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The conditions for branching in depositional rivers

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This appendix provides a brief description of the methods used to compute values for the avulsion time scale and channel lateral migration time scale. The bulk of rate estimates in the database come from shallow cores with radiocarbon dates. Other methods of dating used Lead and/or Cesium. For very recent rates, aerial photographs, channel surveys and erosion pins were used. Most values presented are averages. Anywhere between 1 and 20 measurements from different cores or surveys may contribute to an average - generally it is 4-5. For the rest of the data, values on our database are in the middle of the range of reported values. For most studies, measured bank erosion rates (and hence calculated mobility numbers, M) are maximum values (see below). This is especially true for rivers with very low lateral migration rates in which no lateral movement was detectable. All data are from modern (currently active) river systems, however aggradation and bank erosion rates may be averages from very long times, or maximum values from Holocene sea-level rise – table DR2 explains how rates were estimated.

Vertical aggradation rates (v_A) are derived from sandy channel deposits (often with datable material), and so represent accumulation rates on channel belts – some cores are from the bottoms of channels, while others are from bank and levee deposits at channel margins. No check of model ages is performed for dated materials. The following methods were used to estimate v_A:

1) depth to a dated material (usually dated with radiocarbon, sometimes lead or cesium) is measured, and rate computed as depth divided by sample age;
2) some authors report in-channel deposition rate - these values are used without any quality control checks;
3) some authors report total Holocene sediment thickness, and suggest an estimate for the time associated with the onset of deposition;
4) historical surveys document the deposition of a river bed.

Lateral migration rates (v_C) were estimated from a variety of methods, generally one of the following:

1) a core taken in a river bank at a known distance from the main channel has a radiocarbon date. We assume the river has migrated less than this distance over the dated interval. In this case, bank erosion rate is a maximum. In some cases, no lateral movement was detected, so reported lateral migration rate (and hence calculated mobility number, M) may be much larger than the actual value;
2) a core taken within a channel deposit has a radiocarbon date and depth associated with it. We assume the channel has migrated less than one channel width over this time. In this case, bank erosion rate is a maximum;
3) authors of some papers present depth/age plots of an evolving river channel from many cores. This allows an estimate of channel migration from the diagrams;
4) authors report a bank erosion estimate (for modern river systems) - these values are used without any quality control checks;

5) repeat channel surveys were performed and reported, from which bank erosion rate could be estimated;

6) erosion pins were used;

7) aerial photography was used.

This appendix contains two tables: table DR1 is the river system database with measured and calculated parameters used to estimate mobility number, Parker stability number and avulsion frequency; table DR2 contains specific comments of how each measurement was made in individual river systems, along with the relevant references. Channel geometry was usually obtained directly from reported values in the literature. In some cases, estimates of width and depth were made from diagrams of channel surveys. In other cases, width was estimated from aerial photographs. These are documented in the database. It should be noted that **all values for channel geometry come from modern rivers**. Channel width and depth may have changed throughout the Holocene for some rivers, but these changes are not accounted for in this dataset. The reader is cautioned about such shortcomings in these data in order to guide against over-interpretation of specific values reported for mobility number.

Channel number was reported by some authors. In some cases, channel number was estimated from aerial photographs or channel cross-section surveys.

Water discharge is usually either a "bankfull" discharge as reported by authors, or a 1-2 year flood as reported by authors. In some cases discharge was estimated as the annual flood from records available online. In a few cases, discharge was estimated from water surface slope, mean channel geometry and an assumed friction factor. These cases are documented on the database.

Grain size is always a median value and was often reported by the authors. In some cases, only qualitative descriptions of grain size were reported (e.g., medium/coarse sand). For these cases an estimate of grain size was assigned. They are marked in the database.

Friction factor was computed directly from reported shear stress and water velocity measurements using a Chezy flow resistance relationship, if data were available. If no data were available, friction factor was taken as 0.01, the mean value from an extensive data set reported in Parker et al. (*32*) and expanded on by us. These data are marked in the database.

Avulsion frequency was reported by authors, or was easy to calculate from the documented record of avulsions in aerial photographs presented by authors. In addition to rivers reported in tables DR1 and DR2, laboratory data on avulsion frequency comes from Bryant et al. (1995) and Ashworth et al. (2004).

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Table DR1. Database of river characteristics. See Fig. 2.

System	Pattern[a]	d_{50} [mm]	θ	c_f	$\bar{h}$ [m]	B [m]	N	S	Q [m^3]	v_A [mm/yr]	v_C [mm/yr]	$1/f_A$ [yr]	M	ε
Branching														
Orinoco R. Delta, Venezuela	D - M	0.3	1.5	0.01[b]	12	2000	3	6.0E-5	38000	2.1	7	1000	0.02	0.07
Upper Narew R., Poland	A - M	0.6	0.6	0.05	3	33	3	2.0E-4	35	2	1		0.05	0.03
Magdalena R., Columbia	A - M	0.35	1.0	0.01[b]	6	1630	10	9.5E-5	8800	3.8	71		0.07	0.22
Lower Sandover R., Australia	D - M	0.5	2.0	0.01[b]	3.3	225	2	5.0E-4	945	0.7	4		0.08	0.15
Okavango Delta, Botswana	D - M	0.35	1.5	0.03	4.5	50	3	1.9E-4	50	10	10	100	0.09	0.06
Magela Creek, N. Australia	A - T	0.42	0.7	0.02	1	135	14	5.0E-4	40	1.5	23		0.12	0.71
Little River, Arkansas	A - M	0.3	1.2	0.01[b]	2	75	3	3.0E-4	280	2.5	15		0.16	0.03
Upper Columbia R., B.C.	A - M	2	0.08	0.01[b]	2.6	150	4	9.6E-5	275	1.8	20	333	0.20	0.04
Lower Niobrara R., Nebraska	A - B	0.28	0.9	0.01	0.3	200	1-2	1.3E-3	48	75	10000	4	0.21	1.89
Cooper Creek, Australia	A - T	0.1	1.2	0.01	1	300	~10	2.0E-4	100	0.1	8		0.27	0.56
Gilbert R. Delta, Australia	D - M	0.5	0.4	0.01[b]	6	2100	7	6.0E-5	7488	0.7	65		0.29	0.27
Upper Parana R., Argentina	A - B	0.3	1.4	0.01	7	3000	2-3	9.6E-5	16000	5	635	1633	0.30	0.45
Lower Saskatchewan R., B.C.	A - M	0.38	1.2	0.01[b]	6.3	275	4	1.2E-4	1400	1.3	20	667	0.35	0.05
Suwanee R. Delta, Florida	D – M	0.5	0.25	0.01[b]	3	300	3	7.0E-5	570	1	35		0.44	0.06
N. Saskatchewan R., Alberta	A - T	10	0.09	0.01[b]	1.5	70	3	1.0E-3	165	1.8	40		0.48	0.11
Lower Alexandra R., Alberta	A - T	10	0.06	0.01[b]	1.6	70	3	6.0E-4	85	1.8	40		0.51	0.14
Transitional														
McArthur R. Delta, N. Australia	WD - M	0.5	0.4	0.01[b]	5	800	2	6.0E-5	2170	0.5	60		0.75	0.12
Middle Amazon (@ R. Negro)	WA - M	0.25	0.9	0.01[b]	12	4500	1-2	3.0E-5	36815	5	2250		1.20	0.18
Upper Rhone R. Delta	WD - M	0.3	0.5	0.01[b]	5.9	377	2	4.0E-5	2100	2	198	1450	1.55	0.02
Mississippi Delta	WD - M	0.3	1.5	0.01[b]	25	1450	2	3.0E-5	25000	10	5700	1250	10.0	0.04
Rhine-Meuse delta	WD - M	0.5	0.7	0.01	5	1000	2	1.1E-4	3500	1.6	1000	1450	3.13	0.22
Brahmaputra R., Upper Delta	WA - T	0.5	0.8	0.01[b]	7	3300	1-2	1.0E-4	20000	20	30000	500	3.18	0.45
Middle Baghmati R., India	WA - M	0.8	0.5	0.01[b]	4.9	325	4	1.4E-4	1000	55	26000	29	7.10	0.10
Single channel														
Emerald Lake fan, B.C.	US - B	50	0.13	0.10	0.3	20		3.5E-2	2	3650	1.8E+6		7.5	10
Rolling Stone fan, Minnesota	US - B	0.1	1.8	0.01	0.1	320		6.4E-3	8	625	3.5E+7		12	72
Beni and Mamore R., Bolivia	S - M	0.1	1.7	4.E-4	4	1270	1	7.0E-5	6000	50	200000		13	0.12
Yellow R. Delta	S - M	0.1	2.4	4.E-4	2	500	1	2.0E-4	3000	100	400000	12	16	0.07
Assiniboine R. Fan, Manitoba	S - M	0.5	2.5	0.01[b]	4.2	150	1	5.0E-4	626	1.4	1000	1000	20	0.12
XES 1999 lab fan Run1, Stage 3	US - B	0.12	3.0	0.59	0	0.45	9	6.0E-2	1E-4	17520	5.7E+7	5.E-5	72	27
Lower Mississippi alluvial plain	S - M	0.3	1.8	0.01[b]	30	950	1	3.0E-5	25000	4	50000		395	0.02

[a]Indicates [Channel branching style - channel pattern]. D = distributary, A = anabranching, S = single channel, US = unstable, ill-defined channels, WD and WA = weakly distributary and weakly anabranching, respectively, indicating the presence of a clearly dominant channel and a small number of secondary channels; M = meandering, B = braided, T = transitional.

[b]Assumed friction factor based on analysis of river data by Parker et al. (*32*) and our own unpublished database.

Table DR2. Additional information for database of river characteristics – see table DR1. Source numbers refer to references listed in Supporting online material.

Sources	River	Method
9; 48	Orinoco River Delta, Venezuela	Bank migration is maximum, estimated from core on meander banks indicating presence of channel for 1500 yr - core was within 10 m of present channel. Aggradation rate is mean from cores, represents late Holocene.
15	Upper Narew River, Poland	Bank migration estimated from core showing less than 2 channel width (11 m) movement in 9727 years; aggradation rate was reported by authors; grain size reported only as medium/coarse sand.
39	Magdalena River, Columbia	Lateral migration is upper bound, estimated from the time sandy channel fill occupied the location of a core. Aggradation rate reported by authors.
44	Lower Sandover-Bundy River	Bank migration is maximum, estimated from core that is ~2m from channel edge and 2400 yr old. Aggradation estimate is also crude, comes from same core – late Holocene.
26; 40	Okavango Delta, Botswana	Lateral migration is negligible from cores - I am conservative and say channel migrated less than 1 m over its 100 year lifetime. Aggradation rate from surveys of channel.
21; 37	Magela Creek, N. Australia	Lateral erosion estimated from 6 nearby channels using erosion pins, but no direct measurements of this channel. Aggradation rate reported by authors.
16	Little River, Arkansas	Lateral migration is upper bound, estimated from the time sandy channel fill occupied the location of a core. Aggradation rate is average from cores for the late Holocene to modern.
2; 25	Upper Columbia River, B.C.	Lateral migration estimated from depth/age plots of Makaske et al., 2002. Aggradation rate reported by authors.
22	Lower Niobrara River, Nebraska	Lateral migration measured from cross section survey, aggradation rate known from historical data.
11; 12; 29	Cooper Creek, Australia	Lateral migration estimated from dated bank accretion surface in one core. Aggradation reported by authors.
23	Gilbert River Delta, Australia	Bank migration estimated from in-channel cores showing channel migrated less than 1 channel width over measured times; mean aggradation rate reported by authors.
30; 42	Upper Parana River, Argentina	Bank migration estimates from cross section showing floodplain position over 3150 yr. Aggradation is average estimated from cores, late Holocene to modern.
34	Lower Saskatchewan River, B.C.	Lateral migration constrained by core on levee that shows no migration over 50 yrs. Aggradation rate reported by authors.
51	Suwanee R. Delta, Florida	Lateral migration is upper bound, estimated from the time sandy channel fill occupied the location of a core. Aggradation rate is average from cores, late Holocene to modern.
40	North Saskatchewan River, Alberta	Lateral migration and aggradation rates reported by authors. Discharge estimate is maximum discharge from year 2005, Alberta Government-Environment
38; 40	Lower Alexandra River, Alberta	Lateral migration comes from cores in banks, and erosion pin measurements. Aggradation rate reported by authors for late Holocene to modern.
23	McArthur River Delta, N. Australia	Bank migration estimated from in-channel cores showing channel migrated less than 1 channel width over measured time, mean aggradation rate reported by authors.
24; 27; 28	Middle Amazon	Bank migration estimates from percent of area change of channel measured over 8 yr; Aggradation rate and grain size reported by authors.
4; 5	Upper Rhone River Delta	Channel properties from authors. Lateral migration is upper bound, estimated from the time sandy channel fill occupied the location of a core. Aggradation rate reported by author.
7; 8; 19;33	Mississippi Delta	Lateral migration from aerial photographs and historical documents; Aggradation from Atchafalaya dated deposit thickness (Aslan et al., 2005) from last 200 years and is middle of reported range; Grain size assumed same as further upstream.
43; 45; 46; 49; 50	Rhine-Meuse delta	Bank migration from historical photographs and diagrams; Aggradation rate reported by authors, represents averaged Holocene.
3; 14; 36	Brahmaputra River, Upper Delta	Lateral migration estimates from aerial photographs and channel surverys; Aggradation rates reported by authors, modern. Observed avulsion time is very crude, average from 2 sources.
20	Middle Baghmati River, India	Aerial photographs and channel surveys used to estimate lateral migration and aggradation rates.
13	Emerald Lake fan, B.C.	Bank migration estimates from map of lobe development, aggradation measured surveys of lobe deposition over 15 days. Discharge crudely estimated from slope, channel area and estimated friction factor
31; 32	Rolling Stone fan, Minnesota	Bank migration from photographs, and aggradation rate is from historical data.
1; 17	Beni and Mamore Rivers, Bolivia	Bank migration rate and channel width from NASA website of space images, depth is crude estimate from 2 sources. Aggradation rate is average modern value, and comes from cores dated with Lead.
47; 52	Yellow River Delta	Aggradation estimate reported by authors is modern. Lateral migration reported by authors.
35	Assiniboine River Fan, Manitoba	Aggradation estimated from 10 m Holocene deposition in 7000 yr. Lateral migration estimated from aerial photographs.
18	Jurassic Tank Experiment, Stage 3	Photographs and topographic surveys were used.
7; 8; 19	Lower Mississippi alluvial plain	Lateral migration reported by authors; Aggradation is more rapid Holocene value reported by Aslan et al., 2005.