Title: Eagle River Stamp Sand Restoration

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Opening Paragraph: An 8.5 mile reach of the Eagle River in Keweenaw County in Michigan's Upper Peninsula is on Michigan's 303(d) list for poor macroinvertebrate communities due to excessive aqueous copper concentrations. The copper is leaching from mining waste deposits that were discharged into stream valleys in the mid to late 1800s. In late 2009, in the first phase of remediating this reach, the Michigan Department of Environment Quality moved or stabilized 800 feet of stream channel within the stamp sand deposit associated with Central Mine #1. The intentions of the remedial activities were to:

1. Relocate portions of the stream channel away from the stamp sand deposits, reducing transport of these materials into the channel, reducing the thickness of the deposits, and decreasing the vertical distance between the riparian zone surface and the groundwater table.
2. Use principles of natural channel design to create a stable, self-sustaining stream channel that will reduce stream bank erosion and provide better instream habitat.
3. Take advantage of the natural revegetation propensity of thin, moist stamp sand deposits to create a stable vegetated riparian zone and stream banks.
4. Actively revegetate upland areas where natural revegetation is improbable.
5. Lower water column copper concentrations such that they meet water quality standards.

Pre-construction monitoring of water quality, macroinvertebrates, and channel stability was performed in 2007 and 2008, and post-construction monitoring was initiated in 2010 (Figure 1).

Problem: An 8.5 mile reach of the Eagle River is on Michigan's 303(d) list for poor macroinvertebrate communities due to excessive aqueous copper concentrations, which originate from historic mining wastes.

Results: At Central Mine #1 the stream was redirected away from the stamp sands entirely and into a constructed channel in an adjacent wetland. In addition, upland stamp sand deposits were stabilized by covering with top soil and seeding with native herbaceous vegetation.

One year after construction (2010), the stream channel appeared to be stable (i.e., the channel dimensions, especially channel depth and width, did not change over the first two years post-construction; Figure 2) and upland herbaceous vegetation was well-established (Figure 3). Aqueous copper concentrations at the sampling site downstream of the Central #1 stamp sand deposit had fallen significantly, by approximately 75 percent (Figure 4), although all measured concentrations still exceeded Michigan's hardness-corrected chronic water quality standard for total copper.

Qualitative macroinvertebrate sampling (Michigan's Procedure 51; Table 1) did not detect significant changes in the macroinvertebrate community. Quantitative aquatic

macroinvertebrate sampling using Surber samplers, however, found major improvements within two years of construction (Table 2):

- The number of macroinvertebrate taxa increased from 2 families prior to construction to 17 families two years after construction.
- The total number of individual macroinvertebrates collected in the study reach increased from 6 prior to construction to 769 two years after construction.
- The large majority of macroinvertebrates collected were found in the new riffle habitat.

Also, a fish spawning "redd," probably made by creek chubs (*Semotilus atromaculatus*), was observed in the Central Mine #1 reach after construction in 2010 (Figure 5), but not prior to construction. Improvements in the macroinvertebrate community and fish spawning habitat are probably due as much to improvements in bank stability and benthic habitat and substrate as to lower aqueous copper concentrations. Four riffles were installed in the Central #1 reach, and a fifth riffle has formed naturally. Prior to construction the channel lacked riffles and was dominated by fine particles (silt and sand), while after construction the riffles are dominated by gravels and cobbles (Table 3) and fine particles are largely restricted to pools behind the riffles.

Lessons Learned: Although copper concentrations dropped dramatically, the failure to achieve water quality standards at Central #1 is probably due to inputs of copper that leaches into groundwater from stamp sands positioned below the water table, a source which was not addressed by the remediation activities performed to date. It is clear that when stamp sands occur below the water table they are a significant source of copper to nearby streams, and that upland remedial activities and even stream channel relocation will not reduce aqueous copper concentrations to below water quality standards. This finding will influence future remedial activities at other stamp sand deposits; the position of the water table relative to the stamp sands will be assessed with soil borings and groundwater sampling wells, and if stamp sands are present below the water table they will be excavated down to native material.

Partners and Funding: The Houghton/Keweenaw Conservation District (HKCD) has received approximately $400,000 for project design, construction and oversight of the Central #1 site. HKCD, in turn, subcontracted project design and construction to the Houghton office of the Natural Resources Conservation District. Section 319 funds also supported the monitoring reported here.

Figures:

Figure 1. Map of the water sampling sites at Central Mine #1. (SS6 upstream reference reach; GLR = Gratiot Lake Road, downstream of the Central Mine #1 deposit)

Figure 2. Cross-channel transect at Central #1, one and two years after construction.

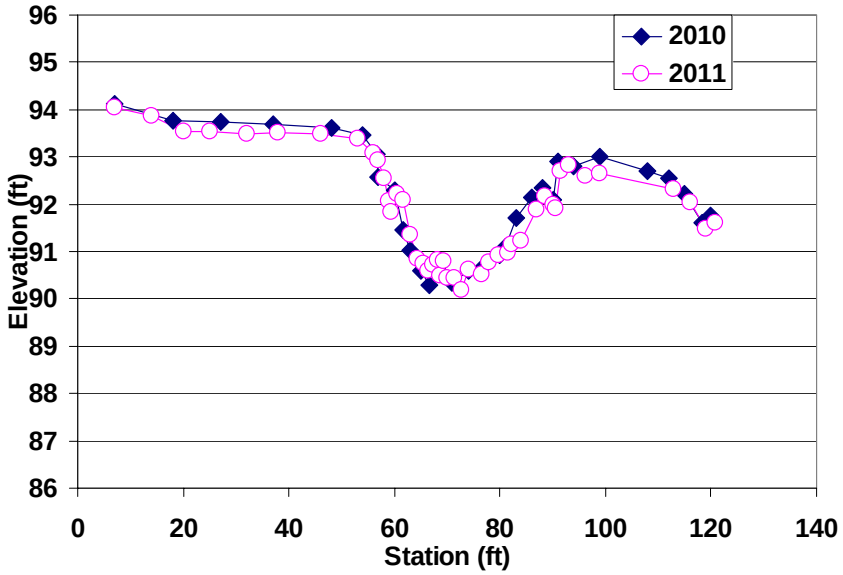

Figure 3. Pre- and post-construction pictures of Central Mine #1 stamp sand deposits.

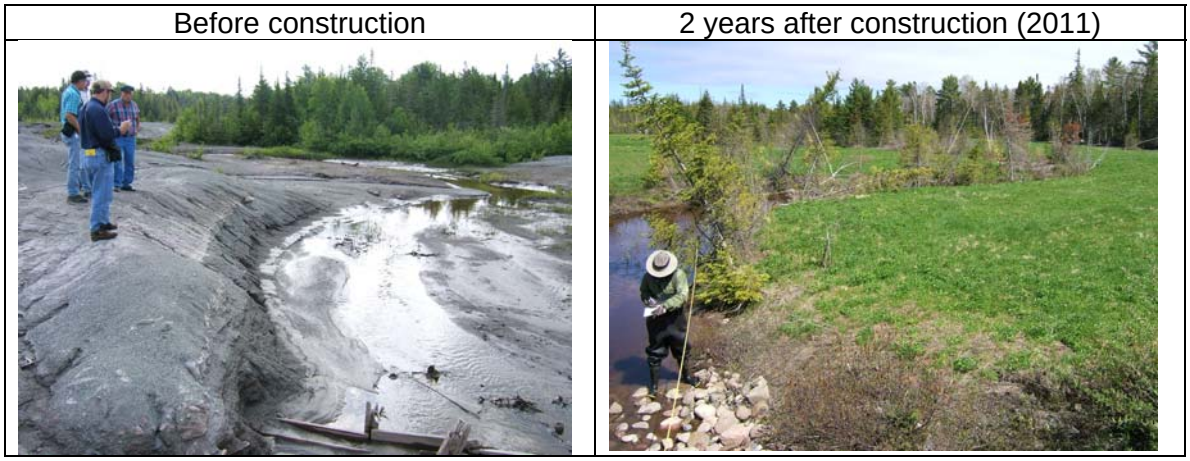

Figure 4. Comparison of aqueous copper concentrations, before and after construction. (Refer to Figure 1 for station locations.)

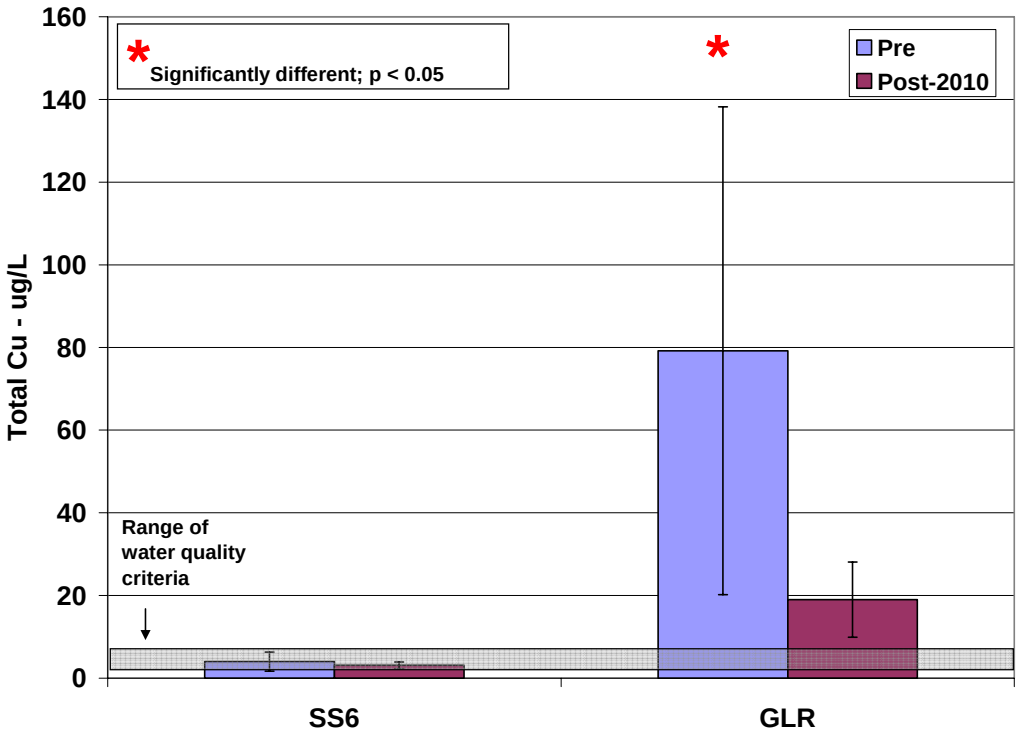

Figure 5. Fish spawning “redd” at Central Mine #1.

Data:

Table 1. Qualitatative Macorinvertebrate Monitoring Data for the Eagle River/Central Mine #1 Remediation Project. (Construction = 2009)

Metric	2008	2010	2011
No. of taxa in study reach	12	7	16
No. of EPT taxa*	6	2	6
Score**	0	-2	-2

*Sensitive macroinvertebrate taxa; mayflies, stoneflies and caddisflies
** Scale = -9 to +9

Table 2. Quantitative Macroinvertebrate Monitoring Data for the Eagle River/Central Mine #1 Remediation Project.
(Construction = 2009; 10 Surber samples collected in study reach)

Metric	2008	2010	2011
No. of taxa in study reach	2	7	17
No. of individuals in study reach	6	22	769

Table 3. Pre- and Post-Construction Pebble Count Data at Central Mine #1.

	2007 Reach-average	Natural Riffle		Pool upstream of third artificial riffle	
		2010	2011	2010	2011
Median particle diameter (D_{50}; mm)	0.38	8.3	21	0.26	0.30

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