Accounting for Irrigation Flows and Sediment Sources in the TMDL Process – Muddy Creek Case Study

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Introduction

The Total Maximum Daily Load (TMDL) process, established by section 303d of the Clean Water Act, provides a powerful tool for management of point and non-point pollution sources. The objective of the TMDL process is to identify and allocate allowable pollution loads among different sources, thereby establishing management goals for stakeholders and landowners. Impairment sources often identified through the TMDL process include construction, and agriculture, recreation, and channelization.

Muddy Creek, located in North central Montana, is considered impaired and is listed on Montana Department of Environmental Quality's (DEQ) 303d list as a high priority stream for TMDL development. Turbidity is the cause of impairment in Muddy Creek while agriculture and grazing are considered the source of impairment . Muddy Creek is the receiving water body of return and spill flows from Greenfield's Irrigation District (GID), a 90,000 acre irrigation project situated West of Muddy Creek. These flows, in turn, generate elevated sediment loads within the channel. Muddy Creek's appearance on the 303d list is largely a function of the following:

- Interbasin transfer of flows
- Widely fluctuating daily flows
- Fluctuating seasonal flows

The input of substantial, fluctuating flows into a once ephemeral channel has resulted in degradation and down cutting of Muddy Creek downstream of GID. In hopes of reducing sediment loads in Muddy Creek and to its receiving water body, the Bureau of Reclamation requested Montana State University, along with the Sun River Watershed Association and Natural Resource Conservation Service, define and quantify contributing flows and sediment sources to Muddy Creek.

Figures 1 and 2: Steep, highly eroded banks of Muddy Creek downstream of GID (non-irrigation season).

Objectives

- Identify and quantify flow contributions to Muddy Creek from canal spillage and irrigation seepage
- Quantify amounts of sediment loading to Muddy Creek from irrigation fed tributaries
- Quantify sediment generation occurring within designated reaches of Muddy Creek
- Identify the relationship between sediment loads in Muddy Creek and flow rates

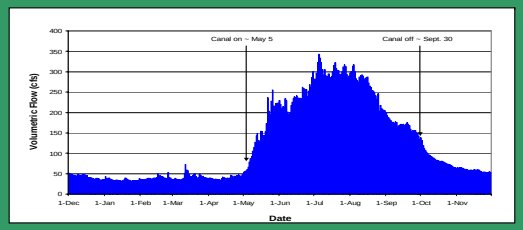

Figure 3. Annual hydrograph of Muddy Creek at Vaughn exhibiting prolonged peak flows throughout the irrigation season.

Approach

To identify contributing irrigation flows and sediment sources, MSU used a TMDL approach. A goal of 50,000 tons of sediment generated annually from Muddy Creek to the Sun River was previously established by the Sun River Watershed Association. MSU developed a sampling scheme to monitor flow and sediment inputs from major tributaries fed by GID. Five tributaries were identified as significant sources of irrigation flows. Three of these tributaries received spill water from the canal operational spill and seepage, while the two others were fed primarily by irrigation seepage. Aquarods were installed at upstream locations receiving canal spillage and on all tributaries just above the confluence with Muddy Creek. Seepage, in channels receiving canal spill and seep, was considered the difference in flow between upstream and downstream stations. To develop flow-rating curves for the aquarod stations, flow measurements were taken on a weekly basis throughout the irrigation season. Sediment samples were collected at the same time. A sediment-flow relationship was then established and sediment contributed by each tributary was estimated for the season. By correlating aquarod data with the flow rating curves, daily and seasonal flows were estimated for each tributary.

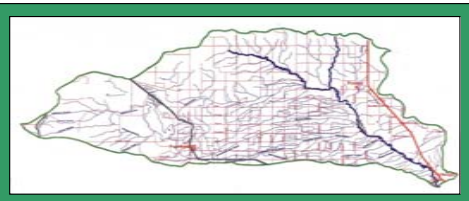

Figure 4. Muddy Creek watershed including Greenfield's Irrigation District west of Muddy Creek, draining 50,000 irrigated acres into the channel.

References

Andrews, John P. 1985. Muddy Creek Special Water Project Final Report. Great Falls, MT.

Montana Department of Environmental Quality. 2003. TMDL Laws and Rules. [Online]. Available at http://www.deq.state.mt.us/ppa/mdm/tmdl/tmdl_index.asp.) (Verified 27 Oct. 2003.)

Systems Technology, Inc. 1979. Muddy Creek Special Water Quality Project. Helena, MT.

Results

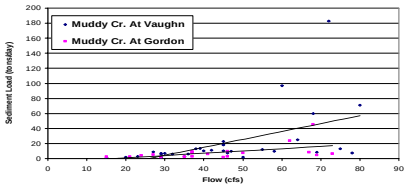

Figure 5. Relationship between sediment and flow at USGS stations: Muddy Creek at Vaughn and Muddy Creek at Gordon, for flows less than 80 cfs.

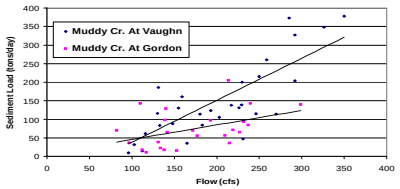

Figure 6. Relationship between sediment and flow at USGS stations: Muddy Creek at Vaughn and Muddy Creek at Gordon, for flows greater than 80 cfs.

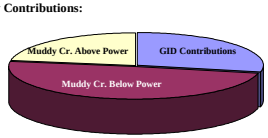

Figure 7. Total flow contributions (acre feet) from Muddy Creek above the irrigation project (Power), from major irrigation fed tributaries, and from Muddy Creek below the irrigation project, for the irrigation season (May 1 to September 30).

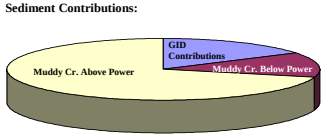

Figure 8. Total sediment contributions (tons) from Muddy Creek above the irrigation project (Power), from major irrigation fed tributaries, and from Muddy Creek below the irrigation project, for the irrigation season (May 1 to September 30).

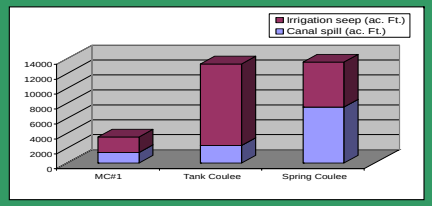

Figure 9. Irrigation seepage plus return flow versus canal spillage originating in GID and contributing to Muddy Creek.

Table 1. Total flow (acre feet) and sediment loads(tons per season) generated in each tributary and within Muddy Creek during the irrigation season (May1 to September 30).

	Total Flow (Acre Feet)	Total Sediment (tons/season)	Tons/Acre Ft
Above Power	22,081.56	4,833.67	0.22
Muddy Cr. #1	3,500.08	343.82	0.10
Tank Coulee	13,277.96	1,555.41	0.12
Spring Coulee	13,532.78	1,329.34	0.10
Muddy Cr. #2	4,223.04	411.34	0.10
Muddy Cr. #3	3,709.12	364.35	0.10
Total At Vaughn	**77761.98**	**30162.57**	0.39

Conclusions

- 71% of seasonal sediment loads are generated within Muddy Creek below GID – tributaries originating within GID are a minor contributor to sediment loads
- One half (49%) of seasonal flow is contributed by irrigation fed tributaries
- Approximately 2/3 of irrigation flow contributions are a result of irrigation seepage plus return flows,while the remaining 1/3 is water spilled or directly discharged out of the canal
- Spring Coulee and Tank Coulee contribute 27,000 acre feet of the total irrigation contributed flow of 38,243 acre feet (or 71%) and are by far the most significant contributors of irrigation produced flows to Muddy Creek

Lessons learned

Altered hydrology within Muddy Creek results in significantly elevated sediment generation downstream of GID. To address the sediment issue in Muddy Creek, address flow generation from GID.