APPENDIX J

LEVEL II ROSGEN WORKSHEETS

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Buffalo River-1-1.19**			Station Number:	**N/A**
LOCATION:	**Buffalo River-1-1.19**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**636224** acres	**994.1** mi^2	Drainage Area Mn ELEV:	**848.05**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**73.1**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.3**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**462.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**76.6**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**0.9**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**420.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**420.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.04**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**681**	ft	Radius of Curvature (R_C)	**94.0**	ft
Belt Width (W_{blt})	**953**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**13.0**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Buffalo River-1-1.19			Location	Buffalo River-1-1.19
Date	9/27/2011	Stream Type	E6	Valley Type	X
Observers	KD, JB			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	462.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.3	D_{bkf} (ft)
Bankfull WIDTH	73.1	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	85.7	W_p (ft)
D_{84} @ Riffle	0.022	Dia. (mm)	D_{84} mm / 304.8 =	0.0001	D_{84} (ft)
Bankfull SLOPE	0.00004	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.4	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	74759	
Drainage AREA	994.1	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.08	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	2.4	ft / sec	1126	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	0.8	ft / sec	367	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	4.5	ft / sec	2087	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.035	0.8	ft / sec	367	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	0.9	ft / sec	420	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Buffalo River-1-1.19**			
Basin:	**Red River Basin**	Drainage Area: **636224** acres	**994.1**	mi^2
Location:	**Buffalo River-1-1.19**			
Twp.&Rge:	**-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.):	**-**	Date: **9/27/2011**		
Observers:	**KD, JB**	Valley Type: **X**		

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**73.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**462.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.5**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.0**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**196.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.7**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0015**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000037**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.2**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Buffalo River-1-1.19**			Location:	**Buffalo River-1-1.19**		
Observers:	**KD, JB**	Date:	**9/27/2011**	Valley Type:	**X**	Stream Type:	**E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**6.3**	ft	Riffle Width (W_{bkf})	**73.1**	ft	Riffle Area (A_{bkf})	**462.7**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/ d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/ W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**9.01**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**0.9**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**420**	cfs	Drainage Area	**994.1**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**681**			ft	Meander Length Ratio (L_m/W_{bkf})	**9.3**		
Radius of Curvature (R_c)	**94**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**1.3**		
Belt Width (W_{blt})	**953**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**13.0**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**17491**	ft	Valley Length (VL)	**8114**	ft	Sinuosity (SL/VL)	**2.2**
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
end		ft	end		ft	end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**9.0**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**98**			D_{16}	**<.001**				mm
% Sand	**2**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0015**				mm
% Cobble	**0**			D_{84}	**0.022**				mm
% Boulder	**0**			D_{95}	**0.063**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wolverton Creek - 1 - 0.64**		Station Number:	**N/A**	
LOCATION:	**Wolverton Creek - 1 - 0.64**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**65920** acres	**103** mi^2	Drainage Area Mn ELEV:	**885.63**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**B6c**		HUC:	__ __ __ __ __ __ __ __ __ __ __ __	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**25.4**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**2.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**53.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**26.9**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**2.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**130.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**130.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.1**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**314**	ft	Radius of Curvature (R_C)	**57.0**	ft
Belt Width (W_{blt})	**656**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**25.8**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.045**	Coeff.

"**n**" = 1.4865 **[**(**A**rea) (Hydraulic **R**adius $^{2/3}$) (**S**lope $^{1/2}$)**]** / Q_{bkf}

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	**Wolverton Creek - 1 - 0.64**			Location	**Wolverton Creek - 1 - 0.64**
Date	**9/28/2011**	Stream Type	**B6c**	Valley Type	**X**
Observers	**KP, AL**			HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	**53.7**	A_{bkf} (ft^2)	Bankfull Mean DEPTH	**2.1**	D_{bkf} (ft)
Bankfull WIDTH	**25.4**	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	**29.6**	W_p (ft)
D_{84} @ Riffle	**0.01**	Dia. (mm)	D_{84} mm / 304.8 =	**0.00**	D_{84} (ft)
Bankfull SLOPE	**0.0012**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**1.8**	R (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	**55337**	
Drainage AREA	**103.0**	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	**0.3**	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	**8.0**	ft / sec	**429**	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	**1.7**	ft / sec	**93**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	**2.8**	ft / sec	**150**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.045	**1.7**	ft / sec	**93**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	**2.5**	ft / sec	**130**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wolverton Creek - 1 - 0.64**			
Basin:	**Red River Basin**	Drainage Area: **65920** acres	**103**	mi^2
Location:	**Wolverton Creek - 1 - 0.64**			
Twp.&Rge: **-**		Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**			Date: **9/28/2011**	
Observers: **KP, AL**			Valley Type: **X**	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**25.4**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**2.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**53.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.2**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**3.3**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**47.5**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.9**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**<0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0012**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.7**	

Stream Type → **B6c** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Wolverton Creek - 1 - 0.64**	Location:	**Wolverton Creek - 1 - 0.64**		
Observers:	**KP, AL**	Date: **9/28/2011**	Valley Type: **X**	Stream Type: **B6c**	

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	2.09	ft	Riffle Width (W_{bkf})	25.4	ft	Riffle Area (A_{bkf})	53.7	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	3.3	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.6	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				2.5	ft/s	Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				130	cfs	Drainage Area	103	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	314			ft	Meander Length Ratio (L_m/W_{bkf})	12.4		
Radius of Curvature (R_c)	57			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	2.2		
Belt Width (W_{blt})	656			ft	Meander Width Ratio (W_{blt}/W_{bkf})	25.8		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	8458	ft	Valley Length (VL)	4883	ft	Sinuosity (SL/VL)	1.7	
Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	3.3			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.6		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	92			D_{16}	<.001				mm
% Sand	8			D_{35}	<.001				mm
% Gravel	0			D_{50}	<0.001				mm
% Cobble	0			D_{84}	0.01				mm
% Boulder	0			D_{95}	0.25				mm
% Bedrock	0			D_{100}	1				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-6-42.36**		Station Number:	**N/A**	
LOCATION:	**Wild Rice River-6-42.36**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**1182080** acres	**1847** mi^2	Drainage Area Mn ELEV:	**904.68**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**76.2**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**462.2**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**80.1**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.1**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**517.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**517.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**20** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1353**	ft	Radius of Curvature (R_C)	**328.0**	ft
Belt Width (W_{blt})	**2214**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**29.1**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.043**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-6-42.36			Location	Wild Rice River-6-42.36
Date	10/1/2011	Stream Type	E6	Valley Type	X
Observers	KD, JB			HUC	_ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	462.2	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.1	D_{bkf} (ft)
Bankfull WIDTH	76.2	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	88.3	W_p (ft)
D_{84} @ Riffle	0.073	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.2	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	21845	
Drainage AREA	1847.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	3.3	ft / sec	1545	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.0	ft / sec	453	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	4.9	ft / sec	2258	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.043	1.0	ft / sec	453	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.1	ft / sec	517	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-6-42.36**				
Basin:	**Red River Basin**	Drainage Area:	**1E+06** acres	**1847**	mi^2
Location:	**Wild Rice River-6-42.36**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**10/1/2011**
Observers:	**KD, JB**			Valley Type:	**X**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**76.2**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**462.2**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**8.4**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**157.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.1**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0027**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000088**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.7**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Wild Rice River-6-42.36**	Location:	**Wild Rice River-6-42.36**
Observers: **KD, JB**	Date: **10/1/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**6.1**	ft	Riffle Width (W_{bkf})	**76.2**	ft	Riffle Area (A_{bkf})	**462.2**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**8.4**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.1**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**517**	cfs	Drainage Area	**1847**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1353**			ft	Meander Length Ratio (L_m/W_{bkf})	**17.8**		
Radius of Curvature (R_c)	**328**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**4.3**		
Belt Width (W_{blt})	**2214**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**29.1**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**14371**	ft	Valley Length (VL)	**5318**	ft	Sinuosity (SL/VL)	**2.7**

Low Bank Height (LBH)			Max Riffle Depth			Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	
start		ft	start		ft	start	
end		ft	end		ft	end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**8.4**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**84**			D_{16}	**<.001**				mm
% Sand	**16**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0027**				mm
% Cobble	**0**			D_{84}	**0.073**				mm
% Boulder	**0**			D_{95}	**1.6**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-5-38.49**	Station Number:	**N/A**
LOCATION:	**Wild Rice River-5-38.49**		
Period of RECORD:	**N/A** yrs	Mean Annual DISCHARGE:	**N/A** cfs
Drainage AREA:	**1191680** acres; **1862** mi^2	Drainage Area Mn ELEV:	**901.37** ft
Reference REACH SLOPE:	ft/ft	Valley Type:	**X**
Stream Type:	**E6**	HUC:	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**74.1**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**7.0**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**516.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**79.0**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.0**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**517.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**517.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1709**	ft	Radius of Curvature (R_C)	**352.0**	ft
Belt Width (W_{blt})	**2019**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**27.2**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.043**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-5-38.49		Location	Wild Rice River-5-38.49	
Date	10/2/2011	Stream Type: E6	Valley Type	X	
Observers	KD, JB		HUC	_ _ _ _ _ _ _ _ _ _ _ _	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	516.1	A_{bkf} (ft^2)	Bankfull Mean DEPTH	7.0	D_{bkf} (ft)
Bankfull WIDTH	74.1	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	88.1	W_p (ft)
D_{84} @ Riffle	0.013	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.9	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	142927	
Drainage AREA	1862.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}]u*$	3.9	ft / sec	2037	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	1.0	ft / sec	520	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	5.3	ft / sec	2738	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.043	1.0	ft / sec	520	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.0	ft / sec	517	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-5-38.49**			
Basin:	**Red River Basin**	Drainage Area: **1E+06** acres	**1862**	mi^2
Location:	**Wild Rice River-5-38.49**			
Twp.&Rge:	**-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.):	**-**		Date: **10/2/2011**	
Observers:	**KD, JB**		Valley Type: **X**	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**74.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**7.0**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**516.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**10.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**236.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.2**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0025**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000081**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.9**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Wild Rice River-5-38.49**		Location: **Wild Rice River-5-38.49**	
Observers: **KD, JB**	Date: **10/2/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**7.0**	ft	Riffle Width (W_{bkf})	**74.1**	ft	Riffle Area (A_{bkf})	**516.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**9.6**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.0**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**517**	cfs	Drainage Area	**1862**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1709**			ft	Meander Length Ratio (L_m/W_{bkf})	**23.1**		
Radius of Curvature (R_c)	**352**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**4.8**		
Belt Width (W_{blt})	**2019**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**27.2**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**42195**	ft	Valley Length (VL)	**21767**	ft	Sinuosity (SL/VL)	**1.9**
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**9.6**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**94**			D_{16}	**<.001**				mm
% Sand	**6**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0025**				mm
% Cobble	**0**			D_{84}	**0.0125**				mm
% Boulder	**0**			D_{95}	**0.13**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-4-22.94**			Station Number:	**N/A**
LOCATION:	**Wild Rice River-4-22.94**				
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A** cfs
Drainage AREA:	**1219200** acres	**1905**	mi^2	Drainage Area Mn ELEV:	**892.85** ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**
Stream Type:	**B6c**			HUC:	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**75.5**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**5.6**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**424.6**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**78.8**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.2**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**517.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**517.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1514**	ft	Radius of Curvature (R_C)	**613.0**	ft
Belt Width (W_{blt})	**2633**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**34.9**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.043**	Coeff.

"**n**" = 1.4865 **[**(**A**rea) (Hydraulic **R**adius $^{2/3}$) (**S**lope $^{1/2}$)**]** / Q_{bkf}

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-4-22.94			Location	Wild Rice River-4-22.94
Date	10/3/2011	Stream Type	B6c	Valley Type	X
Observers	KD, JB			HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	424.6	A_{bkf} (ft^2)	Bankfull Mean DEPTH	5.6	D_{bkf} (ft)
Bankfull WIDTH	75.5	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	86.7	W_p (ft)
D_{84} @ Riffle	0.012	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	4.9	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	124350	
Drainage AREA	1905.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \mathrm{Log}\{R / D_{84}\}] u^*$	4.6	ft / sec	1963	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$; n =	1.2	ft / sec	492	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$; n = ; Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	4.9	ft / sec	2065	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; c) Manning's 'n' from Stream Type; n = 0.043	1.2	ft / sec	492	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.): HEC-RAS	1.2	ft / sec	517	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-4-22.94**				
Basin:	**Red River Basin**	Drainage Area:	**1E+06** acres	**1905**	mi^2
Location:	**Wild Rice River-4-22.94**				
Twp.&Rge: **-**		Sec.&Qtr.: **-**			
Cross-Section Monuments (Lat./Long.): **-**				Date:	**10/3/2011**
Observers:	**KD, JB**			Valley Type:	**X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**75.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**5.6**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**424.6**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**13.4**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**8.2**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**144.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.9**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0032**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00014**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.8**	

Stream Type **B6c** — **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Wild Rice River-4-22.94**		Location:	**Wild Rice River-4-22.94**			
Observers:	**KD, JB**	Date:	**10/3/2011**	Valley Type:	**X**	Stream Type:	**B6c**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**5.6**	ft	Riffle Width (W_{bkf})	**75.5**	ft	Riffle Area (A_{bkf})	**424.6**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**8.2**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.2**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**517**	cfs	Drainage Area	**1905**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1514**			ft	Meander Length Ratio (L_m/W_{bkf})	**20.1**		
Radius of Curvature (R_c)	**613**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**8.1**		
Belt Width (W_{blt})	**2633**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**34.9**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**63892**	ft	Valley Length (VL)	**36411**	ft	Sinuosity (SL/VL)	**1.8**	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**8.2**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**99**			D_{16}	**<.001**				mm
% Sand	**1**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0032**				mm
% Cobble	**0**			D_{84}	**0.012**				mm
% Boulder	**0**			D_{95}	**0.045**				mm
% Bedrock	**0**			D_{100}	**0.85**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-3-17.52**			Station Number:	**N/A**	
LOCATION:	**Wild Rice River-3-17.52**					
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**1260800** acres	**1970**	mi^2	Drainage Area Mn ELEV:	**888.52**	ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**	
Stream Type:	**E6**			HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**73.8**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**450.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**77.1**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.2**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**517.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**517.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1346**	ft	Radius of Curvature (R_C)	**283.0**	ft
Belt Width (W_{blt})	**1344**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.2**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.03**	Coeff.

"**n**" = 1.4865 **[**(**A**rea) (Hydraulic **R**adius $^{2/3}$) (**S**lope $^{1/2}$)**]** / Q_{bkf}

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-3-17.52		Location	Wild Rice River-3-17.52	
Date	10/4/2011	Stream Type: E6	Valley Type	X	
Observers	KD, JB		HUC		

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	450.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.1	D_{bkf} (ft)
Bankfull WIDTH	73.8	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	86.0	W_p (ft)
D_{84} @ Riffle	0.0046	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.2	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	347177	
Drainage AREA	1970.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness: $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}]u^*$	3.8	ft / sec	1709	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$; n =	1.3	ft / sec	575	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$; n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	4.8	ft / sec	2153	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; c) Manning's 'n' from Stream Type; n = 0.03	1.3	ft / sec	575	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.): HEC-RAS	1.2	ft / sec	517	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-3-17.52**				
Basin:	**Red River Basin**	Drainage Area:	**1E+06** acres	**1970**	mi^2
Location:	**Wild Rice River-3-17.52**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**10/4/2011**
Observers:	**KD, JB**			Valley Type:	**X**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**73.8**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**450.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.1**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**8.7**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**150.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.0**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000073**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.5**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Wild Rice River-3-17.52** Location: **Wild Rice River-3-17.52**

Observers: **KD, JB** Date: **10/4/2011** Valley Type: **X** Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**6.1**	ft	Riffle Width (W_{bkf})	**73.8**	ft	Riffle Area (A_{bkf})	**450.7**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**8.7**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})	**1.2**	ft/s	Estimation Method	**HEC-RAS**				
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})	**517**	cfs	Drainage Area	**1970**	mi^2			

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1346**			ft	Meander Length Ratio (L_m/W_{bkf})	**18.2**		
Radius of Curvature (R_c)	**283**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.8**		
Belt Width (W_{blt})	**1344**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.2**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**32534**	ft	Valley Length (VL)	**21177**	ft	Sinuosity (SL/VL)	**1.5**
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**8.7**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**95**			D_{16}	**<.001**				mm
% Sand	**5**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.001**				mm
% Cobble	**0**			D_{84}	**0.0046**				mm
% Boulder	**0**			D_{95}	**0.071**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-2-4.23**			Station Number:	**N/A**
LOCATION:	**Wild Rice River-2-4.23**				
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A** cfs
Drainage AREA:	**1287040** acres	**2011**	mi^2	Drainage Area Mn ELEV:	**880.59** ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**
Stream Type:	**E6**			HUC:	__ __ __ __ __ __ __ __ __ __ __ __

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**84.3**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.2**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**525.3**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**87.5**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.1**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**600.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**600.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**745**	ft	Radius of Curvature (R_C)	**153.0**	ft
Belt Width (W_{blt})	**1608**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**19.1**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.045**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-2-4.23	Location	Wild Rice River-2-4.23
Date	10/4/2011	Stream Type	E6
Valley Type	X		
Observers	KP, AL	HUC	

INPUT VARIABLES / OUTPUT VARIABLES

INPUT VARIABLES	Value	Unit	OUTPUT VARIABLES	Value	Unit
Bankfull Cross-sectional	525.3	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.2	D_{bkf} (ft)
Bankfull WIDTH	84.3	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	96.8	W_p (ft)
D_{84} @ Riffle	0.05	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.4	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	33090	
Drainage AREA	2011.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	3.5	ft / sec	1853	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.0	ft / sec	503	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	5.0	ft / sec	2644	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.045	1.0	ft / sec	503	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.1	ft / sec	600	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-2-4.23**			
Basin:	**Red River Basin**	Drainage Area: **1E+06** acres	**2011**	mi^2
Location:	**Wild Rice River-2-4.23**			
Twp.&Rge:	**-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.):	**-**		Date:	**10/4/2011**
Observers:	**KP, AL**		Valley Type:	**X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**84.3**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.2**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**525.3**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**13.5**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**8.5**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**283.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.4**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0029**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000088**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.3**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Wild Rice River-2-4.23**		Location: **Wild Rice River-2-4.23**	
Observers: **KP, AL**	Date: **10/4/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	6.2	ft	Riffle Width (W_{bkf})	84.3	ft	Riffle Area (A_{bkf})	525.3	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	8.5	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.4	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				1.1	ft/s	Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				600	cfs	Drainage Area	2011	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	745			ft	Meander Length Ratio (L_m/W_{bkf})	8.8		
Radius of Curvature (R_c)	153			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	1.8		
Belt Width (W_{blt})	1608			ft	Meander Width Ratio (W_{blt}/W_{bkf})	19.1		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	55572	ft	Valley Length (VL)	24623	ft	Sinuosity (SL/VL)	2.3	
Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	8.5			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.4		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	89			D_{16}	<.001				mm
% Sand	11			D_{35}	<.001				mm
% Gravel	0			D_{50}	0.0029				mm
% Cobble	0			D_{84}	0.05				mm
% Boulder	0			D_{95}	0.3				mm
% Bedrock	0			D_{100}	4.75				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wild Rice River-1-3.01**		Station Number:	**N/A**	
LOCATION:	**Wild Rice River-1-3.01**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**1287680** acres	**2012** mi^2	Drainage Area Mn ELEV:	**875.87**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:	_ _	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**79.2**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**7.0**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**556.2**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**83.8**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.1**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**600.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**600.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**910**	ft	Radius of Curvature (R_C)	**137.0**	ft
Belt Width (W_{blt})	**1940**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.5**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.045**	Coeff.

$$"n" = 1.4865 \left[(Area)(Hydraulic\ Radius^{2/3})(Slope^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wild Rice River-1-3.01		Location	Wild Rice River-1-3.01	
Date	10/4/2011	Stream Type: E6	Valley Type	X	
Observers	KP, AL		HUC	_ _	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	556.2	A_{bkf} (ft^2)	Bankfull Mean DEPTH	7.0	D_{bkf} (ft)
Bankfull WIDTH	79.2	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	93.2	W_p (ft)
D_{84} @ Riffle	0.022	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	6.0	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	82706	
Drainage AREA	2012.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	4.3	ft / sec	2400	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.1	ft / sec	614	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	5.5	ft / sec	3085	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.045	1.1	ft / sec	614	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.1	ft / sec	600	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wild Rice River-1-3.01**				
Basin:	**Red River Basin**	Drainage Area:	**1E+06** acres	**2012**	mi^2
Location:	**Wild Rice River-1-3.01**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**10/4/2011**
Observers:	**KP, AL**			Valley Type:	**X**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**79.2**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**7.0**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**556.2**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.3**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**10.2**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**333.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**4.2**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0031**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00010**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**3.9**	

Stream Type **E6** **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Wild Rice River-1-3.01**	Location:	**Wild Rice River-1-3.01**
Observers: **KP, AL**	Date: **10/4/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**7.0**	ft	Riffle Width (W_{bkf})	**79.2**	ft	Riffle Area (A_{bkf})	**556.2**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/ d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/ W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**10.2**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.1**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**600**	cfs	Drainage Area	**2012**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**910**			ft	Meander Length Ratio (L_m/W_{bkf})	**11.5**		
Radius of Curvature (R_c)	**137**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**1.7**		
Belt Width (W_{blt})	**1940**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.5**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**21405**	ft	Valley Length (VL)	**5483**	ft	Sinuosity (SL/VL)	**3.9**	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**10.2**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**95**			D_{16}	**<.001**				mm
% Sand	**5**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0031**				mm
% Cobble	**0**			D_{84}	**0.022**				mm
% Boulder	**0**			D_{95}	**0.075**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-8-55.75**				Station Number:	**N/A**	
LOCATION:	**Sheyenne River-8-55.75**						
Period of RECORD:	**N/A**	yrs			Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2179840**	acres	**3406**	mi^2	Drainage Area Mn ELEV:	**911.79**	ft
Reference REACH SLOPE:		ft/ft			Valley Type:	**X**	
Stream Type:	**E5**				HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**74.7**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**8.3**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**616.4**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**80.5**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.6**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1000.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1000.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.5**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge……..=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1265**	ft	Radius of Curvature (R_C)	**210.0**	ft
Belt Width (W_{blt})	**2807**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**37.6**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.052**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-8-55.75			Location	Sheyenne River-8-55.75
Date	10/2/2011	Stream Type	E5	Valley Type	X
Observers	KP, AL			HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	616.4	A_{bkf} (ft^2)	Bankfull Mean DEPTH	8.3	D_{bkf} (ft)
Bankfull WIDTH	74.7	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	91.2	W_p (ft)
D_{84} @ Riffle	0.24	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	6.8	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	8765	
Drainage AREA	3406.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	3.8	ft / sec	2334	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.0	ft / sec	643	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	6.2	ft / sec	3794	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.052	1.0	ft / sec	643	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.6	ft / sec	1000	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-8-55.75**				
Basin:	**Red River Basin**	Drainage Area:	**2E+06** acres	**3406**	mi^2
Location:	**Sheyenne River-8-55.75**				
Twp.&Rge: **-**		Sec.&Qtr.: **-**			
Cross-Section Monuments (Lat./Long.): **-**				Date:	**40818**
Observers:	**KP, AL**			Valley Type:	**X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**74.7**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**8.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**616.4**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**9.0**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**13.1**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**898.5**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**12.0**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.18**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00010**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**4.0**	

Stream Type → **E5** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Sheyenne River-8-55.75**			Location:	**Sheyenne River-8-55.75**		
Observers:	**KP, AL**	Date:	**40818**	Valley Type:	**X**	Stream Type:	**E5**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**8.26**	ft	Riffle Width (W_{bkf})	**74.7**	ft	Riffle Area (A_{bkf})	**616.40**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**13.1**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.584**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})	**1.625**	ft/s	Estimation Method	**HEC-RAS**				
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})	**1000**	cfs	Drainage Area	**3406**	mi^2			

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1265**			ft	Meander Length Ratio (L_m/W_{bkf})	**####**		
Radius of Curvature (R_c)	**210**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.811**		
Belt Width (W_{blt})	**2807**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**####**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**93167**	ft	Valley Length (VL)	**23447**	ft	Sinuosity (SL/VL)	**4.0**
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.000**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.000**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**####**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.584**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**6**			D_{16}	**0.125**				mm
% Sand	**94**			D_{35}	**0.16**				mm
% Gravel	**0**			D_{50}	**0.18**				mm
% Cobble	**0**			D_{84}	**0.235**				mm
% Boulder	**0**			D_{95}	**0.265**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-7-43.27**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River-7-43.27**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2190720** acres	**3423** mi^2	Drainage Area Mn ELEV:	**895.49**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**80.8**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**10.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**819.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**89.0**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1200.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1200.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.7**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1028**	ft	Radius of Curvature (R_C)	**217.0**	ft
Belt Width (W_{blt})	**1646**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**20.4**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.052**	Coeff.

$$"n" = 1.4865 \left[(Area)(Hydraulic\ Radius^{2/3})(Slope^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-7-43.27	Location	Sheyenne River-7-43.27
Date	10/5/2011	Stream Type: E6	Valley Type: X
Observers	KD, JB	HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	819.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	10.1	D_{bkf} (ft)
Bankfull WIDTH	80.8	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	101.1	W_p (ft)
D_{84} @ Riffle	0.12	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0000	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	8.1	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	20600	
Drainage AREA	3423.0	DA (mi^2)	Shear Velocity	0.0	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u*$	0.5	ft / sec	380	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$; n =	0.1	ft / sec	100	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$; n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	4.1	ft / sec	3400	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type; n = 0.052	0.1	ft / sec	100	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	1200	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1.	For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.
Option 2.	For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.
Option 3.	For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-7-43.27**
Basin: **Red River Basin**	Drainage Area: **2E+06** acres **3423** mi^2
Location:	**Sheyenne River-7-43.27**
Twp.&Rge: **-**	Sec.&Qtr.: **-**
Cross-Section Monuments (Lat./Long.): **-**	Date: **10/5/2011**
Observers: **KD, JB**	Valley Type: **X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**80.8**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**10.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**819.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**8.0**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**14.8**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**903.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**11.2**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0495**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00000**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.8**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Sheyenne River-7-43.27**	Location:	**Sheyenne River-7-43.27**
Observers: **KD, JB**	Date: **10/5/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**10.1**	ft	Riffle Width (W_{bkf})	**80.8**	ft	Riffle Area (A_{bkf})	**819.7**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**14.8**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1200**	cfs	Drainage Area	**3423**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1028**			ft	Meander Length Ratio (L_m/W_{bkf})	**12.7**		
Radius of Curvature (R_c)	**217**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.7**		
Belt Width (W_{blt})	**1646**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**20.4**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**43888**	ft	Valley Length (VL)	**24110**	ft	Sinuosity (SL/VL)	**1.8**	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**14.8**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**66**			D_{16}	**<.001**				mm
% Sand	**34**			D_{35}	**0.026**				mm
% Gravel	**0**			D_{50}	**0.0495**				mm
% Cobble	**0**			D_{84}	**0.12**				mm
% Boulder	**0**			D_{95}	**0.19**				mm
% Bedrock	**0**			D_{100}	**2**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River - 6 - 35.82**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River - 6 - 35.82**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2197120** acres	**3433** mi^2	Drainage Area Mn ELEV:	**891.87**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**72.0**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**7.9**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**568.9**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**78.0**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**860.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**860.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.4**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**936**	ft	Radius of Curvature (R_C)	**224.0**	ft
Belt Width (W_{blt})	**1744**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.2**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.046**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River - 6 - 35.82		Location	Sheyenne River - 6 - 35.82
Date	11/21/2010	Stream Type: E6	Valley Type	X
Observers	KP, AL		HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	568.9	A_{bkf} (ft^2)	Bankfull Mean DEPTH	7.9	D_{bkf} (ft)
Bankfull WIDTH	72.0	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	87.8	W_p (ft)
D_{84} @ Riffle	0.12	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	6.5	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	16455	
Drainage AREA	3433.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	4.8	ft / sec	2709	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.4	ft / sec	789	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	6.2	ft / sec	3540	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.046	1.4	ft / sec	789	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	860	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River - 6 - 35.82**				
Basin:	**Red River Basin**	Drainage Area:	**2E+06** acres	**3433**	mi^2
Location:	**Sheyenne River - 6 - 35.82**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**11/21/2010**
Observers:	**KP, AL**			Valley Type:	**X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**72.0**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**7.9**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**568.9**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**9.1**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**11.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**810.8**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**11.3**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0175**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00015**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.8**	

Stream Type **E6** — **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Sheyenne River - 6 - 35.82**		Location: **Sheyenne River - 6 - 35.82**	
Observers: **KP, AL**	Date: **11/21/2010**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**7.9**	ft	Riffle Width (W_{bkf})	**72.0**	ft	Riffle Area (A_{bkf})	**568.9**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**11.6**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**860**	cfs	Drainage Area	**3433**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**936**			ft	Meander Length Ratio (L_m/W_{bkf})	**13.0**		
Radius of Curvature (R_c)	**224**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.1**		
Belt Width (W_{blt})	**1744**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.2**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**61075**	ft	Valley Length (VL)	**34279**	ft	Sinuosity (SL/VL)	**1.8**	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**11.6**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**73**			D_{16}	**<.001**				mm
% Sand	**27**			D_{35}	**0.0035**				mm
% Gravel	**0**			D_{50}	**0.0175**				mm
% Cobble	**0**			D_{84}	**0.12**				mm
% Boulder	**0**			D_{95}	**0.18**				mm
% Bedrock	**0**			D_{100}	**2**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-5-26.47**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River-5-26.47**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2224640** acres	**3476** mi^2	Drainage Area Mn ELEV:	**881.57**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E5**		HUC:	_ _	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**62.7**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**379.3**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**67.5**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**580.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**580.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**850**	ft	Radius of Curvature (R_C)	**196.0**	ft
Belt Width (W_{blt})	**2230**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**35.5**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.046**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})\,(\text{Hydraulic Radius}^{2/3})\,(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-5-26.47			Location	Sheyenne River-5-26.47
Date	10/5/2011	Stream Type	E5	Valley Type	X
Observers	KP, AL			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	379.3	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.1	D_{bkf} (ft)
Bankfull WIDTH	62.7	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	74.9	W_p (ft)
D_{84} @ Riffle	0.24	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	5.1	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	6435	
Drainage AREA	3476.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	4.0	ft / sec	1525	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	1.2	ft / sec	467	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	5.1	ft / sec	1946	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.046	1.2	ft / sec	467	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	580	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-5-26.47**			
Basin:	**Red River Basin**	Drainage Area: **2E+06** acres	**3476**	mi^2
Location:	**Sheyenne River-5-26.47**			
Twp.&Rge: **-**		Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**			Date: **10/5/2011**	
Observers: **KP, AL**			Valley Type: **X**	

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**62.7**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**379.3**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**10.4**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.9**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**376.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**6.0**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.12**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00017**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.7**	

Stream Type → **E5** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Sheyenne River-5-26.47** Location: **Sheyenne River-5-26.47**

Observers: **KP, AL** Date: **10/5/2011** Valley Type: **X** Stream Type: **E5**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**6.1**	ft	Riffle Width (W_{bkf})	**62.7**	ft	Riffle Area (A_{bkf})	**379.3**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**9.89**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**580**	cfs	Drainage Area	**3476**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**850**			ft	Meander Length Ratio (L_m/W_{bkf})	**13.5**		
Radius of Curvature (R_c)	**196**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.1**		
Belt Width (W_{blt})	**2230**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**35.5**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**32606**	ft	Valley Length (VL)	**19226**	ft	Sinuosity (SL/VL)	**1.7**	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**9.9**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**37**			D_{16}	**<.001**				mm
% Sand	**63**			D_{35}	**0.071**				mm
% Gravel	**0**			D_{50}	**0.12**				mm
% Cobble	**0**			D_{84}	**0.24**				mm
% Boulder	**0**			D_{95}	**0.49**				mm
% Bedrock	**0**			D_{100}	**5**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.

[b] Composite sample of riffles and pools within the designated reach.

[c] Active bed of a riffle.

[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-4-22.27**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River-4-22.27**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2229120** acres	**3483** mi^2	Drainage Area Mn ELEV:	**871.97**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**71.5**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**8.6**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**571.8**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**73.8**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1030.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1030.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.5**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**923**	ft	Radius of Curvature (R_C)	**178.0**	ft
Belt Width (W_{blt})	**1243**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**17.4**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.054**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-4-22.27	Location	Sheyenne River-4-22.27
Date	10/1/2011	Stream Type	E6
Valley Type	X		
Observers	KP, AL	HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	571.8	A_{bkf} (ft²)	Bankfull Mean DEPTH	8.6	D_{bkf} (ft)
Bankfull WIDTH	71.5	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	88.6	W_p (ft)
D_{84} @ Riffle	0.13	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0003	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	6.5	R (ft)
Gravitational Acceleration	32.2	g (ft / sec²)	Relative Roughness R (ft) / D_{84} (ft)	14902	
Drainage AREA	3483.0	DA (mi²)	Shear Velocity $u^* = \sqrt{gRS}$	0.3	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [\,2.83 + 5.66\text{Log}\{ R / D_{84} \}\,]u^*$	7.0	ft / sec	3980	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.7	ft / sec	996	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	6.8	ft / sec	3895	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.054	1.7	ft / sec	996	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.8	ft / sec	1030	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream: **Sheyenne River-4-22.27**	
Basin: **Red River Basin**	Drainage Area: **2E+06** acres **3483** mi^2
Location: **Sheyenne River-4-22.27**	
Twp.&Rge: **-**	Sec.&Qtr.: **-**
Cross-Section Monuments (Lat./Long.): **-**	Date: **10/1/2011**
Observers: **KP, AL**	Valley Type: **X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**71.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**8.6**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**571.8**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**8.4**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**12.8**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**535.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**7.5**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.073**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00033**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.8**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Sheyenne River-4-22.27**			Location:	**Sheyenne River-4-22.27**		
Observers:	**KP, AL**	Date:	**10/1/2011**	Valley Type:	**X**	Stream Type:	**E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**8.6**	ft	Riffle Width (W_{bkf})	**71.5**	ft	Riffle Area (A_{bkf})	**571.8**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**12.8**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.8**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1030**	cfs	Drainage Area	**3483**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**923**			ft	Meander Length Ratio (L_m/W_{bkf})	**12.9**		
Radius of Curvature (R_c)	**178**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.5**		
Belt Width (W_{blt})	**1243**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**17.4**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**23284**	ft	Valley Length (VL)	**13295**	ft	Sinuosity (SL/VL)	**1.8**

Low Bank Height (LBH)	start		ft	Max Riffle Depth	start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end		ft		end		ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**12.8**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**54**			D_{16}	**0.0029**				mm
% Sand	**46**			D_{35}	**0.045**				mm
% Gravel	**0**			D_{50}	**0.073**				mm
% Cobble	**0**			D_{84}	**0.132**				mm
% Boulder	**0**			D_{95}	**0.16**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-3-18.15**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River-3-18.15**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**3179520** acres	**4968** mi^2	Drainage Area Mn ELEV:	**867.44**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**93.8**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**9.4**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**881.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**100.3**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.9**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1680.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1680.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.4**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1538**	ft	Radius of Curvature (R_C)	**246.0**	ft
Belt Width (W_{blt})	**1749**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.6**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.048**	Coeff.

$$"n" = 1.4865 \left[(Area)(Hydraulic\ Radius^{2/3})(Slope^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-3-18.15		Location	Sheyenne River-3-18.15	
Date	9/30/2011	Stream Type: E6	Valley Type	X	
Observers	KD, JB		HUC		

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	881.1	A_{bkf} (ft²)	Bankfull Mean DEPTH	9.4	D_{bkf} (ft)
Bankfull WIDTH	93.8	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	112.6	W_p (ft)
D_{84} @ Riffle	0.1	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	7.8	R (ft)
Gravitational Acceleration	32.2	g (ft / sec²)	Relative Roughness R (ft) / D_{84} (ft)	18340	
Drainage AREA	4968.0	DA (mi²)	Shear Velocity	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u*$	6.4	ft / sec	5644	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.8	ft / sec	1610	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	7.6	ft / sec	6709	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.048	1.8	ft / sec	1610	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.9	ft / sec	1680	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-3-18.15**			
Basin:	**Red River Basin**	Drainage Area: **3E+06** acres	**4968**	mi^2
Location:	**Sheyenne River-3-18.15**			
Twp.&Rge: **-**		Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**			Date: **9/30/2011**	
Observers: **KD, JB**			Valley Type: **X**	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**93.8**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**9.4**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**881.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**10.0**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**12.9**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**534.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.7**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.73**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00022**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.9**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Sheyenne River-3-18.15**		Location: **Sheyenne River-3-18.15**	
Observers: **KD, JB**	Date: **9/30/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**9.4**	ft	Riffle Width (W_{bkf})	**93.8**	ft	Riffle Area (A_{bkf})	**881.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**12.9**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})	**1.9**	ft/s	Estimation Method	**HEC-RAS**				
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})	**1680**	cfs	Drainage Area	**4968**	mi^2			

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1538**			ft	Meander Length Ratio (L_m/W_{bkf})	**16.4**		
Radius of Curvature (R_c)	**246**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.6**		
Belt Width (W_{blt})	**1749**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.6**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**34110**	ft	Valley Length (VL)	**18101**	ft	Sinuosity (SL/VL)	**1.9**

Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**12.9**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**56**			D_{16}	**<.001**				mm
% Sand	**44**			D_{35}	**0.035**				mm
% Gravel	**0**			D_{50}	**0.73**				mm
% Cobble	**0**			D_{84}	**0.13**				mm
% Boulder	**0**			D_{95}	**0.155**				mm
% Bedrock	**0**			D_{100}	**0.3**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.

[b] Composite sample of riffles and pools within the designated reach.

[c] Active bed of a riffle.

[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-2-11.56**		Station Number:	**N/A**	
LOCATION:	**Sheyenne River-2-11.56**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**3255040** acres	**5086** mi^2	Drainage Area Mn ELEV:	**862.08**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E5**		HUC:	__ __ __ __ __ __ __ __ __ __ __ __	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**111.5**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**8.8**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**988.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**116.6**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1750.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1750.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.5**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1474**	ft	Radius of Curvature (R_C)	**291.0**	ft
Belt Width (W_{blt})	**1861**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**16.7**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.048**	Coeff.

$$"n" = 1.4865 \left[(\text{Area}) (\text{Hydraulic Radius}^{2/3}) (\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Sheyenne River-2-11.56			Location	Sheyenne River-2-11.56
Date	10/3/2011	Stream Type	E5	Valley Type	X
Observers	KP, AL			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	988.1	A_{bkf} (ft^2)	Bankfull Mean DEPTH	8.8	D_{bkf} (ft)
Bankfull WIDTH	111.5	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	129.2	W_p (ft)
D_{84} @ Riffle	1.8	Dia. (mm)	D_{84} mm / 304.8 =	0.01	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	7.7	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	1318	
Drainage AREA	5086.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	4.1	ft / sec	4032	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.5	ft / sec	1508	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	7.2	ft / sec	7100	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.048	1.5	ft / sec	1508	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.8	ft / sec	1750	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-2-11.56**			
Basin:	**Red River Basin**	Drainage Area: **3E+06** acres	**5086**	mi^2
Location:	**Sheyenne River-2-11.56**			
Twp.&Rge: **-**		Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**			Date: **10/3/2011**	
Observers: **KP, AL**			Valley Type: **X**	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**111.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**8.8**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**988.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**13.0**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**787.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**7.1**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.51**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00016**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.5**	

Stream Type **E5** **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Sheyenne River-2-11.56**		Location: **Sheyenne River-2-11.56**	
Observers: **KP, AL**	Date: **10/3/2011**	Valley Type: **X**	Stream Type: **E5**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**8.8**	ft	Riffle Width (W_{bkf})	**111.5**	ft	Riffle Area (A_{bkf})	**988.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**13**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.8**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1750**	cfs	Drainage Area	**5086**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1474**			ft	Meander Length Ratio (L_m/W_{bkf})	**13.2**		
Radius of Curvature (R_c)	**291**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.6**		
Belt Width (W_{blt})	**1861**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**16.7**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**8966**	ft	Valley Length (VL)	**6195**	ft	Sinuosity (SL/VL)	**1.4**	
Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**13.0**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**26**			D_{16}	**0.016**				mm
% Sand	**72**			D_{35}	**0.16**				mm
% Gravel	**2**			D_{50}	**0.51**				mm
% Cobble	**0**			D_{84}	**1.77**				mm
% Boulder	**0**			D_{95}	**3.4**				mm
% Bedrock	**0**			D_{100}	**9.5**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary....***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Sheyenne River-1-4.20**			Station Number:	**N/A**		
LOCATION:	**Sheyenne River-1-4.20**						
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A**	cfs	
Drainage AREA:	**3359360**	acres	**5249**	mi^2	Drainage Area Mn ELEV:	**851.8**	ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**		
Stream Type:	**E6**			HUC:	_ _		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**86.9**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**9.4**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**820.3**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**93.2**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**2.3**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1900.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1900.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.5**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge......... =	**N/A**	cfs	**10** Year **R.I.** Discharge........ =	**N/A**	cfs
2.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**25** Year **R.I.** Discharge.........=	**N/A**	cfs
5.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**50** Year **R.I.** Discharge........ =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1238**	ft	Radius of Curvature (R_C)	**283.0**	ft
Belt Width (W_{blt})	**2100**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.2**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.036**	Coeff.

$$"n" = 1.4865 \left[(Area)(Hydraulic\ Radius^{2/3})(Slope^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	**Sheyenne River-1-4.20**			Location	**Sheyenne River-1-4.20**
Date	**10/6/2011**	Stream Type	**E6**	Valley Type	**X**
Observers	**KP, AL**			HUC	_ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	**820.3**	A_{bkf} (ft^2)	Bankfull Mean DEPTH	**9.4**	D_{bkf} (ft)
Bankfull WIDTH	**86.9**	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	**105.8**	W_p (ft)
D_{84} @ Riffle	**0.15**	Dia. (mm)	D_{84} mm / 304.8 =	**0.00**	D_{84} (ft)
Bankfull SLOPE	**0.0002**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**7.8**	R (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	**15763**	
Drainage AREA	**5249.0**	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	**0.2**	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}]u*$	**5.5**	ft / sec	**4476**	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	**2.1**	ft / sec	**1724**	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	**7.3**	ft / sec	**5995**	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.036	**2.1**	ft / sec	**1724**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	**2.3**	ft / sec	**1900**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Sheyenne River-1-4.20**				
Basin:	**Red River Basin**	Drainage Area:	**3E+06** acres	**5249**	mi^2
Location:	**Sheyenne River-1-4.20**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**10/6/2011**
Observers:	**KP, AL**			Valley Type:	**X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**86.9**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**9.4**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**820.3**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**9.2**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**14.7**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**437.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.0**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.175**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00017**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.8**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Sheyenne River-1-4.20**		Location: **Sheyenne River-1-4.20**	
Observers: **KP, AL**	Date: **10/6/2011**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**9.4**	ft	Riffle Width (W_{bkf})	**86.9**	ft	Riffle Area (A_{bkf})	**820.3**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**14.7**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**2.3**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1900**	cfs	Drainage Area	**5249**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1238**			ft	Meander Length Ratio (L_m/W_{bkf})	**14.3**		
Radius of Curvature (R_c)	**283**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.3**		
Belt Width (W_{blt})	**2100**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.2**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**59311**	ft	Valley Length (VL)	**21222**	ft	Sinuosity (SL/VL)	**2.8**

Low Bank Height (LBH)	start		ft	Max Riffle Depth	start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start
	end		ft		end		ft	end

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**14.7**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**71**			D_{16}	**<.001**				mm
% Sand	**28**			D_{35}	**0.0033**				mm
% Gravel	**1**			D_{50}	**0.175**				mm
% Cobble	**0**			D_{84}	**0.15**				mm
% Boulder	**0**			D_{95}	**0.22**				mm
% Bedrock	**0**			D_{100}	**9.5**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Rush River-2-6.15**			Station Number:	**N/A**		
LOCATION:	**Rush River-2-6.15**						
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A**	cfs	
Drainage AREA:	**89152**	acres	**139.3**	mi^2	Drainage Area Mn ELEV:	**884.59**	ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**		
Stream Type:	**E6**			HUC:	__ __ __ __ __ __ __ __ __ __ __ __		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**27.0**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**3.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**84.4**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**29.7**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.9**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**150.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**150.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge……..=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2344**	ft	Radius of Curvature (R_C)	**234.0**	ft
Belt Width (W_{blt})	**1408**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**52.2**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.04**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Rush River-2-6.15			Location	Rush River-2-6.15
Date	9/27/2011	Stream Type	E6	Valley Type	X
Observers	KP, AL			HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	84.4	A_{bkf} (ft^2)	Bankfull Mean DEPTH	3.1	D_{bkf} (ft)
Bankfull WIDTH	27.0	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	33.2	W_p (ft)
D_{84} @ Riffle	0.0017	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0007	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	2.5	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	456233	
Drainage AREA	139.3	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	8.1	ft / sec	688	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.8	ft / sec	151	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	3.4	ft / sec	290	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.04	1.8	ft / sec	151	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.9	ft / sec	150	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Rush River-2-6.15**		
Basin:	**Red River Basin**	Drainage Area: **89152** acres	**139.3** mi^2
Location:	**Rush River-2-6.15**		
Twp.&Rge:	**-**	Sec.&Qtr.: **-**	
Cross-Section Monuments (Lat./Long.):	**-**		Date: **9/27/2011**
Observers:	**KP, AL**		Valley Type: **X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**27.0**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**3.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**84.4**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**8.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**5.0**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**79.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.9**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**<0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00067**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.43**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	Rush River-2-6.15		Location:	Rush River-2-6.15	
Observers:	KP, AL	Date: 9/27/2011	Valley Type: X	Stream Type: E6	

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	3.1	ft	Riffle Width (W_{bkf})	27.0	ft	Riffle Area (A_{bkf})	84.4	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	5.0	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.6	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				1.9	ft/s	Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				150	cfs	Drainage Area	139.3	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	2344			ft	Meander Length Ratio (L_m/W_{bkf})	86.9		
Radius of Curvature (R_c)	234			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	8.7		
Belt Width (W_{blt})	1408			ft	Meander Width Ratio (W_{blt}/W_{bkf})	52.2		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	48503	ft	Valley Length (VL)	39164	ft	Sinuosity (SL/VL)	1.2	
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start		
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end		

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	5.0			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.6		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	98			D_{16}	<.001				mm
% Sand	2			D_{35}	<.001				mm
% Gravel	0			D_{50}	<0.001				mm
% Cobble	0			D_{84}	0.0017				mm
% Boulder	0			D_{95}	0.0046				mm
% Bedrock	0			D_{100}	4.75				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	Rush River - 1 - 0.08			Station Number:	N/A
LOCATION:	Rush River - 1 - 0.08				
Period of RECORD:	N/A	yrs		Mean Annual DISCHARGE:	N/A cfs
Drainage AREA:	98944 acres	154.6	mi^2	Drainage Area Mn ELEV:	869.61 ft
Reference REACH SLOPE:		ft/ft		Valley Type:	X
Stream Type:	E6			HUC:	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	37.4	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	3.3	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	111.1	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	36.0	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	1.4	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	150.0	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	150.0	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	1.2	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	N/A	cfs	**10** Year **R.I.** Discharge…….. =	N/A	cfs
2.0 Year **R.I.** Discharge……….=	N/A	cfs	**25** Year **R.I.** Discharge………=	N/A	cfs
5.0 Year **R.I.** Discharge……….=	N/A	cfs	**50** Year **R.I.** Discharge…….. =	N/A	cfs

MEANDER GEOMETRY

Meander Length (L_m)		ft	Radius of Curvature (R_C)		ft
Belt Width (W_{blt})		ft	Meander Width Ratio (W_{blt}/W_{bkf})	0.0	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	0.04	Coeff.

$$"n" = 1.4865 \left[(\text{Area}) (\text{Hydraulic Radius}^{2/3}) (\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Rush River - 1 - 0.08		Location	Rush River - 1 - 0.08	
Date	9/29/2011	Stream Type: E6	Valley Type	X	
Observers	KP, AL		HUC	_ _ _ _ _ _ _ _ _ _ _ _	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	111.1	A_{bkf} (ft^2)	Bankfull Mean DEPTH	3.3	D_{bkf} (ft)
Bankfull WIDTH	37.4	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	43.9	W_p (ft)
D_{84} @ Riffle	0.0055	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0004	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	2.5	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	140176	
Drainage AREA	154.6	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	6.0	ft / sec	663	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.4	ft / sec	159	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	3.2	ft / sec	359	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.04	1.4	ft / sec	159	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.4	ft / sec	150	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Rush River - 1 - 0.08**				
Basin:	**Red River Basin**	Drainage Area:	**98944** acres	**154.6**	mi^2
Location:	**Rush River - 1 - 0.08**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**9/29/2011**
Observers:	**KP, AL**			Valley Type:	**X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**37.4**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**3.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**111.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.5**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**5.2**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**91.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.5**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**<0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00043**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).		

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Rush River - 1 - 0.08**			Location:	**Rush River - 1 - 0.08**		
Observers:	**KP, AL**	Date:	**9/29/2011**	Valley Type:	**X**	Stream Type:	**E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**3.3**	ft	Riffle Width (W_{bkf})	**37.4**	ft	Riffle Area (A_{bkf})	**111.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**5.2**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.4**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**150**	cfs	Drainage Area	**154.6**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**0**			ft	Meander Length Ratio (L_m/W_{bkf})	**0.0**		
Radius of Curvature (R_c)	**0**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**0.0**		
Belt Width (W_{blt})	**0**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**0.0**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**48503**	ft	Valley Length (VL)	**39164**	ft	Sinuosity (SL/VL)	**1.2**	
Low Bank Height (LBH)	start: / end:	ft	Max Riffle Depth	start: / end:	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**5.2**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**99**			D_{16}	**<.001**				mm
% Sand	**1**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**<0.001**				mm
% Cobble	**0**			D_{84}	**0.0055**				mm
% Boulder	**0**			D_{95}	**0.06**				mm
% Bedrock	**0**			D_{100}	**0.25**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.

[b] Composite sample of riffles and pools within the designated reach.

[c] Active bed of a riffle.

[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-8-521.18**		Station Number:	**N/A**	
LOCATION:	**Red River-8-521.18**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2189440** acres	**3421** mi^2	Drainage Area Mn ELEV:	**902.14**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**138.0**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.6**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**914.5**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**141.6**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1650.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1650.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1298**	ft	Radius of Curvature (R_C)	**507.0**	ft
Belt Width (W_{blt})	**2568**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.6**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$\text{"n"} = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-8-521.18		Location	Red River-8-521.18	
Date	10/5/2011	Stream Type: C6c-	Valley Type	X	
Observers	KD, JB		HUC		

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	914.5	A_{bkf} (ft^2)	Bankfull Mean DEPTH	6.6	D_{bkf} (ft)
Bankfull WIDTH	138.0	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	151.3	W_p (ft)
D_{84} @ Riffle	3.2	Dia. (mm)	D_{84} mm / 304.8 =	0.01	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	6.0	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	576	
Drainage AREA	3421.0	DA (mi^2)	Shear Velocity	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u*$	3.2	ft / sec	2943	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.8	ft / sec	1611	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	5.9	ft / sec	5389	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.035	1.8	ft / sec	1611	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.8	ft / sec	1650	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream: **Red River-8-521.18**			
Basin: **Red River Basin**	Drainage Area: **2E+06** acres	**3421**	mi^2
Location: **Red River-8-521.18**			
Twp.&Rge: **-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**		Date: **10/5/2011**	
Observers: **KD, JB**		Valley Type: **X**	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**138.0**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**6.6**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**914.5**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**20.8**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.7**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**788.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.7**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.007**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00016**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.6**	

Stream Type → **C6c-** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Red River-8-521.18**		Location: **Red River-8-521.18**	
Observers: **KD, JB**	Date: **10/5/2011**	Valley Type: **X**	Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	6.6	ft	Riffle Width (W_{bkf})	138.0	ft	Riffle Area (A_{bkf})	914.5	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	9.72	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.5	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				1.8	ft/s	Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				1650	cfs	Drainage Area	3421	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	1298			ft	Meander Length Ratio (L_m/W_{bkf})	9.4		
Radius of Curvature (R_c)	507			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	3.7		
Belt Width (W_{blt})	2568			ft	Meander Width Ratio (W_{blt}/W_{bkf})	18.6		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	138749	ft	Valley Length (VL)	53266	ft	Sinuosity (SL/VL)	2.6
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	9.7			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.5		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	63			D_{16}	<.001				mm
% Sand	25			D_{35}	0.0025				mm
% Gravel	12			D_{50}	0.007				mm
% Cobble	0			D_{84}	3.2				mm
% Boulder	0			D_{95}	13.5				mm
% Bedrock	0			D_{100}	19				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-7-492.47**		Station Number:	**N/A**	
LOCATION:	**Red River-7-492.47**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2215040** acres	**3461** mi^2	Drainage Area Mn ELEV:	**879.8**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**120.8**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**8.9**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1073.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**125.4**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1650.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1650.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2002**	ft	Radius of Curvature (R_C)	**500.0**	ft
Belt Width (W_{blt})	**3121**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**25.8**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$"n" = 1.4865 \, [(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2})] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-7-492.47			Location	Red River-7-492.47
Date	9/30/2011	Stream Type	C6c-	Valley Type	X
Observers	KD, JB			HUC	_ _ _ _ _ _ _ _ _ _ _ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	1073.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	8.9	D_{bkf} (ft)
Bankfull WIDTH	120.8	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	138.6	W_p (ft)
D_{84} @ Riffle	1.0	Dia. (mm)	D_{84} mm / 304.8 =	0.0	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	7.7	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	2271	
Drainage AREA	3461.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	3.0	ft / sec	3197	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.4	ft / sec	1542	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	6.6	ft / sec	7109	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.035	1.4	ft / sec	1542	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	1650	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Red River-7-492.47**				
Basin:	**Red River Basin**	Drainage Area:	**2E+06** acres	**3461**	mi^2
Location:	**Red River-7-492.47**				
Twp.&Rge: **-**		Sec.&Qtr.: **-**			
Cross-Section Monuments (Lat./Long.):	**-**			Date:	**9/30/2011**
Observers:	**KD, JB**			Valley Type:	**X**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**120.8**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**8.9**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1073.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**13.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**13.3**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**404.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.3**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.025**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000075**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.6**	

Stream Type **C6c-**

See Classification Key (Figure 2-21)

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Red River-7-492.47**			Location:	**Red River-7-492.47**		
Observers:	**KD, JB**	Date:	**9/30/2011**	Valley Type:	**X**	Stream Type:	**C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**8.9**	ft	Riffle Width (W_{bkf})	**120.8**	ft	Riffle Area (A_{bkf})	**1073.7**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**13.3**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1650**	cfs	Drainage Area	**3461**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**2002**			ft	Meander Length Ratio (L_m/W_{bkf})	**16.6**		
Radius of Curvature (R_c)	**500**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**4.1**		
Belt Width (W_{blt})	**3121**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**25.8**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**74148**	ft	Valley Length (VL)	**29010**	ft	Sinuosity (SL/VL)	**2.6**
Low Bank Height (LBH)	start: ft; end: ft		Max Riffle Depth	start: ft; end: ft		Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: ; end:

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**13.3**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**53**			D_{16}	**<.001**				mm
% Sand	**47**			D_{35}	**0.0035**				mm
% Gravel	**0**			D_{50}	**0.025**				mm
% Cobble	**0**			D_{84}	**1.04**				mm
% Boulder	**0**			D_{95}	**1.78**				mm
% Bedrock	**0**			D_{100}	**2.2**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Summary....*USGS GAGE STATION* Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River - 6 - 470.23**		Station Number:	**N/A**	
LOCATION:	**Red River - 6 - 470.23**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**2298240** acres	**3591** mi^2	Drainage Area Mn ELEV:	**869.48**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:	_ _	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**118.0**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**9.3**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1084.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**124.0**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.7**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**1780.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**1780.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge......... =	**N/A**	cfs	**10** Year **R.I.** Discharge........ =	**N/A**	cfs
2.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**25** Year **R.I.** Discharge.........=	**N/A**	cfs
5.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**50** Year **R.I.** Discharge........ =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1310**	ft	Radius of Curvature (R_C)	**350.0**	ft
Belt Width (W_{blt})	**1880**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**15.9**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.040**	Coeff.

$$"n" = 1.4865 \left[(\text{Area}) (\text{Hydraulic Radius}^{2/3}) (\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River	Location	Red River - 6 - 470.23
Date	11/16/2010	Stream Type	C6c-
Valley Type	X		
Observers	KD, JB	HUC	0 9 0 2 0 1 0 4 0 5 0 1

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	1084.1	A_{bkf} (ft^2)	Bankfull Mean DEPTH	9.3	D_{bkf} (ft)
Bankfull WIDTH	118.0	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	136.5	W_p (ft)
D_{84} @ Riffle	0.0125	Dia. (mm)	D_{84} mm / 304.8 =	0.0	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	7.9	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	193627	
Drainage AREA	3591.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	6.2	ft / sec	6694	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	1.7	ft / sec	1891	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	7.3	ft / sec	7893	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.04	1.7	ft / sec	1891	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.7	ft / sec	1780.0	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Stream:	**Red River of the North**
Basin:	**Red River Basin** Drainage Area: **2298240** acres **3591** mi^2
Location:	**Red River - 6 - 470.23**
Twp.&Rge: **-**	Sec.&Qtr.: **-**
Cross-Section Monuments (Lat./Long.): **-**	Date: **11/16/2010**
Observers: **KD, JB**	Valley Type: **X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**118.0**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**9.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1084.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**16.2**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**404.7**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.4**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0017**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00014**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.3**	

Stream Type **C6c-** **See Classification Key (Figure 2-21)**

Stream: **Red River of the North** Location: **RM66.89-66.07**

Observers: **KD, JB** Date: **11/16/2010** Valley Type: **X** Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**9.3**	ft	Riffle Width (W_{bkf})	**118.0**	ft	Riffle Area (A_{bkf})	**1084.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**16.2**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.7**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.7**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**1780**	cfs	Drainage Area	**3591**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1310**			ft	Meander Length Ratio (L_m/W_{bkf})	**11.1**		
Radius of Curvature (R_c)	**350**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.0**		
Belt Width (W_{blt})	**1880**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**15.9**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**68433**	ft	Valley Length (VL)	**30431**	ft	Sinuosity (SL/VL)	**2.2**	
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start		
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end		

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**16.2**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.7**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar
% Silt/Clay	**95**		
% Sand	**5**		
% Gravel	**0**		
% Cobble	**0**		
% Boulder	**0**		
% Bedrock	**0**		

	Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
D_{16}	**<.001**				mm
D_{35}	**<.001**				mm
D_{50}	**0.00165**				mm
D_{84}	**0.0125**				mm
D_{95}	**0.1125**				mm
D_{100}	**4.75**				mm

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-5-463.56**		Station Number:	**N/A**	
LOCATION:	**Red River-5-463.56**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**3585920** acres	**5603** mi^2	Drainage Area Mn ELEV:	**864.46**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:	_ _	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**143.1**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**11.1**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1581.4**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**149.3**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**2380.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**2380.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2449**	ft	Radius of Curvature (R_C)	**449.0**	ft
Belt Width (W_{blt})	**1646**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**11.5**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$"n" = 1.4865 \, [(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2})] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-5-463.56			Location	Red River-5-463.56
Date	10/6/2011	Stream Type	C6c-	Valley Type	X
Observers	KD, JB			HUC	_ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _ | _ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	1581.4	A_{bkf} (ft^2)	Bankfull Mean DEPTH	11.1	D_{bkf} (ft)
Bankfull WIDTH	143.1	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	165.2	W_p (ft)
D_{84} @ Riffle	0.005	Dia. (mm)	D_{84} mm / 304.8 =	0.00002	D_{84} (ft)
Bankfull SLOPE	0.00005	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	9.6	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	583548	
Drainage AREA	5603.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	4.4	ft / sec	6884	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	1.3	ft / sec	2117	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	7.5	ft / sec	11853	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.035	1.3	ft / sec	2117	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	2380	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Red River-5-463.56**			
Basin:	**Red River Basin**	Drainage Area: **4E+06** acres	**5603**	mi^2
Location:	**Red River-5-463.56**			
Twp.&Rge: **-**		Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**			Date: **10/6/2011**	
Observers: **KD, JB**			Valley Type: **X**	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**143.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**11.1**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1581.4**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**12.9**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**17.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**949.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**6.6**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000049**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.4**	

Stream Type → **C6c-** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Red River-5-463.56**			Location:	**Red River-5-463.56**		
Observers:	**KD, JB**	Date:	**10/6/2011**	Valley Type:	**X**	Stream Type:	**C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**11.1**	ft	Riffle Width (W_{bkf})	**143.1**	ft	Riffle Area (A_{bkf})	**1581.4**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**17.6**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**2380**	cfs	Drainage Area	**5603**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**2449**			ft	Meander Length Ratio (L_m/W_{bkf})	**17.1**		
Radius of Curvature (R_c)	**449**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.1**		
Belt Width (W_{blt})	**1646**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**11.5**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**66116**	ft	Valley Length (VL)	**27371**	ft	Sinuosity (SL/VL)	**2.4**
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**17.6**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar
% Silt/Clay	**100**		
% Sand	**0**		
% Gravel	**0**		
% Cobble	**0**		
% Boulder	**0**		
% Bedrock	**0**		

	Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
D_{16}	**<.001**				mm
D_{35}	**<.001**				mm
D_{50}	**0.001**				mm
D_{84}	**0.005**				mm
D_{95}	**0.0095**				mm
D_{100}	**0.12**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Summary....***USGS GAGE STATION*** Data/Records for

STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River at Fargo, ND**		Station Number:	**N/A**	
LOCATION:	**Red River - 4 - 452.52**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**3659520** acres	**5718** mi^2	Drainage Area Mn ELEV:	**862.9**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:	__ __ __ __ __ __ __ __ __ __ __ __	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**159.5**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**10.3**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1633.0**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**164.4**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**2380.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**2380.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.26**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge......... =	**N/A**	cfs	**10** Year **R.I.** Discharge........ =	**N/A**	cfs
2.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**20** Year **R.I.** Discharge.........=	**N/A**	cfs
5.0 Year **R.I.** Discharge..........=	**N/A**	cfs	**50** Year **R.I.** Discharge........ =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2750**	ft	Radius of Curvature (R_C)	**581.0**	ft
Belt Width (W_{blt})	**1890**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**11.85**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$"n" = 1.4865 \left[(\text{Area}) (\text{Hydraulic Radius}^{2/3}) (\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River		Location	Red River - 4 - 452.52	
Date	11/16/2010	Stream Type	C6c-	Valley Type	X
Observers	KD, JB		HUC	0 9 0 2 0 1 0 4 0 5 0 6	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional AREA	1633.0	A_{bkf} (ft^2)	Bankfull Mean DEPTH	10.3	D_{bkf} (ft)
Bankfull WIDTH	159.5	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	180.1	W_p (ft)
D_{84} @ Riffle	0.6	Dia. (mm)	D_{84} mm / 304.8 =	0.002	D_{84} (ft)
Bankfull SLOPE	0.0002	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	9.1	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	4685	
Drainage AREA	5718.0	DA (mi^2)	Shear Velocity $u* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u*$	5.3	ft / sec	8589	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	2.4	ft / sec	3932	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	8.3	ft / sec	13593	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.035	2.4	ft / sec	3932	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.5	ft / sec	2380	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Stream: **Red River**			
Basin: **Red River Basin**	Drainage Area: **3659520** acres	**5718**	mi^2
Location: **Red River - 4 - 452.52**			
Twp.&Rge: **-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**		Date: **11/16/2010**	
Observers: **KD, JB**		Valley Type: **X**	

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**159.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**10.3**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1633.0**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**15.5**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**15.0**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**709**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**4.4**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index representsthe mean diameter of channel materials,as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0027**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00017**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.2**	

Stream Type → **C6c-** ← **See Classification Key (Figure 2-21)**

Stream: **Red River** Location: **Red River - 4 - 452.52**

Observers: **KD, JB** Date: **11/16/2010** Valley Type: **X** Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	10.3	ft	Riffle Width (W_{bkf})	159.5	ft	Riffle Area (A_{bkf})	1633.0	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	15.0	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.5	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})	1.5	ft/s				Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})	2380	cfs				Drainage Area	5718	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	2750			ft	Meander Length Ratio (L_m/W_{bkf})	17.2		
Radius of Curvature (R_c)	581			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	3.6		
Belt Width (W_{blt})	1890			ft	Meander Width Ratio (W_{blt}/W_{bkf})	11.9		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	48061	ft	Valley Length (VL)	22157	ft	Sinuosity (SL/VL)	2.2

Low Bank Height (LBH)			Max Riffle Depth			Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	
start		ft	start		ft	start	
end		ft	end		ft	end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	15.0			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.5		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	77			D_{16}	<.001				mm
% Sand	23			D_{35}	<.001				mm
% Gravel	0			D_{50}	0.0027				mm
% Cobble	0			D_{84}	0.59				mm
% Boulder	0			D_{95}	1.39				mm
% Bedrock	0			D_{100}	2				mm

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-3-440.57**			Station Number:	**N/A**
LOCATION:	**Red River-3-440.57**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**3688320** acres	**5763** mi^2	Drainage Area Mn ELEV:	**856.05**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:	_ _ _ _ _ _ _ _ _ _ _ _	

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**136.0**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**9.8**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1333.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**141.1**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**2380.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**2380.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.3**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1901**	ft	Radius of Curvature (R_C)	**280.0**	ft
Belt Width (W_{blt})	**2945**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**21.7**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.03**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-3-440.57	Location	Red River-3-440.57
Date	10/4/2011	Stream Type: C6c-	Valley Type: X
Observers	KD, JB	HUC	__ __ __ __ __ __ __ __ __ __ __ __

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	1333.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	9.8	D_{bkf} (ft)
Bankfull WIDTH	136.0	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	155.6	W_p (ft)
D_{84} @ Riffle	0.11	Dia. (mm)	D_{84} mm / 304.8 =	0.0	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	8.6	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	23752	
Drainage AREA	5763.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness: $u = [2.83 + 5.66\text{Log}\{R / D_{84}\}]u^*$	3.8	ft / sec	5026	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$; n =	1.7	ft / sec	2275	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$; n = . Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	7.1	ft / sec	9485	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$; c) Manning's 'n' from Stream Type; n = 0.03	1.7	ft / sec	2275	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.): HEC-RAS	1.8	ft / sec	2380	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$; Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Red River-3-440.57**				
Basin:	**Red River Basin**	Drainage Area:	**4E+06** acres	**5763**	mi^2
Location:	**Red River-3-440.57**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**	Date:	**10/4/2011**		
Observers:	**KD, JB**	Valley Type:	**X**		

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**136.0**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**9.8**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1333.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**13.9**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**13.5**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**619.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**4.6**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.026**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000068**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.2**	

Stream Type → **C6c-** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Red River-3-440.57**		Location: **Red River-3-440.57**	
Observers: **KD, JB**	Date: **10/4/2011**	Valley Type: **X**	Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**9.8**	ft	Riffle Width (W_{bkf})	**136.0**	ft	Riffle Area (A_{bkf})	**1333.7**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**13.5**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.8**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**2380**	cfs	Drainage Area	**5763**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1901**			ft	Meander Length Ratio (L_m/W_{bkf})	**14.0**		
Radius of Curvature (R_c)	**280**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.1**		
Belt Width (W_{blt})	**2945**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**21.7**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**108377**	ft	Valley Length (VL)	**50295**	ft	Sinuosity (SL/VL)	**2.2**	
Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**13.5**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**83**			D_{16}	**0.0125**				mm
% Sand	**15**			D_{35}	**0.023**				mm
% Gravel	**2**			D_{50}	**0.026**				mm
% Cobble	**0**			D_{84}	**0.11**				mm
% Boulder	**0**			D_{95}	**1.9**				mm
% Bedrock	**0**			D_{100}	**9.5**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-2-419.14**		Station Number:	**N/A**	
LOCATION:	**Red River-2-419.14**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**7068160** acres	**11044** mi^2	Drainage Area Mn ELEV:	**840.54**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**150.6**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**11.5**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**1725.4**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**156.9**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**2.5**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**4280.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**4280.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.21**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge……..=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2248**	ft	Radius of Curvature (R_C)	**769.0**	ft
Belt Width (W_{blt})	**3639**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.16**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.025**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-2-419.14			Location	Red River-2-419.14
Date	9/29/2011	Stream Type	C6c-	Valley Type	X
Observers	KD, JB			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	1725.4	A_{bkf} (ft^2)	Bankfull Mean DEPTH	11.5	D_{bkf} (ft)
Bankfull WIDTH	150.6	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	173.6	W_p (ft)
D_{84} @ Riffle	0.0031	Dia. (mm)	D_{84} mm / 304.8 =	0.0	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	9.9	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	977363	
Drainage AREA	11044.0	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.2	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	5.5	ft / sec	9512	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	2.3	ft / sec	3979	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	8.1	ft / sec	13938	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.025	2.3	ft / sec	3979	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	2.5	ft / sec	4280	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream: **Red River-2-419.14**			
Basin: **Red River Basin**	Drainage Area: **7E+06** acres	**11044**	mi^2
Location: **Red River-2-419.14**			
Twp.&Rge: **-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**		Date: **9/29/2011**	
Observers: **KD, JB**		Valley Type: **X**	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**150.6**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**11.5**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1725.4**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**13.1**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**16.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**790.5**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.2**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**<0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000070**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.2**	

Stream Type → **C6c-** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Red River-2-419.14** Location: **Red River-2-419.14**

Observers: **KD, JB** Date: **9/29/2011** Valley Type: **X** Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**11.5**	ft	Riffle Width (W_{bkf})	**150.6**	ft	Riffle Area (A_{bkf})	**1725.4**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**16.6**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**2.5**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**4280**	cfs	Drainage Area	**11044**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**2248**			ft	Meander Length Ratio (L_m/W_{bkf})	**14.9**		
Radius of Curvature (R_c)	**769**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**5.1**		
Belt Width (W_{blt})	**3639**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**24.2**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**56175**	ft	Valley Length (VL)	**25772**	ft	Sinuosity (SL/VL)	**2.2**	
Low Bank Height (LBH)	start	ft	Max Riffle Depth	start	ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end	ft		end	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**16.6**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**99**			D_{16}	**<.001**				mm
% Sand	**1**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**<0.001**				mm
% Cobble	**0**			D_{84}	**0.0031**				mm
% Boulder	**0**			D_{95}	**0.0625**				mm
% Bedrock	**0**			D_{100}	**0.085**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Red River-1-410.65**		Station Number:	**N/A**	
LOCATION:	**Red River-1-410.65**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**7850880** acres	**12267** mi^2	Drainage Area Mn ELEV:	**836.35**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**C6c-**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**185.2**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**11.9**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**2156.7**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**187.4**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**2.2**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**4700.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**4700.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.19**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**2066**	ft	Radius of Curvature (R_C)	**433.0**	ft
Belt Width (W_{blt})	**2330**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**12.6**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.025**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Red River-1-410.65			Location	Red River-1-410.65
Date	9/28/2011	Stream Type	C6c-	Valley Type	X
Observers	KD, JB			HUC	_ _ _ _ _ _ _ _ _ _ _ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	2156.7	A_{bkf} (ft^2)	Bankfull Mean DEPTH	11.9	D_{bkf} (ft)
Bankfull WIDTH	185.2	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	208.9	W_p (ft)
D_{84} @ Riffle	0.027	Dia. (mm)	D_{84} mm / 304.8 =	0.0001	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	10.3	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	116545	
Drainage AREA	12267.0	DA (mi^2)	Shear Velocity $\sqrt{}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u*$	4.6	ft / sec	9863	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	2.2	ft / sec	4840	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	8.2	ft / sec	17751	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.025	2.2	ft / sec	4840	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	2.2	ft / sec	4700	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Red River-1-410.65**				
Basin:	**Red River Basin**	Drainage Area:	**8E+06** acres	**12267**	mi^2
Location:	**Red River-1-410.65**				
Twp.&Rge:	**-**	Sec.&Qtr.:	**-**		
Cross-Section Monuments (Lat./Long.):	**-**	Date:	**9/28/2011**		
Observers:	**KD, JB**	Valley Type:	**X**		

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**185.2**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**11.9**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**2156.7**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**15.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**17.9**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**683.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.7**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0018**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000063**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.0**	

Stream Type **C6c-** **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Red River-1-410.65** Location: **Red River-1-410.65**

Observers: **KD, JB** Date: **9/28/2011** Valley Type: **X** Stream Type: **C6c-**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	11.9	ft	Riffle Width (W_{bkf})	185.2	ft	Riffle Area (A_{bkf})	2156.7	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	17.9	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	1.5	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				2.2	ft/s	Estimation Method	HEC-RAS	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				4700	cfs	Drainage Area	12267	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	2066			ft	Meander Length Ratio (L_m/W_{bkf})	11.2		
Radius of Curvature (R_c)	433			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	2.3		
Belt Width (W_{blt})	2330			ft	Meander Width Ratio (W_{blt}/W_{bkf})	12.6		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	65270	ft	Valley Length (VL)	33364	ft	Sinuosity (SL/VL)	2.0	
Low Bank Height (LBH)	start: / end:	ft / ft	Max Riffle Depth	start: / end:	ft / ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: / end:	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.0			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	1.0		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	17.9			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	1.5		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	98			D_{16}	<.001				mm
% Sand	2			D_{35}	<.001				mm
% Gravel	0			D_{50}	0.0018				mm
% Cobble	0			D_{84}	0.027				mm
% Boulder	0			D_{95}	0.063				mm
% Bedrock	0			D_{100}	0.23				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Maple River - 2 - 11.39**		Station Number:	**N/A**	
LOCATION:	**Maple River - 2 - 11.39**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**934400** acres	**1460** mi^2	Drainage Area Mn ELEV:	**885.5**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**72.1**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**6.5**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**463.0**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**77.0**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.4**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**650.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**650.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.16**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1831**	ft	Radius of Curvature (R_C)	**261.0**	ft
Belt Width (W_{blt})	**2333**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**32.4**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.03**	Coeff.

$$"n" = 1.4865\,[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2})] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	**Maple River - 2 - 11.39**		Location	**Maple River - 2 - 11.39**	
Date	**11/20/2010**	Stream Type: **E6**	Valley Type	**X**	
Observers	**KP, AL**		HUC	__ __ __ __ __ __ __ __ __ __ __ __	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	**463.0**	A_{bkf} (ft²)	Bankfull Mean DEPTH	**6.5**	D_{bkf} (ft)
Bankfull WIDTH	**72.1**	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	**85.1**	W_p (ft)
D_{84} @ Riffle	**0.018**	Dia. (mm)	D_{84} mm / 304.8 =	**0.0**	D_{84} (ft)
Bankfull SLOPE	**0.0001**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**5.4**	R (ft)
Gravitational Acceleration	**32.2**	g (ft / sec²)	Relative Roughness R (ft) / D_{84} (ft)	**92181**	
Drainage AREA	**1460.0**	DA (mi²)	Shear Velocity $u^* = \sqrt{gRS}$	**0.1**	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	**3.4**	ft / sec	**1573**	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	**1.3**	ft / sec	**589**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	**4.9**	ft / sec	**2268**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = .03	**1.3**	ft / sec	**589**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	**1.4**	ft / sec	**650**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Maple River - 2 - 11.39**		
Basin:	**Red River Basin**	Drainage Area: **934400** acres	**1460** mi^2
Location:	**Maple River - 2 - 11.39**		
Twp.&Rge: **-**		Sec.&Qtr.: **-**	
Cross-Section Monuments (Lat./Long.): **-**			Date: **11/20/2010**
Observers: **KP, AL**			Valley Type: **X**

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**72.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**6.5**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**463.0**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.1**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.0**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**672.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**9.3**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000069**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.7**	

Stream Type **E6**

See Classification Key (Figure 2-21)

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Maple River - 2 - 11.39**	Location:	**Maple River - 2 - 11.39**		
Observers:	**KP, AL**	Date: **11/20/2010**	Valley Type: **X**	Stream Type: **E6**	

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**6.5**	ft	Riffle Width (W_{bkf})	**72.1**	ft	Riffle Area (A_{bkf})	**463.0**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**9.0**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.4**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.4**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**650**	cfs	Drainage Area	**1460**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1831**			ft	Meander Length Ratio (L_m/W_{bkf})	**25.4**		
Radius of Curvature (R_c)	**261**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.6**		
Belt Width (W_{blt})	**2333**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**32.4**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**34852**	ft	Valley Length (VL)	**20900**	ft	Sinuosity (SL/VL)	**1.7**

Low Bank Height (LBH)	start		ft	Max Riffle Depth	start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start
	end		ft		end		ft	end

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**9.0**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.4**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	**97**			D_{16}	**<.001**				mm
% Sand	**3**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.001**				mm
% Cobble	**0**			D_{84}	**0.018**				mm
% Boulder	**0**			D_{95}	**0.07**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….***USGS GAGE STATION*** Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Maple River-1-0.78**			Station Number:	**N/A**	
LOCATION:	**Maple River-1-0.78**					
Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**948480** acres	**1482**	mi^2	Drainage Area Mn ELEV:	**874.5**	ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**	
Stream Type:	**E6**			HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**68.5**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**5.8**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**399.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**72.5**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.6**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**650.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**650.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**739**	ft	Radius of Curvature (R_C)	**153.0**	ft
Belt Width (W_{blt})	**1284**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.7**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.030**	Coeff.

$$"n" = 1.4865 [(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2})] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	**Maple River-1-0.78**			Location	**Maple River-1-0.78**
Date	**11/16/2010**	Stream Type	**E6**	Valley Type	**X**
Observers	**KP, AL**			HUC	_ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	**399.1**	A_{bkf} (ft^2)	Bankfull Mean DEPTH	**5.8**	D_{bkf} (ft)
Bankfull WIDTH	**68.5**	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	**80.2**	W_p (ft)
D_{84} @ Riffle	**1.1**	Dia. (mm)	D_{84} mm / 304.8 =	**0.0**	D_{84} (ft)
Bankfull SLOPE	**0.0001**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**5.0**	R (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	**1380**	
Drainage AREA	**1482.0**	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	**0.1**	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	**2.8**	ft / sec	**1102**	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	**1.5**	ft / sec	**610**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	**4.8**	ft / sec	**1925**	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.03	**1.5**	ft / sec	**610**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	**1.6**	ft / sec	**650**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream: **Maple River-1-0.78**			
Basin: **Red River Basin**	Drainage Area: **948480** acres	**1482**	mi^2
Location: **Maple River-1-0.78**			
Twp.&Rge: **-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.): **-**		Date: **11/16/2010**	
Observers: **KP, AL**		Valley Type: **X**	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**68.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**5.8**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**399.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**9.1**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**377.3**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.5**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0091**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00011**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**2.2**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream: **Maple River-1-0.78**		Location: **Maple River-1-0.78**	
Observers: **KP, AL**	Date: **11/16/2010**	Valley Type: **X**	Stream Type: **E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**5.8**	ft	Riffle Width (W_{bkf})	**68.5**	ft	Riffle Area (A_{bkf})	**399.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**9.1**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.6**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**650**	cfs	Drainage Area	**1482**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**739**			ft	Meander Length Ratio (L_m/W_{bkf})	**10.8**		
Radius of Curvature (R_c)	**153**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**2.2**		
Belt Width (W_{blt})	**1284**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**18.7**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**36138**	ft	Valley Length (VL)	**16792**	ft	Sinuosity (SL/VL)	**2.2**

Low Bank Height (LBH)	start		ft	Max Riffle Depth	start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start	
	end		ft		end		ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**9.1**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**57**			D_{16}	**<.001**				mm
% Sand	**33**			D_{35}	**0.0019**				mm
% Gravel	**0**			D_{50}	**0.0091**				mm
% Cobble	**0**			D_{84}	**1.1**				mm
% Boulder	**0**			D_{95}	**2.96**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.

[b] Composite sample of riffles and pools within the designated reach.

[c] Active bed of a riffle.

[d] Height of roughness feature above bed.

Summary….*USGS GAGE STATION* Data/Records for
STREAM CHANNEL CLASSIFICATION

Station NAME:	**Lower Rush River-2-6.03**	Station Number:	**N/A**
LOCATION:	**Lower Rush River-2-6.03**		

Period of RECORD:	**N/A**	yrs		Mean Annual DISCHARGE:	**N/A**	cfs	
Drainage AREA:	**34144**	acres	**53.4**	mi^2	Drainage Area Mn ELEV:	**N/A**	ft
Reference REACH SLOPE:		ft/ft		Valley Type:	**X**		
Stream Type:	**B6c**			HUC:	_ _		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**63.1**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**1.6**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**108.6**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**63.6**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**0.7**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**60.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**60.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.1**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**1532**	ft	Radius of Curvature (R_C)	**230.0**	ft
Belt Width (W_{blt})	**663**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**10.5**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.06**	Coeff.

$$"n" = 1.4865 [(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2})] / Q_{bkf}$$

Bankfull VELOCITY / DISCHARGE Estimates

Site	Lower Rush River-2-6.04			Location	Lower Rush River-2-6.03
Date	11/18/2010	Stream Type	B6c	Valley Type	X
Observers	KP, AL			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional AREA	108.6	A_{bkf} (ft^2)	Bankfull Mean DEPTH	1.6	D_{bkf} (ft)
Bankfull WIDTH	63.1	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	66.4	W_p (ft)
D_{84} @ Riffle	0.032	Dia. (mm)	D_{84} mm / 304.8 =	0.0001	D_{84} (ft)
Bankfull SLOPE	0.0001	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.6	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	15588	
Drainage AREA	53.4	DA (mi^2)	Shear Velocity $u* = \sqrt{gRS}$	0.06	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u*$	1.6	ft / sec	171	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865*R^{2/3}*S^{1/2}/n$ n =	0.3	ft / sec	33	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39S^{.38}R^{-.16}$ n = **Note:** This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	1.8	ft / sec	196	cfs
2. Roughness Coefficient: $u = 1.4865* R^{2/3}*S^{1/2}/n$ c) Manning's 'n' from Stream Type n = 0.055	0.3	ft / sec	33	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	0.7	ft / sec	60	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Stream:	**Lower Rush River**		
Basin:	**Red River Basin**	Drainage Area: **34144** acres	**53.4** mi^2
Location:	**Lower Rush River-2-6.03**		
Twp.&Rge:	**-**	Sec.&Qtr.: **-**	
Cross-Section Monuments (Lat./Long.):	**-**		Date: **11/18/2010**
Observers:	**KP, AL**		Valley Type: **X**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**63.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.6**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**108.6**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**38.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.9**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**90.5**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.4**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0019**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.000066**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.3**	

Stream Type → **B6c** ← **See Classification Key (Figure 2-21)**

Stream: **Lower Rush River**		Location: **Lower Rush River-2-6.03**	
Observers: **KP, AL**	Date: **11/18/2010**	Valley Type: **X**	Stream Type: **B6c**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**1.6**	ft	Riffle Width (W_{bkf})	**63.1**	ft	Riffle Area (A_{bkf})	**108.6**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**2.9**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.8**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**0.7**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**60**	cfs	Drainage Area	**53.4**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**1532**			ft	Meander Length Ratio (L_m/W_{bkf})	**24.3**		
Radius of Curvature (R_c)	**230**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**3.6**		
Belt Width (W_{blt})	**663**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**10.5**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)		
Stream Length (SL)	**37133**	ft	Valley Length (VL)	**29667**	ft	Sinuosity (SL/VL)	**1.3**	
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start		
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end		

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**2.9**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.8**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**97**			D_{16}	**<.001**				mm
% Sand	**3**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0019**				mm
% Cobble	**0**			D_{84}	**0.032**				mm
% Boulder	**0**			D_{95}	**0.058**				mm
% Bedrock	**0**			D_{100}	**2**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Lower Rush River-1-1.10**		Station Number:	**N/A**	
LOCATION:	**Lower Rush River-1-1.10**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**38009.6** acres	**59.4** mi^2	Drainage Area Mn ELEV:	**880.9**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**B6c**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**45.3**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**1.8**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**80.5**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**45.8**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**0.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**65.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**65.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.1**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)		ft	Radius of Curvature (R_C)		ft
Belt Width (W_{blt})		ft	Meander Width Ratio (W_{blt}/W_{bkf})	**0.00**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.05**	Coeff.

"**n**" = 1.4865 **[**(**Area**) (Hydraulic **Radius** $^{2/3}$) (**Slope** $^{1/2}$)**]** / Q_{bkf}

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Lower Rush River-1-1.10			Location	Lower Rush River-1-1.10
Date	9/29/2011	Stream Type	B6c	Valley Type	X
Observers	KP, AL			HUC	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	80.5	A_{bkf} (ft^2)	Bankfull Mean DEPTH	1.8	D_{bkf} (ft)
Bankfull WIDTH	45.3	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	48.9	W_p (ft)
D_{84} @ Riffle	0.0022	Dia. (mm)	D_{84} mm / 304.8 =	0.0	D_{84} (ft)
Bankfull SLOPE	0.0003	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	1.6	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	228195	
Drainage AREA	59.4	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.1	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 \text{Log}\{R / D_{84}\}] u^*$	4.5	ft / sec	360	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	0.8	ft / sec	62	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	2.2	ft / sec	178	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = .050	0.8	ft / sec	62	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	0.8	ft / sec	65	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Lower Rush River-1-1.10**			
Basin:	**Red River Basin**	Drainage Area: **38010** acres	**59.4**	mi^2
Location:	**Lower Rush River-1-1.10**			
Twp.&Rge:	**-**	Sec.&Qtr.: **-**		
Cross-Section Monuments (Lat./Long.):	**-**		Date:	**9/29/2011**
Observers:	**KP, AL**		Valley Type:	**X**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**45.3**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section (d_{bkf} = A / W_{bkf}).	**1.8**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**80.5**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**25.5**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.9**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**72.2**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.6**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**<0.001**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0003**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).		

Stream Type **B6c** **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Lower Rush River-1-1.10**			Location:	**Lower Rush River-1-1.10**		
Observers:	**KP, AL**	Date:	**9/29/2011**	Valley Type:	**X**	Stream Type:	**B6c**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**1.8**	ft	Riffle Width (W_{bkf})	**45.3**	ft	Riffle Area (A_{bkf})	**80.5**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**2.9**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.6**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**0.8**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**65**	cfs	Drainage Area	**59.4**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**0**			ft	Meander Length Ratio (L_m/W_{bkf})	**0.0**		
Radius of Curvature (R_c)	**0**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**0.0**		
Belt Width (W_{blt})	**0**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**0.0**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**37133**	ft	Valley Length (VL)	**29667**	ft	Sinuosity (SL/VL)	**1.3**
Low Bank Height (LBH)	start: ft; end: ft		Max Riffle Depth	start: ft; end: ft		Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)	start: ; end:

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**2.9**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.6**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**99**			D_{16}	**<0.001**				mm
% Sand	**1**			D_{35}	**<0.001**				mm
% Gravel	**0**			D_{50}	**<0.001**				mm
% Cobble	**0**			D_{84}	**0.0022**				mm
% Boulder	**0**			D_{95}	**0.028**				mm
% Bedrock	**0**			D_{100}	**0.2**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.

[b] Composite sample of riffles and pools within the designated reach.

[c] Active bed of a riffle.

[d] Height of roughness feature above bed.

Worksheet 2-1. Gage station and field data (Rosgen and Silvey, 2007).

Summary….*USGS GAGE STATION* Data/Records for STREAM CHANNEL CLASSIFICATION

Station NAME:	**Wolverton Creek-2-2.02**		Station Number:	**N/A**	
LOCATION:	**Wolverton Creek-2-2.02**				
Period of RECORD:	**N/A**	yrs	Mean Annual DISCHARGE:	**N/A**	cfs
Drainage AREA:	**63443.2** acres	**99.13** mi^2	Drainage Area Mn ELEV:	**893.45**	ft
Reference REACH SLOPE:		ft/ft	Valley Type:	**X**	
Stream Type:	**E6**		HUC:		

"BANKFULL" CHARACTERISTICS

Determined from FIELD MEASUREMENT			Determined from GAGE DATA Analysis		
Bankfull WIDTH (W_{bkf})	**24.2**	ft	Bankfull WIDTH (W_{bkf})		ft
Bankfull Mean DEPTH (d_{bkf})	**3.2**	ft	Bankfull MEAN DEPTH (d_{bkf})		ft
Bankfull Xsec AREA (A_{bkf})	**73.1**	ft^2	Bankfull Xsec AREA (A_{bkf})		ft^2
Wetted PERIMETER (W_p)	**27.4**	ft	Wetted PERIMETER (W_p)		ft
Bankfull STAGE (Gage Ht)		ft	Bankfull STAGE (Gage Ht)		ft
Est. Mean VELOCITY (u)	**1.8**	ft/sec	Mean VELOCITY (u)		ft/sec
Est. Bkf. DISCHARGE (Q_{bkf})	**130.0**	cfs	Bankfull DISCHARGE (Q_{bkf})		cfs

Bankfull DISCHARGE associated with **"field-determined"** Bankfull STAGE	**130.0**	cfs
Recurrence Interval (Log-Pearson) associated with **"field-determined"** Bankfull Discharge	**1.2**	yrs

From the *Annual Peak Flow Frequency Analysis* data for the Gage Station, determine:

1.5 Year **R.I.** Discharge……… =	**N/A**	cfs	**10** Year **R.I.** Discharge…….. =	**N/A**	cfs
2.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**25** Year **R.I.** Discharge………=	**N/A**	cfs
5.0 Year **R.I.** Discharge……….=	**N/A**	cfs	**50** Year **R.I.** Discharge…….. =	**N/A**	cfs

MEANDER GEOMETRY

Meander Length (L_m)	**625**	ft	Radius of Curvature (R_C)	**171.0**	ft
Belt Width (W_{blt})	**207**	ft	Meander Width Ratio (W_{blt}/W_{bkf})	**8.6**	ft/ft

HYDRAULIC GEOMETRY

Based on *USGS Discharge Summary Notes* data (Form 9-207) and regression analyses of measured discharge (**Q**) with the hydraulic parameters of Width (**W**), Area (**A**), Mean Depth (**d**) & Mean Velocity (**u**), determine the *intercept coefficient* (**a**) and the *slope exponent* (**b**) values for a power function of the form $Y = aX^b$, when **Y** is one of the selected hydraulic parameters and **X** is a given discharge value (**Q**).

	Width (**W**)	Depth (**d**)	Area (**A**)	Velocity (**u**)
Intercept Coefficient: (**a**)				
Slope Exponent: (**b**)				

Hydraulic Radius: $R = A / W_p$		ft	**Manning's "n"** at Bankfull Stage	**0.035**	Coeff.

$$"n" = 1.4865 \left[(\text{Area})(\text{Hydraulic Radius}^{2/3})(\text{Slope}^{1/2}) \right] / Q_{bkf}$$

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY / DISCHARGE Estimates

Site	Wolverton Creek-2-2.02			Location	Wolverton Creek-2-2.02
Date	9/28/2011	Stream Type	E6	Valley Type	X
Observers	KP, AL			HUC	_ _

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Cross-sectional	73.1	A_{bkf} (ft^2)	Bankfull Mean DEPTH	3.2	D_{bkf} (ft)
Bankfull WIDTH	24.2	W_{bkf} (ft)	Wetted PERIMETER ~ $2 * d_{bkf} + W_{bkf}$	30.5	W_p (ft)
D_{84} @ Riffle	0.039	Dia. (mm)	D_{84} mm / 304.8 =	0.00	D_{84} (ft)
Bankfull SLOPE	0.0011	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	2.4	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R (ft) / D_{84} (ft)	18714	
Drainage AREA	99.1	DA (mi^2)	Shear Velocity $u^* = \sqrt{gRS}$	0.3	u* (ft / sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 Log\{R / D_{84}\}] u^*$	7.9	ft / sec	575	cfs
2. Roughness Coefficient: a) Manning's 'n' from friction factor / relative roughness (Figs. 2-18, 19) $u = 1.4865 * R^{2/3} * S^{1/2} / n$ n =	2.5	ft / sec	184	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ b) Manning's 'n' from Jarrett (USGS): $n = 0.39 S^{.38} R^{-.16}$ n = Note: This equation is for applications involving **steep, step-pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for stream types A1, A2, A3, B1, B2, B3, C2 and E3.	3.5	ft / sec	253	cfs
2. Roughness Coefficient: $u = 1.4865 * R^{2/3} * S^{1/2} / n$ c) Manning's 'n' from Stream Type n = 0.035	2.5	ft / sec	184	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) HEC-RAS	1.8	ft / sec	130	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.)		ft / sec		cfs
4. Continuity Equations: a) Regional Curves u = Q / A Return Period for Bankfull Discharge Q = 1.46 Yr.		ft / sec		cfs
4. Continuity Equations: b) USGS Gage Data u = Q / A		ft / sec		cfs

Options for using the D_{84} term in the relative roughness relation (R/D_{84}), when using estimation method 1.

Option 1. For **sand-bed** channels: Measure the **"protrusion height"** (h_{sd}) of sand dunes above channel bed elevations. Substitute an average sand dune protrusion height (h_{sd} in ft) for the D_{84} term in est. method 1.

Option 2. For **boulder-dominated** channels: Measure several **"protrusion heights"** (h_{bo}) of boulders above channel bed elevations. Substitute an ave. boulder protrusion height (h_{bo} in ft) for the D_{84} term in est. method 1.

Option 3. For **bedrock-dominated** channels: Measure several **"protrusion heights"** (h_{br}) of rock separations/steps/joints/ uplifted surfaces above channel bed elevations. Substitute an average bedrock protrusion height (h_{br} in feet) for the D_{84} term in estimation method 1.

Worksheet 2-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen , 2006b).

Stream:	**Wolverton Creek-2-2.02**				
Basin:	**Red River Basin**	Drainage Area: **63443** acres		**99.13**	mi^2
Location:	**Wolverton Creek-2-2.02**				
Twp.&Rge: **-**		Sec.&Qtr.: **-**			
Cross-Section Monuments (Lat./Long.): **-**				Date: **9/28/2011**	
Observers: **KP, AL**				Valley Type: **X**	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**24.2**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**3.2**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**73.1**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**7.6**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**4.8**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**129.0**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**5.3**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.0016**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0011**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.3**	

Stream Type → **E6** ← **See Classification Key (Figure 2-21)**

Worksheet 2-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen, 2006b; Rosgen and Silvey 2007).

Stream:	**Wolverton Creek-2-2.02**		Location:	**Wolverton Creek-2-2.02**			
Observers:	**KP, AL**	Date:	**9/28/2011**	Valley Type:	**X**	Stream Type:	**E6**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	**3.2**	ft	Riffle Width (W_{bkf})	**24.2**	ft	Riffle Area (A_{bkf})	**73.1**	ft^2
Mean Pool Depth (d_{bkfp})		ft	Pool Width (W_{bkfp})		ft	Pool Area (A_{bkfp})		ft^2
Mean Pool Depth/Mean Riffle Depth		d_{bkfp}/d_{bkf}	Pool Width/Riffle Width		W_{bkfp}/W_{bkf}	Pool Area / Riffle Area		A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	**4.8**	ft	Max Pool Depth (d_{maxp})		ft	Max Riffle Depth/Mean Riffle Depth	**1.5**	
Max Pool Depth/Mean Riffle Depth			Point Bar Slope		ft/ft	Inner Berm Width (W_{ib})		ft
Inner Berm Depth (d_{ib})		ft	Inner Berm Width/Depth Ratio		W_{ib}/d_{ib}	Inner Berm Area (A_{ib})		ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				**1.8**	ft/s	Estimation Method	**HEC-RAS**	
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				**130**	cfs	Drainage Area	**99.1**	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	**625**			ft	Meander Length Ratio (L_m/W_{bkf})	**25.8**		
Radius of Curvature (R_c)	**171**			ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	**7.1**		
Belt Width (W_{blt})	**207**			ft	Meander Width Ratio (W_{blt}/W_{bkf})	**8.6**		
Individual Pool Length				ft	Pool Length/Riffle Width			
Pool to Pool Spacing				ft	Pool to Pool Spacing/Riffle Width			
Riffle Length				ft	Riffle Length/Riffle Width			

Channel Profile

Valley Slope (VS)		ft/ft	Average Water Surface Slope (S)		ft/ft	Sinuosity (VS/S)	
Stream Length (SL)	**23172**	ft	Valley Length (VL)	**18342**	ft	Sinuosity (SL/VL)	**1.3**
Low Bank Height (LBH) start		ft	Max Riffle Depth start		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) start	
Low Bank Height (LBH) end		ft	Max Riffle Depth end		ft	Bank-Height Ratio (BHR) (LBH/Max Riffle Depth) end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	**0.0**			ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	**1.0**		
Run Slope (S_{run})				ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)			
Pool Slope (S_p)				ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)			
Glide Slope (S_g)				ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)			

Feature Midpoint [a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	**4.8**			ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	**1.5**		
Max Run Depth (d_{maxrun})				ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})			
Max Pool Depth (d_{maxp})				ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})			
Max Glide Depth (d_{maxg})				ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})			

Channel Materials

	Reach [b]	Riffle [c]	Bar		Reach [b]	Riffle [c]	Bar	Protrusion Height [d]	
% Silt/Clay	**91**			D_{16}	**<.001**				mm
% Sand	**9**			D_{35}	**<.001**				mm
% Gravel	**0**			D_{50}	**0.0016**				mm
% Cobble	**0**			D_{84}	**0.039**				mm
% Boulder	**0**			D_{95}	**0.22**				mm
% Bedrock	**0**			D_{100}	**4.75**				mm

[a] Min, max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.