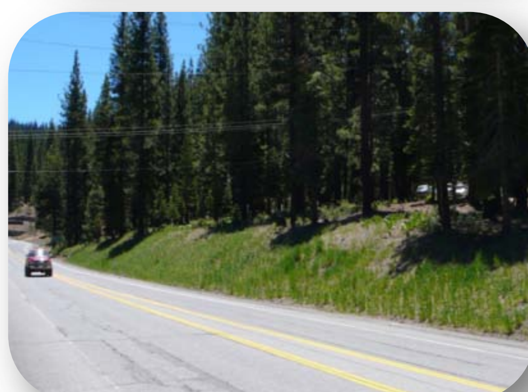
Road Cut and Fill Slope Sediment Loading Assessment Tool

User's Guide

Version 1.0

August 2010



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INTEGRATED ENVIRONMENTAL
RESTORATION SERVICES, INC

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Tool Overview

Achieving the fine sediment load reduction targets set forth in the Lake Tahoe TMDL depends on an accurate understanding and characterization of sediment source areas. Road cut and fill slopes are persistent and readily treatable sources of fine sediment particle (FSP, <16 microns) loading. The Road Cut and Fill Slope Sediment Loading Assessment Tool (RCAT) is a simple and repeatable field assessment methodology and spreadsheet tool. It is designed to assist Lake Tahoe erosion control and stormwater professionals in characterizing the functional condition of road cut and fill slopes and estimating the associated sediment and FSP loading from these areas. RCAT has been developed using data from more than 900 rainfall simulations conducted on disturbed and treated sites in the Tahoe Basin between 2002 and 2009. RCAT is designed to provide accurate estimates of sediment and FSP yield from small-scale (<1 acre), relatively uniform cut and fill slope areas. Depending on the goals and needs of each user, the RCAT can be used to:

> **Definition:**
> **Road Cut and Fill Slopes**
>
> Cut and fill slopes are defined as unpaved areas adjacent to roadways that have been re-graded to accommodate construction of a roadway. In contrast to road shoulders, cut and fill slopes are those slopes of 10% slope angle or greater and generally oriented perpendicular to the road alignment.

- quantify FSP loading from individual road cut and fill slope areas
- prioritize sediment source control treatment implementation efforts to maximize cost-effectiveness
- support more accurate baseline and post-treatment pollutant load reduction modeling analyses for Lake Tahoe TMDL implementation.

Field Assessment Preparation

Timing of Field Assessment

Two key variables should be considered when determining the timing of field assessments: plant maturity and soil moisture.

Plant Maturity – Mature plants allow for direct comparison between data from different years. If an assessment were conducted when plants were mature in year 1 and repeated when plants were immature in year 2, the measured total cover would likely decrease, resulting in higher predicted sediment loading. Timing of plant maturity depends on many factors including elevation, aspect, temperature, and precipitation regime. Generally speaking, plants on road cut and fill slopes in the Tahoe Basin tend to reach maturity sometime between mid-May and early July.

Soil Moisture – Soil moisture should be below 15% at the time of the field assessment. Penetrometer depth to refusal generally increases with increasing soil moisture[1], but does not

[1] Ayers, G.H., and J.V. Perumpral. 1982. Moisture and density effects on cone index. Trans. ASAE 25(5):1169-1172.

vary greatly when soil moisture levels are less than approximately 15%. Penetrometer measurements taken at higher soil moisture levels are not directly comparable to penetrometer measurements taken at lower soil moisture levels. Soil moisture levels during the summer season in the Lake Tahoe basin are generally less than 6%. Following a summer rain storm, users are advised to wait 48 hours before conducting field assessments. Refer to the Measurement Methods section for guidance on measuring and estimating soil moisture levels.

Time Required

Once setup is complete, the assessment for one area can be completed in one half-hour with two people. If field measurements are directly entered into the RCAT spreadsheet (Excel file), loading estimates are calculated immediately.

Equipment List and Sources

The basic equipment needed to conduct this assessment is listed in Table 1. Most of the equipment is also pictured in Figure 1.

Table 1. Assessment Equipment, Uses and Sources

Equipment	Use	Source
11 ft^2 (1m^2) quadrat	Defining monitoring area	Any hardware store. Constructed from 4 pieces of PVC pipe and 4 corners. See Figure 2, Figure 3, and Figure 4.
Level, meter stick, or any similar flat object one meter in length	To set the digital level on to measure slope	Hardware, home improvement or office supply store
Ruler	To measure mulch depth	Office supply store
Digital level	To measure slope	Home improvement store
Choose one For marking plot corners -Hammer and 10-12"nails -Pin flags -Survey arrows	To define areas and sub-areas	Home Improvement store (for hammer, nails, and pin flags) Ben Meadows (for survey arrows): http://www.benmeadows.com/search/arrow/9656/100952/?isredirect=true (item# 100952)
Cone penetrometer (soil compaction meter)	To measure soil compaction	Spectrum Technologies: http://www.specmeters.com/Soil_Compaction/Soil_Compaction_Meter.html Item# 6100 **OR** Ben Meadows: http://www.benmeadows.com/search/221003/9221/221003/?isredirect=true Item# 221003
Camera	Photos of areas and quadrats	Many
Field laptop	For data entry	Many
Optional Soil moisture meter	To measure soil moisture	Option 1: Campbell Scientific Volumetric Soil Moisture Meter Sensor: http://www.campbellsci.com/cs620 (item# cs620) Display: http://www.campbellsci.com/cd620 (item# cd620) Probe Rods: 12 cm (need at least 2, suggest 4) Option 2: Ben Meadows Spectrum Soil Moisture Meter http://www.benmeadows.com/search/221166/21358/221166/?isredirect=true (item# 221166) Option 3: Use the subjective methods explained below
Optional Measuring tape (at least 30 feet)	Defining and measuring plot area. Use with hammer and 10-12" nails or survey arrows, not pin flags (see below).	Ben Meadows: http://www.benmeadows.com/search/122730/6796/122730/?isredirect=true (item# 122730)

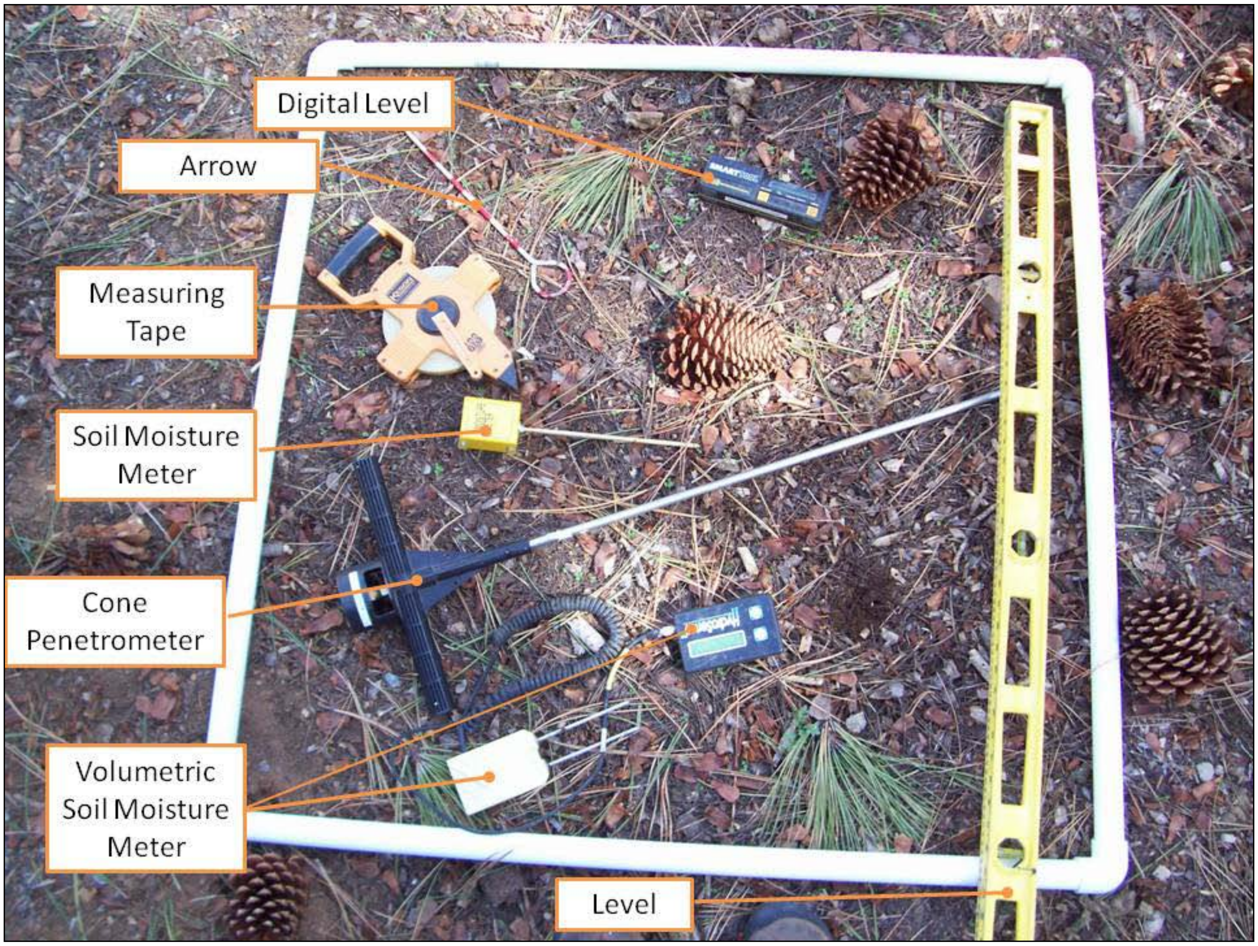

Figure 1. Some of the measurement tools for rapid assessment. Equipment alternatives are described in Table 1.

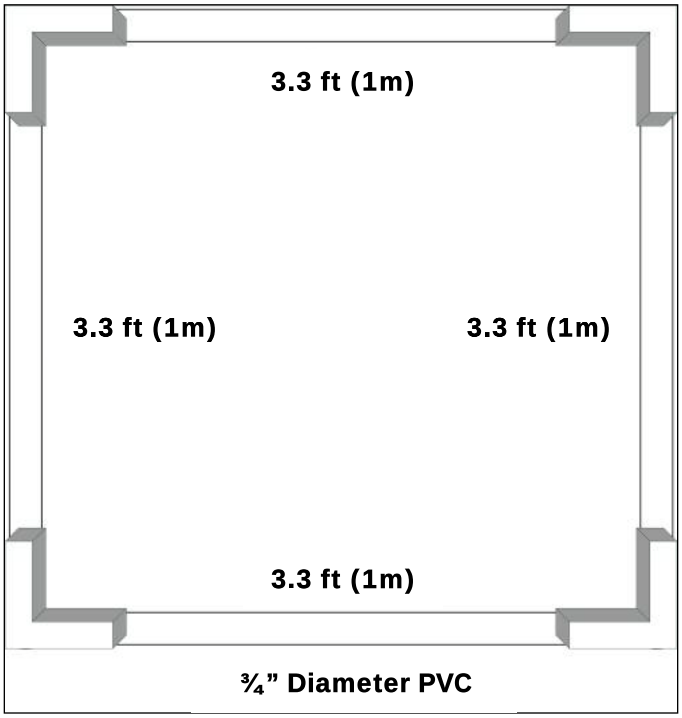

Figure 2. Sketch of quadrat construction with PVC pipe. Quadrats are 11ft^2 (1m^2) and can be constructed with ¾" PVC pipe.

Figure 3. Close up of corner construction of quadrat.

Figure 4. Quadrat marked with tape at ¼, ½, and ¾ points.

Field Assessment Methods

Note: The information collected using the field assessment methods described below is intended to be directly entered into the RCAT spreadsheet using a laptop computer in the field.

Area Selection and Documentation

1. **Define the project area of interest.** This may be a catchment, Environmental Improvement Project boundary, jurisdictional boundary, etc. Enter a unique name for your area of interest into the Information tab on the RCAT spreadsheet.
2. **Create inventory of road cut and fill areas (optional).** For most projects, it will be useful to create an inventory of cut and fill slope areas within the area of interest using GIS or another spatially-explicit mapping or documentation method. Some users may choose to only inventory and treat known "problem" cut and fill slopes based on observations of active erosion, connectivity to surface water, or other criteria. Other users may choose to inventory all cut and fill slopes within an area of interest in order to prioritize treatment implementation efforts or to support catchment-scale modeling efforts. Each user must determine the appropriate scale at which to apply this assessment methodology based on project-specific goals.
3. **Choose assessment areas.** Within the project area of interest, choose "areas", which are contiguous sections of cut and fill slopes sections with similar characteristics. These areas will span the length of the slope (Figure 5), but can vary in width. Areas should be no larger than 11,000 ft^2. If a larger area exists, divide it into smaller areas. Each area will have consistent:
    a. aspect [North, South, East, West](within 45 degrees)
    b. slope angle (within 15%)
    c. slope length (within 6 feet, measured from the toe of the slope to the top of the slope; Figure 5)
    d. toe characteristics (rock protection/walls)
    e. total cover (within 25%)
    f. rock cover (within 25%)
    g. plant cover (within 25%)
    h. plant type (trees, shrubs, forbs, grasses). For example, one half of the area of interest should not be dominated by mature trees while the other half is dominated by grasses. However, there could be mature trees and grasses spread evenly throughout the area.
    i. mulch depth (within 2 inches)

Figure 5. Slope length is measured from the toe (bottom) of the slope to the hinge (top) of the slope.

Example:

This road cut slope should be divided into two areas (Figure 6, Figure 7, and Figure 8). The key differences between area 1 and area 2 are cover condition and slope aspect. Area 1 is dominated by grasses and has high mulch cover while area 2 is dominated by shrubs and has lower mulch cover and some larger rocks on the surface.

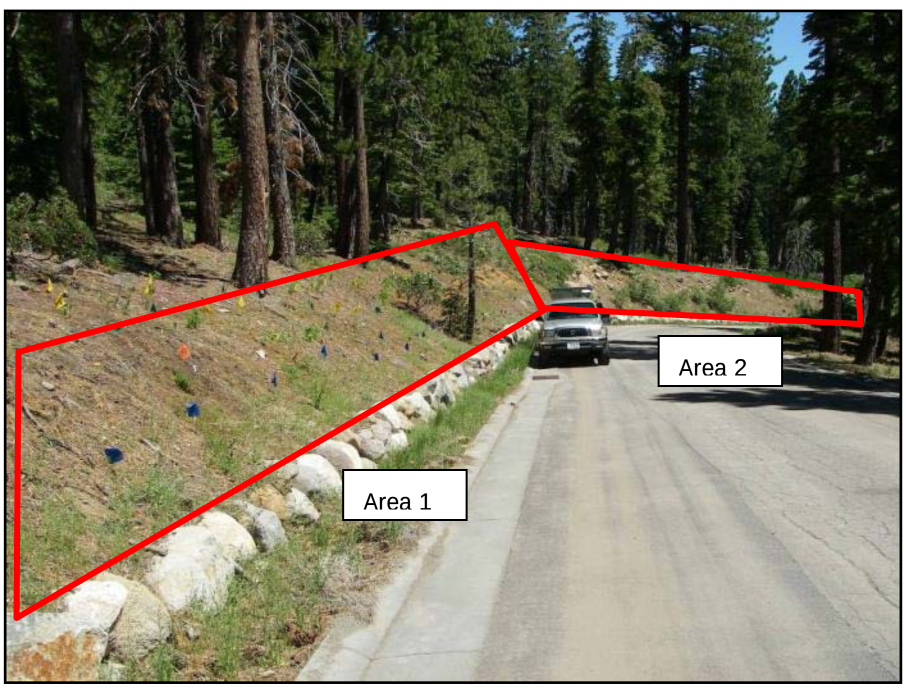

Figure 6. Example of a contiguous road cut slope divided into two areas.

Figure 7. Close up view of area 1. Area 1 is dominated by grasses and has high mulch cover compared to area 2.

Figure 8. Close up view of area 2. Area 2 is dominated by shrubs and has lower mulch cover than area 1. Area 2 also has some larger rocks on the surface.

4. **Determine the size of the area.** Either use a measuring tape or pace the area. Enter the area in the RCAT spreadsheet on the Information tab.
5. **Choose sub-areas within the area.** Assign unique numbers to the sub-areas.
    a. The sub-area size should be chosen according to the following guidelines:

Table 2. Guidelines for choosing sub-area size based on area size.

Area Size (ft^2)	Sub-Area Size (ft^2)
≤100	entire area
101-550	entire area
551-1,100	entire area
1,101-5,500	1,100
5,501-11,000	1,100

    b. The sub-area will span the entire length of the slope, from hinge (top) to toe (bottom). If a toe wall or retaining wall is present, the effective toe of the slope is defined as the top of the toe wall.
    c. This sub-area should be as representative of the entire area as possible (see site characteristics outlined in Step 3). Check the site characteristics before proceeding.
    d. Mark this area by placing pin flags in the bottom corners. Use a color that will be easily visible in a photograph. *Note: this photograph will provide important documentation so you can return to approximately the same area following treatment.*

Example 1: In this case, the sub-area is the same as the area because the area is just shy of 1,100ft^2. Had the area been greater than 1,100ft^2, a 1,100ft^2 representative sub-area would have been chosen.

Figure 9. Sub-area selection. In this case, the sub-area is the same as the area. *Note: pin flags in photo are marking recently planted seedlings, not sub-area corners.*

Example 2: In this case, the area is larger than 1,100ft^2; therefore the sub-area is 1,100ft^2. The sub-area was selected in a representative location.

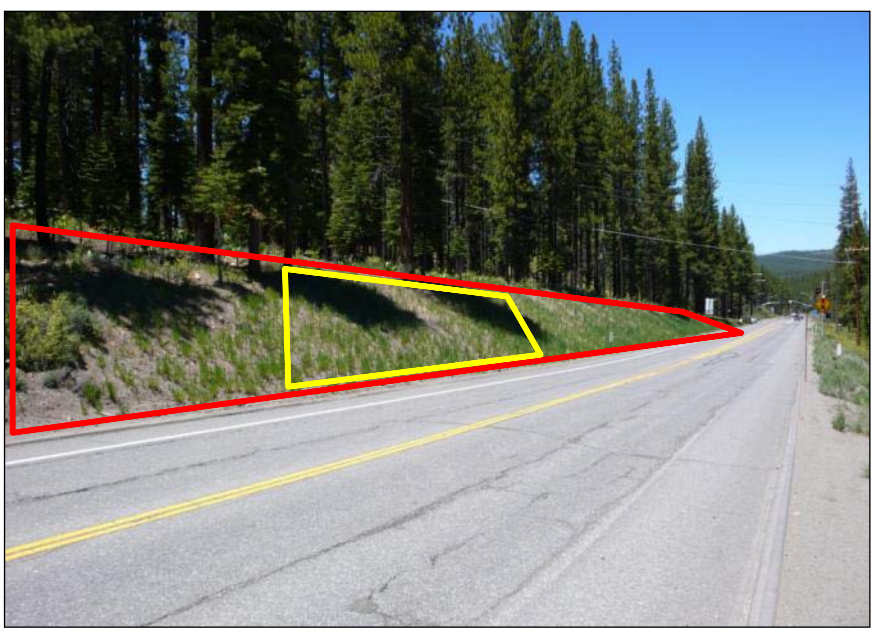

Figure 10. Area is outlined in red; sub-area is outlined in yellow.

6. **Create a map of the areas and sub-areas.** Assign a unique number to each area and sub-area. For example, start with area 01, sub-area 01. This map may be created using GIS, construction plans, hand drawing, or other method, as long as the map is clear enough to enable a person who is unfamiliar with the area to return to the sub-area in subsequent years to repeat measurements.
7. **Determine the number of quadrats and distribute quadrats.**
   a. Determine the number of quadrats (as defined in Table 1) necessary by using the guidelines in Table 3. See #6 on the Information tab in the RCAT spreadsheet, which will display the number of quadrats required.

Table 3. Guidelines for determining the number of quadrats based on area size.

Area Size (ft^2)	# of Quadrats
≤100	1
101-550	2
551-1,100	3
1,101-5,500	4
5,501-11,000	5

   b. Distribute the quadrats in the sub-area. If only one quadrat is necessary, ensure that it is placed in the most representative location possible. When more than one quadrat is necessary, distribute the quadrats so that variation within the sub-area is captured. For example, if the top half of the slope is bare and the bottom half has established vegetation, place one quadrat in the top half and the other quadrat in the bottom half.
      i. The bottom of the quadrat should be parallel with the road.
      ii. If the quadrats are placed in a steep area, use the 12 inch nails or other small stakes to secure the quadrat to the slope. The nails can be placed just below the quadrat and the quadrat can rest on them.
      iii. If it is difficult to access a steep area, a ladder may be placed on the slope and monitoring can be conducted while standing on the ladder for support. Use of a ladder can also prevent extensive disturbance on steep slopes (Figure 11).
      iv. Take photos of the entire sub-area and each quadrat and record on the Information tab in the RCAT spreadsheet (Figure 12).

Figure 11. Use of a ladder on a steep slope for safety and to prevent excessive slope disturbance. Quadrat monitoring may also be conducted with a ladder.

Figure 12. Quadrat (11ft^2, 1m^2). The sub-area of interest is delineated with measuring tapes in this case. The area could also be marked by placing pin flags at the bottom corners of the sub-area.

Measurement Methods

8. **Take measurements.** Enter measured values into the RCAT spreadsheet for each quadrat. Use the Quadrat 1 tab for the first quadrat, then the Quadrat 2 tab for the second quadrat, etc.
    a. Slope
        i. Measured in the steepest area
        ii. Measured over a 3.3 ft distance (set digital level on meter stick or level; Figure 13)

Figure 13. Digital level. Ensure that the digital level is on a level surface before taking the reading.

    b. Total Cover (%)
        i. Ocular estimate to the nearest 25%. Select the following ranges (0-25%, 26-50%, 51-75%, 76-100%). Figure 15 to Figure 22 show examples for each cover category.

Definition: Total Cover

Total cover is sometimes referred to as "first hit" cover, because it is the first plant, mulch, rock, or woody debris cover hit by a raindrop falling vertically from the sky. Bare soil is not included in this measurement. Total cover does include: plants (less than 3 feet tall), any type of mulch/litter, and 'other' cover such as rocks, gravel, logs, pine cones, and any type of woody debris. Total cover is measured from 3 feet above the soil surface and therefore includes most shrubs, but not mature trees.

Tip: imagine how much of the area would be covered by vegetation, mulch/litter, rocks, gravel, logs, etc if all the vegetation present were moved to one corner of the quadrat (Figure 14). Use the tape marking the halfway point on the quadrat for guidance. If the imagined moved vegetation and other cover can fill one of the four equal sections in the qudarat, the cover is 0-25%, if it fills two sections the cover is 26-50%, etc.

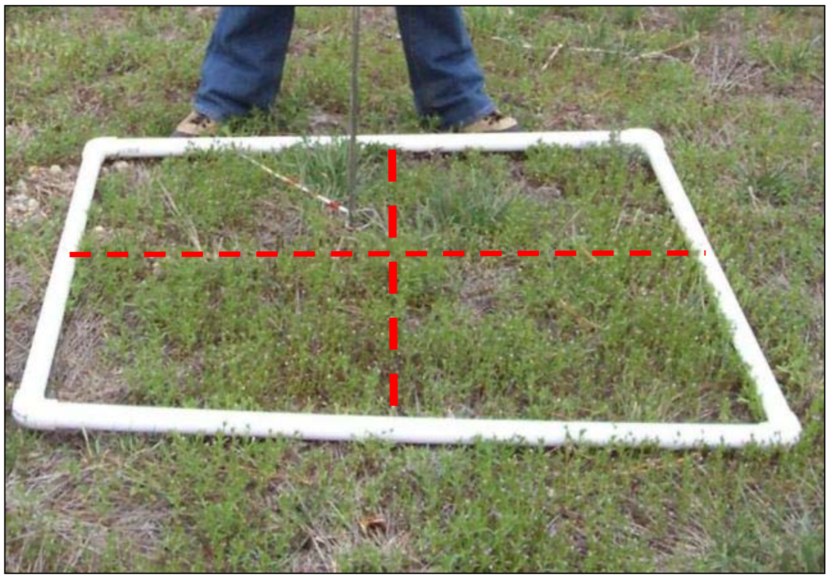

Figure 14. 11ft^2 quadrat divided into a grid to help with an ocular estimate of cover to the nearest 25%. The ocular estimate for this quadrat falls into the 75-100% range.

ii. Record types of cover including mulch/litter (any type), rocks, gravel, logs, pine cones, woody debris, and vegetation types (i.e. grass, shrub, forb, tree) by checking the boxes in the RCAT spreadsheet.

Definition: Vegetation Types
Grass: herbaceous (non-woody) plants with slender leaves
Forb: any herbaceous (non-woody) plant that is not a grass
Shrub: a woody perennial plant with many branches from the base
Tree: woody perennial plant with a distinct trunk

Figure 15. Total cover: 0-25% as viewed from above. There is very low mulch, other, and vegetative cover in this quadrat.

Figure 16. Total cover: 0-25% as viewed from a standing position. There is very low mulch, other, and vegetative cover in this quadrat.

Figure 17. Total cover: 26-50% as viewed from above. There is moderate mulch, other, and vegetative cover in this quadrat.

Figure 18. Total cover: 26-50% as viewed from a standing position. There is moderate mulch, other and vegetative cover in this quadrat.

Figure 19. Total cover: 51-75% as viewed from above. There is moderate mulch and other cover and very low vegetative cover in this quadrat.

Figure 20. Total cover: 51-75% as viewed from a standing position. There is moderate mulch and other cover and very low vegetative cover in this quadrat.

Figure 21. Total cover: 76-100% as viewed from above. There is high mulch and other cover and moderate vegetative cover in this quadrat.

Figure 22. Total cover: 76-100% as viewed from a standing position. There is high mulch and other cover and moderate vegetative cover in this quadrat.

c. Mulch/Litter Depth (inches)

   i. Ensure that the readings can be conducted without stepping inside the quadrat.
   ii. Use the tape markings to determine the location of the 9 measurements (Figure 23). Each reading will be conducted at the intersection of the imaginary line connecting the ¼, ½, and ¾ tape markings.
   iii. Use your finger to brush aside a small area of mulch to ensure that the ruler is sitting on the soil surface (Figure 24). Take the measurement next to the mulch that has not been disturbed or brushed aside. Measure depth to the nearest ¼ inch with a ruler.
   iv. Take 9 readings within the quadrat. The 9 values will be averaged in the RCAT spreadsheet.

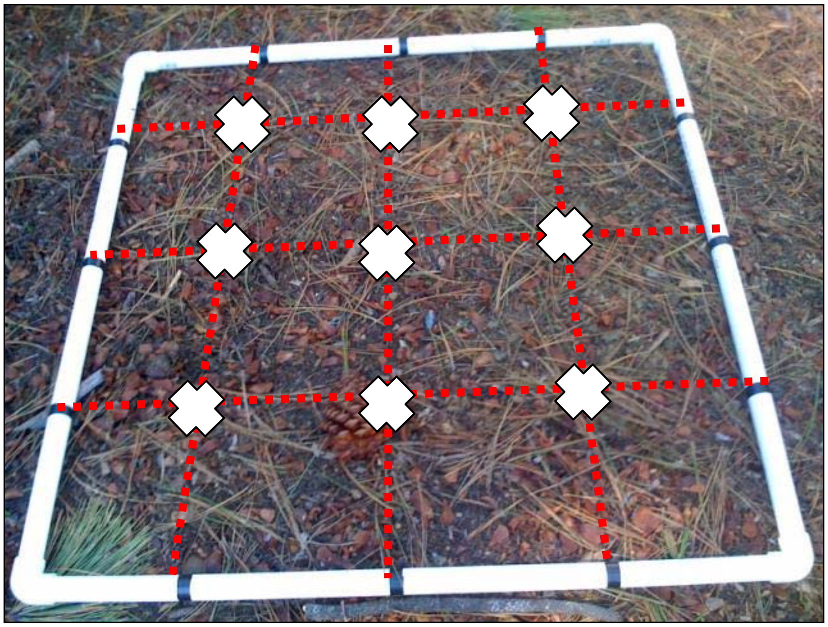

Figure 23. Quadrat with X's designating mulch/litter measurement locations.

Figure 24. Conducting mulch depth measurements to the nearest ¼ inch. The mulch is brushed aside so that the ruler can be placed on the soil surface.

d. Surface Cover Index
   i. Calculated from Total Cover and Mulch/Litter Depth
   ii. Surface cover index = Total Cover x Mulch/Litter Depth

Example:

Total Cover = 50%

Mulch/Litter Depth = 1.75 inches.

Surface cover = 0.50 x 1.75=0.88 inches

Note: This is a calculated value and does not need to be measured or entered in the RCAT spreadsheet. The RCAT spreadsheet will calculate this value for you.

e. Soil Moisture

  i. Ensure that the readings can be conducted without stepping inside the quadrat.
  ii. Brush aside the mulch in the area where you will insert the probe.
  iii. Press the probe(s) vertically into the soil. The probe(s) must be fully inserted into the soil. Press the "read" button to obtain a reading on the Hydrosense or look at the display on the Spectrum soil moisture meter. If the probe cannot be fully inserted, do not use the reading. Instead, move the moisture meter 5 inches to the right of the original reading and try again. If the probe still cannot be fully inserted, take another reading 5 inches below the original reading, then 5 inches to the left, then 5 inches above the original reading. If readings are not possible in all 5 of these locations, skip the reading.
  iv. Soil moisture must be less than 15% for the Campbell Scientific Hydrosense volumetric meter and less than 3 when using the Spectrum soil moisture meter to continue with the cone penetrometer measurements. Read the Cambpell meter to the nearest 1% and the Spectrum meter to the nearest 0.5%.
  v. Collect 9 readings at the locations in Figure 23. The 9 values will be averaged in the RCAT spreadsheet.

Alternatively: If a soil moisture meter is unavailable, the following "feel test" can be used to assess soil moisture level (Table 4). Dig a small hole with a trowel, pick up a handful of soil, then refer to the table below.

Table 4. Guidelines for determining whether soil moisture is appropriate for penetrometer measurements in coarse, medium, and fine textured soils. The soil must meet the following guidelines to continue with penetrometer monitoring.

Coarse Textured Soils	Medium Textured Soils	Fine Textured Soils
The soil is dry, loose, and flows through fingers when picked up. It appears dry and will not hold together with pressure.	The soil is powdery, crumbles easily and may or may not hold with pressure.	The soil is hard and difficult to break into powder. It can be pliable and hold together under pressure.

Figure 25. Hydrosense Soil Moisture Meter (sensor plus display)

Figure 26. Hydrosense soil moisture meter in use. The probes are fully inserted into the soil.

Figure 27. Spectrum Soil moisture meter, mulch is being brushed aside.

Figure 28. Spectrum soil moisture meter in use. The probe is inserted fully into the soil.

f. Cone Penetrometer Depth to Refusal (DTR, inches)

   i. Do not proceed until it has been determined that the soil moisture is less than 15% for the Hydrosense meter, less than 3 when using the Spectrum soil moisture meter, or meets the “feel test” guidelines in Table 4.

   ii. For steep slopes it is recommended that the penetrometer readings are conducted in rows from top to bottom. Read the top 3 measurements, and then continue to the middle row, and then to the bottom row. Only step inside the quadrat once the top row of measurements is completed.

iii. Hold the meter with both hands and press the rod vertically into the soil (Figure 29). Stop when the dial reads approximately 350 psi (make sure you are reading the ½" tip scale on the dial; Figure 30).
iv. Put your finger on the penetrometer rod where it meets the soil and remove the penetrometer from the soil while keeping your finger on the penetrometer rod (Figure 31).
v. Read the number of inches the penetrometer rod penetrated into the soil by rounding up to the nearest inch. Each line on the penetrometer represents 3 inches (Figure 32).
vi. If the penetrometer tip hits a rock, repeat the reading 5 inches to the right of the original reading. If more rocks are hit, take another reading 5 inches below the original reading, then 5 inches to the left, then 5 inches above the original reading. If rocks are found in all 5 of these locations, skip the reading.
vii. If the penetrometer hits bedrock, record the reading.
viii. Collect 9 readings at the locations marked in Figure 23. The 9 values will be averaged in the RCAT spreadsheet.
ix. Note anything unusual such as a breakthrough at the same depth on each reading, which may indicate a hardpan layer.

Figure 29. Pressing the penetrometer rod vertically into the soil.

Figure 30. Penetrometer dial at 350 psi. Read the inner scale for the ½ inch tip.

Figure 31. Put your finger on the rod where it meets the soil.

Figure 32. Read the number of inches the penetrometer rod penetrated into the soil by rounding up to the nearest inch. Each line on the penetrometer represents 3 inches. The reading here is 11 inches.

9. **Repeat steps outlined in #**8 **for each of the quadrats.**
10. **Review results.** Average Total Sediment Yield, Average Fine Sediment Yield, and Functional Condition Class are tabulated in the Output tab in the RCAT spreadsheet. See Applying the Results section (below) for description of output data and application of the results.

Applying the Results

Estimating Sediment and FSP Loading

Total sediment loading and FSP loading values for each area are tabulated in the Existing Conditions cells in the Output tab in the RCAT spreadsheet based on field measurements entered in the Quadrat tabs during the field assessment. To estimate sediment and FSP loading from multiple areas, simply open a new RCAT spreadsheet, repeat the field assessment for each area, then add up the resulting sediment yield estimates in the Output tab for each area.

Estimating Post-Treatment Load Reductions

The Output tab on the RCAT spreadsheet also includes a column of cells for entering *expected* post-treatment conditions in order to calculate an *expected* sediment load reduction. By entering expected post-treatment conditions for the road cut or fill slope area in the yellow cells, the user can generate an expected sediment load reduction and expected functional condition class (see below). This feature is intended to support treatment planning by enabling the user to define a desired sediment load reduction and/or functional condition class and adjust different conditions (i.e. slope angle, surface cover, or soil density) to determine appropriate treatments and to define appropriate success criteria for revegetation or erosion control treatment areas.

Functional Condition Classes

A *Functional Condition Class* for each assessment area is generated in the Output tab in the RCAT spreadsheet based on field measurements entered in the Quadrat tabs during the field assessment. Functional condition classes have been created to provide a relative index of the *functional* condition (or erosion resistance) of each assessment area based on field measurements. Functional condition classes range from 1-5, with 1 being the least desirable (highest sediment loading) and 5 being the most desirable (lowest sediment loading). Each of the functional condition classes correspond to sediment loading regression equations developed from extensive rainfall simulation research in the Lake Tahoe Basin. Functional condition class is similar to a RAM score in the BMP RAM or Road RAM and is intended to provide a common framework for integrating RCAT results with the Lake Clarity Crediting Program.

Applying Results within the Pollutant Load Reduction Model

RCAT estimates sediment and fine sediment yield from discrete road cut and fill slope areas. It does not account for downstream pollutant removal via stormwater treatment BMPs or particle settling/sediment storage due to landscape configuration. Project implementers can perform pollutant removal calculations for downstream treatment BMPs independently of RCAT if desired.

RCAT is intended to eventually be integrated as a unique module within the Pollutant Load Reduction Model (PLRM). At this time, there are two options for using RCAT in conjunction with PLRM:

1. **Account for road cut and fill slope loading externally from PLRM.** The total area of road cut and fill slopes can be subtracted from the urban area of interest modeled in the PLRM and the output (sediment and fine sediment load) from RCAT can simply be added to pollutant loads generated from PLRM. However, this method assumes that road cut and fill slope areas are not directly hydrologically connected to a treatment BMP and there will be no downstream treatment of sediment loads generated from road cut and fill slope areas. This is similar to the approach currently recommended for gully erosion in the PLRM Applications Guide.
2. **Match loading outputs from RCAT with PLRM output for the same area.** (*Note: this work-around is only appropriate for experienced users of PLRM*).
    a. Estimate pollutant loading from the cut and fill slopes using RCAT.
    b. Define the cut and fill slopes as a separate catchment in PLRM and connect this catchment in PLRM to another catchment using a junction. Make a first guess at the land use class for the cut and fill slope (i.e. a land use class of Erosion Potential 1 through 5).
    c. Adjust the saturated hydraulic conductivity for the "Other Land Uses" category in the PLRM Drainage Conditions Editor until the average annual runoff volume predicted for the catchment by PLRM is close to the volume predicted from RCAT.
    d. Adjust the Erosion Potential land use class (EP 1-5) in the PLRM for the cut and fill slope until the average annual fine sediment load for the catchment is close to the load predicted by RCAT.
    e. Repeat steps a – d for baseline and post-project loading estimates.

Frequently Asked Questions

Does RCAT account for downstream treatment of runoff?

No. RCAT is designed to estimate sediment and FSP yield from small-scale (<1 acre), relatively uniform road cut and fill slope areas. It does not account for downstream pollutant removal via stormwater treatment BMPs or particle settling/sediment storage due to landscape configuration. Users can perform downstream pollutant removal calculations independently of RCAT if desired.

Is slope length accounted for in RCAT?

Slope length is not directly accounted for in RCAT. The rainfall simulation-derived erodibilities used in RCAT are based on a 1m length of run. However, since many cut and fill slopes in Tahoe have relatively small run lengths, RCAT is expected to be accurate for smaller slope sections up to about 3 m in length as rill development was rarely observed in such plot lengths during rainfall simulations when either adequate cover or infiltration capacity was present. Studies with compacted or low infiltration soils suggest that plot length is a factor affecting sediment yields as a result of possible rill formation in plots longer than ~3 m, depending on slope. Though disagreement exists in the scientific literature, there is a general acceptance that for bare soils subject to the same artificially induced runoff rate, plot lengths greater than 2-4 m up to about 17 m exhibit a roughly linear increase in sediment yield with increasing plot length. However, this has not been observed in the field under natural rainfall conditions where no dependence of sediment loss with increasing slope lengths of fallow soils between 0.4 and 44 m on ~15% slopes was observed (e.g. Bagarello and Ferro, 2010)[2]. The effects of plot length on sediment yields under surface mulch cover conditions are expected to diminish as a result of reduced potential for rill formation. Relative certainty in sediment yield estimates is likely to decrease for longer slope lengths. RCAT is expected to over-predict sediment yields where cover is present (e.g. vegetation, mulch) and probably under-predict sediment yields for bare soil conditions as a result of rill formation, especially on an event basis. In either case, no local data exists considering the effects of longer run lengths on sediment yields.

How is annual runoff volume calculated in RCAT?

The annual runoff fraction used in RCAT is determined solely by slope angle (%) using a square-root relationship between runoff fraction and slope angle. The maximum runoff fraction associated with very steep slopes of 90% was set at 15% based largely on an assessment of runoff from a range of urban/suburban slopes in the Brockway area on the

[2] Bagarello, V. and V. Ferro. 2010. Analysis of soil loss data from plots of differing length for the Sparacia experimental area, Sicily, Italy. Biosystems Engineering. Volume 105, Issue 3. p.411-422

north shore of Lake Tahoe for 2007-2008 (Heyvaert et al. 2008)[3], which suggested that on an annual basis, and in some cases for individual storms, the maximum runoff rate was <15% of total precipitation. A square-root relationship between runoff fraction and slope or headloss was used to set the runoff fraction from progressively flatter road cut/fill slopes. Thus, the runoff fractions of total precipitation range from 5 to 15% non-linearly for slopes from 10 to 90%. Clearly, this fraction depends on several factors at the local scale including antecedent soil moisture, infiltration rates and capacities and prevailing surface cover conditions during the year, however, for rapid assessment purposes, no more sophisticated soil-water modeling is proposed.

I adjusted several input parameters but the sediment yield estimated by in the RCAT spreadsheet did not change, or changed very little. Why is this?

There are two categories of reasons why changes in input parameter combinations may result in little change in calculated sediment yields.

1. Selected slopes and/or areas are small. The relative rates of erosion on relatively flat slopes (<15%) under all surface cover and cone penetrometer depth to refusal (DTR) conditions in the Tahoe Basin are relatively small unless the soils are bare and extremely compacted (e.g. a bare roadbed). For example, in each soil type, RCAT uses the same erosion rates for each class of cover and penetrometer DTR conditions within the 5-15% slope range, hence changing slopes within this range for the same cover and penetrometer DTR conditions will result in no change in computed sediment yields. Similarly, very small study areas that result in sediment yields of only a few pounds per year may show little change as a result of changing site conditions (input parameters), as yields are rounded to the nearest lb/yr values.
2. The sediment yields as determined in RCAT are based on incremental ranges of conditions for each soil type based on slope angle (± 5%), depth of cover (± 2 inches) and cone penetrometer DTR (± 3 inches). When determining yields for proposed or changing conditions that are still within the particular ranges of any one of these three site parameters, calculated yields may not change. Similarly, should the new conditions result in a small change that is beyond an incremental range, yields may seem to change more than anticipated.

Why are runoff nutrient concentrations not estimated by RCAT?

Nutrient concentrations of rainfall simulation plot runoff were not measured in this study as the initial studies from 2002 found that TKN, TP and TDP concentrations in the plot runoff could not be realistically distinguished from that of the rainfall water used in the simulations. Generally, TKN levels in the rain water used averaged 0.1-1 mg/L and those in the runoff samples about 1-2 mg/L. Similarly, though with no detectable increase, levels of TP in the rainwater and runoff samples averaged ~0.1 mg/L, while TDP concentrations were an order of magnitude less. Runoff nutrient concentrations could not be correlated to soil type or

[3] Heyvaert, A.C., A. T. Parra, C. Strasenburgh, R. P. Townsend. 2008. Brockway Project Area Stormwater Runoff and Characterization Study. DRI Report to Placer County and CTC.

treatment at the time (Grismer & Hogan, 2004)[4], and these measurements were abandoned in favor of later measurements of particle-size-distributions (PSD). Alternatively, we considered the nutrient loading concentration factors employed in the LSPC modeling for TMDL loading in the Basin, but found these too variable and inconsistent with other runoff-related nutrient loading measurements, such as those reported by Heyvaert et al. (2008)[5]. Runoff water datasets containing both PSDs and nutrient concentrations are needed to more accurately predict nutrient concentrations in runoff and relate this to treatment effects, but no such datasets yet exist in the Basin.

Can I get Clarity Credits for treating road cut and fill slopes?

Yes. The Lake Clarity Crediting Program is designed to allow for a variety of methods for estimating pollutant load reductions. RCAT can be used in conjunction with PLRM (see Applying Results within the Pollutant Load Reduction Model on page 26-27) on as a stand-alone tool for cut and fill slope areas that are not hydrologically connected to downstream stormwater treatment BMPs. Clarity Credits are awarded on an annual schedule and credit award amounts are based on condition assessments and RAM scores. Unlike treatment BMPs, which require regular maintenance to maintain desired pollutant removal effectiveness, it is possible to achieve long-term sediment source control with one-time restoration/revegetation treatments and no ongoing maintenance. Therefore, RCAT users are encouraged to work with Basin regulatory agencies to define appropriate benchmark and threshold values (success criteria) and to develop and test the feasibility of short-term (3-5 year) credit award schedules during the initial vegetation establishment period, after which additional condition assessments could be conducted at a lower frequency (or perhaps waived altogether) while maintaining an established credit award schedule. The RCAT output table includes functional condition classes, which are similar to RAM scores in the BMP RAM or Road RAM, and are intended to provide a consistent metric for integrating RCAT results with the Lake Clarity Crediting Program.

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[4] Grismer, M.E. and M.P. Hogan. 2004. Evaluation of Revegetation/Mulch Erosion Control Using Simulated Rainfall in the Lake Tahoe Basin: 1. Method Assessment. Land Degradation & Dev. 13:573-588.

[5] Heyvaert, A.C., A. T. Parra, C. Strasenburgh, R. P. Townsend. 2008. Brockway Project Area Stormwater Runoff and Characterization Study. DRI Report to Placer County and CTC.