APPENDIX C
REFERENCE VALUE DEVELOPMENT & TARGET JUSTIFICATION

Reference condition values for various water quality parameters were identified using the guidance presented in **Section 3.0** and **Appendix B**. In general, reference conditions represent either conditions that have not been noticeably affected by anthropogenic activities (in other words, natural conditions) or conditions that represent the best water quality/land conditions achievable through the proper implementation of all best management practices if a return to natural condition is unachievable or unreasonable.

Potential internal reference reaches were identified via aerial assessments, but, during field reconnaissance, the reaches were determined to be more than minimally impacted by anthropogenic sources. Thus, no internal reference data were available for target development. Regional reference data provide the primary approach for most parameters and are used in conjunction with secondary reference approaches.

The suite of water quality targets and supplemental indicators selected for the Shields River TPA are listed below and described in detail within this appendix. The water quality targets are considered to be the most reliable and robust measures of the pollutant. Supplemental indicators are typically not sufficiently reliable to be used alone as a measure of support. These are used as supplemental information, in combination with the water quality targets, to better define potential problems caused by a pollutant.

<u>Water Quality Targets</u>:

- Percent Surface Fines in Riffles < 6.35 mm (pebble count)
- Percent Surface Fines in Riffles < 2 mm (pebble count)
- Percent Surface Fines < 6.35 mm in Pool Tails (grid toss or equivalent)
- Width-to-Depth Ratio (ratio of bankfull width to bankfull depth at riffle cross sections)
- Macroinvertebrate Population Metrics

<u>Supplemental Indicators</u>:

- Entrenchment Ratio
- Bank Erosion Hazard Index (BEHI) values
- Percent Eroding Banks
- Significant Human Caused Sources

The above parameters cover a broad range of direct habitat measures and measures of channel conditions, as well as a direct measure of aquatic life (macroinvertebrate metrics). All of the above parameters are measures of sediment-related stream health and can help define sediment-related impairments. Specific values for the targets and supplemental indicators are based on the best available data, but may be modified in the future as additional reference data within the watershed are collected or if they are determined to be inappropriate relative to the natural loading rate.

C.1 Channel Morphology and Substrate Measurements

USFS data for approximately 200 reference sites were used as a basis for determining departure from reference geomorphic condition and substrate size distribution. Approximately 70 of the reference sites were from the Greater Yellowstone Area, while the remaining sites were surveyed within the Beaverhead-Deerlodge National Forest (BDNF, n.d.). Streams described as “reference” were not necessarily in pristine watersheds, though the streams had to be stable and in “proper functioning condition.” The entire reference dataset is available upon request from the BDNF and has been provided to the Montana DEQ.

The 75th percentile was calculated from the reference dataset and will be used as a basis for sediment water quality targets (**Table C-1**). Since the water quality target depends on the stream type, the term “comparable to reference values” should be interpreted as “less than or equal to” the 75th percentile for the percent surface fines, width/depth ratio, and BEHI, while “comparable to reference values” should be interpreted as “greater than or equal to” the 75th percentile for the entrenchment ratio. In essence, lower values for surface fine sediment, width/depth ratio, and BEHI rating are more desirable and suggest support of the cold water fishery and aquatic life beneficial uses. In general, higher values are desirable for the entrenchment ratio. No fine sediment targets (i.e. percent surface fines in riffles and pools) will be applied to the low gradient E streams in the Shields River TPA because these stream types naturally have high amounts of fine sediment, regional reference sediment values vary greatly, and there is insufficient internal reference data.

The 75th percentiles of entrenchment ratios for C and E channels in the reference dataset range from 3.7 to 15.9 (**Table C-1**). Although a higher entrenchment ratio is more desirable, if a channel is not entrenched, having an even higher ratio does not indicate a problem and is not a reasonable target. Rosgen and Silvey (1996) define a slightly entrenched C or E channel as having an entrenchment ratio greater than 2.2. Although this number is a generalization based on channel type data collected throughout the U.S. and not as applicable as regional reference data, it provides a frame of reference for an unentrenched channel. The smallest reference entrenchment ratio for a C channel is 5.1 and for an E channel is 3.7. These numbers will be used as the entrenchment ratio target for C and E channels.

Table C-1. Greater Yellowstone Area and Beaverhead Deerlodge National Forest Reference Dataset 75th Percentiles for Individual Rosgen Stream Types.

Parameter	B3	B4	B	C3	C4	C	E3	E4	E
% surface fines < 6mm	12	25	20	14	29	29	20	38	44
Width/Depth Ratio	15	17	16	31	20	23	10	7	7
Entrenchment Ratio	1.8	1.9	1.8	5.1	~~14.1~~	~~10.1~~	~~14.0~~	~~15.9~~	3.7
Reach Average BEHI	27.1	31.7	29.7	26.9	26.5	26.5	26.3	24.2	23.6

C.2 Percentage Surface Fine Sediment

The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a stream bed and is directly linked to the support of the cold water fishery and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival (Magee et al. 1996; Suttle et al. 2004) and macroinvertebrate abundance and taxa richness (Mebane 2001; Zweig et al. 2001). Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Reiser and White 1988; Suttle et al. 2004) whereas other studies have concluded the most harmful percentage falls within 10 and 40 percent fine sediment (Bjornn et al. 1977; Bjornn and Reiser 1991; Relyea et al. 2000).

The <6 mm fine sediment target for riffles is based on Wolman pebble count reference data from within the Greater Yellowstone Area and the BDNF (**Table C-1**). Particularly for B and C channel types, the reference dataset correlates with a study by Mebane (2001), which was based on Wolman riffle pebble counts and found the greatest number of salmonid and sculpin age classes when the 75th percentile of fine sediment <6 mm was less than 20-30%. The USFS dataset is based on the "zigzag" pebble count method, which includes multiple habitat types (e.g. riffles and pools), and because the riffle pebble count is only from riffles, it is more likely to provide lower fines estimations than the zigzag method. Nonetheless, comparisons with 2004 Shields River pebble count datasets are reasonable and make a stronger case for sediment impairment if the 75th percentiles of the reference values are exceeded.

The Greater Yellowstone Area and BDNF reference dataset does not include substrate size classes smaller than 6 mm. Other regional data from pebble counts in the Middle Blackfoot Watershed, Nevada Creek Watershed, and Kootenai National Forest generally found fine sediment <2 mm to comprise less than 10% of riffle substrate. As the Shields River watershed is mostly in the Northwestern Great Plains ecoregion, which has a higher background level of fine sediment than most of the reference data, a target range of less than 10-15% fine sediment <2 mm will be used for riffles. Since sediment <2 mm is a fraction of the sediment <6 mm, this correlates well with most of the <6 mm regional data for sediment being greater than 15% (**Table C-1**). For all sites sampled on the Shields River (n=9), the median value was 3 % fines <2 mm and the 75th percentile was 7%. Based on reference values, literature values, and field observations, a target of less than 10-15% sediment <2 mm is protective of beneficial uses and feasible.

C.3 Percent Surface Fines in Pool Tail-Out Gravels

A 49-point grid toss was used to estimate percent surface fines in pool tails; four grid tosses were performed in each pool tail, and the total percentage of fine sediment for each pool was averaged with all other pools in each sample reach. The wire grid method is less-commonly used for determining percent fines in surface substrate than the Wolman pebble count, but provides the advantage of focusing on critical habitat, and is therefore more directly related to aquatic habitat support.

A particle size of 6 mm is commonly used to define fine sediment because of its potential to clog spawning redds and smother fish eggs by limiting oxygen availability (Irving and Bjornn 1984; Shepard et al. 1984). Survival of several salmonid species greatly declines as subsurface fine sediment <6 mm increases (Shepard et al. 1984; Reiser and White 1988; Weaver and Fraley 1991). Increasing surface fine sediment <6 mm also negatively affects both salmonids and sculpins (Mebane 2001), and sedimentation of pools reduces summer and overwintering habitat, causing a reduction in pool salmonid density (Bjornn et al. 1977).

Reference development for percent surface fines using the grid-toss method is based on results from several studies (**Table C-2**). Some of the reference data are from least impacted streams, and because of limited least impacted streams in other watersheds, other reference data are from percentiles from entire sample datasets. Because excess sediment was noted in most pool tails during field work in the Shields River TPA and there were no internal reference sites, it is not reasonable to use a percentile of the dataset. Instead, the target is based on reference data from regional watersheds. Because the Shields River TPA is mostly in the Northwestern Great Plains ecoregion, which has a higher background level of fine sediment than much of the reference data, the pool tail target is on the higher end of the regional reference data. The most applicable regional reference data are from the Middle Blackfoot and Nevada Creek watersheds. Based on conditions within the Shields River TPA and available reference data, the water quality target for percent surface fine sediment <6 mm in pool tails is a reach average less than 20% for B and C channels.

Table C-2. Regional reference data for grid toss surface fines (<6 mm)

Source	Percent Fines
Blackfoot Headwaters TMDL Reference Condition	6 – 8 (75th percentile)
Lolo NF (USFS 1998)	6 – 8 (Average); 10 – 15 probable range of 75th percentiles
Prospect Creek Watershed	13 (Average); 6 (median); 14 (75th percentile)
Ruby River Watershed	B channel: 8 (median)
	C channel: 6 (median)
	Ea channel: 7 (median)
Middle Blackfoot Watershed	B channel: 17 (75th percentile from Nevada Creek data)
	C channel: 20 (75th percentile)
	E channel: 48 (75th percentile of reference)
Nevada Creek Watershed	B channel: 17 (75th percentile)
	C channel: 23 (75th percentile of reference)
	E channel: 82 (25th percentile)

C.4 Width/Depth Ratio and Entrenchment Ratio

The width/depth ratio and the entrenchment ratio are fundamental aspects of channel morphology, and each provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). Width/depth ratio is the ratio of channel bankfull width to the mean bankfull depth, and the entrenchment ratio is the ratio of the width of the flood-prone area to the channel bankfull width (Rosgen and Silvey 1996). In essence, the entrenchment ratio is the vertical containment of a stream, or how easily it can access its floodplain. Changes in both the width/depth ratio and entrenchment ratio can be used as indicators of change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess coarse sediment load (MacDonald et al. 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in channel width as the stream attempts to regain a balance between sediment load and transport capacity. Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios signify that stream energy is concentrated in-channel during flood events versus having energy dissipation on the floodplain. Accelerated bank erosion and an increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Knighton 1998, Rowe et al. 2003, Rosgen and Silvey 1996).

During data collection in 2004 (as discussed in **Section 4.5**), width/depth and entrenchment ratios were measured at five cross sections per reach. The reach median width/depth ratios and entrenchment ratios collected in 2004 will be compared to the reference range for the appropriate stream type (see **Table C-1**). Width/depth ratio will be used as a water quality target for sediment impairments, and, because entrenchment is not as responsive to land-use changes within the watershed as the width/depth ratio, entrenchment will be used as a supplemental indicator.

C.5 Macroinvertebrates

Siltation exerts a direct influence on benthic macroinvertebrates assemblages through several mechanisms. These include limiting preferred habitat for some taxa by filling in interstices or spaces between gravel. In other cases, fine sediment limits attachment sites for taxa that affix to substrate particles. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site, and are used by the Montana DEQ to evaluate impairment condition and beneficial use support. The advantage to these bioindicators is that they provide a measure of support of associated aquatic life, an established beneficial use of Montana’s waters. Although macroinvertebrates provide an important measure of aquatic life support, they are used as a supplemental indicator for support of sediment impairment because they can be affected by other impairments (e.g. nutrients and metals).

In 2006, Montana DEQ adopted impairment thresholds for bioassessment scores based on two separate methodologies. The **Multi-Metric Index (MMI)** method assesses biologic integrity of a sample based on a battery of individual biometrics. The **River Invertebrate Prediction and Classification System (RIVPACS)** method utilizes a probabilistic model based on the taxa assemblage that would be expected at a similar reference site. Based on these tools, DEQ adopted bioassessment thresholds that were reflective of conditions that supported a diverse and biologically unimpaired macroinvertebrate assemblage, and therefore a direct indication of beneficial use support for aquatic life. The rationale and methodology for both indices are presented in, “Biological Indicators of Stream Condition in Montana Using Benthic Macroinvertebrates,” (Jessup et al., 2006).

The MMI is organized based on three different bioregions within Montana. The three MMIs are Mountain, Low Valley, and Plains. Each region has specific bioassessment threshold criteria that represent full support of macroinvertebrate aquatic life uses. The Shields River watershed falls within both Mountain and Plains MMI bioregions. The Plains MMI is most applicable to the typical warmwater eastern Montana plains stream. Because the Shields River is at the border of the Northern Great Plains ecoregion and predominantly a coldwater fishery, the Low Valley MMI is a more appropriate tool and will be used instead of the Plains MMI to evaluate macroinvertebrates in the mainstem Shields River. The Plains MMI is appropriate for Potter Creek and Antelope Creek and will be used to assess macroinvertebrate populations in those water bodies. The MMI score is based upon the average of a variety of individual metric scores. The metric scores measure predictable attributes of benthic macroinvertebrate communities to make inferences regarding aquatic life condition when pollution or pollutants affect stream systems and in-stream biota. For the MMI, individual metric scores are averaged to obtain the final MMI score, which ranges between 0 and 100. **The impairment thresholds are 63 for the Mountain MMI, 48 for the Low Valley MMI, and 38 for the Plains MMI.** These values are established as water quality targets for sediment impairments in the Shields River TPA. The impairment threshold (10th percentile of the reference dataset) represents the point where DEQ technical staff believes macroinvertebrate populations are affected by some kind of impairment (e.g. loss of sensitive taxa), and an MMI score less than the threshold suggests impairment.

The RIVPACS model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled. The RIVPACS model provides a single dimensionless ratio to infer the health of the macroinvertebrate community. This ratio is referred to as the Observed/Expected (O/E) value. Used in combination, the results suggest strong evidence that a water body is either supporting or non-supporting its aquatic life uses for aquatic invertebrates. **The RIVPACS impairment threshold for all Montana streams is any O/E value <0.8.** However, the RIVPACS model has a bidirectional response to nutrient impairment. Some stressors cause macroinvertebrate populations to decrease right away (e.g. metals contamination) which causes the score to decrease below the impairment threshold of 0.8. Nutrient enrichment may actually increase the macroinvertebrate population diversity before eventually decreasing below 0.8. The 90th percentile of the reference dataset was selected (1.2) to account for these situations and any value above this score may present support for nutrient impairment (Feldman 2006). However, RIVPACS scores >1.0 are considered unimpaired for all other stressor types. A supplemental indicator value RIVPACS score of >0.80 is established for sediment impairments in the Shields River TPA. A score of greater than 1.2, when combined with other data, may present support for nutrient impairment (Feldman 2006).

C.6 Bank Erosion Hazard Index (BEHI)

Stream flows, sediment loads, riparian vegetation, and streambank material all influence bank stability, which, in turn, influences sediment contribution to the stream. The BEHI is a composite metric of streambank characteristics that affect overall bank integrity and is determined based on bank height, bankfull height, rooting depth, bank angle, surface protection, and bank materials/composition (Rosgen and Silvey 1996). Measurements for each metric are combined to produce an overall score or “rating” of bank erosion potential. Low BEHI values indicate a low potential for bank erosion. A bank erosion hazard index beyond the reference range for the appropriate stream type (see **Table C-1**) will be used as a supplemental indicator for sediment impairments.

The percent of eroding streambanks within a survey reach will be applied as a supplemental indicator for sediment impairments. Since streambank erosion is a natural process, this indicator will be used with caution. For example, just because eroding banks are present does not necessarily mean the erosion is human-induced or that there is an in-stream sediment problem. Additional information, such as observed bank trampling, removal of stabilizing vegetation, or increased water yield from timber harvest, will be considered. Departure from reference condition will apply when the percent of eroding banks within a survey reach exceeds 15% for B, C, and E type streams. These values are based on least impacted stream surveys in the Ruby Watershed.

C.7 Significant Human Caused Sediment Sources

Human caused sources need to be present for a TMDL to be written. If the only departure from reference conditions are stream channel conditions that do not affect sediment transport, a habitat restoration plan will be written. TMDLs need to address a reduction of sediment from applying restoration practices to human caused activities. The analysis that supports this parameter is supplied in the Sediment Source Assessment Section (**Section 7.0**) of this document.

REFERENCES

Beaverhead-Deerlodge National Forest (BDNF). 2008. Unpublished Stream Morphology Data, Dillon, MT.

Bjorn, T. C., Brusven, M. A., Molnau, M. P., Milligan, J. H., Klamt, R. A., Chacho, E., and Schaye, C. 1977. Transport of Granitic Sediment in Streams and Its Effects on Insects and Fish. Bulletin Number 17. Washington DC, USDI Office of Water Research and Technology.

Bjorn, T. C. and D. W. Reiser. 1991. "Habitat Requirements of Salmonids in Streams," in *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*, Special Publication 19, (Bethesda, MD: American Fisheries Society), 83-138.

Feldman, David. 2006. A Report to the DEQ Water Quality Planning Bureau on the Proper Interpretation of Two Recently Developed Macroinvertebrate Bioassessment Models. Helena, MT, Montana Department of Environmental Quality.

Irving, J. S. and Bjorn, T. C. 1984. Effects of Substrate Size Composition on Survival of Kokanee Salmon and Cutthroat Trout and Rainbow Trout Embryos. Technical Report 84-6. Moscow, ID, University of Idaho.

Jessup, Benjamin, Hawkins, Chuck, and Stribling, James. 2006. Biological Indicators of Stream Condition in Montana Using Macroinvertebrates. Owings Mills, MD, Tetra Tech, Inc.

Knighton, David. 1998. *Fluvial Forms and Processes: A New Perspective*, New York, New York: John Wiley and Sons Inc.

MacDonald, Lee H., Smart, Alan W., and Wissmar, Robert C. 1991. Monitoring Guidelines to Evaluate Effects of Forestry on Streams in the Pacific Northwest and Alaska. EPA 910/9-91-001. Seattle, WA, U.S.Environmental Protection Agency.

Magee, James P. and Thomas E. McMahon. 1996. Spatial Variation in Spawning Habitat of Cutthroat Trout in a Sediment-Rich Stream Basin. *Transactions of the American Fisheries Society* 125, no. 5: 768-779.

Mebane, C. A. 2001. Testing Bioassessment Metrics: Macroinvertebrate, Sculpin, and Salmonid Responses to Stream Habitat, Sediment, and Metals. *Environmental Monitoring and Assessment* 67, no. 3 (March): 293-322.

Reiser, D. W. and R. G. White. 1988. Effects of Two Sediment Size-Classes on Survival of Steelhead and Chinook Salmon Eggs. *North American Journal of Fisheries Management* 8: 432-437.

Relyea, C. B., Minshall, G. W., and Danehy, R. J. 2000. Stream Insects as Bioindicatores of Fine Sediment. Water Environment Federation Specialty Conference. Watershed 2000 . Boise, ID, Idaho State University.

Riggers, B. W., Rosquist, A., Kramer, R. P., and Bills, M. 1998. An Analysis of Fish Habitat and Population Conditions in Developed and Undeveloped Watersheds on the Lolo National Forest. 64 pp. USDA Forest Service.

Rosgen, David L. 1996. *Applied River Morphology*, Pagosa Springs, CO: Wildland Hydrology.

Rowe, Mike, Essig, Don, and Jessup, Benjamin. 2003. Guide to Selection of Sediment Targets for Use in Idaho TMDLs. Pocatello, ID, Idaho Department of Environmental Quality.

Shepard, B. B., Leathe, Stephen A., Weaver, Thomas M., and Enk, M. D. 1984. Monitoring Levels of Fine Sediment within Tributaries of Flathead Lake, and Impacts of Fine Sediment on Bull Trout Recruitment. Wild Trout III Symposium.

Suttle, K. B., M. E. Power, J. M. Levine, and C. McNeeley. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. *Ecological Applications* 14, no. 4: 969-974.

Weaver, Thomas M. and Fraley, J. J. 1991. Fisheries Habitat and Fish Populations in Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program. Kalispell, MT, Flahead Basin Commission.