



# Standard Operating Procedure for the Collection of Pebble Counts

Water Quality Control Division • Watershed Section

## 1.0 Introduction

This Standard Operating Procedure (SOP) will address the collection of pebble counts in wadeable streams. Pebble counting involves enumerating and measuring particle sizes of streambed substrate.

Substrate size is one of the most important determinants of habitat character for fish and benthic macroinvertebrates. Substrate can influence the hydraulic roughness and consequently the range of water velocities in the channel. It may also influence the size range of interstices that provide critical living areas and cover for macroinvertebrates and fish, such as mottled sculpins. Fine sediments are a sensitive indicator of the effects of human activities on streams.

The intent of this SOP is to discuss three procedures that support attainment/impairment determinations listed in Water Quality Control Commission Policy 98-1. While each procedure acquires different substrate counts (quantities), each results in uniform substrate sizes.

The primary standard operating procedure will be a 105-count method, which will be used as the default method during routine water quality investigations. A second, acceptable procedure is the 400-count method, which may be used liberally as an alternative to the primary procedure in the event a more robust enumeration is necessary<sup>1</sup>. The final procedure discusses how to evaluate fish spawning habitat using Montana Department of Environmental Quality's grid toss method.

## 2.0 105-Count Procedure

The 105-count method will be considered the primary standard operating procedure for all Water Quality Control Division (Division) field activities.

The 105-count method is a modified procedure created from elements of the Environmental Protection Agency's (EPA) EMAP-Western Pilot Study Field Operations Manual for Wadeable Streams (Peck et al, 2006). The main advantage of this procedure is that only pebbles within the wetted width are enumerated.

### 2.1 Equipment

- Tape measure
- Measuring stick
- Gravelometer
- 10" galvanized nails
- Pebble Count Data Sheet - 105 Count

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<sup>1</sup> Based on problem statements and needs identified in program-specific Sample Analysis Plans

- Clipboards
- Pencils

## 2.2 Establish Reach

A length of stream will be sampled corresponding to a sampling point (site). This length of stream is referred to as a “reach”. The reach is where all biological, physical and chemical sampling will be conducted while at the site. All of the particle (pebble) counts will be performed within this reach.

The extent of the reach is determined by multiplying the average wetted channel width by 40. The steps to establish a reach are detailed below:

- Use a tape measure to determine the wetted width of the channel at 3 to 5 locations considered to be of typical width within approximately 5 channel widths upstream of the sample site. Average the readings together and round to the nearest 0.5 ft mark. If the average width is less than 11.5 ft, use 500 ft as the minimum reach length.

If a braided channel is encountered during the reach determination phase then measure the individual wetted widths along the cross-section and add them up. A braided channel is characterized by numerous sub-channels with no obvious dominant channel (i.e. unvegetated bars).

- The length of the reach is calculated by multiplying the average wetted channel width by 40.
- Record the reach length on the Pebble Count Data Sheet -105-Count (Data Sheet).
- Determine if the reach needs to be adjusted around the sampling site due to confluences, impoundments (i.e. lakes, reservoirs or ponds), physical barriers, or because of access restrictions to a portion of the reach.

If a confluence, barrier or access restriction is present, note the distance on the Data Sheet and mark the restriction as one endpoint of the reach. Move the other endpoint of the reach an equivalent distance from the sampling point. This results in a reach length that remains the same but slides up or down around the sampling point.

*Note: Do not adjust the reach to avoid man-made obstacles such as bridges, culverts, rip-rap or channelization.*

- The reach is now set. Proceed to establishing transects.

### 2.2.1 Modifications for Reaches with Interrupted Flow

At transects where the channel is dry, record the wetted width as 0 ft. Modifications to wadeable streams that are considered “interrupted” or have some form of water present can be sampled.

Count the pebbles depending on the flow status listed below.

- **Dry Reach** - The sampling site is completely dry

Do not collect pebble counts.

- **Dry Channel** - No surface water anywhere in the cross-section transect

Collect pebble counts. Use unvegetated areas of the channel to determine the channel width and the locations of the substrate sampling points. Record the wetted width as 0 ft. Record pebble counts at the sampling points located in the unvegetated, but dry, channel.

- **Damp Channel** - No flowing water in transect, only pools < 4 inches deep

Collect pebble counts.

- **Water Present** - Transect has flow or pools > 4 inches deep

Collect pebble counts.

If at the end of sampling, there were more than 2 transects that were dry or damp, then take additional samples from other places (known as replacement transects) in the stream reach that had sufficient water. Take samples from the mid-point between transects if possible, but when necessary, they may be taken anywhere in the stream with a small amount of water.

### 2.2.2 Partially Wadeable Sites

At some sites, it may not be possible to safely wade the majority or all of the reach because of excessive depth or velocity, rapids or extreme siltation. The amount of sampling that can actually be done will depend on site-specific conditions observed. Do only what can be done safely.

On the Data Sheet, be sure to make detailed comments describing what the conditions were like and how much sampling could actually be performed.

### 2.3 Establish Transects

The downstream or bottom endpoint of the reach serves as the first transect, known as Transect 1. Transect 1 is equivalent to the sampling point unless barriers or restrictions necessitated adjusting the bottom endpoint. This will be the first of 21 total transects that are set at equidistant locations upstream of Transect 1.

- Using a tape measure, measure  $1/20^{\text{th}}$  of the reach length from the start point (Transect 1) while measuring along one side of the stream. Avoid disturbing the stream channel prior to sampling activities. Flag this spot as the next cross-section (Transect 2).
- Continue measuring  $1/20^{\text{th}}$  of the reach length while moving in an upstream direction and flag the remaining cross-sections (Transects 3-21). See Figure 1.

**Note:** EPA's method instructs the user to set the first 11 transects (A-K) at  $1/10^{\text{th}}$  the stream length and then add 10 additional transects (1-10) in between the first 11 transects. This method results in 21 equidistant transects. The Division will aggregate the two sets of transects into one set of 21 transects.

- All transects are now set. Proceed to pebble counts.

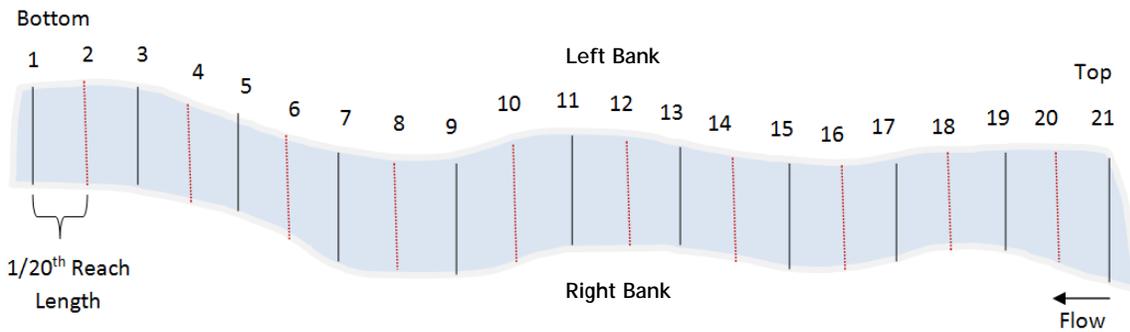


Figure 1 Transect Layout

## 2.4 Substrate Measurement

Particles (referred herein as “pebbles”) will be enumerated and measured at each of 21 cross-section transects. The basis of the protocol is a systematic selection of 5 substrate pebbles from each of the 21 cross-section transects resulting in a total enumeration of 105 pebble counts.

The method is as follows:

- Beginning at Transect 1, extend a tape measure from bank to bank being careful not to disturb the substrate beneath or immediately downstream of the tape measure.
- Note the wetted width for Transect 1 and write that width on the Data Sheet. See Figures 3 and 4.
- The sampling points along each transect are located at the 0, 25, 50, 75, and 100 percent positions of the measured wetted width. The first and last points will be located at the water’s edge just within the left and right banks. See Figure 2.

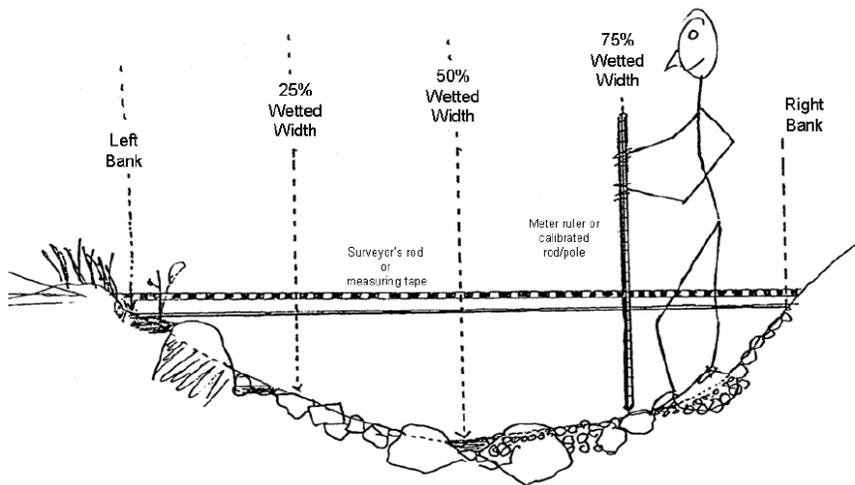


Figure 2 Illustration of sampling points along a cross-section transect.

- The sampler may begin on either the left or right bank. However, when documenting particle sizes on the Data Sheet, the sizes shall be entered based on the starting bank. See Figures 3 and 4.

	Transect #	Wetted Width (ft)			50%			
Left Bank	1	10	2.8	2	<180			Right Bank
	2							
	3							

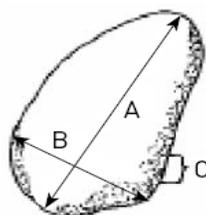
Figure 3 Example of documenting particle sizes starting on left bank at Transect 1.

	Transect #	Wetted Width (ft)			50%			
Left Bank	1	10	2.8	2	<180	<180	32	Right Bank
	2	14			90	>180	45	
	3							

Figure 4 Example of documenting particle sizes starting on right bank at Transect 2.

- Place the measuring stick flush against the tape measure line at the first position (0 percent) and drop the measuring stick straight down to the substrate. It is important to concentrate on the correct placement of the measuring stick along the cross-section and to select the pebble immediately beneath the measuring stick. Do not bias the sample by selecting a more noticeable large pebble just to the side of the stick.
- Pick up the pebble from the substrate and classify the pebble into one of the size classes available on the Gravelometer. Size classes are measured in millimeters (mm).

The holes on the Gravelometer correspond to Wentworth particle size classes that are based on the intermediate axis, known as the b-axis, of the pebble. See Figure 5. Determine a particle's median dimension in terms of "smaller than" the hole of a given size. For example, a pebble with a 60 mm b-axis would be tallied as smaller than 64 mm in the "smaller than" approach.



A = Longest Axis (length)  
 B = Intermediate Axis (width)  
 C = Shortest Axis (thickness)

Figure 5 Example of b-axis dimension.

If the pebble is over-sized or embedded into hardpan and cannot be easily removed, then judge the median dimension and classify the pebble into one of the size classes on the Gravelometer.

- Write the pebble size on the Data Sheet in the appropriate box for Transect 1 based on the start position. See Figures 3 and 4.

If the pebble was removed from its original location, discard it further downstream of the cross-section to avoid duplication at the current transect or transects further upstream. Move to the next position and repeat the procedure at the 25, 50, 75 and 100 percent positions.

- When 5 pebbles are measured on Transect 1, remove the tape measure and move upstream to the next transect. Repeat the steps described in this section at Transect 2 through Transect 21.

*Note: When bedrock is encountered enter the code "BR". Always distinguish concrete or asphalt from bedrock. Denote artificial substrate as "RC". Code other artificial substrates (such as metal, refuse, tires, etc.) as Other "OT".*

### 3.0 400-Count Procedure

The 400-count procedure will be a substitute to the 105-count procedure when sampling techniques are needed to increase the accuracy of pebble-count particle-size distributions used for stream studies in gravel-bed or sandy bottomed streams or when appropriate to answer needs identified in program-specific Sample Analysis Plans.

Pebble counts are prone to sampler errors introduced through subjective particle selection, serial correlation, and inaccurate particle-size measurements (Bunte and Abt, 2001). Errors in particle-size measurements can be minimized by using a gravel template while sampler influence on particle selection can be minimized by using a sampling frame, 60 by 60 cm, in which sampling points are identified by the cross points of thin elastic bands.

Serial correlation can be minimized by adjusting the spacing between the cross points and setting it equal to the dominant large particle size (=D95).

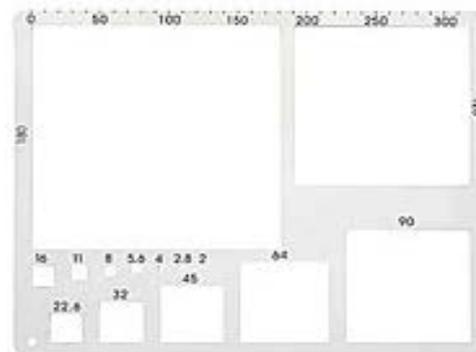
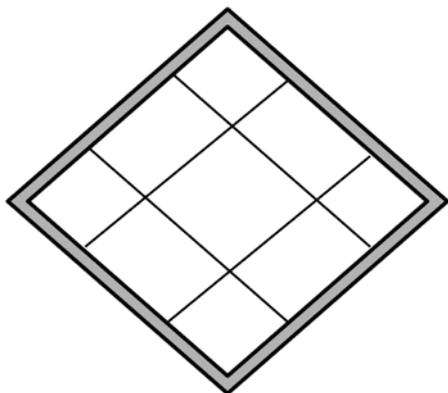
### 3.1 Equipment

- Sampling frame (see section 3.1.1)
- Gravelometer (see section 3.1.2)
- Tape measure
- 10" galvanized nails
- Pebble Count Data Sheet - 400 Count
- Clipboards
- Pencils

#### 3.1.1 Sampling Frame

The sampling frame consists of 4 aluminum bars that are connected to form a square with an inside diameter of 60 by 60 cm. The frame is sturdy and can be stepped upon to hold it down on the stream bottom in fast flow. Small slots cut in 5 cm increments along the outside edges of the frame hold thin white elastic bands in place that are stretched horizontally across the frame. Together with elastic bands stretched in a vertical direction, a grid with four or more cross-points is defined. The spacing of the "grid points" is adjusted to a size equal to or larger than the  $D_{max}$  particle size. See Figure 6.

*Note:  $D_{max}$  is the maximum diameter of averaged particles and reflects the common particle size at a given site.*



### 3.1.2 Gravelometer

A Gravelometer is an aluminum template with several sieve-sized square-holes. See Figure 7. The hole sizes correspond to Wentworth particle size classes (Wentworth 1922). After the particle is selected for measurement, the sampler pushes the particle through the various holes in the template. The aim is to determine a particle's sieve diameter in terms of "smaller than" the hole of a given size. This approach records the smallest hole size through which the pebble could be passed. For example, a pebble with a 60 cm b-axis (see Figure 5 in Section 2.4 of this SOP) would be tallied as smaller than 64 mm hole. The Division will use the "smaller than" approach.

### 3.2 Establish Reach

A length of stream will be sampled corresponding to a sampling point (site). This length of stream is referred to as a reach. The reach is where all biological, physical and chemical sampling will be conducted while at the site. All of the particle (pebble) counts will be performed within this reach.

The extent of the reach is determined by multiplying the average bankfull width by 20. The steps to establish a reach are detailed below:

- Locate the bankfull position of the stream near the sampling point (site).

Bankfull is the location on the bank where the stream rises during a large water event, which is a 1-2 year flood event. Look for evidence of bankfull location on stream banks such as changes in slope, vegetation, no soil vs. soil, snags, or evidence of scouring (bare tree roots). See Figure 8.

Indicators of bankfull stage include the following:

**Top of Point-Bars** - Point-bars consist of channel material deposited on the inside of meander beds. The top elevation of point-bars is the lowest bankfull stage, because this is the location where the floodplain is being constructed by deposition.

**Changes in Vegetation** - Look for the low limit of perennial vegetation on the bank, or a sharp break in the density or type of vegetation.

**Changes in Slope** - Changes in slope occur often along the cross-section (i.e. from vertical to sloping, from sloping to vertical, or from vertical or sloping to flat at the floodplain level).

**Changes in Bank Materials** - Any clear change in particle size may indicate the operation of different processes (i.e. coarse, scoured gravel moving as bedload in the active channel giving way to fine sand or silt deposited by overflow).

**Bank Undercuts** - Look for bank sections where the perennial vegetation forms a dense root mat.

**Stain Lines** - Look for frequent-inundation water lines on rocks. These may be marked by sediment or lichen.

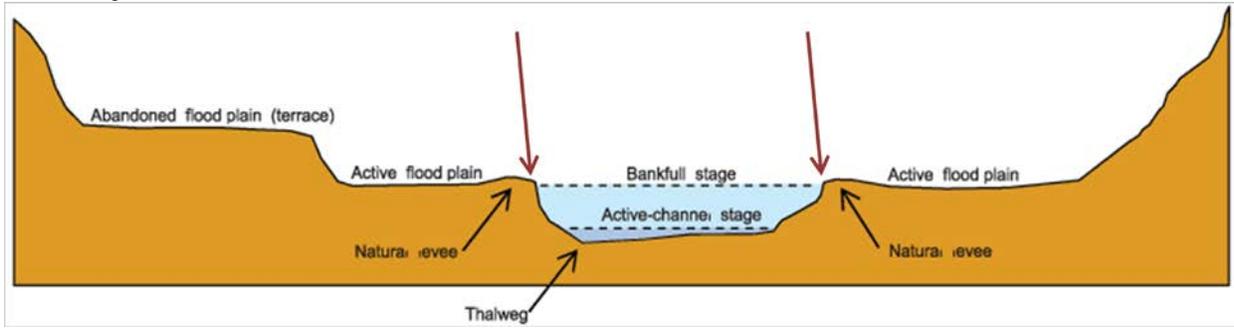


Figure 8 Illustration of determining bankfull location

- Measure the distance from bankfull to bankfull across the stream. Take the average of 3 bankfull measurements at different locations near the sampling point. This is the bankfull width. The average bankfull width must be representative of the overall reach.
- The reach is defined as 20 times the average bankfull width.

**Example:** The average bankfull width is 40 ft. Multiply 40 ft by 20. The sampling reach would be 800 ft.

The reach begins at the bottom endpoint, which is equivalent to the sampling point, unless adjustments are necessary. See below for adjustments.

- Determine if the reach needs to be adjusted around the sampling site due to confluences, impoundments (i.e. lakes, reservoirs or ponds), physical barriers, or because of access restrictions to a portion of the reach.

If a confluence, barrier or access restriction is present, note the distance on the Data Sheet and mark the restriction as one endpoint of the reach. Move the other endpoint of the reach an equivalent distance from the sampling point. This results in a reach length that remains the same but slides up or down around the sampling point.

**Note:** *Do not adjust the reach to avoid man-made obstacles such as bridges, culverts, rip-rap or channelization.*

- Mark the bottom of the reach with a tape measure and the top of the reach with a flag to signify endpoints of the reach.
- The reach is now set. Proceed to establishing transects.

### 3.3 Establish Transects

The downstream or bottom endpoint of the reach serves as the first transect, known as Transect 1 unless barriers or restrictions necessitate adjusting the bottom endpoint. This will be the first of 10 total transects that are set at equidistant locations upstream of Transect 1.

- Using a tape measure, measure 1/10<sup>th</sup> of the reach length from the start point (Transect 1) while measuring along one side of the stream. Avoid disturbing the stream channel prior to sampling activities. Flag this spot as the next cross-section (Transect 2).
- Continue moving upstream in the same manner to set Transects 3-10.
- All transects are now set. Proceed to pebble counts.

### 3.4 Substrate Measurement

Particles (referred herein as “pebbles”) will be enumerated and measured at each of 10 cross-section transects. The basis of the protocol is a systematic selection of 40 substrate pebbles from each of the 10 cross-section transects resulting in a total enumeration of 400 pebble counts.

The method is as follows:

- Beginning at Transect 1, extend a tape measure from bankfull to bankfull being careful not to disturb the substrate beneath or immediately downstream of the tape measure. Secure each end of the tape measure with 10” galvanized nails so the tape is taut and does not sag into the stream.
- Note the wetted width for Transect 1 and write that width on the Data Sheet. See Figure 9.

<b>Transect</b>	<b>T1 Bankfull Width: 14</b> 	
<b>Distance Between Transects</b>	<b>0'</b>	
	T1:	T1:
	T2:	T2:
	T3:	T3:
	T4:	T4:

Figure 9 Example of documenting bankfull width at Transect 1

- Divide the transect length by 10. This is the interval used to move the sampling frame along the tape measure.

**Example:** The bankfull width for Transect 1 is 50 ft. Divide 50 ft by 10. The result is 5 ft.

- Beginning at either left or right bankfull position, place the sampling frame at the start of the tape measure stretched across the stream. This will be called Position 1. Left and right bank will be determined working upstream.
- Document the predominate habitat type present along the transect, such as riffle “RF”, run “RN” or pool “PL” on the Data Sheet next to the first transect position. See Figure 10.

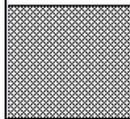
<b>Transect</b>	<b>T1 Bankfull Width: 14</b>	
<b>Distance Between Transects</b>	0' RF 	
	T1:	T1:
	T2:	T2:
	T3:	T3:
	T4:	T4:

Figure 10 Example of documenting predominate habitat type at Transect 1

- Document the starting bank position as “LB” (left bank) or “RB” (right bank) on the Data Sheet. See Figure 11.

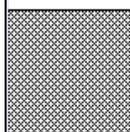
<b>Transect</b>	<b>T1 Bankfull Width: 14</b>	
<b>Distance Between Transects</b>	0' RF	
	T1: LB 	
	T2:	
	T3:	
	T4:	

Figure 11 Example of documenting left bank at Position 1 on Transect 1

- Grid points at the intersections of the 4 elastic bands are used to visually define the particles to be selected. The pebbles directly under the grid intersections are the particles that will be measured with a Gravelometer.
- A pointed index finger is placed in a corner of the grid intersection, and vertically lowered onto the substrate surface. Do not bias the sample by selecting a more noticeable large pebble just to the side of your finger.
- Pick up the pebble from the substrate and classify the pebble into one of the size classes available on the Gravelometer. Size classes are measured in millimeters (mm). Discard the pebble in a downstream direction. Repeat for grid positions 2-4.

If the flow is too deep or too fast to see the particle under the grid intersection, the particle to be included in the sample must be identified by touch.

If the pebble is over-sized or embedded into hardpan and cannot be easily removed, then judge the median dimension and classify the pebble into one of the size classes on the Gravelometer.

- Pebbles are collected from under all four grid points and recorded on the Data Sheet. Grid points are grouped on the Data Sheet as T1, T2, T3 and T4. See Figure 12.

<b>Transect</b>	<b>T1 Bankfull Width: 14</b>	
<b>Distance Between Transects</b>	0' RF	
	T1: LB <2	T1:
	T2: <45	T2:
	T3: <45	T3:
	T4: <5.6	T4:

Figure 12 Example of documenting pebble sizes at four grid points at Position 1 on Transect 1

If the waterline is encountered at Position 1 (or any position along the transect) document the sampling frame grid positions where the water surface would be touched if the index finger were to be vertically lowered. See Figure 13. Document the waterline as "WL" on the Data Sheet. See Figure 14.

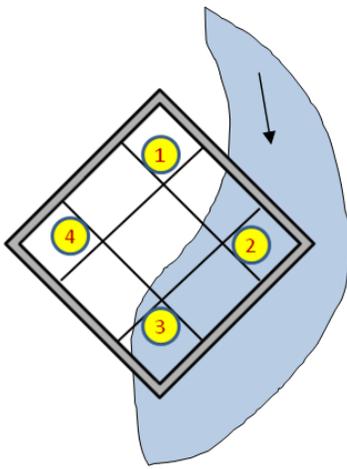


Figure 13 Example of left bank waterline at grid positions 2 and 3

<b>Transect</b>	<b>T1 Bankfull Width: 14</b>	
<b>Distance Between Transects</b>	0' RF	
	T1: LB <2	T1:
	T2: WL <45	T2:
	T3: WL <45	T3:
	T4: <5.6	T4:

Figure 14 Example of documenting waterline ("WL") grid positions at Frame Position 1 on Transect 1

- On the Data Sheet, it is important to document the first 5 grid positions and 20 pebble sizes in the first column under Transect 1 while working from top to bottom. Document the second 20 pebble sizes in the second column under Transect 1 working from top to bottom as well.

- Once four pebbles at Position 1 are measured, the sampling frame will be moved 1/10<sup>th</sup> the bankfull width or in this example, 5 ft along the tape measure to Position 2.
- Continue to count pebbles from Positions 2-10 along the tape measure being vigilant to document waterline grid and opposite bank positions along the way.

**Unbraided Channels** - In cases where the channel is unbraided document the opposite waterline and bank positions on the Data Sheet using the same method as discussed above.

**Braided Channels** - In cases where vegetated, mid-channel island(s) or unvegetated and exposed gravel bars are encountered along the same transect continue to denote waterline and left or right bank positions for each occurrence. For instance, if a single island sits mid-channel, then the sampler will document 2 left banks, 2 right banks, and 4 waterlines.

- Once pebble counts are completed at Position 10 on Transect 1, pull the stake nails and remove the tape measure.
- Move the tape measure upstream to Transect 2 at 1/10<sup>th</sup> of the reach length and repeat the steps in Section 3.4.
- Continue to count 40 pebbles at 10 transects until 400 pebble counts are collected.

## 4.0 Salmonid Spawning Habitat Procedure

The Division will use Montana’s Department of Environmental Quality “grid toss” method to describe the substrate quality in areas most likely used by salmonids for spawning. Please refer to Montana’s grid toss method detailed in Section 3.2.2 of their Sediment Assessment Method (MDEQ, draft 2013).

Salmonids generally can spawn in gravels with a D50 up to about 10% of their body length and tend to spawn in areas of streams where either downwelling or upwelling is present (Kondolf, 2000; Kondolf and Wolman, 1993). As a result, pool tails are likely salmonid spawning locations (Keller et al., 1990).

### 4.1 Equipment

- 0.30 m<sup>2</sup> grid with 7x7 pattern (right)
- Gravelometer
- Clipboards
- Pencils



Figure 15 Metal grid frame

### 4.2 Substrate Measurement

A short version of the procedure is as follows:

- Grid toss counts will be performed in the tail of all scour pools within the sampling site (reach). To be considered a pool, a feature must have a maximum depth of  $\geq 1.5$  times the pool-tail depth (Archer et al., 2012).

**Note:** Do not perform grid toss into scours formed by logs or other debris completely damming the downstream end of the pool.

- Three grid tosses will be performed in each of the pool tails. Grids will be placed at the 25, 50 and 75 percent positions across the pool tail and a distance of 10% of the pool’s length or 1 m, whichever is less, from the pool tail crest. See Figure 16.

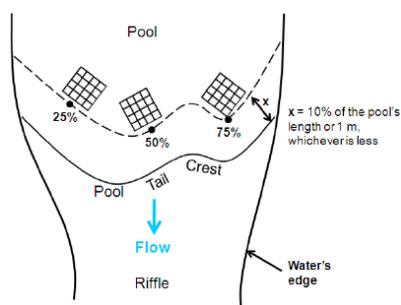


Figure 16 Locations within a pool tail to be sampled with the grid toss

- The pebbles immediately under the grid intersections (n=49) will be measured. The median size (D<sub>50</sub>) of all pebbles observed under each grid toss will be recorded.

**Note:** The Division will use a Gravelometer with Wentworth particle size classes to measure and record pebbles.

## 5.0 References

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## 6.0 Document Version

2.0\_051215

## 7.0 Approval Signatures

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5/13/2015

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