
Columbia Basin BC Hydro Footprint Mapping BC Hydro Reference Number: DFIM040

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External quality assurance was completed for each element of the project by individuals and organizations as indicated below:

Albert Chirico, MSRM

- stream digitization, reach break mapping

Mark Schnider, CBFWCP

- georectification of images and stream digitization

Amy Waterhouse, CBFWCP

- georectification of images and stream digitization, digital final products

Greg Utzig, P.Ag.

- ecosystem mapping

The roles of JMJ Holdings Inc. employees and subcontractors within this project are as follows:

Maureen V. Ketcheson R.P.Bio.

- Project coordination, ecosystem mapping and final report preparation, internal quality control

Kevin Misurak

- Spatial data capture, georectification of MS maps

Vicky Lipinski

- Data manager, air photo preparation and spatial data capture, internal quality control

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·Ecosystem mapping

Tom Dool, Lawson Bradley

·Water features and stream reach spatial data capture

Eric White R.P.Bio. (subcontractor)

·Stream reach delineation

Sylvie Masse R.P.Bio. (subcontractor)

·Stream reach internal quality control

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1.0 Introduction and Objectives

The Columbia Basin Fish and Wildlife Compensation Program identified Ecosystem and Stream mapping as a foundation for the analysis of the effects of flooding within the hydroelectric and water storage reservoirs in the Columbia Basin. The evaluation of the wildlife and fisheries ecosystems lost throughout approximately 700 km² of valley floor landscapes has been identified as the foundation for future analysis and reporting on those ecosystems. MJM Holdings Inc. was contracted to undertake the mapping of ecosystems, geo-rectification of historic MS map series for the flooded areas and the digitization of water features from the historic mapping. This report documents the methods used, and results of that process. Figure 1 illustrates the project area, subunits and map sheet numbers.

The specific objectives of this project are as follows:

1. to georectify 78 MS map series images in GEOTIFF format
2. to join these images as a mosaic

Thirty-nine map sheets also have the following specific objectives:

3. to map stream reaches and calculate their gradients using MS map water features
4. to digitize MS map water features
5. to map ecosystems and register them to the MS maps
6. to document the process and describe ecosystem map units in a final report

2.0 Methods

2.1 Geo rectification of GEOTIFF Images of the MS Series Mapping

The intention was to georectify all 78 map sheets and insets, using the same approach that was utilized in the pilot project (Dool and Misurak 2004) where geo rectification was completed on one example of the map image using a variety of different quantities of interior points for control. Although the change in RMS error was not significantly different for points greater than 10, we routinely utilized more than 10 points per map sheet. The individual RMS error was kept to less than 5.5 meters. It was insured that reference grid points used for geo rectification between the MS series maps and the TRIM data were not shifted as a consequence of going between software. All maps and indices were edge tied. The final projection of the maps is Albers NAD83. Maps were delivered in *.tif and MrSid format.

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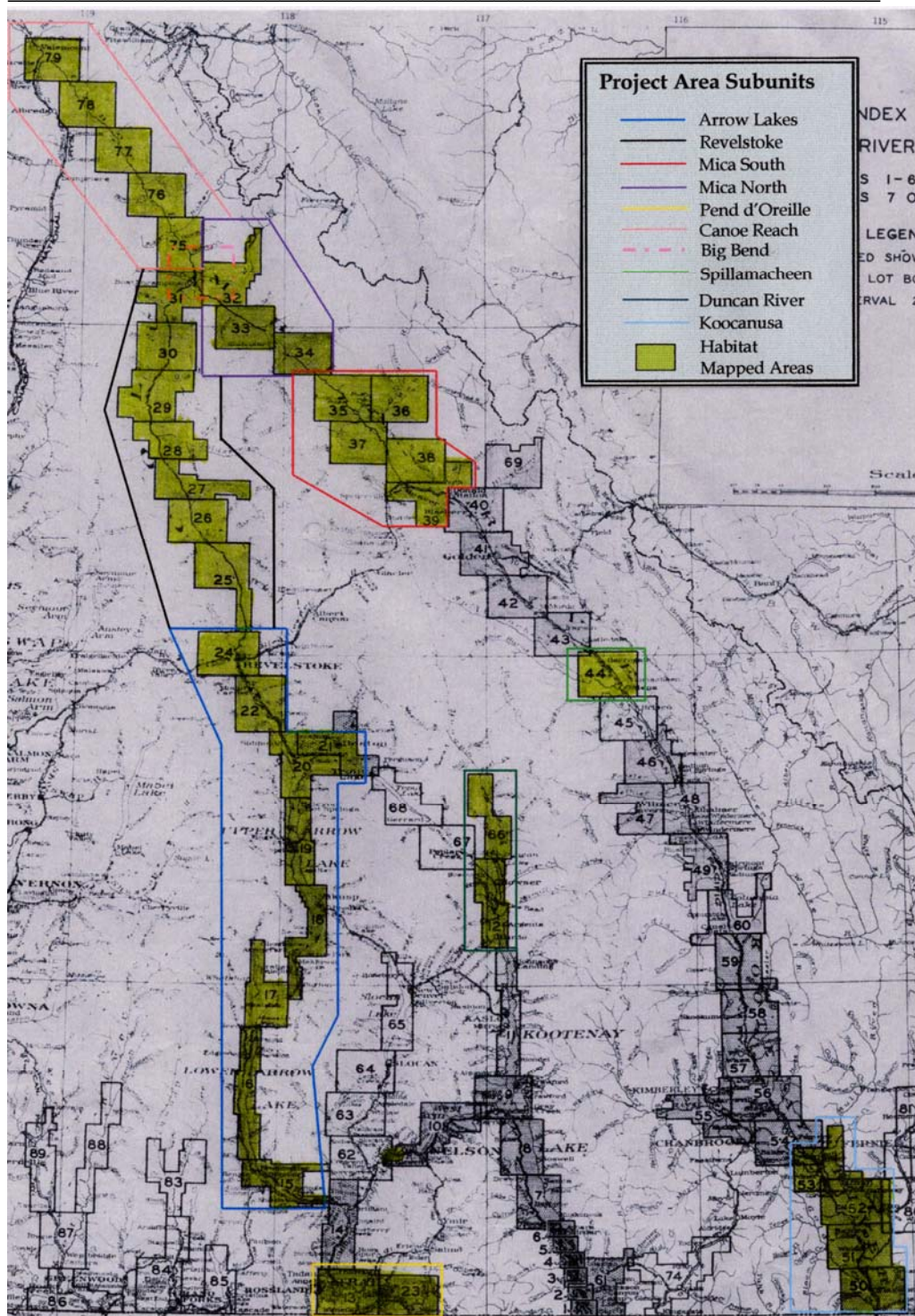


Figure 1. Study Area

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2.1.1 Standards

- Albers Equal Area as defined on:
<http://srmwww.gov.bc.ca/gis/bceprojection.html>
- metadata is provided following the standards on:
<http://srmwww.gov.bc.ca/gis/arcmetadata.html>

2.2 Mosaic of Georectified MS Series Digital Images

An individual map was georectified to lat/long NAD27 format. It is more effective to create the mosaic from the geo referenced lat/long NAD27 projection, as the map did not have the issues of empty space and map rotation that occur when the image is projected in Albers NAD83. The map was then clipped out and, using the four corner lat/long 's, was edge matched to adjacent maps. Once the lat/long mosaic was complete, it was re-projected to Albers NAD83 for final delivery.

The size of the entire mosaic exceeds a reasonable capacity for storage and delivery of the images. The project area was divided into ten subunits for efficient delivery of the mosaics, they are described in Table 1 and illustrated in Figure 1.

Location	MS Map Sheets	File Name
Arrow Lakes	15 – 24 inclusive	Arrow_alb.tif
Revelstoke	24-31 inclusive	Revelstoke_alb.tif
Mica South	35-39 inclusive	Mica_south_alb.tif
Mica North	32-34 inclusive	Mica_north_alb.tif
Pend d'Oreille	13,23	Pend_alb.tif
Canoe Reach	75-79 inclusive	Canoe_alb.tif
Big Bend	31,32,75	Bigbend_alb.tif
Spillamacheen	44	Spill_alb.tif
Duncan River	12,66	Duncan_alb.tif
Koocanusa	50-53 inclusive	Koocanusa_alb.tif
Kootenay Canal	No MS coverage	

Table 1. Project Area Subunits and Mosaic Naming Conventions

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2.2.1 Standards

- Albers Equal Area as defined on:
<http://srmwww.gov.bc.ca/gis/bceprojection.html>
- metadata is provided, following the standards on:
<http://srmwww.gov.bc.ca/gis/arcmetadata.html>

2.3 Reach Break Identification

Stream reach breaks were digitized within the identified project area using the following methods. For all reaches longer than the minimum reach break length of 100 meters at the map scale (.3 cm on the 1:31,640 maps) the reach breaks were identified using air photos and the MS series maps where the scale is appropriate (specifications do not permit reach identification on map materials whose scales are smaller than 1:20,000). Reaches were digitized relative to the water and stream mapping on the MS series maps.

Reaches were determined by noting features such as channel pattern, confinement, gradient, bank and streambed materials. Significant changes in these elements are used to determine the reach boundary. Obstructions or barriers to fish distribution were identified as reach boundaries only if they are less than 100 m long and are consistent with changes in physical criteria used to define the reaches. It is important that reaches that significantly impact fish distribution include the short sections located on valley bottoms and near confluences with larger streams and lakes, and this was the case with the flooded areas we were mapping. This work was undertaken by an R.P.Bio. with specific expertise in fish ecosystems with quality assurance by an R.P.Bio. with specific expertise in reach mapping.

2.3.1 Standards

Mapping followed the standards and procedures identified in Fish and Fish Ecosystem Inventory Standards and Procedures section 2.4.4.1 as found in:

<http://srmwww.gov.bc.ca/risc/pubs/aquatic/recon/recce2c.pdf>

Each reach break was coded using the Standards for Fish and Fish Ecosystem Maps section 2.2:

http://srmwww.gov.bc.ca/risc/pubs/aquatic/fishmaps2k1/fishmaps_april2001.pdf

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2.3.2 Data Capture

For each reach the FCODE, NID, UTM ZONE, EASTING, NORTHING, REACH_NO, PTCLASS and ANGLE were recorded in a point attribute table. Reach numbering followed the criteria in section 2.4.4.2 of the Fish and Fish Ecosystem Inventory Standards. The first reach was recorded closest to the mouth of the stream. Remaining reaches within the study area boundary are numbered in an up-stream ascending order.

2.3.3 Reach Gradient Calculation

The reach gradients were determined using a rise over run calculation based on interpolation of MS map 20 foot contour intervals rounded to the nearest whole number for the downstream and upstream portion of the reach. This information, along with the length of each reach section were added to the reach point attribute table after the MS map water features were digitized and the reaches applied to that coverage.

2.4 Ecosystem Mapping

Within the defined study area boundary of 200 m horizontal distance¹ from the present day TRIM reservoir delineation provided by CBFWCP ecosystems were mapped on 39 MS series maps using a variety of pre-flood air photos as the basis for polygon delineation and attribution in areas not already defined as a stream, lake or river on the MS series mapping (see Stream Digitizing Section 2.5). MS series mapping presents polygons as being either coniferous, deciduous or scrub, but does not specify the variability within these polygons at an ecosystem specific level. A mapping legend for the flood area was created for the flood area mapping by Columbia Basin Fish and Wildlife Compensation Program. It is based on Ministry of Forest site series (Braumandl and Curran 1992) and is cross-walked to US Ecosystem Types (O'Neill et al 2001) and the BC Wetland classification (MacKenzie and Moran 2004). Using the legend located in Appendix 1 ecosystem polygons were delineated on the air photos. This is an approach modified from Terrestrial Ecosystem Mapping (TEM). As bioterrain mapping is lacking for the project area, the ecosystem mapper used the following protocol.

1. Locate the area of interest on both the air photo and the MS series map.
2. Delineate terrain breaks within the study area boundary on the air photo that directly affect the site series which potentially occur on that site paying particular

¹ This distance was initially set at 500 m horizontal distance, but after completion of the Koocanusa subunit it was amended to 200 m.

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- attention to drainage (ie. even a site that is composed of coarse gravels could still support a wet valley floor site series).
3. Delineate breaks in ecosystem and, where appropriate, structural stage within that area.
 4. Give polygon a unique number.
 5. Attribute the ecosystem polygon using the database (see Appendix 2 and map legend (see Appendix 1) making sure to minimize polygon variability but avoid creating polygons less than 2 ha in size. Each polygon must be assigned at least one site series, structural stage, US ecosystem class, slope class, aspect class, forest type and cottonwood cover rating.
 6. Use decile proportioning to describe up to three site series or site series/structural stages per polygon, any ecosystems occupying less than 10% of the polygon can be noted in the comments section of the database.
 7. Make sure that all polygons are closed and that there are no gaps between polygons, insure that there is less than 3 mm overlap between transferred polygons and that feature on the MS series maps (ie. polygon boundaries were superimposed to features of water, wetlands, changes in slope or forest stand composition with NO gaps). Make sure that 100% of the study area within its boundary is allocated to a ecosystem polygon, lake, stream or wetland.

2.4.1 Standards

The format of the mapping and its associated database is based on the Standards for Terrestrial Ecosystem Mapping – Digital Data Capture as found on:

<http://srmwww.gov.bc.ca/risc/pubs/teecolo/temcapture/index.htm>

Standard for Terrestrial Ecosystem Mapping (TEM) - Digital Data Capture in British Columbia Version 3.0

Errata No. 1

Each ecosystem polygon was greater than 2 hectares in size (6 x 6 mm at MS map scale), unless it was a wetland, in which case the maximum size for a unique wetland polygon was 1 hectare (3 x 3 mm at MS map scale). Distinct features smaller than this were included in a larger polygon and described as a proportion of that polygon.

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2.4.2 Data Capture

2.4.2.1 Ecosystem Database

Data attributes recorded for each polygon, as described in Appendix 2 are:

Polygon number
MapID
Ecosection
BEC Zone
BEC Variant
Decile1 proportion
 Site series 1 alpha code
 Site series 1 numeric code
 CB Class (US ecosystem class)
 Wetland class
 Slope class
 Aspect class
 Structural Stage
 Forest type
 Cottonwood presence
Decile 2 proportion
 Site series 2 alpha code
 Site series 2 numeric code
 CB Class (US ecosystem class)
 Wetland class
 Slope class
 Aspect class
 Structural Stage
 Forest type
 Cottonwood presence
Decile 3 proportion
 Site series 3 alpha code
 Site series 3 numeric code
 CB Class (US ecosystem class)
 Wetland class
 Slope class
 Aspect class
 Structural Stage
 Forest type
 Cottonwood presence
Comments

Each polygon within the study area has a unique polygon number, this includes wetlands, two line water features and lakes. There is a one-to-one relationship between each polygon and its associated attribute table.

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2.4.2.2 Ecosystem Polygon Digitization

2.4.2.2.1 Scan aerial photographs and ecosystem linework

The pre-flood aerial photos were scanned at a resolution of 300 dpi, allowing for an output resolution of 1.0 m. The ecosystem linework, drawn on a separate piece of mylar, had been registered to the air photo fiducial points and was indicated with dots. The mylar was scanned in separately as Line Art at a resolution of 72 dpi. This was an acceptable resolution due to the coarseness of the linework.

The scanned files were saved as a TIFF file, <photo_number>.tif.

2.4.2.2.2 Prepare the digital air photos

In PCI XPACE all of the air photos were imported in to a .pix file, which is the native file format for PCI, using the FIMPORT command. Next the air photos that were phototyped had another channel added using PCIMOD which will contain the linework.

2.4.2.2.3 Register the linework

In PCI GCPWorks the linework file was registered to the air photo using the fiducial points on both the air photo and the mylar as the reference points.

2.4.2.2.4 Create orthophotos

The GCPs were collected from the georectified MS maps using PCI's OrthoEngine, Polynomial modeling. Points used were features such as roads, road junctions, stream/river confluences or a unique shoreline feature. Only the portion (as defined by an imposed rectangular boundary) of the air photo that had been bioterrain mapped was used to collect GCPs.

As the MS maps primarily describe river features, collecting GCPs further away from the river could, at times, be problematic. However, after four GCPs are collected, OrthoEngine automatically calculates the RMS error for each GCP, which is then corrected by moving the GCP to reduce the error. The RMS error for each air photo was below one for both the X and Y. Once a suitable number of GCPs with a low RMS error was derived an orthophoto was created.

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2.4.2.2.5 Ecosystem linework extraction

In order to edit the ecosystem linework it was extracted from the *.pix file. This was done in PCI Image Works using the File-Utility-Tools-Subset option and selecting the second channel that contains the linework. The linework was saved as a TIFF file.

2.4.2.3 Ecosystem linework

2.4.2.3.1 Linework preparation

The *.tif file was opened in ArcView (V.3.1) and converted to a grid using the Theme - Convert to Grid function. Next the grid was reclassified so that the linework was 1 and everything else was a 0, or no data. Using the Analysis - Reclassify function values from 0-10 were specified as 1 and 11-254 were specified as No Data. This reclassified grid was then saved as another grid using the Theme - Convert to Grid function.

In Arc/INFO (V8.1) the grid was converted using the GRIDLINE which converts a grid representing raster line features to a line coverage.

```
Arc:gridline <in_grid> <out_cover {positive / data} {thin / nothin} {nofilter / filter}
{round/ sharp} {item} {thickness} {dangle} {weed}
```

```
Arc:gridline <in_grid> <out_cover> positive thin filter round # 28 0 2
```

Next CLEAN was used to generate a coverage with arc topology and to eliminate dangling arcs.

```
Arc: clean <in_cover> {out_cover} {dangle_length}{fuzzy_tolerance}{poly/ line}
```

```
Arc: clean <in_cover>{out_cover} 28 .01 line
```

2.4.2.3.2 Edit the linework

In ArcEdit, the coverage was opened and linework was edited to eliminate additional dangles and gaps. Some editing was necessary as thin sinuous lines were often pinched in spots during the transformation from a grid to an arc coverage.

Once the linework was edited, linework from air photos in an area (i.e. 1:20 000 map sheet) was appended together using the APPEND command.

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Arc: append <out_cover> {feature_class}

Arc: append <out_cover> line

Next it was necessary to edit the linework again to make the arcs contiguous between air photos.

2.4.2.3.3 Labeling

When the ecosystem linework for an area was completed it was opened in Arcview. A new point theme was created. Labels were added and numbered to match with the polygon numbers previously assigned.

2.4.2.3.4 Create polygons

Once the linework and labeling was completed the point shape file was converted to a label coverage and was inserted into the linework coverage using the PUT command in ArcEdit. Next the coverage was cleaned using CLEAN and then built into a polygon coverage using BUILD.

2.4.2.3.5 Internal Quality Control of Ecosystem Linework

Internal quality control occurred throughout the spatial data capture process as documented above.

2.4.3 Internal and External Quality Control Ecosystem Mapping

Internal quality control of ecosystem mapping was completed on a regular basis. Each sheet of ecosystem mapping was either mapped by an R.P.Bio. with direct experience in TEM and at least five years of direct field and air photo based mapping experience in the BEC variants covered by the MS series mapping or by a RISC certified TEM mapper with the above direct experience in the field and in TEM mapping. There was no opportunity to verify the ecosystem mapping in the field, so the mapping can only be considered to be reconnaissance level mapping, with no field verification, only air photo verification according to the TEM mapping standards.

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External Quality Assurance was completed by a P. Ag with field experience in the project area. Comments from QA reports were received and integrated in the final maps. For the external Quality Assurance interim and final reports please contact the client.

2.5 Stream Digitizing

All the streams, lakes, rivers and wetlands were digitized for delivery in .e00 format within the defined project area boundary for the 39 map sheets slated for ecosystem and stream reach mapping.

2.5.1 Standards

This digitizing followed the standards outlined in the TRIM mapping standards as described in:

<http://srmwww.gov.bc.ca/bmgs/trim/1to20specs/specs20.pdf>

The following standards were used:

- Right hand rule
- Downstream rule
- Continuity rule
- Polygon rule where a swamp meets a lake or river
- Connectivity and network rule

2.5.2 Data Capture

Stream data was captured using on-screen digitizing in Arc/INFO 8.1 using the georectified MS series map images as a backdrop.

The IMAGE command was used in Arc/EDIT to display the MS series map images:

*IMAGE <image / image_catalog> COMPOSITE <red_band> <green_band>
<blue_band>*

such that:

IMAGE ms37 COMPOSITE 1 2 3

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This enabled the operator to zoom into the water feature and ensure a fit to the georectified MS maps that meets or exceeds the required 0.5mm (15.84m) error restriction. This allowed the operator to zoom in on complex segments, digitizing at a scale that would be impossible using hardcopy paper maps at a fixed scale.

The methods used to digitize required water features were:

- Obtain georectified image of each MS series map
- Starting in the northwest corner of the mapsheet, digitize all required features to the relevant standards
- Manual review of digitized linework to check for obvious errors
- Clean up linework in Arc/INFO
- Assign FCODE to each line

2.5.3 Database

Stream layer attributes include the following:

- FNODE_
- TNODE_
- LPOLY_
- RPOLY_
- LENGTH

The below are generated by Arc/INFO:

- FCODE
- SOURCE
- GRADIENT

FCODEs were generated from the following source:

http://srmwww.gov.bc.ca:8000/pls/feature_code/FCODE.queryList

2.5.4 Stream Gradient Attribution

Stream reach breaks were snapped to the digital water features and the length of each stream reach calculated using dynamic segmentation principles to intersect the stream arcs. The gradient of each reach was calculated from the previously recorded, interpolated MS map elevations recorded for each reach break. As the project area lacks a Digital Elevation Model (DEM), reach gradient calculations are only as accurate as the interpolations derived from the 20 foot contour intervals of the MS maps.

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2.6 Digitization Procedures and Standards

2.6.1 Feature Codes

All polygons and line features have an associated 'FCODE' assigned. The base layer for the TEM mapping were the water features digitized from the MS series mapping. Ecosystem polygons that are bounded by a water feature used the water feature's linework and its associated 'FCODE' as part of that polygon's delineation rather than re-delineate or re-digitize that line. This insures that the ecosystem polygons are congruous with the MS series water.

The Fcode is stored in a 10-character item consisting of two uppercase letters and eight digits in the associated arc or polygon attribute table. The following 'FCODE's were used within the ecosystem polygons:

- study area boundary WI25100110
- ecosection boundary WI25400500
- BEC variant boundary WI23000130
- ecosystem boundary WI25200100
- when boundaries from another feature (such as a lake) form part of a boundary the original FCODE should be retained
- polygons that have not been mapped and represent a "null" value were assigned an FCODE of XX0000000
- All arcs , other than water features, FF84555000

All of the feature codes conform to the coding scheme outlined in Volume 1 of the Second Draft Report of the National Standards for the Exchange of Digital Topographic Data, July 1984 and as listed in:

<http://srmwww.gov.bc.ca/gis/featurecodes.html>

2.6.2 Polygon Numbering

As stated above, each polygon has a unique polygon number. The unique identifier is entered into the spatial attribute table within the polynum field and the non-spatial attribute tables with a one-to-one relationship between the polygon and its associated attribute tables.

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2.6.3 Data Capture Tolerances

Fuzzy tolerance was set to 2 meters for cleaning and building the polygonal layer. The dangle tolerance was set to 20 meters. Minimum wetland polygon size is one hectare, minimum non-wetland polygon size was two hectares.

2.6.4 Projection

The final coverages were projected into Albers Equal Area as defined on:

<http://srmwww.gov.bc.ca/gis/bceprojection.html>

2.6.5 Digital Deliverables Standards

Digital deliverables will meet standards as outlined in:

<http://srmwww.gov.bc.ca/gis/GISdatastds.html>

This will follow specific Arc/INFO data standards as outlined in:

<http://srmwww.gov.bc.ca/gis/arcddata.html>

3.0 Internal Quality Control and External Quality Assurance

3.1 Professional Sign-off and External Mapping Quality Assurance

Within the working team, each day's work is reviewed by an R.P.Bio. and modifications made to outputs on a regular basis. Materials were released to the client on a regular basis for external Quality Assurance. All efforts were made to insure that materials met the specification within the contract before being sent for external Quality Assurance. Early and iterative QA activities (see Section 4.0 below) assisted in keeping lines of communication open between the client and consultant such that any technical "grey areas" were clarified early in the mapping process.

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3.2 GIS Internal Quality Control Procedures

3.2.1 GeoTif Procedures

As each geotiff was produced a visual check was done and the RMS error report examined to ensure the degree of quality required was being met. Internal QA by Kevin Misurak either approved the work or returned the image for improvements. Final images were then submitted to external QA personnel.

3.2.2 Reach Break Points

Reach break points were examined before digitization by Sylvie Masse R.P.Bio. to ensure that they were in the appropriate locations. Internal QA either accepted the work or returned the reach break mapping for improvements. Reach break points were then digitized following the methods and standards documented in Section 2.3, this work was checked by Tom Dool and either approved or returned for edits. Final reach points were reviewed and approved by Tom Dool before submission to external QA personnel.

3.2.3 Water Streams and Wetlands

Appropriate digitizing practices as documented in Section 2.5 were followed and checked by supervising GIS personnel. As each map sheet was completed it was passed or returned to the mapper for revisions. They checked to ensure all linework was appropriate after edits were completed and the map was considered complete.

3.2.4 Ecosystem Polygons

A selection of typed photos, databases and draft spatial data capture maps depicting ecosystem polygons were checked on a regular basis by Maureen V. Ketcheson R.P.Bio. to ensure that the correct features were being captured as per the map legend found in Appendix 2 and that methods used for ecosystem mapping as documented in section 2.4 were applied consistently. Upon receipt of external QA reports, mapping was revised by the original mapper and reviewed by Ketcheson. Comments were generated and improvements made to the mapping. Mapping not reviewed externally was checked and rendered consistent with external QA comments.

3.2.5 Meta Data and Final Deliverables

The final deliverables were checked against all of the cited standards to ensure that the project requirements were met.

4.0 Discussion of the Mapping Process

This project has been unique and challenging. It differs from most modern digital spatial data capture and mapping processes because it lacks TRIM digital elevation data and TRIM water, as well as ground truth data for checking the reliability of reach break and ecosystem polygon attributes. This section discusses the challenges and consequences of those challenges to the mapping process and result.

4.1 Geo rectification and Mosaic of GEOTIFF Images

As the digital version of the MS maps are derived from 50 year old paper maps, (storage condition unknown) which were then scanned on a flatbed scanner, some distortion is to be expected. Due to this, more GCPs were collected around the borders of each map in order to facilitate the creation of a seamless mosaic.

Once the georectified maps were produced, mosaics of the subunits were created. The mosaics were created in latitude/longitude projection as it was easier to trim the surrounding border on the maps and to mosaic them together. As individual TIFFs the images were loaded in ArcView to investigate which order the TIFFs should be placed in the mosaic in order to create the best product.

Although great care was taken, there may be instances where there are slight gaps between MS maps, none of which prevent map interpretation. It should be noted that there were occurrences where longitudinal lines did not match up, although a few minutes either way they would.

4.2 Reach Break Mapping

The reach breaks were identified by qualified fisheries biologists. The biologists annotated paper maps of the study area noting the break number and elevation of each break. The breaks were then digitized in on screen ArcView 3.1. Fcodes were assigned according to the type of reach break identified by the biologists. The list of available Fcodes was provided by CBFWCP Staff. The line segments of the water features

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characterized by each system of breaks was assigned a set of unique ID's called the ILP and then split to identify the length of each individual reach. Using the length of the reach and the difference in elevation of the start and end point of the reach breaks, the gradient of each stream segment was calculated. Each break has been assigned a unique ID that identifies the water feature it is found on. This attribute is the ILP. The reach breaks and the ILP coverage were then formatted for delivery using the MSRM data standards.

4.3 Ecosystem Mapping

4.3.1 Map Reliability

The reliability of the mapping can be inferred through the short comings within the map legend and data sources. This can be related ultimately to the interpretations that the final mapping will support.

The ecosystem map legend evolved as mapping proceeded and external QA comments were received. The predominant issue around this mapping is the lack of field data describing the relationship between flood plain physical characteristics and site series classification. The ecosystems that were in place before the flood plains were inundated are rare in the present day landscape. The Columbia Basin is an area of high relief with narrow valleys, consequently, level ground and flood plain ecosystems are rare, and where present are often disturbed by human activities such as settlement, golf courses, pastures and transportation corridors. Site series classifications (Braumandl and Curran 1992) were not particularly elaborate in these areas. Not only are undisturbed flood plains rare in the post flooding era, but Ministry of Forests priorities for site series classification were with upland sites, suitable for forestry, during the development of the field guides.

A secondary, but equally important issue related to map reliability was the quality of the air photos used for ecosystem mapping. Table 2 itemizes by map sheet details about air photos and MS map coverage provided for that portion of the mapping and the consequences to the mapping. In general the following problems with the air photos complicated mapping:

- photos were not the source photos used in the MS mapping
- flood plains had changed between the era of the MS map and era of the photo used for this project
- photo water features did not always match MS water features
- photos were often in poor condition and lacked reliable stereo coverage
- flight lines were oriented diagonally across study area causing distortion
- season of photo varied within a single study area

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The combination of photo quality and lack of field data resulted in the photo typing being more or less an “educated estimate” for each attribute in the database. QA discussions were based on “opinion” rather than data, every effort was made to make the mapping consistent with the interpretation of site series/site feature relationships expressed by the external QA personnel. What follows is a discussion of issues related to the above relative to columns in the database used for ecosystem description found in Appendix 2.

4.3.2 BEC Variant

At the onset of mapping BEC variant coverage provided by the BC Ministry of Forests was superimposed on the MS maps within the prescribed mapping buffer. This coverage was based on legacy maps originally intended to be depicted at 1:250,000. When superimposed on MS series maps (scale varied, but approximately 1:32,000) BEC lines proved to be inappropriate and, after review of the Kooecanusa mapping, were adjusted by the ecosystem mappers to better reflect natural landscape boundaries between BEC variants and to prevent unnatural subdivisions within ecosystem polygons. The BEC line was relocated within the mapping buffer with consideration to MS map water (ie. down the centre of the river) changes in aspect and slope (ie. wetter variant moved to cool aspects) or natural landscape shape features. The consequence of adjustment of the BEC lines is that they will not longer match BEC lines used in Ketcheson et al 2001 as the basis of the US Habitat Type mapping project, and to the BEC used in the Arrow TSA PEM (Ketcheson et al 2003), East Kootenay PEM (Ketcheson et al 2002) and Invermere PEM (Ketcheson et al 2004) so if this data is compared to the flood area mapping during subsequent interpretive exercises there will be discontinuities between the BEC linework.

4.3.3 Ecological Classification

The expanded map legend in Appendix 1 and map legend in Appendix 2 describe each ecosystem mapped in the project area relative to their BEC variant, site series, US habitat class, structural stage, modifiers, stand type and, if applicable, wetland class and cottonwood presence. It is certain that there were ecosystems within the flood area that are not adequately described by the site series classification as published by the BC Ministry of Forests. This is especially true for wetlands and floodplain micro site ecosystems. The classification utilized in this project for wetlands lacks enough detail to differentiate between the vast number of diverse wetlands that likely existed in the project area pre-flooding. Most wetlands are classified as WE at the site series level, with graminoid versus shrub dominated wetlands recognized at the structural stage level. The wetland classification (MacKenzie et al 2004) is applied at the Site Class level, recognizing Fen (Wf), Marsh (Ms), Swamp (Sw), Shallow-waters (Ws), Flood Associations (Df) and Shrub-carr Transition Association (Tn). Definitions of these Site Classes can be found in the Appendix 3.

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In situations where the mappers could not distinguish between non wetland site series that occur in similar ecological circumstances a map unit was developed that predicts the possibility of up to three site series occurring within a relatively small area such as narrow toe slopes, or in larger areas such as flood plain mosaic ecosystems. An example of this occurs in the ICHmw2 where RD (06), RH(07), and RS (08) are mapped individually as well as combined to form XX (00) for areas where individual distinction is difficult. Descriptions of these complex map units can be found in Appendix 1 and Appendix 2.

The US Habitat classes used in this project were developed for mapping at much smaller scales than that of this project. However, if the next level of classification “habitat elements” (O’Neil et al 2001) within that system is interpreted and “cross-walked” to the BEC system, it will be possible to use this mapping at a more detailed level within the US Habitat Database at the critical habitat elements level (O’Neil et al 2001).

Interpretation of stand structure was complicated by the inconsistency of air photo quality. In some areas stands were being harvested to make way for the flooding, thus structural stage calls do not reflect pristine, pre-flood circumstances. In other areas, like the Koocanusa the valley floor destined for flooding was under cultivation or grazing.

Interpretation of stand composition and slope class was also complicated by photo quality and lack of field data.

Table 2 below describes specific issues about the air photos and base maps and their consequences to mapping.

4.3.4 Spatial Data Capture of Ecosystem Polygons

Air photo scale and quality complicated spatial data capture of ecosystem polygons. Aligning the scanned polygons from photos to digitized MS water features was complicated by inconsistencies in the MS maps, which were a consequence of the era of the mapping (1950’s). Table 2 itemizes specific issues with the MS base maps to the spatial data capture of ecosystem polygons and other mapping processes such as geo-rectification and mosaic building.

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Table 2. Air Photo and MS Series Base Map Issues and Their Consequences to the Mapping Process

Mapsheet Number and Subunit	Air Photos	MS Series Base map	Consequences
General	<ul style="list-style-type: none">-photo years often different from base map year-some wetlands were difficult to interpret from photos with no field sampling to help	<ul style="list-style-type: none">-base maps drawn based on different years and seasons	<ul style="list-style-type: none">-some transitional problems between map sheets-rivers change over time and do not necessarily reflect what was on the photo-wetland mapping reliability may vary
10 Kootenay Canal	<ul style="list-style-type: none">no problems	<ul style="list-style-type: none">-only partial legacy base map available-present TRIM used to obtain base and buffer	<ul style="list-style-type: none">-no problem because present river level is the same as before canal construction
12 Duncan Lake	<ul style="list-style-type: none">-mixed scale photo coverage-different photo years in coverage-some coverage in spring before trees were flushed	<ul style="list-style-type: none">-river on photos differed from base map	<ul style="list-style-type: none">-more difficult to interpret details of ecosystems from smaller scale photos-structural stages differ between photos and don't give consistent seasonal interpretations-when trees are not flushed, on early spring photos, the deciduous stands are much more difficult to pick out
13 Pend d'Oreille	<ul style="list-style-type: none">-river level different from base map		<ul style="list-style-type: none">-more rock showing within river on photos than indicated on MS series maps
15 Arrow Lakes	<ul style="list-style-type: none">-lake level different from base map-some seasonal flooding in photos; many islands and shoreline are under water-mixed year photo coverage		<ul style="list-style-type: none">-flooded lowland and gravel bars are difficult to interpret because they are flooded on photo, but are indicated on the MS maps-structural stages differ on photos and don't give consistent seasonal interpretations
16 Arrow Lakes	<ul style="list-style-type: none">-lake level different from base map-some seasonal flooding in photos; many islands and shoreline are under water-mixed year photo coverage	<ul style="list-style-type: none">-collecting of control points difficult for some sections	<ul style="list-style-type: none">-flooded lowland and gravel bars are difficult to interpret when flooded on photo-structural stages differ on photos and don't give consistent seasonal interpretations-some polygons may be slightly out spacially due to control point difficulties

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Mapsheet Number and Subunit	Air Photos	MS Series Base map	Consequences
17 Arrow Lakes	-lake level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -some reservoir clearing in photos		-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations -clearing for reservoir does not accurately reflect pre-project structural stage
17 Whatshan Lake	no problems	-base map at post flooding level -photo mosaic used to obtain pre-flooding lake level shape	-does not fit onto legacy base map
18 Arrow Lakes	-lake level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -mixed year and scale photo coverage -some reservoir clearing in photos		-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations -more difficult to interpret details of ecosystems from larger scale photos -clearing for reservoir does not accurately reflect pre-project structural stage
19 Arrow Lakes	-lake level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -mixed year and scale photo coverage		-flooded lowland and gravel bars are difficult to interpret when flooded on photo -more difficult to interpret details of ecosystems from larger scale photos -structural stages differ on photos and don't give consistent seasonal interpretations
20 Galena Bay Arrow Lakes	-lake/river level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -mixed year photo coverage		-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations

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Mapsheet Number and Subunit	Air Photos	MS Series Base map	Consequences
21 Beaton- Arrow Lakes	-lake/river level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -mixed year photo coverage -some photo distortion on steep slopes		-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations -some polygons may be distorted on map
22 Columbia R south of Revelstoke	-river level different from base map -some seasonal flooding in photos; many islands and shoreline are under water -mixed year photo coverage	-different mapping technique was used to draw river high water level	-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations -low water gravel bars are designated as above high water on this mapsheet
23 Pend d'Oreille	river level different from base map		-more rock showing along river on photos than typed in polygons
24 Columbia R at Revelstoke	-river level different from base map -some seasonal flooding in photos; many islands and shoreline are under water	-base map river boundary drawn differently	-flooded lowland and gravel bars are difficult to interpret when flooded on photo -structural stages differ on photos and don't give consistent seasonal interpretations -low water gravel bars are designated as above high water on this mapsheet
25 Columbia River south of Mica	-photo coverage in spring before trees were flushed		-when trees are not flushed, the deciduous stands are much more difficult to pick out
26 Columbia River south of Mica	-photo coverage in spring before trees were flushed -some cloud and over exposure in photos		-when trees are not flushed, the deciduous stands are much more difficult to pick out -fewer details about ecosystem can be seen
27 Columbia River south of Mica	-photo coverage in spring before trees were flushed -some cloud and over exposure in photos		-when trees are not flushed, the deciduous stands are much more difficult to pick out -fewer details about ecosystem can be seen

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Mapsheet Number and Subunit	Air Photos	MS Series Base map	Consequences
28 Columbia River south of Mica	-photo coverage in spring before trees were flushed		-when trees are not flushed, the deciduous stands are much more difficult to pick out
29 Columbia River south of Mica	-photo coverage in spring before trees were flushed		-when trees are not flushed, the deciduous stands are much more difficult to pick out
30 Columbia River south of Mica	-river level different from base map -mixed year photo coverage		-channels and vegetation may be slightly different from those in base map year -structural stages differ on photos and don't give consistent seasonal interpretations
31 Columbia River at Mica	-river level different from base map		-channels and vegetation may be slightly different from those in base map year
32 Columbia/ Wood River	no problems		
33 Columbia River	no problems		
34 Columbia River/ Kinbasket Lake	no problems		
35 Columbia and Bush Rivers	no problems		
36 Bush River	no problems		
37 Columbia River	no problems		
38 Columbia River	no problems		
39 Columbia River	no problems		
40 Columbia River	no problems		
44 Spillamacheen River	-coverage is at edge of photos with much distortion		-polygons may be slightly distorted -ecosystem interpretation was more difficult
50 Koocanusa	-river has changed course from base map -some distortion at edge of photos		-channels and vegetation may be slightly different from those in base map year -some polygons may be slightly distorted

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Mapsheet Number and Subunit	Air Photos	MS Series Base map	Consequences
51 Koocanusa	-river has changed course from base map -some distortion at edge of photos		-channels and vegetation may be slightly different from those in base map year -some polygons may be slightly distorted
52 Koocanusa	-river has changed course from base map -some distortion at edge of photos		-channels and vegetation may be slightly different from those in base map year -some polygons may be slightly distorted
53 Koocanusa	-river has changed course from base map -some distortion at edge of photos		-channels and vegetation may be slightly different from those in base map year -some polygons may be slightly distorted
66 Duncan River	-mixed scale photo coverage -different photo years in coverage -some coverage in spring before trees were flushed -some photos overexposed -some photos were only laser copies	river on photos differed from base map	-more difficult to interpret details of ecosystems from larger scale photos -structural stages differ on photos and don't give consistent seasonal interpretations -when trees are not flushed, the deciduous stands are much more difficult to pick out -fewer details about ecosystem can be seen with photo overexposure and using laser copies
75 Canoe River	no problems		
76 Canoe River	no problems		
77 Canoe River	-some reservoir clearing in photos		-clearing for reservoir does not accurately reflect pre-project structural stage
78 Canoe River	-some reservoir clearing in photos		-clearing for reservoir does not accurately reflect pre-project structural stage
79 Canoe River	-some reservoir clearing in photos		-clearing for reservoir does not accurately reflect pre-project structural stage

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5.0 Deliverables

1. Regular meetings with CBFWCP and MWLAP personnel prior to and during duration of contract to insure materials being submitted are appropriate for future interpretive needs, as well as clarification of any technical issues that may arise.
2. Georectified TIFF images of MS series mapping and mosaics (delivered via DVD to client).
3. Reach Break and Ecosystem Mapping digital deliverables (delivered via FTP to client).
4. MS series water feature digital deliverables (delivered via FTP to client).
5. Final report and expanded legend (four hard copies plus digital copy in .pdf format).

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