# 2003 LAST FISH SURVEYS FOR EASTERN WASHINGTON WATER TYPING MODEL DEVELOPMENT

FINAL REPORT

Prepared for

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## EXECUTIVE SUMMARY


- The In-stream Scientific Advisory Group (ISAG) to the Cooperative Monitoring, Evaluation, and Research Committee (CMER) is currently working to develop a logistic regression model to classify fish-bearing waters in eastern Washington. ABR, Inc. was contracted by DNR in 2003 to collect field data to augment the existing model data set and to provide data coverage of north central Washington State east of the Cascade Mountains crest. The primary objective of this study was to collect data to support the development of a multi-parameter, field-verified GIS logistic regression model that accurately predicts the locations of Type F (fish bearing) and Type N (non-fish bearing) boundaries across eastern Washington. A second objective of this study was to evaluate the effectiveness of hand-held computers, or Personal Data Assistants (PDAs) at collecting spatially-explicit field data.
- Surveys were performed in eight watersheds, ranging in size from ~11,000 to ~41,000 acres, between July 8 and September 11, 2003. Field crews investigated 425 channels depicted on DNR water type maps. Defined channels were observed at 159 (38%) of the map-depicted channels. Last fish points were established on all defined channels. A total of 55 terminal and 104 lateral last fish points were identified across all eight watersheds, with nearly one third of all identified last fish points occurring in the NF Toats Coulee watershed.
- Lateral last fish points were most often associated with small tributaries that supported too little water and habitat to support fish (i.e., stream size or natural end), while terminal last fish points were most frequently associated with bedrock falls and cascades or temporary impasses created by large woody debris; last fish occurred below large woody debris impasses on 18 occasions. At 12 of 18 terminal last fish locations associated with woody debris, gradient increased by 3% or less. At 5 of these 18 locations, gradient was lower above the impasse than it was below, indicating that, at most of these locations, upstream habitat is usable and only temporarily being blocked by debris jams. Last fish coincided with permanent gradient-related features at 17 of 55 (31%) terminal points.
- Stream habitat above lateral points typically was limiting or non-existent and characterized by narrow channel widths, steep channel gradients, or a combination of both features. Wetted width above lateral last fish points averaged 0.5 m and bankfull width averaged 1.8 m. No surface water occurred in 31 channels above lateral last fish points. Upstream channel gradient exceeded 20% at 29 of 104 lateral last fish points, averaging 16.2% and ranging from 2.8 to 68.1% across all lateral points. Habitat characteristics varied widely among terminal points; stream bankfull and wetted widths above last fish ranged from 0.5 to 8.7 and 0.3 to 6.3 m, respectively. Wetted width above terminal last fish locations averaged 1.8 m; bankfull width above averaged 3.0 m. Stream gradient above and below terminal points ranged from 4.0 to 37.9% and 1.0 to 23%, respectively. Average stream gradient increased from 10.2% below terminal last fish points to 12.6% above terminal last fish points. Terminal last fish points most frequently occurred at wetted widths of less than two meters, and at gradients ranging from 6 to 15 percent.
- Maps frequently depicted Type 9 streams that did not occur in the field, as no defined channel was located at 235 of 343 mapped Type 9 locations. Seventeen of 55 terminal last fish points (31%) occurred in Type 4 or 5 waters, while three terminal points occurred within waters currently typed as fish bearing. Two streams in NF Toats Coulee classified as Type 3 waters did not hold fish. Fish were absent from 73 of 108 channels (68%) depicted as Type 9 streams on DNR maps.
- Stream discharge was measured at three or four locations within each surveyed watershed. Flows became lower as summer progressed, as watersheds with larger drainage areas surveyed later in the season (e.g. Sinlahekin and NF Toats Coulee creeks) had lower flows than did

smaller watersheds surveyed earlier (e.g. Trout and Robinson creeks). Stream discharge data collected at USGS gage station 12447383 on the Methow River above Goat Creek indicate that stream flows in the region substantially declined during the survey period of July 9 to September 11. This wide range in flow conditions from early to late in the sampling season suggests that fish distribution could have contracted within study watersheds within the survey period as a result of loss of usable habitat through drying of streams.

- Testing and use of the PDAs occurred in Sinlahekin and NF Toats Coulee creeks. We quantified performance of the PDAs by the percentage (%) of successful position fixes acquired from satellites at last fish locations. During the first two weeks of PDA-GPS deployment (Sinlahekin Creek), 21 of 26 (81%) last fish GPS waypoints were acquired. During the last two weeks of GPS field testing (in N.F. Toats Coulee Creek), 49 of 50 (98%) last fish points were successfully acquired.The units greatly increased navigational efficiency and eliminated any uncertainty in the location of the crew in the field. Personnel reported that the unit was easy to learn and use. Field crew members were comfortable collecting and storing spatial data and associated attribute information in the field with less than one hour of training.

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## INTRODUCTION

The In-stream Scientific Advisory Group (ISAG) to the Cooperative Monitoring, Evaluation, and Research Committee (CMER) is currently working to develop a logistic regression model to classify fish-bearing waters in eastern Washington. Since 2001, the Washington Department of Natural Resources (DNR) has contracted out the collection of field data to be used for model development. ABR, Inc. was contracted by DNR in 2003 to collect field data to augment the existing data set and to provide data coverage of north central Washington State east of the Cascade Mountains crest. The primary objective of this study was to collect data to support the development of a multi-parameter, field-verified GIS logistic regression model that accurately predicts the locations of Type F (fish bearing) and Type N (non-fish bearing) boundaries across eastern Washington.

A second objective of this study was to evaluate the effectiveness of hand-held computers, or Personal Data Assistants (PDAs) at collecting spatially-explicit field data. PDAs are gaining popularity for use in field data collection because PDAs allow for field collection of spatial data with the use of integrated global positioning systems (GPS) and GIS applications installed on the computer.

## METHODS

### STUDY AREA AND SITE SELECTION

Surveys were performed in eight watersheds occurring on public forestlands within Water Resource Inventory Areas (WRIAs) 48 and 49 (Table 1). Six of the watersheds occur in the Okanogan National Forest, while the other two occur in the Loomis State Forest (Figure 1). Three of the surveyed watersheds are located partially or entirely within designated wilderness in the Okanogan National Forest.

### LAST FISH SURVEYS

Last fish locations were determined using standard protocols following the Guidelines for Determining Fish Use for the Purposes of Typing Waters (WAC 222-16-030). These guidelines prescribe procedures used to identify the upstream extent of fish use by electrofishing a minimum of 1/4 mile (~400 m) upstream of the last fish detected. Specific survey methods largely followed the approach described by Cupp (2001) and were performed as follows.

Survey crews systemically worked their way through each watershed, visiting each stream depicted on water typing maps provided by DNR. Stream courses appearing on maps, yet not occurring in the field were marked on the maps as “NDC” (i.e. no defined channel); these locations were not assigned last fish points and no data were collected. If a defined channel lacked sufficient water for electrofishing (i.e. dry channels) the channel was classified as a lateral point and a physical habitat survey was performed.

All surveys were conducted by two-person crews using a Smith-Root Model 11-A, 12-B, or LR-24 backpack electrofisher. Electrofishing surveys generally began at the confluence with known fish-bearing waters. Crews proceeded upstream, periodically electrofishing pools and other holding waters (approximately every 50–100 feet) to ascertain fish presence; while also observing habitat size, quality, and potential impediments to fish passage. As habitat breaks were encountered, electrofishing was performed immediately upstream to verify fish presence. If no fish were encountered during these periodic checks, the crew proceeded to shock in a downstream direction until a fish was encountered, at which point the location was temporarily noted and sampling direction reversed. From that point on, the survey crew electrofished all water continuously, tallying criteria pools and noting stream gradient en route. The survey continued upstream for 400 m, unless the stream gradient exceeded and remained above the 20% gradient threshold and channel width decreased to 2 ft (0.6 m) or less. In situations with long steep (>20%) reaches below moderately steep to low gradient reaches (<10), the upstream lower-gradient reach was surveyed separately and for a distance of at least 400 m. When last fish occurred below beaver dams, crews electrofished all accessible habitat within the pond, as well as an additional ¼ mile of stream above the pond to confirm the absence of fish. As additional fish were encountered, new temporary last fish points were established with flagging and survey efforts

Table 1. Watersheds surveyed in summer 2003 to support eastern Washington water typing model development.

| Watershed Name | WRIA | Basin | Drainage Area (acres) | Elevation Range (ft) |
|---|---|---|---|---|
| Beaver/Lightning Cr | 48 | Methow R. | +/- 41,000 | 2500-6000 |
| Black Canyon Cr. | 48 | Methow R. | +/- 26,000 | 1000-5000 |
| Little Bridge Cr. | 48 | Twisp R. | +/- 27,000 | 2200-5000 |
| NF Toats Coulee Cr. | 49 | Okanogan R. | +/- 39,000 | 3000-6500 |
| Robinson Cr. | 48 | Methow R. | +/- 12,000 | 3000-6500 |
| Sinlahekin Cr. | 49 | Okanogan R. | +/- 30,000 | 2000-6000 |
| Trout Cr. | 48 | Methow R. | +/- 11,000 | 3000-6000 |
| War Cr. | 48 | Twisp R. | +/- 30,000 | 2500-6500 |

continued until these effort criteria were met to establish the 2003 last fish location.

After locating the last fish, surveyors first permanently marked the location according to the point type (terminal or lateral). Terminal points were marked by nailing a plastic red tag labeled with the watershed name, stream identification number, and date to a live tree adjacent to the stream channel. Yellow and pink flagging were tied on or near the tag to aid relocation by future surveyors. Lateral points were flagged at the confluence with the fish-bearing stream with a single yellow flag labeled with the watershed name, the stream identification number, and date. Last fish locations were marked with a Garmin III Plus or Matsushita Global Positioning System (see GPS-PDA Evaluation) and were also noted on the field-corrected water typing maps provided by DNR.

On a field form labeled "Last Fish Point Data", the last fish species and other species encountered during the survey were noted and the last fish feature was identified. When last fish occurred below a barrier (waterfall, chute, log-jam, etc.); length, height, and gradient of the impediment were measured. When the barrier was too steep to allow percent gradient to be measured using a clinometer, percent gradient was visually estimated or noted as vertical. Additional barrier characteristics were noted to provide further information regarding conditions preventing upstream movement by fish. Instantaneous water temperature and conductivity also were measured at the 2003 last fish location using a YSI Model 85 multiparameter water-quality meter.

Habitat characteristics at terminal points were measured over a distance of 100 m above and below the 2003 last fish location and recorded on "Last Fish Habitat" field data forms. Habitat characteristics at lateral points were measured in an upstream direction over a distance of 100 m. Measurements included (a) channel gradient, (b) bankfull and wetted channel width, (c) pool count, and (d) dominant substrate.

Wetted (WW) and bankfull channel widths (BFW), as indicated by the margins of perennial vegetation or high-water scour marks on exposed sediment, were measured to the nearest 0.1 m at transects spaced 20 m apart using a fiberglass tape. All quiet water areas suitable for fish holding/resting were tallied and residual pool depths measured. Dominant substrate was visually characterized (Cole & Lemke 2003, <0.25 cm = silt and sand; 0.26–7.5 cm = gravel; 7.6–30 cm = rubble; >30 cm = boulders/bedrock) at five evenly-spaced points across each transect (10, 30, 50, 70, and 90% of the distance across the channel). Channel gradient was measured at least every 20 m (i.e. between each survey transect) and at significant changes in slope using a clinometer. To ensure an accurate gradient measurement, the surveyor would sight upstream to the other crew member standing at the gradient break or next upstream transect.

Within each watershed, cross-sectional streamflow measurements were taken at 3–4 locations to characterize discharge patterns while

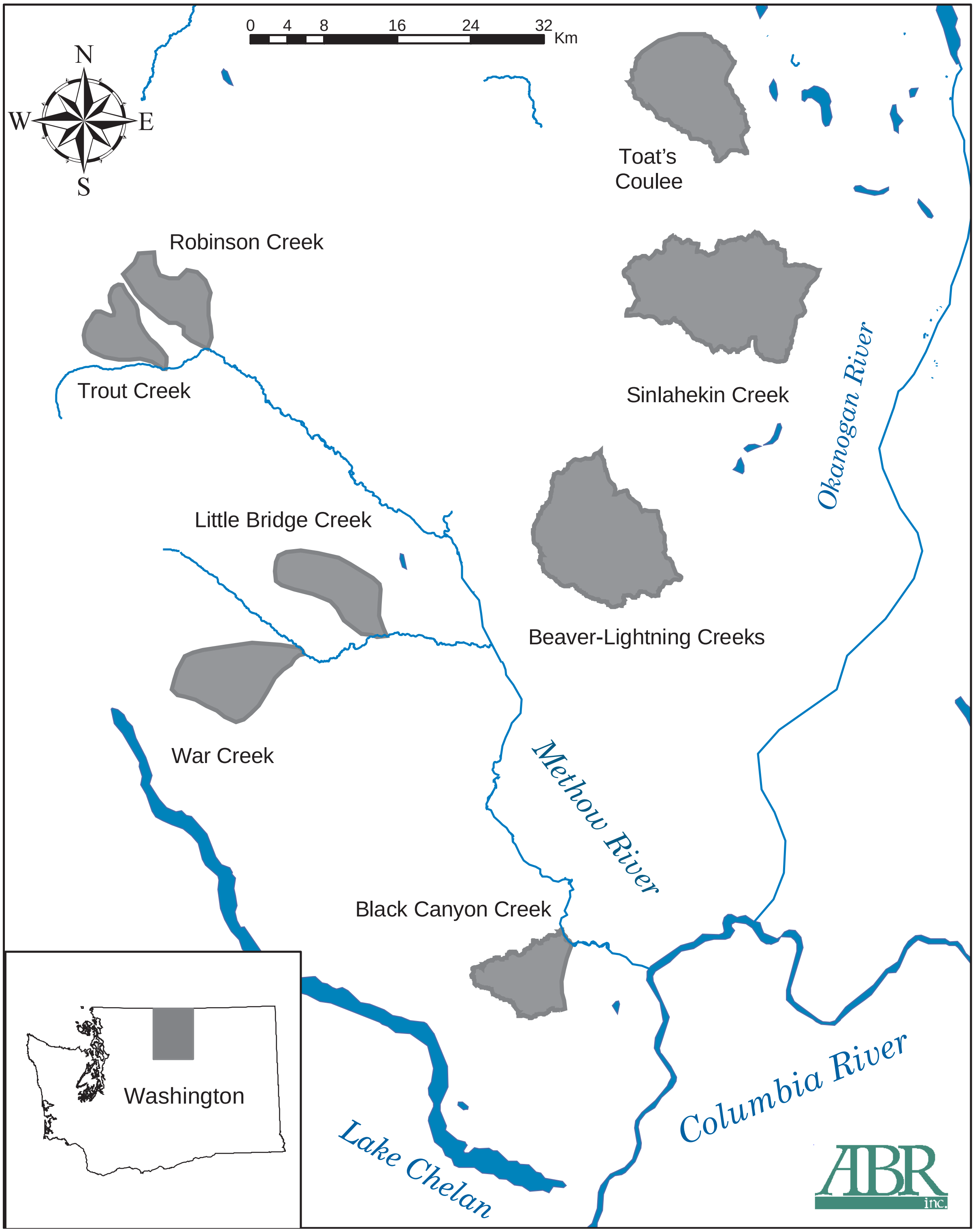


Figure 1. Map depicting watersheds surveyed for last fish and associated physical habitat in north central Washington State during summer 2003.

surveys were taking place. Flow measurements were performed following protocols described by Gallagher and Stevenson (1999) with a Marsh-McBirney Model 2000 FlowMate flowmeter. Flow stations were marked with a GPS and the precise location of the station was noted in relation to nearby road crossings, when available.

## GPS-PDA EVALUATION

In the last two watersheds surveyed (i.e., Sinlahekin and NF Touts Coulee creeks), field crews were provided with Panasonic Toughbook 01 ruggedized PDAs for field testing and evaluation. A Matsushita GPS was integrated into each unit for collection of GPS data. The PDAs ran on Windows Pocket PC 3.0 operating systems onto which ArcPad GIS software was loaded. The built-in GPS was read through ArcPad. ESRI provided a .DLL extension file named FindGPS that significantly enhanced the performance of the GPS when read through ArcPad. GIS coverages provided by DNR, including the DNR hydro layer, roads layer, and digital ortho photos, were added to the PDA to facilitate navigation and data collection in the field. Prior to using the PDA, crew members were trained on the use of the operating system, GPS, and ArcPad software, then tasked with navigating and collecting field data with the unit. An ArcPad point layer was created on each unit and an attribute table was set up with the core set of attributes required by DNR (Table 2).

Field crews typically powered on the PDA, opened the ArcPad software, and activated the GPS at the beginning of the field day prior to initiating surveys to allow the unit to acquire a GPS location fix. The units then were turned on and off during the course of each survey day to aid in navigation and collect data at last fish points. At each last fish point, the crew attempted to acquire and capture the GPS location in ArcPad by turning on the last fish point layer and adding the last fish point to the layer, as determined by the GPS position fix. The crew then entered all attribute information associated with that new point (Table 2). After the new point was added to the point layer and associated attribute information was entered, the edited layer was saved and turned off until a new GPS point was to be acquired. At the end of the each day, data were backed up on a laptop computer and the PDA was recharged.

## DATA ARCHIVING AND ANALYSIS

Last fish resurvey data were entered into an MS Access database (filename: 03-285_Last_Fish_Database). Raw physical data that included multiple measurements on the same variable first were entered into an MS Excel spreadsheet (filename:03-285_Last_Fish_Raw_Physical_Data) , in which means or frequencies were calculated, and then imported into the Access database. Summary statistics (means, frequencies, ranges, and standard deviations) were calculated to characterize relationships between 2003 last fish points and physical conditions. Finally, a GIS database was created of all 159 last fish points established in 2003.

# RESULTS

Surveys were performed in the eight watersheds, ranging in size from ~11,000 to ~41,000 acres, between July 8 and September 11, 2003. Field crews investigated 425 channels depicted on DNR water type maps. Defined channels were observed at 159 (38%) of the map-depicted channels. Last fish points were established on all defined channels. A total of 55 terminal and 104 lateral last fish points were identified across all eight watersheds, with nearly one third of all identified last fish points occurring in the NF Toats Coulee watershed (Table 3).

## LAST FISH POINT FEATURES

### LATERAL POINTS

Lateral last fish points were most often associated with small tributaries that supported too little water and habitat to support fish (i.e., were associated with stream size or natural end). Ninety-four percent of lateral points occurred at such locations (Table 4). Four lateral last fish locations occurred below impassable falls or cascades on streams that otherwise supported adequate habitat.

### TERMINAL POINTS

Terminal last fish points were most frequently associated with bedrock falls and cascades or temporary impasses created by large woody debris

Table 2. List of core attributes provided by DNR and set up in ArcPad and recorded at each last fish point. Attribute information was entered into ArcPad at each last fish location recorded and stored on the GPS-PDA as part of ABR's evaluation of the GPS-PDA technology.

| Attribute | GIS Field Name |
|---|---|
| Township, Range | TWP |
| Section | SECT |
| Survey Number | SURVEY_NO |
| Point Identification | PT_ID |
| Sponsor | SPONSOR |
| Date | DATE |
| Protocol | PROTOCOL |
| Point Type | PT_TYPE |
| Boundary Type | BND_TYPE |
| Determining Method | DET_MET |
| End Type | END_TYPE |
| Comments | COMMENTS |
| Fish Species | FISH_SPP |
| Unique Identifier | UN_ID |

Table 3. Total number of last fish points established during 2003 eastside surveys. Streams depicted on DNR maps but not occurring in the field (i.e. where no defined channels occurred) are not included in these totals.

| Watershed | Terminal Points | Lateral Points |
|---|---|---|
| Beaver/Lightning Cr | 12 | 14 |
| Black Canyon Cr. | 3 | 10 |
| Little Bridge Cr. | 6 | 8 |
| NF Toats Coulee Cr. | 14 | 36 |
| Robinson Cr. | 2 | 7 |
| Sinlahekin Cr. | 9 | 17 |
| Trout Cr. | 3 | 1 |
| War Cr. | 6 | 11 |
| Total | 55 | 104 |

(Table 5); last fish occurred below large woody debris impasses on 18 occasions. These woody debris jams ranged from 0.2 m to 1.3 m in height, averaged 0.8 m high, and most often produced a close-to-vertical barrier to upstream fish movement. Fish were often located above debris jams in the range of the dimensions described above, suggesting, in part, that these small and transient barriers only temporarily impede upstream fish movements, especially if usable habitat occurs upstream, as was frequently encountered above these debris jams. The location and size of such barriers can shift from year to year, and fish may be able to negotiate some debris jams under certain flow conditions, depending on the particular size and structure of, and the resulting flow through and around, the barrier. Additionally, as long as fish occur above debris jams at the time they are formed, fish may remain

Table 4. Frequency of last fish features associated with lateral last fish locations (*n* = 106) identified in eastern Washington during summer 2003.

| Watershed | Stream Size | Gradient | Size & gradient | Size & Culvert |
|---|---|---|---|---|
| Beaver/Lightning | 12 | 2 | 0 | 1 |
| Black Canyon | 9 | 0 | 1 | 0 |
| Little Bridge | 9 | 0 | 0 | 0 |
| NF Toats Coulee | 36 | 0 | 0 | 0 |
| Robinson | 6 | 1 | 0 | 0 |
| Sinlahekin | 16 | 0 | 1 | 0 |
| Trout | 1 | 0 | 0 | 0 |
| War | 10 | 1 | 0 | 0 |
| Total | 98 | 3 | 2 | 1 |
| Percent | 94.2 | 2.9 | 1.9 | 0.9 |

Table 5. Frequency of last fish features associated with terminal last fish locations (*n* = 53) identified in eastern Washington during summer 2003.

| Watershed | Stream Size | Gradient | Large Woody Debris | Culvert | Temp. Dam | Not Apparent | Stream Size & Culvert |
|---|---|---|---|---|---|---|---|
| Beaver/Lightning | 3 | 4 | 1 | 1 | 2 | 1 | 0 |
| Black Canyon | 0 | 2 | 0 | 0 | 1 | 0 | 0 |
| Little Bridge | 1 | 0 | 3 | 0 | 1 | 1 | 0 |
| NF Toats Coulee | 7 | 2 | 4 | 0 | 1 | 0 | 0 |
| Robinson | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Sinlahekin | 0 | 2 | 6 | 0 | 0 | 0 | 1 |
| Trout | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| War | 0 | 4 | 2 | 0 | 0 | 0 | 0 |
| Total | 11 | 17 | 18 | 1 | 5 | 2 | 1 |
| Percent | 20.0 | 30.9 | 32.7 | 1.8 | 9.1 | 3.6 | 1.8 |

above even those that appear to be completely impassable.

Gradient increased by an average of only 0.2% from below to above last fish points associated with woody debris jams. At 12 of 18 terminal last fish locations associated with woody debris, gradient increased by 3% or less. At 5 of these 18 locations, gradient was lower above the impasse than it was below, indicating that, at most of these locations, upstream physical habitat is usable, and only temporarily being blocked by debris jams. However, one must consider that physical habitat, alone, does not determine the suitability of a particular stream reach for fish use. Limited food resources may preclude fish from taking up residence in some of these areas located above transient barriers, as limited food has been suggested to limit fish distribution in small forested streams (Trotter 2000).

Last fish coincided with permanent gradient-related features at 17 of 55 (31%) terminal points. Most of these features were bedrock or boulder waterfalls or cascades. Vertical height of these waterfall and cascade obstructions ranged from 0.3 m to 25.0 m, averaged 4.0 m, and varied widely in length and gradient characteristics. As encountered during 2001 and 2002 surveys, fish were occasionally encountered above prominent waterfalls and cascades that clearly were barriers to fish passage.

Terminal last fish points coincided with a "natural end" on 11 of 55 occasions. Last fish was considered to occur at a natural end if the point coincided with a noticeable and permanent reduction or end in streamflow or channel dimensions. Five terminal last fish points occurred below beaver dams, while two terminal last fish points occurred immediately below impassable culverts.

## HABITAT CHARACTERISTICS

### LATERAL POINTS

Lateral last fish points occurred almost exclusively at abrupt changes in stream size and/or gradient. Stream habitat above lateral points typically was limiting or non-existent and was characterized by narrow channel widths, steep channel gradients, or a combination of both features (Table 6). Wetted width above lateral last fish points averaged 0.5 m (range 0.0–3.3 m) and bankfull width averaged 1.8 m (range 0.4–9.0 m). No surface water (WW = 0.0 m) occurred in 31 (30%) channels above lateral last fish points (Figure 2). Upstream channel gradient exceeded 20% at 29 of 104 lateral last fish points, averaging 16.2% and ranging from 2.8 to 68.1% across all lateral points (Table 6). Pools >15 cm deep above lateral last fish points occurred infrequently, and were often absent, as pool frequency averaged 2.7 per 100 m of channel (range 0–23/100 channel m). Pool habitat (pools >15 cm deep) above lateral last fish locations was absent in 58 (56%) channels.

### TERMINAL POINTS

Habitat characteristics varied widely among 2003 terminal points; stream bankfull and wetted widths above last fish ranged from 0.5 to 8.7 and 0.3 to 6.3 m, respectively (Table 7). Wetted width above terminal last fish locations averaged 1.8 m; bankfull width above averaged 3.0 m. Stream gradient above and below terminal points ranged from 4.0 to 37.9% and 1.0 to 23%, respectively. Average stream gradient increased from 10.2% below terminal last fish points to 12.6% above terminal last fish points. Terminal last fish points most frequently occurred at wetted widths of less than two meters, and at gradients ranging from 6 to 15 percent (Figure 3). Pool counts above and below terminal last fish points varied widely, as well, with pool frequencies (pools >15 cm deep per 100 m) of less than 10 per 100-m occurring most often both above and below terminal points (Figure 3).

## MAP ACCURACY

Maps frequently depicted Type 9 (unclassified) streams that did not occur in the field, as no defined channel occurred at 235 of 343 mapped Type 9 locations. Less frequently, mapped Type 5 streams did not occur in the field, most notably in Sinlahekin Creek, where no defined channel occurred at 25 of 37 mapped Type 5 locations (Table 8). Field crews investigated all streams indicated on maps and marked all mapped streams where no defined channel occurred as "NDC". We suspect that the relatively low number of non-fish bearing stream channels within the study area is a result of the steep, mountainous terrain of the area that precludes development of stream channels on steep valley side walls. Most of the mainstem streams within which 2003 surveys occurred were tightly confined and bound by steep-sided mountains. Areas depicted as stream channels in these areas were frequently dry draws containing colluvium and other debris from upslope or were altogether lacking any distinct topographic features that could allow channel development. On occasion, streams not occurring on DNR maps occurred in the field. Such streams were hand drawn onto field-corrected maps and included in the survey.

Seventeen of 55 terminal last fish points (31%) occurred in Type 4 or 5 (non-fish bearing) waters (Table 8), only three terminal points occurred within waters currently typed as fish bearing. Fish were absent from 29 of 46 Type 4 or 5 streams that were found to have a defined channel. Two streams in NF Toats Coulee classified as Type 3 (fish bearing) waters did not hold fish. Fish were absent from 73 of 108 channels (68%) depicted as Type 9 streams on

Table 6. Channel characteristics occurring in first 100 m above lateral last fish points ($n$ = 104).

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| Gradient | 16.2 | 11.4 | 2.8 | 68.1 |
| WW | 0.5 | 0.6 | 0.0 | 3.3 |
| BFW | 1.8 | 1.7 | 0.4 | 9.0 |

DNR maps. When combined, fish occurred in 52 of 154 (34%) DNR Type 4, 5, and 9 channels.

**STREAM DISCHARGE**

Stream discharge was measured and recorded at three or four locations within each surveyed watershed (Table 9). Flows became lower as summer progressed, as watersheds with larger drainage areas surveyed later in the season (e.g. Sinlahekin and NF Toats Coulee creeks) had lower flows than did smaller watersheds surveyed earlier (e.g. Trout and Robinson creeks). Stream discharge data collected at USGS gage station 12447383 on the Methow River above Goat Creek (approximately 10 river miles downriver of the confluence with Robinson Creek) indicate that stream flows in the region substantially declined during the survey period of July 9 to September 11 (Figure 4). Additionally, during 2003 field surveys, crews occasionally noted smaller streams that held water on the first field visit were dry on later days. This wide range in flow conditions from early to late in the sampling season suggests that fish distribution may contract within study watersheds even within the survey period as a result of loss of usable habitat through drying of streams.

Finally, discharge data collected over the past 13 years on the Methow River above Goat Creek indicate that flows were lower in summer 2003 than they are during a more typical water year. July 12 discharge at this station was 440 cfs versus an average of 1160 cfs on July 12 during the previous 12 years (Table 10). Without any empirical data to elucidate how variation in streamflow may affect fish distribution in small forested streams, we can not be sure whether lower summer flows contract fish distribution, but the possibility suggests that fish may have been less widely distributed than during more typical water years.

**SPECIES ENCOUNTERED**

Four species of fish were observed during 2003 last fish surveys, including brook trout (*Salvelinus fontinalis*), bull trout (*Salvelinus confluentus*), cutthroat trout (*Oncorhynchus clarki*), and redband trout (*Oncorhynchus mykiss*) (Table 11). Across all watersheds, redband trout were the most commonly encountered fish, occurring in six of eight watersheds. Cutthroat trout occurred in two watersheds, Robinson and War creeks, while bull trout and brook trout were encountered only in the Beaver/Lightning creeks watershed.

Bull trout were sampled from only one stream, Blue Buck Creek, in the upper Beaver Creek drainage. Ten individuals were captured and released unharmed during last fish surveys of Blue Buck Creek (LF point ABR6_106). Bull trout of the following size categories were sampled: 2–4 inches (1 individual), 4–6 inches (4 individuals), 6–8 inches (2 individuals), 8–10 inches (1 individual), and 10–12 inches (2 individuals). Size classes were estimated to reduce handling and minimize stress of captured bull trout.

**HANDHELD GPS-PDA EVALUATION**

SOFTWARE INSTALLATION & PROGRAMMING NEEDS

PDAs were received preloaded with Windows Pocket PC 3.0 operating systems (see Table 12 for complete list of PDA specifications). Two software programs and one utility extension were installed; no programming was necessary to enable the units for use in the field. Software installed included ArcPad 6.01 (manufacturer: Environmental Systems Research Institute (ESRI)), an ArcPad extension named FindGPS 1.0.5., and Microsoft ActiveSync 3.7.1. Microsoft Active Sync 3.7.1 enables communication between a source computer (laptop or desktop) and the PDA. Active

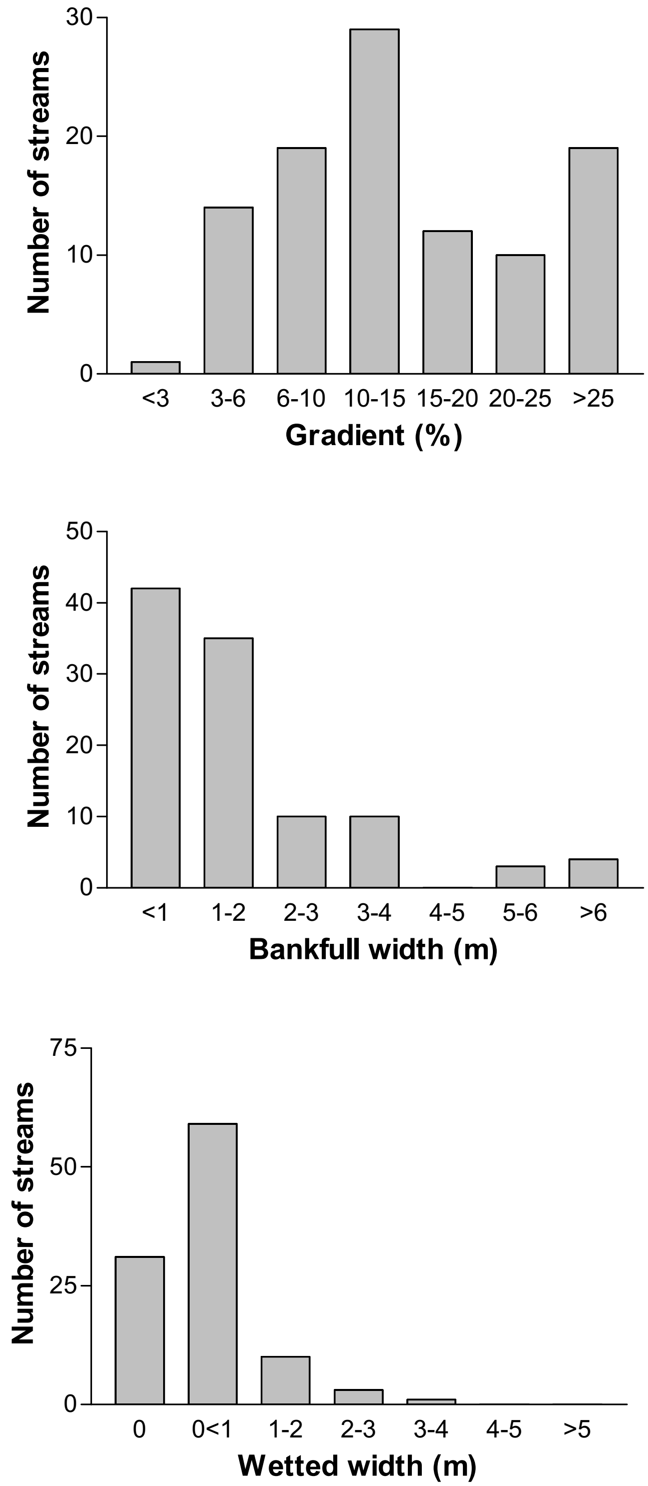


Figure 2. Frequency of occurrence of habitat characteristics occurring above lateral last fish points established in eastern Washington in 2003 (n = 104).

Table 7. Channel characteristics occurring in first 100 m above and below terminal last fish points ($n = 55$).

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| **Gradient** | | | | |
| Above | 12.6 | 6.6 | 4.0 | 37.9 |
| Below | 10.2 | 4.8 | 1.0 | 23.0 |
| **Wetted Width** | | | | |
| Above | 1.8 | 1.5 | 0.3 | 6.3 |
| Below | 1.9 | 1.7 | 0.1 | 8.8 |
| **Bankfull Width** | | | | |
| Above | 3.0 | 2.1 | 0.5 | 8.7 |
| Below | 3.1 | 2.6 | 0.5 | 13.4 |
| **Pool Count** | | | | |
| Above | 9 | 7 | 0 | 23 |
| Below | 10 | 8 | 0 | 30 |

Sync software is used to install software from the source PC to the PDAs. Active Sync should also be installed on the source computer prior to uploading PDA software to the source PC.

RESOURCES ADDED

Several GIS layers and orthophotos provided by DNR were added to the PDA prior to field deployment and testing. These orthophotos were processed with the ArcPad extension in ArcView 8.2 on a desktop computer to compress the images in MrSID format. GIS layers included the DNR forest roads and hydro layers, ortho-rectified digital aerial photographs of the study areas, and DEM-derived stream layers.

DATA TRANSFER

Data transfer was a relatively simple process with the aid of ActiveSync software. When the source PC and the PDA are "connected" through ActiveSync and a USB or serial port, the PDA functions like another drive on the source PC, allowing for copying, pasting, and cutting of files. Additionally, data storage on the SD card allows data to be transferred to a laptop or PC via an SD card reader through a USB port on the PC. Loaded with the data files were ArcPad Project files (.apm) and master data entry files with the data entry fields needed to comply with the requirements of the study. The project files were developed on the desktop version of ArcPad to take advantage of the processing power of a PC and reduce development time on the PDA.

PERFORMANCE ASSESSMENT

Testing and use of the PDAs occurred in Sinlahekin and NF Toats Coulee creeks. We quantified performance of the PDAs by the percentage (%) of successful position fixes acquired from satellites at last fish locations. During the first two weeks of PDA-GPS deployment (Sinlahekin Creek), 21 of 26 (81%) last fish GPS waypoints were acquired. We attributed the inability of the GPS to acquire position fixes at 5 locations to the occasional failure of the GPS unit to be detected by the ArcPad software, through which the GPS was being read. Following completion of work in Sinlahekin, an ESRI .dll extension named FindGPS 1.0.5 was installed on the units which optimized GPS detection through ArcPad. During the last two weeks of GPS field testing (in N.F. Toats Coulee Creek), 49 of 50 (98%) last fish points were successfully acquired.

Personnel found that the use of the GIS orthophotos, stream layers, and GPS locations, in combination, greatly increased navigational efficiency and eliminated any uncertainty in the location of the crew in the field. We found that navigational assistance was the most beneficial aspect of having the units in the field. Personnel reported that the units were easy to learn and use.

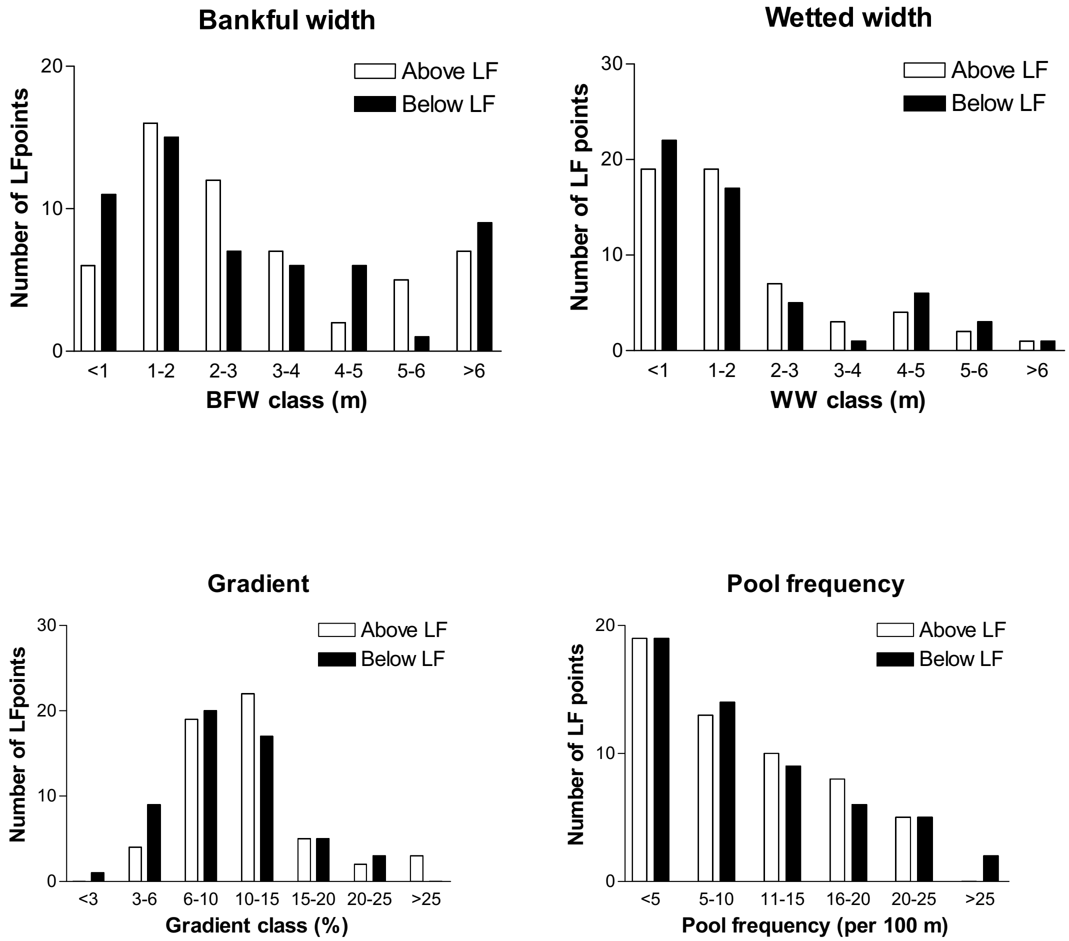


Figure 3. Frequency of occurrence of habitat characteristics occurring above and below terminal last fish points established in eastern Washington in 2003 (n = 55).

Field crew members were comfortable collecting and storing spatial data and associated attribute information in the field with less than one hour of training. Understanding other aspects of the technology's functionality, such as in-depth knowledge of the ArcPad software, transferring and managing field data, and troubleshooting require more training. We assigned one person to these latter tasks to minimize risks of data loss and to maintain work efficiency in the field.

## UTILITY OF DEM STREAMS LAYER FOR ACCURATE LF POINT PLACEMENT

We examined the potential utility of using gradient information on the DEM-derived stream layer to help accurately place LF points that occur at a gradient break in the corresponding location on the DEM layer. The DEM-derived stream layer was color-coded into 5% upstream gradient bins to enable rapid identification of gradient breaks. We examined the frequency with which above/below-last-fish gradient breaks indicated by the field data corresponded with gradient breaks occurring on the DEM layer. Seven of twenty-three terminal points in the NF Toats Coulee and Sinlahekin creek watersheds had above/below last fish gradient breaks of greater than 5%, 3 of which were also greater than 10%. Corresponding gradient breaks occurred on the DEM layer only at the 3 last fish locations with above/below gradient breaks of greater than 10%, indicating that the DEM layer likely best assists with accurate point placement in relation to gradient information when gradient breaks are relatively large. Because

Table 8. Actual occurrence of no defined channels, fish-bearing streams, and non-fish-bearing streams by DNR water type in eight eastern Washington watersheds surveyed during summer 2003..

| | | Water Type | | | | |
|---|---|---|---|---|---|---|
| Survey Result | Watershed | 3 | 4 | 5 | 9 | Total |
| No Defined Channel | Beaver/Lightning | | | | 21 | 21 |
| | Black Canyon | | | 1 | 41 | 42 |
| | Little Bridge | | | | 4 | 4 |
| | N.F.Toats Coulee | | 2 | 3 | 51 | 56 |
| | Robinson | | | | 7 | 7 |
| | Sinlahekin | | | 25 | 93 | 118 |
| | Trout | | | | 8 | 8 |
| | War | | | | 10 | 10 |
| | **TOTAL** | | **2** | **29** | **235** | **266** |
| Fish-Bearing Stream (at least portion of length) | Beaver/Lightning | | | | 12 | 12 |
| | Black Canyon | | 2 | | 1 | 3 |
| | Little Bridge | | | | 6 | 6 |
| | N.F.Toats Coulee | | 7 | 2 | 5 | 14 |
| | Robinson | | | | 2 | 2 |
| | Sinlahekin | 3 | 6 | | | 9 |
| | Trout | | | | 3 | 3 |
| | War | | | | 6 | 6 |
| | **TOTAL** | **3** | **15** | **2** | **35** | **55** |
| Non-Fish-Bearing Stream (entire length) | Beaver/Lightning | | | | 14 | 14 |
| | Black Canyon | | 1 | 1 | 8 | 10 |
| | Little Bridge | | | | 8 | 8 |
| | N.F.Toats Coulee | 2 | 3 | 8 | 23 | 36 |
| | Robinson | | | | 7 | 7 |
| | Sinlahekin | | 4 | 12 | 1 | 17 |
| | Trout | | | | 1 | 1 |
| | War | | | | 11 | 11 |
| | **TOTAL** | **2** | **8** | **21** | **73** | **104** |

waypoints captured with the PDA-GPS in the field can be viewed in relation to the DEM layer at any later time, we found that examining the DEM layer for accurate point placement with corresponding gradient information was best performed post-hoc, following the calculation of mean gradients upstream and downstream of last fish points.

ADDITIONAL COMMENTS AND RECOMMENDATIONS

ABR performed several simple analyses to begin to asses the relative accuracy of the hydro and DEM-derived streams layers using the PDAs. At 31 locations in the NF Toats Coulee watershed, waypoints were collected with both the Garmin and PDA GPSs. PDA-Garmin waypoint pairs deviated from each other by an average of 10.8 m, providing us with a measure of precision of these paired points. We then measured the distance from 39 PDA-captured waypoints in NF Toats Coulee to the hydro and DEM-derived stream layers to determine whether one layer more closely aligned with PDA waypoints than the other. Mean distance from the PDA-derived waypoints averaged 43.9 m to the Hydro layer and 44.8 m to the DEM-derived layer, indicating that one layer was not

Table 9. Stream discharge from watersheds surveyed in eastern Washington for the upper limits of fish distribution during summer, 2003.

| | | | Discharge (cfs) | | | |
|---|---|---|---|---|---|---|
| Watershed | Dates Surveyed | Drainage Size | 1 | 2 | 3 | 4 |
| Beaver/ Lightning | 7/26-8/3 | 41,000 | 0.7 | 1.6 | 3.1 | 3.2 |
| Black Canyon | 7/26-7/29 | 26,000 | 0.4 | 0.6 | 1.5 | |
| Little Bridge | 7/15-7/24 | 27,000 | 2.2 | 2.2 | 2.2 | |
| N.F.Toats Coulee | 8/29-9/11 | 39,000 | 1.5 | 1.4 | 2.3 | 3.9 |
| Robinson | 7/9-7/11 | 12,000 | 4.0 | 10.3 | 19.8 | |
| Sinlahekin | 8/13-8/24 | 30,000 | 0.4 | 2.0 | 2.5 | 2.7 |
| Trout | 7/14-7/15 | 11,000 | 5.1 | 8.6 | 8.1 | |
| War | 7/17-7/25 | 30,000 | 1.3 | 3.2 | 6.0 | 14.3 |

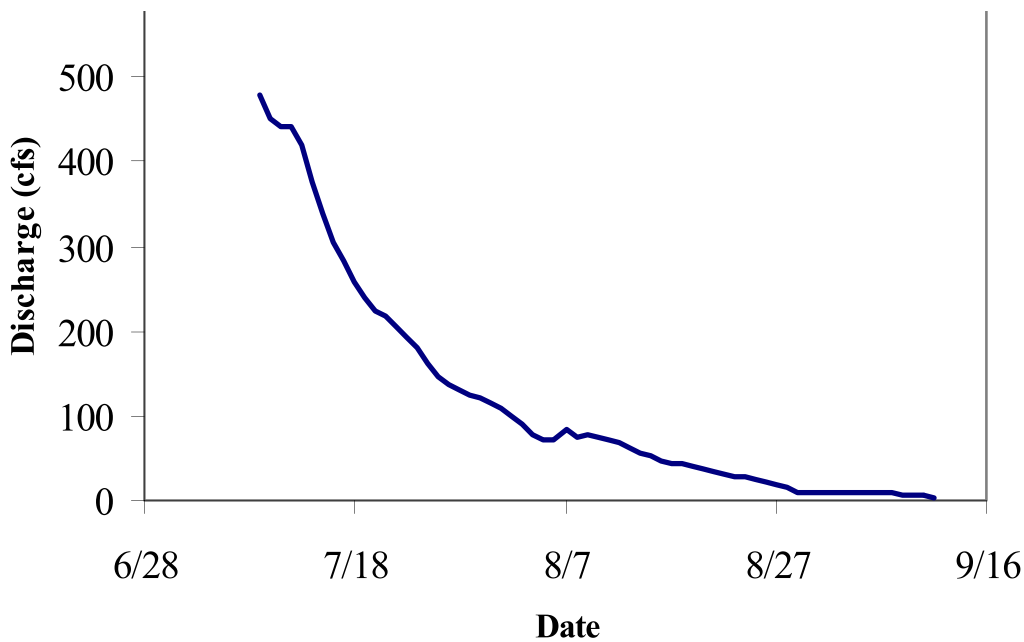


Figure 4. Discharge on the Methow River above Goat Creek for the period July 9 to September 11, 2003 when last fish surveys were being performed in area watersheds.

considerably more accurate than the other. In addition, a number of non-fish-bearing tributaries located in the watershed by field crews did not occur on either layer. Simply put, we found that the DEM layer sometimes more closely corresponded with last fish points, while other times the hydro layer appeared more accurate. We recommend that a much more thorough evaluation of the relative accuracy of DEM-derived and DNR hydro layers be performed with a differential GPS across a larger geographic area. There may soon be inexpensive options available that would allow an external GPS to be connected to a PDA that would provide post-processed GPS locations with sub-meter accuracy. We did not purchase these units with such an exercise in mind.

During field testing of the PDA, Garmin waypoints were collected at most LF locations where waypoints were collected with the PDA. When the data were later transferred into and viewed in ArcView, a noticeable difference of about 25 m to the NNW was observed in the PDA-captured waypoints. ABR GIS staff recognized the problem as a transformation error.

Table 10. July 12 discharge at USGS gage station 12447383 on the Methow River above Goat Creek for the past 13 years.

| Year | July 12 Discharge |
|---|---|
| 1991 | 2220 |
| 1992 | 411 |
| 1993 | 220 |
| 1994 | 238 |
| 1995 | 926 |
| 1996 | 1610 |
| 1997 | 1160 |
| 1998 | 633 |
| 1999 | 3800 |
| 2000 | 836 |
| 2001 | 221 |
| 2002 | 1650 |
| 2003 | 440 |
| 12-Year Average | 1160 |

Table 11. Number of streams within each watershed where each observed salmonid species was observed.

| Watershed | Bull trout | Brook trout | Cutthroat trout | Redband trout |
|---|---|---|---|---|
| Beaver/ Lightning | 1 | 11 | | 1 |
| Black Canyon | | | | 3 |
| Little Bridge | | | | 6 |
| N.F.Toats Coulee | | | | 14 |
| Robinson | | | 2 | |
| Sinlahekin | | | | 9 |
| Trout | | | | 3 |
| War | | | 6 | |
| Total Streams | 1 | 11 | 8 | 36 |

After researching the problem, a thread in the ArcPad user forum dated 9 September 2003 titled “Datum Problem Fixed” and correspondence with an ESRI ArcPad engineer provided answers to the issue. When ArcPad uses data layers in a datum other than WGS84 (native Datum for the GPS system) the default ESRI transformation is not the proper one for the region the data were gathered in.

We were able to correct the position of the data points by first re-projecting them from the local NAD 1927 StatePlane Washington South FIPS 4602 to WGS84 using the 1530, NAD_1927_To_WGS_1984_30 transformation (the ArcPad default WGS84-NAD27 transformation). To project the data back into the local projection, there were two acceptable transformations tested; for the US contiguous states, west of the Mississippi, 8075 NAD_1927_To_WGS_1984_6 and for British Columbia and Alberta, 8079 NAD_1927_To_WGS_1984_10. The second one,

Table 12. Specifications of Personal Data Assistant (PDA) devices tested during 2003 eastern Washington last fish surveys.

| | |
|---|---|
| **Manufacturer** | Panasonic |
| **Model** | Toughbook 01 |
| **Features** | Durability: Designed using MIL-STD-810F test procedures, Moisture-resistant casing, sealed port and connector covers, drop-shock-resistant design (Ruggedized)<br>Accessories: integrated Matsushita GPS |
| **Connectivity** | USB or Serial Port connection (both provided) to host desktop or laptop computer via Microsoft Active Sync Software |
| **CPU** | Intel® 206 MHz Microprocessor |
| **Storage & Memory** | 128MB SDRAM (not standard) |
| **Power Supply** | Lithium Ion Rechargeable Battery. Up to 12 hours operation, 3 hours charging time.<br>Lithium Ion Rechargeable Backup Battery |
| **Software** | Preloaded: Microsoft® Windows® Pocket PC 3.0<br>User loaded (for project): ArcPad, ESRI FindGPS (ArcPad extension), Microsoft Active Sync 3.7.1 |

8079, gave a better position relative to the positions recorded on the Garmin GPS in the field.

From entries on the ArcPad user forum it seems this problem has occurred quite a few times, yet transformation selection assistance is poorly documented in the ArcPad manual. ABR initially assumed that ArcPad was performing the transformations properly because projections were assigned for the data files. Additionally, ABR equipment and software tests in Alaska and Oregon were in either WGS84 or Decimal Degrees NAD 83 so the shift was not observed. To circumvent this problem in the future, we highly recommend that ArcPad base layers are converted from NAD27 to WGS84, eliminating the need to transform waypoints as they are captured by the PDA-GPS. All data can later be transformed back to the original projection following field data collection.

We caution against the use of the PDAs for extended periods of time without recharging the Lithium Ion batteries. Although Panasonic reported to us that batteries can be changed in these units without the loss of any information (once the unit is powered off), our one attempt at such a transfer resulted in loss of software from the PDA. The PDA notifies the user when the battery levels are low. The user should power off and recharge the unit. If the batteries lose all power, all software and data are lost from the PDA and severe damage to the battery can result. Consequently, when not in use, the PDA was always left on a charger, as recommended by the manufacturer.

PDAs ordered from the vendor recommended by the manufacturer were received by ABR in August, one month after the order was placed and with only two watersheds left to complete. The late shipment, coupled with ordering the units only after the work contract was finalized, prevented deployment and testing of the units until late in the survey season. Our field staff member responsible for the operation of these units (Matt Killian) spent considerable time learning and troubleshooting the technology during the first two weeks of deployment in Sinlahekin Creek. Such problems can be avoided in the future by acquiring and learning the technology prior to the field season and by receiving training from someone already familiar with the technology. Other than these problems associated with the late arrival of these units, crews reported no significant problems during 2003 field surveys.

## RECOMMENDATIONS

Efforts to characterize the upper limits of fish distribution in eastern Washington watersheds have focused exclusively on performing last fish surveys during the summer months of June through September, with surveys beginning as late as early July during the past two years. Because variation in streamflow may induce shifts in fish distribution, we recommend performing last fish surveys during several consecutive seasons to assess the effects of seasonal changes in streamflow on the upper limits of fish distribution.

Examination of regional discharge data indicates that streamflows decrease substantially, even within the summer survey period of early July to early September. We suspect that available habitat may contract during late summer and fall during these low-flow periods. Data from the upper Methow River indicate that discharge may decrease by as much as two orders of magnitude even within the period over which summer surveys are performed. Surveys of streams early in the summer (June-early July) and again later in the summer and fall (August and September), as well as during higher-flow periods in late fall and early winter would allow for examination of the effects of seasonal variation in flow on fish distribution, with a focus on examining the effects of late-summer low flows on contracting fish habitat and distribution.

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