THE CHARACTER OF CHANNEL PLANFORM CONTROL ON THE MORPHOLOGY AND SEDIMENTOLOGY OF THE GRAVEL-BED SQUAMISH RIVER FLOODPLAIN, BRITISH COLUMBIA

by

GARY J. BRIERLEY

B.A.(Hons), Durham University, 1981

M.Sc., Simon Fraser University, 1984

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in the Department

of

Geography

SIMON FRASER UNIVERSITY

February, 1989

APPROVAL

Name: Gary John Brierley

Degree: Doctor of Philosophy

Title of Thesis: The Character of Channel Planform Control on the Morphology and Sedimentology of the Gravel-Bed Squamish River Floodplain, British Columbia

Examining Committee:

Chairman: J.T. Pierce
Associate Professor

E.J. Hickin
Professor
Senior Supervisor

M.C. Roberts
Professor

A.D. Miall
Professor
Department of Geology
University of Toronto

D.G. Smith
Professor
External Examiner
Department of Geography
University of Calgary

Date Approved: February 24, 1989

Title of Thesis/Project/Extended Essay

The Character of Channel Planform Control on the Morphology and Sedimentology of the Gravel-Bed Squamish River Floodplain, British Columbia

Author: ____________
(signature)

Gary John Brierley
(name)

April 7, 1989
(date)

ABSTRACT

The gravel based, high energy Squamish River exhibits a distinct downstream sequence of river channel planform styles. In the 20km study reach, the river changes from a braided through a wandering gravel-bed to a meandering planform type. To assess the sedimentologic distinctiveness of these planform styles, sediment sequences were examined in a series of holes, regularly spaced in a grid-like fashion on 10 channel bar surfaces, in 9 trenches, dug perpendicular to the main channel at the bar/floodplain margin of 5 bars, and in 13 longitudinal bank exposures, divided equally among the three planform styles. A specific facies coding scheme was developed, based on channel bedform features. An alternative, broader scale depositional unit (termed elements), based on geomorphic criteria, also was employed in the trench and bank exposure data sets.

Sedimentologic differentiation of the three channel planform styles was examined in terms of facies and element abundance, their composition and character, their spatial organization (vertically, laterally and longitudinally), particle size trends, and basal surface characteristics. Markov-derived planform facies models indicate complex sediment associations in each planform reach. Observed differences between models are largely insignificant and sediment trends relate much more closely to local depositional environment (or locales, namely bar platform, chute channel, ridge and established floodplain) than to channel bar type, or channel planform style.

Locale spatial association varies by planform, but this variability is not reflected in floodplain deposits, as channel bar sediments are reworked by chute channels prior to being incorporated into the floodplain (i.e. bar platform deposits have extremely low preservation potentials). In both the trench and bank exposure data sets, facies are extremely laterally discontinuous, and vertical sediment sequences typically are characterized by upward transitions from channel framework gravels to lower energy depositional units, irrespective of channel planform type.

When analysed in vertical sequence, locale type is evaluated in elemental terms. The established floodplain locale is divided into flood cycle and sand sheet elements. These vertically accreted, top stratum deposits, are the dominant component of the Squamish River floodplain. In the older sediment sequences of bank exposures, distal overbank deposits occasionally are observed. In these instances, the preserved proportion of bar platform (bottom stratum) sands is

greater, as chute channel reworking of sediments is minimized by rapid shifting or avulsion of the main channel.

When based on small scale sediment structures, facies types and their organization can not be used to differentiate between river depositional environments, as they merely reflect local scale flow conditions. Similarly, as there is no process differentiation between planform types, river channel planform style can not be detected from sediment patterns. In contrast, the element scale, based upon field geomorphic units, provides much more insight into environment of deposition, and offers greater reliability in past environmental reconstruction.

ACKNOWLEDGEMENTS

This thesis could not have been completed without the digging efforts of many graduate colleagues and friends. Thanks are especially extended to my summer field assistants, namely John Olyslager, Rod Malcolm, Kelly Thompson and Graham Schnare. The Eluck cabin, along with hospitality from Sue and Marty Vanderhoof, made the Upper Squamish experience much easier and more enjoyable than it might otherwise have been. Computing assistance for Markov Analysis was provided by Eddie Leung.

The intellectual stimulation and financial support for this study were supplied by Professor Edward Hickin (and his NSERC grant). Thanks Ted, for help during the many ups and downs of this project. Thanks also to the other members of my supervisory/examining committee, for their advice and comments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

PART A

FRAMEWORK OF THE STUDY

CHAPTER I

INTRODUCTION

1 : 1 Introductory statement

The foundations of any scientific discipline are the questions asked and the methods used to collect data and evaluate results. Since the introduction of quantified approaches to geomorphology following the Second World War, there has been a tendency for research questions to become technique oriented, rather than asking questions of more fundamental concern (Anderson and Burt, 1981; Kellerhals et al., 1976). These dilemmas also are evident in fluvial sedimentology. Research is largely empirically based, methods used vary greatly from study to study, and the theoretical framework is poorly developed. These problems are compounded by the vast range of sediment types and depositional environments encountered and the many different scales of approach adopted in research by different practitioners. To date the natural link between geomorphology and sedimentology has received limited attention. As Brakenridge (1984, 9) noted:

> "... there have long existed significant differences in investigative methods between sedimentary geologists on the one hand, who commonly infer base-level, tectonic or climatic changes as controls over fluvial sedimentary successions (Fisk, 1944; Otvos, 1980), and process geomorphologists on the other hand, who study rivers as dynamic and complex systems ... where geomorphic variables tend towards readjustment (Leopold and Wolman, 1957; Schumm, 1977; Bull, 1979)."

The major goal of this thesis is to demonstrate the role geomorphology can play in the interpretation of alluvial depositional sequences.

1 : 2 Objectives

According to Walther's 'Law of the correlation of facies', "only those facies and facies areas can be superimposed primarily which can be observed beside each other at the present time" (Walther, 1894, 979; in Middleton, 1973). This principle can be invoked at various scales. For example Schumm (1981, 19-20) noted that :

> "Both braided and meandering river sediments should frequently be found in close proximity in the rock record, as a paleoriver abruptly alters its pattern or as the pattern changes in a downstream direction."

Implicit within this statement is the notion that each channel pattern must yield a distinctive lithofacies produced by distinctive depositional processes (Jackson, 1978). From this basis, river planform facies models have been developed.

River channel planforms are visually very distinctive. The continuum of styles has several end members, but the characteristics used to describe these channel conditions vary for each planform style, including factors such as sinuosity, lateral stability, number of channels and channel lineation. None of these characteristics, however, are indicative of the process mechanisms required to create that particular style. Indeed, planform differentiation does not result from distinctive processes operative in different channel reaches; rather, the environmental setting conditions river style by imposing limiting factors upon the nature of channel adjustment.

The overlap in environmental settings and the lack of distinctive processes for different planforms seemingly precludes the existence of mutually distinctive planform facies models. From this comes the null hypothesis for this study :

"Although river channel planforms are morphologically distinct, they can not be differentiated in geomorphic process terms, and accordingly there are no predictable variations in floodplain sedimentology by planform."

This postulate is tested over a variety of scales by extensive field analysis of a 20km reach of the Squamish River, in southwestern British Columbia, which demonstrates down-valley change from a braided, through a wandering gravel-bed, to a meandering channel planform style. The primary objectives of study are as follows :

1. Develop a sampling procedure suitable to characterize sediment sequences in each channel planform reach, at a variety of spatial scales, relating broader scale (elemental) sediment coding schemes to geomorphic principles.

2. Compare and contrast observed sediment sequences in each channel planform reach.

3. Comment on observed mechanisms of floodplain growth and develop a three dimensional picture of the floodplain sedimentology of the study reach.

1 : 3 Outline and organization of the study

This thesis is divided into four major parts. The first provides the framework for the study, examining related literature (Chapter 2), the regional setting (Chapter 3) and methods used (Chapter 4). The second part of the thesis focusses upon sedimentologic analysis of contemporary river channel bars in three contiguous planform reaches. Chapter 5 examines summary statistics of channel bar deposits for both the overall data set and between planforms. One-dimensional facies models are derived using Markov analysis. Within-planform sedimentologic variability is assessed using both summary statistics and visual analysis in Chapter 6. An alternative scale of sedimentologic analysis, based upon field morphologic units (i.e. geomorphic criteria) and referred to as locales, is developed and analysed for contemporary river bars in Chapter 7.

The third part of the study examines the lateral and longitudinal continuity of sediment units at both the facies and elemental (locale) scales. These are evaluated both for a series of trenches dug perpendicular to the contemporary channel (Chapter 8) and extensive bank exposures (Chapter 9). In the final part of the thesis the sedimentology of the three channel planform reaches is compared, and implications of the study are described (Chapter 10).

CHAPTER II

LITERATURE REVIEW

2 : 1 Introduction and outline of chapter

Primary goals of study in fluvial sedimentology typically include both description of a sedimentologic sequence and interpretation of the depositional processes responsible for it. Associations between sedimentologic units over space and their environmental attributes are geographic modes of enquiry. Understanding the mechanisms of deposition is essentially a study in fluvial geomorphology (Reineck and Singh, 1980, 5). The character and configuration of rivers vary markedly in different environmental settings. Unfortunately this is often overlooked and continues to haunt attempts to classify and model river systems. Visually distinctive planform types can be found in relatively similar settings (section 2:2). The floodplain geomorphology of differing planform reaches is examined in section 2:3.

The second half of the chapter is concerned with fluvial sedimentology. A hierarchical scale of sedimentologic units is defined and described (section 2:4). The environment of deposition of a sedimentologic sequence can be inferred from the internal organization of facies. Facies associations have been described for individual river-channel bars (section 2:5:1), floodplain units (section 2:5:2) and planform types (section 2:6). In recent years, the usefulness of river planform facies models has been viewed with much scepticism and alternative modes of analysis sought. Of particular interest is architectural element analysis (section 2:7), a three-dimensional approach based upon geomorphologically-defined units. The state of the art in fluvial sedimentology is assessed in section 2.8.

2 : 2 River classification and geomorphic controls upon channel planform style

A vast range of river morphologies exist in nature (e.g. Galay et al, 1973; Mollard, 1973; Schumm, 1985) and it is only for reasons of academic convenience that the continuum is divided into discrete types (Richards, 1986). Schumm (1977) devised a river classification scheme based on combining the predominant mode of sediment transport (suspended, bedload or mixed) with channel stability (aggrading, poised or degrading), creating nine different regimes with alternative combinations of W/D ratio, sinuosity, slope and erosion/deposition. Unfortunately this scheme, along with the alternative approach based upon river reach analysis suggested by Kellerhals et al (1976), has received limited attention, and focus continues to be placed upon channel planform, a scheme based upon visual and morphologic character with little reference to geomorphic process.

Channel planform refers to the configuration of a river in plan view. Distinction generally is made upon the basis of sinuosity and number of channels (Rust, 1978a). Five major types are recognized : braided, wandering, anastamosed, meandering and straight. However, this simple division is seldom satisfactory in practise (Lewin, 1978a) and the terms are not mutually exclusive (Jackson, 1978). Braids can meander (e.g. Fahnestock, 1963; Williams and Rust, 1969), meanders locally braid (e.g. Shelton and Noble, 1974; Teisseyre, 1977; Brice, 1984; Hooke, 1986), and planform styles may alter at different discharge stages (e.g. Smith, 1970), or following flood events (e.g. Anderson and Calver, 1980).

In braided river reaches, flow diverges and rejoins around bars and/or islands on a scale of the order of channel width (Schumm, 1971). Channel sinuosities are less than 1.5. Typically there are several topographic levels (Williams and Rust, 1969); some islands may be dry and vegetated. The degree of braiding generally decreases downstream; proximal and distal floodplain zones may be highly variable in character.

Wandering gravel-bed river reaches are characterized by fewer channels and active bar platform areas than in braided reaches. Generally there is one dominant channel (Neill, 1973). This is irregularly sinuous in outline and splits around vegetated islands (Church, 1983; Desloges and Church, 1987; Morningstar, 1988). Bar grow and channels wander primarily across- rather than down-valley.

Meandering river reaches generally are single-channeled and have sinuosities greater than 1.5. Such reaches have well defined floodplains, made up of distinct morphologic units (Happ et al, 1940), in which there is clear process differentiation from the channel zone (Collinson, 1978). Channel character is dependent upon channel sinuosity (Schumm, 1963).

The general effect of the many environmental variables upon planform type is shown in Table 2.1. Individual river planform types are not found under unique sets of circumstances. Rather, they represent a state of fluvial adjustment to combinations of inter-related environmental

TABLE 2.1 : GEOMORPHIC CRITERIA USED TO DIFFERENTIATE BETWEEN BRAIDED AND MEANDERING PLANFORMS

Factor	Braided	Meandering
1) Setting		
Discharge	High/variable	More stable
Slope	Steep	Relatively gentle
Sediment supply	High/variable	More consistent/low
Bed material size	Coarse to fine	Finer (some coarse)
Bank erodibility	High, with limited vegetation	Low, generally cohesive, more vegetated banks
2) Properties of flow		
Transport mechanism	Mainly bedload	Mainly suspended
Flow resistance	High	Lower
Bed roughness	High	Lower
Flow competence	Undercompetent/ Overloaded	Overcompetent
Shear stress	High	Lower
3) Morphologic response of channel		
Number of channels	High	One
Sinuosity	Low	High
W/D ratio	High	Low

Planform may be an historical artifact (i.e. a result of former flow conditions).

variables, in which limiting factors may impose a particular morphologic response (see review by Ferguson, 1987). This geomorphic convergence implies that planform styles are not a direct response to specific flow properties.

Combinations of the geomorphic and hydraulic variables described in Table 2.1 influence the relative energy of flow, or stream power, at a site (Chang, 1979). The braided channel planform type generally is associated with higher energy geomorphic settings, in which flow is either unable to carry its entire sediment load, or parts of the sediment load are too coarse (capacity and competence limits respectively). Such conditions are evidenced in a wide range of environments (e.g. subarctic, Church, 1972; semi-arid, McKee et al, 1967; mountainous, Fahnestock, 1963), with highly variable particle size domains (from fine sands to gravels, e.g. Nanson et al, 1986; Williams and Rust, 1969), or simply are a response to sediment or discharge inputs (e.g. Carson, 1984b, 1984c; Bradley, 1984; Smith and Smith, 1984). Similar ranges in environmental settings are evidenced for the meandering channel planform style (e.g. subarctic, Forbes, 1983; temperate, Jackson, 1975; semi-arid, McGowen and Garner, 1970), with particle size ranges from fine sands to gravels (e.g. Fisk, 1947; Gustavson, 1978).

Planform type may be sensitive to changes in environmental setting (river metamorphosis; e.g. Schumm, 1968, 1969; Hickin, 1983). For example, as sediment availability has diminished in the post-glacial period, many rivers have adjusted their planform style from braided to meandering (e.g. Fisk, 1944, 1952; Leopold and Wolman, 1957; Knox, 1972; Kozarski and Rotnicki, 1977; Rose et al, 1980; Maizels, 1983). Similar adjustments may result from sea level or climatic changes; indeed, any alteration of the aggradation/poised/degradation balance results in river style change (Schumm, 1977). In some instances, planform type may be an historical artifact, as rivers adjust to their former flood history (e.g. Schumm and Lichty, 1963; Burkham, 1972).

As planform types are a response to certain combinations of environmental variables, they often are found in characteristic locations. For example, as slope and particle size typically decrease downstream, the likelihood of a meandering planform being adopted increases. Accordingly, principal mechanisms of floodplain formation may change down-valley (e.g. Brown, 1987). However, given the overlap between the environmental domains within which planform types are encountered, some reaches exhibit different planforms at different flow stages (e.g. Fahnestock, 1963; Williams and Rust, 1969; Smith, 1971; Bluck, 1974; Blodgett and Stanley, 1980; Werrity and Ferguson, 1980; Ferguson and Werrity, 1983; Carson, 1984b; Rundle, 1985a).

Geomorphic differentiation of planform types has been a recurrent theme of discussion since the papers by Lane (1957) and Leopold and Wolman (1957) which described discriminating functions for braided/meandering planform differentiation based on the relationship between channel slope and discharge. Carson (1984a) attributed the failure in discriminant analysis to problems of definition and interdependence of the terms used (neither discharge nor slope are independent), and the fact that functions derived in one region, with one particle size range, cannot necessarily be applied to another. For example, irrespective of planform, gravel-bed rivers must plot higher than sand-bed streams on discharge-slope plots because of the greater requirements for bed material movement (as Wilson, 1973). Hence, ranges of thresholds may be seen to apply for different particle size ranges.

Laboratory studies (e.g. Ackers and Charlton, 1970; Schumm and Khan, 1972; Anderson and Calver, 1981; Ashmore, 1982; Edgar, 1984), empirical studies (e.g. Chitale, 1970, 1973; Osterkamp, 1978) and theoretical studies (e.g. Engelund and Skovgaard, 1973; Parker, 1976; Fredsoe, 1978; Chang, 1978, 1985; Hayashi and Ozaki, 1980; Begin, 1981) have demonstrated that a continuum exists between channel patterns and their flow and sedimentary patterns (Bridge, 1985). As such, favourable settings for the development of one planform type as opposed to another are contingent upon the combined interaction of many environmental variables, rather than any distinctive property of flow.

2 : 3 Floodplain geomorphology

River floodplains are sediment sinks adjacent to river channels in which eroded and sorted sediments accumulate and are reworked by various processes, producing a vast array of sedimentary forms. This relatively thin (channel depth) veneer exhibits pronounced variability between proximal and distal zones (Happ et al, 1940). Mechanisms of floodplain growth generally are differentiated into within-channel and overbank processes, although distinguishing between the two is often not very clear (e.g. Nunnally, 1967).

The primary within-channel mechanism of floodplain sedimentation is lateral accretion, wherein bedload deposits on the inner side of bends become part of the floodplain as the channel migrates (Gilbert, 1877; Russell, 1898; Fenneman, 1906; Mackin, 1937). Eventually the surface of the convex bank approaches the elevation of the older part of the floodplain (Wolman and Leopold, 1957). The nature of bend movement often results in a ridge and swale pattern at the point bar margin (Fisk, 1944, 1947; Sundborg, 1956; Wolman and Leopold, 1957; Hickin, 1974; Hickin and Nanson, 1975; Koutaniemi, 1979; Nanson, 1980). Overflow across the bar surface leaves a veneer of fine materials, often infilling the swales to produce a relatively flat surface (e.g. Schmudde, 1963; Alexander and Prior, 1971). In river systems characterized by an irregular pattern of channel bars and shifting channel positions, floodplains may develop by island formation and channel abandonment (e.g. Schumm and Lichty, 1963; Nordseth, 1973; Morningstar, 1988). Major floods may remove coarse grained floodplain sediments, with replacement by channel bar and chute fill deposits (e.g. Baker, 1977). Until overbank deposits smooth out the floodplain surface, the hummocky appearance of former channels is retained. Finally, concave bank benches, produced by eddy accretion in the concave areas of bends, may merge with the floodplain (e.g. Carey, 1969; Hickin, 1979, 1986; Nanson and Page, 1983).

As a river overtops its banks, it loses power due to both the greatly reduced depth of the unconfined sheet-like overbank flow and the inhibiting effects of vegetation. The cyclical nature of these vertical accretion deposits reflect the rising and falling stages of floods. Wolman and Leopold (1957) pointed out the difficulty in reconciling substantial overbank deposits with regular recurrence intervals of bankfull discharge and considered such deposits to make up only 20% of floodplain sediments. These findings have been confirmed in many studies (e.g. Lattman, 1960; Allen, 1965; Douglas, 1977; Bridge and Leeder, 1979). Other authors have noted the prominence of overbank deposits in migrating channel regimes (e.g. Melton, 1936; Schumm and Lichty, 1963; Schmudde, 1963; Blake and Ollier, 1971; Mollard, 1973; Nanson and Young, 1981). The floodplains of streams which exhibit little or no lateral migration may be composed largely of vertical accretion deposits (e.g. Speight, 1965; Ritter et al, 1973). Controls upon the lateral stability of river channels are described by Friend et al (1979). The relative proportions of lateral and vertical accretion deposits also are affected by sediment supply and land use changes (e.g. Knox, 1972; Jacobson and Coleman, 1986). In general, floodplain sequences beyond the meander belt are dominated by overbank deposits (e.g. Fisk, 1947, 1952).

In some instances, high energy floods may strip away significant proportions of floodplain deposits, with subsequent replacement by vertical accretion deposits (e.g. Nanson, 1986; Ritter and Blakley, 1986). Furthermore, floodplain elevation may constrain depositional mechanisms. For example, Bishop (1987) noted that whereas lateral accretion mechanisms were more prominent on the smaller, lower floodplain unit, the upper floodplain was dominated by vertical accretion deposits. In contrast, Burrin and Scaife (1984) observed that in the contemporary time frame both lateral and vertical accretion mechanisms are relatively insignificant, and channel shrinkage and colluviation are more important sources for sediment accumulation. Over time, floodplain sediments initially deposited by one mechanism often are reworked and redeposited by others (Schmudde, 1963; Schumm and Lichty, 1963; Sigafoos, 1964; Brakenridge, 1984; Hereford, 1984).

2 : 4 : 1 Introduction to fluvial sedimentology

The vast array of scales of sedimentologic research can be classified into a hierarchy of field and conceptual units (Table 2.2) that form a continuum to which no specific spatial scales can be applied. For example, a mid-channel bar unit on a major river such as the Brahmaputra is equivalent in scale to an entire planform reach on a smaller river.

Small scale experimental studies of grain-by-grain interaction upon bedforms, along with theoretical notions on flow/sediment interaction, sediment packing, bedform migration and bedload transport are critical elements in understanding river processes, but as yet these mechanisms cannot be applied reliably at broader scales of sediment analysis. As such, recourse is taken to largely empirical, field studies of facies differentiation (at bar unit, channel bar and river reach scales). These varied studies, often with very different goals and carried out on very different styles and scales of rivers in a wide range of environments, are extremely difficult to synthesize, resulting in the poor state of theoretical development. Planform facies modelling and basin analysis provide conceptual frameworks of value for teaching or preliminary resource evaluation, but generally fail as analytical/interpretive tools. Architectural element analysis, based upon geomorphic field units, attempts to redress this problem. These different field and conceptual scales of sediment analysis are evaluated in following sections.

TABLE 2.2 : HIERARCHICAL ARRANGEMENT OF SEDIMENTARY SCALES

FIELD UNIT	CONCEPTUAL UNIT
Grain-by-grain interaction	
Bedforms (ripples, waves, dunes) + Bedding character	Combined with particle size as facies types
Bedsets, cosets, composite beds	Facies associations, often referred to as models
Locale (bar unit scale)	
River bar types	Architectural element analysis
Floodplain units	
Planform types	
River system	Basin analysis
Regional scale analysis	

2 : 4 : 2 The facies concept and facies modelling principles

Sediment classification styles can be differentiated into generic and genetic forms; clearly the latter is more useful although as yet there is no unifying scheme. Modern usage of the term facies dates back to Gressly (1838) in which the term refers to the "sum total of the lithological and paleontological aspects of a stratigraphic unit" (Walker, 1984, 1). This is a broad definition of the term; since then many other scales and meanings have been applied, resulting in different interpretations by different practitioners. Reading (1978, 4) defined facies as "a distinctive rock that forms under certain conditions of sedimentation, reflecting a particular process or environment". Following suggestions of Miall (1977, 1978b), the term is used in this study to describe sediment units of similar character at the scale of channel bedform units. Bedding and textural characteristics are combined with bedform structures in defining facies types (Chapter 4).

Only in the last thirty years has knowledge been attained of associations between flow and bed deformation in rivers (largely through laboratory studies; e.g. Simons and Richardson, 1961, 1962; Simons et al, 1961). In essence these studies have shown that as the relative energy of flow increases the nature of bed deformation alters, the specific manner of change depending upon bed material size. This linkage between flow conditions and bedform structures provides the basis of sedimentologic classification.

It was only following detailed field inventories of river deposits (e.g. Fisk, 1944, 1947; Sundborg, 1956) along with these laboratory studies of the hydrodynamics of bedform genesis that associations between sedimentary sequences and their environment of deposition could be determined. The key to positive identification of the environment of deposition of a particular sediment unit is the facies assemblage, including both the vertical profile and lateral lithologic variability. According to Walther's dictum, those units found laterally adjacent in the field should be found in adjacent positions in vertical sequence (e.g. Beerbower, 1964; Visher, 1965).

Examination of facies types in vertical sequence can be used to produce a facies model. These models aim to provide a general summary of a specific sedimentary environment (Walker, 1984), often in schematic form. Facies associations in vertical sequence can be avaluated at a variety of scales using Markov analysis (Miall, 1973), ranging in scale from depositional units upon river bars, to river bars themselves, to channel planform reaches, and to entire river systems

(Walker, 1984). Of particular interest in this study are river channel planform facies models.

Given the vast range of river channel styles and depositional types, planform facies models must be viewed as fixed points in a continuum, as proximal-distal relations can be expected (e.g. Jackson, 1978; Miall, 1985) and flow regimes adjust in response to climatic change (e.g. Brady, 1984). The "classic" meandering facies model was conceptualized by Allen (1964). Jackson (1978) envisaged a range of meandering models based upon hydrologic and sediment size controls. Models for the braided river depositional environment were summarized by Miall (1977, 1978b; Rust, 1978b). Facies models have subsequently been derived for other river styles (e.g. Smith and Smith, 1980; Bridge et al, 1986; see Walker, 1984). Prior to describing sedimentologic characteristics of braided and meandering channel planform styles, the sedimentology of channel bar and floodplain units are described.

2 : 5 : 1 Channel bar sedimentology

Channel bars are non-periodic (i.e. irregular) areas of net sedimentation of size comparable in magnitude to the channels in which they occur (Smith, 1978). They adopt many varied forms, contingent upon both regional scale environmental setting and local scale flow conditions. Specific bar types are found in characteristic locations (Table 2.3) and generally change in a downstream direction (Church and Jones, 1982). Bed material character, and the competence of flow to transport it, are primary factors affecting longitudinal (mid-channel) bar formation (Leopold and Wolman, 1957). With flow oriented obliquely to the long axis of the bar, a diagonal feature is produced (Church, 1972). These two bar types are generally associated with gravelly braided environments. In sandy braided conditions, flow divergence results in transverse or linguoid bars (Collinson, 1970; Smith, 1974; Cant and Walker, 1976). Lateral and point bars are found at channel margins under both sandy and gravelly conditions, and refer to sediment accumulations accreted laterally onto banks at the insides of river bends.

Most river bars are not simple unit features (Smith, 1974), but are complex, compound features made up of many zones, reflecting local erosional and depositional history. There are two main elements in bar form. The basal element or platform is made up of coarser material of constant form and composition. The supraplatform, or overlying sediment, has varying forms and is subject to removal and replacement during floods (Bluck, 1976). Down-bar trends have been

TABLE 2.3 : CLASSIFICATION OF BAR TYPES (After Miall, 1982)

BAR TYPE	CHARACTER	HEIGHT	LENGTH	OCCURRENCE	MODE OF FORMATION	SEDIMENTOLOGIC CHARACTER AND INTERNAL STRUCTURE
Longitudinal Diagonal Spool	Diamond or lozenge shaped mid-channel bars, elongated parallel to flow, with a slightly convex surface.	1.0m	>100m	Dominant in gravel-bed rivers (e.g. proximal braided streams). Diagonal bars are found where channel cross-sectional flow is asymmetrical.	Form by segregation of clasts as thin gravel sheets and grow by vertical clast accretion and development of downstream slip faces.	Generally coarse-grained, poorly sorted, massive or crudely horizontal gravels. Bars become finer both downstream (where they pass into cross-bedded sands) and vertically. Some lateral sorting is possible.
Transverse Linguoid Lobate	Downstream migrating sand bars with straight, lobate or sinuous downstream margins, oriented transverse to flow. Upstream surfaces dip gently, whereas steep steep avalanche slope (foreset) terminations may characterize downstream sections.	0.5- 1.0m	>100m	Found in areas of flow divergence, especially in sandy braided rivers. Rarely found in gravel streams.	Grow by down-current extension of slipfaces (avalanche face propagation).	Usually planar cross-bedded sand; rarely gravel. Often bars fine upwards and downstream, with better sorting at the bar tail.
Point Lateral Side	Bank-attached bars, typically associated with channel curvature. Different sediment zones are observed 'around-the-bend' of these arcuate shaped bars.	Qbf	100- 1000m	Occur in all types of rivers but best developed in sandy meandering streams.	Platform builds as channel laterally migrates, resulting in coalescence of mesoforms.	Complex sand and/or gravel mixes, with several types of cross-bedding and internal erosion surfaces. Sediment zones vary 'around-the-bend', with trough and planar cross-beds in the upstream unit, upward fining trough cross-beds and levee deposits in the intermediate zone, and upward coarsening trough cross-beds with planar cross-beds atop in the fully-developed zone. Overbank deposits are thicker in intermediate and downstream zones. Lateral bars may have steep, well-developed riffle faces.

demonstrated for longitudinal and diagonal bars, and Jackson (1976) showed the differing patterns of sediment types as one moves around a meander bend. Indeed, sediment variability within-bar may greatly exceed between-bar variability.

2 : 5 : 2 River floodplain sedimentologic zones

As this study focuses in large part upon floodplain sedimentation in and around the channel zone of the Squamish River, the many different styles and forms of floodplain deposits described for a wide range of different environments (Table 2.4) will be given scant regard here.

Flow energy decreases notably away from the main channel (e.g. Kesel et al., 1974; Lewin, 1978b; Pizzuto, 1987), resulting in pronounced differentiation between proximal and distal floodplain zones (TASK Committee, 1971). Proximal (channel marginal) features include bars and concave benches. Channel shifting or migration patterns may result in abandoned channels and ox-bows. Once sediment builds up to a certain level on the floodplain, overbank mechanisms become more important, and levees may develop. Higher energy flows that breach these levees may result in crevasse splay deposits. Channel avulsion may produce abrupt lateral facies and paleocurrent variability (e.g. Allen, 1978; Bridge, 1984). In general, more distal parts of the floodplain are made up of alternating cycles of roughly horizontally bedded, flood deposits; in areas furthest from the channel, backswamp conditions may prevail (e.g. Carey, 1969). Deposits from each flood are so thin in this zone that they are unlikely to accumulate to any great thickness (Schmudde, 1963). Finally, at valley margins the floodplain may no longer be influenced by present alluvial processes, and slope processes may prevail, resulting in colluvium or debris flow accumulations, or alluvial fans at tributaries.

2 : 6 : 1 Sedimentology of braided river reaches

Depositional sequences associated with the distinctive shifting behaviour of braided river channels were first noted by Doeglas (1962), Krigstrom (1962) and Ore (1964). Within-channel bars, formed continuously in association with channel thalweg shifting, become part of the floodplain upon channel abandonment. Bar development may include lateral accretion, although longitudinal growth is favoured. This produces alluvial plains with a network of channels, but no

TABLE 2 : 4 CLASSIFICATION OF VALLEY SEDIMENTS (after Happ, 1940)

Place of deposition	Process	Type(s)	Characteristics
Channel	Sediment transport/ aggradation	Transitory	Bedload at rest - part may be preserved in channel fills or lateral accretions
		Lag	Segregation of larger/heavier particles - discontinuous lenticular patches in deeper flow sections - quickly covered by fines
	Abandonment	Channel fill	Accumulations in former channels, often upward fining from coarse bedload/lag to fines
	Eddy accretion	Concave bench	Fines, possibly with interbedded organics
Channel margin	Lateral accretion	Point/marginal bars	Fine gravels to silts, commonly trough cross-bedded, preserved by channel shifting. Some bars show extremely varied and complex accumulations. Referred to as bottom-stratum deposits. May be associated with ridge and swale features.
Overbank	Vertical accretion	Flood basin	Broad, low relief plain. Settling basin in which suspended fine-grained sediments settle from overbank flows. Often alternating sand/silt layers or finely laminated muds - may show convolute bedding. High proportion of organics. Referred to as top-stratum deposits.
		Levee	Wedge-shaped sediment ridges bordering channels - slope away from channel. Best developed on inside of meander loop. Material finer than point bar, with sedimentary structures similar to top-stratum deposits. Rapid deposition, with multiple shallow waning flow cycles producing alternating sand/mud layers and clay drapes.
		Backswamp	Areas furthest from the channel with silt, clay and peat accumulations.
		Cut-offs/ Ox-bows	Three types - chute cut-off, neck cut-off and avulsion, with slow infilling of former channels from suspended overbank flow (clayey sediments and organics).
	Erosive break in levee	Crevasse splay	Most frequent at concave banks. Coarser grained than levee as associated with local bedload deposits. May have crenulate distal margin, in parts with avalanche fronts. Heterogeneity in sediments due to multiple flood events, shallow flow conditions and rapid sedimentation. Some low energy flow structures. Scour and fill common, with sands overtopped by muds.
Valley margin	Slope activity	Colluvium and debris flows	Largely unsorted deposits from soil creep, slope wash and mass movements. Frequently in alluvial fans at tributary junctions.

clearly defined overbank terrain.

Alluvium of braided streams consists largely of imbricated, channel lag gravels, with erosional bases, and randomly preserved fragments of channel and bar deposits. Channel fill deposits vary widely, with lenses of bedload sediment (structureless or trough cross-stratified deposits), or broad, tabular, dip-oriented multi-lateral sand belts in sand-bed rivers (Galloway and Hobday, 1983). Abandoned braid channels may have sandy mud or clay fills, resulting in rare shoestring forms upon the floodplain. Channel bar deposits exhibit a wide range of forms and depositional sequences, resulting from coalescence and accretion of smaller bedforms during flood events. Longitudinal or transverse lenses, or even foresets associated with lateral accretion, may be found (Reineck and Singh, 1980; Cant, 1982), producing complex patterns of tabular sets of cross-bedded sands and/or gravels, often with reactivation surfaces and ripple cross-laminations preserved above the sets (Smith, 1974; Collinson, 1978).

The sediment character of braided streams varies in a proximal-distal sense for both gravel and sand-bedded streams (e.g. Bluck, 1987). Proximal reaches of gravel-bed braided streams are dominated by imbricated, horizontally bedded clast-supported gravels (often massive), deposited upon longitudinal bars (Williams and Rust, 1969; Rust, 1972, 1975, 1978b, 1979; Smith, 1970; Church and Gilbert, 1975; Cant, 1982). These fine upwards to trough- and horizontally bedded sands, with occasional accumulations of vertically accreted fines deposited upon inactive tracts raised above the general channel level (Williams and Rust, 1969; Rust, 1979). The proportion of horizontally and planar cross-bedded sands increases as one moves downstream (Smith, 1970). Sand-bedded braided river reaches are composed largely of tabular sets of cross-bedded sands deposited upon bars and sand flats, with trough and ripple sequences atop (Collinson, 1970; Smith, 1970; Church and Gilbert, 1975; Cant and Walker, 1976, 1978). Laterally interfingered channel, bar, and sand flat deposits succede one another vertically (Cant, 1978). At high discharge stages, sand-bedded braided streams may have plane bed conditions (Coleman, 1969), but as flow wanes, sand sheets are dissected into a variety of forms with low angle erosion surfaces and lateral accretion of ripples and silty drapes. Vertical accretion deposits seldom are observed.

In summary, braided river deposits exhibit random interbedding of trough and tabular sets with occasional ripple units. Local scour units, discontinuous lags, and diffuse pebble sheets are common, whereas muds are rarely deposited from suspension, accumulating only in abandoned channels. The relative proportion of sheet and channel deposits depends upon local circumstance, especially the discharge regime. Systematic upward change of particle size or cross-bedding set is unlikely except during channel abandonment, as sequences demonstrate large facies changes over short distances.

Miall (1977, 1978b) and Rust (1978b) synthesized these sequences into six braided planform facies models based upon differing environmental settings and bed material size characteristics (Table 2.5). The braided section of the Squamish River falls between the Scott and Donjek facies model styles.

2 : 6 : 2 Sedimentology of wandering gravel-bed river reaches

The sedimentologic character of wandering gravel-bed river reaches (first described by Neill, 1973) has received considerably less attention than braided or meandering styles. Distinction can be made between two zones of river activity, distinguished by the irregular pattern of channel instability. Stable channel reaches consist of gravel-based, lateral and point bars with planar and trough cross-bedded sands and occasional silt drapes (Desloges and Church, 1987). Unstable sections, or sedimentation zones (Church, 1983), also have a single dominant channel, with sporadically active mobile bed gravels and sands. In these reaches, medial bars and islands are made up of massive and planar gravels, with occasional horizontally bedded sands. Morningstar (1988) described a mechanism wherein lateral channel shifting results in islands accreting onto the floodplain, with channel abandonment resulting in a slough between the former island and floodplain deposits. A variety of sedimentary forms were observed in a distinct hierarchy of within-chute channel facies. Floodplain deposits consist of roughly horizontally bedded sands and scour and fill units within old slough-channel fills. Trough cross-bedded units may overlie these deposits. Massive fines are found as either thin drapes or as thicker fills of back channels upon the distal floodplain.

TABLE 2 : 5 BRAIDED FACIES MODELS (after Miall, 1977, 1978b; Rust, 1978b)

Model Name	Depositional Environment	Depositional Mechanisms	Sediment character
Trollheim	-arid/semi-arid fans -steep slopes -abundant sediment supply	-flash flooding -debris flows	Dominantly poorly sorted massive or matrix-supported gravels, with some horizontal bedding. Non-channeled deposits, with abrupt bases. Lobate geometry.
Scott	-very proximal gravel rivers -includes fan units	-longitudinal bar accretion -occasional debris flows -minor channel infill units	>90% gravel; Mainly horizontally bedded, imbricated clasts, with some trough or planar cross-bedded sands. Little cyclicity.
Donjek	-distal gravel river reaches, with well-developed active channels and elevated to entirely inactive reaches	-longitudinal bar accretion -some transverse/lobate units -occasional lateral/point	10-90% gravel; generally upward-fining channel infill units, with imbricated horizontally bedded basal lag gravels, trough and planar cross-bedded sands above, and horizontally laminated or climbing ripple fines atop.
South Saskatchewan	-sandy systems with deep channels, complex bars and well-developed floodplain	-within channel deposits -accretion as sand waves/ flats producing many subenvironments -vertical accretion	<10%gravels; generally moderately-well sorted sands. Upward fining cycles reflect pattern of channel and bar evolution. Horizontally bedded lag gravels are covered by sinuous crested cross-bedded sandy troughs. Above these, stacked planar cross beds from sand flats are interbedded with trough cross-bedded, rippled and horizontally bedded sands. Rippled fines accumulate upon topographic highs. Atop this sequence are cohesive, vertically accreted thick silty/sandy mud laminates (occasionally rippled).
Platte	-sandy systems with broad shallow rivers and fairly steady discharge -areas lack well-defined topographic differentiation between active and inactive areas	-linguoid and transverse bars	No well developed cyclicity due to limited relief. Some trough cross-beds in channels, but system dominated by superimposed sets of planar cross-bedded sands, often driven onto the floodplain. Lower stage dissection may result in ripple and horizontally bedded sands and locally preserved muds.
Bijou Creek	-sandy systems with ephemeral discharges; prone to catastrophic flooding	-flash flooding	No vertical segregation of particle size. Sheet flooding results in upper flow regime horizontally laminated sands, with some planar cross bedding and climbing ripple sequences produced at waning stages.

2 : 6 : 3 Sedimentology of meandering reaches

Meandering reaches form deposits primarily by the action of lateral accretion, wherein bedload deposits upon point bars become part of the floodplain as the channel migrates (Fenneman, 1906; Wolman and Leopold, 1957). Stable, vegetated banks, made up largely of fine deposits, result in high width/depth ratios. The characteristic asymmetrical channel form is maintained as the river migrates across its meander belt, producing a series of scroll bars (alternating ridges and swales). Vertical accretion of overbank deposits raises the point bar surface to that of the floodplain; these deposits also produce a range of secondary features away from the well-defined channel. Each subenvironment of meandering river floodplains, the main channel, point bars, levees, the flood basin and meander cut-offs, generate deposits with characteristic grain sizes and sedimentary structures (Boggs, 1987; see Table 2.4).

Channel sediments are primarily imbricated lag deposits with indistinct bedding. At bankfull stages, helical flow develops within channel bends, carrying sediment up the convex slope of the point bars, with coarser grains and dune structures lower on the point bar, and finer grains and ripple structures higher up, as shear stresses decline (Allen, 1970). Interspersed within these sediments may be upper flow regime plane-bed parallel laminations (Walker and Cant, 1979; Koutaniemi, 1984). This highly organized internal structure of point bars, with upward reduction in both particle size and sedimentary structure (Galloway and Hobday, 1983), reflects progressive downvalley channel migration, causing these sequences to successively overlie former positions of the channel thalweg, now recorded by a basal surface. Vertical accretion of fine sediment of flood origin subsequent to meander abandonment or channel avulsion, leads to formation of a complete upward fining cycle. The relative importance of lateral versus vertical accretion deposits is dependent largely upon the stability of the channel position.

The first studies indicating the distinctly upward-fining nature of sediments associated with channel meandering were completed by Barrell (1912) and Dixon (1921). Although these sediment styles were described further by Melton (1936) and Mackin (1937), it was not until the 1960's that the process of lateral accretion was incorporated into a model of floodplain growth by point bar development (Allen, 1963, 1964, 1965; see review in Miall, 1978a). At this stage, Allen considered the presence of epsilon cross-stratification, associated with the lateral accretion mechanism, to be diagnostic of meandering rivers, with the horizontal extent of a single epsilon unit representing approximately two-thirds of the bankfull discharge (Allen, 1965). Thickness of cross-bed sets were associated with channel depth, and dips from 1° to 25° observed in large and small rivers respectively. Studies of ancient alluvial facies showed upward fining cycles between 1-20m thick, repeating over great thicknesses of strata (Allen, 1964; Friend, 1965; Allen and Friend, 1968). Further examples are described by Puigdefabregas and Van Vliet (1978).

As research upon contemporary meandering rivers continued, however, it soon became apparent that this model is grossly oversimplified and applies to only a small range of fine-grained meandering systems. Jackson (1975a, 1975b, 1976) and Ray (1976) demonstrated considerable variation in composition, vertical sequence and internal structure within a single point bar. Bar head units reflect the transition from reversed hydraulic and sedimentologic conditions of the preceding bend. Current velocities are strongest and dunes or sand waves are best developed. Only in the downstream, or "fully-developed zone" is the classic point bar model seen to apply, as only part way around the bend is the helical overturn of flow fully developed. The extent of this zone is conditioned by the ratio of channel curvature to channel width : if values are very high or low the fully developed zone may not exist.

The classic point bar model has even less relevance for coarse-grained meandering river reaches. Point bars in these low sinuosity, relatively high gradient, bedload streams often are modified by chute channels and chute bars (McGowen and Garner, 1970; Levey, 1978). Whereas basal platform deposits are composed of uniform, thick low-angled cross-beds, supra bar platform deposits demonstrate a variety of complex sediment sequences (Bluck, 1971), contingent in large part upon the coarseness of the gravel and the sand/gravel mix (Jackson, 1978). However, these sequences characteristically exhibit little vertical fining; indeed, some of the coarsest grain sizes and largest structures may be found atop sequences in chute or chute bar deposits (McGowen and Garner, 1970).

Active grain segregation upon coarse-grained point bar surfaces results in a series of sediment units around bends (Bluck, 1971). At the bar head, inclined gravels are interstratified with ripple and horizontally bedded sand sheets, and steeply dipping beds at the margins. Cross-bedded sands and occasional organics predominate at the bar tail. The bar lee has foresets of silty-clay and organic bands, with thicker ripple units. Similar units accumulate at the inner accretionary bank, grading upward into silts and clays of the floodplain.

Slightly different point bar units were noted by Levey (1978), with poorly stratified channel lag gravels at the bar apex, grading to horizontal or trough cross-bedded, coarse-medium sands at the mid-bar unit. Distal bar facies consist of a variety of forms, with some megaripples and scour and fill structures developed in chute channels, along with climbing ripple lamination and mud drapes. Levey (1978) synthesized these three units into a hypothesized vertical sequence of apex, mid-bar and distal forms. A similar pattern was predicted by McGowen and Garner (1970), although in this instance the upper unit is characterized by interlensing, scour-based chute fill and accretionary chute bar sands, demonstrating a wide range of sedimentary forms (including discontinuous channel lags, planar and trough cross-bedding, and ripple laminations). Under even coarser gravel bed conditions, Gustavson (1978) showed upper point bar sequences to be dominated by thin gravel sheets deposited as transverse gravel bars.

In summary, vertical sections vary markedly for different sections of coarse-grained point bars, and there often is greater sedimentologic variability within a bar than between bars (Bluck, 1971). Lateral point bar sedimentation, along with downstream movement of the meander loop, produces a complex, interlocking lithofacies pattern. In a guarded review, Jackson (1978) synthesized this wide range of meandering depositional environments into five facies models (Table 2.6). These must be viewed as end members within a continuum of variability, the Squamish River falling between models 4 and 5 in style.

2 : 6 : 4 Sedimentologic differentiation of channel planforms

Reineck and Singh (1980, 310) observed that :

> "each river pattern does not produce a single characteristic sequence, but a number of sequences of highly variable character. Similar-looking sequences may be produced by rivers of different patterns."

Rundle (1985b) and Bridge (1985) noted that there are no indications of sedimentary structures peculiar to individual planform types. Despite these reservations, planform differentiation continues to be used in analysis of river deposits. Many sedimentologic criteria have been used to make this distinction (Table 2.7), but as Jackson (1978) and Bridge (1985) commented, these must be viewed with much scepticism, given the complexity of river depositional environments and the continuum of planform styles.

TABLE 2 : 6 MEANDERING PLANFORM FACIES MODELS (after Jackson, 1978)

Class	Type and environment	Morphologic character	Sedimentologic character
1	Muddy fine-grained river systems, typically in broad flat valleys (e.g. old lake bottoms)	- small W/D ratio - very high sinuosity - prominent levees - scrolls/chutes absent - steep point bar slope (often >20°)	Well defined channel fill, with erratic cross-section shape. Upward fining of bottom stratum deposits common but not ubiquitous. Often thick mud sequences. Epsilon cross-stratification possible, with thin laminae of fine sand and silt. Bed materials are primarily medium sand or finer, but the fine member is dominant, with abundant overbank fines.
2	Sand-bed systems with modest thickness of fine member. Rapid rates of channel migration with many chutes and neck cut-offs.	- variable W/D ratio - prominent point bars of modest slope - prominent scrolls and chutes - prominent levees	Asymmetrical channel cross-section. Upward fining of bottom-stratum deposits common, but not ubiquitous and although overbank muds are prominent top stratum deposits are less abundant than point bar deposits. Substantial scour and fill during floods - channel fill muds are common. Epsilon cross-beds are common and may dip steeply in small streams.
3	Sand bed streams with a very limited size range of sediment supply (no mud or gravel).	- wider channels than classes 1 and 2 - no natural levees - scrolls may be prominent	Particle size characteristics are contingent upon sediment supply - channel fill muds are absent, giving relatively uniform sequences.
4	Gravelliferous sand-bed streams	- prominent point bars - levees prominent - chutes/scrolls common	Well-developed textural zonation around bend, with gravels in deep channels/lower point bar and bar supraplatform made up of sandy bedforms - dunes on lower point bar and planar cross beds in mid point bar. Channel fill muds are common, but represent a small percentage of the overall alluvial fill. Simple epsilon cross beds are rare, but may be present in the coarse member. Very little mud observed.
5	Streams in higher energy depositional environments commonly near mountains - steep slopes - coarse gravel/little sand	- bends are long but not tight - irregular bed topography, with prominent riffles - complex point bar units	Dominantly horizontally bedded clast-supported gravels, with some gravel planar beds and sand/mud-filled scour units atop. The fine member is very variable in thickness, although there is little overbank mud and alternating sand/silts as levee-type deposits. Epsilon cross beds are absent.

TABLE 2.7 : COMMONLY CITED SEDIMENTOLOGIC CRITERIA USED TO DIFFERENTIATE BETWEEN MEANDERING AND NON-MEANDERING PLANFORMS

Characteristic	Meandering	Non-Meandering
<u>Facies and particle size characteristics (*1)</u>		
Gravels	few clasts; Gm, Gt, Gp rare to absent	Gm common; some Gp, Gt
Sand	St, Sh, Sr common; often thick, with little lateral change in texture	St, Sp, Sh, Sr common; often lenticular and discontinuous
Fines (silts/clays)	normally Fl, Fm are common and thick	uncommon and thin
Sediment mix	relatively few gravels; predominantly sands, with high proportion of silt/clay	often gravel abundant; may be very coarse in proximal reaches. Other reaches are sand dominant; silt and clay are seldom observed
<u>Facies associations</u>		
Vertical facies sequence	fining upwards cycles of grain sizes and sediment structures	no consistent sequence
Lateral facies variability	consistent/predictable pattern of facies change	Wide range of facies variability, over short distances
<u>Channel fill characteristics</u>		
Abundance	low	high
Thickness	commonly >3m	rarely >3m
Shape	typically asymmetrical	broad range
Nature of fill	gradual infill of fine-grained material following sudden neck cut-off; few scour surfaces	progressive infilling of upward-fining flood cycles; frequent scour surfaces
<u>Other sedimentologic properties</u>		
Epsilon cross-stratification	common	absent
Dispersion of current indicators	large, often >180°	small, often <90°
Geometry of channel belt deposits	tabular sand body, with channel ribbon deposits, stacked as multi-storey units	sheet deposits, stacked as multi-lateral units
Natural levees	often prominent	uncommon
Scroll bars	common	absent
Chute fill/chute bars	common in coarse-grained rivers	uncommon
Basal gravel contact character	tilts at consistent angle towards the main channel	highly irregular

(*1) Facies coding scheme according to Miall (1977, 1978)

Since the mid 1960's, two criteria have been considered diagnostic of a meandering channel planform, namely the presence of upward fining cycles of both grain sizes and sedimentary structures, and epsilon cross-stratification (Moody Stuart, 1966). Both of these phenomena result from changing depositional conditions upon point bars as river bends laterally migrate. Recent research has found these to be oversimplified generalities, however, as these criteria are not always observed in meandering rivers. Epsilon cross-stratification is very difficult to recognize with low dips (Nijman and Puigdefabregas, 1978) and there are only 11 examples in the 231 upward-fining cycles studied by Allen (1970). Meandering river systems are not always characterized by upward fining units (e.g. McGowen and Garner, 1970; Bluck, 1971; Jackson, 1976). Spiral flow associated with bend migration depends upon local flow geometry and river stage, and is not unique to any particular channel planform. Furthermore, lateral accretion deposits and epsilon cross-stratification have been observed in braided river depositional environments (e.g. Long, 1978; Bluck, 1979; Ori, 1983; Allen, 1983; Bridge, 1985). Finally, bars and islands, which are characteristic features of braided depositional environments, also have been described for high sinuosity meandering rivers (e.g. Schwartz, 1978; Forbes, 1983).

Bridge (1985, p582) commented that

> "... if channel-forming discharge, width/depth, slope and bed material size of an ancient channel belt can be reconstructed ... the pattern can be ascertained by comparison with ... modern rivers".

Of the many criteria used to differentiate between river channel planforms only three have proven reliable consistently (Jackson, 1978; Bridge, 1985) namely :

1. Particle size character and distribution : Open framework clast-supported gravels are found only in pockets in meandering reaches whereas gravels may be laterally extensive and very coarse in proximal braided environments (Rust, 1979; Bluck, 1980). Particle size distributions of channel fill and floodplain deposits are more distinct in meandering planform reaches, with laterally extensive accumulations of fines.

2. Paleocurrent variability : Low range of paleocurrent variability in coarse materials generally is indicative of low sinuosity conditions (Bluck, 1974; Rust, 1975), although this is dependent on scale of measurement and sediment reworking (i.e. preservation potential).

3. Facies associations and their lateral variability : In general, within-channel facies are the most diagnostic component of planform sedimentology (Galloway and Hobday, 1983). While low sinuosity streams are noted for vertical channel infilling by bed accretion processes, high sinuosity streams infill horizontally by lateral accretion mechanisms. Theoretically, sediment sequences are laterally more consistent in meandering planforms, whereas braided deposits show large facies change over short distances, with a higher proportion of channel fill sediments and limited cyclicity.

The questionable usefulness of the channel planform scale in sediment analysis, along with the lack of discriminating geomorphic factors, have prompted the search for alternative means of river sediment classification. Of particular concern have been the limitations imposed by the essentially one- and two-dimensional approaches of facies modelling analysis. Three dimensional, architectural element analysis has been proposed as an alternative method of sedimentologic investigation.

2 : 7 Architectural element analysis

The wide range of river channel planform models developed for each planform type reflects their broad environmental domains. Facies models are inhibited by their inherent one-dimensional approach and the questionable field and statistical methods used in their derivation. The simplicity of derived models often means they have limited real-world sense (e.g. Jackson, 1978; Collinson, 1978; Miall, 1980, 1985, 1987; Friend, 1983; Anderton, 1985; Bridge, 1985; Reading, 1987; Dott, 1988). However, such models remain widely used in circumstances where the only available data are one-dimensional core logs.

Given these limitations, recent research has moved towards three-dimensional approaches to river sedimentary units wherein the architecture of a depositional body is evaluated in terms of its shape and larger scale internal geometry (e.g. Collinson, 1978; Allen and Williams, 1982; Allen, 1983; Friend, 1983; Ramos and Sopena, 1984; Blakey and Gubitosa, 1984; Miall, 1985, 1987, 1988; Ethridge et al, 1987). Several interrelated field components make up the architectural framework of a river system, such as channel, levees, crevasse splays and floodplain units. The character and extent of these components reflect the regional and local environmental setting.

Geomorphic processes differ in type and propensity under these different environmental settings, conditioned by factors such as channel shape and shifting behaviour, load type, discharge regime and subsidence rate (Miall, 1984). These processes can be classified into a limited number of styles. For example, Friend (1983) differentiated between fixed, mobile and sheet channel units and inter-channel sediments. Miall (1985, 1988) refined this scheme into a series of eight architectural elements, namely : channel, gravel bars and bedforms, sandy bedforms, foreset macroforms, lateral accretion deposits, sediment gravity flows, laminated sand sheets, and overbank fines. These elements are defined by their internal composition and geometry, external geometry, scale and bounding surfaces. The relative abundance and spatial association of architectural elements depend upon local field scale; each river system has its own local suite.

2 : 8 The state of the art

Research in river sedimentology remains largely empirical in approach, reflecting the diversity of sediment sequences associated with a vast range of river types, and little sense of overall order prevails. In some instances, sediment sequences exhibit convergence wherein similar depositional forms and associations are found under seemingly very different environmental conditions. This is evidenced by river channel planform sedimentology. The degree of overlap between the environmental domains of braided and meandering river reaches is such that it may be impossible to differentiate between their resulting sedimentary sequences. Prior to the introduction of fluvial architecture, the role played by fluvial geomorphology has been largely neglected within sedimentology. Because they relate directly to geomorphic processes, architectural elements may provide a more meaningful scale for evaluating river depositional sequences.

CHAPTER III

REGIONAL SETTING

3 : 1 Introduction

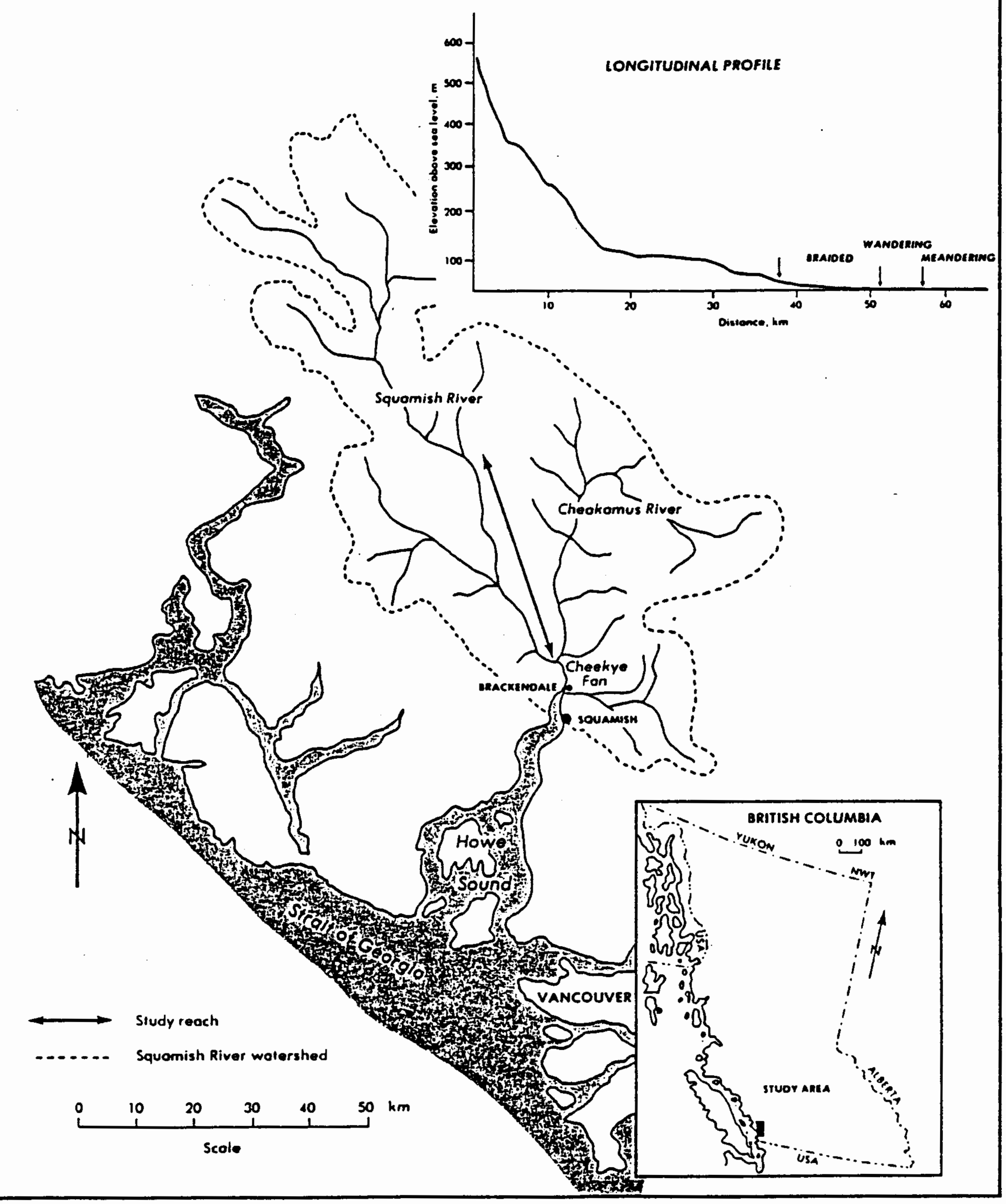
British Columbia has a high-relief, structurally controlled, mountainous coastline which has been extensively modified by glaciers, producing many long, narrow and deep basins (Clague and Bornhold, 1980). Located 60km north of Vancouver, the high energy, gravel-based Squamish River is over 150km long, and drains an area of almost 3600km^2 in the Coast Mountain Ranges (Figure 3.1). In this chapter the geologic and glacial histories of the area, regional climate, and associated hydrologic regime of the Squamish River are described briefly. Finally, the geomorphic setting of the study reach is examined in detail, focussing upon downstream planform variability.

3 : 2 Geologic Background

The Coast Mountain Plutonic Complex, intruded in the Late Jurassic - Early Cretaceous, is mainly granitic (quartz diorite and granodiorite) in composition, with minor occurences of gneiss and schist (Roddick and Woodsworth, 1979; Woodsworth, 1977). The northwest/southeast trending Coast Mountain Ranges have a width of 125-160km (Holland, 1964). On the western side of the Squamish Valley the Tantalus Ranges reach elevations in excess of 2200m. Higher peaks (Mount Garibaldi, 2678m and Mount Cayley, 2393m) on the eastern side of the valley were formed during the Quaternary by intrusion of andesitic volcanoes. Recent eruptions were ice-contacted, resulting in very friable volcanic materials upon oversteepened slopes very prone to collapse (Mathews, 1952a, 1952b, 1958a, 1958b; Souther, 1980; Clague and Souther, 1982), thereby producing very distinct sediment sources (Brierley, 1984; Brierley and Hickin, 1985).

Ryder (1981) divided the regional geomorphic history of southwestern British Columbia into three phases. Tectonic processes and subaerial denudation during the Tertiary resulted in a series of structural lineaments and fragments of relict erosion surfaces. These major linear structures in the Coast Mountains have been excavated by glacial and fluvial processes during the Pleistocene to form striking alignments and grid-like patterns of valleys and fjords parallel to regionally developed sets of joints or faults. The Holocene has been a period of fluvial reworking of glacially

FIGURE 3.1 FIELD AREA SHOWING THE STUDY REACH OF THE SQUAMISH RIVER



derived sediments, along with slope modifications of valley sides.

3 : 3 Recent glacial history and its consequences

Southwestern British Columbia has a complex Pleistocene history of glacial advances and readvances. The most recent ice sheet phase, locally referred to as the Fraser Glaciation, reached its maximum extent between 18000 and 13000 years B.P. (the Vashon Stade; see Clague, 1981). Ice depth in the Squamish Valley was greater than 1950m, with the ice surface at 2100m in the Garibaldi region and 1800m in the Tantalus Ranges (Mathews, 1951). The last notable readvance of the Fraser Glaciation (the Sumas Stade, about 11300 years B.P.) produced a large terminal moraine separating the inner and outer sills of Howe Sound, indicating that a major valley glacier occupied the Squamish Valley after the ice sheet phase (Ryder, 1981). Low level cirques were not reoccupied at this time (Mathews, 1951) and recession was very rapid. The regional history of neoglacial ice advances is complex and uncertain, although three general phases have been identified at 5800-4900 and 3200-2300 years ago and during the last 1000 years (Ryder, 1981).

Regional isostatic and eustatic sea level changes of up to 230m resulted from major ice advances of the Fraser Glaciation (Armstrong and Hicock, 1976). Sea level adjustments in the early Holocene were very rapid, and the shore has stood close to its present level for the past 2250 years in all parts of the area (Mathews et al, 1970; Clague et al, 1982; Clague and Luternauer, 1983; Roberts, personal communication, 1989).

3 : 4 Climate, hydrology and other physical factors

Squamish presently experiences a temperate maritime climate, with a wet winter/dry summer regime, annual precipitation totals in excess of 2000mm, and average annual temperature ranges from 0-15°C (Environment Canada, 1982a, 1982b). The abrupt nature of atmospheric uplift associated with the mountain ranges, along with the transition from an ocean to a land surface, result in high precipitation totals in the mountains. Indeed, alpine ranges remain glacierized at 1500m on northerly slopes and 1800m on southerly slopes. The combined effect of these factors produce hydrologic regimes with a distinctly seasonal nature.

The Squamish River system drains an area of about $3600km^2$, of which 2300, 950 and $330km^2$ are contributed by the Squamish, Cheakamus and Mamquam basins respectively (Water Survey of Canada, 1973). The discharge of the Squamish River at Brackendale has an annual average of $250m^3s^{-1}$, with monthly averages ranging from about $90m^3s^{-1}$ in March to over $500m^3s^{-1}$ in July (Figure 3.2). In general, smaller, snowmelt-induced flood events occur annually in spring (the freshet), whereas rainfall induced floods in fall and winter are more sporadic, and often more severe. Recorded annual floods range from 700 to $2600m^3s^{-1}$. Gumbel flood frequency analysis (Figure 3.3) indicates that bankfull discharge for the Squamish River at Brackendale is about $900m^3s^{-1}$ (using the 1.5 year recurrence interval).

The Squamish River floodplain is densely vegetated with a mixed forest of conifers and deciduous trees. Spruce and cedar are interspersed with maple, alder and cottonwood, the latter two being the primary colonizers of channel bars. Log jams often provide nuclei for channel bar sedimentation (Hickin, 1984). The floodplain lower canopy is often very dense. Soils are generally highly leached, acidic, reddish-brown ferro-humic podzols, interspersed with regosols and gleysols.

3 : 5 :1 Geomorphology of the Squamish River Basin : Introduction

The Coast Mountain area of British Columbia is a very dynamic, high-energy landscape undergoing adjustment to geologically recent ice-sheet activity. River valleys are confined by steep mountain slopes; fjords are incised deeply along the coastline; glacially-derived sediments and ice-contacted lavas on valley sides are prone to failure producing extensive alluvial fans, in some cases leading to temporary damming of rivers; rivers themselves are in a state of adjustment as they rework vast volumes of bed-calibre material produced by former events within their basins. High drainage basin relief and associated climatic/hydrologic regimes result in very high regional sediment yields and bedload dominance in contributing rivers and river distributaries (Kostachuk, 1984). The rapidly evolving nature of the Squamish River system is testified by contemporary growth rates of the delta front, which is extending at a rate between 6-10m/annum into Howe Sound.

In this section, the geomorphology of the Squamish River basin is divided into three parts: Howe Sound fjord and the delta; sediment sources within the system; and river response to its environmental setting in terms of planform variability.

FIGURE 3.2 MEAN MONTHLY DISCHARGE SQUAMISH RIVER AT BRACKENDALE (1955-1987)

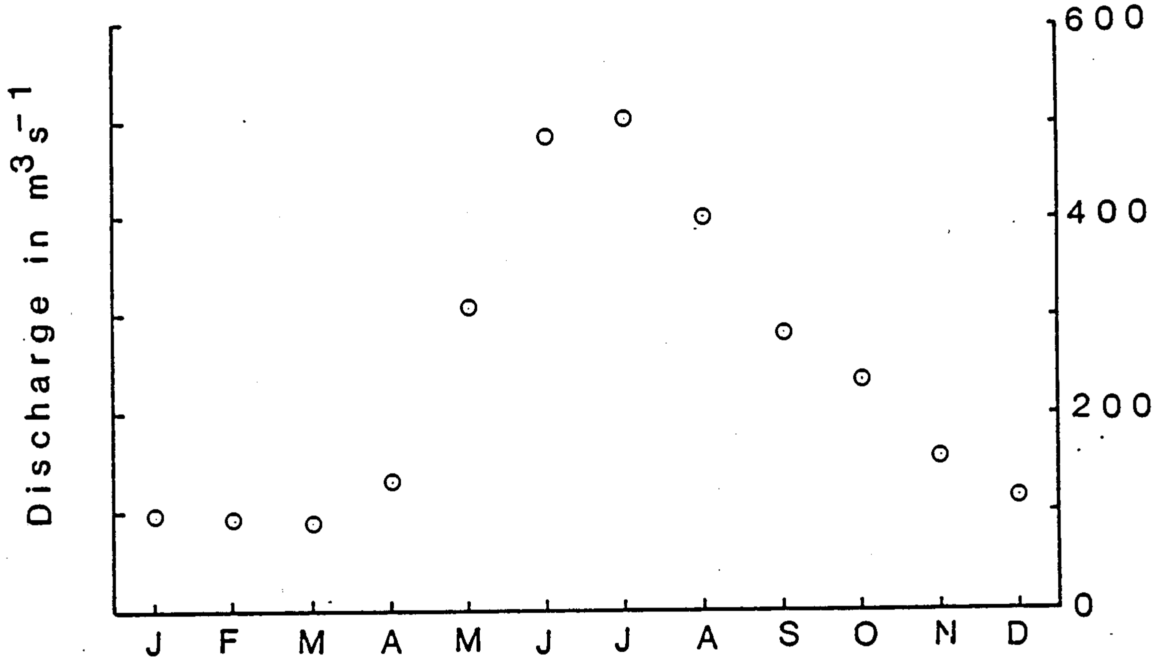
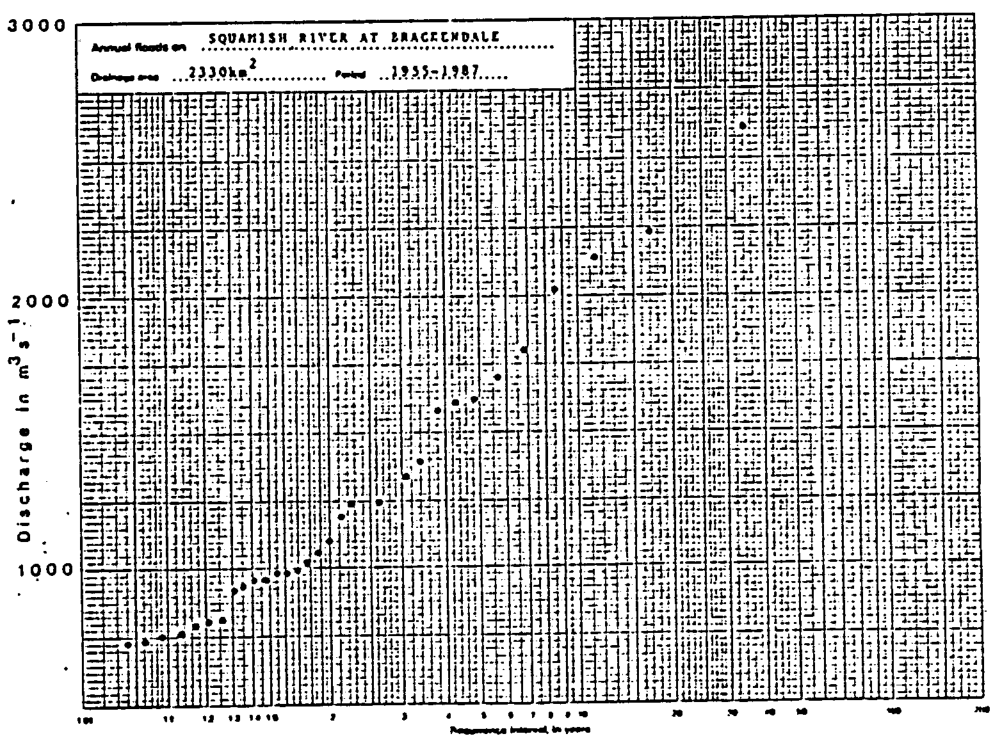


FIGURE 3.3 GUMBEL FLOOD ANALYSiS



Source : Water Survey of Canada (1955-1987)

3 : 5 : 2 Howe Sound fjord and the Squamish River delta

Howe Sound is a geomorphologically complex N-NW oriented fjord consisting of many U-shaped submarine valleys that have deep basins, steep sides and submerged sills (Syvitski and Macdonald, 1982). The Porteau Cove morainal sill, 30m below the present water surface, divides inner and outer arms of the fjord. The northern arm is a simple silled (70m deep) U-shaped basin approximately 3km in width, increasing in depth seaward to 325m. This inner sill is largely a coarse boulder-laden moraine of Pleistocene age. Beyond the inner sill the fjord flares out, becoming three U-shaped channels with a maximum depth of less than 250m. Channel bottoms are covered by 50-150m of Holocene sediment that overlies thick deposits of Pleistocene sediment (100-600m; Syvitski and Macdonald, 1982).

The highly constructive, fluvially dominated Squamish River delta has an area of $3.8 \times 10^5 m^2$ and is composed in large part of silts and fine sands (Hoos and Vold, 1975). Comparison of bathymetric surveys from 1930 and 1973 showed the western and central parts of the delta (between 1-100m) to be advancing at 6m/annum, whereas the eastern sector advanced at an average of 2.7m/annum (Bell, 1975). Reanalysis of this data, along with a more recent (1984) bathymetric survey, gave a mean addition of 8.01×10^5 tonnes/annum. Given the confined nature of the fjord, and the constrained nature of flow upon the delta due to dyking, the upper 100m of the delta are presently advancing at a rate of 9-10m/annum at the western margin (between 1973-1984).

3 : 5 : 3 Sediment sources within the Squamish system

Unfortunately little is known of either the chronology or the relative importance of the many sediment sources within the Squamish system. In late glacial/ early post-glacial times sediment availability was doubtless very high, vegetative stabilization of river bars minimal, and discharge regimes both high and variable. Under these paraglacial conditions (Church and Ryder, 1972), debris was deposited to great depths on valley floors and at the head of fjords. Mathews (1952a) estimated that between 90-120m of alluvial deposits have accumulated on the post-glacial valley floor of the Squamish.

Isostatic readjustment and resultant changes in land/sea positions led to entrenchment and terracing of late-glacial and older deposits (Clague, 1981). Limited evidence remains of such features in the lower Squamish Basin, however, although Mathews (1952a) documented remnants of fluvioglacial gravels 130m above the contemporary valley floor just north of the Mamquam River. Slope collapse and fluvial reworking in this confined, steep-sided valley, have incorporated most of these units into the extensive valley fill.

The many alluvial fans within the Squamish Valley are testament to former sediment supply conditions and presently represent large sediment storage units available for redistribution by the river. Apart from slope failures associated with ice-contacted lavas on Mount Garibaldi, debris flow events on Mount Cayley, and bedload sediment inputs at the low gradient alluvial fan of the Ashlu River, most fans appear to be relatively stable. Despite their relative inactivity, however, these fans continue to influence both channel configuration and channel position within the valley.

Mount Cayley is an extremely steep, dissected Pleistocene volcano. For about 4km, materials from this volcanic complex form a fan unit on the eastern side of the Squamish Valley, supplying debris to the river via three creeks, Terminal, Turbid and Shovelnose. Clague and Souther (1982) documented a 1963 landslide event upon Mount Cayley consisting of $5 \times 10^6 m^3$ of angular, poorly consolidated blocks up to 3m in diameter. Souther (1980) indicated that this area has a recurrent history of slope failure, althought the three channel positions appear to be relatively well established. A landslide of similar magnitude to the 1963 event occured in the summer of 1984 (Jordan, 1987). In the same year two surging debris flow events supplied large volumes of mud and debris to the Squamish, temporarily damming the river. Terrace remnants between the Elaho confluence and the Terminal Creek Fan, indicate that deposits from the Mount Cayley fan complex have blocked the Squamish on several occasions in the past (Jordan, 1987).

Cheekye Fan, extending from 7-13km above the mouth of the Squamish River, has an estimated volume of $2.5km^3$. A 13m exposure at the toe of the fan reveals two cycles of rapid aggradation by debris flows and subsequent phases of fluvial deposition in braided channels (Eisbacher, 1983). A ^{14}C date from the lower fluvial unit (about 3m above the base of the exposure) gave a minimum date of 5890$\pm$ 100 years B.P. (GSC - 3256). In similar fashion to the Mount Cayley area, Cheekye Fan is prone to debris flows on a recurrent basis. A 1958 mudflow built a 5m high dam across the Cheakamus River; it is thought an even larger event may have occured 30 years earlier (Jones, 1959).

The shallow gradient alluvial fan formed at the confluence of the Ashlu River and the Squamish marks a transition point in river planform character of the Squamish. Downstream of this point the Squamish Valley widens considerably, probably in response to former glacial activity, and the river becomes predominantly single-channeled. This latter point indicates that although the Ashlu system is highly sediment-charged, with large volumes of post-glacial fill remaining perched in terraces and thick lacustrine sequences (Brooks, 1987, pers. comm.), bedload contribution to the Squamish is not particularly significant, as the Ashlu has entrenched itself into a bedrock canyon and flows upon a coarse lag.

The steep-sided valley walls of the Squamish are dotted with former rockfalls, scree deposits and avalanche trails. Logging activity may exacerbate some of these processes, although O'Loughlin (1972) suggested that while sediment yields may increase, the density of landslide activity does not appear to be directly affected by logging. In general, these sediment inputs are localized and appear to be relatively insignificant in terms of the longer term geomorphic evolution of the river system.

3 : 5 : 4 Downstream planform variability of the Squamish River

The regional geology, glacial history and sediment supply events of the early post-glacial period have imposed a set of environmental conditions upon the Squamish Valley to which the river is continually in a state of adjustment. The downstream sequence of planform styles represents local responses to these imposed environmental conditions. Over 150 river kilometres from the mouth of the Squamish, glacier-fed Clendenning Creek falls very steeply to the Elaho River (see longitudinal profile on Figure 3.1). A few kilometres downstream of this junction, the Elaho has a wide sand-bed channel, with well developed meanders and occasional concave bank-benches. The Elaho is the larger river at the confluence with the Squamish (67 river kilometres from the mouth); in its lower few kilometres the Elaho flows through a bedrock canyon. From its source in a sprawling icefield complex, the Upper Squamish River drops 1200m in 22km, also flowing through a bedrock canyon.

The Squamish River is gravel based throughout its course. The 2km river section downstream of the Elaho tributary is a zone of sediment storage, with divided channels flowing around large mid-channel bars. For the next 4km, the Squamish River is confined in a 250m wide canyon between landslide and debris flow deposits upon fans from the Mount Cayley Volcanic Complex on its eastern valley side and granitic bedrock bluffs and derived colluvium on the west.

In the 7.5km below the canyon, the Squamish Valley widens gradually from 600 to 1200m, with a valley flat slope of 0.006. The large volumes of sediment supplied from upstream are spread liberally across the floodplain, with D_{95} values for the gravel fraction in the main channel in excess of 500mm (Brierley, 1984; Brierley and Hickin, 1985). Sediment overloading, its coarseness, and the relatively steep slope have resulted in a braided channel planform, brought about by upstream channel control.

The nature of the braided reach changes down-valley, as sediments are redistributed, their coarseness reduced, valley slope declines and valley width changes. The first 7.5km downstream of the Squamish Canyon, referred to as the upper braided reach, is characterized by large, mid-channel bars, with many secondary channels between braids. Between 1947-1980 the primary changes in this reach were longitudinal bar accretion, and interbraid stabilization (Sichingabula, 1986). Several high magnitude floods between 1980-1984 eroded island banks and increased channel multiplicity as old floodplain channels were reactivated. These changes were largely cosmetic in comparison to the effects of an October 1984 flood, with an instantaneous discharge of $2610 m^3 s^{-1}$, which created new islands by channel avulsion and floodplain dissection (Sichingabula, 1986; Hickin and Sichingabula, 1988), with notable aggradation for several kilometres downstream (Jordan, 1987).

Immediately downstream of the upper braided reach, valley width is reduced to about 700m for 2.5km. In the next 15.5km down-valley, channel planform type changes from braided through wandering to meandering. This valley section forms the study reach. Geomorphic settings for the three planform sections are summarized in Table 3.1.

The lower braided reach of the Squamish extends for 5.5km. The upper 4.5km have a width of 1000m; in the lower 1km the valley narrows to a width of 700m. The floodplain is more extensive than in the upper braided reach. The main channel has a broadly sinuous outline, dividing around a series of complex, compound bars. Expansive bar platform units are prevalent,

Table 3.1 : General character of planform variability in the study reach

Planform	Length studied	Character of bars	Sinuosity (*1)	Braided parameter (*2)	Channel multiplicity (*3)	Slope (*3)	Gravel particle size (b axis, in mm; *4)		Mean Valley width (in m) (*3)
							D50	D95	
Braided	5km	Generally complex, compound units	1.197	3.67	3 - 4	.0058	70-120	150-260	800-1200
Wandering	7km	Complex, mid-channel units, often becoming bank-attached by chute abandonment	1.317	2.50	2 - 3	.0015	50-70	120-150	1100-1900
Meandering	7km	Point and lateral bars on convex banks of bends	1.433	0.67	1 - 2	.0013	35-60	85-130	1700-2200

(*1) Ratio of thalweg length to valley length (Leopold and Wolman, 1957)

(*2) Number of braids per mean meander wavelength (Rust, 1978)

(*3) From 1:5000 scale 1980 air photo mosaics

(*4) From Brierley (1984)

but frequently are dissected by smaller channel features. Over the past forty years bars have exhibited considerable lateral and down-valley shifting

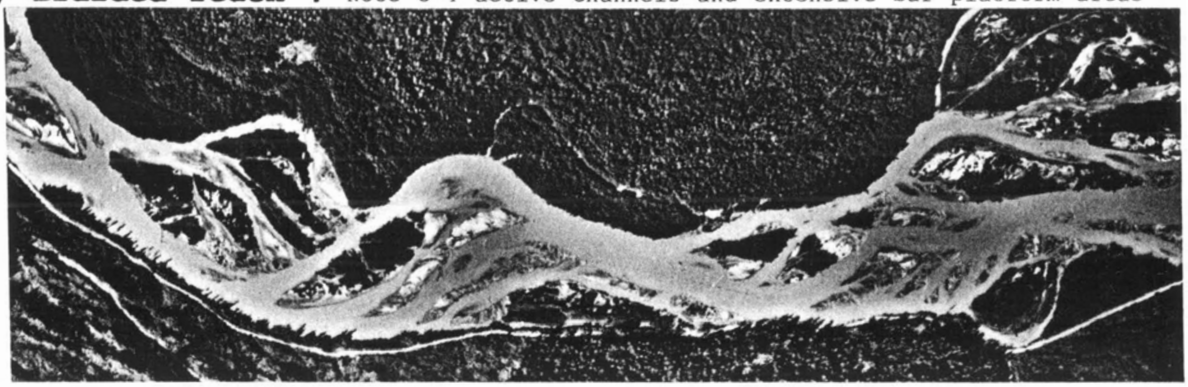
The next 4km of the valley are notably wider (about 1400m) and the number of channels reduced, as the major flow filament alternates between one or two major channels. This wandering gravel-bed channel planform reach is transitional between the braided and meandering sections. Although the river remains laterally unstable, with island formation and destruction, channel changes are less pronounced than in upstream sections, and the floodplain is better-developed and more extensive. Active bar platform areas are less pronounced than up-valley, and the preferred channel shifts laterally (i.e. wanders). Over the past 40 years, the bend opposite the Ashlu River confluence has retreated by 550m, and the lower 1km of the Ashlu River has adjusted its position upon its shallow fan (Sichingabula, 1986).

Downstream of the Ashlu confluence, the orientation of the Squamish Valley changes from NNW to NW. The next 6km of the valley, termed the upper meandering reach, has a mean width of 2000m. This predominantly single channeled reach has a sinuosity of almost 1.5, and contemporary bar platforms are found solely on the convex banks of meander bends. The river flows along the western edge of the valley, and some meanders are confined as they impinge against the bedrock valley wall. Major channel changes over the last 40 years have been phasic lateral and downstream migration of meander bends (up to 200m and 250m respectively; Sichingabula, 1986). A major abandoned channel on the eastern side of the valley, evidenced by its outline and adjacent cedar stumps cut for indian canoes, suggest that the main Squamish flow occurred down the opposite side of the valley in the relatively recent past. This channel extends from opposite the present Ashlu confluence to the Pillchuck confluence (the end of the study reach). Representative air photographs of the three planform reaches in the study area are presented in Figure 3.4.

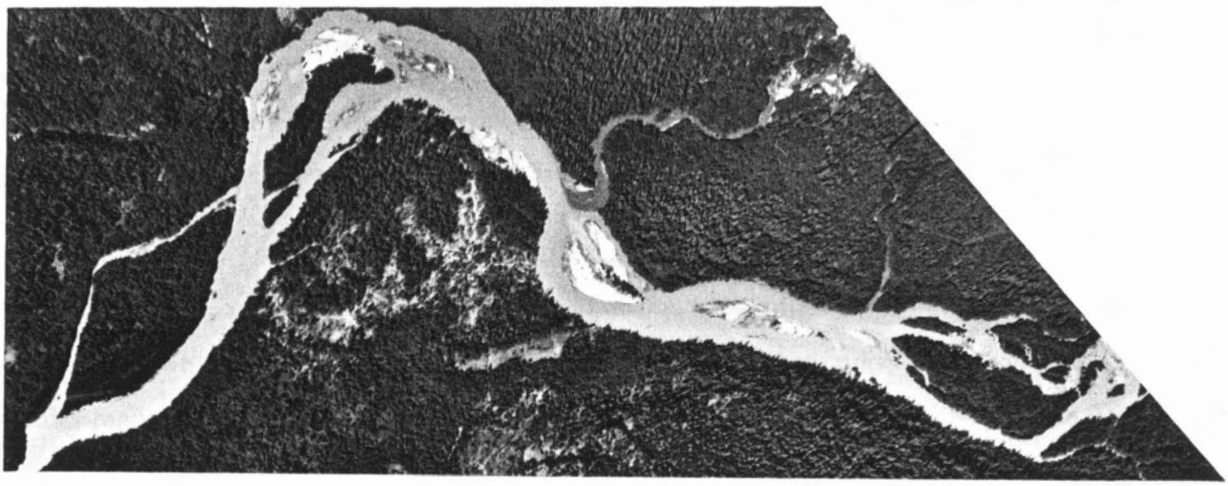
The 4km lower meandering reach, along with a 5km straight stretch of the river, occupy a 1500m wide section of the valley. A meander loop cut-off and concave bank benches on two consecutive bends characterize this reach (Hickin, 1979). Over the past 90 years, meanders have maintained their form while migrating down-valley (Stathers, 1958; Sichingabula, 1986). The higher flood discharges of the early 1980's brought about bend collapse in one instance, resulting for 75m of erosion of the next bend during the October 1984 (Hickin and Sichingabula, 1988). The

FIGURE 3.4 : REPRESENTATIVE AIR PHOTOGRAPHS OF THE THREE RIVER CHANNEL PLANFORM STUDY REACHES (flow from right to left)

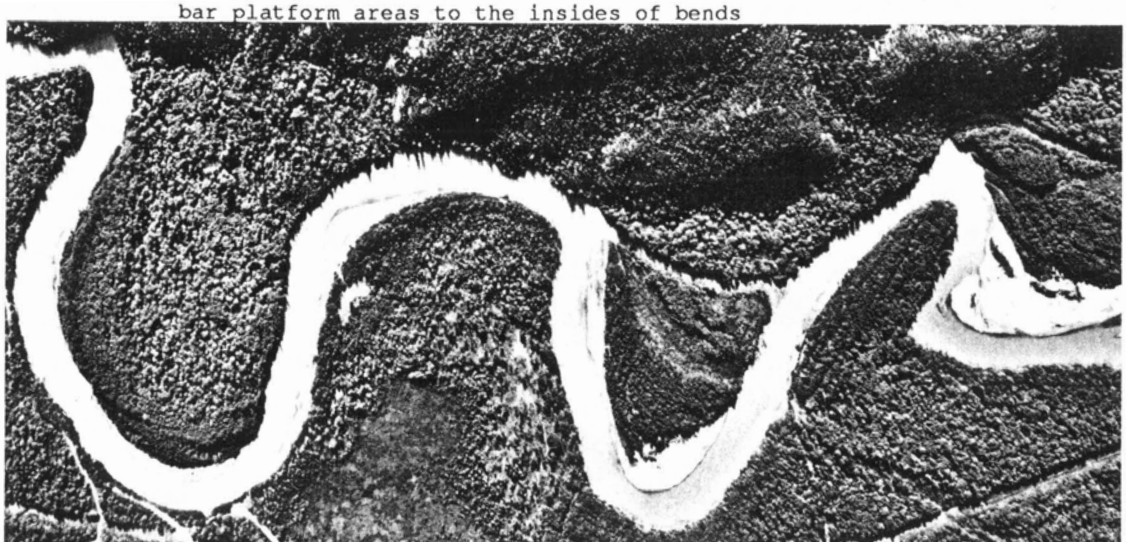
A) Braided reach : Note 3-4 active channels and extensive bar platform areas



B) Wandering gravel bed river reach : Note 1-2 active channels, sinuous outline, and less prevalent bar platform areas than up-valley



C) Meandering reach : Note single channel, sinuous outline, and restriction of bar platform areas to the insides of bends



relatively straight channel section downstream is well entrenched in the flatter slopes. The valley flat slope upstream of the Cheekye Fan deposits is about 0.001, indicating that downstream river control has determined the character of the lower Squamish River, as the channel has been pushed against the eastern valley wall.

For 3km beneath the Cheekye Fan, the Squamish Valley reaches its maximum width of 3000m. Overloading of the river by sediments supplied by the Cheakamus tributary (derived largely from the Mount Garibaldi Volcanic Complex), results in a braided channel planform. The eastern channel bank has been dyked in the lower 9km of the valley (where valley width is 2500m), confining flow to the western edge of the delta.

In summary, the valley fill of the Squamish River is largely an historical artifact, conditioned by former glacial processes, base level changes and sediment supply events. During the Holocene, the river has moved, sorted and redistributed glacially and slope-derived sediments within its high-relief, confined valley. This, along with associated slope adjustments and the fluctuating discharge regime, has resulted in a distinct down-valley gradation in channel planform style. Contemporary processes merely rework a thin veneer of surficial floodplain and slope-marginal deposits.

In the study reach, the valley flat gradient decreases gradually from 0.006 to 0.001 down-valley, while D_{95} values for the gravel population upon contemporary bars decrease in a regular manner from in excess of 500mm to about 100mm (Brierley, 1984). Sediments from the Mount Cayley Volcanic Pile have overloaded the Squamish River, exerting upstream channel control, whereas downstream control has been affected by adjustments to channel base level brought about by sediments from Mount Garibaldi. Within the down-valley gradation from braided to wandering to meandering channel planform style, the braided index gradually decreases, whereas channel sinuosity gradually increases. Given this environmental setting, the Squamish River differs from others in which facies models have been derived.

CHAPTER IV

METHODS

4 : 1 : 1 Methodology in fluvial sedimentology

Fluvial sedimentology is a field science. Questions about regional sediment history and environments of deposition arise largely from observations made in the field. Problems are posed for sedimentologists by the incomplete sedimentary record and the non-representative nature of available exposures or cores. The best has to be made of what is available and an appropriate sampling design applied rigorously to attain a balance between any unique/distinctive features and summary knowledge of regional sedimentology. The almost infinite range and spatial association of sedimentary types and depositional environments pose a second problem in field sampling. Finally, the relative skill and experience of practitioners vary and, given the tendencies to either focus on what one knows or seek out the new, it is often difficult to give an unbiased perspective on the relative abundance or importance of particular features in any sedimentologic unit. The many practical and conceptual problems faces in sedimentologic field work and the limited methodologic consistency, suggest that fluvial sedimentology remains a science in its infancy.

4 : 1 : 2 Outline of procedures adopted in the study

For this study, data were required which enabled the sedimentology of three contiguous planform reaches of the Squamish River to be compared over a range of different spatial scales. A specific sediment classification scheme was developed (section 4:2:1), and a three-scale approach taken in field analysis (section 4:2:2), namely :

1. Digging series of holes (about 1.5m square) on, and adjacent to, contemporary bar platforms, to examine facies-scale variability,

2. Trenching (up to 25m long) at bar/floodplain margins, to evaluate lateral facies variability and define the element scale, and

3. Analysis of bank exposures (up to 220m in length) to examine established/developed floodplain sequences at the facies and element scale.

These are referred to as the 1985, 1986 and 1987 sampling procedures respectively.

4 : 2 : 1 Variables to be measured in the field

In field sampling, a compromise must be made between collecting either a small number of high-quality samples or a much larger number of less detailed samples. In this study, emphasis was placed upon the latter approach, as the general nature of planform sedimentology was considered to be a more likely basis of differentiation than any specific micro-scale depositional characteristic.

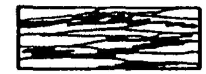
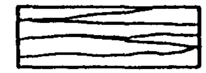
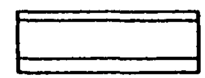
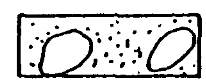
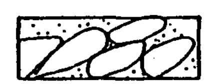
As described earlier, there are almost as many approaches to sediment analysis as there are sedimentologists. Preliminary field studies indicated that existing facies schemes were unsatisfactory for this study, as they overemphasize primary sedimentary structures while neglecting bedding aspects. Hence a specific facies coding scheme, incorporating particle size, bedding type and primary sedimentary structures, was developed and adapted as the study progressed (Table 4.1).

Emphasis in facies coding was placed upon particle size in the first instance, and this forms the group classification (first initial, F, S, G, representing fines, sands and gravels respectively). In instances where deposits were dominated by organic materials, the facies code O was used. Secondly, sedimentary structures were assessed. If no primary sedimentary structures were apparent, emphasis was placed upon bedding character. Facies Fm represents massive or poorly laminated fine sands. Facies Sw represents wavy bedded sands. These are generally fine grained in texture, and the beds typically are non-parallel and discontinuous. Coarser sand units with no visible evidence of structure or notable bedding planes are referred to as facies Ss (massive sands). As this study was limited to analysis of sand and finer deposits, gravel facies were divided simply into matrix- and clast-supported units (facies Gm and G respectively).

Beds characterized by structural units were divided into four types. Ripple units of all types were coded as facies Sr. Structural units in coarser sands fall into three categories. Horizontal lamination reflecting plane bed conditions are referred to as facies Sh. Trough and planar cross-bedded units, resulting from migrating sand dunes and sand waves respectively, were designated facies codes St and Sp.

To analyse sediment texture, the geometric system of Wentworth (1922), referred to as the ϕ classification (Krumbein, 1934), was used, as it condenses size groupings, yet retains meaningful

Table 4.1: Facies coding scheme used in the study

Facies code	Lithofacies and bedding properties	Sedimentary structures	Mechanism interpretation	Visual representation
Fm	Massive or finely laminated fines (≤62.5µ)	None visible	Overbank/drape suspended sediments deposited from slackwater	
O	Organically dominated fines/ sands with thin, loose litter layers	None visible	Overbank/drape suspended sediments deposited from slackwater	
Sw	Wavy bedded fine sands generally <5cm thick but often in units >1m. Beds typically discontinuous and non-parallel	None visible	Low energy flow regime, just beyond the threshold of motion (?)	
Sr	Fine-coarse sand (≤0.6mm)	Ripples, with a wide range of internal structures (conditioned by flow velocity and rate of sediment supply). Generally <5cm in height, 30cm in length.	Lower flow regime	
Ss	Massive medium-coarse sands	None visible	Deposited from suspension on bar platforms	
Sh	Horizontally bedded fine-coarse sands	Horizontal lamination	Upper flow regime plane bed (or lower flow regime for sands ≤0.6mm)	
St	Sand, medium-very coarse; may be pebbly	Cross-bedded troughs with low L/H ratio; set thickness typically 5-60cm	Dune migration of lower flow regime	
Sp	Sand, medium-very coarse; may be pebbly	Planar-tabular cross-beds, tilting at 15-35°, with sharp, flat or slightly scoured bases and tops	Foresets from avalanche faces of advancing sand sheets/waves	
Gm	Massive or crudely-bedded matrix-supported gravels	Occasional horizontal bedding	Deposited from bedload	
G	Clast-supported gravels	Not analysed- often imbricated	Channel lag = framework gravels	

differentiation between sizes. Internal trends in sediment texture within any particular bed, and trends between beds, are important indicators of flow conditions and energy of deposition. Given the vast number of sediment beds observed in the study, recourse was taken to field analysis of texture using a particle size analysis card (Miall, 1984) and a hand lens. Visual estimates of sorting were made in the field using a four value scheme (well, moderately well, moderately and poorly).

To test the accuracy of this method, 28 samples were analysed both in the field and in the laboratory, using a visual accumulation tube. Comparison of particle size parameters, derived using procedures suggested by Folk and Ward (1957), showed that 22 estimates of mean particle size were within one 0.5ϕ class (of these, 20 card estimates were one 0.5ϕ class too coarse). The remaining six samples were accurate to within 1.5ϕ. Estimated and actual sorting values also showed good agreement. Well sorted samples had a sorting value of 0.5ϕ, moderately well 0.75ϕ, moderately 1.0ϕ and poorly sorted samples gave too wide a spread for reliable estimates to be made. These sorting values accord very closely with those suggested by Folk and Ward (1957). Particle sizes for the gravel fraction were recorded by direct field measurement of b axes. These and other sedimentologic variables measured in the field are summarized for each sampling style in Table 4.2.

4 : 2 : 2 Specifics of the sampling procedure

The primary goal in selecting sample sites was to attain as much consistency as possible given the extremely wide range of depositional environments encountered, as only then could data from differing sites be meaningfully compared. Aerial photographs enabled prospective sample locations to be evaluated prior to field study. For logistical reasons, sampling was restricted to the zone adjacent to the main channel. This had numerous advantages. As contemporary deposits and depositional environments were observed consistently in each planform reach, the relationship between known depositional environments and their deposits could be evaluated, site accessibility along the river was unrestricted, there was less vegetation to hinder digging holes/trenches, and bank erosion had exposed floodplain sediment sequences.

In the 1985 data set, holes were dug in sections upon contemporary bar surfaces, perpendicular to the main channel. Given the observed variability in depositional environment,

TABLE 4.2 SEDIMENT VARIABLES MEASURED IN THE FIELD

Variable	Sampling style 1985 Hole data set	1986 Trench data set	1987 Bank exposure data set
Facies type	See Table 4.1	See Table 4.1	See Table 4.1
Bed thickness	Recorded from surface in cm	Recorded from surface in cm	Recorded from surface in cm
Element type	n/a	See Table 4.7	See Table 4.7
Internal character	Sp - tilt and orientation Gm - Bmax	Sw - parallel vs non-parallel - even vs wavy vs curved - continuous vs discontinuous - thickness and tilt Sr - concordant vs discordant - depth, length and amplitude - symmetrical vs asymmetrical - crest shape Sp - tilt and orientation St - concordant vs discordant - width, depth and length Gm/G - Bmax and matrix size	Sr - depth and length Sp - tilt and orientation St - width and depth Gm/G - Bmax
Basal surface	n/a	Sharp vs diffuse/graded Flat vs tilted vs irregular	Sharp vs diffuse/graded Flat vs tilted vs irregular
Particle size	0.5Ø interval using P.S. card	0.5Ø interval using P.S. card	0.5Ø interval using P.S. card
Sorting	Visually estimated	Visually estimated	Visually estimated
Sediment mix	Uniform vs upward fining vs upward coarsening vs internally graded	Cohesive vs loose Uniform vs heterogenous vs rhythmical vs internally graded vs upward fining vs upward coarsening	Cohesive vs loose Uniform vs heterogenous vs rhythmical vs internally graded vs upward fining vs upward coarsening
Organics	n/a	Presence and abundance of rootlets, roots, logs, mats and litter layers	Note presence
Color	n/a	Dark/Light brown - note banding	Dark brown scale 1 to 5 Light brown Pink/Grey or other
Paleocurrent direction	n/a	Recorded whenever possible	n/a

this sampling procedure aimed to assess the types of sediment unit, and the manner of their association, in each specific field location. Specific procedural steps, and an example of a field data coding sheet, are presented in Tables 4.3 and 4.4 respectively.

Site selection for the 1985 data set was conditioned by three major considerations, namely :

1. site availability,

2. distances between sites, and

3. consistency/representativeness of site.

The extensive active channel zone and large number of contemporary bar platforms in the braided reach presented few problems in site selection. Site availability decreased downstream as the proportion of established floodplain increases. Indeed, sites in the meandering reach were restricted to lateral and point bars associated with the pattern of bends. In total 10 bars were sampled, three in both braided and wandering planform reaches and four in the meandering reach. Given these limitations, downstream site separations are remarkably consistent, averaging 1.8, 1.9 and 1.5km within each planform reach respectively, and 2.0km over the entire study reach.

Since site consistency between a large, compound mid-channel braid bar and a well-developed point bar on the convex bank of a river bend is impossible, sites were selected which appeared to be characteristic of the local river reach. Holes were dug in systematic manner within each micro-environmental unit of every bar, ensuring that undue focus was not placed upon anomalous depositional environments. Hence, while knowledge of individual features was obtained, emphasis was placed upon assessing the overall sedimentologic pattern.

Diagrammatic representations of the section holes in the 1985 data set, showed lateral facies trends to be highly discontinuous (Chapter 6). To examine this variability further, several trenches were dug and analysed at the margins of contemporary bars and the established floodplain (1986 data collection). Geomorphologically derived, broader scale sediment units, termed elements, were analysed within each trench (Table 4.5). Specific procedural steps and an example of a field data coding sheet are presented in Tables 4.6 and 4.7 respectively. Given the large amount of digging involved in trenching, convenient locations were selected. An attempt was made to select representative bars; a compound mid-channel bar was sampled in the braided reach, two complex

TABLE 4.3 : STEP-BY-STEP 1985 SAMPLING PROCEDURE

1) From air photo analysis designate appropriate field sites, located on roughly equidistant contemporary bar surfaces.

2) In initial field reconnaisance, pace the bar, *noting* the *range* of subenvironments based on bar position, vegetation pattern and local topography.

3) Establish sampling sections roughly equidistant both laterally and downstream adjusting the sampling *frame* distances *to* obtain data *from* the range of subenvironments. Locate sections perpendicular to the main channel, separated by 30-50m in *downstream* sense. Number of sections is contingent on the magnitude of the bar and the range of local subenvironments.

4) A series of holes was dug to gravel depth roughly 10-20m apart on each of the sections. Holes were *roughly* 1-2m square, with an average depth of 2m. Steps were dug in holes >3m.

5) Prior to analysing each hole two adjacent faces were cleaned off and a tape placed down from the surface.

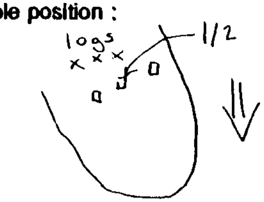
6) Identify individual beds/facies units and mark off their thickness.

7) Complete analysis of sediment sequence (see example, Table 4.4).

8) Survey sample sites for both position and elevation.

TABLE 4.4 : EXAMPLE OF 1985 DATA SHEET

Bar name : Basbar
Hole position :



Hole code : 1/2
Local setting : Dug in ridge adjacent to chute cutting diagonally across bar behind log jam just downstream of major bar head gravel locale.

Internal character of hole :

Thickness	Facies	P.S.	S.	Sed. Mix	Comments
0-14	Sw	2.75	3	-	V. loose sands
14-17	Sw	2.75	3	-	-
17-21	O	3.25	2	-	litter layer
21-30	Sw	3.25	2	-	-
30-41	O	3.25	2	-	litter layer
41-60	Sw	3.25	2	-	lenticular organics
60-66	Sr	2.75	2	-	clean sands
66-80	Sw	2.75	2	-	-
80-135	Sh	1.75	2	-	clean sands, waterlogged at base
>135	G				Framework gravels

TABLE 4.5 : ELEMENT CODING SCHEME USED IN THE STUDY

Element	Position	Character	Bounding surface	Mechanism
Flood cycle	Top of sequence. Laterally and longitudinally very extensive. Thins away from the main channel.	Interbedded units; generally fine-grained.	Typically well-defined; follow underlying relief often infilling/flattening the floodplain surface.	Waxing and waning flood deposits. Some slackwater deposits.
Sand sheet	Generally at, or close to, the top of the sequence. Thins notably away from the main channel.	High energy, loose, light-coloured flood deposits. Generally either amorphous or upward fining.	Contrast sharply with darker, cohesive flood cycle units, yet acts in a similar way by infilling underlying relief.	High energy flood deposits. Not slackwater units.
Distal overbank	Laterally and longitudinally extensive, thinning away from the main channel. These are surficial facies unless the channel re-avulses atop.	Dark, low energy thinly interbedded/laminated fines, often appearing massive.	Often very distinct basal contact (if the channel avulses). Typically flatten out the floodplain surface, with slight tilt away from the main channel.	Low energy slackwater sediments.
Ridge	Characteristically above platform or chute deposits (according to pattern of channel migration).	Typically lower energy units.	Typically sharp, tilted basal contacts, in an extended S-shape towards the adjacent channel. Distinct cross-sectional form.	Localized lateral accretion during flood events (see Figure 7.2).
Chute	Found in a variety of types of differing scales and forms in different locations. Typically found between platform and and flood cycle or sand sheet units in vertical section.	Irregular or sinuous outline, with different types of infill unit.	Erosional, scoured depressions, typically with a well-defined, shallow U-shaped or asymmetrical cross-section.	Infill by flows of varying energy (from dune fields to suspended deposits).
Bar platform	Immediately above basal (channel framework) gravels. May be extensive both laterally and longitudinally.	Contemporary bar deposits immediately adjacent to the main channel. Often coarse, high energy units.	Very irregular as above basal gravels. Base may tilt notably towards the main channel.	Result from bar migration (both downstream and laterally) with many different forms in response to local setting.
Framework gravels	At the base of studied sediment sequences. Spread across valley both laterally and longitudinally.	n/a	n/a	Channel bed deposits.

TABLE 4.6 : STEP-BY-STEP 1986 SAMPLING PROCEDURE

1) Locate trench position *perpendicular* to the main channel at the bar/floodplain margin.

2) *Dig straight trench* to *gravel depth*, length contingent upon local conditions (dependent upon practical considerations, the range of local subenvironments, and lateral continuity of elements). Clean off both faces.

3) Place a tape along one edge of the trench and mark off 1m intervals.

4) Determine a regular sampling interval (between 1-3m) based upon the lateral continuity of sediment units and their character.

5) At designated sampling points put a second tape down vertically from the surface.

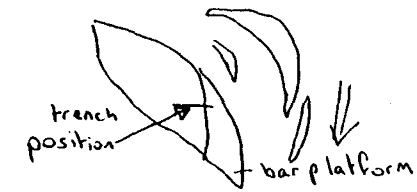
6) Identify individual beds/facies units, describe their character, thickness and lateral continuity by ascribing each unit a coding label and complete analysis for each position (see example in Table 4.7).

7) Using the same coding labels complete similar analyses at the other sampling points in the trench.

8) Survey sample locations within trench, and tie in with 1985 data set using temporary bench marks.

TABLE 4.7 : EXAMPLE OF 1986 DATA SHEET

Bar name : Upash   Section # : 21m (E. margin) at chute bottom
Trench position : in vegetated section,
in downstream unit of diagonal bar.
Local character : cut among series of
diagonal runnels. Bar made up of loose,
uncompacted sand sheet deposits.



Code	Depth	Facies	P.S.	S.	Basal Surface	Internal Character	Sed. Mix	Organics	Color	Flow	Comments
A	0-30	Sr	1.75	3	Sharp Tilts 5°W	Discord.; D = 3; L = 10; A = 20; Asym.; Non-llel	Loose Int. Grad.	Minor rootlets	Lt. Br.	125°	Part of channel fill
B	30-38	Fm	3.25	2	Sharp, Tilts 10°W	n/a	Coh. hetero	mat at top; many roots	Banded Dk.Br.	n/a	Channel fill
C	38-72	Sw	1.25	3	Diffuse *Irreg.*	Non-llel; curved; Disc.; 1-10cm	Loose Int. Grad.	many roots +lenses(4cm thick).	Lt/Dk bands	n/a	n/a
D	72-89	Sw	2.75	2	Sharp Tilts 10°W	Non-llel; wavy; Disc., 1-4cm	Coh. Hetero	Many roots +lenses(10cm thick).	Banded Dk.Br.	n/a	Channel fill
E	89-105	Ss	u0.25 l1.25	4 3	Diffuse Wavy	n/a	Loose U.C.	occ. roots	Lt.Br.	n/a	Channel fill
F	105-120	Sw	2.75	2	Diffuse Tilts 10°W	Non-llel; wavy; Disc.; 1-4cm	Coh. Hetero	many roots, decaying logs	Banded Dk.Br.	n/a	Channel fill
G	120-160	St	1.25	4	Diffuse Tilts 7°W	Conc.; W = >60; D = >20; L = >50	Loose Int. Grad.	occ. roots	Lt. Br.	160°	Sheet-like unit
H	160-175	Sw	2.75	3	Diffuse Tilts 4°W	Non-llel; wavy; cont.; 1-6cm	Coh. hetero	occ. roots some decaying logs	Mottled Banded Dk. Br.	n/a	occ. Fm bands
J	175-202	Sp	0.75	2	Sharp, flat	15° d'st	Loose, I.G.	none	Lt.Br.	170°	Sheet-like
K	>202	G	0.75	2		Bmax 65mm					

All units are continuous to 19m section

mid-channel units were sampled in the wandering reach, and a lateral bar and point bar were sampled in the meandering reach.

Evidence from the 1985 and 1986 data sets showed that elements provide a more fruitful methods for examining the sedimentology of river depositional environments. To examine these features in longitudinal section, assessing their variability by channel planform, the final phase of field research focussed upon floodplain sections in channel banks. Bank exposures were cleaned up, and contemporary bench deposits removed. Length and spacing of sections were conditioned by availability and downstream continuity of each unit. The sampling procedure and an example of a field coding sheet are presented in Tables 4.8 and 4.9 respectively.

Exposures in the braided reach were found either along secondary channels or at the margins of bar platforms. Sites in the wandering and meandering reaches were either exposed by lateral erosion at concave banks of bends or were constructive deposits at bar platform margins. Spacing of 1987 sites gradually increased downstream, averaging 1.0, 1.6 and 1.9km respectively for the three planform reaches, and 1.6km overall. Analysis of these exposures at both facies and elemental scales enabled comparison to be made between planforms at both these scales, and also in terms of facies composition of elements. A summary of sampling site position, character and the number of samples collected for all three procedures is presented in Table 4.10. Sample sites are located upon Figure 4.1.

4 : 3 Summary of data collection techniques

In analysing the sedimentology of three contiguous planform reaches of the Squamish River, the first priority was to apply selected site selection and field procedures as consistently as possible. Data collected do not do not represent a complete floodplain inventory; rather, they focus upon within-channel bars, islands and proximal floodplain deposits. Emphasis was placed upon the sand and fines fraction in this distinctly gravel-bed, high energy river depositional environment. Data on channel character, bar morphology and local setting were assessed from recent (1980) 1:5000 scale air photographs.

In the 1985 data set, 293 holes were examined upon ten contemporary bars, with 76, 98 and 119 holes in the braided, wandering and meandering reaches respectively. Nine trenches were dug

TABLE 4.8 : STEP-BY-STEP 1987 SAMPLING PROCEDURE

1) Locate section in the field. Use an undisturbed bank exposure with a downstream extent >100m.

2) At a regular down-section interval, clean off or dig out the bank, using steps when necessary. Analysis point spacing depends upon field conditions and down-valley continuity of elements, but is generally between 10-30m.

3) Place tape down from the floodplain surface at the sample location.

4) Interpret and divide the vertical sediment sequence into elements (Table 4.5) and describe their thickness and character.

5) Identify individual beds/facies units within each element and complete the analysis at each analysis point (see example, Table 4.9).

6) Reapply analysis for each other sample location in the bank exposure, noting the longitudinal continuity and character of each element.

7) Survey sample sites for both position and elevation.

TABLE 4.9 : EXAMPLE OF 1987 DATA SHEET

Section name : Sumart — Location : In concave bank opposite Bigbar point bar

Local character : Dug in well-established floodplain deposits, with large (logged) trees atop. Surface has many undulations reflecting flood flows. Section is very extensive, with many logs washed atop at the downstream end. A large bench of contemporary sediments has accumulated adjacent to the bank exposure from lower stage discharge flows - this is removed by flod flows, and had to be cleared off prior to analysis.

Position in section :
#1 = Upstream end of section

Elemental composition :

0-218	Flood cycles
218-483	Distal overbank unit
483-558	Bar platform sands
>558	Framework gravels

Depth	Facies	P.S.	S.	Basal surface	Internal character	Sed. Mix	Color	Flow	Comments
0-55	Sr	2.75	3	Sharp, wavy	w=10, d=3	Het	Dk(3)	n/a	
55-56	O	<4	-	Irreg	n/a	Unif	Dk(5)	n/a	charcoal
56-60	Fm	3.75	2	Sharp, wavy	n/a	Unif	Dk(3)	n/a	
60-62	O	<4	-	Irreg	n/a	Unif	Orange	n/a	charcoal
62-75	Sw	3.25	2	Diffuse, 10°D	n/a	Het	Dk(2)	n/a	
75-87	Sr	2.75	3	Sharp, wavy	w=10, d=3	Het	Dk(3)	n/a	lenticular
87-90	O	3.75	2	Irreg	n/a	Unif	Black	n/a	charcoal
90-110	Sr	2.75	3	Sharp, wavy	w=7, d=3	Het	Dk(3)	n/a	
110-138	Sw	3.25	3	Sharp, even	n/a	Het	Lt/dk	175°	
138-166	Sw	3.25	2	Diffuse, arch	n/a	Het	Dk(2)	n/a	
168-196	Sr	2.75	3	Diffuse, even	w=12, d=4	I.G.	Lt	175°	discordant
198-216	Sw	2.75	2	Sharp, wavy	n/a	Het	Dk(2)	n/a	
216-218	O	<4	-	Sharp, 7°D	n/a	Unif	Black	n/a	charcoal
218-323	Fm	<4	-	Diffuse, Irreg	n/a	Unif	Mottled Dk(4)	n/a	Sumart 1-1 @270 1cm charcoal @261
323-483	Fm	<4	-	Sharp, 12°D	n/a	Unif	Mottled Grey	n/a	Sumart 1-2 @330 V. fine laminates
483-503	Ss	2.25	2	Diffuse, Irreg	n/a	U.C.	Orange	n/a	
503-545	Ss	2.75	2	n/a	n/a	Unif	Grey	n/a	
545-558	Ss	1.75	2	n/a	n/a	Het	Orange	n/a	
>558	G	Bmax	40mm						

TABLE 4.10 : SAMPLE SITE CHARARACTERISTICS

Planform	Bar name	Type of sample	Samples taken	River km from Squamish (*1)	Elevation in m (*1)	Number of channels (*1)	Total channel width in m (*1)	Valley width in m (*1)	Gravel particle size (b axis, in mm; *3) D50	D95	Bar type and character/ Section character	Channel changes over the last 40 years (*2)
Braided	BASBAR	1985	27 holes in 6 sections	48	63	4	115	800	118	260	Complex, compound feature, with many units of different ages. Large gravel platform at head.	Dissection of existing floodplain and development of new bars which have attached to old floodplain segments. Being actively eroded at eastern margin.
		1986	11 points in 21m trench								Trench dug at mid-bar; vegetation ≥ 20 years.	
Braided	DBAS	1987	8 points in 110m section	47.2	61	5	175	1050	n/a	n/a	In bank of secondary channel	
Braided	BRABEND	1987	5 points in 88m section	46.6	54	4	155	800	n/a	n/a	In laterally cut exposure of secondary channel.	
Braided	ROADUP	1985	17 holes in 5 sections	46.4	47-48	3	125	1250	98 58	188 147	Complex diagonal bar, dissected into many units with prominent bar platform at head.	Channel widening, with mid-channel bar/ island formation.
Braided	UPSTAT	1987	8 points in 119m section	45.5	48	4	180	1150	n/a	n/a	In bank of secondary channel.	
Braided	STATBAR	1985	32 holes in 8 sections	44.4	42-43	3	165	750	73	166	Complex bank-attached bar with many seasonal channels of varying orientation, large gravel exposures and large log accumulations.	Stabilization and bank attachment of bar.
		1987	9 points in 188m section								Exposure in mid-bar section among diagonally-oriented chutes with prominent sand sheets.	
Braided	DSTAT	1987	7 points in 196m section	43.1	40	3	100	1350	n/a	n/a	In bank of prominent secondary channel.	
Wandering	WIDEWAND	1987	7 points in 123m section	41.0	38	3	115	1250	n/a	n/a	Exposure in very cohesive bank in concave section of bend.	
Wandering	UPASH	1985	30 holes in 9 sections	40.3	35-36	3	120	1100	53	126	Mid-channel complex bar, with shifting channel orientation.	Lateral shifting of main channel, eroding older floodplain. Much erosion/deposition on islands, acting as temporary storage units.
		1986	10 points in 21m trench								Trench dug adjacent to first ridge in established floodplain (vegetation ≥20 years) among ridge and swale features.	
		1987	8 points in 142m section								Trench dug among diagonally oriented chute channels	

TABLE 4.10 CONTINUED

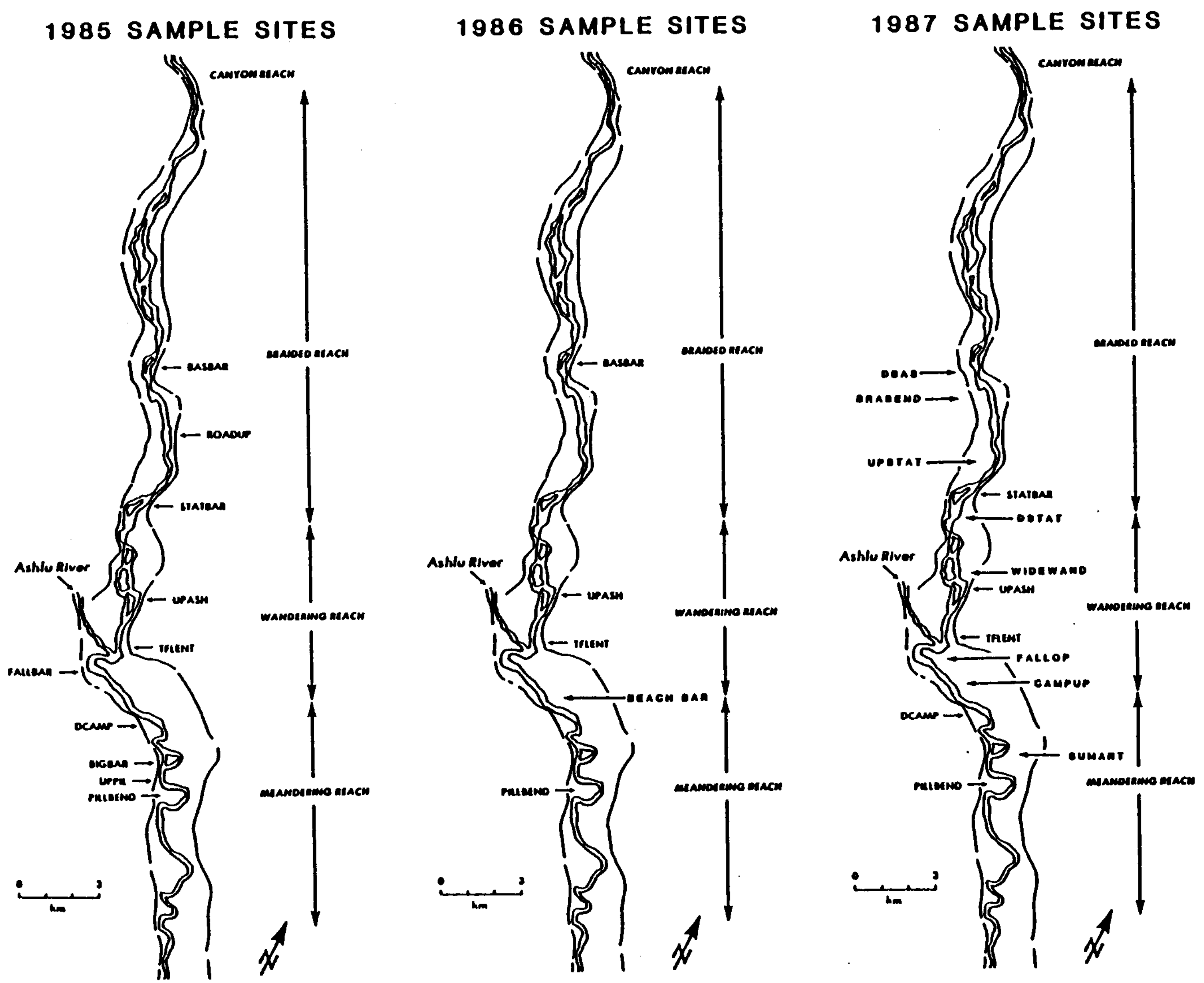
Planform	Bar name	Type of sample	Samples taken	River km from Squamish (*1)	Elevation in m (*1)	Number of channels (*1)	Total channel width in m (*1)	Valley width in m (*1)	Gravel particle size (b axis, in mm; *3) D50	D95	Bar type and character/ Section character	Channel changes over the last 40 years (*2)
Wandering	TFLENT	1985	34 holes in 12 sections	39	34-35	2	115	1650	55	123	Bank-attached compound bar, very prone to channel reoccupation.	Developed from small island since 1947, increasing in size by an order of magnitude. Expanded from 7.4 x 10^3 m^2 in 1960 to > 7.3 x 10^4 m^2 in 1984. Bar became bank attached in early 1970's.
		1986	7 points in 13m trench								Trench dug in bar head unit among runnels	
		1966	9 points in 18m trench								Trench dug at eastern bar margin, among ridges adjacent to the main channel.	
		1986	7 points in 13m trench								Trench dug in established vegetation (≥20 years) among ridges with prominent sand sheets atop.	
		1986	9 points in 23m trench								Trench dug in first prominent ridge at floodplain margin.	
		1987	6 points in 170m section								In bank of secondary channel.	
Wandering	FALLBAR	1965	34 holes in 11 sections	36.5	30-31	3	160	1950	65 59	125 140	Diagonal/compound bar, very prone to channel reoccupation. Large log jam at head.	Downstream migration of bar, with roughly equal erosion at head and deposition at tail (>85 x 10^3 m^2 between 1947-1984).
Wandering	FALLOP	1987	14 points in 200m section	36.3	30	3	160	1750	n/a	n/a	In old channel fill at downstream end of bend.	
Meandering	CAMPUP	1987	12 points in 150m section	34.7	30	1	95	2300	n/a	n/a	In very cohesive bank upstream of lateral bar.	
Meandering	BEACH	1966	9 points in 17m trench	34.2	28-29	1	90	2050	50 56	95 108	Bank attached bar. Trench dug in ridge at floodplain margin.	
		1966	6 points in 11m trench								Trench dug at margin of established floodplain adjacent to large log on first ridge.	

TABLE 4.10 CONTINUED

Planform	Bar name	Type of sample	Samples taken	River km from Squamish (*1)	Elevation in m (*1)	Number of channels (*1)	Total channel width in m (*1)	Valley width in m (*1)	Gravel particle size (b axis, in mm; *3) D50	D95	Bar type and character/ Section character	Channel changes over the last 40 years (*2)
Meandering	DCAMP	1985	29 holes in 8 sections	33.7	27-28	2	125	2200	48 44	98 124	Point bar with large, heavily dissected, gravel platform. Ro = 460m. Many samples taken in major chute.	Predominantly downstream erosion. Between 1947-1984 >450 x 10^3 m^2 were eroded and >340 x 10^3 m^2 added.
		1987	10 points in 158m section								In exposure at head of point bar.	
Meandering	BIGBAR	1985	42 holes in 14 sections	31.4	25-26	2	120	2000	37	88	Very large point bar with distinct changes around bend and major chute. Ro = 315m.	Unconfined lateral and downstream migration, with >400 x 10^3 m^2 eroded and >250 x 10^3 m^2 added between 1947-1984.
Meandering	SUMART	1987	9 holes in 115m section	31.1	25	2	135	1750	n/a	n/a	In very cohesive bank in concave section of large meander.	
Meandering	UPPIL	1985	27 holes in 8 sections	29.9	23-24	1	125	1700	n/a	n/a	Lateral bar at downstream end of bedrock constrained bend. Many scour holes on platform. Prominent ridge/swale pattern. Ro = 410m.	Downstream translation of bend, with equal rates of erosion/deposition (>50 x 10^3 m^2 between 1947-1984).
Meandering	PILLBEND	1985	21 holes in 10 sections	28.9	22-25	1	80	1650	54	114	Point bar, recently constrained by dyking, resulting in poorly developed platform. Ridge/ swale pattern present. Ro = 410m.	Constrained downstream translation of bend, with equal rates of erosion/deposition (>85 x 10^3 m^2 between 1947-1984).
		1988	15 points in 26m trench								Trench dug in two ridge and swale features at floodplain margin.	
		1987	7 points in 212m trench								In exposure at head of point bar.	

(*1) Data from 1980 1:5000 air photo mosaic
(*2) Channel changes assessed from Sichingabula (1986)
(*3) Data from Brierley (1984)

FIGURE 4.1 SAMPLE SITE LOCATIONS



at the bar/floodplain margin for the 1985 data set (1 in the braided reach, 5 in the wandering reach, and 3 in the meandering reach). Thirteen established floodplain sections were analysed for the 1987 data set, with 5, 4 and 4 sections in the three downstream reaches respectively.

PART B

ANALYSIS OF CONTEMPORARY BAR DEPOSITS

CHAPTER V

ANALYSIS OF THE OVERALL AND CHANNEL PLANFORM DATA SETS

5 : 1 Introduction

The make-up of contemporary bar deposits in the three planform reaches (1985 data set) is analysed in Part B of the thesis. Internal organization of facies types and summary statistical analyses of the overall and planform data sets are completed in Chapter 5, Chapter 6 examines between- and within-bar sedimentologic variability, and Chapter 7 describes an alternative scale of sedimentologic analysis (termed locales), based upon morphologic units defined in the field.

The many sedimentologic criteria used to differentiate between river channel planform deposits can be divided into four components : particle size characteristics, facies characteristics, the nature of channel fills, and a variety of distinct morphologic sedimentary units (such as levees, scroll bars, and channel belt geometry; see Table 2.7). The scales of observation adopted in this study restrict analysis to particle size and facies type associations, ranging from one-dimensional at-a-point holes to three-dimensional pictures of channel bar and floodplain sedimentology.

As the thesis focusses upon river channel planform sedimentology, depositional sequences within each planform reach are assessed firstly in summary statistical terms, prior to examining at-a-site variability. In section 5.2, Markov analysis describes internal facies organization within holes at the channel planform scale for the 1985 data set. In subsequent sections, several summary sedimentologic statistics are examined, both for the overall data set (section 5.3) and the channel planform data (section 5.4).

5 : 2 : 1 Markov Analysis of channel planform facies organization : Methods

Relations among facies types inventoried in the field were examined by the application of Markov-chain based statistics. A first-order Markov process is a stochastic process in which the state of the system at time t is influenced by or dependent on the state of the system at time t_{n-1}, but not the previous history that led to the state at time t_{n-1}. Comparison of the observed upward facies transitions in the vertical sequence of sediments with randomly generated transitions can be used to examine the strength of association between facies types. These can be used subsequently to derive a pathway of facies associations - a facies model.

Despite much methodologic controversy in derivation of the randomly generated matrix, Markov analysis remains a consistently applied tool in facies model derivation (note changes in Walker, 1979, 1984; Harper, 1984). The method outlined by Walker (1979) follows that used by Miall (1973) and derives random upward facies transitions in the manner :

$r_{ij} = n_{+j} / n_{++} - n_{+i}$, where

r_{ij} = random upward facies transition,

$n_{+i,+j}$ = row totals for facies i, j respectively, and

n_{++} = Grand total of facies transitions.

Hiscott (1981) questioned the applicability of this method due to the use of single row subscripts in deriving the random matrix of upward facies transitions and suggested that column subscripts be used (in accordance with Gingerich (1969) and Read (1969)) wherein :

$r_{ij} = n_{j+} / n_{++} - n_{i+}$, where

$n_{i+,j+}$ = column totals for facies i, j respectively.

This is referred to herein as the G-R method.

Although an improvement on the previous method, structural zeroes in the observed data matrix (Carr, 1982) along with the use of constrained row, but not column, totals violates the assumption of independence and hence the technique does not truly test for randomness. Powers and Easterling (1982) consequently proposed a 'quasi-independent' model based upon an iterative procedure which equalizes row and column effects :

$r_{ij} = a_i b_j$, where

$$a_i^{(I)} = n_{i+} / \Sigma_{j \neq i} b_j^{(I-1)}, i = 1, 2, \ldots . m$$

$$b_i^{(I)} = n_{+j} / \Sigma_{i \neq j} a_i^{(I)}, j = 1, 2, \ldots . m$$

which is the I'th iteration in which there is less that 1% difference from the (I-1)th iteration (m is the number of facies states). This is referred to herein as the P-E iterative method.

In general, Markov analysis has been used in analysis of cyclothems (e.g. Allen, 1970; Mack and James, 1986), but in this case facies transitions were analysed upwards from framework gravels to the contemporary bar surface, without a return to gravels. Hence, facies G was omitted in Markov analysis of internal facies organization (thereby giving a 9 by 9 facies transition matrix). Upward facies transitions from one facies type to another unit of the same type were not included in the analysis. Six of the holes from the 1985 data set dug on Uppil were not incorporated in the analysis, as they were not dug within the contemporary (last 30 years) bar surface (see Figure 6.9).

5 : 2 : 2 Results of Markov Analysis

Results and Markov statistical analysis for the overall data set (all ten bars) are presented in Table 5.1. As no statistically viable procedure can be used to derive significant facies associations from the G-R observed-random transition matrix, arbitrary cut-offs are applied. In other studies the selected cut-off varies, as each researcher biases the data to best suit their needs. For example, Fraser (1982), Johnson (1984) and Andrews-Speed (1986) selected values of 0.02, 0.04 and 0.05 respectively.

In the data shown in Table 5.1, only 4 transitions have values equal to or greater than +0.10. If a cut-off value of +0.05 is selected, however, there are 10 transitions including all facies types. Hence this value was adopted and the 10 transitions were combined into a facies model (Figure 5.1). Although facies G was not included in the Markov analysis, it clearly must form the starting point for sedimentologic sequences for this data set. Hence facies G has been included in the model, showing upward facies transitions to facies Sp and Ss, which make up 25% and 21% of transitions respectively.

Examination of the observed upward facies transition matrix in Table 5.1A shows the dominance of facies Sw and Sr, whereas facies Gm and Sh were seldom noted. Subtracting the column from the row totals for each facies gives two positive totals, for facies Ss and Sp. These are the facies types found at the base of the sediment sequence. Conversely, the high negative values for facies Sr and Sw indicate that these facies commonly are found close to the contemporary bar

TABLE 5.1 : OBSERVED AND PREDICTED UPWARD FACIES TRANSITION COUNT MATRICES FOR THE OVERALL 1986 DATA SET

TABLE 5.1A : Upward facies transition count matrix

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm	G	Row total
Fm	X	3	72	76	26	4	21	18	0	0	220
O	6	X	93	29	5	4	13	2	0	0	152
Sw	61	81	X	141	30	3	23	23	4	0	366
Sr	76	36	108	X	18	9	18	25	3	0	293
Ss	44	8	45	41	X	5	11	4	0	0	158
Sh	3	5	10	8	3	X	11	3	0	0	43
Sp	11	14	41	58	7	10	X	21	7	0	169
St	7	5	28	47	8	2	12	X	2	0	111
Gm	2	1	8	5	1	1	3	3	X	0	24
G	17	0	20	16	39	10	47	30	8	X	187
Column total	227	153	425	421	137	48	159	129	24	0	1723
Row-column total	-7	-1	-59	-123	21	-5	10	-18	0	187	

TABLE 5.1B : Relative frequency upward facies transition count matrix

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm
Fm	X	0.014	0.327	0.345	0.118	0.018	0.095	0.082	0.000
O	0.039	X	0.612	0.191	0.033	0.026	0.086	0.013	0.000
Sw	0.167	0.221	X	0.385	0.082	0.008	0.063	0.063	0.011
Sr	0.259	0.123	0.369	X	0.061	0.031	0.061	0.085	0.010
Ss	0.278	0.051	0.285	0.259	X	0.032	0.070	0.025	0.000
Sh	0.070	0.116	0.233	0.186	0.070	X	0.256	0.070	0.000
Sp	0.065	0.083	0.243	0.343	0.041	0.059	X	0.124	0.041
St	0.063	0.045	0.252	0.423	0.072	0.018	0.108	X	0.018
Gm	0.083	0.042	0.333	0.208	0.042	0.042	0.125	0.125	X

TABLE 5.1C : Q - R expected frequency matrix for the overall data set

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm
Fm	X	0.102	0.284	0.281	0.092	0.032	0.106	0.086	0.016
O	0.145	X	0.271	0.268	0.087	0.031	0.101	0.082	0.015
Sw	0.175	0.118	X	0.324	0.106	0.037	0.122	0.099	0.018
Sr	0.174	0.118	0.326	X	0.105	0.037	0.122	0.099	0.018
Ss	0.143	0.096	0.268	0.265	X	0.030	0.100	0.081	0.015
Sh	0.136	0.091	0.254	0.251	0.082	X	0.095	0.077	0.014
Sp	0.145	0.098	0.272	0.269	0.088	0.031	X	0.082	0.015
St	0.142	0.096	0.267	0.264	0.086	0.030	0.100	X	0.015
Gm	0.134	0.090	0.250	0.248	0.081	0.028	0.094	0.076	X

TABLE 5.1D : Q - R observed - random upward facies transition matrix

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm
Fm	X	-0.088	0.043	0.064	0.026	-0.014	-0.011	-0.004	-0.016
O	-0.106	X	0.341	-0.077	-0.054	-0.005	-0.015	-0.069	-0.015
Sw	-0.008	0.103	X	0.061	-0.024	-0.029	-0.059	-0.036	-0.007
Sr	0.085	0.005	0.043	X	-0.044	-0.006	-0.061	-0.014	-0.008
Ss	0.135	-0.045	0.017	-0.006	X	0.002	-0.030	-0.056	-0.015
Sh	-0.066	0.025	-0.021	-0.065	-0.012	X	0.161	-0.007	-0.014
Sp	-0.080	-0.015	-0.029	0.074	-0.047	0.028	X	0.042	0.026
St	-0.079	-0.051	-0.015	0.159	-0.014	-0.012	0.008	X	0.003
Gm	-0.051	-0.048	0.083	-0.040	-0.039	0.014	0.031	0.049	X

TABLE 5.1E : P - E Expected upward facies transition matrix

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm
Fm	X	22.55	75.25	69.22	14.42	5.24	16.78	14.16	2.10
O	21.49	X	49.74	45.75	9.53	3.47	11.09	9.36	1.39
Sw	67.13	45.56	X	142.93	29.78	10.83	34.65	29.24	4.33
Sr	51.98	36.05	120.31	X	23.06	8.38	26.83	22.64	3.35
Ss	21.58	14.96	49.94	45.94	X	3.48	11.14	9.40	1.39
Sh	5.65	3.92	13.09	12.04	2.51	X	2.92	2.46	0.36
Sp	23.31	16.17	53.96	49.63	10.34	3.76	X	10.15	1.50
St	15.14	10.50	35.04	32.23	6.72	2.44	7.81	X	0.98
Gm	3.11	2.16	7.20	6.63	1.38	0.50	1.61	1.36	X

TABLE 5.1F : P - E Normalized differences matr (*1)

	Fm	O	Sw	Sr	Ss	Sh	Sp	St	Gm
Fm	X	-4.14	-0.04	0.81	3.05	-0.54	1.03	1.02	-1.45
O	-3.34	X	6.13	-2.48	-1.47	0.28	0.35	-2.41	-1.18
Sw	-0.75	5.05	X	-0.16	-0.04	-2.38	-1.98	-1.15	-0.16
Sr	3.33	-0.01	-1.12	X	-1.05	0.21	-1.70	0.08	-0.19
Ss	4.83	-1.80	-0.13	-0.73	X	0.81	-0.04	-1.76	-1.18
Sh	-1.11	0.55	-0.85	-1.16	0.31	X	4.73	0.34	-0.60
Sp	-2.55	-0.54	-1.76	1.19	-1.04	3.22	X	3.41	4.49
St	-2.09	-1.70	-1.19	2.60	0.49	-0.28	1.49	X	1.03
Gm	-0.63	-0.79	0.30	-0.63	-0.29	0.71	1.10	1.41	X

(*1) CHI-SQUARE TOTAL = 289.6, which is well beyond the 99.9 percentile of the chi-square distribution for 55 degrees of freedom. Positive values >1.96 are statistically significant at the 95% confidence interval for one of freedom (Hobday et al, 1975).

FIGURE 5.1: OVERALL AND PLANFORM FACIES MODELS

FIGURE 5.1A: OVERALL FACIES MODEL

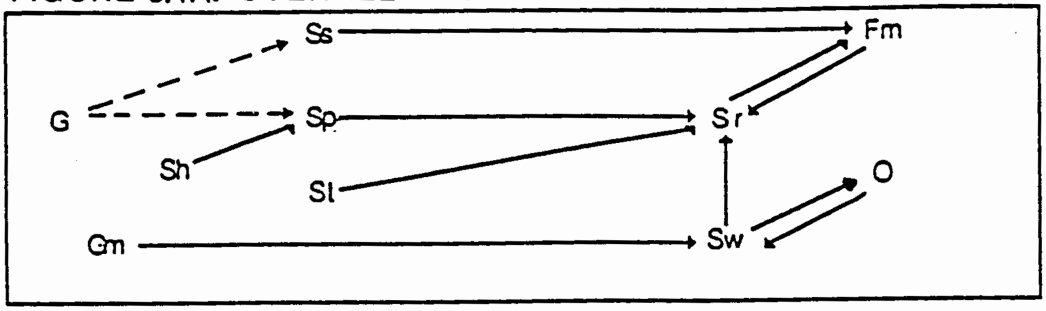


FIGURE 5.1B: BRAIDED FACIES MODEL

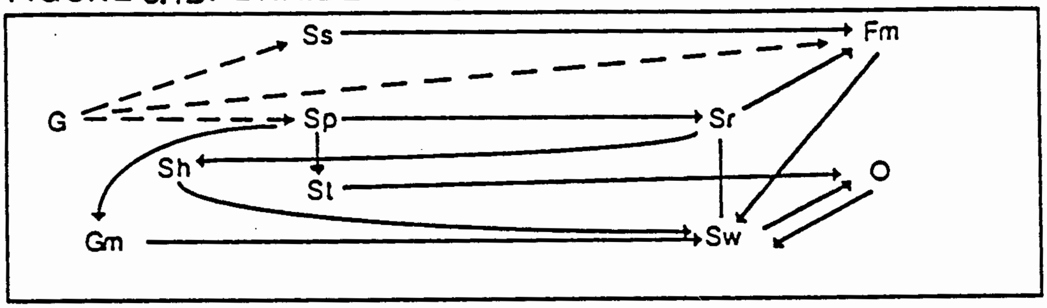


FIGURE 5.1C: WANDERING FACIES MODEL

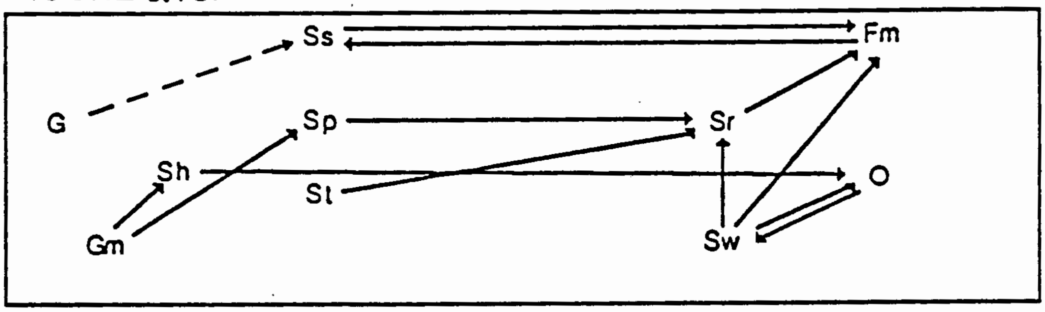
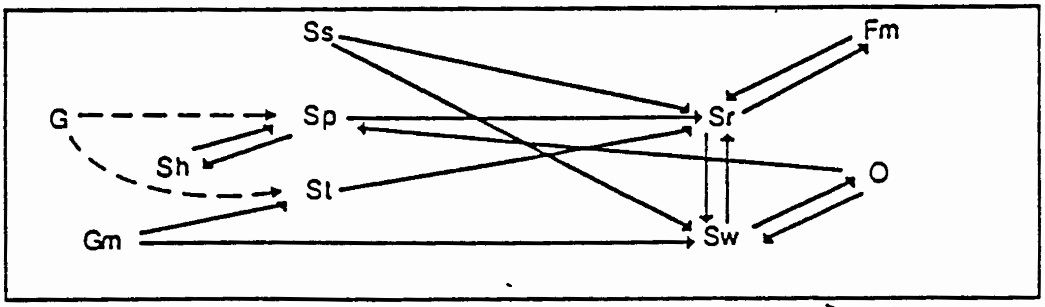


FIGURE 5.1D: MEANDERING FACIES MODEL



⟶ Upward transitions with G – R observed – random values ≥ 0.05

– – –→ Upward transitions from facies G which occur in ≥ 20 % of all instances surface.

These observations are borne out in the facies model for the overall data set (Figure 5.1). Many alternative sediment sequences are predicted upward from the framework gravels (facies G). In general these pathways represent combinations of within-channel facies above the gravels, with overbank facies (Sr, Sw, Fm and O) atop. These sequences can be summarized as :

G - Ss - Fm/Sr

G - Sp - Sr/Fm

Sh - Sp - Sr/Fm

St - Sr/Fm

Gm - Sw - Sr/Fm

Gm - Sw/O

These trends all reflect up sequence reduction in energy of deposition.

Predicted pathways such as these are typical outputs from Markov-derived facies models. Using the P-E iterative method, 10 upward facies transitions are found to be statistically significant (Table 5.1F, Table 5.2). Four of these transitions are different from those predicted in the G-R overall model. Of the significant facies transitions, many are non-continuous and pathways of facies transitions cannot be inferred. For example, the most frequently occuring facies, Sw, is only considered transitional to facies O. Most statistically significant transitions are predicted for facies types that seldom occur (as suggested by Harper, 1984). This can be accounted for by a deficiency in assessing significance. For example, if the expected frequency is less than 0.3, whereas the observed occurrence is 2, a significant χ^2 value (9.63) is attained. However, if the expected frequency is 40, and occurrence is 50, the χ^2 value is 2.00 and not significant. Given these deficiencies it is not possible to create a meaningful facies model for the overall data set using statistically significant relationships from the P-E iterative method.

In order to test the planform variability of facies models, procedures identical to those outlined above (in Table 5.1) were applied to each of the planform data sets. The smallest data set, for the braided planform, had 343 transitions. Predicted upward facies transitions are shown in Table 5.2. These are presented as planform facies models in Figure 5.1.

Row - column totals for each planform data set indicate subtle changes in the internal organization of facies types by planform. In the braided reach there is no readily definable basal

TABLE 5.2 : UPWARD FACIES TRANSITIONS USED IN MODEL DERIVATION

Overall	Braided	Wandering	Meandering
Fm - Sr			Fm - Sr
(Fm - Ss)		Fm - Ss (*)	
	Fm - Sw	Fm - Sw	
O - Sw (*)	O - Sw (*)	O - Sw (*)	O - Sw (*)
			O - Sp (*)
Sw - O (*)	Sw - O	Sw - O (*)	Sw - O (*)
Sw - Sr	Sw - Sr		Sw - Sr
Sr - Fm (*)	Sr - Fm	Sr - Fm (*)	Sr - Fm(*)
			Sr - Sw
		(Sr - St)	
	Sr - Sh (*)		
Ss - Fm (*)	Ss - Fm (*)	Ss - Fm (*)	
			Ss - Sw
			Ss - Sr
		(Ss - Sh)	
		Sh - O	
	Sh - Sw		
Sh - Sp (*)		Sh - Sp (*)	Sh - Sp (*)
Sp - Sr	Sp - Sr	Sp - Sr	Sp - Sr
			Sp - Sh (*)
	Sp - St (*)		
	Sp - Gm (*)		(Sp - Gm)
(Sp - Sh)			
(Sp - St)			
(Sp - Gm)			
	St - O (*)		
St - Sr (*)	St - Sr	St - Sr	St - Sr
			(St - Ss)
		St - Sp (*)	
Gm - Sw	Gm - Sw		Gm - Sw
	Gm - Sr		
		Gm - Sh	
	Gm - St		Gm - St (*)
		Gm - Sp	

Fm - Sr	Transition with observed - random values greater than 0.05 using the G - R method
(Fm - Ss)	Transition with statistically significant observed - random values predicted using the P - E method not predicted using the G - R method
O - Sw(*)	Transition predicted by both the G - R and P - E methods

facies, whereas facies Ss and facies Ss/Sp have positive row - column totals for the wandering and meandering reaches respectively. Conversely negative totals (indicating that facies are found commonly at the bar surface) are found for facies Sr/Sw in the braided reach, facies Sr in the wandering reach, and facies Fm/Sr/Sw in the meandering reach.

This subtle variability of facies positioning within depositional sequences is shown clearly in the facies models (Figure 5.1). The initial upward facies transition from facies G varies from facies Ss and Sp in the braided reach, to facies Ss in the wandering reach, and facies Sp and St in the meandering reach. Beyond this point there are many different internal pathways of facies associations predicted for each planform type. Variation is apparent in the organization of within-channel facies but in gener   as with the overall facies model, combinations of these facies are transitional upwards to different cycles of overbank deposits.

Of the 29 different one-step upward facies transitions predicted in the three planform models using the G-R method, only 11 are found in either two or three of the planform types (Table 5.2). Of these, only five are predicted for all planforms. Two-step facies associations, produced by combining predicted one-step transitions, vary to an even greater degree for each planform type.

Statistically significant P-E transitions indicate that planform sedimentologic variability is pronounced at the selected facies scale as only one transition (O-Sw) is predicted for all three planform types. These transitions present an unclear picture of the internal organization of facies and are biased once more to infrequently observed transitions, although in each case χ^2 totals are well beyond the 99.9 percentile of the χ^2 distribution.

5 : 2 : 3 The relevance of predicted planform facies models

To test the applicability of the G-R planform facies models, each one- and two-step facies transition predicted for each planform type was compared with the absolute frequencies observed for the other two planforms. Results for the one-step transitions (Table 5.3) show that in four instances transitions predicted for one planform type were actually relatively more abundant in another planform type! Indeed, transitions Ss-Sw and Ss-Sr, predicted for the meandering planform, are actually more abundant in both the braided and wandering reaches. This effect is even more pronounced in the two-step analysis (Table 5.4). In this case less than half of the

TABLE 5.3 : ONE STEP FACIES TRANSITION ANALYSIS FOR EACH CHANNEL PLANFORM (*1)

Facies transition	Planform predicted (*3)	Observed transitions in relative terms Braided	Wandering	Meandering	Notable change
Fm - Sr	A, M	4.66	3.12	5.88	
Fm - Sw	B, W	5.25	4.43	3.27	
Fm - Ss	W	3.21	1.82	0.16	yes
O - Sw	A, B, W, M	3.21	7.03	4.58	
O - Sp	M	0.00	0.65	1.31	
Sw - O	A, B, W, M	1.75	6.51	4.08	
Sw - Sr	A, B, M	5.53	8.07	9.80	yes
Sr - Fm	A, B, W, M	2.92	3.52	6.37	
Sr - Sh	B	1.17	0.39	0.33	
Sr - Sw	M	3.79	5.34	8.82	
Ss - Fm	A, B, W	5.53	2.73	0.65	
Ss - Sw	M	4.37	2.73	1.47	yes
Ss - Sr	M	2.92	2.47	1.96	yes
Sh - Sp	A, W, M	0.00	0.91	0.65	
Sh - Sw	B	1.46	0.52	0.16	
Sh - O	W	0.00	0.52	0.16	
Sp - Sr	A, B, W, M	2.62	3.39	3.76	
Sp - St	B	1.75	1.04	1.14	
Sp - Gm	B	0.87	0.26	0.33	
Sp - Sh	M	0.00	0.52	0.98	
St - Sr	A, B, W, M	2.33	1.95	3.92	
St - O	B	0.87	0.13	0.16	
Gm - Sw	A, B, M	0.58	0.26	0.65	
Gm - Sr	B	0.58	0.13	0.33	
Gm - St	B, M	0.29	0.00	0.33	
Gm - Sh	W	0.00	0.13	0.00	
Gm - Sp	W	0.00	0.26	0.16	
Total number of transitions		343	768	612	

(*1) Each transition has been divided by the total number of one-step transitions for each planform, thereby equalizing the probability of each facies transition

(*2) As for (*1), except for two-step transitions

(*3) A = *all data*, B = *braided*, W = *wandering*, M = *meandering*

TABLE 5.4 : TWO STEP FACIES TRANSITION ANALYSIS FOR EACH CHANNEL PLANFORM (*2)

Facies Transition	Planform Predicted (*3)	Observed transitions in relative terms Braided	Wandering	Meandering	Notable change
Fm - Sw - Sr	B	5.22	3.20	2.95	
Fm - Sw - O	B, W	0.00	2.22	1.69	yes
Fm - Sr - Sw	M	0.75	1.72	2.53	
O - Sw - Sr	A, B, M	0.75	3.94	3.38	yes
O - Sp - Sh	M	0.00	0.00	0.00	yes
O - Sp - Sr	M	0.00	0.00	0.00	yes
Sw - Sr - Fm	A, B, M	1.49	1.23	4.64	
Sw - Sr - Sh	B	0.75	0.25	0.00	
Sw - O - Sp	M	0.00	0.49	0.00	yes
Sr - Fm - Sw	B	0.00	1.23	2.11	yes
Sr - Sh - Sw	B	2.24	0.00	0.00	
Sr - Fm - Ss	W	0.75	0.98	0.42	
Sr - Sw - O	M	1.49	3.20	1.27	yes
Ss - Fm - Sr	A	2.99	1.48	0.84	
Ss - Fm - Sw	B, W	4.48	1.23	0.42	
Ss - Sr - Fm	M	0.75	1.23	0.00	yes
Ss - Sr - Sw	M	1.49	0.74	2.11	
Ss - Sw - Sr	M	2.24	1.72	0.42	yes
Ss - Sw - O	M	0.75	1.48	1.27	yes
Sh - Sp - Sr	A, W, M	0.00	0.49	0.42	
Sh - Sw - Sr	B	0.75	0.74	0.00	
Sh - Sw - O	B	0.00	0.00	0.42	yes
Sh - O - Sw	W	0.00	0.00	0.00	yes
Sp - Sr - Fm	A, B, W, M	0.00	0.25	1.69	
Sp - Sr - Sh	B	0.00	0.00	0.42	yes
Sp - St - Sr	B	0.75	0.49	0.42	
Sp - St - O	B	1.49	0.00	0.00	
Sp - Gm - St	B	0.00	0.00	0.00	yes
Sp - Gm - Sw	B	0.75	0.25	0.42	
Sp - Gm - Sr	B	1.49	0.00	0.00	
Sp - Sr - Sw	M	0.00	0.98	1.69	
St - Sr - Fm	A, B, W, M	0.00	0.00	2.95	
St - Sr - Sh	B	0.00	0.25	0.00	yes
St - O - Sw	B	0.00	0.00	0.00	yes
St - Sp - Sr	W	0.75	0.98	0.00	
St - Sr - Sw	M	0.00	0.49	1.27	
Gm - Sw - Sr	A, B	0.00	0.00	0.84	yes
Gm - Sw - O	A, B	0.00	0.00	0.00	yes
Gm - St - Sr	B, M	0.75	0.00	0.00	yes
Gm - St - O	B	0.00	0.00	0.00	yes
Gm - Sr - Sh	B	0.00	0.00	0.00	yes
Gm - Sr - Fm	B	0.00	0.00	0.42	yes
Gm - Sh - Sp	W	0.00	0.00	0.00	yes
Gm - Sh - O	W	0.00	0.00	0.00	yes
Gm - Sp - Sr	W	0.00	0.00	0.00	yes
Gm - Sw - O	M	0.00	0.00	0.00	yes
Gm - Sw - Sr	M	0.00	0.00	0.84	
Total number of transitions		134	406	237	

sequences predicted for one planform type are found in the field, or occur with greater frequency for other planforms.

Given these observations, it is concluded that the sedimentologic order associated with planform variability, as suggested by the G-R method, is entirely misleading. Predicted facies associations are not indicative of transitions likely to be observed in the field; rather, they are statistical artifacts. This results from superimposing one-step transitions into two- and further-step transitions which have little real world meaning. For example, while one-step facies transitions from Sr-Fm and Fm-Sw are predicted for the braided planform, thereby indicating the presence of the two step Sr-Fm-Sw transition, this two-step transition is never actually found in the braided reach.

This, in part, accounts for the large number of facies models predicted for each planform type. Several sequence types are statistically superimposed upon each other, averaging out real pathways and producing meaningless synthesized sequences. Given this observation, channel planform sedimentologic variability suggested by Markov-derived facies models of one-dimensional data sets must be disregarded, and alternative sedimentologic summaries need to be considered.

5 : 3 : 1 Summary statistical analysis of the overall data set

Summary statistical data for the 293 holes studied on the contemporary bar platforms of the Squamish River study reach are presented in Table 5.5. Holes analysed are dominated by facies Sw, Sr and Sp, which account for almost 70% of all sediment in roughly equal proportions. Of the remainder, most abundant is facies St, with facies Fm, O, Ss, Sh and Gm combined taking up just 18%.

Facies abundance directly reflects the combined effects of bed thickness and number of occurrences. In terms of the latter variable, facies Sw and Sr clearly predominate with almost 600 appearances apiece, whereas facies Sp is found roughly half as frequently, yet its average thickness of 29cm is twice that of facies Sw and Sr. In contrast, facies Fm is found almost as frequently as facies Sp, yet is about one-fifth its thickness on average. Facies O, Ss and St are found with the same frequency in the overall data set (about 180), yet their percentage abundance ranges widely, as these beds have average thicknesses of 2.6, 13.8 and 26.8cm respectively.

TABLE 5.5 SUMMARY STATISTICAL ANALYSIS OF THE OVERALL 1985 DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
Fm	273	5	51	6.0	Sr .31; Sw .29	3.6	2.2
O	173	1	34	2.6	Sw .62	3.0	2.3
Sw	598	21	67	12.7	Sr .29; Sw .23	2.9	2.4
Sr	604	23	73	14.0	Sr .33; Sw .26	2.8	2.4
Ss	184	7	43	13.8	Fm .30; Sw .26; Sr .24	2.3	2.4
Sh	68	4	17	21.1	too spread	2.3	2.5
Sp	307	24	48	28.8	Sp .35; Sr .21	1.1	3.0
St	183	14	40	26.8	Sr .31; Sw .22	1.3	3.1
Gm	24	1	7	17.0	Sw .33; Sr .21	-1.0	4.0
G	196	-	67	-	Sp .27; Ss .20	-	-

Number of holes 293 Overall mean particle size 2.16Ø Upward particle size ratio 1 : 0.82

TABLE 5.6 : SUMMARY STATISTICAL ANALYSIS OF THE 1985 CHANNEL PLANFORM DATA

BRAIDED PLANFORM DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%Presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
Fm	62	7	50	6.6	Sw .31; Sr .27	3.5	2.2
O	13	1	13	3.5	Sw .92	3.1	2.5
Sw	96	22	59	13.2	Sr .28	3.0	2.5
Sr	85	19	67	12.9	Sw .26; Sr .24	2.8	2.4
Ss	57	12	50	12.2	Fm .37; Sw .29	2.3	2.4
Sh	10	5	16	30.8	Sw .50; Sr .20; Ss .20	2.5	2.3
Sp	39	19	37	27.2	Sp .28; Sr .23	0.7	3.3
St	37	14	38	21.1	Sw .26; St .26	1.5	3.1
Gm	6	1	7	10.7	Sw .33; Sr .33	-1.0	4.0
G	68	-	87	-	Sp .26; Ss .22; Fm .20	-	-

Number of holes 76 Overall mean particle size 2.21Ø Upward particle size ratio 1 : 0.88

WANDERING GRAVEL-BED RIVER PLANFORM DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%Presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
Fm	98	3	53	4.2	Sw .35; Sr .25	3.6	2.3
O	85	2	51	2.7	Sw .64; Sr .20	2.9	2.4
Sw	280	25	80	12.8	Sw .29; Sr .24	2.9	2.3
Sr	239	23	89	13.7	Sr .34; Sw .22	2.7	2.6
Ss	93	9	60	14.2	Fm .23; Sw .23; Sr .21	2.3	2.4
Sh	32	5	21	21.4	Sh .27; Sp .24	2.3	2.6
Sp	129	25	56	28.0	Sp .30; Sr .22	1.7	2.8
St	51	7	35	20.2	Sr .31; Sw .21	2.3	2.7
Gm	9	1	8	21.9	Sw .22; Sp .22	-1.0	4.0
G	54	-	55	-	Ss .35	-	-

Number of holes 98 Overall mean particle size 2.39Ø Upward particle size ratio 1 : 0.88

MEANDERING PLANFORM DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%Presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
Fm	113	5	49	7.3	Sr .39; Sw .23	3.8	2.2
O	75	1	34	2.3	Sw .54	3.0	2.2
Sw	222	17	61	12.5	Sr .37; O .22	3.0	2.4
Sr	280	25	84	14.8	Sr .34; Sw .29	2.9	2.3
Ss	34	3	25	15.2	Sr .41; Sw .28	2.2	2.1
Sh	26	3	13	17.0	St .29	2.1	2.3
Sp	139	26	48	30.1	Sp .42	0.7	3.0
St	95	19	46	32.6	Sr .32; Sw .23	1.0	3.2
Gm	9	1	7	16.2	Sw .44; Sr .22; St .22	-1.0	4.0
G	77	-	65	-	Sp .33; St .32	-	-

Number of holes 119 Overall mean particle size 1.93Ø Upward particle size ratio 1 : 0.75

Finally, facies Sh and Gm are found considerably less frequently, although their average thickness (about 20cm) indicates that they form a significant part of some sequences. Facies Sr and Sw are found in roughly 70% of all holes, facies Fm and Sp in half the holes, facies St and Ss in roughly 40%, facies O in one-third, facies Sh in 17% and facies Gm in less than 10%. Two-thirds of the holes had a framework gravel base, the remainder were either waterlogged or had an inpenetrable log accumulation at depth.

Upward facies transitions counted for each hole were summarized in matrix form as shown in the Markov analysis section. All 1985 holes were included in analysis and upward facies transitions from one facies type to another unit of the same type were included in the percentage relative frequency values. Only those transitions occuring $\geq 20\%$ of the time are shown in Table 5.5. Facies Sw and/or Sr are the preferred upward facies in all instances except from framework gravels. As transitions upwards from facies G are primarily to facies Sp and Ss, these can be taken as basal facies which in turn are transitional upwards to lower energy facies (Sw, Sr and Fm). Hence, particle size trends are upward-fining, and the upward particle size ratio (the ratio of upward transitions between beds that go from a coarser to a finer unit to transitions that go from a finer to a coarser unit) of 1 : 0.82 indicates that 55% of transitions fine upwards.

On average, facies Sp and St are medium sands, facies Sw, Sr, Ss and Sh are fine sands and facies Fm and O are very fine sands. Facies Sp and St have bimodal 0.5ϕ particle size distributions, with modes at 2.0-2.5ϕ and 2.5-3.0ϕ respectively, and at the fine-gravels size class. Over 50% of facies Sr are in the 2.5-3.0ϕ class and 85% of the facies Sw are in the 2.5-3.5ϕ range, with the modal group in the finer half (i.e. in general, facies Sr units are 0.5ϕ unit coarser than facies Sw units). Modal groups for facies Ss and Sh are in the 2.5-3.0ϕ class. Sorting values are relatively consistent for facies Fm, O, Sw, Sr, Ss and Sh (between 2.0 and 2.5 units; i.e. moderately well sorted) whereas facies Sp and St have values ≥ 3.0 (i.e. moderately sorted).

5 : 3 : 2 Interpretation of the overall data set

Facies organization and the upward fining particle size trends upon contemporary bars of the Squamish River reflect up-sequence reduction in energy of deposition. Bars are made-up of high energy facies (Sp, St, St and Gm) and lower energy facies (Fm, O, Sw and Sr) in equal proportion. Within-channel deposits, dominated by sand wave and dune structures, are transitional upwards to interbedded facies Sw and Sr units. The latter are flood cycle deposits, with facies Fm occasionally preserved as the late, waning-stage deposit. The markedly different presence/absence percentages demonstrated by the various facies indicate the highly variable nature of contemporary bar surfaces. Medium-fine sands are dominant, in stark contrast to the coarse basal gravels. Bulk sieve samples, along with other assessments of total particle size characteristics (Brierley, 1984) confirmed the bimodal nature of size distributions, the size gap occuring in the coarse sand fraction.

5 : 4 : 1 Statistical summary of 1985 channel planform data

Summary statistical data on facies and particle size characteristics at the channel planform scale are presented in Table 5.6. Facies abundance varies remarkably little between the three planform styles, according closely with the overall data set. Holes in all planforms are dominated by facies Sw, Sr, Sp and St, occupying $>75\%$ of combined holes. The lower proportion of facies Ss in the meandering planform is made up by the higher proportions of facies Sp and St.

Similarly, bed thicknesses are roughly equivalent for each planform, although facies Sh units are thinner downstream, whereas facies St and Gm units thicken downstream. Facies Sr is the most prevalent facies in all three planform types, with facies Sw almost as common (occuring in $\geq 60\%$ of all holes). Facies Fm, St, Sh and Gm are found consistently in 50, 40, 15 and 7% of holes respectively. However, the presence/absence of facies O and Ss varies notably by planform. Facies O is found in $>50\%$ of wandering planform holes, but $\leq 15\%$ of braided planform holes. Facies Ss is found in 60% of wandering planform holes, but only 25% of meandering planform holes.

Upward facies transitions occuring in $\geq 20\%$ of instances are remarkably similar for each planform for all facies except facies G. Facies Sw or Sr are the preferred next-state in virtually all instances. Upward transitions from facies G are to facies Fm, Ss and Sp in the braided planform, facies Ss in the wandering planform, and facies Sp and St in the meandering planform.

Average particle size and sorting values are notably consistent for all facies, and only for facies Sp and St are deviations from the overall data set pronounced. Facies Sp is 0.5ϕ finer than the overall data in the wandering planform and 0.5ϕ coarser in the braided and meandering reaches. A similar trend is observed for facies St, which is 1.0ϕ finer in the wandering data set.

Trends observed in the overall data set for 0.5ϕ modal particle size groups by facies show very little variability by planform. The modal group for facies Sr is the 2.5-3.0ϕ size class throughout, whereas the dominant size class for facies Sw is 3.0-3.5ϕ in the braided and meandering planforms, and equally divided between the 3.0-3.5ϕ and 2.5-3.0ϕ classes in the wandering reach. In a similar manner, on average facies O and Ss are 0.5ϕ class coarser in the wandering reach than elsewhere (2.5-3.0ϕ and 2.0-2.5ϕ respectively). Modal size groups for facies Sh and Sp are 2.5-3.0ϕ and 2.0-2.5ϕ for each planform type, but facies St is 0.5ϕ class coarser in the meandering reach (2.0-2.5ϕ). The proportion of gravels within these high energy facies units is quite variable, with notably high percentages for facies Sp in the braided reach and facies Sp and St in the meandering reach. Sorting estimates for each facies vary little between the three planform reaches, although the higher energy facies (Sp and St) do tend to be better sorted in the bars of the wandering reach.

These particle size trends are reflected in the overall average particle size values for each planform, as wandering planform holes are 0.5ϕ finer than meandering planform holes. In all three instances, upward particle size ratios indicate the predominance of upward fining units, but the effect is notably more pronounced in the meandering reach.

5 : 4 : 2 Interpretation of channel planform sedimentologic variability in terms of summary statistics

In Table 5.7, predicted variations in facies and particle size characteristics between river channel planform sediments are compared with observed trends from the three transitional planform reaches studied on the Squamish River. Typically, the proportion of lower energy depositional facies is expected to increase downstream from the braided to the meandering sedimentary environment. However, as shown in Table 5.6, the proportion of lower energy facies actually is higher in the wandering reach, whereas proportions in the braided and meandering reaches are equal. This finding, along with the observed consistency in upward facies transitions irrespective of channel planform type, indicates that there is limited agreement between predicted and observed sedimentologic characteristics in terms of these selected summary statistical variables. The variability in upward facies states from the basal gravels in each planform simply reflects the differing manner of sediment reworking within each reach.

TABLE 5.7 COMPARISON OF PREDICTED AND OBSERVED SEDIMENTOLOGIC VARIABILITY BETWEEN PLANFORM TYPES AS INDICATED BY SUMMARY STATISTICS

Characteristic	Predicted trend	Observed trend
Facies abundance	Higher proportion of lower energy facies (Fm, O, Sw, Sr) in meandering reach as distinction of within-channel and overbank deposits becomes more apparent	Proportion of lower energy facies is highest in the wandering gravel-bed reach (53%), but consistent in the braided and meandering reaches at 48%
Facies associations and upward trends	Random pattern expected in braided, but upward fining pattern expected in meandering	All sequences are indicative of upward fining, are dominated by upward transitions to facies Sw and Sr, and show upward transitions from facies G to higher energy facies
Particle sizes	As energy of flow decreases downstream, fining of particle sizes may be predicted in that direction	Overall, mean particle size is coarser in the meandering reach than elsewhere. In general facies are very consistently sized for all three planforms, although facies Sp is finer in the wandering gravel-bed reach and facies St is coarser in the meandering reach.
Upward trend in particle sizes	Consistent upward fining trends characterize meandering reaches whereas braided reaches are typically much more disorganized	All planforms have predominantly upward fining sequences, but the effect is more pronounced in the meandering reach

Given the similarity in facies abundance and associations regardless of planform type it can be asserted that the same depositional mechanisms must be operative throughout the study reach. This supposition is supported by the observed similarity in facies particle sizes for all three planform reaches and the consistently upward-fining nature of summary particle size statistics.

5 : 5 Summary

Facies models derived for each of the three planform reaches are quite distinctive, but this has been shown to be largely a statistical artifact. Sediment sequences upon contemporary bars typically are made up of high and lower energy facies in roughly equal proportion, and tend to be upward fining in nature. In high energy alpine systems such as the Squamish, the fundamental hydraulics of steep channels produce depositional suites that are relatively insensitive to variations in planform style when analysed using summary statistics of one-dimensional data. These observations are tested in the following chapter which evaluates within-planform sedimentologic variability at the channel bar scale.

CHAPTER VI

WITHIN-PLANFORM SEDIMENTOLOGIC VARIABILITY AT THE CHANNEL BAR SCALE

6 : 1 Introduction

Following the procedures outlined in the previous chapter, analysis of within-planform sedimentologic variability is assessed firstly in general terms, prior to considering more specific, at-a-site variability. Summary sedimentologic statistics of individual bars are analysed both within-planform (sections 6.2 to 6.4) and in a down-stream sense (section 6.5), followed by within-bar sedimentologic analysis. The latter is assessed using both summary statistics and visual representations of individual holes (section 6.6). These within-bar trends are summarized by channel planform and compared with predicted trends in section 6.7.

6 : 2 : 1 Statistical summary of within-braided reach channel bar sedimentology

Statistical summaries of facies and particle size characteristics for the three braided planform bars are presented in Table 6.1. The setting and character of these bars are described in Table 4.10 and Figure 4.1. Facies abundance varies appreciably between the three bars studied in the braided reach. Although facies Sw, Sr and Sp are generally the most abundant facies, their relative proportion differs substantially. Facies Sw and Sr combined occupy about 40% of holes upon all three bars but the proportion of facies Sw is notably reduced on Statbar, whereas facies Sr and Sp are considerably more abundant at this location. Facies St is less prevalent upon Basbar, facies Ss is less prevalent upon Statbar and facies Sh is not observed upon Roadup. Facies O is seldom observed throughout this reach, whereas facies Fm occupies between 5-9% upon all bars.

These variations in percentage sedimentologic make-up reflect facies presence/absence to a much greater degree than changes in average bed thickness. Only facies St (which has half its average thickness on Roadup) and the variable thicknesses of facies Sh and Gm (which are seldom observed in this reach), differ from the overall data set. However, the percentage presence/absence of facies by holes statistic ranges widely for each facies. This is generally reflected by the absence of particular facies upon particular bars. Hence, in comparison to the overall data set, facies O, Sp

TABLE 6.1 SUMMARY STATISTICAL ANALYSIS OF THE 1985 WITHIN-BRAIDED PLANFORM REACH DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
BASBAR							
Fm	30	9	63	7.3	Sw .36; Sr .32	3.5	2.0
O	6	1	19	3.8	Sw 1.00	3.2	2.2
Sw	53	30	85	13.8	Sr .31	3.0	2.3
Sr	31	15	70	11.6	Sw .36; Fm .28	2.7	2.3
Ss	25	14	59	13.6	Fm .36; Sw .32	2.3	2.2
Sh	8	9	33	27.1	Sw .63; Sr .25	2.6	2.4
Sp	12	13	22	26.0	Sp .50; Sw .25	1.3	3.0
St	7	8	19	27.8	Sw .33; St .33	2.5	2.7
Gm	2	1	4	5.5	Sw 1.00	-1.0	4.0
G	20	-	74	-	Ss .40; Sh .20	-	-

Number of holes 27 Overall mean particle size 2.62Ø Upward particle size ratio 1 : 0.89

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
ROADUP							
Fm	14	8	53	6.1	Sr .50; Ss .29	3.5	2.3
O	1	0	6	2.0	Sw 1.00	2.2	3.0
Sw	24	28	71	12.3	Fm .24; Sw .24; St .24	2.8	2.8
Sr	10	12	41	12.8	Ss .50	2.8	2.5
Ss	16	17	47	10.9	Fm .40; Sw .40	2.2	2.4
Sh	0	-	-	-	-	-	-
Sp	5	14	29	28.4	Sr .40; Gm .40; Sw .20	1.6	2.5
St	13	17	53	13.7	St .50; Sw .25	2.3	3.0
Gm	2	4	11	19.5	Sr 1.00	-1.0	4.0
G	16	-	94	-	Ss .27; Sp .27; Fm .20	-	-

Number of holes 17 Overall mean particle size 2.38Ø Upward particle size ratio 1 : 1.05

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
STATBAR							
Fm	18	5	38	5.9	Sr .35	3.8	2.5
O	6	1	13	3.3	Sw .83	3.0	2.9
Sw	19	11	31	12.7	Sr .38	3.1	2.8
Sr	44	27	78	13.8	Sr .45	2.9	2.5
Ss	16	8	44	11.4	Sr .58; Fm .33	2.3	2.6
Sh	2	4	9	45.5	Ss .50; St .50	2.4	2.2
Sp	22	27	53	27.5	Sr .27; Sp .23; St .23	0.2	3.5
St	17	18	41	24.1	Sr .41	0.6	3.3
Gm	2	1	6	7.0	Fm .50; St .50	-1.0	4.0
G	30	-	94	-	Sp .33; Fm .27	-	-

Number of holes 32 Overall mean particle size 1.71Ø Upward particle size ratio 1 : 0.79

and St are less prevalent upon Basbar, facies O, Sr and Sp are less prevalent on Roadup and facies Fm, O, Sw and Sh are less prevalent on Statbar.

Upward transitions in facies types occuring $\geq$20% of the time show much greater variability within- than between planform, although facies Sw, Sr and Fm again predominate as preferred next-states. The only upward facies transitions observed consistently for all three bars are O-Sw and Ss-Fm; other than these, upward transitions seldom are the same for even two of the three bars.

This marked between-bar variability in the braided reach is not reflected by average facies particle sizes, which are very similar to values from the overall data set. Exceptions are the coarseness of facies O on Roadup (the only occurrence), whereas facies Sp and St are relatively fine on Basbar and Roadup (facies St being 1.0ϕ finer than the overall data set on both bars). Modal 0.5ϕ particle size classes exhibit very little difference between the three bars, in all instances being within 0.5ϕ of the values demonstrated for the overall data set. Facies St is consistently 0.5ϕ finer than facies Sp, and facies Sr is consistently 0.5ϕ coarser than facies Sw. Variations in the proportions of gravels in the high energy facies have resulted in a relatively coarse mean particle size for Statbar, whereas both Basbar and Roadup are finer than the overall data set. Sorting values exhibit relatively little variability, although there is a general tendency for facies to become less well sorted downstream upon bars in the braided reach. Finally, upward particle size ratios are quite different for the three bars. While Statbar is notably upward fining in terms of particle size, Basbar is less so, and Roadup is actually upward coarsening!

6 : 2 : 2 Interpretation of sedimentologic variability between bars in the braided reach

Within-braided reach sedimentologic variability is pronounced, and sediment character of the three bars studied are very different. This is particularly evident in terms of facies abundance, facies presence by hole, and upward facies transitions. Indeed, the proportion of higher energy facies varies from 45% on Basbar to 52% on Roadup to 56% on Statbar. This variability is explained either by the different nature of the bars studied (see section 6.6), or by the character of the sub-environment within which the hole was dug; see Chapter 7). Applying summary statistics for the overall braided reach (as in section 5.4) is misleading, as these data represent statistical averages, masking within-reach sedimentologic variability at channel bar and smaller scales.

6 : 3 : 1 Statistical summary of within-wandering reach channel bar sedimentology

Facies abundances upon the three bars studied in the wandering reach are roughly equal, although the proportion of facies Sw increases downstream from 15% on Upash to 34% on Fallbar (Table 6.2). This differential is made up for by the higher proportion of facies Sp on Upash and facies Ss on Tflent. The high proportion of facies Sw on Fallbar is accounted for primarily by the extremely high number of occurrences (averaging almost 5 occurrences/hole). This, along with the high number of occurrences of facies Sr and the considerably thinner nature of all beds on Fallbar, indicate the distinctly interbedded nature of these holes. Average facies bed thicknesses on Upash and Tflent are roughly equal, other than the greater thickness of facies Sh and Gm on Upash (facies seldom actually observed). Whereas facies Sw, Sr and Ss are several centimetres thicker than average values for the overall data set on these bars, facies St is several centimetres thinner.

Facies presence by hole varies considerably variability between the three bars of the wandering reach. Facies Sr and Sw are found in >85% and >70% of holes respectively on all three bars (over 90% on Fallbar in the latter case). Facies Fm and O are considerably more prevalant on Fallbar than elsewhere. Facies Ss is less prevalent on Upash, but is found in almost 70% of holes on the other two bars. Facies St is notably less prevalent on Fallbar; only 32% of holes on this bar were dug to gravel depth, the remainder generally being waterlogged, thereby reducing the observed presence of high energy facies lower in the sequence. Upward facies transitions upon all three bars of the wandering reach are dominated by facies Sw, Sr and Fm, with limited consistency in preferred next-facies state. In no instance are observed upward facies transitions found with the same relative frequency for all three bars.

Average particle sizes for lower energy facies are consistently almost identical to those observed in the overall data set. This is also true for facies Ss, but facies Sh is notably finer on Fallbar (0.5ϕ). Facies Sp is 0.5ϕ finer than overall of Upash and Fallbar (1.0ϕ finer on Tflent) and facies St is almost 1.0ϕ finer on Upash and 1.5ϕ finer on Tflent and Fallbar. Sorting values for each facies are consistent throughout, other than the higher value for facies Sh on Tflent and the lower value for facies St on Fallbar.

Observed particle size trends are mirrored in the 0.5ϕ class modal groups for each facies. Modal groups are consistent with previously noted trends for facies Fm, O, Sw, Sr, Ss and Sh, but

TABLE 6.2 SUMMARY STATISTICAL ANALYSIS OF THE 1985 WITHIN-WANDERING GRAVEL-BED PLANFORM REACH DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
UPASH							
Fm	24	3	47	5.9	Sw .38; Sp .21	3.5	2.2
O	18	1	47	3.4	Sw .61; Sr .22	2.7	2.5
Sw	48	15	73	14.1	Sr .32	2.8	2.3
Sr	59	23	93	17.8	Sr .34	2.7	2.6
Ss	19	7	43	16.3	Fm .39; Sr .28	2.3	2.3
Sh	8	8	23	45.4	O .29; Sp .29	2.0	2.8
Sp	52	32	73	28.3	Sp .45	1.6	2.8
St	20	9	40	21.4	Sr .28; St .28; Sw .22	2.1	2.8
Gm	2	2	7	49.5	Sp 1.00	-1.0	4.0
G	19	-	63	-	Sp .26; Ss .21	-	-

Number of holes 30 Overall mean particle size 2.16Ø Upward particle size ratio 1 : 0.71

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
TFLENT							
Fm	27	3	38	4.6	Sw .33; Sr .30	3.6	2.2
O	22	1	38	2.4	Sw .50; Sr .27	2.9	2.3
Sw	70	25	74	16.0	Sw .27	2.8	2.4
Sr	59	23	85	17.4	Sr .26; Fm .21	2.6	2.7
Ss	35	13	68	16.5	Sr .27; Sw .24	2.3	2.3
Sh	7	3	21	16.6	Sp .40; O .20; Sr .20; St .20	2.1	3.3
Sp	36	22	62	27.3	Sr .30; Sw .23; Sp .20	2.0	3.0
St	18	9	38	21.9	Sw .24; Sr .24; Sp .24	2.5	2.8
Gm	1	0	3	11.0	Sw 1.00	-1.0	4.0
G	24	-	71	-	Ss .54; Sw .25	-	-

Number of holes 34 Overall mean particle size 2.48Ø Upward particle size ratio 1 : 0.83

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
FALLBAR							
Fm	47	3	74	3.1	Sw .34; Sr .28	3.6	2.5
O	45	2	68	2.6	Sw .71	3.0	2.3
Sw	162	34	91	11.1	Sw .33; Sr .24; O .21	2.9	2.2
Sr	121	22	88	9.8	Sr .38; Sw .31	2.8	2.4
Ss	39	8	68	11.1	Fm .29; Sw .26	2.4	2.7
Sh	17	4	21	12.1	Sh .47	2.9	2.3
Sp	41	22	65	28.1	Sw .24; Sr .22	1.6	2.8
St	13	4	26	16.1	Sr .46	2.7	2.3
Gm	6	2	15	14.5	too spread	-1.0	4.0
G	11	-	32	-	Sr .36; Sp .27	-	-

Number of holes 34 Overall mean particle size 2.52Ø Upward particle size ratio 1 : 1.00

facies Sp and St have smaller proportions of fine gravels, with modal groups generally in the 2.5-3.0ϕ class. These lower-than-average particle sizes for high energy facies resulted in overall mean particle sizes 0.5ϕ unit finer than the overall data set for Tflent and Fallbar, whereas the mean particle size on Upash is directly equivalent with the overall data set. The upward particle size ratio indicates that trends are notably upward fining on Upash. This effect is less pronounced upon Tflent, and the upward particle size ratio on Fallbar is 1 : 1.0, indicating upward consistency of particle sizes (or an equalization of fining and coarsening trends).

6 : 3 : 2 Interpretation of sedimentologic variability between bars in the wandering reach

Sedimentologic variability between bars in the wandering reach is similar to that observed for the braided planform, in that facies abundance and upward transitions are notably inconsistent between bars, while particle size trends are almost uniform by facies but variable in terms of overall mean particle sizes and upward particle size ratios. The three bars exhibit marked variability in relative depositional energies, the proportion of high energy facies ranging from 39% on Fallbar to 48% on Tflent to 58% on Upash. Once more, summary statistical characteristics for this planform reach mask pronounced within-reach sedimentologic variability. Hence, only at the scale of the channel bar or smaller can meaningful sedimentologic interpretations be made.

6 : 4 : 1 Statistical summary of within-meandering reach channel bar sedimentology

Facies abundance percentages upon bars studied in the meandering reach show even greater within-reach variability than observed elsewhere (Table 6.3). Only facies O and Gm are found in equal proportion on all bars, neither facies occupying $\geq$3% of any particular bar. Whereas Uppil is dominated by facies Sp (making up 54% of all deposits), facies St is dominant on Dcamp and Pillbend, and facies Sw is the most abundant facies on Bigbar. The percentage of high energy facies is extremely variable, ranging from 40% on Pillbend and Bigbar to 70% on Uppil.

These differences in facies abundance by bar are accounted for by variability in both facies presence by hole and average bed thickness. Facies presences are significantly lower than the overall data set for facies O, Ss and Sh on Dcamp, facies Sw, Ss and St on Bigbar, facies Sw, Sr, Ss and Gm on Uppil and facies Fm, O, Sr, Ss, Sh and Sp on Pillbend. Conversely, notably higher

TABLE 6.3 SUMMARY STATISTICAL ANALYSIS OF THE 1985 WITHIN-MEANDERING PLANFORM REACH DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
DCAMP							
Fm	30	4	62	4.3	Sr .46	3.7	2.2
O	11	1	24	2.6	Sw .73	3.3	2.0
Sw	56	17	66	10.6	Sr .36; Sw .25	3.1	2.3
Sr	66	23	76	12.0	Sw .35; Fm .28; Sr .25	2.9	2.2
Ss	7	1	24	6.4	Sr .50; Sw .33	2.6	2.0
Sh	3	2	10	18.0	Sr .33; Sh .33; Sp .33	0.6	3.0
Sp	30	23	52	26.9	Sp .39; Sw .21	0.1	3.4
St	28	27	59	33.5	Sr .48	0.5	3.3
Gm	4	2	14	13.0	Sw .50; Sp .25; St .25	-1.0	4.0
G	28	-	97	-	Sp .36; St .36	-	-
Number of holes 29		Overall mean particle size 1.57Ø			Upward particle size ratio 1 : 0.64		
BIGBAR							
Fm	31	8	50	14.6	Sr .46; Sw .36	3.5	2.3
O	29	1	40	2.3	Sw .45; Sr .28	2.9	2.1
Sw	86	13	56	8.4	Sr .43	3.0	2.3
Sr	137	38	83	15.2	Sr .44; Sw .23	2.9	2.3
Ss	16	5	31	15.3	Sw .40; Sr .33; Fm .20	2.5	2.2
Sh	1	0	2	11.0	Sp 1.00	2.2	2.0
Sp	42	21	40	27.7	Sp .51; Sr .31	0.9	3.0
St	21	13	31	32.9	Sr .44; St .28	1.3	2.7
Gm	3	1	5	8.7	Sw .33; Sr .33; St .33	-1.0	4.0
G	17	-	40	-	Sw .29; Sp .29	-	-
Number of holes 42		Overall mean particle size 2.31Ø			Upward particle size ratio 1 : 0.85		
UPPIL							
Fm	35	5	56	4.6	Sr .34; Fm .25	3.4	2.5
O	13	1	44	1.7	Sw .39; Fm .31	2.7	2.5
Sw	26	10	59	12.4	O .29; Sr .29	2.6	2.6
Sr	42	14	63	11.5	Fm .30; Sw .30; Sr .30	2.4	2.6
Ss	7	5	30	23.9	Sr .57	2.0	1.7
Sh	14	5	41	11.5	Sh .30; Fm .20; Sw .20; Sp .20	2.0	2.4
Sp	59	54	93	30.8	Sp .42	1.0	2.7
St	11	6	41	24.2	Fm .20; Sw .20; Sp .20	2.2	3.1
Gm	-	-	-	-	-	-	-
G	14	-	52	-	Sp .86	-	-
Number of holes 27		Overall mean particle size 1.64Ø			Upward particle size ratio 1 : 0.81		
PILLBEND							
Fm	8	2	19	4.8	Sw .63; Sr .38	4.1	0.7
O	11	2	24	3.1	Sw .64	3.2	2.1
Sw	33	31	71	22.0	O .32; Sr .32	3.0	2.5
Sr	24	26	57	25.0	Sw .31; Fm .25	2.9	2.6
Ss	2	2	10	17.0	Sw .50; Sr .50	1.2	4.0
Sh	1	1	5	26.0	Sw 1.00	2.7	3.0
Sp	-	-	-	-	-	-	-
St	15	34	67	52.5	Sw .54; Sr .39	0.4	3.8
Gm	2	3	10	34.0	Sw .50; Sr .50	-1.0	4.0
G	18	-	86	-	St .56	-	-
Number of holes 21		Overall mean particle size 1.97Ø			Upward particle size ratio 1 : 0.68		

than average facies presences are observed for facies Fm, St and Gm on Dcamp, facies Sr on Bigbar, facies O, Sh and Sp on Uppil and facies St on Pillbend. Average facies thicknesses are almost twice those of the overall data set for facies Fm on Bigbar and facies Sw, Sr, St and Gm on Pillbend. In contrast, facies Ss on Dcamp and facies Sh on Bigbar are half the thicknesses noted for the overall data set. Remaining facies are relatively consistent in terms of bed thickness.

Upward facies transitions are dominated by facies Sw, Sr and Fm, and are generally less variable than in the braided and wandering reaches. Once more facies G is transitional to high energy facies which are in turn transitional to lower energy facies, indicating up-sequence reduction in energy of deposition. Average particle sizes and sorting values are less consistent between bars studied in the meandering reach than elsewhere, but are always upward fining in trend. Mean particle sizes range over at least 0.5ϕ for all facies, with facies Sh and St ranging over almost 1.5ϕ between bars. This can be attributed to the variable proportions of fine gravels in the high energy facies or the relatively small sample sizes of several of the facies. Examination of 0.5ϕ modal size classes for each facies reveals that this implied particle size variation is misleading, as dominant size classes are consistent for all four bars, other than facies Sw and Sr on Uppil, which are 0.5ϕ coarser than in other instances (at 2.5-3.0ϕ and 2.0-2.5ϕ respectively).

Finally, mean particle sizes for each bar are coarser than exhibited for the overall data set on Dcamp, Uppil and Pillbend, the former two bars being the coarsest examined in this study. In contrast, the high proportion of lower energy facies on Bigbar resulted in its relatively fine nature. Upward particle size ratios show that all four bars are upward fining, the effect being especially pronounced on Dcamp and Pillbend.

6 : 4 : 2 Interpretation of sedimentologic variability between bars in the meandering reach

Analysis of summary statistics indicates that the four bars studied in the meandering reach have quite different sedimentologic character, confirming the previous observation that a misleading interpretation of average conditions is attained by examination of the planform data set. Although bar types are fairly similar in this reach, the proportion of high energy facies observed upon each bar varies considerably. Depositional conditions vary with respect to bend radius of curvature and within-bar sediment trends. These characteristics are analysed in section 6.6 and Chapter 7. In general, however, sediment sequences in the meandering reach are clearly upward fining, representing upward reduction in relative energy of deposition.

6 : 5 : 1 Summary statistical analysis of downstream sedimentologic character at the channel bar scale

In all three planform reaches, within-planform sedimentologic variability is far greater than between-planform variability. In this section, downstream sedimentologic variability is examined irrespective of channel planform. The downstream pattern of bar types in the study reach accords closely with trends on other rivers, exhibiting transitions from longitudinal compound and diagonal bars to lateral/bank attached and point bars (Church and Jones, 1982). However, in the ten bars studied there are no clear downstream patterns to facies abundance or facies presence by hole. Average bed thicknesses by facies vary markedly but in no consistent manner. Overall particle size trends for each bar demonstrate no clear downstream trend.

Rather than exhibiting clearly defined downstream trends in the selected sedimentologic characteristics, some variables are consistent on all bars studied, whereas other variables are highly irregular. There is no consistent trend in upward facies transitions and average facies particle sizes are remarkably consistent. Sediment sequences generally are upward fining in terms of facies type and particle size, indicating lower depositional energy as one moves up-sequence. In only two instances (Roadup and Fallbar) are upward particle size ratios not indicative of upward fining trends.

In summary, the visually distinct channel bars in the three planform reaches exhibit no consistent downstream trends for any of the selected sedimentologic parameters throughout the 20km study reach. Local scale variability at the channel bar scale appears to be a much more important control upon observed sediment sequences, implying that this scale more closely reflects formative depositional conditions. This effect is observed in the following sections on within-bar sedimentologic variability.

6 : 6 : 1 Within-bar sedimentologic variability in the braided reach : Outline of methods

Sediment sequences observed in each hole are schematically reproduced for each bar in Figures 6.1 to 6.10. Facies type is symbolically represented and particle size is represented by the width of each bedding unit (see code on each figure). Thicknesses of units and lateral spacing of holes within each section are incorporated into the diagrams. The position of each hole is indicated on the map outline shown for each bar.

Several parameters were selected to evaluate within-bar sedimentologic variability. Facies and particle size trends were analysed down-bar, both laterally and vertically. Finally, bed thickness, hole depth and changes in surface and basal gravel elevations were evaluated for each bar. In describing these trends, reference is made to section numbers as noted on the maps for each figure, the coded number for each hole being the section number in the first instance, and hole number second (expressed in sequence from left to right for each section). Trends have been summarized in tabular form for each bar and are described below. Examination of these trends is made with reference to their field character and setting (Table 4.10; Figure 4.1) in an attempt to explain observed patterns.

6 : 6 : 2 Within-bar sedimentologic variability upon Basbar

Basbar, the most upstream bar in the study reach, is a complex, compound mid-channel bar composed of a variety of units which have become attached at different stages over the last 40 years. This is reflected by visual analysis of sediment patterns (Figure 6.1, Table 6.4). There are no consistent trends for either facies type or particle size down-bar, laterally or up-sequence. Instead there is a random arrangement of sediment units, with irregular mixtures of high and lower energy facies. The internal organization of facies within each hole show no clear trends. High energy facies frequently are found close to or at the bar surface, whereas in several instances facies Sw and Sr are basal facies. Up-sequence particle size trands often are markedly variable in adjacent holes. Similarly, bar surface and basal gravel elevation, along with hole depth, show no consistent within-bar pattern. Indeed, there are no clear within-bar trends for any of the parameters studied.

FIGURE 6.1 BASBAR

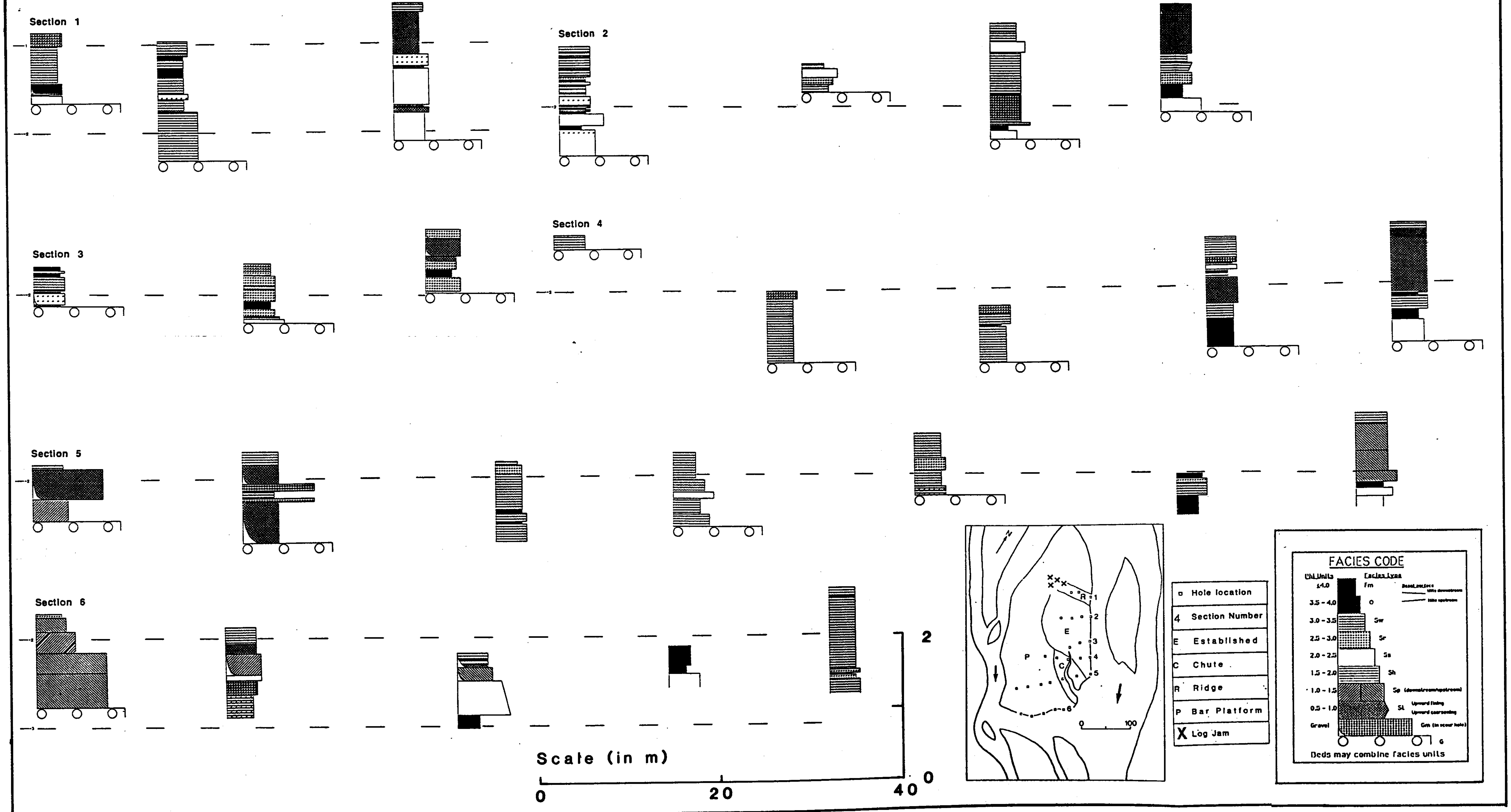


TABLE 6.4 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON BASBAR

Facies characteristics	
Downstream trend	No consistent pattern. All holes are made up of a mix of high and lower energy facies.
Across-bar trend	Very laterally discontinuous. High energy facies dominate adjacent to the main channel on sections 1 to 5, and away from the channel on section 6. Holes 4-1 to 4-3 and 5-3 to 5-5 are dominated by facies Sw and Sr. Thick facies Fm units are found on 4-1, 5-6 and 6-4.
Vertical sequence trend	Very irregular, with no evident down-bar or lateral patterns. High energy facies frequently are found high up in the sediment sequence, whereas facies Sw and Sr are often found immediately above the gravel base.
Particle size characteristics	
Downstream trend	No trends are evident.
Across-bar trend	Highly irregular from one hole to the next.
Vertical sequence trend	Most holes show relatively little up-sequence variation, but local scale variability in trends is pronounced (e.g. Hole 6-1 is clearly upward fining, but adjacent holes show no consistent upward patterns).
Other characteristics	
Bed thickness trends	Beds tend to be thicker at bar margins, where the proportion of high energy facies is greater.
Bar surface elevation	Drops 1m from section 1 to 6. Lateral patterns in elevation vary from section to section, but there is a tendency for mid-section elevations to be lower.
Basal surface elevation	Drops 1m from section 1 to 6. Generally varies by 0.5-1m across section, but inconsistent due to chute channels.
Hole depth	Very irregular across- and down-bar, averaging about 1m.

It is only when each hole is examined in relation to its local field setting that observed sediment sequences can be explained. There is a close association between these sequences and the irregular pattern of field morphologic units (shown in the map on Figure 6.1). These units are referred to as locales (see Chapter 7).

The high proportion of lower energy facies on Basbar is surprising given the high degree of braiding, coarse gravel size upon the bar platform (D_{95} of 260mm; Brierley, 1984), and confined valley width at this location. However, channels are deep and well established, reducing the number of erosive flows upon the well-developed vegetated floodplain. The proportion of high energy facies is greater at the bar margins reflecting high energy depositional conditions adjacent to the main channel. In contrast, adjacent established floodplain vegetation reduces the erosive effectiveness of floods and aids in both deposition and preservation of lower energy facies at their waning stage. Finally, sediment sequences on Basbar are influenced by a large log jam at the bar head which dissipates flow energy, resulting in lower energy facies at the bar surface and low-energy runoff chute channels at the bar tail.

6 : 6 : 3 Within-bar sedimentologic variability upon Roadup

Although bar character and local field setting for Roadup differ from those for Basbar, the sedimentologic sequences are similarly inconsistent down-bar, laterally or vertically (Figure 6.2, Table 6.5). Holes are made up of irregular mixtures of high and lower energy facies, reflecting sediment reworking and discontinuous preservation. In many instances, high energy facies are found at the bar surface. Upward particle size trends and mean particle sizes are often highly variable for adjacent holes. Local scale differences seemingly occur at the locale scale (see map on Figure 6.2), with a wide range of local depositional environments observed in juxtaposition producing an irregular bar surface relief and variable hole depths.

Roadup is a diagonal bar feature with a less complex history than Basbar. Valley width is much greater at this point, and the channel occupies a much smaller proportion of the valley. An expansive sand/gravel dune field at the bar head reflects high energy flows, which have resulted in coarser average particle sizes at this location and irregular vertical facies sequences. Reworking of these expansive sand sheets by small scale diagonal chutes has produced an irregular pattern of ridges and chutes with erosional remnants of established, vegetated floodplain.

FIGURE 6.2 ROADUP

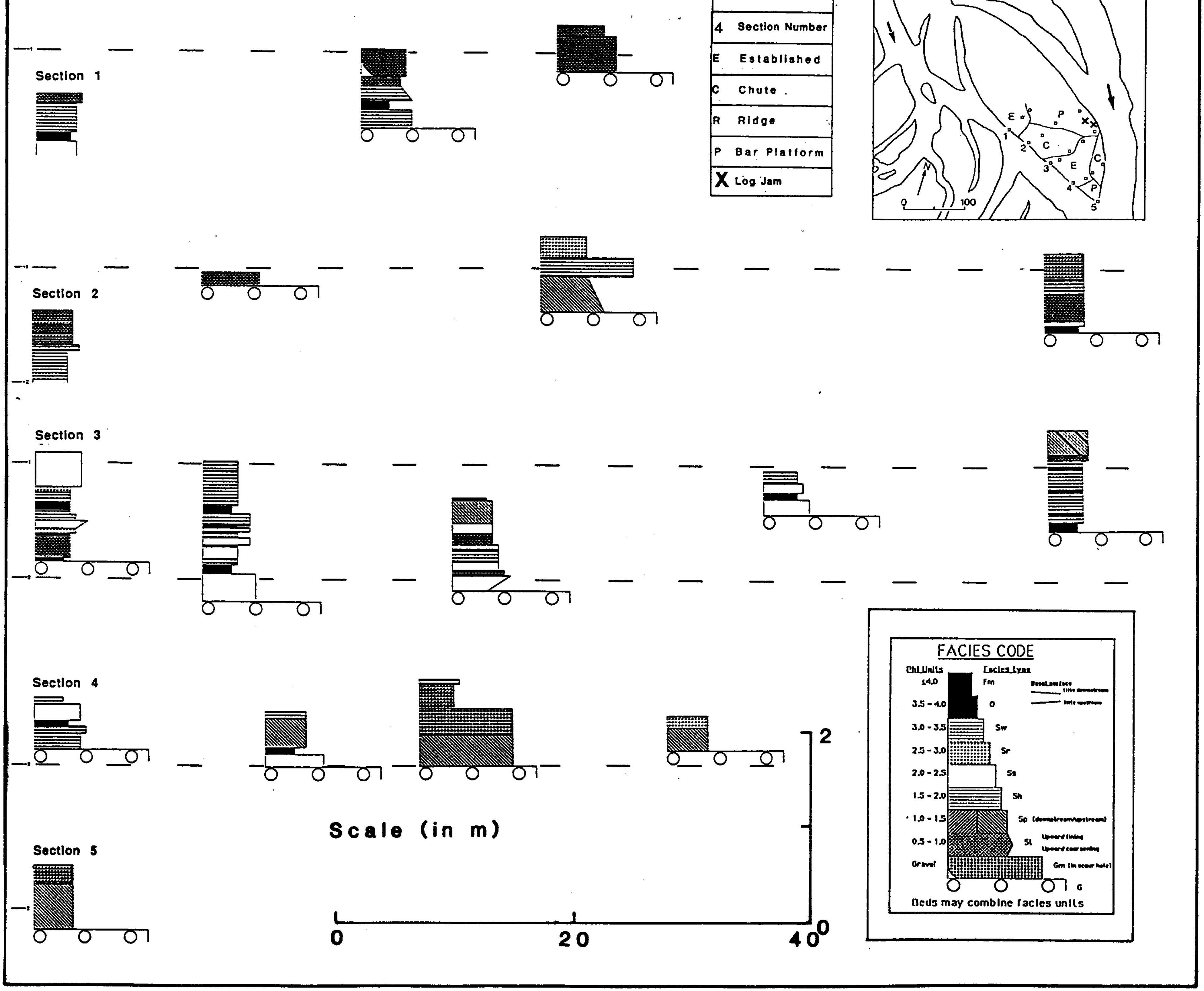


TABLE 6.5 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON ROADUP

Facies characteristics	
Downstream trend	No consistent pattern. All holes are made up of a mix of high and lower energy facies.
Across-bar trend	Notably laterally discontinuous; no across-bar facies trends are evident and there is no clustering of similar sediment sequences.
Vertical sequence trend	Extremely irregular within-bar upward sequences of facies. In irregular locations facies St, Sp and Ss are found at the surface. Many abrupt transitions from high to lower energy facies and vice-versa are apparent.
Particle size characteristics	
Downstream trend	No clear trends are evident. Some holes are made up of coarse sands, but most are dominated by medium sands.
Across-bar trend	Lateral particle size trends are very discontinuous. For example, holes 2-3 and 4-3 are much coarser than surrounding holes, whereas hole 3-5 is notably finer.
Vertical sequence trend	Generally upwardly consistent throughout the bar, although some holes are upward fining (e.g. 3-2 and 4-3) others are upward coarsening (e.g. 3-1 and 3-5) and some have coarse units in mid-section (e.g. 2-3). These tendencies are seemingly randomly located.
Other characteristics	
Bed thickness trends	Highly variable, but there are no consistent trends either down-bar or laterally.
Bar surface elevation	Drops 0.5m from section 1 to 5. Lateral elevation patterns are inconsistent, with section 1 becoming higher towards the main channel, section 2 higher in mid-section, and section 3 lower in mid-section.
Basal surface elevation	Roughly similar to surface elevations, showing irregular trends across and down-bar. In contrast, section 4 has an almost flat basal gravel surface.
Hole depth	Inconsistent both down-bar and laterally, but holes tend on average to be thicker (≥1m) on section 3 than elsewhere (averaging 0.75m).

The chaotic mix of field morphologic units has resulted in discontinuous down-bar and lateral trends shown for facies type, particle sizes and bar surface elevations. Locally, log jams have complicated these patterns further by dissipating flows, protecting some floodplain sections, and partially rerouting flows, thereby affecting the character of channel shifting and ridge formation. Nearby floodplain sections, at the western margin of the valley, are much better established, indicating that the channel has been pinned against the eastern valley wall for some time and that recent flow conditions on and adjacent to Roadup have been extremely dynamic.

6 : 6 : 4 Within-bar sedimentologic variability upon Statbar

Sediment patterns and cross-bar elevational changes upon Statbar are more orderly than upon Basbar and Roadup (Figure 6.3, Table 6.6), but again trends are more a function of locale zonation than overall within-bar patterns. There is a clear zonation of holes dominated by high energy facies at the bar head and towards the main channel, whereas the vegetated mid- and tail bar sections are characterized by lower energy facies. Abrupt down-bar and lateral variation in facies types is echoed by particle size trends. Coarse sediment units in mid-sequence of holes at the western bar margin indicate deposition from high energy flow events associated with the adjacent channel. Other holes exhibit little disruption in their vertical sequence. Hole depth and basal gravel surface both generally decrease towards the west.

The zonation of locales upon Statbar, with an exposed sand plateau at the bar head and western margins and downstream-oriented ridges and chutes elsewhere, appears to be the primary control upon observed sedimentologic patterns. Many of these secondary channels represent flood routes, with coarse sediment units reflecting high energy flows. Air photo evidence indicates that over the last 40 years these channels have gradually become less significant, and the sampled bar unit has become bank attached, with a large log jam in the major chute at the bar head. As yet little lower energy deposition has occurred upon the bar head sand platform. The recent lateral shifting pattern of the main channel adjacent to Statbar indicates that this bar clearly is transitional in character with bars studied in the wandering channel planform reach.

FIGURE 6.3 STATBAR

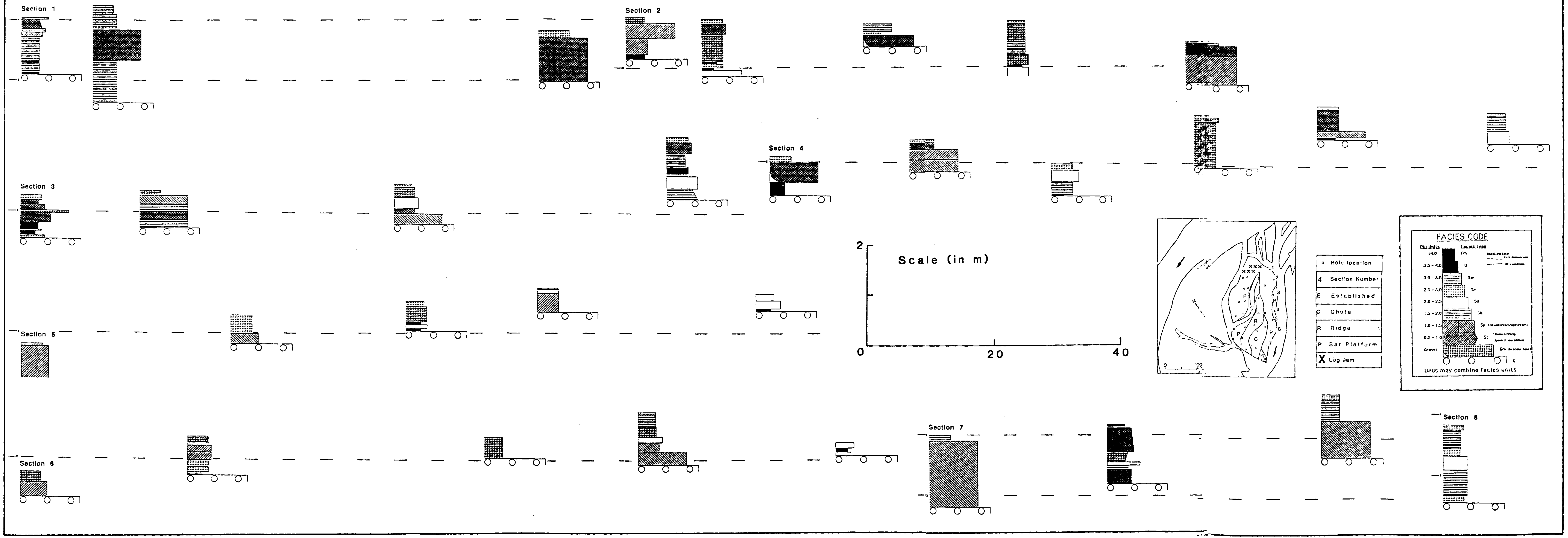


TABLE 6.6 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON STATBAR

Facies characteristics	
Downstream trend	Sections at the bar head (1 to 3) and section 7 are dominated by high energy facies, whereas the proportion of lower energy facies is much greater elsewhere.
Across-bar trend	Extremely discontinuous, with several abrupt transitions from holes dominated by high energy facies to holes dominated by lower energy facies or vice versa (e.g. 1-1 to 1-2, 2-1 to 2-2, 2-4 to 2-5). Higher energy facies are more prevalent towards the main channel on sections 3 to 6, and holes 3-4, 4-4, 5-3 and 6-3 have notably lower energy deposits than adjacent holes. Section 7 is dominated by high energy facies, but the middle hole (7-2) clearly has a different sediment composition to surrounding holes.
Vertical sequence trend	Many holes at the bar head and on section 7 have thick, high energy facies units above the gravels with lower energy facies atop. Internal variability is pronounced in other holes.
Particle size characteristics	
Downstream trend	Most sections are dominated by medium sands, but units at the bar head and on section 7 are notably coarser.
Across-bar trend	Extremely variable (as shown for facies) with some areas of the bar notably finer than elsewhere (e.g. holes 4-4, 4-6, 5-3 to 5-5, 6-3 and 6-5).
Vertical sequence trend	Notably irregular, with coarse sediment units halfway up-sequence in holes 1-2, 2-1, 3-1 and 4-1. Most holes, however, are upward fining, although some show no vertical trend.
Other characteristics	
Bed thickness trends	Extremely variable from hole to hole both down- and across-bar.
Bar surface elevation	Drops 1m from section 1 to 6, but rises again in sections 7 and 8. Elevations are laterally highly variable.
Basal surface elevation	Highly irregular in sections 2 and 4, but most sections tend to slope gradually towards the main channel.
Hole depth	Extremely variable laterally, but holes tend to be deeper at the bar head and tail (up to 1.5m) and shallower in mid-bar.

6 : 6 : 5 Within-bar sedimentologic variability upon Upash

The predominance of high energy facies in all sections on Upash reflects the bar position in a wider section of the valley in which the channel divides into two or three units. The bar is dominated by thickly bedded sediment units deposited from floods, with some holes >3m in depth. Over the last 40 years the main channel has shifted positions around the complex, Upash bar on several occasions. A series of smaller chutes and ridges, along with a third major chute which presently divides the bar, reflect this history of channel shifting.

Contrary to predicted down-bar trends in particle size characteristics, Upash has a greater proportion of coarse sand units at its tail than at its head (Figure 6.4, Table 6.7). This reflects the dominant role played by locale type, as the bar head is a remnant section of vegetated floodplain, with many fines deposited behind a large log jam, whereas the tail unit is a recently accreted sand plateau unit made up of coarse sand, high energy facies. The extremely discontinuous lateral patterns in facies type, particle size and elevation, along with the irregular trends in vertical sediment sequence displayed in the head and mid-bar sections reflect the different patterns of ridge and chute units cutting across the bar. Facies St units high up in sediment sequences reflect high energy flood flows within chutes. In contrast, sediment sequences in the sand plateau deposits at the bar tail typically are laterally consistent and vertically upward fining.

6 : 6 : 6 Within-bar sedimentologic variability upon Tflent

The Squamish Valley widens considerably adjacent to Tflent, but the main channel is pushed against its eastern margin by the shallow angle Ashlu Fan. At present the Squamish River is eroding the shallow fan (i.e. migrating towards the west). Tflent is a linear compound bar which has recently become bank attached at the bar head. The down-bar addition of discrete sediment units has increased the bar size by an order of magnitude over the last 25 years.

The irregular nature of bar growth is reflected by extremely variable down- and across-bar sedimentologic patterns (Figure 6.5, Table 6.8). High energy facies are dominant in some sections but seldom observed elsewhere. They frequently are found at the bar surface, reflecting high energy flood flows within a series of diagonal channels which cut across the bar and, along with adjacent ridge deposits, account for the pronounced lateral discontinuities in sediment type and

FIGURE 6.4 UPASH

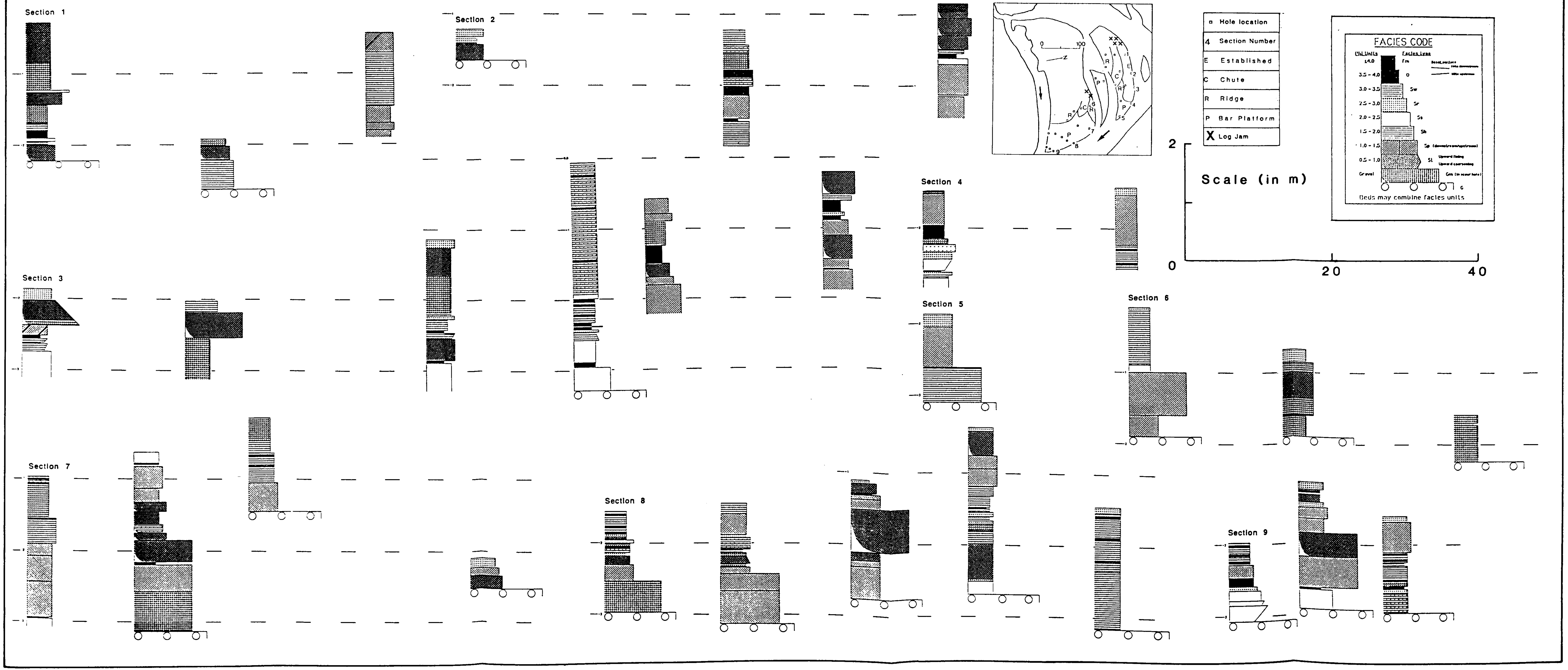


TABLE 6.7 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON UPASH

Facies characteristics	
Downstream trend	High proportion of high energy facies throughout. No distinct down-bar trends are apparent.
Across-bar trend	Extremely discontinuous in all sections, with many abrupt lateral transitions from holes dominated by high energy facies to lower energy deposits (e.g. 3-4 to 3-5 and within section 9). Whereas facies St and Sp are absent in many holes (e.g. 3-4, 6-3 and 8-5) they dominate in most holes, although they tend to become less prevalent towards the main channel on sections 6-9.
Vertical sequence trend	Higher energy facies typically are found at the base of units, but often recur higher up-sequence (especially facies St - see holes 1-1, 2-3, 3-2, 3-3, 6-2, 8-2 and 8-4). Upward facies transitions exhibit no clear patterns either down- or across bar.
Particle size characteristics	
Downstream trend	Somewhat finer at the bar head (sections 1 and 2), the proportion of coarser units increasing gradually down-bar.
Across-bar trend	Each section has one or two holes considerably coarser than the others, often with abrupt lateral transitions in overall mean particle sizes (e.g. in sections 7 and 9). These coarser units are found in an irregular pattern.
Vertical sequence trend	Several holes exhibit classic upward fining sequences (e.g. 5-1, 7-2, 8-1 and 8-2). This tendency is more prominent at the bar tail. Other holes are dominated by coarser units in mid-sequence (e.g. 3-2, 8-3 and 9-2) while particle size trends at the bar head and adjacent to the main channel at the tail are much more upwardly consistent.
Other characteristics	
Bed thickness trends	Most holes are dominated by very thick units. In contrast several irregularly placed holes exhibit many thin beds of variable composition (e.g. 3-4, 4-1, 8-4, 9-1 and 9-3).
Bar surface elevation	Increases 0.5m down-bar from section 1 to 3, then drops 1.5m to sections 4 and 5 before rising back 1.5m to section 6. Between sections 6 to 9 elevation drops off more regularly by about 1m. Lateral variability is pronounced in all cases except sections 2 and 4, with no consistency between section. Section 1 is considerably lower in mid-section, holes close to the main channel are 2m higher in section 3, the bar surface slopes towards the main channel in section 6, while sections 6 to 9 are highest at different holes in mid-section.
Basal surface elevation	Impossible to interpret in bar-head sections. Sections 6, 8 and 9 exhibit very flat gravel contacts whereas the gravel surface rises sharply by 1.5m in mid-section 7.
Hole depth	Extremely variable, with depths ≥3m on section 3, and up to 2m on sections 7 to 9 but generally deeper in mid-section at the bar tail. Holes thin markedly towards the main channel on sections 6 and 7.

FIGURE 6.5 TFLENT

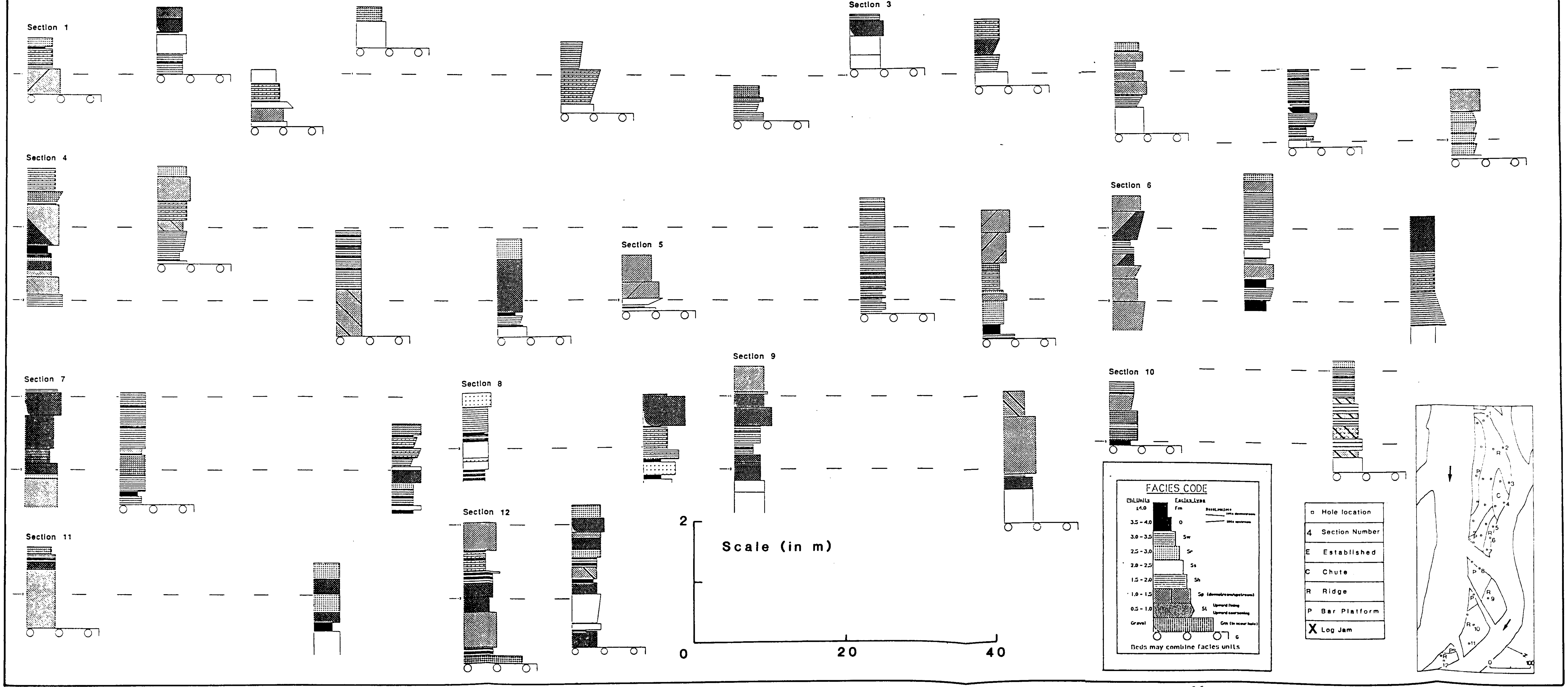


TABLE 6.8 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON TFLENT

Facies characteristics	
Downstream trend	Proportion of high energy facies is markedly variable (e.g. dominant in sections 4 to 6, 9 and 12, but seldom observed in sections 2 and 10).
Across-bar trend	No two holes for any section are laterally consistent.
Vertical sequence trend	No within-bar trends are detectable, and beds often alternate between high and lower energy units. Holes are generally very irregularly interbedded sequences, but some holes are dominated by one facies (e.g. Sw in 4-3 and 5-2; Sr in 3-5; Sp in 6-1; St in 7-1). In many instances high energy facies are observed at the bar surface (especially facies Sp).
Particle size characteristics	
Downstream trend	Relatively uniform for all sections.
Across-bar trend	Extremely limited variability.
Vertical sequence trend	No prominent trends are detectable for any hole (i.e. holes are consistent up-sequence).
Other characteristics	
Bed thickness trends	Holes are thinly interbedded in virtually all sequences.
Bar surface elevation	Drops gradually 0.5m down-bar, tilting notably towards the side channel in sections 2, 3, 4, 7, 9 and 11 (dropping by up to 1m). Remaining sections are either higher in mid-bar or flat.
Basal surface elevation	Tilts towards the side channel in virtually all instances (dropping by over 1m in sections 2 to 4).
Hole depth	Increases gradually down-bar, from 1m at the bar head to 2m at the tail. Holes in each section are of roughly equal depth.

vertical facies sequence by section (see Chapter 7). In contrast, particle sizes are remarkably consistent down-, across-bar and vertically. The role of vegetative protection is indicated by the thinly interbedded nature of virtually all holes on Tflent. Hole depth increases from 1 to 2m down-bar, whereas basal gravel and bar surfaces tilt gradually away from the main channel.

6 : 6 : 7 Within-bar sedimentologic variability upon Fallbar

Downstream of the Ashlu River confluence, the main channel of the Squamish River is more deeply entrenched into the floodplain, banks are more cohesive, and the well-developed floodplain is considerably more extensive. Fallbar is a diagonal compound bar unit separated from the western valley wall by a relatively narrow channel. This channel is becoming less significant, as the main channel erodes the floodplain on its eastern bank. Consequently, Fallbar recently has become a more stable bar unit, and diagonal channels which cut across the bar surface are presently being infilled. Many of these chutes have prominent log jams at their head. Air photo evidence indicates significant downstream accretion over the last 40 years, with lateral accretion of platform sands at the bar tail.

Observed sediment trends accord closely with this locale pattern (Figure 6.6, Table 6.9), and lateral bar surface elevations are highly irregular. The considerable lateral and vertical mixing of high and lower energy facies reflects shifting chute channel positions in each section. Down-bar facies type and particle size trends are more consistent than observed elsewhere, although a fining trend is noted at the tail. The presence of lower energy facies in contact with basal gravels indicates that coarser units either have not been deposited, or not preserved. The latter is more likely as coarse units are observed in mid-sequence adjacent to either the main or side channel.

In summary, holes upon Fallbar are dominated by lower energy facies and exhibit less down- and across-bar variability than shown elsewhere. This consistency is attributable to similar despositional conditions throughout the bar, with conditions conducive to deposition and preservation of lower energy sediments in extensive, thinly interbedded units. Two factors aid in this process. Firstly, the main channel thalweg is at the opposite bank which is being rapidly undercut, while side channels adjacent to Fallbar support considerably smaller flows than in the past. As a consequence, depositional flows upon Fallbar are relatively shallow, low energy events, hindered further by vegetation. Secondly, the prominent log jams at the bar head dissipate flood

FIGURE 6.6 FALLBAR
Section 1
Section 2
Section 3
Section 4
Section 5
Section 6
Section 7
Section 8
Section 9
Section 10
Section 11
0
20
40
2
Scale (in m)
Hole location
4 Section Number
E Established
C Chute
R Ridge
P Bar Platform
X Log Jam
FACIES CODE
Phi Units
Facies type
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
Gravel
Fm
O
Sw
Sr
Ss
Sh
Sp
St
G
Beds may combine facies units

TABLE 6.9 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON FALLBAR

Facies characteristics	
Downstream trend	No dominant trends are apparent. High energy facies are notably less prevalent than on other bars, but tend to be dominant in at least one hole in each section (except section 9). Only in section 6 are high energy facies apparent in each hole.
Across-bar trend	Extremely inconsistent for specific facies types, but adjacent holes in mid-bar sections often are roughly equivalent with respect to position and relative thickness of high or lower energy facies (e.g. sections 3 and 6, holes 4-2 to 4-3, 5-1 to 5-2, 7-2 to 7-5 and 8-1 to 8-3). Sections 1 and 2 have much greater proportions of high energy facies adjacent to the main channel; this trend is reversed on section 10.
Vertical sequence trend	Notable mixing of high and lower energy facies, with no clear upward patterning. Lower energy facies are actually found in contact with gravels more frequently than high energy facies (e.g. section 9).
Particle size characteristics	
Downstream trend	Sections at the bar tail (7 to 11) are generally finer than up-bar sections.
Across-bar trend	Within-section variability is minimal, other than for holes which have a coarser unit in mid-sequence (1-2, 2-2, 3-1, 5-1, 6-1 and 7-1).
Vertical sequence trend	Most holes are consistent upwards. No fining or coarsening upwards trends are apparent, but several holes have a coarser unit in mid-sequence (1-2, 2-2, 3-1, 5-1, 6-1 and 7-1). Whereas the first two holes are adjacent to the main channel, the other four holes are at side-channel margins.
Other characteristics	
Bed thickness trends	Most holes are dominated by thinly interbedded units, with as many as 25 beds in a 2m hole (see sections 6 and 7).
Bar surface elevation	Rises 1m from section 1 to 2 and 3, then drops 1m to sections 4 and 5, but rises again by 0.5m to section 6, before dropping gradually by 1.5m to section 11. Lateral variability is pronounced, being higher in mid-section in sections 3, 4, 5, 6, 8 and 9, roughly flat in sections 1, 7 (except 7-2) and 10, and dipping towards the main channel in section 2.
Basal surface elevation	Not available, due to waterlogging.
Hole depth	Not available, due to waterlogging, but holes in mid-bar are ≥2.5m deep.

flow energy, and also act to redirect the main flow filament to the opposite bank.

6 : 6 : 8 Within-bar sedimentologic variability upon Dcamp

Dcamp is a point bar in a freely meandering bend. The preferred direction of migration of this broad bend is downstream, with over 400m of erosion of the opposite bank in the last 40 years. Valley width is over 2km at this location. This bar represents the first bar in the study reach which exhibits clear down- and across-bar change in facies characteristics (Figure 6.7, Table 6.10). These trends are consistent with observations for other point bar units (see Table 2.3), with distinct bar head, mid-bar and bar tail units. The character of lateral facies transitions, however, cannot be explained by reference to bar position alone; the locale pattern also is critical.

The bar head unit of Dcamp is dominated by an extensive gravel platform, which grades down-bar into a large sand/gravel dune field. In mid-bar sections, holes dug in the central part of the contemporary bar are finer grained, with a greater proportion of lower energy facies than adjacent holes. This reflects the roughly parallel zonation of locales upon Dcamp, with high energy units on the bar platform (adjacent to the main channel) and in a major chute unit adjacent to the established floodplain. High energy facies are prominent in all units of the bar, but lower energy depositional units are more significant in holes dug at the bar tail. Vertical facies sequences are indicative of upward reduction in energy of deposition in most zones of the bar, but the tendency is better pronounced at the bar tail. The central parts of mid-bar sequences are dominated by lower energy facies throughout. Hole depth increases notably from less than 1m adjacent to the gravel locale at the bar head to about 2m at the bar tail. In contrast to the prominent down-bar zonation of facies types, there is little variation in particle size, as holes are made up largely of medium-coarse sand units.

Across-bar sediment variations conform to locale zonation, with many abrupt transitions between adjacent holes in mid-section. Only those holes adjacent to the main channel are clearly upward fining. In other holes, coarse sand basal facies are not found, possibly indicating random preservation of these units (associated with chute channel reworking), and holes exhibit consistent up-sequence trends of medium-fine sands. Basal gravel surface and bar surface elevations tilt gradually towards the main channel, consistent with lateral bend migration.

FIGURE 6.7 DCAMP

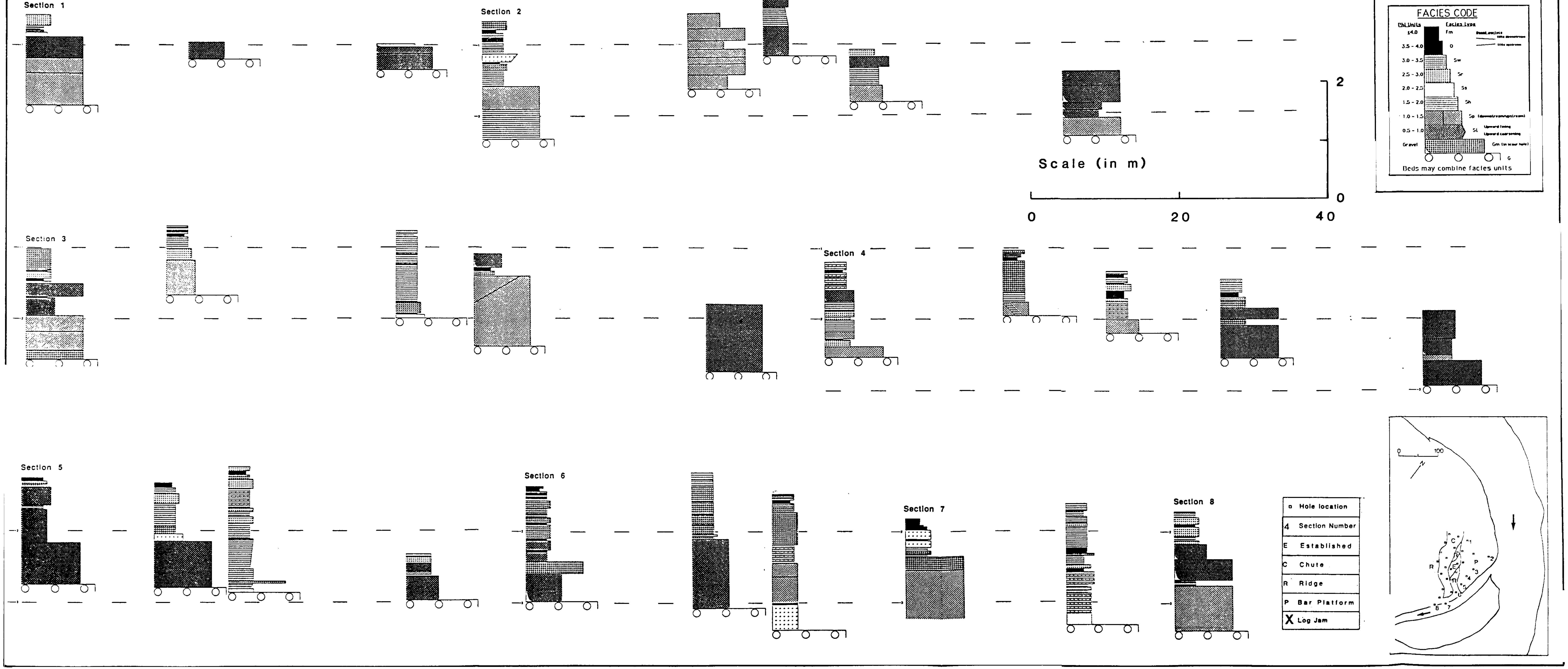


TABLE 6.10 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON DCAMP

Facies characteristics	
Downstream trend	Proportion of high energy facies gradually diminishes down-bar, but these facies are still prominent at the bar tail.
Across-bar trend	Extremely variable from section to section, although certain trends are detectable. Sections 1 and 2 are dominated by high energy facies throughout. Sections 3 to 5 have 1 or 2 holes in mid-section dominated by lower energy facies (3-3, 4-2, 4-3 and 5-3) with predominantly high energy facies at either side, while in sections 6 and 7 these holes made up of lower energy facies are found adjacent to the main channel (6-3 and 7-2).
Vertical sequence trend	Sequences are characteristically indicative of reduced energy of deposition up-sequence in virtually all instances other than those holes dominated by one of either high or lower energy facies (as described above). Many holes at the bar head have just 1 or 2 facies types per hole, but holes become more complex down-bar.
Particle size characteristics	
Downstream trend	High proportion of medium-coarse sands found in all sections, with no detectable down-bar trends.
Across-bar trend	Notable lack of lateral continuity in all sections, with many abrupt transitions from coarse to fine units or vice versa (e.g. 2-2 to 2-3, 3-3 to 3-4, 4-3 to 4-4, 5-2 to 5-3 and 7-1 to 7-2).
Vertical sequence trend	An irregular mix of upward fining and upwardly consistent units. No down-bar trends are discernable, but holes most distant from the main channel typically are upward fining.
Other characteristics	
Bed thickness trends	Holes are often dominated by very thick high energy units, whereas other holes are characterized by thinly interbedded lower energy facies. There is no identifiable pattern to these tendencies in terms of within-bar position.
Bar surface elevation	Drops gradually by 1m down-bar. Laterally bar surfaces tend to decrease by up to 1m towards the main channel.
Basal surface elevation	Highly irregular in bar head sections (1 to 3) but down-bar sections tend to tilt gradually towards the main channel.
Hole depth	Tends to increase from about 1m at the bar head to about 2m at the tail. In general depth decreases towards the main channel.

6 : 6 : 9 Within-bar sedimentologic variability upon Bigbar

Down-bar and lateral trends in sedimentologic characteristics described for Dcamp are even more evident upon Bigbar (Figure 6.8, Table 6.11). This is the tightest of the bends studied. The concave bank has been eroded by over 300m in the last 40 years. A prominent ridge and swale pattern has developed on the established floodplain, separated from the contemporary point bar platform deposits by chute units in a morphologic arrangement very similar to that described for Dcamp. Indeed, the only major difference is that the chute unit on Bigbar is not continuous down-bar but divided into two units, a coarse sand, high energy chute at the bar head and a fine sand, low energy run-off chute at the bar tail.

The bar head unit on Bigbar is dominated by a large gravel unit, which is marginal to upward fining, high energy facies (Sp and St), with occasional ripples atop. Occasionally, holes adjacent to the main channel are indicative of an up-sequence increase in energy. The proportion of high energy facies is similar in the mid-bar unit. Laterally discontinuous sediment trends reflect the parallel, down-bar oriented, chute, ridge and bar platform locales. Holes adjacent to the main channel are composed solely of high energy facies and contrast sharply with sediment trends exhibited by holes away from the main channel, which are made up entirely of thinly interbedded lower energy facies. Between these two units are a series of holes which show a complex intermingling of high and lower energy facies reflecting series of flood flows within chutes. Vertical particle size trends are consistent in the mid-bar zone, but mean particle size is notably finer in the deeper holes (>2m) away from the main channel. As on Fallbar and Dcamp, this is indicative of the limited preservation and sediment reworking associated with chute channel flows. High energy facies are not apparent in holes dug at the bar tail. Rather, these shallow holes are composed solely of fine sand, lower energy facies, reflecting secondary flow circulation patterns in the run-off chute at the bar tail.

Basal gravel surfaces are highly irregular on Bigbar reflecting erosion by chutes. A consistent tilt of the basal gravel surface towards the main channel is not observed. The platform sediment locale adjacent to the main channel has a series of distinct levels, probably reflecting different flow stages.

FIGURE 6.8 BIGBAR

TABLE 6.11 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON BIGBAR

Facies characteristics	
Downstream trend	High energy facies predominate in bar head sections (1 to 3). Their proportion gradually diminishes down-bar to section 12, and they are not observed in sections 13 and 14.
Across-bar trend	In sections 1 to 3 high energy facies predominate across sections. Lower energy facies dominate in mid-section 4, while 4-1 exhibits high/lower energy facies in equal proportion. In sections 5 to 12 holes most distant from the main channel are composed almost entirely of lower energy units. In adjacent units the proportion of high energy units is greater, while holes adjacent to the main channel are completely made up of high energy facies other than occasional ripple beds. Lower energy facies dominate in all holes on section 13.
Vertical sequence trend	Five tendencies are observed, representing units at the bar head, bar tail and zones parallel to the main channel : 1) up-sequence reduction in energy (1-1, 1-2, 2-1, 3-1 and 4-1) 2) up-sequence increase in energy (2-2 and 3-2) 3) upward consistency of lower energy facies (4-2, 5-1, 6-1, 7-1, 8-1, 9-1, 10-1, 11-1, 12-1, 12-2, 13-1, 13-2, 13-3 and 14-1) 4) upward consistency of high energy facies (5-2, 7-4, 8-4, 9-4, 10-4 and 11-3) 5) complex intermingling of high/lower energy facies (6-2, 6-3, 7-2, 7-3, 8-2, 8-3, 9-2, 9-3 and 10-3).
Particle size characteristics	
Downstream trend	Sections 1 to 5 are notably coarser than other sections, which are consistent in particle size from section 6 to 11 and finer on sections 12 to 14.
Across-bar trend	Sections 1 to 3 are consistently coarse for all holes. Section 4 fines towards the main channel, but this tendency is reversed on sections 5 to 11. Sections 12 and 13 are consistently fine for all holes.
Vertical sequence trend	Upward fining sequences are notable for several holes at the bar head, but virtually all other holes are upwardly consistent.
Other characteristics	
Bed thickness trends	Bar head holes are dominated by thick units, but mid-bar and tail sections are very thinly interbedded sequences (with the exception of some thick high energy units adjacent to the main channel).
Bar surface elevation	Drops gradually by 2.5m down-bar. Laterally bar surfaces drop by almost 1m towards the main channel on sections 2 to 6, whereas sections 7 to 12 are 0.5m higher in mid-section.
Basal surface elevation	Tilts towards the main channel on sections 2 and 5, but away from the main channel on sections 1, 4 and 6. Information is not available for other sections.
Hole depth	Holes are deeper (≥2m) in mid-bar, away from the main channel, becoming notably shallower at the bar tail.

6 : 6 : 10 Within-bar sedimentologic trends upon Uppil

Uppil is a lateral bar located at the downstream end of a broad bend that is confined by a bedrock buttress on the western valley wall. Air photo evidence indicates very little downstream translation of this bend in the last 40 years. Sediment sequences are much simpler than those demonstrated by Dcamp and Bigbar as trends upon this lateral bar are not disrupted by a series of chutes. Rather, the discontinuous ridge and swale pattern of the established floodplain (examined in sections 1 and 5) is simply marginal to bar platform sands (Figure 6.9, Table 6.12). No down-bar trends are evident for facies type, particle size or bar surface elevation.

Holes adjacent to the main channel are made up of medium-coarse sand, high energy facies units. In developed floodplain sequences, these units are covered by thinly interbedded lower energy facies in a laterally continuous fashion, reflecting upward reduction in energy of deposition and particle size. These holes are quite deep (>3.5m). Basal surfaces tilt notably towards the main channel, dropping by over 3m in some instances.

6 : 6 : 11 Within-bar sedimentologic variability upon Pillbend

Pillbend is a point bar depositional unit contained within a broad bend at the lower limit of the study reach. Channel width is notably narrower at this location. This bend has migrated laterally (not downstream) by 200m in the last 40 years, most of this movement taking place since 1969. This movement is now inhibited by a coarse boulder dyke on the concave bank. The process of bend migration has produced a series of discontinuous ridge and swale features adjacent to the bar platform. These features represent discrete morphologic units (or locales) upon Pillbend.

The character of down-bar sedimentologic trends observed upon Pillbend is slightly different to that shown upon Dcamp and Bigbar, with the bar head unit composed of finer, lower energy facies (Figure 6.10, Table 6.13). Mid- and tail bar sequences are roughly equivalent. Mid-bar sections are composed of coarser, higher energy facies than observed at the bar head or tail. Facies and particle size trends are laterally discontinuous and conform with a series of locale units around the bend. The locale adjacent to the main channel has coarse scour hole deposits, with occasional lower energy facies atop. These sequences differ notably from neighbouring holes which are affected by down-bar oriented chute channels. Flows within these chutes have removed high

FIGURE 6.9 UPPIL

TABLE 6.12 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON UPPIL

Facies characteristics	
Downstream trend	No notable trends apparent.
Across-bar trend	In sections 2 to 4 holes furthest from the main channel are similar in character but notably different from other holes in these sections, as they are made up of lower energy facies. All other holes are made up of higher energy facies (as shown in all holes on section 6). This discontinuity is explained by reference to sections 1 and 5, which display remarkable lateral continuity of facies types across-section.
Vertical sequence trend	The continuity of units described above clearly indicates reduced energy of deposition as one moves up-sequence - this trend simply has not been completed in holes adjacent to the main channel, which are presently dominated solely by high energy facies.
Particle size characteristics	
Downstream trend	No clear trends are evident.
Across-bar trend	Holes become finer away from the main channel in all sections.
Vertical sequence trend	All holes are either upward fining or upwardly consistent (except 3-3) with no clear patterning to differentiate between these trends.
Other characteristics	
Bed thickness trends	No down-bar trends are evident. High energy facies are characteristically quite thick units, whereas holes away from the main channel, with high proportions of lower energy facies, are thinly interbedded high up in their sequence.
Bar surface elevation	Drop down-bar from section 1 to 5 is nominal. In all instances, however, the bar surface drops notably towards the main channel (by ≥3m in section 5).
Basal surface elevation	Insufficient evidence to recognize any trends.
Hole depth	Holes up to 3.5m deep were dug away from the main channel, whereas maximum depth to gravel attained close to the main channel was 1.5m. This trend appears to be consistent down-bar.

FIGURE 6.10 PILLBEND

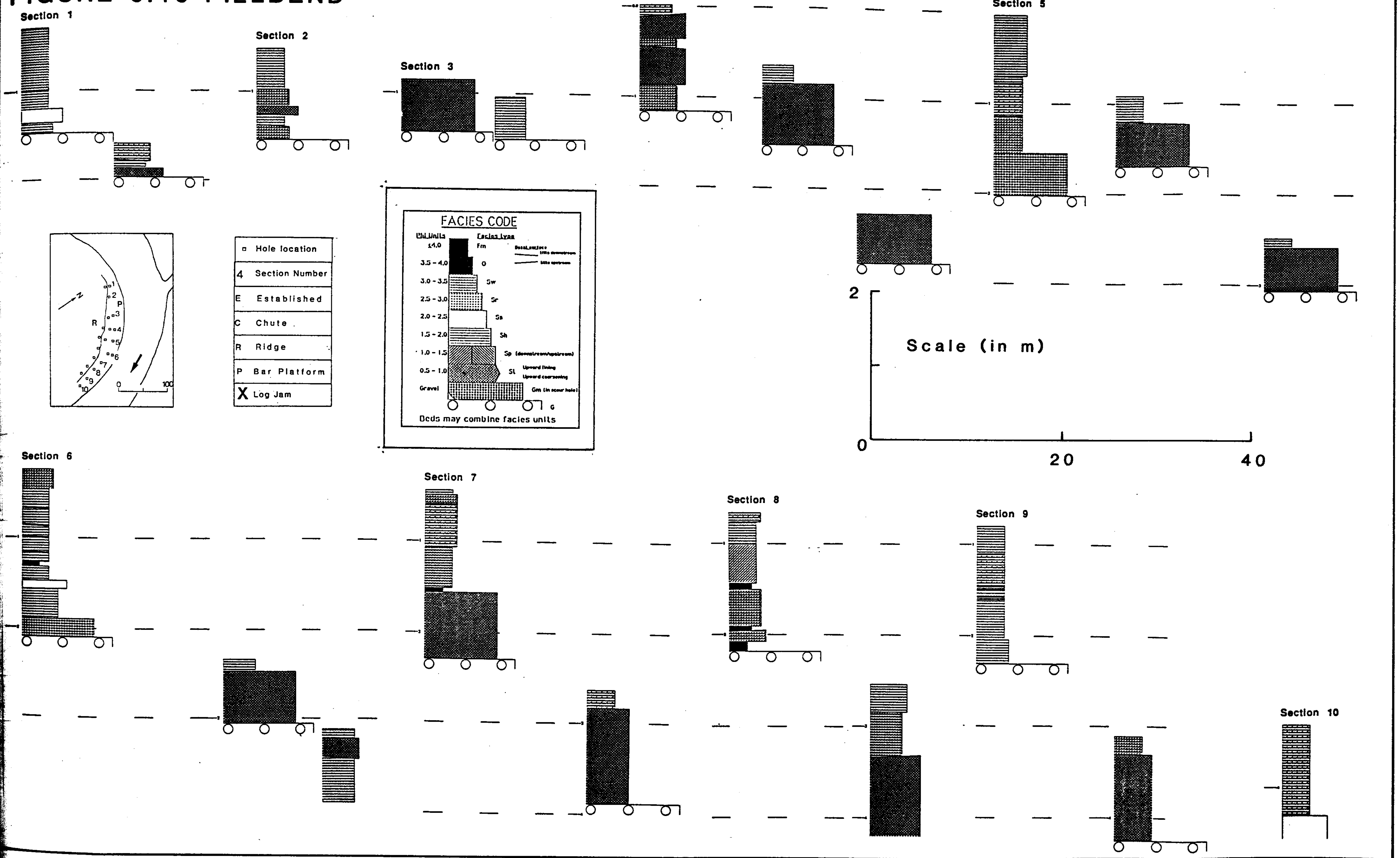


TABLE 6.13 WITHIN-BAR SEDIMENTOLOGIC TRENDS UPON PILLBEND

Facies characteristics	
Downstream trend	Proportion of high energy facies is notably higher in sections 3 to 7, whereas bar head and tail sections are made up largely of lower energy facies.
Across-bar trend	Very little lateral consistency is apparent. Bar head sections (1 and 3) have very different sediment sequences positioned virtually side by side. Sections 4 to 9 are characterized by similar lateral trends in which the proportion of high energy facies declines notably away from the main channel.
Vertical sequence trend	High energy facies typically are found above the basal gravels and are transitional upwards to lower energy units. Only in hole 4-1 are high energy beds found up-sequence.
Particle size characteristics	
Downstream trend	Sediment units are finer at the bar head and tail, and notably coarser in sections 3 to 7.
Across-bar trend	Sections 3 and 7 coarsen away from the main channel, whereas other sections show an opposite tendency as the proportion of lower energy facies is reduced.
Vertical sequence trend	While several holes in mid and tail bar sections (5-1, 6-1, 6-2, 7-1, 8-2 and 9-2) are upward fining, by far the majority are upwardly consistent.
Other characteristics	
Bed thickness trends	Many holes are characterized by just one or two thick units. This effect is dominant in holes adjacent to the main channel, the extent of thinly interbedded units increasing away from the main channel. This tendency is consistent down-bar.
Bar surface elevation	Remains consistent down-bar from sections 1 to 9, but lateral variation is great, with steep slopes dropping by $\geq$2m to the main channel. This effect becomes more pronounced down-bar.
Basal surface elevation	Available evidence indicates a very similar trend to bar surface elevation.
Hole depth	In general hole depth increases away from the main channel to a maximum observed depth of about 2m. Hole depth appears to increase slightly down-bar.

energy facies, and preferentially preserved lower energy units, with no vertical particle size trends. Finally, sediment units at the bar tail are similar to Bigbar with fine sand, lower energy facies reflecting secondary flow circulation in the tail chute locale. Bar surface slope tilts notably (>2m) towards the main channel, in a manner consistent with bend migration.

6 : 7 : 1 Comparison of expected and observed within-bar sedimentologic variability by planform

Braided river reaches are high energy environments characterized by frequently shifting channels which are prone to abandonment and reoccupation. As such, chaotic sediment sequences may be expected, with abrupt transitions in facies type and particle size laterally and vertically, and highly irregular surface morphologies. Furthermore, a small proportion of lower energy deposits would be predicted. These tendencies are all in evidence for the three complex, compound bars studied in the braided reach (Table 6.14). Local scale variability is pronounced down- and across-bar and in vertical sequences. Lower energy depositional units are observed in isolated irregular patches across the valley, in established floodplain areas.

Down-bar trends in facies type or particle size may be expected for longitudinal or mid-channel bars (Table 2.3) but the complex nature of the three bars studied precludes the existence of such trends. Although these compound bars are markedly different in character and local field setting, they are made up of similar field morphologic units. The random pattern of locale zonations upon Basbar and Roadup is clearly reflected in the irregular within-bar sediment patterns. Statbar appears marginal to conditions in the nearby wandering reach, exhibiting down-bar linearity in locale pattern, resulting in more consistent sediment trends (see Chapter 7).

In the wandering planform reach, trends in sedimentologic characteristics are expected to be more consistent than those observed in the braided reach as the number of channels is smaller, bar sections are more stable, and the manner of channel shifting is more regular. Abrupt facies transitions from high to lower energy deposits characterize channel abandonment. Subsequent infill sequences typically are upward fining. Finally, basal gravel surfaces depend entirely upon the nature of channel shifting, and therefore should be more consistent than observed upon bars studied in the braided reach.

TABLE 6.14 SUMMARY OF WITHIN-BAR SEDIMENTOLOGIC VARIABILITY BY PLANFORM

	BRAIDED	WANDERING GRAVEL-BED RIVER	MEANDERING
FACIES TRENDS	Very irregular from hole to hole, with no distinct patterns down-bar, across bar or in vertical sequence on Basbar and Roadup. Statbar has high energy facies at the bar head, but exhibits pronounced lateral and vertical sequence variability.	Very different trends for each bar. Down-bar, Upash and Fallbar are consistent with high and low proportions of high energy facies respectively, whereas the down-bar pattern on Tlient is highly variable. Lateral patterns are extremely discontinuous on Upash and Tlient, but much more regular on Fallbar. Vertical sequences exhibut pronounced mixing of high and lower energy facies.	Head, mid- and tail bar units on Dcamp and Bigbar indicate reduced energies around the bend at these locations, while Uppil is consistent down-bar and the head unit on Pillbend is made up of lower energy facies. The proportion of high energy facies is greatest adjacent to the main channel in all instances. On Uppil this trend is consistent away from the channel, whereas patterns are extremely discontinuous on other bars, as chutes disrupt sequences and lower energy facies are deposited. Vertical sequences indicate upward reduction of energy in undisturbed holes (e.g. Uppil, Pillbend) or in some chute infills (e.g. Dcamp), but most holes are dominated by one of either high or lower energy facies units.
PARTICLE SIZE TRENDS	No distinct trends are apparent down- or across bar. Vertical sequences are often highly variable from hole to hole.	Upash is coarser at the tail, Fallbar finer at the tail and Tlient internally consistent. Lateral and vertical trends are extremely variable on Upash but consistent on Tlient and Fallbar.	No down-bar trends are apparent on Dcamp and Uppil. Pillbend is coarser in mid-bar, and Bigbar fines gradually down-bar. Lateral trends tend to coarsen towards the main channel in all instances, but this pattern is much less regular on the point bars. Holes unaffected by secondary reworking are upward fining (e.g. Uppil, bar head on Bigbar); other holes are almost always upwardly consistent.
OTHER CHARACTERISTICS	Basal surfaces tilt down-bar at slopes between .003-.005. They are laterally highly variable due to chute incision although Statbar does tend to tilt towards the main channel. Hole depths are highly variable, reaching a maximum of 1.5m.	Down-bar slopes on Tlient and Fallbar are very gentle (.001-.002) but Upash is extremely irregular. Laterally they vary greatly on Upash and Fallbar, but slopes tilt away from the main channel on Tlient. Hole depth is locally highly variable, but depths >3m were attained. Bed thickness is highly variable, but Tlient and Fallbar are primarily made up of very thinly interbedded units.	Down-bar slopes on Dcamp and Bigbar are between .004-.005, whereas Uppil and Pillbend are virtually flat. Slopes tilt considerably towards the main channel on Dcamp, Uppil and Pillbend (with up to 3m variation), but trends are somewhat irregular on Bigbar. Hole depths increase greatly away from the main channel, reaching a maximum observed depth of >3.5m on Uppil.

Observed sedimentologic variability upon each of the three bars studied in the wandering reach conforms with the expectations outlined above. Facies and particle size distributions vary for each bar, reflecting their different characters and field settings. While Upash is a more-exposed mid-channel/diagonal bar unit, with a high proportion of coarse, high energy facies, Tflent and Fallbar are protected side-bar depositional environments, relatively distant from the main channel thalweg. Sediment patterns upon bars in the wandering reach are related primarily to the local manner of chute channel reworking of deposits. Consistent trends in sediment units are closely aligned with the pattern of field morphologic units. These locales are much larger and less randomly organized than observed in the braided reach (see Chapter 7).

Vertical sequences exhibit pronounced mixing of high and lower energy facies, reflecting the disruptive role of high energy chute flows. Upward particle size trends upon bars in the wandering reach are not clearly upward fining. They are widely variable upon Upash, but Tflent and Fallbar are characterized primarily by upwardly consistent particle size trends. The extensive units of thinly interbedded deposits observed on these bars are quite different from anything observed in the braided reach. This trend possibly reflects removal of coarser materials during floods and replacement by fine sand, waning stage flood deposits. The pattern of chutes has resulted in highly irregular basal gravel surfaces on Upash and Fallbar, whereas mid- and tail bar sections on Tflent tilt gradually away from the main channel.

Predicted within-bar sedimentologic variability also accords closely with observed trends upon bars studied in the meandering reach. Distinct sediment zones are apparent around bends for each of the point bars, whereas Uppil (a lateral bar) has much more consistent down-bar trends. Facies type and particle size trends are generally indicative of reduced energy of deposition around the bend in agreement with patterns outlined in Table 2.3. Variability in these trends may be accounted for by the tightness of the three bends and upstream bend character, as these are the primary controls upon fully developed bend flow (Jackson, 1976).

In bar sections unaffected by chute flows, vertical sediment sequences exhibit up-sequence reduction in energy of deposition and particle size, conforming with the classic model of meandering channel planform sedimentology. However, downstream-oriented chute flows are dominant features adjacent to the established floodplain in most sections. These chutes have disrupted laterally consistent sediment sequences and created arcuate, down-bar locale zones around each bend. Sediments reworked and redeposited in chutes are much lower energy units than the coarse high energy platform deposits observed adjacent to the main channel. Whereas chute sediments are upwardly consistent lower energy deposits composed of medium-fine sands, platform deposits are upwardly consistent high energy deposits composed of medium-coarse sands. Between these locales is a unit of largely mixed trends. The main implication of this locale distribution is that coarse units are not preserved as the bend laterally migrates. As a consequence, classic upward fining sequences seldom are observed. In contrast to these findings, trends in facies type and particle size are laterally consistent upon Uppil, a lateral bar experiencing no lateral migration and minimal downstream translation. Vertical size trends upon this bar clearly are upward fining.

Locales upon bars in the meandering reach are larger and conform to a much more predictable pattern than observed in the other planform reaches. Basal gravel surfaces exhibit much greater lateral consistency. Surfaces tilt steeply towards the main channel in accordance with bend migration on Dcamp, Uppil and Pillbend, although trends are much more variable on Bigbar. In all instances, slopes are more continuous and steeper than the trends shown on Statbar and Tflent. This implies that there is a much greater degree of order in sediment sequences upon point bars, which is only detectable when viewed at the within-bar scale.

6 : 7 : 2 The use of within bar sedimentology in planform differentiation

In contrast to the meaningless planform facies models produced by Markov analysis for one-dimensional data, and the inaccuracies noted in the summary statistical analysis of sedimentologic character by planform, the three-dimensional pictures of channel bar sedimentology present several criteria which are reliable predictors of planform differentiation. Although depositional mechanisms are the same irrespective of planform or bar type, the spatial scale and association of within-bar sediment units exhibits several tendencies by planform. The following within-bar trends are indicators of planform differentiation of Squamish River deposits :

1. Laterally and longitudinally extensive sequences of fairly consistent lower energy facies (often thinly interbedded) are characteristic of bars found in downstream areas of the study reach (either wandering or meandering), while highly irregular, random sequences with alternating high and lower energy facies or coarse and fine particle sizes are indicative of braided conditions.

2. Consistently upward fining units observed horizontally over scales from tens to hundreds of metres are indicative of meandering river conditions, or circumstances in which the manner

of channel migration is consistently unidirectional. Upward fining units are found under all three planform styles, but are much more localized in the braided and wandering reaches.

3. Basal gravel surface contacts dipping steeply in a regular lateral manner (towards the main channel) are observed only under meandering conditions.

Comparing trends for each planform from Table 6.14, it is evident that facies and particle size trends are highly irregular in the braided reach, but exhibit increasing order downstream in the study reach, with well-defined patterns upon bars in the meandering reach. Average hole depth increases notably downstream, and basal gravel surfaces become much more laterally consistent in that direction. These tendencies, however, are transitional in character, and it is not possible to create a "type" sequence of sediments for any particular bar or planform type. While the channel bar scale provides a more important control upon observed sedimentologic patterns than does channel planform style, within-bar trends are not consistent with predicted trends in all instances. Rather, the pattern of locales is the primary control upon sediment sequences. As related to specific geomorphic processes, locales refer directly to environment of deposition (as does architectural element analysis, Miall, 1985). The scale, morphology, spatial association and sedimentology of locales is assessed by planform in Chapter 7.

CHAPTER VII

SEDIMENTOLOGIC ANALYSIS AT THE LOCALE SCALE

7 : 1 Definition of terms

Sediment patterns upon bars studied are zonal in nature, reflecting local scale depositional environment to a greater extent than bar-scale trends. These field morphologic units are independent of planform or bar type and are referred to as locales. From field knowledge of the contemporary bars studied on the Squamish River, four locales have been defined (Table 7.1). The proportion of established floodplain deposits in each reach increases downstream, as the number of channel decreases and valley width increases. The chute locale unit is a summary term for a wide range of channelized units (including cut-offs, runnels and swales). Ridge units are discontinuous raised strips with an irregular outline found adjacent to river channels. Finally, the most prominent locale upon contemporary bars are channel platform deposits, large exposures of unvegetated sands and gravels typically located adjacent to the main channel.

Each bar has a distinct set of locale components; indeed, the different character of river channel bars is a reflection of the make-up, extent and pattern of locale types. Bars in the braided reach are made up largely of small, irregularly arranged, remnant locale units. The nature of channel shifting, abandonment and reoccupation results in poorly developed ridge and established floodplain units, whereas chute and platform locales are dominant. In all three bars, prominent platform locales are located at the bar head, but air photo evidence indicates that these units are extremely prone to change.

Maps of locale distributions (on Figures 6.1 to 6.10) indicate that Statbar, at the downstream limit of the braided reach, exhibits a greater degree of spatial ordering in locale type than bars upstream, and is marginal in character to bars studied in the wandering reach. Down-bar parallel locales are oriented longitudinally or diagonally, dependent upon chute channel pattern. Ridge, chute and established floodplain locales alternate laterally, with platform units in areas of recent bar accretion. The platform locale varies in position from bar to bar; it is located at the bar tail on Upash, in a lateral zone on Tflent and in irregular positions on Fallbar.

TABLE 7.1 : LOCALE DEFINITION

Locale	Character	Scale and morphology	Mechanism
Bar platform	Unvegetated sediment unit, often plateau-like, but may exist as a series of steps (especially upon point bars). Generally located adjacent to the main channel.	Often the largest locale upon contemporary bars in the study reach. Exists as irregular remnants in the braided and wandering reaches (observed up to 200m wide and 500m long on bars studied). Platform deposits are much more regular in shape on bars in the meandering reach, exhibiting an arcuate form around each bend, with the widest section at the bend apex. Units are generally up to 100m wide and extend up to 500m around each bend.	Result from within-channel processes, with dune-fields and sand waves prominent.
Ridge	Narrow strips of deposits elevated up to 3m above the level of the bar platform. Often have young vegetation atop. Found at the margin of the contemporary bar and the established floodplain.	Linear, sinuous or irregular in outline in the braided and wandering reaches, generally <30m wide, with highly variable length (>200m in some instances, but often very discontinuous. The number of ridges is greater in the wandering reach, located adjacent to diagonally cutting chute channels. Ridges typically are narrower (up to 25m), longer, and more regular in outline in the meandering reach. Their curved, non-parallel nature are indicative of the character of bend migration.	Result from ridge/lateral accretion.
Chute	Longitudinal depressions of highly variable depth and cross-sectional form. These may be cut into either bar platform or established floodplain deposits, with relief variation up to several metres. Many types exist in a hierarchy of forms. Most are cut-offs (i.e. large scale channels short-circuiting the path of the main flow. On point bars high energy chutes are found at the bar head, while low energy run-off channels occur at the bar tail. Swales refer to channel units between ridges at the floodplain margin. Finally, runnels are series of diagonally cutting small-scale features which notably disrupt bar surface morphology.	Both scale and morphology of chutes vary markedly by type and planform. In general this locale is up to 50m wide in the braided and wandering reaches, reflecting the shifting nature of channel position. Outlines are sinuous or irregular, and lengths highly variable (up to 150m across bars), often ending abruptly as these may be remnant forms. Bars in the wandering reach are characterized by many small-scale diagonally oriented runnels. In the meandering reach three types of chute are prevalent. High energy bar head chutes are the largest, their linear form often >100m in length and up to 50m in width. In contrast, lower energy bar tail run-off chutes are narrower (up to 25m) and longer (up to 200m). Finally, swales are narrow and deep, curved or irregular, discontinuous features, typically <20m wide.	Scoured by fluvial erosion and infilled in varying manner, contingent upon position, local environment and flood history.
Established floodplain	Extensive vegetated areas away from the main channel, with little surface relief.	The dominant locale in the meandering reach, occuring as extensive units marginal to ridge and swale topography. On bars studied in the braided and wandering reaches established floodplain sections are randomly preserved as irregularly shaped and sized units. Whereas some units are very small (<25m x 25m) and widely spaced, others are up to 150m wide and 200m long. As in the meandering reach, this locale is much larger and better developed away from the main channel, especially in wider areas of the valley.	Typically flood-related processes, with lower energy cycles reflecting the waxing and waning stages of floods and occasional higher energy sand sheet units. Different units may be found at depth as the channel laterally shifts.

Bars studied in the meandering reach exhibit a similar banded locale pattern to that demonstrated in the wandering reach, but in this case it adopts an arcuate form around the bend. Alternating locale patterns are not present other than in ridge and swale sequences; rather, a simple lateral zonation is found away from the main channel. There is considerably greater ordering than in the other planform types (Figure 7.1).

The locale scale represents a geomorphic approach to sediment analysis as there is a direct link to processes of sediment deposition and accumulation. Whereas processes are independent of planform or bar type, they are directly linked to the locale scale. However, several processes may be operative within one locale, resulting in overlap in sediment sequences between types. Platform units are derived from high energy within-channel flows, with occasional lower energy depositional units atop. Chute deposits are derived from infill of small-scale cut-off channels. The character of channel fill depends upon whether the chute shifts laterally or is abandoned. The former are systematically infilled initially by high energy units, with the proportion of lower energy deposits increasing up-sequence, whereas abandoned units may have an upwardly consistent low energy fill. The relative proportion of these mechanisms is contingent upon chute position and local environmental character. Ridge deposits accumulate from lateral accretion mechanisms associated with channel shifting and deposition from floods. Observations from a flood event in 1986 demonstrated the manner of lateral accretion upon ridges adjacent to the main channel (Figure 7.2). Finally, established floodplain deposits are made up of flood cycle and sand sheet deposits, although basal materials may be made up of coarser/higher energy units, reflecting former platform/channel positions.

These visually distinct field morphologic units are not necessarily variable in terms of facies type, composition and association, as principles of convergence may apply. However, differing scales and morphologies of locales may aid in their determination in environmental interpretation. Before assessing the sedimentologic response to this process differentiation by planform, the four locales are first summarized for the overall data set.

FIGURE 7.1 SCHEMATIC REPRESENTATION OF LOCALE ORGANIZATION

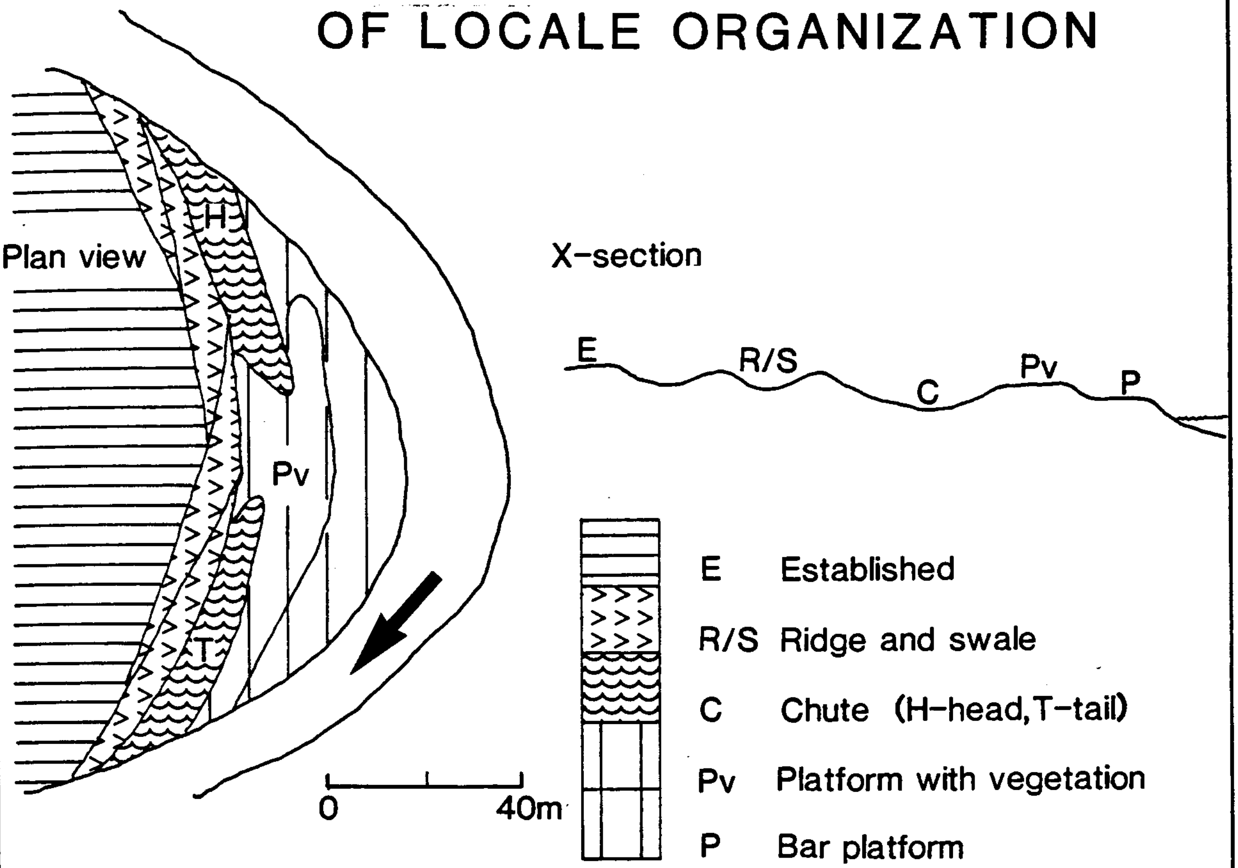
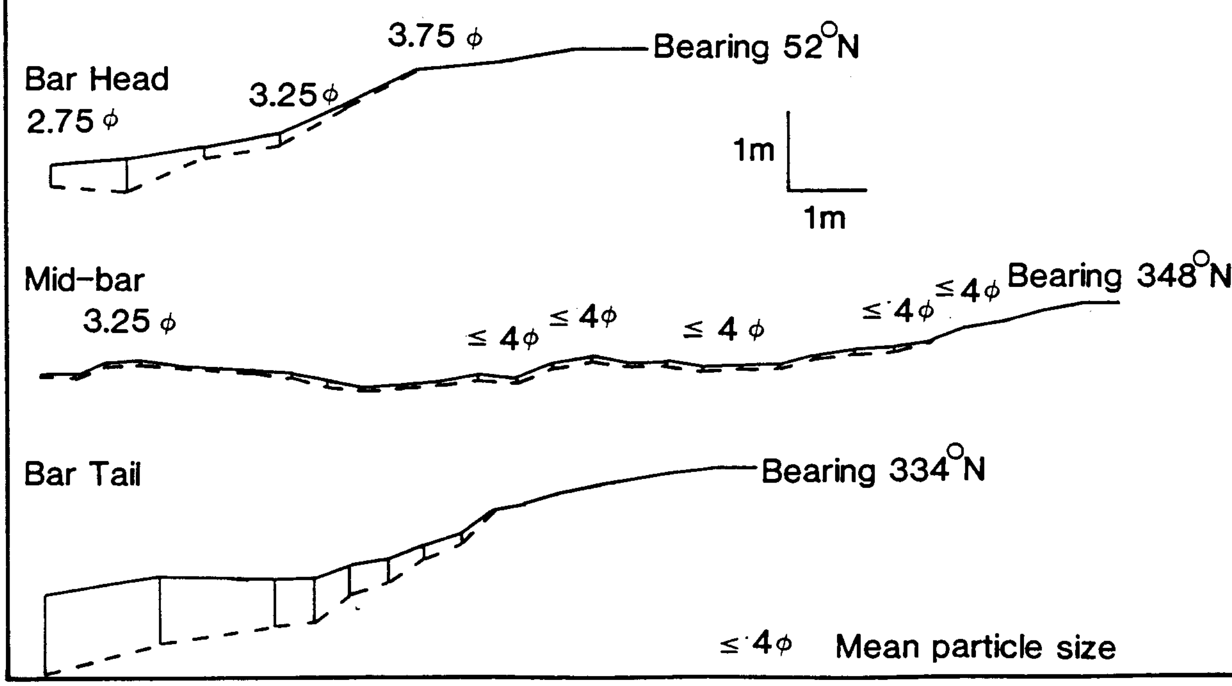


FIGURE 7.2 RIDGE ACCRECTION UPON UPPIL DURING JUNE 1986 FLOOD EVENT



7 : 2 : 1 Locale sedimentologic character

In order to assess the sedimentologic character of the four locale types, summary statistics were derived for each locale, for both the overall data set and by planform, and are evaluated along with diagrammatic representations of each bar (Figures 6.1 to 6.10). Chute, established floodplain and ridge locales are sedimentologically very similar, but all differ notably from the platform locale (Table 7.2). The proportion of high energy facies is >60% upon bar platforms, but as low as 39% in chute infill. Facies Fm occupies almost 10% of both the chute and established floodplain locales. Facies Sw and Sr are especially prevalent in the ridge and chute locales, occupying >50% of all observed sediments in both instances. Facies Ss and Sh are most prevalent in the established floodplain locale, but even here they occupy ≤20% of all sediments. The major compositional difference between platform deposits and the other locales is expressed in terms of the abundance of facies Sp and St, which occupy 52% of the platform locale (20% higher than elsewhere).

Observations noted for facies abundance by locale are influenced primarily by facies presence, as average bed thicknesses are consistent for all four locales. Facies Fm is found in >60% of chute, ridge and established floodplain holes (90% in the latter case), but only 28% of platform holes. Similarly, facies Sw is found in >70% of chute, ridge and established floodplain holes, but only 55% of platform holes. Facies O is observed twice as frequently in chute and ridge locales as elsewhere. In similar manner, facies Sr is present in >85% of chute and ridge holes, but only about 60% of established floodplain and platform holes. Facies Sw and Sh are most prevalent in the established floodplain locale, whereas facies Sp, St and Gm are more prevalent in the platform locale.

Preferred upward facies transitions are very similar for each locale. Facies Sw and/or facies Sr are dominant in virtually all instances except from facies G. Transitions from basal gravels are primarily to facies Ss in both the established floodplain and ridge locales, and either facies Sp or St in the chute and platform locales.

Mean particle sizes are remarkably consistent for lower energy facies (Fm, O, Sw and Sr) in each locale. The modal particle size group for facies Sw is 0.5ϕ finer than for facies Sr (3.0-3.5ϕ as opposed to 2.5-3.0ϕ) for each locale except platform deposits, where the modal group is 2.5-3.0ϕ for both facies. Facies Ss is 0.5ϕ coarser in the platform locale and facies Sh is 0.5ϕ finer in the

TABLE 7.2 SUMMARY STATISTICAL ANALYSIS OF THE 1985 LOCALE DATA SET

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
ESTABLISHED FLOODPLAIN							
Fm	43	10	90	6.7	Sw.49; Sr .35	3.5	2.2
O	8	1	24	3.1	Sw .57	3.2	2.5
Sw	58	24	79	12.4	Sw .30; Fm .23	2.9	2.3
Sr	40	16	59	11.8	Fm .31; Sr .31	2.8	2.4
Ss	33	11	69	10.0	Fm .45; Sw .26	2.4	2.6
Sh	9	7	24	24.8	Sw .22; Sr .22; Sh .22; Sp .22	2.7	2.5
Sp	25	20	34	24.4	Sp .38	2.2	2.6
St	16	12	34	22.4	St .42; Sw .25	2.4	2.8
Gm	0	0	0	-	-	-	-
G	20	-	69	-	Ss .45		
Number of holes 29		Overall mean particle size 2.65Ø			Upward particle size ratio 1 : 1.00		
CHUTE							
Fm	68	8	63	7.4	Sw .35; Sr .27	3.8	2.2
O	39	1	58	2.5	Sw .64; Sr .26	2.9	2.5
Sw	136	25	71	12.1	Sr .36; Sw .21	3.0	2.3
Sr	145	27	85	12.7	Sr .35; Sw .29	3.0	2.2
Ss	37	7	48	13.4	Sw .30; Sr .30; Fm .24	2.6	2.1
Sh	5	3	10	36.0	St .40; Fm .20; O .20; Ss .20	2.5	2.1
Sp	33	16	35	32.1	Sp .34; Sr .22	0.2	3.6
St	35	13	33	25.4	Sr .28; St .25	1.7	2.9
Gm	3	0	4	6.3	Sw .33; Sr .33; Sp .33	-1.0	4.0
G	34	-	65	-	Sp .29; St .20	-	-
Number of holes 52		Overall mean particle size 2.37Ø			Upward particle size ratio 1 : 0.75		
RIDGE							
Fm	106	4	62	5.2	Sr .38	3.5	2.2
O	73	2	46	2.6	Sw .63	3.1	2.2
Sw	219	22	78	12.9	Sr .34; O .23	2.9	2.4
Sr	245	30	92	15.7	Sr .34; Sw .28	2.8	2.5
Ss	64	8	52	15.9	Sw .30; Sr .25; Fm .21	2.3	2.3
Sh	30	5	22	20.4	Sh .24; Sp .24	2.0	2.7
Sp	86	19	53	29.2	Sp .25; Sr .22	1.6	2.9
St	53	10	34	23.5	Sr .29; Sw .22	1.9	3.0
Gm	7	1	8	19.3	Sw .71	-1.0	4.0
G	59	-	69	-	Ss .27	-	-
Number of holes 85		Overall mean particle size 2.42Ø			Upward particle size ratio 1 : 0.91		
PLATFORM							
Fm	56	2	28	5.5	Sw .32	3.6	2.3
O	53	1	26	2.6	Sw .59	2.9	2.2
Sw	185	18	55	13.1	Sw .31; Sr .23	2.9	2.4
Sr	174	17	66	13.1	Sr .29; Sw .23	2.6	2.5
Ss	50	5	31	13.8	Sr .28; Fm .21	2.0	2.5
Sh	24	3	14	17.4	Sw .24	2.5	2.2
Sp	163	34	69	28.7	Sp .40; Sr .22	1.0	2.9
St	79	18	47	30.5	Sr .37	0.8	3.2
Gm	14	2	9	18.1	Sr .21	-1.0	4.0
G	83	-	65	-	Sp .37; St .24		
Number of holes 127		Overall mean particle size 1.70Ø			Upward particle size ratio 1 : 0.72		

ridge locale. The modal particle size group for both these facies is 2.5-3.0ϕ other than for facies Ss in the established floodplain and platform locales (2.0-2.5ϕ). Particle size variability exhibited for facies Sp and St by locale can be attributed to the presence/absence of gravels within each data set. Facies Sp is considerably coarser in the chute and platform locales, representing high energy basal units. Similarly, facies St is much coarser upon bar platforms than elsewhere. Average facies sorting values are remarkably similar in each locale, although in the chute locale facies Ss and Sh are better sorted, while facies Sp is notably less well sorted than elsewhere. All facies are well sorted other than facies Sp and St (moderately well sorted).

The coarseness of high energy facies, which are considerably more abundant in the platform locale, result in mean particle sizes which are 0.75ϕ coarser in this locale than elsewhere. The other three locales demonstrate little overall particle size variability. Upward fining trends are more evident in the platform and chute locales. Facies organization, particle size and bed thickness are consistent in each locale, indicating that depositional mechanisms are operating in a similar manner. Facies abundance varies considerably, however, with the platform reflecting a much higher energy, coarser sand, depositional environment.

7 : 2 : 2 Sedimentologic variability of the established floodplain locale by planform

As the study at this stage focussed upon contemporary bars, the established floodplain was not analysed in the meandering reach; rather emphasis was placed upon exposed deposits adjacent to the main channel and only two holes within established floodplain units were examined. Hence, analysis of the established floodplain locale was restricted to holes dug in irregular remnant floodplain units upon within-channel bars of the braided and wandering reaches. The data exhibit considerable sedimentologic variability by planform in the established floodplain locale (Table 7.3). While the abundances of facies O, Sw, Sr, Sh and Gm are consistent, facies Fm and Ss are considerably more abundant in the braided reach. Facies Sp is very prominent in the established floodplain locale upon bars in the wandering reach, but seldom observed in the braided reach. This trend is reversed for facies St. This variability is expressed in terms of both facies presence by hole and average bed thicknesses. For example, facies Fm and Ss are found with equal thickness in the braided and wandering reaches, but are much more prevalent in the braided reach. In contrast, facies Sw is less prevalent in the wandering reach, but has twice the thickness of the braided reach

TABLE 7.3 SUMMARY STATISTICAL ANALYSIS OF THE 1985 ESTABLISHED FLOODPLAIN LOCALE DATA SET BY PLANFORM

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
BRAIDED							
Fm	28	13	94	6.8	Sw .36; Sr .32	3.4	2.2
O	3	0	18	2.0	Sw 1.00	3.4	2.3
Sw	36	22	88	8.8	Fm .27; Ss .23	2.8	2.6
Sr	18	15	53	12.1	Fm .31	2.7	2.4
Ss	28	19	88	10.2	Fm .48; Sw .32	2.3	2.6
Sh	5	7	29	20.0	Sw .40; Sr .40; Ss .20	2.8	2.3
Sp	4	8	12	23.0	Sw .50; Sp .50	2.6	2.7
St	10	17	41	24.2	Sp .43; Sw .29	2.5	2.7
Gm	0	0	0	-	-	-	-
G	15	-	88	-	Ss .47; Fm .20	-	-

Number of holes 17 Overall mean particle size 2.74Ø Upward particle size ratio 1 : 1.10

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
WANDERING							
Fm	11	5	80	6.8	Sw .46; Sr .36	3.7	2.2
O	5	1	40	3.8	Sw .40; Sr .20; Sp .20; St .20	3.1	2.5
Sw	16	21	60	18.3	Sw .36; O .21	2.7	2.1
Sr	18	14	60	11.1	Sr .56; Fm .25	2.9	2.4
Ss	6	4	40	10.0	Sr .40; Sp .40; Fm .20	2.4	2.3
Sh	4	9	20	30.8	Sh .50; Sp .50	2.5	2.8
Sp	20	36	70	25.0	Sp .38; Fm .25	2.1	2.8
St	6	8	30	19.3	St .40; O .20; Sw .20; Sp .20	2.0	2.8
Gm	0	0	0	-	-	-	-
G	3	-	30	-	Sr .67; Ss .33	-	-

Number of holes 10 Overall mean particle size 2.49Ø Upward particle size ratio 1 : 0.93

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
MEANDERING							
Fm	4	10	100	5.0	Sw .50; Sr .50	3.7	2.0
O	0	0	0	-	-	-	-
Sw	6	53	100	18.5	Sw .75; Fm .25	3.3	2.0
Sr	4	28	100	13.3	Fm .50; Sw .25; Sr .25	3.0	2.2
Ss	1	2	50	5.0	Fm 1.00	2.2	2.0
Sh	0	0	0	-	-	-	-
Sp	1	9	50	19.0	Sr 1.00	1.7	2.0
St	0	0	0	-	-	-	-
Gm	0	0	0	-	-	-	-
G	2	-	100	-	Ss .50; Sp .50	-	-

Number of holes 2 Overall mean particle size 3.08Ø Upward particle size ratio 1 : 0.71

(giving roughly equal abundances). The greatest variability is for facies Sp, which is found in ≥70% of holes dug in the established floodplain locale in the wandering reach, but only 12% of holes dug in the established floodplain locale in the braided reach (thicknesses are roughly equal).

Several factors may account for this variability. Only 30% of holes dug in the established floodplain locale in the wandering reach were in contact with basal gravels, so proportions of each facies may be highly misleading. In general, however, these holes were deeper than those observed in the braided reach. Secondly, from visual analysis of sediment patterns within the established floodplain locale there is much evidence for localized reworking of established floodplain sediment sequences. Vertical sequences exhibit abrupt transitions from high to lower energy facies, with according changes in particle sizes, indicating that the sedimentary record is incomplete. For example, holes dug in the established floodplain locale in an eroding bank adjacent to the main channel on Basbar are dominated by high energy facies deposited from sand sheets and are quite different from established floodplain sediment sequences observed elsewhere on the bar. Similarly, on Roadup, flood events have deposited several sheet-like units of facies Ss across the bar surface.

Observed sediment sequences in the established floodplain locale are quite different in the wandering reach. Upash has many more coarse sediment units than observed elsewhere, with facies Sp units prevalent, at various positions in vertical sequence. The established floodplain locales upon Tflent and Fallbar are disrupted by chute channels. Once more facies Sp is prevalent, but holes are dominated by lower energy facies. Sequences are primarily upward fining in terms of both energy of deposition and particle size. The two established floodplain locale holes examined in the meandering reach (on Dcamp) are upward fining wavy interbedded sequences with occasional facies Fm units.

Statistical summary of upward facies transitions indicates that there are pronounced differences between the braided and wandering reach established floodplain locales. Only for facies Fm are upward transitions actually consistent. Facies Fm and Sw are dominant upward facies transitions in the braided reach, whereas facies Sr and Sp are the preferred next-state facies in many instances in the wandering reach data set. In neither instance are transitions from framework gravels to either facies Sp or St; rather, facies Ss and Sr are the preferred upward transitions in the braided and wandering reach established floodplain locales respectively. In 20% of instances, upward transitions from basal gravels in the braided reach are to facies Fm. These findings reflect sediment reworking upon contemporary bars, producing extremely complex facies sequences.

There is little within-locale variability in average facies particle size by planform, although modal particle size groups are 0.5ϕ coarser for facies Sw, Sp and St in the wandering reach. Average facies sorting values are also very consistent by planform, the only variability being the better degree of sorting of facies Sw in the wandering reach. In virtually all instances, sediment sequences are dominated by moderately-well sorted medium fine sands, with little upward particle size variability. Sedimentologic character of the established floodplain locale is quite variable by planform, since a broad range of mechanisms have produced the subsurface sediments. Only at the surface are mechanisms of lower energy infill consistently applied.

7 : 2 : 3 Sedimentologic variability of the ridge locale by planform

Sedimentologic variability by planform of the ridge locale is considerably less than demonstrated for the established floodplain locale (Table 7.4). The abundances of each lower energy facies (Fm, O, Sw and Sr) are virtually identical in each planform reach to those of the overall ridge data set. In contrast, the proportions of facies Sp and St are notably lower in the braided reach, but are compensated for by the higher proportions of facies Ss and Sh. Variations are affected primarily by the facies presence by hole statistic, as average thicknesses for each facies vary little, other than the thicker facies O and Sh units in the braided reach (both are seldom observed). Facies St was only occasionally seen in the braided reach ridge locale. Facies Sp is notably more prevalent in the wandering reach. Finally, facies Fm and Gm are found more frequently and facies Ss less frequently in the meandering reach than elsewhere.

Upward facies transitions in the ridge locale exhibit consistent trends, indicating up-sequence reduction in energy of deposition in all three planform reaches. The only notable variability is upwards from basal gravels, which occurs primarily to facies Ss in the braided and wandering reaches and to facies Sp in the meandering reach. However, sequences in the ridge locale exhibit much less disrupted internal organization than shown in the established floodplain locale. Thinly interbedded lower energy facies are dominant in the braided reach. These are laterally discontinuous upon Basbar, and mixed with occasional high energy facies on Statbar. Particle size trends are upward coarsening in the braided reach, due to the high presence of facies Fm and Sw

TABLE 7.4 SUMMARY STATISTICAL ANALYSIS OF THE 1985 RIDGE LOCALE DATA SET BY PLANFORM

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
BRAIDED							
Fm	5	3	30	5.2	Sr .40; Ss .40; Sw .20	3.5	2.0
O	4	3	20	7.0	Sw 1.00	3.1	2.4
Sw	18	25	70	12.4	Sr .44	3.0	2.5
Sr	17	26	90	13.8	Sw .40; Sr .20; Sp .20	2.9	2.4
Ss	10	18	70	16.4	Sr .44; Fm .33; Sw .22	2.4	1.8
Sh	2	12	30	51.5	Sw 1.00	2.4	2.5
Sp	4	11	30	24.3	Ss .75; Sp .25	2.4	2.7
St	1	2	10	18.0	Sr 1.00	2.2	3.0
Gm	0	0	0	-	-	-	-
G	10	-	100	-	Ss .30; Fm .20; Sw .20	-	-

Number of holes 10 Overall mean particle size 2.74Ø Upward particle size ratio 1 : 1.19

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
WANDERING							
Fm	33	3	49	4.3	Sw .30; Sr .27	3.5	2.3
O	28	1	43	2.3	Sw .64	2.9	2.2
Sw	91	23	81	13.3	Sr .27; O .22	2.9	2.3
Sr	81	26	89	17.1	Sr .35; Sw .24	2.7	2.6
Ss	43	13	73	15.8	Sw .33; Fm .21	2.3	2.5
Sh	11	3	19	16.2	Sh .36; Sp .36	1.3	3.4
Sp	46	23	65	26.5	Sp .31; Sr .28; Sw .21	2.2	2.8
St	18	7	35	20.1	Sr .25; Sp .25	2.5	2.6
Gm	2	1	5	14.0	Sw 1.00	-1.0	4.0
G	24	-	65	-	Ss .44; Sw .20	-	-

Number of holes 37 Overall mean particle size 2.50Ø Upward particle size ratio 1 : 0.98

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
MEANDERING							
Fm	68	6	84	5.6	Sr .44	3.5	2.2
O	41	2	55	2.4	Sw .59	3.1	2.2
Sw	110	20	76	12.6	Sr .39; 0 .24	3.0	2.4
Sr	147	33	95	15.2	Sr .35; Sw .29	2.8	2.4
Ss	11	3	26	16.1	Sr .46; Sw .27	2.5	2.2
Sh	17	5	24	19.5	too spread	2.2	2.4
Sp	36	18	47	33.1	too spread	0.9	3.0
St	34	13	39	25.5	Sr .29; Sw .24	1.6	3.1
Gm	5	2	13	21.4	Sw .60; Sr .20; St .20	-1.0	4.0
G	25	-	66	-	Sp .28	-	-

Number of holes 38 Overall mean particle size 2.30Ø Upward particle size ratio 1 : 0.83

at the base of sequences, as both these facies are upwardly transitional from basal gravels in ≥20% of circumstances. In the wandering reach, ridges are characterized by thinly interbedded lower energy facies atop occasional high energy units, upwardly consistent with respect to particle size. Sequences on Upash are somewhat coarser, reflecting higher energy flows upon this mid-channel bar. In the meandering reach, sequences are also made up primarily of thinly interbedded lower energy facies. These are generally upwardly consistent on Dcamp and Pillbend, but some holes on Bigbar and Uppil are upward fining with respect to both particle size and energy of deposition. Ridge deposits on Pillbend tend to increase in depth around the bend.

Average facies particle sizes are very consistent for each reach other than the coarseness of facies Sh in the wandering reach and facies Sp and St in the meandering reach. In each planform reach the modal particle size class for facies Sr is 0.5ϕ coarser than for facies Sw. Modal groups for facies Sh, Sp and St are also consistent at either 2.0-2.5ϕ or 2.5-3.0ϕ, indicating that observed variability in average particle size is accounted for by the proportion of gravels in each unit. Average facies sorting values are extremely consistent by planform for lower energy facies, but vary by up to 1.0ϕ unit for high energy facies. Overall particle sizes for the ridge locale coarsen by 0.5ϕ in a downstream sense, from the braided to the meandering reach.

In summary, the sedimentologic make-up and internal organization of ridge locale deposits is relatively uniform, noted differences being accounted for by occasionally preserved coarse sand, high energy deposits. Observed sequences are less complex than noted in the established floodplain locale, as there is a much closer association to a specific depositional mechanism upon ridges.

7 : 2 : 4 Sedimentologic variability of the chute locale by planform

Summary statistics for chute locale deposits indicate pronounced variability between the three planform reaches (see Table 7.5). Although the ratio of lower:high energy facies is roughly consistent in each case (60:40), the make-up of these two components varies by planform. Facies Sw and Sr are roughly equally abundant in the braided reach, but facies Sw is the dominant lower energy facies in the wandering reach chutes and facies Sr dominates in chutes in the meandering reach bars. Facies Ss is the major high energy facies in the braided reach, facies Ss, Sh, Sp and St are equally spread in the wandering reach, and facies Sp and St are dominant in the meandering reach. These trends are accounted for by the variety of chute channel types, as indicated by

TABLE 7.5 SUMMARY STATISTICAL ANALYSIS OF THE 1985 CHUTE LOCALE DATA SET BY PLANFORM

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
BRAIDED							
Fm	9	8	38	7.1	Fm .43; Sw .43	3.8	2.0
O	2	1	15	2.0	Sw 1.00	2.7	3.0
Sw	14	22	54	11.9	Sr .36	3.0	2.5
Sr	13	25	77	14.7	Sw .29	3.0	2.4
Ss	10	19	46	14.5	Sw .40; Sr .40	2.6	2.3
Sh	1	3	15	21.0	Ss 1.00	2.7	3.0
Sp	3	8	15	19.0	Sr .33; Ss .33; Sp .33	1.4	3.0
St	8	15	31	14.4	St .50	2.2	2.7
Gm	0	0	0	-	-	-	-
G	11	-	85	-	Ss .30; Sr .20; Sp .20; St .20	-	-
Number of holes	13	Overall mean particle size 2.74Ø			Upward particle size ratio 1 : 0.72		
WANDERING							
Fm	23	4	75	3.4	Sw .30; Sr .26	3.7	2.4
O	14	3	58	3.8	Sw .64; Sr .29	2.7	2.7
Sw	50	39	83	15.0	Sw .36; Sr .29	3.0	2.2
Sr	38	23	92	11.8	Sw .32; Sr .29	2.7	2.4
Ss	13	7	58	9.6	Fm .46	2.8	2.2
Sh	2	7	17	62.0	Fm .50; O .50	2.4	2.0
Sp	5	10	42	36.4	O .20; Sw .20; Sr .20; Ss .20; Sp .20	0.8	3.1
St	4	8	25	37.3	Sw .50; Sr .50	2.7	2.5
Gm	0	0	0	-	-	-	-
G	6	-	50	-	Sw .33; Ss .33	-	-
Number of holes	12	Overall mean particle size 2.65Ø			Upward particle size ratio 1 : 0.95		
MEANDERING							
Fm	36	9	70	10.1	Sw .37; Sr .33	3.5	2.2
O	23	1	52	1.7	Sw .61; Sr .26	3.2	2.3
Sw	72	18	74	10.2	Sr .40; O .21	3.1	2.4
Sr	94	30	89	12.8	Sr .39; Sw .28	3.1	2.2
Ss	14	6	44	16.0	Sw .36; Sr .36	2.5	1.9
Sh	2	1	4	17.5	St 1.00	2.5	2.0
Sp	25	20	41	32.8	Sp .38; Sr .21	0.0	3.7
St	23	15	37	27.1	Sr .32; St .23	1.3	3.1
Gm	3	1	7	6.3	Sw .33; Sr .33; Sp .33	-1.0	4.0
G	17	-	63	-	Sp .39; St .28	-	-
Number of holes	27	Overall mean particle size 2.17Ø			Upward particle size ratio 1 : 0.67		

variability in both facies presence by hole and average bed thickness by planform.

In comparison to downstream reaches, facies Fm, O and Sp are found in half or less the number of holes in braided reach chutes. This simpler facies composition reflects the increased depths of chutes infills in bars downstream. Average facies bed thicknesses are more variable by planform in chutes than in any other locale, with many facies ranging in thickness by up to 300% between planforms. For example, facies Fm and Ss are notably thinner in the wandering reach than elsewhere, while facies O, Sw, Sh and St are notably thicker. Facies Sp and St units are considerably thinner in the braided reach.

Upward facies transitions in the chute locale vary notably by planform, although lower energy facies are the preferred next-state in all instances other than from basal gravels. A wide range of depositional conditions is evidenced in chutes upon bars in the braided reach. Chutes on Basbar are dominated by facies Sw, with thick facies Fm units in bar-tail run-off chutes. Conditions on Roadup are highly variable, with a mix of high and lower energy chute infill. Chute deposits on Statbar, however, are clearly high energy deposits made up largely of medium sand facies St and Sr units.

Chute units form a very prominent part of contemporary bar sediment sequences in the wandering reach. On Upash, chutes often have a very high energy coarse sediment infill, whereas the proportion of lower energy facies is much greater on Tflent and Fallbar, often with many thin facies Fm units. Only in the meandering planform are upward transitons from basal gravels clearly to high energy facies (Sp and St). There are two major chute units on point bars, with bar head chutes characterized by coarse, high energy facies (typically St) while tail chutes are made up of fine sand, lower energy units. Particle sizes within the major chute unit on Dcamp fine notably down-bar, the proportion of lower energy facies increasing in that direction. In both head and tail chute units, upward particle size trends are irregular.

Average facies particle sizes within the chute locale are consistent by planform in all instances other than the finer nature of facies O and the coarser nature of facies Sp and St in the meandering reach. The latter tendency reflects the higher proportion of gravels in this reach. In all cases, 0.5ϕ modal particle size groups for each facies vary at most by 0.5ϕ by planform. The previously discussed 0.5ϕ differentiation between facies Sw and Sr in flood cycle deposits is apparent in the braided and wandering data sets, but not in the meandering reach. Average facies sorting values are roughly equivalent by planform, but facies O and Ss are better sorted, and facies Sp and St less well sorted in the meandering reach. Overall mean particle sizes increase by $>0.5\phi$ from the braided to the wandering chute deposits. Whereas the braided and meandering sediment sequences are generally upward fining, wandering sediment sequences are upwardly consistent.

In summary, although summary statistics indicate that chute deposits are quite variable by planform, visual analysis of facies and particle size characteristics within chutes by bar position indicates that several types of chute can be distinguished. Of primary significance is the distinction between bar head and tail chutes in the meandering reach, which are characterized by high and lower energy fills respectively. As such, observed sedimentologic variability in this locale is more a function of chute type than planform type.

7 : 2 : 5 Sedimentologic variability of the platform locale by planform

Sedimentologic conditions in the platform locale are quite different to those described for the other three locales. In all three planform reaches, the proportion of high energy facies is greater than the proportion of lower energy facies. This effect is especially pronounced upon bars in the meandering reach, where the ratio of high:lower energy facies is 75:25 (see Table 7.6). The sedimentologic make-up of bar platform deposits is quite similar in the braided and wandering reaches, but the abundances of facies Sw and Sr are lower, and facies Sp and St greater, in the meandering reach.

The variation in facies abundance among the meandering and other planforms is explained primarily by facies presence/absence by hole, although facies Fm, Sr and St also are considerably thicker than usual within meandering reach platform deposits. While facies Fm and Sr are observed less frequently in meandering reach platform holes than elsewhere, facies St is more prevalent (being found in almost 60% of holes), and is more abundant in this locale than under any other field condition. Differences between braided and wandering bar platform locale deposits are particularly apparent for facies Fm and St, which are considerably thicker in the braided reach. Other facies vary notably in presence by hole between these two planforms, but this effect is compensated for by the differing average facies thicknesses. For example, facies Sw is found twice as frequently in the wandering reach, but has half the average thickness of units observed in the braided reach.

TABLE 7.6 SUMMARY STATISTICAL ANALYSIS OF THE 1985 PLATFORM LOCALE DATA SET BY PLANFORM

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
BRAIDED							
Fm	20	5	39	6.5	Sr .26; Sw .21; Ss .21	3.6	2.4
O	4	0	8	1.8	Sw .75; Ss .25	3.2	3.0
Sw	28	21	44	20.0	Sr .31	3.1	2.6
Sr	37	17	64	12.2	Sr .44; Fm .22; Sw .22	2.8	2.5
Ss	11	5	28	11.2	Fm .38; Sp .25	1.8	2.7
Sh	2	3	6	42.0	Sw .50; St .50	2.2	2.0
Sp	28	31	58	29.0	Sr .29; Sp .25; St .21	0.2	3.4
St	18	15	42	22.6	Sr .35	0.8	3.4
Gm	8	2	14	10.7	Sw .33; Sr .33	-1.0	4.0
G	29	-	81	-	Sp .47; Fm .23	-	-

Number of holes 36 Overall mean particle size 1.60Ø Upward particle size ratio 1 : 0.87

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
WANDERING							
Fm	31	2	44	3.8	Sw .39	3.5	2.4
O	38	2	59	2.5	Sw .66	2.9	2.2
Sw	123	23	82	10.8	Sw .34; Sr .23	2.8	2.4
Sr	102	21	95	12.1	Sr .32; Sw .22	2.8	2.6
Ss	31	8	54	14.7	Sr .28	2.3	2.5
Sh	15	5	26	17.3	O .25; Sw .25	2.9	2.3
Sp	58	30	74	29.4	Sp .29; Sr .25	1.4	2.9
St	23	7	38	17.6	Sr .39	2.1	2.8
Gm	7	3	15	24.1	Sp .29	-1.0	4.0
G	20	-	51	-	Sp .30; Ss .25; Sr .20	-	-

Number of holes 39 Overall mean particle size 2.18Ø Upward particle size ratio 1 : 0.77

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Upward facies transitions found in ≥20% of occurrences	Mean particle size (Ø units)	Mean sorting value
MEANDERING							
Fm	5	1	10	12.0	St .75; Sw .25	3.9	2.0
O	11	1	13	3.3	Sp .55; Sw .27	2.5	2.0
Sw	34	10	42	15.7	Sp .24	2.7	2.5
Sr	35	12	46	17.1	Sw .32	2.8	2.4
Ss	8	2	15	14.0	Sr .50	1.2	2.5
Sh	7	1	12	10.7	Fm .33; Sp .33; St .33	1.3	2.1
Sp	77	42	52	28.0	Sp .55	0.9	2.8
St	38	31	58	42.2	Sr .36; Sw .29	0.5	3.2
Gm	1	0	2	20.0	St 1.00	-1.0	4.0
G	34	-	65	-	St .48; Sp .32	-	-

Number of holes 52 Overall mean particle size 1.21Ø Upward particle size ratio 1 : 0.67

Upward facies transitions in the platform locale are very inconsistent by planform. Irregularly interbedded high and lower energy facies sequences, indicating a range of scour flow conditions and random preservation of units, are found in the meandering platform locale. Wandering reach platform holes are more regular in trend. In the braided reach basal gravels are transitional upwards to facies Fm in 23% of instances, reflecting sediment reworking and replacement.

Platform deposits in all three planform reaches are made up primarily of coarse sand, high energy facies in irregular upward sequences. Whereas the bars studied in the braided reach exhibit little internal organization in the platform locale, there is some within-locale zonation of facies and particle size characteristics upon bars in the wandering and meandering reaches. Upash and Fallbar both exhibit down-bar coarsening within recent longitudinally accreted platform units. Some zones are characterized by upward fining sequences, while others have coarse units in mid-sequence. In contrast, platform holes on Tflent have relatively few high energy facies. Platform deposits upon point bars exhibit clear patterning around each bend, with head, mid-bar and tail locales. The tail unit is notably finer. Whereas platforms on Bigbar and Uppil are made up largely of facies Sp units, facies St predominates on Dcamp and Pillbend. Sediment sequences typically fine upwards.

Average facies particle sizes of lower energy facies are fairly consistent for each planform, but quite variable for high energy facies. The modal 0.5ϕ particle size groups for facies Sw is $2.5\text{-}3.0\phi$ for each planform, the same as for facies Sr (i.e. the distinct particle size cyclicity is not apparent). Facies Ss and Sh are coarser in the meandering reach, facies Sp coarser in the braided reach and facies St coarser in the braided and meandering reaches, reflecting the variable proportions of fine gravels observed for each facies. Overall mean particle size is notably finer in the wandering reach, as fewer holes were dug in open platform deposits in this reach. In all instances, upward particle size ratios are clearly indicative of upward fining conditions.

In summary, the platform locale is consistently coarser and made up of higher energy facies than observed for other locales. Although all three planform reaches are similar in this regard, the wandering and meandering reaches exhibit much clearer within-locale spatial patterning of facies associations.

7 : 3 Summary of locale sedimentologic variability by planform

The sedimentology, abundance and spatial association of the four locale types are assessed by planform in Table 7.7. Platform deposits predominate upon bars in the braided reach. These are primarily gravel and sand plateaux, with isolated remnants of established floodplain units upon within-channel bars and larger remnants against the valley walls. Mid-channel bars are heavily dissected by chute channels of differing magnitudes, with many discontinuous ridges. Locale spatial associations are generally haphazard upon Basbar and Roadup, but are much more regular upon Statbar. In the latter case, conditions are transitional with the wandering reach bars, as locales are oriented linearly down-bar.

Locale spatial organization is much more ordered in the wandering reach. The established floodplain locale is much more prevalent, as the channel switches from one side of the valley to the other, with large floodplain segments within these loops. Within-channel and bank-attached bars are characterized by large platform areas reflecting recent accretional units. Over time these have been reworked and dissected by chute channels, resulting in discontinuous marginal ridge and established floodplain locales. These typically are oriented either in parallel fashion with the main channel or diagonally adjacent to major chutes.

In the meandering reach, the single channel of the Squamish River is presently located against the western valley wall, resulting in 2km of laterally continuous established floodplain. Other than a large former channel adjacent to the eastern valley wall, there is little evidence of contemporary reworking of these sediments. In zones of recent sediment accumulation upon point bars, locales are differentiated in curvilinear manner around the bend (Figure 7.1), indicative of sediment reworking by secondary chutes. Discontinuous ridge and swale deposits are found at the floodplain/bar margin; these become relatively indistinct away from the main channel due to flood-related infilling mechanisms.

Facies composition and particle size characteristics of the established floodplain, ridge and chute locales are very similar in the overall data set. In turn, these are quite different from the bar platform deposits, which are considerably coarser and have a far larger proportion of high energy facies. However, internal facies organization is relatively consistent by locale.

TABLE 7.7 SUMMARY OF LOCALE SEDIMENTOLOGIC VARIABILITY BY PLANFORM

Planform	Locale abundance	Locale spatial association	Locale sedimentologic characteristics Established floodplain	Ridge	Chute	Platform
BRAIDED	Valley width roughly equally divided between channel and bar units and extensive established floodplain units at valley margins. Platform locales dominate bars, with dissected remnants of other locales.	Haphazard, with irregularly oriented and sized chutes dissecting platform units. More regular linear pattern noted on Statbar.	Many abrupt facies transitions from high to lower energy facies and vice versa. Evidence of fluvial reworking at the base of sequences and some coarse sand sheet units atop (e.g. Basbar and Roadup) giving very irregular vertical sequences.	Typically upward fining, but notable lateral inconsistency on Basbar and irregular mixing of facies on Statbar.	Much evidence of reworking. Sequences are not clearly upward fining. Adjacent holes are often both very simple, but compositionally very different. Chutes on Statbar are notably coarser.	Largely high energy facies; upward fining with respect to particle size but a variable mix of facies; massive fines frequently are found as a basal facies.
WANDERING GRAVEL-BED	Established floodplain occupies about 2/3 of valley width. Within-channel zone has large platform units upon expansive mid-channel and bank-attached bars. Large tracts of these bars have been reworked by chutes, producing discontinuous ridge and established floodplain units.	Distinct parallel linear locale pattern oriented down-bar or diagonally, associated with local shifting chute pattern.	Sequences tend to be upward fining, although facies Sr is the preferred basal facies (indicating much reworking). Facies Sp is found in 70% of holes. Units are thicker and coarser on Upash, but much finer and more thinly interbedded on Tlient and Fallbar.	Upwardly consistent particle sizes, but vertical sequences indicate upward reduction in energy of deposition, with thinly interbedded, lower energy facies atop sand wave units (facies Sp).	Deeper holes than in the braided reach and sedimentologically much more complex, with a wide range of basal facies. Chutes on Upash are filled predominantly by high energy units with troughs at the surface whereas Tlient and Fallbar have thinly interbedded lower energy infill sequences following abandonment.	Upward fining with respect to particle size. Proportion of high energy facies is considerably greater than lower energy facies. Laterally consistent high energy facies on Upash, with notably upward fining trends. Recently accreted units coarsen down-bar.
MEANDERING	Over 80% of valley width is made up of established floodplain deposits. Bars are bank-attached, with discontinuous ridge and swale units prominent at the floodplain margin and chutes cutting across extensive bar platform deposits adjacent to the main channel.	Curvilinear pattern of locales around point bar, associated with bend migration (see Figure 7.1).	Only two holes - these are upward fining wavy interbedded units with occasional massive fine units.	Upwardly consistent lower energy facies on Dcamp and Pillbend, but upward fining with respect to both facies type and particle size on Bigbar and Uppil.	Wide range of types reflecting differing chute positions upon the bar. Bar head chutes have complex intermingled sequences of high and lower energy facies, with lower energy facies at the base on Dcamp and high energy facies at the surface on Bigbar indicating much sediment reworking. Chutes on Pillbend are infilled with lower energy deposits, yet are adjacent to high energy platform sands. Bar tail chutes typically have lower energy facies - on Bigbar a thick amorphous massive fill has accumulated. Sediments in the major chute on Dcamp fine notably down-chute.	Made up of 75% high energy facies. Facies Sp dominates on Bigbar and Uppil, whereas facies St is dominant on Dcamp and Pillbend. Sequences are upward fining with respect to particle size. Point bars exhibit zonation around the bend. Head units are upward fining with respect to particle size and facies type. Mid-bar units are dominated by facies Sp and St, while bar tail deposits are made up of fine sand lower energy facies. Bar platform deposits on Uppil, a lateral bar, are upwardly consistent medium-coarse sand high energy facies.

As deposition upon ridges is tied to a specific geomorphic process (Figure 7.2), their composition and character are fairly consistent by planform. Similarly, the character of bar platform deposits varies little by planform, with coarse sand, high energy facies dominant. These sequences typically are upward fining, with either trough or planar cross-bedded basal units. The wide range of chute types, and their different locations upon bars, results in their variable sedimentologic character. The nature of their alluvial fill depends also upon the manner of channel shifting or abandonment. As such, a suite of chute-style deposits can be determined, with lower energy fill (e.g. Tflent, Fallbar), upward fining fill (e.g. Pillbend), or complex intermingled sequences (e.g. braided bars, Dcamp, Bigbar). In all instances there is much evidence of sediment reworking; the end product merely reflects the local sequence of flow events.

In the established floodplain locale, contemporary processes infill existing relief, as vegetation traps lower energy suspended load from floods, whereas subsurface sediments have been deposited by a wide range of processes, resulting in little consistency of composition by bar or planform in established floodplain locale deposits. In both the braided and wandering planforms, established floodplain locale deposits show much evidence of reworking (Table 7.7), with highly irregular vertical sequences in the braided reach, and upward fining sequences in the wandering reach (with much sedimentologic variability between bars).

7 : 4 Sedimentologic differentiation of contemporary bar deposits by planform

Analysis of contemporary bar sediments for three different planform reaches of the Squamish River has shown that sedimentologic differentiation of deposits by planform cannot be made from analysis of internal facies organization, summary facies statistics, or locale composition. River planform facies models are conceptually compelling as they synthesize complex data sets into simple norms, thereby providing excellent teaching guides and bases for comparison. However, Markov analysis of one-dimensional data sets is very misleading. Similarly, summary sedimentologic statistics evaluated by planform are largely meaningless, as they mask notable between-bar variability. This is apparent in terms of both facies abundance (lower energy facies making up 61% of holes on Fallbar but only 30% on Uppil) and within-bar sediment patterns. However, sediment trends at the channel bar scale are not consistent with trends observed elsewhere (Table 6.14); rather, they conform to field morphologic units, referred to as locales.

It is evident from these findings that three-dimensional approaches to sedimentology provide far greater insight into environment of deposition. Locale analysis provides an alternative form of architectural element analysis, in that locales are field morphologic units defined by geomorphic phenomena. They are applied at a smaller scale than units envisaged by Miall (1985, 1987). The abundance and spatial patterning of locales varies notably by planform. For example, whereas braided depositional environments are dominated by platform locales, with haphazard spatial associations of other locales, meandering depositional environments are characterized primarily by established floodplain locales, with well-defined spatial associations of other locales in curvilinear fashion around bends.

Each hole in the 1985 data set represents conditions within one particular locale type. However, in accordance with Walther's dictum, those locales found in horizontal juxtaposition should be found superimposed upon each other in vertical sequence, given unidirectional channel migration and preservation of all units. Given the differing abundances and spatial associations of locale by planform, sedimentologic differentiation of planforms can be predicted at this scale, contingent upon the sedimentologic distinctiveness of individual features. In order to evaluate this principle, the lateral continuity of sediment units and their three-dimensional configuration needs to be assessed. Planform sedimentologic analysis at the locale (element) scale is carried out in part C of the thesis.

PART C

SEDIMENTOLOGIC ANALYSIS AT THE ELEMENT SCALE

CHAPTER VIII

TRENCH ANALYSIS OF LATERAL SEDIMENTOLOGIC VARIABILITY

8 : 1 : 1 Introduction

Part C of the thesis examines the utility of broader scale sediment units (elements) in differentiating between river depositional sequences. Emphasis is placed upon the scale, morphology, position and compositional character of elements, and how these components vary with planform in the study reach. The lateral continuity of facies units and elements are assessed by trench analysis in chapter 8. The longitudinal aspect and downstream continuity of elements are analysed for bank exposures in chapter 9.

8 : 1 : 2 Introduction to element analysis

Analysis of the 1985 data set showed sediment sequences upon contemporary river bars of the Squamish River to exhibit pronounced lateral facies discontinuity, regardless of planform type. This results largely from reworking of sediments by chute channels. Sediment sequences relate much more closely to field morphologic units (locales).

Locale analysis cannot be applied directly to the 1986 data set. Sediment sequences are examined in trenches dug at the contemporary bar/established floodplain margin. In these better developed (older), depositional environments, locale deposits are stacked in vertical sequence. Hence, an alternative, broad scale sediment classification scheme was developed (see Table 4.7). The 'established floodplain locale' concept was abandoned, and reference made to the formative mechanisms of vertical accretion. These mechanisms produce laterally and longitudinally extensive suites of deposits at, or close to, the floodplain surface, namely flood cycle deposits and sand sheets. Six "elements" have been defined, each of which relates to a specific geomorphic process : channel framework gravels, bar platform deposits, chute deposits, ridge deposits, flood cycle deposits, and sand sheet deposits.

Channel framework gravels are basal deposits which, for practical reasons, are not examined in this study. Bar platform sediments are within-channel deposits, located immediately above framework gravels in vertical sequence. As described in chapter 7, they are composed primarily of coarse sand, high energy facies, regardless of either bar type or channel planform, and vary significantly from other locale deposits.

Chute deposits exhibit a wide range of sediment types dependent upon their location and the manner of channel migration. Ridge deposits are marginal to chutes and bar platforms, and result from a mix of within channel and overbank mechanisms associated with accretion on the inner bank as bends migrate (see Figure 7.2). Flood cycle deposits are suites of overbank (lower-energy flood related) sediments. Higher energy overbank deposits, in which coarser, loose sands are washed and dispersed onto floodplain surfaces in sheets during flood events, are termed sand sheet deposits.

To examine the differing scale, character and spatial relationships between these elements nine trenches were dug at the contemporary bar/established floodplain margin in differing environmental settings (Table 4.10). In trenching analysis, elements were outlined and the lateral continuity of individual facies units assessed by analysis at sampling points 1-3m apart, both within and between elements.

Prior to analysing the sediment character of each trench, summary statistics for the 1986 data set are compared with those for the 1985 data set (section 8.2). The sedimentology of locales and elements are compared. Secondly, statistical measures and visual representations are used to examine facies, particle size and element characteristics for each trench (section 8.3). Analyses from each trench are compared in section 8.4, both down-valley and by planform. Finally, the value of geomorphologically-derived elements is assessed in section 8.5, and a summary model of element association is proposed from the Squamish River data.

8 : 2 : 1 Summary statistical analysis of the 1986 data set

Facies composition, abundance and character for all 1986 trench data are summarized in Table 8.1. Trenches are composed primarily of lower energy facies, with facies Fm, O, Sw and Sr combined occupying 65% of all trenches. Facies Sw is especially abundant, being observed in virtually 90% of all analysis points and taking up almost 40% of all trenches. Facies Sw and Sr are roughly of equal average thickness (20cm), whereas facies Fm averages less than 10cm thick and facies O occurs in thin litter layers ($\leq$ 2cm).

TABLE 8.1 SUMMARY STATISTICAL ANALYSIS OF THE 1986 TRENCH DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	136	9	70	8.2	3.5	2.1	40% H, 36% U, 22% I.G.	63% Dk3, 21% Dk4	Sw .45 Sr .32	74% S 83% S	39% Tt, 21% W 29% Tt
O	52	1	36	1.9	3.0	2.3	96% H	81% Dk4	Sr .44 Sw .34	91% S 59% S	59% W 71%Tt
Sw	226	37	87	20.6	2.9	2.5	66% H, 32% I.G.	33% Dk3, 24% Lt, 23% Lt/Dk	Sw .38 Fm .25	58% S 82% S	37% Tf, 25% Tt, 21% I 56% Tt
Sr	119	18	64	18.9	2.7	2.5	51% H, 43% I.G.	66% Lt	Fm .39	97% S	40% Tt, 20% E
Ss	31	2	29	7.7	1.9	2.6	65% U	81% Lt	Sw .32 Fm .29	50% S 100% S	40%Tt, 30% Tf 44% I, 22% E, 22% Tt
Sh	11	3	13	29.5	1.8	2.9	64% I.G., 27% H	64% Lt, 27% Dk2	Fm .64	100% S	71% E
Sp	30	10	25	40.4	1.6	2.9	35% H, 31% I.G.	78% Lt	Sw .31 Sr .21	56% S 50% S	67% Tt 50% Tf
St	64	16	48	34.0	0.6	3.6	76% I.G.	97% Lt	Sw .37 Fm .32	68% S 100% S	41% Tt 26% W, 26% Tt, 21% I, 21% Tf
Gm	19	3	22	20.9	26.3	-	-	-	Sw .63 Fm .21	83% S 100% S	33% E, 33% Tt 50% E, 50% W
G	81	-	98	-	71.4	-	-	-	St .26	75% S	70% I

Number of analysis points 83 Overall mean particle size 2.28Ø Upward particle size ratio 1 : 0.80 (*8) Sr L = 10, D = 3; St W = 69, D = 17

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Tt = tilts towards *the main channel*, Tf = *tilts away from the main channel*, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

Of the high energy facies, facies St is most prevalent, being found in almost 50% of analysis points, taking up almost 20% of all trenches. Facies Sp units typically are thicker (averaging over 40cm), but are notably less abundant. Facies Gm and Sh each occupy only 3% of all trenches, the greater presence of facies Gm being countered by the greater average thickness of facies Sh. Finally, facies Ss occurs in almost 30% of all sample locations, characteristically occurring in thinly bedded sequences (averaging $\leq$8cm).

The distinction between lower and high energy facies is evidenced clearly by their average particle size, mean sorting value, sediment mix and color characteristics. Lower energy facies are notably finer and better sorted than high energy facies. The modal particle size group for facies Sw, Sr and O is 2.5-3.0ϕ (facies Fm is 0.5ϕ finer), whereas average particle sizes for high energy facies are roughly 1.0ϕ coarser. As observed in the 1985 data set, however, facies Sw is slightly finer than facies Sr. Typically, lower energy facies are heterogenously mixed, dark brown sediments, whereas high energy facies are light brown, internally graded sediment sequences. Facies organization in trenches indicate up-sequence reduction in energy of deposition, in which facies Sw, Fm and Sr dominate as preferred next-states. Accordingly, particle size trends generally are upward fining. In all instances, basal contacts are predominantly sharply defined, with a wide range of outlines.

Trenches studied are made up primarily of ridge and chute deposits in equal proportions (making up 55% of sediment sequences combined; Table 8.2). Platform sands occupy almost 20% of trench sequences, whereas overbank depositional mechanisms (flood cycle and sand sheet deposits) account for 25% of exposures. Each of these overbank units is not observed in three of the nine trenches dug. Platform and chute deposits each are missing in one trench, but ridge and framework gravels are observed within each trench. Platform, ridge and chute deposits have roughly equivalent average thicknesses (about 0.6m), whereas flood cycle and sand sheet units are notably thinner ($\leq$0.35m).

Platform sand deposits are considerably coarser and less well sorted than the other elements. Ridge and flood cycle deposits have modal particle size groups of 3.0-3.5ϕ, while sand sheets are 0.5ϕ coarser. In contrast, the average particle size value for chute deposits is almost 1.0ϕ coarser, and the particle size distribution is evenly spread among the 0.5ϕ particle size groups. Average sorting values for these four elements are fairly consistent. Within-element particle size trends are

TABLE 8.2 SUMMARY STATISTICAL ANALYSIS OF THE 1986 TRENCH DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	%Presence by trench	Average Element thickness (in cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	52	14	67	34.5	2.9	2.4	1 : 0.90	59% H, 33% I.G.	31% Dk3, 28% Lt	10	3	-	-	SS .64 CHUTE .22	61% S 88% S	52% I, 35% W 38% Tt, 25% E, 25% I
SS	45	12	67	31.8	2.7	2.6	1: 1.0	61% H, 32% I.G.	69% Lt	12	3	42	11	FC .54 RIDGE .31	100% S 75% S	36% I, 21% W, 21% Tf 38% Tt, 25% W, 25% Tf
RIDGE	55	28	100	64.0	2.8	2.5	1 : 0.7	53% H, 32% I.G.	42% Dk3, 24% Lt	8	2	43	10	CHUTE .44 FC .28 SS .28	100% S 100% S 60% S	63% Tt 40% Tt, 40% Tf, 20% E 40% I, 40% Tt, 20% W
CHUTE	55	27	89	60.3	2.0	2.8	1 : 1.0	40% H, 34% I.G.	40% Lt, 33% Dk3	8	2	70	18	FC .36 RIDGE .34	94% S 53% S	36% W, 25% I, 25% Tt 40% Tt, 40% Tf
PLAT	42	19	89	57.3	1.1	3.3	1 : 0.5	46% I.G., 32% H	65% Lt	8	2	91	21	RIDGE .31 CHUTE .31 SS .21	69% S 54% S 67% S	62% Tt, 23% E 31% W, 31% Tt 33% I, 33% Tt
GRAVELS	81	-	100	-	-	-	-	-	-	-	-	-	-	PLAT .46 CHUTE .25	50% S 80% S	53% I 35% I, 20% W, 20% Tt

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.3 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR THE 1986 TRENCH DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands Abundance	Platform sands Upward transitions ≥ 20%
Fm	24	Sw .48, Sr .38	0	-	8	Sw .65, Sr .35	11	Sw .37, Sr .30	2	St .67
O	2	Fm .33, Sr .33, Sw .22	1	Sr 1.00	1	Sw .70, Fm .20	1	Sw .46, Sr .23	0	-
Sw	33	Fm .52	34	Sw 1.00	61	Sw .54, Fm .21	30	Sw .42	19	Fm .40, Sw .20
Sr	32	Fm .47, Sw .24, Sr .24	40	O .92	18	Fm .71, Sr .24	11	Fm .44	5	Fm .50, St .50
Ss	1	Fm 1.00	2	-	1	Sw .40, O .20, Sp .20, St .20	3	Sw .60	3	Sp .50, St .50
Sh	9	Fm .86	-	-	1	Fm 1.00	3	St 1.00	1	-
Sp	-	-	0	-	5	Sw .25, Sr .25, Ss .25, Gm .25	14	Fm .20, Sr .20, Sp .20, St .20	25	Sw .50
St	-	-	24	-	6	Fm .29, Sw .29, Sr .29	26	Fm .30, Sw .30, St .20	32	St .50, Sw .33
Gm	-	-	-	-	1	Ss 1.00	2	Sw 1.00	13	Sw .60, Sr .20, Sp .20

clearly upward-fining in platform and ridge elements. This effect is considerably less pronounced in other elements.

Sediment mixes are predominantly heterogenous within all elements except platform deposits (where sequences characteristically are internally graded). Within-channel deposits (i.e. platform sands and chute elements) are primarily light-brown sands, as are the vertically accreted, sand sheet units. In contrast, ridge and flood cycle deposits are darker brown sediment sequences. Larger than average trough dimensions are found in the platform and chute elements, whereas ripple marks are larger in the sand sheet element than elsewhere.

Platform and chute sands are found above the framework gravels, transitional upwards to ridge, chute and sand sheet deposits in roughly equal abundance. Chute and ridge deposits are marginal features, and both grade upwards to flood cycle deposits, with sand sheet units atop. In all instances, basal contacts between elements are sharply defined, but shapes of surfaces vary markedly. Contacts to and from ridge and chute deposits are predominantly tilted, while contacts to and from other elements are not characterized by any particular shape. One exception to this is the irregular nature of surface contacts above the channel gravel element.

Over 90% of flood cycle deposits are made up of alternating sequences of facies Sw, Sr and Fm, with occasional Sh, O and Ss units (Table 8.3). Lower energy facies also make up 75% of sand sheet deposits. There are very few upward facies transitions, as each unit is made up of one or two facies types (especially facies Sr, Sw and St). In both ridge and chute elements, upward transitions from facies Sp and St are spread among three or four options, suggesting that there is little consistency in the specific pathway of upward facies association. Lower energy facies predominate in the ridge element, making up 75% of these deposits (facies Sw alone accounts for 61%). In chutes, upward facies transitions from high to lower energy facies are quite spread among facies types, with lower and high energy facies in equal abundance. Facies Sw, Sr and Fm predominate as the preferred next-facies state. Upward facies transitions within the bar platform element are much more irregular than demonstrated elsewhere, with transitions from high to lower energy facies and vice versa. Lower energy facies are considerably less abundant than elsewhere, occupying 26% of platform sands. A characteristic vertical facies sequence cannot be defined.

8 : 2 : 2 Interpretation of 1986 data set summary statistics and comparison with the 1985 data set

Several differences are apparent between the hole and trench data sets (compare Tables 5.5 and 8.1). The proportion of lower energy facies is significantly greater in the trench data set, as trenches were dug at the bar/floodplain margin, typically among ridges and chutes away from the main channel. The proportion of Sw is considerably greater in trenches, whereas the proportion of facies Sr is notably reduced. This reflects relative energy of deposition, as bar marginal areas experience a greater proportion of waning flood flow depositional conditions. The proportion of facies St is greater and facies Sp smaller in the 1986 data set. Facies Sp were observed primarily upon bar platforms in the 1985 data set. These deposits are not preserved in trenches, as chute channels rework sediments, redepositing a series of facies St units and lower energy depositional sequences away from the main channel.

Average bed thicknesses are similar for the two data sets, although facies Sw and Sp have thicker beds in the 1986 data set, whereas facies Ss beds are thinner. Particle size and sorting characteristics are virtually identical for lower energy facies in the hole and trench data sets. Facies St, Ss and Sh are 0.5ϕ coarser in the 1986 data set (on average), whereas facies Sp units are 0.7ϕ finer. These differences are misleading, however, as 0.5ϕ particle size modal groups are very similar for the two data sets, and average values are offset by the variable proportions of samples in the fine gravels class. Facies Sh and Sp are also less well sorted in the trench data set, possibly reflecting disruption by vegetation during deposition. The overall mean particle size is 0.12ϕ finer for the 1986 data set, reflecting these lower energy depositional conditions. Upward particle size ratios are consistent, indicating upwardly fining sediment sequences in both data sets.

Internal facies organization is indicative of up-sequence reduction in energy of deposition in both the hole and trench data sets, the only apparent difference being the increased frequency of upward transitions to facies Fm from high energy facies in the trench data. This indicates that sediment sequences at bar margins are more prone to alternating sequences of high and lower energy depositional units than is the case upon contemporary bar platforms.

In summary, facies and particle size characteristics, and their organization, are similar for the hole and trench data. In both cases, sequences are primarily upward fining with respect to energy of deposition, with upward transitions from gravels to high energy facies and lower energy facies atop. In neither case, however, are specific up-sequence pathways apparent at the individual facies scale; rather, complex intermingling of facies types is dominant, with lower energy facies more prevalent in the trench data set. These differences are explained by the location of trench samples at the bar/floodplain margin as opposed to upon the contemporary bar platform.

8 : 2 : 3 Comparison of 1985 locale analysis with 1986 element analysis

Summary statistical analyses of the 1985 locale data set (Table 7.2) and the 1986 element data set (Tables 8.2 and 8.3) are compared in Table 8.4. Although the established floodplain locale compares directly with neither the flood cycle nor sand sheet element alone, there is a strong degree of agreement when these two elements are combined. Differences in facies abundance are explained by the greater proportion of coarse, high energy facies at the base of sediment sequences in the established floodplain locale, which are incorporated into other elements in the 1986 data set. Particle size characteristics are very similar, and upward facies transitions are almost identical for the flood cycle element and established floodplain locale, with complex intermingling of lower energy facies. The sand sheet element is rather different, however, as there are few internal upward facies transitions.

Facies abundances within chutes are very similar in the two data sets, other than the increased proportion of facies St in trenches, at the expense of facies Sr. This indicates that chutes observed in the trench data set experienced higher energy depositional flows. An alternative hypothesis would propose that facies St is preferentially preserved at the base of chute channels away from the main channel. The greater proportion of high energy facies is reflected by the coarser average particle sizes within chutes of the trench data set. Many of the chutes examined in the 1985 data set were low energy depositional environments, such as run-off channels at the tail end of point bars. The wide spread in the 0.5ϕ particle size distribution for chutes observed in trenches indicates that a broad range of depositional conditions occur within this element. However, sequences in trenches are not upward fining, in contrast to the sediments infilling chutes for the 1985 data set. Upward facies transitions in chutes are similar for both the hole and trench data sets, other than the greater frequency of transitions to facies Fm in chutes observed within trenches. This indicates that the sediment sequences are more complex in these locations, with

TABLE 8.4 COMPARISON OF 1985 SUMMARY LOCALE ANALYSIS WITH 1986 SUMMARY ELEMENT ANALYSIS

Locale/Element	Facies abundance	Particle size characteristics	Internal facies organization
Established floodplain Flood Cycle Sand Sheet	Proportion of facies Fm is much higher in flood cycle deposits, but as this facies is not found in sand sheet deposits the element and locale sequences are roughly equivalent. The proportions of facies Sw and Sr are considerably higher in both the flood cycle and sand sheet elements than in the established locale; in contrast, all high energy facies (except facies St in the sand sheet element) are much more prevalent in the established locale.	Flood cycle deposits are 0.2Ø finer than the sand sheet or established locale units. In no case is there any evidence of either upward fining or upward coarsening.	Flood cycle deposits and the established locale are very similar, dominated by complex intermingling of lower energy facies. The sand sheet element is quite different, with few upward facies transitions, but the transition of facies St units to other facies St units is consistent with the established locale.
Chute	Extremely consistent for the hole and trench data sets other than the reduced proportion of facies Sr in the 1986 data set, which is made up almost entirely by the higher proportion of facies St.	Chute deposits are 0.4Ø finer in the 1985 hole data. Sediment sequences in holes are upward fining, but there is no evidence of such trends in chute deposits within trenches.	Upward transitions are similar for all facies other than facies Sr and St. In chutes observed within trenches, facies Fm is a more prevalent upward transiton, along with facies Sw in the case of facies St.
Ridge	Trench data set ridges are dominated by facies Sw, whereas the proportions of facies Sr, Sp and St are greatly lower in the hole data set.	Overall mean particle size is 0.4Ø finer upon ridges in the trench data set. Both data sets indicate upward fining sequences; this effect is more pronounced in the trench data ridges.	In both the hole and trench data sets, upward facies transitions within ridge sediments are dominated by lower energy facies. Actual facies transitions are very similar, other than from facies Sw, which is transitional to facies Sr and O in the hole data set, but to facies Fm and Sw in the trench data set.
Platform	The proportions of facies Sr and Sp are considerably lower in the trench platform data. These differences are made up for by the increased proportion of facies St.	Sediment sequences are 0.6Ø coarser and more clearly upward fining in the 1986 trench data, but in both instances this is the coarsest element in which up-sequence particle size fining is most pronounced.	Upward facies transitions differ markedly between the hole and trench data sets for each facies. Whereas the hole data clearly indicate upward reduction in energy of deposition, the trench data are made up of very mixed high/lower energy facies combined in an irregular manner.

many thin, waning-stage flood deposits.

The proportion of facies Sw is considerably greater in the 1986 ridge element deposits than in the 1985 deposits, at the expense of facies Sr, Sp and St. This, along with the reduced overall particle size for the 1986 ridge data set, is explained by the manner of ridge accretion and preservation of sediments. The flood event responsible for deposition of ridge sediments in Figure 7.2, resulted in a lateral gradation in facies and particle size characteristics, with finer sand, lower energy facies deposited on the ridge top away from the main channel. High flow events later that summer removed the coarser sand, high energy facies adjacent to the main channel, leaving the finer ridge sediments aloft. As the 1986 trench sequences are at contemporary bar margins, rather than upon bar surfaces themselves, coarse fractions have not been preserved to the same extent in ridges. Upward facies transitions to lower energy facies are dominant in both the hole and trench data sets, although upward fining particle size trends are better developed in the trench data set. Given their different sample locations, ridge deposits are very similar in the 1985 and 1986 data sets.

Bar platform deposits in the trench data set differ from the hole data set in terms of facies abundance, internal facies organization and particle size characteristics, due to processes of sediment reworking. Thick, contemporary bar platform sand units are not observed at the base of trench sequences. Rather, the increased proportion of facies St, coarse overall particle size, and intermingled nature of high and lower energy facies, indicate that sequences are severely disrupted as channels laterally migrate and bar platform deposits are preserved. Furthermore, differences are accounted for by the manner of analysis for the two data sets. In locale analysis, lower energy overbank mechanisms operating upon the bar platform are included in the platform locale, whereas these sediments constitute flood cycle or sand sheet deposits in the 1986 trench data set. Among the five elements studied, however, the proportion of high energy facies is greatest, overall particle sizes are coarsest, upward particle size sequences are most clearly upward-fining, and depositional units are indicative of up-sequence reduction in energy, for the platform locale in both data sets.

In summary, the sedimentologic nature of 1985 locales and 1986 elements is very similar in terms of facies abundance and their internal organization and particle size characteristics. These properties, along with sediment mix, color and basal surface character, all provide insight into environment of deposition and are summarized for each element in Table 8.5. Examination of this

TABLE 8.5 : SEDIMENTOLOGIC SUMMARY OF EACH ELEMENT

	Flood cycles	Sand sheets	Ridge deposits	Chute deposits	Platform deposits
Facies character	Dominated by intermingled lower energy facies.	Primarily loose mixes of high or lower energy facies with very little intermingling.	Primarily lower energy facies, especially facies Sw	Mix of high/lower energy facies with much intermingling.	Primarily high energy facies, occasionally intermingled with lower energy facies.
Particle size character	Fine sand	Fine-medium sand	Upward fining - fine sands	Mix of fine/medium sands - some coarse	Poorly-sorted medium/ coarse upward fining sands
Sediment mix	Heterogenous	Heterogenous	Heterogenous	Mix of heterogenous and internally graded	Mix of internally graded and heterogenous
Color	Mix of dark and light brown	Light brown	Dark brown	Mix of light and dark brown	Primarily light brown
Basal surface	Wavy/irregular	Wavy/irregular	Tilts to/from main channel	Tilts to/from main channel	Irregular

table, along with Table 4.7, indicates that when different aspects are combined, individual elements are quite distinctive. The sedimentologic criteria described for each element in Table 8.5, along with the scale, morphology and spatial association between elements, are assessed for each trench in subsequent sections.

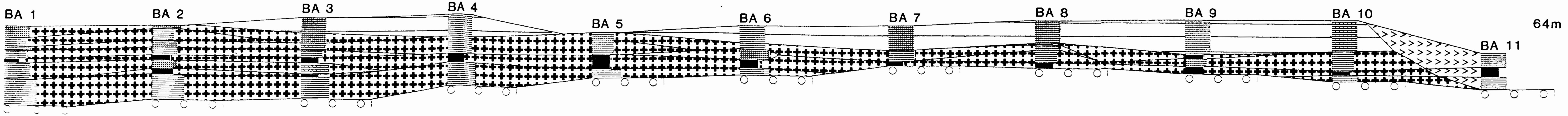
8 : 3 : 1 Within-trench sedimentologic analysis : Basbar trench

Basbar trench is the only trench dug within the braided section of the study reach (Figure 4.1). Site characteristics and within-bar sedimentologic variability upon this compound, mid-channel bar are outlined in section 6.6.2. Sediment sequences exhibit no consistent trends in facies type laterally, down-bar or vertically. Fine sand, lower energy facies are dominant. The trench was dug at the channel margin perpendicular to an actively eroding bank. Local vegetation was well established floodplain (≥ 20 years old), but could be pushed over easily due to the shallow depth and loose composition of surficial sands.

Basbar trench is dominated by lower energy facies, which make up 80% of sediment sequences (Figure 8.1, Table 8.6). While facies are complexly intermingled, with pronounced lateral discontinuity (event stratigraphy; Ager, 1983), element organization is quite straightforward (Table 8.7). The extensive, coarse sand and gravel plateaux, composed of high energy facies, observed adjacent to Basbar, are dissected by numerous chute channels, and are not preserved in established floodplain zones; indeed, facies St, Sp and Ss are not observed in Basbar trench. Flood cycle deposits extend atop basal gravels across the trench, gradually thickening to about 1.0m depth away from the main channel. The basal contact is sharply defined, and rises by 0.5m towards the centre of the trench, reflecting the former bar surface. Flood cycle deposits are composed of thinly interbedded lower energy facies (Table 8.8); the degree of interbedding increases away from the main channel, with some facies Fm units traceable across the trench. The proportions of facies Sr and Fm are notably higher than for the overall data set, and facies Sr, Sw and O are thinner than elsewhere.

Sedimentologically simple, laterally discontinuous, wedge-shaped sand sheet deposits (with a maximum thickness of 0.5m), have been deposited atop flood cycle deposits, with a gradually sloping basal contact. These deposits thin out as energy of deposition decreases away from the main channel. They are composed primarily of facies Sr (72%), with a higher proportion of facies

FIGURE 8.1 BASBAR TRENCH



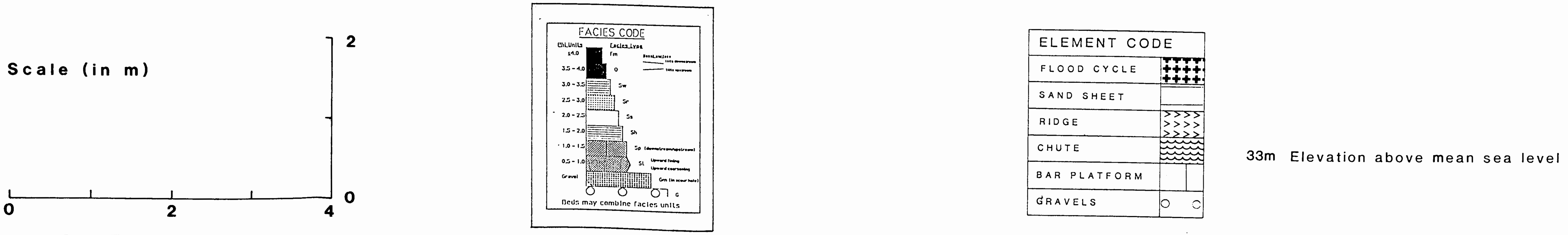


FIGURE 8.2 UPASH TRENCH

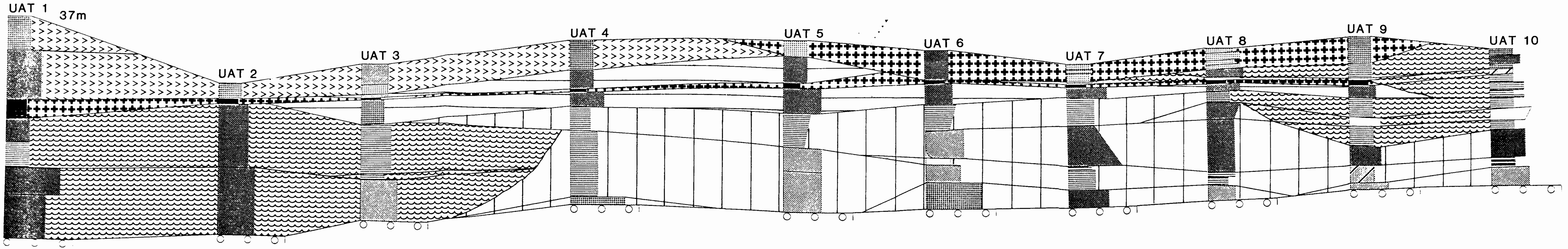


TABLE 8.8 SUMMARY STATISTICAL ANALYSIS OF BASBAR TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	15	15	100	9.5	3.8	1.8	100% H	73% Dk4, 20% Dk3	Sw .60 Sr .40	78% S 100% S	56% W, 22% E, 22% Tt 83% W
O	12	1	36	1.0	2.7	2.7	100% H	100% Dk4	Sr 1.00	100% S	100% W
Sw	16	31	91	17.7	3.0	2.4	100% H	38% Dk2, 28% Lt, 25% Dk1	Sr .67 Sw .25	100% S 100% S	88% W 67% W, 33% Tt
Sr	28	32	73	10.5	2.7	2.9	61% H, 39% I.G.	96% Lt	O .57	100% S	100% W
Ss	-	-	-	-	-	-	-	-	-	-	-
Sh	8	21	73	23.4	2.1	2.9	50% I.G., 38% H	50% Lt, 38% Dk2	Fm .88	100% S	71% E
Sp	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-
G	11	-	100	-	105.5	-	-	-	Sh .73 Fm .27	100% S 100% S	100% I 100% I

Number of analysis points 11   *Overall mean particle size* 2.81Ø   Upward particle size ratio 1 : 1.31   (*6) Sr L = 11, D = 3; St W = n/a, D = n/a

(*1) Average bmax values for facies Gm and G (in mm)
(*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact
(*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

TABLE 8.7 SUMMARY STATISTICAL ANALYSIS OF BASBAR TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	10	67	61.0	2.8	2.6	1 : 1.1	77% H, 21% U	33% Lt, 23% Dk4, 21% Dk2	11 3	- -	SS 1.00	100% S	86% W
SS	7	27	35.3	2.6	2.6	1 : 1.0	82% H	61% Lt, 39% Dk4	12 3	- -	-	-	-
RIDGE	1	6	52.0	3.0	2.0	1 : 1.0	100% H	33% Lt, 33% Dk1, 33% Dk2	- -	- -	-	-	-
CHUTE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
PLAT	-	-	-	-	-	-	-	-	- -	- -	-	-	-
GRAVELS	11	-	-	-	-	-	-	-	- -	- -	FC .91	100% S	100% I

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.8 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR BASBAR TRENCH DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands Abundance	Platform sands Upward transitions ≥ 20%
Fm	19	Sw .67, Sr .33	1	Sr 1.00	27	Sw 1.00	n/a	n/a	n/a	n/a
O	-	-	5	Sr 1.00	-	-	-	-	-	-
Sw	34	Sr .71	22	-	39	-	-	-	-	-
Sr	19	Fm .43, Sw .43	72	O .92	-	-	-	-	-	-
Ss	-	-	-	-	-	-	-	-	-	-
Sh	28	Fm .86	-	-	35	Fm 1.00	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-

O than observed elsewhere (5%). As facies Sr is slightly coarser than other lower energy facies, particle size trends coarsen upwards. The shallow depth of the trench, along with the disturbed history of sediment reworking and emplacement of loose sand sheets, have resulted in conditions which are not conducive for vegetative survival, and local cottonwood can be easily pushed over. Finally, ridge deposits are observed only at the analysis point adjacent to the main channel (i.e. they are less than 2m wide). They have a steeply curved contact above the sand sheet and flood cycle elements and are composed of a facies Sh-Fm-Sw transitional unit.

Basbar trench is composed of a mix of dark and light brown, heterogenously mixed, fine sand units. Average particle sizes are similar for all three elements, although ridge sands are notably better sorted. There are no evident lateral particle size trends. Average facies Sr dimensions are consistent with the overall data set for both the flood cycle and sand sheet elements.

Flood cycle and sand sheet elements are both overbank depositional mechanisms. As both are observed upon a mid-channel bar, however, they are produced by within-channel processes. Hence, the conventional notion differentiating within-channel and overbank deposits needs to be re-evaluated. Perhaps the latter should be viewed as unconfined flood-related deposits which, in turn, can be differentiated into lower energy (flood cycle) and high energy (sand sheet) components. Flood cycle deposits are thinly interbedded mixes of facies Sr, Sw and Fm, whereas sand sheet units have a simpler composition, in this instance dominated by the facies Sr-O-Sr linkage.

8 : 3 : 2 Analysis of Upash trench

Upash is a mid-channel compound bar at the upstream end of the wandering channel reach (Figure 4.1). The main channel has shifted position on either side of this bar over the last 40 years. Contemporary deposits are primarily thick sequences of medium-coarse sand, high energy facies, with much local scale variability (section 6.6.5). Upash trench was dug among well-established floodplain (≥25 years old) vegetation at the fringe of the coarse sand plateau at the bar tail. The discontinuous ridge and swale pattern indicates that lateral channel migration has not been uniform.

The mixed sediment sequences observed upon contemporary bar zones are echoed within Upash trench (Table 8.9), which is made up of roughly horizontal platform, sand sheet and flood

TABLE 8.9 SUMMARY STATISTICAL ANALYSIS OF UPASH TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	12	4	100	7.6	3.4	2.2	83% H	67% DkB	St .50	67% S	67% W
O	3	0	20	2.3	2.4	2.9	100% H	100% Dk4	Sw .33	100% S	100% Tt
									Sr .33	100% S	100% Tt
									Ss .33	100% S	100% E
Sw	20	23	80	27.2	2.3	3.0	79% H	42% Dk/Lt, 32% Lt	St .26	60% G	40% I, 40% Tf, 20% Tt
									Sw .21	75% G	50% I, 50% Tt
Sr	12	16	100	31.4	2.5	2.8	83% H	75% Lt	Fm .33	100% S	100% Tf
									Sw .33	100% S	100% Tf
									St .33	100% G	100% Tt
Ss	6	2	50	8.7	1.6	3.0	67% U	67% Lt, 33% Dk3	Sw .50	67% S	33% W, 33% Tt, 33% Tf
									St .33	100% S	100% E
Sh	2	5	20	55.0	2.1	2.7	100% I.G.	100% Lt	Sr .50	100% G	100% Tf
									St .50	100% G	100% I
Sp	10	14	70	32.5	1.0	3.1	56% I.G., 44% H	60% Lt, 40% Dk3	Sw .50	60% S	60% Tt, 20% I, 20% Tf
									Sr .20	100% S	50% W, 50% Tf
St	21	35	90	40.1	1.0	3.7	76% I.G.	100% Lt	Fm .36	100% S	25% W, 25% I, 25% Tf
Gm	1	2	10	40.0	18.0	-	-	-	Sp 1.00	100% G	100% Tf
G	10	-	100	-	59.4	-	-	-	Sp .50	100% S	60% Tt, 40% W
									St .30	100% S	67% W, 33% Tt

Number of analysis points 10 Overall mean particle size 1.65Ø Upward particle size ratio 1 : 0.76 (*6) Sr L = 10, D = 3; St W = 72, D = 19

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

cycle elements, which have been disrupted by chute channels, resulting in laterally discontinuous units (Table 8.10, Figure 8.2). The proportion of high energy facies (especially facies St) is notably greater in this trench than elsewhere, at the expense of facies Fm and Sw. Flood flows override the bar top with great energy, resulting in diagonal chutes and large troughs both within chutes and upon bar platform surfaces. Accordingly, average facies units are thicker and less well sorted, and the overall particle size is considerably coarser in Upash trench than elsewhere.

At the western end of the trench, a 7m wide, 2m deep high energy facies infill chute sits atop basal gravels, with flood cycle and ridge units atop. Flood cycle deposits are made up of thin, dark brown, facies Fm units (Table 8.11), whereas the ridge unit is ≥ 1.0m thick at the west end of the trench, thinning notably towards the main channel, with a basal contact tilting the opposite way. The ridge has a mixed high and lower energy facies composition, with heterogenously mixed, light brown, medium-fine sands.

At the eastern margin of the major chute, an 0.5m thick sand sheet (composed of individual units of facies Sr and St), forms a wedge tilting away from the main channel, above 1.5-2.0m thick bar platform deposits. This is the basal element for 15m of the 21m trench, sitting above a basal gravel surface which rises gradually by 0.75m towards the present channel position. Upash is the only trench in which bar platform sands are the major element, occupying 40% of the trench. These are composed of heterogenously mixed, light brown, mixed high and lower energy facies (especially facies St, Sp and Sw). A second thin, discontinuous (facies St) sand sheet pinches out out to the west (beneath the ridge unit). The platform, sand sheet and flood cycle elements at the eastern margin of the trench have been disrupted by two small chute channels (about 4m wide, 1m deep, with mixed high and lower energy facies infills). The upper flood cycle unit is dominated by facies Sr.

Average element particle sizes are 0.6-0.8ϕ coarser, and 0.5-0.6 units less well sorted, for the chute, sand sheet and ridge elements in Upash trench than in the overall 1986 data set. Lower energy facies exhibit a broad range of light and brown colors and have heterogenous sediment mixes. This contrasts with light colored, internally graded, high energy facies units. High and lower energy facies are both intermingled in vertical sequence and laterally discontinuous, resulting in irregular vertical and lateral particle size trends.

TABLE 8.10 SUMMARY STATISTICAL ANALYSIS OF UPASH TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	13	10	18.5	2.7	2.6	-	73% H	53% DkB	9	3	-	-	SS .38 CHUTE .38 RIDGE .25	100% S 100% S 100% S	67% W, 33% Tf 33% E, 33% W, 33% Tt 100% W
SS	10	10	24.2	1.9	3.2	-	50% H, 50% I.G.	100% Lt	10	2	45	11	FC .80 RIDGE .20	100% S 100% S	25% I, 25% Tt, 25% Tf 50% I, 50% Tf
RIDGE	4	10	58.8	2.2	3.0	-	71% H, 29% I.G.	86% Lt	11	2	30	10	-	-	-
CHUTE	8	31	93.1	1.3	3.4	1 : 1.3	48% I.G., 35% H	58% Lt	10	3	75	26	FC .71 SS .29	100% S 100% G	40% W, 40% Tt, 20% Tf 100% Tf
PLAT	7	39	132.3	1.5	3.2	1 : 0.4	55% H, 28% I.G.	52% Lt, 24% Dk3	10	3	112	25	SS .71 CHUTE .29	60% G 100% S	40% I, 40% Tt, 20% Tf 50% Tt, 50% Tf
GRAVELS	10	-	-	-	-	-	-	-	-	-	-	-	PLAT .70 CHUTE .30	71% S 100% S	57% W, 43% Tt 67% W, 33% Tt

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.11 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR UPASH TRENCH DATA SET

	Flood Cycles		Sand Sheet		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%
Fm	31	Sr 1.00	-	-	-	-	-	-	2	St 1.00
O	0	-	-	-	-	-	0	Ss 1.00	1	Sw 1.00
Sw	-	-	-	-	13	-	22	Sw .33, Ss .33	38	Fm .50, Sw .33
Sr	68	-	15	-	56	Sw 1.00	4	-	2	-
Ss	-	-	-	-	-	-	5	Sw .75, St .25	2	Sp .50, St .50
Sh	-	-	-	-	-	-	15	St 1.00	-	-
Sp	-	-	2	-	14	Sr 1.00	8	Sw 1.00	25	Sw .57
St	-	-	83	-	17	Sp 1.00	46	St .67, Sh .33	28	Sw .50, Sr .25, St .25
Gm	-	-	-	-	-	-	-	-	4	Sp 1.00

8 : 3 : 3 Trench analysis upon Tflent : Tflent Head trench

Although only 1.5km downstream of Upash, and located within the same planform reach, sedimentologic conditions upon Tflent are quite different (section 6.6.6). The bar head unit on Tflent has recently become bank attached, and the bar has grown primarily in a downstream direction over the last 40 years, but there has been a distinct lateral component to this growth, indicating uniform channel migration. A diagonal series of chutes and marginal ridges are the dominant locales upon this bar. Sediment sequences in the 1985 data set are dominated by thinly interbedded lower energy facies. Each of the four trenches dug upon Tflent is analysed individually in the next four sections.

Tflent Head trench was dug at a 60° angle to the main channel, oriented across the head of the major bar unit immediately downstream of the bank-attached section, among vegetation more than 30 years old. The channel separating these two bar units is about 10m wide at this point, but widens considerably (to about 40m) to the tail of Tflent. Two small chute channels and their marginal ridges are the major elements in these relatively thin sediment sequences. These chutes extend diagonally down-bar, increasing in size in that direction.

Tflent Head trench is dominated by facies Sw, which occupies 54% of the trench (Figure 8.3, Table 8.12). Almost 75% of the trench is made up of thinly interbedded, internally graded, dark brown colored, lower energy facies. Facies St and Sp are seldom observed and troughs have smaller dimensions than elsewhere. Hence, the overall mean particle size for Tflent Head trench is slightly finer than for all trench data and sequences are upward fining in nature. Average facies particle sizes and sorting values are consistent with the overall data set, although facies Ss is better sorted than elsewhere. Upward facies transitions in Tflent Head trench are dominated by transitions to facies Sw.

Both facies and elements are abruptly laterally and vertically transitional in Tflent Head trench (event stratigraphy). This is evidenced by the surficial facies at the eastern trench margin, which changes from a facies Sr unit within the chute, to a facies Sp unit at the ridge base, to a thinner facies Sw unit at the ridge top (in similar fashion to the ridge sequences in Figure 7.2; section 8.2.3). Coarse sand, high energy facies are located in mid-sequence at the western margin, as basal units in mid-trench, and are intermingled at the eastern margin. The basal gravel surface

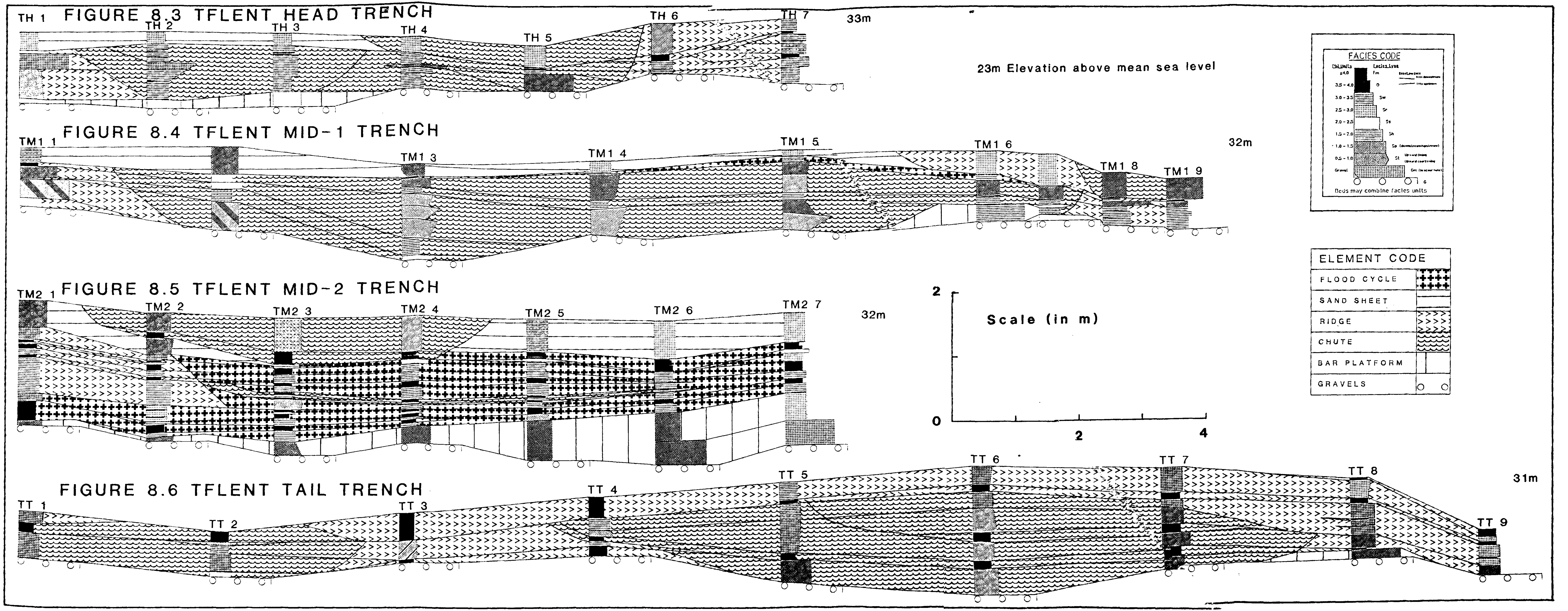


FIGURE 8.3 TFLENT HEAD TRENCH

FIGURE 8.4 TFLENT MID-1 TRENCH

FIGURE 8.5 TFLENT MID-2 TRENCH

FIGURE 8.6 TFLENT TAIL TRENCH

TABLE 8.12 SUMMARY STATISTICAL ANALYSIS OF TFLENT HEAD TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	3	3	29	7.7	3.3	2.2	50% U, 50% H	67% Dk3, 33% Dk4	Sw 1.00	67% S	67% I, 33% E
O	5	1	57	2.0	3.0	2.0	100% H	80% Dk3, 20% Dk4	Sr .60 Sw .40	100% S 100% S	67% I, 33% Tf 50% W, 50% I
Sw	31	54	86	12.4	2.6	2.3	60% I.G., 20% H, 20% U.C.	55% Dk3, 39% Lt	Sw .67	58% S	58% I, 42% Tf
Sr	4	15	57	26.0	3.0	2.0	100% I.G.	50% Dk3, 25% Lt, 25% Lt/Dk	-	-	-
Ss	4	8	43	13.3	1.5	1.5	100% U	100% Lt	Sw .50 O .25 Sp .25	100% G 100% S 100% G	50% I, 50% Tf 100% I 100% Tf
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	1	7	14	48.0	2.2	3.0	100% U.F.	100% Lt/Dk	Gm 1.00	100% G	100% I
St	2	5	29	16.5	-1.0	4.0	100% I.G.	100% Lt	O .50 Sw .50	100% S 100% S	100% W 100% Tf
Gm	2	8	29	27.5	9.0	-	-	-	Sw .50 Ss .50	100% G 100% G	n/a 100% I
G	7	-	100	-	77.1	-	-	-	Sw .43 Ss .43	100% S 100% S	100% I 100% I

Number of analysis points 7 Overall mean particle size 2.15Ø Upward particle size ratio 1 : 0.81 (*6) Sr L = 9, D = 3; St W = 25, D = 12

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, *I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike*
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

dips by 0.5m to the west, in the 13m trench.

The lateral and vertical discontinuities described above are accounted for by the spatial pattern of elements within Tflent Head trench. Platform sands form a thin, laterally discontinuous basal unit ($\leq$0.3m thick), extending over 6m, composed solely of facies Ss (Tables 8.13, 8.14). They are truncated by two chute units, both of which are about 5m wide and 1m deep. These have variable internal compositions, with facies St, Sw and Sr dominant. At the western margin an 0.4m thick sand sheet, composed solely of facies Sr, sits atop the chute. This unit has been eroded by the more recent chute channel. Ridge deposits, composed largely of facies Sw and Fm, are marginal to the chutes at either end of the trench. Chute and ridge elements combined occupy 84% of Tflent Head trench.

Average particle sizes and sorting values for each element vary considerably from the overall data set. Sand sheet and platform sands are finer and better sorted, whereas ridge deposits are coarser. Ridge deposits are primarily heterogenous or uniform, and dark brown in color, whereas other elements are made up of light and dark brown banded beds with internally graded sediment mixes. Basal contacts between elements are sharply defined, other than from the platform element, and generally are tilted or irregular in shape.

8 : 3 : 4 Analysis of Tflent Mid-1 trench

Tflent Mid-1 trench was dug in a similar environment to Tflent Head trench, among vegetation about 25 years old, and diagonally oriented chute channels. The main channel is located about 10m beyond the western margin of the trench, and a major secondary channel lies about 30m to the east. The surface chute that runs through Tflent Head trench is located at the eastern margin of Tflent Mid-1 trench. Although element proportions in these two trenches are virtually identical, their facies compositions are very different, as chute units in Tflent Mid-1 trench have high energy facies infills.

There is a wide range of facies types in Tflent Mid-1 trench, with high proportions of facies St, Sp, Sr and Sw (Table 8.15). High energy facies predominate, however, occupying almost 65% of the trench. This, along with the fact that particle sizes are consistent with the overall data set for lower energy facies, but coarser for facies Sh and Sp, accounts for the coarser overall mean

TABLE 8.13 SUMMARY STATISTICAL ANALYSIS OF TFLENT HEAD TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (φ units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	-	-	-	-	-	-	-	-	- -	- -	-	-	-
SS	3	9	21.3	3.2	2.0	-	100% I.G.	67% Lt/Dk, 33% Lt	14 4	- -	-	-	-
RIDGE	3	38	89.3	2.3	2.7	1 : 1.0	50% H, 25% I.G.	65% Dk3	- -	- -	SS 1.00	100% S	100% I
CHUTE	4	46	82.3	1.9	2.5	1 : 0.9	46% I.G., 30% H	50% Dk3, 46% Lt	4 2	25 12	SS 1.00	100% S	100% I
PLAT	3	7	16.0	1.4	1.5	-	100% I.G.	100% Lt	- -	- -	CHUTE .67 RIDGE .33	100% G 100% G	50% I, 50% Tf 100%Tf
GRAVELS	7	-	-	-	-	-	-	-	- -	- -	PLAT .43 RIDGE .29 CHUTE .29	100% S 100% S 100% S	100% I 100% I 100% I

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.14 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR TFLENT HEAD TRENCH DATA SET

	Flood Cycles		Sand Sheet		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%
Fm	n/a	n/a	-	-	9	Sw 1.00	-	-	-	-
O	-	-	-	-	1	-	2	Sw .50, Sr .50	-	-
Sw	-	-	28	-	62	Sw .67, Fm .33	61	Sw .66	-	-
Sr	-	-	72	-	-	-	18	-	-	-
Ss	-	-	-	-	2	O .22	-	-	100	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	18	Gm 1.00	-	-	-	-
St	-	-	-	-	-	-	10	O .50, Sw .50	-	-
Gm	-	-	-	-	9	Ss 1.00	9	Sw 1.00	-	-

TABLE 8.15 SUMMARY STATISTICAL ANALYSIS OF TFLENT MID-1 TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix . (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	3	1	33	3.3	3.2	2.0	100% U	100% Dk3	St .67 Sr .33	50% S 100% G	50% I, 50% Tt 100% I
O	11	2	56	1.5	2.8	2.2	91% H	82% Dk4	Sw .46 Sr .36	80% G 50% S	80% Tt, 20% W 25% W, 25% I, 25% Tt, 25% Tf
Sw	20	15	78	7.7	2.7	2.1	65% H, 35% I.G.	95% Dk3	Sw .35 O .30 St .20	100% S 83% G 75% G	57% Tf, 43% W 83% Tt 75% Tt, 25% Tf
Sr	12	20	67	17.3	2.9	2.5	50% H, 50% I.G.	42% Lt, 42% Dk3	O .29 Ss .29 St .29	50% S 100% G 50% S	50% W, 50% Tt 50% E, 50% I 50% Tt, 50% Tf
Ss	8	6	56	7.9	1.5	2.8	63% U, 25% H	50% Lt, 50% Dk3	Sw .25 Sr .25 St 1.00	50% S 50% S 100% G	50% Tt, 50% Tf 50% I, 50% Tf 100% I
Sh	1	3	11	28.0	-1.0	4.0	100% I.G.	100% Lt	Sw 1.00	100% G	100% Tt
Sp	8	24	56	30.8	0.6	3.4	63% U.C., 25% H	100% Lt	Sr .25 Sp .25 St .25	50% S 100% S 50% S	100% Tt 67% I, 33% W
St	13	30	89	24.6	1.5	3.5	69% I.G.	100% Lt	Fm .33 Sw .33 O .22	100% S 67% S 100% S	67% W, 33% Tt 50% W, 50% I
Gm	-	-	-	-	-	-	-	-	-	-	-
G	9	-	100	-	62.6	-	-	-	Ss .33 Sp .33 Sw .22	67% S 67% S 100% S	100% Tf

Number of analysis points 9 Overall mean particle size 1.70Ø Upward particle size ratio 1 : 0.83 (*6) Sr L = 8, D = 2; St W = 61, D = 13

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = *Sharply defined contact*, G = *Gradational contact* (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

particle size for Tflent Mid-1 trench. Indeed, this trench is made up primarily of medium sands. Facies Sw and Sp are notably better sorted than elsewhere.

Average facies thicknesses are thinner for virtually all facies in Tflent Mid-1 trench. This is particularly evident for facies Fm and Sw, which are less than half their thicknesses in the overall data set. Facies organization is complex, with upward transitions divided among two or three facies in all instances. Thin units of dark colored, heterogenous, lower energy facies are interbedded with light colored, high energy facies which exhibit a range of sediment mixes. Basal surfaces are considerably less well defined than elsewhere, and are primarily tilted in shape.

Facies organization, particle size trends, and the tilted shape of basal contacts are attributable to the large proportion of chute and ridge elements which make up 84% of Tflent Mid-1 trench (Table 8.16; Figure 8.4). Facies types vary markedly across-trench both within and between elements. For example, the surficial bedding unit varies laterally from wavy bedded ripples to troughs to ripples within the sand sheet unit, is observed as ripples in the ridge unit, but is observed as troughs in the chute at the eastern trench margin. Facies sequences are similarly variable in a vertical sense, with variation pronounced both within and between elements. Upward transitions at one analysis point in the major chute go from facies G-Ss-Sw-Sp-Sr-St, with facies Fm in flood cycles and facies St in a sand sheet unit atop. Particle size trends are similarly variable, with no consistent lateral or vertical trends.

Basal gravels within Tflent Mid-1 trench dip notably in mid trench, coincident with the major chute unit. This, along with the adjacent small (3m wide, 0.4m thick) platform unit (composed solely of facies Sh; Table 8.17), suggests that flows within this chute unit scoured both coarse basal sands and framework gravels, prior to being infilled by irregularly mixed coarse sand, high energy facies Sp, St and Ss units. This 15m wide, 1.5m deep chute dominates the trench. Ridge elements are found at both chute margins. The ridge unit at the western end of the trench is about 1m thick and has a mixed facies composition. The upper part of the ridge has been removed and replaced by a sand sheet unit composed of individual, light brown, internally graded, medium sand, facies St and Sr units. The surficial sand sheet thins out (from 0.5m) towards the east. This indicates that these deposits were washed onto the floodplain from the main channel during a flood event. A thin, heterogenously mixed, dark brown, fine sand flood cycle unit, with many organic litter layers, separates this sand sheet from the underlying chute deposits. The smaller ridge at the eastern

TABLE 8.16 SUMMARY STATISTICAL ANALYSIS OF TFLENT MID-1 TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	4	3	6.5	2.8	2.0	-	78% H, 22% U	78% Dk3, 22% Dk4	7	1	-	-	SS .75 RIDGE .25	100% G 100% G	100% I 100% I
SS	5	11	23.8	2.3	2.6	-	80% I.G., 20% H	100% Lt	6	3	38	14	-	-	-
RIDGE	6	26	44.3	1.9	2.7	1 : 0.8	50% I.G., 27% H, 23% U	59% Dk3, 36% Lt	6	3	28	4	CHUTE .75 SS .25	100% S 100% G	67% Tf, 33% Tt 100% I
CHUTE	8	58	75.8	1.6	3.2	1 : 1.0	49% H, 21% I.G.	46% Lt, 33% Dk3	9	2	75	14	FC .67	100% S	50% W, 50% I
PLAT	1	3	28.0	-1.0	4.0	-	100% I.G.	100% Lt	-	-	-	-	CHUTE 1.00	100% G	100% Tt
GRAVELS	9	-	-	-	-	-	-	-	-	-	-	-	RIDGE .44 CHUTE .44	100% S 50%G	75% Tf, 25% I 50% Tt, 50% Tf

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.17 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR TFLENT MID-1 TRENCH DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands Abundance	Platform sands Upward transitions ≥ 20%
Fm	8	-	-	-	3	-	-	-	-	-
O	19	Sw .33, Sr .33, Ss .33	-	-	0	Sr 1.00	2	Sw .57, Sr .29	-	-
Sw	31	O 1.00	-	-	28	Sw .78, St .22	12	O .63, Sp .25	-	-
Sr	35	O 1.00	45	-	34	-	9	Ss .40, St .40, O .20	-	-
Ss	8	-	-	-	9	Sp .50, St .50	6	Sw .67, Ss .33	-	-
Sh	-	-	-	-	-	-	-	-	100	-
Sp	-	-	-	-	12	Ss 1.00	36	Sr .29, Sp .29, St .29	-	-
St	-	-	56	-	14	Fm .67, Sw .33	36	Sw 1.00	-	-
Gm	-	-	-	-	-	-	-	-	-	-

edge of the trench has been cut by the diagonal chute which runs through Tflent Head trench. This has deposited a coarse sand facies St unit atop the ridge.

Element particle sizes are coarser than the overall data set for all elements, except flood cycles, in Tflent Mid-1 trench. Both chute and ridge elements have higher energy compositions than shown elsewhere. Basal contacts are primarily gradational, indicating the marginality of depositional environments.

8 : 3 : 5 Analysis of Tflent Mid-2 trench

Tflent Mid-2 trench differs from the other trenches on this bar as floodplain sequences are thicker, and chute channel reworking of deposits has not been so prevalent. Vegetation in this area is 15-20 years old, and can be easily pushed over. As indicated for Basbar, this can be related to thick deposits of loose sand sheets at the bar surface. At its western margin, the trench is located about 5m from the main channel, among thick ridges of sand wave deposits, oriented diagonally across the bar and mounded around trees.

Facies composition of Tflent Mid-2 trench is similar to Tflent Head trench, as $\geq 70\%$ of deposits are made up of lower energy facies, but in this instance sequences are thicker than in other trenches on this bar, and over 70% of sediments are made up of vertically accreted, flood related deposits. A thick sand sheet is observed at the bar surface, but most of the trench is composed of thinly interbedded, lower energy facies within flood cycle elements. Accordingly, overall particle size is notably finer in this trench than elsewhere.

Of the four trenches dug on Tflent bar, bar platform and flood cycle deposits are most prevalent in Tflent Mid-2 trench. This, along with the horizontal stacking of elements, results from less chute channel disruption of sediments than evidenced elsewhere (Figure 8.5). Accordingly, sediment sequences are thicker than elsewhere, with vertically intermingled high and lower energy facies. High energy facies are internally graded and light brown in color, whereas the character of lower energy facies is more variable than elsewhere (especially facies Fm and Sw; Table 8.18). Facies St deposits in the basal platform unit are transitional to mixes of thinly interbedded lower energy facies (especially facies Fm and Sw) in flood cycle and chute elements, with facies Sr and high energy facies in sand sheet and chute elements atop. Individual facies units extend across the

TABLE 8.18 SUMMARY STATISTICAL ANALYSIS OF TFLENT MID-2 TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	45	20	100	6.9	3.4	2.2	56% I.G., 24% U, 20% H	88% Dk3	Sw .49	64% S	41% Tt, 36% I
									Sr .31	64% S	36% Tt, 29% E, 21% I
O	4	0	57	1.0	3.4	2.2	75% H, 25% U	100% Dk4	Fm 1.00	100% S	100% I
Sw	32	27	100	12.8	2.7	2.4	78% I.G., 22% H	50% Lt, 34% Lt/Dk	Fm .81	77% S	54% Tt, 23% I
Sr	18	24	86	22.7	2.8	2.2	50% H, 50% I.G.	75% Lt, 25% Lt/Dk	Fm .42	100% S	60% E, 40% Tt
									Sw .25	67% S	33% I, 33% Tt, 33% Tf
Ss	8	2	86	4.0	2.4	2.8	50% I.G., 50% U	100% Lt	Fm 1.00	100% S	50% I, 25% E, 25% Tt
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	1	4	14	58.0	2.7	2.0	100% I.G.	100% Lt	-	-	-
St	10	20	86	31.2	0.9	3.1	60% I.G., 20% U	90% Lt	Sw .63	60% G	60% Tt, 20% E, 20% Tf
									Fm .25	100% S	50% Tt, 50% Tf
Gm	1	3	14	40.0	34.0	-	-	-	Sr 1.00	100% S	100% I
G	7	-	100	-	43.4	-	-	-	St .86	100% S	100% I

Number of analysis points 7   Overall mean particle size 2.37Ø   Upward particle size ratio 1 : 0.86   (*6) Sr L = 11, D = 3; St W = 79, D = 13

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

13m trench, but once more these vary in character both within and between elements. At the western trench margin, facies change from facies St-Ss within a sand sheet unit. Moving west from the sand sheet element to the chute at the eastern trench surface, facies types change from facies Sr-Sp-St. Lateral facies variability is less prevalent in the horizontally aligned flood cycle, chute channel and platform elements in the lower two-thirds of the trench. Accordingly, particle size trends are extremely variable vertically, but lateral trends are fairly consistent within each bedding unit, with no evidence of gradation of particle sizes away from the main channel.

The laterally continuous, medium sand, bar platform element thins westward across the trench from 1.0 to 0.15m (Tables 8.19, 8.20). These facies St units rest above an irregular basal surface, which rises by 0.5m at both ends and at the middle of the trench. Flood cycle deposits above platform sands are about 1.0m thick across the trench. These deposits are dominated by transitions to facies Fm, which makes up 38% of this element, typically interbedded with facies Sw. Within this element, in mid trench, is a very thin (0.2m deep, 9m wide) lower energy chute unit, with a small ridge (composed of lower energy facies), at its western margin. An 0.5m thick sand sheet rests atop the flood cycle deposits above this ridge. This unit is composed of facies Sr, the average dimensions of which are twice those of the overall data set. The sand sheet thins notably to the east, having been eroded by a 6m wide, 0.75m deep channel, which has a high energy facies infill. Facies Fm units in a flood cycle element rest atop the thin sand sheet at the eastern trench margin, with a second, 0.75m thick, sand sheet above. This second sand sheet has also been disrupted by the aforementioned chute channel, and is composed solely of facies St. Flood cycle and sand sheet elements combined account for 70% of deposits in Tflent Mid-2 trench. Chute infill deposits have a lower energy facies composition than elsewhere, with facies Fm abundant (making up 29% of this element), and smaller abundances of facies Sp, Sr and St. These internally graded deposits are somewhat darker than noted elsewhere, with smaller average trough dimensions.

8 : 3 : 6 Analysis of Tflent Tail trench

Tflent Tail trench was dug in a recently accreted bar unit, among vegetation with a maximum age of 20 years. A series of parallel-oriented down-bar ridges at the bar surface indicate that this bar has grown by lateral accretion. The trench was dug within a vegetated unit in

TABLE 8.19 SUMMARY STATISTICAL ANALYSIS OF TFLENT MID-2 TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	16	41	38.8	3.0	2.2	1 : 0.7	53% I.G., 36% H	45% Dk3, 29% Lt, 21% Lt/Dk	9 3	- -	SS .63 CHUTE .25	60% G 75% S	90% I 50% I, 25% E, 25% Tt
SS	10	17	25.6	2.4	2.5	-	50% I.G., 40% U	100% Lt	19 4	33 8	FC .50 CHUTE .50	100% S 100% S	100% I 33% E, 33% I, 33% Tt
RIDGE	2	9	65.5	2.6	3.0	1 : 1.0	100% I.G.	50% Lt, 33% Dk3	- -	- -	FC 1.00	100% S	100% Tf
CHUTE	7	15	32.0	2.6	2.5	1 : 1.3	74% I.G., 21% U	53% Dk3, 26% Lt	- -	45 10	FC 1.00	75% S	50% I, 25% E, 25% Tt
PLAT	7	19	42.3	0.6	3.0	-	56% I.G., 22% U	88% Lt	9 2	97 14	FC 1.00	57% S	71% Tt
GRAVELS	7	-	-	-	-	-	-	-	- -	- -	PLAT 1.00	100% S	100% I

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.20 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR TFLENT MID-2 TRENCH DATA SET

	Flood Cycles		Sand Sheet		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%
Fm	38	Sw .41, Sr .37	-	-	9	Sw 1.00	29	Sw .43	-	-
O	1	Fm 1.00	-	-	-	-	0	Fm 1.00	-	-
Sw	44	Fm .83	-	-	91	Fm 1.00	6	Fm 1.00	-	-
Sr	16	Fm .83	64	-	-	-	25	-	15	-
Ss	1	Fm 1.00	9	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	26	-	-	-
St	-	-	28	-	-	-	14	-	71	St 1.00
Gm	-	-	-	-	-	-	-	-	14	Sr 1.00

mid-bar, perpendicular to the main channel, with a sand plateau adjacent at the western margin, and a shallow angled framework gravel bar surface at the eastern margin.

The proportion of facies Fm is higher in Tflent Tail trench than in any of the other trenches (Table 8.21). This, along with the extremely high proportion of facies Sr (39%), means that 75% of Tflent Tail trench is made up of lower energy facies. Facies St and Sp make up the remaining 25% of the trench. Facies characteristics are consistent with those observed elsewhere, although high energy facies are notably finer and better sorted. Hence, the overall mean particle size is in the fine sand class, and is 0.6ϕ finer than for all trenches combined. Above the irregularly contacted, basal facies G-St transition, all sediment assemblages in Tflent Tail trench are dominated by facies Fm and Sr, with tilted surfaces. Contacts are primarily sharply defined.

Other than a very thin (0.3m), laterally discontinuous platform sand unit, Tflent Tail trench is composed entirely of upward fining heterogenously mixed, dark and light brown banded, ridge and chute elements (Table 8.22). Depth of sediment sequences varies greatly in the nine analysis points in Tflent Tail trench (Figure 8.6), reflecting lateral bar growth. The bar surface, however, is not in phase with the basal gravel contact, as the trench is deepest, and basal contact lowest, beneath the major ridge unit in the trench. A large (12m wide, 1.5m deep) chute channel is beneath the surface at this location. Substantial ridge units are adjacent to this channel, and also to a more recent, smaller ($\geq$5m wide, 1m deep) chute, at the western trench margin. Ridge elements are both marginal to, and provide a cap above, chute elements, as the main channel migrates laterally at this location.

Facies compositions of elements in Tflent Tail trench are fairly simple (Table 8.23). Facies Sr and Fm dominate ridge deposits ($\geq$80%), whereas there is a broader mix of lower and high energy facies in chute channels. Even within the chute channel element, however, facies Fm is the preferred next-facies state, and in neither the ridge or chute elements are upward facies transitions divided among more than two facies for any facies type. Chute infill units are 0.7ϕ finer and better sorted than in the overall data set. Ripple dimensions are smaller than observed elsewhere.

Facies units are notably thicker, and fewer in number, in Tflent Tail trench than observed elsewhere, reflecting fewer formative events. Lateral facies variability is prevalent both within and between the chute and ridge elements. Facies sequences are notably vertically intermingled at each analysis point. In contrast, vertical particle sizes trends are fairly consistent. Lateral

TABLE 8.21 SUMMARY STATISTICAL ANALYSIS OF TFLENT TAIL TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	28	27	100	10.4	3.5	2.1	54% H, 36% U	78% Dk3	Sr .52	92% S	42% Tt, 25% Tf
O	-	-	-	-	-	-	-	-	-	-	-
Sw	5	8	44	16.0	3.2	2.3	100% H	80% Dk3, 20% Lt	Fm .75 Sr .25	100% S 100% S	67% Tt, 33% Tf 100% E
Sr	25	39	78	16.8	2.7	2.3	56% I.G., 24% H	64% Lt, 32% Dk3	Fm .73 Sr .22	94% S 100% G	44% Tt 60% Tf, 40% A
Ss	1	1	11	8.0	2.7	2.0	100% H	100% Lt	Sr 1.00	100% G	100% I
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	4	11	22	30.5	2.4	2.3	50% H, 50% U.F.	100% Lt	Fm .50 Sr .50	100% S 100% G	100% A 50% A, 50% Tf
St	7	14	44	21.7	1.8	2.7	67% I.G., 33% H	100% Lt	Fm .57 Sr .43	100% S 67% G	50% Tt, 25% W, 25% Tf 67% Tf, 33% I
Gm	-	-	-	-	-	-	-	-	-	-	-
G	9	-	100	-	82.9	-	-	-	St .44 Fm .22	100% S 100% S	67% I, 33% Tf 50% I, 50% Tt

Number of analysis points 9 Overall mean particle size 2.80Ø Upward particle size ratio 1 : 0.79 (*6) Sr L = 9, D = 2; St W = 69, D = 13

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

TABLE 6.22 SUMMARY STATISTICAL ANALYSIS OF TFLENT TAIL TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	9	53	62.9	3.0	2.3	1 : 0.7	49% H, 27% I.G.	51% Dk3, 43% Lt	9	2	70	14	CHUTE 1.00	100% S	100% Tf
CHUTE	7	46	70.3	2.7	2.3	1 : 0.8	41% H, 31% I.G.	50% Lt, 47% Dk3	8	2	69	12	RIDGE .75 CHUTE .25	67% G 100% S	50% Tf, 33% Tt 50% A, 50% Tf
PLAT	1	1	14.0	-1.0	4.0	-	n/a	n/a	-	-	-	-	CHUTE 1.00	100% S	100% Tt
GRAVELS	9	-	-	-	-	-	-	-	-	-	-	-	CHUTE .56 RIDGE .33	100% S 100% S	60% I, 20% Tt, 20% Tf 67% I, 33% Tt

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 6.23 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR TFLENT TAIL TRENCH DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands Abundance	Platform sands Upward transitions ≥ 20%
Fm	n/a	n/a	n/a	n/a	30	Sr .60, Sw .40	25	Sr .46, Sp .27	-	-
O	-	-	-	-	-	-	-	-	-	-
Sw	-	-	-	-	12	Fm 1.00	3	Sr 1.00	-	-
Sr	-	-	-	-	52	Fm .71, Sr .29	26	Fm .86	-	-
Ss	-	-	-	-	-	-	2	Sr 1.00	-	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	25	Fm 1.00	-	-
St	-	-	-	-	7	Sr 1.00	20	Fm 1.00	100	-
Gm	-	-	-	-	-	-	-	-	-	-

variability is apparent, however, as analysis points within chutes are notably coarser than their ridge counterparts.

8 : 3 : 7 Trench analysis upon Beach Bar : Beach Bar Head trench

Beach bar is a large lateral bar, located at the margin of the wandering and meandering planform reaches. Over the last 40 years there has been steady lateral accretion at the bar head, while the bar tail has remained stationary. The bar has a substantial gravel platform, which has been used by local residents as a source of gravel, excluding Beach Bar from 1985 analysis. Two trenches were dug in prominent ridges at the bar margin, among substantive vegetation.

Beach Bar Head trench was dug perpendicular to the main channel among vegetation which increased notably in age away from the main channel. The western margin of the trench is immediately adjacent to unvegetated bar platform sands. A large log (diameter 0.75m) was located at the base of the major ridge in the trench. This was oriented downstream (i.e. along the axis of the ridge).

In no trench are sedimentologic properties as simple as in Beach Bar Head trench (Figure 8.7, Table 8.24). The trench is made up entirely of facies Gm units transitional upwards to extensive facies Sw units. The latter facies has twice its average thickness, and occupies 92% of trench deposits. Wavy bedded sands are heterogenous, banded light and dark brown, moderately well sorted, fine sands. Internally, bed sequences generally are tilted towards the main channel. The lack of high energy facies results in an overall particle size 0.5ϕ finer than for the entire trench data set. As sequences are transitional from facies Gm-Sw, the upward particle size ratio indicates that trends are dominantly upward fining.

Elemental composition of Beach Bar Head trench is almost as simple as shown for facies (Table 8.25). Ridge and chute elements make up 92% of the trench (the facies Sw component; Table 8.26). The ridge element alone accounts for 71% of the trench. The remainder of the trench is composed of thin basal platform deposits, made up of facies Gm, which roughly evens out the basal surface adjacent to the contemporary bar. Ridge deposits thicken appreciably to $\geq$ 1.5m away from the main channel, and extend across the 17m trench. These are disrupted by a small, basal chute channel (5m wide, 1m deep), at the eastern end of the trench. Chute infill and ridge

FIGURE 8.7 BEACH BAR HEAD TRENCH

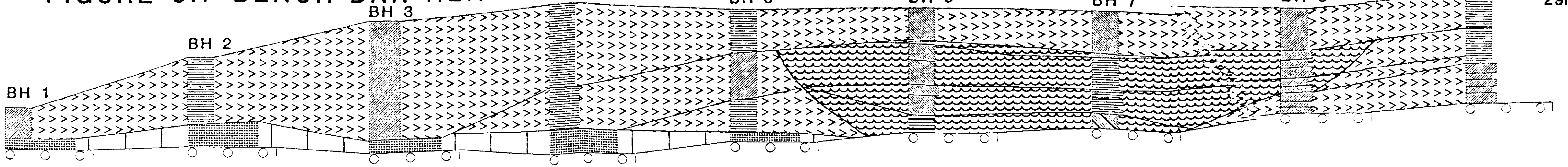


FIGURE 8.8 BEACH BAR TAIL TRENCH

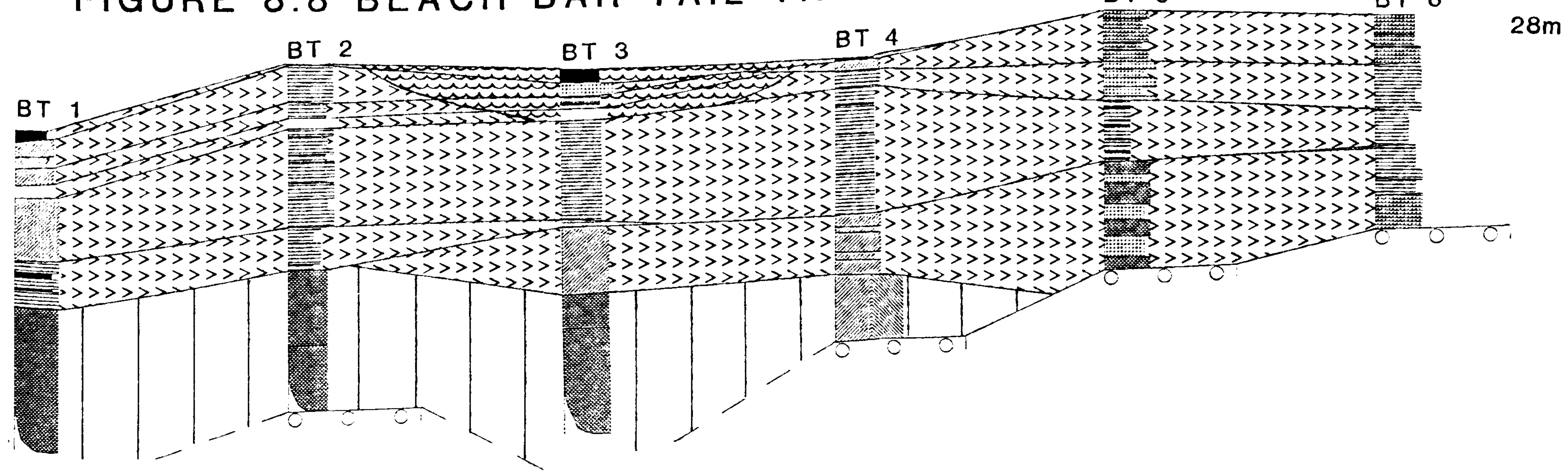
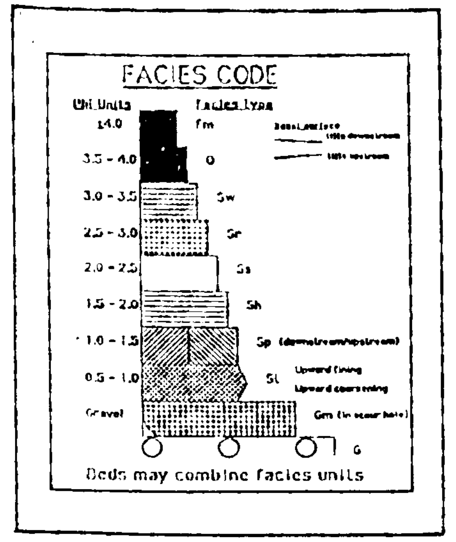
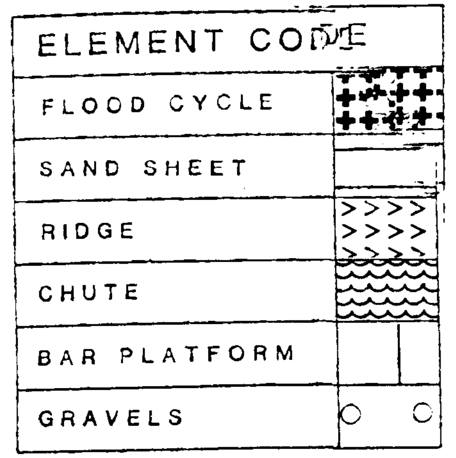


FIGURE 8.9 PILLBEND TRENCH



33m Elevation above mean sea level



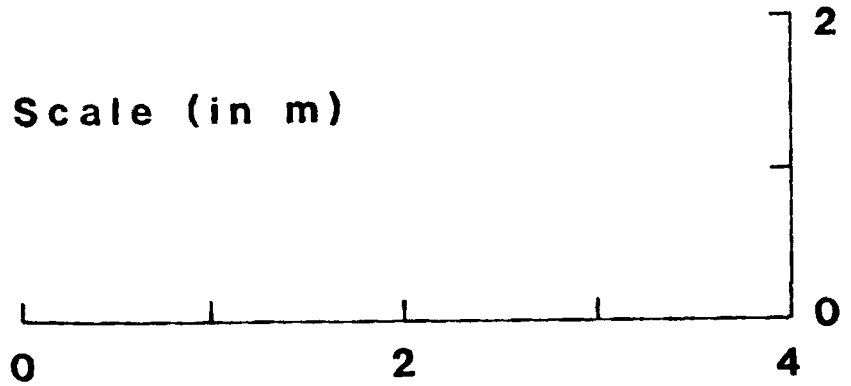


TABLE 8.24 SUMMARY STATISTICAL ANALYSIS OF BEACH BAR HEAD TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	2	0	22	2.0	3.7	3.0	100% H	100% Lt/Dk	Sw 1.00	100% S	50% W, 50% Tf
O	1	0	11	1.0	3.2	3.0	100% H	100% Dk4	Sw 1.00	100% S	100% Tt
Sw	30	92	100	35.2	3.1	2.5	53% H 47% I.G.	60% Lt/Dk, 27% DkB	Sw .86	50% S	50% Tf, 39% Tt
Sr	-	-	-	-	-	-	-	-	-	-	-
Ss	-	-	-	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-
Gm	5	8	56	18.4	10.6	-	-	-	Sw 1.00	100% S	60% Tt, 40% E
G	9	-	100	-	41.4	-	-	-	Gm .56 Sw .44	100% G 100% S	60% E, 20% Tt, 20% Tf 25% E, 25% W, 25% Tt, 25% Tf

Number of analysis points 9   Overall mean particle size 2.77Ø   Upward particle size ratio 1 : 0.38   (*6) Sr L = -, D = -; St W = -, D = -

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

TABLE 8.25 SUMMARY STATISTICAL ANALYSIS OF BEACH HEAD TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	10	71	82.1	3.1	2.5	-	65% H, 35% I.G.	41% DkB, 41% Lt/Dk	9	2	70	14	CHUTE 1.00	100% S	100% Tf
CHUTE	3	21	80.3	3.1	2.3	1 : 1.2	50% H, 50% I.G.	81% Lt/Dk	8	2	69	12	RIDGE .75 CHUTE .25	67% G 100% S	50% Tf, 33% Tt 50% A, 50% Tf
PLAT	5	8	18.4	-1.0	4.0	-	n/a	n/a	-	-	-	-	RIDGE 1.00	100% S	60% Tt, 40% E
GRAVELS	9	-	-	-	-	-	-	-	-	-	-	-	PLAT .56 RIDGE .22 CHUTE .22	100% G 100% S 100% S	60% E, 20% Tt, 20% Tf 50% E, 50% Tt 50% W, 50% Tf

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.26 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR BEACH BAR HEAD TRENCH DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands % Abundance	Platform sands Upward transitions ≥ 20%
Fm	n/a	n/a	n/a	n/a	-	-	2	Sw 1.00	-	-
O	-	-	-	-	O	Sw 1.00	-	-	-	-
Sw	-	-	-	-	100	Sw 1.00	98	Sw .82	-	-
Sr	-	-	-	-	-	-	-	-	-	-
Ss	-	-	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	100	-

deposits, however, have the same facies composition; both are made up of tilted facies Sw units. As such, both facies and particle size characteristics are laterally consistent in Beach Bar Head trench. The gravels-platform and chute-ridge transitions are gradational in nature. Basal gravel contacts are primarily wavy or even in outline. Other contacts are almost entirely tilted. Both ridge and chute elements have heterogenous or internally graded sediment mixes. Ridge deposits are banded dark brown in color, while chute deposits are light/dark brown bands.

8 : 3 : 8 Analysis of Beach Bar Tail trench

Local environmental conditions around Beach Bar Tail trench differ markedly from those at the bar head. The floodplain is well established ($\geq$35 years), with a series of small chutes cut diagonally across its surface. There is no vegetative evidence of recent lateral accretion, and the adjacent gravel bar platform is dissected by many smaller channels. A prominent secondary channel adjacent to the western margin of the trench divides the bar platform at high flows. A large tree stump ($\geq$1.0m in diameter) was found at this point, along with many other logs in the trench. As in the bar head trench, these were oriented down-valley, at the base or within ridge deposits.

Although the proportion of lower energy facies in Beach Bar Tail trench is consistent with the overall data set (65%), the proportion of facies Sw is greatly increased (as in the head trench; Table 8.27). This increase is at the expense of facies Fm and Sr. Facies Sp dominates the high energy facies, in thicker units than observed elsewhere. Whereas average particle sizes are roughly consistent with the overall trench data for lower energy facies, high energy facies are 1.0ϕ finer, resulting in a finer overall mean particle size (by 0.65ϕ).

As observed elsewhere, lower energy facies generally have heterogenous or internally graded sediment mixes and are dark brown in color. Facies Fm units often have a uniform mix, and facies Sr units are primarily light brown, with larger dimensions than in the overall data set. High energy facies are light brown with occasional dark brown bands. Facies Sp units are heterogenously mixed, whereas facies St units are internally graded (with smaller dimensions than observed in the overall trench data).

TABLE 8.27 SUMMARY STATISTICAL ANALYSIS OF BEACH BAR TAIL TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	8	2	83	3.9	3.5	2.0	50% U, 50% I.G.	63% Dk3, 25% Lt/Dk	Sw 1.00	75% S	75% Tt, 25% E
O	13	1	100	1.2	3.4	1.7	100% H	77% Dk4, 23% Dk3	Sw .54 Fm .31	57% S 100% S	86% Tt 50% Tt, 25% E, 25% Tf
Sw	36	52	100	19.7	3.0	2.3	64% H, 36% I.G.	47% Dk3, 33% Lt/Dk	Sw .47 O .33	65% G 75% S	41% Tt, 25% Tf 75% Tt
Sr	7	10	50	20.0	2.7	2.8	57% I.G., 43% H	71% Lt, 29% Lt/Dk	Sr .60 Fm .20 O .20	100% S 100% S 100% S	67% Tt, 33% E 100% Tt 100% Tf
Ss	3	2	50	8.7	2.9	3.0	100% U	100% Lt	Sw 1.00	67% S	67% Tt, 33% E
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	4	27	50	93.3	2.9	2.7	100% H	100% Lt/Dk	Sw .75 Sp .25	67% G 100% G	67% Tt, 33% E 100% Tt
St	1	6	17	83.0	2.7	3.0	100% I.G.	100% Lt/Dk	Sw 1.00	100% S	100% Tt
Gm	-	-	-	-	-	-	-	-	-	-	-
G	4	-	67	-	90.0	-	-	-	Sw .25 Sr .25 Sp .25 St .25	100% S 100% S n/a 100% S	100% Tt 100% Tt n/a 100% Tt

Number of analysis points 6   Overall mean particle size 2.92Ø   Upward particle size ratio 1 : 0.67   (*6) Sr L = 12, D = 3; St W = 30, D = 12

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike
(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

Facies organization within Beach Bar Tail trench is extremely complex, with a mix of upward transitions for virtually all facies. Indeed, the four upward transitions from basal gravels are divided among four facies types! For most facies, however, facies Sw is the preferred next-facies state, and there is notable intermingling of lower energy facies. In general, basal surfaces are sharply defined, and tilted towards the main channel.

Ridge, flood cycle and chute elements are dominantly upward fining, with heterogenous sediment mixes. Adjacent to the main channel, thick bar platform deposits are the basal facies (Figure 8.8). These are light brown colored, internally graded, planar bedded sand units. Depth to gravel varies markedly within platform sediments, possibly associated with scour around logs. Beyond the platform element, however, the basal gravel contact tilts notably towards the main channel, in a classic ridge form. This ridge element is roughly 1.5m thick across the 11m of the trench, and is made up primarily of thick, facies Sw units. This makes up 58% of the trench (Table 8.28), and is composed of a mix of dark and light brown beds, with a broad range in facies composition (Table 8.29). The floodplain surface of the ridge tilts notably adjacent to the main channel. A small chute (4m wide, 0.5m deep) has reworked part of the floodplain surface, with a lower energy fill (especially facies Fm). Adjacent to this chute, atop the ridge away from the main channel, are flood cycle deposits, which thicken up to 0.75m thick. These are lighter brown in tone than elsewhere, associated with the high facies Sr content.

At the facies scale, sequences are indicative of up-sequence reduction in energy of deposition, but this is not reflected by particle size trends, which are roughly upwardly consistent. Similarly, facies types vary laterally within and between elements, but no particle size trends are evident in that direction.

8 : 3 : 9 Analysis of Pillbend trench

Pillbend is a well-defined point bar at the downstream end of the meandering section of the study reach. Sediment conditions upon the contemporary bar platform and marginal ridge are described in section 6.6.11. The eastern end of the trench was dug at the bar apex in the first ridge at the contemporary bar platform margin. Surface morphology upon the floodplain at this location is dominated by a series of discontinuous, irregularly oriented ridge and chutes. All deposits have accumulated since 1969, but vegetation patterns have been severely disrupted by chute channels.

TABLE 8.28 SUMMARY STATISTICAL ANALYSIS OF BEACH BAR TAIL TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	3	12	54.0	2.8	2.6	1 : 0.2	85% H	54% Lt	13 4	- -	CHUTE 1.00	100% S	100% Tt
SS	-	-	-	-	-	-	-	-	- -	- -	-	-	-
RIDGE	6	58	133.0	3.1	2.3	1 : 0.5	55% H, 36% I.G.	38% Dk3, 34% Lt/Dk	5 2	30 12	FC .75 CHUTE .25	100% S 100% S	67% Tt, 33% E 100% Tt
CHUTE	2	3	22.0	2.9	2.7	1 : 0.7	50% H, 38% U	63% Dk3, 25% Lt	12 3	- -	-	-	-
PLAT	4	27	93.0	2.6	2.9	-	100% I.G.	100% Lt	- -	- -	RIDGE 1.00	75% G	50% Tt, 25% E, 25% I
GRAVELS	4	-	-	-	-	-	-	-	- -	- -	PLAT .50 RIDGE .50	100% S 100% S	100% Tt 100% Tt

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.29 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR BEACH BAR TAIL TRENCH DATA SET

	Flood Cycles		*Sand Sheet*		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%
Fm	-	-	n/a	n/a	2	Sw 1.00	32	Sw 1.00	-	-
O	3	Sw .50, Sr .50	-	-	1	Sw .75, Fm .25	2	Fm 1.00	-	-
Sw	33	Sw .60, O .40	-	-	75	Sw .48, O .36	21	Fm .50, Sr .50	14	-
Sr	65	Sr 1.00	-	-	3	Fm 1.00	25	O 1.00	-	-
Ss	-	-	-	-	2	Sw 1.00	21	Sw 1.00	-	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	7	Sw 1.00	-	-	86	-
St	-	-	-	-	10	Sw 1.00	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-

Percentage facies abundances in Pillbend trench are remarkably similar to those of the overall data set (Table 8.30), other than the slightly greater proportion of facies Sw and the reduced proportion of facies Sp. Lower energy facies make up 71% of the trench. Overall mean particle size is in the fine sand class. Sediment mix and color characteristics by facies are consistent with trends outlined for virtually all other trenches. Lower energy facies are primarily darker brown, heterogenously mixed sediments. Facies Fm is more uniform in composition than noted elsewhere, while facies Sr units are slightly darker and more heterogenous, with slightly smaller dimensions than noted overall. High energy facies are light brown, internally graded deposits.

Individual beds are consistent, or similar, in composition from analysis point to analysis point, but are extremely laterally discontinuous (Figure 8.9). This is exemplified by the basal facies St unit at the eastern trench margin, as this unit extends laterally over only 3m of the trench. Similarly, the facies St unit in mid trench extends over only 8m. In both instances, these relate to broader scale depositional mechanisms. The former unit is at the edge of the contemporary bar platform, whereas the latter unit is found within a small chute unit at mid trench. The mixed lateral facies sequences are echoed in a vertical sense. Vertical sequences at the eastern trench margin indicate up-sequence reduction in energy of deposition. In mid-trench, however, lower and high energy facies are intermingled. At one analysis point the entire sequence is made up of lower energy facies. At the western trench margin, there are thin high energy facies units at the base of the trench, with thick intermingled lower energy facies atop.

Particle size trends in Pillbend trench also exhibit lateral variability. The proportion of fine sands increases away from the main channel. Medium sands take up roughly 50% of analysis points in the eastern half of the trench, but are found only as thin basal units at the western trench margin. Above this thin basal unit, vertical particle size trends are fairly upwardly consistent. In mid trench, vertical particle size trends are highly irregular, while holes adjacent to the contemporary bar platform are clearly upward fining. Other than the basal facies G-Gm transition, basal surfaces are sharply defined. Basal gravel contacts are irregular in outline; other transitions have a mix of wavy, tilted and even outlines.

These sediment and particle size trends indicate that the element scale is much more instructive in evaluating formative mechanisms, as patterns relate closely with element

TABLE 8.30 SUMMARY STATISTICAL ANALYSIS OF PILLBEND TRENCH DATA AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	% presence by analysis point	Average bed thickness (in cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	20	10	60	11.2	3.7	1.8	90% U	45% Dk3, 45% Dk4	Sw .60	83% S	42% W, 42% Tt
									Sr .30	100% S	33% W
O	3	1	20	10.3	3.1	2.3	100% H	67% Dk4, 33% B	Sw 1.00	100% S	100% I
Sw	36	45	100	28.7	3.0	2.5	100% H	39% Dk1, 22% Dk2	Fm .30	100% S	78% Tt, 22% W
									Sw .20	83% S	67% W
									Sr .20	67% S	50% Tf, 33% Tt
Sr	15	15	60	23.1	3.0	2.3	80% H	40% Dk2, 33% Dk1, 20% Lt	Fm .38	100% S	67% Tt, 33% Tf
									Sw .25	50% S	50% W, 50% Tt
Ss	1	0	7	6.0	2.7	3.0	100% H	100% Lt	Fm 1.00	100% S	100% W
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	2	2	13	20.5	2.2	3.0	100% I.G.	100% Lt	Fm .50	100% S	100% Tt
									Sw .50	100% S	100% Tt
St	12	19	67	36.3	-0.6	3.9	100% I.G.	100% Lt	Sw .67	100% S	38% Tt, 25% E
Gm	10	7	60	17.0	22.3	-	-	-	Sw .60	83% S	33% E, 33% W
									Fm .40	100% S	50% E, 50% W
G	15	-	100	-	47.7	-	-	-	Gm .53	87% G	63% I, 25% Tf
									St .40	100% S	83% I

Number of analysis points 15 Overall mean particle size 2.08Ø Upward particle size ratio 1 : 0.74 (*6) Sr L = 7, D = 2; St W = 74, D = 25

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

(*6) Average ripple and trough dimensions : L = length, D = depth, W = width (in cm)

composition across the trench. In particular, the disruptive roles of chute channels and sand sheets are evident. Elemental composition of Pillbend trench is more equally spread among types than in any other instance (Tables 8.31, 8.32). High energy facies seldom are preserved in deposits away from the main channel.

The basal surface in Pillbend trench has a well defined ridge and chute outline, with depth variation up to 1m. This outline is roughly in phase with elements within the trench. Basal elements are either platform sands or chute channels. Atop these elements are mixes of ridge, sand sheet and flood cycle elements. Element association exhibits a distinct lateral patterning. At the eastern trench margin, coarse sand, high energy facies, bar platform sands have a low energy facies, ridge unit atop. The platform unit is about 0.6m thick, but is laterally discontinuous, extending only 3m into the trench. It is composed of fine gravels facies St units. Basal and surface contacts tilt consistently towards the main channel.

Two other bar platform elements, also about 0.6m thick, are laterally discontinuous, having been disrupted by flows within chute channel and sand sheet elements. These are composed of medium-coarse sand, mixed high and lower energy facies. The platform element in mid-trench has a deeply scoured, high energy infill (especially facies St), chute channel beneath it. This 7m wide, 1m deep channel differs notably in internal character from two lower energy infill chutes. An 11m wide, 0.5m deep chute, above platform deposits at the western margin, is composed of thinly interbedded facies Fm and Sw units. This chute is marginal to, and intermingles with, a ridge unit. Finally, a third, clearly defined, chute in mid-trench, sits atop this chute, a sand sheet, and platform deposits. Internal composition of this, 9m wide, 1m deep, channel, is dominated by facies Sw.

Ridge units are found at both margins of Pillbend trench. These are composed of relatively thick facies Sw (often tilted) and facies Fm units. At the western margin, the 1.5m deep ridge has been disrupted by a sand sheet element. The ridge element adjacent to the main channel is a continuous 0.5m thick unit, composed of individual lower energy facies units, which tilt towards both the chute in mid-trench and the main channel.

The two sand sheet element units in Pillbend trench have roughly equal average thickness (0.75m). They are located at both margins of the trench. The unit at the western margin lies within a ridge unit, and maintains a relatively uniform thickness over 9m, until disrupted by the

TABLE 8.31 SUMMARY STATISTICAL ANALYSIS OF PILLBEND TRENCH AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	6	6	22.3	3.1	2.2	-	100% H	50% Dk2	7	2	-	-	-	-	-
SS	10	22	50.3	3.1	2.5	-	100% H	55% Dk1, 36% Lt	8	3	-	-	RIDGE .60	67% S	50% Tt, 33% W
													FC .30	100% S	67% W, 33% Tf
RIDGE	14	17	27.5	3.1	2.3	1 : 0.5	80% H, 20% I.G.	40% Dk3, 30% Dk2	6	2	-	-	SS .60	67% S	67% Tt, 33% W
													CHUTE .40	100% S	100% Tt
CHUTE	14	28	45.3	2.2	2.7	1 : 0.9	47% H, 38% U	32% Lt, 24% Dk4, 21% Dk1	-	-	87	27	RIDGE .36	80% S	60% Tt, 20% W, 20% Tf
													FC .21	100% S	67% W, 33% Tf
													SS .21	100% S	67% I, 33% W
													PLAT .21	100% S	67% E, 33% I
PLAT	14	28	44.9	0.3	3.6	1 : 1.2	67% I.G., 21% H	67% Lt	5	2	69	24	CHUTE .50	86% S	57% W, 29% E
													SS .29	100% S	25% W, 25% A, 25% Tt, 25% Tf
													RIDGE .21	100% S	100% Tt
GRAVELS	15	-	-	-	-	-	-	-	-	-	-	-	PLAT .73	91% G	82% I
													CHUTE .27	50% S	50% I, 25% W, 25% Tf

(*1) FC = Flood cycle, SS = Sand sheet, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Tt = tilts towards the main channel, Tf = tilts away from the main channel, A = archlike

TABLE 8.32 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR PILLBEND TRENCH DATA SET

	Flood Cycles		Sand Sheet		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%	Abundance	Upward transitions ≥ 20%
Fm	-	-	-	-	7	Sr 1.00	27	Sw .67, Sr .33	4	Sw .33, Sp .33, St .33
O	16	-	-	-	2	-	0	Sw 1.00	-	-
Sw	30	-	81	Sw 1.00	66	Fm .75, O .25	43	Fm .50, St .33	10	Fm .25, Sp .25, St .25, Gm .25
Sr	54	-	19	-	26	Sr 1.00	3	Fm .33, Sw .33, Ss .33	10	Fm .50, St .50
Ss	-	-	-	-	-	-	1	Fm 1.00	-	-
Sh	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	7	Fm 1.00
St	-	-	-	-	-	-	22	Sw 1.00	47	St 1.00
Gm	-	-	-	-	-	-	4	Sw 1.00	23	Sw 1.00

upper chute channel. The morphology of the second sand sheet is somewhat different, as this is found atop platform sands and pinches out away from the main channel, as it rises in a ridge-shaped unit. In both sand sheets, however, facies composition is dominated by facies Sw, and particle size are finer than elsewhere. Indeed, particle sizes are finer than, or consistent with, adjacent elements. Finally, flood cycle deposits in Pillbend trench form a relatively thin (≤ 0.4m) unit, extending 13m atop the lower energy infill upper chute, and the sand sheet element away from the main channel. Facies composition varies within element, from facies Sw to facies Sw/Fm, to facies Sr, moving away from the main channel. These are moderately well sorted fine sands.

Lateral and downstream migration of Pillbend are reflected by a series of discontinuous ridge and swales. These have resulted in an irregular basal surface and complex lateral facies associations. Element organization, however, is consistent with patterns shown for other trenches, with basal gravels transitional to a mix of chute and their marginal ridge elements, with sand sheet and flood cycle deposits atop. The disruptive nature of flow upon former sediment surfaces is indicated by scour at the base of one chute, the discontinuous pattern of platform elements, and the presence of two distinctive sand sheet elements. Once more, chute channels have been the primary control upon element organization. Internal character of these chutes is highly variable, with differing mixes of high and lower energy facies infill. Indeed, there is a wider spread of both elements and facies in Pillbend trench than in any other trench.

In general, sediment conditions in Pillbend trench are consistent with observations made elsewhere at the facies scale. Sequences are upward fining in terms of both relative energy of deposition and particle size, with most units in the fine sand class. Individual facies exhibit similar characteristics with the overall data set, but are notably laterally discontinuous and variable in type. Lateral variability in vertical facies sequence across the trench is closely related to the pattern of chutes and ridges described above. In general, the proportion of fine sands increases away from the main channel, reflecting both the lower average energy of deposition in that environment, and the longer time period since initial deposition, allowing greater time for removal/disruption of high energy, coarser sand facies.

8 : 4 : 1 Down-valley and planform differentiation of sediment character within trenches

Average particle size, sediment mix and color are remarkably similar for each facies in all of the trenches observed, and are consistent with the 1985 data set. Sediment sequences generally are upward fining and indicative of up-sequence reduction in energy of deposition. In general, lower energy facies contrast markedly with high energy facies, as they are darker brown in tone, have more heterogenous sediment mixes, and are both finer and better sorted. In virtually all trenches, facies are both laterally discontinuous, and vary in type within the same bedding unit (event stratigraphy).

In stark contrast to these similarities, however, the proportion and internal organization of facies varies markedly from trench to trench (Table 8.33). Accordingly, mean overall particle size by trench is also highly variable, although generally in the fine-medium sand size class. Indeed, no trends are evident for sedimentologic composition down-valley, by planform style, or by bar type. Rather, the sedimentologic composition of trenches studied is related primarily to the extent and nature of local chute reworking of floodplain deposits. As such, sediment patterns relate to local geomorphic processes expressed at the element scale. The relative abundance of sediments accumulated by differing mechanisms varies significantly at each trench location, but cannot be related to planform scale phenomena. Hence, although there are larger numbers of visible chute channels within braided river planform reaches, chute channel reworking of floodplain sediments is seemingly just as prevalent upon lateral bars and point bars of the wandering and meandering river reaches.

Variability in chute abundance and sediment infill character are the primary reasons for the widely differing facies compositions of each trench. For example, Beach Bar Head and Tflent Mid-1 trenches are both dominated by chute and ridge deposits, but their proportion of lower energy facies varies from 92% to 38% respectively, and the four trenches on Tflent bar exhibit widely varying facies and element compositions.

Facies Sw is a dominant facies in all but two trenches, but its absolute proportion varies widely. Only in Upash and Tflent Mid-1 trenches are high energy facies prevalent. In both these instances, chute channels exhibit high energy flow characteristics, with scoured basal contacts. The proportion of fine sands is highest in Basbar, Tflent Tail and Beach Bar trenches. These were

TABLE 8.33 SEDIMENTOLOGIC SUMMARY OF TRENCH COMPOSITION

Trench	%Lower : High Energy Facies ratio	Dominant facies	Mean overall Particle size (ø units)	%Element Composition Vertical Accretion	Chute/ Ridge	Bar Platform
Overall	65 : 35	37% Sw	2.28	26	55	19
Basbar	79 : 21	32% Sr, 31% Sw	2.81	94	6	-
Upash	43 : 57	35% St, 23% Sw	1.65	20	41	39
Tflent Head	73 : 27	54% Sw	2.15	9	84	7
Tflent Mid-1	38 : 62	30% St, 24% Sp, 20% Sr	1.70	14	84	3
Tflent Mid-2	71 : 29	27% Sw, 24% Sr, 20% Fm, 20% St	2.37	58	24	19
Tflent Tail	74 : 26	39% Sr, 27% Fm	2.80	-	99	1
Beach Bar Head	92 : 8	92% Sw	2.77	-	92	8
Beach Bar Tail	65 : 35	52% Sw, 27% Sp	2.92	12	61	27
Pillbend	71 : 29	45% Sw	2.08	28	45	28

dug in quite different environmental settings, within each of the three planform styles studied. This reaffirms that local flow history is a more important control upon sedimentologic character, than bar type or channel configuration.

Basbar trench was the only trench studied in the braided planform reach. The complex pattern of laterally discontinuous, fine sand, mixed lower energy facies is consistent, however, with many other trenches. Flood cycle and sand sheet sequences extend across the trench, without disruption by chute channels. Bar platform sands are not observed. Indeed, only in Upash and Tflent Mid-2 trenches are platform sands preserved to a substantial extent. No specific environmental similarities were observed at these two trench locations, implying that preservation may be a randomly controlled mechanism.

Trenches on Upash, Tflent and Pillbend bars are all dominated by chute related deposits, although their character varies substantially. Upash and Tflent Mid-1 trenches have high energy chute infill units, and, hence, have the coarsest overall mean particle sizes of trenches studied. This can be related to trench position on Upash, as two prominent channels are adjacent to this mid-channel bar. High energy flows have swept across the floodplain surface, producing large abundances of facies St. Conditions are very different at Tflent Mid-1 trench, and the characteristics at this trench are anomalous with those observed elsewhere upon Tflent bar.

Sediment patterns most similar to those of Upash are observed upon Pillbend, a point bar within the meandering planform reach! In both instances, trenches have roughly horizontally stacked elements, which have become laterally discontinuous as chute channels rework deposits. Both trenches have distinct ridge and swale surface patterns. Resulting sediment patterns exhibit a wide range of facies types and configurations. The proportion of coarse sands gradually diminishes away from the main channel, associated with the manner of lateral bend migration.

Chute channels observed in trenches on Tflent bar, other than Tflent Mid-1 trench, have thinly interbedded, lower energy facies infills (as shown in the 1985 data set). Chute and ridge elements dominate these trenches, although in Tflent Mid-2 trench, chute disruption of sediment sequence is minimal, and flood cycle deposits are abundant. The only other trenches in which substantial flood cycle units were observed are Basbar and Beach Bar Tail. In the latter instance, these thicken away from the main channel. Sediment patterns in Beach Bar trenches differ from others, as ridge units have accumulated on the inner accretionary bank as the main channel has migrated laterally, producing larger, more laterally continuous ridges than observed elsewhere. These dominantly lower energy facies configurations are very similar to those observed upon Basbar, but element types are different for the two bars.

In summary, while some comparisons between trench depositional sequences can be made, these refer to local scale phenomena at the element scale, rather than down-valley position, planform style, or bar type scales. In particular, the manner and extent of chute reworking is critical.

8 : 4 : 2 Summary of element character and composition for each trench

The sedimentologic properties described for each element in Table 8.5 are consistent for virtually all trenches. As outlined in section 8.2.3, they are also consistent with 1985 data locale properties. This implies that element composition is independent of trench position in both down-valley and planform senses. This notion is reviewed for each element in this section.

The morphology, scale, position in trench and sedimentologic character of all observed flood cycle depositional units are summarized for each trench in Table 8.34. These deposits are located either at the floodplain surface, or beneath sand sheet deposits, in each of the six instances in which they are observed. Only in Basbar trench do they occur as a basal element. They occur in either an infill shape, adopting the form of surface relief (e.g. Upash, Pillbend) or extend across trenches in a wedge or sheet-like shape. They are composed primarily of lower energy facies, especially facies Sw and Sr. In general, these are thinly interbedded, dark brown banded, heterogenously mixed deposits. Mean particle sizes are in the fine-very fine sand class.

Sand sheet elements typically are coarser than flood cycle deposits (Table 8.35), although their overall particle size by trench varies markedly according to their facies composition. When facies St dominates, mean particle sizes are in the medium sand class (e.g. Upash), whereas particle sizes are notably finer when lower energy facies predominate (e.g. facies Sw in Pillbend). Coarser sand sheet units typically are lighter brown in color, with more internally graded sediment mixes. Sand sheets occur at, or close to, the floodplain surface. They adopt wedge-shaped forms, thinning out away from the main channel. While their morphology, position and scale are relatively consistent in each trench, their facies composition varies markedly, but in an irregular

TABLE 8.34 SUMMARY OF FLOOD CYCLE ELEMENT CHARACTER AND COMPOSITION BY TRENCH

Trench	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Basbar	Laterally extensive sheet, directly atop basal gravels, extending across 21m trench, thickening to 1.2m away from the main channel.	72 : 28	34% Sw, 28% Sh	2.8	Simple facies composition. Heterogenous, mixed light/dark brown sediments.
Upash	Two units : 1) Very thin (<0.3m) extending across-trench in mid-sequence, atop sand sheet and chute elements. 2) Infill unit (10m wide, 0.4m deep) at the bar surface between ridge and chute elements.	100 : 0	68% Sr	2.7	Very simple facies composition. Banded dark brown, heterogenous sediments.
Tilent Head	Not observed				
Tilent Mid-1	Very thin (<0.2m) unit extending across a major chute unit for 11m.	93 : 7	35% Sr, 31% Sw	2.8	Mix of heterogenous, dark brown, lower energy facies, with many thin organic litter layers.
Tilent Mid-2	Dominant unit in trench. Up to 1.5m thick, this unit extends across the 13m trench, atop platform sands. Thin chute, ridge and sand sheet elements are observed within, and a sand sheet is positioned atop.	99 : 1	44% Sw, 38% Fm	3.0	Made up of thinly interbedded lower energy facies, which are primarily transitional upwards to facies Fm. Beds exhibit a range of colors, and generally are internally graded.
Tilent Tail	Not observed				
Beach Bar Head	Not observed				
Beach Bar Tail	Wedge-shaped unit, extending laterally over 5m of the trench, increasing in thickness to 0.6m away from the main channel. Located atop a ridge unit, adjacent to a small chute.	100 : 0	65% Sr, 33% Sw	2.8	Made up of facies Sw/Sr and Fm, the relative proportions of which vary across the unit. Sediments are mainly light brown colored and heterogenous, although vertical sequences are notably upward fining.
Pillbend	Thin (0.3m thick) unit, located within a depressed part of the floodplain surface, atop sand sheet and chute units, with ridges at either margin.	100 : 0	54% Sr, 30% Sw	3.1	Notable event stratigraphy within-element, with no upward element transitions. Sediments are dark brown colored, with heterogenous sediment mixes.

TABLE 8.35 SUMMARY OF SAND SHEET ELEMENT CHARACTER AND COMPOSITION BY TRENCH

Trench	Morphology, scale and position in trench	Sedimentologic character			Other aspects
		%Lower : High energy facies	Dominant facies	Mean particle size (ø units)	
Basbar	Discontinuous wedge unit (up to 10m wide, <1m thick) which pinches out away from the main channel. Located at the bar surface, atop sand sheets.	100 : 0	72 % Sr	2.8	Extremely simple composition, with few upward facies transitions. These are loose, light-brown sands, with heterogenous sediment mixes.
Upash	Two discontinuous wedge units 1) 16m wide, thickens to 0.4m away from the main channel, atop a basal platform unit, with chutes at both margins. 2) Upper unit, 7m wide, 0.6m deep, which pinches out away from the main channel. Located between flood cycle and ridge elements.	15 : 85	83% St	1.9	No internal upward facies transitions. Sediments are light brown with heterogenous or internally graded sediment mixes.
Tflent Head	Small unit, 0.3m deep, atop chute at the western trench margin surface (adjacent to the main channel), extending 6m before disrupted by a second chute unit.	100 : 0	72% Sr, 28% Sw	3.2	Relatively uniform facies Sr composition. Ripples have fairly large dimensions. Sediments are banded light and dark brown in color, and internally graded.
Tflent Mid-1	Laterally discontinuous unit, extending 14m from the western margin of the trench, gradually thinning from 0.4m thick, in a wedge shape. Sand sheet sits atop ridge, chute and flood cycle elements.	45 : 55	55% St, 45% Sr	2.3	Light brown, internally graded sediments vary in composition from analysis point to analysis point within the unit.
Tflent Mid-2	Two units, both atop flood cycle elements : 1) Thins from 0.5m towards the east, as it has been cut by a chute channel. 2) Thicker (0.6m) unit, extending >5m before being cut by the same chute as above.	64 : 36	64% Sr, 28% St	2.4	Principles of event stratigraphy apply. Facies Sr dimensions are notably larger than elsewhere. Sediments are internally graded or uniform, light brown sands.
Tflent Tail	Not observed				
Beach Bar Head	Not observed				
Beach Bar Tail	Not observed				
Pillbend	Two discontinuous (up to 0.7m thick) units, located at opposite ends of the trench : 1) At the west margin, within a ridge unit and adjacent to a chute, with flood cycle deposits atop. Basal surface tilts towards the main channel. 2) Unit tilts notably towards the main channel atop a platform unit, with ridge deposits atop.	100 : 0	81% Sw	3.1	Heterogenously mixed, light or dark brown sands, with no internal upward facies transitions. Units are either tilted facies Sw and Sr deposits, or laterally continuous facies Sw deposits.

manner (i.e. it can not be related to down-valley, planform, or bar type sense). Whenever sand sheet deposits are abundant, their loose sand composition is not conducive for vegetative survival.

Ridge units observed within trenches vary greatly in scale, contingent upon the magnitude of the adjacent marginal channel (Table 8.36). Accordingly, different styles of flow conditions within chutes result in quite different sediment suites, with differential preservation of coarser sand, high energy facies. For example, ridges within Basbar, Upash, Tflent Head and Tflent Mid-1 trenches have considerably greater proportions of light brown, internally graded, high energy facies than elsewhere. This is reflected in coarser overall particle sizes in Upash and the Tflent trenches, whereas the ridge unit within Basbar and remaining trenches are composed of fine sands. Whenever units exhibit a range of facies types, these are laterally transitional in character within beds. In most instances, however, coarse sands are not preserved in ridges, as described in section 8.2.3, and sequences are heterogenously mixed, banded dark brown, lower energy facies. Facies Sw is dominant, especially in Beach Bar trench ridges. Ridges in these trenches are laterally extensive, and up to 1.5m thick. In contrast to other observed ridge depositional sequences, these broader scale features relate to the main channel itself. In all instances, basal surfaces of ridges tilt towards their marginal channels, often with gradational contacts.

Within element sedimentologic properties are considerably more variable in chute channels than in any other element (Table 8.37). Chute channel scale, position within trench and character of internal composition varies greatly from trench to trench. This variability, however, cannot be related directly to down-valley position, river planform style or channel bar type. Indeed, the character of chutes is often highly variable within a trench (e.g. Upash, Pillbend). Rather, it reflects local flow character, which in turn probably reflects local surface morphology (as chutes naturally adopt courses of minimum resistance upon floodplain or bar surfaces).

There are essentially two style of chute channel. High energy chute infill units generally have low width-depth ratios. These typically are observed at, or close to, the base of trench deposits, with scoured basal contacts and high energy facies infills (e.g. Upash, Tflent Mid-1, Pillbend). Mean particle sizes are in the medium sands class, and sediments have very jumbled compositions, with intermingled facies, a wide range of sediment mixes, and mixed light and dark brown colored beds.

TABLE 8.36 SUMMARY OF RIDGE ELEMENT CHARACTER AND COMPOSITION BY TRENCH

Trench	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Sedimentologic character: Dominant facies	Mean particle size (ø units)	Other aspects
Basbar	Small (2m wide, 0.5m deep), recently accreted unit at the bar margin, with a steeply curved contact.	66 : 34	39% Sw, 35% Sh, 27% Fm	3.0	Heterogenous sediment mix, with a wide range of colors.
Upash	Thickens to >1m deep at the western margin of the trench, extending across 11m. Basal contact dips away from the main channel, atop sand sheet and flood cycle units.	69 : 31	56% Sr	2.2	Notable within-element lateral facies variability. Sediments are generally light brown, with heterogenous sediment mixes.
Tflent Head	Two 1m thick units, at either end of the trench, with tilted basal contacts and marginal chute channels. Units sit atop remnant platform sands at the western end, and atop basal gravels at the eastern end.	72 : 28	62% Sw	2.3	Intermingled dark brown, heterogenously mixed lower energy facies. These become more thinly interbedded away from the main channel.
Tflent Mid-1	Three units, two of which are about 0.8m deep, marginal to the major chute unit in mid-trench. These sit atop basal gravels. The third unit is smaller (4m wide, 0.6m deep), and is located adjacent to a smaller chute and a sand sheet at the floodplain surface.	67 : 33	34% Sr, 28% Sw	1.9	The two lower ridges are made up of intermingled lower and high energy facies, whereas the upper unit is composed solely of facies Sr. Deposits exhibit a range of sediment mixes and colors.
Tflent Mid-2	Small unit (0.8m deep), adjacent to a shallow chute, contained within a large flood cycle element at mid-trench depth.	100 : 0	91% Sw	2.6	Very simple facies composition, with interbedded facies Sw and Fm units. Deposits are internally graded, and occur as light/dark brown bands.
Tflent Tail	The dominant element in the trench, thickening to 1.4m. Sits atop basal gravels or chute deposits, and is always marginal to the latter.	94 : 8	52% Sw, 30% Fm	3.0	Facies units are laterally discontinuous and change in character within the ridge, but are primarily facies Sw or Fm units, with a mix of light and dark brown colors and heterogenous or internally graded sediment mixes.
Beach Bar Head	The dominant element in the trench. The ridge has a roughly even basal surface, but the floodplain surface tilts towards the main channel. Sequences thicken notably from 0.3 to 1.5m away from the main channel. They rest atop a remnant bar platform unit, and have a chute element within them.	100 : 0	100% Sw	3.1	Mainly tilted, dark brown banded, heterogenous or internally graded, facies Sw units, which occur in a laterally continuous manner.
Beach Bar Tail	Thick (1.5m) unit, which extends across the trench. It is located above either remnant platform deposits or basal gravels, with a notable tilt towards the main channel. Small chute and flood cycle units are located atop.	81 : 19	75% Sw	3.1	Mix of dark brown banded, upward fining lower energy facies sequences, in which facies Sw dominates as the preferred next-state. Units have either heterogenous or internally graded sediment mixes. Interbeds become notably thinner towards the main channel.
Pilbend	Two major units, both with prominent tilted basal surfaces : 1) 1.5m thick units, intermingled with a chute element at the western trench margin, interrupted in mid-unit by a sand sheet. Adjacent to flood cycle unit at the bar surface. 2) 0.4m thick unit, located atop chute, sand sheet and bar platform deposits, which thins either side of the ridge top. Adjacent to flood cycle deposits at its western edge.	100 : 0	66% Sw, 26% Sr	3.1	Mainly dark brown banded, heterogenously mixed sediments, with an upward fining particle size trend. Ridge 1 has intermingled facies Sw and Fm, whereas ridge 2 is made up largely of individual facies Fm, Sw Sr, with few upward transitions.

TABLE 8.37 SUMMARY OF CHUTE ELEMENT CHARACTER AND COMPOSITION BY TRENCH

Trench	Morphology, scale and position in trench	Sedimentologic character		Mean particle size (φ units)	Other aspects
		%Lower : High energy facies	Dominant facies		
Basbar	Not observed				
Upash	Three units, of very different character : 1) Basal, high energy infill chute (>8m wide, 2m deep) at the western trench margin, adjacent to a bar platform unit. 2) >4m wide, 0.7m deep, cut into bar platform deposits at the eastern trench margin. 3) Cuts flood cycle and sand sheet units at the floodplain surface at the eastern trench margin (>6m wide, <1m deep).	31 : 69	46% St, 22% Sw	1.3	Predominantly light brown, internally graded or heterogenously mixed sediments, the facies character of which varies by trench. Chute 1 has high energy facies infill, whereas chutes 2 and 3 are mixes of high and lower energy facies.
Tfient Head	Two units, in mid-trench : 1) 4m wide, 1m deep, atop bar platform sands, adjacent to ridge deposits and the second chute channel, with sand sheet deposits atop. 2) 5m wide, 1m deep, atop basal gravels, extending to the bar surface, marginal to a ridge element and the second chute.	81 : 19	61% Sw	1.9	Mixed light and dark brown, internally graded sediments. Facies Sr and St dimensions are smaller here than elsewhere. Both chutes have mixed facies compositions.
Tfient Mid-1	Trench is dominated by a 16m wide, 1.5m deep chute, which has scoured basal gravels, leaving a remnant bar platform unit. Ridges are marginal at both edges, and flood cycle and sand sheet elements are atop.	23 : 77	36% Sp, 36% St	1.6	Very jumbled internal composition, with a mix of light and dark brown, heterogenous or internally graded sediment mixes. High energy facies are dominant, with a broad range of upward transitions.
Tfient Mid-2	Two relatively small chutes : 1) Very shallow (8m wide, 0.2m deep) unit within flood cycle deposits in mid-vertical sequence. 2) 6m wide, 0.8m deep unit, cut in sand sheet deposits at the bar surface.	60 : 40	29% Fm, 26% St, 25% Sr	2.6	Simple facies compositions, with internally graded, light and dark brown, upward coarsening sands. *Chute 1 is a run-off chute composed solely of lower* energy facies (facies Fm, Sw), while chute 2 has a mix of high and lower energy facies.
Tfient Tail	Two prominent chutes. A 12m wide, 1.8m deep chute has scoured basal gravels, in the deepest section of the trench. This is marginal to a small, remnant bar platform unit and ridge features. A smaller (>5m wide, 1m deep) chute at the western trench margin extends from basal gravels to the floodplain surface, with ridges at both margins.	54 : 46	26% Sr, 25% Fm, 25% Sp, 20% St	2.7	Mix of heterogenous and internally graded sediments, which are light or dark brown in color. Upward transitions are dominated by *facies Fm. Chute 1* is a mix of high and lower energy facies, whereas chute 2 has a dominantly lower energy infill.
Beach Bar Head	6m wide, 1m deep unit, contained within ridge deposits, sitting atop basal gravels.	100 : 0	98% Sw	3.1	Laterally continuous (occasionally tilted) facies Sw fill, which are mixed light and dark brown and heterogenous or internally graded.
Beach Bar Tail	Very small (4m wide, 0.4m deep) channel located within a ridge unit at the bar surface, with flood cycle deposits adjacent, away from the main channel.	80 : 20	32% Fm, 25% Sr, 21% Sw, 21% Ss	2.9	Thinly interbedded, heterogenous or uniform, dark or light banded, facies Fm, Sr, Sw and Ss units.
Pillbend	Three channels, with very different character : 1) 11m wide, 0.6m deep chute, which intermingles with ridge deposits at the western trench margin. Sits atop basal gravels. 2) 7m wide, 1m deep chute, scoured into basal gravels, with bar platform and chute deposits atop. 3) 9m wide, 1m deep chute in mid-section of mid-trench. Sits atop bar platform and chute deposits, with marginal sand sheet deposits and both flood cycle and ridge deposits atop.	73 : 27	43% Sw, 27% Fm, 22% St	2.2	Chute 2 has a dominantly high energy facies infill, whereas the other chutes have solely lower energy infills (with facies Sw and Fm interbeds). Trough units in chute 2 have larger dimensions than noted elsewhere. Sediments have a broad mix of colors, and have heterogenous or uniform sediment mixes.

Lower energy chute infill units typically are smaller channels, with greater width-depth ratios (e.g. Tflent Mid-2, Beach Tail). These chutes are found at varying positions within vertical sequences; indeed, they often are found at the present floodplain surface. Facies Sw and Fm predominate, generally in thinly interbedded sequences. Accordingly, sediment mixes are generally heterogenous or uniform, and beds typically are dark brown colored. Mean particle sizes are in the fine sands class. These chutes are similar in character to the run-off chutes described in chapter 7.

Observed bar platform deposits typically occur as small remnant units at the base of trenches (Table 8.38). These units are less than 10m wide and less than 1m deep. Only in Upash and Tflent Mid-2 trenches are platform sands prominent, but even in these cases they are laterally discontinuous. Platform sands are never observed with the abundance noted in the 1985 data set. Their reduced presence seemingly relates to chute channel reworking of sediments, as chutes often are found at platform element margins. In all instances, platform sediments are light brown colored, internally graded, high energy facies, the character of which varies from trench to trench. Facies compositions are extremely simple throughout. Mean particle sizes vary markedly, due to variability in the proportion of fine gravels.

In summary, while elements in themselves are distinct from each other in terms of their summary properties, they are either consistent in character for all trenches or exhibit no regular variability in down-valley position, planform type, or channel bar type. This implies that the element scale provides a more insightful manner for evaluating river depositional sequences than any of these alternative schemes. Element abundance, however, varies notably from trench to trench, associated with local-scale flow properties. The spatial association of observed elements is assessed for each trench in the following section.

8 : 4 : 3 Summary of element association by trench

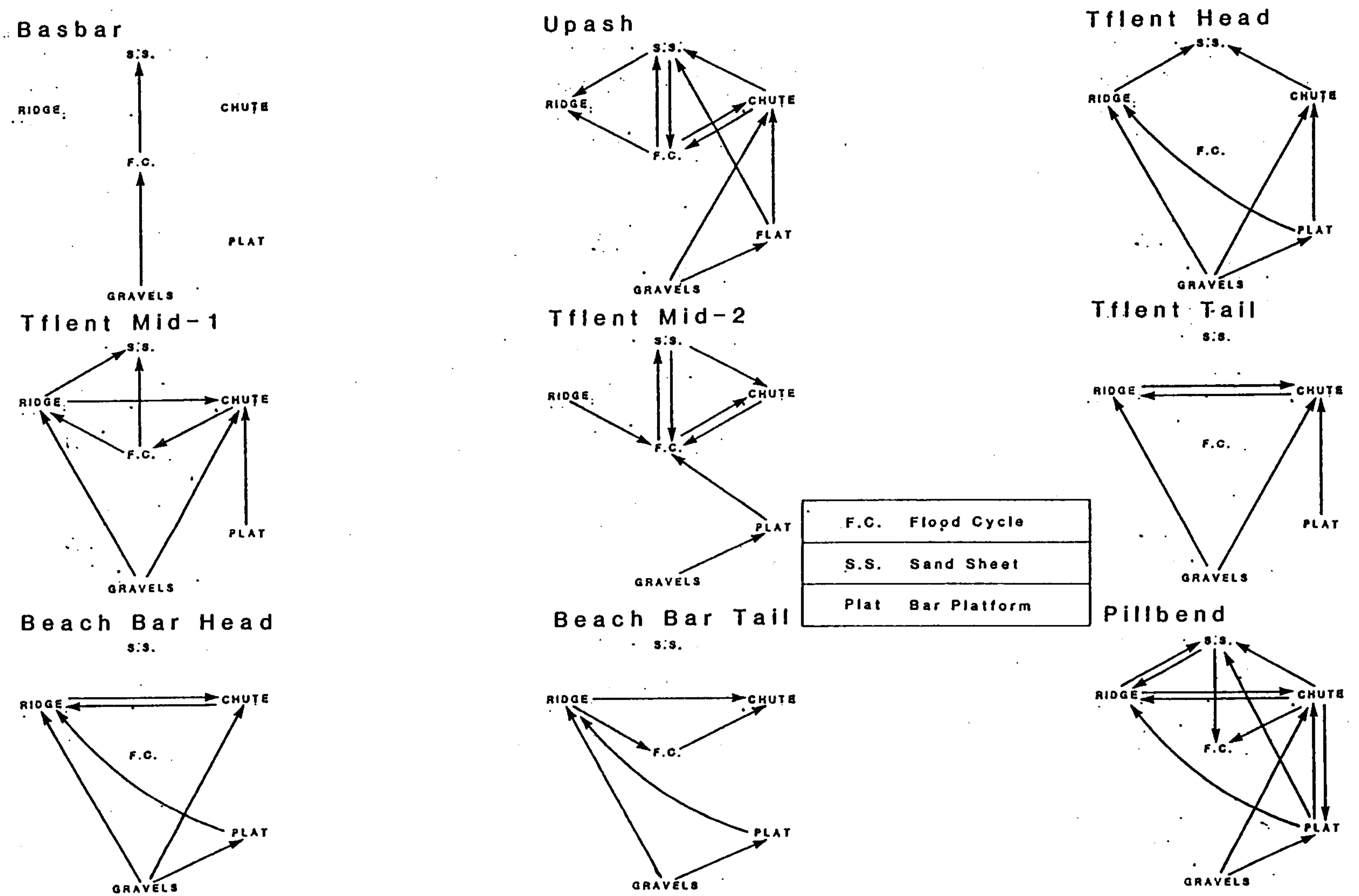
Summaries of element associations for each trench are presented graphically in Figure 8.10. Upward element transition sequences are very similar for each trench. Variable positions within sequences are noted solely for chute and ridge elements. Basal gravels are transitional upwards to platform sands, whenever these units are left with any prominence. If removed, chute and ridge deposits form the basal element. Only in Basbar do these principles not apply. In this case, flood

TABLE 8.38 SUMMARY OF BAR PLATFORM ELEMENT CHARACTER AND COMPOSITION BY TRENCH

Trench	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Basbar	Not observed				
Upash	Thick (up to 2m) basal unit, >14m wide, disrupted by chute channels at its western margin and at the surface at the eastern margin.	33 : 67	38% Sw, 28% St, 25% Sp	1.5	Light brown, internally graded sediments, with mixed facies organization. trough dimensions are notably larger than elsewhere.
Tflent Head	Remnant unit, 0.2m thick, at the western trench margin, cut by a chute, with ridge and chute deposits atop.	0 : 100	100% Ss	1.9	Solely composed of light brown, internally graded, facies Ss.
Tflent Mid-1	Remnant unit, 3m wide, 0.4m deep, at the eastern margin of a major chute unit.	0 : 100	100% Sh	-1.0	Solely composed of light brown, internally graded, facies Sh.
Tflent Mid-2	Major platform unit observed within trenches. Wedge shaped, basal unit, thinning from 1.2 to 0.1m from east to west across the trench. Flood cycle deposits are located atop (i.e. this unit is not directly associated with chute deposits).	15 : 85	71% St	0.6	Light brown, primarily internally graded facies St units.
Tflent Tail	Very small, remnant unit (3m wide, 0.3m deep) at the eastern margin of a major chute unit.	0 : 100	100% St	-1.0	Light brown, internally graded, small facies St unit.
Beach Bar Head	Small, remnant unit (0.3m thick), in a wedge shape, which flattens out the basal surface, with a major ridge unit atop, adjacent to the main channel.	0 : 100	100% Gm	-1.0	
Beach Bar Tail	Thick basal (>1.5m) wedge unit, which flattens out the basal surface adjacent to the main channel, with a major ridge unit atop.	16 : 84	86% Sp	2.6	Solely composed of light brown, internally graded, facies Sp.
Pillbend	Three remnant, basal units : 1) 0.8m thick unit at the western trench margin; this unit pinches out adjacent to a chute channel, and has ridge and chute deposits atop. 2) 0.6m thick unit in mid-trench, which pinches out at both ends, intermingling with chute deposits at the western margin, and eroded by a sand sheet at the eastern margin. 3) 0.8m thick unit, which is laterally discontinuous to the east atop a small ridge (eroded by a sand sheet unit), but continuous with the main contemporary bar platform unit.	24 : 76	47% St, 23% Gm	0.3	Some facies Fm in unit 1, and a greater proportion of lower energy facies in unit 2, but sequences are dominated by high energy facies. These upward coarsening units are light brown in color and have internally graded or heterogenous sediment mixes.

FIGURE 8.10 ELEMENTAL ORGANIZATION IN EACH TRENCH

Transitions are drawn for each instance which occurs with a frequency $\geq 20\%$



cycle deposits are found atop basal gravels. Chute deposits vary considerably in their within-trench position. Indeed, as flows within these units rework other sediments, they are the pivotal element in within trench element association. In some instances chute and ridge elements occur at floodplain surfaces, but sand sheet and flood cycle deposits are more typically found in this position. In neither the five trenches studied in the wandering reach, nor the three trenches studied in the meandering reach, are the postulated models of planform locale association (suggested in chapter 7) consistently observed. Rather, chute reworking of sediments is prevalent in virtually all trenches observed, suggesting that depositional sequences are relatively consistent throughout the study reach and cannot be differentiated by planform.

8 : 4 : 4 The value of the element scale in sedimentologic analysis

Sedimentologic composition and character of each trench reflect local environmental character and flow history to a much greater extent than down-valley position, planform style or channel bar type. For example, the four trenches on Tflent bar vary markedly in composition. This indicates that formative conditions for producing distinctive sedimentologic suites occur at scales greater than the facies level (see Part B of the thesis), but cannot be differentiated at the channel bar type or river planform scale, using procedures outlined in this study. Local environmental character seemingly is best evaluated at the element scale. It is possible, however, that broader scale environmental differentiation may be facilitated at a valley-width scale.

Individual elements are defined by a range of differing properties (see Table 8.5), the character of which varies little within trenches studied. Elements can only be defined by summaries of their properties, however, as individual components may be similar for two or more elements. For example, facies compositions may be indistinct between flood cycle and lower energy chute infill units, or platform deposits and high energy chute infill units, but the position in sequence and morphology of these elements aids in their differentiation. In Beach Head trench, both ridge and chute elements are composed solely of facies Sw. Although facies compositions of elements are variable, however, facies themselves are consistent in character everywhere. Lower energy facies are dark brown, heterogenous fine sands, whereas high energy facies are light brown, internally graded medium sands. Variable proportions of these components result in differing elemental character.

As directly related to flow mechanisms, geomorphologically defined elements provide a much better basis for sedimentologic differentiation than facies, channel bar or planform scales. No consistent variation has been demonstrated for element style or association at broader scales, although it is possible that relative abundances of elements may vary according to down-valley position.

8 : 4 : 5 Summary model of element association for Squamish River data

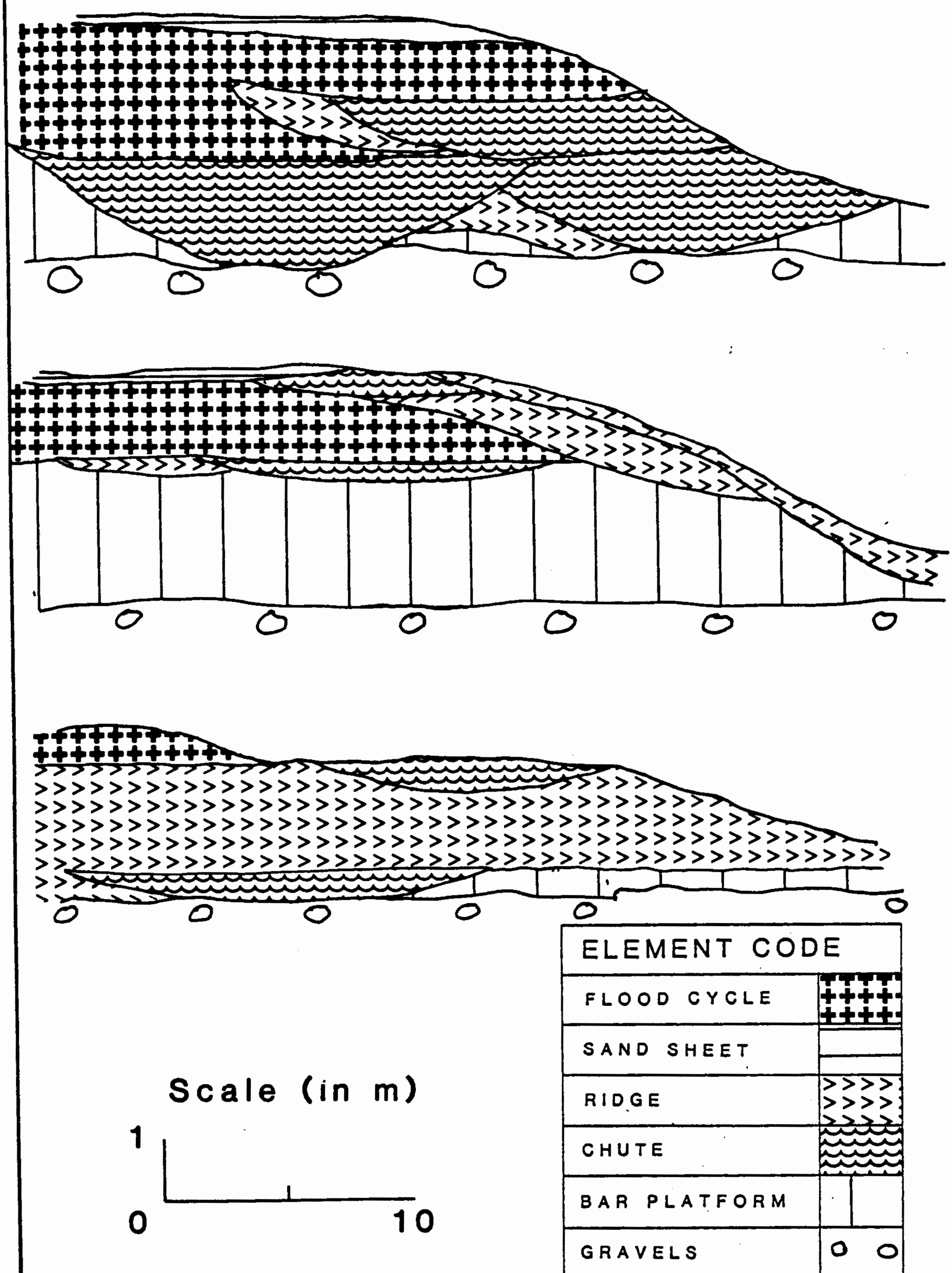
As no distinct sedimentologic differentiations can be made for element character or composition by planform style or down-valley position, it is possible to build up an element-scale model of sedimentologic sequences for the entire study reach. In essence, three scenarios can be painted, contingent upon the character of chute channel reworking of deposits (Figure 8.11). In the first scenario, platform deposits sit atop basal framework gravels with an irregular basal surface. These small, remnant units, typically less than 10m wide, 0.5m deep, seldom are observed with any abundance, as most of these deposits have been removed by high energy flows within chutes. The basal chute channel scours framework gravels, and has a high energy facies infill, intermingled with lower energy facies. Maximum dimensions for an observed chute channel were 16m wide and almost 2m deep.

Ridge deposits accumulate at the margin of the chute channel, ultimately developing to a roughly equivalent depth. In most instances these are made up of lower energy facies, as high energy facies deposited at the chute margin are removed by subsequent flows within the chute. The surface between ridge and chute elements is typically tilted and less well defined than other contacts.

Atop ridge and chute deposits, with a sharply defined, wavy outline, are flood cycle deposits. These are composed of thinly interbedded lower energy facies, and extend laterally across the trench, up to 1.5m deep. These deposits are often marginal at the surface to wedge-shaped, discontinuous sand sheet deposits, which are loose, fine-medium sand units which thin away from the main channel. In many instances these have eroded part of the flood cycle element.

In the second scenario, chute reworking of bar platform sands is less prevalent, and chutes have a lower energy facies infill. These chutes are also smaller, and may be found at the bar

FIGURE 8.11 SCHEMATIC REPRESENTATION OF TRENCH ELEMENTAL COMPOSITION



surface. Just as chutes are smaller, so are their marginal ridges. These also vary in position within the trench. Under such circumstances, both platform sands and flood cycle deposits occur in thicker wedge-shaped units, with high and lower energy facies compositions respectively. Sand sheet elements play a similar role to that described in scenario one.

An alternative to these two postulated models of element association for Squamish River floodplain deposits is presented by Beach Bar trench sediment sequences, in which ridge deposits are dominant across the trench, since they are associated with the main channel, rather than chute channels. This scenario may only apply under conditions of uniform channel migration.

In summary, details of the overall trench data set sedimentologic properties described in section 8.2.3 apply consistently for each trench. Elements can be differentiated successfully using the criteria outlined in Tables 4.7 and 8.5. While elements themselves are relatively uniform in character, their spatial arrangement varies according to three scenarios, although these scenarios cannot be located specifically within the study reach. Rather, they are contingent upon local flow character, especially the manner of chute reworking of sediments. Accordingly, elements often are laterally discontinuous. Their spatial distribution, however, offers much more meaningful insight into river depositional sequences than can be offered at facies or channel planform scales.

Sedimentologic properties of the 1986 trench data set are roughly consistent with those described for the 1985 hole data set in part B of the thesis. Observed differences are explained by the lower energy depositional environments, located further from the main channel, in which trench samples were obtained. Elements analysed in trenches have similar sedimentologic compositions to locales. The surface floodplain expression, however, is not always a good guide to subsurface element composition. Sediment sequences generally are indicative of up-sequence reduction of energy of deposition, but element organization indicates that sequences are laterally discontinuous. Internal unconformities result from the removal of coarse sand, high energy facies within platform elements, associated with chute channel reworking. The general applicability of this scenario is tested in chapter 9, which examines the longitudinal continuity of elements in bank exposures within the study reach.

CHAPTER IX

LONGITUDINAL ANALYSIS OF CHANNEL PLANFORM SEDIMENTOLOGIC VARIABILITY

9 : 1 Introduction

Element character, composition and spatial association were shown not to vary in any consistent manner by river planform style or channel bar type in chapter 8. The character of sediment sequences in trenches dug perpendicular to the main channel were either relatively consistent down-valley, or varied in an irregular manner, conditioned by local scale chute reworking of sediments. In this chapter these principles are evaluated at a broader scale in 13 bank exposures, divided equally among the three planform styles in the study reach. These vary in length from 90 to 210m (contingent upon length of exposure and disturbance). Site availability in the braided reach was restricted to exposures adjacent to secondary channels. In the wandering and meandering planform reaches, extensive exposures were studied at either the concave banks of bends, or immediately upstream from contemporary bar deposits.

Depositional sequences in the 1987 data set include a broader range of sediment types than those of the 1985 and 1986 data sets, and a new element, distal overbank deposits, was included in analysis. These deposits were lain down among well-developed vegetation away from the main channel, and typically occur as extensive sheets of thinly interbedded, (in some instances even massive or laminated), fine sand, lower energy facies. As samples in previous data sets were collected upon contemporary bars and at their margins, distal overbank deposits were not observed. In the 1987 data set, these deposits are observed in mid-sequence, characteristically with flood cycle and sand sheet deposits atop. Thick sequences of distal overbank deposits were observed in each of the three planform styles studied.

In section 9.2, facies and element composition, character, and spatial associations in the 1987 data set are compared with the 1985 and 1986 data. Sediment sequences in each bank exposure are summarized by planform reach in sections 9.3 to 9.5, using both statistical data and visual representations of each bank exposure. Down-valley and channel planform sedimentologic trends are analysed for elements observed in bank exposures in section 9.6, and a three-dimensional model of Squamish River floodplain deposits is proposed at this scale.

9 : 2 Comparison of 1987 section analysis of bank exposures with other data sets

Lower energy facies account for 80% of observed bank exposures (Table 9.1), as opposed to 65% in the 1986 data set. The proportions of facies Fm and Sr are notably higher, the former occupying 23% of observed bank exposures. Average facies Fm bed thicknesses are considerably greater than elsewhere, as this is the dominant facies noted in the distal overbank element. In contrast, the proportion of facies Sw (29%), is lower and in thinner units than in the other data sets. All lower energy facies are found in a greater proportion of analysis points than in previous data sets, reflecting both the thicker depositional sequences and the predominance of flood cycle and sand sheet elements (Table 9.2).

As observed previously, lower energy facies have particle sizes in the fine sand class, have predominantly heterogenous sediment mixes, and are banded dark brown, with occasional light brown beds, in color. Facies Fm, O and Sw are all slightly finer than observed in other summary data sets (by $\leq 0.5\phi$ in all instances). Facies Fm is more uniform in composition and Sr more internally graded than in other data sets. Facies Sr units are lighter brown than other lower energy facies. Their average dimensions are consistent with the 1986 data set.

Among the high energy facies, the proportion of facies Ss (6%) is greater than in the 1986 data set (with significantly thicker average bed thicknesses), whereas facies Sp and St are much less prevalent (the former is seldom observed). Facies Gm has roughly the same abundance as elsewhere, but occurs less frequently, in thicker units. Indeed, all high energy facies are observed in a lower proportion of analysis points than elsewhere, possibly reflecting their lower preservation potential in these older sediment suites.

High energy facies are notably coarser than lower energy facies, although facies Ss, Sh and St are finer than observed in the 1986 data set. This, along with the greater proportion of lower energy facies in bank exposures, accounts for the significantly reduced overall particle size of this data set (0.6ϕ finer than the 1986 data set). High energy facies in the 1987 data set have more heterogenous sediment mixes than demonstrated for the 1986 data, but all are either heterogenous or internally graded, and light brown in color. Facies St dimensions are consistent with those for the trench data set.

TABLE 9.1 SUMMARY STATISTICAL ANALYSIS OF THE 1987 SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	450	23	80	15.7	4.1	0.6	52% H, 31% U	56% Dk4	Sw .46 Sr .25	74% S 92% S	51% W 50% W
O	108	1	51	1.9	3.4	2.4	94% H	41% Dk4, 28% B, 21% Dk5	Sw .57 Fm .24	84% S 92% S	61% W 42% W, 35% Td
Sw	575	29	96	15.5	3.1	2.4	91% H	39% Dk2	Fm .37 Sr .25	76% S 90% S	44% W 42% W, 22% Td
Sr	389	27	88	21.5	2.7	2.7	51% H, 47% I.G.	53% Lt, 27% Dk1	Sw .37 Fm .29 Sr .22	93% S 98% S 91% S	47% W, 26% Td 22% Td 59% W
Ss	58	6	39	33.8	2.5	2.8	65% H	66% Lt	Fm .51 Sw .32	96% S 100% S	33% Td, 25% E, 25% W 33% W, 23% Tu
Sh	14	1	11	22.5	2.3	3.0	64% H, 36% I.G.	91% Lt	Fm .50 Sw .25	100% S 100% S	100% E 67% Td, 33% E
Sp	9	1	7	36.1	1.0	3.0	67% H, 33% I.G.	63% Lt, 25% Dk1	Sw .33 Fm .22 St .22	100% S 100% S 100% S	67% Tu, 33% Td 50% Td, 50% I 100% W
St	80	11	41	40.4	1.1	3.4	85% I.G.	84% Lt	Sw .33 Sr .29	100% S 86% S	44% W, 20% Tu 50% W, 23% Td
Gm	15	2	13	32.9	34.0	-	-	-	Sw .33 Sr .27	100% S 67% G	67% W, 33% E 67% W, 33% I
G	89	-	79	-	135.0	-	-	-	Sw .25 Sr .21 St .20	100% S 100% S 100% S	85% I 71% I 33% I, 20% Td

Number of analysis points 112   Overall mean particle size 2.89Ø   Upward particle size ratio 1 : 0.95   (*6) Sr L = 12, D = 3; St W = 69, D = 19

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.2 SUMMARY STATISTICAL ANALYSIS OF THE 1987 SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	%Presence by trench	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	123	41	100	102.0	3.1	2.4	1 : 1.0	77% H	21% Dk2, 21% Dk4	11	3	50	17	SS .71	96% S	63% W
SS	74	12	92	50.8	2.5	2.9	1 : 1.1	61% H, 33% I.G.	66% Lt	19	5	96	27	FC .83	95% S	60% W, 25% E
DISTOB	45	19	38	127.2	4.1	0.4	1 : 1.2	53% U.C., 28% H	43% Dk4, 21% Dk2	9	2	-	-	FC .84	70% S	32% E, 32% W, 24% Td
RIDGE	5	1	31	51.2	3.1	2.3	1 : 0.7	80% H	40% Lt, 20% Dk1	16	3	20	7	FC .40 SS .40 DISTOB .20	100% S 100% S 100% S	50% W, 50% A 50% A, 50% Tu 100% Tu
CHUTE	26	6	69	66.3	2.7	2.8	1 : 1.1	74% H	38% Lt	11	3	53	14	FC .33 SS .22 DISTOB .22 CHUTE .22	100% S 100% S 50% S 100% S	67% W, 33% Tu 100% E 100% I 50% Td, 50% Tu
PLAT	70	22	92	97.4	1.6	3.0	1 : 0.7	50% H, 39% I.G.	41% Lt	12	3	73	19	DISTOB .47 FC .41	61% S 96% S	47% E, 30% Td 29% W, 29% Td, 25% Tu
GRAVELS	89	-	100	-	-	-	-	-	-	-	-	-	-	PLAT .56 FC .33	97% S 100% S	57% I 76% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = Internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.3 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR THE 1987 SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥ 20%	Chute Infill Abundance	Chute Infill Upward transitions ≥ 20%	Platform sands Abundance	Platform sands Upward transitions ≥ 20%
Fm	12	Sw .59, Sr .30	1	Sr .67, Ss .33	93	Fm .60, Sw .35	5	Sw .50, St .50	7	Sr .45, Sw .35	2	Sr .47, Sw .32
O	2	Sw .62, Fm .26	1	Sr .57, Sw .43	-	-	-	-	1	Sr .63, Fm .38	-	-
Sw	45	Fm .38, Sr .24	41	Sw .40, Sr .32	3	Fm 1.00	43	Sr .50, Fm .25, Sw .25	26	Fm .29, Sw .29, Sr .29	14	Sr .40, Fm .20
Sr	34	Sw .40, Fm .31, Sr .21	35	Sw .47	3	Fm 1.00	43	Fm .33, Sw .33, Sr .33	56	Sr .30, Fm .25, Sw .25	23	Sw .48, Sr .27
Ss	4	Sw .56, Fm .38	6	Sr .67, Sw .33	0	Fm 1.00	2	Sw 1.00	0	Fm .50, Sr .50	18	Sw .30, Ss .30, St .20
Sh	1	Fm .50, Sw .25, Sr .25	1	-	-	-	-	-	1	Sw .50, St .50	3	Fm .67, Sr .33
Sp	0	Sw 1.00	-	-	-	-	-	-	2	Fm 1.00	4	St .67, Ss .33
St	4	Fm .35, Sw .35, Sr .24	12	Sw .60, Sr .40	-	-	7	-	8	Fm .50, Sw .20; Sh .20	32	Sr .45, St .21
Gm	-	-	3	-	-	-	-	-	-	-	5	St .40, Sw .20, Ss .20, Sp .20

Upward facies transitions from basal gravels occur primarily to lower energy facies (facies Sw and Sr), producing upwardly consistent particle size trends. Although preferred upward facies states vary from those demonstrated in previous data sets, all are dominated by lower energy facies, and are indicative of up-sequence reduction in energy of deposition. In the 1987 data set, however, facies Fm plays a much more significant role, indicating a greater degree of intermingling of facies than observed elsewhere. Indeed, two or three upward facies transitions occur with a frequency $\geq 20\%$ for each facies type. As in the 1986 data set, basal contacts are all sharply defined with wavy contacts, other than the irregular shape of surfaces above basal gravels.

Element composition of the 1987 data set differs markedly from the 1986 trench data set, largely due to the greater thickness of these older floodplain sequences and the presence of distal overbank deposits (Table 9.2). Although found in only 5 of the 13 bank exposures studied, distal overbank deposits make up 19% of observed 1987 sediments. In other words, when observed, these are the dominant element within exposures. This is indicated by their average thickness of almost 1.3m.

Of the other elements, flood cycle deposits make up 41% of bank exposures, compared to only 14% in the trench data set, and are observed in all instances. Flood cycle elements have an average thickness in excess of 1m, as opposed to 0.35m in the trench data. The prevalence of this element is related directly to the greatly reduced proportion of ridge and chute elements, which occupy only 7% of bank exposures combined. Differences in the prevalence of these elements result from the orientation of exposures. Ridge and chute deposits generally are found marginal to flood cycle deposits, and often have similar facies compositions (as demonstrated in chapters 7 and 8). As these elements are better defined in a lateral sense, the criteria used in their identification are not apparent when viewed in longitudinal section. Ridge and chute outlines are not evident, unless oriented diagonally or perpendicular to the bank exposure. Although observed in four and nine of the thirteen exposures respectively, ridge and chute elements generally are observed at only one or two analysis points within sections, and have thinner average thicknesses than in the 1986 data.

Sand sheet and bar platform elements occupy identical proportions in the 1987 data set to those demonstrated for the trench data (12% and 20% respectively). They are both observed in all exposures except one. Average thickness of platform units is comparable to those shown for the trench data (almost 1m), whereas sand sheet deposits are somewhat thicker (0.5m as opposed to

0.3m).

Particle size and sorting characteristics of elements are similar to those demonstrated for the trench data set for each element, although chute and platform deposits are 0.5ϕ finer. These differences are explained by the smaller percentage of facies observed within the fine gravels particle size class. As in the 1986 data, ridge and platform elements have the most clearly defined within-element upward fining particle size sequences, while the remainder are generally upwardly consistent or slightly upward coarsening.

Sediment mixes are dominantly heterogenous for each element, although sand sheet and platform deposits have a high proportion of internally graded beds, and most beds within distal overbank sequences are upward coarsening. The latter sequences, along with flood cycle deposits, are dominantly dark brown in color. The proportion of light brown bands is greater in ridge deposits, while sand sheet, chute and bar platform elements are dominated by light brown sands. Facies Sr dimensions are bigger in sand sheet and ridge elements than the others; in both instances these are notably larger than in the 1986 data set. Facies St dimensions are considerably smaller for most elements in the bank exposure data, but are significantly larger within sand sheets.

Element organization within observed bank exposures is dominated by flood cycle and sand sheet elements. Indeed, in 33% of instances, upward transitions from basal framework gravels are to flood cycle units. In general, gravels are upwardly transitional to platform sands, which in turn are transitional to distal overbank or flood cycle deposits. Flood cycle and sand sheet deposits alternate atop these sequences. Ridge and chute deposits are not found at specific positions within sequences, and are upwardly transitional to a much broader range of elements than are other types. Basal contacts between elements are dominantly sharply defined, and exhibit a broad range of shapes.

As observed previously, flood cycle deposits are composed of alternating sequences of lower energy facies, especially facies Sw, Sr and Fm (Table 9.3). The proportion of facies Fm is lower than observed within trenches, and facies Sw is the preferred upward facies transition. Sand sheet deposits have high proportions of facies Sw and Sr, with a smaller proportion of facies St, as observed in the trench data set. Within element facies organization is less simple within the bank exposure data set, but upward transitions are dominated by facies Sw and Sr. The distal overbank element has the simplest facies composition observed, as 93% of deposits are made up of facies Fm.

In ridge deposits, facies Sw and Sr are interbedded with thin facies Fm units. Facies Sr is more prevalent than in the trench data set, and high energy facies are much less spread among types. Accordingly, within element facies organization is much simpler. The proportion of high energy facies observed in the chute element is considerably lower in bank exposure deposits than in trenches (11%, as opposed to 47%). Facies Sr is dominant in 1987 chute deposits, but within element facies organization is very complex, with a broad mix of upward transitions from each facies state.

Bar platform sands in the bank exposure data set have a considerably greater proportion of lower energy facies (36%) than found in the trench data (26%). Facies St is the dominant facies in each instance, and facies Ss is more abundant in this element than elsewhere. Given the broader range of facies types observed within platform sands, there are two, three or even four upward transitions from each facies.

In summary, lower energy facies are more prevalent within elements in the 1987 data set. This is especially evident for facies Fm, the high proportion of which is explained by the presence of distal overbank deposits. As observed in previous data sets, sediment sequences generally have upward fining particle size trends, with facies organizations indicative of up-sequence reduction in energy of deposition. Fine sand units are dominant, however, as medium-coarse sands have lower preservation potentials. Problems in identification of ridge and chute deposits in longitudinal section seemingly have resulted in their inclusion within the flood cycle element. Facies compositions of these elements are consistent, but ridge and chute elements occupy only 7% of observed bank exposures, while flood cycle deposits occupy 41%. Elemental character differs little from that described in Table 8.5. These characteristics are examined by planform for each bank exposure in subsequent sections.

9 : 3 : 1 Analysis of bank exposures in the braided channel planform reach : Dbas section

Five, evenly-spaced bank exposures were examined in the braided planform section of the study reach (Figure 4.1). Dbas is located about 0.8km down-valley from Basbar, at the margin of a secondary channel, adjacent to a recent gravel platform accumulation. Vegetation is very well developed on the floodplain surface.

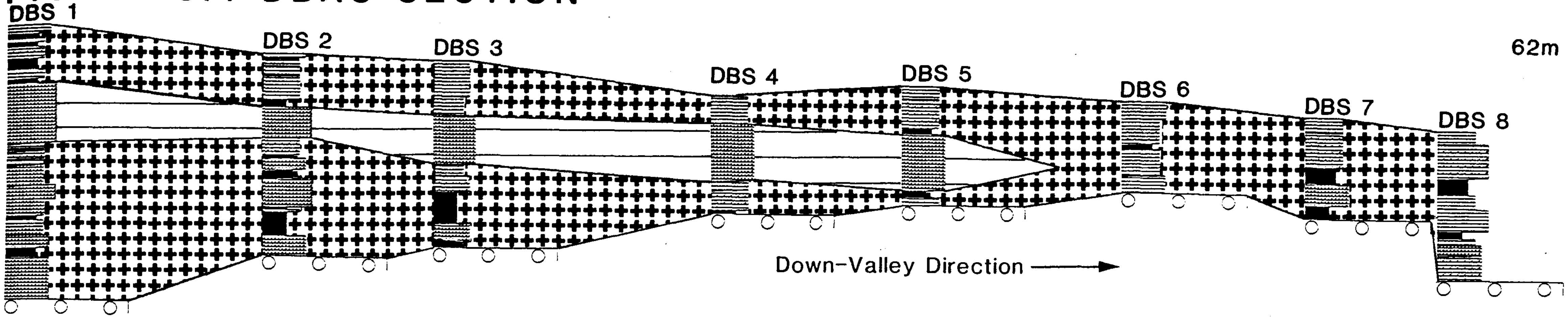
As shown for Basbar in the 1985 and 1986 data sets, Dbas is composed almost solely of lower energy facies (Figure 9.1, note that the vertical exaggeration is 10x that of the trench diagrams in chapter 8; Table 9.4). Facies Sr is dominant, occupying 53% of the section. Other than the upstream analysis point, the basal surface dips by over 1m down-section, while the floodplain surface remains relatively flat.

Flood cycle deposits extend atop basal gravels for the entire 110m of the section. These occupy 77% of the bank exposure (Table 9.5). Facies Sr deposits are thinly interbedded with facies Sw and Fm, in a cyclical fashion, with sharply defined basal contacts, which are wavy or tilted in outline. Facies Fm is more prevalent than observed elsewhere.

A prominent sand sheet unit, occupying 21% of the section, is found within these flood cycle deposits in the downstream half of the section. This retains a relatively uniform thickness of 0.5m, before pinching out as the trench depth diminishes up-valley. This sand sheet unit has a relatively flat basal contact. Facies Sr makes up 96% of this element; the remaining 4% is composed of facies Sw and Fm. Particle size trends coarsen upwards. Facies Sr dimensions are notably larger than observed elsewhere. At one analysis point, bar platform sands form a very thin basal element, composed solely of facies Gm.

Facies sequences and particle size trends within Dbas section exhibit great down-section and vertical variability within flood cycle deposits, but are consistent in both dimensions within the sand sheet element. Given the dominance of lower energy facies, and the consistency of their particle sizes in comparison to the overall data set, the overall mean particle size for Dbas section is slightly finer than that of the combined bank exposure data set. Facies Sr dimensions are somewhat larger than in the overall data set, and this facies is more internally graded than observed elsewhere. Average colors of facies are consistent with the overall data set, with facies Sr units predominantly light brown, and facies Fm and Sw made up of banded dark brown units. Even basal gravels are transitional upwards to lower energy facies, with sharply defined, irregularly shaped contacts.

FIGURE 9.1 DBAS SECTION



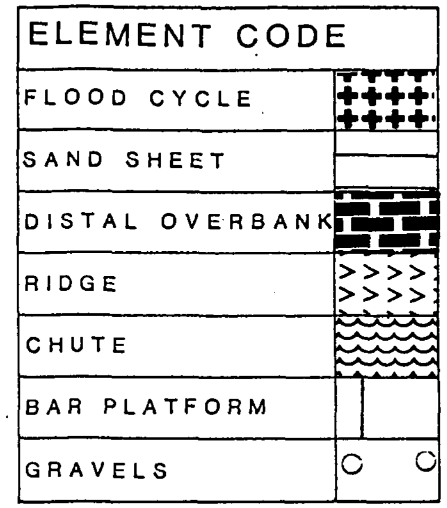
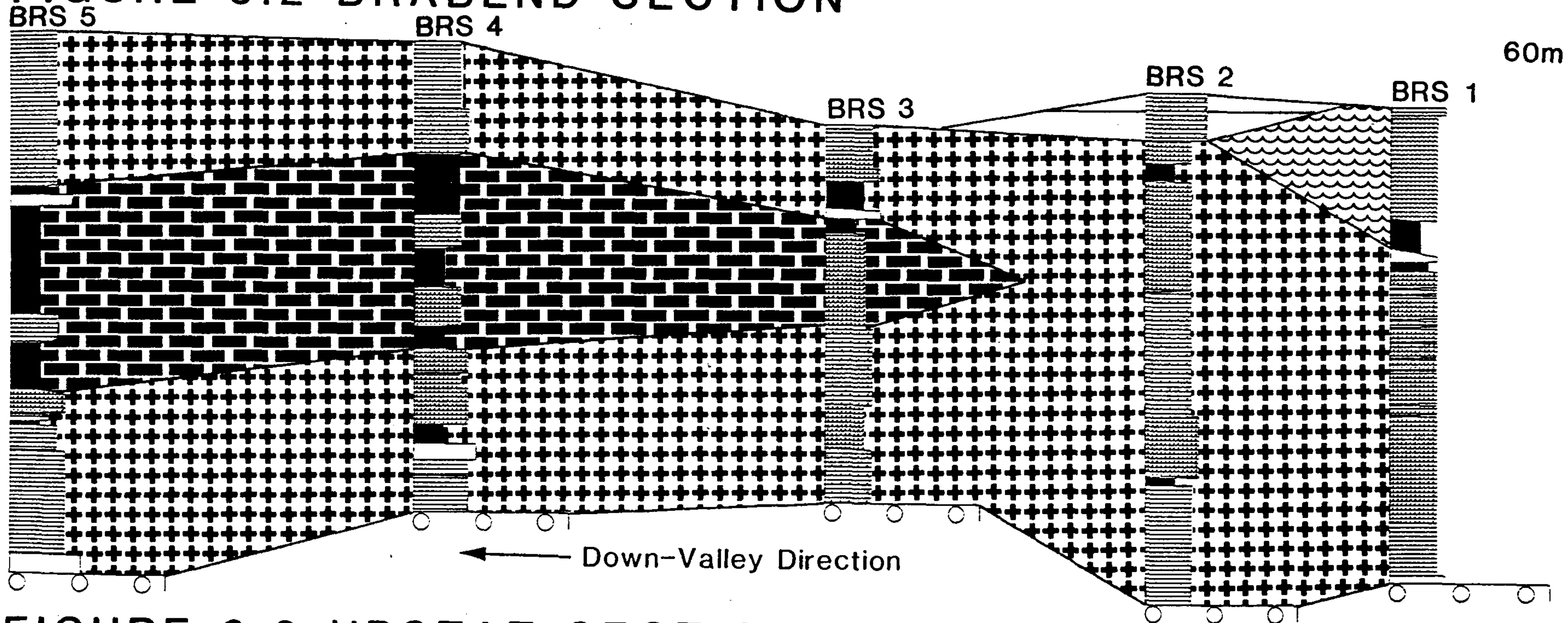


FIGURE 9.2 BRABEND SECTION



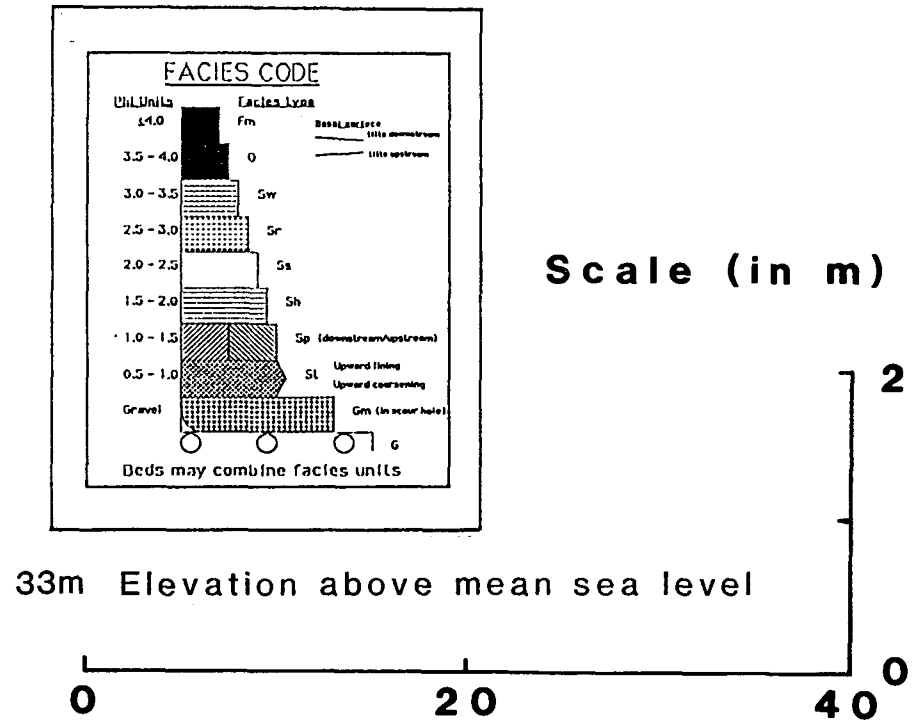


FIGURE 9.3 UPSTAT SECTION

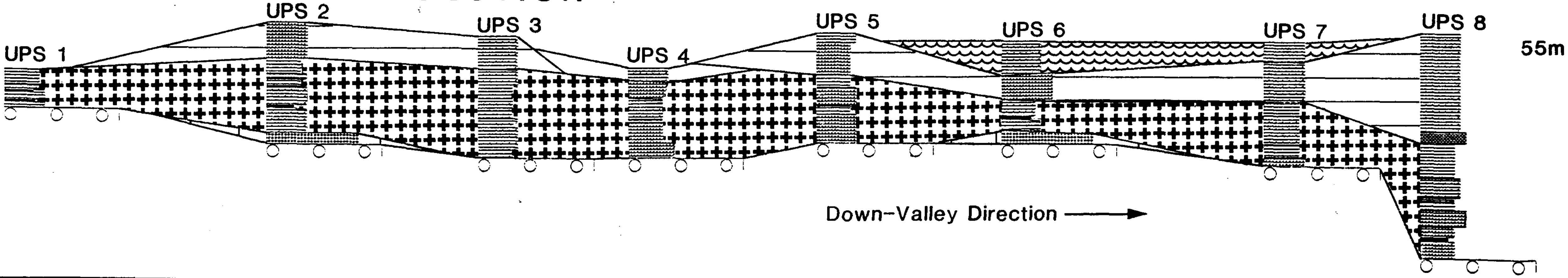


TABLE 9.4 SUMMARY STATISTICAL ANALYSIS OF DBAS SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	26	16	100	6.5	4.0	1.1	62% H, 39% U	62% Dk4, 27% Dk3	Sr .64 Sw .32	81% S 100% S	50% W, 31% Tu 38% W, 25% E, 25% Tu
O	-	-	-	-	-	-	-	-	-	-	-
Sw	29	27	100	9.4	3.2	2.2	100% H	45% Dk2, 24% Dk1	Fm .55 Sw .27	92% S 100% S	58% W, 25% Tu 83% W
Sr	28	53	100	19.5	2.7	2.7	61% I.G., 39% H	61% Lt, 21% Dk1	Sw .43 Fm .39	100% S 100% S	40% W, 40% Tu, 20% I 36% Tu, 27% W
Ss	-	-	-	-	-	-	-	-	-	-	-
Sh	1	2	13	19.0	2.2	3.0	100% I.G.	100% Lt	Sw 1.00	100% S	100% Td
Sp	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-
Gm	1	2	13	23.0	10.0	-	-	-	Sr 1.00	100% G	100% W
G	8	-	79	-	235.0	-	-	-	Fm .38 Sw .25 Sr .25	100% S 100% S 100% S	100% I 50% Td, 50% I 50% Td, 50% I

Number of analysis points 8 Overall mean particle size 2.98Ø Upward particle size ratio 1 : 1.00 (*6) Sr L = 19, D = 5; St W = -, D = -

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.5 SUMMARY STATISTICAL ANALYSIS OF DBAS SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	13	77	61.0	3.2	2.1	1 : 1.0	74% H	24% Dk2, 20% Dk4	13 4	- -	SS 1.00	100% S	60% Tu, 20% W, 20% I
SS	5	21	42.8	2.5	2.9	1 : 1.5	70% I.G.	70% Lt, 20% Dk3	35 9	- -	FC 1.00	100% S	40% E, 20% W, 20% Td, 20% Tu
DISTOB	-	-	-	-	-	-	-	-	- -	- -	-	-	-
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
PLAT	1	2	23.0	-1.0	4.0	-	n/a	-	- -	- -	FC 1.00	100% G	100% W
GRAVELS	8	-	-	-	-	-	-	-	- -	- -	FC .88	100% S	71% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.6 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR DBAS SECTION DATA SET

	Flood Cycles		Sand Sheet		Distal overbank deposits		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%
Fm	21	Sr .59, Sw .36	1	Sr 1.00	n/a	-	n/a	-	n/a	-	-	-
O	-	-	-	-	-	-	-	-	-	-	-	-
Sw	34	Fm .63, Sw .32	3	Sr 1.00	-	-	-	-	-	-	-	-
Sr	43	Sw .47, Fm .32, Sr .21	96	Fm 1.00	-	-	-	-	-	-	-	-
Ss	-	-	-	-	-	-	-	-	-	-	-	-
Sh	2	Sw 1.00	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	100	-

9 : 3 : 2 Analysis of Brabend bank exposure

Brabend section is located in the concave bank of a secondary channel 0.6km from the main channel, 0.6km down-valley of Dbas section. The floodplain surface is scoured by a series of chute channels, with large logs washed onto the surface. Depth of floodplain sediments ($\geq$3.5m) are notably greater than observed up-valley.

As in Dbas section, Brabend section is composed almost entirely of lower energy facies (Table 9.7). Flood cycle deposits are the major element at each analysis point, and make up 71% of Brabend section (Figure 9.2, Table 9.8). These are observed in thick units, averaging 1.3m, immediately above the basal gravels. Particle size, sediment mix and color characteristics of flood cycle deposits are almost identical to those described previously. Facies Sr and Sw are dominant, with a reduced proportion of facies Fm in comparison with the overall data set (Table 9.9). The latter facies, however, predominates as the preferred next-facies state.

In the three down-section analysis points, distal overbank deposits are located within the flood cycle element, forming a 1.2m thick wedge in mid-sequence, which gradually tilts down-section. This element makes up 21% of Brabend section. Although average thickness is thinner than in the overall data set, it still averages almost 1.1m. Facies Fm occupies 60% of this element, and is the dominant upward facies transition (Table 9.9). This is interbedded with facies Sr units, the average dimension of which are greater in these distal overbank sequences than others. Sediments are banded dark brown in color and are heterogenously mixed.

At the upstream end of the section, chute deposits are located atop flood cycle deposits, with sand sheet deposits at their margin. Both these elements occur as wedge-shaped units located at the lowest elevations of the floodplain surface (i.e. the points most likely to be overridden by flood flows). The chute unit has average thickness, but occupies only 6% of the section. It has a lower energy facies fill, with a facies Fm-Sr-Sw transition. Sand sheet deposits are composed solely of facies Sr. The basal surface of the section varies by 0.75m in elevation, and is least deep in mid-section.

At the facies scale, sediment sequences in Brabend section are extremely discontinuous within and between elements, in both longitudinal and vertical senses. Relatively thick facies units are irregularly interbedded throughout the section. In the case of facies Fm, this is explained by its

TABLE 9.7 SUMMARY STATISTICAL ANALYSIS OF BRABEND SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	26	19	100	10.9	4.1	0.8	54% H, 46% U	88% Dk4	Sw .73	100% S	75% W, 25% E
O	-	-	-	-	-	-	-	-	-	-	-
Sw	11	22	100	30.9	2.8	2.1	100% H	58% Dk2, 25% Dk1	Fm .63	100% S	60% W, 40% E
Sr	31	54	100	26.5	3.2	2.1	90% H	52% Dk2, 29% Dk1	Fm .53 Sr .33	100% S 80% S	63% Td 60% W, 20% Td, 20% Tu
Ss	5	3	80	10.2	2.1	2.5	83% H	33% Lt, 33% Dk3	Fm .67 Sw .33	100% S n/a	50% W, 50% Td
Sh	1	2	20	23.0	2.7	3.0	100% H	100% Dk2	Fm 1.00	100% S	100% E
Sp	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-
G	4	-	80	-	100.0	-	-	-	Ss .40 Sw .20 Sr .20 Sh .20	n/a n/a 100% S 100% S	 100% I 100% I

Number of analysis points 5 Overall mean particle size 3.22Ø Upward particle size ratio 1 : 0.97 (*6) Sr L = 10, D = 3; St W = -, D = -

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.8 SUMMARY STATISTICAL ANALYSIS OF BRABEND SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	8	71	134.3	3.1	2.0	1 : 0.9	73% H, 23% U	41% Dk2, 30% Dk4	10 3	- -	DISTOB .60 SS .20 CHUTE .20	100% S 100% S 100% S	67% W, 33% Td 100% W 100% Td
SS	1	2	30.0	2.2	4.0	-	100% I.G.	100% Lt	8 1	- -	FC 1.00	67% S	33% E, 33% W, 33% Td
DISTOB	3	21	108.3	3.8	1.4	1 : 1.0	100% H	50% Dk4, 25% Dk1	11 3	- -	-	-	-
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	1	6	90.0	3.4	1.6	-	67% H, 33% U	67% Lt, 33% Dk4	15 5	- -	-	-	-
PLAT	-	-	-	-	-	-	-	-	- -	- -	-	-	-
GRAVELS	4	-	-	-	-	-	-	-	- -	- -	FC 1.00	100% S	100% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands
(*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact
(*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.9 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR BRABEND SECTION DATA SET

	Flood Cycles		Sand Sheet		Distal overbank deposits		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20%	% Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%
Fm	6	Sr .78	-	-	60	Sr .50, Sw .25, Ss .25	n/a	-	22	Sr 1.00	n/a	-
O	-	-	-	-	-	-	-	-	-	-	-	-
Sw	30	Fm .57	-	-	6	Fm 1.00	-	-	6	-	-	-
Sr	58	Fm .50, Sr .36	100	-	32	Fm 1.00	-	-	72	Sw 1.00	-	-
Ss	4	Fm .50, Sw .50	-	-	3	Fm 1.00	-	-	-	-	-	-
Sh	2	Fm 1.00	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-	-

prevalence within thick distal overbank deposits. Facies Sr is dominant (54%), and is slightly coarser (by 0.5ϕ), has slightly smaller average dimensions, is more heterogenously mixed, and is darker in color than in the overall data set. Other facies types are roughly consistent in terms of particle size, sediment mix and color, but generally are better sorted than in the overall data set. Given the lack of high energy facies, overall mean particle size of Brabend section is 0.3ϕ finer than in the overall data set.

Facies organization in Brabend trench is dominated by transitions to facies Fm. Transitions to lower energy facies are prevalent, even above the basal gravel facies. Basal contacts are sharply defined for all transitions, and generally are wavy or tilted in outline, other than the irregular outlines above basal gravels. Vertical particle size trends are upwardly consistent, or alternate between fine and very fine sand units. There is no evidence of any down-section particle size trends, other than the greater proportion of very fine sands within the distal overbank element at the downstream end of the section.

9 : 3 : 3 Analysis of Upstat bank exposure

Upstat section is located between Roadup and Statbar bars of the 1985 data set, but is marginal to a substantial secondary channel within the established floodplain, 0.6km west of the present main channel. Local environmental conditions are similar to those experienced adjacent to Brabend section, with chute channels at the floodplain surface, but vegetation is not as well established, and floodplain depositional sequences above framework gravels are not nearly as thick.

Facies composition of Upstat section is very similar to Dbas and Brabend sections, as lower energy facies are dominant, occupying 86% of the section (Table 9.10). Once more, facies Sr is the predominant facies (71%), with lower proportions of facies Sw and Fm. All facies have smaller average bed thicknesses than in the overall data set, but particle size, sediment mix and color characteristics are generally consistent. Exceptions to these observations are the primarily uniform nature of facies Fm beds and the black colour of facies O units (observed as thin litter layers). The reduced proportion of facies Fm (the finest facies) results in an overall mean particle size that is consistent with the overall data set. When observed, high energy facies are extremely thin units. Facies St units have smaller dimensions than in the overall data set.

TABLE 9.10 SUMMARY STATISTICAL ANALYSIS OF UPSTAT SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	8	2	63	2.3	3.7	2.0	83% U, 38% H	75% Dk4, 25% Dk3	Sr .50	100% S	100% W
									Sw .38	100% S	67% W, 33% Td
O	10	1	83	1.0	3.2	2.3	100% H	100% B	Sr .50	100% S	80% W, 20% Td
									Sw .40	100% S	100% W
Sw	20	22	100	9.0	3.1	2.1	95% H	45% Dk1, 25% Dk2	Sr .41	100% S	86% W
									O .24	100% S	75% W, 25% Td
Sr	30	71	100	19.0	2.8	2.8	50% H, 47% I.G.	50% Dk1, 47% Lt	Sw .40	100% S	80% W
									Sr .28	100% S	57% W, 29% Td
									O .20	100% S	100% W
Ss	-	-	-	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-
St	1	1	13	10.0	2.2	3.0	100% I.G.	100% Lt	Sr 1.00	100% S	100% E
Gm	2	3	25	10.5	26.0	-	-	-	Fm .50	100% S	100% Td
									Sr .50	100% S	100% Tu
G	8	-	100	-	190.0	-	-	-	Sr .63	100% S	80% I, 20% Td
									Gm .25	100% S	100% I

Number of analysis points 8 Overall mean particle size 2.80Ø *Upward particle size ratio* 1 : 0.95 (*6) Sr L = 12, D = 3; St W = 45, D = 8

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

Facies Sr and Sw are preferred next-facies states for virtually all facies in Upstat section. Indeed, in 63% of instances, facies Sr is the preferred upward facies transition from basal gravels, indicating that lower energy facies are dominant throughout the vertical sequence. Basal contacts are sharply defined in all instances, and are predominantly wavy other than the irregular outlines of surfaces above basal gravels.

Elements are considerably thinner in Upstat section than elsewhere, and floodplain sequences thin gradually down-section, with a relatively uniform surface, but an up-valley tilting basal contact (Figure 9.3). The surface is, however, dissected by two, extremely shallow ($\leq$20cm) chute units. These have a very simple facies make-up, and are composed of heterogenously mixed, light brown, facies Sr and Sw units (Tables 9.11, 9.12). Ripple dimensions are larger than those typically observed within chutes.

Adjacent and beneath these chutes are two sand sheet units which both pinch out down-section. The upstream unit thins considerably down-section. Sand sheet deposits are more abundant in Upstat section than elsewhere (30%). Large scale ripple units are prevalent, occupying 92% of this element. These light brown, internally graded, ripple units are found atop facies St and O units.

Flood cycle deposits occupy 60% of Upstat section, and are found with relatively uniform thickness at the base of the section. Thinly interbedded, lower energy facies are more upward fining and lighter brown in color than observed elsewhere, but mean particle size, sediment mix and ripple dimensions are consistent with the overall data set. Each of the four lower energy facies is transitional upwards to two or three of the others. At two analysis points, thin platform gravels, composed solely of facies Gm, are observed.

Down-section and vertical facies and particle size trends are relatively inconsistent in Upstat section, with much intermingling of units. This is particularly evident between elements in the two analysis points in which platform gravels are observed. The overall mean particle size is roughly consistent with the summary bank exposure data set.

TABLE 9.11 SUMMARY STATISTICAL ANALYSIS OF UPSTAT SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	8	60	60.3	3.0	2.4	1 : 0.8	72% H	35% Dk1	10 3	- -	SS .86	100% S	83% W
SS	6	30	41.0	2.7	3.0	1 : 2.0	56% I.G., 44% H	67% Lt, 22% Dk1	17 4	45 8	CHUTE 1.00	100% S	50% A, 50% Tu
DISTOB	-	-	-	-	-	-	-	-	- -	- -	-	-	-
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	3	7	19.7	2.7	2.7	-	67% H, 33% I.G.	67% Dk1, 33% Lt	14 5	- -	-	-	-
PLAT	2	3	10.5	-1.0	-	-	-	-	- -	- -	FC 1.00	100% S	50% Td, 50% I
GRAVELS	8	-	-	-	-	-	-	-	- -	- -	FC .75 PLAT .25	100% S 100% S	83% I 100% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.12 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR UPSTAT SECTION DATA SET

	Flood Cycles		Sand Sheet		Distal overbank deposits		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%	Abundance	Upward transitions ≥20%
Fm	4	Sw .43, Sr .43	-	-	n/a	-	n/a	-	-	-	-	-
O	2	Sw .44, Sr .44	0	Sr 1.00	-	-	-	-	-	-	-	-
Sw	32	Sr .39, Fm .23, O .23	3	-	-	-	-	-	31	-	-	-
Sr	63	Sw .40, O .25, Sr .20	92	Sw 1.00	-	-	-	-	70	-	-	-
Ss	-	-	-	-	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	4	Sr 1.00	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	100	-

9 : 3 : 4 Analysis of Statbar bank exposure

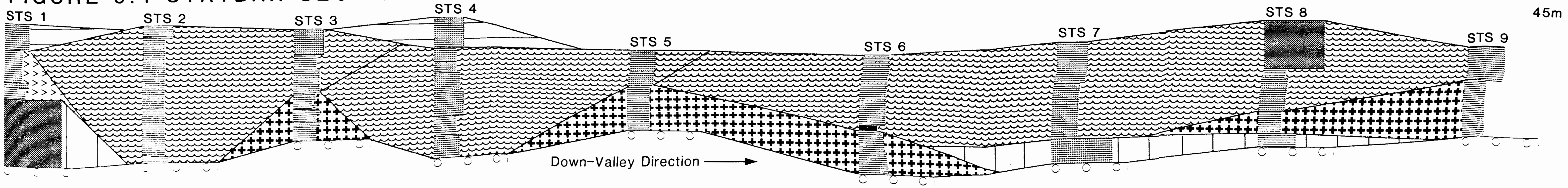
Floodplain deposits examined in the Statbar bank exposure are considerably younger than others sampled in the braided reach. These deposits are located at the opposite edge of a well developed vegetative zone to the bar platform sequences which were examined in the 1985 data set. A series of diagonal chutes cut across the bank exposure. Between the main channel and Statbar section is an expansive, recently deposited, gravel platform.

Although facies composition is much more spread among facies in Statbar section than in previously examined sections, facies Sr is once more the dominant facies, occupying 61% of the section (Figure 9.4, Table 9.13). The proportion of lower energy facies is roughly equivalent with the overall 1987 data set (86%), but the proportion of facies Fm is notably reduced. Facies Sr and Sw units are considerably thicker than in the overall data set, averaging 0.3m apiece. Among high energy facies, facies St is dominant, although this is only observed in two instances. Their average thickness, however, is much greater than elsewhere (almost 0.8m). The greater proportion of this facies, along with its particle size in the fine gravels class, results in an overall mean particle size for Statbar section which is 0.5ϕ coarser than in the overall 1987 data set, although this mean size is still in the fine sand class. Average particle size, sediment mix and color characteristics by facies are consistent with the overall data set. The upward particle size ratio indicates that trends are generally upward coarsening. Average ripple dimensions are consistent with the overall data set, whereas trough dimensions are somewhat larger.

Facies organization is dominated by transitions to lower energy facies, even from the basal gravel facies. Sequences are relatively simple in composition, as one facies is often upwardly dominant (typically facies Sr). As noted elsewhere, basal contacts are sharply defined and wavy in outline, other than the irregular outlines above basal gravels.

Statbar is the only bank exposure studied in which chute infill deposits are the dominant element (Table 9.14). Indeed, the character of this section is more similar to trenches than to other sections, with pronounced longitudinal and vertical transitions (i.e. unconformities) at both the facies and element scales. Facies are extremely longitudinally discontinuous. Particle size trends are equally variable, as these are upward fining at the section head, upwardly consistent in mid-section, and upward coarsening down-section. The basal surface is quite irregular

FIGURE 9.4 STATBAR SECTION



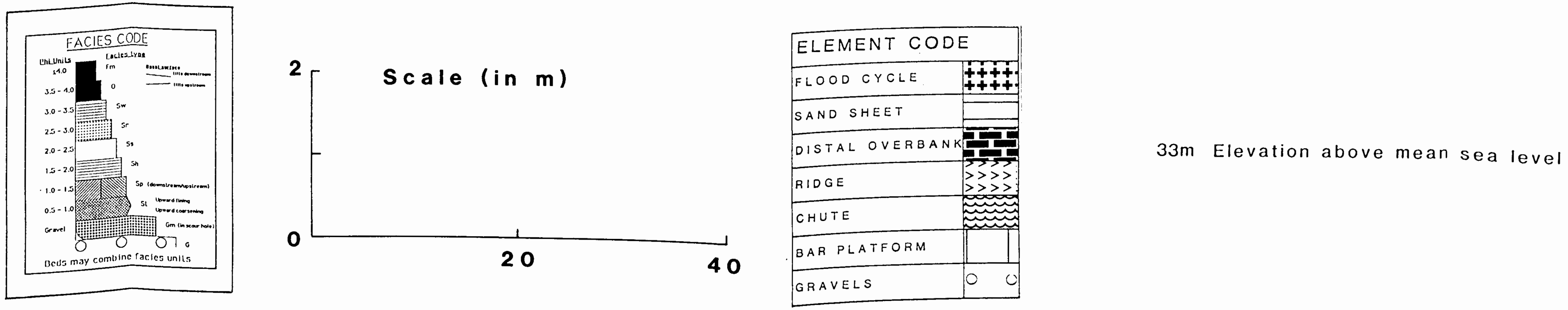


FIGURE 9.5 DSTAT SECTION

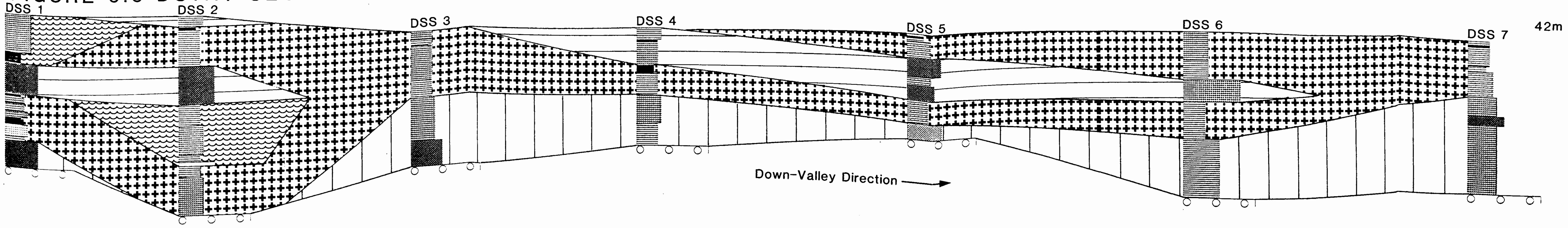


TABLE 9.13 SUMMARY STATISTICAL ANALYSIS OF STATBAR SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	5	1	22	2.6	3.8	1.7	60% H, 40% U	60% Dk4, 20% Dk3, 20% Dk5	Sr .80 Sw .20	100% S 100% S	50% W, 50% I 100% E
O	7	1	44	1.0	3.2	2.4	100% H	100% B	Sr 1.00	100% S	57% W, 29% E
Sw	11	23	56	29.1	3.2	2.1	100% H	73% Dk2	Sr .80	88% S	50% W, 25% Td, 25% Tu
Sr	30	61	100	28.7	2.7	2.7	57% H, 33% I.G.	53% Dk1, 40% Lt	Sr .35 O .26	100% S 100% S	50% W, 25% Td, 25% Tu 50% W, 33% E
Ss	-	-	-	-	-	-	-	-	-	-	-
Sh	3	3	33	11.7	2.0	2.5	67% H	100% Lt	Sw .67 Fm .33	100% S 100% S	50% E, 50% Td 100% E
Sp	-	-	-	-	-	-	-	-	-	-	-
St	2	11	22	77.5	-1.0	4.0	100% I.G.	50% Lt, 50% Dk1	Sw 1.00	100% S	100% W
Gm	1	2	11	33.0	12.0	-	-	-	Sr 1.00	100% G	100% W
G	8	-	100	-	143.0	-	-	-	Sw .33 Sr .22 Sh .22	100% S 100% S 100% S	100% I 100% I 100% I

Number of analysis points 8 Overall mean particle size 2.34Ø Upward particle size ratio 1 : 1.16 (*6) Sr L = 12, D = 3; St W = 100, D = 28

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = *Sharply defined contact*, G = *Gradational contact* (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.14 SUMMARY STATISTICAL ANALYSIS OF STATBAR SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (φ units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	5	21	58.4	3.1	2.2	1 : 1.2	67% H	39% Dk1, 28% Dk2	10	4	-	-	CHUTE 1.00	80% S	40% W, 40% Tu, 20% Td
SS	1	8	113.0	2.7	2.7	-	86% H	43% B, 29% Dk1, 29% Lt	14	4	-	-	-	-	-
DISTOB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	1	5	65.0	3.5	2.1	1 : 1.0	67% H, 33% I.G.	33% Dk1, 33% Dk2, 33% Lt	14	3	-	-	SS 1.00	100% S	100% A
CHUTE	8	57	101.6	2.5	2.7	1 : 1.1	71% H, 29% I.G.	39% Lt, 29% Dk1	12	3	150	40	SS 1.00	100% S	100% E
PLAT	3	10	47.0	-0.7	3.9	-	100% I.G.	50% Dk1, 50% Lt	-	-	50	15	FC .33 RIDGE .33 CHUTE .33	100% S 100% S 100% G	100% E 100% W 100% W
GRAVELS	8	-	-	-	-	-	-	-	-	-	-	-	FC .44 PLAT .33 CHUTE .22	100% S 67% S 100% S	100% I 100% I 100% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.15 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR STATBAR SECTION DATA SET

Facies type	*Flood Cycles* % Abundance	*Flood Cycles* Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill Abundance	Chute Infill Upward transitions ≥20%	Platform sands Abundance	Platform sands Upward transitions ≥20%
Fm	2	Sr .75, Sw .25	-	-	n/a	-	-	-	1	Sr 1.00	-	-
O	-	-	3	Sr 1.00	-	-	-	-	1	Sr 1.00	-	-
Sw	72	Sr .67, Sh .33	-	-	-	-	23	Sr 1.00	12	O .50, Sr .50	-	-
Sr	24	Fm .60, Sw .40	97	O .50, Sr .50	-	-	77	Sr 1.00	78	Sr .50, O .25	-	-
Ss	-	-	-	-	-	-	-	-	-	-	-	-
Sh	2	Fm 1.00	-	-	-	-	-	-	1	Sw 1.00	13	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	8	-	64	-
Gm	-	-	-	-	-	-	-	-	-	-	23	-

down-valley, varying by up to 0.5m, and actually rising down-valley. The floodplain surface is also irregular, but variability is not in phase with the gravel surface, resulting in widely varying depths of sediments at each analysis point. These trends all relate to element organization within Statbar section, especially the position and character of chute channels and their infill.

Given their diagonal orientation, chute channel dimensions cannot be recorded directly from the section diagram. Their internal character varies widely, but chutes are dominantly made up of light brown, heterogenously mixed, fine-medium sand, lower energy facies (facies Sr alone occupies 78% of this element; Table 9.15). Facies St units are notably coarser than elsewhere. The chute at the up-valley part of the section is deeper than the others, and has an upwardly consistent, lower energy facies infill. Lower energy facies are much more intermingled in the chute in mid-section, whereas sediment sequences coarsen upwards in the larger chute at the down-valley end of the section. This latter trench is the only unit which has not scoured to basal gravels. Rather, it rests upon relatively thin, remnant, wedge-like units of flood cycle deposits and bar platform sands. These units have broadly tilted outlines (i.e. they are not horizontally aligned).

Remnant bar platform and flood cycle deposits are also marginal to the up-valley chute. While the former is composed solely of poorly sorted, coarse sand facies St, the latter is made up of thinly interbedded lower energy facies immediately above basal gravels (i.e. with distinct unconformity). Mean particle size, sediment mix and ripple dimension characteristics of flood cycle deposits are consistent with the overall data set, but sediment sequences are slightly upward coarsening and lighter brown in color. They are composed predominantly of facies Sw (72%) and facies Sr (24%), with intermingling among lower energy facies in a similar fashion to that shown elsewhere. In contrast, wedge-shaped sand sheet deposits at the floodplain surface have twice their average thickness, with extremely simple facies composition (facies Sr occupies 97% of the element). These heterogenously mixed, loose sands exhibit a wide range in color, and are slightly coarser than sediments beneath them.

Given the high proportion of chute units (57%), ridge deposits are less prevalent in Statbar section than expected (5%). As with chutes, however, their average thickness is greater than shown for the overall data set. These heterogenously mixed, banded light and dark brown fine sand sediments, are not upward fining, as indicated for the overall data set. Located atop a remnant bar platform unit, ridge deposits are composed solely of facies Sr and Sw.

9 : 3 : 5 Analysis of Dstat bank exposure

Dstat is located at the downstream end of the braided section of the study reach. The section has substantial vegetation atop, with some trees ≥50 years old. Root systems and old log jam deposits have severely disrupted sediment sequences in this section. The section is separated from the main channel by a substantial gravel platform, which is itself separated from the section by a secondary channel. Gravels at the floodplain base rest about 0.4m above the general elevation of this platform.

Although facies Sr is the dominant facies in Dstat section, its prominence (46%), is less marked than in other sections of the braided reach (Table 9.16). Lower energy facies occupy 77% of the trench, which is somewhat less than in previous sections. Mean particle sizes are roughly consistent with the overall data set for all facies (except facies Sh, which occurs only once), resulting in an overall mean particle size for Dstat which is 0.4ϕ coarser. Lower energy facies generally are less well sorted than elsewhere. Whereas lower energy facies (except facies Fm) are thicker than in the overall data set, high energy facies are thinner. As observed previously, lower energy facies are primarily banded dark brown, heterogenously mixed, fine sands, while high energy facies are internally graded, light brown, medium sands sands. Ripple and trough dimensions are roughly consistent with the overall data set.

Other than a single ridge element, average element thicknesses in Dstat section is lower than for the overall data set (Table 9.17). Platform sands are found as the basal element across most of the section (Figure 9.5), and make up 31% of deposits. Their thickness varies markedly, thinning as the basal surface rises towards mid-section, and pinching out at the deepest part of the section. Facies composition of platform sands varies notably from one analysis point to the next, with transitions from high to lower energy facies sequences, and upward fining, upward coarsening and upwardly consistent particle size trends at different locations. 67% of this element is made up of lower energy facies, with facies Sr and St as basal facies. Although ripple dimensions are larger than elsewhere, trough dimensions are smaller. Individual facies units are more internally graded than in the overall data set, and the overall mean particle size for platform sands is 0.5ϕ finer.

Flood cycle deposits rest atop platform sands, with a tilted basal contact. These deposits make up 41% of the trench. They are composed primarily of facies Sr and Sw (94% combined),

TABLE 9.16 SUMMARY STATISTICAL ANALYSIS OF DSTAT SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant *Sediment mix* (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	6	3	57	7.3	3.7	3.2	100% H	67% Dk4, 33% Dk3	Sr .50	100% S	67% W, 33% Td
									Sw .33	100% S	100% W
O	4	1	57	2.5	3.4	3.2	100% H	50% B, 25% Dk3, 25% Dk5	Sw .75	100% S	67% W, 33% E
									Fm .25	100% S	100% Td
Sw	18	27	100	21.7	2.9	2.8	94% H	33% Dk1, 33% Dk3, 22% Lt	Sr .43	83% S	67% W, 33% Tu
Sr	20	46	100	33.5	2.7	3.0	65% H, 35% I.G.	65% Lt, 20% Dk1	Sw .41	100% S	29% W, 29% Td, 29% Tu
Ss	1	0	14	5.0	1.7	3.0	100% H	100% Lt	Sw 1.00	100% S	100% W
Sh	1	2	14	30.0	3.2	3.0	100% I.G.	100% Lt	Sr 1.00	100% S	100% Tu
Sp	1	2	14	23.0	1.2	3.0	100% I.G.	100% Lt	Sr 1.00	100% S	100% Td
St	7	17	71	34.9	1.5	3.0	100% I.G.	100% Lt	Sr .57	50% S	100% W
									Sw .29	100% S	50% W, 50% Tu
Gm	1	2	14	31.0	20.0	-	-	-	Sw 1.00	100% S	100% E
G	7	-	100	-	108.0	-	-	-	Sr .29	100% S	100% I
									St .29	100% S	100% I

Number of analysis points 7   Overall mean particle size 2.52Ø   Upward particle size ratio 1 : 0.71   (*6) Sr L = 11, D = 3; St W = 60, D = 20

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening

(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands

(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.17 SUMMARY STATISTICAL ANALYSIS OF DSTAT SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	10	41	58.9	3.1	2.9	1 : 0.4	91% H	31% Lt	10	3	-	-	SS .83	100% S	60% W, 40% Td
SS	6	18	43.0	1.7	2.6	1 : 2.0	60% H, 40% I.G.	80% Lt	8	3	70	24	FC .75 CHUTE .25	67% S 100% S	67% W, 33% E 100% Td
DISTOB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	1	6	85.0	2.9	2.5	1 : 0.5	75% H, 25% I.G.	50% Dk3, 25% Dk1, 25% Lt	20	3	-	-	SS 1.00	100% S	100% Tu
CHUTE	1	5	87.0	2.8	3.2	-	100% H	33% Dk4, 33% Dk5, 33% Lt	18	4	-	-	-	-	-
PLAT	6	31	75.0	2.1	3.0	1 : 1.0	90% I.G.	80% Lt, 20% Dk1	15	6	47	15	FC 1.00 CHUTE .33	100% S 100% G	33% Td, 33% Tu 100% W
GRAVELS	7	-	-	-	-	-	-	-	-	-	-	-	PLAT .86	100% S	100% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.18 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR DSTAT SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥20%
Fm	5	Sw .50, Sr .50	-	-	n/a	-	-	-	18	Sr 1.00	-	-
O	1	Sw 1.00	2	Sw 1.00	-	-	-	-	3	Fm 1.00	-	-
Sw	41	Sr .56, Fm .22, O .22	12	-	-	-	47	Sr 1.00	-	-	18	-
Sr	53	Sw .44, Fm .33, Sr .22	17	O .50, St .50	-	-	47	Sw 1.00	79	-	49	St 1.00
Ss	-	-	-	-	-	-	6	Sw 1.00	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	7	Sr 1.00
Sp	-	-	-	-	-	-	-	-	-	-	5	-
St	-	-	57	Sr 1.00	-	-	-	-	-	-	21	Sr 1.00
Gm	-	-	12	-	-	-	-	-	-	-	23	-

with complex intermingling of lower energy facies. Deposits are lighter brown in color and more clearly upward fining than elsewhere, but their character varies markedly at each analysis point in the section (Figure 9.5). The morphology of flood cycle deposits is highly irregular, as they have ridge deposits within and sand sheet deposits both within and atop. Contacts with these elements are sharply defined, and either tilted or wavy in outline.

Sand sheets are either at the surface, within flood cycle units, or have chute deposits atop. These occupy 18% of Dstat section, and are upward coarsening in character. Mean particle size is coarser than noted elsewhere. As in the overall data set, there are a mix of heterogenous and internally graded beds, which are predominantly light brown in color. Although all units have simple facies compositions, their facies character varies markedly in different analysis points. The smallest unit is only 0.2m thick, and extends over about 15m at the floodplain surface in an infill unit. A second sand sheet unit rests beneath the first, and is enclosed within flood cycle deposits. This unit is composed solely of facies St. It maintains an average thickness of 0.5m, with a flat basal contact, before pinching out sharply down-section. In contrast, the major sand sheet unit tilts considerably down-section, gradually thinning in that direction. Facies composition varies markedly from point to point, switching from a lower energy facies composition, to a mixed composition, to a high energy facies composition. Average facies Sr and St dimensions in the sand sheet element are finer than in the overall data set.

Ridge deposits form an infill unit within flood cycle deposits at the deepest part of the section. These deposits are not marginal to a well defined channel, evidencing the difficulty in establishing definitive boundaries to these units in longitudinal section. The unit is composed of interbedded facies Sw and Sr, and has an upward fining particle size trend. Sediments have heterogenous mixes and exhibit a range of brown color tones. Average ripple dimensions are notably larger than those observed within other ridge elements. Chute deposits in Dstat section form a thin surface unit at the upstream end of the section. This unit is marginal to flood cycle deposits, and has a lower energy facies infill, with a wide range of colors and heterogenous sediment mixes.

Given the irregular pattern of element associations, and within element facies variability, facies organization is extremely complex within Dstat section. There are no consistent within or between element trends either down-section or in vertical sequence at any analysis point. Facies Sr is even a preferred transition above basal gravels, with predominantly upwardly consistent lower energy facies above. Occasionally, thin remnant high energy facies are found at the base of sediment sequences, which are more upward fining than observed previously. Basal contacts are sharply defined, with irregular outlines above gravels, and a mix of surfaces elsewhere. Although the floodplain surface is relatively even, with minimal chute disruption, the basal surface and element configuration are complex, with notably down-valley discontinuity. This seemingly reflects a previous history of floodplain reworking, with contemporary leveling of the surface by flood cycle deposits.

9 : 3 : 6 Summary analysis of braided channel planform reach bank exposures

Given their differing local environmental characters, age of deposits and down-valley positions, the five bank exposures studied in the braided reach vary remarkably little one from the other. Lower energy facies are dominant throughout, occupying ≥75% of each section, and ≥95% of the three up-valley sections. These latter three sections are composed primarily of vertically accreted, flood-related deposits, especially flood cycle units. Statbar section is made up primarily of lower energy facies, chute channel infill deposits. Only at the down-valley reach limit, in Dstat section, are bar platform deposits preserved to a significant extent (31% of the section) and, even in this case, 67% of the element is composed of lower energy facies. Sediment sequences in bank exposures in the braided reach are characterized by upward transitions from basal gravels to vertically consistent lower energy facies, with occasional high energy facies units (occuring either as basal bar platform remnants, or within surficial sand sheet units). This unconformity within the floodplain depositional suite is evidenced at virtually all analysis points. Indeed, bar platform deposits are not evidenced at all in the two up-valley bank exposures, Dbas and Brabend sections.

The thickness of floodplain deposits varies greatly from section to section. This is the primary control upon element thickness. Element organization in bank exposures accords with the framework predicted by locale analysis (section 7.4), in that there is an irregular mix of flood cycle, sand sheet, ridge and chute channel elements above occasional bar platform deposits. These elements are longitudinally discontinuous, and are not horizontally aligned in vertical sequence. Sequences are dominated by flood cycle deposits, which rest atop basal gravels and extend virtually to the floodplain surface in the three up-valley sections, and are prominent units in Statbar and Dstat sections. These are over 3m thick in Brabend section, but generally are between 1-2m thick in other braided reach bank exposures.

Discontinuous sand sheet deposits are found within this element in Dbas and Dstat sections, and atop flood cycle deposits in Brabend, Upstat and Statbar sections. These range up to 1m in thickness. In general, flood cycle and sand sheet elements have roughly evened out floodplain surfaces, whereas basal gravel contacts are highly irregular in outline. Chute channels are observed marginal to sand sheet deposits, in all sections examined in the braided reach except Dbas, with small ridge units in Statbar and Dstat section. Both chute and ridge deposits are relatively thin ($\leq$ 1m, except in Statbar), and extremely discontinuous down-section. In Brabend section, distal overbank deposits are a major element in mid-sequence, but they pinch out up-valley. Indeed, flood cycle deposits are the only longitudinally extensive element. As mentioned previously, basal contacts are sharply defined, and typically are tilted down- or up-valley.

At the facies scale, each element has similar summary sedimentologic characteristics to those described previously (e.g. Table 8.5), but element composition is highly variable from one analysis point to another (i.e. facies are extremely longitudinally discontinuous). This effect is less prevalent in distal overbank deposits, which have a relatively uniform facies Fm composition.

Although considerably less prevalent than in previous data sets, the position of high energy facies units varies within depositional sequences studied in braided reach bank exposures. They are not consistently positioned within or between sections; indeed, they often vary within element. They are typically observed within bar platform, sand sheet or chute elements. Given the variable within-sequence position of the latter two elements, this indicates that one-dimensional examination of sediment sequences in the braided reach could indicate that deposits are upward fining, coarsening, or consistent. These trends are all evidenced within Statbar section, at the section head, tail and in mid-section respectively, and confirm observations made in the 1985 analysis.

Facies characteristics in the braided reach are consistent with those described elsewhere. Sediment sequences are dominated by thinly interbedded facies Sr and Sw units. The proportion of facies Fm is highly variable from point to point, especially whenever distal overbank deposits are observed (e.g. Brabend). Vertical and longitudinal particle size trends are extremely variable both within and between both elements and sections, in virtually all instances. However, sequences are dominated by fine or very fine sands; medium or coarse sands are seldom observed. The lack of these sands, which are prevalent upon adjacent exposed bar surfaces, can be related to chute channel and flood flow reworking of deposits, and replacement by waning-stage deposits. Chute channels are prevalent only on Statbar, but given the evidence from trenches, it is inferred that this mechanism of removal is prevalent throughout the study reach, and is especially effective upon braided planform floodplain deposits. Accordingly, overall mean particle sizes are consistently in the fine sand class for each section in the braided reach.

Although most of the characteristics described above apply equally to all sections in the braided reach, there is some evidence for within-section variability, especially in a down-valley sense. The two down-valley sections have a greater proportion of coarser sand, high energy facies, within chute and bar platform elements. Facies are more thickly interbedded, and less upwardly consistent than in other sections, as they are less dominated by vertically accreted, flood-related deposits. Indeed, the character of Statbar and Dstat sections is clearly marginal to sections observed in the wandering reach (outlined in the section 9.4). In summary, however, lower energy facies are highly intermingled at all braided reach bank exposures, with marked variability at the facies scale from one analysis point to the next.

9 : 4 : 1 Analysis of bank exposures in the wandering river planform reach : Widewand section

Four bank exposures were examined in the wandering reach. Widewand section is located at the outside bank of a formerly significant channel at the upper end of the wandering reach. The floodplain is very extensive, as the valley widens in this area, but there is also a wide expanse of active channel and bars. Floodplain vegetation is substantial, and there are a series of diagonal cutting chutes immediately downstream of the section area. Several substantial logs were found sticking out from the bank.

Lower energy facies dominate Widewand section, with facies Fm especially prevalent, occupying 40% (Figure 9.6, Table 9.19). These form a thick (≥ 1.2m), extensive distal overbank unit atop platform sands or basal gravels across the section (Tables 9.20, 9.21). This unit thins in mid-section, within the deepest sediment sequences. As distal overbank deposits result from low energy depositional mechanisms, they follow underlying relief in form, in this instance with an irregular, arch-like form. These very fine, heterogenously mixed, sands are either dark brown or grey in color.

FIGURE 9.6 WIDEWAND SECTION

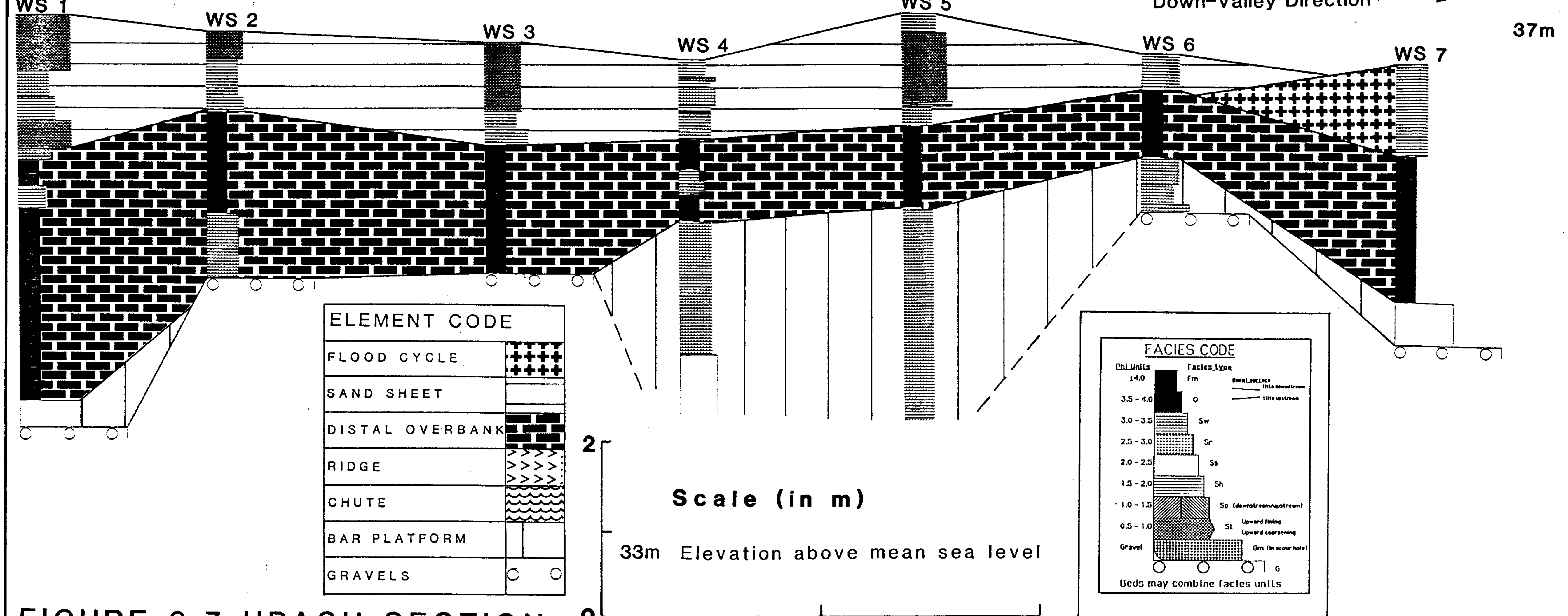


FIGURE 9.7 UPASH SECTION

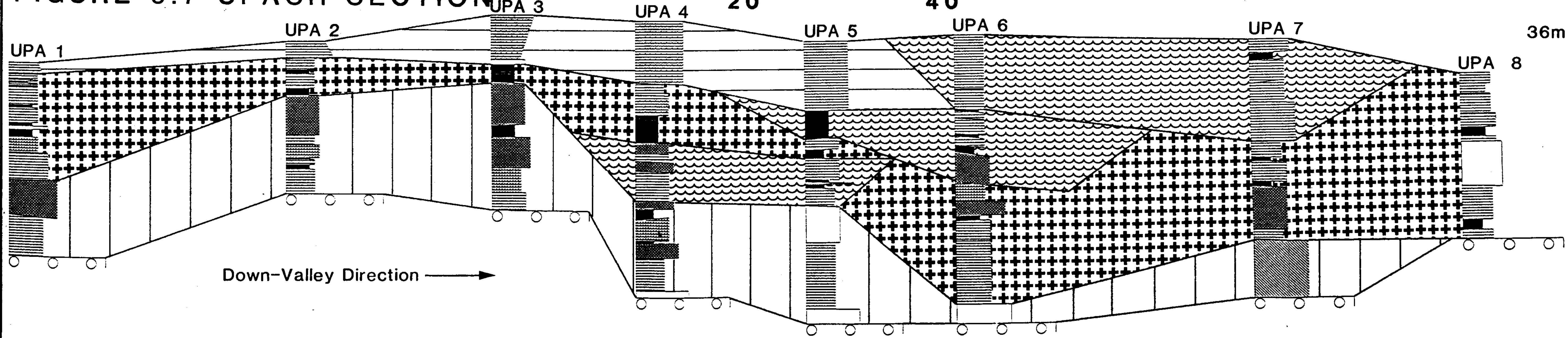


TABLE 9.19 SUMMARY STATISTICAL ANALYSIS OF WIDEWAND SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	10	40	100	77.4	4.2	0.1	70% H, 20% U	80% Dk4	Sw .67 Sr .33	83% S 100% S	67% W 100% E
O	-	-	-	-	-	-	-	-	-	-	-
Sw	15	16	100	20.9	3.1	2.5	93% H	33% Lt, 27% Dk1, 27% Dk2	Fm .27 Sw .27 St .27	100% S 100% S 100% S	33% E, 33% W, 33% A 67% W, 3% Td 33% W, 33% Tu, 33% I
Sr	12	27	71	44.3	3.2	2.5	67% H, 33% I.G.	41% Dk2, 33% Dk1, 25% Lt	Fm .33 Sw .25 Sr .25	100% S 100% S 100% S	50% I, 25% E, 25% Td 67% W, 33% E 100% W
Ss	3	6	43	40.0	1.7	3.0	n/a	50% G, 50% Lt	Fm .67 Sr .33	n/a n/a	- -
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-
St	5	11	43	42.4	2.0	3.0	n/a	100% Lt	Sw 1.00	100% S	67% W, 33% A
Gm	-	-	-	-	-	-	-	-	-	-	-
G	5	-	71	-	140.0	-	-	-	Sr .40 Ss .40 Fm .20	100% S n/a n/a	100% I - -

Number of analysis points 7 Overall mean particle size 3.35Ø Upward particle size ratio 1 : 0.94 (*6) Sr L = 10, D = 3; St W = 126, D = 33

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.20 SUMMARY STATISTICAL ANALYSIS OF WIDEWAND SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (φ units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	1	4	85.0	3.2	2.0	-	100% H	100% Dk1	-	-	-	-	-	-	-
SS	6	26	84.3	2.6	2.8	1 : 0.7	52% H, 48% I.G.	62% Lt	12	4	126	33	-	-	-
DISTOB	7	44	123.4	4.1	0.4	1 : 1.0	85% H	62% Dk4, 23% G	7	3	-	-	SS .86	100% S	50% E, 50% W
RIDGE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CHUTE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLAT	5	25	99.2	2.8	2.6	1 : 0.5	83% H	38% Dk2, 25% Lt, 25% Dk1	10	3	-	-	DISTOB 1.00	100% S	33% E, 33% Td, 33% I
GRAVELS	5	-	-	-	-	-	-	-	-	-	-	-	PLAT .60 DISTOB .40	100% S n/a	100% I -

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = *internally graded*, *U.F.* = *upward fining*, U.C. = *upward coarsening*
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.21 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR WIDEWAND SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥ 20%	*Distal overbank deposits* % Abundance	*Distal overbank deposits* Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥20%
Fm	-	-	5	-	87	Sw .67, Sr .33	n/a	-	n/a	-	-	-
O	-	-	-	-	-	-	-	-	-	-	-	-
Sw	100	-	36	St .38, Sw .25, Sr .25	5	Fm 1.00	-	-	-	-	-	-
Sr	-	-	17	Sw .75, S7 .25	8	Fm 1.00	-	-	-	-	76	Sr 1.00
Ss	-	-	-	-	-	-	-	-	-	-	24	Sr 1.00
Sh	-	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	42	Sw 1.00	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-	-

Bar platform sands are found in two basal units in Widewand section. The upstream unit is a tilted, 0.3m thick, facies Ss unit, within a 4.5m deep analysis point. The other, substantially larger unit, is composed primarily of heterogenously mixed, banded light and dark brown, facies Sr deposits. These deposits thin appreciably down-section, but as with the distal overbank element, they adopt an arch-like form, reflecting the irregular form of the underlying gravels. Their mean particle size is considerably finer than elsewhere, since these are upper bar platform deposits, the lower reaches of which were beneath the water table and hence could not be sampled.

Sand sheet deposits rest atop distal overbank deposits in a wedge-like form, at the floodplain surface, with an average thickness of 0.85m. In contrast to other sand sheets, their internal composition and particle size trends are highly variable. Prominent, light brown, facies St and Sw units are mixed in an irregular manner with facies Sr and thin facies Fm units, producing variable down-section and vertical facies and particle size trends. Their mean particle size is actually coarser than the basal bar platform sands. Trough dimensions are quite large, reflecting high energy depositional flows. As the sand sheet unit pinches out at the downstream end of the section, a small flood cycle unit, composed solely of facies Sw, rests atop the distal overbank deposits.

The dominance of massive, very fine sands in distal overbank deposits results in an overall mean particle size 0.45ϕ finer than for the overall data set. Facies Sr is 0.5ϕ finer and darker brown than elsewhere, with smaller average dimensions. Sedimentologic characteristics are consistent with the overall data set for other facies. Average trough dimensions are significantly larger than elsewhere. Particle size trends are consistent down-section, with no well-defined vertical trend. Facies organization is very irregular, although lower energy facies predominate as preferred next-states. Facies Fm, Sr and Sw are intermingled in thick units. Of the five upward transitions from basal gravels, three are to lower energy facies. Basal surfaces are sharply defined, with wide variability in their outline.

9 : 4 : 2 Analysis of Upash bank exposure

Although geographically very close to Widewand section, sedimentologic conditions around Upash are extremely different. Deposits are not as old, and distal overbank deposits are not observed. Rather, the section is located in a relatively recently deposited unit adjacent to Ashlu

Fan. A secondary channel separates this unit from the contemporary bar deposits studied in the 1985 and 1986 data sets. Numerous chutes have disrupted deposits at the floodplain surface, resulting in complex facies and element mixes (Figure 9.7, Tables 9.22, 9.23). The proportion of lower energy facies is considerably greater than demonstrated in Upash hole or trench data sets (sections 6.6.5 and 8.3.2), probably reflecting the greater elevation of these deposits above the main channel.

The three chute channels each have a predominantly lower energy facies infill (86%; Table 9.24), but facies organizations are quite different in each instance. The chute at the floodplain surface rests atop and adjacent to vertically accreted, flood-related deposits, and has a laterally and vertically consistent facies Sw fill. The two other chutes both rest within flood cycle deposits (one atop the platform element). These are smaller units, the facies composition of which varies at each analysis point, with upwardly consistent, upward fining and upward coarsening trends! Whenever observed, facies St units have small average dimensions. All chutes are composed of heterogenously mixed, fine sands, with a wide range in colors between beds.

The sand sheet element which sits atop and adjacent to these chute and floodplain deposits at the floodplain surface consists of individual units of facies Sw and Sr, the average particle size of which are considerably coarser than surrounding units. These deposits thicken to 0.8m deep down-section, prior to being disrupted by a chute channel. Their basal contact has a shallow arch-like form. Although the thickness and form of flood cycle deposits varies considerably, they rest atop platform sands at each analysis point. Their facies composition and particle size trends are very mixed, with interbedded lower and high energy facies, and no consistent down-section or vertical trends. Facies Fm dominates as the preferred next-facies state. Sediments are heterogenously mixed, banded dark brown fine sands.

Inconsistencies in flood cycle depositional form and character stems in part from the irregular bar platform surface upon which they are deposited. The basal surface varies by over 1.0m down-section. Platform sands tend to thin in that direction, averaging 0.8m thick. They exhibit different facies and particle size characteristics at each analysis point, with mixed lower and high energy facies. Sediments are finer grained and darker in tone than observed elsewhere.

Lower energy facies are somewhat coarser and have thicker beds than in the overall data set, with consistent sediment mix and color characteristics. They are less prevalent than

TABLE 9.22 SUMMARY STATISTICAL ANALYSIS OF UPASH SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	34	12	100	6.6	3.8	1.7	72% H, 28% U	56% Dk4, 27% Dk3	Sw .62	90% S	42% W, 32% Td
O	5	0	38	1.2	3.7	2.3	100% H	80% Dk4, 20% Dk5	Fm .80 Ss .20	100% S 100% S	50% S, 50% Tu 100% W
Sw	48	52	88	19.9	2.8	2.6	91% H	48% Dk2	Fm .45 Sw .36	94% S 93% S	35% W, 33% Tu, 30% Td 33% E, 33% W
Sr	8	12	63	27.9	2.3	3.4	50% I.G., 38% H	75% Dk1, 25% Lt	Fm .50	100% S	33% E, 33% W, 33% Tu
Ss	8	7	75	16.9	1.9	2.8	67% H, 33% U	80% Lt, 20% Dk1	Sw .63 Fm .25	100% S 100% S	50% Td, 50% I 50% W, 50% Td
Sh	1	0	13	8.0	2.7	3.0	100% H	100% Lt	St 1.00	100% S	100% Td
Sp	2	5	25	45.5	1.8	2.3	100% I.G.	50% Dk1, 50% Lt	Fm .50 Sw .50	100% S 100% S	100% Td 100% Td
St	9	11	63	23.1	2.2	3.1	100% I.G.	67% Lt, 33% Dk1	Fm .44 Sw .22	100% S 100% S	50% W, 25% E, 25% Td 100% W
Gm	-	-	-	-	-	-	-	-	-	-	-
G	8	-	100	-	115.0	-	-	-	Sw .38 Ss .38	100% S n/a	100% I -

Number of analysis points 8 Overall mean particle size 2.68Ø Upward particle size ratio 1 : 0.98 (*6) Sr L = 12, D = 3; St W = 44, D = 14

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.23 SUMMARY STATISTICAL ANALYSIS OF UPASH SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (φ units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	8	35	79.4	3.1	2.5	1 : 1.0	83% H	34% Dk2, 25% Dk4	10 2	50 15	SS .57 CHUTE .43	100% S 100% S	25% E, 25% W, 25% Td, 25% Tu 33% W, 33% Td, 33% Tu
SS	5	12	42.6	1.6	3.6	-	33% U.F.	83% Lt	11 2	- -	-	-	-
DISTOB	-	-	-	-	-	-	-	-	- -	- -	-	-	-
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	6	21	65.2	2.9	2.5	1 : 0.9	79% H	31% Lt, 21% Dk4	- -	29 6	FC .50 SS .25 CHUTE .25	100% S 100% S 100% S	100% W 100% E 100% Td
PLAT	7	33	86.7	2.5	2.5	1 : 1.2	53% H, 35% I.G.	42% Dk1, 21% Dk3	13 3	48 17	FC .71 CHUTE .29	100% S 100% S	50% W, 50% Td 50% W, 50% Td
GRAVELS	8	-	-	-	-	-	-	-	- -	- -	PLAT .88	100% S	67% I, 33% Td

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.24 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR UPASH SECTION DATA SET

	Flood Cycles		Sand Sheet		Distal overbank deposits		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥ 20% ≥20%	% Abundance	Upward transitions ≥ 20%
Fm	19	Sw .72	-	-	n/a	-	n/a	-	14	Sw .63, O .25	8	Sr .43, Sw .29, St .29
O	1	Fm 1.00	-	-	-	-	-	-	1	Fm 1.00	-	-
Sw	62	Fm .55, Sw .35	47	-	-	-	-	-	70	Sw .50, Fm .40	30	St .50, Fm .33
Sr	9	Fm .50, Sw .50	51	-	-	-	-	-	-	-	10	Fm .67, St .33
Ss	8	Fm .50, Sw .50	2	Sr 1.00	-	-	-	-	1	Fm 1.00	13	Sw 1.00
Sh	-	-	-	-	-	-	-	-	2	St 1.00	-	-
Sp	-	-	-	-	-	-	-	-	8	Fm 1.00	10	-
St	2	Sr 1.00	-	-	-	-	-	-	5	Sh 1.00	29	Fm 1.00
Gm	-	-	-	-	-	-	-	-	-	-	-	-

elsewhere, occupying 76% of the section. Facies Fm and Sw dominate as the preferred next-facies state. High energy facies are coarser sands than lower energy facies, but are finer and in thinner beds than in the overall data set. Trough dimensions are notably smaller. Overall mean particle size is 0.2ϕ coarser than for the summary 1987 data. Upward particle size trends are highly irregular, both within and between elements. Basal surfaces are sharply defined, and generally wavy or tilted in outline. Recent reworking of sediments has resulted in a much more regular floodplain surface than basal gravel contact, implying that deposits have equalized existing relief.

9 : 4 : 3 Analysis of Tflent bank exposure

Tflent section is located in the bank of a secondary channel at the eastern margin of the Squamish Valley floodplain, roughly 0.5km east of Tflent bar. Diagonal chutes and thick sand sheet deposits are observed on the adjacent floodplain surface. As noted in the 1985 and 1986 data sets (sections 6.6.6 and 8.3), lower energy facies are prominent (78%), especially thinly interbedded facies Sw units (which occupy 66% of Tflent section; Figure 9.8, Table 9.25). Facies composition is much simpler than in the other wandering channel planform sections, however, as facies Sr is seldom observed. Vertical facies and particle size trends are either upwardly consistent, or indicative of up-sequence reduction in energy of deposition.

Although the general relationship between elements is similar in Upash and Tflent sections, there is much less disruption of sediment sequences by chute channels in the latter case. Basal gravels are transitional to platform sands, with flood cycle deposits atop. Sand sheet and chute elements form discontinuous units at the irregular floodplain surface (which increases in elevation by 1m down-section).

Platform deposits extend across framework gravels at all but the upstream analysis point, occupying 31% of the section (Table 9.26). These medium sands thicken to ≥ 1.5m down-section, with a ridged basal outline. They have simple facies compositions at each analysis point, but facies are discontinuous down-section. As observed in the 1985 and 1986 data sets, facies St and Ss are dominant (Table 9.27). Trough dimensions are larger than observed elsewhere. At the upstream end of the section, a thin ridge element, composed solely of lower energy facies Sw and Fm, rests atop platform sands. These are banded dark brown, heterogenously mixed, fine sands.

FIGURE 9.8 TFLENT SECTION

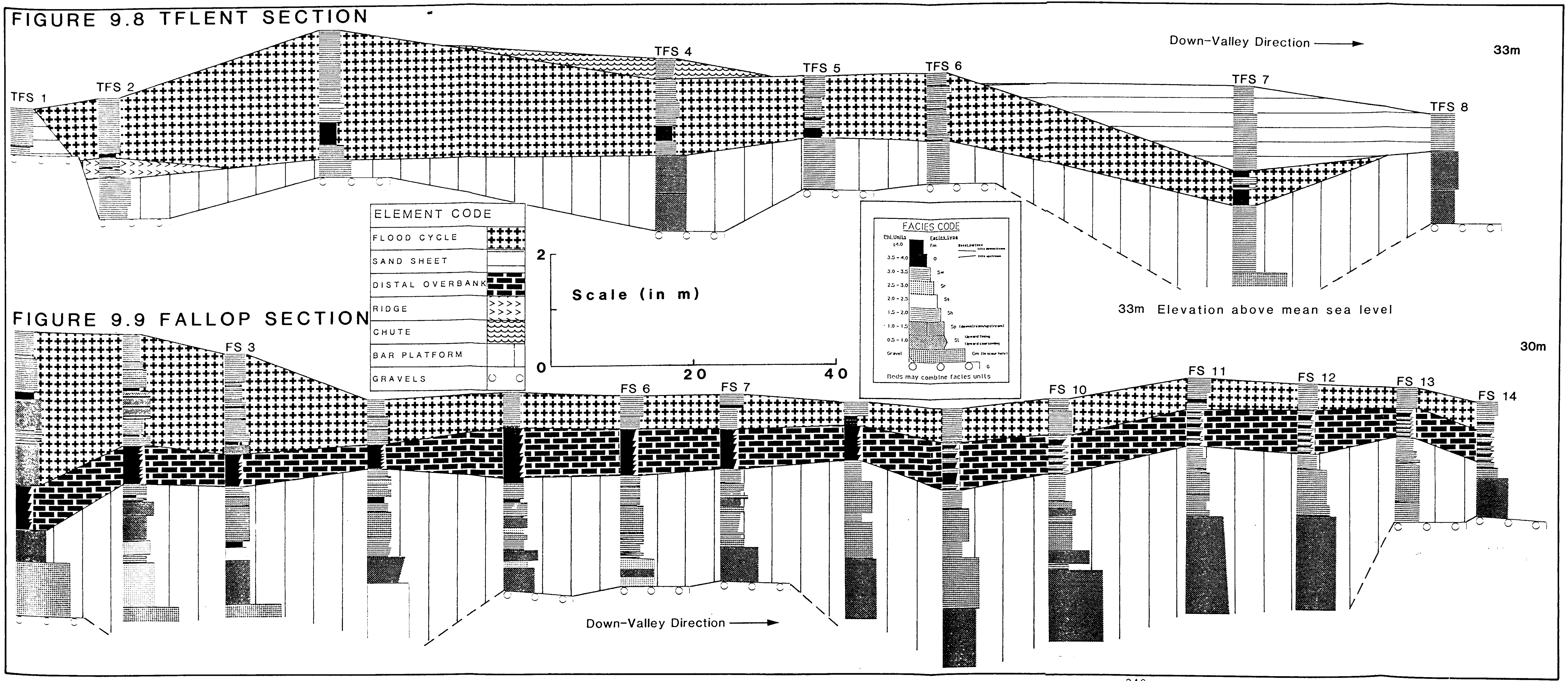


FIGURE 9.9 FALLOP SECTION

TABLE 9.25 SUMMARY STATISTICAL ANALYSIS OF TFLENT SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	13	9	75	10.1	3.8	2.4	62% U, 39% H	77% Dk4	Sw .85	82% S	73% W
O	2	0	13	1.0	3.2	2.5	100% H	100% Dk5	Sw .50 Sr .50	100% S 100% S	100% Tu 100% Tu
Sw	39	66	100	25.3	2.9	2.5	100% H	39% Dk1, 39% Dk2, 21% Lt	Sw .59 Fm .28	90% S 89% S	68% W 56% W
Sr	2	3	25	23.5	3.4	2.6	50% H, 50% U.C.	100% Dk2	Fm 1.00	100% S	100% W
Ss	2	0	25	3.0	2.7	2.0	100% H	100% Lt	Fm .50 Sw .50	100% S 100% S	100% W 100% W
Sh	1	5	13	75.0	1.7	3.0	100% I.G.	100% Lt	Fm 1.00	100% S	100% E
Sp	-	-	-	-	-	-	-	-	-	-	-
St	6	15	25	35.8	2.1	3.0	67% H, 33% I.G.	67% Dk1	St .67 Sw .33	100% S 100% S	100% W 50% W, 50% Tu
Gm	1	2	13	25.0	12.0	-	-	-	Sw 1.00	100% S	n/a
G	7	-	88	-	118.0	-	-	-	Sw .57 St .29	100% S 100% S	75% I, 25% E 50% E, 50% W

Number of analysis points 8 Overall mean particle size 2.76Ø Upward particle size ratio 1 : 0.83 (*6) Sr L = 9, D = 3; St W = 130, D = 45

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.26 SUMMARY STATISTICAL ANALYSIS OF TFLENT SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	6	42	103.5	3.3	2.3	1 : 1.2	82% H	32% Dk2, 26% Dk1, 24% Dk4	10	3	-	-	SS .50 CHUTE .50	100% S 100% S	100% E 100% Tu
SS	4	23	85.8	2.8	2.8	1 : 1.0	100% H	50% Lt, 30% Dk2, 20% Dk1	-	-	-	-	FC 1.00	100% S	100% W
DISTOB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	1	2	29.0	3.3	1.9	1 : 1.0	67% H, 33% U	33% Dk1, 33% Dk2, 33% Dk4	-	-	-	-	FC 1.00	100% S	100% A
CHUTE	1	2	30.0	3.2	3.0	-	50% H, 50% U.C.	50% Dk2, 50% Dk4	8	2	-	-	-	-	-
PLAT	7	31	66.3	1.9	2.7	-	75% H, 25% I.G.	46% Dk1, 39% Lt	-	-	130	45	FC .57 SS .29	100% S 100% S	25% E, 25% W, 25% Td, 25% Tu 100% W
GRAVELS	8	-	-	-	-	-	-	-	-	-	-	-	PLAT .86	100% S	50% E, 33% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.27 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR TFLENT SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥20%
Fm	21	Sw .82	-	-	n/a	-	7	Sw 1.00	-	-	-	-
O	0	Sw 1.00	-	-	-	-	-	-	3	Sr 1.00	-	-
Sw	75	Sw .53, Fm .29	100	-	-	-	93	Fm 1.00	-	-	32	Sw 1.00
Sr	3	Fm 1.00	-	-	-	-	-	-	97	-	-	-
Ss	1	Fm .50, Sw .50	-	-	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	16	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	-	-	46	St 1.00
Gm	-	-	-	-	-	-	-	-	-	-	5	-

Flood cycle deposits are the dominant element, occupying 42% of Tflent section. These extend atop platform sands, thinning out from a maximum thickness of ≥ 2m down-section. At the section head, these deposits are at the floodplain surface, but they are disrupted by a small chute in mid-section, and a thick sand sheet at the down-section end. The thickness and degree of interbedding of facies Sw and Fm vary markedly within flood cycle deposits at each analysis point. They are banded dark brown, heterogenously mixed, fine/very fine sands.

The previously mentioned surficial chute channel unit is very thin (0.3m), and has an upward coarsening, lower energy facies fill (97% facies Sr). Sand sheet deposits are found in two units, both composed solely of facies Sw, at either end of Tflent section. At the upstream end, an upward coarsening, loose sand unit is observed atop basal gravels, marginal to flood cycle deposits. The down-section unit thickens down-valley, evening out the floodplain surface atop and adjacent to flood cycle deposits.

As observed in all previous sections, lower energy facies are found atop basal gravels and extend in an irregular manner up-sequence. Three of the eight analysis points in Tflent section have sequences indicative of up-sequence reduction in energy of deposition, and upward fining particle size trends. Overall mean particle size and facies characteristics in the section are similar to those of the overall data set, although facies Sr is 0.7ϕ finer and has smaller average dimensions.

9 : 4 : 4 Analysis of Fallop bank exposure

Fallop section is located in a very large, rapidly eroding, concave bank, immediately opposite Fallbar, downstream of a chute cut-off from a major point bar unit. Vegetation on the floodplain surface is very well developed, with a wide range of species (maximum age ≥ 50 years). Active channel width is extensive at this part of the valley. This section is at the margin of the wandering and meandering channel planform reaches, and is a more extensive (≥ 200m long, ≥ 4m deep) section than those observed up-valley. It has a very simple element composition (Figure 9.7), with basal gravels transitional to platform sands, which in turn are transitional to distal overbank deposits, with flood cycle deposits at the floodplain surface throughout the section.

Facies composition in Fallop section, however, is divided among facies Sw, St, Sr and Fm, although lower energy facies make up 71% of the section (Table 9.28). The high proportion of facies Fm relates to the distal overbank element, which occupies 20% of the section (Tables 9.29, 9.30). Bar platform and flood cycle deposits both thin down-section, althought the basal contact is highly irregular. The floodplain surface tilts down-valley.

Sediment sequences are consistent at each analysis point, with basal gravels transitional to upward fining bar platform deposits, which have a higher proportion of lower energy facies than observed elsewhere. Thick, coarse sand, facies St units typically are transitional upwards to facies Sw and Sr units, which are slightly coarser than in the overall data set. As composed of a broader range of facies than in other sections, the ≥1.7m thick, bar platform deposits in Fallop section exhibit a broader range of sediment mixes and colors than observed elsewhere. The abundance of bar platform sands (53%) is greater than in any other section.

Distal overbank deposits occupy 20% of Fallop section. They have an average thickness of 0.55m, which is maintained consistently down-section, with an irregular shape. Sediment sequences are extremely similar, with six to eight upward coarsening, lower energy facies units at each analysis point. In up-section points, these are composed solely of facies Fm units, but these are interbedded with facies Sw units down-section. These are dark brown, very fine sands.

Flood cycle deposits thin notably from ≥2.5m to 0.5m down-section. The proportion of lower energy facies increases notably in that direction; indeed, facies St units are observed only in the upper four analysis points and occupy just 15% of this element. These units possibly reflect a high energy chute unit, as flood cycle deposits are lower in elevation at this point. The remainder of this element is composed primarily of facies Sw (61%). Deposits are somewhat coarser than observed elsewhere (reminiscent of surficial sand sheets), but generally are compact and cohesive, dark brown sands. Particle size trends are inconsistent both down-section and vertically. The lack of sand sheet deposits is possibly explained by the greater elevation of these deposits above the channel.

In summary, sediment sequences in Fallop section are upward fining, with high energy facies generally at the base of sequences, and interbedded massive fine sands in mid-sequence (distal overbank deposits). Lower energy facies are more thinly interbedded than in the overall data set, but less intermingled. In contrast, high energy facies are thicker and slightly coarser,

TABLE 9.28 SUMMARY STATISTICAL ANALYSIS OF FALLOP SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	122	18	100	6.5	3.8	1.9	58% U.C., 41% H	72% Dk4	Sw .48	61% G	48% W, 24% Td
									Fm .38	100% G	48% E, 38% Td
O	13	1	71	1.7	3.2	2.5	100% H	46% Dk5, 39% Dk4	Sw .85	73% S	46% W, 36% I
Sw	113	28	100	11.0	3.3	2.5	64% H, 37% U.C.	46% Dk2, 27% Dk3	Fm .58	65% G	40% W, 26% Td
Sr	50	24	100	20.9	2.3	2.9	61% I.G., 39% H	60% Lt	Sw .49	96% G	42% W, 29% Td
									Fm .20	90% S	50% W, 30% Td
									Sr .20	70% S	40% W, 30% Tu, 30% I
Ss	3	2	21	33.3	0.8	2.8	100% U	67% Lt, 33% Dk3	Fm .33	100% S	100% Tu
									Sw .33	100% S	100% E
									St .33	n/a	-
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-
St	22	25	86	51.0	1.0	3.5	86% I.G.	96% Lt	Sr .46	100% S	50% W, 33% Td
									Fm .27	83% S	33% W, 33% Tu
Gm	3	3	21	40.0	38.0	-	-	-	-	-	-
G	11	-	79	-	131.0	-	-	-	St .67	100% S	100% W
									Sr .33	n/a	-

Number of analysis points 14 Overall mean particle size 2.39Ø Upward particle size ratio 1 : 0.88 (*6) Sr L = 12, D = 3; St W = 72, D = 16

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.29 SUMMARY STATISTICAL ANALYSIS OF FALLOP SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	16	27	74.1	3.1	2.6	1 : 1.0	85% H	29% Dk4, 25% Lt	11	3	65	15	DISTOB 1.00	100% G	50% W, 50% Td
SS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DISTOB	14	18	55.6	3.8	2.0	1 : 1.2	84% U.C.	55% Dk4, 30% Dk2	-	-	-	-	FC 1.00	50% S	50% W, 21% E, 21% I
RIDGE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CHUTE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLAT	14	55	176.1	1.6	3.1	1 : 0.6	53% H, 36% I.G.	39% Lt, 22% Dk3	12	3	74	16	DISTOB .86	92% G	50% E, 25% Td
GRAVELS	11	-	-	-	-	-	-	-	-	-	-	-	PLAT 1.00	100% S	50% Td, 33% Tu

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands
(*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact
(*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.30 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR FALLOP SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	*Distal overbank deposits* % Abundance	*Distal overbank deposits* Upward transitions ≥ 20%	*Ridge* Deposits % Abundance	*Ridge* Deposits Upward transitions ≥20%	Chute infill % Abundance	Chute infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥ 20%
Fm	5	Sw .75, Sr .21	n/a	-	86	Fm .57, Sw .43	n/a	-	n/a	-	2	Sr .60, Sw .40
O	2	Sw .85	-	-	-	-	-	-	-	-	-	-
Sw	61	Fm .48, Sw .24, O .21	-	-	12	Fm 1.00	-	-	-	-	17	Sr .54
Sr	18	Fm .40, Sw .30	-	-	-	-	-	-	-	-	34	Sw .57, Sr .24
Ss	-	-	-	-	-	-	-	-	-	-	4	Fm .33, Sw .33, St .33
Sh	-	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	15	Fm .80, Sr .20	-	-	-	-	-	-	-	-	39	Sr .53, Sw .27
Gm	-	-	-	-	-	-	-	-	-	-	4	St 1.00

resulting in an overall mean particle size 0.5ϕ coarser than for the summary data set. Facies and element characteristics are similar to those demonstrated elsewhere.

9 : 4 : 5 Summary analysis of wandering channel planform reach bank exposures

The four bank exposures studied in the wandering reach have highly variable elemental compositions, whereas their facies compositions are relatively consistent (the lowest proportion of lower energy facies is 73% in Fallop section). Elements are organized roughly horizontally in each instance. In Widewand section, distal overbank deposits and sand sheet units are atop irregular bar platform deposits. The vertical elemental arrangement from platform to flood cycle to sand sheet deposits is evidenced in both Upash and Tflent sections, but is disrupted in the former instance by three chute channels. In Fallop section, platform, distal overbank and flood cycle elements are very clearly vertically stacked with an horizontal arrangement down the entire section. Indeed, only in Upash section are elements longitudinally discontinuous to a major degree.

Floodplain sequences are considerably thicker in Fallop section than in other wandering reach sections, extending to $\geq$4m. The greater elevation of the floodplain at this location possibly precludes the presence of sand sheet deposits at the surface of this section. Other than at the heads of Tflent and Fallop sections, floodplain surfaces are roughly flat, as vertically accreted, flood-related deposits have smoothed former depositional surfaces. Sand sheet deposits are prevalent at the surfaces of other sections, with wedge-shaped units up to 1.2m thick. These extend over virtually the entire 125m surface of Widewand section. In general, these units have very simple facies compositions, and are primarily loose, fine-medium sand, facies Sr or Sw units. In Widewand section, these are mixed in an irregular manner with facies St units.

Flood cycle deposits extend across Upash, Tflent and Fallop sections (at the surface in the latter two instances). In Upash, these units often thin at various analysis points, but in Tflent and Fallop sections flood cycle deposits thin down-section, with a maximum thickness of almost 2m. Although composed primarily of lower energy facies, their composition varies markedly from analysis point to analysis point, especially in terms of the proportion of facies Fm. At the tail of Upash section and at the head of Fallop section, facies St units are observed, possibly reflecting former chute channels, which could not be recognized in longitudinal exposure. Accordingly, particle size trends within flood cycle deposits are highly irregular both vertically and down-section.

Distal overbank deposits extend across both Widewand and Fallop sections in mid-sequence, but are not observed in the other bank exposures in the wandering planform reach. Deposits are thicker in Widewand section (up to 2.5m), but their thickness varies, with an irregular arch-like form. The basal contact is similarly irregular in Fallop section, where the deposits retain a uniform thickness of about 0.6m down-section. Other than thin facies Sw units, distal overbank deposits are composed solely of facies Fm in Widewand section, whereas in Fallop section there are six to eight upward coarsening facies Fm units at each analysis point, interbedded with facies Sw in the downstream half of the section.

Chute channels are apparent as discontinuous longitudinal units in Upash and Tflent sections. In both instances, these are generally found close to, or at, the floodplain surface, and have lower energy facies infills (although the character of the three chute channels in Upash section varies markedly). A thin, lower energy facies, ridge unit is observed in Tflent section.

The major difference between sections studied in the braided and wandering reaches is the significantly greater proportion of bar platform deposits in the latter. These extend across most of the bases of each section, their thickness gradually increasing from section to section down-valley. Indeed, in Fallop section these are the dominant element, and are up to 3m in thickness. They are more disrupted in other sections, with highly variable thicknesses down-section. Composition varies widely form analysis point to analysis point in each instance, with mixed high and lower energy facies, although in Fallop section facies St units are transitional upwards to facies Sr and Sw deposits, with an according upward fining particle size trend. In each section, basal gravel contacts are highly irregular.

Given the different facies organizations within-element in each section, there are no consistent facies trends either vertically or down-section. High energy facies are found within sand sheets in Widewand section, within chutes in Upash section, within flood cycle deposits in Upash and Fallop sections, and in bar platform deposits throughout. The spatial arrangement of these elements ensures intermingling of facies types within each section. Vertical facies sequences in Widewand and Fallop sections are further disrupted by thick facies Fm units in mid-sequence. Although particle size trends are evident by element type, when combined, sequences have highly irregular trends both vertically and down-section, although fine sands are predominant. In summary, the elemental composition of the four sections in the wandering reach varies considerably, but in general elements are horizontally stacked. Within-element facies compositions are highly variable, but consistent with observations elsewhere in summary terms. Fine sand, lower energy facies are dominant in each section. The proportion of platform deposits is considerably greater than observed in the braided reach, and elements are more longitudinally continuous.

9 : 5 : 1 Analysis of bank exposures in the meandering channel planform reach : Campup section

Of the four sections sampled in the meandering reach, two are in relatively young depositional sequences, in banks immediately upstream of point bars, while the others are thicker and older, in cohesive banks on the eastern side of the channel in which distal overbank deposits are prominent. One of these sections, Campup, is located at the head of the single channel section of the study reach, 0.5km upstream of a major lateral bar (Beach Bar of the 1986 data set). To examine the section, major slumps of material had to be removed to construct a vertical section.

The elemental character of Campup section is consistent at all but the downstream analysis point (Figure 9.9). At this point, recent lateral bar deposits have been plastered onto the pre-existing floodplain, with a very sharp contact. The distal overbank element curves away from the main channel adjacent to these contemporary bar deposits.

Vertical and down-section particle size trends are extremely consistent in Campup section. Other than the very fine sand, distal overbank deposits (which occupy 35% of the section, composed solely of facies Fm), the section is made up of fine sands (Tables 9.31, 9.32, 9.33). This is explained partially by the fact that basal channel framework gravels were not reached at any analysis point, even though sediment sequences are over 5m thick! The observed basal bar platform deposits have an average thickness of 0.7m (they are thinner in mid-section), and are composed primarily of medium-brown, medium-fine sand, facies Ss. At all but the down-section analysis point these are transitional upward to distal overbank deposits, which rest horizontally above bar platform sands with a uniform 1.7m thickness. These grey-colored, very fine sands are either massive or finely laminated, and have several charcoal layers within them, representing localized forest fires at former floodplain surfaces. In several instances charcoal layers are longitudinally contiguous down-section, over distances up to 130m.

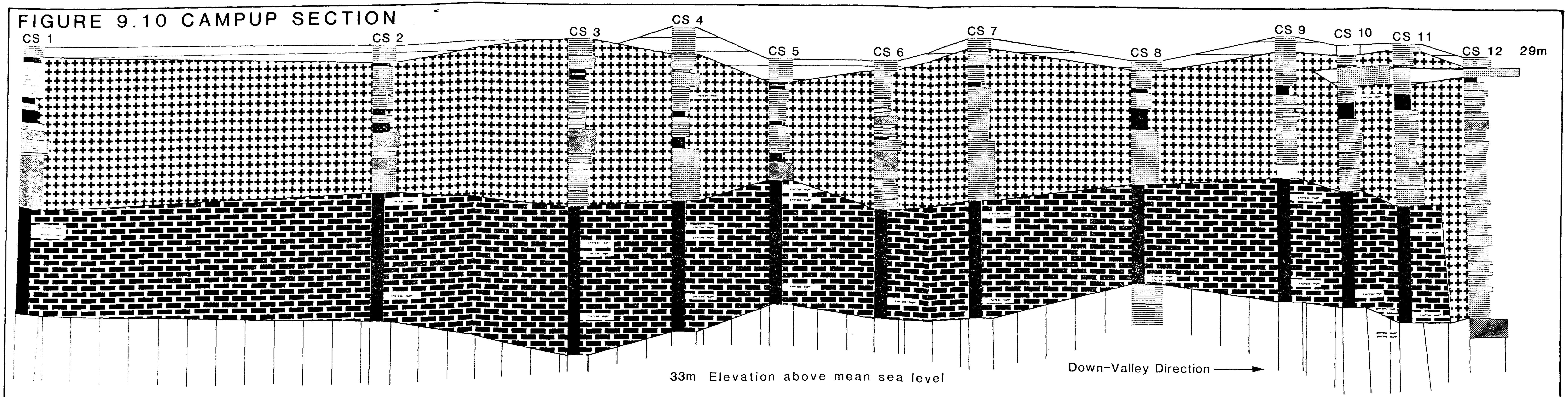


FIGURE 9.10 CAMPUP SECTION
CS 1
CS 2
CS 3
CS 4
CS 5
CS 6
CS 7
CS 8
CS 9
CS 10
CS 11
CS 12
29m
33m Elevation above mean sea level
Down-Valley Direction

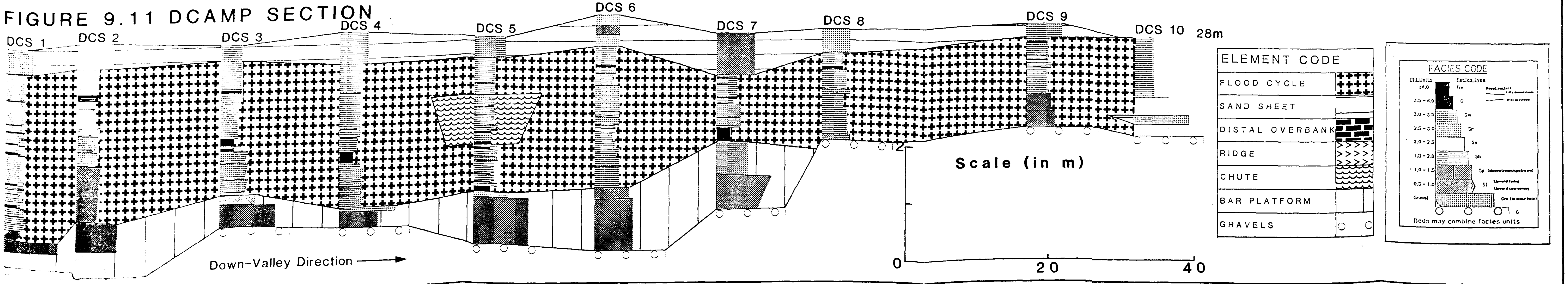


FIGURE 9.11 DCAMP SECTION
DCS 1
DCS 2
DCS 3
DCS 4
DCS 5
DCS 6
DCS 7
DCS 8
DCS 9
DCS 10
28m
Down-Valley Direction
Scale (in m)
2
0
20
40
ELEMENT CODE
FLOOD CYCLE
SAND SHEET
DISTAL OVERBANK
RIDGE
CHUTE
BAR PLATFORM
GRAVELS
FACIES CODE
Beds may combine facies units

TABLE 9.31 SUMMARY STATISTICAL ANALYSIS OF CAMPUP SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	66	40	100	33.5	4.2	0.2	53% U, 47% H	34% G, 30% Dk4	Sw .55	72% S	42% W, 25% Td
O	24	1	83	2.0	3.6	2.3	100% H	58% Dk4, 21% Dk5	Sw .67 Fm .29	80% S 86% S	63% W 43% Td, 29% W, 29% Tu
Sw	108	23	100	11.8	3.2	2.5	98% H	30% Dk2, 29% Dk3	Sr .31 Fm .25 Sw .21	87% S 83% S 80% S	43% W, 23% Td 38% W, 29% Td 80% W
Sr	47	15	100	17.9	2.7	2.8	75% I.G., 26% H	62% Lt	Sw .64	97% S	50% W, 30% Td
Ss	14	15	92	58.1	2.5	3.1	60% H, 20% U.F., 20% U.C.	50% Lt, 25% Dk3	Fm .77	90% S	87% E, 22% Td
Sh	3	1	8	19.3	1.7	3.0	67% H, 33% I.G.	-	Fm 1.00	100% S	100% E
Sp	-	-	-	-	-	-	-	-	-	-	-
St	11	5	42	25.4	2.1	3.2	90% I.G.	78% Lt, 22% Dk1	Sw .46	100% S	100% W
Gm	1	0	8	12.0	60.0	-	-	-	O 1.00	100% S	100% W
G	0	-	0	-	-	-	-	-	-	-	-

Number of analysis points 12 Overall mean particle size 2.35Ø Upward particle size ratio 1 : 1.11 (*6) Sr L = 12, D = 2; St W = 59, D = 21

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.32 SUMMARY STATISTICAL ANALYSIS OF CAMPUP SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average Element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	15	45	165.3	3.1	2.5	1 : 1.0	73% H, 20% I.G.	20% Dk3	12 2	48 20	SS 1.00	93% S	79% W
SS	14	3	19.0	2.2	3.1	-	94% H	73% Lt	8 3	150 30	FC 1.00	100% S	100% W
DISTOB	11	35	174.5	4.2	-	-	86% U	79% G	- -	- -	FC 1.00	82% S	73% E, 27% Td
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
PLAT	12	16	72.2	2.4	3.1	1 : 1.5	50% H	100% Dk3	- -	- -	DISTOB .92	91% S	70% E, 20% Td
GRAVELS	0	-	-	-	-	-	-	-	- -	- -	-	-	-

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.33 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR CAMPUP SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute infill % Abundance	Chute infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥20%
Fm	12	Sw .87	-	-	100	-	n/a	-	n/a	-	0	Sh 1.00
O	2	Sw .58, O .37	-	-	-	-	-	-	-	-	-	-
Sw	44	Sr .33, Fm .27	70	Sw 1.00	-	-	-	-	-	-	-	-
Sr	33	Sw .63	9	Sw 1.00	-	-	-	-	-	-	-	-
Ss	1	Sw .50, Sr .50	6	-	-	-	-	-	-	-	90	St 1.00
Sh	-	-	-	-	-	-	-	-	-	-	7	Fm 1.00
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	9	Sw .56, Fm .22	10	-	-	-	-	-	-	-	4	-
Gm	-	-	5	-	-	-	-	-	-	-	-	-

Flood cycle deposits in Campup section have a similar character to those observed elsewhere, as these are heterogenously mixed, banded dark brown, fine sands, composed primarily of lower energy facies (90%). They occupy 45% of the observed bank exposure, and are found in a uniform thickness (1.6m thick) unit atop the distal overbank element, with a roughly horizontal contact. Adjacent to the lateral bar, at the section tail, flood cycle deposits are over 4m thick, with many thinly interbedded lower energy facies units (primarily facies Sw and Sr). The proportion of facies Fm within flood cycle deposits is notably greater in other analysis points. These are observed at very irregular positions within-sequence. At several analysis points, internal facies organizations are indicative of up-sequence reduction in energy of deposition, with facies St units at the base of sequences. These may represent chute channel deposits, which cannot be readily identified in longitudinal section. Whenever observed, basal contacts between facies Fm and St generally are tilted, possibly indicating scouring. Given the irregularity in within-element facies organization, particle size trends are inconsistent both down-section and vertically.

Sand sheet deposits in Campup section are found in three units, all of which are at, or close to, the floodplain surface. The up-section unit is a thin, fine sand, facies Sw unit. The second unit at the floodplain surface thins down-section. Although primarily composed of facies Sw, these deposits are notably coarser than flood cycle deposits beneath them. Finally, the third unit is at the tail of the section, and has an irregular composition, with a distinct gravel component. Overall, sand sheets are heterogenously mixed, light brown sands, which occupy 19% of the observed bank exposure.

In summary, Campup differs from sections studied previously in that basal gravels were not reached, and hence coarse sand, high energy facies are not observed at the base of the section. Lower energy facies are typically thinly interbedded, especially within the flood cycle element. Basal contacts are sharply defined, and predominantly wavy in outline. Individual facies characteristics are consistent with the overall data set; the predominance of facies Fm results in an overall mean particle size which is almost 0.5ϕ finer. No vertical particle size trends are evident (i.e. there is mixing of fine and medium-fine sands at each analysis point).

9 : 5 : 2 Analysis of Dcamp bank exposure

Dcamp section is located at the margins of the major chute at the head of Dcamp point bar. Vegetation at the floodplain surface is relatively young, and could be pushed over easily. These are sand sheet deposits, as noted in several trenches of the 1986 data set. Large logs have been washed onto the floodplain surface, disrupting sediment sequences. About 100m up-section there is the outline of a major former channel within remnant, very disturbed, floodplain deposits, around which a large log jam has accumulated.

As shown in most sections, lower energy facies, vertically accreted, flood-related sediments are dominant in Dcamp section, making up 79% of observed deposits (Tables 9.34, 9.35, 9.36; Figure 9.10). These, and a small chute channel, are located atop 0.6m thick bar platform deposits at the upper end of the section, and basal gravels in the lower three analysis points (marginal to the contemporary bar platform).

The bar platform deposits thicken slightly down-section, but pinch out abruptly as the basal gravel surface rises by over 1m. Upstream of this point the basal surface is also irregular, rising by 0.5m in mid-section. Bar platform sands are dominated by poorly sorted, coarse sand, large dimension, facies St units. These are light brown, internally graded units.

Flood cycle deposits rest atop bar platform sands and basal gravels with a surface which tilts gradually up-section, and have an average thickness of 1.4m. Their composition varies notably from point to point down-section, especially in terms of facies Fm presence. In general, facies Sr or facies St units are transitional upwards to facies Sw units. Units are notably thinner than in the overall data set. These are banded dark brown, heterogenously mixed, fine sands. Contained within these flood cycle deposits, in mid-section, is a small, very thinly interbedded, lower energy facies, chute infill channel.

A fairly thick (0.3m) sand sheet rests atop Dcamp section at all but the last analysis point. This retains a relatively consistent, even outline, and has a simple facies composition at each analysis point, but is very variable in longitudinal section, with alternating facies Sr, Sw and St units. These light brown, internally graded deposits are significantly coarser than the flood cycle deposits beneath them. A second sand sheet is found within the flood cycle deposits adjacent to the contemporary bar platform. This is a thin, facies Gm unit.

TABLE 9.34 SUMMARY STATISTICAL ANALYSIS OF DCAMP SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface, a) Definition (*4)	b) Shape (*5)
Fm	27	5	70	4.4	4.0	0.9	58% H, 41% U	74% Dk4	Sw .63	88% S	65% W
									Sr .30	100% S	75% W
O	21	2	100	2.6	3.2	2.5	100% H	71% Dk4	Sw .95	90% S	75% W
Sw	76	37	100	12.1	3.3	2.4	100% H	61% Dk2	Sr .43	100% S	36% Tu, 32% Td, 26% W
									O .23	94% S	77% W
Sr	55	35	90	15.6	2.5	2.8	56% I.G., 44% H	67% Lt, 20% Dk1	Sw .47	96% S	48% Td, 30% Tu
									Fm .22	100% S	64% W, 27% Tu
									Sr .22	91% S	46% W, 27% Td
Ss	4	0	30	2.5	3.0	2.2	100% H	75% Lt, 25% Dk1	Fm .50	100% S	50% Td, 50% Tu
									Sw .50	100% S	100% Tu
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	4	4	30	21.5	2.1	3.0	100% H	75% Lt, 25% Dk1	Sw .50	100% S	100% Tu
									St .50	100% S	100% W
St	8	15	70	46.3	0.2	3.8	88% I.G.	100% Lt	Sr .43	100% S	33% W, 33% Td, 33% Tu
									Sw .29	100% S	50% Td, 50% Tu
									Sp .29	100% S	50% E, 50% Tu
Gm	1	2	10	55.0	10.0	-	-	-	Sw 1.00	100% S	100% W
G	10	-	100	-	104.0	-	-	-	St .50	100% S	40% A, 40% I, 20% Tu
									Sr .20	100% S	50% E, 50% Td
									Sp .20	100% S	100% I

Number of analysis points 10 Overall mean particle size 2.40ø Upward particle size ratio 1 : 0.97 (*6) Sr L = 12, D = 3; St W = 90, D = 24

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.35 SUMMARY STATISTICAL ANALYSIS OF DCAMP SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L D (cm)	Trough dimensions W D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	11	63	142.3	3.2	2.4	1 : 1.0	84% H	30% Dk3, 23% Dk4	10 3	- -	SS .90	100% S	78% W
SS	10	16	38.5	1.5	3.4	-	73% I.G., 27% H	82% Lt	31 7	50 30	FC 1.00	100% S	100% W
DISTOB	-	-	-	-	-	-	-	-	- -	- -	-	-	-
RIDGE	-	-	-	-	-	-	-	-	- -	- -	-	-	-
CHUTE	1	3	71.0	3.4	2.1	1 : 1.2	n/a	33% Lt, 27% Dk2, 27% Dk4	8 2	- -	FC 1.00	100% S	100% Tu
PLAT	7	18	64.7	0.2	3.7	1 : 0.5	69% I.G., 23% H	83% Lt	13 4	96 24	FC 1.00	100% S	57% Tu
GRAVELS	10	-	-	-	-	-	-	-	- -	- -	PLAT .70 FC .20	100% S 100% S	57% I, 28% A 50% E, 50% Td

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.36 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR DCAMP SECTION DATA SET

	Flood Cycles		Sand Sheet		Distal overbank deposits		Ridge Deposits		Chute Infill		Platform sands	
Facies type	% Abundance	Upward transitions≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%	% Abundance	Upward transitions ≥20%
Fm	7	Sw .65, Sr .30	-	-	n/a	-	n/a	-	15	Sw .50, Sr .25, Ss .25	-	-
O	4	Sw .95	-	-	-	-	-	-	-	-	-	-
Sw	54	Sr .34, O .29, Fm .20	13	-	-	-	-	-	45	Sr .80, Fm .20	-	-
Sr	34	Sw .50, Sr .25	57	Sw 1.00	-	-	-	-	38	Fm .50, Sw .50	16	-
Ss	1	Fm .50, Sw .50	-	-	-	-	-	-	1	Sw 1.00	-	-
Sh	-	-	-	-	-	-	-	-	-	-	-	-
Sp	1	Sw 1.00	-	-	-	-	-	-	-	-	16	St 1.00
St	-	-	16	-	-	-	-	-	-	-	68	Sr .75, Sp .25
Gm	-	-	14	-	-	-	-	-	-	-	-	-

In summary, elements in Dcamp section are roughly horizontally arranged when viewed in longitudinal section. This principle applies for all but the bar platform sands, which are disrupted by an abrupt rise in the basal gravel surface. Lower energy facies make up 77% of the section; these are the primary constituent of the dominant flood cycle element. The proportion of high energy facies is notably lower in those analysis points adjacent to the contemporary Dcamp bar platform, as the platform element is not observed at these points. Facies characteristics are similar to those observed elsewhere. Vertical sequences are roughly upward fining, other than the coarser sand sheet deposits at the surface. Given the coarseness of the platform sands, and the lack of distal overbank deposits, the overall mean particle size is 0.5ϕ coarser than in the summary bank exposure data set.

9 : 5 : 3 Analysis of Sumart bank exposure

Sumart section was dug in the concave bank immediately opposite Bigbar. These thick $\geq$5.5m, very old, floodplain sequences are similar in type to Campup, with a major, very cohesive, distal overbank unit in mid-sequence. A major bench of contemporary sediments had to be dug away prior to examining the vertical section. Basal framework gravels could not be reached in the four down-section analysis points

Lower energy facies occupy 76% of Sumart deposits, 42% of which are taken up by facies Fm alone (Figure 9.12, Table 9.37). These are primarily found in a thick distal overbank element, which thins gradually from 2.5m to 1.5m down-section. Although the surface of this unit is relatively flat, its basal contact is quite irregular, but tilts slightly up-section. These uniform, grey or dark brown, very fine sands, have several (up to four) charcoal layers within (Tables 9.38, 9.39).

Sediment sequences beneath the distal overbank element vary greatly in the two halves of Sumart section. In the upstream, gravel based, analysis points, very coarse sand or fine gravel facies are observed up to 1.4m thick, with dominantly upward fining sequences. The composition of these platform sands varies among facies Ss, Sp, St and Gm at each analysis point. The basal surface varies in an irregular manner by almost 1m.

FIGURE 9.12 SUMART SECTION

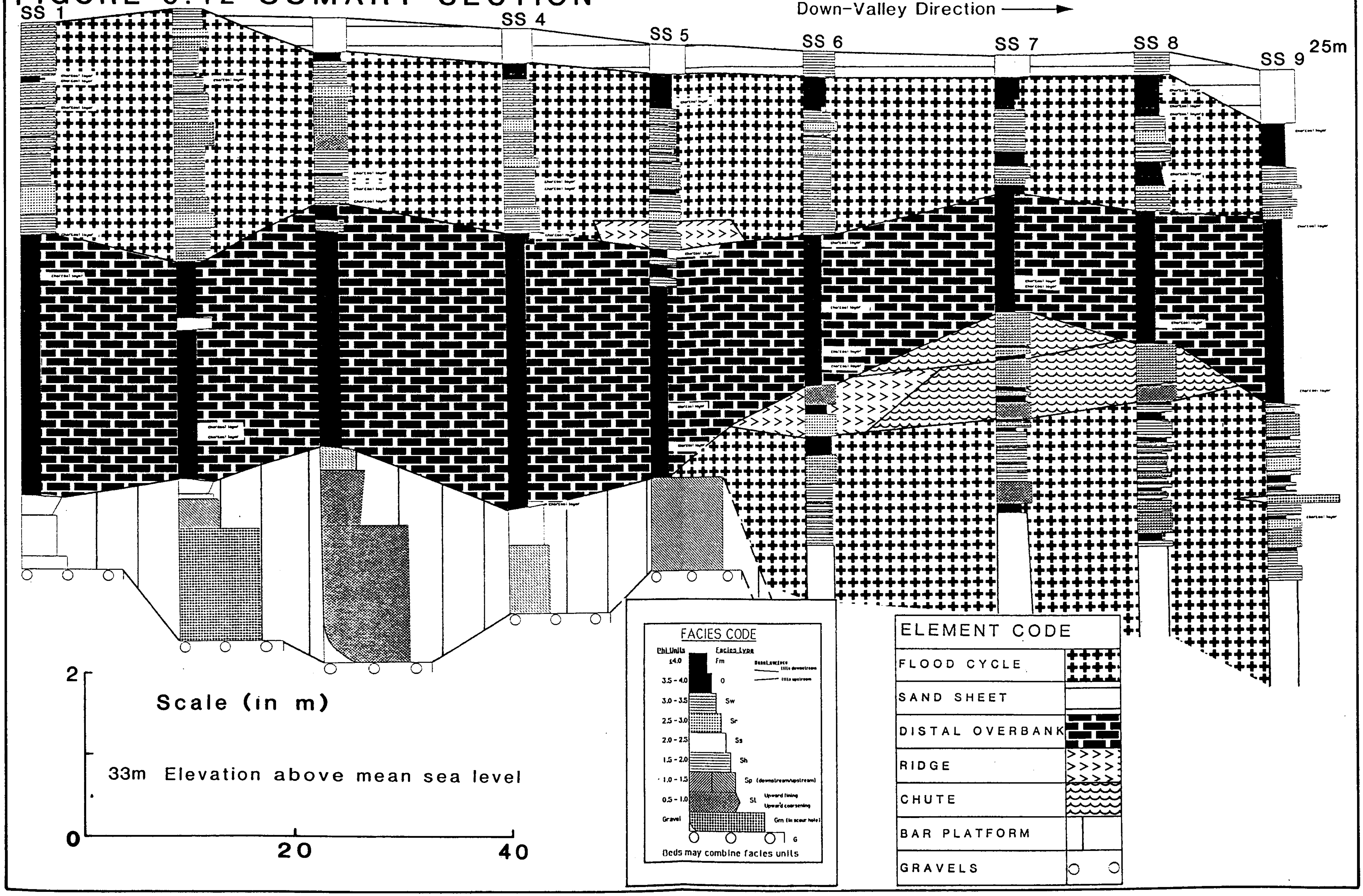


TABLE 9.37 SUMMARY STATISTICAL ANALYSIS OF SUMART SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	b) Shape (*5)
Fm	102	42	100	22.1	4.1	0.4	60% H, 38% U	36% G, 29% Dk3, 28% Dk4	Sw .35 Sr .29	97% S 93% S	50% W, 22% Tu 67% W
O	19	1	78	2.0	3.7	1.5	63% H, 37% U	42% B, 32% Dk5, 21% Dk4	Fm .58 Sw .21 Sr .21	100% S 75% S 100% S	46% W, 36% Td 50% W, 25% Td, 25% I 100% W
Sw	64	15	100	12.6	3.0	2.4	98% H	23% Lt, 23% Dk1	Fm .60	100% S	42% W, 24% Tu
Sr	62	18	100	15.5	2.9	2.6	72% H, 28% I.G.	55% Lt, 22% Dk1	Fm .49 Sr .25	97% S 100% S	60% W 87% W
Ss	16	13	100	43.1	2.9	2.4	54% H	67% Lt	Fm .46 Sw .27 Ss .27	100% S 100% S 50% S	40% Td, 20% W, 20% Tu 67% W, 33% Tu 50% W, 50% I
Sh	3	1	33	22.3	2.7	3.1	100% H	100% Lt	Sr 1.00	100% S	100% W
Sp	2	2	22	62.5	-0.5	3.5	100% H	100% Dk3	Fm .50 Ss .50	100% S 100% S	n/a 100% W
St	7	5	33	40.6	0.8	3.6	57% I.G., 29% H	100% Lt	Fm .43 Sw .29	100% S 100% S	67% Tu, 33% E 50% W, 50% I
Gm	4	3	44	43.3	63.0	-	-	-	Sw .50 Ss .25 Sp .25	100% S n/a 100% G	100% W - 100% I
G	4	-	44	-	30.0	-	-	-	Sp .33 St .33 Gm .33	n/a n/a n/a	- - -

Number of analysis points 9   Overall mean particle size 3.13ø   Upward particle size ratio 1 : 0.91   (*6) Sr L = 10, D = 3; St W = 34, D = 11

(*1) Average bmax values for facies Gm and G (in mm)   (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact   (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.38 SUMMARY STATISTICAL ANALYSIS OF SUMART SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	Basal Surface b) Shape (*6)
FC	14	44	169.1	3.1	2.3	1 : 0.9	77% H	21% Lt	10	3	-	-	SS .67	100% S	63% W
SS	8	4	29.1	2.7	3.0	-	86% H	100% Lt	-	-	-	-	FC 1.00	100% S	100% W
DISTOB	9	34	204.1	4.2	0.1	1 : 1.0	65% U, 35% H	35% G, 31% Dk3	5	1	-	-	FC .89	88% S	50% W, 38% Td
RIDGE	2	1	38.5	3.0	2.5	1 : 0.5	100% H	80% Lt, 20% G	15	4	20	7	FC .50 DISTOB .50	100% S 100% S	100% W 100% Tu
CHUTE	3	3	56.3	2.6	2.5	1 : 1.0	75% H	58% Lt, 33% G	10	4	15	8	DISTOB .67 CHUTE .33	50% S 100% S	100% I 100% Tu
PLAT	5	13	142.0	0.5	2.7	1 : 0.1	42% H, 25% I.G., 25% U.C.	46% Lt, 27% Dk3, 27% G	-	-	63	15	DISTOB 1.00	100% S	60% Td, 20% Tu, 20% I
GRAVELS	4	-	-	-	-	-	-	-	-	-	-	-	PLAT 1.00	n/a	-

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands
(*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact
(*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.39 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR SUMART SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥ 20%
Fm	18	Sw .50, Sr .30	-	-	98	-	13	St 1.00	12	Sr 1.00	-	-
O	2	Fm .58, Sw .21, Sr .21	-	-	-	-	-	-	-	-	-	-
Sw	28	Fm .62	-	-	1	Fm 1.00	36	Sw 1.00	-	-	13	Ss 1.00
Sr	34	Fm .43, Sr .28, Sw .22	-	-	1	Fm 1.00	27	Fm 1.00	68	Fm 1.00	-	-
Ss	16	Sw .75, Fm .25	76	-	1	Fm 1.00	-	-	-	-	18	Ss 1.00
Sh	1	Sr 1.00	21	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	18	Ss 1.00
St	2	Sw .50, Sr .50	-	-	-	-	23	-	20	Fm 1.00	28	Sw .50, St .50
Gm	-	-	3	-	-	-	-	-	-	-	23	Sw .33, Ss .33, Sp .33

A mix of chute, ridge and flood cycle deposits are found beneath distal overbank sediments in the down-section half of Sumart section. These are all composed primarily of intermingled, lower energy facies. The two chutes units differ in character and scale, but both have light brown, heterogenously mixed, medium-fine sands. The smaller, upper unit has a facies Sr/Fm composition, whereas the second channel has a facies St-Fm-Sr make-up. Average chute thickness is 0.5m. A small ridge unit is marginal to the larger chute, and has a similar, but reversed, facies Sr-Fm-St composition. A second, small ridge unit, composed solely of facies Sw, is located above the distal overbank element in mid-section.

Beneath the ridge and chute deposits, adjacent to the bar platform sands, are very thinly interbedded and intermingled, fine sand, lower energy facies, with thick facies Ss units at their bases. These thick ($\geq$2m), flood cycle deposits differ from those found above the distal overbank element, as they have a smaller proportion of facies Fm and are more thinly interbedded. The upper flood cycle element thins gradually down-section, although the basal contact with distal overbank deposits is roughly flat. The proportion of facies Fm is much greater in the down-section analysis points. Several charcoal layers are found throughout these flood cycle deposits. As this element thins down-section, a sand sheet element atop them thickens, to a maximum depth of 0.5m. These are very simple in composition, with either facies Ss or facies Sw units. On average, these loose sands are 0.5ϕ coarser than deposits beneath them.

Elements in Sumart section are roughly horizontally aligned in vertical section, other than the noted discontinuities beneath distal overbank deposits. Facies composition within elements varies markedly from bar platform to distal overbank to flood cycle to sand sheet deposits in vertical sequence. Other than the basal element, however, these are all fine sands, resulting in a very fine overall mean particle size. Just as elements are intermingled, so are facies, typically in very thin beds (except facies Fm in distal overbank deposits). Individual facies characteristics are similar to those observed elsewhere.

9 : 5 : 4 Analysis of Pillbend bank exposure

Pillbend section is located in the bank of the main channel immediately upstream of the point bar at the downstream end of the study reach. This is an area of relatively recent sediment accumulation, and vegetation is, as yet, poorly established, and sediment sequences have been much disrupted by logs washed onto the floodplain. The floodplain itself is characterized by a series of discontinuous ridges and chutes, with predominantly vertically accreted flood-related deposits preserved away from the main channel (see section 8:4:9). This is echoed in Pillbend section, which is dominated by lower energy facies, primarily within sand sheet deposits Figure 9.13, Tables 9.40, 9.41, 9.42.

Other than very small chute channel and bar platform elements, Pillbend section is composed solely of vertically accreted flood-related deposits. Of these, sand sheet deposits occupy 64% of the section, with an average thickness of 1.3m, extending from close to, or at, the basal gravel contact to within 0.4m of the floodplain surface. The shape of this element is highly irregular, roughly following the underlying ridge pattern. They are composed primarily of loose, heterogenous, light brown, facies Sw, with a smaller proportion of facies Sr. Facies compositions are not consistent for any two analysis points in terms of either facies type of particle size trends. Sand sheet deposits are finer than observed elsewhere, and are distinguished from flood cycle deposits by their color and looseness.

Flood cycle deposits are found in two units within Pillbend section. Their facies composition is similar to sand sheet deposits, but facies Fm is more abundant. These are dark brown, heterogenously mixed, fine sands. The basal unit pinches out sharply down-section, as it thins notably from a ridge to a swale, and is composed of thinly interbedded, intermingled lower energy facies. In contrast, the flood cycle deposits at the floodplain surface retain a relatively uniform thickness of 0.4m throughout most of the section, and have very simple facies compositions, with facies Sw dominant at each point. At the down-section end, this element is marginal to a small chute channel, which has an upward fining, facies St-Sw composition. A small, remnant bar platform unit is found in mid-section, atop a ridged area of the basal gravels, and is composed solely of facies St. Pillbend section is dominated by upwardly consistent, thickly interbedded, lower energy facies, with sharply defined, wavy or irregular basal contacts. Fine sands are observed throughout the section.

FIGURE 9.13 PILLBEND SECTION

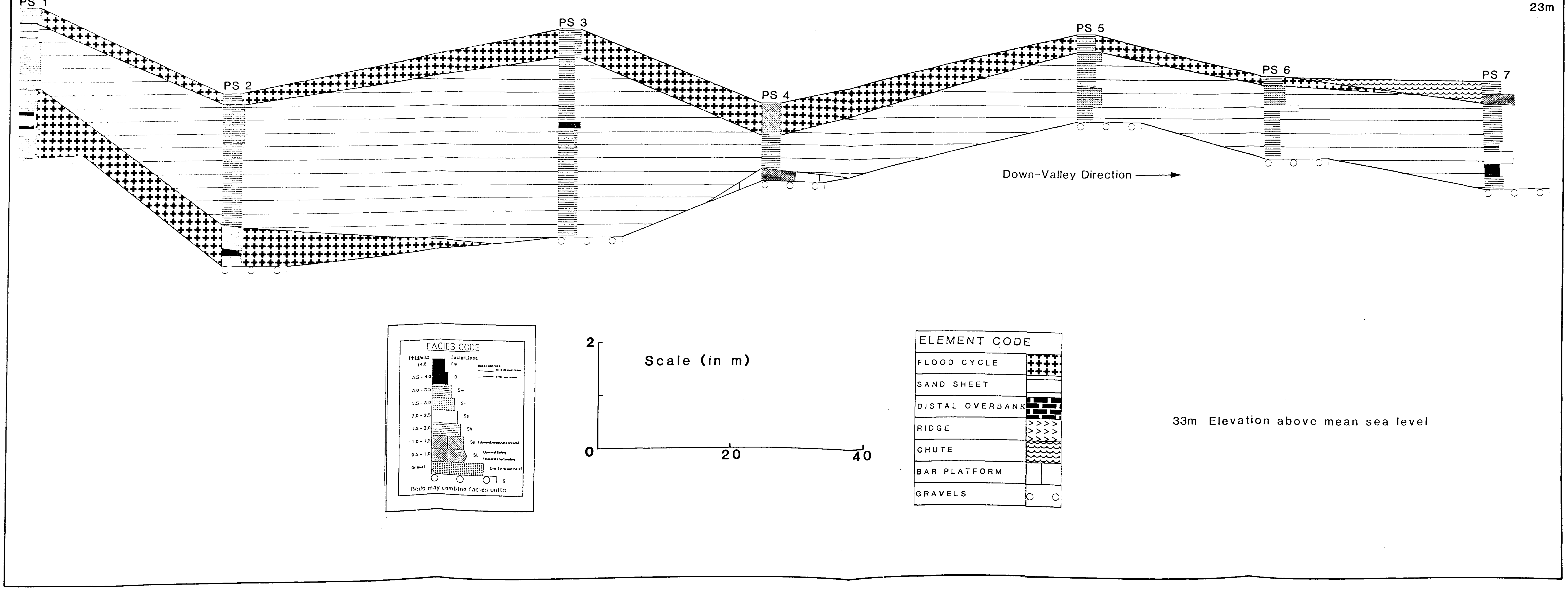


TABLE 9.40 SUMMARY STATISTICAL ANALYSIS OF PILLBEND SECTION DATA SET AT THE FACIES SCALE

Facies type	Number of occurrences	Facies abundance (%)	%presence by holes	Average bed thickness (cm)	Mean particle size (ø units) (*1)	Mean sorting value	Predominant Sediment mix (*2)	Predominant Color (*3)	Upward facies transitions found in ≥20% of occurrences	Basal surface a) Definition (*4)	Basal surface b) Shape (*5)
Fm	5	3	43	10.0	3.7	2.0	60% U, 40% H	80% Dk4, 20% G	Sw .60	100% S	67% W, 33% Td
									Sr .20	100% S	100% W
									Ss .20	100% S	100% I
O	3	1	43	4.7	2.9	3.4	100% H	67% Dk4, 33% B	Sw 1.00	67% S	67% I, 33% E
Sw	23	60	100	38.5	3.3	2.3	96% H	35% Dk1, 22% Dk3	Sr .41	57% S	43% I, 29% E, 29% W
									Sw .24	50% S	50% W, 25% Td, 25% I
Sr	14	25	86	26.7	2.9	2.9	64% I.G., 36% H	71% Lt	Sw .39	60% G	80% W, 20% Td
									Sr .31	75% S	50% W, 25% E, 25% Tu
Ss	2	2	29	15.0	1.4	4.0	100% H	100% Lt	Sw .50	100% S	100% I
									Sr .50	100% S	100% I
Sh	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-
St	2	9	29	67.5	0.8	4.0	100% I.G.	100% Lt	Sw 1.00	100% S	100% Td
Gm	-	-	-	-	-	-	-	-	-	-	-
G	7	-	100	-	80.0	-	-	-	Sw .71	100% S	100% I

Number of analysis points 7 Overall mean particle size 2.97Ø Upward particle size ratio 1 : 1.07 (*6) Sr L = 10, D = 3; St W = 34, D = 11

(*1) Average bmax values for facies Gm and G (in mm) (*2) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*3) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*4) S = Sharply defined contact, G = Gradational contact (*5) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike
(*6) Average ripple and trough dimension : L = length, D = depth, W = width (in cm)

TABLE 9.41 SUMMARY STATISTICAL ANALYSIS OF PILLBEND SECTION DATA SET AT THE ELEMENT SCALE

Element type (*1)	Number of occurrences by analysis point	Element abundance (%)	Average element thickness (cm)	Mean element particle size (ø units)	Mean element sorting value	Within element upward particle size ratio	Predominant sediment mix (by count) (*2)(*3)	Predominant color (by count) (*2)(*4)	Ripple dimensions L (cm)	Ripple dimensions D (cm)	Trough dimensions W (cm)	Trough dimensions D (cm)	Upward element transitions found in ≥20% of occurrences	Basal Surface a) Definition (*5)	b) Shape (*6)
FC	8	26	47.5	3.2	2.4	1 : 1.7	71% H	29% Dk4	11	3	22	9	SS 1.00	50% S	50% W, 50% Td
SS	7	64	136.3	3.2	2.5	1 : 1.2	72% H, 24% I.G.	52% Lt, 28% Dk1	-	-	-	-	FC .86	100% S	50% W, 33% E
DISTOB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIDGE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CHUTE	1	2	35.0	2.4	2.9	-	50% H, 50% I.G.	50% Dk4, 50% Lt	10	4	15	8	-	-	-
PLAT	1	8	120.0	0.7	4.0	-	100% I.G.	100% Lt	5	1	-	-	SS 1.00	100% S	100% Td
GRAVELS	7	-	-	-	-	-	-	-	-	-	-	-	SS .57 FC .29	100% S 100% S	100% I 50% Tu, 50% I

(*1) FC = Flood cycle, SS = Sand sheet, DISTOB = Distal overbank, Plat = Bar platform sands (*2) Calculated as percentage count for all facies contained within this element
(*3) H = heterogenous, U = uniform, I.G. = internally graded, U.F. = upward fining, U.C. = upward coarsening
(*4) Dk1-5 = Gradational sequence of dark brown shading, with 5 = darkest, Lt = light brown, B = black, G = grey, Lt/Dk = light and dark brown bands, DkB = dark brown bands
(*5) S = Sharply defined contact, G = Gradational contact (*6) E = even, W = wavy, I = irregular, Td = tilts downstream, Tu = tilts upstream, A = archlike

TABLE 9.42 SUMMARY ANALYSIS OF ELEMENT COMPOSITION AND INTERNAL FACIES ORGANIZATION FOR PILLBEND SECTION DATA SET

Facies type	Flood Cycles % Abundance	Flood Cycles Upward transitions ≥20%	Sand Sheet % Abundance	Sand Sheet Upward transitions ≥20%	Distal overbank deposits % Abundance	Distal overbank deposits Upward transitions ≥20%	Ridge Deposits % Abundance	Ridge Deposits Upward transitions ≥20%	Chute Infill % Abundance	Chute Infill Upward transitions ≥20%	Platform sands % Abundance	Platform sands Upward transitions ≥20%
Fm	8	Sw .75, Sr .25	2	Ss 1.00	n/a	-	n/a	-	-	-	-	-
O	1	Sw 1.00	1	Sw 1.00	-	-	-	-	-	-	-	-
Sw	65	Fm .50, Sr .50	65	Sr .56	-	-	-	-	57	-	-	-
Sr	27	Fm .50, Sw .25, Sr .25	29	Sw .50, O .25, Sr .25	-	-	-	-	-	-	-	-
Ss	-	-	3	Sw .50, Sr .50	-	-	-	-	-	-	-	-
Sh	-	-	-	-	-	-	-	-	-	-	-	-
Sp	-	-	-	-	-	-	-	-	-	-	-	-
St	-	-	-	-	-	-	-	-	43	Sw 1.00	100	-
Gm	-	-	-	-	-	-	-	-	-	-	-	-

9 : 5 : 5 Summary analysis of meandering channel planform reach bank exposures

The horizontal stacking of elements evidenced in the wandering reach sections is echoed in the bank exposures of the meandering reach, although elements are longitudinally more extensive in this instance. Floodplain sequences are thicker than elsewhere, especially in the two cohesive banks, Campup and Sumart, which have depths of ≥ 5m and 6m respectively. Floodplain surfaces are relatively flat for all surfaces (reflecting lower energy depositional infill), except Pillbend, where a prominent ridged outline reflects the young marginal swale pattern. Both Dcamp and Pillbend are located immediately upstream of the bar platform units of point bars, but are dominated by vertically accreted flood related deposits, with depths up to 4m, and very few platform sands.

In contrast, platform sands are prominent in Campup and Sumart sections, and are observed at all gravel-based analysis points. These have thick distal overbank deposits atop, transitional upwards to extensive flood cycle and sand sheet deposits, with occasional ridge and chute deposits adjacent to the distal overbank unit in Sumart section. In the down-valley part of this section, flood cycle deposits are beneath these ridge and chute units. Despite these variations in elemental composition, facies compositions of sections are very similar to other reaches, as each bank exposure in the meandering reach is composed of fine sands, with $\geq 75\%$ of sections made up of lower energy facies.

In general, sand sheet deposits are the surficial element, extending virtually down-section, with depths ≤ 0.5m. In Pillbend section, however, these are the dominant element, and are up to 2.5m thick, atop the ridged basal surface, with thin flood cycle deposits atop. Facies composition of sand sheet deposits varies in each section, with sedimentologically simple facies Sw and facies Sw and Sr compositions in Campup and Sumart sections, but more variable compositions in exposures upstream of point bars. In Dcamp section, facies Sw, Sr and St units occur at adjacent analysis points, whereas sequences in Pillbend are much more vertically intermingled, with facies Sw and Sr interbedded with other occasional facies. In the latter case, within-element vertical and down-section particle size trends are highly irregular, but they are very consistent in other sections.

Flood cycle deposits are a major element in each meandering reach section, but they are less prevalent in Pillbend section, where they occur as two thin (≤ 1m) units. The surficial unit thins down-section, with a wedge-like form, composed of facies Sw and occasional facies Sr. At the section head, thinly interbedded lower energy facies are observed in flood cycle deposits, with a tilted basal contact atop basal gravels, in a sequence reminiscent of those noted in the braided reach.

In the three other sections, flood cycle deposits extend down-section, with depths ≥ 2m, thinning down-section in Dcamp and Sumart sections, but thickening to ≥ 4m at the final analysis point in Campup section. In the latter instance, flood cycle deposits are atop distal overbank deposits, with a horizontal basal contact, but lateral bar deposits form the final analysis point. Flood cycle deposits are composed of thinly interbedded lower energy facies, with occasional facies St units. The proportion of facies Fm increases down-section. Facies compositions are very similar in Dcamp and Sumart sections, with occasional facies St units in the former, and a higher proportion of facies Fm, along with several charcoal layers, in the latter. Basal contacts of flood cycle deposits tilt up-section in Dcamp section, atop platform sands and basal gravels, and are horizontal atop distal overbank deposits in Sumart section. A second unit, also ≥ 2m thick, is observed beneath the distal overbank element in the down-section half of Sumart section, composed of very thinly interbedded lower energy facies, with a high proportion of facies Fm and thick basal facies Ss units (these are not gravel-contacted).

The distal overbank units of Campup and Sumart sections are the dominant elements in these bank exposures, as these cohesive dark brown/grey deposits of finely laminated or massive very fine sands inhibit bank erosion, producing near-vertical sections. In both instances these extend over great longitudinal distances (≥ 90m), are ≥ 2m thick, and have several charcoal layers within.

In Sumart section, two chute channels and two ridge elements are noted adjacent to the distal overbank deposits. These are all ≤ 1m thick, and have predominantly lower energy facies infills. Similar chutes are noted within flood cycle deposits in Dcamp section and at the floodplain surface in Pillbend section. Facies St units within the flood cycle elements of Campup and Sumart section may also reflect former chute channels, but these are non-identifiable in longitudinal section.

Whenever observed, bar platform sands are the basal element in sections, but their abundance and character varies markedly in each meandering reach section. In Dcamp and Sumart sections, platform sands extend across the upstream half of the sections, with irregular basal contacts, and differing mixes of high and lower energy facies at each analysis point, but these pinch out as the framework gravels rise in Dcamp section, and dip beneath flood cycle deposits at depths too great to be sampled in Sumart section. Similarly, basal gravels could not be reached in Campup section, where platform sands composed solely of facies Ss extend as the basal unit down-section. In Pillbend section, platform sands are observed as a thin, basal remnant unit, in similar fashion to sections described previously in which sediment reworking is prevalent. Chute channel redistribution of deposits in Dcamp and Pillbend sections is directly related to their position among recently accreted floodplain sediments in former ridge and swale units at the head of point bars, marginal to prominent bar head chutes.

Whereas elements are organized in a fairly regular manner in the four meandering reach sections, facies exhibit no consistent down-section or vertical trends, and vary enormously from analysis point to analysis point both within and between elements. Accordingly, particle size trends are very variable, although platform and sand sheet deposits generally are coarse and medium sands, respectively, while flood cycle and distal overbank deposits are fine and very fine sands. The variable proportions of platform deposits results in differentiation between generally upward fining and roughly upwardly consistent particle size trends.

No down-valley trends are evident within the meandering reach. Rather, Campup and Sumart sections exhibit very similar depositional suites, whereas Dcamp section is more reminiscent of wandering reach sections, and Pillbend section closely resembles units observed in the braided reach.

9 : 6 : 1 Summary of down-valley and planform variability in the character and spatial association of elements in bank exposures

The 13 roughly equidistantly spaced bank exposures in the study reach are divided equally among the three channel planform styles, thereby presenting a more complete picture of elemental variability than the 1986 trench data set. Summary sedimentologic properties of all sections are presented in Table 9.43.

TABLE 9.43 SEDIMENTOLOGIC SUMMARY OF SECTION COMPOSITION

Trench	%Lower : High Energy Facies ratio	Dominant facies	Mean overall particle size (ø units)	%Element Composition Vertical Accretion	Distal Overbank	Chute/ Ridge	Bar Platform
Overall	80 : 20	29% Sw, 27% Sr, 23% Fm	2.89	53	19	7	22
Dbas	96 : 4	53% Sr, 27% Sw	2.98	98	-	-	2
Brabend	98 : 2	54% Sr, 22% Sw	3.22	73	21	6	-
Upstat	96 : 4	71% Sr, 22% Sw	2.80	90	-	7	3
Statbar	86 : 14	61% Sr, 23% Sw	2.34	29	-	62	10
Dstat	77 : 23	46% Sr, 27% Sw	2.52	59	-	11	31
Widewand	83 : 17	40% Fm, 27% Sr	3.35	30	44	-	25
Upash	76 : 24	52% Sw	2.68	47	-	21	33
Tflent	78 : 22	66% Sw	2.76	65	-	4	31
Fallop	71 : 29	28% Sw, 25% St, 24%Sr	2.39	27	20	-	53
Campup	79 : 21	40% Fm, 23% Sw	3.35	48	35	-	16
Dcamp	79 : 21	37% Sw, 35% Sr	2.40	79	-	3	18
Sumart	76 : 24	42% Fm	3.13	48	34	4	13
Pillbend	89 : 11	60% Sw, 25% Sr	2.97	90	-	2	8

The ratio of lower:high energy facies is remarkably consistent for each section, with an equal range of proportions in each planform reach (with 77-98%, 71-83% and 76-89% lower energy facies in the braided, wandering and meandering planform reaches respectively). Facies Sr, Sw or Fm are the dominant facies in each instance. In general, framework gravels are transitional upwards to either lower energy facies or remnant high energy facies, with intermingled lower energy facies and occasional high energy facies atop (as in chapter 8, representing a major depositional unconformity, associated with sediment reworking). This results in either upwardly consistent particle sizes, or upward fining trends. These tendencies are independent of channel planform; indeed, overall mean particle sizes are in the mean-fine sand class, with an equal range of particle sizes in each instance (2.3-3.3ϕ, 2.3-3.4ϕ, and 2.4-3.4ϕ in the braided, wandering, and meandering planforms respectively). Facies and particle size trends are indistinct by planform, whether viewed vertically or longitudinally.

The proportion of each section taken up by the six different elements varies markedly from section to section. Ridge and chute deposits are more difficult to identify in longitudinal section, and hence their proportions are significantly less than in the 1986 data set (averaging only 7% combined), although these are the dominant elements in Statbar section, and make up a large proportion of Upash section, where chutes are oriented diagonally across the floodplain.

Whenever observed, distal overbank deposits make up a significant proportion of a section (from 20-44%). Although more commonly observed down-valley, where floodplain width is greater, and the distal floodplain area is larger and better defined, this element also is observed in the braided and wandering reaches (Brabend and Widewand sections respectively). Indeed, the five sections in which these deposits are observed are much more similar in type, and more different from any other section, than any tendencies that are observed at the channel planform scale.

The relative proportion of vertical accretion deposits (flood cycle and sand sheet deposits combined) varies markedly (from 27 to 98%) from section to section, within each planform style. For example, elemental composition of Pillbend section, at the down-valley limit of the study reach, is more similar to Dbas and Upstat sections at the head of the braided reach, than to any other section. Finally, bar platform deposits generally reflect the extent of local floodplain sediment reworking, their extent being less than 30% of sediment sequences in all sections except Fallop. These deposits are especially poorly preserved in sections at the head of the braided reach, but they also occupy $\leq 20\%$ of the four meandering reach sections (i.e. they are most abundant in the wandering reach, although many down-valley analysis points are not gravel contacted).

Flood cycle deposits are the major element in 9 of the 12 sections. Although their average thickness increases (to 2.5m) down-valley, there are occasional thick units up-valley (e.g. Brabend; Table 9.44). They generally extend down the entire section, either at the floodplain surface, or with sand sheet deposits atop, but are less disrupted, and have more horizontal (less irregular) basal contacts down-valley. Facies composition, mean particle size, and other sedimentologic characteristics are very similar in each section. These are upwardly consistent fine sand, intermingled, lower energy facies, with facies Sw and Sr dominant. These typically are heterogenously mixed, with variable proportions of thinly interbedded facies Fm units, resulting in a wide range of dark brown tones. Occasional facies St units, observed in four sections, possibly reflect chute channel deposits which could not be positively identified due to the longitudinal orientation of the exposures. The greater thickness/abundance of this element in the 1987, as opposed to the trench data set, is attributable both to this fact, and the greater thicknesses of older (established) floodplain sediments (as opposed to bar marginal sediments).

The proportion, facies composition, and character of sand sheet deposits vary quite markedly by section (Table 9.45). In all instances, however, these are found at, or close to, the floodplain surface, their thickness ranging from very thin, discontinuous units in most sections, to extensive, thicker units in Widewand, Tflent and Pillbend sections. They typically have wedge-like forms, with horizontal, tilted or ridge-like basal contacts (and no evident trends by planform style). In general, medium-fine sand, lower energy facies (especially facies Sr) dominate, with simple (often uni-) facies compositions at each analysis point. These are loose, light brown and internally graded in character.

Distal overbank deposits are the main sedimentologic difference between the 1986 (trench) and 1987 (bank exposure) data sets. They form thick (up to 2.8m), extensive units whenever observed, with ridged or roughly horizontal basal contacts (Table 9.46). Cohesive, dark brown or grey, massive or finely laminated very fine sands characterize each unit.

Ridge and chute elements form longitudinally discontinuous, relatively shallow units, whenever observed (Table 9.47). Their character varies little from section to section, with medium-fine sand, lower energy facies dominant. These are heterogenously mixed sediments,

TABLE 9.44 SUMMARY OF FLOOD CYCLE ELEMENT CHARACTER AND COMPOSITION BY SECTION

Section	Morphology, scale and position in trench	Sedimentologic character			
		%Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Dbas	Makes up almost the entire 110m section, thinning down-section from 1.5m thick, atop irregular basal gravel contact. Thin sand sheet within.	98 : 2	43% Sr 34% Sw 21% Fm	3.2	Intermingled, mixed dark brown, heterogenously mixed, lower energy facies with no evident internal facies or particle size trends.
Brabend	Makes up almost the entire section. Up to 3m thick, atop irregular basal gravels. Distal overbank unit within, and thin sand sheet/chute units atop.	94 : 6	58% Sr 30% Sw	3.1	Thick, mixed dark brown, heterogenous or uniform, upwardly consistent fine sand, lower energy facies.
Upstat	0.5m thick unit extends down 120m section, atop basal gravels and irregular remnant bar platform units, with thin sand sheet and chute units atop.	100 : 0	63% Sr 32% Sw	3.0	Thinly interbedded and intermingled, light brown, heterogenously mixed, fine/very fine sand, lower energy facies. No internal particle size trends are evident.
Statbar	Two thin (≤1m), discontinuous (up to 60m) units atop either irregular basal gravels or platform sands, with surface scoured by chute channels.	98 : 2	72% Sw 24% Sr	3.1	Mixed lighter brown, heterogenous fine sand, lower energy facies, with simple facies composition.
Datat	Irregular unit, varying greatly in thickness down the 200m section. Ridge and sand sheet elements are within at the head (where deposits are 3m thick atop basal gravels) and a thin, tilted, sand sheet unit is within down-section (where deposits are about 1m thick atop a tilted bar platform sand contact).	100 : 0	53% Sr 41% Sw	3.1	Intermingled facies at the section head, becoming more uniform down-section. These are light brown, heterogenously mixed, fine sand, lower energy facies.
Widewand	1.0m thick unit, observed only at the down-section analysis point, marginal to sand sheet deposits, atop distal overbank fines.	100 : 0	100% Sw	3.2	Light brown, heterogenously mixed, facies Sw unit.
Upash	Two units (0.5 to 1.5m) thick, disrupted by chute channels, extending over 90m down-section atop platform sands with a highly irregular basal contact, and sand sheet deposits above in the upstream half of the section.	91 : 9	62% Sw	3.1	Mixed dark brown, heterogenous fine sands, with occasional facies St units intermingled. The proportion of facies Fm varies greatly down-section.
Tfient	Up to 2m thick unit which pinches out down-section as sand sheet unit atop thickens and basal platform sand unit rises in elevation. Basal contact is is notably flatter than in up-valley sections.	99 : 1	75% Sw 25% Fm	3.3	Broad range of dark brown, heterogenously mixed, lower energy facies. The proportion of facies Fm (and hence mean particle size) varies greatly down-section.
Fallop	Surface unit with flat basal contact atop distal overbank deposits. Deposits thin from 2.5 to 0.5m down the 200m section.	86 : 14	61% Sw	3.1	Thinly interbedded lower energy facies, with occasional facies St units (possibly chute infill). Highly variable particle size trends and facies characteristics down-section.
Campup	Almost 2m thick uniform unit over 200m of the 210m section, thickening to ≥4m at the down-valley analysis point, where distal overbank deposits curve away from the main channel. Thin, discontinuous sand sheet deposits are above over most of the section.	91 : 9	44% Sw 33% Sr	3.1	Thinly interbedded lower energy facies with occasional facies St units and highly variable proportions of facies Fm. Sequences generally have upwardly consistent particle size trends, with occasional upward fining trends. These are dark brown, heterogenously mixed fine sands, with occasional charcoal layers.
Dcamp	Unit thins from 2.5 to 1.5m down the 150m section, atop a basal contact which tilts up-valley (with bar platform sands and basal gravels beneath). Unit has a small chute channel within, and a thin sand sheet atop.	98 : 2	54% Sw 34% Sr	3.2	Often basal facies Sr or St units transitional upwards to facies Sw and Fm units. These thinly interbedded, mixed dark brown, heterogenous fine sands exhibit either upward fining or are upwardly consistent particle size trends.
Sumart	Unit thins from 2.5 to 1.5m down the 120m section, atop roughly even distal overbank deposits, with a small ridge within, and a thin sand sheet (sloping down-section) atop. A second unit, beneath the distal overbank deposits in the down-section half, has a depth of ≥2m at the base of the sequence, and is not gravel contacted.	82 : 18	34% Sr 28% Sw	3.1	Predominantly light brown, heterogenously mixed, intermingled lower energy facies. Generally fine sands, but very fine sands down-section where the proportion of facies Fm is higher. Several charcoal layers, some of which are longitudinally continuous in the upper unit. In the lower unit, thick basal facies Ss units have thinly interbedded lower energy facies atop.
Pillbend	Two 0.5m thick units which thin out down-section. Lower unit extends 40m atop basal gravels, with a down-valley tilted contact. Surface unit extends with a ridge-like outline atop a thick sand sheet for 125m down-section.	100 : 0	65% Sw 27% Sr	3.2	Simple facies composition, with thickly bedded, heterogenously mixed, dark brown, fine sand, lower energy facies and occasional facies Fm units.

TABLE 9.45 SUMMARY OF SAND SHEET ELEMENT CHARACTER AND COMPOSITION BY SECTION

Section	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Dbas	≤0.5m thick unit extends over 50m down-section, with a down-section tilted basal contact within flood cycle deposits.	100 : 0	96% Sr	2.5	Composed almost entirely of light brown, internally graded facies Sr, with large ripple dimensions. These are loose, fine-medium sands.
Brabend	Discontinuous (15m long) unit, marginal to a small chute channel, atop flood cycle deposits, at the floodplain surface.	100 : 0	100% Sr	2.2	Fine-medium sand, light brown, internally graded facies Sr unit.
Upstat	Two thin (0.5m thick) discontinuous units at, or close to, the floodplain surface, marginal to chute channel deposits, atop roughly even flood cycle deposits. The units extend over 15 and 40m down-section, the second unit thickening down-section.	96 : 4	92% Sr	2.7	Dominated by fine-medium sand, light brown, internally graded facies Sr, with large ripple dimensions.
Statbar	Two thin (0.8m thick), discontinuous (20m) units at the floodplain surface, atop chute channel deposits, with tilted basal contacts.	100 : 0	97% Sr	2.7	Light brown, internally graded, fine-medium sand facies Sr units.
Dstat	Three units, all within, or atop, flood cycle deposits : 1) 0.2m thick unit, extending over 20m at the floodplain surface, 2) 0.5m thick unit atop ridge deposits, within thick flood cycle deposits, 3) Tilted unit, thins out down-section (over 70m) within flood cycle deposits.	31 : 69	57% St	1.7	High energy, medium sand, facies St units, with large trough dimensions. These are loose, light brown sands, other than the darker, facies Sw, unit.
Widewand	≥1.2m thick wedge-shaped unit, which thins out down-section marginal to flood cycle deposits. Atop distal overbank deposits, with an even contact.	58 : 42	42% St 36% Sw	2.8	Intermingled lower and high energy facies, with large dimension facies St units. The loose, light brown sands have variable sediment mixes and exhibit variable particle size trends down-section.
Upash	Wedge shaped unit, extends over 60m at the floodplain surface, thickening to 0.8m atop flood cycle and chute channel deposits, with a ridge-shaped basal contact.	98 : 2	51% Sr 47% Sw	1.6	Loose, coarse sand units, with simple facies composition. Some upward fining/coarsening particle size trends.
Tilent	Two units, at either end of the section. 0.8m thick upstream unit extends to the floodplain surface atop basal gravels, marginal to flood cycle deposits. A 1.2m thick, wedge-shaped unit extends over 40m down-section, with a tilted basal contact atop flood cycle and bar platform deposits.	100 : 0	100% Sw	2.8	Mixed light brown, heterogenous fine-medium sand facies Sw units.
Fallop	Not observed.				
Campup	Three thin (≤0.5m) discontinuous units, extending up to 75m at the floodplain surface atop flood cycle deposits, with even or ridge-shaped basal contact.	79 : 21	70% Sw	2.2	Single facies units of light brown, heterogenous medium-fine sands.
Dcamp	0.5m thick unit with ridged outline at the floodplain surface, extending over 90m down-section atop flood cycle deposits. A second (0.2m thick) unit lies within the flood cycle deposits down-section analysis.	70 : 30	57% Sr	1.5	Very simple facies compositions in vertical sequence, but highly variable facies and particle size trends down-section. These are light brown, internally graded medium sands with large ripple dimensions.
Sumart	0.5m unit with a tilted basal contact atop flood cycle deposits, which pinches out up-section (extends over 60m).	0 : 100	76% Ss 21% Sh	2.7	Simple facies composition, with light brown, internally graded, fine-medium sands.
Pillbend	The dominant element in the section, extending over 140m, with a ridge-like outline atop remnant flood cycle and bar platform units. Variable depth (up to 2.4m.	97 : 3	65% Sw 29% Sr	3.2	Predominantly loose, heterogenous, light brown, fine sands, with intermingled lower energy facies and variable particle size trends.

TABLE 9.46 SUMMARY OF DISTAL OVERBANK ELEMENT CHARACTER AND COMPOSITION BY SECTION

Section	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Dbas	Not observed				
Brabend	Wedge-shaped unit, up to 1.5m thick, extending up to 40m, down-section, with a tilted basal contact, within flood cycle deposits.	98 : 2	60% Fm 32% Sr	3.8	Dark brown, heterogenous, cohesive very fine sands - the proportion of facies Fm increases down-section.
Upstat	Not observed				
Statbar	Not observed				
Dstat	Not observed				
Widewand	Extends down entire section with variable thickness (1-2.2m) and ridge shaped outline atop bar platform sands and basal gravels. Sand sheet and flood cycle deposits are found atop.	100 : 0	87% Fm	4.1	Cohesive, dark brown/grey, heterogenously mixed fine sands, with facies Fm dominant.
Upash	Not observed				
Tflent	Not observed				
Fallop	Extends down-section (over 120m), with a roughly even contact above bar platform sands (ridged at extremes of the section) and flood cycle deposits atop.	100 : 0	88% Fm	3.8	Six to eight upward coarsening facies Fm or facies Fm/Sw units. These are cohesive, dark brown, very fine sands.
Campup	Thick unit (≥1.7m) atop bar platform sands with a roughly even contact, and flood cycle deposits atop.	100 : 0	100% Fm	4.2	Dominantly uniform, grey, cohesive very fine, massive sands, with several charcoal layers within.
Dcamp	Not observed				
Sumart	Ridged outline unit, with irregular thickness (from 1.5 to 2.8m), atop ridge, chute and bar platform sands, with ridge and flood cycle units above.	99 : 1	98% Fm	4.2	Cohesive grey or dark brown very fine, massive sands, with many charcoal units within.
Pilbend	Not observed				

TABLE 9.47 SUMMARY OF RIDGE AND CHUTE CHANNEL ELEMENTAL CHARACTER AND COMPOSITION BY SECTION

Section	Morphology, scale and position in trench	Sedimentologic character: %Lower : High energy facies	Dominant facies	Mean particle size (Ø units)	Other aspects
Dbas	Not observed				
Brabend	Small, ≤1m deep chute channel observed down-section, marginal to a sand sheet, atop flood cycle deposits.	100 : 0	72% Sr 22% Fm	3.4	Upward coarsening, facies Fm-Sr fill. These are predominantly light brown, *heterogenously mixed fine sands.*
Upstat	Two small chute channels, both ≤0.3m deep at the floodplain surface atop and/or marginal to sand sheet deposits, extending up to 25m down-section.	100 : 0	70% Sr 30% Sw	2.7	Mix of light and dark brown, predominantly heterogenously mixed fine sands, with simple facies composition (typically facies Sr or Sw units).
Statbar	Section is dominated by three chute channel units, which cut diagonally across the floodplain surface, disrupting flood cycle and bar platform deposits (two chutes contact basal gravels). Channels are up to 2m deep and the largest chute extends up to 60m down-section.	92 : 8	78% Sr	2.5	Highly variable in character down-section, with upwardly consistent and upward coarsening particle size trends. These are light brown, heterogenous, fine-medium sands.
	A small ridge is found marginal to the up-section chute. This 0.5m deep unit is atop bar platform sands and has sand sheet deposits atop.	100 : 0	77% Sr 23% Sw	3.5	Thinly interbedded, mixed light brown, heterogenous fine sands.
Dstat	Small chute (0.6m thick, extends 10m) at the up-section end, marginal to flood cycle deposits, with sand sheet units atop and beneath.	100 : 0	79% Sr	2.6	Upward coarsening, facies Fm - Sr transition, both of which are fine sands.
	0.8m thick ridge located within flood cycle deposits has sand sheet deposits atop, extending over 20m down-section in a wedge-shaped unit.	94 : 8	47% Sw 47% Sr	2.9	Mix of dark and light brown, heterogenously mixed, fine sands.
Widewand	Not observed				
Upash	Three small, relatively thin (up to 1m thick) chute channels, extending up to 25m down-section. These chutes are marginal to each other, their lateral and vertical displacement implying shifting channel positions. Located atop bar platform and flood cycle deposits, marginal to sand sheet deposits at the floodplain surface.	65 : 15	70% Sw	2.9	Broad range in composition, with many thin units and much variability between the three chutes. The upper (and larger) chute has a predominantly facies Sw fill with thicker units than in the other instances. Facies Fm, and occasional facies St units are observed in the lower chutes. Sediments are mixed light and dark brown in color, heterogenously mixed fine sands, typically upwardly consistent in size.
Tfient	Very small, thin (0.3m) chute channel at the floodplain surface, atop flood cycle deposits.	100 : 0	97% Sr	3.2	Upward coarsening, fine sand facies Sr unit.
	0.3m thick ridge is observed atop platform sands, beneath flood cycle deposits.	100 : 0	93% Sw	3.3	Mixed dark brown, heterogenous fine sands.
Fallop	Not observed				
Campup	Not observed				
Dcamp	0.8m thick unit within flood cycle deposits	99 : 1	45% Sw 38% Sr	2.1	Very thinly interbedded lower energy facies, with a broad range of colors. Contacts between facies tilt up-section.
Sumart	Two (≤0.8m thick) chute channels marginal to each other beneath distal overbank deposits, with marginal ridge and flood cycle deposits beneath. These have a ridge shaped outline within the distal overbank element.	80 : 20	68% Sr 20% St	2.6	Small dimension, thinly interbedded facies Sr and St units, thinly interbedded with grey facies Fm units. These are upwardly consistent fine-medium sands.
	The thin (≤0.6m) marginal ridge also lies atop flood cycle deposits. A second (0.4m thick) ridge lies within flood cycle deposits atop the distal overbank element.	76 : 24	36% Sw 27% Sr 23% St	3.0	Heterogenously mixed, light brown fine sands.
Pillbend	Thin unit (≤0.3m) observed only at the down-section analysis point, marginal to flood cycle deposits, atop a sand sheet.	57 : 43	57% Sw 43% St	2.9	Facies St - Sw transition, with according upward fining particle size trend. These have mixed color and sediment mix characteristics.

typically with a range of dark and light brown tones. They differ from units observed in the trench data set, as virtually no high energy facies were noted.

Bar platform deposits are the most variable element, in terms of character, from section to section (Table 9.48). In most instances, they form a thin, discontinuous basal unit, composed of coarse sand, high energy facies. Sequences are much thicker (i.e. better preserved) in Widewand, Fallop and Sumart sections, where distal overbank deposits rest atop. Down-valley from Dstat and Campup sections, bar platform deposits are much finer than elsewhere, with a broader range in facies types and more upward fining facies type and particle size trends. Accordingly, color and sediment mix characteristics are more variable in these sections. A particular sediment arrangement, such as framework gravels to flood cycle deposits to sand sheets, or gravels to a small platform unit to distal overbank deposits to flood cycle deposits, could be observed in any of the three planform reaches (as evidenced by Dbas, Tflent and Pillbend sections in the first instance, and Brabend, Widewand and Sumart sections in the second). In summary, similar sediment sequences can be observed at individual analysis points within any section, regardless of channel planform style.

In contrast to the many sedimentologic similarities described by planform, floodplain depositional sequences are thicker, elements are more longitudinally extensive (and hence less randomly organized), and are more horizontally aligned down-valley. This increasing down-valley order at the element scale accords closely with the postulated scenarios of locale associations suggested in chapter 7. These characteristics are all qualitative, however, expressing extent or continuity of a trends, as described for within-bar sediment trends in chapter 6. As such, recognition of these geographic phenomena requires extensive, undisturbed exposures, in which there is equal preservation of deposits from each down-valley planform reach, as these are 'relative' tendencies. Since this is highly unlikely, given chute channel reworking of the thin veneer of floodplain sediments, it is unlikely that sediments reflecting the down-valley progression of channel planform styles, inferred from Walther's dictum, can be identified in stratigraphic section. Rather, on the basis of individual exposures it is impossible to infer river channel planform environment of deposition from facies and element types and their abundance, their stacking arrangement, or particle size trends.

TABLE 9.48 SUMMARY OF BAR PLATFORM ELEMENT CHARACTER AND COMPOSITION BY SECTION

Section	Morphology, scale and position in trench	Sedimentologic character			
		%Lower : High energy facies	Dominant facies	Mean particle size (ø units)	Other aspects
Dbas	Thin, discontinuous basal unit, with flood cycle deposits atop.	0 : 100	100% Gm	-1.0	Solely matrix supported gravels atop framework gravels.
Brabend	Not observed.				
Upstat	Two very thin (≤0.2m) discontinuous, remnant basal units, with flood cycle deposits atop.	0 : 100	100% Gm	-1.0	Solely matrix supported gravels atop framework gravels.
Statbar	Two thin (≤1m thick) remnant basal units, at either end of the section. The up-section unit is marginal to a deeply scoured chute, and has a ridge unit atop. The down-section unit is thinner, extending 40m in a wedge-shaped unit, with marginal flood cycle deposits, and a chute channel atop.	0 : 100	64% St 23% Gm	-0.7	Internally graded, light brown coarse sands and gravels.
Datat	Two remnant units. A small unit is observed up-section, with a deeply scoured base. The second unit extends ≥100m down-section with a ridge-like outline atop basal gravels, varying up to 1.5m in thickness.	67 : 33	49% Sr 21% St	2.1	Small dimension, light brown, internally graded facies St units, with large dimension facies Sr units. Facies composition varies down-section.
Widewand	Two units, separated by a ridged basal contact, with distal overbank deposits atop. The up-section unit has a tilted basal contact. Down-section, bar platform sands are >2m thick (framework gravels were not always reached), with sharply tilted basal contacts.	76 : 24	78% Sr 24% Ss	2.8	Medium-fine sands with simple facies compositions.
Upash	Continuous unit, up to 1.4m thick, extends down 90m section, with a ridged basal contact, and flood cycle and chute channel deposits atop.	48 : 52	30% Sw 29% St	2.5	Broad range of compositional types, with more intermingling at up-section analysis points. There are no consistent particle size trends - these are mixed dark brown, heterogenous or internally graded medium-fine sands.
Tflent	Continuous unit, up to 1.6m thick, extends down 115m section atop ridged basal gravel contact, with flood cycle, ridge and sand sheet deposits above.	32 : 58	46% St 32% Sw	1.9	Extremely simple facies compositions down-section, with large dimension facies St units. These are light brown, typically heterogenous, medium sands.
Fallop	These very thick (up to 3m) sequences are only gravel contacted at the up- and down-section limits and in mid-section (i.e. the basal gravel contact is steeply ridged in outline). Distal overbank deposits above tilt up-section.	55 : 45	39% St 34% Sr	1.8	Upward fining sequences, with a broad range of facies types, color and sediment mix characteristics.
Campup	Thin, basal unit beneath distal overbank deposits, not contacted with framework gravels in any instance.	0 : 100	90% Ss	2.4	Heterogenous, dark brown fine-medium sands.
Dcamp	Observed only as the basal element in the upper half of the section, where sediment depths are greatest. These have a wedge-like shape, with a maximum depth of 1m, atop a ridged basal gravel contact, and flood cycle deposits atop.	16 : 84	68% St	0.2	Light brown, internally graded, coarse sand/gravel, large dimension facies St units, which exhibit a range of upward fining and upward coarsening particle size trends.
Sumart	Sequences are up to 2m deep, but are observed only in the up-section half of the bank exposure, with a ridged outline above basal gravels and distal overbank or flood cycle deposits atop.	13 : 87	28% St 23% Gm	0.5	Upward fining, coarse sand/gravel high energy facies, with a broad mix of colors and sediment mixes.
Pillbend	Extremely thin (≤0.3m) remnant basal unit, observed at only one analysis point, with sand sheet deposits atop.	0 : 100	100% St	0.7	Small dimension, light brown, internally graded facies St unit.

There is often a tendency to stress occasional differences between sediment units, at the expense of noting the similarities, which may be observed more frequently. This is undoubtedly the case in examination of sediment sequences in the three planform reaches. On the basis of selected parameters, it would not be possible to positively identify one planform depositional style, as opposed to another, in stratigraphic section. Rather, it would be sufficient to identify the depositional environment as a high energy fluvial depositional system, which is not intuitively obvious given the unconformity in floodplain depositional suites noted above. Given these problems, elements are considered to provide a more insightful approach in sedimentologic analysis, as they relate specifically to environment of deposition, whereas facies refer specifically to range of flow conditions, and channel planforms relate to visually distinct environmental settings. A three-dimensional elemental picture of the Squamish River floodplain is presented in the next section.

9 : 6 : 2 Three-dimensional elemental floodplain sedimentology of the Squamish River

The Squamish River floodplain is composed of upward fining or upwardly consistent fine sand, lower energy facies, atop occasionally preserved basal medium-coarse, high energy facies and coarse channel framework gravels. In all reaches, the proportion of high energy facies is considerably greater upon contemporary bars (1985 data) than in bar marginal or established floodplain areas (1986 and 1987 data). The elemental composition of the floodplain is much more variable at-a-site, related specifically to the character and extent of sediment reworking. This, in turn, reflects the relative age of sediments and their position upon the floodplain.

From analysis of elemental associations (Figure 9.14), two styles of floodplain sedimentologic sequence can be discerned (Figure 9.15); in neither case do they refer to particular channel planform styles. In the first instance, framework gravels are transitional upwards to thin, discontinuous bar platform deposits and, more frequently, thick flood cycle deposits. These deposits have relatively thin chute, ridge and sand sheet deposits atop. In general, such sequences are associated with relatively "recent" floodplain deposits, marginal to contemporary bars, in which sediment reworking is prevalent (as evidenced in Chapter 8). For example, Statbar, Upash, Tflent, Dcamp and Pillbend sections are all located immediately upstream of contemporary bars, and reflect sediments which have accumulated as bars have migrated down or across-valley.

FIGURE 9.14 ELEMENTAL ORGANIZATION IN EACH SECTION

Transitions are drawn for each instance which occurs with a frequency ≥20%

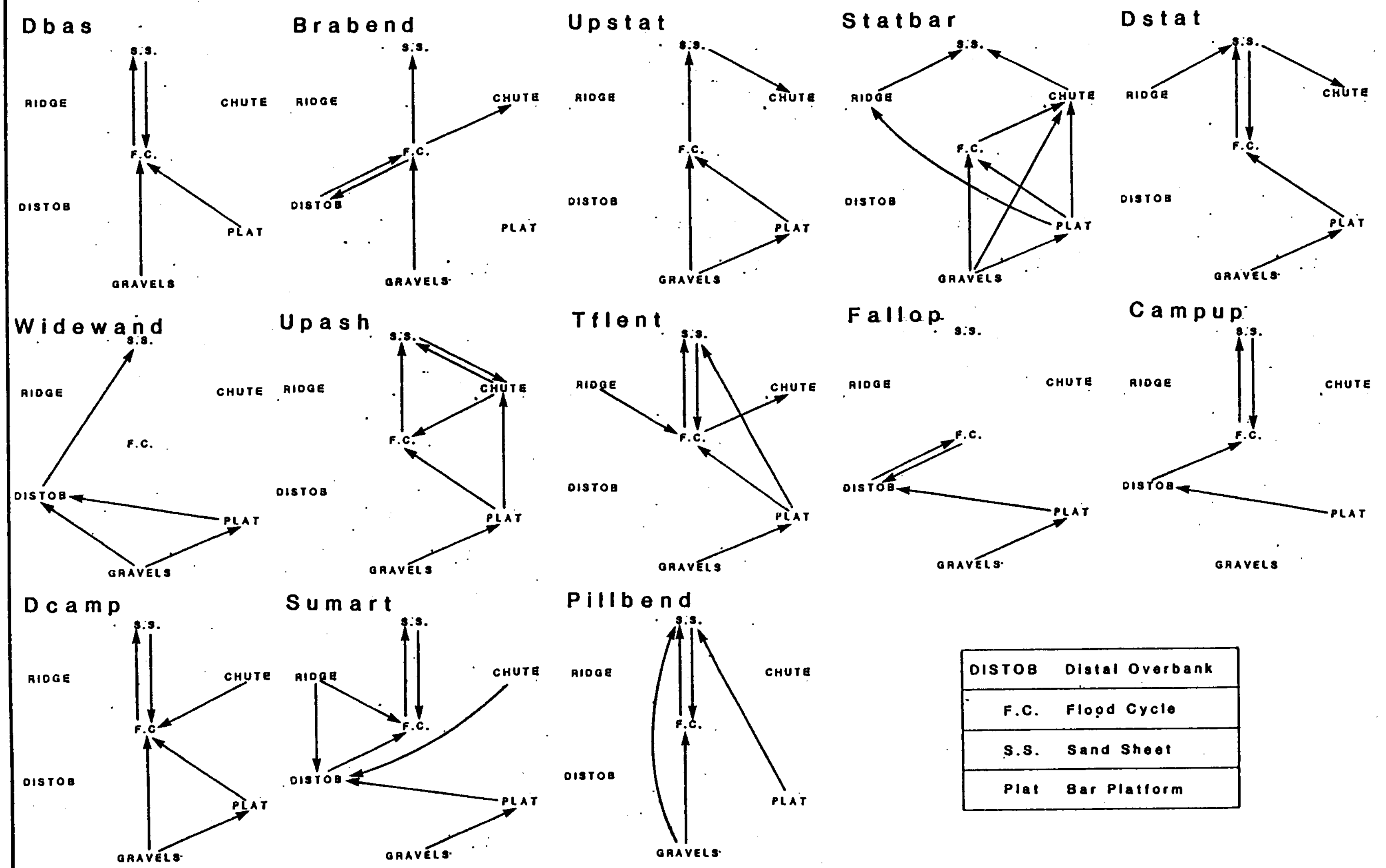
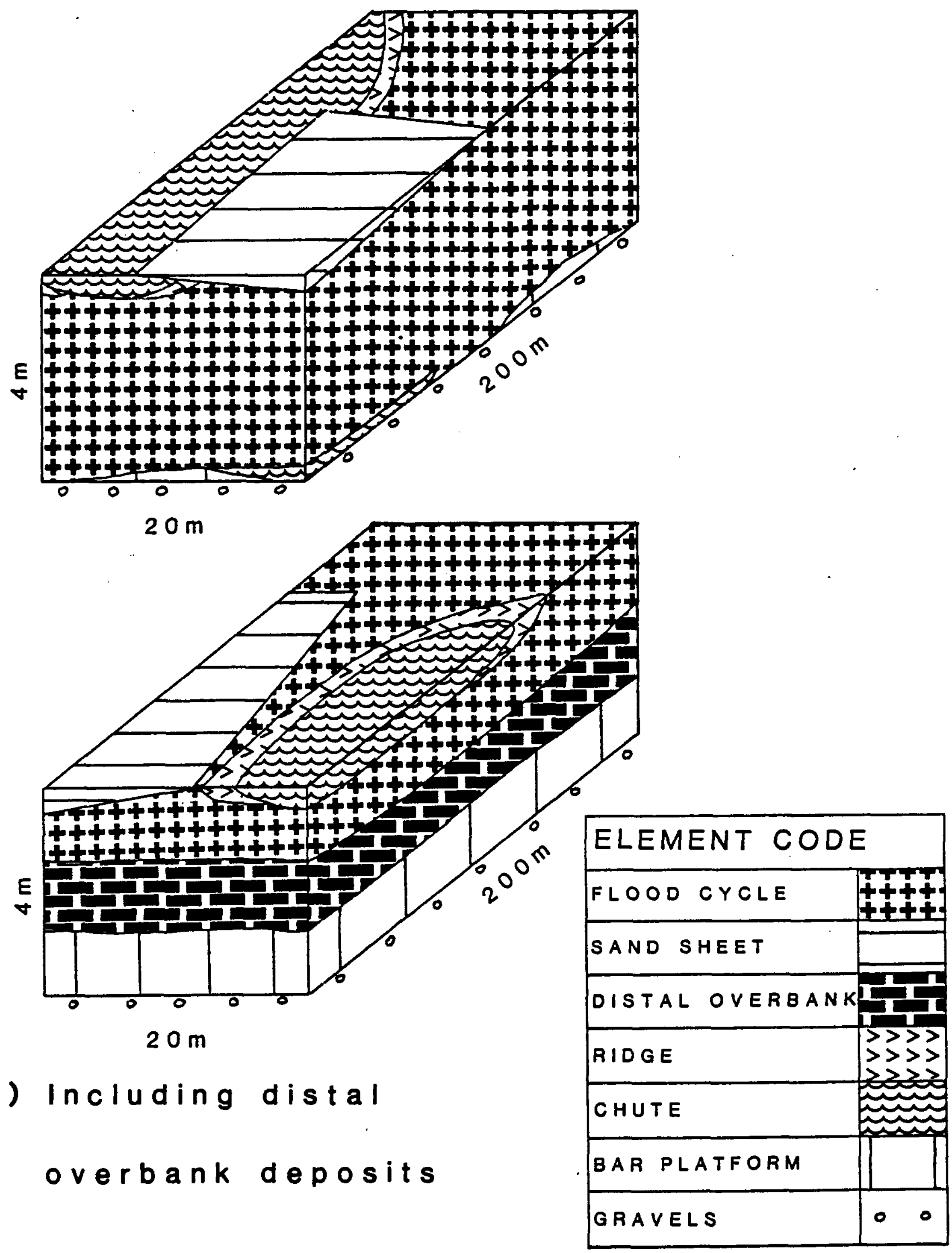


FIGURE 9.15 THREE DIMENSIONAL ELEMENTAL FLOODPLAIN SEDIMENTOLOGY

a) Marginal to contemporary bars



b) Including distal overbank deposits

In contrast, sediment sequences in which distal overbank deposits are observed occur either at contemporary floodplain margins, or in areas which have experienced channel shifting in the relatively recent past. Brabend section exemplifies the former scenario, whereas sediment sequences on the eastern side of the contemporary channel down valley of the Ashlu River confluence, namely Fallop, Campup and Sumart sections, have thick distal overbank deposits which probably accumulated when the main Squamish River channel was against the eastern valley wall (as described in Chapter 3). These deposits were not observed marginal to the western valley wall, as contemporary sediment reworking has resulted in sequences representing the former model.

In instances in which distal overbank deposits are observed, bar platform deposits are notably thicker, since channel shifting probably occurred relatively quickly, thereby minimizing chute channel reworking of bar platform deposits. Sediment accumulations atop the distal overbank element are primarily lower energy facies within flood cycle deposits (and occasional chutes and ridges, reflecting some reworking), and discontinuous sand sheet deposits.

PART D

CHANNEL PLANFORM CONTROL UPON THE FLOODPLAIN SEDIMENTOLOGY OF THE SQUAMISH RIVER : CONCLUDING REMARKS

CHAPTER X
CONCLUSION

10 : 1 Variability in channel planform sedimentology

Although the 20km study reach along the Squamish River exhibits down-valley environmental gradients expressed by many inter-related variables, such as valley slope and width, gravel bed material particle size, and river channel planform style, the character and composition of contemporary channel bar and floodplain depositional sequences do not vary consistently in that direction. The degree of overlap among the sedimentologic domains of the three planform styles clearly is much more significant than their differences. Hence, the hypothesis as originally stated can not be rejected, as there are no predictable variations in floodplain sedimentology of the Squamish River by planform. These findings are confirmed in section 10.1, implications for future research are suggested in section 10.2 and a closing statement is made in section 10.3.

Visually distinct river channel planform types provide an obvious scale for differentiating between river depositional environments. Research in fluvial geomorphology, however, has demonstrated no discriminating functions to distinguish river planform styles, and planform differentiation is based upon a series of environmental variables, as opposed to specific process mechanisms. In theory, braided rivers possess little or no well developed floodplain and overbank deposits are virtually non-existent. Rather, floodplains are produced by within-channel processes (bottom stratum deposits), either by lateral or downstream accretion of channel bars, or channel abandonment and island formation. This latter mechanism is an important component of wandering gravel-bed river sedimentology. Meandering river floodplains exhibit a range of lateral accretion and vertical accretion deposits, conditioned by lateral stability of the channel and the flow regime. Regardless, vertical accretion (or top stratum) deposits are more significant in this planform than elsewhere.

Although long recognized to be transitional in nature, there have been very few studies on downstream river channel planform variability (exceptions include Ori, 1979; Schwartz, 1983). Given its dynamic, high energy environment, contained within a confined glaciated valley, the Squamish River differs from those rivers in which empirical observations in "classical" river engineering have been derived. Not only are there no reliably applicable bed transport formulae, but no existing facies models exist for floodplain sedimentology in such environments. To evaluate the differing responses of the three river channel planform styles to imposed environmental conditions, the sedimentology of each planform reach was studied extensively, using three different sampling approaches.

In the 1985 data set, holes were dug in sections perpendicular to the main channel on 10 contemporary channel bar surfaces. Bar types change down-valley, from complex, compound mid-channel bars in the braided reach, to bank-attached lateral and point bars down-valley. To examine lateral continuity of facies units, and broader scales of sedimentary units, 9 trenches were dug and analysed at the contemporary bar/floodplain margin upon 5 bars (1986 data set). The scale of depositional environment was increased even further in the 1987 data set, which focussed upon elemental scale analysis of sediment sequences in 13 extensive (up to 210m) longitudinal bank exposures, divided equally among the three planform types.

Facies models derived for each planform reach using Markov analysis of one-dimensional sediment sequences upon contemporary bars (in the 1985 data set), using consistent field and analytical procedures, indicate considerable variability in pathways of sediment association by planform (Chapter 5). These complex patterns are shown to be unrepresentative of observed sediment sequences, however, as one- and two-step facies transitions predicted for one planform style may actually be observed with greater frequency elsewhere. As such, Markov Chain analysis is irrelevant in terms of real understanding of depositional processes (as Miall, 1985).

Summary statistical analysis of various sedimentologic properties by planform revealed insignificant differences; indeed, observed differences are actually contrary to predicted trends (Table 5.7). These observations are deceptive, however, as summary statistics mask considerable within planform (sections 6.2 to 6.4), and even within-bar (section 6.6) sedimentologic variability. In all instances, sediment sequences upon contemporary bars exhibit complex lateral, vertical and down-bar trends, although particle sizes typically fine upwards, with lower energy facies atop.

Analysis of sediment trends at the channel bar scale revealed that sequences relate more closely to their local environment of deposition than they do to position upon bar or bar type. The spatial association of local depositional environments, termed locales, results in differing facies and particle size trends across- and down contemporary bars. These occasional spatial and scalar trends provide the only basis upon which sediment sequences can be differentiated by planform (Table 6.14). Four locales (which refer to field morphologic units) were defined, namely established floodplain, ridge, chute and bar platform deposits. While sedimentologic properties of established floodplain, ridge and lower energy chutes are similar in facies terms, with upwardly consistent fine sand particle size trends, they differ significantly from upward fining, medium-coarse sand, high energy chute and bar platform deposits, which have a significant proportion of high energy facies.

Differing locale organization results in different sediment patterns across- and down-bar, with random arrangements in the braided reach, but a greater degree of sediment order down-valley (e.g. Figure 7.1). However, as shown in chapters 8 and 9, these within channel bar sediment sequences are unlikely to be preserved due to chute channel reworking and lateral variability in facies deposition, associated with event stratigraphy. Indeed, the proportion of lower energy facies is significantly greater in the trench and bank exposure data sets than upon contemporary bar surfaces. Secondly, as they refer merely to extent, or scale, of a trend, rather than the character of sediments themselves, or their vertical associaiton, these trends provide an insufficient basis for differentiating between planform styles in the stratigraphic record. The pronounced lateral variability of facies, and their relation to broader scales of sedimentary units, was confirmed in trench analysis (Chapter 8). As viewed in vertical section, the locale coding scheme was modified and an elemental approach adopted, in which flood cycle and sand sheet deposits replaced the established floodplain locale. The character of bar marginal floodplain sediments was roughly equivalent in each trench, with minimal preservation of bar platform sands, due to chute channel and sand sheet reworking of deposits. Rather, lateral sediment sequences typically are dominated by upwardly consistent, fine sand, lower energy facies in each of the three channel planform reaches. These are expressed graphically in Figure 8.11.

The longitudinal character of Squamish River floodplain sediments, examined in bank exposures, is also consistent by planform, and similar to sequences observed in trenches (Chapter 9). Chute and ridge elements were less prevalent, however, due to problems of positive identification in longitudinal exposure. The major difference between sediment sections was the presence and proportion of distal overbank deposits, which are observed in each planform reach, but are more prevalent down-valley. Any particular sedimentologic arrangement could be observed in any of the three planform reaches, and the floodplain sedimentology of the study reach was best viewed by two models, reflecting the presence of distal overbank deposits (Figure 9.15).

Only in the latter instance are bottom stratum deposits preserved to any extent, as shifting of the main channel has limited the degree of reworking of bar platform deposits.

In general, sediment sequences are thicker and more longitudinally continuous, with more horizontally aligned contacts between elements, down-valley. As with the within-channel bar data, however, these trends are qualitative, and not detectable by planform in vertical section for an individual stratigraphic exposure (i.e. they are relational trends).

Of the many sedimentologic criteria used to differentiate between river channel planform deposits (Table 2.7), this thesis has focussed upon sediment type composition (at facies and element scales), their scale, morphology and spatial association, along with particle size trends. Expected and observed patterns are described for each planform in Table 10.1. Whereas conventional notion predicts considerable variability in sediment composition, particle size and basal contact of floodplain sediments by planform, these are not evidenced in observed sediment patterns. Rather, sediment sequences of the Squamish River floodplain primarily are transitional upwards from basal channel framework gravels to top stratum deposits in each reach. Ironically, the proportion and coarseness of bottom stratum deposits are actually greater down-valley, where they are preserved beneath distal overbank deposits.

In summary, the morphodynamics of high energy, gravel bed rivers, such as the Squamish, are such that it is is impossible to differentiate between river channel planform sediments on the basis of small scale sedimentary structures and their vertical association. Rather, principles of convergence apply, and similar facies and element associations and characteristics are observed in each planform reach. Differentiation of river sediment sequences at the channel planform scale has limited significance, since depositional processes are not planform dependent. Rather, observed trends are more a function of down-valley postion and local depositional environment, and Walther's dictum cannot be meaningfully applied at the element scale.

10 : 2 Implications and suggestions for future work

Fluvial sedimentology is a science in its infancy, with little methodologic consistency. As such, the bases upon which depositional environments are inferred often times are highly questionable. In examining stratigraphic sequences, there are tendencies to overemphasize "new"

TABLE 10.1 : COMPARISON OF CONVENTIONAL CHANNEL PLANFORM SEDIMENTOLOGY WITH OBSERVED SEDIMENT PATTERNS IN THE STUDY REACH

Planform style	Sediment patterns described by conventional notion for confined high energy, gravel bed rivers (such as the Squamish River)	Observed sediment patterns
BRAIDED	<u>Sediment composition and trends</u> : Largely within-channel deposits, with very limited established floodplain. Longitudinal and diagonal bars exhibit down-bar trends of high energy facies (Sp and St), with occasional facies Sr drape. Many chutes, with large proportions of facies Gm, St, Sp and Sh, result in very jumbled lateral and down-valley sediment patterns. Vertical patterns are also very mixed, due to the wide range in flow conditions.	Extremely discontinuous facies patterns, vertically, laterally and longitudinally. Although coarse gravels sheets and dune fields are observed on bar surfaces, these are seldom observed within floodplain exposures; indeed, lower energy facies are prominent in flood cycle deposits, with only remnant bar platform sequences. In one section, distal overbank deposits are dominant.
	<u>Particle size trends</u> : Large proportion of gravels and coarse sands, with some down-bar fining, but patterns are highly mixed both laterally and vertically.	Lateral and longitudinal trends are highly irregular, but vertical trends typically are transitional upwards from coarse gravels to fine sands.
	<u>Basal surface character and extent</u> : Floodplain sequences are thinner in braided reaches than elsewhere, with highly irregular basal contacts (due to the large number of channels).	Extremely irregular basal contacts. Sediment sequences are thinner than elsewhere (maximum depth 3m).
WANDERING GRAVEL-BED	<u>Sediment composition and trends</u> : Mix of gravel-based lateral and point bars (with high proportions of facies Sp and St, and occasional facies Fm drapes) and sporadically active sand/gravel sheets (facies Gm, Sp, St and Sh) in major channels. Laterally migrating chutes result in facies Sh, St and Sr units, with facies Fm drapes atop channels or in distal floodplain areas. Down-bar fining trends are evident on bars, but the large number of chutes (and associated range in flow conditions) result in disrupted lateral and vertical sediment sequences.	Sediment sequences are highly variable laterally and longitudinally, with lower energy facies dominant. Gravels are transitional upwards to lower energy facies, with much evidence of chute channel reworking, giving remnant bar platform units. Flood cycle deposits dominate sections, with thick distal overbank deposits in one instance.
	<u>Particle size trends</u> : Mix of coarse and fine sands, with down-bar fining, and upward fining channel fills, but much lateral variability.	Extremely irregular laterally and longitudinally, but vertically gravels are transitional to fine sands, with occasional basal coarse sand units.
	<u>Basal surface character and extent</u> : More extensive, and less irregular sediment sequences than exhibited in braided deposits, with predominantly tilted basal contacts associated with channel margins.	Sequences are thicker, laterally and longitudinally more extensive, and have more consistently tilted basal contacts than observed in the braided reach.
MEANDERING	<u>Sediment composition and trends</u> : Sequences reflect up-sequence reduction in energy of deposition, with basal gravels transitional to within-channel deposits (facies St, Sp and Sh), and overbank deposits atop (facies Sr, Sw and Fm). Occasional chute channels/bars at the head of point bars disrupt this sequence, producing facies St/Sp units at the bar/floodplain surface. Lateral and 'around-the-bend' sediment sequences are better organized than elsewhere, with distinct lateral gradation towards the main channel.	Although some within-bar sediment trends are observed upon point bars, these are highly disrupted by chute channels and are not preserved in floodplain sections. Once more, gravels typically are transitional upwards to lower energy facies (especially within chutes or vertically accreted flood deposits), with thicker bar platform deposits preserved beneath distal overbank deposits (associated with channel shifting).
	<u>Particle size trends</u> : Generally consistently upward fining, with occasional upward coarsening trends associated with chute bars. This gradation is from gravels to coarse to fine sands. Lateral and longitudinal trends exhibit much less variability than in other planform reaches.	Sequences typically are upwardly consistent fine sands, with occasional (thin) basal medium-coarse sands. Such trends are both laterally and longitudinally continuous over great distances.
	<u>Basal surface character and extent</u> : Sediment sequences are thicker, with more extensive and continuous basal contacts than in other planforms, and predominantly laterally tilted basal contacts towards the main channel.	Much more laterally and longitudinally extensive elements, within thicker floodplain sequences then observed elsewhere (up to 6m). Basal gravel contacts are tilted gradually towards the main channel, with roughly horizontally aligned elements atop.

aspects, or focus on aspects similar to those observed elsewhere, rather than rationally represent the entire picture within an exposure.

Facies coding schemes based upon small scale sedimentary structures and bedding style cannot infer river environment of deposition, as they refer to local scale flow conditions. Conversely, river channel planform types are not process-dependent, and hence provide a generic mode for classifying river style, not depositional environment. A genetic approach is required, which relates sedimentary units to their geomorphic origin. The elemental scale approach adopted in this study, following guidelines proposed by Miall (1985), offers great hope in past environmental reconstruction, as sediments deposited within chutes, upon ridges, in bar platform environments, in distal floodplain sections, or upon channel marginal floodplain surfaces (as flood cycle or sand sheet units), relate directly to their field depositional setting. Although not always mutually exclusive in process terms, for example, flood cycle or sand sheet deposits may infill a chute unit, the location and morphology of the feature define the element (i.e. it is not dependent upon sediment type). The three dimensional organization of these elements thus provides the environmental context for the particular sediments observed, especially when applied at a valley width scale. This has many implications for basin analysis of fluvial depositional suites.

In this study, floodplain sediments were examined only in the channel marginal zone of the Squamish River. No significant elemental scale differences were observed between channel planform reaches; rather, the sediments in all three reaches were composed primarily of top-stratum deposits, while chute channel reworking has removed most of the basal high energy facies. This process insight, provided at the elemental scale, is very instructive in reconstructing the history of sediment accumulation adjacent to river channel bars.

The Squamish River floodplain has been derived from events which are not directly responsible for channel bar deposits. Seemingly, during high flow stages, active chute channels remove bar marginal high energy facies, and replace them with fine sand, lower energy facies at the waning flow stage. As such, distinction between within-channel and overbank mechanisms is largely meaningless, and more important distinction needs to be made between constructive (flowing water) and passive (slackwater) mechanisms. These can be further differentiated into traction vs suspension, or advection vs convection mechanisms. In element terms, these represent bar platform, as opposed to flood cycle deposits. Whereas high energy facies characterize the former, the latter element is composed of thinly interbedded, lower energy facies, which accumulate in vegetated/sheltered environments at the waning stages of flood flows.

Given the high energy, dynamic geomorphic setting, floodplain sediments of the Squamish River are quite different to intuitive expectations. Due to the prevalence of chute channel reworking of bar sediments, high energy, bottom stratum deposits, which have been shown to be preferentially preserved under certain environmental conditions (e.g. Cant, 1976; Mader, 1985), seldom are observed, and channel framework gravels predominantly are transitional upwards to fine sand, top stratum deposits. Although similar mechanisms for removal of coarse sand/gravel, high energy facies have been described elsewhere (e.g. Alexander and Nunnally, 1972; Bluck, 1976; Baker, 1977; Lewin, 1978b; Brakenridge, 1984), their replacement by lower energy deposits has not previously been described. In the Squamish River system, the coarse sands observed upon sparcely vegetated bar platforms seemingly act as a sediment slug, mobilized on a regular basis during flood events, with replacement by lower energy deposits at bar margins at the waning flood stage.

10 : 3 Closing statement

In summary, the major findings of the thesis are as follows :

1. Facies and particle size trends in observed sediment sequences do not relate to river channel planform style, and there are no distinct sediment features, or sediment associations, by planform,

2. To understand within-bar sediment trends, local scale geomorphologic features (locales) must be defined,

3. Locale/elemental sediment compositions are consistent by planform and are vertically stacked in the same fashion throughout the study reach, and

4. A three-dimensional picture of the Squamish River floodplain indicates that the floodplain is composed primarily of lower energy facies (typically in flood cycle units) atop coarse channel framework gravels.

From this it is concluded that :

1. Facies and river channel planform scale analyses can not reliably be used to infer river depositional environments,

2. Elemental scale analysis provides a more reliable framework for environmental interpretation, as it is based upon geomorphic (form and process) terms, and

3. The floodplain character of the Squamsish River is different to intuitive expectations as it is dominated by fine sands, reflecting chute channel reworking of coarser sand bar platform deposits prior to their incorporation into the floodplain (i.e. preservation potential of depositional units is critical).

The sedimentologic suites in differing river channel planform reaches of the Squamish River can not categorically be differentiated; rather, overlap and similarities between types greatly exceed differences, and any individual depositional unit could be found in any of the reaches studied, as they vary only in terms of scale and abundance. Given the redundancy of the channel planform scale of sedimentologic differentiation, the element scale, based upon geomorphic criteria, provides a much more insightful guide to environment of deposition, and offers much hope in past environmental reconstruction and interpretation. River reach analysis, as proposed by Kellerhals et al (1976), provides a more meaningful manner for describing contemporary river characteristics than does reference to channel planform style.

REFERENCES

Ackers, P. and F.G. Charlton, 1970, Meander geometry arising from varying flows, *Journal of Hydrology*, 11, 230-252.

Ager, D.V., 1983, *The nature of the stratigraphic record*, Second Edition, Macmillan, London.

Alexander, C.S. and N.R.Nunnally, 1972, Channel stability on the lower Ohio River, *Annals of the Association of American Geographers*, 62, 411-417

Alexander, C.S. and J.C. Prior, 1971, Holocene sedimentation rates in overbank deposits in the Black Bottom of the Lower Ohio River, southern Illinois, *American Journal of Science*, 270, 361-372.

Allen, J.R.L., 1963, The classification of cross-stratified units with notes on their origin, *Sedimentology*, 2, 93-114.

Allen, J.R.L., 1964, Studies in fluviatile sedimentation : Six cyclothems from the Lower Old Red Sandstone, Anglo-Welsh Basin, *Sedimentology*, 3, 163-198.

Allen, J.R.L., 1965, A review of the origin and characteristics of recent alluvial sediments, *Sedimentology*, 5, 89-191.

Allen, J.R.L., 1970, Studies in fluviatile sedimentation : a comparison of fining-upwards cyclothems, with special reference to coarse-member composition and interpretation, *Journal of Sedimentary Petrology*, 40, 298-323.

Allen, J.R.L., 1978, Studies in fluviatile sedimentation: an exploratory quantitative model for the architecture of avulsion-controlled alluvial suites, *Sedimentary Geology*, 21, 129-147.

Allen, J.R.L., 1983, Studies in fluviatile sedimentation : bars, bar-complexes and sandstone sheets (low sinuosity braided streams) in the Brownstones (L. Devonian), Welsh Borders, *Sedimentary Geology*, 33, 237-293.

Allen, J.R.L. and P.F. Friend, 1968, Deposition of the Catskill facies, Appalachian region: with notes on some other Old Red Sandstone basins, in: Klein, G. de V., (Ed.), *Late Palaeozoic and Mesozoic Continental Sedimentation, northeastern north America*, Geological Society of America Special Paper 106, 21-74.

Allen, J.R.L. and B.P.J. Williams, 1982, The architecture of an alluvial suite: Rocks between the Townsend Tuff and Pickard Bay Tuff Beds (Early Devonian), Southwest Wales, *Philosophical Transactions of the Royal Society of London*, Series B, 297, 51-89.

Anderson, M.G. and T.P. Burt, 1981, Process determination in space and time, in: Goudie, A., (Ed.), *Geomorphological Techniques*, Allen and Unwin, London, 1-21.

Anderson, M.G. and A. Calver, 1980, Channel plan changes following large floods, in: Cullingford, R.A., D.A. Davidson and J. Lewin, (Eds.), *Timescales in Geomorphology*, Wiley, Chichester, 43-52.

Anderson, M.G. and A. Calver, 1981, Laboratory channel pattern variability, *Area*, 13, 277-284.

Anderton, R., 1985, Clastic facies models and facies analysis, in: Blenchley, P.J. and B.P.J. Williams, (Eds.), *Sedimentology: Recent Developments and Applied Aspects*, Geological Society of London, Special Publication Number 18, 31-47.

Andrews-Speed, C.P., 1986, Gold-bearing fluvial and associated tidal marine sediments of Proterozoic age in the Mporokoso Basin, northern Zambia, *Sedimentary Geology*, 48, 193-222.

Armstrong, J.E. and S.R. Hicock, 1976, Quaternary multiple valley development of the lower Coquitlam Valley, Coquitlam, British Columbia, *Geological Survey of Canada Paper*, 76-1B, 197-200.

Ashmore, P.E., 1982, Laboratory modelling of gravel braided stream morphology, *Earth Surface Processes and Landforms*, 7, 201-225.

Baker, V.R., 1977, Stream channel response to floods, with examples from central Texas, *Geological Socity of America Bulletin*, 88, 1057-1071.

Barrell, J., 1912, Criteria for the recognition of ancient delta deposits, *Geological Society of America Bulletin*, 23, 377-446.

Beerbower, J.R., 1964, Cyclothems and cyclic depositional mechanisms in alluvial plain sedimentation, *Bulletin of the Kansas Geological Society*, 169, 31-42.

Begin, Z.B., 1981, The relationship between flow-shear stress and stream pattern, *Journal of Hydrology*, 52, 307-319.

Bell, L.M., 1975, Factors influencing the sedimentary environments of the Squamish River delta in southwestern British Columbia, *Unpublished M.A.Sc Thesis*, University of British Columbia, 145pp.

Bishop, P., 1987, Geomorphic history of the Yom River floodplain, north central Thailand, and its implications for floodplain evolution, *Zeitschrift fur Geomorphologie*, 31, 195-211.

Blake, D.H., and C.D. Ollier, 1971, Alluvial plains of the Fly River, Papua, *Zeitschrift fur Geomorphologie*, 12, 1-17.

Blakey, R.C. and R. Gubitosa, 1984, Controls of sandstone body geometry and architecture in the Chinle Formation (Upper Triassic), Colorado Plateau, *Sedimentary Geology*, 38, 51-86.

Blodgett, R.H. and K.O. Stanley, 1980, Stratification, bedforms, and discharge relations of the Platte braided river system, Nebraska, *Journal of Sedimentary Petrology*, 50, 139-148.

Bluck, B.J., 1971, Sedimentation in the meandering River Endrick, *Scottish Journal of Geology*, 7, 93-138.

Bluck, B.J., 1974, Structure and directional properties of some valley sandur deposits in southern Iceland, *Sedimentology*, 21, 533-554.

Bluck, B.J., 1976, Sedimentation in some Scottish rivers of low sinuosity, *Transactions of the Royal Society of Edinburgh*, 69, 425-456.

Bluck, B.J., 1979, Structure of coarse grained braided stream alluvium, *Transactions of the Royal Society of Edinburgh*, 70, 181-221.

Bluck, B.J., 1980, Structure, generation and preservation of upward fining braided stream cycles in the Old Red Sandstone of Scotland, *Transactions of the Royal Society of Scotland*, 71, 29-46.

Bluck, B.J., 1987, Bed forms and clast size changes in gravel-bed rivers, in: Richards, K., (Ed.), *River channels : Environment and Process*, Blackwell, U.K., 159-178.

Boggs, S., 1987, *Principles of Sedimentology and Stratigraphy*, Merrill, Columbus, 784pp.

Bradley, J.B., 1984, Transition of a meandering river to a braided stream due to high sediment concentration flows, in: Elliott, C.M., (Ed.), *River Meandering*, Proceedings of the Rivers '83 Conference, American Society of Civil Engineering, New York, 89-100.

Brady, R.H., 1984, Neogene stratigraphy of the Avawatz Mountains between the Garlock and Death Valley fault zones, southern Death Valley, California : Implications as to Late Cenozoic tectonism, *Sedimentary Geology*, 38, 127-158.

Brakenridge, G.R., 1984, Alluvial stratigraphy and radiocarbon dating along the Duck River, Tennessee: Implications regarding flood-plain origin, *Geological Society of America Bulletin*, 95, 9-25.

Brice, J.C., 1984, Planform properties of meandering rivers, in: Elliott, C.M., (Ed.), *River Meandering*, Proceedings of the Rivers '83 Conference, American Society of Civil Engineers, New York, 1-14.

Bridge, J.S., 1984, Large-scale facies sequences in alluvial overbank environments, *Journal of Sedimentary Petrology*, 54, 583-588.

Bridge, J.S., 1985, Paleochannel patterns inferred from alluvial deposits : a critical evaluation, *Journal of Sedimentary Petrology*, 55, 579-589.

Bridge, J.S. and M.R. Leeder, 1979, A simulation model of alluvial stratigraphy, *Sedimentology*, 26, 617-644.

Bridge, J.S., N.D. Smith, F. Trent, S.L. Gabel and P. Bernstein, 1986, Sedimentology and morphology of a low-sinuosity river: Calamus River, Nebraska Sand Hills, *Sedimentology*, 33, 851-870.

Brierley, G.J., 1984, *Channel stability and downstream changes in particle size on the Squamish River, B.C.*, Unpublished MSc Thesis, Simon Fraser University, 150pp.

Brierley, G.J. and E.J. Hickin, 1985, The downstream gradation of particle sizes in the Squamish River, British Columbia, *Earth Surface Processes and Landforms*, 10, 597-606.

Brown, A.G., 1987, Holocene floodplain sedimentation and channel response of the lower River Severn, United Kingdom, *Zeitschrift fur Geomorphologie*, 31, 293-310.

Bull, W.B., 1979, Threshold and critical power in streams, *Geological Society of America Bulletin*, 90, 453-464.

Burkham, D.E., 1972, Channel changes in the Gila River in Safford Valley, Arizona, 1846-1870, *United States Geological Survey Professional Paper*, 655-G, 24pp.

Burrin, P.J. and R.G. Scaife, 1984, Aspects of Holocene valley sedimentation and floodplain development in southern England, *Proceedings of the Geological Association*, 95, 81-96.

Cant, D.J., 1978, Development of a facies model for sandy braided river sedimentation: Comparison of the South Saskatchewan River and the Battery Point Formation, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Engineers, Memoir 5, Calgary, 627-639.

Cant, D.J., 1982, Fluvial facies models and their application, in: Scholle, P.A. and D. Spearing, (Eds.), *Sandstone Depositional Environments*, American Association of Petroleum Geologists Memoir 31, Tulsa, Oklahoma, 115-138.

Cant, D.J. and R.G. Walker, 1976, Development of a braided-fluvial facies model of the Devonian Battery Point Sandstone, Quebec, *Canadian Journal of Earth Sciences*, 13, 102-119.

Cant, D.J. and R.G. Walker, 1978, Fluvial processes and facies sequences in the sandy braided South Saskatchewan River, Canada, *Sedimentology*, 25, 625-648.

Carey, W.C., 1969, Formation of flood plain lands, *Journal of the Hydraulics Division, American Society of Civil Engineers*, 95, HY3, 981-994.

Carr, T.C., 1982, Log-linear models, Markov chains and cyclic sedimentation, *Journal of Sedimentary Petrology*, 52, 905-912.

Carson, M.A., 1984a, The meandering-braided river threshold : a reappraisal, *Journal of Hydrology*, 73, 315-334.

Carson, M.A., 1984b, Observations on the meandering-braided river transition, the Canterbury Plains, New Zealand, Part One, *New Zealand Geographer*, 40, 12-17.

Carson, M.A., 1984c, Observations on the meandering-braided river transition, the Canterbury Plains, New Zealand, Part Two, *New Zealand Geographer*, 40, 89-99.

Chang, H.H., 1979, Minimum stream power and river channel patterns, *Journal of Hydrology*, 41, 303-327.

Chang, H.H., 1985, River morphology and thresholds, *Journal of Hydraulic Engineering*, 110, 503-519.

Chitale, S.V., 1970, River channel patterns, *Journal of the Hydraulics Division, American Society of Civil Engineers*, 96, 201-221.

Chitale, S.V., 1973, Theories and relationships of river channel patterns, *Journal of Hydrology*, 19, 285-308.

Church, M., 1972, Baffin Island sandurs : A study of Arctic fluvial processes, *Geological Survey of Canada Bulletin*, 216, 208pp.

Church, M., 1983, Pattern of instability in a wandering gravel bed channel, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 169-180.

Church, M. and R. Gilbert, 1975, Proglacial fluvial and lacustrine environments, in: Jopling, A.V. and B.C. McDonald, (Eds.), *Glacio-fluvial and glacio-lacustrine sedimentation*, Society of Economic Paleontologists and Mineralogists, Special Publication Number 23, 22-100.

Church, M. and D. Jones, 1982, Channel bars in gravel-bed rivers, in: Hey, R.D., J.C. Bathurst and C.R. Thorne, (Eds.), *Gravel-bed Rivers : Fluvial Processes, Engineering and Management*, Wiley, Chichester, 291-338.

Church, M. and J.M. Ryder, 1972, Paraglacial sedimentation : A consideration of fluvial processes conditioned by glaciation, *Geological Society of America Bulletin*, 83, 3059-3072.

Clague, J.J., 1981, Late Quaternary geology and geochronology of British Columbia, Part 2 : Summary and discussion of radiocarbon-dated Quaternary history, *Geological Survey of Canada Paper*, 80-35, 41pp.

Clague, J.J. and B.D. Bornhold, 1980, Morphology and littoral processes of the Pacific Coast of Canada, in: McCann, S.B., (Ed.), *The Coastline of Canada*, Geological Survey of Canada Paper 80-10, 339-380.

Clague, J.J., J.R. Harper, R.J. Hebda and D.E. Howes, 1982, Late Quaternary sea levels and crustal movements, coastal British Columbia, *Canadian Journal of Earth Sciences*, 19, 597-618.

Clague, J.J. and J.L. Luternauer, 1983, Late Quaternary geology of southwestern British Columbia, *Field Trip Guidebook*, Trip 6, Geological Association of Canada, Victoria, B.C., 112pp.

Clague, J.J. and J.G. Souther, 1982, The Dusty Creek landslide on Mount Cayley, British Columbia, *Canadian Journal of Earth Sciences*, 19, 524-539.

Coleman, J.D., 1969, Brahmaputra River: Channel processes and sedimentation, *Sedimentary Geology*, 3, 129-239.

Collinson, J.D., 1970, Bedforms of the Tana River: Norway, *Geografiska Annaler*, 52A, 31-55.

Collinson, J.D., 1978, Vertical sequence and sand shape body in alluvial sequences, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geology, Memoir 5, Calgary, 577-586.

Desloges, J.R. and M. Church, 1987, Channel and floodplain facies in a wandering gravel-bed river, in: Ethridge, F.G., R.M. Flores and M.D. Harvey, (Eds.), *Recent Developments in Fluvial Sedimentology*, Society of Economic Paleontologists and Mineralogists, Special Publication Number 39, Tulsa, Oklahoma, 99-109.

Dixon, E.E.L., 1921, The geology of the South Wales Coalfield; Part XIII: The country around Tenby, *Geological Survey of Great Britain*, Memoir.

Doeglas, D.J., 1962, The structure of sedimentary deposits of braided streams, *Sedimentology*, 1, 167-190.

Douglas, I., 1977, *Humid Landforms*, Australian National Univeristy Press, Canberra, 288pp.

Dott, R.H., 1988, Perspectives: Something old, something new, something borrowed, something blue - a hindsight and foresight of sedimentary geology, *Journal of Sedimentary Petrology*, 58, 358-364.

Edgar, D.E., 1984, The role of geomorphic thresholds in determining alluvial channel morphology, in: Elliott, C.M., (Ed.), *River Meandering*, Proceedings of the Rivers '83 Conference, American Society of Civil Engineers, New York, 44-54.

Eisbacher, G.H., 1983, Slope stability and mountain torrents, Fraser Lowlands and southern Coast Mountains, British Columbia, *Field Trip Guidebook*, Trip 15, Geological Association of Canada, Victoria, B.C.

Engelund, F. and O. Skovgaard, 1973, On the origin of meandering and braiding in alluvial streams, *Journal of Fluid Mechanics*, 57, 289-302.

Environment Canada, 1982a, *Canadian climate normals: Temperature, 1951-1980*, Volume 2, Ottawa, p6.

Environment Canada, 1982b, *Canadian climate normals: Precipitation, 1951-1980*, Volume 3, Ottawa, p7.

Ethridge, F.G., R.M. Flores and M.D. Harvey, (Eds.), *Recent Developments in Fluvial Sedimentology*, Society of Economic Paleontologists and Mineralogists, Special Publication Number 39, Tulsa, Oklahoma, 389pp.

Fahnestock, R.K., 1963, Morphology and hydrology of a glacial stream - White River, Mount Rainier, Washington, *United States Geological Survey Professional Paper*, 422-A, 70pp.

Fenneman, N.M., 1906, Floodplains produced without floods, *American Geographical Society Bulletin*, 38, 89-91.

Ferguson, R.I., 1987, Hydraulic and sedimentary controls of channel planform, in: Richards, K., (Ed.), *River channels: Environment and Process*, Blackwell, U.K., 129-158.

Ferguson, R.I. and A. Werrity, 1983, Bar development and channel changes in the gravelly River Feshie, Scotland, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Depositional Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 181-193.

Fisk, H.N., 1944, Geological investigation of the alluvial valley of the lower Mississippi River, *Mississippi River Commisssion Waterways Experiment Station*, Vicksburg, Mississippi, 78pp.

Fisk, H.N., 1947, Fine-grained alluvial deposits and their effects on Mississippi River activity, *Mississippi River Commission Waterways Experiment Station*, Vicksburg, Mississippi, 82pp.

Fisk, H.N., 1952, Mississippi River Valley geology relation to river regime, *Transactions of the American Society of Civil Engineers*, 117, 667-689.

Folk, R.L., and W.C. Ward, 1957, Brazos River bar - a study in the significance of grain size parameters, *Journal of Sedimentary Petrology*, 27, 3-26.

Forbes, D.L., 1983, Morphology and sedimentology of a sinuous gravel-bed channel system: lower Babbage River, Yukon coastal plain, Canada, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 195-206.

Fraser, J.Z., 1982, Derivation of a summary facies sequence based on Markov-chain analysis of the Caledon outwash : a Pleistocene braided glacial fluvial deposit, in: Davidson-Arnott, R., W. Nickling and B.D. Fahey, (Eds.), *Research in Glacial, Glacio-fluvial and Glacio-lacustrine systems*, Proceedings of the 6'th Guelph Symposium on Geomorphology (1980), Geobooks, Norwich, 175-199.

Fredsoe, J., 1978, Meandering and braiding of rivers, *Journal of Fluid Mechanics*, 84, 609-624.

Friend, P.F., 1965, Fluviatile sedimentary structures in the Wood Bay Series (Devonian) of Spitsbergen, *Sedimentology*, 5, 39-68.

Friend, P.F., 1983, Towards the field classification of alluvial architecture or sequence, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 345-354.

Friend, P.F., M.J. Slater and R.C. Williams, 1979, Vertical and lateral building of river sandstone bodies, Ebro Basin, Spain, *Journal of the Geological Society of London*, 136, 39-46.

Galay, V.J., R. Kellerhals and D.I. Bray, 1973, Diversity of river types in Canada, in: *Fluvial Processes and Sedimentation*, Proceedings of Hydrology Symposium, National Research Council, Edmonton, 217-250.

Galloway W.E. and D.K. Hobday, 1983, *Terrigenous clastic depositional systems*, Springer-Verlag, New York, 423pp.

Gilbert, G.K., 1877, Report on the geology of the Henry Mountains, *United States Geography and Geology Survey*, 160pp.

Gingerich, P.D., 1969, Markov analysis of cyclic alluvial sediments, *Journal of Sedimentary Petrology*, 39, 330-332.

Gressly, A., 1838, Observations geologiques sur le Jura Soleurois, *Neue Denkschr. allg. schweiz. Ges. ges. Naturw.*, 2, 1-112.

Gustavson, T.C., 1978, Bed forms and modern stratification types of modern gravel meander lobes, Nueces River, Texas, *Sedimentology*, 25, 401-426.

Happ, S.C., G. Rittenhouse and G.C. Dobson, 1940, Some principles of accelerated stream and valley sedimentation, *United States Department of Agriculture Technical Bulletin*, 695, 134pp.

Harper, C.W., 1984, Improved methods of facies sequence analysis, in: Walker, R.G., (Ed.), *Facies Models*, Second Edition, Geoscience Canada Reprint Series 1, Toronto, 11-13.

Hayashi, T., and S. Ozaki, 1980, Alluvial bedform analysis, I. Formation of alternating bars and braids, in: Shen, H.W. and H. Kikkawa, (Eds.), *Application of Stochastic Processes in Sediment Transport*, Water Resources Publication, Colorado, 7-1 - 7-40.

Hereford, R., 1984, Climate and ephemeral-stream processes: Twentieth-century geomorphology and alluvial stratigraphy of the Little Colorado River, Arizona, *Geological Society of America Bulletin*, 95, 654-668.

Hickin, E.J., 1974, The development of meanders in natural river channels, *American Journal of Science*, 274, 414-442.

Hickin, E.J., 1979, Concave-bank benches on the Squamish River, British Columbia, Canada, *Canadian Journal of Earth Sciences*, 16, 200-203.

Hickin, E.J., 1983, River channel changes: retrospect and prospect, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 61-83.

Hickin, E.J., 1984, Vegetation and river channel dynamics, *Canadian Geographer*, 28, 111-126.

Hickin, E.J., 1986, Concave-bank benches in the floodplains of Muskwa and Fort Nelson Rivers, British Columbia, *Canadian Geographer*, 30, 111-122.

Hickin, E.J. and G.C. Nanson, 1975, Character of channel migration on the Beatton River, north-east British Columbia, Canada, *Geological Society of America Bulletin*, 86, 487-494.

Hickin, E.J. and H.M. Sichingabula, 1988, The geomorphic impact of the catastrophic October 1984 flood on the planform of Squamish River, southwestern British Columbia, *Canadian Journal of Earth Sciences*, 25, 1078-1087.

Hiscott, R.N., 1981, Chi-square tests for Markov chain analysis, *Mathematical Geology*, 13, 69-80.

Hobday, D.K., R. Tavener-Smith and D. Mathew, 1975, Markov analysis and the recognition of palaeoenvironments in the Ecca Group near Vryheid, Natal, *Transactions of the Geological Society of South Africa*, 78, 75-82.

Holland, S.S., 1964, Landforms of British Columbia, a physiographic outline, *British Columbia Department of Mines and Petroleum Resources Bulletin*, 48, 138pp.

Hooke, J.M., 1986, The significance of mid-channel bars in an active meandering river, *Sedimentology*, 33, 839-850.

Hoos, L.M. and C.L. Vold, 1975, *The Squamish River Estuary : Status of Environmental Knowledge to 1974*, Report of the Estuary Working Group, Department of the Environment, Regional Board Pacific Region, Environment Canada, Special Estuary Series, Number 2, 178pp.

Jackson, R.G., 1975a, Velocity-bed form-texture patterns of meander bends in the lower Wabash River of Illinois and Indiana, *Geological Society of America Bulletin*, 86, 1511-1522.

Jackson, R.G., 1975b, Hierarchical attributes and a unifying model of bedforms composed of cohesionless material and produced by shearing flow, *Geological Society of America Bulletin*, 86, 1523-1533.

Jackson, R.G., 1976, Depositional model of point bars in the lower Wabash River, *Journal of Sedimentary Petrology*, 46, 579-594.

Jackson, R.G., 1978, Preliminary evaluation of lithofacies models for meandering alluvial streams, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 543-576.

Jacobson, R.B. and D.J. Coleman, 1986, Stratigraphy and recent evolution of Maryland piedmont flood plains, *American Journal of Science*, 286, 617-637.

Johnson, S.Y., 1984, Cyclic fluvial sedimentation in a rapidly subsiding basin, northwest Washington, *Sedimentary Geology*, 38, 361-391.

Jones, W.C., 1959, Cheekye River mudflows, *British Columbia Department of Mines Report*, 11pp.

Jordan, P., 1987, Impacts of mass movement events on rivers in the southern Coast Mountains, *Water Resources Branch, Environment Canada Report*, IWD-HQ-WRB-SS-87-3, 62pp.

Kellerhals, R., M. Church and D.I. Bray, 1976, Classification and analysis of river processes, *Journal of the Hydraulics Division, American Society of Civil Engineers*, 102, HY7, 813-829.

Kesel, R.H., K.C. Dunne, R.C.McDonald, K.R. Allison and B.E. Spicer, 1974, Lateral erosion and overbank deposition on the Mississippi River in Louisiana caused by 1973 flooding, *Geology*, 2, 461-464.

Knox, J.C., 1972, Valley alluviation in southwestern Wisconsin, *Annals of the Association of American Geographers*, 62, 401-410.

Kostachuk, R., 1984, Sedimentation in a fjord-head delta, Bella Coola, British Columbia, *Unpublished PhD Thesis*, McMaster University, 298pp.

Koutaniemi, L., 1979, Late-glacial and post-glacial development of the valleys of the Oulanka river basin, north-eastern Finland, *Fennia*, 157, 13-73.

Koutaniemi, L., 1984, The role of ground frost, snow cover, ice break-up and flooding in the fluvial processes of the Oulanka River, N.E. Finland, *Fennia*, 162, 127-161.

Kozarski, S. and K. Rotnicki, 1977, Valley floor and changes of river patterns in the north Polish Plain during the late Wurm and Holocene, *Quaestiones Geographicae*, 4, 51-93.

Krigstrom, A., 1962, Geomorphological studies of sandur plains and their braided rivers in Iceland, *Geografiska Annaler*, 44, 328-346.

Krumbein, W.C., 1934, Size frequency distribution of sediments, *Journal of Sedimentary Petrology*, 4, 65-77.

Lane, E.W., 1957, A study of the shape of channels formed by natural streams flowing in erodible material, *Missouri River Division Sediments Series*, 9, United States Army Engineer Division, Missouri River, Corps of Engineers, Omaha, Nebraksa, 106pp.

Lattmann, L.H., 1960, Cross section of a floodplain in a moist region of moderate relief, *Journal of Sedimentary Petrology*, 30, 275-282.

Leopold, L.B. and M.G. Wolman, 1957, River channel patterns, braided, meandering and straight, *United States Geological Survey Professional Paper*, 282-D, 35-85.

Levey, R.A., 1978, Bed-form distribution and internal stratification of coarse-grained point bars, Upper Congaree River, South Carolina, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, 105-128.

Lewin, J., 1978a, Floodplain geomorphology, *Progress in Physical Geography*, 2, 408-437.

Lewin, J., 1978b, Meander development and floodplain sedimentation : a case study from mid-Wales, *Geological Journal*, 13, 25-36.

Long, D.G.F., 1978, Proterozoic stream deposits: some problems of recognition and interpretation of ancient sandy fluvial systems, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geology, Memoir 5, Calgary, 313-341.

Mack, G.H. and W.C. James, 1986, Cyclic sedimentation in the mixed siliclastic-carbonate Abo-Hueco transitional zone (Lower Permian), southwestern New Mexico, *Journal of Sedimentary Petrology*, 56, 635-647.

Mackin, J.H., 1937, Erosional history of the Big Horn Basin, Wyoming, *Geological Society of America Bulletin*, 48, 813-894.

Mader, D., 1985, Depositional mechanisms controlling formation of coarse fluvial conglomerates in the Lower Triassic Continental Red Beds of Middle Europe, in: Mader, D., (Ed.), *Aspects of fluvial sedimentation in the Lower Triassic Buntsandstein of Europe*, Lecture Notes in Earth Sciences, 4, Springer, Berlin, 251-280.

Maizels, J.K., 1983, Proglacial channel systems : change and thresholds for change over long, intermediate and short time-scales, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 251-266.

Mathews, W.H., 1951, Historic and prehistoric fluctuations in alpine glaciers in the Mount Garibaldi map area, *Journal of Geology*, 59, 357-380.

Mathews, W.H., 1952a, Mount Garibaldi, a supraglacial Pleistocene volcano in southwestern British Columbia, *American Journal of Science*, 250, 81-103.

Mathews, W.H., 1952b, Ice dammed lavas from Clinker Mountain, southwestern British Columbia, *American Journal of Science*, 250, 533-560.

Mathews, W.H., 1958a, Geology of the Mount Garibaldi map area, southwestern British Columbia, Canada, 1 : Igneous and metamorphic rocks, *Geological Society of America Bulletin*, 69, 161-178.

Mathews, W.H., 1958b, Geology of the Mount Garibaldi map area, southwestern British Columbia, Canada, 2 : Geomorphology and Quaternary volcanics, *Geological Society of America Bulletin*, 69, 179-198.

Mathews, W.H., J.G. Fyles and H.W. Nasmith, 1970, Post-glacial crustal movements in southwestern British Columbia and adjacent Washington State, *Canadian Journal of Earth Sciences*, 7, 690-702.

McGowen, J.H. and L.E. Garner, 1970, Physiographic features and stratification types of coarse-grained point bars : modern and ancient examples, *Sedimentology*, 14, 77-111.

McKee, E.D., E.J. Crosby and H.L. Berryhill, 1967, Flood deposits, Bijou Creek, Colorado, June 1965, *Journal of Sedimentary Petrology*, 37, 829-851.

Melton, F.A., 1936, An empirical classification of floodplain streams, *Geographical Review*, 26, 593-609.

Miall, A.D., 1973, Markov chain analysis applied to an ancient alluvial plain succession, *Sedimentology*, 20, 347-364.

Miall, A.D., 1977, A review of the braided-river depositional environment, *Earth Science Reviews*, 13, 1-62.

Miall, A.D., 1978a, Fluvial sedimentology : An historical review, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 1-47.

Miall, A.D., 1978b, Lithofacies types and vertical profile models in braided river deposits : A summary, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 597-604.

Miall, A.D., 1980, Cyclicity and the facies model concept in fluvial deposits, *Bulletin of Canadian Petroleum Geology*, 28, 59-80.

Miall, A.D., 1984, *Principles of Sedimentary Basin Analysis*, Springer-Verlag, New York, 490pp.

Miall, A.D., 1985, Architectural-element analysis : A new method of facies analysis applied to fluvial deposits, *Earth Science Reviews*, 22, 261-308.

Miall, A.D., 1987, Recent developments in the study of fluvial facies models, in: Ethridge, F.G., R. M. Flores and M.D. Harvey, (Eds.), *Recent Developments in Fluvial Sedimentology*, Society of Economic Paleontologists and Mineralogists, Special Publication Number 39, Tulsa, Oklahoma, 1-9.

Miall, A.D., 1988, Architectural elements and bounding surfaces in fluvial deposits: Anatomy of the Kayenta Formation (Lower Jurassic), Southwestern Colorado, *Sedimentary Geology*, 55, 233-262.

Middleton, G.V., 1973, Johannes Walther's law of correlation of facies, *Geological Society of America Bulletin*, 84, 979-988.

Mollard, J.D., 1973, Air photo interpretation of fluvial features, in: *Fluvial Processes and Sedimentation*, Proceedings Hydrology Symposium, National Research Council, Edmonton, 341-380.

Moody-Stuart, M., 1966, High- and low-sinuosity stream deposits, with examples from the Devonian of Spitsbergen, *Journal of Sedimentary Petrology*, 36, 1102-1117.

Morningstar, O.R., 1988, Floodplain construction and overbank deposition in a wandering reach of the Fraser River, Chilliwack, B.C., *Unpublished MSc thesis*, Simon Fraser University, 129pp.

Nanson, G.C., 1980, Point bar and floodplain formation of the meandering Beatton River, northeastern British Columbia, Canada, Sedimentology, 27, 3-30.

Nanson, G.C., 1986, Episodes of vertical accretion and catastrophic stripping: A model of disequilibrium flood-plain development, *Geological Society of America Bulletin*, 97, 1467-1475.

Nanson, G.C. and K. Page, 1983, Lateral accretion of fine-grained concave benches on meandering rivers, in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 133-143.

Nanson, G.C., B.R. Rust and G. Taylor, 1986, Coexistent mud braids and anastamosing channels in an arid-zone river: Cooper Creek, central Australia, *Geology*, 14, 175-178.

Nanson, G.C. and R.W. Young, 1981, Overbank deposition and floodplain formation on small coastal streams of New South Wales, *Zeitschrift fur Geomorphologie*, 25, 332-347.

Neill, C.R., 1973, Hydraulic and morphologic characteristics of Athabasca River near Assiniboine, *Highway and River Engineering Division Report*, REH/73/3, Alberta Research Council, Edmonton, 23pp.

Nijman, W. and C. Puigdefabregas, 1978, Coarse-grained point bar structure in molasse-type fluvial system, Eocene Castisent Sandstone Formation, South Pyrenean Basin, in: Miall, A.D., (Ed.). *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 487-510.

Nordseth, K., 1973, Floodplain construction on a braided river: The islands of Koppangoyene on the River Glomma, *Norsk Geografisk Tidsskrift*, 27, 109-126.

Nunnally, N.R., 1967, Definition and identification of channel and overbank deposits and their respective roles in flood plain formation, *The Professional Geographer*, 19, 1-4.

O'Loughlin, C.L., 1972, A preliminary study of landslides in the Coast Mountains of southwestern British Columbia, in: Slaymaker, H.O. and H.J. McPherson, (Eds.), *Mountain Geomorphology : Geomorphological Processes in the Canadian Cordilleran*, British Columbian Geographical Series Number 14, Tantalus, Vancouver, 101-112.

Ore, H.T., 1964, Some criteria for recognition of braided stream deposits, *University of Wyoming Contributions to Geology*, 3, 1-14.

Ori, G.G., 1983, Braided to meandering channel patterns in humid-region alluvial fan deposits, River Reno, Po Plain (northern Italy), *Sedimentary Geology*, 31, 231-248.

Osterkamp, W.P., 1978, Gradient, discharge, and particle size relations of alluvial channels in Kansas, with observations on braiding, *American Journal of Science*, 278, 1253-1268.

Otvos, E.G., 1980, Stream terraces of gulf coastal streams, *Quaternary Research*, 13, 80-92.

Parker, G., 1976, On the cause and characteristic scales of meandering and braiding in rivers, *Journal of Fluid Mechanics*, 76, 457-480.

Pizzuto, J.E., 1987, Sediment diffusion during overbank flows, *Sedimentology*, 34, 301-317.

Powers, D.W. and R.G. Easterling, 1982, Improved methodology for using embedded Markov chains to describe cyclical sediments, *Journal of Sedimentary Petrology*, 52, 913-923.

Puigdefabregas, C. and A. Van Vliet, 1978, Meandering stream deposits from the Tertiary of the southern Pyrenees, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 469-486.

Ramos, A. and A. Sopena, 1983, Gravel bars in low sinuosity rivers (Permian and Triassic, central Spain), in: Collinson, J.D. and J. Lewin, (Eds.), *Modern and Ancient Fluvial Systems*, Special Publication Number 6 of the International Association of Sedimentologists, Blackwell, Oxford, 301-312.

Ray, P.K., 1976, Structure and sedimentological history of the overbank deposits of a Mississippi River point bar, *Journal of Sedimentary Petrology*, 46, 788-801.

Read W.A., 1969, Analysis and simulation of Namurian sediments in central Scotland using a Markov-process model, *Mathematical Geology*, 1, 199-219.

Reading, H.G., 1978, (Ed.), *Sedimentary Environmnents and Facies*, Blackwell, Oxford, 557pp

Reading, H.G., 1986, (Ed.), *Sedimentary Environments and Facies*, Second Edition, Blackwell, Oxford, 615pp.

Reading, H.G., 1987, Fashions and models in sedimentology: a personal perspective, *Sedimentology*, 34, 3-9.

Reineck, H.-E. and I.B. Singh, 1980, *Depositional Sedimentary Environments with Reference to Terrigenous Clastics*, Springer, Berlin, Second Edition, 549pp.

Richards, K.S., 1986, Fluvial geomorphology, *Progress in Physical Geography*, 10, 401-420.

Ritter, D.F., and D.S. Blakley, 1986, Localized catastrophic disruption of the Gasconade River floodplain during the December 1982 flood, southeast Missouri, *Geology*, 14, 472-476.

Ritter, D.F., W.F. Kinsey and M.E. Kaufman, 1973, Overbank sedimentation in the Delaware River Valley during the last 6000 years, *Science*, 179, 374-375.

Roddick, J.A., and G.J. Woodsworth, 1979, Geology of Vancouver west half and mainland part of Alberni, *Geological Survey of Canada*, Open file # 611.

Rose, J., C. Turner, G.R. Coope and M.D. Bryan, 1980, Channel changes in a lowland river catchment over the last 13,000 years, in: Cullingford, R.A., D.A. Davidson and J. Lewin, (Eds.), *Timescales in Geomorphology*, Wiley, Chichester, 159-175.

Rundle, A., 1985a, The mechanism of braiding, *Zeitschrift fur Geomorphologie*, 55, 1-13

Rundle, A., 1985b, Braid morphology and the formation of multiple channels: the Rakaia, New Zealand, *Zeitschrift fur Geomorphologie*, 55, 15-37.

Russell, I.C., 1898, *River development as illustrated by the rivers of North America*, Patnams, New York, 327pp.

Rust, B.R., 1972, Structure and process in a braided river, *Sedimentology*, 18, 221-245.

Rust, B.R., 1975, Fabric and structure in glaciofluvial gravels, in: Jopling, A.V. and B.C. McDonald, (Eds.), *Glacio-fluvial and Glacio-lacustrine Sedimentation*, Society of Economic Palaentologists and Mineralogists, Special Publication Number 23, 238-248.

Rust, B.R., 1978a, A classification of alluvial channel systems, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 187-198.

Rust, B.R., 1978b, Depositional models of braided alluvium, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 605-625.

Rust, B.R., 1979, Facies models 2. Coarse alluvial deposits, in: Walker, R.G., (Ed.), *Facies Models*, Geoscience Canada Reprint Series Number 1, Waterloo, 9-21.

Ryder, J.M., 1981, Geomorphology of the southern part of the Coast Mountains of British Columbia, *Zeitschrift fur Geomorphologie*, 37, 120-147.

Schmudde, T.H., 1963, Some aspects of landforms of the lower Missouri River floodplain, *Annals of the Association of American Geographers*, 53, 60-73.

Schumm, S.A., 1963, Sinuosity of alluvial rivers on the Great Plains, *Geological Society of America Bulletin*, 74, 1089-1100.

Schumm, S.A., 1968, River adjustment to altered hydrologic regimen - Murrumbidgee River and paleochannels, Australia, *United States Geological Survey Professional Paper*, 598, 65pp.

Schumm, S.A., 1969, River metamorphosis, *Journal of the Hydraulics Division, American Society of Civil Engineers*, 95, HY1, 255-273.

Schumm, S.A., 1971, Fluvial geomorphology : channel adjustment and river metamorphosis, in: Shen, H.W., (Ed.), *Fluvial Geomorphology in River Mechanics*, Water Resources Publication, Colorado State University, Fort Collins, 5.1-5.22.

Schumm, S.A., 1977, *The Fluvial System*, Wiley, New York, 338pp.

Schumm, S.A., 1981, Evolution and response of the fluvial system, sedimentologic implications, *Society of Economic Paleontologists and Mineralogists Special Publication*, Number 31, 19-29.

Schumm, S.A., 1985, Patterns of alluvial rivers, *Annual Review of Earth and Planetary Sciences*, 13, 5-27.

Schumm, S.A. and H.R. Khan, 1972, Experimental study of channel patterns, *Geological Society of America Bulletin*, 83, 1755-1770.

Schumm, S.A. and R.W. Lichty, 1963, Channel widening and flood-plain construction along Cimarron River in southwestern Kansas, *United States Geological Survey Professional Paper*, 352-D, 71-88.

Schwartz, D.E., 1978, Hydrology and current orientation analysis of a braided-to-meandering transition: the Red River in Oklahoma and Texas, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 105-127.

Shelton, J.W. and R.L. Noble, 1974, Depositional featurees of braided-meandering stream, *The American Association of Petroleum Geologists Bulletin*, 58, 742-752.

Sichingabula, H.M., 1986, *Character and causes of channel changes on the Squamish River, southwestern British Columbia*, Unpublished MSc thesis, Simon Fraser University, 156pp.

Sigafoos, R.S., 1964, Botanical evidence of floods and floodplain deposition, *United States Geological Survey Professional Paper*, 485-A, 35pp.

Simons, D.B. and E.V. Richardson, 1961, Forms of bed roughness in alluvial channels, *Proceedings of the American Society of Civil Engineers*, 87, 87-105.

Simons, D.B. and E.V. Richardson, 1962, Studies of flow in alluvial channels. The effect of bed roughness on depth-discharge relations in alluvial channels, *United States Geological Survey Water Supply Papers*, 1498E, 26pp.

Simons, D.B., E.V. Richardson and M.L. Albertson, 1961, Flume studies using medium sand (0.45mm), *United States Geological Survey Water Supply Papers*, 1498A, 76pp.

Smith, D.G. and N.D. Smith, 1980, Sedimentation in anastamosed river systems : Examples from alluvial valleys near Banff, Alberta, *Journal of Sedimentary Petrology*, 50, 157-164.

Smith, N.D., 1970, The braided stream depositional environment: Comparison of the Platte River with some Silurian clastic rocks, north central Appalachians, *Geological Society of America Bulletin*, 81, 2993-3014.

Smith, N.D., 1971, Transverse bars and braiding in the lower Platte River, Nebraska, *Geological Society of America Bulletin*, 82, 3407-3420.

Smith, N.D., 1974, Sedimentology and bar formation in the Upper Kicking Horse River, a braided outwash stream, *Journal of Geology*, 82, 205-223.

Smith, N.D., 1978, Some comments on terminology for bars in shallow rivers, in: Miall, A.D., (Ed.), *Fluvial Sedimentology*, Canadian Society of Petroleum Geologists, Memoir 5, Calgary, 85-88.

Smith, N.D. and D.G. Smith, 1984, William River: An outstanding example of channel widening and braiding caused by bed-load addition, *Geology*, 12, 78-82.

Souther, J.G., 1980, Geothermal reconnaisance in the central Garibaldi Belt, British Columbia, *Current Research, part A, Geological Survey of Canada*, Paper 80-1A, 1-11.

Speight, J.G., 1965, Flow and channel characteristics of the Angabunga River, Papua, *Journal of Hydrology*, 3, 16-36.

Stathers, J.K., 1958, A geographical investigation of development potential in the Squamish Valley region, British Columbia, *Unpublished M.A. thesis*, Department of Geology and Geography, University of British Columbia, 194pp.

Sundborg, A., 1956, The River Klaralven - A study of fluvial processes, *Geografiska Annaler*, 38A, 127-316.

Syvitski, J.P.M. and R.D. McDonald, 1982, Sediment character and provenance in a complex fjord: Howe Sound, British Columbia, *Canadian Journal of Earth Sciences*, 19, 1025-1044.

TASK Committee, 1971, Sediment transportation mechanics: Genetic classification of valley sediment deposits, *Journal of the Hydraulics Division, American Society of Civil Engineers*, 97, HY1, 43-53.

Teisseyre, A.K., 1977, Meander degeneration in bed-load proximal streams: repeated chute cut-off due to bar-head gravel accretion - a hypothesis, *Geologica Sudetica*, 12, 103-120.

Visher, G.S., 1965, Use of vertical profile in environmental reconstruction, *Bulletin of the American Association of Petroleum Geologists*, 49, 41-61.

Walker, R.G., 1979, *Facies Models*, Geoscience Canada, Waterloo, 211pp.

Walker, R.G., 1984, *Facies Models*, Geoscience Canada, Waterloo, Second Edition, 317pp.

Walker, R.G. and D.J. Cant, 1979, Facies models 3 : Sandy fluvial systems, in: Walker, R.G., (Ed.), *Facies Models*, Geoscience Canada, Waterloo, 23-31.

Water Survey of Canada, 1973, Flow data for the Squamish, Cheakamus, Mamquam and Stawamus rivers, *Water Survey of Canada Unpublished data*, 48pp.

Water Survey of Canada, 1955-1987, *Surface Water Data, British Columbia*, Environment Canada, Ottawa.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments, *Journal of Geology*, 30, 377-392.

Werrity, A. and R.I. Ferguson, 1980, Pattern changes in a Scottish braided river over 1, 30 and 200 years, in: Cullingford, R.A., D.A. Davidson and J. Lewin,. (Eds.), *Timescales in Geomorphology*, Wiley, Chichester, 53-68.

Williams, P.F. and B.R. Rust, 1969, The sedimentology of a braided river, *Journal of Sedimentary Petrology*, 39, 649-679.

Wilson, I.G., 1973, Equilibrium cross-section of meandering and braided rivers, *Nature*, 241, 393-394.

Wolman, M.G. and L.B. Leopold, 1957, River flood plains: some comments on their formation, *United States Geological Survey Professional Paper*, 282-C, 87-107.

Woodsworth, G.J., 1977, Geology of Pemberton (92J) map area, B.C., *Geological Survey of Canada*, Open file # 482.