Stream Channel Succession and Sediment Yield

Black Vermillion River, Kansas

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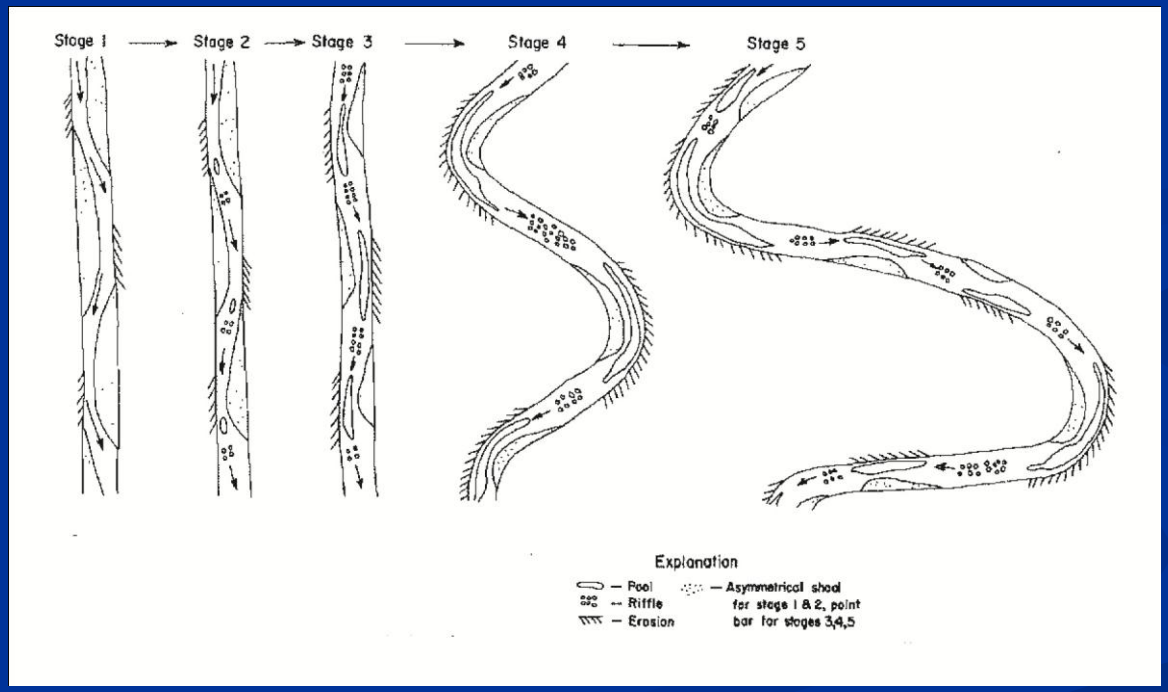
Geomorphic Channel Evolution/Succession

"…alluvial channels in different environments, destabilized by different natural and human-induced disturbances, pass through a sequence of channel forms with time…These systematic temporal adjustments are collectively termed 'channel evolution' and permit interpretation of past and present channel processes, and prediction of future channel processes."

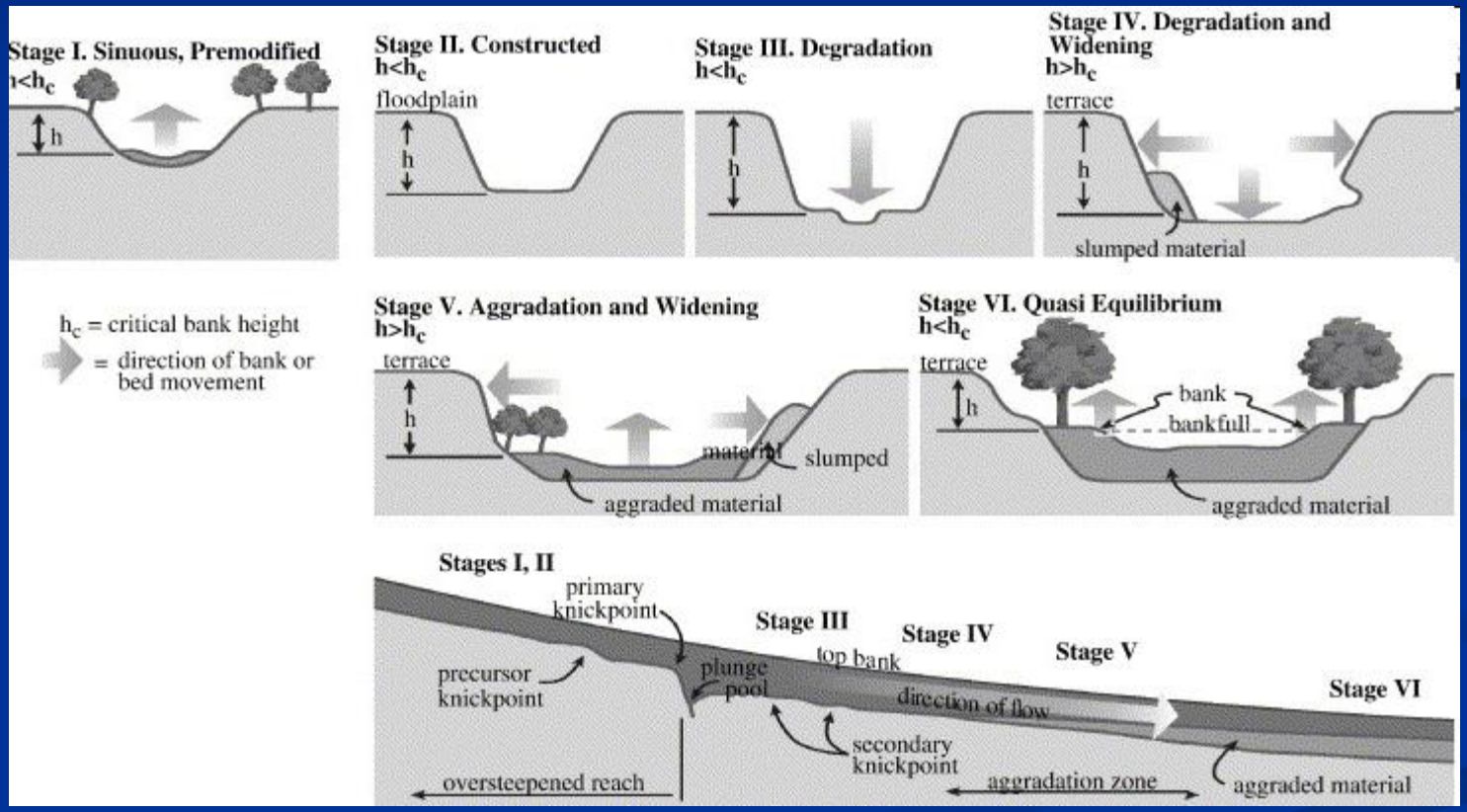
(Simon & Rinaldi, 2000)

Prevailing Evolutionary/ Successional Models

Keller's Five Stage model of fluvial stream channels. (Keller, 1972)

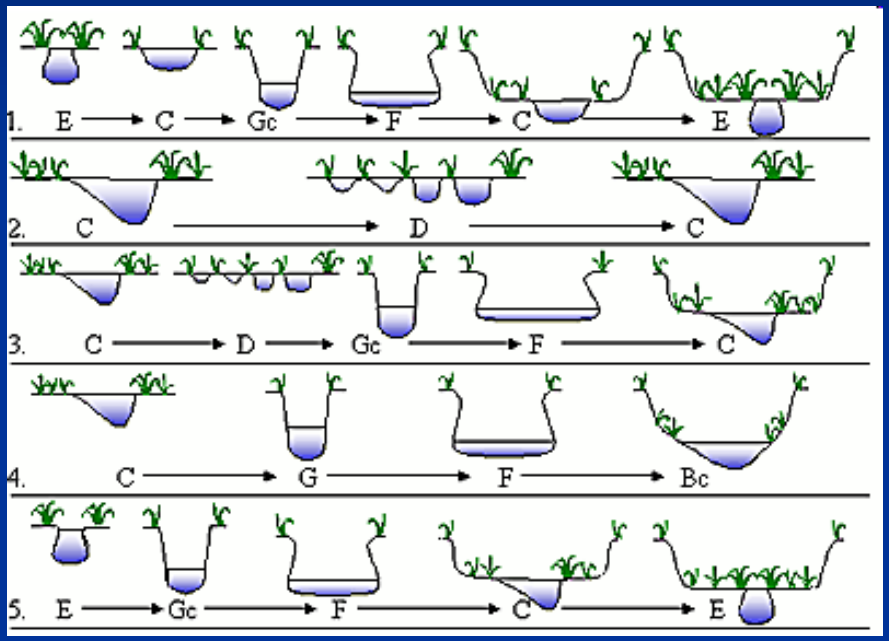


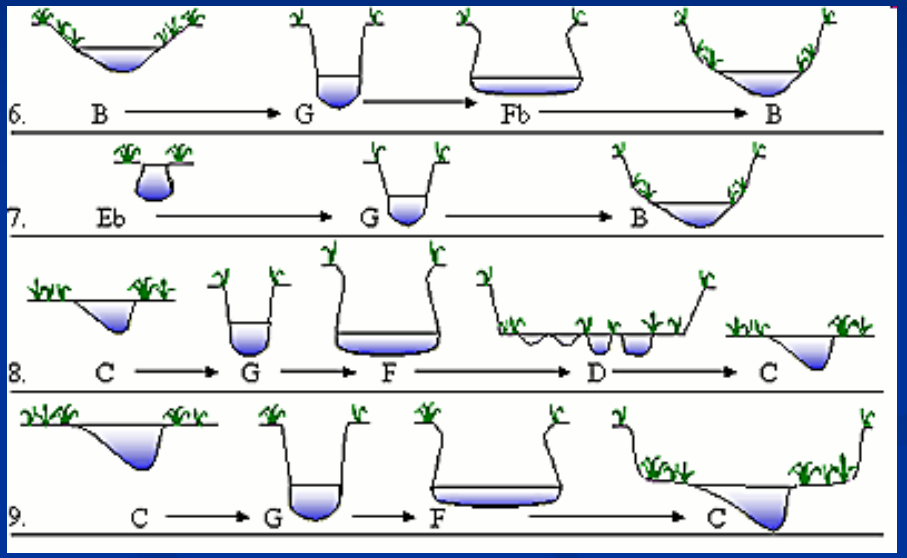
Schumm, Harvey, Watson (1984)
Simon & Hupp (1986)



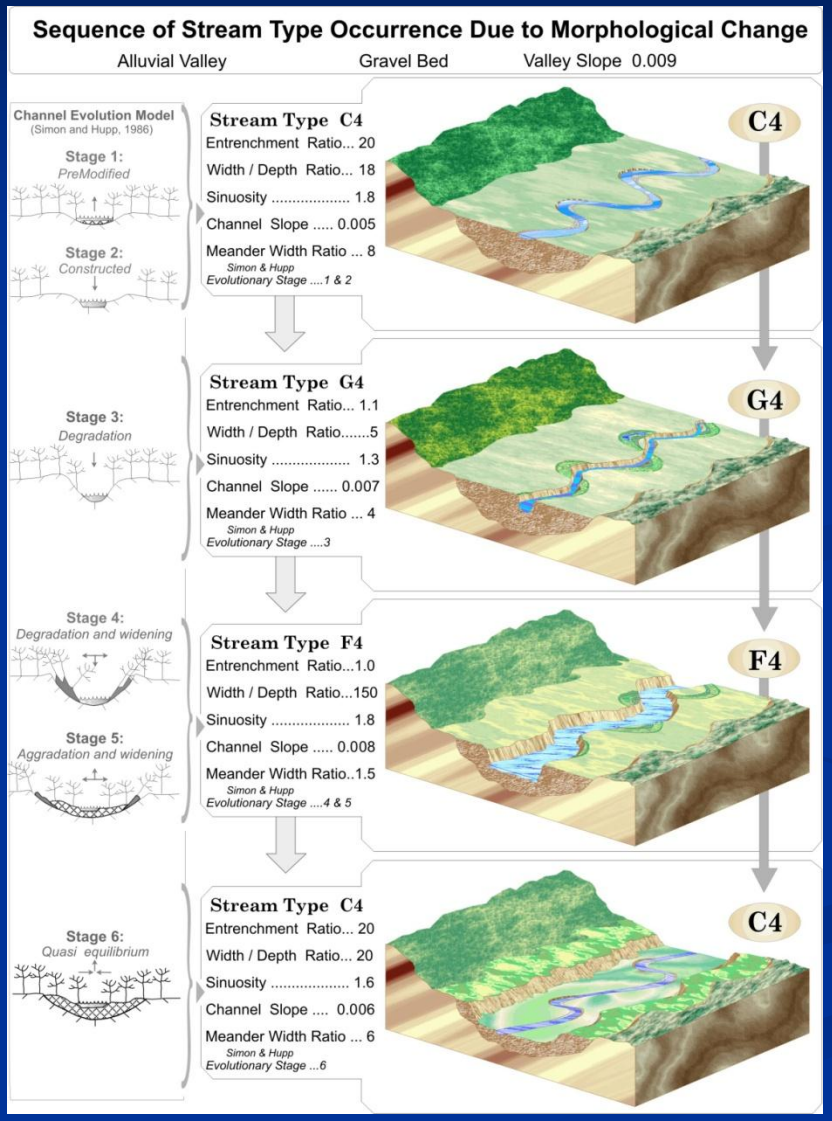
Simon & Hupp, 1986

Rosgen Successional Sequences



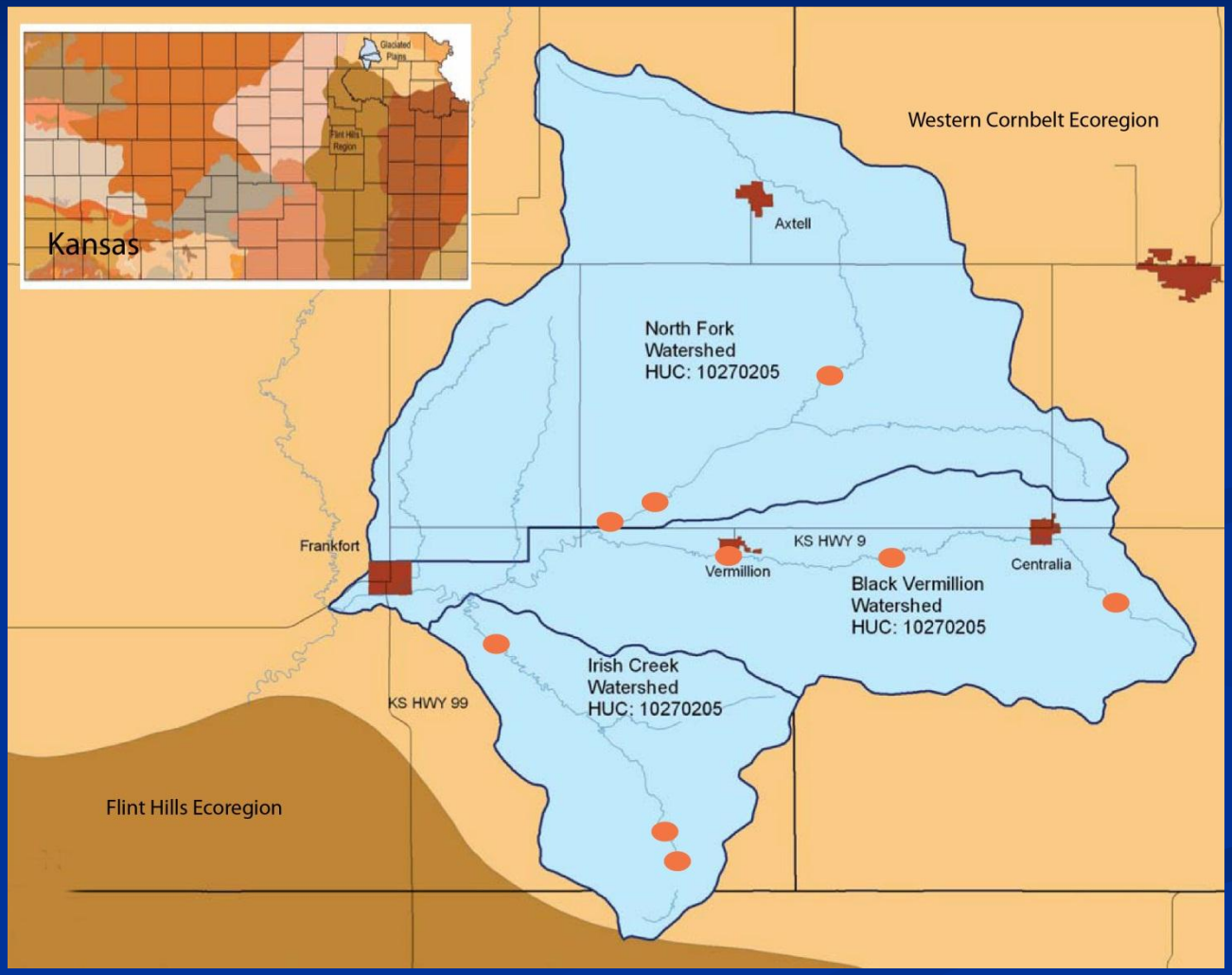


Debate and Speculation



Complements of Wildland Hydrology

Black Vermillion Watershed and study area (ovals illustrate study reach locations)

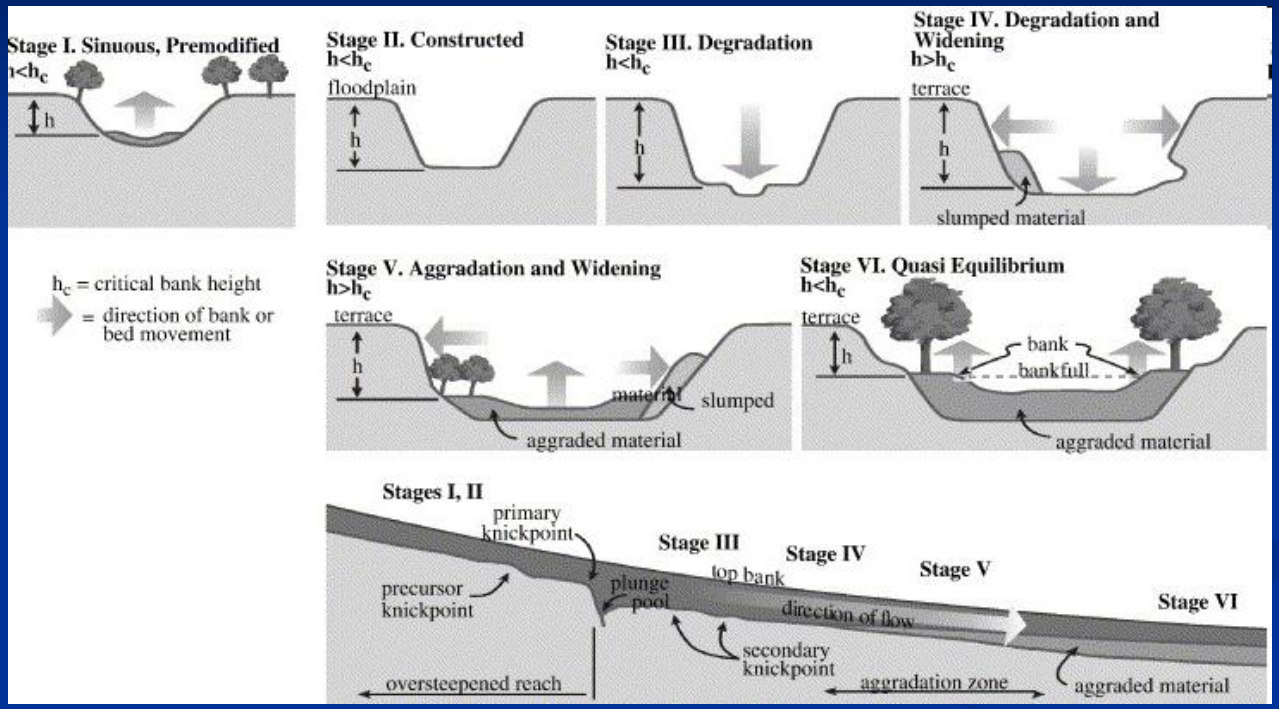


Black Vermillion Study Reach Characteristics

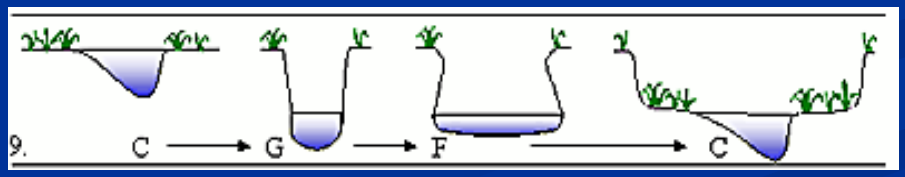
	Rosgen Stream Type	D_{50} (mm)	W_{bkf} (m)	W/D	Entren-chment ratio	Slope (m/m)	K	Reach Length (m)	Average Bank Height (m)
Main Stem 1	G5c	0.82	10.3	8.8	1.5	0.0015	1.2	317	4.27
Main Stem2	G5c	10.25	11.5	8.8	1.5	0.0014	1.2	473	4.60
Main Stem 3	F5	9.13	14.1	13.5	1.3	0.0007	1.2	415	5.73
North Fork 1	G5c	2.92	13.9	7.1	1.6	0.0013	1.2	511	6.31
North Fork 2	G5c	2.78	19.5	10.9	1.5	0.0008	1	697	4.94
North Fork 3	G5c	1.86	20.5	10.6	1.5	0.0013	1.2	622	4.91
Irish Creek 1	G4c	6.98	10.3	9.9	1.4	0.0014	1.3	376	5.15
Irish Creek 2	G4c	18.86	13.6	8.7	1.2	0.0017	1.3	510	6.74
Irish Creek 3	B5c*	0.35	13.0	7.7	2.1	0.0006	1.3	525	5.24

* Irish Creek 3 classified as a B5c at chosen riffle; however, the reach alternates stream classification between B5c and G5c. W_{bkf} = Width at bankfull (1.5-year recurrence interval); W/D = width/depth ratio; K = Sinuosity.

Stage / Scenario

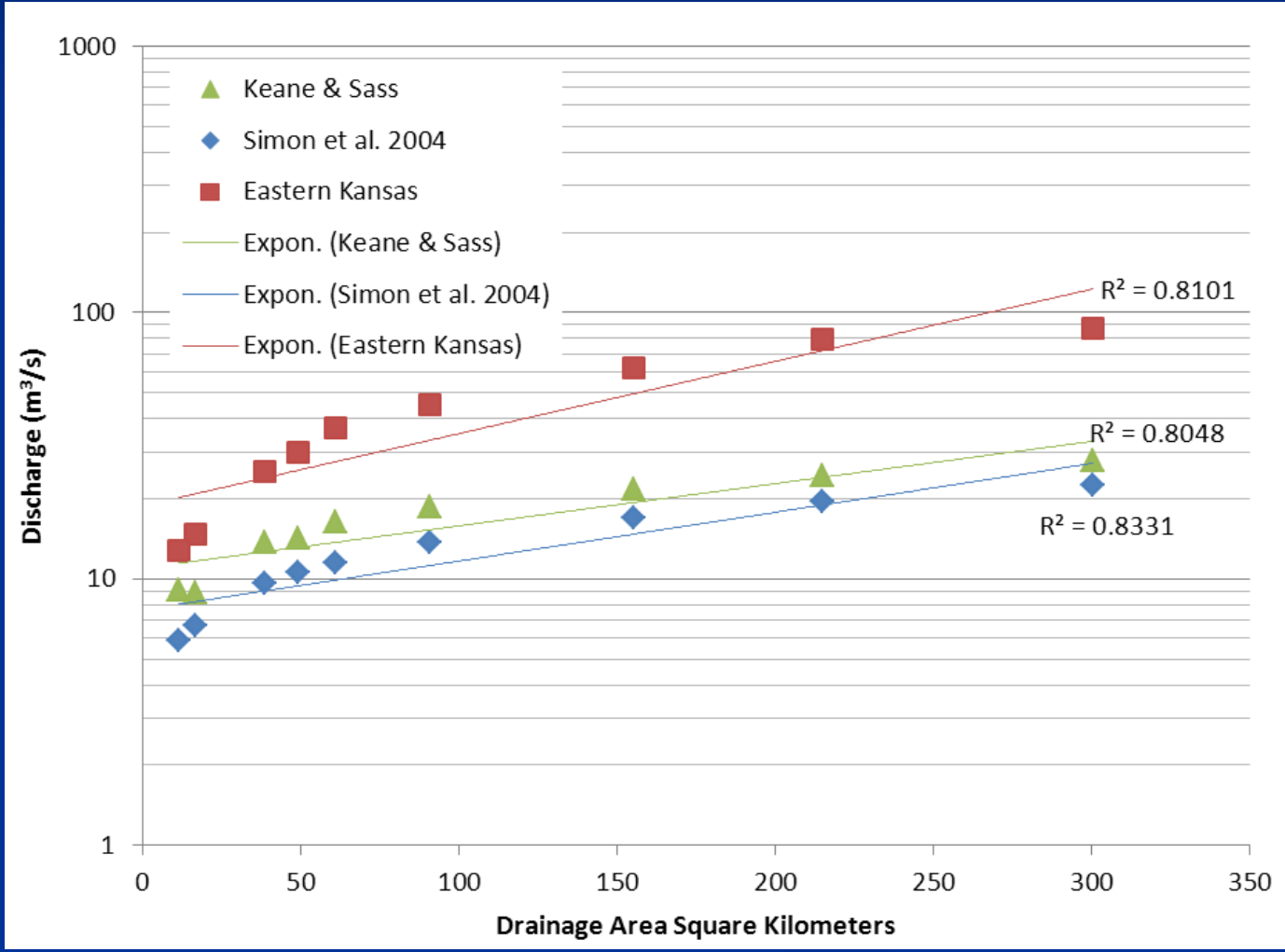


Simon & Hupp, 1986



Rosgen, 2006

Expected bankfull (1.5-year) recurrence discharge

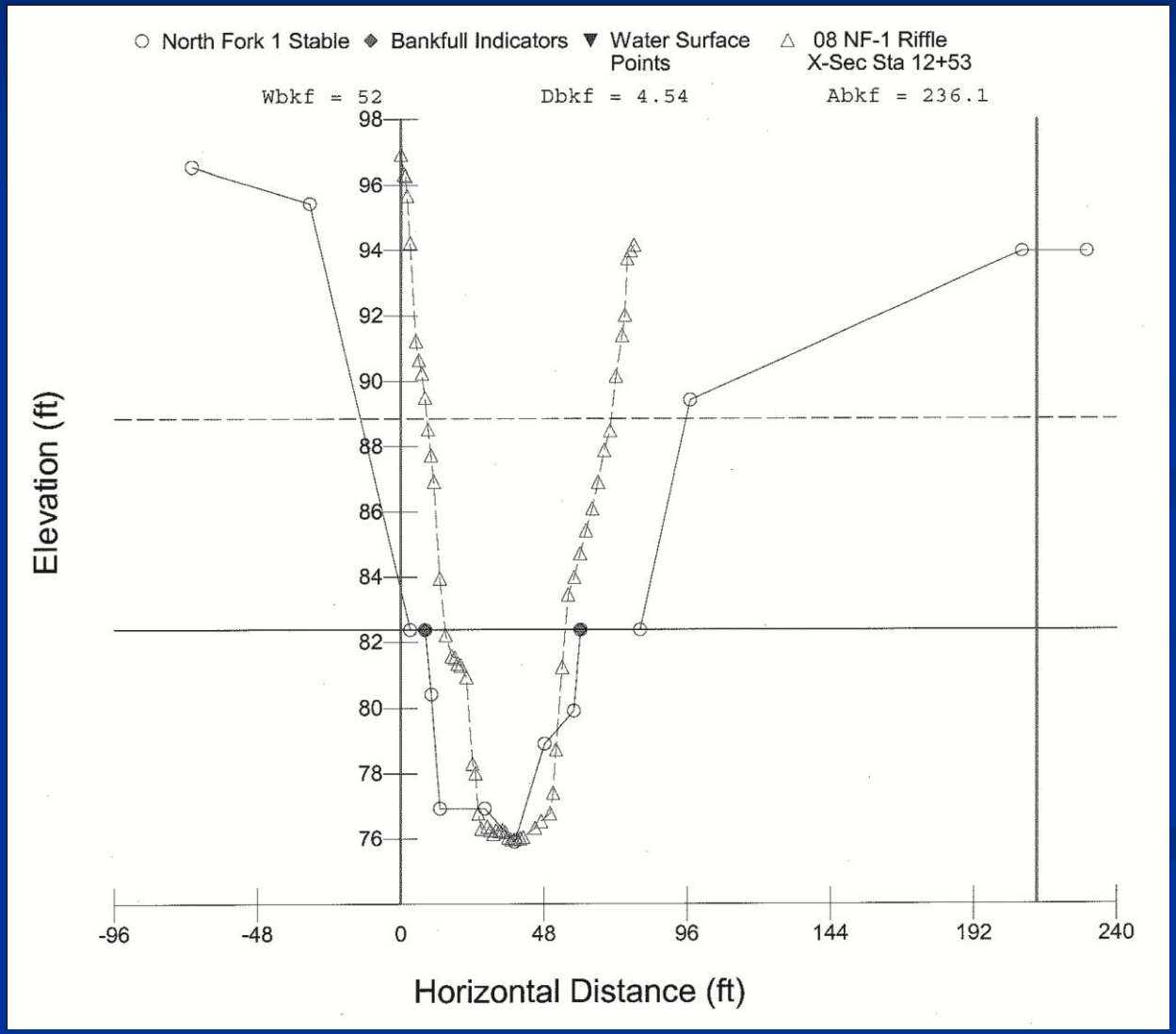


Design parameters and dimensions

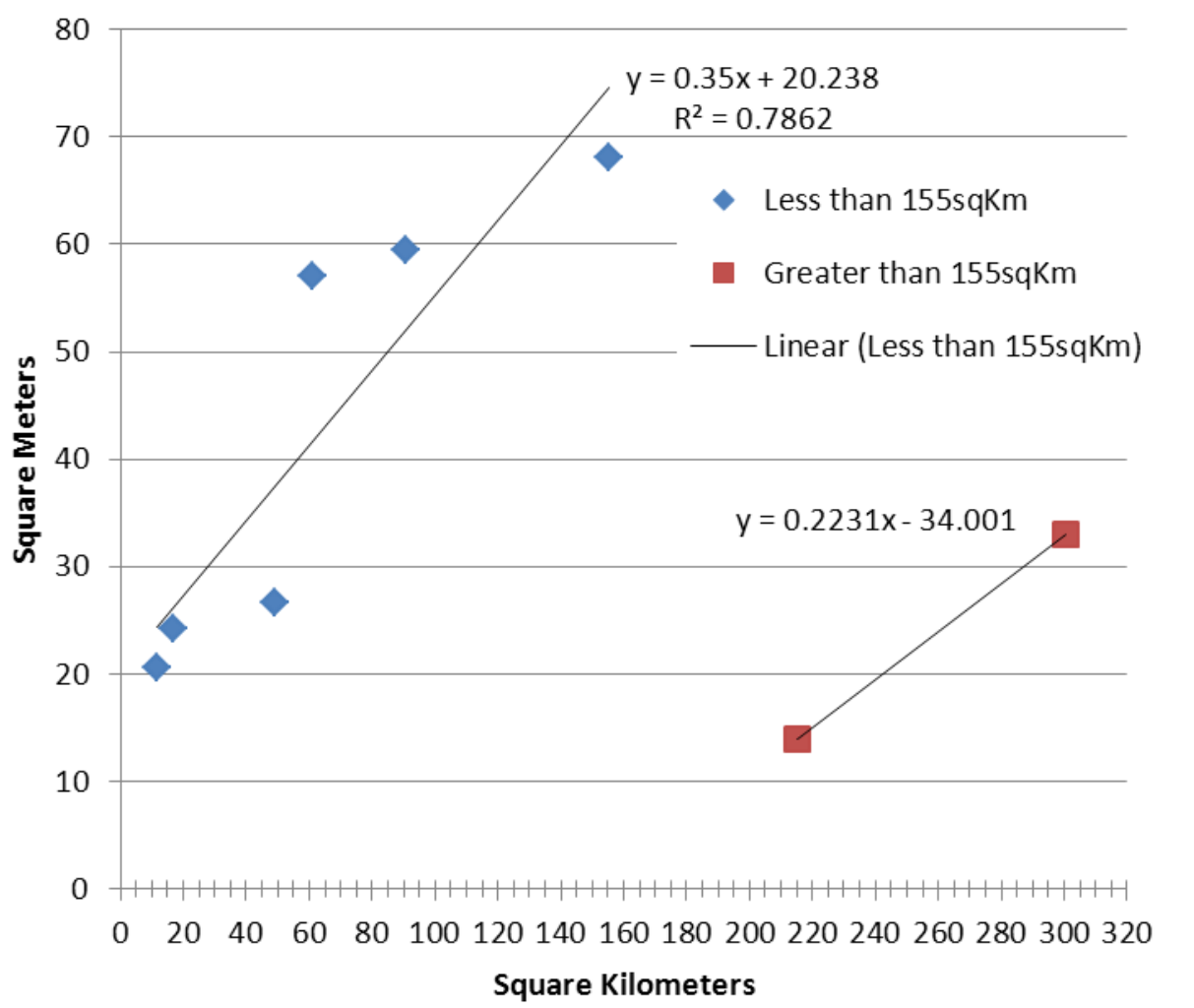
	IC 1	IC2	IC3	NF1	NF2	NF3	BV1	BV2	BV3
DA (sq. Km)	11.61	38.7	60.63	154.8	214.14	299.28	16.77	49.02	90.30
Q_{bkf} (m)	6.4	9.7	11.6	15.36	17.3	19.6	6.3	10	13.2
Entrenchment ratio	~1.7	2.0-2.2	2.0-2.2	2.0-2.2	2.0-2.2	2.0-2.2	~1.7	2.0-2.2	2.0-2.2
W/D ratio	>10	10-12	>10	10-12	10-12	10-12	10-12	10-12	10-12
W_{bkf} (m)	10.4	11.4	11.4	15.2	14.9	17.7	8.8	11.6	12.5
D_{mean} (m)	0.9	1.0	1.1	1.5	1.4	1.5	0.9	1.2	1.0
D_{max} (m)	1.4	1.4	1.5	2.0	1.8	2.0	1.8	1.5	1.5
W_{fpa} (m)	18.3	24.4	24.1	41.1	31.4	36.6	15.2	24.4	27.4
LBH (m)	1.4	1.4	1.5	2.0	2.3	2.0	1.8	1.5	1.5
MWR	~4	4.0-3.5	9.12	4.8	4.8	4.8	2.96	>4.8	4.8
Beltwidth (m)	30.5	54.9	103.6	73.2	71.6	85.3	26.2	55.8	76.2

***Key:** DA = Drainage area; Q_{bkf} = Bankfull discharge ($Q_{1.5}$); W_{bkf} = Width at bankfull; D_{mean} = Depth mean; D_{max} = Depth max; W_{fpa} = Width of flood prone area (depth at twice max depth of riffle); LBH = Low bank height; MWR = Meander width ratio.

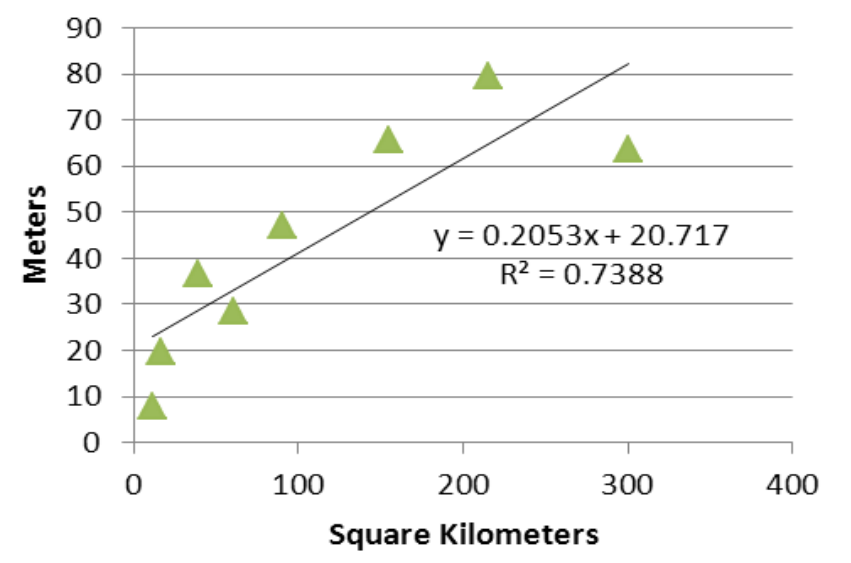
Overlay of designed cross-section and existing cross-section. Note existing bed elevation is used as bed elevation of designed channel. End of designed channel is suggested beginning line of agricultural production.



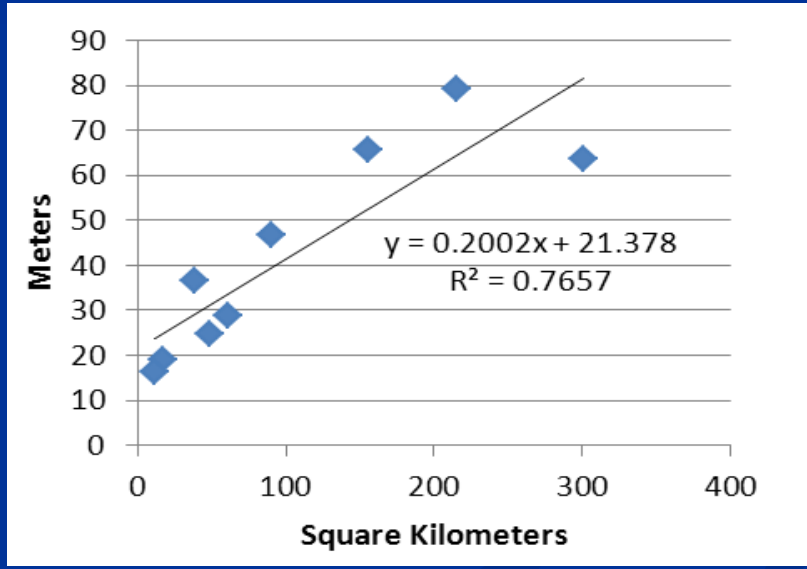
Predicted cross-sectional area change according to drainage basin area. Drainage area less than 155Km^2 are illustrated as diamonds and drainage area greater than 155Km^2 are illustrated as squares



Expected belt width change. Belt width was used at reaches that had been straightened by channelization.



Expected top width change. Top width was used at reaches that had sinuosity greater than 1.2 but were entrenched and required additional floodplain area.



Irish Creek sediment estimations for *total drainage areas subtracting watershed area controled by flood control structures*.

Mile Marker	DA (sqmi)	Cross-sectional Change (sqft)	Cubic feet	Acre feet	Tons	Metric Tons
1	0.78	225.21	1,189,120	27.30	53,510	48,694
2	1.69	234.08	1,235,950	28.37	55,618	50,612
3	0.09	218.49	1,153,612	26.48	51,913	47,240
4*	3.12	248.02	1,309,539	30.06	58,929	53,626
5*	4.69	263.32	1,390,333	31.92	62,565	56,934
6	7.24	288.17	1,521,558	34.93	68,470	62,308
7	8.38	299.28	1,580,224	36.28	71,110	64,710
8	12.7	341.39	1,802,535	41.38	81,114	73,814
9	13.73	351.43	1,855,540	42.60	83,499	75,984
10	15.25	366.24	1,933,761	44.39	87,019	79,188
11	17.03	383.59	2,025,362	46.50	91,141	82,939
12	17.46	387.78	2,047,490	47.00	92,137	83,845
13	18.36	396.55	2,093,805	48.07	94,221	85,741
14*	19.44	407.08	2,149,383	49.34	96,722	88,017
15	21.46	426.77	2,253,334	51.73	101,400	92,274
		Totals	25,541,56	586.35	1,149,368	1,045,926

* indicates measured stream reach locations

Irish Creek sediment estimations for *total drainage areas not counting control structures*.

Mile Marker	DA (sqmi)	Cross-sectional Change (sqft)	Cubic feet	Acre feet	Tons	Metric Tons
1	0.78	225.21	1,189,120	27.30	53,510	48,694
2	1.69	234.08	1,235,950	28.37	55,618	50,612
3	3.43	251.04	1,325,492	30.43	59,647	54,279
4*	8.22	297.73	1,571,990	36.09	70,740	64,373
5*	12.93	343.63	1,814,371	41.65	81,647	74,299
6	22.66	438.46	2,315,087	53.15	104,179	94,803
7	24.04	451.91	2,386,103	54.78	107,375	97,711
8	33.84	547.43	2,890,421	66.35	130,069	118,363
9	37.26	580.76	3,066,417	70.40	137,989	125,570
10	39.57	603.28	3,185,292	73.12	143,338	130,438
11	42	626.96	3,310,343	76.00	148,965	135,559
12	42.71	633.88	3,346,880	76.83	150,610	137,058
13	43.69	643.43	3,397,312	77.99	152,879	139,120
14*	44.83	654.54	3,455,977	79.34	155,519	141,522
15	46.92	674.91	3,563,531	81.81	160,359	145,927
		Totals	38,054,286	873.61	1,712,443	1,558,328

* indicates measured stream reach locations

Controlled (watershed structures accounted for) sediment estimations for the Black Vermillion watershed by sub-watershed.

Watershed	Cubic Meters	Metric Tons	Acre Feet
Black Vermillion	1,961,423	2,827,708	1590
Irish Creek	723,256	1,042,690	586
North Fork	1,232,459	1,776,790	999

Uncontrolled (watershed structures ignored) sediment estimations for the Black Vermillion watershed by sub-watershed.

Watershed	Cubic Meters	Metric Tons	Acre Feet
Black Vermillion	1,464,109	2,110,749	1187
Irish Creek	1,077,577	1,553,502	873
North Fork	1,296,363	1,868,916	1050

Bank erosion totals and time needed to gain stability.

Tributary	Average annual bank erosion rate (m)	Average bank height (m)	Stream length (Km)	Annual sediment yield (m^3)	Total predicted sediment yield (m^3)	Time to stable form (years)
Irish Creek	0.36	5.06	24.15	43,691	1,076,936	24.6
Main Stem	0.36	4.45	49.91	79,519	1,463,238	18.4
North Fork	0.36	5.41	38.64	74,920	1,295,592	17.3

Big Blue watershed flowing into Tuttle Creek Reservoir predicted sediment yields not counting watershed flood control structures.

	Metric Tons	Acre Feet
North Fork	1,869,029	1,051
Irish Creek	1,553,528	873
Black Vermillion	2,110,785	1,187
Big Blue / Little Blue	50,075,117,420	3,308,986
Totals	50,080,650,762	3,312,097

Summary

Questions ?