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INSTREAM FLOW: INCREASED ACCURACY USING HABITAT MAPPING

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ABSTRACT

The U.S. Fish and Wildlife Service Incremental Flow Instream Methodology commonly utilizes either of two quite different hydraulic models (in conjunction with a habitat suitability model) to evaluate the effects of proposed stream discharge regimes on fish habitats. The newer of these, the IFG4 model, has the potential to overcome many of the limitations of the earlier IFG2 (WSP) model. This paper describes the use of habitat mapping and selectively dispersed transect placement to improve the accuracy of habitat predictions using the IFG4 model.

INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) Incremental Flow Instream Methodology (IFIM) is intended to convert measurements of hydraulic and other physical characteristics of streams into a relationship between stream discharge and habitat suitability for fish. It does this by using field hydraulic measurements in hydraulic simulation models interfaced with biological suitability models.

The IFG4 hydraulic simulation model, one of the commonly used IFIM hydraulic models, allows the use of data collected from widely separated points in a stream. This paper describes a new approach to instream flow data collection and extrapolation that takes full advantage of this feature of the IFG4 model. It includes mapping the habitat in a stream segment prior to determining where to take measurements, stratifying the entire segment into the habitat types of interest, and placing data-collection transects in the most representative of these anywhere in the stream segment. The Weighted Useable Area (the index of habitat quality produced by the IFIM HABTAT model run in conjunction with the hydraulic simulation model) associated with

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each transect is then extrapolated to the whole stream segment in direct proportion to the amount of the habitat type in the segment represented by that transect. Summing the Weighted Useable Area (WUA) of each habitat gives the total WUA for the segment.

This technique is much more likely to produce an accurate representation of the WUA in a stream segment than if all data are taken in a short "representative" reach and generalized to apply to the rest of the segment.

The data collection methods currently being taught by the FWS and published in their information papers (and consequently adopted by many state agencies) are based on the representative reach requirements of the quite different Water Surface Profile (WSP) hydraulic simulation model. Since data collected for the WSP model work well with the IFG4 model (but not necessarily vice versa) the FWS has encouraged the collection of data in a way compatible with both models. The rationale is that if the IFG4 model fails to work on a particular data set (for example, because the investigators only managed to collect data at a single flow) the WSP model would still be available.

By constraining the collection of data to WSP data collection requirements, a considerable amount of information about a stream segment can be missed unnecessarily, and accuracy of extrapolation from the study site can be poor.

Further, there are many streams in which the WSP model will not work properly and there is no reason whatever to be constrained by its requirements.

The purpose of this paper is to describe the use of habitat mapping and selection of transects independent of representative reaches as methods for increasing the accuracy of the IFIM. As a preface to that discussion, the data requirements, advantages, and limitations of the two hydraulic simulation models are described. It is also pointed out that even if sampling is limited to short representative reaches, extrapolation to the rest of a stream segment through habitat mapping is preferable to assuming equality between the representative reach and the rest of the segment.

WHAT ARE THE DIFFERENCES IN DATA COLLECTION REQUIREMENTS BETWEEN THE IFG4 AND THE WSP MODELS?

The WSP Model:

Data Requirements: The WSP model utilizes field hydraulic data from a single discharge rate to extrapolate depths (stages) and velocities at all discharge rates. To do this, it depends on a very accurate set of measurements of the relative water surface elevations and bed elevations throughout the entire stream reach being modeled. In particular, water surface elevations, bed elevations, and velocities must be known for every hydraulic control (point at which there is a break or inflection in the slope of the water surface). The measurements in the entire reach must be made relative to a single benchmark, and must be surveyed using accurate surveying equipment. Cost considerations associated with surveying usually limit the sampling to short reaches of the stream under consideration. Figure 1a shows a reach of typical mountain streams with transects placed in each of the hydraulic controls. Figure 1b shows the same reach with transects both in the hydraulic controls and in each habitat type each time it is encountered. As the Figure shows, in complex streams, the number of transects required by the WSP model can be very large.

The more hydraulic controls that occur, the more difficult it is to identify them, survey them, and model the streambed roughness accurately. Hydraulic controls tend to increase in numbers both with gradient and particularly with irregularities of the bed. If the bed is irregular or the gradient is more than a few percent, (as both are in many mountain streams) it is usually impossible to calibrate the model.

In addition, as the number of hydraulic controls increases, the number of data collection transects necessary per length of stream increases, and the data collection effort can become increasingly expensive, while at the same time becoming decreasingly accurate.

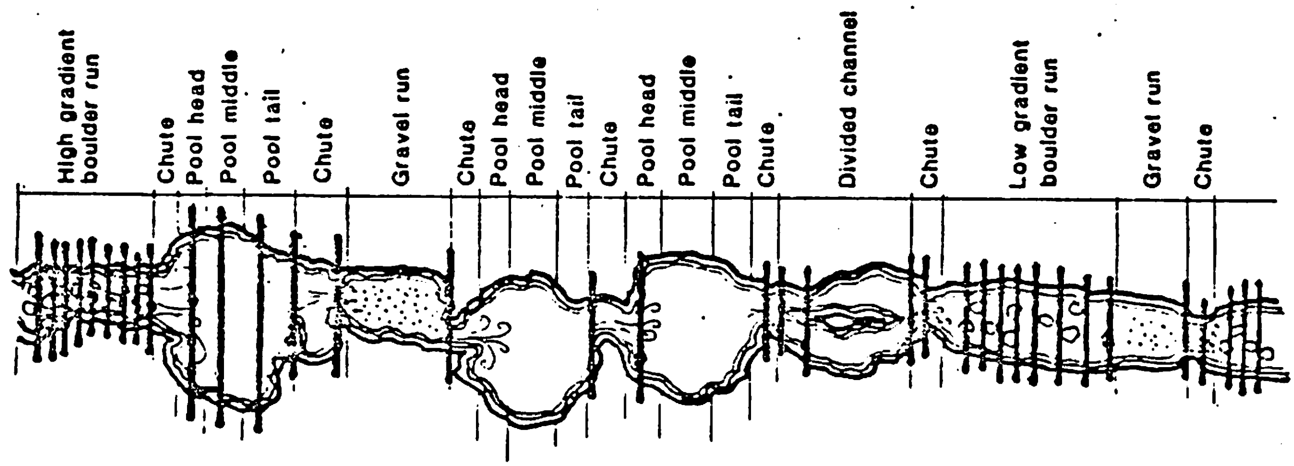
Potential decreases in accuracy occur for three reasons:

a) the hydraulic predictions made by the model are less good

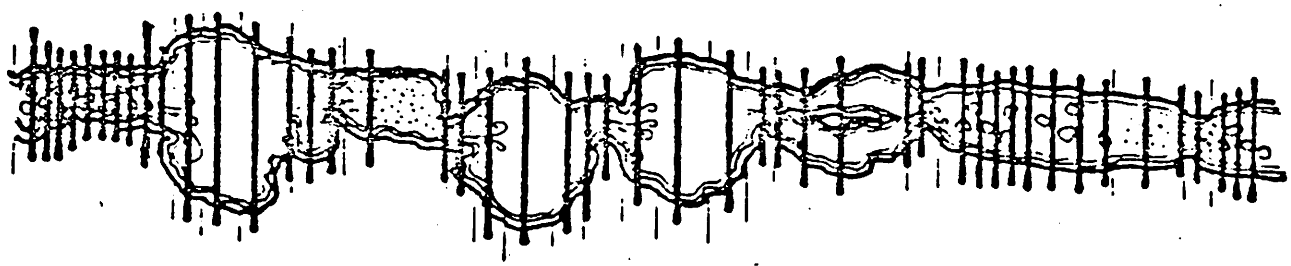
b) a larger percentage of the available time is likely to be put into surveying and placing transects which are related only to hydraulic controls, and not necessarily to fish habitat considerations, and

c) the length of stream it is feasible to survey decreases, and consequently the representativeness of the sample decreases.

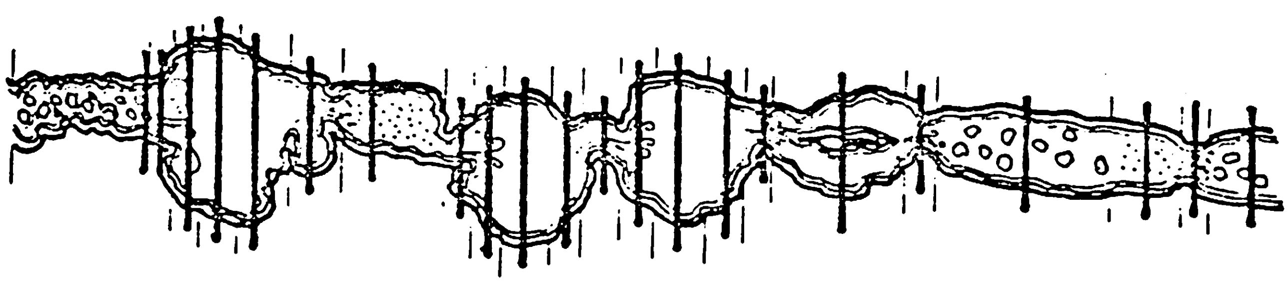
In the many mountain streams in which the WSP model will not function properly, there is absolutely no reason to be constrained by its data collection requirements.



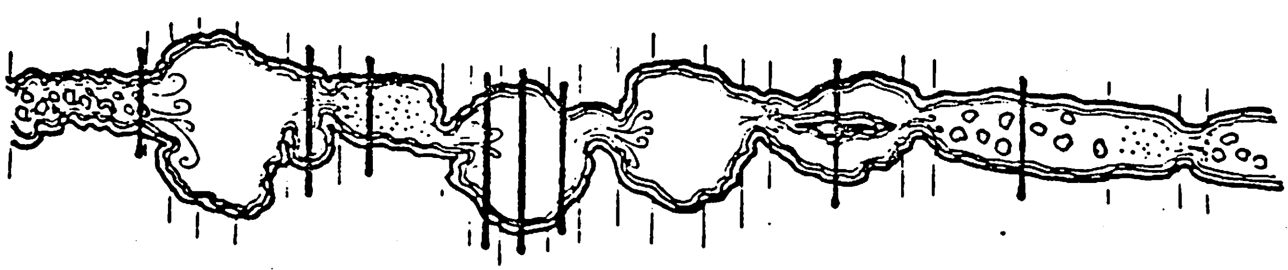
a. Transects in all hydraulic controls.



b. Transects in all hydraulic controls and all contiguous habitat types.



c. Transects in all contiguous habitat types.



d. One transect in each habitat type.

Figure 1 Transect placement in a high gradient mountain stream.

The IFG4 Model: The IFG4 model utilizes field hydraulic data from at least three different discharge rates and extrapolates to all other discharges through regression analysis. Unlike the WSP model, each physical point at which data are taken is modeled completely independently of all others, and the IFG4 model is indifferent to the relative location and elevations of the other sampling points. Consequently, individual sampling locations (cross-stream transects) can be positioned without regard to the other sampling locations. There is also no requirement that hydraulic controls be sampled, so all of the transects can be placed in habitats of interest and none need to be established solely for the purpose of hydraulic simulation. Figure 1c shows a short reach of stream in which transects are placed in order to monitor just the habitat types as required by the IFG4 methodology and not the hydraulic controls needed for the WSP model.

Notice that each habitat type encountered throughout the reach has its own transect, and that in order to have transects in all of the habitat types of interest within this reach, it has been necessary to sample several identical habitat types several times. The way the IFG4 model is normally operated, transects must be placed in adjacent habitat types whether or not the data are intended to be compatible with the WSP model. Without that operational constraint, transects could be selectively placed in the best examples of each habitat type, regardless of their location within the reach, and redundant sampling could be avoided. An example of transect placement to include one of each of the habitat types is shown in Figure 1d. (It may be desirable to have more than one transect in each habitat type, but that decision should be an intentional part of the sampling design).

WHY IS THE IFG4 MODEL USUALLY CONSTRAINED TO DATA FROM TRANSECTS IN CONTIGUOUS HABITATS?

Once the hydraulic simulation is completed for each transect, the simulated hydrology is run through the HABTAT model which accomplishes two separate functions:

1. it assigns a habitat quality factor to each increment across the transect based on suitability or probability-of-use curves supplied by the investigator, and

2. it assigns this quality to an area of the stream based on the amount of stream represented by the transect.

The result is the Weighted Useable Area (WUA) assigned to the particular section of stream characterized by an individual transect.

Ultimately, the WUA for each transect and the habitat type it represents, must be combined with all the other transects to arrive at a total WUA for the reach, and by extension for the whole stream. Figure 2a shows schematically how this is usually done in the IFG4 model.

The model computes the total area between two adjacent transects, then multiplies it times the fraction of the distance between the transects to the transition point between habitat types.

HOW CAN AREA BE CALCULATED IN THE ABSENCE OF ADJACENT TRANSECTS?

It is evident that an equivalent calculation can be made equally accurately in the absence of adjacent transects simply by measuring the distance to adjacent habitat transitions in either direction. Figure 2b shows the method. Either with or without adjacent transects, the distance to the habitat transition points must be known, so the calculations are identical. Within the constraints of the IFG4 model, this is handled computationally by assigning to each transect the total area its habitat type represents in the reach, and setting weighting factors to 1.0.

WHY ARE REPRESENTATIVE REACHES USED?

Representative reaches are intended to contain representative subsets of the habitat types occurring throughout a homogeneous segment of stream. With the high density of transects required in the WSP model, or in the usual application of the IFG4 model, it would be impractical to put transects at every hydraulic control and at every change of habitat type throughout a stream segment. If transects are always treated in groups as required by the WSP model, the only way to subset the stream is by using representative reaches.

WHAT ARE THE LIMITATIONS OF USING REPRESENTATIVE REACHES?

To the extent the reach selected is not representative, the entire analysis is correspondingly inaccurate. Because of the way the data are usually combined in this approach, not only are errors introduced if the types of habitat differ from the ones they are taken to represent elsewhere in the stream segment, errors are also introduced if the relative amounts of each habitat type differ between the representative reach and the

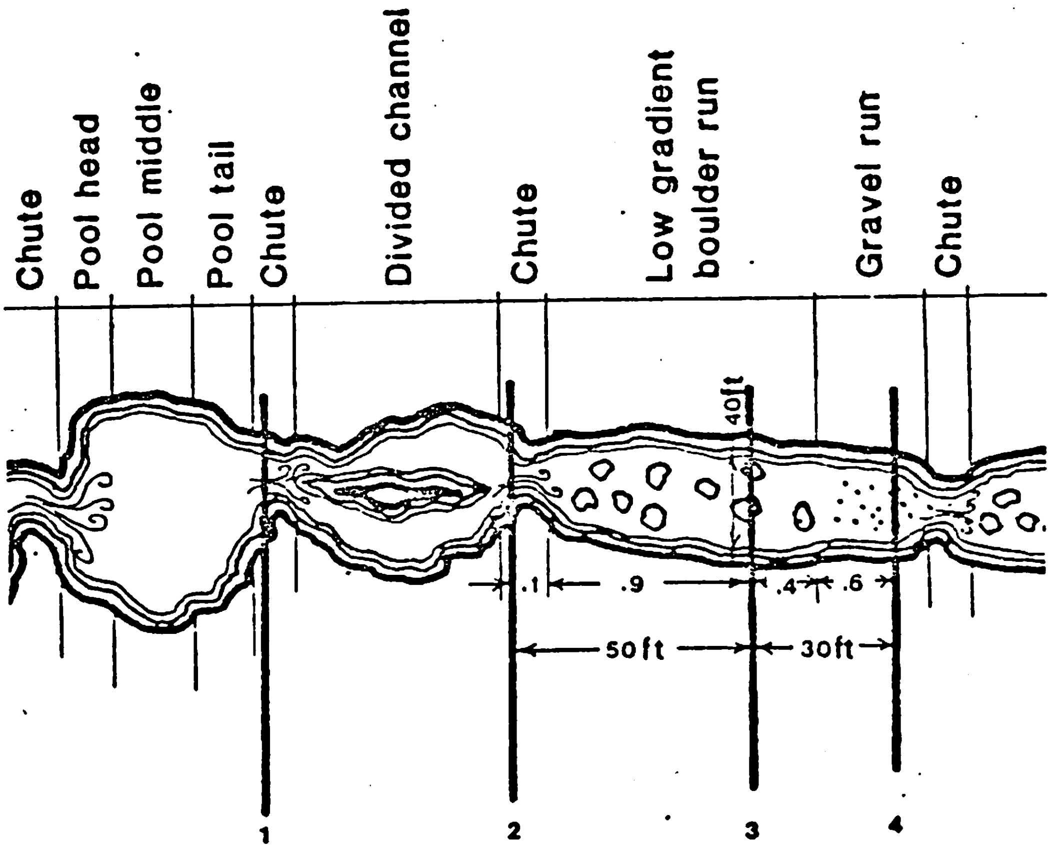


Figure 2a.

The usual method for determining the area of habitat represented by a transect. The area between transects 2 and 3 is 50 ft long by 40 ft wide = 2,000 sq ft. The distance between transects 2 and 3 is 50 ft, and nine tenths of it is a habitat type representated by transect 3. Thus the area upstream of transect 3 represented by it is 2,000 sq ft x 0.9 (called a weighting factor) = 1,800 sq ft. A similar analysis for the area between transects 3 and 4 results in 1,200 sq ft, for a total area of 1,200 x 0.4 = 480 sq ft.

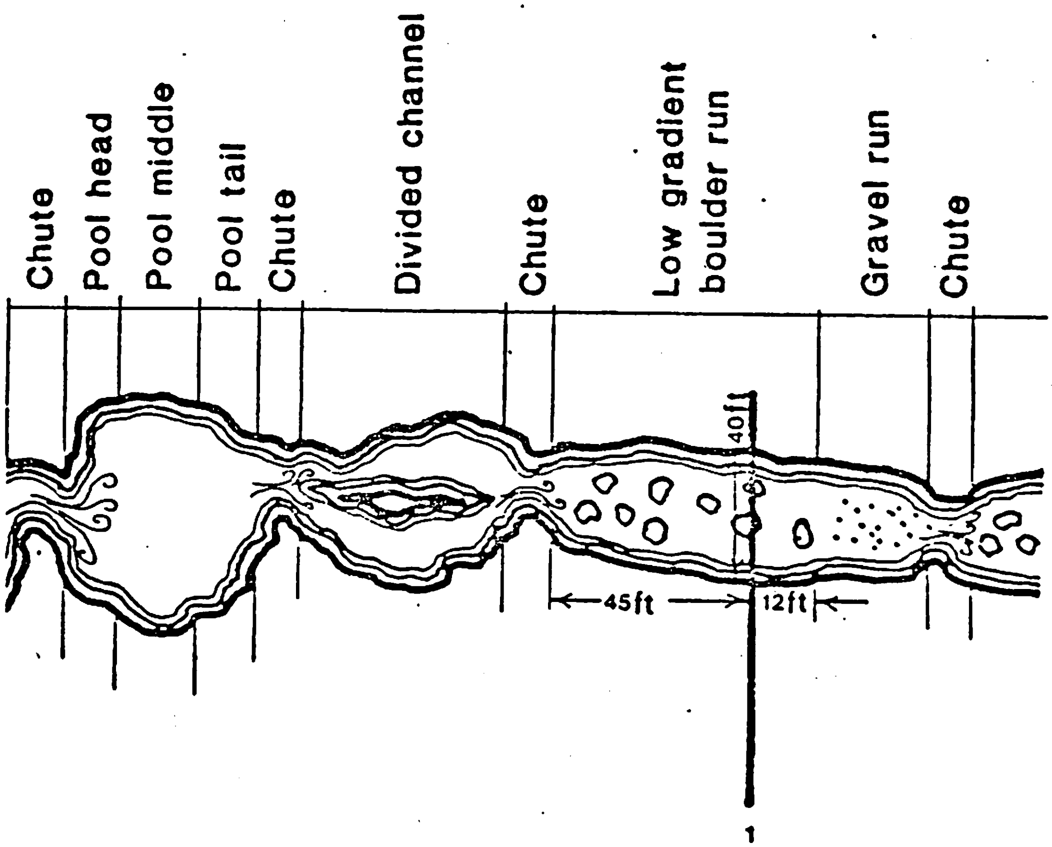


Figure 2b.

A method for determining the amount of habitat represented by a single transect. The total area between the habitat transition points at either side of transect 1 is (45 + 12) x 40 = 2,280 ft. This result uses the same input as the method shown in Figure 2a, and produces identical results.

remainder of the segment. This occurs because the weighting of individual transects is a direct function of the percentage of habitat to which each corresponds in the representative reach. The representative reach approach is entirely logical and suitable only if three criteria are met:

1. All habitat types are present in the reach in the same relative amounts as in the stream segment being studied,

2. All habitat types are encountered more or less sequentially when moving upstream or downstream in the reach,

3. There are stream segments sufficiently homogeneous to warrant subsetting into representative reaches.

To the extent that the various habitat types are not encountered sequentially, the requirement that a new transect be placed each time there is a change of habitat can result in a large number of redundant transects and an unnecessarily expensive data collection and processing effort.

WHERE ARE REPRESENTATIVE REACHES LIKELY TO BE INAPPROPRIATE?

In mountain streams with continuously changing gradients, it can be difficult or impossible to find homogeneous segments that can be subsetted into representative reaches. In this situation, the entire stream segment may be, in effect, a representative reach. Putting in transects each time the habitat changes would result in an unnecessarily large number of redundant transects.

In other instances, for example when the geology and topography are complex, subsetting can result either in very short homogeneous non-recurring segments, or in short homogeneous segments that recur, separated by other habitat types.

In either of these circumstances, truely representative reaches may not exist, and even when they do, may necessitate data collection of large numbers of redundant transects to insure inclusion of all habitat types.

In most instances, more information would be gained about the stream if redundant sampling could be avoided, and the effort put into maximizing the numbers of habitat types sampled.

ARE REPRESENTATIVE REACHES REQUIRED?

Not when using the IFG4 methodology. It is equally correct to select widely separated transects as long as there is a method of combining the information from them into an accurate characterization of the total WUA in the stream.

HOW CAN DATA FROM NON CONTIGUOUS TRANSECTS BE COMBINED TO CALCULATE TOTAL WUA FOR THE STREAM?

The WUA for each transect is calculated as shown in Figure 2b. The weighting factor used is the fraction of the area of the entire stream segment being modeled represented by that transect, rather than the fraction of the distance between the two transects. Whether or not transects are in a designated representative reach, the IFG4/HABTAT model simulates hydrology and calculates WUA for each transect independent of all of the others. This allows complete freedom to select representative transects without designating a representative reach, or being confined to a particular section of a stream segment. The criteria for selection of individual transects are the same as those used in a representative reach with the exceptions that any number of habitat types can be left unsampled between adjacent transects and hydraulic controls need not be sampled unless they constitute an important habitat type.

HOW IS THIS WEIGHTING FACTOR DETERMINED?

Through habitat mapping.

Habitat mapping can be as simple or as complex as the investigator wishes. The simplest approach is to portray the stream segment as a line with the distances corresponding to each habitat type delineated by bars. Even better are detailed representational drawings like those shown in Figures 1 and 2.

Depending on the situation, the map can be constructed by walking along the stream and measuring sequential distances and widths of each habitat type, by overflying the stream in a helicopter where access is difficult, or by using aerial photography. If mapping is done prior to establishing a representative reach or transects, the map can be used for their selection. If it is done following transect emplacement, the mapping should be done in terms of the habitat types characterized by the transects.

EVEN IF REPRESENTATIVE REACHES ARE USED, CAN HABITAT MAPPING INCREASE THE ACCURACY OF PREDICTIONS BASED ON THEM?

Yes. By summing the amounts of various habitat types in a representative reach, and comparing them to the percentages of each habitat type in the entire stream segment, the degree to which the representative reach corresponds in habitat amount to the stream segment can be determined.

To determine the effect of using data from the entire stream segment (rather than from just the representative reach) on WUA, the IFG4/HABTAT model can be run once using the transect weighting imposed by the representative reach, and a second time, weighting each transect based on the total amount of habitat it represents in the entire stream segment.

SUMMARY

In many Sierran streams, the selection of a representative reach is either confounded by the absence of homogeneous stream segments, or results in unnecessary redundant data collection and analysis efforts because of the standard approach that stipulates an additional transect each time the habitat changes within the reach. These problems can be solved by mapping the habitat of the entire stream segment under study, and by using that information as the basis for extrapolating the data from representative transects to the entire stream segment.

An important feature of mapping the habitat of the entire segment is that if the IFG4/HABTAT model is being used, there is little reason to even attempt to find a representative reach. The only constraint is that transects representative of the mapped habitat types be identified.