STREAM CHANNEL CLASSIFICATION USING LARGE SCALE AERIAL PHOTOGRAPHY FOR SOUTHEAST ALASKA WATERSHED MANAGEMENT

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ABSTRACT

Stream channel management units called channel types have been identified using stream morphologic and landform characteristics. Channel types have been mapped for approximately 800,000ha of Chichagof Island in Southeast Alaska. Techniques are described for using mapping differentia to distinguish and map channel types on 1:15,840 scale color aerial photographs. Channel types provide a framework for making aquatic resource management interpretations at various forest planning levels. A current application to a timber sale project plan is described.

INVENTORY PURPOSE

The need for a reliable watershed and stream inventory in Southeast Alaska arose with the rapid development of timber resources in conjunction with increasing pressure on natural fish production from commercial, subsistence, and sports fishermen. Timber harvesting and fishing are not always fully compatible resource uses. Soil erosion and subsequent sedimentation from logging has the potential to reduce fish spawning and rearing habitat quality. Streamside canopy removal may also affect stream temperature, food sources, and large organic debris (LOD-tree stems greater than 10cm in diameter) that influence fish habitat quality and channel stability (Chamberlin 1982). These potential timber harvesting impacts on highly productive fish habitat are a major forest management issue in the region.

An aquatic resource inventory has been developed on the Tongass National Forest-Chatham Area (TNF-CA) to provide a means for addressing this resource issue. In addition, other resource issues such as maintenance of water quality and design of inchannel structures (e.g., bridges, fish passes) are addressed.

This reconnaissance level inventory procedure is intended for forest resource planning applications. On the broad forest land use planning level, it provides general aquatic resource information applicable to the development of national and regional forest management direction. For specific project planning applications, aquatic resource inventory data is used to make preliminary fish habitat quality and habitat sensitivity management interpretations on identifiable stream segments. These channel type management interpretations are categorizations of a given channel area according to a management concern, problem, or constraint encountered in conducting a given management activity.

The remoteness, difficulty of access, and large size of the survey area make detailed ground surveys of streams impractical. Channel type mapping combined with a systematic field sampling scheme, provides a reliable, cost effective, and efficient method for TNF-CA stream inventories.

SETTING

The area inventoried encompasses approximately 800,000ha of the TNF-CA on Chichagof Island, located between Juneau and Sitka, Alaska (figure 1). The climate is maritime, with annual precipitation ranging between 200 and 450cm. Vegetation is predominantly western hemlock - Sitka spruce rain forest with interspersed muskeg bogs composed primarily of sphagnum mosses and sedges. These vegetation communities grade to subalpine brush fields and alpine tundra at elevations between 500 and 700m. Streams draining Chichagof Island commonly occupy glaciated valleys. Runoff originates in alpine snowfields or small cirque lakes and descends rapidly to the many fiords and inlets that dissect the archipelago.

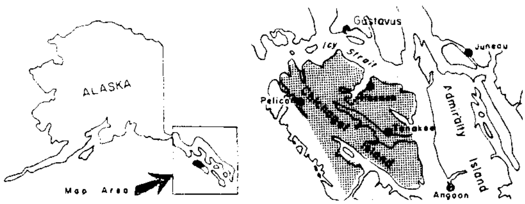

Figure 1. SE Alaska and Chichagof Island survey area.

THEORY AND APPROACH

The TNF-CA Aquatic Resource Inventory is a combination of channel classification, channel type mapping, and field data collection. Classification is the determination of channel characteristics that distinguish channels areas of similar forest management interpretations (see "Channel Type Descriptions" in USDA Forest Service Alaska Region 1983a, for a complete discussion of classification characteristics). Channel type mapping is the use of differentia to locate channel types using 1:15,840 color aerial photographs. Differentia are certain channel characteristics that can be inferred from aerial photographs. They are also characteristics that are correlated to the other, nonobservable channel classification characteristics such as bed substrate size.

Field data collection is used to make observations on all classification characteristics so as to determine the specific management interpretations associated with each channel type.

The TNF-CA Channel Type Classification System (CTCS) is based on three concepts. First, geomorphic processes that are independent of inchannel processes affect stream channel characteristics. Watershed geomorphic factors directly or indirectly influence: streamflow characteristics; chemical and physical water quality characteristics; and stream channel size, shape, and substrate characteristics (Beschta 1978). In aggregate these stream characteristics represent the physical surroundings or habitat of aquatic organisms. The relationship of these geomorphic variables to fish habitat has been supported by several investigators. Platts (1979) demonstrated the relationship of stream order to the distribution of fish populations in Idaho river basins. Swanston et al. (1977) used quantitative geomorphic variables to qualitatively differentiate between good and poor pink and chum salmon producing streams in Southeast Alaska. Parsons et al. (1981) showed significant correlation between geo-morphic parameters and fish habitat quality in Oregon salmon streams.

The second concept is that fluvial processes within a drainage network affect inchannel characteristics and fish habitat quality. Schumm (1979) describes three fluvial system zones according to their dominant function: sediment source, transport, and deposition zones. Physical stream channel characteristics and associated aquatic habitat are largely dependent upon the dominant fluvial process shaping them. In the source zone (high gradient, 1st order channels) high velocity streamflow, and active channel erosion, and sediment transport precludes the development of stable, diverse aquatic habitat. At the other end of the spectrum more consistent streamflow and sediment transport characteristics of deposition zone channels (low gradient, 3rd order channels) promotes the establishment of more diverse and productive aquatic communities.

The third concept is that riparian functions within a channel area affect fish habitat quality. Riparian zone function has been described by Meehan et al. (1977) and Swanson et al. (1981) in terms of the role stream side vegetation canopy, stems, roots, and inchannel LOD play in shaping aquatic habitat. Streamside canopy shading influences primary food production by reducing photosynthetic rates and overall rates of biological activity. Riparian vegetation also controls the availability of organic detritus as a basic food source for aquatic organisms. Tree roots and low lying brush increase stream bank stability; provide undercut banks for fish cover; and retard the movement of sediment and water during flood flows. Inchannel LOD helps to shape the distribution of pool, riffle, and undercut bank habitat. It also acts as a trap for fine particulate organic matter and serves as a substrate for biological activity.

The CTCS is a hierarchical approach in which channel types are components of larger hydrologic groupings of drainage segments within watersheds. The first level of classification for management interpretation is made using subsections. Subsections are physiographic regions having different climate, geology, and topography (USDA Forest Service, Alaska Region 1983b). Subsections are used to first group watersheds according to broad regional trends in water quality and channel stability. The TNF-CA is divided into 16 subsections, each approximately 175,000ha in size. Information from past TNF-CA water resource inventories indicates that subsection boundaries separate watersheds with significantly different water chemistry characteristics. In addition, though the same channel types occur in each subsection, they can have important differences in fish habitat quality and sediment regime characteristics.

The next level in the classification hierarchy is the channel type association. Channel type associations are defined by the dominant fluvial geomorphic processes influencing the development of stream environments. Channel type associations are segregated by their dominant fluvial functional zones of sediment source (A association), transport (B association), and deposition (C association). Factors important in this categorization include: contributing watershed area, relief, and stream order. Individual channel types within each association are differentiated by adjacent landforms, channel morphology, and riparian vegetation communities. The average lengths of channel types are 1200m, 1800m, and 2200m for the A, B, and C associations respectively. Each channel type has a relatively consistent range of fish habitat and channel stability characteristics. Consequently, for forest planning purposes, a specific set of management interpretations is applicable to a given channel type.

Table 1. Selected Channel Type Mapping Differentia, TNF-CA

Channel Type	Adjacent Landform(s)[1]	Channel Characteristics[2]	Basin Area[3]	Canopy Cover[4]
A1	Subalpine sideslopes, mountain slopes, hills, gently sloping lowlands	- Very high gradient - Deep incision - Narrow width - Single channel	Small	Moderate to high
C1A	Flood plain	- Low gradient - Shallow incision - Moderate width - Multiple channels	Moderate to large	Low to moderate
C3A	Mountain slopes, hills, infrequently dissected footslopes, frequently dissected footslopes and alluvial fans	- Moderate gradient - Moderate incision - Moderate width - Single channel	Large to very large	Moderate

SOURCE: USDA Forest Service Alaska Region 1983a.

NOTE: All feature interpretations are made using 1977 1:15,840 color aerial photographs.

1. Landforms are defined according to the Chatham Area "Integrated Resource Inventory Landform Descriptive Legend" (USDA Forest Service Alaska Region 1983b).

2. Channel incision ranks: shallow = less than 3m; moderate = 3m to 10m; deep = 10m to 30m; very deep = greater than 30m. Channel gradient ranks: low = less than 3%; moderate = 3% to 6%; high = 6% to 10%; very high = greater than 10%. Channel pattern classes: Single channels have one continuous main channel bed; multiple channels have a main channel bed that is frequently broken by overflow channels or islands; braided channels have numerous, interlaced channels and extensive gravel bar development. Channel width ranks: narrow = less than 10m; moderate = 10m to 30m; broad = greater than 30m.

3. Basin area classes: small = less than 500ha; moderate = 500ha to 1300ha; large = 1300ha to 3900ha; very large = greater than 3900ha.

4. Canopy cover classes: low = less than 25%; moderate = 25% to 50%; high = greater than 50%.

CHANNEL TYPE MAPPING PROCEDURE

The mapping differentia used to locate channel types on 1:15,840 aerial photographs are listed in table 1. Adjacent landform and basin area are characteristics that account for geomorphic processes acting outside of the stream channel proper which affect channel characteristics. Actual channel characteristics used as differentia are channel gradient, incision depth, width, and pattern. These characteristics account for inchannel fluvial processes which affect channel characteristics. Canopy cover reflects riparian functions which affect fish habitat quality. All of these differentia are correlated to, and reflect, channel characteristics affecting channel type management interpretations. The differentia subdivisions defined in table 1 are the breaks in these differentia determined to be significant in making channel type management interpretations.

Adjacent landform refers to the landform type that occurs directly adjacent to the channel area. Landforms are defined according to the TNF-CA "Landform Descriptive Legend" in Integrated Resource Inventory: Legends Handbook II (USDA Forest Service, Alaska Region 1983b). In certain cases, only a single landform is associated with a given channel type, whereas in other cases, there is a group of landforms. Limited inclusions of other landforms not defined as being associated with a channel type are also possible, but must meet inclusion rules defined for each channel type (USDA Forest Service, Alaska Region 1983a). Adjacent landform influences channel bank stability and sediment delivery to the the channel.

Landforms are primarily classified by slope shape and gradient, external relief, drainage dissection frequency, and dissection depth. Drainage dissection frequency and slope shape (e.g., concave, convex, straight, or flat) are directly observable from features on the aerial photographs. Dissection depth is estimated using observable tree heights for comparison. External relief represents the range in landform elevation and is measured from 1:63,360, 100 feet contour interval topographic maps until the intrepreter is sufficiently experienced to estimate it directly from the aerial photographs.

Basin area is the catchment size of a given channel type. Peak and base flow magnitudes are strongly influenced by basin area. It is measured from aerial photographs using a transparent dot grid overlay.

Channel characteristics includes four criteria: channel gradient, incision depth, width, and pattern. Channel gradient is the channel bed slope. It greatly influences channel stability, stream power, and fish passage. Using aerial photographs, gradient is inferred from the adjacent landform slope or by the relative frequency of cascades, and gravel bars (the steeper the gradient, the more frequent are cascades, and the less frequent are observable gravel bars).

Incision depth is the vertical distance from the channel bed to the nearest observable slope break above the lower stream bank. Incision depth influences bridge crossing design and channel flow containment. It is estimated by making comparisons to nearby trees of known heights.

Channel width is defined as the horizontal distance between opposing high water marks (i.e., bankfull stage). Channel width influences stream crossing design and indicated peak flow magnitudes. It is measured directly from aerial photos using a scale conversion factor.

Channel pattern is a description of the main channel bed continuity. It reflects flooding and sediment routing characteristics, flow containment, channel stability, and fish habitat characteristics. The aerial photograph features used to distinguish channel patterns are listed in footnote 2 of table 1.

Canopy cover is defined as the percent of shading provided during the annual peak insolation period (July for the TNF-CA). It affects stream temperature extremes, dissolved oxygen content, riparian vegetation cover, and organic inputs to the aquatic environment. Channel type canopy cover characteristics are described using typical groupings of canopy classes defined for adjacent landtype mapping units (USDA Forest Service, Alaska Region 1983b). Crown density is measured from aerial photos using a crown closure comparator overlay.

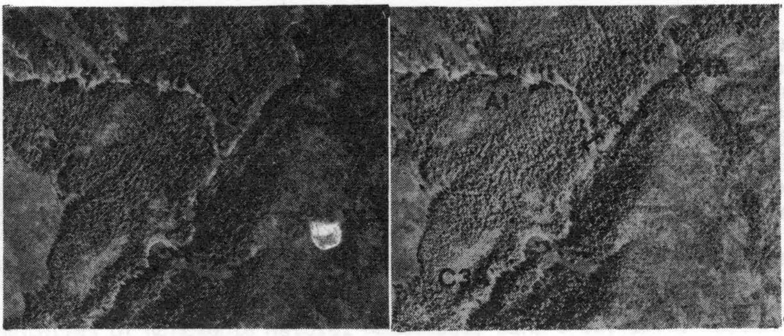

Figure 2. An example of three Tongass National Forest, Chatham Area channel types on a 1:15,840 scale stereo photograph pair. Color aerial photography generally permit better distinction of incision depth and gravel bars.

An example of channel type mapping is shown in figure 2. Continuous chutes and falls and the lack of observable gravel bars are indicative of very high gradients. These features are apparent in the A1 channel type in figure 2. A moderate overall gradient is inferred for the C3A channel type because observable falls and chutes are lacking, but so are observable gravel bars. The C1A channel type also lacks falls and chutes, but has obvious gravel bar development. This is characteristic of a low channel gradient. Channel width differences are clearly apparent between the A1 (less than 10m) and either the C3A or C1A (10m to 15m) channel types. Adjacent landform differences are also apparent between the C1A (flood plain adjacent) and either the A1 or C3A (combination of subalpine sideslopes and mountain slopes adjacent) channel types.

The actual channel type mapping procedure is divided into three parts: premapping, field sampling, and final mapping. Premapping is the initial differentiation and mapping of channel types as described above. Field sampling is the ground truthing of the channel type mapping and collection of additional resource data for making management interpretations.

Final mapping entails mapping corrections, channel type correlation, and mapping transfer to the final map base. Incorrectly mapped channel types are reexamined on the aerial photographs to determine the interpretation error. Correlation is performed once all watersheds are mapped to consolidate those channel types with insignificant management interpretation differences, or to eliminate those channel types that occur infrequently. The final map product is to be 1:31,680 topographic quadrangle maps.

APPLICATIONS

Channel type classification and inventory using aerial photographs is a framework within which aquatic resource information can be collected, compiled, mapped, and applied in a systematic manner. Each channel type represents a distinct range of aquatic resource characteristics and management concerns. Intensively field sampling all streams is generally not a practical approach for the management of extensive land areas such as the TNF-CA. Channel types serve as a basis for extrapolating stream field data to unsurveyed areas with a reasonable degree of confidence. Channel type maps also provide a means for aggregating stream survey information. By accumulating lengths of channel types, for example, a relative measure of the total amount of fish habitat classes found within a watershed or subsection can be obtained.

Two levels of classification and inventory have been mentioned. The first level, represented by TNF-CA subsection delineations, pertains to very general resource management applications. The second level defined by channel types is applicable to more detailed project planning needs. The project planning applications of the channel type classification will be elaborated upon in the following discussion.

Channel type mapping was used in the evaluation of proposed resource management alternatives for the Alaska Lumber and Pulp 1986-90 Operating Plan Draft Environmental Impact Statement (USDA Forest Service, Alaska Region 1983c). For this application each channel type was assigned an aquatic resource value rating based on channel sensitivity and fish habitat quality indices. Channel sensitivity factors include: sediment input and conveyance potential; riparian vegetation influence; and large organic debris (LOD) influence. Sediment related factors are derived from channel bank and bed stability and stream power measurements. Riparian vegetation and LOD influences are based on streamside canopy type and closure, and the distribution and stability of natural inchannel LOD accumulations.

The habitat quality index is a dimensionless number derived from empirical equations relating fish populations to physical habitat characteristics (Barber, Oswood, and Deschermeier 1981). These habitat features are defined by spawning gravel area, instream debris, riparian cover, and water depth and velocity classes. The product of the channel type sensitivity index, the habitat quality index, and the channel type length yields the aquatic value rating (AVR).

In its present form the AVR is not a measure of fish biomass production. The AVR is a relative measure of stream value. The rating is based on the extent and quality of the fish habitat the stream contains; as modified by the streams sensitivity to change from management disturbances. Color coded stream resource maps developed from AVR habitat quality and sensitivity classes provided planners with a visual display for locating potential management conflict areas and evaluating possible consequences of management alternatives. For example, channel types coded red on the aquatic resource map rank high in habitat quality and sensitivity rating. Those stream segments may then be avoided in planning timber cutting units. Where potential conflicts cannot be avoided, those conflict areas can be prioritized by resource specialists for on-site review and the development of activity mitigation prescriptions.

SUMMARY

Stream channels can be classified using aerial photo differentia according to their morphological, biological, and management response attributes. The systematic process of classification and mapping provides the basis for identification of homogeneous stream and channel adjacent units called channel types. Channel types represent a definable mapping unit for data collection, land management planning, and management activity prescriptions relating to aquatic stream resources.

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