# APPENDIX E

# SEDIMENT MONITORING AND ASSESSMENT METHODOLOGY

## E.1 Introduction

This document describes methods used in monitoring and assessment conducted for the Ruby River sediment TMDLs. Some methodology may also be incorporated in the main body of the TMDL report. To begin the discussion about stream assessments, a basic understanding about monitoring scale is needed. The following terms relate to specific spatial scales:

| | |
|---|---|
| Stream Segment – | A 303(d) listed stream segment. For methods see Montana's Integrated Water Quality Report. |
| Stream Reach – | A portion of a stream segment with similar attributes identified according to an aerial photo assessment. |
| Stream Section – | A portion of a stream reach where field monitoring occurs. |

## E.2 Remote Sensing

### E.2.1 Aerial Photo Interpretation

Aerial photo interpretation (API) is a useful tool for stratifying stream and riparian condition to create a framework for stream assessment and water quality monitoring. Aerial photo analysis involves examination of recent aerial photos of the watershed, looking at factors such as riparian condition, sediment source areas, and slope and stream stability factors, using methods patterned after Somers and others (1991).

Low-level color aerial photos are most useful for this technique. The scope of this project did not include budget for additional flights, therefore the aerial photo analysis was limited by photo availability. Color photos at a scale of 15,840 (4 inch/mile) from 2001 were available for most public lands, but did not cover all reaches of all streams. Other photos were in black and white and varied in scale and completeness of coverage.

Copies of recent color aerial photos were copied and laminated for use in ground-truthing aerial photo interpretation with on-site assessments of riparian area and channel condition. Low-level color infrared photographs were also available on the upper Ruby River on Forest Service land. These photos were also used in the aerial photo interpretation for the upper Ruby River. After the API was completed, the low-level digital IR photos at 1 ft resolution were georeferenced by USFS. Additionally, the color aerial photographs were scanned and georeferenced by USFS. While these images were not available as cohesive digital layers at the time the API was conducted, they were available for GIS overlay for later tasks. Parameters used to determine riparian condition from aerial photo interpretation are summarized in Table E-1, below.

**Table E-1. Aerial Photo Interpretation Parameters.**

| **Parameter** | **Description** | **Data Description** |
|---|---|---|
| Riparian Cover Class | Description of vegetation types | Categorical |
| Riparian Canopy Opening | Estimate of canopy cover over stream, as percent of length | Estimated to nearest 10% |
| Large Woody Debris Recruitment Potential | Estimate based on canopy cover and belt width | Categorical (Low, Medium, High) |
| Presence of near-stream sediment sources | Abundance of adjacent road-stream crossings and potential sediment sources such as steep slopes and high skid road densities | Number of discrete sources is recorded; landscape features noted and delineated on maps, plotted in GIS |
| Evidence of historic channel manipulation | Notes straightened, severely incised, or armored sections of stream, where visible | Described in comments and estimated to nearest 10% of channel altered |

The riparian condition as determined from aerial photo assessment is broken into four general categories for mapping:

*Very Poor*- Severe lack of vegetation, evidence of channelization and wetland ditching, no large woody debris (where the potential for LWD exists).
*Poor*- Cleared riparian vegetation on one or more sides, lack of riparian buffer, low large woody debris.
*Fair*- Generally good buffer but may lack large woody debris, or shows evidence of other land clearing disturbance adjacent to stream.
*Good*- Little to no evidence of clearing in riparian zone or channel manipulation, high vegetation density and large woody debris recruitment potential.

Reaches were designated from the aerial photo interpretation and delineated on 1:24,000 scale topographic maps, color coded by condition as defined above, to serve as a guideline for field assessment. Maps of these broad-scale changes in condition provide a basis for determining locations of field assessment reaches, and ensure sampling of the range of conditions existing on listed water bodies.

Pre field work remote sensing also included a stream morphological analysis based on topographic maps and aerial photos. This analysis was conducted on all impaired streams, over the range of conditions present. Factors examined in the morphological analysis include stream sinuosity, valley slope, average valley width, Rosgen level 1 stream type, soil types on the floodplain, and existing and potential riparian vegetation seral stage. Some of these factors, specifically valley width and slope, are also are determined through GIS-based analysis. In addition, any indicators of landslide prone areas or other unstable slopes are noted and delineated on maps. Stream condition, Rosgen Level 1 stream type and sediment sources as determined from the aerial photo interpretation were plotted in GIS layers in draft maps for field use. Maps delineating API reach condition and reach boundaries were used as a foundation for placing reaches for field-based assessments. Information from the API was updated after field-based assessment.

# E.3 Field Methods

## E.3.1 Stream Assessment and Ground-Truthing of Aerial Photo Interpretation

Placement of stream assessment reaches was based on changes in stream condition mapped in the aerial photo interpretation (API) completed before the initiation of field work. Placement of field assessment reaches started with reconnaissance of the larger aerial photo interpretation reaches. Reaches were placed in representative areas of API reaches. In general, one on-site stream assessment was completed per API reach, although more than one on-site assessment was completed on several API reaches, and in some cases API reaches were combined where field reconnaissance determined the two reaches were alike.

Stream assessments include channel surveys using the Rosgen (1996) methodology, stream condition assessment using the USDA NRCS Riparian Assessment/MDEQ Stream Reach Assessment Form (SRAF), and collection of additional data to ground-truth the aerial photo interpretation and strengthen determination of reach condition. These methodologies are described in detail below.

### E.3.1.1 Channel morphology

Channel morphology was measured at a cross-section representative of channel conditions on each reach, following the Rosgen (1996) methodology. Cross-sections are located based on sites which best represent the conditions in the overall reach. The following information is gathered:

1) GPS location of cross-section
2) Bankfull width
3) Slope
4) Width/depth ratio
5) Entrenchment
6) Sinuosity
7) Bank erosion hazard index (BEHI)
8) Bed mobility and substrate size distribution using Wolman pebble count methodology, as outlined in Rosgen (1996) methodology

Channel dimensions used to determine Rosgen stream type (entrenchment, slope, width/depth and substrate size distribution) are measured using standard methods outlined in Rosgen (1996). BEHI is also determined using standard Rosgen methodology (Rosgen, 2001). The BEHI methodology evaluates a streambank's inherent susceptibility to erosion as a function of seven factors, including:

1. Ratio of streambank height to bankfull stage
2. Ratio of riparian vegetation rooting depth to streambank height
3. Degree of rooting density
4. Composition of streambank materials
5. Streambank angle (i.e., slope)

6. Bank material statigraphy and presence of soil lenses
7. Bank surface protection afforded by debris and vegetation

Pebble counts consisted of measuring substrate size at 100 points from bankfull to bankfull distributed on ten transects placed to sample a representative proportion of aquatic habitats in the assessment reach. Fine sediment data more specific to spawning substrate was determined using a 49-point grid, placed by means of a blind toss in tail-outs of every pool within the channel morphology reach (20 times bankfull width minimum length). The percent of intersections in the grid overlying fine sediment (<2 mm) was calculated and averaged for the reach. This percentage of fine sediment is calculated by different means than the Wolman percent fines, and should not be considered directly comparable.

### E.3.1.2 Stream Assessments

Attributes examined for the stream assessments include channel factors such as stream incisement, lateral cutting, sediment vs. water supply, streambank soil and rootmass, and vegetative factors such as weed infestations, cover of shallow-rooted disturbance-caused plants, woody species establishment and regeneration, browse levels on woody species, and vegetative cover of the streambanks and floodplain.

Additional data collected for the stream assessments include habitat types, community types, or dominant canopy, mid-story, and understory vegetation on the lower streambanks and upper banks/floodplain, large woody debris frequency and recruitment potential, and attributes used in the aerial photo interpretation, including percent canopy density and overhanging vegetation on streambanks, riparian beltwidth, percent of streambanks artificially armored, straightened, and stable, presence and nature of beaver activity, vegetation cover class, presence of impervious surface and structures within 100 feet of the stream reach, and evidence of irrigation affecting the stream reach. Monitoring also included taking digital photos looking upstream and downstream from the channel morphology cross-section of each reach, as well as additional photos of influences on stream condition or water quality.

All field personnel were trained in these methods, and all worked together for the first week of assessment. Teams were made up of one technician working with one water resource professional. Despite quality control efforts, some uncertainty should be assumed for field methods. Many parameters for stream assessments are estimated to the nearest 10% or are recorded as categorical data. After the training period quality control testing for repeatability in the field yielded an error of roughly 10% among observers for most parameters collected by ocular estimation. This was determined by comparing results among observers for percent canopy cover estimates and ocularly estimated bank erosion variables measured individually in duplicate efforts for the same reach. Results of the different methods were compared on three reaches. Using a suite of indicators of condition helps counteract uncertainty by providing several lines of evidence pertaining to stream condition and describing a wide range of influences on stream reaches.

### E.3.1.3. Comparison of API and Field Assessment Data

Field assessment data and API data for selected parameters (streambank canopy cover, overhanging vegetation, and riparian beltwidth) were compared in an MS Excel spreadsheet to calculate differences between datasets. Due to the large scale of many of the available photographs, API results do not always correspond with stream condition determined from on-site assessments used to ground-truth the API results. However, the API assessment reaches were very useful for determining changes in conditions, and therefore provided an excellent framework for locating field assessment reaches to achieve representative distribution of monitoring sites.

## E.3.2 Sediment Source Inventory and Mapping

### E.3.2.1 Near-Stream Sediment Sources

The sediment source inventory expanded on the aerial photo assessment of sediment sources, and was conducted on-site in conjunction with stream reach assessments. Watershed Consulting developed a sediment source assessment form using parameters commonly used in road inventories and landslide prone area assessments.

The attributes collected in the stream sediment source inventory include:

- Sediment source location (reach name and latitude/longitude)
- Sediment source type
- Cause of sediment source
- Streambank length or contributing length
- Gully dimensions
- Source height
- Vegetation percent cover
- Percent of stream reach
- Severity

The attributes collected for each source may vary, depending on the nature of the source. Near-stream sediment sources were either general sources for the entire on-site assessment reach or were discrete sources, for which GPS points were taken. Road-related sources encountered during the streambank inventory were only collected for private road crossings not accessible to most road traffic to avoid duplication with the road-related sediment source inventory.

Near-stream sediment source inventory was conducted using a “semi-quantitative” approach commonly used in extensive surveys. Dimensions for sediment sources were derived using a measuring rod or pacing, or estimated for parameters such as percent reach length, height of high banks, and vegetation cover. Sediment source severity is estimated using best professional judgment and is based contribution potential, vegetation buffer, and extent of deposited fine sediment originating from the sediment source. This rapid inventory approach was necessary to cover the large number of listed stream miles within the limited timeframe and budget available for such monitoring. Modeling is often used to predict sediment yields; however, no available models provide reliable calculations of streambank erosion.

Relative sediment yields from streambank sources are calculated by multiplying the sediment source erosional area (height x length), by literature values for rate of erosion per year based on severity, and by bulk density of bank soils to derive tons/year.

Yearly sediment load produced by eroding banks was determined using rates based on a range of values from similar stream systems published in scientific literature. These rates are presented in Table E-2.

**Table E-2. Bank Retreat Rates Used for Banks of Varying Severity of Erosion.**

| | Migration Rate (m/y) Values in Parentheses are in Feet | | |
|---|---|---|---|
| **Condition** | **Zaroban and Sharp (2001)** | **Rosgen (2001)** | **Nanson and Hickin (1986)** |
| Slight | 0.032 (0.10) | 0.061 (0.20) | 0.10 (0.33) |
| Moderate | 0.070 (0.23) | 0.189 (0.62) | 0.40 (1.31 |
| Severe | 0.183 (0.47) | 0.335 (1.10) | 0.70 (2.30) |

Evaluation of the three sources of lateral migration rates of eroding banks indicates that the moderate values (Rosgen, 2001) are most appropriate to apply in this instance. As well, these values have been used in streambank erosion calculations for other TMDLs in Montana (Blackfoot Headwaters TMDL). Rosgen (2001) examined lateral streambank erosion rates for the Lamar River basin in Yellowstone National Park and a series of streams along the Colorado Front Range. Of the three study areas, these streams most closely resemble the Ruby River watershed in geomorphic setting.

The following are steps used to calculate total sediment load from eroding banks:

- Assign retreat rates based on severity of sediment source, based on field observations, fracturing, vegetative cover, and signs of deposition;
- Assign percent of erosion due to separate types and causes of erosion for each eroding bank;
- Calculate tonnage of sediment produced yearly by each eroding bank and each cause (length × height × retreat rate from Table E-2 × bulk density of streambank soils);
- Extrapolate from field inventory reaches to the applicable larger reaches determined from aerial photo interpretation to derive yields for entire water bodies;
- Summarize relative yield of each cause of erosion for each water body.

An average bulk density of 1.5 tons/yard was used for streambank soils, based on numbers used by rock and soil companies, which base their bulk density numbers on USACE research (Pers comm. Schumaker Rock and Gravel, 2004).

A horizontal area as well as a vertical area of streambank had to be added to the overall area of some eroding features. For instance, private road crossings affect a length of streambank and have an average height, but also include a contributing length and tread width on both sides of the stream. These sources are minor and are not likely to influence overall sediment loads significantly. Gullies also have a horizontal component, but are included in upland sediment modeling as areas with bare ground. Additionally, gullies have vertical areas on either side that vary according to how much the gully has cut into the landscape. There is no way to know the rate at which gullies are eroding downward. Vertical eroding areas in gullies are not considered in upland load calculations.

The 2003 streambank sediment source inventory identified the following causes of erosion:

- Natural (includes wildlife use)
- Grazing-related (livestock)
- Road-related
- Past overuse
- Channel manipulation
- Other human-caused
- Unknown

Road-related sources were only considered on private road crossings because public access road-related sources were considered in the road sediment source inventory.

In many cases, more than one cause of erosion is considered for a sediment source. Best Professional Judgment is used to determine causes of erosion, based on bank condition, vegetation cover, vegetation condition, vegetation type, associated landslide areas, hillslope conditions, presence of tracks, hoof shear, and other direct signs of land uses, and other supporting information from stream assessments.

A sediment yield in tons per year was determined for each of the potential sources listed above. For road crossings the erosional area was calculated by multiplying the contributing length of tread by the road surface width because the private road crossings generally did not have a bank height component or cut and fillslopes. Landslides were considered natural sediment sources. Erosion from landslides was included in upland sediment yield modeling based on areas extent of bare ground. The erosional area at landslide toeslopes was included in the near-stream sediment source inventory, measured in the same manner as a high eroding bank.

The yields for each source were totaled to give an overall yield per reach assessed. An erosion rate was then calculated by dividing the sediment yield by the length of the assessed reach, giving a value in tons per year per mile.

Estimated sediment delivery rates and yields were extrapolated to stream reaches that were not assessed or on which no sediment source inventory was completed to allow calculation of a total estimated sediment load for all sources of sediment on each listed water body. Calculated erosion rates were extrapolated to the non-assessed streams within the Ruby watershed using rates from assessed reaches, which were then multiplied by the length of the non-assessed reaches to give a sediment yield (in tons per year) for all reaches on the Ruby. In order to extrapolate from inventoried to un-inventoried reaches with the highest accuracy possible, several factors were considered in determining appropriate reaches to compare for extrapolation.

The following is a list of the factors used in determining which assessed reaches to use as a source for erosion rates to extrapolate to any given non-assessed reach:

- Physical vicinity – The erosion rate from a reach just up or downstream on the same drainage was used to extrapolate sediment loading where applicable.
- Rosgen stream type and landscape – Erosion rates were applied to reaches with similar slope and sinuosity, Rosgen type, or landscape.
- Upland sediment yields- The AGWA model mapped relative event-based sediment yields for subbasins within listed watersheds. A map showing these modeled sediment yields was used in choosing reaches for extrapolation.
- Presence of landslides or landslide-prone topography – A GIS polygons shapefile of landslides was utilized to extrapolate sediment among reaches with similar influence from unstable topography.
- Management – Notes from sediment source inventories and notes and pictures from stream assessments were used to double-check that sediment delivery rates were applied among reaches with similar management, where information was available.

Total rates for each sediment source category were calculated for each water body by adding yields from inventoried and un-inventoried reaches. Yields from natural and human-caused sediment sources are tabulated in Section 7.0, Sediment, and are used as a basis for TMDL and allocations.

**Uncertainty and adaptive management**

Uncertainty is inherent in most field-based rapid inventory methods. Uncertainty potentially stems from variability among observers, estimations of sediment source dimensions, variation between literature values for bank erosion rate and conditions on the listed water bodies, and estimations of the amount of erosion due to separate causes. However, even given the inherent uncertainty in these methods, the extensive sediment source inventory provides a more reliable estimate of relative sediment yield from near stream sources than can be provided by any remote sensing methodology or modeling.

The process of extrapolating sediment erosion rates from inventoried reaches to un-inventoried reaches is another source of uncertainty. Landscape conditions and management are variable over the watershed, and, while care was taken to use the most appropriate source reaches possible for erosion rates, no two reaches are exactly alike.

Due to uncertainty in erosion rates, and because methods are semi-quantitative, numbers derived from sediment yield calculations should not be interpreted as actual sediment yields, but as an estimated relative yield.

While this approach involves some uncertainty, error inherent in estimations of sediment source dimensions generally were within approximately 10% and less often up to 20% when tested in the field. This method provides reliable relative yields, and is not expected to give absolute sediment yields for every streambank sediment source.

Uncertainty is accounted for in management application of sediment yield analysis through use of an adaptive management approach. This approach includes long-term monitoring using quantifiable sediment targets to determine if management and restoration recommendations are effective in reducing habitat degradation related to sediment and direct sediment inputs. Sediment targets are discussed in Section 3.3 of the Ruby River TMDL document text. These targets are more useful for reflecting effects of management changes on a shorter-term timeframe than can be detected by repeating the streambank sediment source inventory. Monitoring design and timeframe for monitoring and restoration implementation are outlined in Section 11.0 of the Ruby River TMDL document text. If management and restoration recommendations prove not to be effective, other alternatives must be implemented. Monitoring recommendations include establishing permanent cross-section transects and monitoring changes in cross-sectional area and measuring bank retreat rate over time to determine actual bank erosion rates.

### E.3.2.2 Road-Related Sediment Sources

Sediment loading from road-related sources was estimated from data collected in two separate assessments. The near stream sediment source assessment estimated sediment loading from private road crossings not publicly accessible using by recording the extent of contributing erosional area, which was then used in the calculations for the road source inventory methods. An inventory of sediment source on public roads was also conducted to estimate sediment inputs from public roads.

The road-related sediment source inventory included traveling all roads within 200 feet of listed water bodies and documenting all sediment sources delivering sediment to the stream or active floodplain. In addition, all road-stream crossings for side roads on the mainstem or tributaries within 200 feet of the listed water body were documented. Washington Timber, Fish, and Wildlife methodologies (WTFW, 1998) consider roads from 100-200 feet of streams to be moderate risks for sediment delivery, all other factors equal.

The road sediment methodology follows a revised Washington Forest Practices Board (WFPB, 1997) method, which includes calculating the contributing area of the tread, cutslope and fillslope of the road. This erosional area is modified to account for vegetative and tread surface factors. The attributes considered in the road-related sediment sources also include crossing information, including type of crossing, culvert dimensions, channel dimensions, and qualitative information about risk of failure, based on appropriateness of culvert sizing and condition. Digital photos were taken to illustrate different sediment delivery issues and to document severe sediment inputs.

Relative sediment yield from road-related sources is derived similarly to streambank sources, except that different dimensions are multiplied. Contributing length and tread width are multiplied for road area, and then multiplied with a surface material rating multiplier to address erodibility of the surface. Total erosional area is the sum of the road surface area, fillslope area, and cutslope area. The total erosional area is multiplied by a severity rating based on delivery potential as determined from proximity to the water body, drainage patterns, and presence of filtering vegetation or other filtering structures. In the case of culverts, fillslope area is generally the primary erosional surface considered, unless ditches drain to the crossing, which was true in several cases. Erosional area is multiplied by a severity rating based on appropriateness of culvert sizing, evidence of scouring, and presence of filtering vegetation or other filter structures.

To calculate the volume of sediment contribution from each road location the following steps are followed:

1. Assign a base (natural) erosion rate from roads in tons/acre/year. This commonly comes from a combination of published values and professional knowledge of the soils in the watershed.
2. Calculate the area of erosion (length times width) for the tread, cut and fillslopes, and convert it to acres.
3. Apply each multiplier (cover, gravel, and traffic).
4. Multiply all of these together for the road tread, cutslopes and fillslopes individually to derive the sediment volume from each of these features.
5. Sum these three values for the total delivery for that location, in tons of sediment per year.
6. Location totals are then summed by watershed to arrive at a total estimated fine sediment yield from roads for each listed water body.

Base erosion rate was determined using best professional judgment, based on regional rates previously published and characteristics of the study watershed. The base rate for the Ruby Watershed is estimated at 30 tons/acre/year. This is similar to that used for roads in granitic terrain (31 tons/acre/year in the Priest River TMDL) and significantly higher than that used in Belt Supergroup lithology (20 tons/acre/year in Plum Creek methodology). The erosion rate is used to derive relative sediment yield from roads in listed subwatersheds, and is assumed to be similar for similar road conditions in all watersheds.

The amount of vegetation on the cut and fillslopes reduces the erosional area by the following factors:

**Table E-3. Vegetation Factors for Sediment Yield Calculations.**

| Percent Cover | Multiplier |
|---|---|
| >80% | 0.18 |
| 50% | 0.37 |
| 30% | 0.53 |
| 20% | 0.63 |
| 10% | 0.77 |
| 0% | 1.0 |

Tread surface material on most of the roads inventoried was dirt or gravel. Tread erosion is reduced by 0.5 for roads with gravel surface.

The sediment yield from roads for each water body was found by using the yield from the inventoried roads and dividing it by the miles of roads inventoried to establish a rate of sediment loading from roads for each watershed, in tons/yr/mile. GIS was then utilized to establish the number of un-inventoried road miles within 200 feet of streams in each watershed. The sediment loading rate for inventoried roads in each sub-basin was then multiplied by the miles of un-inventoried roads to come up with a yield for un-inventoried roads. This yield was added to the yield from inventoried roads for each watershed, giving a total sediment yield per listed water body. This yield was multiplied by 0.7 because a 70% sediment delivery rate was assumed for this area. Finally, this number was added to the yields from road-related sources found in the near stream sediment source inventory to give a final road-related sediment yield for each sub-watershed on the Ruby.

Sediment delivery of 70% was assumed because the road sediment source inventory is actually of delivery points, not a general measure of erosion over all road miles. Other TMDLs have used this approach, where actual delivery is examined (ID DEQ, Priest River TMDL). This rate is reasonable when compared to protocols for other studies. In the Washington Watershed Assessment Protocols (WFPB, 1997), assumed delivery ranges from 10 to 100%, depending on connectedness of the sediment sources to the stream. The assumed delivery rate of 70% is based on a midpoint of this range, with a 10% Margin of Safety. This approach was taken because probable sediment delivery varied widely among sediment routing points and estimated delivery was not collected as part of the inventory. The Swan River TMDL (MDEQ, 2004 Swan Lake Watershed TMDL) included an extensive forest road assessment, in which sediment delivery from roads was estimated using the judgment of the observer. In their delivery categories, 50% delivery represents “direct sediment delivery but minor amounts or older events” and 75% delivery is assumed for “direct delivery evident but not chronic, effective buffer (provided by distance, gentle topography, or vegetation) during low intensity erosional events.” These descriptions apply to the average conditions found in the Ruby watershed, therefore 70% delivery appears to be reasonable and to provide a margin of safety.

Relative sediment yield due to roads for entire subwatersheds were also modeled using the revised AGWA model, described below in Section E.3.2.3.

**Uncertainty and Adaptive Management**

Considerations for defining uncertainty in estimation of road-related sediment yield are similar to those discussed for streambank sediment sources. However, all road inventory data were collected by one observer, therefore error among observers is not an issue for this methodology. As with streambank sediment yield calculations, some error should be assumed in applying literature values for rates of erosion to this watershed. Actual rates of erosion are not known, however, the literature values are sufficient for use in relative sediment yield calculations. Additional error is inherent in the methodology used for road-related sources because all crossings were not inventoried in all watersheds and an extrapolation process was used.

As with streambank sediment sources, yield numbers are considered estimations of relative sediment yield. These yields are useful for comparison of road-related sediment inputs among watersheds and comparison of road-related yields compared to other causes of sediment loading. Yield estimates assuming 70% delivery would tend to err on higher loading rates than what is actually occurring, and help account for uncertainty and provide a margin of safety in sediment yield calculations.

## E.3.2.3 Modeled Sediment Yield

Relative sediment yield and erosion potential of listed subwatersheds have been modeled using a revised Automated Geospatial Watershed Assessment (AGWA) tool calibrated for the Ruby watershed. This model was also used to determine increases in sediment yield due to roads for separate subwatersheds. Modeling sediment yields from roads does not provide as detailed information about sediment routing as the road sediment source inventory, but does quantify the increase in watershed sediment yield due to the hydrological effects of roads. Specific subwatersheds were selected for more in-depth analysis, which entailed addition of riparian buffer for entire stream length, increased floodplain cover, and removal of road segments with high sediment contribution, to simulate conditions with BMPs in place. Additionally, the AGWA model was used to predict changes in runoff and sediment trapping by simulated beaver complexes digitized into GIS in areas likely to have supported beaver complexes in the past.

The AGWA model has been developed under an interagency research agreement between the U.S. Environmental Protection Agency, Office of Research and Development and the U.S. Department of Agriculture, Agricultural Research Service. AGWA is an assessment tool that uses widely available data to run two hydrologic models (KINEROS and SWAT). It was designed to be applied easily by managers and scientists to evaluate likely outcomes of management scenarios and rank different areas in a watershed in terms of likely consequences to change. It also is designed to perform watershed analyses over large areas such as entire basins or to evaluate problem areas down to smaller scales such as subwatersheds that include small communities or rural areas.

AGWA modeling for the Ruby watershed uses the Kineros2 model, calibrated for this watershed. Inputs for Kineros2 model (the event based model of AGWA) include:

Topography, soils type and characteristics, land cover using NLCD cover types, and precipitation data. Roads have also been incorporated into the model. Topography and land cover are limited to 30-meter resolution for the Ruby watershed. Streamside vegetation was ground-truthed for the model by changing cover types along streams based on vegetation types documented in 2003 field assessments.

AGWA outputs include:

- Infiltration (mm; $m^3$/km)
- Infiltration (in; acft/mi)
- Runoff (mm)
- Runoff ($m^3$)
- Sediment yield (kg/ha)
- Peak flow ($m^3$/s)
- Peak flow (mm/hr)
- Peak sediment discharge (kg/s)
- Channel scour/deposition (mm/$m^3$)

AGWA methods and modeling results are provided in tabular data and in maps included in Appendix H.

A version of the Universal Soil Loss Equation model (USLE-3D) was also used to estimate average annual upland sediment yield by listed sub-basins in the Ruby watershed. Allocations to upland sediment sources were also derived using this model. Detailed methods for the USLE-3D modeling are provided in Appendix H (USLE report).

## E.3.2.4 Assimilating All Source Assessments Into Total Loads

Sediment load estimates from all assessments were totaled for each water body to determine which sources should be considered for allocations. Load estimates from all assessments were calculated in tons/year to allow direct comparison of all loads. The upland sediment loads due to grazing were modeled in USLE (see Appendix H). These loads were added to the near-stream sediment loads attributed to grazing to derive a total load estimate due to grazing. Similarly, natural sediment loading estimates include the loads modeled in USLE and near-stream sediment sources attributed to natural sources. The loads attributed to road crossings in the near-stream sediment source inventory were added to loads estimated from the road-related sediment source inventory to derive a total load due to roads for each water body. Total loads for each cause of sediment loading were used as one of the bases for determining if an allocation the source should occur.

## E.3.2.5 Sediment Allocation Strategies

The allocation strategy for sediment is described in detail in Section 7.0.

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