7.5	
Riffle % of Reach								

				Pati	tern			
	Existing	۲V	Reference	Reach Da	ta	Put	lished Data	Design
	Channel	Mean	Range	Sample Size	Power	Mean	Range / Value	
Meander Length Ratio								
Meander Width Ratio			•					
Radius To Width Ratio								
Sinuosity								
Meander Length					812.27		1,456.46 ***	
Bend Length					488.06		985.91 ***	
Belt Width					319.94		829.06 ***	
Radius Of Curvature					231.41		291.29 ***	
Radius Of Curvature			* Ros	gen ^{××} Le		Williams	291.29 ***	

** Leopold *** Williams

					Materials			
Riffle			Reach Me	ean		Bar		
	Existing Channel	Design		Existing Channel	Design		Existing Channel	Design
RiffleD16	0 mm		MeanDl6	0.386 mm		BarD16	221221	
RiffleD35	43 mm		MeanD35	25.61 mm		BarD35	nm	
RiffleD50	86 mm		MeanD50	58.9 mm		BarD50	nm	
RiffleD84	202 mm		MeanD84	175 mm		BarD84	22221	

Figure 1Example Database Reports

Stream Geomorphic Assessment Handbooks

Interrelations Between Meander Features (Eqns 2-13)

Equation #2: Mean	der Length (ft) as a f	unctio	on of Bend Lengt	h (ft)
	Equation	n	Range	R2
VT Linear	Lm=1.671Lb	4	127.8 - 698.5 ft	0.995
VT Power	Lm=1.232Lb^1.046	4	127.8 - 698.5 ft	0.967
Williams (1986)	Lm=1.25Lb	102	18 - 43600 ft	0.980
Equation #3: Mean	der Length (ft) as a f			
	Equation	n	Range	R2
VT Linear	Lm=3.244B	4	50 - 330 ft	0.938
VT Power	Lm=5.661B^0.873	4	50 - 330 ft	0.773
Williams (1986)	Lm=1.63B	155	12.1 - 44900 ft	0.980
Fauation #4. Mean	der Length (ft) as a f	unctio	on of Radius of C	urvature (ft)
	Equation	n	Range	R2
VT Linear	Lm=4.206Rc	4	56.9 - 263.5 ft	0.982
VT Power	Lm=3.111Rc^1.05	4	56.9 - 263.5 ft	0.987
Williams (1986)	Lm=4.53Rc	78	8.5 - 11800 ft	0.980
Equation #5: Bend	Length (ft) as a func			
	Equation	n	Range	R2
VT Linear	Lb=0.597Lm	4 4	227.1 - 1181.5 ft	
VT Power	Lb=0.99Lm^0.925		227.1 - 1181.5 ft	0.967
Williams (1986)	Lb=0.8Lm	102	26 - 54100 ft	0.960
Equation #6: Bend	Length (ft) as a func	tion c	of Beltwidth (ft)	
	Equation	n	Range	R2
VT Linear	Lb=1.953B	4	50 - 330 ft	0.963
VT Power	Lb=3.366B^0.884	4	50 - 330 ft	0.896
Williams (1986)	Lb=1.29B	102	12.1 - 32800 ft	0.980
Equation #7: Bend	Length (ft) as a fund			
VT Linear	Equation Lb=2.512Rc	n 4	Range 56.9 - 263.5 ft	R2 0.976
VT Power	Lb=2.942Rc^0.963	4	56.9 - 263.5 ft	0.938
Williams (1986)	Lb=3.77Rc	78	8.5 - 11800 ft	0.960
(,				
Equation #8: Beltw	idth (ft) as a function			
	Equation	n	Range	R2
VT Linear	Equation B=0.299Lm	n 4	Range 227.1 - 1181.5 ft	R2 0.938
VT Linear VT Power	Equation B=0.299Lm B=0.667Lm^0.885	n 4 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft	R2 0.938 0.773
VT Linear	Equation B=0.299Lm	n 4	Range 227.1 - 1181.5 ft	R2 0.938
VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885	n 4 4 155	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft	R2 0.938 0.773
VT Linear VT Power Williams (1986) Equation #9: Beltw	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm <i>idth (ft) as a function</i> Equation	n 4 155 n of <u>B</u> n	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range	R2 0.938 0.773
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm <i>idth (ft) as a function</i> Equation B=0.503Lb	n 4 155 <u>n of B</u> n 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft	R2 0.938 0.773 0.980 R2 0.963
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.503Lb B=0.491Lb^1.013	n 4 155 n of B n 4 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft	R2 0.938 0.773 0.980 R2 0.963 0.896
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm <i>idth (ft) as a function</i> Equation B=0.503Lb	n 4 155 <u>n of B</u> n 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft	R2 0.938 0.773 0.980 R2 0.963
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm idth (ft) as a function Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb	n 4 155 n of B n 4 4 102	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986)	Equation B=0.692Lm B=0.667Lm<0.885	n 4 155 n of <u>B</u> n 4 4 102 n of J	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvate	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb width (ft) as a function Equation	n 4 155 n of <u>B</u> n 4 4 102 n of <u>I</u> n	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvati Range	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 0.980 0.980 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear	Equation B=0.627Lm^0.885 B=0.667Lm^0.885 B=0.61Lm idth (ft) as a function Equation B=0.53Lb B=0.491Lb^1.013 B=0.78Lb width (ft) as a function Equation B=1.268Rc	n 4 155 n of <u>B</u> n 4 4 102 n of J	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Range 6.9 - 263.5 ft 26.9 - 263.5 ft	R2 0.938 0.773 0.980 R2 0.963 0.963 0.896 0.980 ure (ft)
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb width (ft) as a function Equation	n 4 155 n of B n 4 4 102 n of I n 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvati Range	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 0.980 ure (ft) R2 0.949
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power	Equation B=0.299Lm B=0.667Lm^{0.885} B=0.61Lm idth (ft) as a function Equation B=0.503Lb B=0.491Lb^{41.013} B=0.491Lb^{41.013} B=0.491Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=0.481Lb^{41.013} B=1.268Rc B=1.87Rc^{0.924}	n 4 155 n of B n 4 4 102 n 0n of l n 4 4 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Range 66.9 - 263.5 ft 56.9 - 263.5 ft	R2 0.938 0.773 0.960 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb width (ft) as a function B=1.268Rc B=1.87Rc^0.924 B=2.88Rc us of Curvature (ft) a	n 4 155 n 6 4 4 102 n 4 4 78 as a fu	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 18.4 of the state of t	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 0.980 0.980 0.980 0.980 0.980 0.980 0.980 0.949 0.753 0.960 0.753 0.960
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #11: Radi	Equation B=0.697Lm^0.885 B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb width (tt) as a function Equation B=1.268Rc B=1.268Rc B=1.27Rc^0.924 B=2.88Rc us of Curvature (tt) a Equation	n 4 155 n of B n 4 102 0n of I n 4 4 78 as a fu n	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvatu Rage 56.9 - 263.5 ft 8.5 - 263.5 ft 8.5 - 263.5 ft 8.5 - 263.5 ft 8.5 - 263.5 ft 8.7 - 11800 ft unction of Meand Rage	R2 0.938 0.773 0.980 R2 0.963 0.986 0.986 0.980 ure (ft) R2 0.949 0.753 0.960 ier Length (ft) R2
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Inear VT Linear VT Linear	Equation B=0.629Lm B=0.667Lm^0.885 B=0.661Lm idth (ft) as a function Equation B=0.53Lb B=0.78Lb width (ft) as a function Equation B=0.78Lb width (ft) as a function Equation B=1.268Rc B=1.87Rc^0.924 B=2.88Rc us of Curvature (ft) at Equation Rc=0.235Lm	n 4 155 <u>n of B</u> n 4 102 <u>on of I</u> n 4 4 4 78 as a ft n 4 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Range 56.9 - 263.5 ft 8.5 - 11800 ft not of Meando Range 222.7 - 1181.5 ft	R2 0.938 0.773 0.980 R2 0.963 0.980 ure (ft) R2 0.949 0.753 0.960 ver (ft) R2 0.949 0.753 0.960 ver Length (ft) R2 0.982
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #11: Radi VT Linear VT Linear VT Power	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Midth (ft) as a function Equation B=1.288Rc B=1.87Rc^0.0.924 B=2.88Rc Us of Curvature (ft) 2. Equation Rc=0.235Lm Rc=0.36Lm^0.94	n 4 4 155 n 6 6 7 6 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18.4 3600 ft Radius of Curvati Radius of Curvati 8.6 - 9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 1263.5 ft 26.3 - 1180.0 ft Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft	R2 0.938 0.773 0.980 0.980 R2 0.963 0.980 0.980 ure (tt) R2 0.949 0.753 0.960 0.960 er Length (tt) R2 0.982 0.982 0.982 0.987
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Iower Williams (1986) Equation #11: Radi VT Linear	Equation B=0.629Lm B=0.667Lm^0.885 B=0.661Lm idth (ft) as a function Equation B=0.53Lb B=0.78Lb width (ft) as a function Equation B=0.78Lb width (ft) as a function Equation B=1.268Rc B=1.87Rc^0.924 B=2.88Rc us of Curvature (ft) at Equation Rc=0.235Lm	n 4 155 <u>n of B</u> n 4 102 <u>on of I</u> n 4 4 4 78 as a ft n 4 4	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Range 56.9 - 263.5 ft 8.5 - 11800 ft not of Meando Range 222.7 - 1181.5 ft	R2 0.938 0.773 0.980 R2 0.963 0.980 ure (ft) R2 0.949 0.753 0.960 ver (ft) R2 0.949 0.753 0.960 ver Length (ft) R2 0.982
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Power Williams (1986) VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb B=0.78Lb B=1.87Rc^0.0324 B=1.87Rc^0.0324 B=2.88Rc Us of Curvature (ft) of Equation Rc=0.23Lm Rc=0.326Lm^0.94 Rc=0.22Lm	n 4 155 n of B n 4 4 102 n of I n 4 4 78 as a fu n 4 4 78	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft ange 127.8 - 698.5 ft 56.9 - 263.5 ft 65.9 - 263.5 ft 8.5 - 11800 ft unction of Meander Range 227.1 - 1181.5 ft 32 - 54100 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.960 ver (ft) R2 0.960 ver (ft) 0.753 0.960 ver (ft) R2 0.982 0.987 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Power Williams (1986) VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Midth (ft) as a function Equation B=1.288Rc B=1.87Rc^0.0.924 B=2.88Rc Us of Curvature (ft) 2. Equation Rc=0.235Lm Rc=0.36Lm^0.94	n 4 155 n of B n 4 4 102 n of I n 4 4 78 as a fu n 4 4 78	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft ange 127.8 - 698.5 ft 56.9 - 263.5 ft 65.9 - 263.5 ft 8.5 - 11800 ft unction of Meander Range 227.1 - 1181.5 ft 32 - 54100 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.960 ver (ft) R2 0.960 ver (ft) 0.753 0.960 ver (ft) R2 0.982 0.987 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Power Williams (1986) VT Linear VT Power Williams (1986)	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Width (ft) as a function Equation B=1.268Rc B=1.87Rc^0.924 B=2.88Rc Us of Curvature (ft) a Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.22Lm	n 4 155 n of B n 4 4 102 n of I n 4 4 78 as a fu 78 as a fu	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvat Radius of Curvat Radius of Curvat Radius of Curvat Range 56.9 - 263.5 ft 56.9 - 263.5 ft 8.5 - 11800 ft unction of Meand Range 227.1 - 1181.5 ft 3 - 54100 ft unction of Beand It	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753 0.960 (er Length (ft) R2 0.982 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #11: Radii VT Linear VT Power Williams (1986) Equation #12: Radii	Equation B=0.697Lm^0.885 B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Width (ft) as a function Equation B=1.268Rc B=1.268Rc B=1.87Rc^0.924 B=2.88Rc us of Curvature (ft) a Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.22Lm us of Curvature (ft) a Equation	n 4 4 155 n 6 of B n 4 4 102 n n 102 n n 4 4 4 78 as a ft n 4 4 3 78 as a ft n n 4 4 3 78 as a ft n n n n n n n n n n n n n n n n n n n	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvatt Rage 26.9 - 263.5 ft 8.5 - 11800 ft nange 227.1 - 1180.5 ft 33 - 54100 ft Range action of Bend I Range	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753 0.960 ver (ft) R2 0.949 0.753 0.960 ver Length (ft) R2 0.982 0.987 0.980 .ength (ft) R2
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #12: Radi VT Linear	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb B=0.78Lb B=1.87Rc^0.0.924 B=1.87Rc^0.0.924 B=2.88Rc US of Curvature (ft) : Equation Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.324Lb	n 4 4 155 n 6 6 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvati Range 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 3.5 - 11800 ft unction of Meand Range 227.1 - 1181.5 ft 327.1 - 1181.5 ft 33 - 54100 ft unction of Bend I Range 27.8 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft	R2 0.938 0.773 0.980 0.980 R2 0.963 0.980 0.980 ure (tt) R2 0.949 0.753 0.960 0.960 ter Length (ft) R2 0.982 0.982 0.980 0.980 Length (ft) R2 0.980 0.980 0.980 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Power Williams (1986) Equation #11: Radi VT Linear VT Power Williams (1986)	Equation B=0.697Lm^0.885 B=0.61Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb B=0.491Lb^1.013 B=0.78Lb B=1.268Rc B=1.87Rc^0.924 B=2.88Rc Equation Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.36Lm^0.94 Rc=0.394Lb Rc=0.467Lb^0.974 Rc=0.36Lb	n 4 155 n 6 6 7 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18.4 3600 ft Radius of Curvati Range 56.9 - 263.5 ft 56.9 - 263.5 ft 8.5 - 11800 ft Range 227.1 - 1181.5 ft 33 - 54100 ft Inction of Bend I Range 127.8 - 698.5 ft 127.8 - 43600 ft 227.3 - 43600 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753 0.960 ter Length (ft) R2 0.980 uest 0.980 0.980 0.980 Length (ft) R2 0.976 0.938 0.960
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltv VT Linear VT Power Williams (1986) Equation #11: Radi VT Linear VT Power Williams (1986)	Equation B=0.697Lm^0.885 B=0.67Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Width (t) as a function Equation B=1.268Rc B=1.268Rc B=1.87Rc^0.924 B=2.88Rc Uss of Curvature (t) a Equation Rc=0.235Lm Rc=0.394Lb C=0.394Lb C=0.394Lb Rc=0.394Lb Rc=0.26Lb Uss of Curvature (t) a Rc=0.26Lb	n 4 1155 n 6 102 n 102 n 102 n 4 4 7 8 as a fu 4 4 7 8 as a fu 4 4 7 8 as a fu 7 8 as a fu 7 8 as a fu 7 8 3 8 3 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvat Range 56.9 - 263.5 ft 8.5 - 11800 ft narge 227.1 - 1181.5 ft 227.3 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 227.3 - 43600 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (tt) R2 0.949 0.753 0.960 Ver Length (ft) R2 0.982 0.987 0.986 0.987 0.986 0.987 0.986 0.986 0.987 0.986 0.986 0.987 0.986 0.986 0.987 0.986 0.986 0.986 0.986 0.986 0.986 0.986
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power VT Linear VT Dower Williams (1986) Equation #11: Radii VT Linear VT Power Williams (1986) Equation #12: Radii VT Linear VT Power Williams (1986) Equation #13: Radii	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb B=0.78Lb B=0.78Lb B=0.78Lb B=1.87Rc^0.924 B=1.87Rc^0.924 B=2.88Rc US of Curvature (ft) a Equation Rc=0.235Lm Rc=0.235Lm Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.394Lb Rc=0.467Lb^0.974 Rc=0.36Lb US of Curvature (ft) a Equation Rc=0.394Lb Rc=0.467Lb^0.974 Rc=0.26Lb US of Curvature (ft) a Equation	n 4 155 n of B n 4 4 102 n of I n 4 4 78 as a fi 4 4 78 as a fi n 4 4 78 as a fi n 78 as a fi n 78 as a fi n 4 4 78 as a fi n 4 4 78 as a fi n 9 78 78 78 78 78 78 78 78 78 78 78 78 78	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 128 - 698.5 ft 18 - 43600 ft Radius of Curvati Range 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 227.1 - 1181.5 ft 227.1 - 34.5 (360.5 ft) 227.1 - 34.5 (360.5 ft) 22.8 - 698.5 ft 22.8 - 698.5 ft 22.8 - 698.5 ft 22.8 - 343000 ft unction of Beltwid Range	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.948 0.753 0.960 ter Length (ft) R2 0.982 0.987 0.980 Length (ft) R2 0.976 0.938 0.960 dth (ft) R2
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #12: Radii VT Linear VT Power Williams (1986) Equation #13: Radii VT Linear	Equation B=0.637Lm^0.885 B=0.67Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Width (ft) as a function Equation B=1.268Rc B=1.87Rc^0.924 B=2.88Rc B=1.87Rc^0.924 B=2.88Rc B=2.88Rc B=0.65Lm^0.924 Rc=0.235Lm Equation Rc=0.235Lm Equation Rc=0.236Lm Rc=0.394Lb Rc=0.394Lb Rc=0.394Lb Rc=0.26Lb B=0.502Km Carrier (ft) at Equation Rc=0.26Lb Carrier (ft) at Equation Rc=0.271B	n 4 155 n 6 100 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 102 n 105 5 5 105 102 n 105 105 102 102 102 102 102 102 102 102 102 102	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvati Range 56.9 - 263.5 ft 56.9 - 263.5 ft 8.5 - 11800 ft matrix of Meand Range 227.1 - 1181.5 ft 32 - 54100 ft Inction of Beand I Range 127.8 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 22.3 - 43600 ft matrix of Beltwin Range 22.3 - 43600 ft 22.3 - 3300 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753 0.960 ler Length (ft) R2 0.982 0.980
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power VT Linear VT Dower Williams (1986) Equation #11: Radii VT Linear VT Power Williams (1986) Equation #12: Radii VT Linear VT Power Williams (1986) Equation #13: Radii	Equation B=0.299Lm B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb B=0.78Lb B=0.78Lb B=0.78Lb B=1.87Rc^0.924 B=1.87Rc^0.924 B=2.88Rc US of Curvature (ft) a Equation Rc=0.235Lm Rc=0.235Lm Rc=0.235Lm Rc=0.366Lm^0.94 Rc=0.394Lb Rc=0.467Lb^0.974 Rc=0.36Lb US of Curvature (ft) a Equation Rc=0.394Lb Rc=0.467Lb^0.974 Rc=0.26Lb US of Curvature (ft) a Equation	n 4 155 n of B n 4 4 102 n of I n 4 4 78 as a fi 4 4 78 as a fi n 4 4 78 as a fi n 78 as a fi n 78 as a fi n 4 4 78 as a fi n 4 4 78 as a fi n 9 78 78 78 78 78 78 78 78 78 78 78 78 78	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 26 - 76100 ft end Length (ft) Range 127.8 - 698.5 ft 128 - 698.5 ft 18 - 43600 ft Radius of Curvati Range 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 56.9 - 263.5 ft 227.1 - 1181.5 ft 227.1 - 34.5 (360.5 ft) 227.1 - 34.5 (360.5 ft) 22.8 - 698.5 ft 22.8 - 698.5 ft 22.8 - 698.5 ft 22.8 - 343000 ft unction of Beltwid Range	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.948 0.753 0.960 ter Length (ft) R2 0.982 0.987 0.980 Length (ft) R2 0.976 0.938 0.960 dth (ft) R2
VT Linear VT Power Williams (1986) Equation #9: Beltw VT Linear VT Power Williams (1986) Equation #10: Beltw VT Linear VT Power Williams (1986) Equation #12: Radii VT Linear VT Power Williams (1986) Equation #13: Radii VT Linear VT Linear VT Linear VT Linear VT Linear VT Linear VT Linear	Equation B=0.697Lm^0.885 B=0.667Lm^0.885 B=0.61Lm Equation B=0.503Lb B=0.491Lb^1.013 B=0.78Lb Equation B=1.268Rc B=1.268Rc B=1.268Rc B=1.28Rc Us of Curvature (11) d Equation Rc=0.235Lm Rc=0.235Lm Rc=0.235Lm Rc=0.235Lm Rc=0.366Lm^0.944 Rc=0.22Lm Us of Curvature (12) d Equation Rc=0.394Lb Carbon State Control Control Control Control Control Control Control Control Control Control Control Control Control Control Control Control Control Control C	n 4 155 n of B n 4 4 4 102 n of 1 n 4 4 78 as a fi n 4 4 78 as a fi n 4 4 3 78 as a fi n 4 4 4 78 as a fi n 4 4 4 78 78 8 78 8 78 78 78 78 78 78 78 78 78	Range 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 1181.5 ft 227.1 - 208.5 ft 127.8 - 698.5 ft 127.8 - 698.5 ft 18 - 43600 ft Radius of Curvat Range 56.9 - 263.5 ft 56.9 - 263.5 ft 8.5 - 11800 ft nation of Meand Range 227.1 - 1181.5 ft 227.3 - 43600 ft Range 127.8 - 698.5 ft 22.3 - 43600 ft metion of Bend I Range 50 - 330 ft 50 - 330 ft 50 - 330 ft	R2 0.938 0.773 0.980 R2 0.963 0.896 0.980 ure (ft) R2 0.949 0.753 0.960 Ver Length (ft) R2 0.982 0.982 0.987 0.988 0.960 ength (ft) R2 0.976 0.938 0.960 cth (ft) R2 0.976 0.938 0.960

Relations of Channel Size to Meander Features (Eqns 14-25)

				165 (Lq115 14-2.
Equation #14: XS A	rea (sq ft) as a funct	ion o	f Meander Length	n (ft)
	Equation	n	Range	R2
VT Linear	A=0.151Lm	4	227.1 - 1181.5 ft	
VT Power	A=28.029Lm^0.218	4	227.1 - 1181.5 ft	
Williams (1986)	A=0.009Lm^1.53	66	33 - 76100 ft	0.922
Equation #15: XS A	rea (sq ft) as a funct	ion o	f Bend Length (ft)
	Equation	n	Range	R2
VT Linear	A=0.258Lb	4	127.8 - 698.5 ft	0.145
VT Power	A=22.898Lb^0.273	4	127.8 - 698.5 ft	0.113
Williams (1986)	A=0.015Lb^1.53	41	20 - 43600 ft	0.903
Equation #16: XS A	rea (sq ft) as a funct	ion o	f Beltwidth (ft)	
	Equation	n	Range	R2
VT Linear	A=0.554B	4	50 - 330 ft	0.265
VT Power Williams (1986)	A=14.745B^0.396 A=0.021B^1.53	4 63	50 - 330 ft 16 - 38100 ft	0.275 0.941
Williams (1960)	A=0.0218-1.55	03	10-361001	0.941
Equation #17: XS A	rea (sq ft) as a funct	ion o		ature (ft)
	Equation	n	Range	R2
VT Linear	A=0.692Rc	4	56.9 - 263.5 ft	0.229
VT Power	A=26.415Rc^0.295	4 28	56.9 - 263.5 ft 7 - 11800 ft	0.134 0.941
Williams (1986)	A=0.117Rc^1.53	20	7 - 11800 11	0.941
Equation #18: Widt	h (ft) as a function o	f Mea	nder Length (ft)	
	Equation	n	Range	R2
VT Linear	W=0.062Lm	4	227.1 - 1181.5 ft	
VT Power	W=11.117Lm^0.229 W=0.19Lm^0.89	4 191	227.1 - 1181.5 ft 26 - 76100 ft	0.140
Williams (1900)	W=0.19LIIP0.09	191	20 - 70100 1	0.922
Equation #19: Widt	h (ft) as a function o	f Ben	d Length (ft)	
1001	Equation	n	Range	R2
VT Linear VT Power	W=0.106Lb W=11.548Lb^0.242	4 4	127.8 - 698.5 ft 127.8 - 698.5 ft	0.196 0.138
	W=0.26Lb^0.89	102	16 - 43600 ft	0.941
Equation #20: Widt	h (ft) as a function of			
VT Linear	Equation W=0.223B	n 4	Range 50 - 330 ft	R2 0.306
VT Power	W=10.701B^0.288	4	50 - 330 ft	0.224
Williams (1986)	W=0.31B^0.89	153	10 - 44900 ft	0.922
Equation #21: Widt	h (ft) as a function of Equation	fRad n	Range	(<i>ft)</i> R2
VT Linear	W=0.283Rc	4	56.9 - 263.5 ft	0.300
VT Power	W=10.759Rc^0.303	4	56.9 - 263.5 ft	0.220
Williams (1986)	W=0.81Rc^0.89	79	8.5 - 11800 ft	0.941
E				
Equation #22: Mean	n Depth (ft) as a func Equation	n	Range	R2
VT Linear	D=0.003Lm	4	227.1 - 1181.5 ft	
VT Power	D=2.546Lm^-0.011	4	227.1 - 1181.5 ft	0.002
Williams (1986)	D=0.04Lm^0.66	66	33 - 76100 ft	0.740
Equation #23: Mea	n Depth (ft) as a func	tion	of Bend I enath (f	()
Equation #25. Mean	Equation	n n	Range	R2
VT Linear	D=0.005Lb	4	127.8 - 698.5 ft	0.234
VT Power	D=2.008Lb^0.03	4	127.8 - 698.5 ft	0.012
Williams (1986)	D=0.054Lb^0.66	41	23 - 43600 ft	0.810
Equation #24: Mear	n Depth (ft) as a func	tion a	of Beltwidth (ft)	
	Equation	n	Range	R2
VT Linear	D=0.01B	4	50 - 330 ft	0.355
VT Power	D=1.38B^0.11	4	50 - 330 ft	0.178
vviiliams (1986)	D=0.055B^0.66	63	16 - 38100 ft	0.810
Equation #25: Mear	n Depth (ft) as a func	tion o	of Radius of Curv	ature (ft)
	Equation	n	Range	R2
VT Linear	D=0.013Rc	4	56.9 - 263.5 ft	0.248
VT Power	D=0.013Rc D=2.452Rc^-0.006 D=0.127Rc^0.66	4 4 28	56.9 - 263.5 ft 56.9 - 263.5 ft 8.5 - 11800 ft	0.248 0.001 0.810

Relations of Meander Features to Channel Size (Eqns 25-37)

Equation #26: Mea	nder Length (ft) as a			
	Equation	n	Range	R2
VT Linear	Lm=3.473A	4	56.4 - 239.7 ft	0.133
VT Power	Lm=74.774A^0.377	4	56.4 - 239.7 ft	0.082
Williams (1986)	Lm=21A/0.65	66	0.43 - 225000 ft	0.922
Equation #27: Bend	d Length (ft) as a fun	ction	of XS Area (sq fi	t)
	Equation	n	Range	R2
VT Linear	Lb=2.117A	4	56.4 - 239.7 ft	0.145
VT Power	Lb=39.116A^0.416	4	56.4 - 239.7 ft	0.113
Williams (1986)	Lb=15A^0.65	41	0.43 - 225000 ft	0.903
Equation #28: Belt	width (ft) as a functio	n of)	(S Area (sq ft)	
	Equation	n	Range	R2
VT Linear	B=1.172A	4	56.4 - 239.7 ft	0.265
VT Power	B=5.686A^0.693	4	56.4 - 239.7 ft	0.275
Williams (1986)	B=13A^0.65	63	0.43 - 225000 ft	0.941
Equation #29: Radi	us of Curvature (ft) a	s a fi	unction of XS Are	ea (sq ft)
	Equation	n	Range	R2
VT Linear	Rc=0.891A	4	56.4 - 239.7 ft	0.229
VT Power	Rc=13.183A^0.455	4	56.4 - 239.7 ft	0.134
Williams (1986)	Rc=4.1A^0.65	28	0.43 - 225000 ft	0.941
Equation #30: Mea	nder Length (ft) as a	funct	ion of Width (ft)	
	Equation	n	Range	R2
VT Linear	Lm=9.345W	4	30.6 - 91.6 ft	0.189
VT Power	Lm=42.207W^0.612	4	30.6 - 91.6 ft	0.140
Williams (1986)	Lm=6.5W^1.12	191	4.9 - 13000 ft	0.922
Equation #31: Bend	d Length (ft) as a fun	ction	of Width (ft)	
	Equation	n	Range	R2
VT Linear	Lb=5.664W	4	30.6 - 91.6 ft	0.196
VT Power	Lb=31.067W^0.57	4	30.6 - 91.6 ft	0.138
Williams (1986)	LD=4.4VV/1.12	102	4.9 - 7000 ft	0.941
Equation #32: Belt	width (ft) as a functio	n of I	Width (ft)	
	Equation	n	Range	R2
VT Linear	B=3.081W	4	30.6 - 91.6 ft	0.306
VT Power	B=7.418W^0.779	4	30.6 - 91.6 ft	0.224 0.922
Williams (1986)	D=3.7 W^1.12	153	4.9 - 13000 ft	0.922
Equation #33: Radi	us of Curvature (ft) a			(ft)
	Equation	n	Range	R2
VT Linear	Rc=2.378W	4	30.6 - 91.6 ft	0.300
VT Power	Rc=6.999W^0.724 Rc=1.3W^1.12	4 79	30.6 - 91.6 ft 4.9 - 7000 ft	0.220 0.941
Williams (1966)	RC=1.3W/1.12	19	4.9 - 7000 II	0.941
Equation #34: Mea	nder Length (ft) as a		ion of Mean Dep	
\/T Linear	Equation	n 4	Range	R2
VT Linear VT Power	Lm=216.464D Lm=498.185D^-0.163	4	1.8 - 2.9 ft 1.8 - 2.9 ft	0.195 0.002
	Lm=129D^1.52	66	0.1 - 59 ft	0.740
williams (1900)	LIII=1230-1.52	00	0.1 - 55 1	0.740
Equation #35: Bend	d Length (ft) as a fun			
\/T Lincor	Equation	n 4	Range	R2
VT Linear VT Power	Lb=133.144D	4 4	1.8 - 2.9 ft	0.234 0.012
Williams (1986)	Lb=193.533D^0.391	4 41	1.8 - 2.9 ft 0.1 - 57.7 ft	0.012
				5.010
Equation #36: Belty	width (ft) as a functio			
VT Linear	Equation B=71.796D	n 4	Range 1.8 - 2.9 ft	R2 0.355
VT Power	B=35.104D^1.623	4	1.8 - 2.9 ft	0.355
		63	0.1 - 59 ft	0.810
Williams (1986)				
Williams (1986)	us of Curvature (ft) a			
Williams (1986) Equation #37: Radi	us of Curvature (ft) a Equation	n	Range	R2
Williams (1986)	us of Curvature (ft) a	n 4		

Figure 2 Empirically derived meander geometry equations (following Williams, 1986).

Stream Geomorphic Assessment Handbooks

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