**Cooperative Monitoring, Evaluation, and Research Committee (CMER)**

# Final Report

For the

# Status and Trend Monitoring for Fish Passage in Washington Forestlands: Methodology Review and Preferred Study Design

**With Study Options Attachment**

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for the
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## Background

The Forests and Fish Report (FFR 1999) outlines an agreement where the performance target was that all fish passage barriers on Washington private and stated owned forestlands will allow for the passage of fish at all life stages within 15 years. The provisions within FFR were subsequently codified in statute (RCW 76.09) and state rules (WAC 222-24).

The Cooperative Monitoring, Evaluation, and Research Committee (CMER) is responsible for implementing the monitoring of FFR performance targets. Status and trends monitoring of fish passage is an important priority among CMER's monitoring responsibilities. Within CMER, status and trend monitoring is often referred to as 'extensive monitoring', and will be used as such throughout this document.

## Introduction

Extensive fish passage monitoring will assess progress in meeting the performance target of providing passage for fish in all life stages at road crossings on state and privately owned forestland through time. With the completion of the Monitoring and Design Team report (MDT 2002), CMER has a statistically rigorous approach to monitoring fish passage for status and trends. Recently, alternative monitoring designs that may reduce costs or provide greater statistical rigor have been suggested. We examined two broad categories of monitoring approaches: one was based on using existing regulatory processes for RMAPs that landowners must follow but was not designed as an extensive monitoring program, and the other was based on developing a new program specifically designed to status and trend data.

The Washington Department of Fish and Wildlife (WDFW) was contracted to examine study designs for the fish passage extensive monitoring program that would answer these primary questions: (1) are fish passage barriers on private and state forestlands declining over time? and (2) have fish passage barriers been eliminated on forestland 15 years after the adoption of rules implementing the FFR.

We examine cost-benefit of two basic approaches:

1. Use the RMAP process (i.e., an landowner inventory of stream crossing) to examine status and trends of fish passage, and
2. Develop a sampling program, independent of RMAP and similar to the MDT design, of stream crossings from all forestlands.

<u>Small Land Ownerships</u>

Our assessment of approaches is currently limited to private timberlands where stream-crossing data are either known or can be obtained. The extent of these lands currently includes large forest landowners, but excludes most small forest landowners[1]. As of May

[1] Defined in RCW 76.09 as those landowners that have harvested or expect to harvest less than 2 mbf of timber from their own property.

2003, small forest landowners are not required to submit RMAP information about their road conditions, including fish passage crossings, to the Department of Natural Resources (DNR). Because small forest landowners do not submit inventories of stream crossings on their lands, and statewide databases identifying the location of small forestland parcels do not currently exist, we designed a program that excludes monitoring fish passage barriers on these ownerships.

The absence of small forest landowner data from a monitoring plan reduces the area for which we can make inference (estimated at approximately 4.2 million acres). Recently, the DNR and CMER have initiated efforts to map the location of small forest landowner parcels. If these efforts are successful, we recommend that ISAG and CMER revisit the feasibility of a fish passage monitoring program for small forest landowners as soon as possible. We believe that our assessment of a preferred sampling approach would be as valid for small forestland owners as it is for industrial landowners all else being equal. Importantly, costs and sampling bias may increase when access to property is denied, as we expect with greater frequency among small forest landowner parcels. Small ownerships have a different time frame in which to complete their fish passage work than for larger forest landowners. Therefore, when a monitoring plan is implemented, there is strong reason to report the data and results separately.

## WDFW's Preferred Study Design: Single Random Sampling with Partial Replacement (SRSPR)

Single random sampling with partial replacement (SRSPR) is designed to maximize the geographic spread of samples in Washington while improving trend detection by resampling a percentage of road crossings through time. Whereas maximum trend detection is obtained by sampling the same sites repeatedly over time, status information is best obtained by sampling a maximum number of locations. When both objectives are desired at regional scales, a sampling scheme with partial replacement is known to have a robust statistical foundation with precision and flexibility (Skalski 1990).

One hundred sites in western Washington will be sampled in years 1, 3, 5, 10, and 15, beginning in 2005. Likewise, 100 sites will be sampled in eastern Washington in years 2, 4, 6, 11, and 16. Postponing eastern Washington fieldwork allows additional time for the fish habitat model, or alternative system development in that region. This is important because the fish habitat model defines the upstream end of the area from which samples will be drawn. Sampling frequency is greatest early in the study. It may be important to detect trends sooner in the study so that adaptive management can occur if results are different than expectations. Additionally, because substantial effort has been applied to fish passage barrier repairs since 1999 or before, and trends will be statistically more difficult to detect in later years of the study, it is important that the study begin quickly with frequent sampling intervals.

An additional 200 sampling sites will be selected in western and eastern Washington as a reserve to allow for sites that cannot be accessed, sites that are not forest roads, sites with specific stream typing changes (see below), or sites that cannot be evaluated for other reasons.

The Environmental Protection Agency (EPA) will select random sample locations on streams with ISAG and DNR support using the Environmental Monitoring and Assessment Program (EMAP) sampling scheme. The EMAP approach provides a well-established methodology to obtain random and spatially balanced sample locations of forested stream reaches from GIS-based stream networks (Larsen et al., 2001; Peck et al., 2001; Fausti et al., 2004; and Larsen et al., 2004). The nearest forest road crossing to each selected location becomes the sample fish passage structure.

It may be that repaired fish passage projects are more likely to exist near other repaired projects than might occur by random chance (and vise versa) because landowners probably will concentrate their efforts in a specific area rather than in a random fashion. To minimize this potential bias in sampling, EMAP sampling utilizes an artificial dispersion mechanism to ensure that randomly selected sites are not clustered, thereby minimizing autocorrelation concerns without jeopardizing randomness. The SRSPR design is statistically rigorous, and can be initiated immediately. Of course, nonclustered samples will increase travel costs.

The SRSPR sampling design uses a rotating panel strategy (Skalski 1990). Except for the first and last sample year, approximately 66% of sites will be resampled the following sample year. Additionally, 33% of sites will be sampled in two consecutive periods. No sites will be sampled more than three times. Repetitive sampling with replacement, or rotating panel design, has multiple benefits. First, variance estimates are more precise because variability can be accounted for in two ways, including among-year variability, so there is greater confidence in the data. Second, there may be reduced time relocating sites after the first year because a portion of the sites would be revisited. Third, repetitive sampling allows for an estimate of the proportion of repaired barriers that subsequently fail. Although failure rates for road crossings have been previously described in forest environments (Cafferata et al., 2004; Furniss et al., 1998), failure rates have not been quantified for crossings under current upgraded forest road standards.

Conceivably, the rotating panel design could result in bias if areas scheduled for resample receive greater repair effort than unsampled areas. While we do not believe this is of great concern we have the ability to examine differences between re-sampled and newly sampled data using simple ad hoc comparisons.

Sites will be randomly assigned to one of three sample bins. Bin A will contain sites that are assessed only during the first sample year. Bin B will contain sites that are sampled during the first year, and again on the second sample year (i.e., year 3 in western Washington). Bin C will contain sites that are sampled for 3 consecutive sample years. After each sample year, sites in Bin A are not sampled again, sites in Bin B move to Bin A, sites in Bin C move to Bin B, and 33 new sites from the randomized list are assigned to Bin C (Figure 1).

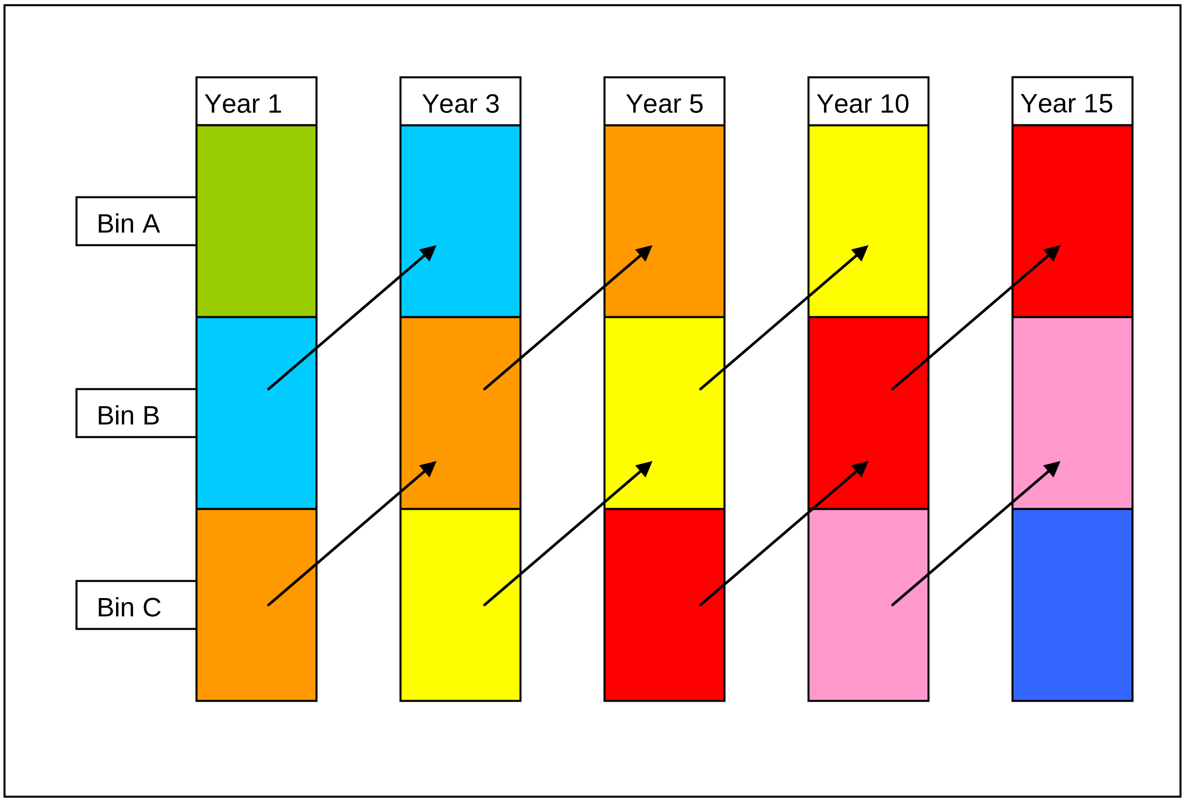


**Figure 1**. WDFW's preferred sampling design for western Washington. Thirty-three sites are randomly assigned to each of three bins in Year 1. Those sites are sampled again in subsequent years as diagramed. Sites within Bin A in Year 1, and Bin C in Year 15 are sampled only once. The Eastern Washington sampling design is similar except sample years are 2, 4, 6, 11, and 16.

**Technical Methods**

The nearest road crossing to each randomly selected site will be determined using a combination of GIS, aerial photos, ortho-photos, and DNR Forest Practice maps. For each site the 2-person field crew will identify the most efficient access route, contact the landowner to gain permission and access to the site (including obtaining necessary keys), and determine how to most efficiently incorporate the sampling site into the overall sampling plan.

To insure that crews sample the fish passage structure closest to the randomly selected point, they will walk the stream from the nearest identified road crossing using aerial photos to the selected point. The nearest identified forest road crossing to the randomly selected point will be evaluated regardless of RMAP status, or whether it is actively used, abandoned, or orphaned.

Fish passage barrier /non-barrier status at each stream crossing will be determined by WDFW's Hydraulic code criteria (WAC 220-110-070), as referenced in DNR's current rules (WAC 222-24-010). Assessments at each crossing will be conducted using the WDFW barrier assessment protocol (WDFW 2000), replacing streambed toe width with bankfull width. CMER has requested that additional data be collected concurrently so that analyses of stream simulation or other thresholds of fish passage could be analyzed in the future. To ensure that potential stream simulation analyses can be conducted with the data, representative reach gradient will be obtained at each site. Also, to accommodate FishXing (USFS 1999) and level B (WDFW 2000) analyses, downstream reach cross sections will be conducted where backwater occurs at individual stream crossings (see guidance in WDFW 2000). At each crossing the following variables will be measured or evaluated.

**Table 1**. Data collected at each stream crossing with associated fish passage barrier thresholds.

| Variable | Criteria | Barrier Threshold[2] |
|---|---|---|
| Hydraulic drop at outfall of structure | | > 0.8 feet |
| Minimum flow depth in structure (without natural stream bed) | | < 0.8 feet |
| Velocity | culverts less that 100 feet in length | > 4.0 fps |
| | culverts 100 to 200 feet in length | > 3.0 fps |
| | culverts longer than 200 feet | 2.0 fps |
| Reach gradient | 100 m up- and downstream | N/A |
| Bankfull width | | N/A |
| Bankfull depth | Collected only where backwater at the culvert outlet is present. | N/A |

Selection of sample sites will occur using GIS layers of the fish habitat model and forestlands, provided by DNR. Invariably, observations in the field will deviate from GIS data layers. In addition, the delineation of forestland and forest roads may be unclear in some regions, especially in eastern Washington where agriculture activities are frequently integrated with forest-related activities. To ensure that individual samples fall into areas regulated by DNR forest practices, a DNR forester or RMAP specialist will review each site prior to sampling. Often, this will be an office exercise where landownership or terrain is obviously recognized as falling within DNR's regulatory jurisdiction. Where jurisdiction is less certain, field visits by DNR may be required. To maximize efficiency, EMAP sites will be selected, and aerial photos consulted prior to contacting landowners and DNR RMAP specialists for any additional information.

The extensive fish passage monitoring program will make use of the new Fish Habitat Model and GIS layer. Using the model will mean making some informed choices about how prediction errors can be overcome. In many cases the model over- or underestimates fish habitat. Additionally, some streams remain unmodeled. Often, these errors are in

[2] Determined by WDFW's Hydraulic code criteria (WAC 220-110-070). Fish passage barrier assessments are made relative to the fish passage criteria for a six-inch trout.

headwater streams, which could impose a bias in the sampling design. Sampling from headwater streams is important because many contain fish habitat. However, it is important to safeguard against over-sampling these streams because many are not fish bearing. We propose that where a modeled end of fish habitat point exists on a stream, the point serves as the uppermost point of the sampling frame for selecting EMAP points. Where streams lack a modeled point, we propose that the existing water type maps, using designations 1 – 4, be used to complete the EMAP sampling frame. To decrease the likelihood of assessing fish passage in non-fish habitat streams, Type 4 streams that are sampled will be verified with fish presence/absence protocol surveys. Landowners will be contacted to obtain additional stream typing information prior to the initiation of surveys. ISAG and DNR are currently developing stream-typing protocols, which may necessitate further discussion with ISAG prior to implementing this protocol. We expect that the need to verify Type 4 streams where EMAP sample points exist to be an uncommon event. Although stream classifications are subject to change as knowledge about fish and fish habitat increases, stream typing will not be verified for streams that have modeled or empirically derived end of fish points prior to sampling due to associated costs. Instead, all samples will be georeferenced and included in a database so that future changes to stream classifications can be reviewed annually using a simple semi-automated computer procedure. Specifically, if samples are collected on stream segments that later change from fish habitat to non-fish habitat within the 15-year sample period, then those samples could be dropped from analyses. Stream segments that are changed from non-fish habitat to fish habitat during the course of the study will not be considered in the sampling frame.

Some road crossing repairs can be difficult to detect over time. Because abandoned road crossings, temporary culvert sites, and fords can become revegetated years after they are removed, all samples will be compared with georeferenced data that exists from DNR's RMAP specialists and landowners, as possible. In addition, agreements are made in rare cases among landowners, WDFW biologists, and DNR staff where individual fish passage barriers are not required to be replaced (i.e., "excused") within the 15-year RMAP period. These instances have most commonly occurred near the uppermost extent of fish habitat, and immediately above or below natural fish passage barriers. To ensure that these data are not included in the trend analyses, georeferenced sample sites will be compared with DNR RMAP data, landowner data, and WDFW data after each sample season.

## Statistical Methods

*Trend Analyses*

A linear regression model will be employed after the third sample year to test if the proportion of fish passage barriers is decreasing through time. The linear model for the regression analysis is simply,

$$f\left(p_{Bi}\right) = \alpha + \beta * year_i ,$$

Where $p_{Bi}$ is the percentage of road crossings that are barriers in the $i^{th}$ survey year and where $f\left(p_{Bi}\right)$ increases or decreases with $\hat{p}_{Bi}$. The slope ($\beta$) is the rate of change of

$f\left(p_{Bi}\right)$ and $\alpha$ is the value of $\hat{p}_B$ estimated from the first survey, year 0. A slope, ($\beta$) of less than zero indicates a reduction in $p_B$ over time. Power for detecting a trend in the regression analysis comes from two sources: the sample size of the surveys in each year, and the spread in time over which the surveys were conducted. Increases in either or both of these will increase the ability to detect trends. Conversely, approaches using pairwise comparisons of $p_B$ among survey years merely depend on the sample sizes in each of the two surveys. Hence, the pairwise comparisons may be less sensitive to changes in $p_B$ over time. Subsequently, after the third year's survey, we would test for trends in $p_B$ using regression methods.

The current regulations require that barriers to fish passage be zero (or 5% for practical testing purposes) by 2016. One alternative to the simple hypothesis that the slope is less than zero, is to test that the rate in the reduction of $p_B$ follows a trajectory that will yield a $p_B$ = 0.05 by year 15, for a given starting value in year 0. For example, if in the first survey year the percentage of road crossings that were fish barriers was 50% ($p_{Bi} = 0.50$; $\ln\left(\dfrac{0.50}{1-0.50}\right) = 0$), then the slope would have to be equal to -0.1963 to arrive at $p_{B,15} = 0.05$ by year 15. Assuming these values, the hypothesis test would be written as follows, $H_o : \beta \geq -0.1963$ vs. $H_a : \beta < -0.1963$. The hypothesis, that the percentage of road crossings that are barriers will be 0.05 by year 15, will be initially tested in the third year, and again after each survey year with appropriate values. The analysis is not predictive, but rather a test in an observed rate reduction in $p_B$.

Due to the nature of proportional data, analysis of trends would require the use of logistic regression where $f\left(p_{Bi}\right) = \ln\left(\dfrac{p_{Bi}}{1-p_{Bi}}\right)$. More detail on logistic regression can be found in McCullough and Nelder (1989, pp 98:135) and Neter et al. (1996 pp 573:580). Repeated sampling of some sites will mean that observations will be correlated between years. This will effect the variance of the slope, though not point estimates. Hence, a random intercept, common slope regression model will be used to make inferences about the overall trend in $p_B$. This type of mixed effect model accounts for the correlation between observations (Diggle et al., 1995; pp 146:162).

After each sample year, the variance of the slope is calculated to test for a reduction of the proportion of fish passage barriers. The variance of the slope estimate in the SRSR design, $\hat{\beta}$, is proportional to the spread of the data as follows:

$$Var\left(\hat{\beta}\right) \propto \frac{1}{\sum_{i=1}^{n} v_i^2 \left(x_i - \overline{x}\right)^2},$$

where $v_i^2 = p_{iB}\left(1 - p_{iB}\right)$, and

$x_i$ = the survey year and

$n$ = the number of surveys.

Increases in the number of surveys conducted, and carrying out surveys over a long period will decrease the variance and increase the precision of the slope estimate (Larsen et al. 2001).

A t-test is subsequently used to test for reductions in $p_B$ as follows:

$$t_{df,\alpha/2} = \frac{\hat{\beta} - \beta_0}{\sqrt{Var\left(\hat{\beta}\right)}}$$

where $df$ = the degrees of freedom, equal to $n-2$ and,

$\beta_0$ = the hypothesized slope.

Based on the sample size calculations in the MDT report, sample sizes of 100 allow us to detect a difference of 0.2 for proportions between 0.2 and 0.8 at $\alpha = 0.05$ and power of 0.9, using a simple z-test for the 2 proportions. However, as the numbers of fish passage barriers decrease, differences in $p_B$ become smaller as $p_B$ tends toward 0.05. Therefore, sample sizes will need to increase dramatically in order to detect small differences in low values of $p_B$ with the same significance level and power. As differences become small, it may be advisable for CMER to consider the benefits of calculating differences in such small values with the costs of conducting surveys. We suggest using a minimum sample size of 100 for at least the first two surveys to test for a reduction. Future sample sizes can be calculated after initial sample years. To minimize the likelihood of falsely concluding that significant reductions in fish passage barriers has occurred, we suggest conducting all tests at the $\alpha = 0.10$ level, which reduces the probability of type II errors, increasing power. A reduction in type II errors will be more protective of fish habitat.

*Status Analyses*

Once the percentage of road crossing that are barriers is near 5%, status monitoring can be used to test a second hypothesis that $p_B$ remains near 0.05. Power calculations to estimate sample size require a predetermined minimal detectable difference or effect size. However, no effect sizes were given in the MDT report. Below is a table of sample sizes needed for a given effect size, $\Delta$, $\alpha$ and power $(1-\beta)$ (Table 2). Sample sizes were calculated using S-Plus 6.2 (Insightful 2001). Note that the rejection region for the test would be when $p_B \geq 0.05 + \Delta$. To minimize the risk of type II errors (concluding that $p_B$ □□ 0.05 when in fact it isn't), we suggest using $\alpha = 0.10$ and $\beta = 0.10$. For example, to obtain confidence that the proportion of fish passage barriers on forested landscapes was less than 5% ±5%($\Delta$), a sample size of 217 culverts is required.

**Table 2**. Sample sizes needed to test the second hypothesis for different levels of $\alpha$ and power $(1-\beta)$.

| | $\Delta = 0.02$ | $\Delta = 0.03$ | $\Delta = 0.04$ | $\Delta = 0.05$ |
|---|---|---|---|---|
| $\alpha = 0.05$ $\beta = 0.20$ | 922 | 450 | 275 | 190 |
| $\alpha = 0.10$ $\beta = 0.10$ | 1019 | 504 | 311 | 217 |
| $\alpha = 0.10$ $\beta = 0.20$ | 711 | 353 | 220 | 154 |

It is essential that WDFW and DNR routinely provide their in-house data for analyses. WDFW and DNR data allow for comparisons of road crossings that are cooperatively agreed as 'unnecessary to replace' (i.e., "excused") within the 15-year time frame. As described earlier, these situations are rare, but should not be included in statistical trend analyses. In the event that an excused structure is selected as a random sample point, then the location of the structure will be recorded, and a cumulative total of such events will be reported as a separate statistic after each sample year. Additionally, as individual DNR stream classifications change with increased fish habitat information, stream crossing status information may become more or less relevant. Therefore, cross-referencing DNR spatial data is needed to ensure appropriate data inclusion. Likewise, landowner data will be especially useful in appropriately determining fish passage status on forestlands prior to 2005.

## Alternative Designs Considered in the Extensive Fish Passage Monitoring Program

**The RMAP Tracking Approach**

We examined the possibility of using RMAP tracking as a status and trend monitoring approach in lieu of or in support of a sampling program described above. RMAP tracking would take advantage of an existing regulatory system – the mandated reporting of road maintenance and abandonment plans. RMAP tracking is probably less costly than alternative approaches. Under RMAP rules, large forest landowners have 5 years, until 2006, to plan their maintenance and repairs and 15 years, until 2016, to make those changes. Planning and subsequent work must generally follow an even flow over these periods. Orphan roads must be inventoried by 2006, but maintenance and repair schedules for these roads are not defined by the FFR at this time. Additionally, beginning in May 2003, landowners that harvest trees at a rate of less than 2 million board-feet/year on average are exempt from most RMAP rules, including inventory requirements.

Landowners, DNR, and WDFW all have highly trained staff currently engaged in collecting, analyzing and prioritizing fish passage structures for maintenance or repair. Conceptually, RMAP tracking could obviate the need to hire or contract additional staff and resources. Additionally, RMAP tracking may yield faster trend detection. Using RMAP data could mean that annual analyses of trends would be conducted, providing prompt information to adaptive management processes. Data collected using the RMAP tracking approach may be concurrently useful in satisfying compliance monitoring obligations under FFR. RMAP tracking would also allow trend detection in each of the six DNR regions in addition to statewide reporting. Lastly, using RMAP tracking would be more informative about conditions pre-2005 because data have been collected since 2001 or before. Reportedly, most large forest landowners have made substantial progress in repairing fish passage barriers on their ownership since the signing of the FFR agreement in 1999 (R. Ramsdell, DNR, pers. comm.). By using the RMAP tracking approach, these fish passage crossings become part of the trend data. Without added effort, alternative approaches would merely consider repaired crossings as part of the current status of fish passage structures, substantially underestimating the progress that has been made to date.

Despite its potential advantages we believe that insurmountable problems currently preclude RMAP tracking as a stand-alone monitoring program.

An extensive fish passage monitoring program taking advantage of the RMAP tracking system already in place must rely on a complete inventory of the fish passage structures within forestlands or a randomly obtained subset drawn from the area to which inference will be made. Meeting one of these two criteria is important if we are to obtain a non-biased sample of passage structures. Unfortunately neither of these conditions is likely to be met at least until 2006 at the earliest. A census of stream crossings would allow a simple proportion of barriers to all crossings to be represented each year. Progress would be easily measured if the proportion of barriers were less each year. In the absence of a complete census, the RMAP data could be used to develop a sampling scheme if the data were not biased. Unfortunately, orphan roads and headwater stream crossings are more commonly cited omissions from some RMAPs (R. Ramsdell, DNR; S. Kolb WDFW, pers. comm.). Although considerable effort has been made on the part of large forest landowners, some landowner representatives cite expansive ownership, low GIS sophistication, and the difficulty of assessing orphan roads as some reasons for incomplete RMAP inventories (R. Ramsdell, DNR, pers. comm.).

<u>Suggested Modifications to the RMAP Process to Improve Status and Trend Monitoring</u>
We believe that a sampling methodology is the most effective approach to establishing a status and trend monitoring scheme in Washington forestlands. Our decision was based on our understanding of limitations to the RMAP process and the need for an expeditious implementation plan. However, improvements in the RMAP tracking approach may yield productive results in an already established program for large ownerships. We offer the following suggested improvements to facilitate policy discussions.

1. Centralized database tracking. Although some DNR regions have designed useful databases for their regions, some regions currently track RMAP

progress on paper forms and maps. A digital and centralized database would greatly enhance monitoring capabilities.

2. Randomized sub-sampling of RMAP crossings. For monitoring purposes, the accuracy and completeness of RMAPs could be better understood by randomly selecting landowner road 'blocks' and sub-sampling stream crossings in the RMAP.
3. Standardized data collection. Landowners currently provide stream crossing information on standardized forms and maps. However, in a monitoring context, specific stream crossing information is often variable. Additional and specific information collected consistently would improve monitoring capabilities within the RMAP program.
4. Effective information transfer from DNR to CMER. Data collected by DNR as part of the RMAP process would be need to be transferred to CMER to facilitate statistical analyses and report writing.
5. Data analyses within CMER. CMER would either need to assign existing staff or contract data analyses and report writing.
6. An alternative strategy for small land ownerships. Each of the sampling designs evaluated are capable of being used for status and trend monitoring for small forest landowners as data layers improve. Unfortunately, RMAP inventory data are not useful to describe status and trends in these ownerships. An alternative strategy, such as our preferred SRSPR design, would still be necessary as an extensive monitoring approach in small forest land ownerships.

Alternative EMAP Sampling Approaches

In addition to WDFW's preferred design, we examined three additional approaches using the EPA's EMAP sampling methodology.

EMAP Cluster Sampling designs

The cluster sampling design has been discussed among ISAG members as having two potential benefits over simple random sampling designs. By collecting data at multiple road crossings from a single sample site, more culverts can be surveyed within a year than by simple random sampling, potentially increasing field crew efficiency. Additionally, cluster sampling has been discussed as a possible method by which statistical inference may be greater than simple random sampling. We examined two sub-approaches to cluster sampling using the EMAP method of selecting samples.

Block Cluster Sampling Sub-approach (BCS)

Block cluster sampling (BCS) requires that a set area be defined and sampled for all road crossings within the block. To evaluate the BCS approach, we blocked various sizes of spatial polygons of forestland and attempted to estimate the effort needed to inventory all road crossings within the area. In order to avoid bias in this approach, all crossings in the block must be assessed to avoid selective sub-sampling. We did not quantify the effort to complete such surveys because field efforts searching for road crossings (past and present) would absorb much more time than other methods. Randomly selecting polygons, even within sub-watersheds, often spanned drainage boundaries, substantially increasing field reconnaissance efforts. We believe that the minimum 40 sites could not be sampled within one year using this design without substantially increasing effort and cost by using multiple crews. As we decreased the size of the polygons to minimize the search for all road crossings within the block, the BCS design more closely resembled, though never attained, the logistic efficiency of the other sampling approaches.

Random Cluster Sampling Sub-approach (RCS)
The second sub-approach to cluster sampling is similar to a single random sampling design, except multiple road crossings are inventoried at the EMAP selected site. For example, once a site was selected, the closest 3-5 road crossings might be surveyed. This method has logistical advantages over the block cluster design because field crews are searching for road crossings along a stream corridor and do not cross basin divides.

Importantly, however, the random cluster design is less statistically robust than single random sampling. Landowners commonly repair fish passage structures within road blocks to maximize operational efficiency. While this strategy conserves resources, it adds non-independence concerns for sampling purposes because the repair status of crossings is more likely to be similar for neighboring structures. Simply, landowners are likely to repair barriers in close proximity to other barrier repairs. The resulting autocorrelation increases variance within each sample. We compared the statistical relationships of RCS to single random sampling below.

*Statistical considerations of the cluster sampling designs*
Cluster sampling involves the selection of a fixed area (block) size and sampling all road crossings within that area (block cluster design), or a site on a stream and inventorying only the first $M$ road crossings encountered on that stream (Random Cluster Sampling). For the RCS design, the proportion of road crossings that are barriers to fish passage, $P_B$, is estimated as follows,

$$P_B = \frac{\sum_{i=1}^{nM} x_i}{nM}$$

where $x_i$ = the number crossings that are barriers out of $M$,
$M$ = cluster size,
$n$ = the number of clusters (sites) visited.
Under the assumption that all streams, or points on a stream have an equal probability of selection, and thus all possible clusters have an equal probability of selection (although, see autocorrelation concerns above), $P_B$ should be unbiased, and equal to a simple random sample of choosing $nM$ road crossings from the population.

However, differences in sampling will result in differences between variance of $P_B$ obtained by cluster sampling ($Var_{clust}(P_B)$) and the binomial variance obtained by a single random sampling, ($Var_{SRS}(P_B)$). We can compare the two variances by the following ratio (Cochran 1977: 247) to demonstrate that cluster sampling has greater variance with increasing road crossings sampled than a single random design:

$$\frac{Var_{clust}\left(p_B\right)}{Var_{SRS}\left(p_B\right)} = \frac{M\sum_{i=1}^{n}\left(p_{Bi} - P_B\right)^2}{NP_{\mathbf{B}}\left(1 - P_B\right)},$$

where $N$ = total number of clusters in the population.

We ran 100 Monte Carlo simulations for each fixed cluster size, between 3 and 9 road crossings, for each of 40 sites against single random sampling. Values in the above ratio greater than one indicate that less precise estimates are obtained by cluster sampling than simple random sampling. Our simulations resulted in the variance ($Var_{clust}\left(P_B\right)$) being consistently greater than the single random sample variance ($Var_{SRS}\left(P_B\right)$), indicating that cluster sampling yields less precise estimates of $P_B$. In all simulations, values of the above ratio were always greater than 1.

<u>Single Random Sampling (SRS) design (MDT Report recommendation)</u>

The MDT Report recommends a sample design that maximizes the spread of randomly selected sites. The study design calls for a random sample of culverts across the state of Washington, selected by choosing 100 points along fish bearing streams and assessing the nearest road crossing. Metrics for establishing the current condition of culverts across the state are based on the percentage of culverts that are barriers to fish passage. In the MDT report, surveys of culverts are proposed to occur in years 1, 5, 10, 15, and in year 7 if statistically significant differences are not observed between years 1 and 5.

*Statistical Considerations of the SRS Sampling Design*

The MDT report proposes a statistical analysis consisting of testing the hypotheses that the percentage of fish barriers observed in the most recent survey was less than in previous surveys in pairwise comparisons, e.g., $p_B$ in yr. 10 versus $p_B$ yr. 5. Once the difference between the comparisons ( $p_B$ ) is small (approaching 0.05), the hypothesis changes to testing that the percentage of impassible road crossings across the state is less than 5%. The first and second hypotheses, respectively, can be expressed mathematically as follows:

1. $H_o : p_{Brecent} \geq p_{Bprevious}$ vs $H_a : p_{Brecent} < p_{Bprevious}$ and
2. $H_o : p_B \leq 0.05$ vs $H_a : p_B > 0.05$.

The first hypothesis is essentially a trend analysis whereas the second test is to determine the status of repaired barriers. Tests for the first hypothesis, that the most recent estimate of $\hat{p}_B$ is less than previous years $\hat{p}_B$, consists of pairwise comparisons between years. Once the percentage of road crossing that are barriers is near 5%, status monitoring begins to test the second hypothesis that the $p_B$ remains near 0.05.

The MDT report proposes a suitable design for extensive monitoring of fish passage on forestlands. However, we believe that improvements can be made in the technical, field and statistical applications of this methodology. The SRSPR approach can detect trends sooner, and with greater statistical robustness than using other approaches. Additionally, the SRSPR design provides a mechanism to report failure rates of improved road crossing standards, and provides a cost effective approach to initiate compliance monitoring.

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**<u>Attachment 1.</u>**

**Estimated Budget and Assumptions**

- We estimate that for each EMAP point, approximately 1.5 hours/site will be required to identify the EMAP location on the ground, determine the nearest road crossing, determine ownership, and gain permission to access the stream. We assumed that less than 20% of sites would not be sampled for reasons determined once crews were on-site. Therefore, we assumed that 125 sites would receive a field visit.

- To standardize estimates, we assumed that a field crew consisted of a mid-level biologist and mid-level assistant. We assumed that a field crew could survey an average of one site per day, plus 10% administrative time (training, sick leave, annual leave accrual, etc.). The selected sites will be distributed over 3.56 million acres (5,500 square miles) of FFR lands in the state, so travel time will be substantial. Some forestlands may be in close proximity to the identified duty station or to nearby lodging facilities, while others may be a full travel day from the duty station to the nearest sample site. We estimate that between 0.5 and 3 sites per day will be completed.

- We apportion staff resources in the following tables.

- Equipment costs (truck with safety light, electrofisher, GPS unit, level, stadia rod, hip chain, etc.) for 1 survey crew - $36,000

- Mileage estimated at 3,000 miles per month – estimated cost $7,500

- Survey crew hotel and per diem costs estimated at $200/day

- In uncommon circumstances, a fish passage engineer may need to be consulted in difficult level B assessments.

## Estimated Monitoring Cost Per Year[3]

| | Year 1 | Year 2 |
|---|---|---|
| Salary and Benefits | $101,000 | $101,000 |
| Equipment | $36,000 | 0 |
| Mileage | $7,500 | $7,500 |
| Lodging & Per Diem | $27,000 | $27,000 |
| Goods and Services | $2,000 | $2,000 |
| Eastern Washington Office Rental | | $3,000 |
| Indirect (28.79%) | $49,950 | $40,450 |
| **Total Estimated Cost** | **$223,450** | **$180,950** |

## Salary and Benefits Estimate

| Task (in Months) | Statistician | High level Biologist | Mid level Biologist | Mid level technician |
|---|---|---|---|---|
| Sample Site Prep | | | 1.1 | |
| Site Assessment | | | 6.2 | 6.2 |
| Data Processing | | | 1.2 | 0.6 |
| Data Analyses | 0.5 | | | |
| Report Preparation | | 1.0 | 1.3 | 0.5 |
| Administration | | 1.3 | | |
| Total Staff Months | | 2.3 | 9.8 | 7.3 |
| Salary and benefits | $6,000 | $13,000 | $52,000 | $30,000 |
| **Total** | | | | **$101,000** |

[3] We based our estimated costs on the expenses from previous WDFW surveys. They are intended as a guide for project development purposes.

Attachment 2.

# Extensive Fish Passage Study – a discussion primer for including small forest landowners in the sampling frame, and costs associated with various study options.

**A brief history**

The Monitoring and Design Team (MDT) Report (2000) was developed to facilitate status and trend monitoring of forest practices activities regulated under the Forest and Fish Agreement. A study design for fish passage trends on FFR lands was included (pp. 42-49). In 2004, ISAG proposed to CMER that a scoping of fish passage trend monitoring was necessary for two reasons: the use of RMAP or cluster sampling may save limited CMER money, and results may be obtained more quickly with alternative designs. CMER subsequently awarded a contract to WDFW to review the MDT report and alternative designs.

**Small Forest Landowner Database Problems**

Both the MDT design and WDFW's preferred alternative relied on a sampling methodology rather than using RMAP reporting mechanisms. Both sampling schemes require the use of a GIS-based layer describing forest and fish lands. One such layer is the Atterbury layer, which has been the primary layer (coverage) used to describe forestlands. Unfortunately, this coverage is an accumulation of large land ownerships, and lacks small forest landownership information. Alternative databases for small forest landowners also have been insufficient for monitoring purposes. For example, efforts to assemble parcel information from county governments have been slowed due to budget and other constraints.

**Small Forest Landowner Database Solution**

Recently, DNR and UPSAG have developed alternative coverages for forestlands that have not previously been available. Notable differences between the two coverages are apparent, but both appear to be far more complete than the original Atterbury data layer. Laura Vaugeios (DNR) has developed a concept to merge the most explanatory attributes of these coverages into a common GIS layer. Merging these datasets into a common coverage will result in a forestlands layer that will feature large and small land ownerships. DNR has expressed a willingness to develop this tool.

**Small Forest Landowner Fish Passage Sampling**

WDFW strongly believes that small forest landowners should be considered separately from large ownerships in the analysis of fish passage status and trends monitoring. Repairing all fish passage barriers on small forest landowners within 15 years is a policy goal of FFR, whereas the 15-year completion date is a requirement for large ownerships. State funding has been obtained to establish and implement the FFFPP program, which prioritizes and repairs barriers on small ownerships. Large ownerships are funded privately. Adjustments to the FFFPP program and the need for future funding are adaptive management links for small ownerships in FFR. Adaptive management for large ownerships may mean adjustments to RMAPs or other regulatory measures.

**Study options and costs.**
Unfortunately, sampling small forest ownerships separately results in increased costs. Efforts to reduce costs will result in trade offs. For example, reducing the number of sample sites or the number of sample years will have consequences in statistical power. In general, reducing sample years, especially early in the study, will have more profound statistical consequences than reducing sample sites. To facilitate discussion, we outline options with rough costs in the following table.

**Costs associated with various options for fish passage status and trend monitoring.** Costs exclude COLAs and adjustments to sample sizes after FY 06.

| Option | FY 06 | FY 07 | FY 08 | FY 09 | FY10 | Total (years 1 – 16) |
|---|---|---|---|---|---|---|
| **1** | $223,450 | $180,950 | $180,950 | $180,950 | $180,950 | $2,937,700 |
| **2** | $233,500 | $191,000 | $191,000 | $191,000 | $191,000 | $3,098,500 |
| **3** | $446,900 | $358,000 | $358,000 | $358,000 | $358,000 | $5,816,900 |
| **4** | $305,200 | $216,400 | $216,400 | $216,400 | $216,400 | $3,551,200 |
| **5** | $315,200 | 0 | $226,400 | 0 | $226,400 | $2,126,400 |
| **6** | $233,500 + DNR | $191,000 + DNR | $191,000 + DNR | $191,000 + DNR | $191,000 + DNR | $3,098,500 + DNR |
| **7** | $318,000 | 0 | 0 | 0 | 0 | $954,000 |

**Option 1: Implement WDFW study design with 100 LLO sample sites for each sample year, and no SLO sample sites.** This design was WDFW's originally proposed concept prior to the new forestland coverage development.

**Option 2: Implement WDFW study design with 100 SLO sample sites for each sample year, and no LLO sample sites.** Sampling costs associated with small land ownerships are more expensive than efforts on large ownerships. We estimate about $10,000/year will be needed to accommodate incorrect land use determinations (e.g., agriculture), misidentification of small (vs. large) ownerships, additional consultation with DNR foresters, greater need to access county records, and more attention to trespass/property rights concerns.

**Option 3: Implement WDFW study design with 100 LLO sample sites, and 100 SLO sample sites for each sample year.** We believe that 100 samples will adequately determine the level of effort that will be needed to adequately detect trends. The number of sample sites may need to increase, or could decrease, depending on proportions of barriers in year 1 and the inter-annual variability among years.

**Option 4: Implement WDFW study design with 60 LLO sample sites, and 60 SLO sample sites for each sample year.** We believe that 60 samples per stratum is the minimum number of samples based on the discussion in Option 3.

**Option 5: Implement WDFW study design with 60 LLO sample sites, and 60 SLO sample sites, but combining east- and west-side data collection each year.** In other words, data would be collected for both east and west side every other year. This scheme would increase travel costs during sample years; decrease the amount of work accomplished per day, may decrease east/west inference, and may increase the time needed to detect trends. However, cost savings are advantageous.

**Option 6: Implement WDFW study design with 100 SLO sample sites, and use RMAPs for LLOs.** The use of RMAPs for LLOs requires a cost estimate from DNR.

**Option 7: Abandon trend monitoring and simply conduct periodic status assessments using a Single Random Sampling Design.** This method is included as an option to greatly reduce costs. Trend detection is not possible, but comparisons of periodic status assessments can be obtained. We recommend that if this option is selected, 3 assessments be conducted in FY 06, FY 11, and FY 15. Sample sizes can be adjusted to obtain desired precision. Costs in Table 1 represent 100 LLO samples and 100 SLO samples statewide.

**Option 8: Combine sampling efforts with fish passage status and trend monitoring being considered by the Governor's forum on monitoring. Cost savings may be realized if enough data are collected so that post stratification can occur by ownership type.** The Governor's Forum on monitoring has expressed some interest in conducting fish passage status and trend monitoring. A partnership could allow a greater chance of successfully post-stratifying among landowner size and land use due to the increased sample size that conceivably would occur. This is merely a concept at this point, and would require at least two years to coordinate.

**Option 9: Develop a cost estimate based on the proportion of acreage by ownership (e.g., 80/20).** This option is not advised because SLO's would likely be under-represented in the sampling frame, if the analyses were stratified between LLOs and SLOs. As we described previously, combining all ownership data for a common statistic may not provide useful adaptive management analyses.

**Option 10: Do not study.** Always an option.