TFW-AM-89-001

VALLEY SEGMENT TYPE CLASSIFICATION FOR FORESTED LANDS OF WASHINGTON

By

C. Edward Cupp

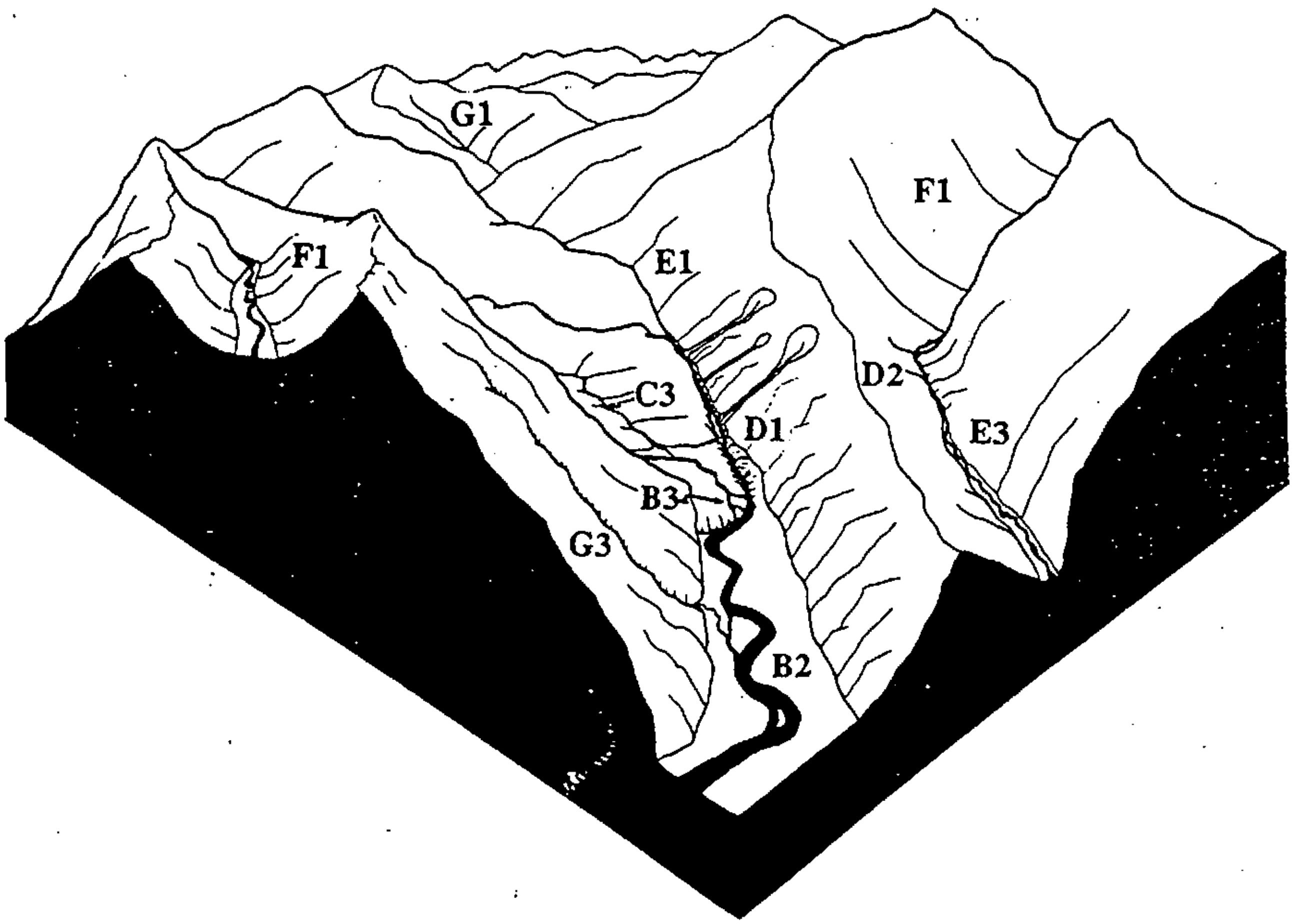
TIMBER/FISH & WILDLIFE

JUNE 1989

Valley Segment Type Classification for Forested Lands of Washington

Timber, Fish, and Wildlife Ambient Monitoring Program

C. Edward Cupp



ACKNOWLEDGMENTS

Thanks go out to those involved in the development and application of this valley segment classification system. Funding was provided by the Washington Forest Protection Association. The U. S. Forest Service, Gifford Pinchot National Forest provided original funding for development and testing. J. A. Metzler provided technical assistance and editorial reviews from the conception of the project. J. Light, K. Sullivan, and D. Somers offered helpful insight into formulating concepts and practical applications of stream classification.

Illustrated by Jo Ann Metzler

INTRODUCTION

Natural resource managers face problems of understanding and managing for the effects of basin-wide and stream-side land use practices on stream conditions. Stream channels and their associated biological components may show large variations in response to perturbations due to differences in their inherent productivity, stability, and resiliency to change. Differences in climate, flow regime, and geomorphic characteristics of drainage basins lead to significant natural variation in physical and biological characteristics of streams. The wide variety of land and associated stream conditions encountered in forested lands of Washington makes it impractical to develop stream management guidelines that would be applicable to all streams. For this reason, the need for an integrated land/stream classification system and systematic stream inventory method is widely recognized.

Stream classification can be used as an important tool to conduct stream inventories and as a foundation on which to develop basin-wide and stream-side management prescriptions. Predicting the outcome of land-use activities on stream systems is generally based on the extrapolation of data collected on one stream reach to another of similar character. However, the unqualified extrapolation of habitat characteristics and fish population estimates from one reach to the entire system, or to a stream reach that is grossly dissimilar, is not biologically or statistically valid (Hankin 1984). A clear system of stream classification is needed to separate natural variation among stream reaches from variation due to land management activities.

Because the structure and function of a stream and its biological communities are strongly associated with the land through which it flows, it is of little value to classify streams as units independent of their watersheds (Lotspeitch and Platts 1982). Consequently, recent development of applied stream classification schemes has emphasized the role basin and valley bottom geomorphology plays on the channel morphology and inchannel habitat characteristics (Paustian 1984, Rosgen 1985, Frissell and Liss 1986). However, these classification systems have not been broadly applied in land management, perhaps due to the paucity of empirical studies which validate their utility. The former two classifications rely primarily on inchanel characteristics for distinguishing classes, while the latter relies more on valley landform and less on the transient inchannel features. Classification relying on features susceptible to change in a relatively short term is likely ineffective for use as a foundation to formulate long term, basin wide management goals. Classification using relatively persistent features to distinguish a particular class is clearly desirable for long term land management planning. Furthermore, any one of the existing classification system do not adequately describe all the stream or valley classes in regions which they were not specifically designed for.

For these reasons, I combined and modified several existing stream classification strategies to develop a locally adapted stream classification system applicable to drainage basins in forested lands of Washington. I adapted a subset of the diagnostic variables from existing classifications and developed classification units. These classification units can be used to stratify stream systems based on easily identifiable valley bottom and side-slope geomorphic characteristics.

The basic classification unit used to identify stream reaches is a valley segment type (modified from Frissell et al. 1986). Valley segments are defined by five general groups of diagnostic features: i) valley bottom longitudinal slope ii) side-slope gradient, iii) ratio of valley bottom width to active channel width, iv) channel pattern, and v) channel adjacent geomorphic surfaces. Valley segments are mappable classification units generally identifiable on topographic map and aerial photographs, and easily field verified.

RATIONALE FOR VALLEY SEGMENT CLASSIFICATION

Regional effects of climate and geology

Stream characteristics are controlled largely by biogeoclimatical processes that operate outside of the channel. The controlling influence of climate and geology on the fluvial system leads to regional differences in channel morphology (Schumm 1977). Regional differences in channel morphology can be significant. Whittier et al. (1988) illustrated these differences by identifying the correspondence between ecoregions (defined by Omernik 1987) and spatial patterns of small streams in Oregon. Ecoregions are based primarily on climate, physiography, and vegetation. However, inherent differences of stream characteristics occur within an ecoregion due to local variations in geomorphic conditions.

Classification of basins at a finer spatial scale is needed for more site specific research and land management planning. Classification of stream corridors based on valley bottom and side-slope geomorphological characteristics can be a foundation for identifying stream variability within ecoregions. The relative position of a stream reach in the drainage network, valley cross-sectional characteristics, or landform, and channel and stream-adjacent slope geomorphology are useful for classifying stream reaches into groups with similar potential for physical habitat development and fish community structure (Frissell et al. 1986).

Position in the drainage network

Stream order classification (Horton 1945, Strahler 1957) has been widely used for grouping streams according to their position in the drainage network. Zonation of fish communities along a gradient of stream order has been noted in mountain regions (Sheldon 1968). Platts (1979) linked physical habitat characteristics, species composition, and lineal salmonid abundance with stream order in an Idaho river drainage. Stream order is potentially useful in identifying variability in stream size, discharge, channel gradient, and fish community structure when used within a discrete geographical setting. However, basin size and relief, adjacent landforms, and localized geomorphic conditions may vary substantially in geographic location or ecoregion. This can lead to variability in channel morphology and fish community structure that stream order alone can only partially identify.

Valley landform

The morphological characteristics of channels and distribution of habitat units (i.e. pools, riffles, cascades) is determined largely by the extent of valley wall constraint. Streams constrained between valley walls have higher gradient channels, commonly exhibiting stairstep profiles, where deep, confined pools alternate with boulder cascades. Unconstrained reaches generally have lower gradient pools and riffles bordered by floodplain and terrace deposits on the valley floors. Valley wall constraint is highly dependent on the underlying geology and geomorphic surface of the valley bottom and side-slopes.

Valley bottom and side-slope geomorphology

The geomorphology of the valley bottom and stream corridor side-slopes has profound effects on the development of stream habitat. Platts (1974) classified aquatic habitats in Idaho based on variables from their geologic process groups and geomorphic types. Stream corridors were classified primarily by the classification of the land system that surrounded them. He demonstrated associations among salmonid densities, species composition and geomorphic conditions in the Idaho Batholith. Rickert et al. (1978) related slope, age, type of bedrock, soil associations and land management to stream channel stability and fish habitat quality in a mountainous area of southwestern Oregon. Fraley and Graham (1982) found that stream habitat parameters and trout densities differed significantly among stream reaches classified according to geologic bedrock types in basins of the Rocky Mountains, Montana.

Existing classifications

Integration of geologic and geomorphic conditions with channel morphological character provides the basic framework for existing stream classification systems. Paustian et al. (1984) developed a stream classification system for watersheds of southeastern Alaska to group stream reaches of similar character and management concerns. Murphy et al. (1987) found salmonid abundance and habitat characteristics differed between six of the more important anadromous fish-bearing channel types in southeast Alaska. Differences, however, were inconsistent between watersheds. Rosgen (1985) presented a classification scheme for western North America. Reeves and Everest (1986) tested the Rosgen system in the Oregon Cascades. They found it useful in understanding the variability of physical characteristics, but of little value in accounting for differences in both species composition and densities of anadromous salmonids. They advocated development of a classification system suited to fit local needs.

Frissell et al. (1986) developed a hierarchical stream classification framework encompassing different spatial and temporal scales. They proposed parameters to be measured at each level of the hierarchy and advocated selecting the level and associated diagnostic variables most useful for specific management or research needs. Frissell and Liss (1986) used this framework and developed classification units, or valley segment types, for south coastal Oregon streams. Frissell et al. (1987) found fish species utilization and susceptibility of channels to aggradation and destabilization differed between two valley segment types in the Coast Range of southeast Oregon.

Locally adapted classification system

The reviewed studies (Platts 1974, Fraley and Graham 1982, Frissell and Liss 1986, Reeves and Everest 1986, Murphy et al. 1987) demonstrate that stream classification does identify variability in stream characteristics. Stream classification can provide fishery managers with a tool to conduct stream inventories and a means to separate natural variability from man-induced variability. But since geologic and geomorphic characteristics may vary between regions, any stream classification system must be locally adapted and tested if it is to be validly used as a foundation for extrapolating results from intensively studied basins to ones of similar character.

My intent was to develop a stream classification system adapted to the for the forested lands of Washington, then gather empirical data to test its usefulness in identifying spatial variability of stream characteristics through the cooperative agreement of the Washington Timber, Fish, and Wildlife Stream Monitoring Program. I felt that the valley segment type classification proposed by Frissell et al. (1986) would provide the most appropriate scale of resolution for basin-wide land management planning and research. Valley segments are easily identified, and barring any large, catastrophic geologic events, remain relatively persistent over a time scale relevant to land management. The scale of the valley segment units is small enough to detect observable and predictable patterns in stream physical habitat characteristics, yet large enough to be identified through by aerial photography and topographic map interpretation.

Modifying the valley segment types defined by Frissell and Liss (1986) for basins of south coast Oregon streams and incorporating concepts of Paustian (1984) and Rosgen (1985), I identified seven groups and 19 individual valley segment types commonly found throughout forested lands of Washington. The following illustrations outline the diagnostic features used to identify valley segments from topographic maps, aerial photographs, and field verification. Appendix A provides five sample portions of typical topographic maps with valley segments delineated. Appendix B illustrates typical spatial array of valley segment types in three different watersheds of Washington. It is important to note that while this classification scheme is a useful tool in accounting for variability in stream corridors and their response to perturbation, it does not completely mirror their organization. In the field, there will be some degree of overlap and complexity that can not be accounted for by the valley segment classification alone. Other levels of land and stream classification, such as geology, soils, vegetation, and past land use, should aid in the development of a robust, predictive land management tool. But perhaps the most valuable attribute of valley segment classification, as well as any other level of land and aquatic classification, is it's usefulness in providing a foundation for understanding the processes involved in shaping streams and their associated biotic assemblages.

Valley Segment Types in Forested Lands of Washington

Mapping Symbol	Valley Segment Type
A1 -	Estuarine Delta
A2 -	Beach and Dune Flats
B1 -	Wide, Alluviated Lowland Plains
B2 -	Wide, Alluviated Valley Floor
B3 -	Alluvial Fan
C1 -	Rolling plains and plateau
C2 -	Moderate Slope Bound Valley
C3 -	Moderate Gradient Footslope
C4 -	Alluviated, Moderate Slope Bound Valley
D1 -	Incised Colluvium/Till, Moderate Gradient Channel Valley
D2 -	Incised Colluvium/Till, High Channel Gradient Valley
E1 -	V-Shaped, Moderate Channel Gradient Valley
E2 -	V-Shaped, Steep Channel Gradient Valley
E3 -	Alluviated Mountain Valley
F1 -	U - Shaped Trough
F2 -	U - Shaped, Active Glacial Outwash Valley
G1 -	Moderate Gradient, Mountain Slope / Headwater
G2 -	High Gradient, Mountain Slope / Headwall
G3 -	Very High Gradient, Mountain Slope / Headwall

VALLEY SEGMENT DIAGNOSTIC FEATURES KEY

Mapping symbol:

Alphanumeric code used to delineate valley segment on maps

VALLEY BOTTOM SLOPE: roughly corresponds to valley bottom longitudinal gradient measured in lengths of at least 40 times the active channel, or bankfull width; initially measured from topographic maps and then field verified

SIDESLOPE GRADIENT: describes the cross sectional profile of stream and valley corridor; gradients are measured for the initial 100 vertical meters and/or the initial 300 meters slope distance; distinct breaks in gradient are not averaged, but instead are qualitatively addressed in descriptions

VALLEY BOTTOM WIDTH: ratio of valley bottom width to active channel width (bankfull width); valley bottom is defined as the essentially flat area adjacent to the stream channel

CHANNEL PATTERN: describes overall amount of channel constraint, degree of sinuosity, and braiding characteristic of channel

CHANNEL ADJACENT GEOMORPHIC SURFACES: brief listing of commonly associated geomorphic surfaces; these are not considered definitive criteria to identify valley segments, but are provided for stream managers with this type of information available

GENERAL DESCRIPTIONS: a brief narrative on landform, general position in the watershed, keys to easy identification, and keys to separate from similar segment types

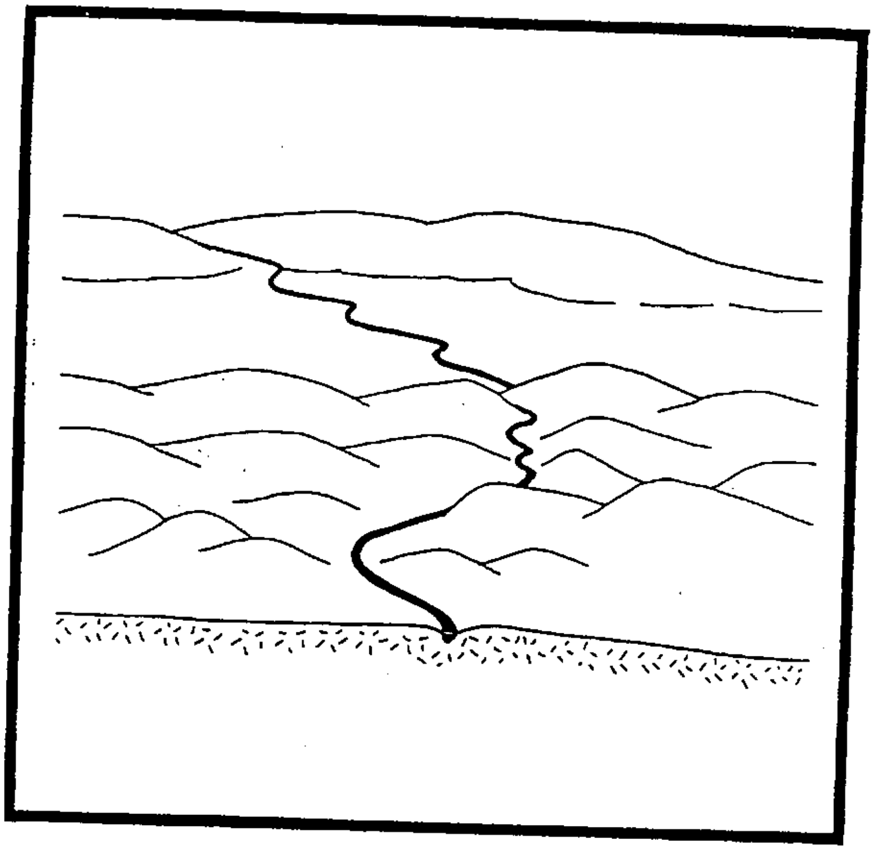
ESTUARINE DELTA

Mapping symbol: A1

VALLEY BOTTOM SLOPE:	< 1%
SIDESLOPE GRADIENT:	< 5%
VALLEY BOTTOM WIDTH:	> 5 X active channel width
CHANNEL PATTERN:	unconstrained, highly meandered; sometimes multiple channels
CHANNEL ADJACENT GEOMORPHIC SURFACES:	estuarine marsh lands; marine terraces; alluvial terraces; fine-grained alluvial fans
GENERAL DESCRIPTIONS:	segments occur at the mouth of streams in or just above coastal zones; lower portions may be totally inundated by tidal fluctuations

BEACH AND DUNE FLATS

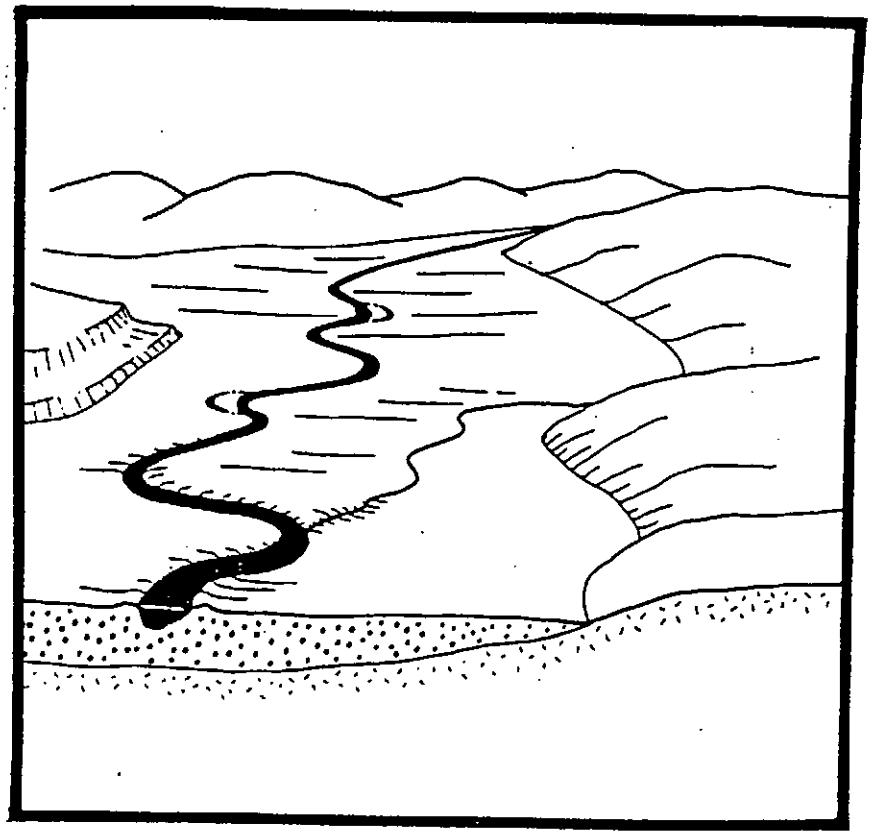
Mapping symbol: A2



VALLEY BOTTOM SLOPE:	≤ 2%
SIDESLOPE GRADIENT:	< 5%
VALLEY BOTTOM WIDTH:	≥ 1 X active channel width
CHANNEL PATTERN:	unconstrained, highly meandered; sometimes multiple channels and braids
CHANNEL ADJACENT GEOMORPHIC SURFACES:	sand dunes; marine terraces
GENERAL DESCRIPTIONS:	low gradient segments located on beach and sand dune landforms; these segments are generally quite short and subject to rapid change due to wind and wave action

WIDE, ALLUVIATED LOWLAND PLAINS

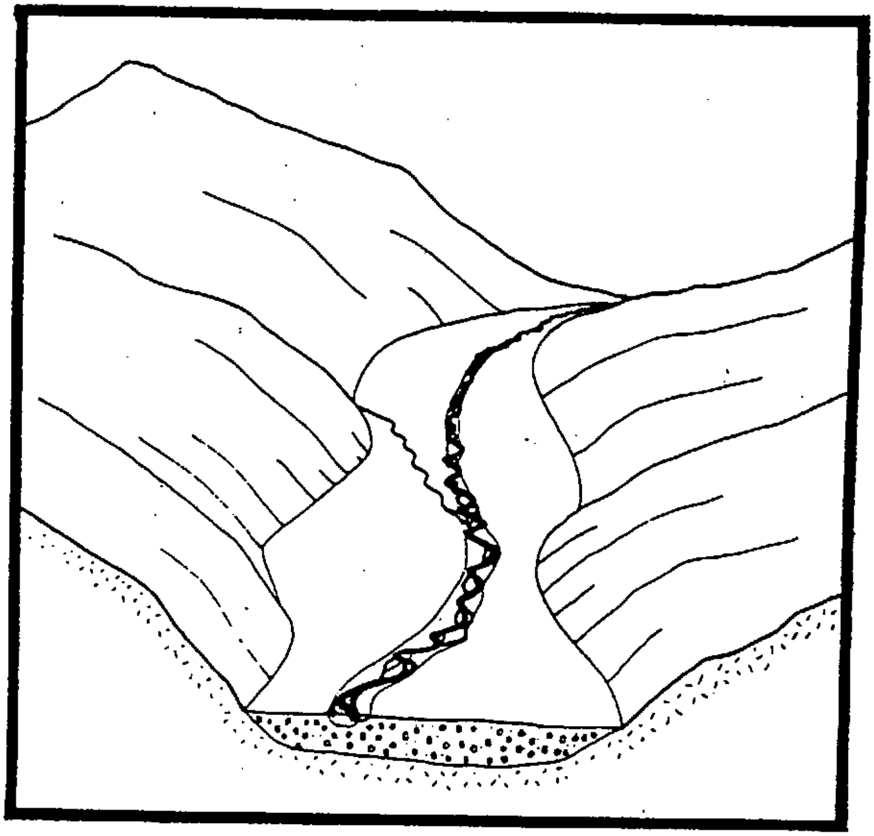
Mapping symbol: **B1**



VALLEY BOTTOM SLOPE:	$\leq 1\%$
SIDESLOPE GRADIENT:	flat, but may have locally steep terrace walls
VALLEY BOTTOM WIDTH:	> 5 X active channel width
CHANNEL PATTERN:	unconstrained, highly meandered, sometimes braided or multiple channels; sloughs and oxbows common along larger rivers
CHANNEL ADJACENT GEOMORPHIC SURFACES:	wide active floodplains; alluvial, lacustrine, or marine terraces; ancient glacial outwash plains
GENERAL DESCRIPTIONS:	segments associated with wide, active or ancient floodplains and terraces of streams located in flat to gently rolling, lowland plains; these segments are generally associated with large rivers, but may also include small streams

WIDE, ALLUVIATED VALLEY FLOOR

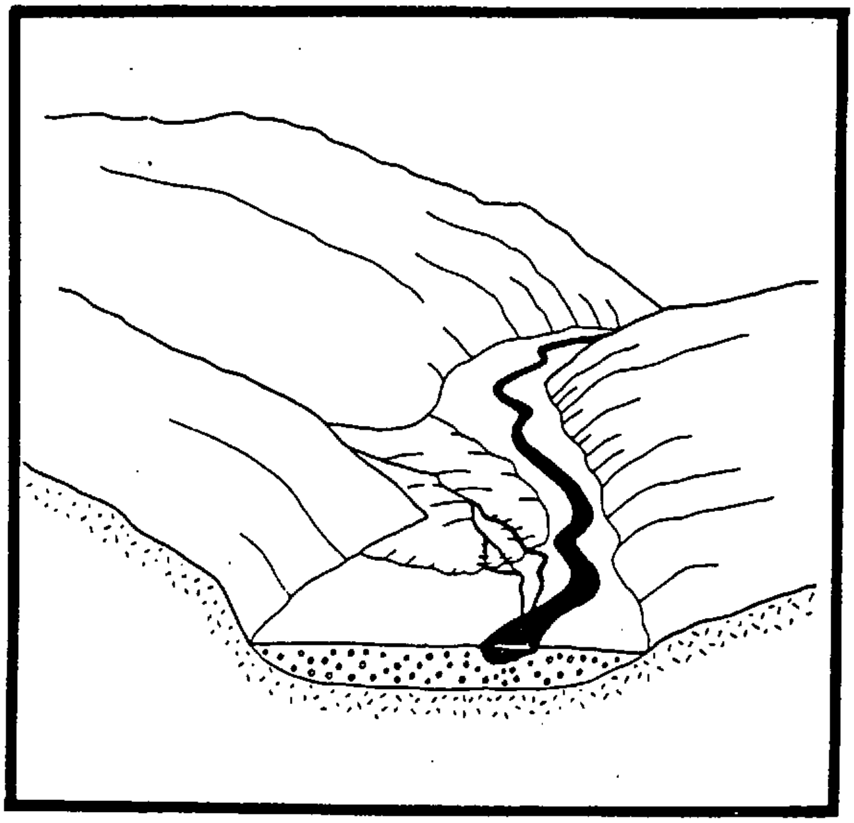
Mapping symbol: **B2**



VALLEY BOTTOM SLOPE:	≤ 2%
SIDESLOPE GRADIENT:	≥ 10%, but eventually increasing to moderate to steep mountain slopes
VALLEY BOTTOM WIDTH:	> 5 X active channel width
CHANNEL PATTERN:	unconstrained, highly meandered, sometimes braided or multiple channels; sloughs commonly associated with larger rivers
CHANNEL ADJACENT GEOMORPHIC SURFACES:	wide active floodplains; glacial outwash valley trains; lacustrine terraces; localized moderate to steep hillslopes on one side
GENERAL DESCRIPTIONS:	segments generally associated with major river systems that are bounded by mountain slopes; commonly formed where large valley glaciers once advanced or within fault block valleys; smaller tributary streams flowing through these large flats are also included in this segment type

ALLUVIAL FAN

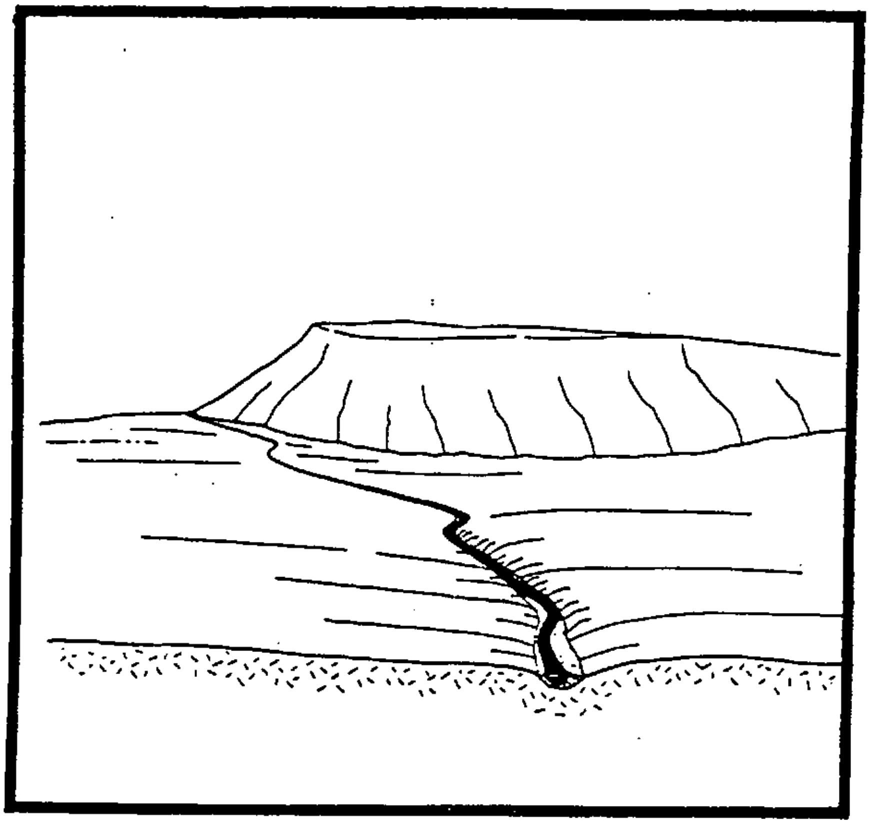
Mapping symbol: B3



VALLEY BOTTOM SLOPE:	generally 1% - 3%, but may be higher in upper reaches of segment
SIDESLOPE GRADIENT:	< 10%, except in upper reaches where streams exit canyons or hillslopes
VALLEY BOTTOM WIDTH:	> 3X active channel width
CHANNEL PATTERN:	unconstrained; highly meandered, sometimes braided or multiple channels
CHANNEL ADJACENT GEOMORPHIC SURFACES:	ancient or active alluvial fans overlying wide active floodplains, glacial outwash valley trains or lacustrine terraces; localized moderate to steep hillslopes on one side
GENERAL DESCRIPTIONS:	segments contain stream channels flowing through their own alluvial fan deposition that overlies **Wide Alluviated Lowland Plains, Wide Alluvial Valleys, or Gently Sloping Plains/Plateau** segment types

ROLLING PLAINS AND PLATEAU

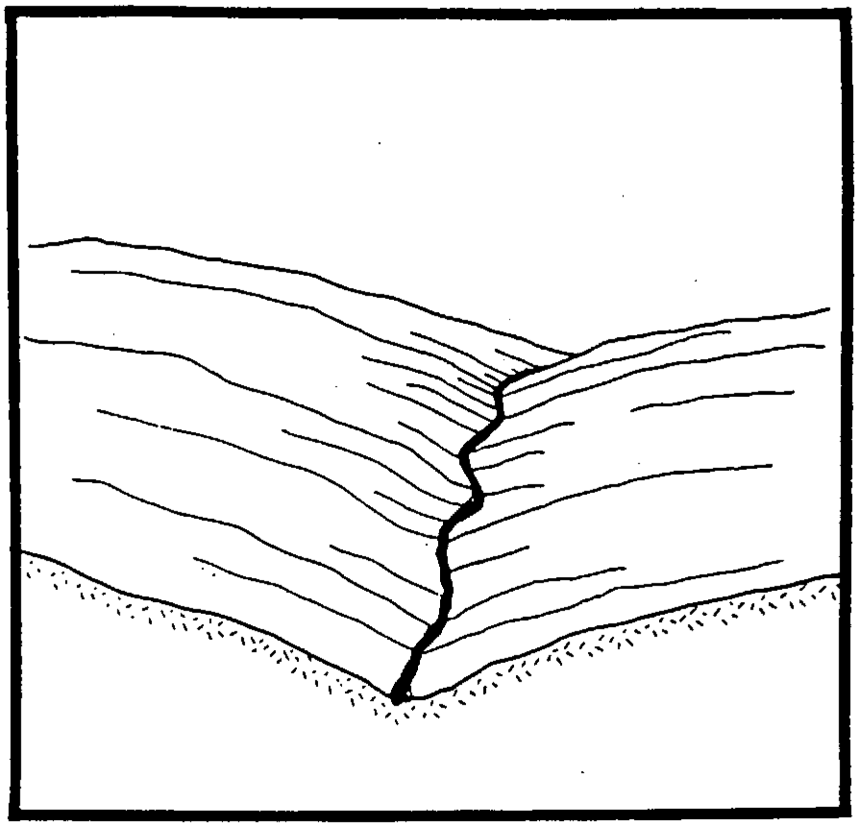
Mapping symbol: C1



VALLEY BOTTOM SLOPE:	< 2%
SIDESLOPE GRADIENT:	< 10%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	generally meandered; sometimes straight
CHANNEL ADJACENT GEOMORPHIC SURFACES:	marine terraces; gently sloping tephra deposits; extrusive volcanic flows; cryic residum uplands;
GENERAL DESCRIPTIONS:	drainageways with channels only slightly incised into relatively flat landforms; the character of the stream is highly dependent upon the geomorphic surface over which it flows; these channels are distinquished from the other relatively flat valley segments by the lack of active alluviated floodplains and terraces

MODERATE SLOPE BOUND VALLEY

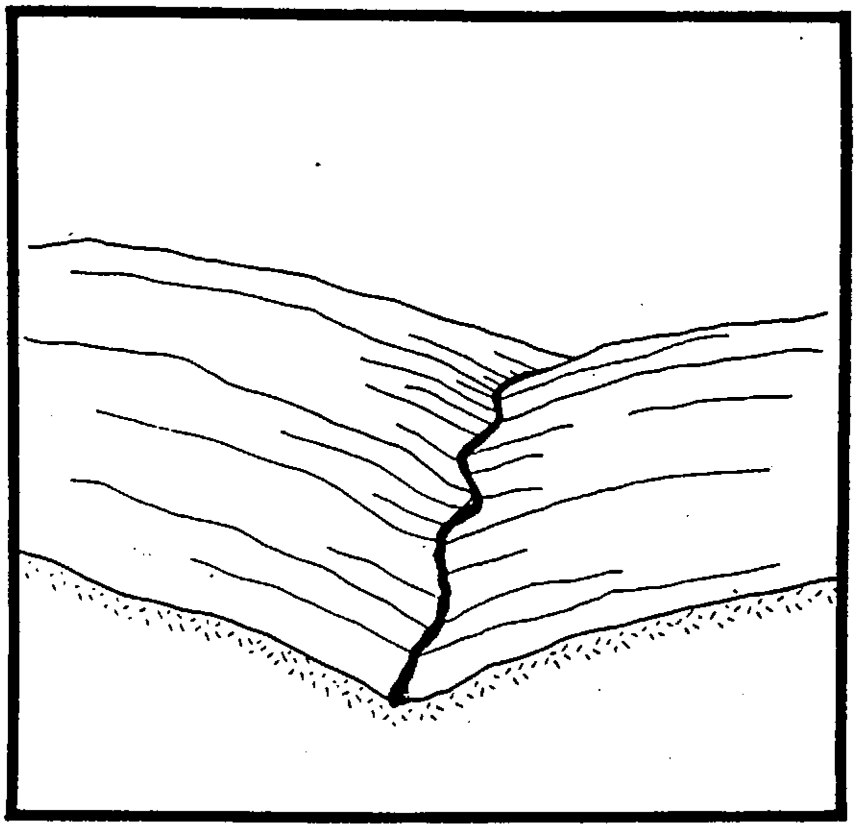
Mapping symbol: C2



VALLEY BOTTOM SLOPE:	2% - 4%
SIDESLOPE GRADIENT:	10% - 30%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	generally constrained and straight, localized meanders
CHANNEL ADJACENT GEOMORPHIC SURFACES:	low to moderate gradient competent hillslopes, glacial drift, colluvial complex slopes, or deep tephra deposits; local inclusions of narrow active floodplains, alluvial terraces, and steep competent hillslopes
GENERAL DESCRIPTIONS:	stream corridor bounded by moderate gradient sideslopes; upper valley walls rarely steep, except near ridgetops; generally located in lowland or foothill areas, or on broken mountain slopes with gently sloping benches

MODERATE SLOPE BOUND VALLEY

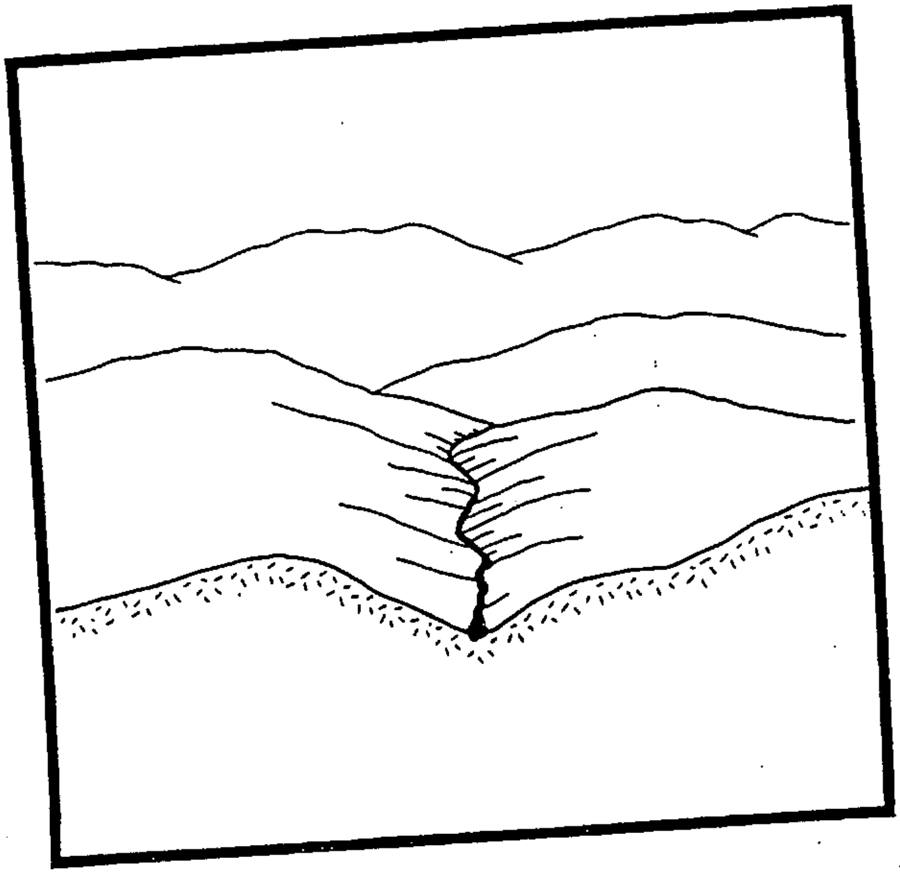
Mapping symbol: C2



VALLEY BOTTOM SLOPE:	2% - 4%
SIDESLOPE GRADIENT:	10% - 30%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	generally constrained and straight, localized meanders
CHANNEL ADJACENT GEOMORPHIC SURFACES:	low to moderate gradient competent hillslopes, glacial drift, colluvial complex slopes, or deep tephra deposits; local inclusions of narrow active floodplains, alluvial terraces, and steep competent hillslopes
GENERAL DESCRIPTIONS:	stream corridor bounded by moderate gradient sideslopes; upper valley walls rarely steep, except near ridgetops; generally located in lowland or foothill areas, or on broken mountain slopes with gently sloping benches

MODERATE GRADIENT FOOTSLOPE

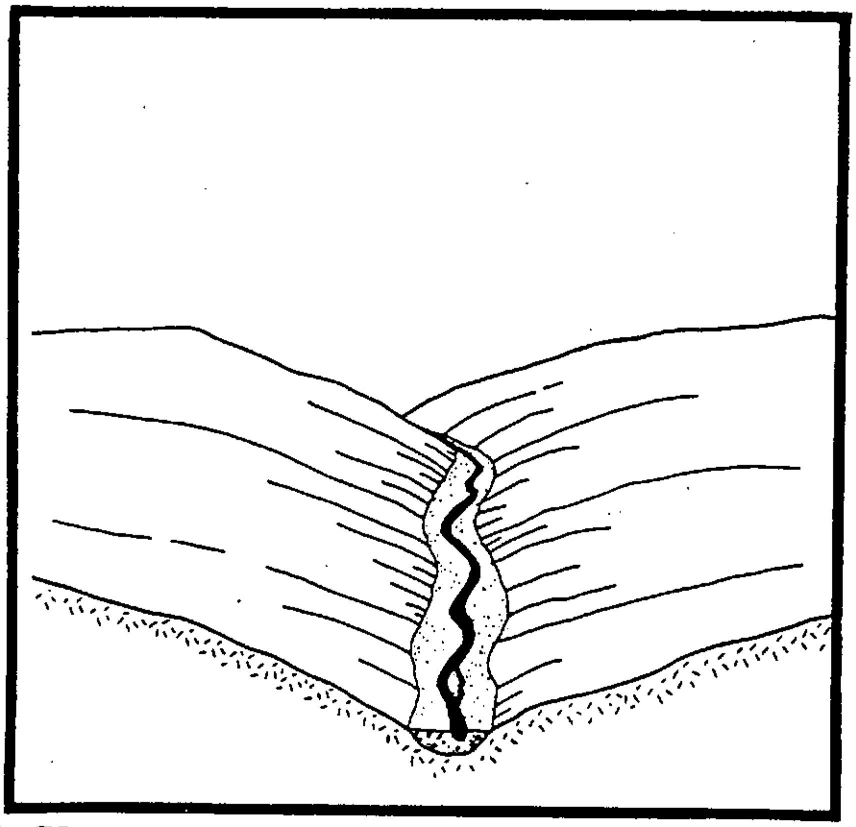
Mapping symbol: C3



VALLEY BOTTOM SLOPE:	2% - 4%
SIDESLOPE GRADIENT:	10% - 30%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	generally constrained and straight
CHANNEL ADJACENT GEOMORPHIC SURFACES:	low to moderate gradient competent hillslopes, glacial till or colluvial complex slopes; lacustrine terraces
GENERAL DESCRIPTIONS:	stream corridor bounded by moderate gradient sideslopes; these segments are distinguished from the similar C2 segments due to their location below mountainslope sidewalls adjacent to B2 segments; often incised into glacial till deposits that are oriented parallel to the valley; also found incised into ancient lacustrine deposits adjacent to steeper mountain slopes

ALLUVIATED, MODERATE SLOPE BOUND VALLEY

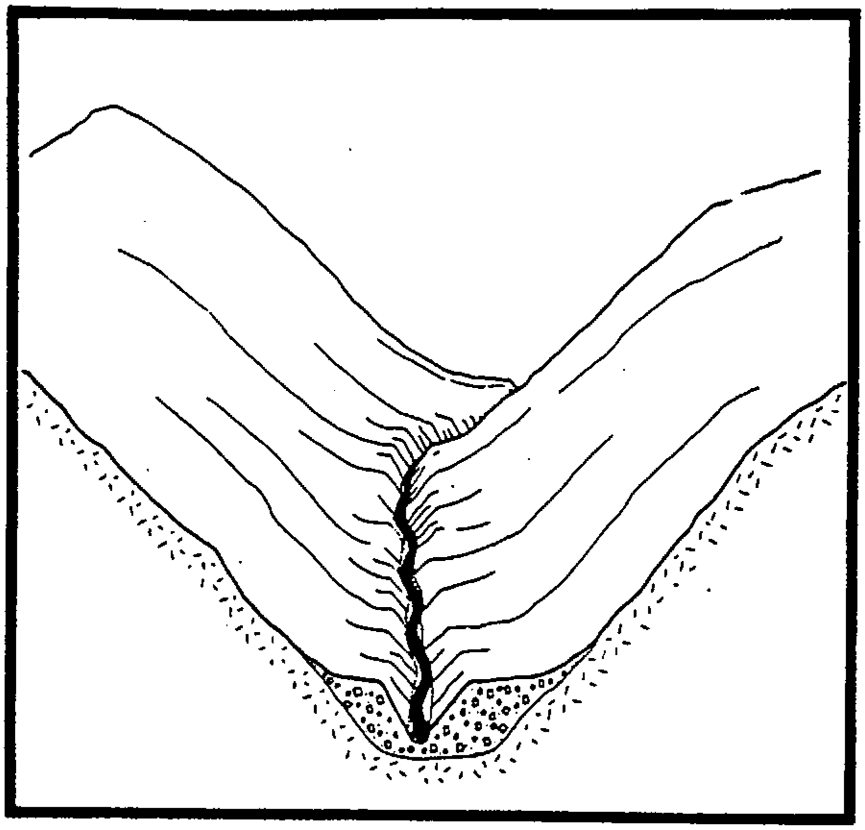
Mapping symbol: C4



VALLEY BOTTOM SLOPE:	≤ 2%
SIDESLOPE GRADIENT:	initially < 10%, gradually increases up to 30%
VALLEY BOTTOM WIDTH:	2 - 4 X active channel width
CHANNEL PATTERN:	generally unconstrained and meandered
CHANNEL ADJACENT GEOMORPHIC SURFACES:	relatively wide active floodplain and alluvial terrace; localized alluvial/colluvial fans; local intrusions of moderate competent hillslopes, colluvial complex slopes, glacial plastered slopes, or gently sloping tephra deposits
GENERAL DESCRIPTIONS:	located in rolling lowlands, foothills, or gently - sloping broken mountainslopes and uplands; valley bottom and channel adjacent sideslopes composed of low gradient alluvial material

INCISED COLLUVIUM / TILL, MODERATE GRADIENT CHANNEL VALLEY

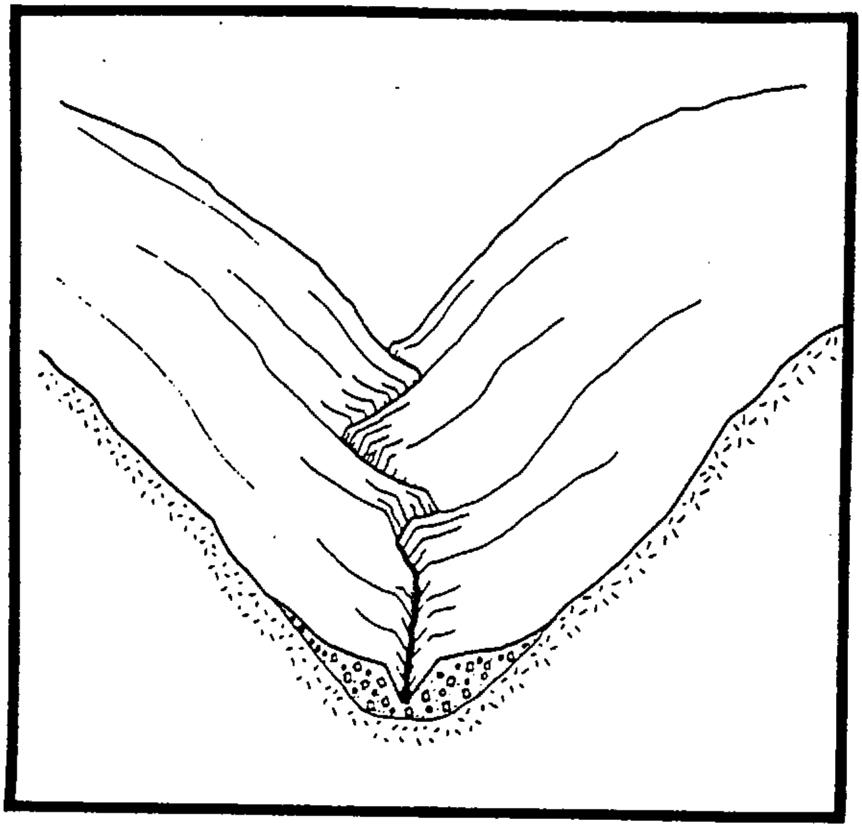
Mapping symbol: D1



VALLEY BOTTOM SLOPE:	2% - 6%
SIDESLOPE GRADIENT:	initially 10% - 30%, increasing to 30% +
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	moderately constrained by unconsolidated coarse grained material; straight; occassional meanders
CHANNEL ADJACENT GEOMORPHIC SURFACES:	unconsolidated colluvial complex slopes, glacial till, or ancient coarse glacio-fluvial terraces on one or both sides of channel
GENERAL DESCRIPTIONS:	stream downcuts through deep valley bottom deposits of glacial drift or colluvium that originated from valley sideslopes or upstream headwalls; cross section profile often weak to strong U-shape with active channel vertically incised 5 - 15 m in valley bottom deposits; upper banks composed of unconsolidated and often unsorted coarse-grained material

INCISED COLLUVIUM / TILL, HIGH CHANNEL GRADIENT VALLEY

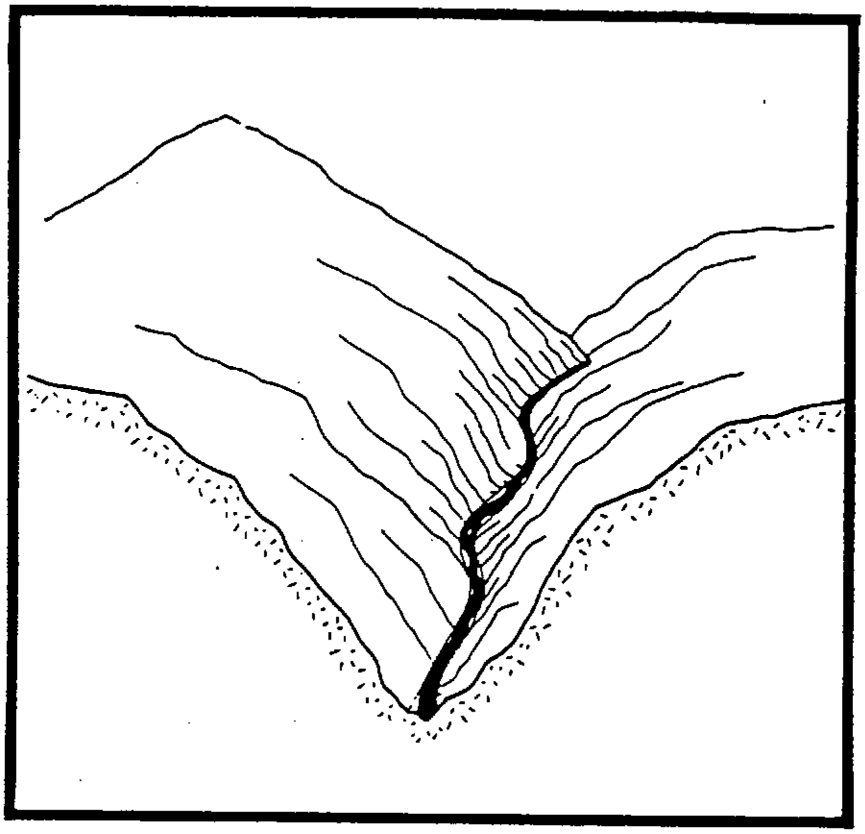
Mapping symbol: D2



VALLEY BOTTOM SLOPE:	6% - 9%
SIDESLOPE GRADIENT:	initially 10% - 30%, increasing to 30% +
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	boulder constrained; straight; stairstepped
CHANNEL ADJACENT GEOMORPHIC SURFACES:	unconsolidated colluvial complex slopes, glacial till, or ancient coarse glacio-fluvial deposits on one or both sides of channel
GENERAL DESCRIPTIONS:	stream downcuts through deep valley bottom deposits of glacial drift or colluvium that originated from valley sideslopes; cross section profile often weak to strong U-shape with active channel vertically incised 5 - 15 m into valley deposits; upper banks composed of unconsolidated and often unsorted coarse grained material

V-SHAPED, MODERATE CHANNEL GRADIENT VALLEY

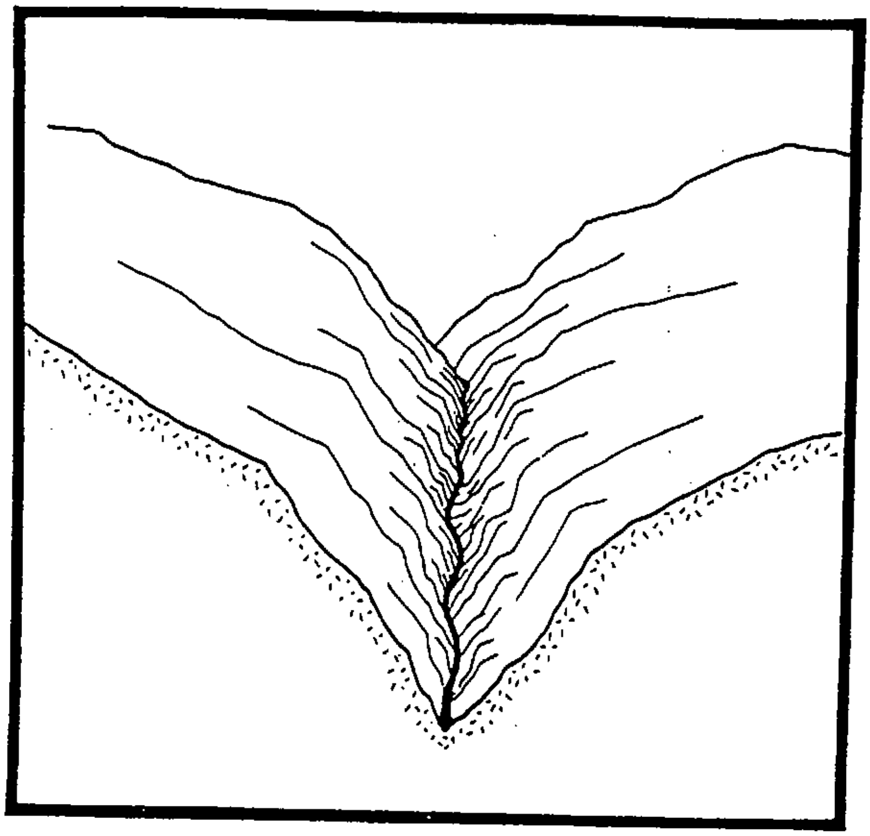
Mapping symbol: E1



VALLEY BOTTOM SLOPE:	2%- 6%
SIDESLOPE GRADIENT:	> 30%, often > 50%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	highly constrained by bedrock and large boulders; straight
CHANNEL ADJACENT GEOMORPHIC SURFACES:	steep competent hillslopes, localized inclusions of steep colluvial complex or steep glacial plastered slopes; infrequent coarse-grained ancient alluvial / colluvial terraces
GENERAL DESCRIPTIONS:	deeply incised drainageways with steep sideslopes and/or vertical rockwalls; bedrock occassionally exposed along stream channel, but does not nessecarily dominate channel and valley bottom

V-SHAPED, STEEP CHANNEL GRADIENT VALLEY

Mapping symbol: **E2**



VALLEY BOTTOM SLOPE: 6% - 11%

SIDESLOPE GRADIENT: > 30%, often > 50%

VALLEY BOTTOM WIDTH: equal to active channel width

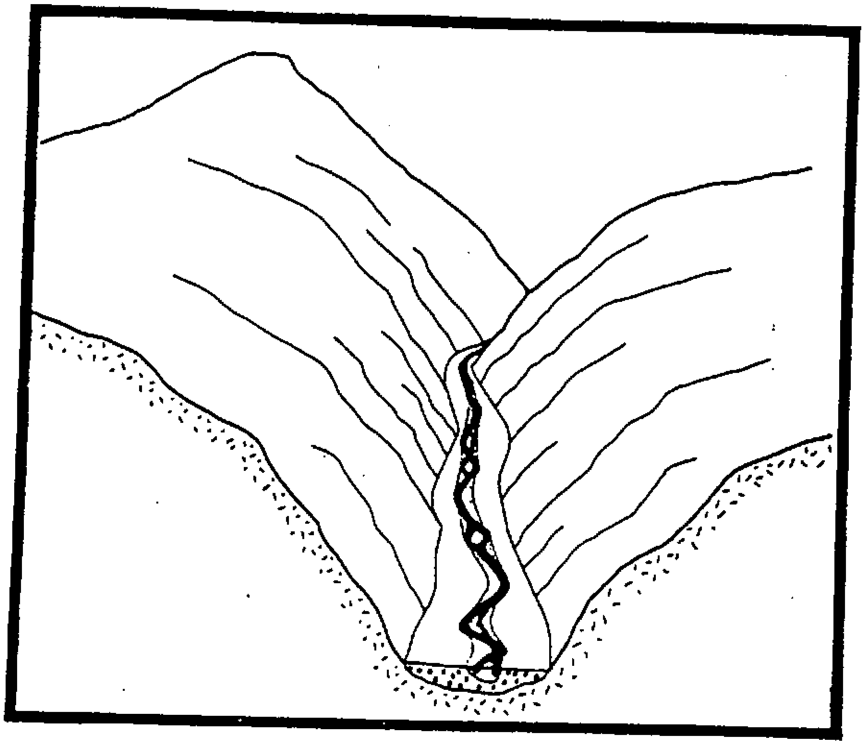
CHANNEL PATTERN: highly constrained by bedrock and large boulders; straight; stairstepped

CHANNEL ADJACENT GEOMORPHIC SURFACES: steep competent hillslopes; localized inclusions of steep colluvial complex or steep glacial plastered slopes

GENERAL DESCRIPTIONS: deeply incised drainageway with steep sideslopes and frequent vertical rockwalls; upper stream adjacent banks generally composed of stable material, but local deposition of unconsolidated material may occur

ALLUVIATED MOUNTAIN VALLEY

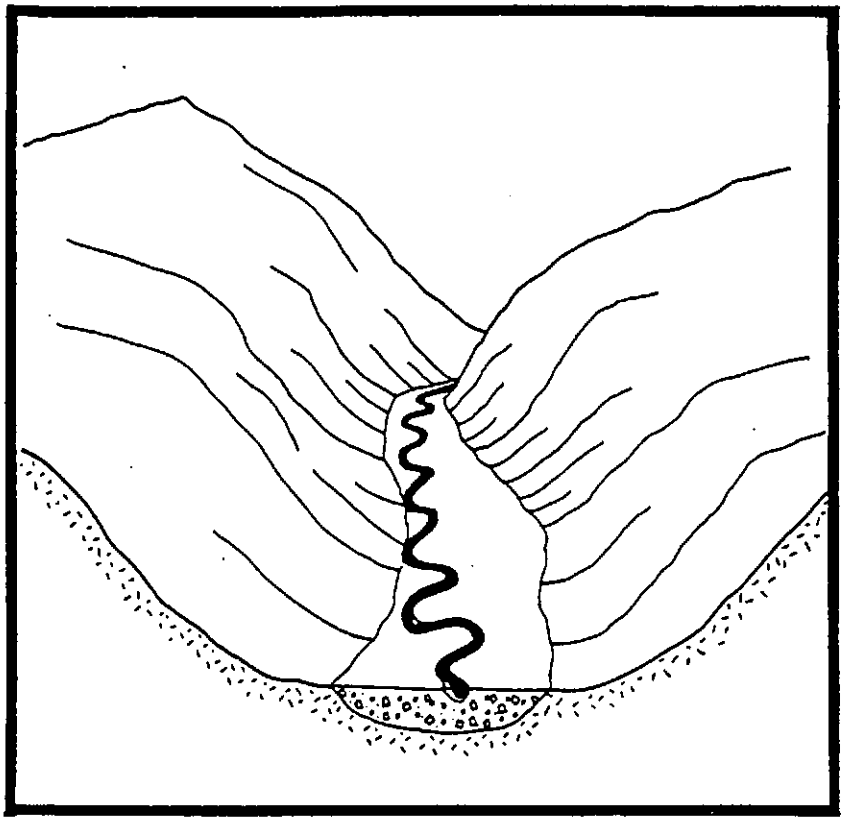
Mapping symbol: E3



VALLEY BOTTOM SLOPE:	≤ 3%
SIDESLOPE GRADIENT:	initially ≤ 5%, but rapidly increases to 30% +
VALLEY BOTTOM WIDTH:	2 - 4 X active channel width
CHANNEL PATTERN:	generally unconstrained and meandered within floodplain, but constrained within mountainous sideslopes
CHANNEL ADJACENT GEOMORPHIC SURFACES:	relatively wide active floodplain and alluvial terrace; localized alluvial/colluvial fans; local intrusions of moderate to steep competent hillslopes, colluvial complex slopes, or glacial plastered slopes
GENERAL DESCRIPTIONS:	generally bound both upstream and downstream by steeper valley segment types; these alluviated "flats" are often formed by downstream bedrock constrictions or by low gradient channel bed releif which effectively results in widened, alluviated segments in otherwise fluvial dissected mountainous valleys

U-SHAPED Glacial TROUGH

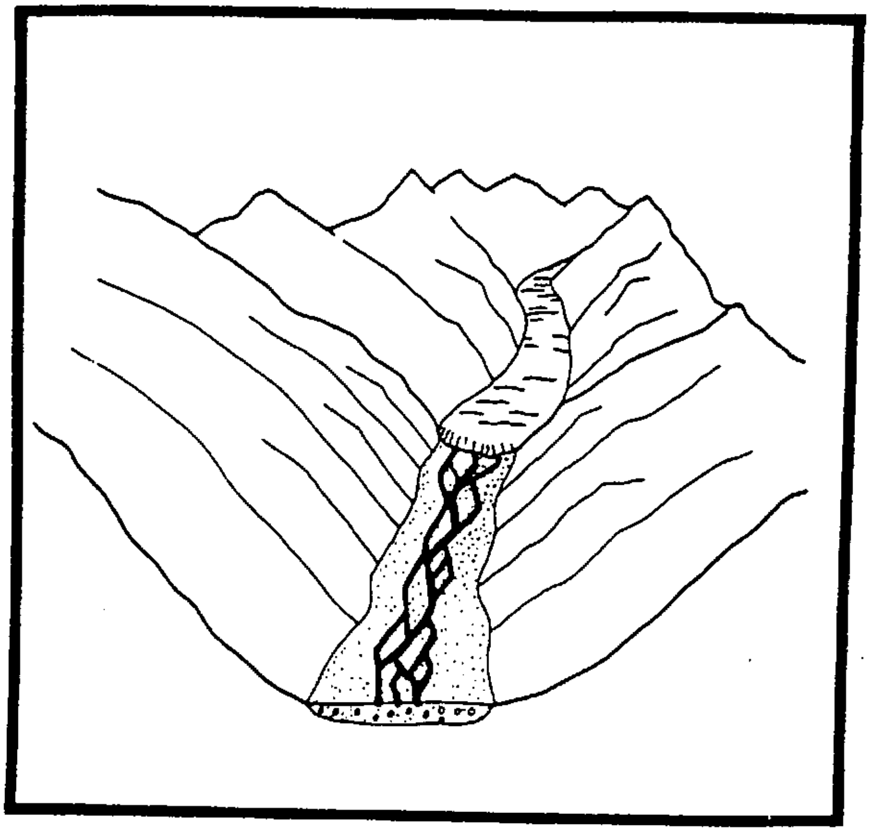
Mapping symbol: **F1**



VALLEY BOTTOM SLOPE:	≤ 2%
SIDESLOPE GRADIENT:	initially 0% - 10% in relatively wide bottom, gradually increasing to 30% +
VALLEY BOTTOM WIDTH:	> 4 X active channel width
CHANNEL PATTERN:	generally unconstrained and meandered; localized reaches of boulder constraint and straight channel pattern
CHANNEL ADJACENT GEOMORPHIC SURFACES:	low gradient glacial drift; small alluvial terraces; active floodplains; local inclusions of moderate to steep competent hillslopes on one side of valley
GENERAL DESCRIPTIONS:	streams located in troughs likely formed from past alpine glaciation; channels meander through generally small-grained glacio-fluvial deposits, but infrequently downcut through coarse grained glacial till moraines

U-SHAPED, ACTIVE GLACIAL OUTWASH VALLEY

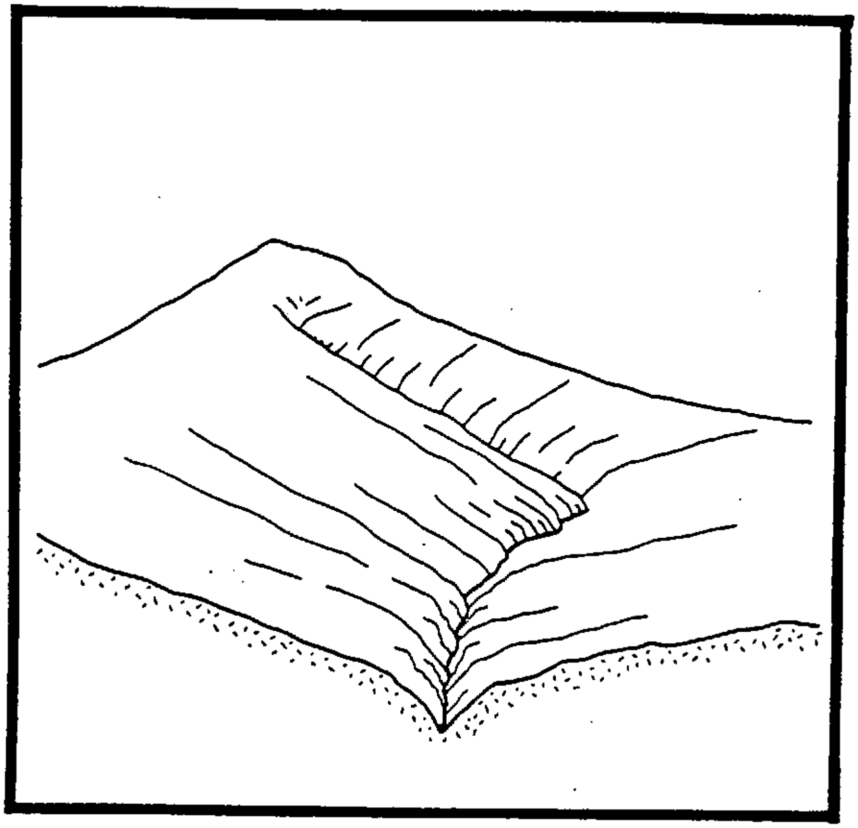
Mapping symbol: **F2**



VALLEY BOTTOM SLOPE:	1% - 7%
SIDESLOPE GRADIENT:	initially < 5%, increasing to > 30%
VALLEY BOTTOM WIDTH:	1 - 2 X active channel width
CHANNEL PATTERN:	highly meandered and braided; unconstrained across an active channel that spans nearly the entire valley bottom
CHANNEL ADJACENT GEOMORPHIC SURFACES:	active glacial outwash, floodplains, and alluvial terraces; other forms of glacial drift
GENERAL DESCRIPTIONS:	streams located directly below active alpine glaciers; channels commonly shift across wide active channel

MODERATE GRADIENT, MOUNTAIN SLOPE / HEADWATER

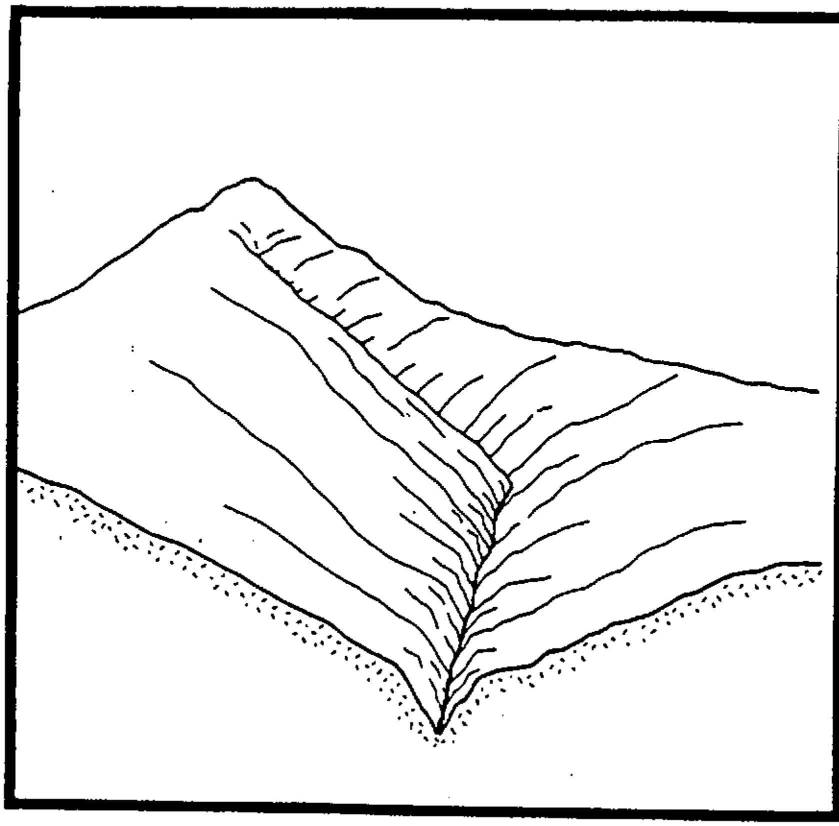
Mapping symbol: **G1**



VALLEY BOTTOM SLOPE:	3% - 7%
SIDESLOPE GRADIENT:	initially 10% - 30%, gradually increasing
VALLEY BOTTOM WIDTH:	equals active channel width
CHANNEL PATTERN:	constrained; straight; stairstepped
CHANNEL ADJACENT GEOMORPHIC SURFACES:	moderate to steep competent hillslopes, glacial till colluvial complex slopes, deep tephra deposits
GENERAL DESCRIPTIONS:	small channels with drainageways slightly to moderately incised into moderate gradient mountain slopes or headwater basins; common in headwaters of fluvial landforms, mountain cirques, or near the junctions of small valley wall tributaries with D, E, and F segment types

HIGH GRADIENT, MOUNTAIN SLOPE / HEADWALL

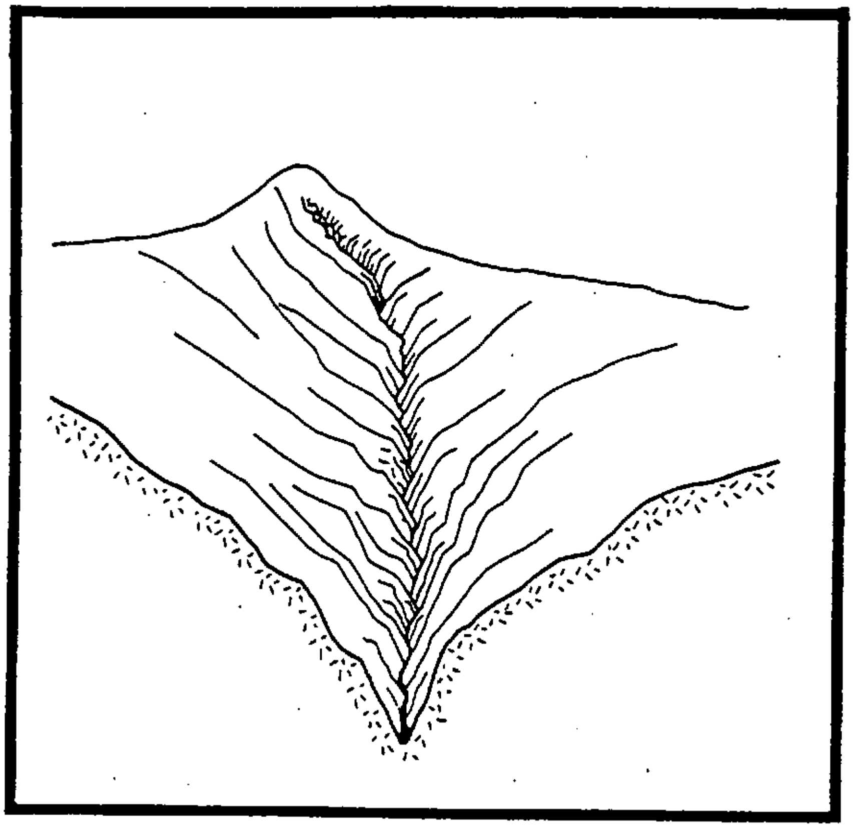
Mapping symbol: G2



VALLEY BOTTOM SLOPE:	8% - 20%
SIDESLOPE GRADIENT:	> 30%
VALLEY BOTTOM WIDTH:	equals active channel width
CHANNEL PATTERN:	constrained by boulder and bedrock; straight; stairstepped
CHANNEL ADJACENT GEOMORPHIC SURFACES:	steep competent hillslopes; steep glacial plastered slopes; steep colluvial complex slopes; channel headwalls
GENERAL DESCRIPTIONS:	small channels with drainageways moderately to deeply incised into moderate to high gradient mountain slopes or headwall basins; exposed bedrock common on stream adjacent banks and steep sluiced areas; localized deposition of moderate gradient alluvial/colluvial terraces

VERY HIGH GRADIENT, MOUNTAIN SLOPE / HEADWALL

Mapping symbol: G3



VALLEY BOTTOM SLOPE:	20% +
SIDESLOPE GRADIENT:	> 30%
VALLEY BOTTOM WIDTH:	equals active channel width
CHANNEL PATTERN:	constrained by boulder and bedrock; straight; stairstepped
CHANNEL ADJACENT GEOMORPHIC SURFACES:	steep competent hillslopes; steep glacial plastered slopes; steep colluvial complex slopes; channel headwalls
GENERAL DESCRIPTIONS:	small channels with drainageways moderately to deeply incised into moderate to high gradient mountain slopes or headwall basins; exposed bedrock common on stream adjacent banks and steep sluiced areas

LITERATURE CITED

Fraley, J. J., and P. J. Graham. 1981. Physical habitat, geologic bedrock types and trout densities in tributaries of the Flathead River drainage, Montana. Pages 178-185 in N.B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland.

Frisell, C. A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Frisell, C. A. and W.J. Liss. 1986. Classification of stream habitat and watershed systems in south coastal Oregon. Unpublished progress report for July 1985 to Sept. 1986. Oak Creek Laboratory of Biology. Corvalis, Oregon.

Hankin, D. G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Canadian Journal of Fisheries and Aquatic Science. 41: 1575-1591.

Horton, R. E. 1945. Erosion development of streams and their dranage basins: hydrophyscial approach to quantitative geomorphology. Bulletin of the Geological Society of America.

Lotspeich, F. B. and W. S. Platts. 1982. An integrated land-aquatic classification system. North American Journal of Fisheries Management 2:138-149.

Murphy, M.L., J.M. Lorenz, J. Heifetz, J.F. Thedinga, K.V. Koski, and S.W. Johnson. 1987. The relationship between stream classification, fish, and habitat in southeast Alaska. Technical Bulletin 12, Tongass National Forest R10-MB-10.

Omernik, J. M. 1987. Ecoregions of the conterminous United States (with map). Annual Association of American Geographical Society. 77:118-125.

Paustian, S. J., D. A. Marion, and D. F. Kelliher. 1984. Stream channel classification using large scale aerial photograpy for southeast Alaska watershed management. RNRF Symposium on the Application of Remote Sensing to Resource Management, May 22-27, 1983, Seattle, WA.

Platts, W. S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. U.S. Forest Service, SEAM Publication, Billings, Montana.

Platts, W. S. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries, 2(4):5-9.

Reeves, G. H. and F. H., Everest. 1986. Relationships between channel class, fish populations and physical habitat: are they valid? In J. W. Buell, editor. Stream habitat enhancement evaluation technical/ training level II workshop, Portland, Oregon.

Rickert, D. A., J. G. Beach, J. E. Jackson, D. M. Anderson, H. H. Hagen, and E. Suwijin. 1978. Oregon's procedure for assessing the impacts of land management activities on erosion related nonpoint source problems. Oregon Department of Environmental Quality. Portland , Oregon.

Rosgen, D. L. 1985. A stream classification. Pages 91-95 in R.R. Johnson, C.D. Ziebell, D.R. Palton, P.F. Ffolliott, and R.H. Hamre, editors. Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, Tucson, Arizona.

Schumm, S. A. 1977. The fluvial system. Wiley and Sons, New York.

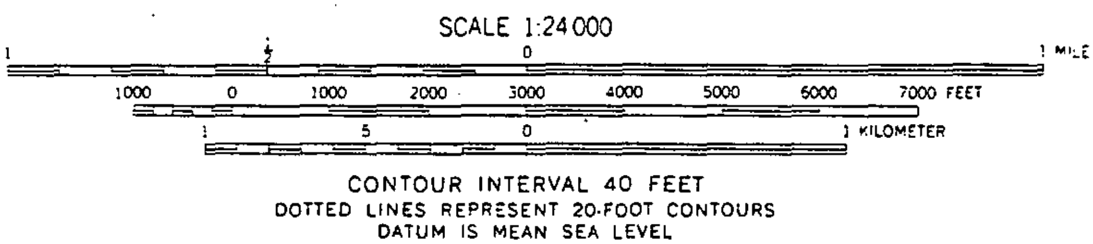
Sheldon, A. L. 1968. Species diversity and longitudinal succession in stream fishes. Ecology 49(2): 193-198.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union. 38:913-920.

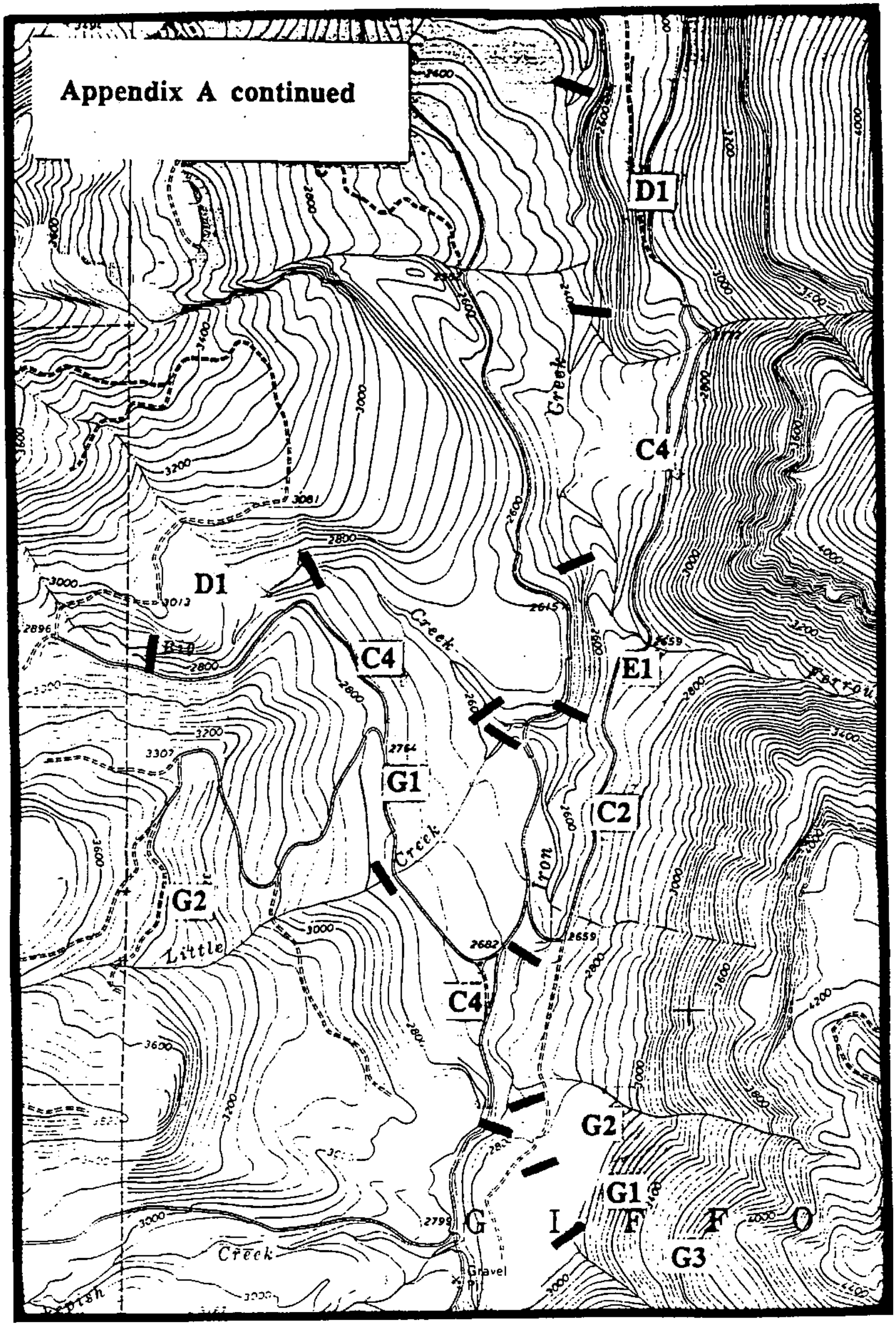
Whittier, T.T., R.M. Hughes, and D.P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Aquatic and Fisheries Science. 45: 1264-1278.

Appendix A

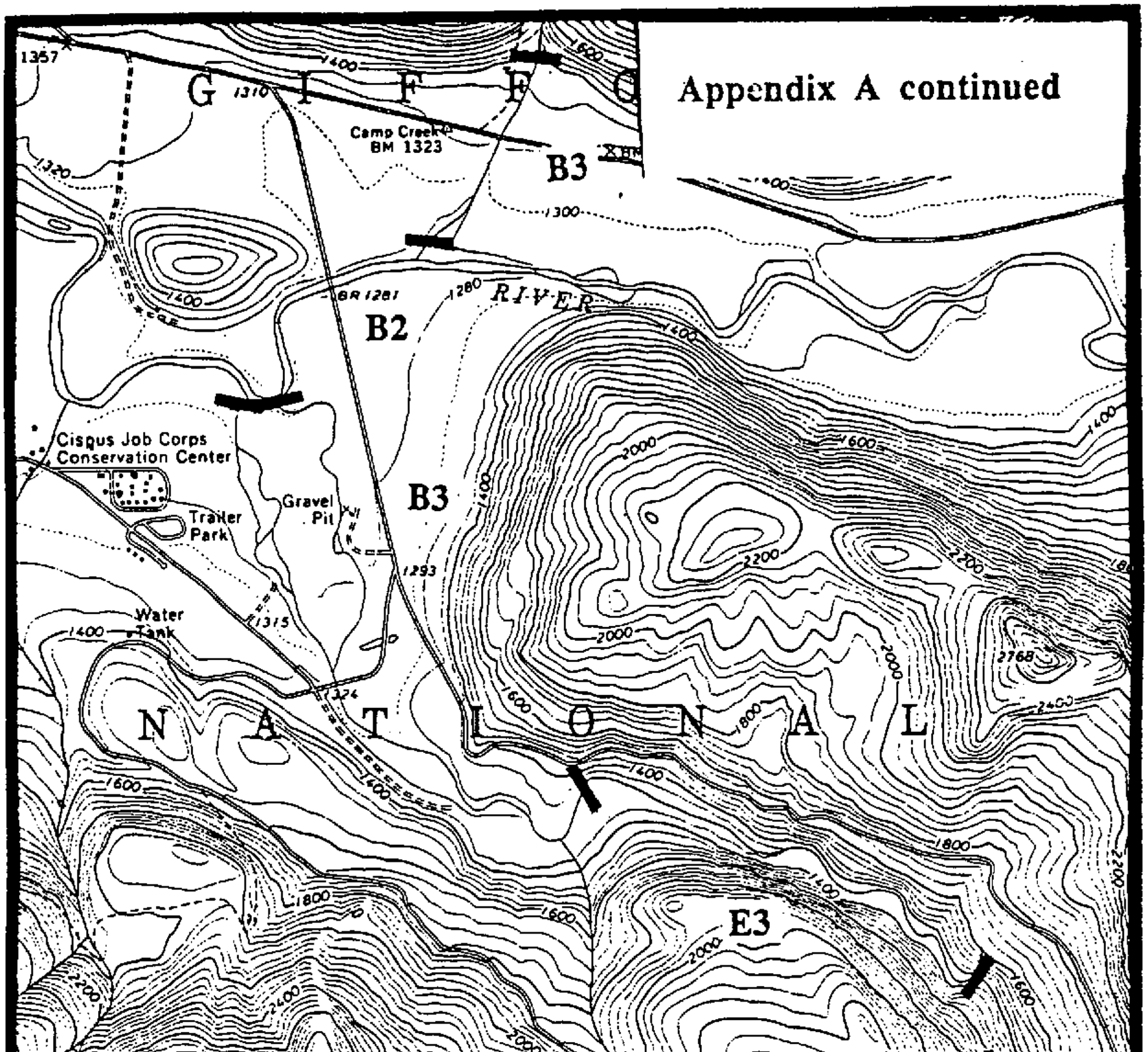
Sample portions of United States Geological Survey topographic maps (1:24,000 scale) with valley segment types delineated. Lines perpindicular to the stream identify valley segment types determined by map and aerial photograph interpretation, and field verification. Therefore, even though some segments appear similar by topographic contour analysis, photo interpretation and field verification of valley bottom morphological characteristics revealed differences. Boldface alphanumeric codes correspond to codes used in diagnostic feature keys. All maps are reproduced at original size and use the scale below. Each contour interval is 40 feet, with the exception of map M4, which has 20 foot contour intervals.

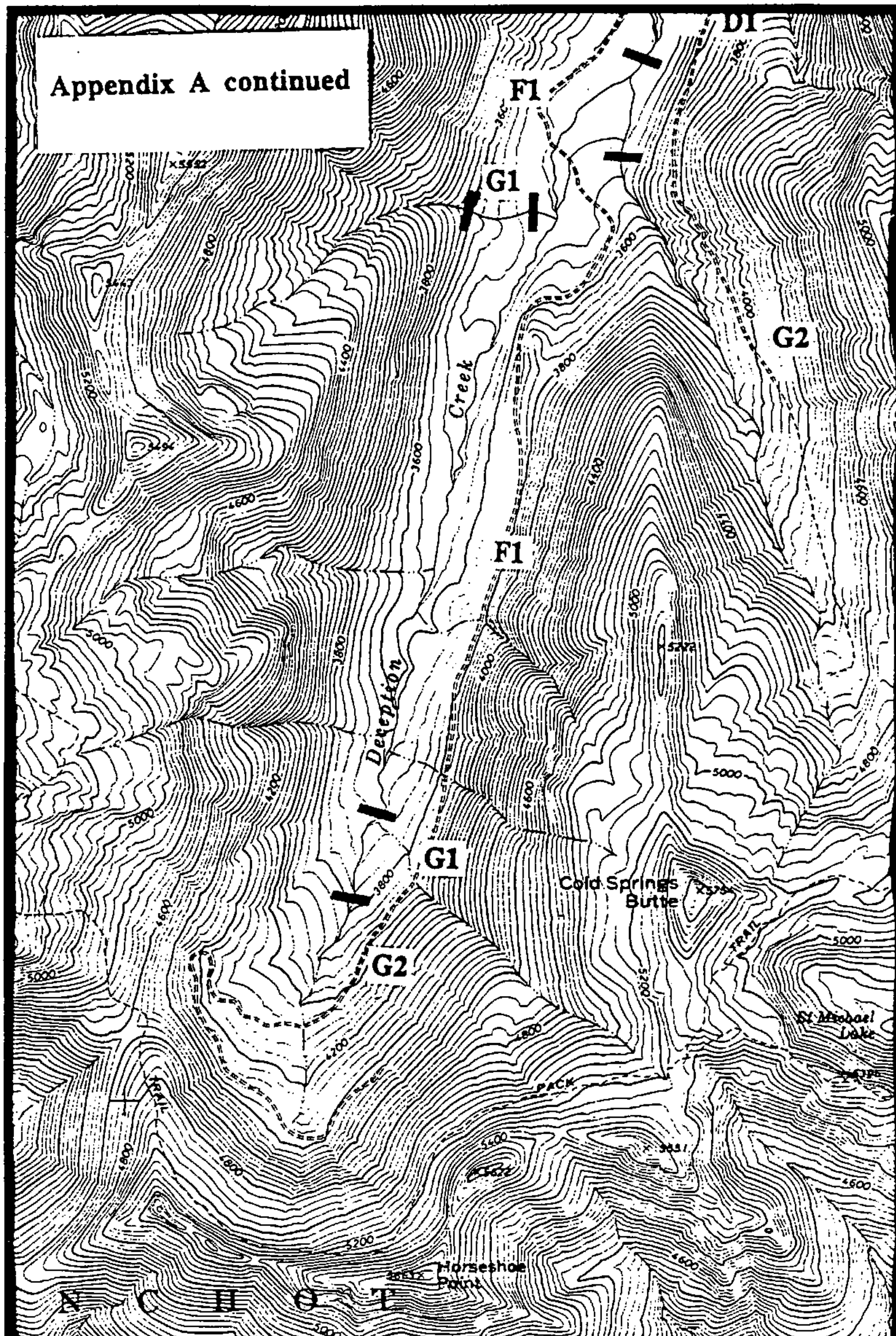


Appendix A continued

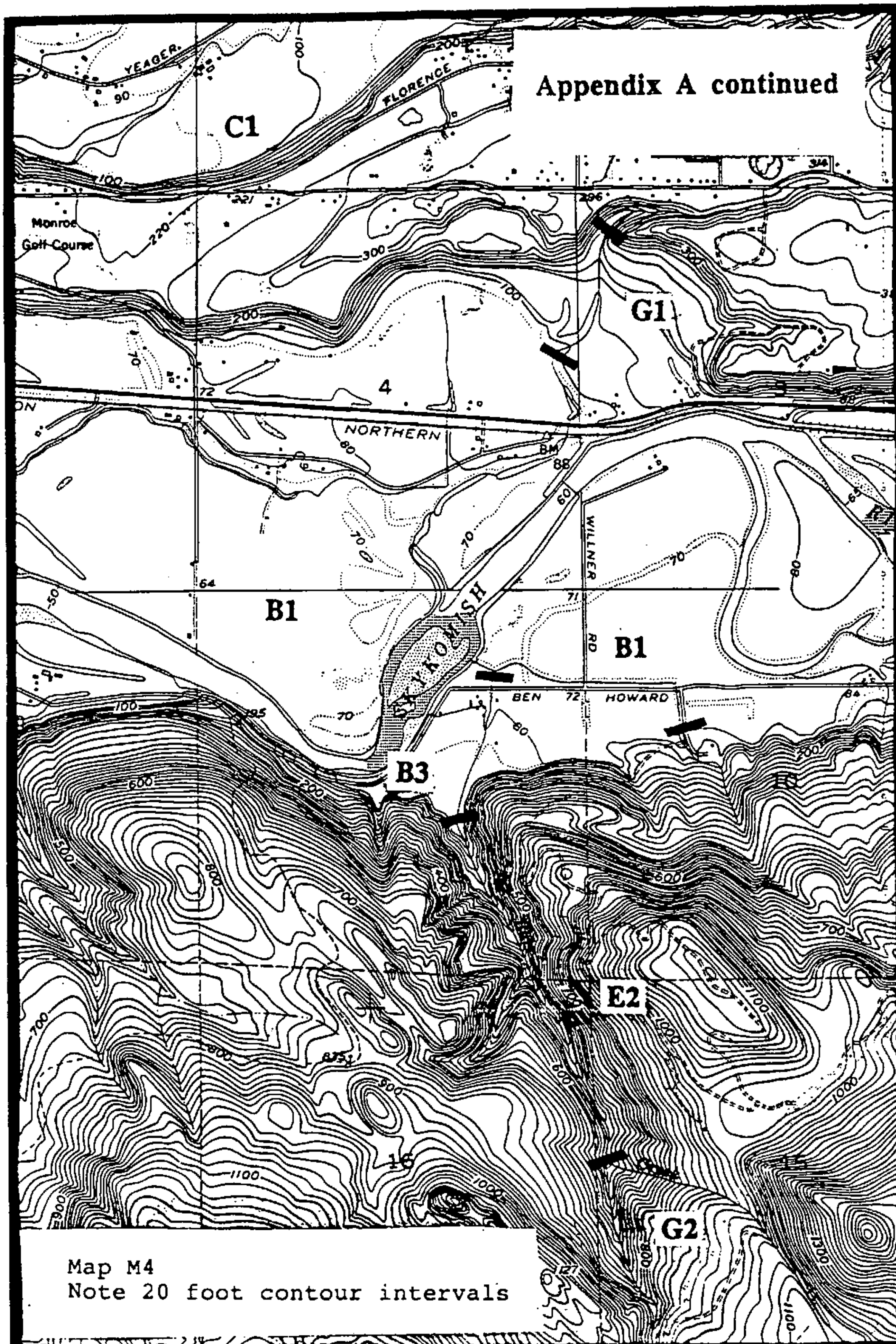


Appendix A continued



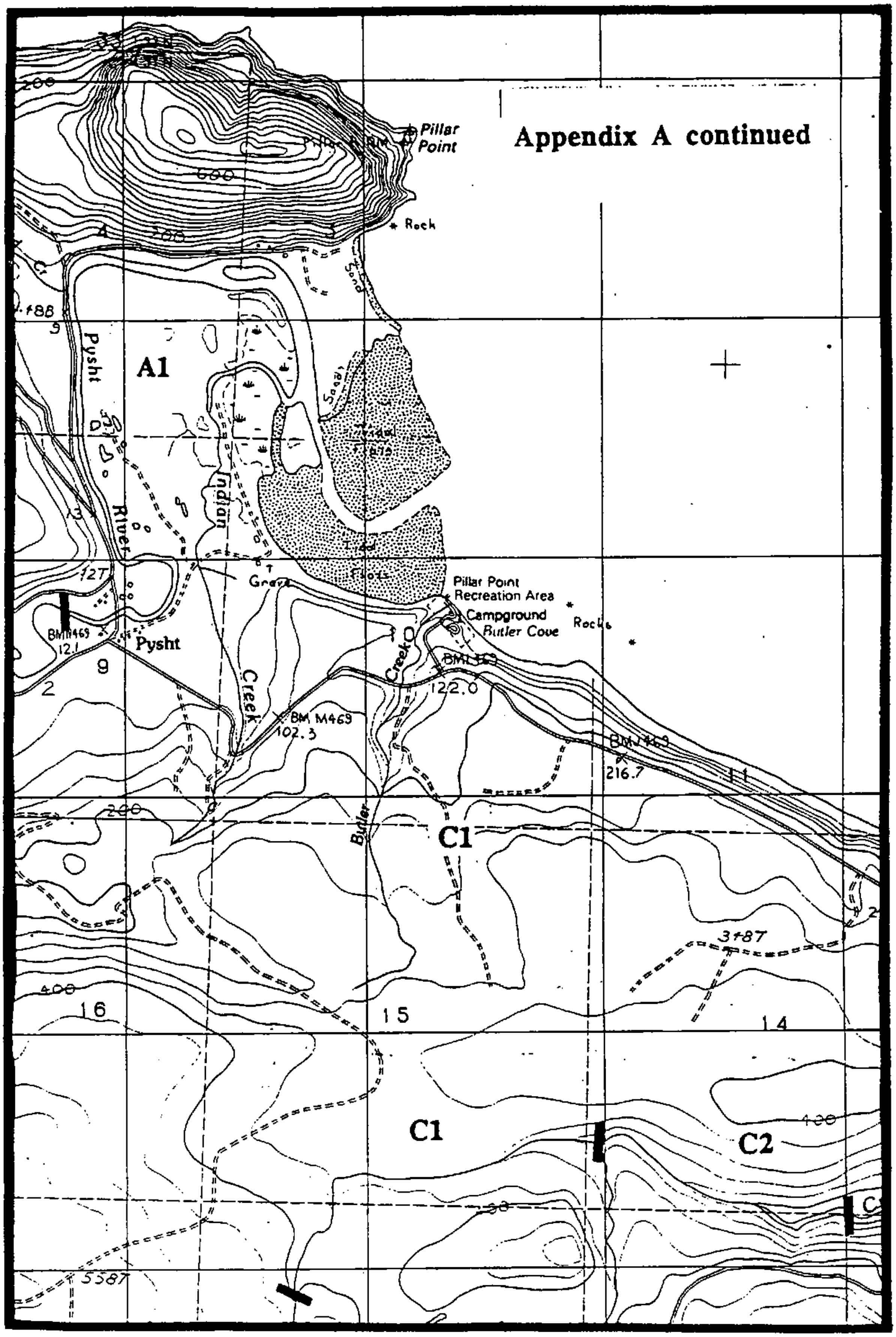

Appendix A continued
D1
F1
G1
G2
Deception
Creek
Cold Springs
Butte
St Michael
Lake
TRAIL
PACK
Horseshoe
Point

Appendix A continued



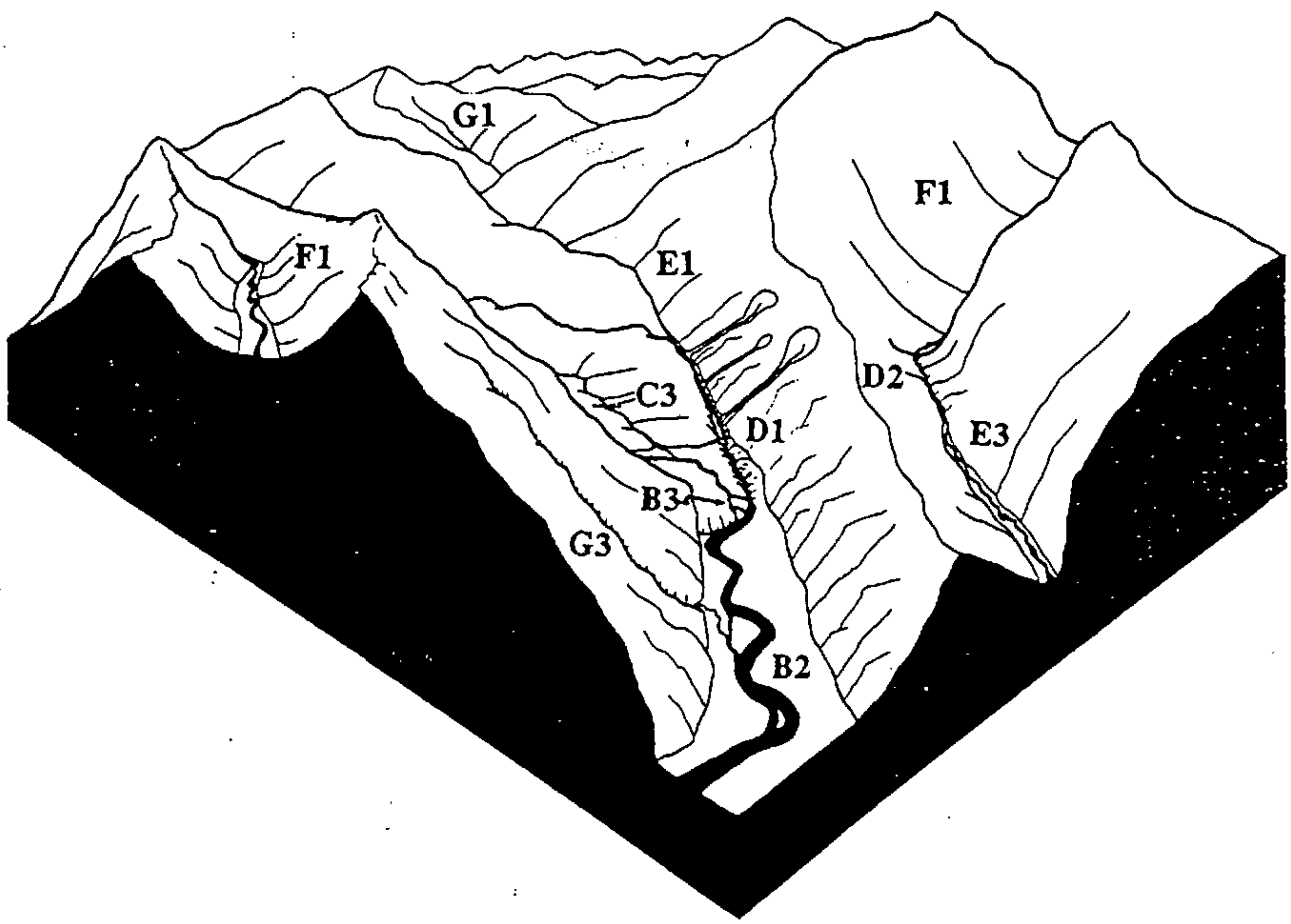
Map M4
Note 20 foot contour intervals

Appendix A continued

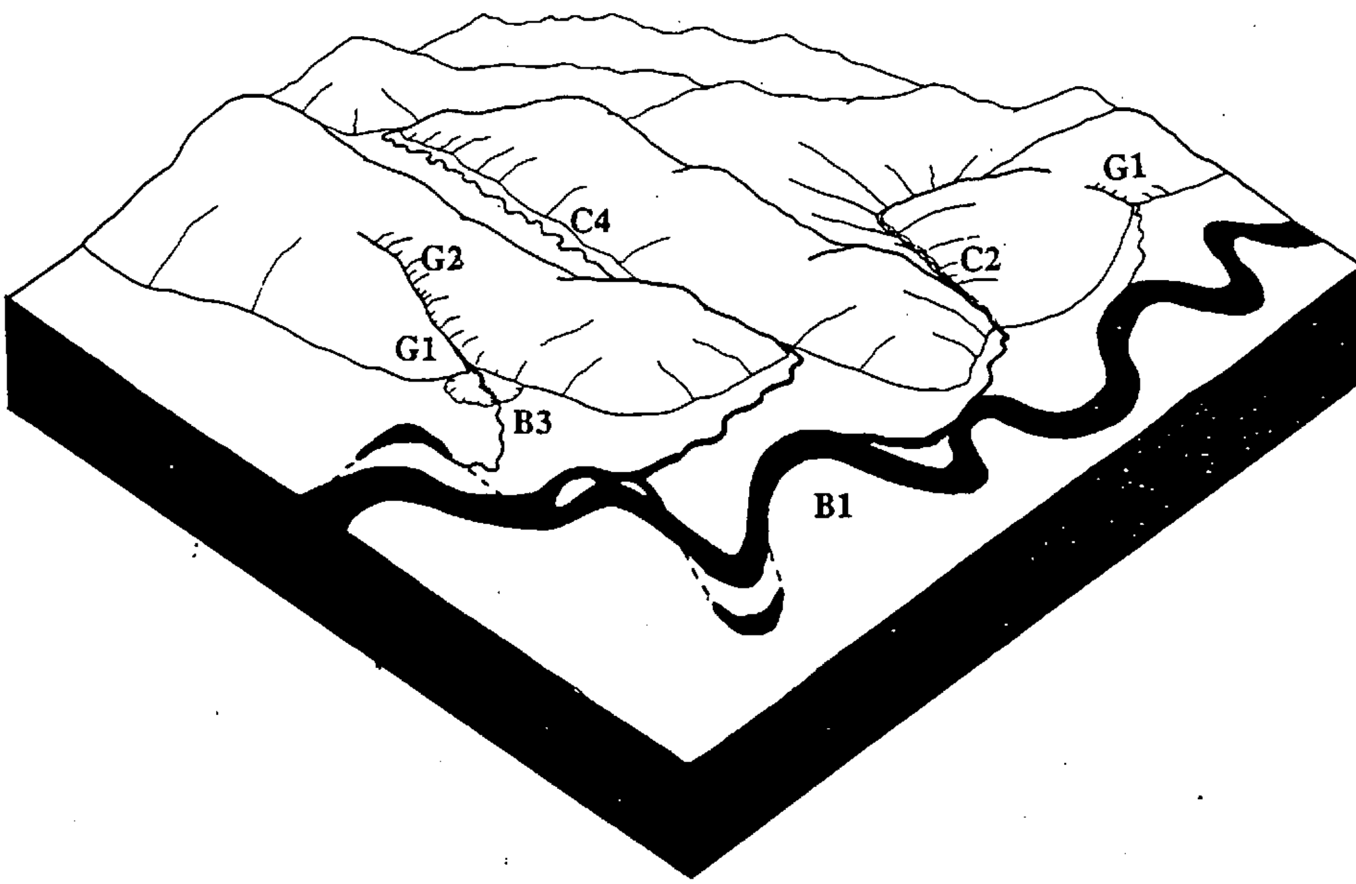


Appendix B

Three schematic diagrams of typical watersheds found in forested lands of Washington. Alphanumeric codes correspond to codes used for valley segments in the diagnostic features keys.



Appendix B continued



Appendix B continued