An Evaluation of Trout Spawning Substrate Composition and Substrate Changes Following Spring Run-off in the Missouri River below Holter Dam.

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ABSTRACT

Survival to emergence estimates for trout in the Missouri River were determined using core sampling. The cumulative median percent fines < 0.85 mm in core samples was 12.1% and gravel <6.4 mm was 29.6% of the total gravel matrix. Comparisons with survival to emergence study results of other salmonids showed the median percent fines found in the Missouri River represents approximately 50% survival to emergence for rainbow and brown trout. The mean Fridle index (FI) for all core samples was 3.2 mm which represents 63% survival to emergence based on steelhead salmon studies. Pebble counts before and after the high water event of 2008 showed a reduction in mean percentage of fines from 12.2 % to 7.8% (-4.4%). The percent of gravel increased from 73.9% of the average total sample to 77.7% (3.8%), and cobble increased from 13.8% to 14.4% (0.6%) of the total sample. These results suggest that despite a prolonged drought in central Montana, adequate spawning gravel exists for rainbow and brown trout reproduction, and that the 2008 peak flow range of 15,000 to 16,300 cfs is sufficient to mobilize fine riverbed materials in the study area.

INTRODUCTION

In 2008, Montana Fish, Wildlife & Parks (MFWP) conducted studies to evaluate trout spawning substrate composition in a 35 mile reach of the Missouri River below Holter Dam and to assess changes in substrate following the spring run-off event. The presence of Holter Dam on the mainstem Missouri River impedes natural recruitment and mobilization of substrate materials in a classic serial discontinuity manner (Stanford and Ward 2001). This section of river can be characterized as gravel limited and the only significant sources of gravel recruitment are from Little Prickly Pear Creek, Dearborn River and Sheep Creek. A nine-year drought in central Montana from 1999-2007 raised further questions about increased sedimentation affecting insect production and trout reproduction. Here we attempt to evaluate the status of trout spawning habitat and changes in substrate composition following a high water event.

STUDY AREA

The study area was a 35 mile reach of the Missouri River spanning from Holter Dam to the town of Cascade. Trout population estimates conducted over the past 28 years in the Craig section average about 3500 rainbow and brown trout per mile and in the Pelican Point section the average is about 1850 trout per mile. There are three major tributaries that provide gravel to the system and offer spawning habitat for trout and whitefish. Little Prickly Pear Creek is located 2.8 miles downstream of Holter Dam on river left, the Dearborn River is located 13.8 miles downstream of Holter Dam on river left and Sheep Creek is located 24 miles downstream of Holter Dam on river right.

METHODS

Core Sample Analysis

We used core sampling to evaluate the substrate composition using the protocol described by McNeil and Ahnell (1964). General rainbow trout spawning locations were identified by MFWP during helicopter flights in 2007. In 2008 these sites were revisited and surveyed to locate new rainbow trout spawning redds so core samples could be taken near them. Core sampling was conducted using a 12-inch diameter tubular coring device based a design by McNeil and Ahnell (1964) (Figure 1). The device was manually driven into the substrate in a twisting motion in order to cut a segment of the stream bed and contain it within the throat of the device. The operator would remove the contents of the throat and deposit them in a holding tray just outside of the throat, but still within the device. Two operators removed the device from the river, fitted a 6 Mil plastic bag to the throat and moved the contents of the tray into the bag. Bags were labeled with information describing the location of the sample and sealed for transport to the laboratory. A sub sample of filled bags was weighed and averaged 42 pounds each.

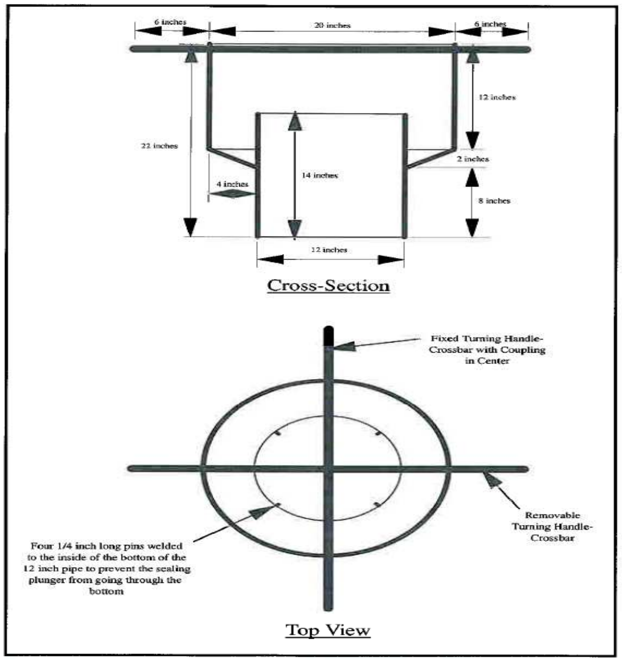

Figure 1. Schematic of 12-inch diameter substrate sampler modeled after the 6-inch diameter sampler developed by McNeil and Ahnell (1964). From R2 Resource Consultants, Inc.(2008).

Forty individual core samples were taken at twenty designated spawning areas within the study area (Figure 2). Core samples were processed in Belgrade, Montana by Piedmont Engineering, Inc. using the dry sieve technique to produce particle size gradation curves to calculate indices. We used the gradation curve summaries to compare with those of Beck et al. (2008) who conducted similar studies on the Madison River in Montana.

To assess survival to emergence, we compared our core sample results to standards established by Kondolf (2000). He evaluated 13 studies that reported a range of fine sediment values that resulted in survival to emergence success between 20% and 80% and determined that a median of 12% fines < 0.85 mm and a median of 30% fines < 6.4 mm, of a total core sample, were associated with 50% egg survival-to-emergence. Kondolf adopted the 50% survival to emergence benchmark from data in these 13 studies. Further, he conceded that this value was arbitrary but justified based on the data in the studies and belief that most biologist would consider 50% survival to emergence productive. In addition, he related particle size impacts to a variety of life stages. High percentages of grain sizes < 0.85 mm within a gravel matrix negatively affect the embryo phase, while high percentages of grain size < 6.4 mm negatively affect the allevin phase by causing them to emerge later than normal. Too much fine sediment in a river system, based on core sample percentages of two fine sediment grain sizes (0.85 mm and 6.4 mm), has been documented to impair salmonid egg survival throughout incubation (McNeil and Ahnell 1964, Kondolf 2000).

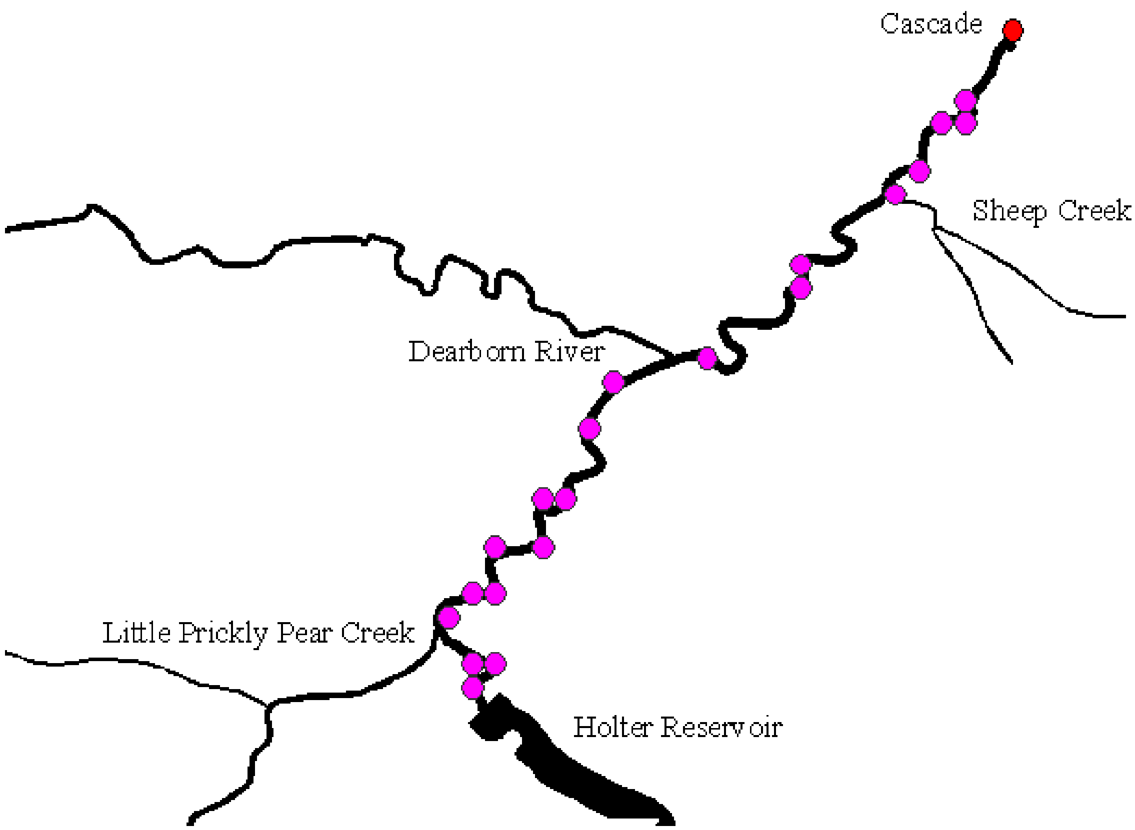

Figure 2. Core sampling sites on the Missouri River below Holter Dam, 2008.

We also used the fredle index (FI) to help describe gravel size (mm) for salmonid reproduction (Lotspeich and Everest 1981). The FI is calculated by dividing the geometric mean particle size (dg) by the permeability of an analyzed core sample based on grain size, which is referred to as the sorting coefficient (So). Lotspeich and Everest (1981) describe the FI as a measure of both pore size and relative permeability within a gravel matrix and as the FI increases, pore size and relative permeability also increase. Inadequate pore size and relative permeability within a gravel matrix have detrimental effects on salmonid survival-to-emergence (Cordone and Kelley 1961, Gibbons and Salo 1973, Iwamoto et al. 1978, and Tappel and Bjornn 1983) and the FI quantifies those effects. For example, Lotspeich and Everest (1981) reported that 50% survival-to-emergence data for steelhead corresponded to a FI of 2.7 and for coho salmon the FI was 3.5. Our FI study results were compared with the standards established by Lotspeich and Everest (1981).

Pebble Counts

Pebble counts were conducted using field procedures from Wolman (1954), Schuett-Hames et al. (1994) and Kondolf (1997). In April 2008, ten 100-ft. transects were established at riffle sites with suitable salmonid spawning habitat that was shallow enough for counters to reach into the water to retrieve samples (Figure 3). Sampling was conducted by walking heel-to-toe across each transect measuring randomly selected individual substrate particles at one-foot intervals until a minimum of 100 samples were collected. Substrate particles were measured across the intermediate axis (Figure 4) using a slide micrometer (mm) and measurements were recorded by particle size. Sampled particle sizes were tallied, totaled by size, and percent values were determined per transect for three main particle category comparisons (fines < 2mm, gravels 2-64 mm, and cobbles 65-256 mm).

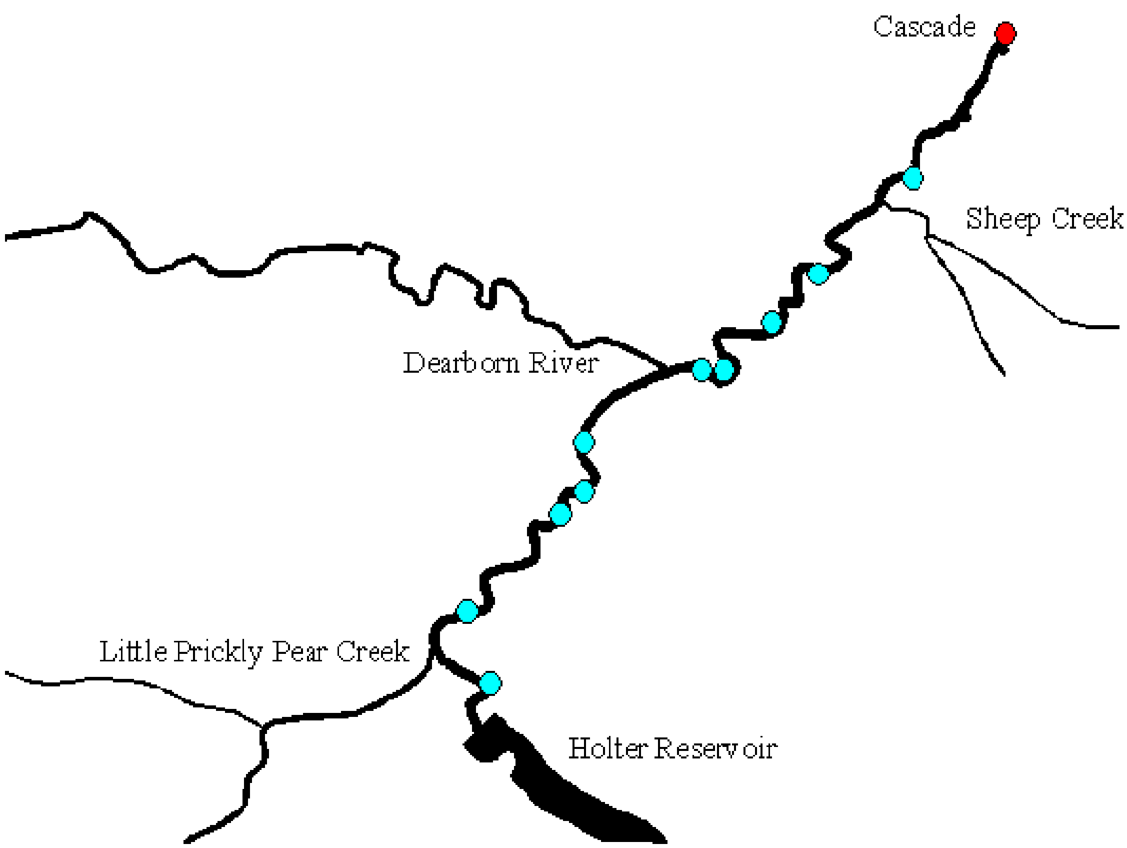

Figure 3. Pebble count sites on the Missouri River below Holter Dam, 2008.

Each transect was compared by category (i.e. fines to fines), first to itself (i.e. Site 1 to Site 1), then the cumulative data from all transects were compared to establish an overall minimum, maximum and average percent change by category within the study area to determine substrate composition changes.

These procedures were repeated in September 2008 and these results were compared to the results of the April sampling.

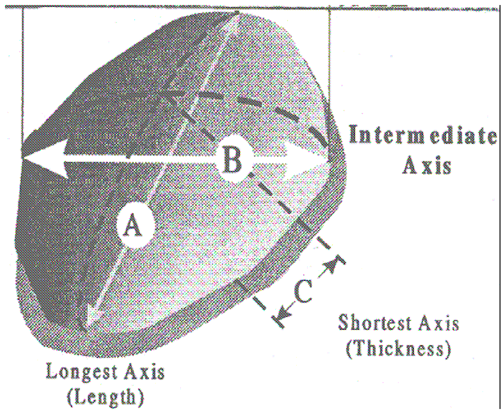

Figure 4. Diagram illustrating how to measure the intermediate axis of a substrate particle, from Kondolf (1997), Wolman (1954) and Schuett-Hames (1994).

RESULTS

Lab analysis of forty core samples from our study area (Table 1) yielded a cumulative median percent fines < 0.85 mm at 12.1%, which was just 0.1% above the suggested target for 50% embryo survival-to-emergence. Similarly, median percent fines <6.4 mm were 29.6% of the total gravel matrix, which was 0.4% below the threshold associated with 50% salmonid survival-to-emergence. The mean FI for all core samples in our study was 3.2 (0.52-11.2) indicating pore size and relative permeability was slightly greater than the 2.7 necessary for 50% survival-to-emergence as described by Lotspeich and Everest (1981). Using their data for steelhead, a FI of 3.2 represents a percent survival to emergence of about 63%. A comprehensive evaluation of 6 studies on survival to emergence involving coho, steelhead and sockeye salmon showed that a FI of 3.2 corresponded to a survival to emergence range between 40% and 70% (Chapman 1988).

Overall, these data suggest that gravel in the Missouri River spawning areas examined in this study is consistent with good survival to emergence. According to Kondolf's (2000) standards there is a "healthy" percentage of fines less than 0.85 mm and 6.4 mm that occurs within the study area.

Beck et al. (2008) reported the results of core sampling in two sections of the Madison River. Their median percent fines < 0.84 mm was 5.1% in the upper Madison River above Ennis Dam and 8.5% in the lower Madison River below Ennis Dam compared to 12.1% in our study area. Their median percent fines < 6.4 mm was 10.5% in the upper Madison and 25.8% in the lower Madison compared to 29.6% in our study area. Also, their median FI was 14.9 in the upper Madison and 4.1 in the lower Madison compared to 3.2 in our study area. All 2007 results from both Madison sections meet 50% survival-to-emergence criteria, for both percent fines and FI, while our study results meet the criteria for only percent fines < 6.4 mm and FI. However, the cumulative percent fines < 0.85

mm value of 12.1 % from our study area was just 0.1% over the standard for 50% egg survival-to-emergence.

Substrate composition comparisons between our study area and the 2007 Madison River core sampling analysis revealed a predictable trend. There are some similarities between the Madison River and our study area in that much of the flow regime is controlled by dams and there are relatively few streams contributing gravel to the system. By comparison the Madison River is higher gradient, but smaller order than the Missouri River Holter tailwater system. Comparisons between the upper Madison River, lower Madison River and our study area show that trend. Percent fines less than 0.85 mm and 6.4 mm increase from the upper Madison River to the lower Madison River and again in our study area. Similarly, the FI decreases from the upper Madison River to the lower Madison River and again in our study area. However, substrate composition in the Missouri River below Holter Dam remains at or above standards for 50% salmonid survival-to-emergence.

Table 1. Laboratory results for forty core samples within the study area. Piedmont Engineering, Inc.

2008 Upper Missouri River– below Holter Dam Core Sample Analysis

	Grain Sizes					Geo. Mean Dia. Milimeters	Sorting Co.	Fredle Ind.	% Finer Than:	
Core #	**D 15.9**	**D 25**	**D 50**	**D 75**	**D 84.1**	**D g**	**S 0**	**Fi**	**0.85 mm**	**6.4 mm**
1	1.733	5.033	13.415	23.554	29.77	7.183	2.163	3.32	12.4	28.4
2	1.598	4.42	12.736	23.218	30.209	6.948	2.292	3.031	12	30.2
3	0.657	5.909	15.485	24.053	28.781	4.348	2.018	2.155	68.2	25.7
4	2.592	8.141	18.301	27.88	33.261	9.285	1.851	5.017	12.3	21.7
5	1.151	9.164	25.632	55.265	84.074	9.837	2.456	4.006	14.7	22.4
6	3.6048	6.623	15.917	32.224	40.29	12.051	2.206	5.464	7.6	24.3
5B(7)	4.5456	8.688	19.514	35.284	44.394	14.206	2.015	7.049	8	20
8	1.4808	4.334	17.631	33.38	43.435	8.02	2.775	2.89	12.2	28.9
9	7.0013	10.94	21.292	38.601	49.767	18.66	1.879	9.935	5.2	14.6
10	2.853	7.407	19.912	36.038	44.338	11.247	2.206	5.099	10.6	22.8
11	2.3274	6.04	31.433	52.686	62.573	12.068	2.953	4.086	12	25.8
12	1.3295	6.903	28.424	53.733	64.748	9.278	2.79	3.326	14.4	23.9
13	1.0181	3.126	11.828	29.532	39.232	6.32	3.073	2.056	14.8	36.4
14	1.1202	3.052	12.409	25.786	33.215	6.1	2.907	2.099	14	35.1
15	2.3034	4.736	14.388	30.289	37.906	9.344	2.529	3.695	8.6	30.4
16	1.8079	3.954	13.237	35.881	47.138	9.232	3.012	3.065	9.9	33
17	0.3612	0.589	6.1397	13.739	18.026	2.552	4.829	0.528	31.6	51
18	0.6527	2.745	11.438	19.161	24.107	3.967	2.642	1.501	18.9	33.9
19	4.4162	7.988	20.619	38.403	46.581	14.343	2.193	6.541	6.5	21
20	3.1318	8.962	25.597	41.045	47.928	12.252	2.14	5.725	12	20.8
21	6.4079	9.894	17.043	25.143	29.576	13.767	1.594	8.636	4.1	15.9
22	7.4416	11.03	18.421	26.942	31.741	15.369	1.563	9.833	2.4	13.6
23	1.3379	3.307	12.221	35.946	44.555	7.721	3.297	2.342	11.6	34.7
24	1.1765	2.836	10.91	24.916	33.652	6.292	2.964	2.123	12.5	37.9
25	3.4505	7.048	17.678	33.43	41.31	11.939	2.178	5.482	6.1	23.3
26	1.3206	2.806	13.102	38.248	46.908	7.871	3.692	2.132	11.5	35.5
27	7.5645	14.32	22.311	31.83	37.394	16.819	1.491	11.282	12	15.1
28	7.3227	11.55	19.495	30.154	36.895	16.437	1.616	10.17	9.1	14.5
29	0.7966	2.281	9.7895	18.314	23.093	4.289	2.834	1.514	16.6	38.9
30	1.0445	3.204	12.379	25.581	31.29	5.717	2.826	2.023	14	34.8
31	1.283	3.444	9.8406	18.368	23.491	5.49	2.309	2.377	13.4	37.6
32	0.7995	1.789	9.9472	19.287	25.272	4.495	3.283	1.369	16.6	40.3
33	1.4229	5.965	17.521	23.951	29.17	6.442	2.004	3.215	13.9	26.1
34	4.2186	8.554	17.431	28.201	34.361	12.04	1.816	6.631	8.4	20
35	2.8968	5.042	10.971	18.387	22.87	8.139	1.91	4.262	7.1	31
36	2.23	3.852	11.847	21.936	27.498	7.831	2.386	3.281	6.8	34.1
37	0.841	2.257	9.8242	21.17	27.875	4.842	3.063	1.581	15.9	40
38	1.2573	3.807	12.94	24.604	31.441	6.287	2.542	2.473	13.3	32.4
39	1.0781	3.054	14.126	33.838	41.637	6.7	3.329	2.013	13.2	33.4
40	0.999	2.838	12.675	30.425	38.445	6.197	3.274	1.893	13.9	35.2
Median	1.5394	4.884	14.257	28.867	35.628	7.9455	2.421	3.248	12.1	29.55

Pebble Counts

The total number of individual particles measured within each transect, both spring and fall, ranged from 100 to 112. Discharge of the Missouri River during the spring 2008 sampling period was 3,330 cfs, measured at the USGS station below Holter Dam. On June 6, 2008 the peak flow in the Missouri River measured at the Holter Dam gauge reached 15,000 cfs and was sustained for a period of three days (Figure 5). The measured discharge at the Holter station confirmed the predictions made by Bureau of Reclamation personnel in April that a near normal flow could be observed in 2008. This higher flow effectively ended the nine-year drought. Half of the pebble count sites were located below the confluence of the Dearborn River, which means these sites were exposed to combined flows from the Missouri River, Little Prickly Pear Creek and the Dearborn River totaling 16,322 cfs on June 8 and was sustained above 16,000 cfs for three days. The fall sampling period occurred on September 25 when flows were 4,310 cfs.

Our results showed that from spring to fall, the percent of fines decreased at 6 of the 10 sites and percent gravel and cobble increased at 6 of the 10 sites. The mean percentage of fines for all samples reduced from 12.2 % to 7.8% (-4.4%), gravel increased from 73.9% of the average total sample to 77.7% (3.8%), and cobble increased from 13.8% to 14.4% (0.6%) of the total sample. These results suggest that a flow of 15,000 to 16,300 cfs is sufficient to mobilize fine riverbed materials in the study area.

We applied the result of our pebble count data to survival to emergence regression equations developed by Phillips et al. (1975) for steelhead. The equation $\hat{Y}= 1.466-0.016x$ estimates survival to emergence of steelhead salmon based on the percentage of fines (1-3 mm dia) in a sample. Acrsine transformations ($\hat{Y}$) are made to normalize percentages for application to the equation. Applying the percent fines data from our pebble counts to this equation for steelhead shows the mean percent fines of 12.2% before the 2008 runoff corresponds to a survival to emergence of 95%. The 4.4% reduction in fines after the high water event represents a 2% increase in survival to emergence. In our study, the highest percentage of fines for any one sample was 45%, which corresponds to 52% survival to emergence using the Phillips et at. (1975) equation.

These results helped us to quantify substrate composition changes in accordance with a specific annual hydrograph and establishes a baseline for substrate composition change when flows below Holter Dam reach 15,000 cfs and range as high as 16,300 cfs downstream of the Dearborn River confluence. We found the survival to emergence estimates based on percent fines in the samples to be quite high despite the lack of a flushing flow over the previous nine years.

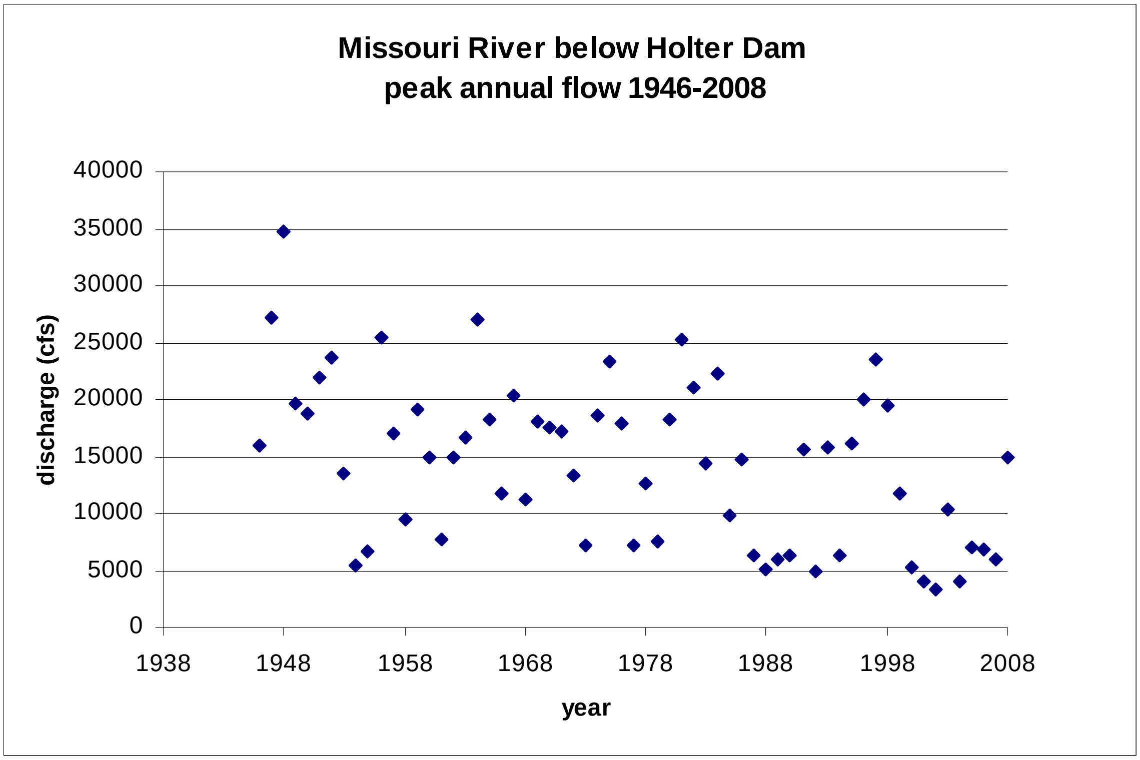

Figure 5. Peak annual flow for the Missouri River below Holter Dam 1946-2008.

In addition to core sampling and pebble counts, we used one empirical measure to evaluate the effects of the high water event in 2008. In 2006 and 2007, one of the principle tributaries to the Missouri River, Sheep Creek, experienced back-to-back floods, which resulted in deposition of alluvium in the Missouri River near their confluence (Figure 6). In 2008, the peak flow of the Missouri River at this site (16,300 cfs) was sufficient enough to mobilize this alluvium and reestablish the historic channel morphology at this site (Figure 7, Figure 8). The photographic evidence supports the results of the pebble counts.

Figure 6. Photograph of the mouth of Sheep Creek demonstrating a large alluvial fan deposit in the Missouri River. April 17, 2008, 3400 cfs.

Figure 7. Photograph of the mouth of Sheep Creek demonstrating 16,120 cfs in the Missouri River on June 3, 2008.

Figure 8. Photograph of the mouth of Sheep Creek on August 5, 2008 when flows in the Missouri River are at 4,350 cfs. Note the alluvium is missing from the river.

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