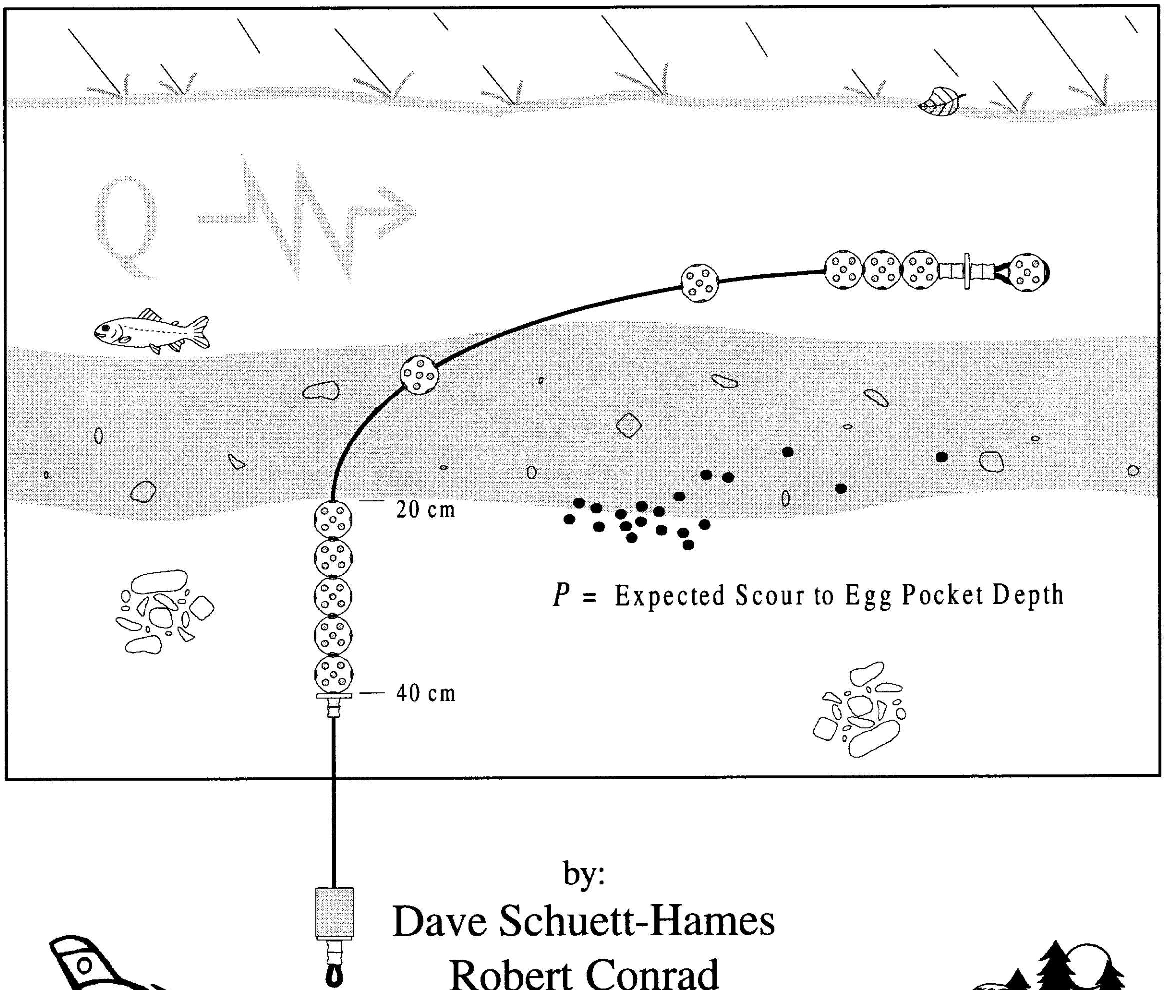
DNR # 110 TFW-AM9-99-008

TFW Monitoring Program

METHOD MANUAL

for the

SALMONID SPAWNING GRAVEL SCOUR SURVEY



by:
Dave Schuett-Hames
Robert Conrad
Allen E. Pleus
Kevin Lautz

NW Indian Fisheries Commission

Timber Fish & Wildlife

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Abstract

The TFW Monitoring Program method manual for the Salmonid Spawning Gravel Scour Survey provides a standard method for assessing and monitoring changes in the depth, frequency and distribution of scour on a stream segment scale. Segments for monitoring scour are selected on the basis of one of three monitoring objectives. Information on frequency and depth of scour is useful when there is a need to evaluate the effect of scour on salmonid incubation, such as in the case of sensitive or declining stocks. It is also useful for evaluating the response of stream channels to changes in peak flow discharge, sediment input, or large woody debris loading due to land-use activities or natural events.

Once objectives are identified and segments have been selected, the spawning gravel is inventoried and categorized by spawning habitat type. Then cross sections are established in a sub-sample of randomly selected spawning gravel areas representing each habitat type. Scour monitors are inserted in potential spawning gravel along each cross section, bed elevations are surveyed and substrate particle size is documented with a pebble count. Data on depth of scour, changes in bed elevation, and substrate particle size are collected after each storm event during the monitoring period. Peak flow discharge is documented. Scour data are analyzed in the TFW Monitoring database, which generates reports that characterize the depth, frequency and distribution of scour by cross section and spawning habitat type. Scour data are interpreted in the context of peak discharge events.

The remainder of section 1 describes the purpose of the Scour Survey, reviews scientific background information, and describes the cooperator services provided by the TFW Monitoring Program. The following sections are presented in order of survey application including: study design, pre-survey preparation, survey method, post-survey documentation, data management, and references. An extensive appendixes includes: copy masters of field forms; examples of completed field forms; scour monitor and inserter size and construction detail instructions; a sample size calculation matrix; a sample site selection worksheet example; a standard field and vehicle gear checklist; and a data management example.

TFW Monitoring Program
Northwest Indian Fisheries Commission
6730 Martin Way East
Olympia, Washington 98516

Ph: (360)438-1180
Fax: (360)753-8659

Internet:
http://www.nwifc.wa.gov

Washington Dept. of Natural Resources
Forest Practices Div.: CMER Documents
P.O. Box 47014
Olympia, Washington 98504-7014

Ph: (360)902-1400

The Authors

Dave Schuett-Hames is the TFW Monitoring Program Coordinator/Biologist at the Northwest Indian Fisheries Commission. He received a B.S. degree in biology (1976) and an M.E.S. degree (1996) from the Evergreen State College. He worked for 12 years as a fish habitat biologist for the Lummi Nation and the Squaxin Island Tribe. He joined the program as coordinator in 1992. E-mail: dschuett@nwifc.wa.gov

Robert Conrad is the NWIFC Quantitative Services Division Manger. He received a B.S. degree in Fisheries (1978 and an M.S. degree in Fisheries (1983) from the University of Washington. He began working for the NWIFC in 1989.

Allen E. Pleus is the TFW Monitoring Program Lead Training and Quality Assurance Biologist at the Northwest Indian Fisheries Commission. He received a B.A. degree in communications (1985) and an M.E.S. degree (1995) from the Evergreen State College. He began working for the program in 1991.
E-mail: apleus@nwifc.wa.gov

Kevin Lautz was formerly the hydrologist for the Washington Department of Fish and Wildlife (WDFW). He received a B.S. degree in Forestry (1982) from the University of Massachusetts and a B.S. in Civil Engineering (1991) from Oregon State University. He began working for WDFW in 1992, and currently works for the Washington Conservation Commission as the regional technical coordinator for salmon recovery in the Yakima and Klickitat watersheds.

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Copying of the TFW Manual

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Salmonid Spawning Gravel Scour Survey

1. Introduction

The TFW Monitoring Program method manual for the Salmonid Spawning Gravel Scour Survey provides a standard method for assessing and monitoring changes in the depth, frequency and distribution of scour on a stream segment scale. Segments for monitoring scour are selected on the basis of one of three monitoring objectives. Information on frequency and depth of scour is useful when there is a need to evaluate the effect of scour on salmonid incubation, such as in the case of sensitive or declining stocks. It is also useful for evaluating the response of stream channels to changes in peak flow discharge, sediment input, or large woody debris loading due to land-use activities or natural events.

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1.1 Purpose

The Timber-Fish-Wildlife Monitoring Program (TFW-MP) provides standard methods for monitoring changes and trends in stream channel morphology and scour characteristics. The Scour Survey method has been approved by TFW's Cooperative Monitoring, Evaluation and Research Committee (CMER) and is accepted as a standard method for monitoring on forest lands in Washington state by tribal governments, state natural resource agencies, timber companies, environmental organizations, and others. The purposes of the Scour Survey include:

1) To assess scour depth, frequency and distribution patterns in salmonid spawning gravel;
2) To detect and monitor changes in scour depth, frequency and distribution patterns over time on a stream segment scale; and
3) To provide information on peak discharge and physical channel characteristics to interpret scour in the context of physical channel processes.

1.2 Background

Background information on spawning gravel scour includes the effects of scour on salmonid incubation, factors affecting vulnerability of salmonids to scour, and physical factors affecting the depth and frequency of scour.

1.2.1 Effects of Scour on Salmonid Incubation

Salmonids reproduce by depositing their eggs in clusters (egg pockets) buried in nests (redds) constructed in stream bed gravel (Burner, 1951; Peterson and Quinn, 1994). While in the gravel, the larvae (alevin) hatch from the eggs and transform into free-swimming fry. Although the gravel environment provides protection from freezing, desiccation, disturbance and predation during this sensitive period of development, the eggs and alevin are vulnerable to scour and mechanical shock (McNeil, 1966). Scour of spawning gravel during peak flow events has been frequently documented (Gangmark and Bakkala, 1960; McNeil, 1966; Duncan and Ward, 1985; Tripp and Poulin, 1986; Lisle, 1989; Nawa et al., 1990; Kondolf et al., 1991; Orsborne and Ralph, 1994; Schuett-Hames et al., 1994). Losses of eggs and alevin due to scour can reach 90 percent of the total population, exceeding mortality from other causes (McNeil, 1966; Tripp and Poulin, 1986). Scour is a major factor affecting survival of coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha*) salmon in southwest Oregon (Nawa et al., 1990) and has caused long-term effects on the size and species composition of resident trout populations in the Sierra Nevada Mountains (Seegrist and Gard, 1972). Partial scour of material above the egg pocket provides an opportunity for fine sediment to infiltrate into, or form a layer immediately above the egg pocket, where it can impede infiltration of oxygenated surface water and block fry attempting to emerge from the gravel (Koski, 1975; Tripp and Poulin, 1986).

1.2.2 Factors Affecting Vulnerability of Salmonid Larvae and Alevins to Scour

Spawning behavior of adult fish and geomorphic processes are the two of the most important factors affecting the vulnerability of salmonid larvae and alevins to scour during incubation. Behavioral factors include the depth of egg deposition and timing of spawning and incubation. Egg burial depth varies within and between salmonid populations (Burner, 1951; van den Berghe and Gross, 1984; Tripp and Poulin, 1986, DeVries, 1997). Factors influencing egg burial depth include water velocity, substrate size and bed compaction (Burner, 1951), and salmonid body size since larger females are able to deposit their eggs at greater depths than their smaller counterparts (van den Berghe and Gross, 1984). Scour to the depth of salmonid egg pockets typically occurs during peak discharges, so the likelihood of mortality from scour is greatest for salmonids that incubate during seasons when peak flows commonly occur. For example, coastal coho eggs incubating through the winter will have a higher probability of encountering peak flow events due to regional hydrology patterns than would steelhead (*Oncorhynchus mykiss*) eggs incubating during late spring and early summer.

1.2.3 Physical Factors Affecting the Depth and Frequency of Scour

Scour of stream bed gravel is a natural process associated with bedload sediment transport. Scour of gravel particles occurs when the energy (shear stress) provided by water flowing over the particles is sufficient to overcome their resistance to motion. The amount of shear stress applied to particles is dependent on the velocity gradient of currents near the surface of the bed (Bathurst, 1979). Depth, frequency, and distribution of scour are influenced by complex interactions between many factors, resulting in highly variable spatial and temporal patterns (Sidle, 1988; Hassan, 1990; Schuett-Hames, 1996). Some major factors affecting scour include the magnitude, duration and timing of peak flows (Duncan and Ward, 1985; Reid et al. 1985; Hassan, 1990), the size and abundance of bedload material (Sidle, 1988; Montgomery et al., 1996), and the frequency and stability of obstructions that trap and store gravel (McNeil, 1966; Tripp and Poulin, 1986).

Land-use activities or natural events that alter peak flows, sediment delivery rates, sediment particle size distribution, or large woody debris (LWD) loading can cause changes in the depth and frequency of scour in downstream spawning habitat. For example, increased storm water runoff from impervious surfaces associated with urban development was estimated to increase the frequency of peak flow events capable of causing scour (Booth, 1990). Scour was greater in channels with elevated coarse sediment input due to upstream landslides (Tripp and Poulin, 1986; Nawa et al., 1990) and channels directly disturbed by debris torrents (Tripp and Poulin, 1986). Increased scour has been observed in stream reaches where LWD was uncommon or unstable (Tripp and Poulin, 1986) and in wider, complex reaches where the thalweg could move laterally and interact with bars and obstructions (Nawa et al., 1990; Schuett-Hames, 1996). Other disturbances resulting in extensive scour include splash damming (Wendler and Deschamps, 1955), debris torrents (Tripp and Poulin, 1986) and stream channelization projects (Cederholm and Koski, 1977). For a more detailed literature review on spawning gravel scour, see Schuett-Hames et al. (1995).

1.3 Services Available to TFW Cooperators

The TFW Monitoring Program provides a comprehensive suite of services to support TFW cooperators collecting data consistent with program goals. Services include study design assistance, pre-season training through annual workshops and on-site visits, pre-season quality assurance reviews, data entry systems, summary reports of monitoring results, and database/data archiving services. These services are offered free of charge. TFW method manuals are available for the following surveys:

TFW Monitoring Program Method Manuals

- Stream Segment Identification
- Reference Point Survey
- Habitat Unit Survey
- Large Woody Debris Survey
- Stream Temperature Survey
- Spawning Gravel Composition Survey
- Spawning Habitat Availability Survey
- Spawning Gravel Scour Survey
- Wadable Stream Discharge Meas. Method

To find out more about TFW Monitoring Program services and products, contact us or visit our link on the NWIFC homepage. The address is:

TFW Monitoring Program
Northwest Indian Fisheries Commission
6730 Martin Way East
Olympia, WA 98516

Ph: (360) 438-1180
Fax: (360) 753-8659

Internet site:
www.nwifc.wa.gov

2. Study Design

There are six elements required in designing studies for monitoring spawning gravel scour on a segment scale including: 1) identifying monitoring segments; 2) identifying monitoring objectives; 3) determining objective precision and confidence levels; 4) selecting the time of year to conduct surveys; 5) finalizing data collection options and survey modifications; and 6) conducting pre-season crew training and quality assurance reviews. The goal is a well-designed scour monitoring study that is able to detect changes in scour patterns over time due to land management or natural disturbances. Effective monitoring study designs require rigorous planning, documentation, and consistency in methods, method application, and data analysis. This ensures that the monitoring data produced meets the objectives of the project and monitoring plan.

2.1 Identifying Monitoring Segments

A basic step in study design development is identifying a group of candidate segments from which to select suitable monitoring segments or sub-segments. The Scour Survey uses the TFW defined stream segment as the fundamental unit of analysis for characterizing scour frequency and distribution.

The TFW method identifies stream segments based on gradient, valley confinement, and flow. A USGS 7.5 minute topographic map (photocopy worksheet) with delineated segments is required for this part of the study design development. Many streams have already been segmented through past TFW monitoring projects, Watershed Analysis processes, and the Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP). If the stream has not been pre-segmented, or pre-segmented boundaries are not suitable for your monitoring plan, partition the river system into stream segments or sub-segments using the TFW Monitoring Stream Segment Identification method (Pleus and Schuett-Hames, 1998) before continuing. Segment data documented on Form 1 and USGS topographic maps are required for data tracking and to provide important information for identifying segment boundary locations and access points.

2.2 Identifying Monitoring Objectives

It is important to carefully identify the monitoring objectives and design the project to achieve these objectives. Some common objectives for scour monitoring studies on forest lands include:

1. Characterizing scour in stream reaches of importance for aquatic resources.
2. Characterizing scour due to land management activities or natural events.
3. Characterizing scour throughout a watershed.

Principles for designing scour monitoring projects to achieve each of these objectives are described in the following sections.

2.2.1 Monitoring to Characterize Scour on Stream Reaches of Importance to Aquatic Resources

The first type of objective is typically used to test whether scour is a problem on a stream segment of interest. This information can be used to determine the need for a more intensive study of the segment, guide land management decisions, or recommend restoration projects. The initial scour survey provides a baseline from which subsequent surveys can be compared to determine changes and trends.

The first step is to identify the stream segments of concern. Typically, scour is an issue for salmonid stocks that incubate during the time of year when peak discharges are likely. Once the stock(s) of concern is determined, information on the location of their spawning grounds can be used to identify potential stream segments for scour monitoring. After potential monitoring reaches have been identified, a sampling plan can be developed. If only few reaches of concern are identified, it may be feasible to monitor all of them. If many reaches are identified it will be necessary to prioritize and sample the most important spawning areas, or to stratify segments on the basis of channel morphology and sub-sample each strata.

2.2.2 *Monitoring to Characterize Scour due to Land Management Activities or Natural Events*

The second type of objective is generally used to test the effectiveness of a land management activity on preventing or reducing scour depth and frequency on a stream reach. It can also be used to test whether changes in scour characteristics were caused by the effects of a natural mass wasting or debris torrent event. For this type objective, several monitoring approaches are available. The preferred approach involves comparing an affected stream reach with an undisturbed control reach. Either a before/after, upstream/downstream, or paired stream design may be used. If a control reach is not available, then scour in the treated reach can be documented. However, this is unlikely to answer questions about the effect of the treatment because the scour regime observed may be due to factors other than the treatment being evaluated. In all cases, the reaches selected for monitoring should be capable of response (have spawning gravel that can be moved by peak flow discharges). Scour can occur in stream segments representing a wide range of gradient/confinement categories. It is especially prevalent in segments subject to increased coarse sediment input or peak flows, or lacking in stable LWD.

The before/after approach requires monitoring of the affected reach both before and after the land management treatment or natural event occurs. The pre-treatment data provides the control against which the post-treatment results are compared to test whether a change occurred due to the treatment/event. The minimum data requirement is one monitoring period before and after treatment. However, this design requires the assumption that the peak flow regime is consistent from year to year, since scour is typically closely correlated with peak discharge. If peak flows during both the before and after monitoring periods are representative and comparable, then the comparison is valid. Variation in peak flows during the pre- and post-treatment monitoring periods would invalidate the assumption of year to year comparability. Gathering more than one year of pre-treatment data to document scour over a wider range of peak discharges increases the likelihood of matching the post-treatment peak discharge conditions.

The upstream/downstream and paired stream design can be completed in a single season. The upstream/downstream design involves sampling at two locations, one at the lower end of the affected stream reach and another above the treated area. The scour regimes at the two locations are compared using the upstream reach as the control. The paired stream reach approach is similar, except a separate, undisturbed stream reach is used as the control. The control and treatment reach must be of similar geomorphology, elevation and drainage area, so that differences in scour between the two reaches is due to the treatment effect. Significant differences between the control and treated reach would invalidate this assumption.

Monitoring post-treatment/event scour in the affected reach and comparing it with a target value is suitable for determining the status of the reach following treatment, but is inconclusive in attributing the condition to the treatment because there is no control for comparison. Another problem with this approach is the lack of accepted target values for spawning gravel scour.

2.2.3 *Monitoring to Characterize Scour Throughout a Watershed*

The third type of objective refers to projects that select multiple stream segments for characterizing scour on a watershed scale. A typical approach is to stratify stream segments on the basis of channel morphology (gradient, confinement, channel width, channel type, and drainage area) and factors influencing scour (sediment input, LWD loading, and land-use). The scour data is collected in a sub-sample of segments in each strata, providing a representation of the scour regime in each class of segments in the watershed. Consultation with a statistician is recommended to develop a suitable sampling plan to accomplish this objective.

2.3 Determining Objective Precision and Confidence Levels

The next step is to determine an appropriate level of precision and confidence for the scour data based on the project's objectives. The two confidence level options recommended are at 90 and 95 percent. The four precision levels recommended are at plus-or-minus 5, 10, 15, and 20 percent. The appropriate confidence level and precision will vary depending on project purpose and data requirements. We recommend that reconnaissance projects and most first-time surveys use a 90% confidence level with precision targets of +/-15% or

+/-20%. The higher level of confidence (95%) and smaller values of relative precision (e.g., +/-5%, +/-10%) are more appropriate for projects intended to detect incremental changes over time and will require more scour monitors to be installed.

2.4 Selecting the Time of Year to Conduct Surveys

The most relevant and useful scour data is collected during the period of time when eggs are incubating in the gravel. This requires research on the salmonid stock(s) of concern and timing the survey accordingly. The best time to install scour monitors is immediately prior to the spawning season to avoid disturbing or damaging eggs deposited in the gravel. Scour monitors are removed after the expected emergence of the fry from the gravel into the stream channel and when the flows have lowered enough to allow access to, and excavation of, buried monitors.

2.5 Finalizing Data Collection Options and Survey Modifications

Data collected using the Scour Survey methods are supported by the TFW-MP database and are used to produce standard data analysis summary reports. Data collected using these methods can be compared with other data collected using the same methods from around the state. The study design information and scour monitoring method presented in this manual relate to segment scale analysis.

The intensity of data gathered using the Scour Survey methodology can be adjusted, depending upon the monitoring objectives. At the most basic or core level, data collection can be limited to gathering information on depth of scour that will document the mean and maximum scour depths and the frequency of scour to egg pocket depth. Additional guidelines and methods are provided for collection of supplemental data on peak discharge, surface substrate particle size, and bed elevation change. This supplemental information takes more time and effort to collect, but is highly recommended because it provides the capability to interpret the scour data in the context of the magnitude of peak flows that occur during the monitoring period, differences in substrate, and changes in bed elevation and form, respectively.

Modifying the Scour Survey to collect data on additional parameters that meet individual cooperator needs is acceptable if it does not compromise the integrity of the core parameters. Survey modifications are defined as any change to the core criteria and methods as documented in the latest version of the TFW method manual. In other words, data collected using the modified method would not be comparable at some level with data collected using the methods and criteria as stated in the manual. Common examples include adding cross sections associated with known spawning gravel areas and adding monitors along cross sections to provide detailed scour profiles. However, any additional data must be separated from the core data to prevent bias of segment scale characteristics. Analysis of modified data is the responsibility of the cooperator. Contact the TFW Monitoring Program for assistance in modifying the methods to ensure data integrity and compatibility.

There are two places where identification of survey modifications are important. The first place is to identify modified data that has been collected on the field forms. Documentation of modifications in the *Survey Notes* sections of Form 10.0 allows accurate interpretation of field data. The second place is to identify if modified data has been entered into the TFW database. It is feasible to have the field forms flagged as modified, but not the database where core data has been extracted by the cooperator before data entry. Documentation of modification in the database allows accurate interpretation of affected parameters and calculations on summary reports. However, in most situations modified data cannot be entered into the database due to validation checks.

The field forms provided in the manuals have been designed for consistent and accurate recording of Scour Survey data. The forms have been refined based on research and monitoring experience to reduce data errors caused by factors such as legibility, required parameter field calculations, and data transfer during database entry. In most cases, the field forms can accommodate the collection of additional parameter data, thus limiting the necessity of cooperators to modify or create new forms.

2.6 Conducting Pre-Season Crew Training and Quality Assurance Reviews

Cooperators are strongly encouraged call the TFW Monitoring Program to make appointments for pre-season training and quality assurance (QA) reviews. This ensures that field crews are applying survey methods correctly from the start and the highest quality data are being collected throughout the survey. Training should be repeated annually to learn new methods, techniques, or simply refresh skills. QA reviews should be repeated seasonally to maintain documentation and to refresh survey skills.

3. Pre-Survey Preparation

This section describes all necessary survey equipment and materials required for field crews to complete the field portion of the Scour Survey. These lists are not intended to cover all possible survey equipment and materials that could be of use.

3.1 Survey Equipment

Survey equipment are those items necessary for crews to conduct a Scour Survey. This list does not cover all possible equipment that can be useful. The TFW-MP database is designed to use metric units so metric measurement equipment should be used. The basic equipment includes:

Survey Equipment

Site Inventory
- Hipchain
- Stadia rod or fiberglass tape
- Flagging & permanent marker

Scour Monitor Installation
- Safety glasses, gloves, ear protection
- Fiberglass tape (30 - 100 meter, depending on channel width)
- Calculator
- Scour monitors (1 monitor per sample- plus a few extra)
- Scour monitor inserter and anchor rod
- (2) C-clamps
- (4) Alligator clips
- Tags, aluminum or durable plastic (2 per cross section)
- Steel rebar rods- 24" or longer (up to 2 per cross section)
- Nails- 20 d (use aluminum if available)
- Pruners/machete
- 2 lb. Hammer
- Pipe wrench (sliding-bead inserter)

Survey Equipment (cont.)

Bed Elevation Survey
- Stadia rod
- Surveying level, total station, or Abney level
- Caliper or plastic ruler

Scour Monitor Inspection Visits
- Scour monitor installation equipment (only a few extra monitors)
- Bed elevation survey equipment (except caliper/ruler)

Scour Monitor Removal
- Safety glasses and gloves
- Fiberglass tape
- Bed elevation survey equipment (except caliper/ruler)
- Shovel
- Nail puller

General
- Standard Field and Vehicle Gear Checklist (Appendix F)

Check all equipment for damage before using. Calibrate all measurement equipment to a standard of known accuracy before and after the survey to ensure that the instruments are providing accurate data during collection. Depending on amount and type of use, surveying levels should be professionally serviced each year. If the level has not been recently serviced, use a two-peg test to check calibration and determine if professional servicing is needed (see "Surveying Level Two-Peg Test" text box on next page for instructions.)

The use of metric measurement equipment complies with standard scientific methods. The cost of purchasing metric equipment is often offset by savings in personnel time and effort required to convert from English to metric units. It also results in the highest quality data due to avoidance of errors during conversion of large data sets. Mixing unit types within a survey is strongly discouraged due to potential for multiple conversion errors. If using English units, all measurements must be converted to metric units before entry into the TFW-MP database.

Surveying Level
TWO-PEG TEST
(from Harrelson et al., 1994)

Check surveying instruments before field work by doing a two-peg test. Perform a peg test the first time the instrument is used, when damage is suspected, or when custody of the instrument changes.
1) Drive two stakes near ground level 200-300 feet apart with a clear line of sight.
2) Set up the level exactly halfway between the two points. Take a rod reading "a" on stake A and a second reading "b" on stake B. The elevation difference computed, "a - b," is the true difference regardless of instrument error.
3) Set up the level close enough to stake A so that a rod reading can be taken either by sighting through the telescope in reverse or by measuring up to the horizontal axis of the telescope with a steel tape.
4) Take a rod reading "c" on Stake A and a rod reading "d" on Stake B.

If the instrument is in adjustment, (c - d) will equal (a - b).
If the instrument is out of adjustment, compute what the correct rod reading "e" on B should be (e = b + c - a) and have the instrument adjusted.
A sample calculation of the peg test follows:

a = 5.93	a - b = 0.33	instrument is okay
b = 5.60	c - d = 0.33	
c = 5.96		
d = 5.63		

Select wading gear to accommodate stream and survey conditions. On most streams, having one crew with chest waders is important for inserting or checking monitors in the deeper parts of the channels. Having only knee or hip boots for a larger stream limits access. However, use of chest waders in fast flowing streams can be dangerous.

3.1.1 Scour Monitor Selection

Selecting the type of scour monitors to use is an important decision. Scour monitors are not available commercially so they must be built before installation can commence. The best type of scour monitor to use depends on many factors including the availability of materials, availability of installation equipment, substrate size and compaction, the likelihood of debris movement during storm events, and water visibility during the monitoring period. A number of different types of scour monitors and installation systems are available. We recommend using scour monitors made either of perforated plastic golf balls or of beads strung on braided wire cable. Both golf ball and sliding-bead monitors have been used successfully to monitor scour in forest streams. These designs are durable, relatively inexpensive, provide a suitable degree of precision, and perform reliably under peak flow conditions for one to three years.

The plastic golf balls are larger and more visible, making it possible to take readings without wading all the way out to the monitors during turbid, high flow conditions between winter storm events. The beads are smaller, making it necessary to get closer to the monitors to record data. The small diameter of the sliding-bead monitors can be an advantage when installing monitors in stream beds that are compacted, because a narrower insertion system allows easier installation under these conditions. The smaller beads also measure scour in finer increments. Depending on the type monitor used, the estimated accuracy is plus or minus half the length of one golf ball or bead. Basic design of each of the two types of monitors, and their respective installation systems, are described below. The number of balls/beads and length of wire can be varied to adjust for differences in expected scour depth and difficulty in inserting the monitor. Refer to Appendix C for detailed construction information on both systems.

Description of the Perforated Golf Ball Monitor and Installation System

The golf ball-type monitor was first developed by McNeil (1962) using ping pong balls, and has been used and refined in a number of other studies (Tagart, 1976; Tripp and Poulin, 1986; Schuett-Hames et al., 1994). Use of perforated plastic golf balls was first described by Tripp and Poulin (1986). The standard design of this type scour monitor consists of threading 10 perforated heavy duty plastic golf balls onto a 1.5 meter length of 1/8 inch stainless steel braided wire (airplane cable) (Figure 1). The balls can be numbered or color-coded to assist in determining depth of scour. To one end of the cable a short piece of wooden dowel

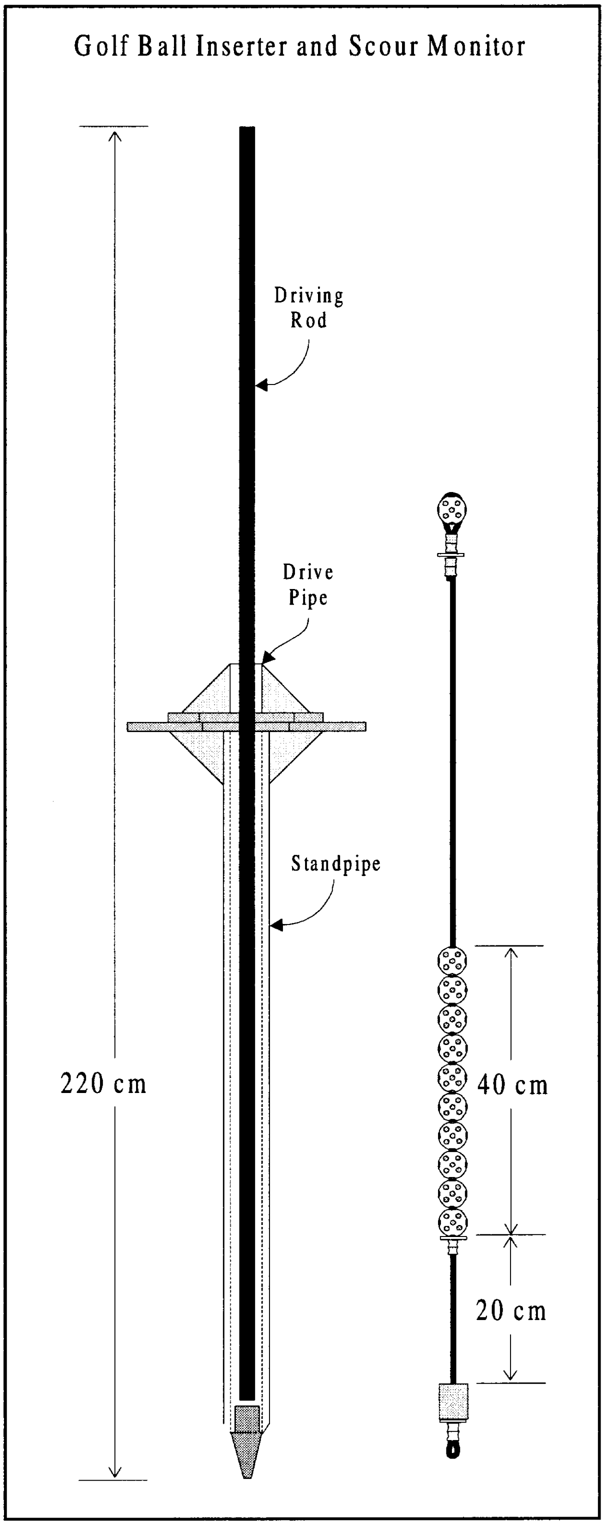


Figure 1. Diagram of a standard golf ball type scour monitor inserter and monitor.

is attached to provide an anchor. A cable stop and washer are attached between the anchor and the bottom ball. At the other end of the cable a float is attached with a steel washer inscribed with identifying information.

The equipment used to insert the golf ball monitors is long and heavy and was first described by Tripp and Poulin (1986). The three main pieces consist of the standpipe, drive pipe, and driving rod. The drive pipe fits inside the standpipe, the driving rod inside the drive pipe, and the rod is then used to pound both pieces into the channel bed similar to a pile driver. A full description of monitor insertion will be described in the method section. This equipment must be fabricated at a welding shop.

Description of the Sliding-Bead Monitor and Installation System

The sliding-bead scour monitor and insertion system described here was developed and has been used extensively by Jim Matthews of the Yakama Nation (personal communication). An alternate system that is acceptable for use is described in Nawa and Frissell (1993). The standard design is to thread 20 steelhead fishing corkies (3/4 inch) onto a 1.5 meter length of 3/32 inch stainless steel braided wire (aircraft cable) (Figure 2). The corkies can be numbered or color-coded to assist in determining depth of scour. A modified toggle bolt is used as the anchor and a PVC float is attached to the top.

The equipment used to insert the bead monitors is much shorter and lighter than the golf ball inserter and can be constructed of material purchased at most hardware stores. The design consists of three main pieces including the standpipe, driving rod, and T-handle. To assemble the inserter, the driving rod with masonry bit tip is inserted into the standpipe, the T-handle is attached to the standpipe, and all three pieces are secured with a pin. The inserter is then augered into the gravel using a masonry drill bit attached to the driving rod. A full description of monitor insertion will be described in the method section.

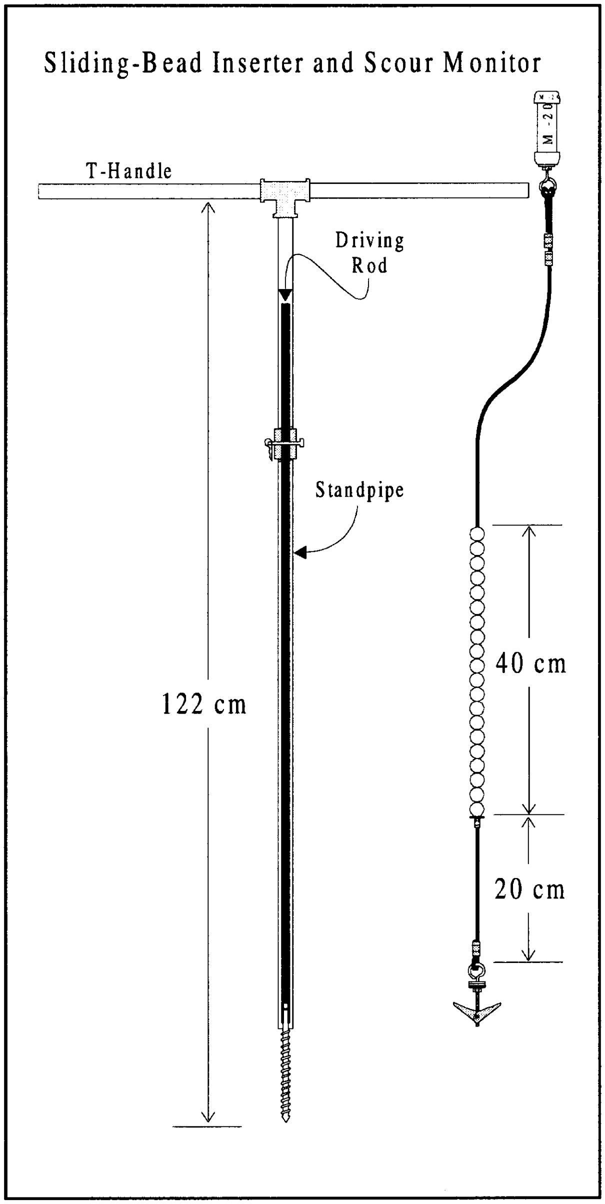


Figure 2. Diagram of a standard sliding-bead type scour monitor inserter and monitor.

3.2 Survey Materials

Survey materials are those items necessary for crews to locate and document the scour cross section location and access points, site conditions, and for recording field data. This list does not cover all possible materials. The basic materials include:

Survey Materials

- USGS 7.5 minute topographic map worksheet
- Aerial photograph(s)
- Road map
- Copy of Segment Identification Form 1.0 and Reference Point Survey Form 2.0
- Copy of Scour Forms 10.0, 10.1, 10.2, 10.3, 10.4, 10.5 (Appendix A)

Start by gathering and organizing site access information and working on logistical factors. Obtain directions and maps; contact landowners and secure permission to access property; acquire necessary permits and passes; and determine if the access roads are gated and get gate keys or make necessary arrangements with landowner to provide access. Next, begin the survey documentation by preparing and completing header and preliminary information on the field data forms. Refer to Appendix B for examples of completed field forms.

3.2.1 SCOUR "HEADER INFORMATION" Form 10.0

One Form 10.0 is completed for each survey segment. Use the Form 10.0 copy master to make a copy on regular white paper (Figure 3). Most header information can be copied directly from the segment's completed Form 1. The Water Resource Inventory Area number (*WRIA #*), unlisted tributary number (*Unlisted Trib*), segment number (*Segment #*), *Sub-Segment Code*,

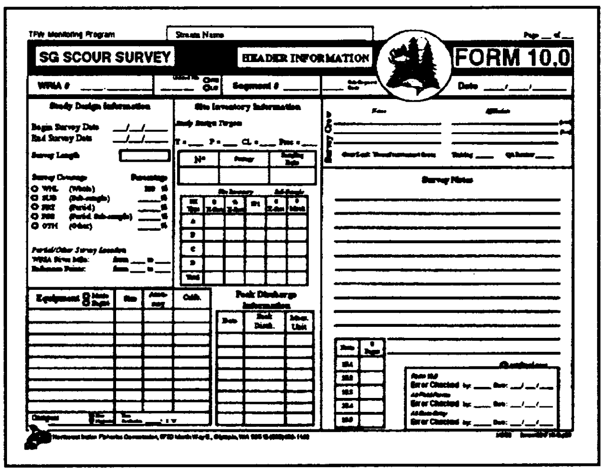

TFW Monitoring Program
Stream Name
SG SCOUR SURVEY
HEADER INFORMATION
FORM 10.0

Figure 3. Scour Survey "HEADER INFORMATION" Form 10.0.

and *Begin Survey Date* are key fields used to identify unique monitoring projects for the TFW-MP database. Refer to the Stream Segment Identification method manual for more information if needed.

Header Section

Stream Name: Record the WRIA-designated stream name. Use "Unnamed" where appropriate.

WRIA #: Record the six digit Water Resource Inventory Area (WRIA) number (00.0000).

Unlisted Trib: Only streams without assigned WRIA numbers require unlisted tributary numbers. For streams with WRIA numbers, fill this space with three zeros (000). For unlisted tributaries, record the previously identified three digit cooperator-designated unlisted tributary number (001 - 999) and mark the appropriate right or left bank (*RB/LB*) circle.

Segment #: Record the one to three digit segment number (1 - 999). Contact the TFW Monitoring Program for guidance on renumbering pre-segmented streams with segment numbers larger than three digits.

Sub-Segment Code: If the survey reach is a sub-segment, record the number or letter character sub-segment code (1 - 99 or a - zz). Record a "0" if not a sub-segment.

Date: Enter the date this form is being filled-out.

Survey Crew Section

Record the names and affiliations of the lead, recorder, and other field crew involved in data collection for the survey. Affiliations correspond to employers such as a tribe, government agency, industry, environmental group, consulting company, etc. Record the most recent year that the lead crew person received official TFW Monitoring Program on-site and/or annual workshop Scour Survey training, and/or a QA Review. Note any other relevant training or field experience in the *Survey Notes* section.

Study Design Information

Begin/End Survey Dates: Record the dates based on Form 10.4 corresponding to scour monitor installation and removal dates for that segment's Scour Survey. The *Begin Survey Date* is a key database field used to track and identify this specific survey.

Survey Length: Where the entire segment was surveyed, record the segment length in the *Study Design Information* section as documented during the site inventory procedure or from either the Reference Point Survey Form 2H or the Reference Point Survey database report. Where only portions of the segment were surveyed, record the total length of reach actually surveyed within the segment.

Survey Coverage: Fill-in the survey's coverage circle and percentage of the survey length that best applies to the survey. Mark *WHL* if the whole or entire segment or sub-segment was inventoried for sample collection (100%). Mark *PRT* if the survey was applied on a consecutive length of a partial segment/sub-segment. For example, where only the first 500 meters of a 2,000-meter-length segment will be inventoried for scour monitoring (25%). Mark *SUB* if the survey was applied using a random or systematic placement sub-sampling strategy. For example, where every other 100 meter interval reach will be inventoried for sample collection (50%). Mark *PSB* if a combination of PRT and SUB was applied. Mark *OTH* if your study design differs from the above and describe in the *Survey Notes* section.

Partial/Other Survey Location: These locations are associated with survey length lower and upper boundaries - that is, the boundaries encompassing the section of stream actually surveyed. Record the WRIA river/stream mile locations to the nearest tenth of a mile (0.0 - 9999.9) and reference point numbers (0 - 9999).

Survey Notes Section

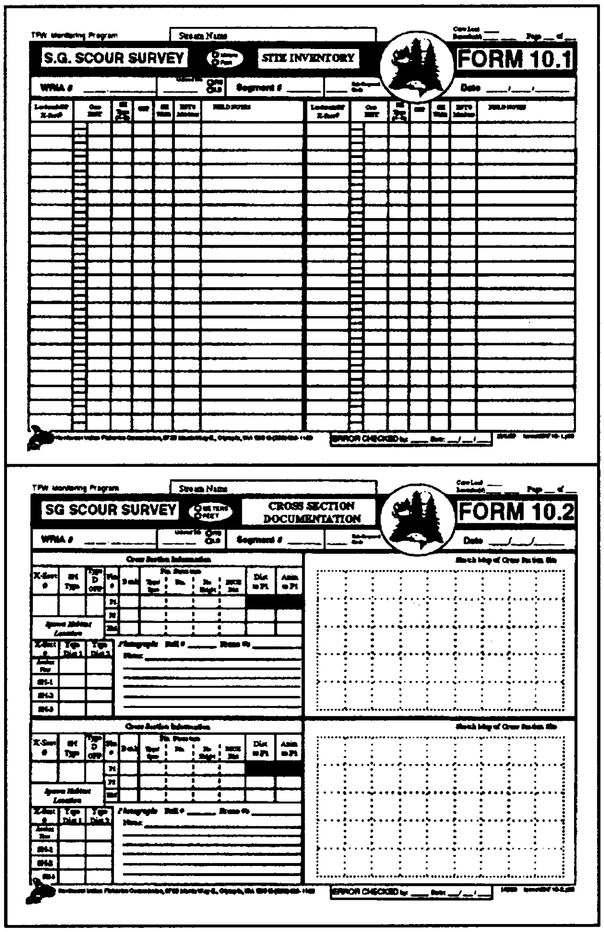
Record driving and access directions sufficient for a person unfamiliar with the area to locate the survey segment area. This section is also used to provided brief notes related to unique survey conditions and problems encountered. Note any additional parameters and modifications made to the Scour Survey procedure used to meet individual cooperator needs. Additional information can be included on the back of the form or on separate sheets of paper.

Site Inventory, Peak Discharge Information, and Error Checking Documentation Sections

This section will be covered in the Post-Survey Documentation section of the manual.

3.2.2 *Scour "SITE INVENTORY" Form 10.1*
Scour "CROSS SECTION DOCUMENTATION" Form 10.2
Scour "PEBBLE COUNT" Form 10.3
Scour "SCOUR AND BED ELEVATION DATA" Form 10.4
Scour "BED ELEVATION SURVEY" Form 10.5

Use the Form 10.1, 10.2, 10.3, 10.4 and 10.5 copy masters to make multiple copies on waterproof paper (Figure 4). Record the *Stream Name/WRIA #/Unlisted Trib/Segment #/Sub-Segment Code* as documented on Form 10.0. Record the initials of the crew lead, recorder, and other crew in the spaces provided in the upper right-hand corner. Leave the *Page __ of __* and *Date* spaces blank as they are recorded in the field during the survey.



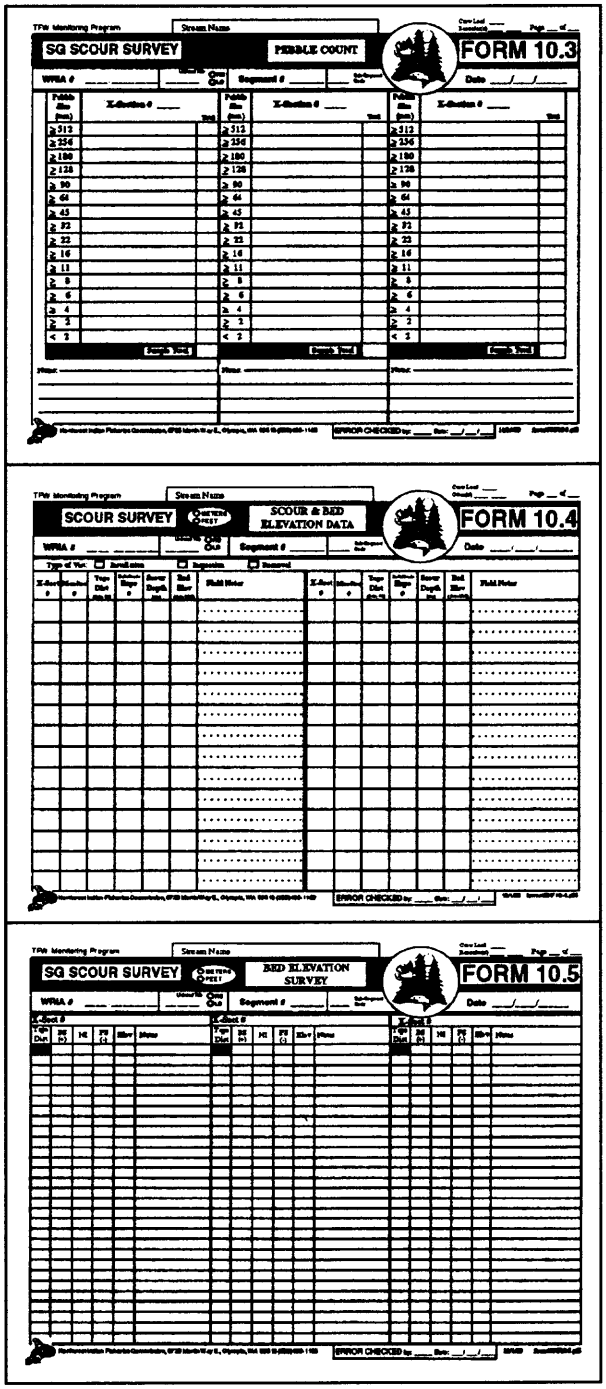


Figure 4. Scour Survey Forms 10.1, 10.2, 10.3, 10.4, and 10.5.

4. Spawning Gravel Scour Survey Method

This section provides the criteria and procedures for conducting the Scour Survey. It is organized in a sequential format to facilitate accurate and consistent application of the methods. This section can be copied for crews to take out into the field for referencing. Forms 10.1, 10.2, 10.3, 10.4 and 10.5 have been designed to record, organize, and track the information gathered using these methods.

The methods section is divided into seven parts: 1) site inventory and sample site selection procedures; 2) establishing cross sections; 3) measuring substrate particle size; 4) installing scour monitors; 5) surveying bed elevations; 6) periodic scour and bed elevation data collection; and 7) determining maximum stage and peak discharge. The Scour Survey procedure will be explained as if a crew were conducting the survey for the first time on one stream segment within a watershed. This procedure can be applied on a watershed level by systematically following the same methods segment by segment. As mentioned in the study design section, collection of data on peak discharge, substrate particle size, and bed elevation are optional, but recommended.

4.1 Site Inventory and Sample Site Selection Procedures

Depth of scour can vary spatially within a stream segment. The depth of scour at different points within one contiguous patch of spawning gravel can vary substantially, due to local differences in shear stress and the resistance of particles to movement. Scour depth tends to vary between the different types of channel units used for spawning due to differences in hydraulics and particle size. Variation in depth of scour between channel units can also occur due to their location along the length of the channel. In order to accurately characterize scour on a stream segment scale, it is essential that a sampling plan scale addresses these sources of variability. Unless spawning habitat is very limited, it usually is not feasible to sample all potential spawning areas within a segment. The sampling plan developed using this procedure will distribute sampling points between different channel units according to their relative abundance in the segment. Monitors will be systematically deployed along cross sections perpendicular to the channel to address variability within channel units. Cross sections will be placed systematically throughout the length of the channel to address longitudinal variation.

The sample site selection procedure begins with an inventory of potential sampling sites to determine the population of channel units with spawning habitat available for sampling. The next step is to determine the sample size, which is the number of monitors needed to characterize the segment. The final step is the selection of the sample sites (cross sections) where the monitors will be installed.

4.1.1 Site Inventory Procedure

A sample site inventory is conducted on each stream segment where monitoring planned and information is recorded on Form 10.1. The inventory procedure includes identification of potential sampling sites and documentation of information about the sites. The inventory always begins at the segment's downstream boundary unless logistical factors make this unsafe for the crews. The inventory is conducted upstream from that point to prevent missing sampling sites due to turbidity caused by crew disturbance of the stream bed. In situations where human structures (bridges, culverts, etc.) affect the hydraulic conditions of the channel, the general guideline is to avoid inventorying cross sections within 50 meters downstream or 25 meters upstream of the site or structure. A smaller buffer area is acceptable on small streams or where clear indicators are present that identify limits of channel influence.

Start by verifying the lower segment boundary using reference point tags or other documentation. Organize inventory equipment and check the hip chain for proper function. Zero out the counter. Next, identify the intersection of the segment boundary and the center of the bankfull channel. Tie the zero end of the hip chain line to a secure object at this point. There are three basic steps to the site inventory method. These are: 1) identify locations of reference points, landmarks, and spawning habitat areas; 2) identify cross section channel location, measure width, and estimate number of monitors; and 3) record field notes.

Step 1: Identify locations of reference points, landmarks, and spawning habitat areas.

General Procedure

Walk up the center of the bankfull channel and record reference point numbers (RP#0, RP#1, RP#2, etc.), landmark structures (bridge, culvert, ...), and cross section numbers in the *Landmark/RP X-Sect #* column as encountered. One cross section is assigned per spawning habitat area and numbered sequentially (1, 2, 3, ...) until the upstream end of the segment. Once calculated, the cross section cumulative distance is recorded in the larger box of the *Cum DIST* column to the nearest half meter. Record the spawning habitat type category in the *SH Type (A-D)* column as either A, B, C, or D (Table 1).

Table 1. Spawning habitat types and corresponding category codes.

Spawning Habitat Type	Spawning Habitat Category
Riffle	A
Pool Tailout	B
Pool (Other)	C
Obstruction Formed Patch	D

Spawning habitat identification criteria & technique

When a suitable spawning habitat area is encountered, stop to investigate and place the hip chain in a dry and secure area downstream of the site to allow greater flexibility to examine the area. To be included in the inventory, a suitable spawning habitat area must meet all of the following criteria (Table 2): 1) dominated by gravel substrate between 8 and 128 millimeters (b-axis); 2) have a contiguous surface area of at least 1 square meter; and 3) fall within one of four habitat types.

Table 2. Criteria for suitable spawning habitat areas to be included in the site inventory.

Spawning Habitat Identification Criteria
Dominant particle size range 8 – 128 mm Minimum 1 square meter surface area One of four spawning habitat types

Spawning habitat type areas are divided into one of the four following categories: riffle (A), pool tailout (B), other pool associated spawning habitat (C), and obstruction formed patch (D). Spawning habitat type is always a riffle unless proven otherwise. Pool habitat types must have a measurable residual depth of at least 0.01 meters. Pool tailouts, if present, are always along the downstream portion of a larger sized pool unit. Pool tailouts are formed by the deposition of gravels from the riffle crest (lower boundary) forward to the lip of the scour cup. If the elevation of the gravel decreases from the riffle crest to the deep parts of the pool in a uniform progression (no clear morphological break at the scour cup lip), and/or there is not the minimum surface area of spawning gravel within the tailout unit's boundary, a tailout is not present. Pool/other spawning habitat are found along the edges of the pool, but not in the scour cup sections of deeper water. The spawning habitat area includes both wetted and adjacent dry areas across the spawnable width of the bankfull channel.

In stream reaches greater than three percent, spawning habitat typically occurs in gravel deposition and storage areas (patches) associated with features such as individual boulders, large woody debris (LWD), or bedrock outcrops. In other words, the gravel patch would not be present if the obstruction were removed. If the spawning habitat category is an obstruction formed patch, it is also necessary to record the code number of the primary feature that caused it in the *OFP* column (Table 3).

Table 3. Types of obstructions forming gravel patches (from TFW Habitat Unit Survey, Pleus et al., 1999).

Code	Pool Forming Factor	Description
1	LWD Log(s)	one to nine dead trees or pieces; 10 cm diameter and 2 meter length; and roots no longer support weight of bole[1]
2	LWD Rootwad(s)	one to nine dead tree root systems; 20 cm diameter and 2 meter length; and roots no longer attached in original location[1]
3	LWD Jam	10 grouped qualifying LWD logs and rootwads[1]
4	Roots of standing tree(s) or stump(s)	live or dead standing trees and stumps
5	Boulder(s)	one or more particles of bed substrate larger than 26 cm (basketball size)
6	Bedrock	geologic protrusion of bedrock material
7	Channel bedform	wetted channel situations (not along the bank) where the channel bed shape itself creates pools, such as where two channels join or where pools form next to bars in the absence of other contributing factors
8	Resistant bank	erosion resist banks due to consolidated substrate materials (not bedrock) and/or general root mass from grasses and/or shrubs
9	Artificial bank	banks protected by human modification (rip-rap, concrete, bridge, culvert, etc.)
10	Beaver dam	the impoundment of flow caused by debris placed in the stream by beavers
11	Other/Unknown	factors contributing to pool formation that are not on the list or where the cause cannot be determined. Describe the factor in the field notes section

[1]Refer to the TFW Large Woody Debris Survey manual (Schuett-Hames et al., 1999) for detailed description.

Where spawning habitat boundaries are not clear, use the confidence/default technique. For example, the complex boundary between a downstream riffle and upstream pool is identified by marking the points where the observer loses 100 percent confidence they are in each habitat type based on hydraulic and geomorphic indicators. The markers identify the transitional area between the two habitat types where it becomes a guess as to the actual boundary location. The default boundary is marked as halfway between the confidence markers. Larger confidence areas are expected with less experienced observers and in more complex boundary situations.

Technique for Cumulative Distance Measurement

The cumulative distance for a cross section or other feature located at the lower segment boundary is "0." Each subsequent feature's cumulative distance reflects its total distance from the lower segment boundary as measured along the center line of the bankfull channel. Cumulative distance is measured to the upstream segment boundary. Using this system, the distance of a cross section from the nearest landmark or reference point can be calculated for backup relocation purposes. Anchor the hip chain line to objects along the channel to maintain proper position, especially when going around channel meanders. Pieces of branches pushed into the gravel are useful as anchor points. Follow the center line within the limits of personal safety and accessibility.

For each cross section number, several factors are collected before calculating its cumulative distance. When a suitable spawning habitat area is encountered, mark the stream location with temporary flagging and record the downstream edge cumulative distance in the small upper left-hand box in the *Cum DIST* column. When the upper edge of the spawning habitat area is encountered, mark its location with temporary flagging and record the upstream edge distance in the lower left-hand box. The cross section's cumulative distance is calculated by: a) subtracting the downstream from the upstream distance; b) dividing the result by two; and c) adding this result to the downstream distance. Record the result in the large *Cum DIST* box.

Difficult Situations

Unverified segment boundaries will require more time for investigation. Refer to the Stream Segment Identification manual for field verification parameters and methods. Conducting the scour site inventory from below to above the suspected segment boundaries can be helpful for verifying boundaries where notes and cumulative distances are recorded that identify changes in channel gradient, confinement, and flow. When boundaries have been verified, cross sections identified outside of the final boundary points are not included in the segment sample population.

In situations where a section of stream cannot be safely accessed, record the distance to the downstream point and break off the line. Estimate the distance to the upstream point where the site inventory can continue and either continue the distance measurement where left off or zero-out the hip chain. Marking the location on aerial photographs provides another level of documentation.

Step 2: Identify cross section channel location, measure width, and estimate number of monitors.

General Procedure

The cross section of a spawning habitat area is located at the midpoint of its channel length and oriented at a 90 degree angle to the centerline of the bankfull channel. Measure the width of the spawning habitat along the cross section and record it in the *SH Width* column to the nearest tenth (0.1) of a meter. One monitor is estimated per full meter of spawning habitat width and recorded in the *EST # Monitors* column. Write the cross section number on a piece of flagging and tie it to vegetation or other adjacent structure to field mark the cross section location.

Technique for Cross Section Identification, Width Measurement, and Estimating Number of Monitors

The length midpoint of the spawning habitat is located using the cross section's cumulative distance information. First, subtract the cross section cumulative distance (large box) from the upper spawning habitat distance measurement. Using a fiberglass tape to measure, walk downstream this distance (or upstream if at lower edge) and mark the location with a weighted flag.

Use a stadia rod to orient the cross section at a 90 degree angle to the centerline of the bankfull channel. Sight down the rod to select features on both banks and temporarily flag them. Next, measure the width of the spawning habitat within the bankfull channel across this line. Wetted or dry channel conditions do not affect the spawning habitat width. The number of estimated monitors is simply the width of the spawning habitat area in meters. For example, a width of 2.1 meters would be 2 monitors, 9.9 meters is 9 monitors, and 15.0 meters is 15 monitors. Where a cross section's spawning habitat area is split into multiple sections by non-spawning habitat areas, use the width of each section independently to determine the total number of monitors for that cross section (e.g., 2.4 [2] + 4.8 [4] + 3.9 [3] = 9 estimated monitors).

Step 3. Record Field Notes.

Field notes are not required, but can be very helpful for characterizing cross section sites and the segment in general. Suggested additional information includes identifying access locations, channel location of the spawning habitat, potential survey problems, and potential scour monitor insertion problems. This can help the installation and survey crew bring appropriate equipment and allow more time for an individual site.

At the end of the site inventory, mark the blank row after the last inventory record "END OF INVENTORY" for documentation. Upon return to the office, ensure that all field forms are complete and organized and check your work to verify that no errors exist in the documentation.

4.1.2 Determining Sample Size

Scour monitor insertion is often difficult and collection of scour data is time consuming, so it is often desirable to determine the minimum number of samples (monitors) necessary to adequately characterize scour within a stream segment. The procedure for determining the sample size identifies the minimum number of scour monitors required to meet the pre-determined project requirements for precision and confidence level, as determined in the Study Design section. The procedure involves a three step process including: 1) making a first approximation of sample size for use in additional calculations; 2) calculate the total sample population of estimated monitors (SP1); and 3) calculate the sample size using the N* formula.

Step 1: Make a first approximation of sample size.

Table 4 is used to make a first approximation of the sample size for use in the formula to calculate the minimum sample size. To use the table, it is necessary to know the project's requirements for precision and confidence level. It is also necessary to estimate *P*, the percentage of scour monitors in the segment where scour is expected to reach or exceed 15 centimeters (the top of egg pocket depth for large bodied salmonids). The choice of *P* values in is 10%, 25%, or 50%. A *P* value of 10% is selected when ten percent or less of the monitors are expected to scour to a depth of 15 cm. A *P* value of 25% is selected when scour to 15 cm is expected to be moderate (greater than 10, but less than or equal to 25 percent of the monitors). The value of *P* = 50% is used when higher levels of scour are expected or when information to estimate *P* is not available.

To use Table 4, find the desired precision level in the left hand column. Follow that row to the right until it intersects with the *P* value and confidence level selected. The resulting number is the first approximation of sample size.

Two Examples

A cooperator is developing a first-time survey and decides that a 90% level of confidence and a precision of +/-15% are required. There is no prior estimate of P for this stream segment so the worst case value of 50% is assumed. To make a first approximation of sample size from Table 4, they find the 15% relative precision in the left hand column, follow the row across to the right to the *P* = 50% columns, and then look in the 90% confidence level cell for a first approximation of 30 samples.

Another cooperator wants to document changes in a segment's scour pattern over a three-year period. They determine this requires annual surveys at a 95% level of confidence with a precision of +/-10%. The results of a previous scour survey in an adjacent similar segment showed a scour value (P) of 25%. Using this information, they make a first approximation of 72 samples.

Table 4. First approximation of sample size for various degrees of precision, confidence level, and expected P *value.*

Precision (±%)	**First Approximation of Scour Monitor Population** by Expected Percentage of Scour (*P*) and Confidence Level (CL)					
	P = 10%		*P* = 25%		*P* = 50%	
	95% CL	90% CL	95% CL	90% CL	95% CL	90% CL
±5.0%	138	98	288	204	384	272
±10.0%	35	25	72	51	96	68
±15.0%	15	11	32	23	43	30
±20.0%	9	6	18	13	24	17

Step 2: Calculate the total sample population of estimated monitors (SP1).

On a spreadsheet or sheet of paper make sample site selection worksheet with two columns, one labeled *X-Sect #* and the other labeled *SP1*. In the *X-Sect #* column, sequentially list each cross section number (1, 2, 3, ...) included in the study design. In the *SP1* column, transfer the estimated number of monitors from Form 10.1 for each cross section. At the bottom of the page, calculate the total number of estimated monitors to determine the segment's sample population. This worksheet will be used later so do not discard it. Refer to Appendix E for an example sample site selection spreadsheet.

Step 3: Calculate the sample size using the N* (N-star) formula.

Using the first approximation of sample size and the inventory sample population, the sample size is calculated by using the following formula:

$$N^* = \frac{FA}{1 + \frac{FA}{SP1}}$$

where: N* = sample size
FA = first approximation
SP1 = inventory sample population

For example, a first approximation of 96 was identified for a project objective having a *P* value of 50%, a confidence level of 95%, and a precision of +/- 10%. If the site inventory estimated that a maximum of 207 scour monitors could be placed in the segment, then the sample size is calculated as follows:

$$N^* = \frac{96}{1 + \frac{96}{207}} = \frac{96}{207} = 66$$

N* can also be identified using the Scour N* Matrix in Appendix D. To use the matrix, find the first approximation number in the left hand (FA) column. Follow that row to the right until it intersects with the closest inventory sample population number (SP1) in the top row. The resulting number is N*. Using the example above where *FA* = 96 and SP1 = 207 (closest SP1 = 200), N* using the matrix is 65. Using the formula is more accurate for calculating N*, but the rest of the selection process generally compensates for any differences.

4.1.3 Sample Site Selection Procedure

Scour monitors are installed on a series of cross sections distributed among the different habitat types based on their abundance within the stream segment. A systematic random sampling strategy is used to select the number and location of cross sections from which samples will be collected. There are three basic steps to sample site selection including: 1) select a strategy for placing monitors along cross sections; 2) systematically select/reject sampling cross sections to meet N*; and 3) record results on Forms 10.0 and 10.1.

Step 1: Select a strategy for placing monitors along cross sections.

The purpose of this procedure is to determine an appropriate distribution of monitors between cross sections. The target is to sample at least 25 percent of the cross sections in the segment. To achieve the target, two strategies for deploying monitors at different spacings along cross sections are evaluated.

The first strategy (SP1) is to deploy the monitors at one meter intervals, the same spacing used during the site inventory part of the survey. To determine if the SP1 strategy is appropriate, calculate the sampling percentage (N*/SP1). If the percentage is equal to or greater than 25% (0.250), then use the SP1 strategy and deploy the monitors at one meter intervals. If the SP1 sampling percentage is less than 25%, then test whether the alternative strategy (SP2) can be used.

The alternative strategy (SP2) reduces the number of monitors per cross section on wider stream systems where it is common to have cross sections with greater than four monitors. Therefore, the first test is whether the site inventory identified any cross sections with greater than four monitors. If not, then apply the SP1 strategy. To continue testing, convert the SP1 into the SP2 population using the criteria provided in Table 5.

Table 5. Table for converting the original sample population of estimated monitors (SP1) to the alternate sample population of monitors (SP2).

# SP1 Monitors	# SP2 Monitors
1	1
2	2
3	3
4 – 10	4
10 – 15	5
15 – 20	6
≥ 20	8

Use the sample site selection worksheet started above and add a new column labeled *SP2*. Next, calculate the total number of SP2 monitors. If SP2 is less than N*, then the SP1 strategy is used. If the SP2 total is greater than N*, then the SP2 strategy is used and its sampling percentage is calculated (N*/SP2).

Step 2: Systematically select/reject sampling cross sections to meet N*.

First, identify the sampling ratio using Table 6. Locate the appropriate row in the *N*/SP_* column based on the sampling percentage calculated above (N*/SP1 or N*/SP2), then find the sampling ratio in the adjacent *Sample Ratio* column. For example, a 20% sampling percentage means that you will sample one cross section out of every five, and a 75% sampling percentage means that you will sample three cross sections out of every four (or not sample every fourth). If a percent falls between two rows, select the closest or higher sampling percentage.

On the sample site selection worksheet, add four more columns labeled *A*, *B*, *C*, and *D* for each spawning habitat type. For each cross section, record the number of monitors based on the selected strategy (SP1 or SP2) for the appropriate spawning habitat type.

Table 6. Table for determining the sampling ratio for a given sampling percentage (N divided by either SP1 or SP2).*

N*/SP_	Sample Ratio
≥ 100%	All
99.00%	99/100
98.00%	49/50
97.06%	33/34
96.00%	24/25
95.00%	19/20
92.86%	13/14
92.31%	12/13
91.67%	11/12
90.91%	10/11
90.00%	9/10
88.89%	8/9
87.50%	7/8
85.71%	6/7
83.33%	5/6
80.00%	4/5
75.00%	3/4
66.67%	2/3
50.00%	1/2
33.33%	1/3
25.00%	1/4
20.00%	1/5
16.67%	1/6
14.29%	1/7
12.50%	1/8
11.11%	1/9
10.00%	1/10
9.09%	1/11
8.33%	1/12
7.69%	1/13
7.14%	1/14
6.67%	1/15
6.25%	1/16
5.88%	1/17
5.56%	1/18
5.26%	1/19
5.00%	1/20

N*/SP_	Sample Ratio
4.76%	1/21
4.55%	1/22
4.35%	1/23
4.17%	1/24
4.00%	1/25
3.85%	1/26
3.70%	1/27
3.57%	1/28
3.45%	1/29
3.33%	1/30
3.23%	1/31
3.13%	1/32
3.03%	1/33
2.94%	1/34
2.86%	1/35
2.78%	1/36
2.70%	1/37
2.63%	1/38
2.56%	1/39
2.50%	1/40
2.44%	1/41
2.38%	1/42
2.33%	1/43
2.27%	1/44
2.22%	1/45
2.17%	1/46
2.13%	1/47
2.08%	1/48
2.04%	1/49
2.00%	1/50
1.00%	1/100

Select a random starting number per spawning habitat type based on the denominator (nominator/*denominator*) of the sampling ratio fraction. Using the examples above, a 1/5 ratio means selecting a random number between 1 and 5, and a 3/4 ratio means selecting a random number between 1 and 4.

In column A, find the starting cross section based on the random number. Depending upon the procedure used, this cross section is either selected or rejected for sampling. For example, a random starting number of 3 means that the third type-A cross section from the beginning of the survey is selected or rejected.

Next, select or reject every n^{th} cross section based on the denominator number. Continuing the examples, a 1/5 ratio means every subsequent 5th type-A cross section is selected, or a 3/4 ratio means every subsequent 4th type-A cross section is rejected. Repeat the cross section selection process for the remaining columns using their individual random starting numbers.

A minimum of two cross sections per spawning habitat category are required, except in situations where the number of cross sections for a given type represents less than 10 percent of the total number of inventoried cross sections. Randomly select extra cross sections from those rejected on the worksheet by spawning habitat type as necessary to meet the criteria.

Finally, calculate the total number of monitors per cross section remaining and compare it to N*. If the total is equal to or greater than N*, the selection process is finished. If the total is less than N*, additional cross sections must be randomly selected from the rejected population until N* is reached or exceeded.

Step 3: Record results on Forms 10.0 and 10.1.

Circle the selected cross section numbers on Form 10.1 for field reference in identifying sampling cross sections. On Form 10.0 in the *Site Inventory* section, record: a) the correlation factor (*CF*), estimated percent scour (*P*), the desired precision (*Prec*), the desired confidence level (*CL*); b) the calculated N*, whether the SP1 or SP2 strategy was used, and the sampling ratio; and c) the number of cross sections (*# X-Sect*), percent cross sections to total (*% X-Sect*), and SP1 population by spawning habitat type category. The subsample information is filled out after installation has been completed.

4.2 Establishing Cross Sections

Once the inventory and cross section selection procedures have been completed, field work can begin. Use Form 10.2 to record cross section installation information. This information will help to document cross section conditions at the time of installation, to relocate the cross section for future visits, and to re-establishing the cross section if one end-point is lost. Each form is set up for recording information about two cross sections. Bring a copy of the completed Form 10.1 to identify the selected cross sections and use the descriptions and location information to find them in the field.

There are four basic steps to establishing cross sections including: 1) install the cross section; 2) record cross section pin location information; 3) record cross section and spawning habitat width information; and 4) complete sketch map of cross section site.

Step 1: Install the cross section.

The first step is to establish a cross section at each of the spawning gravel areas chosen during the site selection process. Once the cross section has been relocated, the next step is to reestablish the orientation across the spawning gravel area. Double-check to make sure that the cross section is located mid-way between the upper and lower boundary of the spawning habitat area.

Orient the cross section perpendicular to the centerline of the bankfull channel and mark the line with flagging where it intersects each bank. This is the best orientation for documenting variation in scour across the channel. Starting with the zero end of the tape at the left bank for consistency (determined facing downstream), stretch the fiberglass tape across the channel so that it follows the flagged cross section line.

While keeping the tape along this line, walk away from the channel to find and establish stable cross section end points. Locate the cross section end points well back from the edge of the bankfull channel to avoid loss or disturbance during flood events. End points are commonly monumented using a fence steel post, rebar stake, or nail in a tree well. If using rebar, a variety of lengths (½ inch diameter) may be required from 0.2 to 1.0 meters long and topped with colored plastic caps obtained from survey supply houses. Attach a marked identification tag (segment, cross section, and pin number) to each end point structure for positive re-identification during later inspection and removal visits. When end points are secure, stretch a fiberglass tape between them with the zero end always at the left-bank side of the stream and temporarily fasten with spring clips. The left bank end point (zero end) is called Pin 1 and the other end point across the channel is called Pin 2.

Step 2: Record cross section pin location information.

Begin recording cross section information on Form 10.2. Make sure all header information is complete including the unit of measure (meters/feet). Record the date the cross section is being established. Record the cross section number (*X-Sect #* column), the spawning habitat type (*SH Type (A-D)* column), and if spawning habitat type D - the primary obstruction formed patch factor (*Type D OFP* column) from Form 10.1.

Next record information that documents the location and type of each anchor pin to help relocate them in the future. Note the bank (*Bank* column) each pin is located on as either right (R) or left (L). Record information regarding the pin structure including the type of structure (e.g. tree, rebar, capped rebar, etc. in the *Type/ Spec* column), the diameter of the tree/rebar/etc. (*Dia* column), and the height of the pin above the ground (nail in tree/rebar top/etc. in the *Pin Height* column), and the distance of the pin from the nearest bankfull channel edge (*BFCE Dist* column). Next, record the total cross section tape distance between pin 1 and pin 2 (*Dist to P1* column; *Pin #2* row only), then take and record a compass bearing (azimuth) from pin 2 along the tape towards pin 1 (*Azim to P1* column; *Pin #2* row only: note "T" for true or "M" for magnetic beside the reading).

Step 3: Record cross section and spawning habitat width information.

Examine the cross section and determine the extent and boundaries of suitable dry and wet spawning gravel using the definitions and procedures previously provided in the site inventory spawning habitat identification criteria section. Include all areas under the cross section that you estimate will be submerged during the spawning season. This avoids biasing the sample sites towards the thalweg or deepest parts of the channel. Tie flagging on the cross section tape to identify the edges of a spawning habitat area.

In the Spawning Habitat Location section on Form 10.2, record the cross section number (*X-Sect #* box), the tape readings corresponding to the cross section anchor pins and to each spawning habitat area edge on separate rows. If only one spawning habitat area is encountered, only the *SH-1* row is filled out. The *Tape Dist. 1* column is for the edge closest to the pin 1 side and the *Tape Dist. 2* column is for the edge closest to the pin 2 side.

Step 4: Complete sketch map of cross section site.

Finally, draw an overhead (plan view) sketch map of each cross section showing the location of the tape ends, adjacent significant trees/shrubs and species, the orientation of the cross section to the channel bed, locations of spawning habitat areas, and other landmarks, trails, and notable channel features (Figure 5). Use the grid marks to maintain relative scale.

4.3 Measuring Substrate Particle Size (Pebble Counts)

Once the cross section has been installed and documented, the next step is to conduct a pebble count to document the spawning habitat surface substrate size composition. This should be done before channel gravel is disturbed due to installing monitors. Since particle size affects the energy necessary to mobilize gravel, this information will be useful when interpreting differences in the relative magnitude and frequency of scour between cross sections and segments. The *PEBBLE COUNT* Form 10.3 is used to record pebble count data for up to three cross sections per page.

A pebble count involves the random collection and measurement of a minimum 100 substrate particles on the surface of the stream bed (Wolman, 1954; Harrelson et al., 1994). Make sure all header information is complete. Record the date the pebble count is being conducted. Record the cross section number (*X-Section# ___* blank) at the top of one pebble count box.

To collect the particles, start at the spawning habitat edge closest to the zero end of the cross section in a

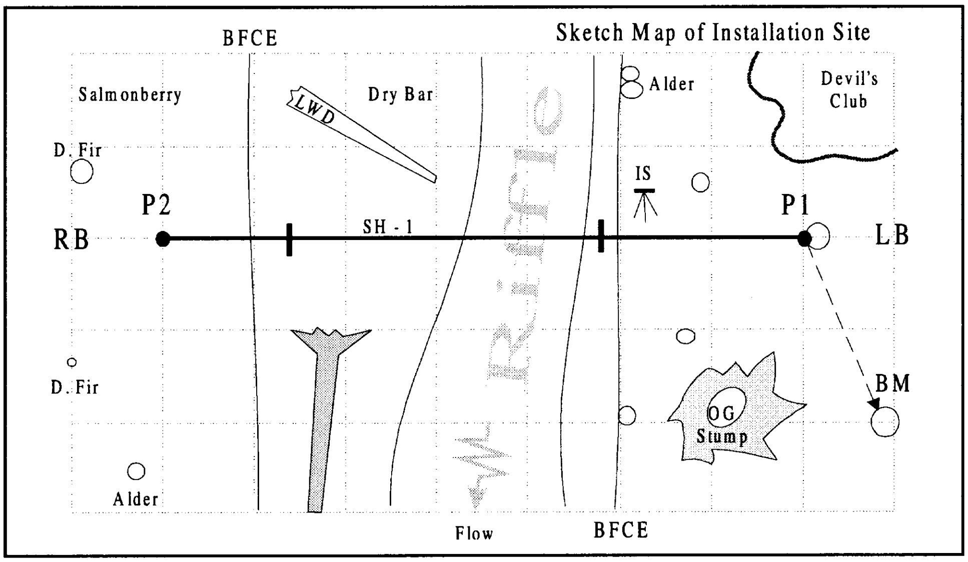


Figure 5. Detail of installation site sketch map from Form 10.2.

place that is within 1.0 meter of the tape. Take one step, avert your gaze and pick up the first particle touched with a finger or pencil at the toe of your boot. Measure the particle along its b-axis with a caliper or ruler to the nearest millimeter (Figure 6). To determine the b-axis, think of each particle as a three dimensional object such as a brick with a long side, a short side, and an intermediate side. The b-axis is the intermediate dimension that determines whether a particle would pass through a sieve with square mesh of that size. Using this measurement, find the appropriate size class row and make a tally mark. One tally mark equals one pebble counted.

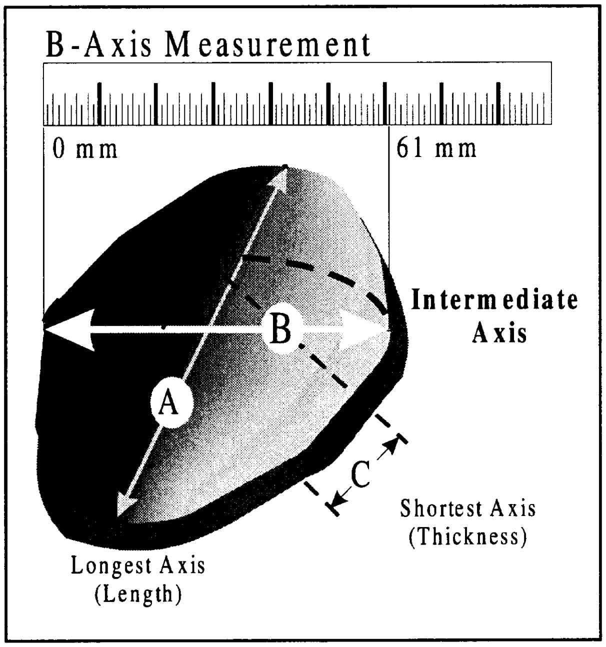


Figure 6. Particle size is determined by measuring across its b-axis using a caliper or ruler.

For example, a particle with a b-axis of 41 mm would have one tally mark placed on the *≥ 32* row. This is because 41 is greater than 32, but less than 45 millimeters. Recorders should verbally repeat each measurement back to the caller for error checking before placing the tally mark.

Continue the pebble count step by step using a zigzag strategy along the spawning habitat area portion(s) of the cross section. Stay within one meter on either side of the tape. Stop after each step, measure the particle and put a tally mark on the row for the appropriate size class. Particles too big to move are measured in place along the smaller of their two exposed axes. Organic matter such as large woody debris is not included in the pebble count. If a sampling point is lightly covered with organic debris such as leaves or twigs, gently remove them without disturbing the gravel underneath. If a step lands on a non-spawning habitat area between two suitable areas, disregard those pebbles and continue walking until a step falls into the next suitable area. Along short cross sections, take as many pebble samples as possible without causing significant disturbance or counting particles exposed below the surface.

When the recorder suspects that the number of tally marks is close to 100, stop and identify the number of remaining pebbles necessary to reach 100. Another technique is to use a tally counter and keep track as each pebble is measured. When at least 100 pebbles have been tallied (over 100 is acceptable), count the tally marks for each size class and record the total number in the *Total* column. Add the size class totals together and record it in the *Sample Total* box. Record any notes related to count accuracy or unusual conditions.

4.4 Installing Scour Monitors

After collecting substrate information, proceed with installation of scour monitors using the appropriate equipment and procedure for the type of monitor being used. Scour monitor installation information is recorded on the *SCOUR & BED ELEVATION DATA* Form 10.4. Make sure all header information is complete. Record the date the installation is being conducted. On the *Type of Visit* row, mark the *Installation* box.

4.4.1 Identifying Monitor Installation Points Along the Cross Section

Identification of monitor installation points along the cross section depends upon whether the SP1 or SP2 strategy is being used. If SP1, then monitors are installed every 1 meter along the cross section starting at a half meter from the beginning edge of the spawning habitat area (Figure 7). The cross section tape can be used to identify positions.

If the SP2 strategy is being used, then monitors are installed in the center of evenly spaced cells based on spawning habitat width (SHW) and a minimum 1 meter distance from each other. Stretch a second fiberglass tape across the spawning habitat area along the cross section. Disregard small non-sample features (< 1 m^2) within the sampling area. Secure the tape at both ends of the sampling area with a chaining pin or stick and a spring clip. The monitor insertion points along the tape are then calculated using the multiplication factors listed in Table 7.

To use the table, find the row where the measured spawning habitat width (SHW) fits. If the SHW is less than (<) 2 meters, multiplying the SHW by 0.5 to identify the one sample point along the tape. If the SHW is equal to or greater than (≥) 2 and < 3 meters, multiplying the SHW by 0.25 and again by 0.75 to identify the two sample points, and so on. Mark the sample point locations with weighted flags.

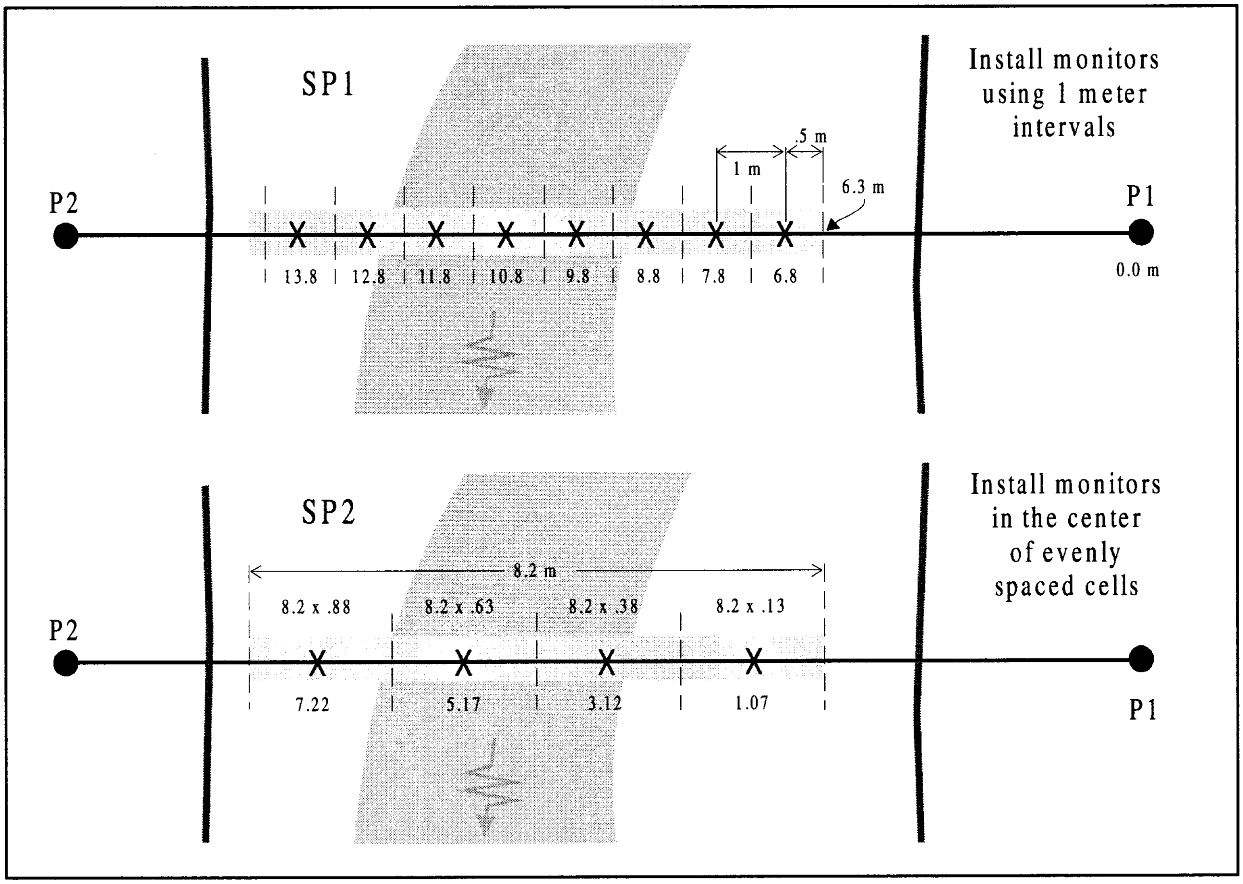


Figure 7. Technique for installing scour monitors along a cross section using either the SP1 or SP2 strategy.

Table 7. Multiplication factors for calculating SP2 monitor sampling points along a cross section.

SHW (m)	**# Monitors**	**Multiply SHW by:**
< 2	1	0.50
≥ 2 - 3	2	0.25 and 0.75
≥ 3 - 4	3	0.17, 0.50, and 0.83
≥ 4 - 10	4	0.13, 0.38, 0.63, and 0.88
≥ 10 - 15	5	0.10, 0.30, 0.50, 0.70, and 0.90
≥ 15 - 20	6	0.08, 0.25, 0.42, 0.58, 0.75, and 0.92
≥ 20	8	0.06, 0.19, 0.31, 0.44, 0.56, 0.69, 0.81, and 0.94

For example, a SHW of 8.2 meters would fit on the ≥ 4 - 10 meter row, require 4 monitors, and the calculated sampling points would be at tape distances 1.07 (8.2 x 0.13), 3.12 (8.2 x 0.38), 5.17 (8.2 x 0.63), and 7.22 (8.2 x 0.83). The tape, chaining pins and spring clips are then removed.

Both systems identify the starting points for taking samples. Occasionally, an interval will fall on an obstruction such as large woody debris or a large particle of gravel within a patch of spawning habitat. In these situations, the placement of the monitor can be adjusted towards the nearest point where a monitor can be successfully inserted, but not where the distance from the last monitor is less than 1 meter.

4.4.2 General Scour Monitor Installation Procedures and Criteria

Instructions are provided for installation of both golf ball and sliding-bead type scour monitors. For each monitor inserted, record the cross section number in the *X-Sect #* column, the monitor number in the *Monitor #* column, the tape distance in the *Tape Dist from P1* column, and the number of balls or beads exposed in the *Balls/Beads Expo #* column. At installation, scour depth is always recorded as "0" even if there are exposed balls/beads. Tracking of balls/beads exposed by factors other than scour is critical throughout the study period so that they are not included in subsequent scour depth calculations. Instructions for collecting data on bed elevation (*Bed Elev* column) are provided in the surveying bed elevations section. Record any information about installation limitations, adjustments, or channel conditions in the *Field Notes* column.

Technique for Installation of Perforated Plastic Golf Ball Monitors

Golf ball monitors are inserted straight into the channel bed through a standpipe. The standpipe is inserted into the stream bed by means of a drive pipe and driving rod that fit inside the standpipe. The drive pipe has a tapered solid tip and flange at top that carries the standpipe into the stream bed with force delivered by the driving rod (Figure 8). The flanges of the two pipes are held together with 2 C-clamps to help distribute the stress on the inserter while pounding. The standpipe is marked on the outside with a permanent pen that identifies the depth required to position the top golf ball just below the surface gravel of the channel bed (approx. 70 cm from end of standpipe).

Assemble the inserter and position at the first sampling point. Wear safety glasses, gloves, and hearing protection. Adjust the inserter so that it is plumb (vertically level) and begin driving the inserter into the gravel. This is a physically demanding task as the driving rod must be lifted and rammed into the inserter repeatedly. Switching crews is encouraged to keep the effort fresh and preventing strain. Adjust the angle of insertion to maintain a plumb line.

When the standpipe has been inserted to the proper depth, the driving rod and pipe are removed . This creates a well inside the standpipe into which the monitor will be lowered anchor first. The objective is to keep all the balls stacked one on top of each other with the bottom ball resting on a cable stop. Start by attaching a small alligator clamp on the monitor cable just above the top ball to temporarily hold it in place. This prevents balls from sliding up during insertion. Tying a piece of flagging or string onto the clip will prevent loss if it is dropped or accidentally disengages during this process. With one hand, secure the tip of the

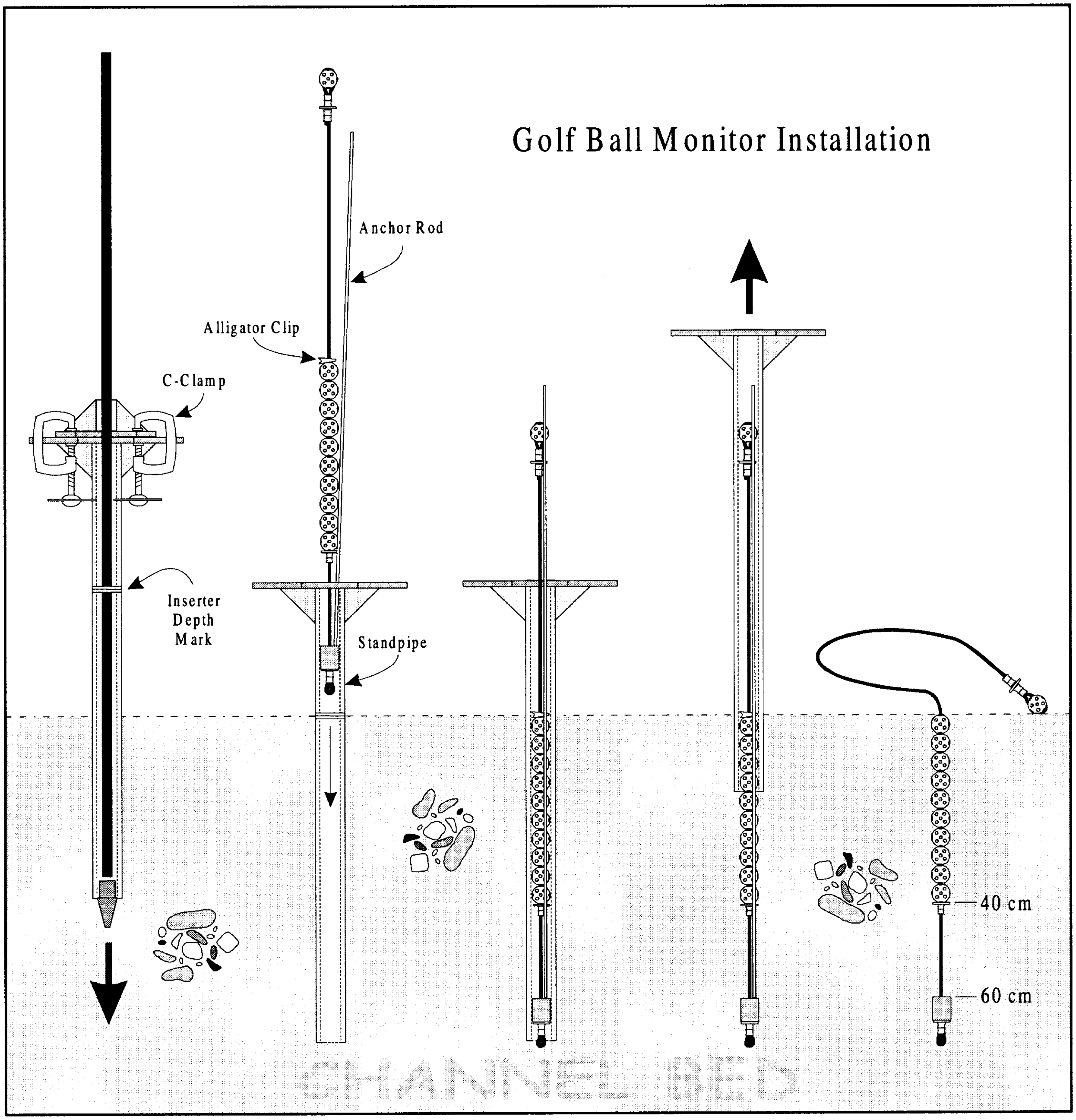


Figure 8. Cross section view of golf ball monitor installation procedure.

anchoring rod to the monitor's anchor. When the rod is secure, use the other hand and pull the cable to stretch it taut until both hands are at the tops of each device. Slide both the monitor and anchor rod into the standpipe and lower until the anchor touches gravel at the bottom of the well.

While one crew keeps the anchor pinned and cable taut, another crew carefully removes the standpipe straight up out of the gravel by rotating the standpipe in a washing machine fashion while applying upward pressure. If this does not work, try tapping the sides of the standpipe with a two-pound hammer or large rock between efforts to raise it. As the standpipe is removed, gravel will automatically be filling in the well around the monitor and locking it in place in the channel bed. Keep pressure on the anchor and cable until the standpipe encases their tops, then let go. Once the standpipe has been fully removed, the anchor rod and alligator clip are carefully removed.

Finally, inspect the monitor to ensure that it has been inserted properly in the channel bed. The top of the upper ball must be just below the surface of the general stream bed and be held by surrounding gravel. Where there is a depression in the gravel formed by insufficient filling of the standpipe well, gravel may be added by hand to make level and properly trap the top golf ball. If a gravel mound that rises above the general bed level is required to hold the top ball, the monitor should be removed and reinstalled to the proper level. If the top ball lays too far down into the gravel, grasp the monitor cable and carefully pull up on the monitor until the top ball reaches the proper level. The cable should extend above the stream bed with the float and tag identification information visible at the end of the cable.

Upon initial insertion, the substrate surrounding the monitor is often loose. Over time, fine sediments and the general substrate will re-intrude and solidify the anchor. If a monitor requires re-installation, it can be pulled straight up by hand or by using the driving rod as a lever. With the rod held at an angle over the monitor, wrap the bare cable around the driving rod shaft about ½ to 2/3 up its length. Rest one end of the rod on the stream bed and lift up on the other end.

Technique for Installation of Sliding-Bead Monitors

Sliding bead monitors are also inserted straight into the channel bed, but through a smaller standpipe. The standpipe is augered into the stream bed by means of a three-piece boring tool. The boring tool consists of the standpipe, a solid driving rod with masonry bit tip that fits inside the standpipe, and a T-handle that covers the top of the drive pipe and is attached to the standpipe by a pipe coupling. The standpipe is marked on the outside with a permanent pen that identifies the depth required to position the top bead just below the surface of the channel bed (approx. 70 cm from end of standpipe).

Assemble the inserter and position at the sampling point. Adjust the inserter so that it is plumb (vertically level) and begin augering (drilling) the inserter into the gravel. Apply downward pressure while augering and adjust the angle of insertion as needed to maintain a plumb line.

When the standpipe has been inserted to the proper depth, unscrew the T-handle from the coupling with the two pipe wrenches. Remove the coupling pin holding the driving rod to the standpipe. While holding the standpipe to keep it at the proper depth, slowly twist and pull the driving rod out the top. This creates a well inside the standpipe into which the monitor will be lowered anchor first. The objective is to keep all the beads stacked one on top of each other with the bottom bead resting on a cable stop. Start by attaching a small alligator clamp on the monitor cable just above the top bead to temporarily hold it in place. This prevents it from sliding up during insertion. Tying a piece of flagging or string onto the clip will prevent loss if it is dropped or accidentally disengages during this process. With one hand, secure the tip of the anchoring rod to the monitor's anchor. When the rod is secure, use the other hand and pull the cable to stretch it taut until both hands are at the tops of each device. Slide both the monitor and anchor rod into the standpipe and lower until the anchor touches gravel at the bottom of the well.

While one crew keeps the anchor pinned and cable taut, another crew carefully removes the standpipe straight up out of the gravel by rotating the standpipe in a washing machine fashion while applying upward pressure. If this does not work, try tapping the sides of the standpipe with a two-pound hammer or large rock between efforts to raise it. As the standpipe is removed, gravel will automatically be filling in the well around the monitor and locking it in place in the channel bed. Keep pressure on the anchor and cable until the standpipe encases their tops, then let go. Once the standpipe has been fully removed, the anchor rod and alligator clip are carefully removed.

Inspect the monitor to ensure that it has been inserted properly in the channel bed. The top of the upper bead must be just below the surface of the general stream bed and be held by surrounding gravel. Where there is a depression in the gravel formed by insufficient filling of the standpipe well, gravel may be added by hand to make level and properly trap the top bead. If a gravel mound that rises above the general bed level is required to hold the top bead, the monitor should be removed and reinstalled to the proper level. If the top bead lays too far down into the gravel, grasp the monitor cable and carefully pull up on the monitor until the top bead reaches the proper level.

Upon initial insertion, the substrate surrounding the monitor is often loose. Over time, fine sediments and the general substrate will re-intrude and solidify the anchor. If a monitor requires re-installation, it can be pulled straight up by hand or by using the driving rod as a lever. With the rod held at an angle over the monitor, wrap the bare cable around the driving rod shaft about ½ to 2/3 up its length. Rest one end of the rod on the stream bed and lift up on the other end.

Finally, attach the PVC float by threading the cable's end loop through the float's eye bolt, the float back through the loop, and then pulling on the cable to cinch the loop securely around the eye bolt. When finished, the cable should extend above the stream bed with the float and tag identification information visible at the end of the cable.

4.4.3 Difficult Situations

Both the perforated plastic golf ball and sliding-bead monitors are designed have their anchors buried rather deep in the stream bed to prevent them from being washed away and lost if deep scour occurs. In streams with large substrate (> 50 cm diameter), it may be difficult to drive the inserter deep enough to fully insert the entire monitor before hitting a large rock or other obstacle. If this situation is infrequent, it is acceptable to note the number of exposed balls/beads when filling out the installation information on Form 10.4. If this is a frequent occurrence, it is better to use shorter monitors rather than having to track multiple monitors with non-scour exposed balls/beads, or to bypass a significant number of monitor locations.

Shorter versions of both the sliding-bead and golf ball monitors can be constructed for these situations, or the plastic monitor can be shortened to 40 cm in the field by sliding the wooden dowel anchor up against the bottom ball/bead and tying the excess cable below the anchor in a tight knot (Joanne Schuett-Hames, Washington Department of Ecology; personal communication). It is important to document modified monitors as they are installed in the *Field Notes* for accurate scour data collection, especially when a monitor has been completely scoured out. In any case, a minimum of 15 cm of balls or beads should be buried below the surface of the stream bed in order to detect scour to the top of egg pocket depth for large bodied salmonids.

4.5 Surveying Bed Elevations

Scour monitors document maximum depth of scour, however they do not document changes in bed elevation and cross section profile due to the combined action of scour and fill. Information on bed elevation can assist in interpreting depth of scour data and provide a greater understanding of channel processes that potentially affect incubation success. The primary field form used in this section is Form 10.5. However, some information gathered during this procedure will also be recorded on Forms 10.2 and 10.4 as noted.

This section briefly describes procedures for surveying elevations, assuming that observers are familiar with basic surveying procedures and the operation of surveying instruments. For those needing more comprehensive instruction, refer to Harrelson et al. (1994) Chapter 5 "Surveying Basics" and Chapter 6 "Measuring Channel Cross section." There are five basic steps to surveying bed elevations including: 1) establish a reference benchmark; 2) select an instrument station; 3) survey the benchmark and establish height of instrument; 4) survey the cross section; and 5) close the cross section survey.

Step 1: Establish a reference benchmark.

The first step in surveying bed elevations along a cross section is to establish a reference benchmark. The purpose of the benchmark is to provide a stable elevation reference from which changes in bed elevation can be calculated. It is not necessary to know the actual elevation of the benchmark, it merely serves as a consistent reference point. Benchmark information and location are added to the *CROSS SECTION DOCUMENTATION* Form 10.2 in the "X-Section Information" and "Sketch Map of Cross Section Site" sections to assist in relocation during subsequent surveys. Do not underestimate how rapidly the exact benchmark location can be forgotten or confused due to changes in vegetation, leaf fall, etc.

Benchmarks can be constructed by pounding a metal post or rebar stake into the ground, by pounding a large spike part way into the base of a tree or stump (check with landowner), or by using a marked spot on a large boulder or bedrock outcrop. The benchmark should be located well back from the edge of the channel in an inconspicuous location protected from human and natural disturbance. Some surveyors establish two benchmarks so future surveys can be successfully completed if one benchmark is disturbed or destroyed. This is especially important if a tree is used, in case the tree falls down. Ideally, the benchmark should be visible from the spot where the instrument will be stationed during the cross section survey and should be lower than the elevation of the instrument. If several cross sections are located in close proximity, it may be possible to use the same benchmark.

Step 2: Select an instrument station.

After the benchmark has been installed at the cross section, the next step is to set up and level your instrument at a selected instrument station. Add the station's location to the sketch map on Form 10.2. The ideal instrument station provides an unobstructed view of the entire cross section and the benchmark. The station must be situated so the elevation of the instrument is higher than any point to be surveyed, including the benchmark. Usually these conditions are met by situating the instrument station on the edge of a terrace adjacent to the channel where the cross section is located. Visibility can be improved by carefully trimming back leaves and brush with a machete or pruners. If the benchmark cannot be seen from the instrument station near the cross section, or is higher than the surveying level, it will be necessary to set the instrument up near the benchmark, take the backsight and then use the turning point procedure to move the instrument to a suitable location near the cross section (described in Step 4).

Step 3: Survey the benchmark and establish height of instrument (HI).

Survey elevation information is recorded on Form 10.5. The first reading is a backsight to the benchmark. This is taken by having the rod-holder place the bottom of the stadia rod on top of the benchmark (e.g., nail, rebar cap, post, etc.). The rod should be held steady and vertically level (plumb) with the numbers facing the instrument. The instrument-reader swings the level so that the cross hairs intersect the stadia rod and then focuses on its measurement scale. Record the elevation reading on the first row in the backsight (*BS*) column and round to the nearest 0.01 meter. If known, record the actual benchmark elevation on the same row in the elevation (*Elev*) column. Since the actual elevation of the benchmark is typically unknown, an arbitrary elevation of 30 meters (100 feet) is assigned. Next, add the backsight reading to the benchmark elevation to calculate the height of the instrument and recorded this number in the height of instrument (*HI*) column on the same row (BS + Elev [benchmark] = HI). Record the word "Benchmark" in the *Notes* column. The height of instrument remains constant for all bed elevations unless a turning point is established.

Step 4: Survey the cross section.

The easiest option for collecting information on bed elevation changes is to survey the stream bed elevation only at the monitor locations. A more complete picture of bed elevation change can be obtained by conducting a complete cross section profile that documents breaks in slope and other channel features including the monitor locations.

If bed elevation readings are only to be taken at the monitor locations, the rod-holder walks along the cross section, placing the rod on the surface of the channel bed at the top of each successive monitor. The rod-holder calls out the distance along the tape and the monitor number. The distance along the tape is recorded in the tape distance (*Tape Dist*) column, and the monitor number is recorded in the *Notes* column. Then the instrument-reader reads the elevation off the stadia rod and records the reading in the foresight (FS) column. It may be necessary to extend the rod in order to take readings at low points. Foresights are subtracted from the height of instrument to determine the elevation at each point (HI - FS = Elev). Bed elevations for each monitor are transferred to the appropriate Form 10.4 for that visit.

If a complete cross section profile is to be surveyed, the rod-holder should begin by taking ground elevation readings at the Pin 1 endpoint and proceed along the cross section taking elevations readings at each break in slope in addition to the monitor locations to the P2 end point. Elevations are also taken at features along the cross section such as bankfull channel and wetted channel edges. Record each elevation reading in the foresight column on separate rows including the distance along the tape and a description of the location.

Turning Point Technique

Turning points are required for the first and last cross sections for quality control and to help detect instrument errors. Otherwise, a turning point is used to move the instrument to a second station (usually located on the other side of the channel) in situations where the entire cross section can not be seen from the first instrument station. Usually, the rod holder stays at the last point where a bed elevation was taken from the last station and the instrument is moved to a new station that can see this point, the remaining cross section, and where the elevation of the instrument is higher than any point to be surveyed, including the benchmark.

If this is not possible, the rod holder must first move to a point that will be visible from the new station location. From the current station, an elevation is taken to the rod holder and recorded in the *FS* column with the turning point number recorded in the *Notes* column. Subtract this foresight from the height of instrument to calculate the elevation of the turning point (HI - FS = Elev [TP]). Keep the rod at the turning point while the instrument is moved and set up at the new station.

When the new instrument station has been established, take a reading on the turning point and record it in the *BS* column on the next row along with the turning point number. Add this backsight to the turning point elevation to calculate the new height of instrument and record it in the height of instrument column with the number of the new instrument station (BS + Elev [TP] = new HI). You are now ready to continue taking the foresight readings along the cross section. The same turning point procedure is used to move the instrument to other stations as needed.

Step 5: Close the cross section survey.

Close the survey by taking a final reading back to the initial benchmark and recording it in the foresight (*FS*) column. If a turning point was used with an instrument height less than the benchmark elevation, a new turning point must be added to bring the instrument to a higher elevation before closing. When the foresight reading on the benchmark is subtracted from the current height of instrument, the elevation should equal the initial benchmark elevation (HI - FS = Elev [initial benchmark]). If the foresight reading is a negative, it is added (two negatives equals a positive) to the current benchmark elevation. A significant deviation (greater than 0.02 meters) indicates that an error has been introduced into the survey. Possible sources of error include disturbance of the instrument, instrument malfunction, rounding errors or miscalculations, and errors made while reading the instrument or recording information. First check the level's bubble to see if the instrument has been disturbed. If not, then check your records and calculations to see if the error can be identified and corrected. Sometimes, re-shooting elevations back along the cross section can identify where the error started. If this does not find the error, change observers and re-shoot the entire cross section. If the error remains, the survey must be suspended until the leveling instrument can be replaced or repaired.

4.6 Periodic Scour and Bed Elevation Data Collection

After installation, we recommend visiting cross sections periodically during the incubation period and after every storm event to check the monitors and record data. At the end of the incubation period, a final visit (either periodic or storm related) is required and monitors are then removed. Periodic scour and bed elevation data are collected on Forms 10.4 and 10.5 as noted.

General Inspection Procedure

Record information on a separate set of Form 10.4 sheets for each visit. Each page can document information on multiple cross sections and up to 28 scour monitors in the same segment. The forms can be set up with cross section numbers (*X-Sect #*), monitor numbers (*Monitor #*), and tape distances (Tape Dist from P1) already copied onto them so this does not need to be done in the field. Note the type of visit (*Inspection*) on the top of the form. Record the number of beads and balls that are exposed in the *Balls/Beads Expo #* column and calculate the scour depth (*Scour Depth*) where caused by peak flows. Document in the *Field Notes* column if a monitor is missing and check the brush and bars immediately downstream to see if it is washed out. If the monitor is not found, the monitor location will need to be excavated at the end of the incubation period to determine whether the monitor was buried or was scoured out and washed away.

Periodic Inspection Visits

Periodic inspection visits of the cross sections should be conducted every two weeks between peak flows. Examine each monitor if possible to ensure that the monitors have not been disturbed by factors such as debris, spawning fish, vandalism, or anchor ice (Eastern Washington). Check the number on the identification tag and remove debris that may have caught on the line or identification tag. If a monitor is not accessible during the visit due to stream conditions such as high water or turbidity, note this in the field notes.

If balls/beads have been exposed by spawning fish building a redd, note the number of exposed balls and cause. Never disturb a salmon redd by trying to remove, rebury exposed balls, or re-install the monitor. Balls/beads exposed by spawning fish are not included in the calculation of scour depth. This will require close tracking for repeated visits.

Monitors that have been disturbed by other factors can either be removed from the study (partial scour data), have exposed balls/beads re-buried, or have the entire monitor re-installed to standard depth (top ball just below current channel bed surface) prior to the next storm event. Re-installing the monitors will require detailed calculations of scour depth based on original installation bed elevation and prior scour depth information. If bed elevations are not being surveyed, data is still useful, but will not be representative of maximum scour depth across the entire monitoring period.

Post-Peak Flow Inspection Visits

When scour occurs during storm events, balls/beads are uncovered and carried to the end of the monitor cable by the water current. When the energy of the peak flow dissipates, gravel scoured from upstream may resettle (fill) over the monitor to varying depths. The monitors should be examined after each peak flow to document scour that occurred during the peak flow event. These visits should occur as soon as the receding water levels allows safe access, which will depend upon the stream system and the weather. Record data using the general inspection visit procedures and resurvey bed elevations using the procedure described in the "Surveying Bed Elevations" section above.

The depth of scour is calculated by counting the number of exposed balls/beads floating on the end of the wire and multiplying the number by the diameter (cable axis) of one ball/bead. Record the depth in the *Scour Depth* column on Form 10.4. Note that balls/beads exposed at the time of installation are never used to calculate scour depth. In situations where balls/beads were exposed by spawning fish or other non-peak discharge factors, depth of scour remains the same as from the last peak discharge inspection visit. The amount of fill is measured by surveying bed elevations at the monitor points. A full cross section profile can provide additional information on overall channel changes.

Post-Incubation Removal Visit

Visit the monitors at the end of the incubation period when the water level is low enough to conduct general inspection visit procedures, surveying bed elevations, and excavating the monitors. Monitors should be inspected and removed promptly at the end of the study period since they become more embedded and difficult to remove as time passes and are likely to be lost due to damage caused by additional abrasion and corrosion.

Inspect all visible monitors and record the final scour information on a separate Form 10.4 with the *Removal* visit type box marked. After collecting scour data and re-surveying the bed elevations, the monitors should be removed. This can often be accomplished by wrapping the cable several times around a stout steel rod and pulling upward.

In cases where the scour monitors are not visible, it is necessary to excavate the site to determine if the monitor was scoured out or is buried. Excavation should occur after the bed elevation has been re-surveyed. Locate the position of each missing monitor along the cross section by re-stretching the tape between the cross section anchor pins and using tape distance location recorded during the installation visit to relocate the point where the monitor was installed.

Carefully excavate to determine whether the missing monitor was scoured out and washed away or was merely buried. Begin the excavation about 0.2 meters downstream of the original installation point and dig carefully downward with a shovel, searching for the buried monitor wire lying horizontally in the gravel. Avoid unnecessary disturbance of the monitor during excavation since you will need to determine how many balls/beads (if any) washed out to the end of the cable before burial occurred. If the line is detected, grab it with one hand before completing the excavation so that the balls/beads at the end of the line are segregated from those that did not scour out prior to burial. The number of balls/beads at the end of the line is recorded on Form 10.4 for the survey date when the monitor first disappeared from sight. After recording the information, the rest of the monitor can be excavated and removed.

If the monitor can not be relocated by digging to the depth of the top of the anchor, it is assumed to be scoured out. Comparing the original bed elevation with the bed elevation at the removal visit can be helpful in determining how deep it is necessary to excavate to reach the anchor depth. In cases where the monitor is not relocated, record the original depth to top of anchor in the *Scour Depth* column on Form 10.4 for the survey date when the monitor first disappeared from sight. Also, remember to transfer monitor bed elevation measurements from Form 10.5 to Form 10.4 as needed.

4.7 Determining Maximum Stage and Peak Discharge

A strong relationship exists between the magnitude of peak discharge and depth of scour, so it is recommended that peak discharge information be collected for interpreting depth of scour data and to predict future scour patterns. Peak flow discharge may be ascertained directly, using a flow rating curve, or indirectly, using detailed cross section and water surface profile data and flow equations.

A rating curve can be developed by plotting stage v. discharge over a range of flows using the methods described in either the United States Geological Survey (USGS) Water Supply Paper 2175 (Rantz and others, 1982) or the TFW Wadable Stream Discharge Measurement (Pleus, 1999) method manual. Direct measurement of flood peaks may be difficult or dangerous (even in smaller streams), and projection of a rating curve above its range of measured values may produce unreliable results, so we recommend estimating peak discharge using an indirect method under the direction of a trained hydrologist or hydraulic engineer.

Two indirect methods of determining peak discharges are suggested. The first, and best method is to use data from a nearby USGS gaging station. The other method involves collecting maximum stage, cross section, and channel roughness data, for use in the standard slope-area method for estimating peak discharge. Peak discharge (cubic feet per second or cubic meters per second), measurement method, and dates for major events are recorded in the *Peak Discharge Information* section on Form 10.0.

4.7.1 Estimation of Peak Discharge using USGS Gaging Station Records

In the event that a gaging station exists on the stream under study, several types of information are available to assist in the evaluation of scour. Information from these stations may supplant information collected using the slope-area method described below if the station is active, is close to the reach under study, and there are no substantial sources of inflow (large springs or tributaries contributing more than 10% of the total flow) between the station and the gage. In the event these criteria are satisfied, then peak stage and discharge information may be obtained directly from the organization operating the gage.

If the station is not currently active, information may still be obtained on the discharge and sediment processing history of the stream. If the period of record is sufficiently long (minimum 10 years), a flood frequency analysis may be conducted to establish how often scour type events are likely to occur. In addition, changes in channel cross section at USGS stations over time may be ascertained by evaluating rating curve information kept on file at the appropriate field office. By identifying when "waves" of sediment are passing the station, it may be possible to associate bed mobility with particular flood events.

4.7.2 Estimation of Peak Discharge using the Slope-Area Method

The USGS slope-area method is best suited for channel conditions commonly found at monitoring sites in forested streams. The method involves identification of high water elevations from recent peak flow events along a channel reach using either a crest-stage gage or other field evidence. Peak flow is calculated from the high water information using Manning's equation. Details regarding field and analytical procedures for this method are provided in Dalrymple and Benson (1967). Other methods are described in Bodhaine (1967) for calculating flow at culverts, Matthai (1967) for calculating flow at bridge abutments, and Hulsing (1967) for calculating flow above spillways. All methods discussed here should only be performed under the direction of a knowledgeable hydrologist or hydraulic engineer.

5. Post-Survey Documentation

After completion of the field portion of the Scour Survey, field forms need to be organized, supplemental information and calculations completed, and all forms and information error checked before the data is ready to be entered into the database. The objective of this section is to organize the field forms and data to ensure high quality, efficient data referencing and transfer, and provide the foundation for this survey to be repeated the same way in the future by different crews.

5.1 Finalizing Forms 10.0, 10.1, 10.2, 10.3, 10.4 and 10.5

Organize the forms and check for missing sheets. Systematically check each Scour Survey form for completeness. All parameter blanks and boxes should contain information or a "/" to designate that no information is available or needed.

All Forms: The following list provides guidance on some common tasks:

- Page numbering is related to form type. Count the number of total pages separately for Forms 10.0, 10.1, 10.2, 10.3, 10.4 and 10.5
- The page number should be filled in as used during the survey (e.g., Page 1 of __, Page 2 of __, Page 3 of __, etc.). Forms that have been copied on both side of one sheet of paper will count as two separate pages.
- The total number of pages for each type of form is filled in at the end of the survey (e.g., Page 1 of 6, Page 2 of 6, Page 3 of 6, etc.).
- Organize the field forms by type and then by page number for easy reference. It is common to have different totals for each type.

Form 10.0: Site Inventory Information - Record final sub-sample population information from which scour data will be analyzed including the number of cross sections (*# X-Sect*) and number of monitors (*# Monit*) for each spawning habitat category.

Form 10.3: Check all Forms 10.3, count up the tally marks for each pebble count size category and record in the total column.

Form 10.4: Go through all Forms 10.4 and fill in missing *Scour Depth* and *Bed Elev* column data. Scour depth is calculated by multiplying the number in the balls/beads exposed times the ball/bead diameter in centimeters. Fill out missing *Bed Elev* column data by going through the Form 10.5s and transferring the elevations of the scour monitors for the various bed elevation survey dates.

Form 10.5: Check the Form 10.5s to make sure that each cross section bed elevation survey has been closed properly.

5.2 Error Checking

Error checking of field forms is a very important task and sufficient time should be taken for its completion. It is best done during or immediately after data collection because it becomes more difficult to reconcile discrepancies and track down correct information as time passes. Contact the TFW-MP for assistance in determining how to handle missing data fields.

Review all field forms and material compiled during the Scour Survey. Have a second person look them over for completeness, legibility and errors. Every page of every form requires error checking for legibility, complete and consistent header information, obvious measurement and transcription errors, and calculation errors. Work systematically through each section and when completed, put your initials and date in the *Error Checked by* box at the bottom of each page. If the person error checking the data is not a crew member, their full name and task should be recorded in the *Survey Notes* section of Form 10.0. When all field forms relating to a Scour Survey have been error checked, record the initials of the responsible crew and date completed.

6. Data Management

The TFW Monitoring Program offers data management services to help cooperators quickly analyze data collected with the program methods and to produce standard monitoring reports. The heart of the service is a database system housed at the Northwest Indian Fisheries Commission. This database calculates parameters, produces reports and archives electronic versions of the data. The database is also an important archive of monitoring data that can be used for developing study designs and identifying control or reference sites. This section describes the process for data preparation, data processing and archiving, and data analysis.

6.1 Data Preparation

Before data entry can occur for the Scour Survey, some preparation must be done. The following materials are needed:

- completed and error-checked Forms 10.0, 10.2, 10.3, and 10.4 as needed for each segment,
- a data entry system;
- a set of data entry system instructions and an "Ambsys" data dictionary
- copy of completed Stream Segment Identification Form 1.0

Before the data entry process can begin, a data entry system must be selected. Choose a data entry system from the list below and request a free copy and user's manual from the TFW Monitoring Program. The database has three entry system options for survey data. These are:

- Microsoft Excel 4.0 pre-formatted spreadsheets;
- Lotus 1-2-3 (vers. 3) pre-formatted spreadsheets; and
- Microsoft Access 7.0 pre-formatted entry forms

Refer to Appendix G for an example of the Excel preformatted spreadsheet. Select a spreadsheet format if your data requires conversion from English to metric units. Replace all English unit measurements with metric equivalents. Read the instructions for the data entry system and the Ambsys data dictionary, noting the field types and data constraints (what type of data can be entered into each field).

6.2 Data Processing, Products and Archiving

Open the section of the entry system pertaining to the Scour Survey on your computer. Following the entry system instructions, enter the data from Forms 10.0, 10.2, 10.3, and 10.4 as directed. After the data has been entered and the session saved, error check the data entry. The most efficient technique for this time-consuming task is to have one person read the data off the screen and another check it with the original field form. Save the file a final time once the data has been error checked. When completed, record the initials of the responsible crew and date on Form 10.0.

Data can be sent to the TFW Monitoring Program using several different methods. Copies of all survey field forms and other documentation are required for archiving and can be hand delivered, mailed, or faxed to the program. An original or copy of a USGS topographic map is also required and can be hand delivered, mailed, or faxed. Maps must have upstream and downstream segment boundaries marked along the stream. If a photocopy of the map is used, make sure the township, range, section, contour intervals, map name, and publishing date are identified. The electronic versions of the data can be sent via e-mail, CD, or on a floppy disk. After the program receives the electronic files, the data is imported into the database by a TFW-MP staff person.

Safe and efficient archiving is also provided by the TFW Monitoring Program to save data and survey reach locations for future use. The data generated by individual cooperators is archived electronically in the database system. Hard copies of the field forms, topographic maps and supplemental information are archived at the TFW-MP facility. Access to data can be limited at the request of the cooperator contributing the data to the database. Call for information on the data access policy.

6.3 Data Analysis

Data collected during the Scour Survey is used to generate summary reports that present analyzed results derived from calculations done by the database. Following is a brief description of the data analysis reports.

An individual monitor summary report summarizes changes in scour depth and bed elevation at each scour individual monitor for each inspection visit. A second set of reports calculate the changes in mean scour depth and bed elevation by storm event, for each cross section, each spawning habitat type, and the entire segment. A third report summarized the number and percentage of monitoring sites where scour reached the mean top of egg pocket depth for three size classes of salmonids (Table 8) by spawning habitat type and the entire segment over the course of the monitoring project.

Table 8. Egg burial depths for three size classes of salmonids (based on preliminary egg burial depth criteria for top of egg pocket from DeVries, 1997).

Species	**Top of Egg Pocket Depth**
Brook, brown, and golden trout; Kokanee salmon	5 cm
Bull, cutthroat, and rainbow trout; Sockeye salmon	10 cm
Chum, chinook, steelhead, coho, and pink salmon	15 cm

Since little scour data is available, it will be difficult to interpret depth of scour data by comparing it with existing data from similar segments, or undisturbed sites. As more data is collected over time, comparisons will become feasible.

7. References

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8. Appendixes

Appendix A
Form 10.0, 10.1, 10.2, 10.3, 10.4, and 10.5 Copy Masters

Appendix B
Examples of Completed Field Forms 10.0, 10.1, 10.2, 10.3, 10.4, and 10.5

Appendix C
Scour Monitor Size and Construction Details

Appendix D
Scour N* Matrix

Appendix E
Sample Site Selection Worksheet Example

Appendix F
Standard Field and Vehicle Gear Checklist Copy Master

Appendix G
Data Management Example

Appendix A

Form 10.0, 10.1, 10.2, 10.3, 10.4 and 10.5 Copy Masters

(Keep original copy master with manual)

Stream Name

SG SCOUR SURVEY

HEADER INFORMATION

FORM 10.0

WRIA # __ __ . __ __ __ __ Unlisted Trib __ __ __ ○ RB ○ LB **Segment #** ______ ______ Sub-Segment Code **Date** ____/____/______

Study Design Information

Begin Survey Date ___/___/_____
End Survey Date ___/___/_____

Survey Length [ ]

Survey Coverage | **Percentage**

- ○ WHL (Whole) 100 %
- ○ SUB (Sub-sample) _____%
- ○ PRT (Partial) _____%
- ○ PSB (Partial Sub-sample) _____%
- ○ OTH (Other) _____%

Partial/Other Survey Location
WRIA River Mile: from ____ to ____
Reference Points: from ____ to ____

Site Inventory Information

Study Design Targets

T = ____ P = ____ CL = ____ Prec = ____

N*	Strategy	Sampling Ratio

	Site Inventory			*Sub-Sample*	
SH Type	# X-Sect	% X-Sect	SP1	# X-Sect	# Monit
A					
B					
C					
D					
Total					

Survey Crew

Name	Affiliation	
		(Lead)
		(Rec.)

Crew Lead: Year of most recent Scour Training _____ QA Review _____

Equipment

○ Metric ○ English

Equipment	Size	Accuracy	Calib.

Compass ○ True ○ Magnetic True Declination _____° E W

Peak Discharge Information

Date	Peak Disch.	Meas. Unit

Survey Notes

Form	# Pages
10.1	
10.2	
10.3	
10.4	
10.5	

○ continued page

Form 10.0
Error Checked by: ____ Date: ___/___/____
All Field Forms
Error Checked by: ____ Date: ___/___/____
All Data Entry
Error Checked by: ____ Date: ___/___/____

TFW Monitoring Program

Stream Name

Crew Lead ____
Recorder(s) ____

Page ___ of

S.G. SCOUR SURVEY

○ Meters
○ Feet

SITE INVENTORY

FORM 10.1

WRIA # __ __ . __ __ __ __

Unlisted Trib __ __ ○ RB ○ LB

Segment # ______

______ Sub-Segment Code

Date ____ / ____ / ______

Landmark/RP X-Sect #	Cum DIST	SH Type (A - D)	OFP	SH Width	EST # Monitors	FIELD NOTES	Landmark/RP X-Sect #	Cum DIST	SH Type (A - D)	OFP	SH Width	EST # Monitors	FIELD NOTES

ERROR CHECKED by: ____ Date: ___/___/ ___

TFW Monitoring Program

Stream Name

Crew Lead ____
Recorder(s) ____

Page ___ of ___

SG SCOUR SURVEY

○ METERS ○ FEET

CROSS SECTION DOCUMENTATION

FORM 10.2

WRIA # __ __ . __ __ __ __ Unlisted Trib __ __ __ ○ RB ○ LB **Segment #** ______ ______ Sub-Segment Code

Date ___/___/_____

Cross Section Information

X-Sect #	SH Type	Type D OFP	Pin #	Bank	Pin Structure: Type/ Spec	Dia	Pin Height	BFCE Dist	Dist to P1	Azim to P1
			P1							
			P2							
			BM							

Spawn Habitat Location

X-Sect #	Tape Dist 1	Tape Dist 2
Anchor Pins		
SH-1		
SH-2		
SH-3		

Photographs Roll # ______ Frame #'s ________

Notes: ________

Sketch Map of Cross Section Site

Cross Section Information

X-Sect #	SH Type	Type D OFP	Pin #	Bank	Pin Structure: Type/ Spec	Dia	Pin Height	BFCE Dist	Dist to P1	Azim to P1
			P1							
			P2							
			BM							

Spawn Habitat Location

X-Sect #	Tape Dist 1	Tape Dist 2
Anchor Pins		
SH-1		
SH-2		
SH-3		

Photographs Roll # ______ Frame #'s ________

Notes: ________

Sketch Map of Cross Section Site

TFW Monitoring Program

Stream Name

Crew Lead ____
Recorder(s) ____

Page ___ of

SG SCOUR SURVEY

PEBBLE COUNT

FORM 10.3

WRIA # __ __ . __ __ __ __   Unlisted Trib __ __ ○ RB ○ LB   **Segment #** ______   ______ Sub-Segment Code   **Date** ___/___/_____

Pebble Size (mm)	X-Section # _____	Total	Pebble Size (mm)	X-Section # _____	Total	Pebble Size (mm)	X-Section # _____	Total
≥ 512			≥ 512			≥ 512		
≥ 256			≥ 256			≥ 256		
≥ 180			≥ 180			≥ 180		
≥ 128			≥ 128			≥ 128		
≥ 90			≥ 90			≥ 90		
≥ 64			≥ 64			≥ 64		
≥ 45			≥ 45			≥ 45		
≥ 32			≥ 32			≥ 32		
≥ 22			≥ 22			≥ 22		
≥ 16			≥ 16			≥ 16		
≥ 11			≥ 11			≥ 11		
≥ 8			≥ 8			≥ 8		
≥ 6			≥ 6			≥ 6		
≥ 4			≥ 4			≥ 4		
≥ 2			≥ 2			≥ 2		
< 2			< 2			< 2		
	Sample Total			Sample Total			Sample Total	

Notes:

Notes:

Notes:

TFW Monitoring Program

Stream Name

Crew Lead ____
Other(s) ____ ____

Page ___ of

SCOUR SURVEY

○ METERS
○ FEET

SCOUR & BED ELEVATION DATA

FORM 10.4

WRIA # __ __ . __ __ __ __ __

Unlisted Trib __ __ __ ○ RB ○ LB

Segment # ________

______ Sub-Segment Code

Date _____ / _____ / ________

Type of Vist: ☐ Installation ☐ spection R☐oval

X-Sect #	Monitor #	Tape Dist (from P1)	Balls/Beads Expo #	Scour Depth (cm)	Bed Elev (from 10.5)	Field Notes	X-Sect #	Monitor #	Tape Dist (from P1)	Balls/Beads Expo #	Scour Depth (cm)	Bed Elev (from 10.5)	Field Notes

TFW Monitoring Program

Stream Name

Crew Lead ____
Recorder(s) ____

Page ___ of

SG SCOUR SURVEY

○ METERS
○ FEET

BED ELEVATION SURVEY

FORM 10.5

WRIA # ___ ___ . ___ ___ ___ ___

Unlisted Trib ___ ___ ___ ○ RB ○ LB

Segment # ________

_____ Sub-Segment Code

Date ____/____/______

X-Sect #						X-Sect #						X-Sect #					
Tape Dist	BS (+)	HI	FS (-)	Elev	Notes	Tape Dist	BS (+)	HI	FS (-)	Elev	Notes	Tape Dist	BS (+)	HI	FS (-)	Elev	Notes

Appendix B

Completed Examples of
Forms 10.0, 10.1, 10.2, 10.3, 10.4 and 10.5

TFW Monitoring Program

Stream Name BLUE CREEK

SG SCOUR SURVEY — HEADER INFORMATION — FORM 10.0

WRIA # 17.9999 Unlisted Trib 000 ○ RB ○ LB Segment # 15 B Sub-Segment Code Date 10/4/99

Study Design Information

Begin Survey Date 10/12/1999
End Survey Date 4/21/00

Survey Length 1100 m

Survey Coverage — **Percentage**

- ● WHL (Whole) 100 %
- ○ SUB (Sub-sample) ___ %
- ○ PRT (Partial) ___ %
- ○ PSB (Partial Sub-sample) ___ %
- ○ OTH (Other) ___ %

Partial/Other Survey Location N/A
WRIA River Mile: from ___ to ___
Reference Points: from ___ to ___

Site Inventory Information

Study Design Targets

T = 96 P = 50% CL = 95% Prec = ±10%

N*	Strategy	Sampling Ratio
66	SPI	1/3

	Site Inventory			Sub-Sample	
SH Type	# X-Sect	% X-Sect	SPI	# X-Sect	# Monit
A	21	55%	154	7	44
B	9	24%	33	4	18
C	6	16%	15	2	3
D	2	5%	5	1	2
Total	38		207	14	67

Survey Crew

Name	Affiliation	
ALLEN PLEUS	TFW MONITORING PROGRAM	(Lead)
DAVE SCHUETT-HAMES	" " "	(Rec.)

Crew Lead: Year of most recent Scour Training 99 QA Review 99

Survey Notes

* EXAMPLE DATA ONLY *

Equipment

● Metric ○ English

Equipment	Size	Accuracy	Calib.
(NEW) GOLF BALL MONITORS	40cm	±2cm	10/1/99
FIBERGLASS TAPES (2)	50m	±0.01	"
" " (1)	30m	"	"
REBAR-½" w/ORANGE CAPS	18-36"	—	—
ALUM. NAILS	20d.	—	—
ALUM. TAGS	1X3"	—	—
AUTO LEVEL	STND	±0.001	10/1/99
STADIA ROD	5.0	±0.01	"
VERNIER CALIPER		±1mm	"

Compass SUUNTO MC-1 ● True ○ Magnetic True Declination 21 ° Ⓔ W ID# 249

Peak Discharge Information

Date	Peak Disch.	Meas. Unit
11/26/99	18.11	cms
1/21/00	21.09	cms
3/15/00	19.42	cms

Form	# Pages
10.1	2
10.2	7
10.3	5
10.4	18
10.5	25

○ continued page X

Form 10.0
Error Checked by: AP Date: 4/26/00
All Field Forms
Error Checked by: AP Date: 4/25/00
All Data Entry
Error Checked by: AP Date: 4/28/00

TFW Monitoring Program

Stream Name BLUE CREEK

Crew Lead AP Recorder(s) DSH / Page 1 of 2

S.G. SCOUR SURVEY

● Meters ○ Feet

SITE INVENTORY

FORM 10.1

WRIA # 17.9999 Unlisted Trib 000 ○RB ○LB Segment # 15 B Sub-Segment Code Date 10/8/99

FIELD NOTES ▶ ◯ = SELECTED FOR SAMPLING; C2 = Adjacent Channel

Landmark/RP X-Sect #		Cum DIST	SH Type (A-D)	OFP	SH Width	EST # Monitors	FIELD NOTES
RP#0		0	-	-	-	-	LOWER SEGMENT BOUNDARY
▶ 1	2/8	5	A	/	2.6	2	
2	15/26	21	A	/	5.4	5	
3	71/87	79	B	/	2.7	2	
4	93/106	100	A	/	17.3	17	Wide Meander bend
RP#1	—	102					
5	111/137	124	C	/	2.1	2	C2
▶ 6	152/177	165	A	/	1.5	1	C2
7	184/193	189	B	/	3.2	3	
RP#2	—	199					
8	204/252	228	A	/	14.8	14	
9	264/289	277	A	/	9.2	9	
▶ 10	268	S-10	C	/	1.4	1	END (S-10 = Cum Dist) SIDE CHANNEL LB
▶ 11		S-13	B	/	1.7	1	
▶ 12	295	S-18	A	/	2.8	2	START
RP#3		303					
13	305/337	321	A	/	16.0	16	
14	341/390	366	A	/	3.5	3	
15	390/394	392	B	/	4.3	4	
16	394/402	398	C	/	2.2	2	
RP#4	—	400			1.7	1	
17	417/421	419	C	/	1.7	1	C2

Landmark/RP X-Sect #		Cum DIST	SH Type (A-D)	OFP	SH Width	EST # Monitors	FIELD NOTES
▶ 18	432/437	435	D	3	2.4	2	CENTER CHANNEL
▶ 19	451/487	469	A	/	19.5	19	
RP#5	—	497					
20	493/518	508	A	/	5.3	5	
▶ 21	518/522	520	B	/	11.1	11	
22	534/562	548	A	/	15.7	15	
▶ 23	568/579	574	A	/	8.2	8	
24	581/603	592	A	/	2.5	2	C2
RP#6		596					
25	619/669	644	A	-	14.6	14	
▶ 26	669/674	672	B	/	4.8	4	
▶ 27	684/689	687	C	/	2.9	2	C2
RP#7		700					
28	703/709	706	B	/	3.1	3	
29	724/729	727	D	3	3.3	3	
30	731/750	741	C	/	7.2	7	OK
BRIDGE	742/817	792					50m Downstream 25m Upstream Buffer
RP#8	—	801	A	/	11.4	11	
▶ 31	821/847	834	A	/	11.4	11	OK
32	847/850	848	B	/	3.9	3	
33	869/879	874	A	/	4.3	4	
34	865/873	869	A	/	2.7	2	ADJ Channel RB / MORE

TFW Monitoring Program

Stream Name BLUE CREEK

Crew Lead DSH
Recorder(s) AP /

SG SCOUR SURVEY

● METERS ○ FEET

CROSS SECTION DOCUMENTATION

FORM 10.2

WRIA # 17.9999 | Unlisted Trib 000 ○RB ○LB | Segment # 15 | B Sub-Segment Code | Date 10/13/99

Cross Section Information

X-Sect #	SH Type	Type D OFP	Pin #	Bank	Pin Structure Type/Spec	Dia	Pin Height	BFCE Dist	Dist to P1	Azim to P1
23	A	/	P1	L	ALDER	0.2	0.5	5.7		
			P2	R	CAP REBAR	½"	0.1	2.9	17.9	318° (T)
Spawn Habitat Location			BM	L	D.FIR	0.5	0.4	7.5	6.1	200° (T)

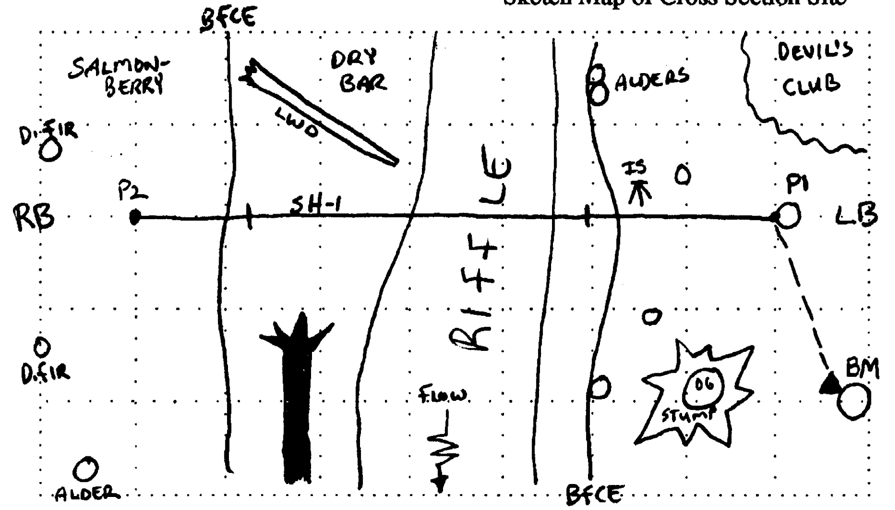
X-Sect #	Tape Dist 1	Tape Dist 2
Anchor Pins	∅	17.9
SH-1	6.3	14.5
SH-2	—	—
SH-3	—	—

Photographs Roll # 005 Frame #'s 17-19

Notes: ACCESS FROM UPSTREAM TRAIL OFF LOGGING ROAD 3300 @ MILE 8
D.FIR = DOUGLAS FIR OG = OLD GROWTH
▲BM = BENCHMARK ⩚ IS = INSTRUMENT STATION
BM HAS NAIL W/SHINER TAG 10

~~EXAMPLE ONLY~~

Sketch Map of Cross Section Site



Cross Section Information

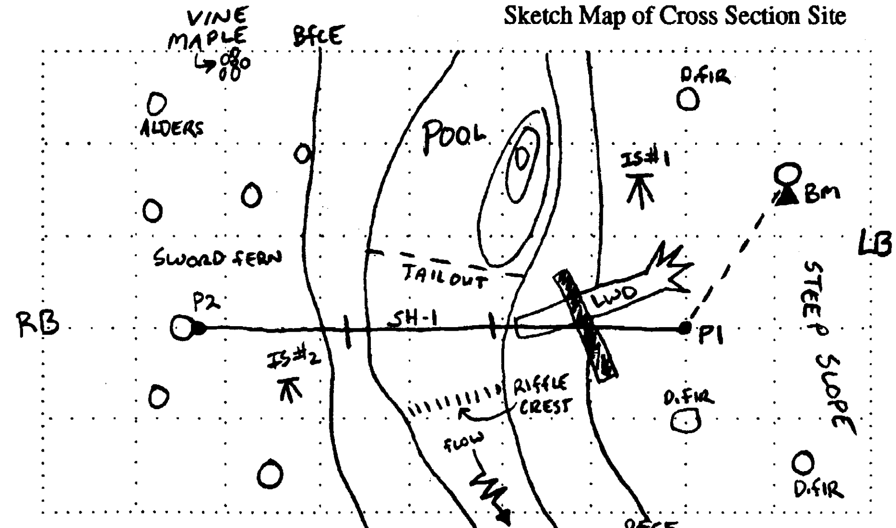
X-Sect #	SH Type	Type D OFP	Pin #	Bank	Pin Structure Type/Spec	Dia	Pin Height	BFCE Dist	Dist to P1	Azim to P1
26	B	/	P1	L	CAP REBAR	½"	0.2	2.8		
			P2	R	ALDER	0.3	0.1	3.4	14.4	212° (T)
Spawn Habitat Location			BM	L	CEDAR	0.3	0.5	7.0	6.5	336° (T)

X-Sect #	Tape Dist 1	Tape Dist 2
Anchor Pins	∅	14.4
SH-1	5.6	10.4
SH-2	—	—
SH-3	—	—

Photographs Roll # 005 Frame #'s 20-21

Notes: ACCESS FROM LB SLOPE ~50 m TO 3300 RD. @ MILE 9
BM HAS NAIL W/SHINER TAG 10

Sketch Map of Cross Section Site



TFW Monitoring Program

Stream Name BLUE CREEK

Crew Lead DSH
Recorder(s) AP -
Page 5 of 5

SG SCOUR SURVEY

PEBBLE COUNT

FORM 10.3

WRIA # 17.9999 Unlisted Trib 000 ○RB ○LB Segment # 15 B Sub-Segment Code Date 10/13/99

Pebble Size (mm)	X-Section # 35	Total
≥ 512		Ø
≥ 256		2
≥ 180		5
≥ 128		4
≥ 90		7
≥ 64		13
≥ 45		7
≥ 32		23
≥ 22		6
≥ 16		8
≥ 11		4
≥ 8		8
≥ 6		5
≥ 4		4
≥ 2		2
< 2		3
	Sample Total	101

Notes:

Pebble Size (mm)	X-Section # 38	Total
≥ 512		Ø
≥ 256		1
≥ 180		2
≥ 128		2
≥ 90		6
≥ 64		3
≥ 45		9
≥ 32		11
≥ 22		6
≥ 16		13
≥ 11		8
≥ 8		19
≥ 6		6
≥ 4		7
≥ 2		3
< 2		4
	Sample Total	100

Notes:

Pebble Size (mm)	X-Section # ___	Total
≥ 512		
≥ 256		
≥ 180		
≥ 128	END	
≥ 90		
≥ 64	OF	
≥ 45		
≥ 32	PEBBLE	
≥ 22	COUNT	
≥ 16		
≥ 11		
≥ 8		
≥ 6		
≥ 4		
≥ 2		
< 2		
	Sample Total	

Notes: * EXAMPLE ONLY *

TFW Monitoring Program

Stream Name BLUE CREEK

Crew Lead AP
Other(s) BH —

Page 2 of 3

SCOUR SURVEY

● METERS ○ FEET

SCOUR & BED ELEVATION DATA

FORM 10.4

WRIA # 17.9999 Unlisted Trib 000 ○RB ○LB Segment # 15 B Sub-Segment Code Date 3/17/2000

Type of Vist: ☐ Installation ■ Inspection ☐ Removal

X-Sect #	Monitor #	Tape Dist (from P1)	Balls/Beads Expo #	Scour Depth (cm)	Bed Elev (from 10.5)	Field Notes
21	17	8.3	1	4	27.98	* EXAMPLE ONLY *
	19	9.3	3	12	27.81	
	22	10.3	2	8	27.84	REMOVED HANGING DEBRIS
	18	11.5	4 (-1)	12	27.77	1 BALL EXPOSED @ Installation
	21	12.5	6	24	27.85	
	20	13.5	10	40	27.89	
	27	14.5	8	32	27.78	
	36	15.5	4 (-2)	8	27.75	2 Balls EXPOSED BY FISH 11/21 VISIT
	4	16.5	1	4	27.85	
	50	17.6	Ø	Ø	27.90	
	52	18.6	Ø	Ø	27.97	
	6	19.9	Ø	Ø	28.10	
23	7	6.8	Ø	Ø	28.85	
	8	7.8	Ø	Ø	28.81	

X-Sect #	Monitor #	Tape Dist (from P1)	Balls/Beads Expo #	Scour Depth (cm)	Bed Elev (from 10.5)	Field Notes
23	9	8.8	2	8	28.80	
	11	9.8	3	12	28.62	
	15	10.8	3	12	28.65	
	14	11.8	2	8	28.78	
	10	12.8	1	4	28.76	
	12	13.8	Ø	Ø	28.81	
26	61	6.1	4	16	28.48	
	59	7.1	6	24	28.31	
	60	8.1	3	12	28.39	
	62	9.1	1	4	28.54	
27	33	11.3	Ø	Ø	27.94	
	34	12.5	1	4	27.87	
31	37	3.4	Ø	Ø	28.74	
	36	4.4	Ø	Ø	28.70	

TFW Monitoring Program

Stream Name BLUE CREEK

Crew Lead DSH
Recorder(s) AP /
Page 19 of 25

SG SCOUR SURVEY

● METERS
○ FEET

BED ELEVATION SURVEY

FORM 10.5

WRIA # 17.9999 Unlisted Trib 000 ○RB ○LB Segment # 15 B Sub-Segment Code Date 3/17/2000

X-Sect # 23

Tape Dist	BS (+)	HI	FS (-)	Elev	Notes (M# = MONITOR ID NUMBER; QC = QUALITY CONTROL)
	0.52	30.52	/	30.00	BENCHMARK
Ø			1.23	29.29	P1 FLOODPLAIN
1.0			1.31	29.21	FLOODPLAIN (FP)
2.0			1.38	29.14	
3.0			1.35	29.17	
4.0			1.37	29.15	
5.0			1.32	29.20	
5.7			1.46	29.06	BFCE-LB (BANKFULL CHANNEL EDGE)
6.0			1.61	28.91	LEW (LEFT EDGE OF WATER)
6.8			1.67	28.85	M # 7
7.8			1.71	28.81	M # 8
8.8			1.72	28.80	M # 9
9.8			1.90	28.62	M # 11
10.8			1.87	28.65	M # 15
11.8			1.74	28.78	M # 14
12.8			1.76	28.76	M # 10
13.8			1.71	28.81	M # 12
14.5			1.62	28.90	REW
15.0			1.45	29.07	BFCE-RB
16.0			1.35	29.17	FP
17.0			1.21	29.31	FP
17.9			1.19	29.33	P2
QC			0.52	30.00	BENCHMARK
					CLOSE SURVEY

X-Sect # 26

Tape Dist	BS (+)	HI	FS (-)	Elev	Notes
	0.05	30.05	/	30.00	BENCHMARK
Ø			0.21	29.84	P1 HILLSLOPE
2.8			1.14	28.91	BFCE-LB
6.1			1.57	28.48	M # 61
6.1	1.55	30.03		28.48	TP1 @ M# 61
7.1			1.62	28.41	M # 59
8.1			1.54	28.49	M # 60
9.1			1.39	28.64	M # 62
11.0			1.00	29.03	BFCE-RB
14.4			0.91	29.12	P2 FLOODPLAIN
QC	0.02			30.01	BENCHMARK
					CLOSE SURVEY

* EXAMPLES ONLY *

X-Sect # 27

Tape Dist	BS (+)	HI	FS (-)	Elev	Notes
	0.33	30.33	/	30.00	
7.3			2.39	27.94	
8.3			2.46	27.87	
QC			0.33	30.00	BENCHMARK
					CLOSE SURVEY

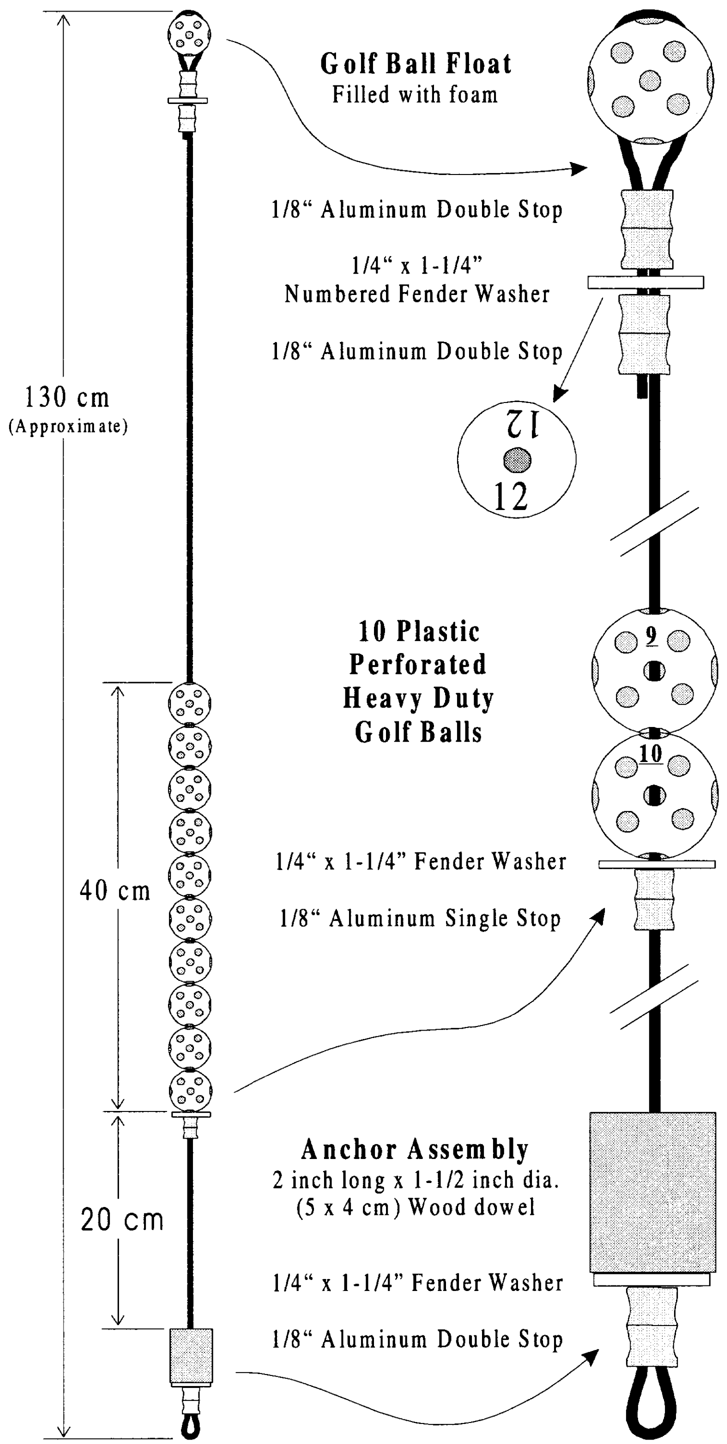
Appendix C

Scour Monitor Size and Construction Details Copy Master

C-1: Standard Golf Ball Scour Monitor Size and Construction Details Sheet
C-2: Instructions for Constructing Standard Golf Ball Scour Monitors
C-3: Standard Golf Ball Scour Monitor Inserter Size and Construction Details Sheet
C-4: Standard Sliding-Bead Scour Monitor Size and Construction Details Sheet
C-5: Instructions for Constructing Standard Sliding-Bead Scour Monitors
C-6: Standard Sliding-Bead Scour Monitor Inserter Size and Construction Details Sheet

(Keep original copy masters with manual)

Standard Golf Ball Scour Monitor
Size and Construction Details



Materials List for 20 Monitors

- ❑ 30.5 meters (100 feet) of 1/8 inch dia. Braided stainless steel aircraft cable
- ❑ 220 each standard size plastic perforated heavy duty golf balls
- ❑ 110 cm (44 inches) of 4 cm (1-1/2 inch) diameter wood closed dowel
- ❑ 60 each 1/4 x 1-1/4 inch stainless steel fender washers
- ❑ 40 each 1/8 inch double-size cable stops
- ❑ 20 each 1/8 inch single-size cable stops
- ❑ 1 can polycell foam insulation

Tools Required:

- ❑ Safety glasses and gloves
- ❑ Cable cutter
- ❑ Saw
- ❑ Drill and 1/8 inch bit
- ❑ Vise
- ❑ Crimping tool
- ❑ Numbering stamping dies and hammer

Stainless steel hardware is recommended if monitors are to be used for more than one season.

11/10/99
Allen Pleus

APPENDIX C-2

Instructions for Constructing Standard Golf Ball Scour Monitors

Construction can be speeded up by completing each step for all monitors before going to the next step. Refer to the figure in Appendix C-1.

1.) *Cut cable to 1.5 meter lengths.* Measure and mark a 1.5 meter length along a section of workbench. Use this to quickly measure the proper length for each monitor. Use a sharp cable cutter to have clean cuts that prevent individual wires in the cable from unraveling. If unraveling is a problem, make cuts through a wrap of electrical or masking tape.

2.) *Cut and drill anchor dowel.* Measure out 5 cm increments along the dowel and cut with a hand saw. If available, use a band, table, or chop saw with a length stop. Secure the cut pieces of dowel on end in a vise, use a 16d nail or the tip of a phillips screwdriver to indent the center of the dowel. Drill a 1/4 inch hole through the center along the entire length of the dowel. If available, use a drill press.

3.) *Prepare Identification tags.* Use the number stamping dies and the hammer to sequentially number 20 of the 60 fender washers and place them in a separate pile. Be sure to place numbers towards outside of washer. Keep the sequential numbering going if constructing more than 20 monitors. Pre-numbered tags are available for purchase through forestry and survey suppliers.

4.) *Assemble and secure monitor anchor.* Thread one end of the cable through one anchor dowel, one unnumbered fender washer, and one double cable stop. Loop the cable end back through the stop and work the cable to make the smallest loop possible while keeping the cut end just above the stop. Crimp the stop in place with the crimping tool. Securing one arm of the crimping tool in a vise can make this an easier task.

5.) *Measure and secure monitor ball washer/stop.* From the other end of the cable (top), thread one single cable stop and one unnumbered fender washer. With the anchor dowel resting on its washer and cable stop, crimp the cable stop so that the top of the new stop is 20 cm from the top of the dowel. A pre-marked length on the workbench and a felt tip marker are useful techniques for quickly identifying this position.

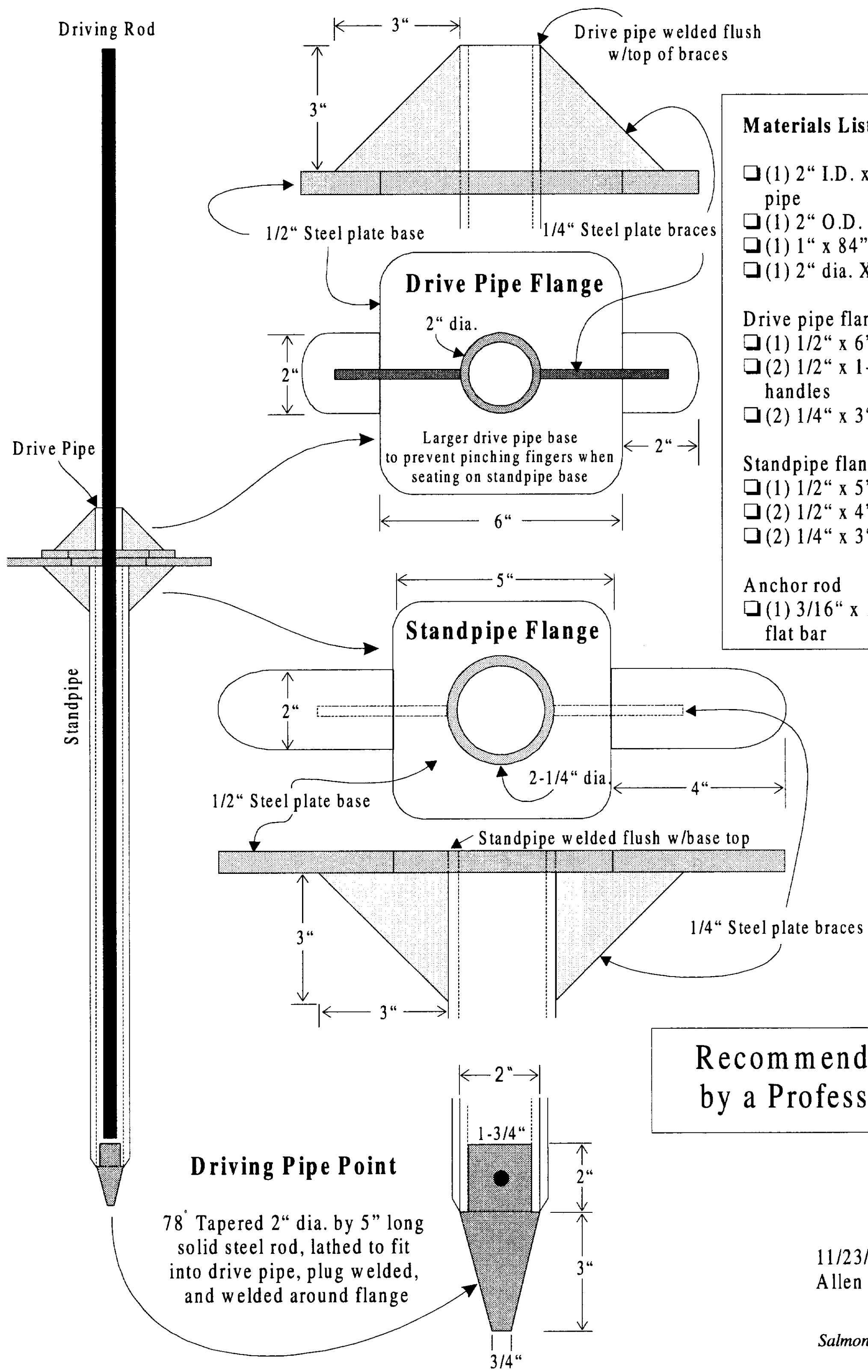
6.) *Thread 10 golf balls onto the monitor cable.* From the top end of the cable, thread the perforated golf balls onto the cable using holes that guide the cable through the center of the balls. Make sure the balls can travel freely along the cable. In rare cases, these two holes may need to be enlarged by drilling. Balls can be of different colors to improve visibility or identify different scour depths. Number the balls with a permanent marker sequentially from 1 to 10 - top ball being #1.

7.) *Secure monitor float and ID tag assembly.* From the top end of the cable, thread on one double cable stop, one numbered fender washer (number side up), one double cable stop, and one perforated golf ball. The cable is looped through holes parallel to the center of the golf ball and then back through the cable stops and fender washer. With about six to eight centimeters of end cable coming back out the golf ball, work the cable to make the loop top rest on the top of the golf ball and the top cable stop just below the ball in the fashion of a slightly loosened necktie. Crimp this stop in place. Adjust the bottom stop so that the end of the cable just comes out and crimp in place.

8.) *Fill monitor golf ball float with foam.* Insert the filling tube into the golf ball float and fill with foam. Set aside in an area that expanding or dripping foam does not harm. The scour monitor is now complete.

9.) *Organize monitors for field transport.* Monitors can be combined in groups of 5 to 20 and placed in 5 gallon buckets for efficient storage and transport for field use.

Standard Golf Ball Scour Monitor Inserter
Size and Construction Details



Materials List for Golf Ball Inserter

- ❑ (1) 2" I.D. x 48" Stainless Sch. 40 pipe
- ❑ (1) 2" O.D. x 51-1/2" Steel Tubing
- ❑ (1) 1" x 84" Solid steel rod
- ❑ (1) 2" dia. X 5" Solid steel rod

Drive pipe flange (Stainless steel)
- ❑ (1) 1/2" x 6" x 6" steel plate base
- ❑ (2) 1/2" x 1-1/2" x 2" steel plate handles
- ❑ (2) 1/4" x 3" x 3" triangle braces

Standpipe flange
- ❑ (1) 1/2" x 5" x 5" steel plate base
- ❑ (2) 1/2" x 4" x 2" steel plate handles
- ❑ (2) 1/4" x 3" x 3" triangle braces

Anchor rod
- ❑ (1) 3/16" x 1/2" x 70" galvanized flat bar

Recommended Assembly by a Professional Welder

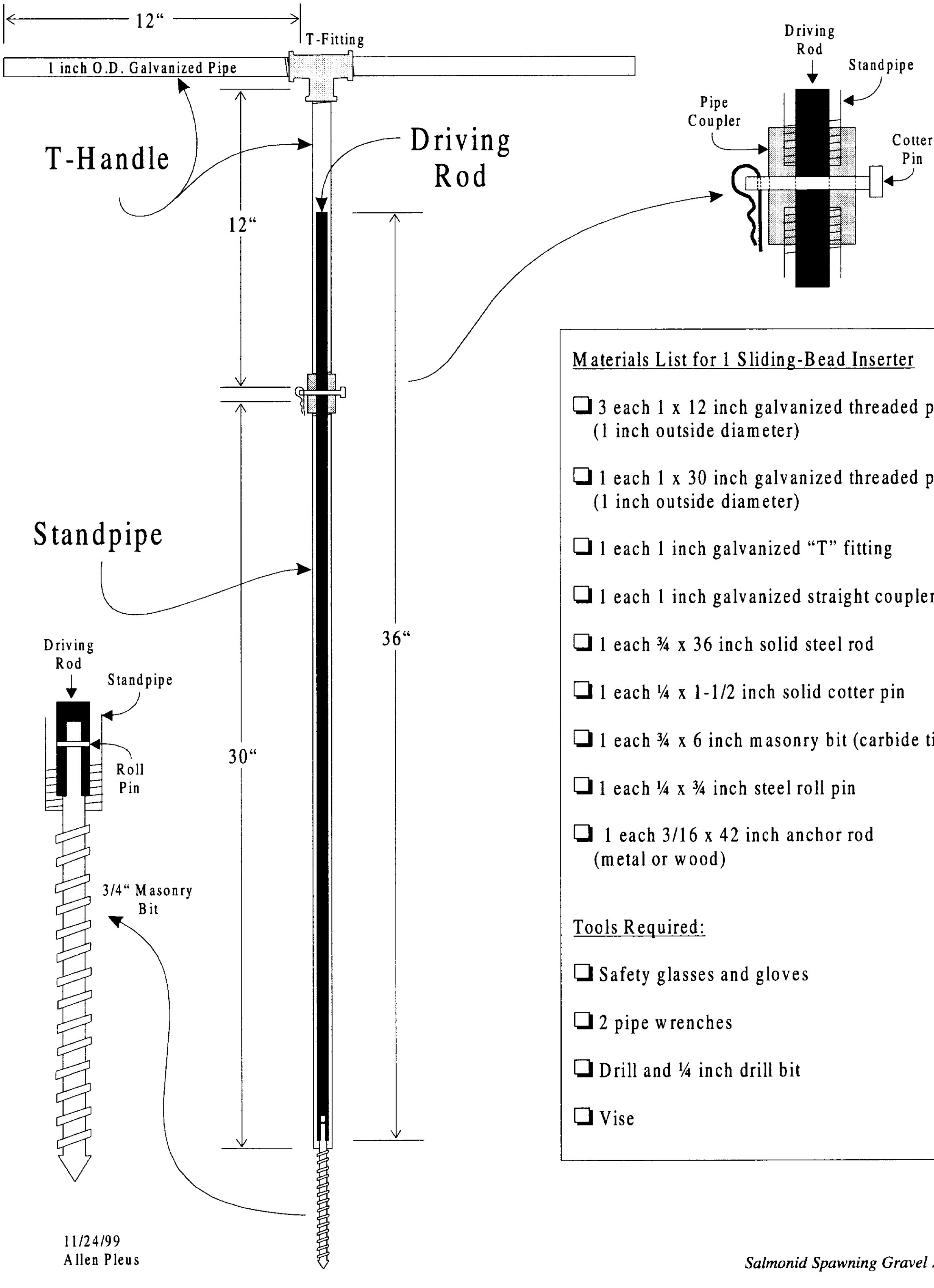
11/23/99
Allen Pleus

APPENDIX C-6

Standard Sliding-Bead Scour Monitor Inserter

Size and Construction Details

Based on Jim Matthews design, Yakama Nation



Materials List for 1 Sliding-Bead Inserter

- ❑ 3 each 1 x 12 inch galvanized threaded pipe (1 inch outside diameter)
- ❑ 1 each 1 x 30 inch galvanized threaded pipe (1 inch outside diameter)
- ❑ 1 each 1 inch galvanized "T" fitting
- ❑ 1 each 1 inch galvanized straight coupler
- ❑ 1 each ¾ x 36 inch solid steel rod
- ❑ 1 each ¼ x 1-1/2 inch solid cotter pin
- ❑ 1 each ¾ x 6 inch masonry bit (carbide tip)
- ❑ 1 each ¼ x ¾ inch steel roll pin
- ❑ 1 each 3/16 x 42 inch anchor rod (metal or wood)

Tools Required:

- ❑ Safety glasses and gloves
- ❑ 2 pipe wrenches
- ❑ Drill and ¼ inch drill bit
- ❑ Vise

Appendix D

Scour N* Matrix

APPENDIX D

Scour N* Matrix

First Approx. Sample Size (FA)	Inventory Sample Population (SP1)																											
(Table 4)	10	20	30	40	50	60	70	80	90	100	120	140	160	180	200	225	250	275	300	350	400	450	500	600	700	800	900	1000
6	4	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
9	5	6	7	7	8	8	8	8	8	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
11	5	7	8	9	9	9	10	10	10	10	10	10	10	10	10	10	11	11	11	11	11	11	11	11	11	11	11	11
13	6	8	9	10	10	11	11	11	11	12	12	12	12	12	12	12	12	12	12	13	13	13	13	13	13	13	13	13
15	6	9	10	11	12	12	12	13	13	13	13	14	14	14	14	14	14	14	14	14	14	15	15	15	15	15	15	15
17	6	9	11	12	13	13	14	14	14	15	15	15	15	16	16	16	16	16	16	16	16	16	16	17	17	17	17	17
18	6	9	11	12	13	14	14	15	15	15	16	16	16	16	17	17	17	17	17	17	17	17	17	17	18	18	18	18
23	7	11	13	15	16	17	17	18	18	19	19	20	20	20	21	21	21	21	21	22	22	22	22	22	22	22	22	22
24	7	11	13	15	16	17	18	18	19	19	20	20	21	21	21	22	22	22	22	22	23	23	23	23	23	23	23	23
25	7	11	14	15	17	18	18	19	20	20	21	21	22	22	22	23	23	23	23	23	24	24	24	24	24	24	24	24
30	8	12	15	17	19	20	21	22	23	23	24	25	25	26	26	26	27	27	27	28	28	28	28	29	29	29	29	29
32	8	12	15	18	20	21	22	23	24	24	25	26	27	27	28	28	28	29	29	29	30	30	30	30	31	31	31	31
35	8	13	16	19	21	22	23	24	25	26	27	28	29	29	30	30	31	31	31	32	32	32	33	33	33	34	34	34
43	8	14	18	21	23	25	27	28	29	30	32	33	34	35	35	36	37	37	38	38	39	39	40	40	41	41	41	41
51	8	14	19	22	25	28	30	31	33	34	36	37	39	40	41	42	42	43	44	45	45	46	46	47	48	48	48	49
68	9	15	21	25	29	32	34	37	39	40	43	46	48	49	51	52	53	55	55	57	58	59	60	61	62	63	63	64
72	9	16	21	26	30	33	35	38	40	42	45	48	50	51	53	55	56	57	58	60	61	62	63	64	65	66	67	67
96	9	17	23	28	33	37	40	44	46	49	53	57	60	63	65	67	69	71	73	75	77	79	81	83	84	86	87	88
98	9	17	23	28	33	37	41	44	47	49	54	58	61	63	66	68	70	72	74	77	79	80	82	84	86	87	88	89
138	9	17	25	31	37	42	46	51	54	58	64	69	74	78	82	86	89	92	95	99	103	106	108	112	115	118	120	121
204	10	18	26	33	40	46	52	57	62	67	76	83	90	96	101	107	112	117	121	129	135	140	145	152	158	163	166	169
272	10	19	27	35	42	49	56	62	68	73	83	92	101	108	115	123	130	137	143	153	162	170	176	187	196	203	209	214
288	10	19	27	35	43	50	56	63	69	74	85	94	103	111	118	126	134	141	147	158	167	176	183	195	204	212	218	224
384	10	19	28	36	44	52	59	66	73	79	91	103	113	123	132	142	151	160	168	183	196	207	217	234	248	259	269	277

Appendix E

Sample Site Selection Worksheet Example

EXAMPLE: Sample Site Selection Worksheet									
X-Sect #	SP1	SP2		X-Sect #	A	B	C	D	
1	2	2		1	2				
2	5	4			5				
3	2	2				2			
4	17	6			17				
5	2	2					2		
6	1	1		6	1				
7	3	3				3			
8	14	5			14				
9	9	4			9				
10	1	1		10			1		
11	1	1		11		1			
12	2	2		12	2				
13	16	6			16				
14	3	3			3				
15	4	4				4			
16	2	2					2		
17	1	1					1		
18	2	2		18				2	
19	19	6		19	19				
20	5	4			5				
21	11	5		21		11			
22	15	6			15				
23	8	4		23	8				
24	2	2			2				
25	14	5			14				
26	4	4		26		4			
27	2	2		27			2		
28	3	3				3			
29	3	3						3	
30	7	4					7		
31	11	5		31	11				
32	3	3				3			
33	4	4			4				
34	2	2			2				
35	1	1		35	1				
36	2	2			2				
37	2	2			2				
38	2	2		38		2			Total
	207	120		# Monitors	44	18	3	2	**67**
				# XS	21	9	6	2	38
Target	N*	N*/SP1		Random #	1	3	2	1	
96	**66**	**31.68%**						(< 10%)	
						Not Sampled			
Sampling Ratio					3	Random systematic sampling strategy			
Sample 1 of every 3 cross sections					2	Randomly added sample to meet N*			
						or 2 spawning habitat type criteria			

Appendix F

Standard Field and Vehicle Gear Checklist Copy Master

(Keep original copy master with manual)

Appendix F

✓ STANDARD FIELD GEAR

- ❑ Field clip board/form holder
- ❑ Survey Forms (on waterproof paper)
- ❑ Copy of survey methods
- ❑ Maps- topographic and road
- ❑ Pencils & erasers
- ❑ Permanent ink marker
- ❑ Calculator
- ❑ 150 mm ruler
- ❑ Pocket field notebook

- ❑ Survey Vest
- ❑ Compass
- ❑ Safety whistle
- ❑ Spring clips (2)
- ❑ Vinyl flagging
- ❑ Pocket knife/multi-purpose tool

- ❑ Backpack or canvas tote bag
- ❑ First aid kit
- ❑ Water bottle and/or filtration system
- ❑ Food/energy bars
- ❑ Rain gear
- ❑ Leather gloves
- ❑ Safety glasses
- ❑ Bug repellant
- ❑ Sun screen
- ❑ Small flashlight or headlamp
- ❑ Matches/fire starter
- ❑ Emergency blanket
- ❑ Snake bite kit (eastern Washington)

✓ STANDARD VEHICLE GEAR

- ❑ Waterproof plastic tote box
- ❑ Backup fiberglass tape
- ❑ Comprehensive first aid kit
- ❑ Rain tarp
- ❑ Rope (100 ft.)
- ❑ Extra water
- ❑ Extra food
- ❑ Extra dry clothes
- ❑ Extra batteries
- ❑ Spare tire/jack/tire iron
- ❑ Tire sealant/inflater
- ❑ Tow strap
- ❑ Come-along winch
- ❑ Fire shovel
- ❑ Fire extinguisher
- ❑ CB radio (to monitor logging activity)
- ❑ Cell phone/VHF radio
- ❑ Brush cutter
- ❑ Ax/bow saw/chain saw
- ❑ Tire chains

For remote work, extra survival & safety gear is recommended.

This gear list is provided as a guideline for outfitting field crews and is not intended to cover all situations. Local conditions may require additional or different gear.

Appendix G

Data Management Example

Excel Data Entry Spreadsheet File Headers

APPENDIX G

EXAMPLE: Excel Data Entry Spreadsheet File Headers

TFW Monitoring Program

Spawning Gravel Scour Survey Header — **Form 10.0** — scrhd.xls

wria basin	wria stream	trib	segm	sub segm	begin survey date	end survey date	leader first name	leader last name	leader affil	recorder first	recorder last	recorder affil

>>>>

begin river mile	end river mile	begin ref pt	end ref pt	survey length	survey coverage	survey percent	field notes

TFW Monitoring Program

Spawning Gravel Scour Survey Peak Discharge Data — **Form 10.0** — scrpkdis.xls

wria basin	wria stream	trib	segm	sub segm	begin survey date	peak discharge date	peak discharge	measureme nt unit	field notes

TFW Monitoring Program

Spawning Gravel Scour Survey Cross-section Data — **Form 10.2** — scrcross.xls

wria basin	wria stream	trib	segm	sub segm	begin survey date	cross-section number	downstream reference point	habitat type	gravel obstruction type	pool-riffle sequence number	cross-section width	right bank pin description

>>>>

right bank compass bearing	left bank pin description	left bank compass bearing	photo roll number	photo frame number	field notes

TFW Monitoring Program

Spawning Gravel Scour Survey Pebble Count — **Form 10.3** — scrpebct.xls

wria basin	wria stream	trib	segm	sub segm	begin survey date	cross-section number	count date	particle size class	pebble tally	field notes

TFW Monitoring Program

Spawning Gravel Scour Survey Scour and Bed Elevation Data — **Form 10.4** — scrdata.xls

wria basin	wria stream	trib	segm	sub segm	begin survey date	cross-section number	inspection date	scour monitor number	tape distance	scour depth (r	bed elevation	bed elevation measureme nt unit

>>>>

field notes