

'State of the Rivers' Project

Report 1. Development and Validation of the Methodology

By

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EXECUTIVE SUMMARY

The 'State of the Rivers' Project originated from a clear need for detailed and comprehensive information on the physical and environmental condition of rivers and streams in Queensland, especially in terms of the instream habitats, values and condition. The Integrated Catchment Working Committee prepared a Discussion Paper on "The State of the Catchments". This paper reviewed and brought together current knowledge of catchment issues in Queensland. The paper successfully showed that problems exist but it also showed that data on many issues were lacking or were only in a qualitative form and were insufficient for designing or assessing programs of action.

In order to participate in Integrated Catchment Management (ICM), the Queensland Department of Primary Industries (DPI) required objective information on the physical and environmental condition of watercourses throughout Queensland. The DPI has already established programs for monitoring water quality and stream flows on a state wide basis. Assessment of the condition of some river sections has been undertaken by several agencies, but these assessments are restricted in scope, usually focusing on only one aspect of condition such as flooding impacts or fisheries. What was needed was an assessment of the ecological and physical condition of all the State's watercourses, which could be conducted on a catchment by catchment basis using a consistent and objective methodology. The data collected should be able to be related to other available databases (particularly GIS), and should establish a baseline for use in long-term monitoring of watercourse condition.

The State of the Rivers Project was initiated to satisfy these needs. Information was required to assess the effects of past activities undertaken or regulated by the DPI and other bodies, and to plan for activities and programs to monitor and to protect the beneficial uses of the State's watercourses. The project was seen as providing fundamental data on instream condition and values which could only be obtained by conducting specific surveys. Remote sensing of various types such as Landsat and aerial photography and catchment based data collection cannot provide this information.

The project is therefore seen as an important part of the ICM process which can provide information for identifying key issues, problems and priorities, for recognising the processes causing the degradation and for initiating the first steps to finding the solutions. The package produced for the 'State of the Rivers' project includes this report on the development of the methodology and a companion report in the form of an implementation manual including a training programme. It also includes a datasheets and database system for compiling the information, and a set of programs for entering and analysing the survey data collected.

There are a number of key aspects of the methodology which are fundamental to understanding the approach taken.

Consultation

Extensive consultation was undertaken for developing the methodology. The methods are basically a development from the Victorian State of the Rivers surveys (Blyth, 1983; Mitchell, 1990) and environmental flow studies (Anderson and Morison 1989). A literature review and consultation within DPI and other departments and with potential user

groups was used to refine the methods for use in Queensland and to meet the specific objectives of the project. Two workshops were held to obtain feed back from a wide cross-section of interested groups and individuals.

'Snap-shot' Approach

The methodology is focused on taking a 'snap-shot' of the conditions of the stream *now*, that is at the time of the survey. It does not itself aim to establishing trends or the dynamics of the changes in condition. It was recognized that the long term consistent record of stream conditions was not available to form the basis for determining the rate of change and the current trends or processed: The surveys establish a baseline against which future trends can be determined through follow-up surveys. It is also possible to estimate the current condition in terms of a perceived extent of deterioration in condition compared with the original pristine condition. Local undisturbed sites in the catchment or in the region are used to establish a regional standard against which the change in condition is assessed on a scale from 100%(= pristine) to 0% (= extremely degraded).

Comprehensive Surveys

The method depends on undertaking a series of rapid but very comprehensive surveys at a large number of sites in each catchment. There are 13 sets of datasheets each of which has a separate linked database in the system.

- Subsection data (sub-catchment data for each. stream section)
- Hydrology and Water Quality (provides links to other sources of information)
- Site Description (each site is a stream reach within a homogeneous stream section. The sites are selected to be representative of the physical and ecological habitat and condition within each section)
- Environs (information on land use, vegetation, land tenure for the land immediately adjacent to the stream section.
- Channel Habitats (classification of the reach into basic types such as pools, riffles, runs, cascades, rapids and backwaters, and the percentage and dimensions of each type present.
- Channel Dimensions (simple cross-sections are taken through the deepest point in a pool and the shallowest section throughout a flowing habitat section such as a run or a riffle, to present the extremes in terms of channel dimensions and sediment particle sizes present. The cross-section is extended from bank top to bank top and includes sediment analysis across the channel and on the banks).
- Bank Condition (the dominant process is established - stable, eroding, slumping or aggrading. The factors contributing to the instability, and the likely causes are also surveyed).
- Bed and Bar Condition (the condition of the bed and bars is established)
- Vegetation (the vegetation structure and density is established in terms of foliage cover. Riparian and submerged, floating and emergent aquatic vegetation are assessed).
- Aquatic Habitat (the condition of the aquatic habitat is assessed in terms of the instream cover by organic debris - logs, branches, etc. and vegetation. The canopy cover, bank cover and depth/ width relationships in the channel and sediment types are also included.
- Scenic, Recreational and Conservation Values

Simple Survey Design

The surveys were designed to be undertaken by untrained technical staff of the DPI. The package includes a training programme to introduce the survey teams to the concepts required. This aspect was tested during a pilot survey and it was very successful. This has been achieved by extensively using graphics for the datasheets and eliminating the need for coding sheets. Only simple and readily available equipment was required. The surveys could be undertaken by other groups and individuals.

Resource Requirements Paramount

The methodology was designed with a careful consideration of the resources required. Large numbers of sites are required in each catchment, but the rapid survey techniques allow the surveys to be completed within a reasonable time. The surveys are undertaken by teams of two persons who should be able to complete 8-10 sites per day including travelling time between a group of sites within close proximity. Two such teams should be able to complete the 250-300 sites required for a catchment the size of the Mary River within 3-4 weeks.

Links to GIS and Integrated Catchment Management

The methodology includes explicit links to GIS both for final analysis and output of the results and as a means of linking the instream data with all the other information about the catchment (land use, soils, geology, slopes, runoff of sediments and nutrients, etc.). A stratification procedure is used to subdivide the rivers and streams into homogeneous sections (homogenous in terms of the physical and ecological habitat and condition at the resolution and scale.. appropriate for the survey). The catchment is sub-divided at each of the section boundaries. The basic unit then consists of a stream section and its associated land parcel. These land parcels are used for the GIS. The package also includes a number code system for the units which allows for real integration in terms of the stream drainage network. This allows the order of the units in the drainage network to be determined at any point along the streams. The relative contribution of each unit upstream from a given point can then be determined in terms of the instream and catchment land parcel information. This allows the source and relative contribution of different units through the drainage network to be assessed. This provides for simple and real integration.

The methods are also designed to provide the fundamental instream data for Integrated Catchment Management. The ratings produced by the analysis allow priorities to be established within catchments by establishing the size, severity and location of the problems, so that limited resources can be directed efficiently. The ratings also allow the dominant processes and cause of the problems in different parts of the catchment to be identified. In one section it may be severe bank erosion, in another a severe loss of habitat value through the loss of riparian vegetation. The methodology is focused on the instream data which can only be collected by survey and which is not available by other means. Comprehensive instream data at a large number of classified and representative sites is fundamental for Integrated Catchment Management.

The data analysis packages allow for the data to be accessed at various levels, initially in the form of the summary ratings and finally in terms of the raw data collected during the surveys. The database runs on lap-top computers and the programs are simple to use. This provides ready access.

Regional Standards for Different Habitat Types

There is a fundamental problem in trying to develop a condition assessment system for Queensland which has such a vast array of different types of streams, both in terms of their original pristine condition and their current condition. How can you compare a rainforest stream with a stream in the channel country or an upper tributary of the Murray-Darling Basin? It is clearly inappropriate to use an absolute rating system which would mean that the western rivers would *a priori* be given lower condition ratings even in their pristine state. A relative rating system has been used, where the assessment is made using the same datasheets, but regional standards are used to scale the rankings in an appropriate way. For example the riparian vegetation of a rainforest stream may originally rank as 100%, whereas the best remnant section in a western stream may only rank as 60%. The raw ranking are maintained by they are also modified as re-scaled rankings. In this case all sites would be multiplied by 100/60 to provide a regional standard for comparison.

Explicit Rating Formulae

The process, concepts and formulae used to produce the overall ratings of the condition have been made explicit at each step. The basic system is to derive a rating for each component from 0%-100%, where 100% represents the pristine or undisturbed condition, or the maximum utility or amenity for the site. The system has been designed so that the weightings can be adjusted during the first phases of the implementation of the project. The formulae and methods used have been made explicit. Once there has been some experience in applying the formulae in different catchments, the formulae would be finalised and applied universally across the State.

Catchment by Catchment

The methodology has been designed to be implemented catchment by catchment for producing single catchment 'State of the Rivers' reports and to service the needs of Integrated Catchment Management groups and various local objectives. It has also been designed to be consistently applied throughout Queensland to eventually provide a State-Wide Condition or 'River Health' assessment. It has also been designed for follow up surveys to be conducted, giving 5-10 year 'check-ups' and to establish trends and to monitor the outcome of remedial measures.

Water Quality Assessment

The methodology is not designed to include water quality assessment as an obligate part of the surveys. The 'snap-shot' approach is not appropriate for water quality assessment which required long-term monitoring to establish seasonal trends and event related processes. However, water quality assessment can be included as an option to establish the variability throughout the catchment at one point in time. Flow data can also be collected and included for similar reasons. The system has been designed to include water quality and hydrology summary statistics in the database itself and to provide ready access to other sources of these data through HYDSYS.

Pilot Study for Testing and Validating the Methodology

A pilot study was undertaken in the Maroochy River catchment to test and validate all aspects of the methodology. This tested not only the survey methods and the general approach taken, but also the training program, and the survey team organization. The training program outlined in the Implementation Manual was developed from this trial. The pilot survey exceeded expectations in the sense that more sites were surveyed

than had been originally targeted. This enabled a complete survey of the Maroochy catchment to be completed. The results of this survey are to be the subject of a separate report.

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1. Aim and Purpose of the Project

The 'State of the Rivers' Project originated from a clear need for detailed and comprehensive information on the physical and environmental condition of rivers and streams in Queensland, especially in terms of the instream habitats, values and condition. The Integrated Catchment Working Committee prepared a Discussion Paper on "The State of the Catchments". This paper reviewed and brought together current knowledge of catchment issues in Queensland. The paper successfully showed that problems exist but it also showed that data on many issues were lacking or were only in a qualitative form and were insufficient for designing or assessing programs of action.

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The State of the Rivers Project was initiated to satisfy these needs. Information was required to assess the effects of past activities undertaken or regulated by the DPI and other bodies, and to plan for activities and programs to monitor and to protect the beneficial uses of the State's watercourses. The project was seen as providing fundamental data on instream condition and values which could only be obtained by conducting specific surveys. Remote sensing of various types such as Landsat and aerial photography and catchment based data collection cannot provide this information.

The project is therefore seen as an important part of the ICM process which can provide information for identifying key issues, problems and priorities, for recognising the processes causing the degradation and for initiating the first steps to finding the solutions.

The purpose of the surveys is to take a 'snap-shot' of the current environmental and physical condition of stream sections within catchments which can be assessed against a local standard representing desirable or pristine conditions (using representative pristine or little disturbed sites in the catchment or region). These data are required to identify processes and causes of the deterioration in condition, and thereby to pinpoint actions needed to rectify the situation. One important outcome is to establish priorities within and between catchments so that the limited resources can be focused on the most serious problems, or the processes which can be most efficiently tackled to reduce the degradation or to start the process of rehabilitation. Establishing the size, extent and seriousness of the problem is a necessary first step in improving the condition of rivers and streams throughout Queensland.

The project is not directed at establishing the trend or rate of change in condition, either now

or at some time in the past. It is quite likely that the major changes in condition are not continuous but are related to natural events such as major floods and cyclones coupled with man-made impacts such as periodic changes in land use or agricultural practices. It was decided that establishing trends was impossible except in a very general way was using historical records, because no consistent and comprehensive data are available. Even the water quality monitoring in Queensland is relatively poor compared with what is available in other States.

However, the project does provide an objective and comprehensive benchmark against which future trends and rates of change of conditions can be assessed by conducting follow-up surveys. The methodology is focused on precisely locating the sites so that they can be re-surveyed easily, using the same techniques. Once surveys have been conducted future trends can be established.

The project is also directed providing some of the fundamental information required to classify rivers streams. Such information is crucial for their management and for identifying river and stream sections which have high conservation and ecological values. It is also important quantifying natural resource type, values and use potential. Currently such classifications can only be based on hydrology and land system information which is clearly inadequate without the detailed instream data.

The project also aims to provide an overview to help identify resource management and utilization practices contributing to the deterioration in physical and ecological condition of rivers. This includes water extraction and diversion, sand and gravel extraction, mining activities and various agricultural and land use management practices.

This assessment of the State of the Rivers will also be of use to Department of Environment and Heritage in compiling "State of the Environment" reports and in preparing and implementing the proposed Nature Conservation Strategy. Other users may include Fisheries Branch of DPI, Local Government Authorities, and River Improvement Trusts and local Integrated Catchment Management and Land Care Groups.

The objectives of the first phase of the project, discussed in this report and the accompanying "Implementation Manual", was to develop and trial a methodology for the State of the Rivers Project. This report discusses the development, trial and validation of the methodology developed to meet these objectives, including a summary of relevant literature. A second report, published separately, consists of a manual for implementation of the methodology.

A primary consideration in developing the methodology was the resources available in terms of time, equipment, personnel (education experience and training). It was anticipated that the study would be conducted progressively on a catchment by catchment basis throughout Queensland, primarily through the use of in-house resources of the Department of Primary Industries (DPI). The methodology had to be suitable for implementation by the DPI's Environmental Scientists with field work undertaken by Regional Technical Officers after a short training program. The method also had to provide for the data needs of ICM and to be compatible with the DPI's Geographic Information System (GIS) application. These aspects were the fundamental constraints for the development of the methodology.

2. Objectives

The purpose of the first phase of the project was to develop and test a methodology to be used by the DPI to gather information on the ecological and physical condition of water courses in Queensland, and to deliver a training program in the use of the methodology to DPI officers. The specific objectives of the project were to :-

1. Provide the DPI with a rigorous, valid and comprehensive methodology to collect information on the ecological and physical condition of streams within catchments.
2. Validate the selected methodology on a selected catchment(s).
3. Develop a database which allows analysis and comparison of the information with other databases such as water quality and land use and which is compatible with the DPI's existing GIS.
4. Provide the DPI with a training package on how to implement this methodology in a way suitable for use by professional and technical officers.

3. Approach, Scope, Requirements and Constraints

The following criteria and conditions outline the basic approach, scope, requirements and constraints for developing the methodology.

3.1 Need for Specific Purpose Surveys

Whilst it was recognised that various pieces of relevant information may already exist for some catchments or rivers, which does provide valuable historical information, and that there are some relevant data already available in various forms, there was a the need for specific instream surveys. The consistency, objectivity, specificity and comprehensive coverage needed for State-wide and Regional comparisons could only be achieved by conducting specific purpose surveys of instream condition.

3.2 Climatic Variation

The methodology should as far as is practical be applicable throughout the range of climates, and types of river and stream present throughout Queensland - from tropical rainforest to the intermittent western draining streams of the Murray-Darling Basin and the braided streams of the channel country. The same methodology should be applicable as far as possible in all these different areas.

3.3 Linkage to GIS and other Data Sources

It was decided that the methodology and database should be developed as an independent stand-alone system which could be operated easily using a lap-top computer to maximize its utility and usefulness by the DPI, and by other State and Local Government

Departments and Agencies, and by ICM and other local groups. However, the system should also be designed to readily and easily interface with other databases and sources of data. The following systems and sources of data were relevant:-

- a) GIS
- b) Hydrology Information (using HYDSYS)
- c) Water Quality Information (using HYDSYS and other survey information)
- d) Catchment based information such as land use, soils, vegetation cover, land system on various maps and through GIS

3.4 Staff for Implementation of the Project

The requirement that the project was to be implemented through the use of in-house resources by the DPI's Environmental Scientists with field work undertaken by regional technical officers after a short training program, meant that the methodology had to be simple and easily understood by staff with varying backgrounds, qualifications and experience. Little direct previous experience with stream condition assessment could be assumed. Also relatively large numbers of staff in the different regions could eventually be involved in applying the program throughout Queensland. These staff would have other commitments and this obviously restricted the resources which could be made available for the project.

This requirement restricted the scope of the surveys in terms of the resources available and the type of technical data that could be collected. It also placed great emphasis on the development of techniques which could be easily taught, learnt and applied consistently by a wide range of staff.

3.5 Requirements for Integrated Catchment Management

To be useful for (ICM) the methodology had to satisfy the following requirements:

- a) The linkage should enable ready access to both the derived integrated condition ratings produced by the programs and databases, and also to the raw data attributes collected during the survey. For example, an overall condition classification of the stream sections within a sub-catchment derived from a combination of riparian vegetation and the condition of the aquatic habitat may be needed for setting priorities and establishing the seriousness of the problem. Then, it may be necessary to look at the raw data to locate sites with specific problems or attributes which have produced these poor ratings. For example there may be a need to locate sites with severe bank erosion, sites where the riparian vegetation has been cleared or severely disturbed, or sites where particular weed species are abundant. The requirement is therefore not only for indicators of the physical and ecological condition, but also the fundamental tools and information to trace the source and cause of the problems, and the processes responsible for the changes.
- b) The methodology should also provide a simple link to land system, land use and other information about the sub-catchment in order to relate the condition of the streams and rivers to catchment processes. For example, the methodology should allow a simple link to catchment data such as land use, slope, soil type, geology, sediment yield, nutrient

sources and transport processes etc. This requires an explicit system for linking the classified stream sections to land parcels in the catchment through the GIS.

3.6 Consultation

It was recognised that extensive consultation was a necessary part of developing a methodology which was widely accepted and would be useful for a wide variety of purposes. This consultation was achieved through the Steering Committee, through a preliminary 'Scooping Workshop', and through extensive consultation during the development of the methodology, especially concerning the scope and content of the surveys and the design of the data sheets. On-going consultation with potential users of the data should continue as part of the implementation of the State of the Rivers Project.

3.7 Level of Detail and Scope

The methodology was developed to encompass a minimum core data set to be collected at each site surveyed. However, it was also considered important that the methodology was expandable allowing for more detailed data to be collected when required and when the expert knowledge was available. This applied to the vegetation surveys and to other aspects of the survey.

Likewise it was important that the level of detail, in terms of the density of sites to be surveyed, and other details were flexible allowing for more sites to be surveyed in certain areas recognized as having particular problems or other needs for more detailed information. This provides scope for the surveys justified for a variety of reasons and to service specific as well as general requirements.

3.8 Resources

The resources available for organising the State of the Rivers Project, conducting the surveys, and producing the analyses were not stipulated. However, the project was planned to be implemented using the DPI's internal resources - not as a separate project with its own resources. This requirement combined with the size of the Queensland, the large number of major rivers present, and the desirability of completing State of the Rivers surveys within a reasonable period of time (e.g. a 5 years period) meant that a rapid assessment technique was required. Pragmatically, it is a matter of making best use of the resources available, and allocating those resources to focus on where they are needed most within a defined timetable.

It was decided that allocating four staff for a period of 3-4 weeks for a moderate size catchment (e.g. Mary River) was reasonable as a starting point for a minimal coverage. It was also decided that the focus should be on surveying as many sites as possible in the time available, allowing a maximum of 1 hour to be spent at each site. This was preferable to the other option of surveying fewer sites in more detail. Minimal and inexpensive equipment and gear was to be required. Any such equipment had to be simple and easily operated by untrained staff.

The adequacy of the sampling effort in terms of the precision and detail required for the output was very difficult to assess or predict. Ultimately some form of a sensitivity analysis

may be used to determine the site density required for the desired outcomes. Initially the sampling density was determined by reviewing the literature and from experience of the author in designing similar surveys. Again the key point is to survey as many sites as possible for the resources available using a stratified sampling procedure to improve, the sampling efficiency. Past experience has shown that it is better to focus on a rapid technique and to sacrifice some detail in the data collected at each site in order to survey as many sites as possible.

3.9 Establishment of a Baseline for Future Follow-up Surveys

The methodology should be able to be repeated in the future to assess trends and the rate of change in condition. This meant that the methodology had to include precise methods for locating the sites which would not be obscured by time, preferably satellite navigation systems. The surveys and data attributes also had to be suitable for follow-up assessments.

3.10 Base Maps and Variability of Supporting Information in Different Areas

The availability of base maps and other supporting information such as geology, soils, land system classification, land use, water quality, flood studies, etc. varies a great deal in different areas. It was important that the methodology was flexible - making use of all relevant data when it is available, but not being reliant or dependent on such data or other information.

The methodology needed to be designed to interface with GIS both as a source of data and as a method for analysing and generating data summaries and reports. However, currently very little of the basic information on streams and rivers, even topographic maps, are currently available at the preferred scale of 1:25,000 or 1:50,000 for such use of GIS. It may be several years before complete coverage of Queensland is available at 1:100,000 scale. The methodology therefore had to be flexible and able to use the GIS information when it was available but not be reliant on it. It would also be desirable to develop simple report generating programs that enabled simple mapped output to be produced independently of the GIS system. Again the availability of suitable GIS varies amongst the potential users of the information. The database system was therefore required to be independent in its operation with flexible linkages to GIS and other systems for input and output.

3.11 Habitat Assessment - Not biological, community or ecosystem measurements

The basic approach was to estimate the ecological condition in terms of the condition of the instream habitat rather than by conducting flora or faunal (fish and macroinvertebrate) surveys. Such an approach was justified in terms of the limited knowledge of the staff to be involved in the survey and the basic lack of understanding of how to interpret the results of such surveys. There are also practical difficulties of dealing with variations in season and flow, which mean that a single 'snap-shot' would be inadequate. Also no system for classifying the communities and habitat types in different areas has been developed so that it is difficult to decide when, where and what to survey. The approach therefore has been to focus on the broad habitat attributes recognized as being of general, rather than of specific importance, to instream and riparian flora and fauna such as fish, macroinvertebrates, birds, mammals, and riparian and aquatic vegetation. The habitat was surveyed comprehensively

for many attributes of general importance rather than individual attributes essential for specific species or communities. Many of the attributes surveyed have relevance both for the physical and the ecological condition, for example the particle size of the sediments on the bed and banks.

3.12 Upstream and downstream limits

Downstream, it was decided that the surveys should include both freshwater and estuarine areas. The downstream survey limit was therefore set at what is generally and locally recognised as the mouth of the rivers. Including the estuarine areas complicates the interpretation because estuarine areas have different communities. The processes affecting the channel and banks are bi-directional (tidal) rather than uni-directional as they are in rivers and streams. This inevitably means that the estuarine areas will have to be classified and dealt with separately in the analysis. There are also some differences in the ways the estuarine and non-tidal riverine areas are administered and managed. Nevertheless it was recognised that the estuarine areas should be included for completeness, recognising the obvious linkages between river condition and the condition in the estuaries through the processes occurring in the rivers and catchments. However it was also decided that the major focus should be on freshwater non-tidal areas.

The upstream limit was hard to define, but it was decided to exclude the streams in the headwaters that did not have a defined channel and to concentrate on the perennial, seasonal and more or less permanent streams. The major emphasis was on the larger perennial and seasonal streams (water depth > 0.2 m). Clearly the types of stream present will vary greatly in different areas throughout Queensland and the choice for the upstream limit may have to vary in different regions and catchments. In terms of land and land use the survey were extended to the catchment boundaries.

3.13 Catchments as the Unit for Survey and Assessment

Catchments as defined by the Australian Water Resources Council formed the basic unit for assessment. Each survey is directed at classifying and assessing the physical and ecological condition of the streams and rivers within the boundaries of a catchment or a major sub-catchment. The larger catchments may need to be sub-divided. Catchments extending across DPI Regional boundaries will need to be surveyed by the one team jointly organised by the Regions.

3.14 Intermittent Streams, Braided Channels, Channel Country Streams

The methodology should be suitable for the wide variety stream types present in Queensland using the same survey methods and approach. The methodology is directed at intermittent and permanent streams, but clearly there will be problems in dealing with braided streams where the channel is not clearly defined or permanent. Streams with dry beds can still be surveyed, and also the survey may be directed at billabongs and water holes. However, some adaptation of the methodology will be required for the streams in the channel country. Once again the methods are directed at more or less permanent water courses with defined channels.

3.15 Water Quality and Stream Flows as Options in the Survey

Modification to the natural flow regime and water quality changes are obviously very important parts of assessing the overall condition of streams and rivers. However, a single survey of flows and discharges and water quality throughout the catchment will provide little information on the average, range or longer term changes in flows and water quality. This requires analysis and interpretation on long term records to deal with the temporal component, including specific and relatively rare events such as floods and peak flows. It was therefore decided that water quality and stream flow measurements would not be an obligate part of the surveys. However, appropriate interfaces and links with flow and water quality data were required so that summaries from other sources could be used in the analysis. Also it was recognized that water quality assessments and flow measurements across the whole catchments at one point in time could be very useful to examine the spatial variability and the adequacy and representativeness of the existing long-term monitoring programs based on very few sites. Specific surveys water quality and hydrology surveys may therefore be useful and should be accommodated within the methodology. Therefore it was decided that flow and water quality measurements could be included as an option during the surveys.

4. Literature Review

This review concentrates on the methods and approaches available for assessing the environmental and physical condition of streams rather than on what is already known about the condition of Queensland Streams and Rivers. An annotated bibliography of literature on the condition of Queensland Streams and Rivers has been prepared by Arthington (1992). The review is also focused primarily on methodologies and approaches which have been developed in Australia. Reviews of literature for developing the survey components and data sheets are dealt with in the section on the survey components (see section 7.).

4.1 Australia Wide and Federal Government Initiatives

The Status of Australian Streams and Rivers (with reference to the Status of Recreational Fish Species) published by The Australian Recreational and Sport Fishing Confederation (1991)

In 1988 the Australian Recreational and Sport Fishing Confederation commissioned a study with the broad aim of assessing the status of Australian streams and rivers, with primary focus on the state of knowledge of freshwater fishes, particularly those of recreational importance. This study was essentially a literature review which aimed

- 1) To identify the major and minor changes threatening freshwater fish.
- 2) To assess the status of recreational and sport fish populations based on both research and the experience of long term anglers and commercial fishermen.
- 3) To establish and list the literature available in relevant government departments and other research centres relating to freshwater bodies and to identify the status of ecological knowledge about important fishing waters.

The following threats to fish and fish habitat were identified (mostly derived from O'Brien et al. (1983)).

- Effects of Dams on rivers in affecting fish passage, altering the physical habitat, inundation, and downstream effects on flow regimes, increased erosion due to reduced sediment loads and increased velocity, and water quality.
- Deterioration of water quality in urban waterways
- River 'Improvements' and Flood Mitigation Works - river straightening, use of willows for bank stabilisation, desnagging, dredging, elimination of floodplain wetlands through drainage, levee banks and flood gates.
- Extractive industries for sand, peat clay, gravel loam, diatomaceous earth and mineral sands leading to alteration in water depth, increased turbidity,
- destruction of reed beds, altered drainage patterns, reduced aquatic plant growth and reduced utility of wetland areas.

- Inappropriate catchment land use and management - large scale clearing of land for agriculture and forestry without of riparian buffer strips and fencing to keep stock off the banks and riparian areas; increased erosion and increased sediment loads; nutrient enrichment; and problems with willows.
- Biological effects of major water pollutants- plant nutrients, organic wastes, sediment and silt, heavy metals, heated water releases, pesticides, petrochemicals, salt, polychlorinated biphenyls.
- Inappropriate fisheries management.

This publication also summarised what is known of the fish distribution and threats to fish in the major rivers along the east coast of Queensland mostly derived from Garman (1983).

Federal Government

Ros Kelly, Minister for the Environment invited CSIRO to report on the issues of "Towards Healthy Rivers", as a technical report setting out the major issues and prescriptions for improvement. The aims of this report was to answer the following questions:

What is a healthy river?

Are our rivers healthy?

How have they got to their current condition? How can we improve their health?

The report has not been released at the time of publishing this State of the Rivers Report, but there would appear to be many similarities. The discussion paper issued by Bob Wasson, CSIRO, Division of Water Resources, Canberra Laboratories (17/8/92) recognizes that river health has physical as well as biological components, and this aligns with the assessment of the physical and ecological condition of streams in the 'State of the Rivers' Project.

There is a major emphasis on water quality and the establishment of receiving water limits for toxicants, but an overall focus on identifying the "fundamental states and processes that must be maintained by relying upon the concepts of ecology and geomorphology." The concept of the need to classify rivers and streams both within and between catchments and to recognise the wide range of uses for river habitats is also included. This project therefore is of considerable relevance to the 'State of the Rivers' Project.

4.2 Queensland

Annotated Bibliography of Literature on the Condition of Queensland Streams and Rivers (Arthington 1992)

Arthington (1992) provides an annotated bibliography of literature on the condition of Queensland Streams and Rivers. Many of the studies being conducted in the Johnson River are also of relevance though they have not yet been published. Studies by Fisheries Division of fish and fish habitat in the Johnson and Mary Rivers have many similarities as the habitat assessment methods were developed by the author for a fish survey database in Victoria. These methods in turn were adapted from those developed by Anderson

and Morison (1989). Many of the other criteria used for the State of the Rivers Project have also been adapted from this same study.

Consultation for the 'State of the Rivers' Project

The project to develop the methodology involved an extensive consultation to identify methods already in use for existing projects in Queensland and potential users of the data that would be collected. All relevant Departments were contacted in various ways to ensure that this was thorough and comprehensive. It included a 'Scoping Workshop' (see 5.2), reviews and workshops organised through the steering committee, and discussion with a wide variety of individuals and groups with relevant information. For example, Fisheries Division of DPI organised a meeting to discuss their response and data requirements.

4.3 New South Wales

New South Wales Rivers and Estuaries Policy - State of the Rivers and Estuaries Environmental Indicators - A Literature Review.

The NSW State Rivers and Estuaries Policy sets clear objectives for sustainable natural resource management, which is dependent upon a sound knowledge of the condition of the resources, the existing and emerging problems and the trends towards either further deterioration or improvement. The policy proposes the compilation of periodical State of the Rivers and Estuaries Reports - every 2 years regionally in each Total Catchment Management Region; every 4 years for statewide State of the Rivers and Estuaries Reports. These reports will monitor trends in resource condition and will assess whether the management strategies proposed by the various component policies are appropriate. As the first stage in this process a Pilot River and Estuaries Resources Study of the Orara River on the NSW north coast was undertaken (as yet unpublished). This study has two components:

1. The identification of a set of environmental indicators with which the condition of the rivers and estuaries could be assessed over time, and the success or otherwise of various strategies for sustainable management.
2. The search for existing data sets which will enable measurement (either qualitative or quantitative) of the indicators.

The approach is focused on using a set of preferred indicators which are monitored regularly to assess changes in the condition of rivers and estuaries over time. Initially the approach is to collate existing data held by State and Local Government agencies and the community to see whether there is enough data already being collected which can be used to assess the preferred indicators. Shortfalls in appropriate data and its accessibility will also be investigated. There is no commitment for the NSW Department of Water Resources to collect the resource information on its own even if the need for new information is identified. To date a draft literature review on environmental indicators has been published (Anon 1992). This states that appropriate indicators of the condition of rivers and catchments should satisfy five conditions if they are to help to reverse the trend of river deterioration (Anon 1992):

1. The indicator must provide a sensitive reflection of changes in the river and stream. Commonly used physico-chemical indicators alone are not sufficiently sensitive to environmental changes.
2. The indicator should be measured relatively easily.
3. For the indicator to be useful in providing information on the trend in quality over a period of time, adequate long term data bases must be available.
4. Key indicators should be chosen for their pivotal position in the system so that changes to the indicator are likely to be of importance to the entire system.
5. Indicator variables should also be causally linked to human impacts where negative impacts need to be determined.

Several different types of indicators were looked at in this review which considered the methods of using the indicator, what the indicator says about the river estuary or catchment, the possible causal links to human impacts and the appropriateness and applicability of the indicator.

1. **Water Quality Indicators** - these include the usual set of physico-chemical parameters - turbidity, temperature, pH, conductivity, phosphorus, nitrogen, chlorophyll-a, soluble organic carbon, silica, dissolved oxygen, biochemical oxygen demand, faecal coli forms and *Escherichia coli*, and a range of specific toxic substances (heavy metals etc.). Various water quality indices, standards or criteria are then set against which to test the indicator. The use of these indices recognises that there will be natural variation in the indicator in time, and in different type of rivers and streams, and that minimum standards or criteria may need to be established for different areas or for different resource uses.
2. **Ecological Indicators** - these include a range of biological indicators involving both single species and taxonomic groups (riparian, catchment and aquatic vegetation). Single species indicators included shrimps, amphipods, bivalve molluscs and selected fish species. At a higher level the indicators included macroinvertebrate community structure; fish kills and fish community structure; algal abundance and species composition; macroinvertebrate community structure; aquatic macrophytes, and waterbirds. Also included were habitat diversity and habitat condition, the number, distribution, type and condition of wetlands, and the presence or absence of key vertebrate fauna (platypus, water rat and waterbirds).
3. **Geomorphic Indicators** - these included erosion, gullyng, floodplain scouring and siltation, total stream length, changes in pool/riffle sequences and width/ depth ratio, sinuosity, estuarine siltation, sediment analysis.
4. **Hydrologic Indicators** - Changes in flow frequency and magnitude, flood extent, duration and recession rate provide various indicators of the direct and indirect impact of human activities on rivers and streams. Changes in watertable and extent of water logging are also important signs of change. Estuarine tidal limit and tidal flushing are important in estuaries.
5. **Human Indicators** - These include changes in land use; river regulation; river

management works; extractive industries; revegetation programs and riparian fencing; specific human impact indicators for estuaries; incidence of water related health problems, community attitudes; and population size.

For each water quality indicator examined a brief summary is provided of what is indicated about the river or estuary, the causes and influences, feasibility and practicality, units and standard methods and alternative measures (Anon 1992). The review is neither critical, comprehensive nor conclusive about the merits or otherwise of this approach and the selection of preferred indicators.

The indicator approach therefore depends upon the notion that one, or relatively few environmental parameters can be measured in a simple way at regular intervals to provide a "early warning system" to detect signs of serious deterioration. It also depends upon knowledge of the how the parameters vary naturally in time and space, and the definition of appropriate thresholds against which to assess changes and trends. The following aspects of this approach illustrate that it is unlikely to be useful for the 'State of the Rivers Project' in Queensland:

1. The requirement that adequate long term data bases must be available to establish trends in time can not be satisfied except for stream flow data and perhaps for water quality information. Additionally the high variability in climatic conditions, flow regimes, water quality and stream biota makes it difficult to establish trends. This means that longer periods of monitoring are required with a strong seasonal basis (Bennison *et al* 1989). The failure to set clear and specific objectives for water quality monitoring undertaken by State agencies (Cullen 1990) has meant that what have been monitored in the past and the sampling regimes adopted have not been purposely designed for monitoring change in condition. In addition, water quality monitoring in Queensland has been less comprehensive than in other states such as New South Wales and Victoria. No long term consistent records are available State wide for Queensland. Only the stream flows have been monitored consistently and over a sufficiently long period to be used as indicators.
2. The concept of using an indicator to monitor change, to monitor trends or as an "early warning system" implies that only few parameters are measured. Also while these parameters are selected to be sensitive of environmental change, they may provide little if any information upon which action can be taken to reduce the perceived impact. As such the indicator concept provides very limited information for ICM. It is implied that the information on the processes causing the problem, it's origin and source, and relative severity in different areas is being gathered elsewhere, or is already available. It therefore signals that change has occurred but provides very little additional information on how, when, where and in what way action should be taken. The requirements for the State of the Rivers project is not only to highlight a need for action but to provide the comprehensive instream information needed for taking such action through ICM. This emphasises the need to monitor and survey a comprehensive range of parameters known to be important in affecting stream condition and factors contributing to the processes leading to the change in the condition as well as the indicators themselves.

Many of the so-called "Ecological Indicators" such as the distribution, width and condition of riparian vegetation are probably not "indicators" in the strict sense, but

are part of a general condition assessment. The riparian zone provides a buffer strip intercepting sediments and nutrients in diffuse runoff, and so may be seen as an important component in affecting the sediment and nutrient loads in the stream. The sediment and nutrient loads are the indicators; the riparian zone distribution, width and condition are controllers - part of the process affecting the size or expression of the indicators.

Therefore a different approach was required for the State of the Rivers methodology. It was required to not only to identify a set of parameters indicative of the condition or state of the streams and rivers, but also to provide the basis for locating the source of the problem and assisting to identify the processes and cause of the problem. This required a strong emphasis on ICM within the methodology itself rather than outside of it, and an ability to link the data collected with other catchment data sources to assist in locating the cause and source of the problem.

3. The initial commitment to trying to use existing data sources rather than undertaking specific surveys is unlikely to provide adequate consistency between catchments. This may be satisfactory for the requirements of each catchment management group but is unlikely to provide for consistent comparisons on a regional or state wide basis.
4. The use of indicators implies that the standards for comparison are identical in all rivers and streams, or that the rivers and streams can be classified into groups which have similar characteristics and responses. This again depends upon the availability of the information upon which to make this classification. This need for a classification of rivers and streams applies particularly in Queensland, which has such a wide range of climates and catchments. Many rivers and streams may have natural ranges of an indicator which would signify poor condition in other systems. This particularly applies to biological and ecological indicators but also to physico-chemical parameters such as dissolved oxygen, nutrient concentrations, salinity etc. Recent efforts have focused on developing measures of aquatic ecosystem condition using the concept of the biological integrity of ecosystems (Karr 1991). Biological integrity in this context has been defined as the ability to support and maintain a balanced integrative, adaptive community of organisms having species composition, diversity and functional organisation comparable to that of the natural habitat of the region (Karr and Dudley 1981). The use of such derived indicators again depends on being able to classify sections of streams within catchments (such as lowland and upland parts) and between catchments into groups having similar characteristics using a process similar to that of "ecoregions" which have been used for regional classification of terrestrial habitats for conservation and management purposes using land system, vegetation types, climate and other parameters. The use of biological integrity or other ecosystem indicators therefore depends on having a sufficient understanding of the ecosystems themselves both in their natural state and which disturbed in various ways and on an adequate system of classifying streams and rivers, within and between catchments into groups sharing similar communities and characteristics. Both of these aspects would appear to be lacking for Australian riverine ecosystems, especially in Queensland where relatively fewer studies have been conducted.

Hydrology, topography (slope and elevation), climate and some form of a land system approach for describing catchment features would appear to be the tools

available for classifying streams and rivers. Again this would appear to be inadequate. Good quality instream channel habitat information (width, depth, flow, substrates, and three dimensional channel shape etc.) are clearly essential for such a classification relating to condition assessment. In some respects the State of the Rivers project should be seen as providing the basic instream data upon which such a classification can be based, and a baseline assessment of habitat condition against which future changes can be assessed.

5. The approach is focused on establishing trends which requires the availability of long term information. The approach adopted for the 'State of the Rivers' Project is that such data are unavailable and that a specific survey is required to establish current condition and to establish a baseline against which future changes can be assessed.

In summary the indicator approach does not appear to be applicable in Queensland, nor does it meet the aims and objectives because : -

- Long term monitoring records essential for use of indicators are not available.
- The data and system for classifying rivers and streams into "homogeneous" groups having similar physical and ecological characteristics are not available nor can they be effectively derived from existing available data.
- The requirement that the condition assessment is made using a consistent approach throughout Queensland for state wide comparisons and the lack of existing data means that specific survey will need to be conducted.
- The output from an indicator approach only signals that the condition of the streams and rivers is changing and it does not of itself provide information as to the source and cause of the problem, nor of how the instream data can be related to catchment and land use information to utilise an ICM approach to initiate action to tackle the problems identified. The requirements for the State of the Rivers project therefore extend beyond the selection of a set of indicators for monitoring stream condition.
- Given the lack of a long term monitoring program the emphasis is on surveying the streams in a consistent and comprehensive way to assess their physical and ecological condition now using a "snap-shot" approach to set priorities for action plans and to set a baseline against which future changes can be monitored.

4.4 Western Australia

The Department of Conservation and Land Management and the Western Australian Water Resources Council, W.A. have undertaken a number of studies related to the State of the Rivers approach (DCLM 1988; WAWAR, 1987; WAWAR, 1990)

The Road, River and Stream Zone System in the Southern Forest of Western Australia. A Review (DCLM 1988)

A network of zones or buffer strips was established in the early 1970's to form a network of mature forest throughout areas where forest was being cut and regenerated by the clear

felling method. These zones provided links to large representative areas of forest set aside in national parks, conservation parks and nature reserves. River and stream zones were established because they were known to be areas of high biological diversity and to protect watercourses. Major rivers have zones of 200m either side (400m total width), most 3rd and 30% of 2nd order streams have zones 100m either side. Stream zones are often extended to interconnect across ridges. Road zones (400m either side) were established to maintain vista of undisturbed forest for travellers through the region. 'Special care zones' are established in areas where there is no stream zone but where slopes exceed 15 degrees or features such as wetlands or rock outcrops exist. Few studies have been conducted into the aquatic fauna of the karri forest or the impact on it by timber cutting and regeneration, but the stream side buffers act to reduce sediment loads, reduce the salinity and temperature increases associated with clear felling, reduce the fall of tree debris into the stream, potentially altering the pattern of water flow and the stream profile and maintain the allochthonous production (i.e. leaf and litter input) to the stream. A review of stream zones by Clinnick (1985) (cited by DCLM 1988) concluded that a width of 30m on either side of the stream was generally required. In some situations (e.g. highly permeable soils and slopes <30 degrees) 20m was considered acceptable, and in other situations >30m may be required. The report recommended the retention of 200m total width on 5th and 4th order stream; 100m total width on 3rd and 2nd order streams and selection criteria for zone allocation for first order streams.

Report on an Investigation into Scientific and Educational Values of Wetlands and Rivers in the Perth-Bunbury Region. (WAWRC, 1990)

The report identifies those wetlands and rivers which have been, or are currently, used for scientific research and educational purposes, and develops a set of criteria for future evaluation of wetland educational potential. The study used an "expert panel" approach where 28 educators and researchers were surveyed to identify significant wetlands and river reaches which were listed and ranked by the panel members. An evaluation system utilising a checklist of ten criteria was developed for use in further describing values of wetlands. Development of the criteria was based upon literature, consultation with survey participants and other educators, experience with the educative uses of wetlands, with a review process using the survey participants. The ten evaluation criteria were:- permanency of water body; representativeness of wetland type, presence of important ecological or geological features; diversity of floral and faunal communities, geomorphic features, or wetland assemblages, pristine or little modified environments; illustrative effects of land use changes, proximity to education institutions; accessibility; availability of facilities; availability of other features of educational merit. Scoring systems were used with each criteria to rank various sites. This study has only marginal relevance to the 'State of the Rivers' project because it deals mostly with wetlands and the scientific and educational values.

Environmental Significance of Wetlands in the Perth to Bunbury Region Volume 1. Main Report . (WAWRC 1987)

This report provides a useful review of wetland classification schemes developed internationally, nationally and for Western Australia. It selects a scheme for classifying wetlands on the basis of landform and water characteristics, and for identifying regions of related wetlands. It also reviews and develops criteria and a procedure of assessing conservation

values of wetlands. The wetland classification system used was based on a combination of water permanence and the shape of the "water container", i.e. cross-sectional landform geometry (basin, channel or flat). The criteria for assessing conservation value of a wetland is a questionnaire approach directed at wetland experts which includes :- representativeness; productive area supporting a fishery; functions in protecting human, animal or plant life; national significance ecologically or geologically; pristine or little modified environment; education value; habitat for rare or endangered species; regional wildlife sanctuary; seasonal or temporary habitat for migratory animals; value as wilderness or conservation area; aesthetics; aboriginal heritage value; recreational value; value as part of a linked natural system; and social values. A 5 level rating system was used for the evaluation.

State of the Rivers of the South West Drainage Division (Olsen and Skidmore 1991)

This review was conducted to create a new awareness of the plight of the rivers among the community as a whole. It is essentially a position statement and a review of issues based on existing information. The study reviewed existing sources of information and no instream surveys were conducted.

The report aimed to identify the major forms of degradation to which rivers in the South West are subject; assess the extent to which the rivers suffer from each form of degradation; report briefly on the history of land and river management that has led to their degraded state; and to identify measures that are needed to restore degraded rivers and to protect those that remain unspoilt.

The major disturbances recognised were loss of habitat diversity; loss of riparian vegetation; erosion of banks and sedimentation of river-beds and estuaries; increased salinity; pollution with nutrients; changes in flow; increased segmentation into isolated sections by dams; the spread of introduced flora and fauna; pollution with toxins such as pesticides and heavy metals; and other changes in water quality. A number of conclusions were reached. Deep pools were in most need of protection. The classification of rivers and their tributaries into conservation categories would enable more explicit consideration of rivers in land use planning processes. The maintenance of habitat diversity, natural flow patterns and adequate flow volumes of unpolluted water were recognised as key requirements for conserving river values.

Recommendations for possible improvements included :- revegetation of riparian zones by excluding stock and replanting or re-seeding.; stabilising river banks and protecting them from erosion by protecting and re-vegetating watercourses and catchments and the use of a variety of run-off management techniques; controlling salinization, excess nutrient discharge and invasion by exotic flora and fauna.

4.5 Victoria

Rapid stream survey to assess conservation value and habitats for invertebrates (Blyth 1983)

This was an inaugural attempt to apply stream assessment and classification techniques

developed overseas (mainly in America) to Australian streams and rivers. The survey approach was based on longitudinal assessment of a range of parameters by teams of bush-walkers starting from the headwaters and proceeding downstream for 3-12km. Observation sheets, notes and photographs were filled in for stream segments up to 50m long for sites selected for their representative nature. Physiography, land use catchment vegetation and some geological details were also collected. Volunteers with limited experience in stream survey were used after a one day training exercise. The focus of the survey was to define the habitats available to the invertebrates of running waters, and also included physical and botanical parameters. An hierarchical scheme was used to collect various types of data which included:

Whole-site description (subcatchment level) - geology, elevation, stream order, terrain type, valley type, land use & vegetation cover, channel pattern, water quality factors.

Definition of the main habitat types (reach or stream section level) - waterfall, cascade, rapid, etc.

Descriptors for conditions within main channel habitat types (at the level of the pool riffle or run etc.) - width, current velocity, depth, total site area, bed substrate characteristics (particle size, shape, sphericity, consolidation, brightness).

Description of individual sampling/collecting points (microhabitat level) - particle size classification, particulate organic matter, aquatic vegetation, width of the riparian zone, percentage canopy cover.

The survey methods were concerned with habitat description and detailed comparisons between streams and sites rather than development of a widely applicable classification. However the features used as habitat descriptors are essentially those recommended by Pennak (1971) and used by Savage and Rabe (1979) to develop classifications of small streams in Idaho, with some alterations to suit local conditions.

This study provided the foundation for most of the stream assessment techniques that were later developed and applied in Victoria with emphasis on a hierarchical classification system moving from the catchment level, to the reach, to the channel habitat and finally to the level of the individual site. The approach using non-expert staff and a rapid largely visual assessment technique are also closely aligned with the 'State of the Rivers' Project. The focus on walking down streams to select representative sites has merit but is only applicable to small catchments, and is too time consuming for large scale work.

Catchment conservation potential was assessed partially in an objective and subjective manner using seven criteria:- richness of habitat types; naturalness; rarity of physical and botanical features; scientific and educational value; representativeness; aesthetic, wilderness and scenic values; and effectiveness as a conservation unit.

A method for identifying all streams of high conservation status. (Macmillan 1983).

Conservation value and status of Victorian Rivers Part III The Wimmera River and its catchment (Kunert & Macmillan 1988).

This approach was essentially a desk-top approach to classifying streams and subcatchments in terms of their conservation status. Catchment clearing and classification of vegetation and land use were important parameters.

Environmental Flow Studies for the Wimmera River, Victoria. - Part B: Fish Habitat Assessment. (Anderson and Morison 1989)

The objective of this study was to assess the effects of river regulation on the condition of the streams and rivers (hydrology, water quality, fish habitat and fish populations) to justify and environmental flow, and to review and recommend appropriate options, strategies and benefits of environmental flows. The methodology and datasheets used for this environmental flow study had been developed by the authors for an unpublished project for developing an hierarchical classification of Victorian streams and rivers in terms of their natural physical and habitat attributes and condition. The methods were an adaptation of the approach of Blyth (1983) and relevant overseas methods adapted for Australian conditions. The approach, procedures and data sheets used in this study formed the basis of that used for the State of the Rivers project. Although the focus was on fish habitat assessment the attributes were generally applicable to macroinvertebrates and to the general habitat features of the stream.

Gippsland Water Resources: Environmental Issues. Background Report (Rice 1987)
Guidelines for Catchment Management
RWC (1987)
The State of the Rivers, Victoria Australia (2nd Edition) SR WSC (1984)
The State of the Rivers and Streams in the Western Port Region.
DWR (1986)
Better Rivers and Catchments.
DCFL (1987)

These reports highlight the problems and issues associated with the degradation of the condition of Victoria's rivers and their catchments, and provide some preliminary approaches to improving the situation.

The Environmental Condition of Victorian Streams (Mitchell 1990)

[Note: This includes the methodology and datasheets developed by J. Tilliard of Ian Drummond and Associates, published in an internal report on the State of the Stream Survey methodology and database, Department of Water Resources, Victoria]

The need for a systematic survey and overview of the condition of Victorian rivers was highlighted by the publication of the various "State of the Rivers" issues publications listed above. A State of The Streams Survey was commissioned by the Department of Water Resources in 1986, to address the lack of quantitative information on the condition of Victorian rivers and streams by establishing the extent of the problem on a state-wide basis and to set priorities for stream and river rehabilitation. This report was the first produced using the results of the State of the Streams Survey and the database produced from it.

The survey examined 868 sections or reaches of rivers and streams which were chosen to

be representative of the stream types present. At each stream section site approximately 200 attributes (mostly qualitative) were recorded describing catchment land use, stream bed and banks, stream verges, channel characteristics and aquatic habitat. The methodology was developed from that of Blyth (1983) and other techniques being developed by other groups in Victoria (e.g. those subsequently published by Anderson & Morison (1989)) through consultation prior to developing the methodology.

An initial stream classification was conducted based on

1. Size - **minor streams** (catchment area less than 5,000 ha)
tributary streams (catchment area 5,000-30,000 ha)
major streams (catchment area greater than 30,000 ha)
2. Catchment Condition - predominantly cleared or forested.
3. Land system (geology and topography) - for cleared catchments.

This initial classification produced 43 stream categories across Victoria. For each river basin, at least one sample was located in each of the categories present and further sites were allocated based on the size categories:

- major streams - one site per 25 km of valley length
- tributary streams - one site per 25 km of valley length
- minor streams with cleared catchments - one site per 200 km of valley length
- minor streams with forested catchments - one site per 500 km of valley length

Sites were chosen to maximize their representativeness and accessibility using 1:250,000 topographic maps, land system classifications and aerial reconnaissance. At each site a sample reach was surveyed which was the shorter length of either 2.5 meander wavelengths long or 25 times the average width of the stream.

The assessment of environmental condition was based 10 environmental factors considered likely to be important for aquatic organisms. The rating criteria varied with the size category for the stream. These factors were:

1. **Bed Composition** - sites with coarse bed materials (boulders, cobbles and shingles) were rated higher than those with finer materials (sands and mud).
2. **Proportion of Pools and Riffles** - sites were rated in terms of the diversity of habitats present.
3. **Bank Vegetation** - sites were rated according to the extent of clearing of the bank vegetation.
4. **Verge Vegetation** - sites were rated according to the extent of modification of the verge vegetation (width, cover and exotic invasion).
5. **Cover for Fish** - instream density cover by snags, boulders and undercover banks was assessed to provide an overall qualitative rating.
6. **Average Flow** - higher velocities were rated more highly.
7. **Water Depth** - only water depths adjacent to the bank was recorded not the channel or pool depths. Deeper sites were rated more highly up to a maximum of 1 m for minor and

tributary streams and 2m for major streams.

8. **Amount of underwater Vegetation** - low levels or very high levels were given a lower rating.
9. **Bed cover by organic debris** - rated according to the percent of bed cover.
10. **Amount of sedimentation or erosion** - sites with extensive erosion or sedimentation were lowly rated compared to stable sites.

A five level overall environmental rating was used

**very poor,
poor,
moderate,
good,
excellent**

This final rating was derived mathematically from the 10 indicators which were given unequal weightings. However, neither the weightings applied, nor the formula used, nor other details about these final ratings were made explicit. Higher weightings were given for erosion and sedimentation, bank and verge vegetation and cover for fish than for the other parameters, some of which were recognised as being of lower quality and reliability.

The length of stream in each environmental rating category was deduced arithmetically in proportion to the number of sites classified into each group in terms of the initial classification of the streams.

Summaries were then prepared on a Statewide basis, and for each basin individually in terms of the length of stream classified into each category. For all Victorian stream, 60% of the stream length was found to be good or excellent environmental condition, 13% in moderate and 27% in poor or very poor condition. In cleared areas 65% of the stream length was rated as poor to very poor and only 5% in excellent and good condition.

The objectives and approach used for this survey were similar in many respects to that required for the 'State of the Rivers' Project in Queensland. It was therefore used along with the methods of Blyth (1983), Anderson and Morison (1989) for developing the methodology.

The Victorian State of the Streams Survey has been reviewed here in terms of the major similarities and differences in approach and requirements in comparison with the 'State of the Rivers' Project and critical comments.

A. Similarities

1. The survey methodology was designed to be conducted by regional hydrography personnel from the Rural Water Commission, after short training program.
2. The methodology was focused on assessing both the physical (bank, bed and bar) and ecological condition (fish cover) of streams or streams and rivers with emphasis on the instream features.
3. The survey elements were stream sections or reaches classified into channel habitat types.
4. Information was collected using a combination of qualitative assessments and

quantitative measurements or various parameters using a set of datasheets.

B. Differences

1. The survey was designed primarily for a state wide assessment rather than
1. providing detailed information for individual catchments or for integrated catchment management. The survey was also conducted throughout the whole state over a short period of time rather than progressively catchment by catchment.
2. The major focus of the survey was on the condition of the bed and banks (stable, eroding or aggrading). The environmental aspects, particularly instream habitat values, received less detailed attention.
3. The survey was not designed to interface with GIS or with catchment information such as land use.

C. Critical Comments

1. Number of sites - Although there were obvious limitation in the number of sites which could be surveyed with the resources available, there was doubt whether the number of sites surveyed was adequate. The site density of one site per 25 km for major and tributary streams, one site per 200km for minors streams in cleared areas and one site per 500km for minor streams in forested areas, would appear to be inadequate especially as no tests were conducted to determine the adequacy of the sampling. For example only 11 sites were allocated for the main Channel of the Wimmera River, whereas Anderson and Morison (1986) allocated 96 sites for their habitat study. These problems were compounded by the failure to describe condition within sub-catchments or regions within a catchment area. This meant that the large number of smaller streams that were not sampled were grouped and classified by sites surveyed in totally different areas of the catchment.
2. Absolute rating system - An absolute rating system was used to derive the environmental condition ratings. Sites with courser sediments, higher flows, riffles and pools present and deeper water were *a priori* given a higher environmental rating. This meant that upland streams were *a priori* rated more highly than lowland streams. There was no separation' between sites which had particular characteristics because of the effects of degradation and sites which had the same conditions, but which were in their original pristine condition. This immediately introduced a number of biases which affected the analysis. There was therefore a failure to recognise a need to classify rivers and streams into basic types and to clearly distinguish and separate the difference arising their natural attributes from those produced by the changes in condition.
 - a) Within any catchment upland stream section with higher gradients would in their pristine condition be rated higher than lowland sites similarly in pristine condition. The failure to separate the natural differences in the attributes due to stream type and location from differences produced by degradation of the stream and catchment made it difficult to provide a realistic diagnosis of the changes in condition which had occurred.
 - b) Catchments in particular regions of Victoria would *a priori* be rated more highly than catchments elsewhere, even in their pristine condition. East Gippsland rivers and streams in the steeper catchments were be rated more

highly than the rivers draining the less steep catchments of the Murray-Darling Basin before considering the effects of degradation. This clearly is hard to justify.

- c) Failure to clearly distinguish between inherent habitat variations and changes caused by deterioration in the habitat meant that the true condition of the rivers and streams could not be assessed.
 - d) Most of the minor streams were naturally located in headwaters of the catchments in the steeper gradient areas where most of the uncleared catchment occurred. This meant that there would be a bias to higher rankings in the minor streams.
3. Environmental rating procedures were not explicit -The derivation of the weightings and other procedures used to produce the overall ratings, combining the 10 environmental factors, were not made explicit. The various components were given different weightings without adequate explanation.
 4. Too great an emphasis on bed and bank stability - Less than 10 of the 200 attributes measured were directed at vegetation and instream habitat values. In terms of other ecological condition survey methods such as Blyth (1982) and Anderson and Morison (1986) the ecological condition assessment was inadequate.
 5. Analysis restricted to individual sites rather than sub-catchments or groups of sites along drainage lines. - No hierarchical system of linking sites through the drainage network was included in the methods. Rivers and streams are linear one-way systems. Consequently disturbances to areas in the headwaters will tend to degrade a series of sites along the drainage lines downstream. Likewise the physical and biological features of streams will tend to be more similar within the same sub-catchment than between different sub-catchments. This applies both to their inherent natural features, and their likely responses to land use changes and disturbances. It therefore appears to be sensible to use sub-catchments and the drainage network as the basis for allocation of the sites and for grouping and classifying the condition assessments rather than using a simple classification based on catchment area. The method of classifying the individual sites surveyed, and then applying these classifications to the total proportion of the length of streams of that size within the catchment was inadequate. It raises questions about the representativeness of the sample.

5. Development of the Methodology

5.1 Basic Approach

To satisfy the objectives and the stated aims of the project the basic approach was to adapt and upgrade the rapid survey concepts of Byth (1983), Anderson and Morison (1989) and Mitchell (1990), to meet the specific requirements of the project and the variability and characteristics of Queensland streams and rivers. These methods have been reviewed in Section 4. These methodologies were considered the most suitable approach for the project. Extensive consultation was undertaken with various Queensland Government Departments and Universities to discuss concepts, ideas and potential uses for the data during the development phase of the project. This consultation was continued to refine the early drafts of the data sheets and other aspects. Extensive feedback was also obtained from the Steering Committee drawn from various Departments.

5.2 "Scoping" Workshop

An introductory workshop for the State of the Rivers project was held on 9 April 1992 with invited participants from a wide range of Departments and interested groups (WRC, Fisheries Division, South East Regional Office of WRC, Queensland Forest Service, Land Conservation, Agricultural Chemistry, and Natural Resources Management). The aims of the workshop were to :

- make people aware of the project;
- to identify and prioritise the future issues in river management for which data on ecological and physical condition would be required;
- to identify existing studies and resources relevant to the project;
- to identify, as far as possible, the kinds of information each type of management task required.

It was seen as important to ensure, from the outset, that the data collected for the State of the Rivers surveys was relevant to the specific needs of all potential users in land and river management. It was also necessary carefully consider and plan the methodology to accommodate present and future needs as the methodology was intended to become a standard practice for many years to come. The workshop identified a total of 51 issues. Eight major issues were identified:

- Provision of environmental flows;
- Conserving aquatic and riparian fauna and flora;
- Managing sand and gravel resources;
- Controlling and reducing erosion and deposition in streams;
- Protecting water quality;
- Conserving instream and riparian habitats;
- Understanding the effects of land management on water quality, habitat and flora/fauna;
- Protecting areas of scenic and recreational value.

The group also identified a number of specific considerations for the methodology. These included:

- the need to identify trends in river condition;
- the problem of monitoring the effects of extreme events;
- the need to identify response times for variables;
- the benefits of a hydrological/regional classification of rivers;
- the benefits of developing a database of projects and studies;
- the need to establish links to related studies (e.g. wetlands survey and marine park monitoring).

Major Concepts and Elements of the Methodology

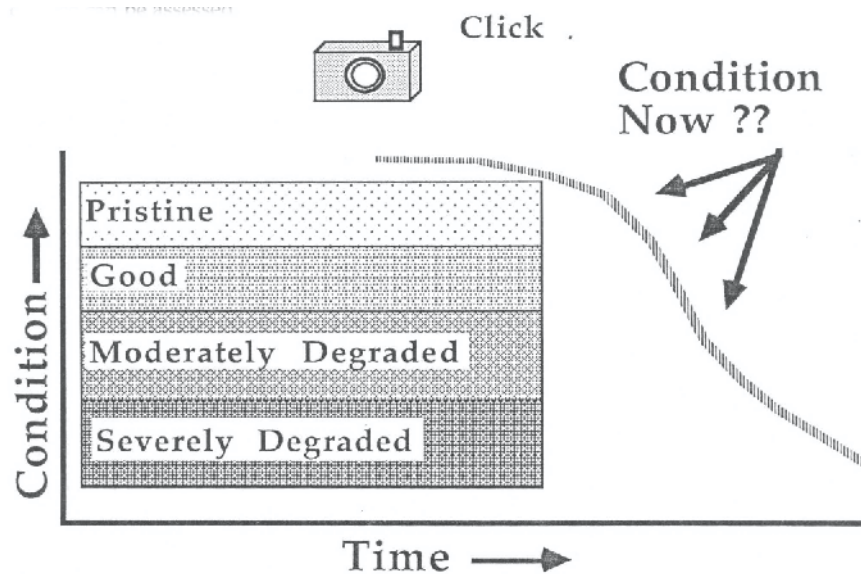
5.3.1 Habitat Condition rather than floral or fauna surveys or assessment of community structure or integrity.

This has been already discussed in section 3.11

5.3.2 A 'snap shot' approach used to assess condition

What is meant by condition and how is it assessed? The method adopted is a 'snap-shot' approach. The aim is to compare different stream sections within catchment, and different catchments in terms of their current condition now, and to assess the extent to which that condition has deteriorated from the original pristine condition or some other standard in terms of the parameters being assessed. Such a 'snap shot' also sets a bench-mark for future comparisons, but does not itself directly measure the rate of change or trend. The problem with assessing trends and the rate of change is that there is no consistent set of historical data against which to compare the present condition of the stream. Historic data such as aerial photographs, local photographic records or recollections or local residents may give a valuable perspective for the 'snap-shot' taken now, but the method does not really focus on establishing the time-frame nor the trends for the changes observed, nor do it depend on the availability of such historical information. The availability of such information is obviously a bonus and it should be used during the analysis and interpretation of the data.

The aim of the project is to provide a snap shot of the physical and ecological condition of the stream now to highlight the most severe and urgent problems and to set a consistent and comprehensive baseline against which future trends and the rate of change can be assessed.



5.3.3 Establishing a baseline or benchmark for follow-up surveys

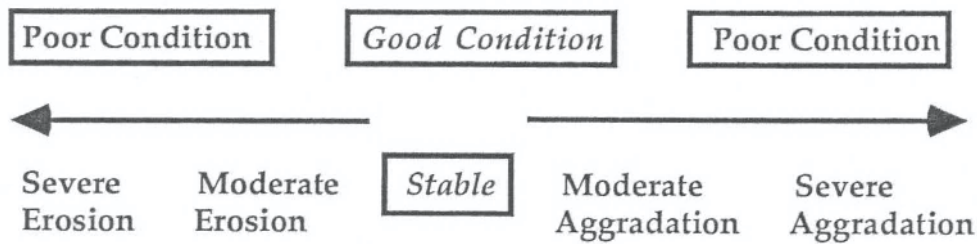
It is important that the methodology allow for future partial or complete follow-up surveys to assess the rate of change or perhaps to assess the effectiveness of remedial measures. This is achieved by adopting a standard methodology which can be easily repeated at a latter date, by including a standard set of photographs, and by precisely locating each survey site using GPS equipment (accurate to between 30-100m).

5.3.4 How is Condition Assessed?

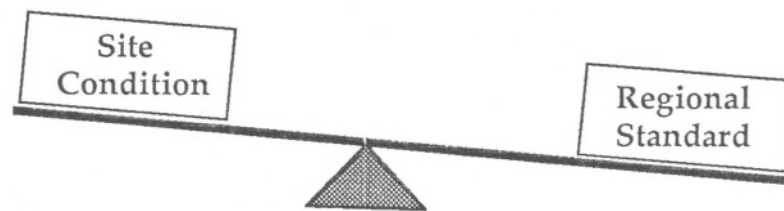
In most instances key concern is the extent to which the attributes, values or perceived functions of streams or rivers have declined from their pristine or undisturbed conditions. The concept of values, uses or functions is important because we are not only interested in conservation values, or protection of the animal and plant communities, but also in the recreational and aesthetic values of streams. We are also interested in their functions and natural resources in conveying and providing water of good quality, in their sand and gravel resources, their biological resources and in their various attributes which affect their functions and utility such as bed and bank stability.

What are the standards against which the change in condition can be assessed? Both absolute and relative standards are used. The stability of the bed and banks is an example of an absolute standard. In assessing the condition of bed and banks we are interested in determining the extent to which the banks have become unstable through either erosion, slumping, gullyng, or the excessive build up of sediments on the bed or banks. Streams and rivers in good condition are assumed to be stable or in a graded state with some form of dynamic equilibrium prevailing between sediment supply, channel form and the sediment carrying capacity of the stream.

Bed and Banks



In other instances the use of an absolute standard may be inappropriate or impossible. For example it would be inappropriate to try to compare the shoreline vegetation of a stream in a tropical rainforest area with that of a stream in south-east Queensland or streams the Murray-Darling Basin in south-west Queensland. The problems with this have already been discussed in the literature review (see 4.5 review of Mitchell (1990)). In these instances the current condition has to be assessed against the attributes for the stream or river in its pristine state or condition. Without historical data we have to rely upon locating pristine or relatively undisturbed sites within the catchment or local region which can be used as standards.



If no remnant sites in good condition area available we have to established the presumed original pristine condition from the data available, including historical data or use sites in other catchments on the same general region. This concept will have to be developed during the course of the implementation of the project as the database is built up and there is more experience with the range of habitat types and conditions present in each area. As an interim measure these standards should be established within each catchment or major sub-catchment type.

5.3.5 Sampling Strategy

The sampling strategy was developed by the author for an unpublished river and stream classification and condition assessment project in Victoria.

What is the most appropriate and efficient sampling procedure to enable the relative condition of stream and rivers in a catchment and in the State to be assessed? As in any sampling procedure the final choice is a compromise between the ideals of ensuring a valid statistical procedure is adopted that adequately represents the conditions present, and the pragmatic constraints of available resources, existing information and access. The following points are relevant :-

- Random sampling is likely to be very inefficient than stratified sampling because neither the natural attributes of the streams nor or their condition are randomly

distributed.

- Rivers are linear systems with their sections interconnected through the drainage network. Therefore what happens upstream in a tributary channel or a sub-catchment area in the headwaters will affect a series of interconnected stream sections downstream in a cumulative way. Therefore we expect rivers to change progressively down the drainage lines and for adjacent sections of rivers to be relatively homogeneous both in terms of their natural attributes and their condition.
- It is expected that the classification of streams into various types and their condition will not be independent. Certain types of streams will be more susceptible to deterioration than others. For example, streams with rock, cobble and boulder substrates will be less susceptible to head ward erosion than section with sands or mud.

Therefore a stratified sampling technique is likely to be much more efficient and more relevant for the survey.

The other major consideration is the method for the stratification and the availability of relevant data upon which it can be conducted. To-date there is no habitat classification system for streams in Australia that covers the diversity of stream types present in Queensland. The methods and data for conducting such a classification are inadequate or unavailable. There is a reasonably good hydrological record, but there has been no agreed approach to producing a hydrological classification in Australia which is meaningful ecologically. The other important data as substrate particle size, channel depths, widths and gradients, etc. are not available. Indeed the State of the Rivers project is seen as representing a major potential source of the comprehensive data required for such a classification.

Likewise it is known that changes in the catchments and sub-catchments through clearing and other land use changes are largely responsible for changes in condition of the stream by changing runoff dynamics, nutrient loads and movements and a range of other influences. Also the construction of dams and weirs, and water extraction and stream diversion have major influences on flow regimes and sediment transport patterns in downstream areas. Various catchment information is therefore also a good potential basis for stratification as well as the natural attributes of the stream. However, again we lack any comprehensive and consistent data about catchments and sufficient understanding of the processes involved to apply such information to streams.

Nevertheless, despite the lack of comprehensive data it is still important that we use whatever data is available as the basis for such a stratification and the allocation of the restricted sampling effort. The approach adopted is somewhat of a compromise but it allows for a flexible approach using the limited data that is available at the time, and encouraging the use of more of this data as it becomes more widely available in a useable form as a GIS. The focus is on using existing data to allocate the samples and then using the data collected to re-assign the sites to the strata after the data collected is analysed. This can continue as an on-going process as more data becomes available.

5.3.6 Preliminary System of Classifying Catchments and Sub-catchments

Several authors have sought to integrate land and aquatic classifications (Lotspeich & Platts 1982; Beschta & Platts 1986; Odum (1990) and have developed the concept of considering

water sheds and catchments as ecological systems (Odum 1969; Lotspeich & Platts 1982; Odum 1990). There have also been attempts to examine the links between biotic assemblages; species richness, diversity and composition, similarity and dissimilarity; and physico-chemical measures and various stream classifications (Harrel et al, 1962; Platts 1979; Matthews 1986; Hughes, R.M., Rexstad and 1987; Davies 1988; Swanson, Miles, Leonard and Genz 1988; Whittier et al 1988; Copp 1989; Boulton & Lake 1990; Poff and Ward 1990; Heede and Rinne 1990). Also there have been attempts to use an integrated catchment management approach to water quality management which takes account of the classified natural and disturbed attributes of catchments (Larsen et al, 1988; Hawkins and Geering 1989; Smart et al. 1985; Beck & Finney 1987).

Naiman et al. (1992) provide an excellent review of the general principles of classification and the assessment of conservation potential in rivers.

"Ideally, a classification scheme should be based on a hierarchical ranking of linkages between the geologic and climatic settings, the stream habitat and the biota. These - the geomorphic and climatic processes that shape the abiotic and biotic features of streams - provide a conceptual and practical foundation for understanding the structure and processes of fluvial systems." page 96.

"A successful classification system should be able to categorize the types and frequencies of disturbance that may impact the stream and predict adjustments in the physical and biotic characteristics." page 98.

The ecoregion concept that was intended to delineate large areas ($>10^3 \text{ km}^2$) based on climate, physiography and vegetation - which were thought to be the most important in stratifying in channel features - have been applied for water resource and fisheries management in the USA (e.g. Bailey 1978; Rohm et al. 1987; Larsen et al. 1986; Whittier et al. 1988; Omernik 1987). This is similar to the ecoregions which have been developed for classifying terrestrial habitats in Queensland for conservation purposes based on similar techniques (Stanton & Morgan 1977). However it is recognised that intensive field investigations based on actual measurements and subsequent classification using clustering techniques (Pennak, 1971; Cushing et al., 1983) are potentially more valuable than *a priori* concepts (Naiman et al., 1992).

Various attempts have been made to recognise the physical and biological attributes which are of fundamental importance for classifying catchments and sub-sections of catchments (Larsen et al. 1986; Rogers and Singh 1986; Miller and Onesti 1988; Huang & Ferng, 1990; Anon 1992; Naiman et al., 1992). The following table summaries the most important attributes.

Catchment and Sub-catchment Level

Type	Attributes
Topography	Altitude Catchment Slope Stream Gradient
Geology	Geology of the Catchment and stream bed or base
Soils	Parent Material Texture Drainage
Climate	Source of bed and bank sediments/supply Rainfall pattern & season Temperature Evapo-transpiration
Vegetation	Type Cover Forestry Practices
Land System	
Terrestrial Ecosystem	
Aquatic Ecosystem	
Drainage basin pattern & network	Number of streams Stream Order Mean Basin Elevation Total stream length Width/depth Ratio Frequency Drainage density Bifurcation ratio Substrates Stream Gradient Sinuosity
Channel morphology and flow	Stream discharge Width Depth Wetted area/perimeter Mean velocity Pool volume / remnant pool volume Gradient Habitat types Diversity of channel habitat types(pool, riffle, etc.)
River Management	Channelization Bank and bed stabilisation works
Extraction Activities	Mining (gold, sand-dredging, etc.) Sand and gravel extraction
Water Abstraction and diversion	Dams, weirs
Natural and Artificial	Waterfalls, cascades, barrages, weirs, dams

barriers diversions	
Hydrology and water management practices	Flow regimes Flooding frequency and hydrograph patterns Variability, seasonality and consistency of flow Low flow events and droughts Environmental flows
Stream Assimilative Capacity Ecosystem Indices	
Indexes of Biological and community Integrity	
Water quality indices	

Reach Habitat and Microhabitat Level

Type	Attribute
Physico-chemical parameters	Temperature Water chemistry Pollutants
Habitat structure	Diversity of Habitats Instream cover Substrate Bank cover Riparian aquatic and emergent vegetation Depth, velocity and substrate patterns Invertebrate drift abundance Specific habitat attributes Bed and bank stability

The systematic use of these concepts and parameters to classify the streams as part of the sampling procedures is not possible because no such classification system has been developed in Australia and very little data is available. Nevertheless the fundamental importance of such a classification means that what data is available should be used to identify stream sections which have similar basic features and attributes as the basis for the sampling. This is initial subdivision is made using vegetation, land use, geology and topographic maps and other data sources. This initial sub-division is then followed up by visual inspection of the sites during a reconnaissance phase of the survey. The establishment of sub-catchment elements associated with each of the stream subsections and their location in the drainage network (discussed later) allows relevant catchment data to be incorporated into the database, and for the sub-sectioning to be upgraded and refined as more data becomes available.

5.3.7 Why biological and ecological indicators were not surveyed to provide the classification?

Classification systems based on biotic communities serving as integrators of ecological conditions (fish (e.g. Karr, 1981; Fausch et al, 1984; Karr et al 1987; Karr 1991); invertebrate assemblages (e.g. Cummins 1974; Wright et al., 1984; Faith et al., 1991); riparian vegetation (Harris 1988) and aquatic plants (Holmes 1989)) have been put forwards as perhaps the ultimate and most sensitive indicators of environmental vitality (Naiman et al, 1992; Anon 1992). These

take the form of the 'Index of Biotic Integrity' for fish community evaluation, species richness, rarity, frequency of occurrence, similarity/dissimilarity and various other measures of integrity or condition, or highly developed models for invertebrate community classification such as that developed by Wright et al. (1984,1989) using intensive biological and physico-chemical surveys of rivers throughout Britain. However, these techniques demand exhaustive field monitoring (Naiman et al, 1992), including sampling for seasonal variation; highly trained staff for sorting, identification and analysis of the samples; and a basic knowledge of the distribution and biogeography of the species and communities concerned. Also the specific impact of various types of disturbance on these indicators has to be known as well as the ability to sort out which type of disturbance has caused the changes observed.

These aspects are well beyond the current state of such knowledge in Queensland. Clearly such an approach was beyond the resources and constraints for the "State of the Rivers Project". As Naiman et al. (1992) concluded:-

"If biotic classification systems are to have broad application, they must be related to physical features of the landscape in order to make inferences on the effects of land-use disturbances"....."Yet disturbances to different landscape elements(e.g. habitat, riparian zone, hill slope) can produce similar" (i.e. *indistinguishable*) impacts on the stream biota." page 116.

The needs of the project, especially in providing data to support Integrated Catchment Management, are therefore more likely to be satisfied by using a broad scale approach collecting a wide range of information about the physical condition and biological habitat features and condition. This approach not only allows identification of the problem, but also provides some of the basic information on the processes, causes and location of the potential causes of the problems.

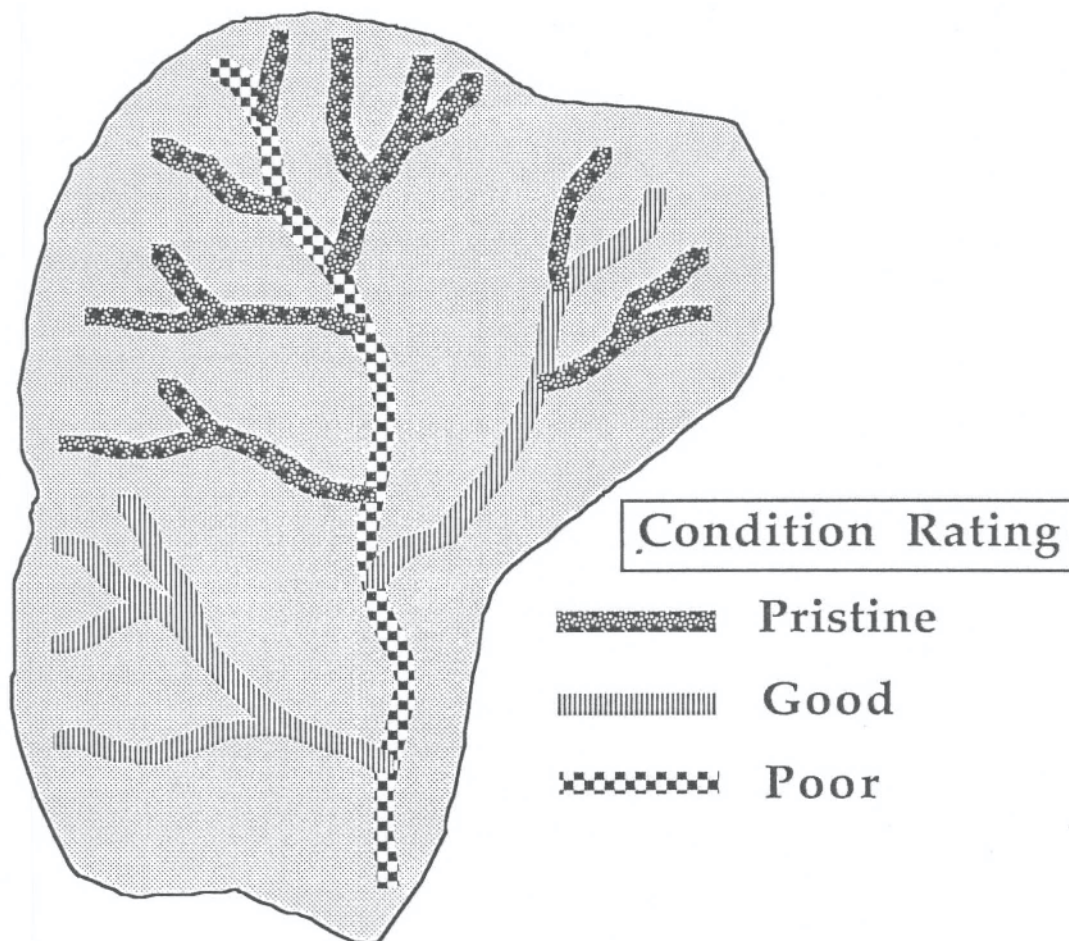
As Naiman et al. (1992) conclude:-

"The search for an ideal classification system is not complete. The fundamental principles of an ideal system are reasonably well articulated. However, it will be necessary for resource managers in specific ecoregions to adapt guiding principles to specific situations using and management approach. The task is difficult and requires a holistic, long-term perspective but, once in place, it provides a solid foundation for making resource decisions that will affect environmental vitality for decades." (Naiman et al. 1992, p. 188)

5.3.8 "Homogeneous" Stream Sections

The target of the methodology is to identify and classify the sections of rivers and streams in a catchment and between catchments into what are termed "homogeneous stream sections". These stream sections are homogeneous in terms of the natural attributes (physical, chemical, biological and utilitarian values and resources) and in terms of their current condition as a result of human activities within the streams themselves and in the catchments. The identification of the homogeneous stream sections is a flexible process as well as an objective or target. It is an on-going process because it depends on the scale and range of attributes which are used to define the homogeneity of various classified stream sections. Additional data can also be added from other sources and the sub-sectioning reviewed and upgraded.

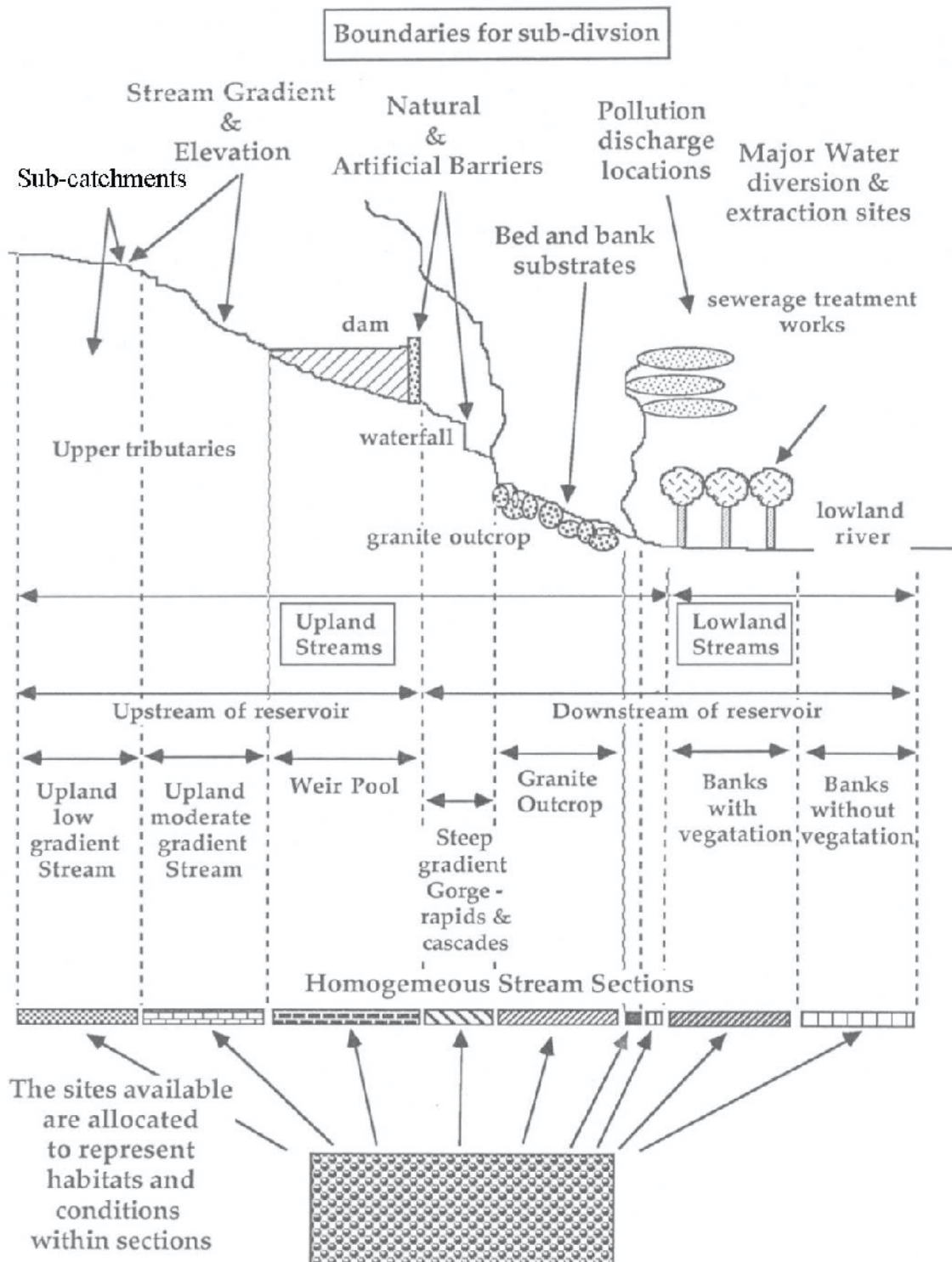
Target = Classified Stream Sections

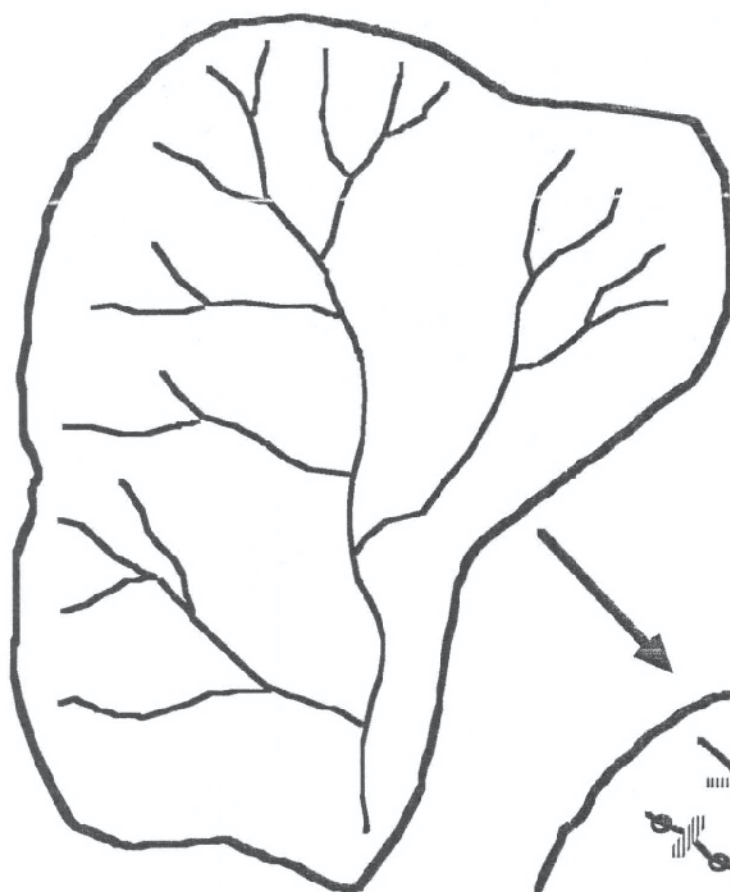


Similar classifications could be made for different combinations of attributes such as substrates, or instream aquatic habitat types. The process of reaching this target is an interactive one proceeding by successive subdivision of the stream network to satisfy the notion of homogeneity using various sources of data. The similarity of the stream conditions and habitat is tested against the set of criteria established for defining "homogeneity" at the scale relevant for the study. The streams are divided into subcatchments and then using

available information and various boundary criteria until the notion of homogeneity within each sub-section is satisfied at the level of resolution required. The process continues initially using map scale attributes, then the results of the reconnaissance, then the results of the survey and compilation of the catchment data.

Homogeneous Stream Sections

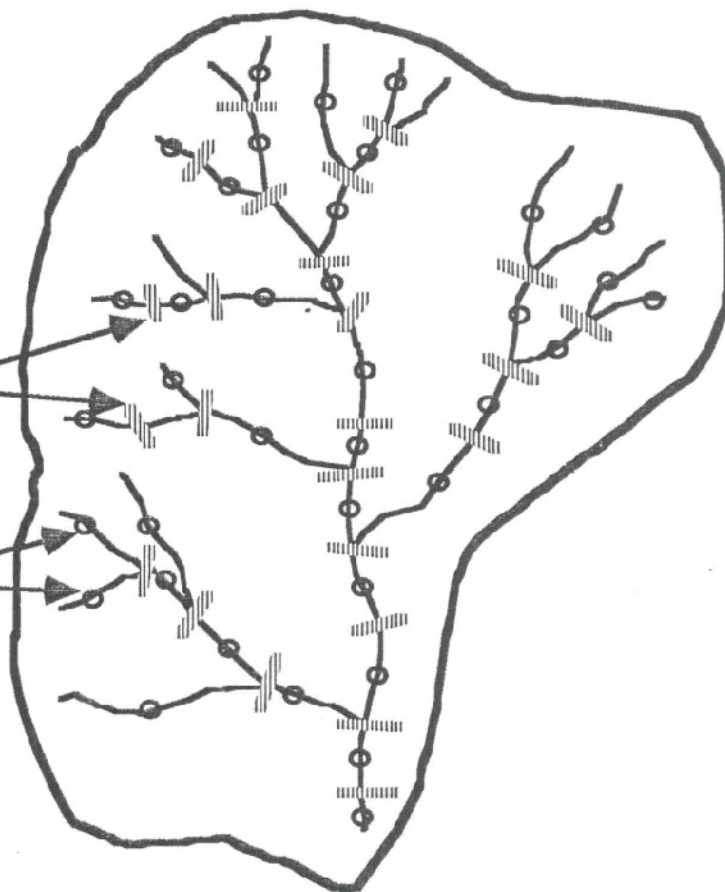


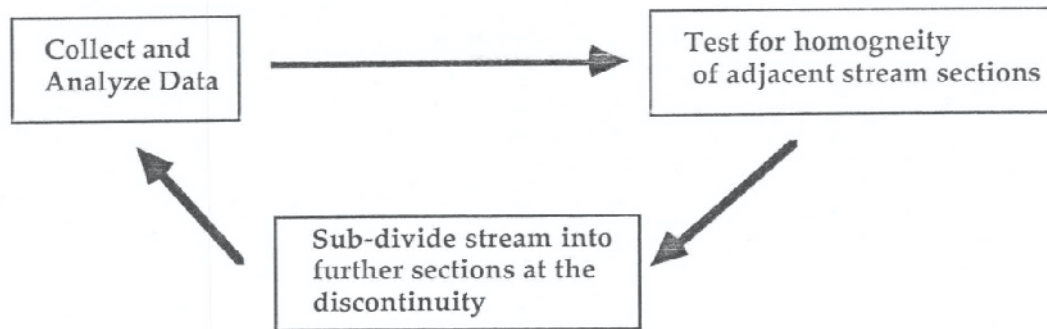


Successive subdivision of rivers and streams into "homogeneous" stream sections using various criteria and an interactive process of successive refinement. Sites are then allocated to the sub-sections and further sub-divisions are made after analysing the site and catchment data.

Homogeneous stream section boundaries

Sites representative of section





This process is carried out hierarchically in various stages (described in more detail later):

1. Map exercise using available catchment and stream information (including location of dams and weirs) and the major sub-catchment divisions (soils, geology, slopes, land use, vegetation type and cover).
2. Visual reconnoitre of catchment to test the initial homogeneity and to further subdivide the rivers and streams at appropriate boundaries.
3. Further sub-sectioning is made in the course of conducting the instream surveys.
4. Analysis of the instream site data and testing of homogeneity between sites in the same section may lead to further sub-divisions.
5. Compilation of relevant catchment data, with further possible revision of sections
6. Final classification of stream sections using different combinations of the attributes for different purposes. These classifications will group the sub-sections in various ways. Permanent amalgamation of the sub-sections may be justified.

The stratification procedure for allocating the samples is therefore based upon the initial mapping exercise, a set of criteria used to initially determine the location of section boundaries, and the visual inspection of rivers and streams throughout the reconnoitre phase.

The limited number of samples, determined by the available resources, are then allocated and sites selected to be representative of the habitats and condition within the subsections. Multiple sites within sections are usually allocated systematically (at set distances along the channels).

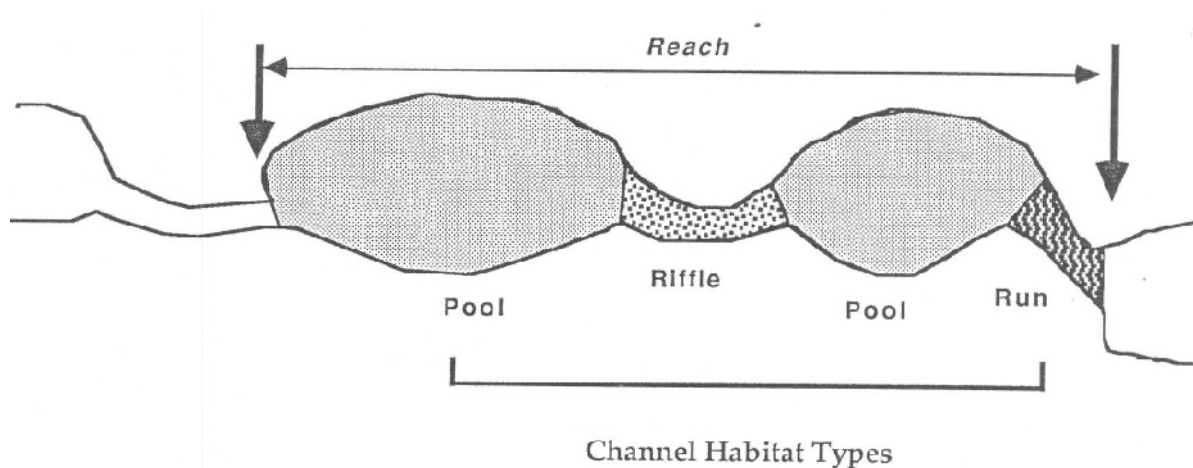
Access is the main determinant of the precise location of the sites most of which are located upstream of ford, bridges and other areas close to vehicular access. The sites are located well upstream of the bridge or ford to get away from any effect it may have on the stream condition. Simple and easy access is essential for minimising the time spent at each site. The extra time required to sample more remote sites is only justified for sampling the pristine sites.

The sampling procedure was therefore a stratified systematic one, but was purposeful and practical rather than being strictly valid statistically. The stratification was based on predictive attributes rather than actual available data. The collection of the actual catchment data such as slope, geology soils, land system classification, vegetative cover etc. is seen as a future option to upgrade the sub-division process rather an obligate part of the sampling. These compromises were justified by the lack of data and the practical requirements of access and limited sampling effort and time.

5.3.9 "Reaches" as the basis for survey

As had been used by Mitchell (1990), Anderson and Morison (1979) and most overseas studies the sampling element or site unit was a representative reach of the river or stream. Access was a dominant consideration in locating the reaches. The reach were selected using the following criteria:-

- The reach should be representative of the types habitat, morphology and physical and ecological condition of the river or stream in the stream section;
- Preferably the reach should contain at least 2 complete pools and riffle / run habitats (represent diversity);
- The whole length of the reach should be visible at one location;
- The reach should contain at least one pool, which should be the largest and deepest in the area.



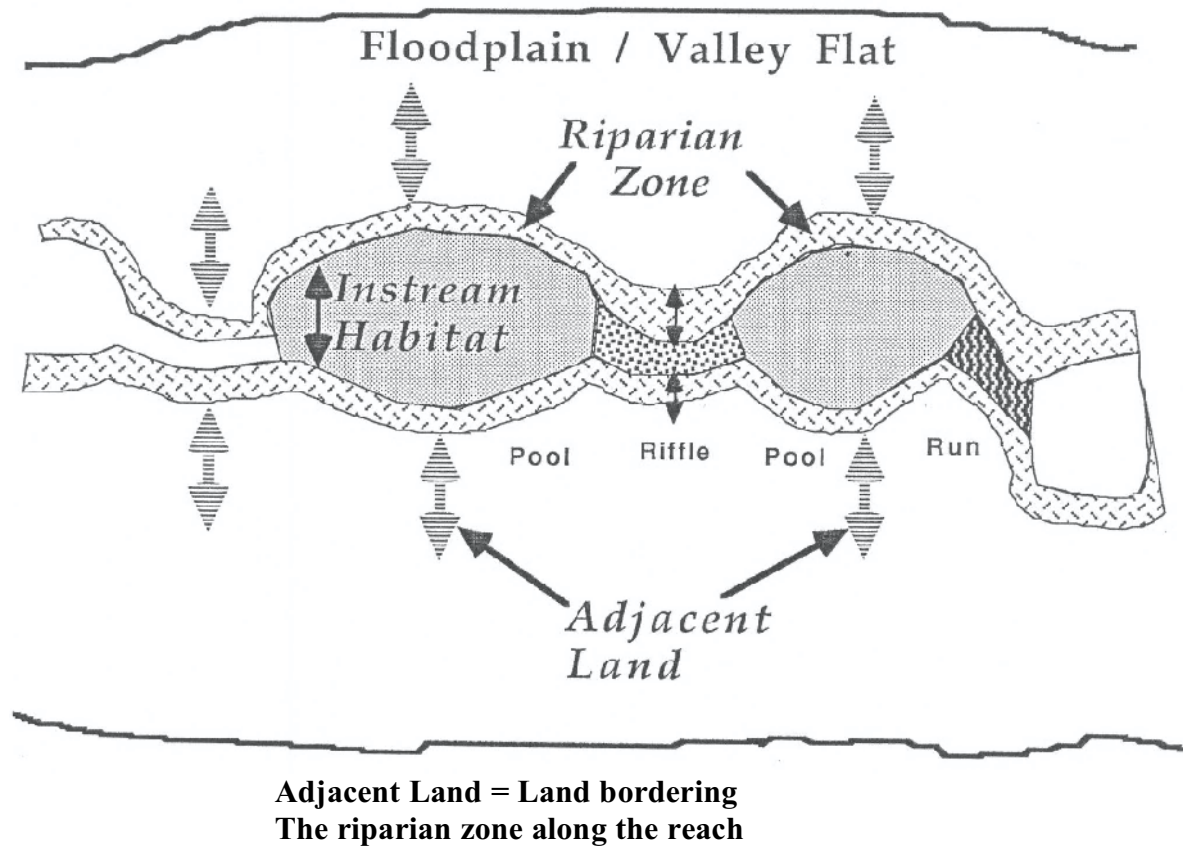
5.3.10 Survey Focused on Instream Data

The focus of the survey was on the instream and riparian habitat that is on the :

- aquatic habitat;
- bed, bar and banks within the confines of the channel;
- riparian zone (defined in the datasheet section) ;
- valley flat and floodplain land immediately adjacent to the riparian zone (land use and general attributes only).

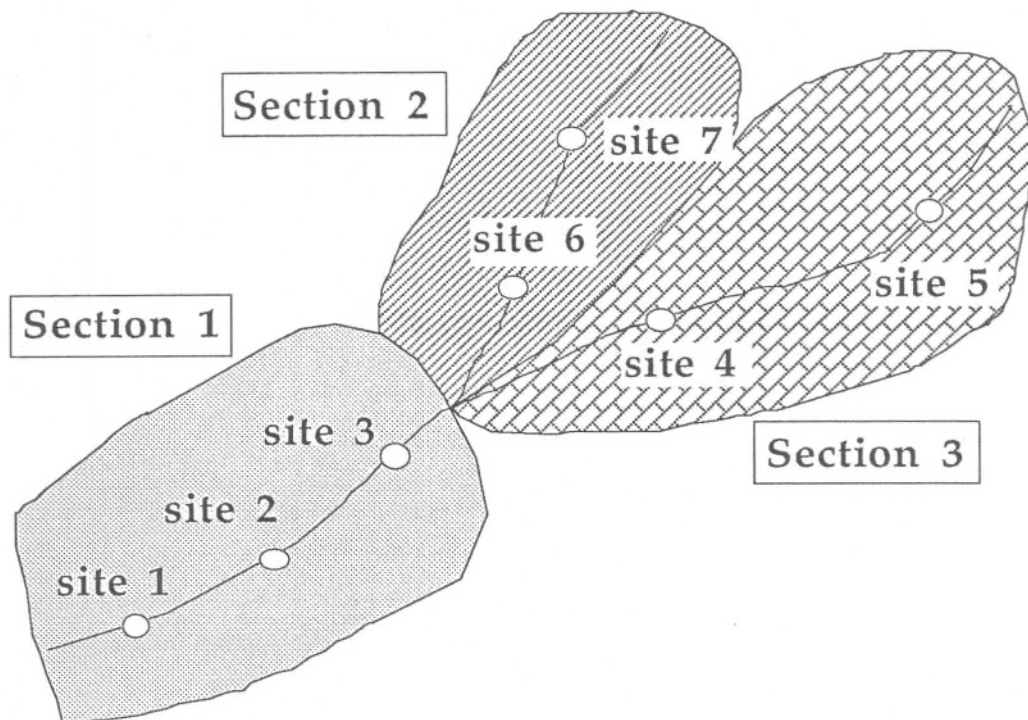
The detailed survey did not include the floodplain beyond the boundaries of the riparian zone, nor the catchment. Only general assessments of the land tenure, land use and

vegetative cover were made for the land (valley flat and floodplain) immediately adjacent to the riparian zone. These restrictions were justified by maintaining a focus on the streams themselves. Information about the floodplains, catchments can usually be obtained from other sources.

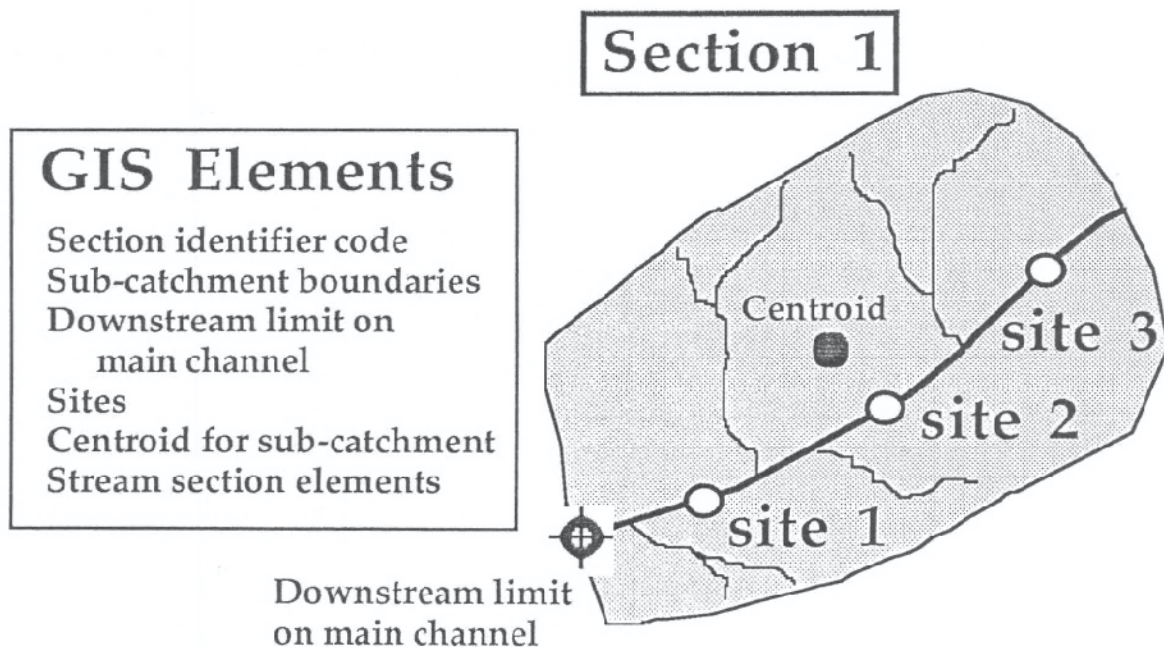


5.3.11 Maintaining links with catchment data through GIS and Integrated Catchment Management

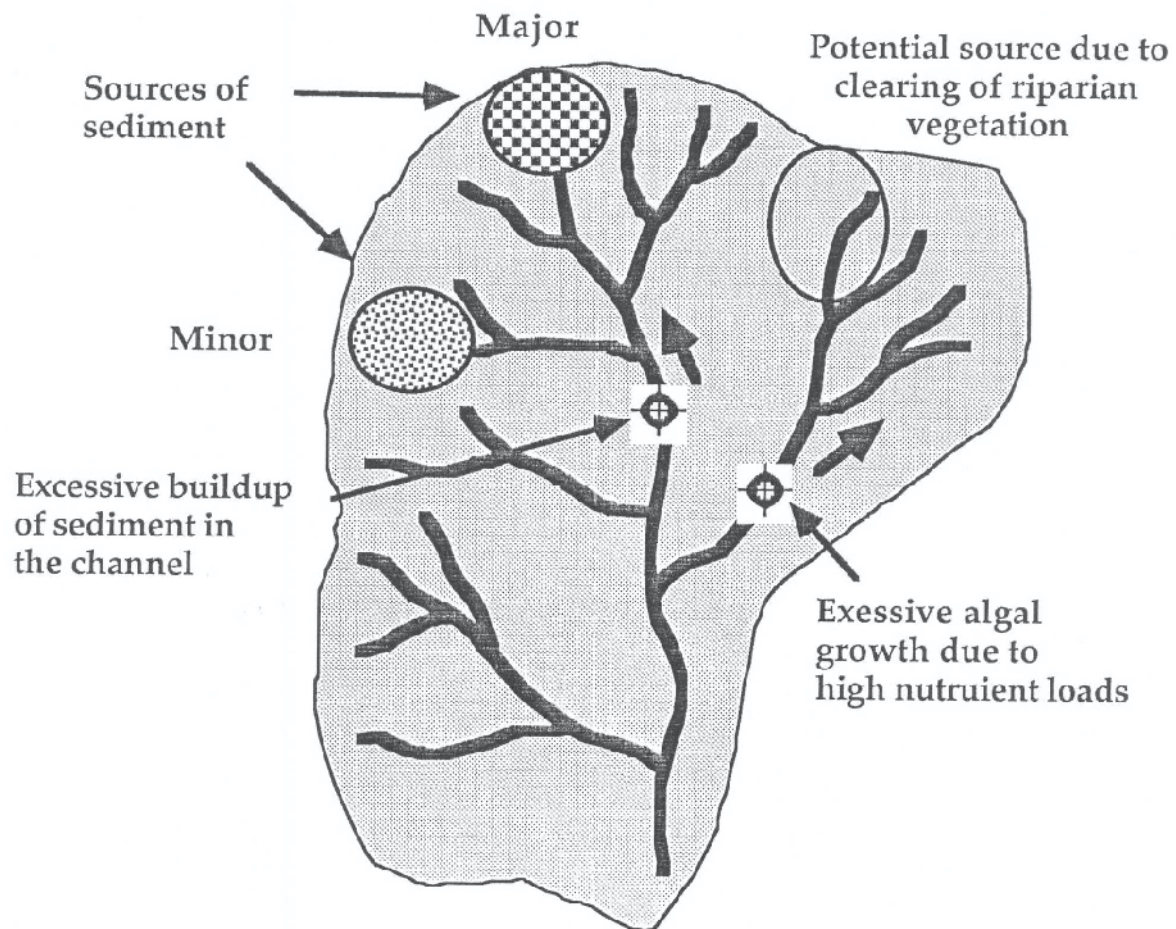
The method used to provide a link to catchment data and other sources of data using GIS, and to provide the needs of integrated catchment management is to link each classified stream section with its associated sub-catchment element. Whenever a new section boundary is recognized a new sub-catchment element is also recognized so that each stream section is linked to a sub-catchment land parcel.



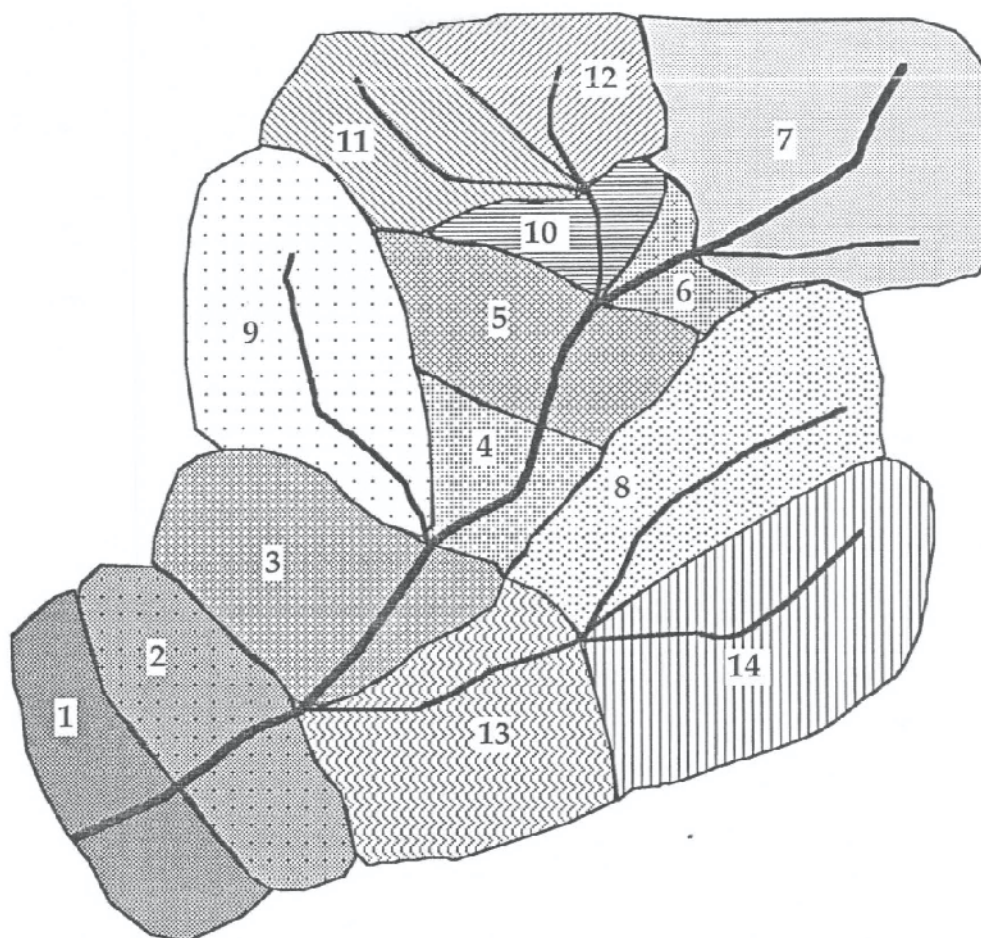
Linkage with GIS Each of the stream sections and its associated sub-catchment land parcels can be linked to a GIS system for producing output and accessing with other sources of information, especially catchment information such as such as land use, soils, vegetation cover, and land system, ecoregion etc.



Methods for Using the data as a tool for Integrated Catchment Management - The database produced by the methodology can be used as a source of data for Integrated Catchment Management either on a site basis or in terms of the classified stream sections. However, in order to provide a method for real integration we need a way to instantly determine which stream sections and sub-catchment land parcels are upstream of a given location in the stream drainage network. An simple hierarchical numbering system for the stream sections has been developed using a reversed stream order concept to achieve this within the data base. Using this numbering systems and simple algorithms the stream sections and sub-catchment parcels upstream of any point in the drainage network can be recognised and their order or position along the drainage lines determined. The database can therefore be used to provide a method for real integration allowing the potential sources of problems to be traced through the drainage network, and their relative contributions to the problem downstream assessed.



Sub-.Section Numbering System A simple numbering system for the stream sections is used to achieve integration through the drainage network.



The sections along the major channel are first assigned sequential numbers - large numbers are used to allow additional sub-sections to be added with minimal changes. Tributary sub-catchment sections are assigned the number of the main tributary section into which they drain plus a sequential number at successive levels of the hierarchical code. The codes allocated to the stream sections shown above are as follows:

Section Number	A	Code B	C	Section Number	A	Code B	C
1.	1000	0	0	8	2000	1000	1000
2.	2000	0	0	9	3000	1000	0
3.	3000	0	0	10	5000	1000	0
4.	4000	0	0	11	5000	2000	0
5.	5000	0	0	12	5000	1000	1000
6.	6000	0	0	13	2000	1000	0
7.	7000	0	0	14	2000	2000	0

For example, stream sections on the main channel (1-7) are assigned numbers from 1000 to 7000. The designation of the main channel is not really critical. Any tributary streams branching from the main channel are assigned the number of the tributary section into which they drain and then another number at the next level of the hierarchy. For example, section 9 includes a tributary that drains into section 3. It is allocated the code 3000-1000. The non-zero entry of a number in the second level of the code signifies that it is a tributary - the first section of the tributary entering section 3. Likewise section 10 is allocated the code 5000 - 1000 i.e. the first section of the tributary branching from the 5th section of the main channel. Section 12 is allocated the code 5000-2000-1000 i.e. its the first section of the tributary branching from the first section of the tributary branching from the 5th section of the main channel. Multiple branching can be accommodated by using more and more sub-code levels.

5.3.12 Preliminary Resources Requirements

It was necessary to set preliminary resource requirements in terms of time, people and equipment to ensure that the survey method was realistic and achievable. In designing the survey it was inevitable that compromises would have to be made between the details collected and time spent at each site and the number of sites which could be surveyed in the time allocated. The emphasis in this methodology has been on surveying as many sites as possible. The basic practical criteria for developing the methodology were:-

1. The survey was designed to be completed by teams of two persons spending about 3/4 - 1 hour at each site, including travelling time. This meant that each team would have a target of 6-10 sites per day. This allows for two teams of two people to survey about 150-200 sites in a two week period (adequate for a catchment of same size as the Mary River).
2. The reconnoitre would require an additional week for two people for a catchment the size of the Mary River, and another week would be required for planning, gathering the available information, meetings with local groups and the training program.
3. Only a minimal set of equipment should be required (tapes, portable echo-sounder, boat, GPS, inclinometer, camera etc.), and only minimal training and experience in the use of the equipment should be necessary.
4. The survey was expandable dependent on the scale of resolution required an for specific purposes, for example to deal with a known problem of bank erosion in a particular sub-catchment, and the resources available.

5.3.13 How many sites are required?

There is no absolute answer to this question. It really depends on the resolution required and the way the data collected is to be used. It also depends on the variability and diversity of habitat types, the condition and range of conditions present in each catchment, the range of issues which need to be addressed and practical aspects of access and travel times in remote or difficult areas.

The following aspects are relevant:-

- The larger river systems will require fewer sites per river kilometre or area of catchment, but this will be offset by the longer travel times between sites.
- Allowance needs to be made for equipment breakdowns, bad weather etc.
- The survey should ideally be done over a relatively short period of intense activity by a small group of people to maintain consistency rather than being done over a longer period. This is necessary to ensure that the data are collected under comparable flow and seasonal conditions. Entire catchment should be surveyed at the one time, with possible exception of the larger catchments such as the Burdekin and Fitzroy Rivers.
- It may be desirable to allocated the limited resources unequally in the catchments or sub-catchments to address specific problems or priorities.

Ultimately, the final numbers of sites required will only become clear after several surveys have been conducted and the data analysed, used and evaluated. Some form of sensitivity analysis could be used to determine the effects of reduced sample size on the results obtained. Also the final determinant of the number of sites which can be surveyed will be the number of staff that can be made available for a set period of time. It is therefore usually a matter of deciding how to best use the available resources to give minimum coverage of the whole catchment whilst focusing on particular areas.

The pilot survey of the Maroochy River can be used to provide an initial guide as to the number of sites and survey days required. About 180 full survey sites were surveyed in the Maroochy River by two teams of two people over a two week period, with an average of about 8-10 sites a day being completed by each team. In retrospect the minimal number of sites for the Maroochy River would be about 100-120 sites, requiring about 8 days by the two teams. The Maroochy River is one of the smallest rivers in Queensland with a catchment area of about 1410 sq. km, but it has many tributaries which extend almost to the estuary, relatively high population and many catchment issues and so the site density of 1 site for every 15 sq km and about 1 site for every 5 km of major tributary is justified to service the needs of integrated catchment management. The following table gives an initial idea of the *minimum* number of sites required for some of the catchments on the east coast of Queensland

Catchment Area (km ²)	Sites	Weeks (2 teams)	Examples on the east coast
<2000	100-120	1.5	Maroochy, Pine, Noosa, Pioneer, Ross,
2000-4000	150	2	Murray, Tully
4000-10,000	200	3	Logan-Albert, Burrum, Kolan, Boyne, Styx, Haughton, Johnstone
10,000-50,000	250	4	Mary River, Olive-Pascoe, Don, Herbert
> 50,000	300-400	5-6	Brisbane, Normanby, Burnett Fitzroy, Burdekin

It should be emphasized that these are suggestions only which do not take account of the diversity of habitats, existing condition or range issues present in each specific catchment. An additional period of 1-3 weeks would be required by one of the teams for the reconnaissance survey. More time has been allowed for the larger catchments, but again these are only estimates to give some idea of what is required. The increase in travelling time between sites means that the number of sites to be surveyed in a day by each team will decrease in the larger catchments.

The sampling density in the above table was about half that used by Anderson & Morison (1989) for the Wimmera River. These minimum site densities are considerably greater than that used by Mitchell (1990) for the State of the Rivers Survey in Victoria where approximately 60 sites were allocated for the larger catchments of around 10,000 - 15,000 sq km. The site allocation for the project was 1 site per 25km of major stream or tributary, 1 site for every 200-500km for minor streams (cleared and uncleared). The greater sampling density is justified because the State of the Rivers project in Queensland is to be carried out on a catchment by catchment basis and is directed at providing information for Integrated Catchment Management within the catchments, rather than simply providing a State-wide assessment.

It should be stressed again that estimates are really only first approximations for the minimal data requirements which need to be revised during implementation of the project.

5.3.14 When should the survey be conducted?

The best time for conducting the survey is the dry season. This avoids problems with bad weather and access problems, but it is also more practical for many aspects of the survey which are best done when water levels are low and water clarity is highest. Standardizing the time and flow conditions during the survey are also important for comparative purposes so that stream depths and channel dimensions all relate to a low flow and low discharge period. The interpretation of the results obviously needs to take account of when the survey was conducted. The survey methodology includes simple methods of standardizing water depths and channel dimension measurements.

5.3.15 Upstream and Downstream limits

The upstream limits of the rivers and streams included are established by only including streams which have a clearly defined channel. The survey methods allow for intermittent streams and streams with braided channels to be included, but they are mostly focused on the larger permanent streams (or streams with more or less permanent channels or permanent pools or billabongs). The survey does not include lakes or wetlands unless they occur along defined stream channels. For example, floodplain wetlands (billabongs and oxbows) or coastal dune wetlands are not included. The survey includes estuaries. The downstream limit is the defined mouth of the river. The inclusion of estuaries was important for completeness, but the survey methodology is primarily designed for the non-estuarine sections of rivers and streams, and so certain additions have been made to allow for estuaries to be included, rather than specifically designing estuarine survey techniques.

5.3.16 Water Quality, Flow and Discharge These aspects have already been discussed (see 3.15)

5.3.17 Data Sheet Design Concepts

The datasheets were developed from those used by Anderson & Morison (1979) and Mitchell (1990). The following aspects were important in designing the datasheets:

1. The datasheets had to be easily understood by technical staff of the DPI with little or no previously experience in stream survey. A graphic approach was adopted to simplify the understanding of the concepts and choice between the various criteria. It was also decided to try to totally eliminate any reliance on coding sheets which make it more difficult for inexperienced staff to complete the datasheets. All the information required had therefore to be provided on the datasheets themselves.
2. The procedures for conducting the survey and completing the datasheets had to be largely self-explanatory and able to be taught during a short training period.
3. The datasheets had to be designed for simple and efficient transfer into the databases and had to interface with the database design concepts.
4. The method included a set of standard photographs which had to be properly archived and linked to the data through the databases.

Types of data

Various types of data were included on the datasheets:

- **Non Survey Data** - This included site location information, various codes and information about catchment areas, elevation and other data derived from maps and other sources. The methodology was designed to allow ready links with GIS system to gain access to site and catchment information available now and in the future. Stream gauging sites with their relevant identification codes were included as special sites during the survey to provide easy access to the hydrologic record for stream classification, and to the water quality information which will be incorporated into the HYDSYS system.
- **Survey Data** - this included a range of data types collected during the surveys. These data are collated in the database and can be used in the following forms:-
 1. **Raw Data** - Raw data of various types were collected. These data will be used independently for various purposes in integrated catchment management and in providing condition ratings (e.g. proportion of the bank which is eroding or the average width of the riparian vegetation). The data will also be used to produce the derived rating.
 2. **Derived Ratings** - Various formulae will be used to derive the various overall condition assessments. The method used will be explicit and easily modified.

$$\text{E.g. Physical Condition} = A(w_1) + B(w_2) + C(w_3) + D(w_4)$$

where A,B,C & D are raw attributes and w1, w2, w3, & w4 are weightings applied to each attribute.

3. **Semi-Subjective Ratings** - The recorders will be asked to make an overall assessment of the component. The value of these ratings will be increased by asking for the assessments to be made after the raw data have been collected. These ratings will provide a valuable 'first-go' assessment which can be qualified using the derived ratings.
4. **Codes and Links to other Sources of Data** - Various codes and other items have been recorded to enable a simple interface with GIS and with HYDSYS (hydrology and water quality data sets).
5. **Photographic Records and Comments** - The methodology includes a standard set of photographs for each site taken looking :- upstream, downstream, towards the left bank, towards the right bank, a photograph of the general environs of the site. Provision is also made to include photographs of specific features at the site. Records of the photographs are included in the database and the photographs (colour slides) will be properly archived to establish a baseline for future reference.

6. Outline of the Steps in the Methodology

The practical details of the methodology are provided in the second report on the implementation of the methodology. The aim here is to outline steps in the method which are an integral part of the methodology itself. The methodology is to be implemented by regional staff (environmental officers and technical staff) with coordination probably provided by a group at head office. The procedure for implementing the methodology is outlined in the following steps and elements:-

6.1 State-wide Coordination and Planning

Overall coordination of the project and planning of its implementation is required on a State-wide basis. This would include setting priorities, schedules and targets and providing overall support for the methodology, software, hardware and data analysis aspects. This group would also be responsible for organising and running workshops, training programs and various promotion activities for the project. This group could also be responsible for liaising with various interest groups and agencies who are seen as potential users of the data. Overall back-up and support will also be required to deal with problems which will inevitably arise with the datasheets, data base and the data analysis and interpretation. There will also need to be on-going development work to refine the analysis methods and to develop the linkages with land use and catchment data through the GIS. The final ratings and formulae to be used to produce a state-wide assessment of the condition of rivers and streams throughout Queensland will require further work which can only be done once some of the surveys have been carried out. There will also need to be some form of a classification of instream habitats if the data are to be used to set conservation goals and

objectives.

6.2 Introductory "State of the Rivers" Workshops

Regional workshops could be held to introduce regional staff to the "State of the Rivers" Project and its resource requirements. This could be in the form of a seminar followed by group discussion.

6.3 Planning and Scheduling

Following the workshop, the regional implementation of the "State of the Rivers" Project for the catchments in the region can be planned and scheduled. Once this has occurred the actual surveys can begin.

6.4 Step 1. Preliminary Planning Workshop -1-2 days

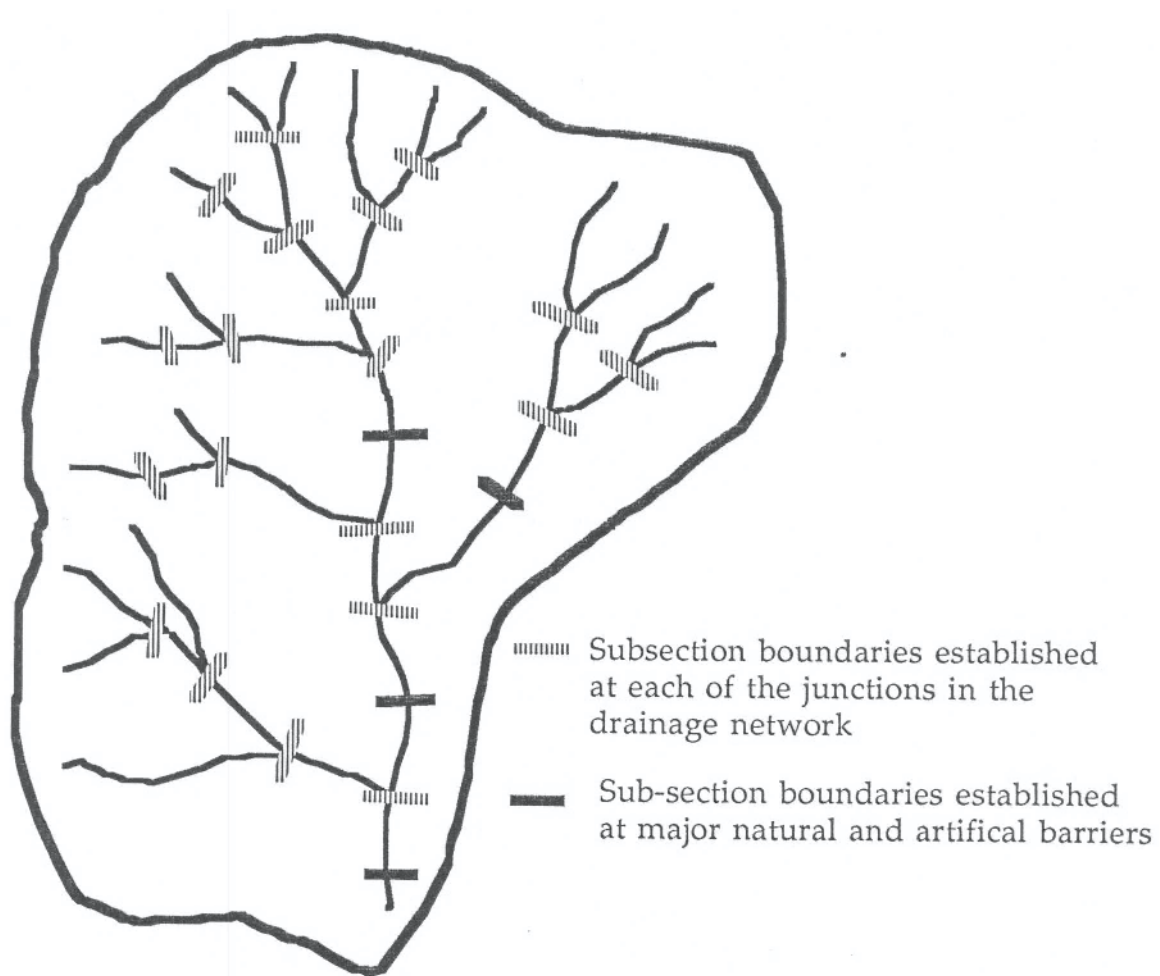
The aim of the workshop is to gather together the various local maps and data sources relevant for the study and to discuss important local issues. The workshop should involve local government representatives, Land Care and Integrated Catchment Management Groups and other interested groups and individuals who are potential users of the information and who may also provide information and assistance for the survey. Flood studies, environmental reports, vegetation surveys, water quality monitoring records and other local information are all relevant.

6.5 Step 2. Preliminary Sub-division of Streams and Rivers - Map Exercise 1-2 days

The aim of this exercise is to take all the available information and maps and to use it to begin the subdivide the streams and rivers into "homogeneous stream sections". The type and extent of information available will vary greatly in different catchments. Where available 1:25,000 series maps should be used for this initial subdivision as these maps show some instream river characteristics such as the location of falls, large pools, fords roads and tracks and other details important for the survey. The finest scale maps possible should be used to prepare a base map.

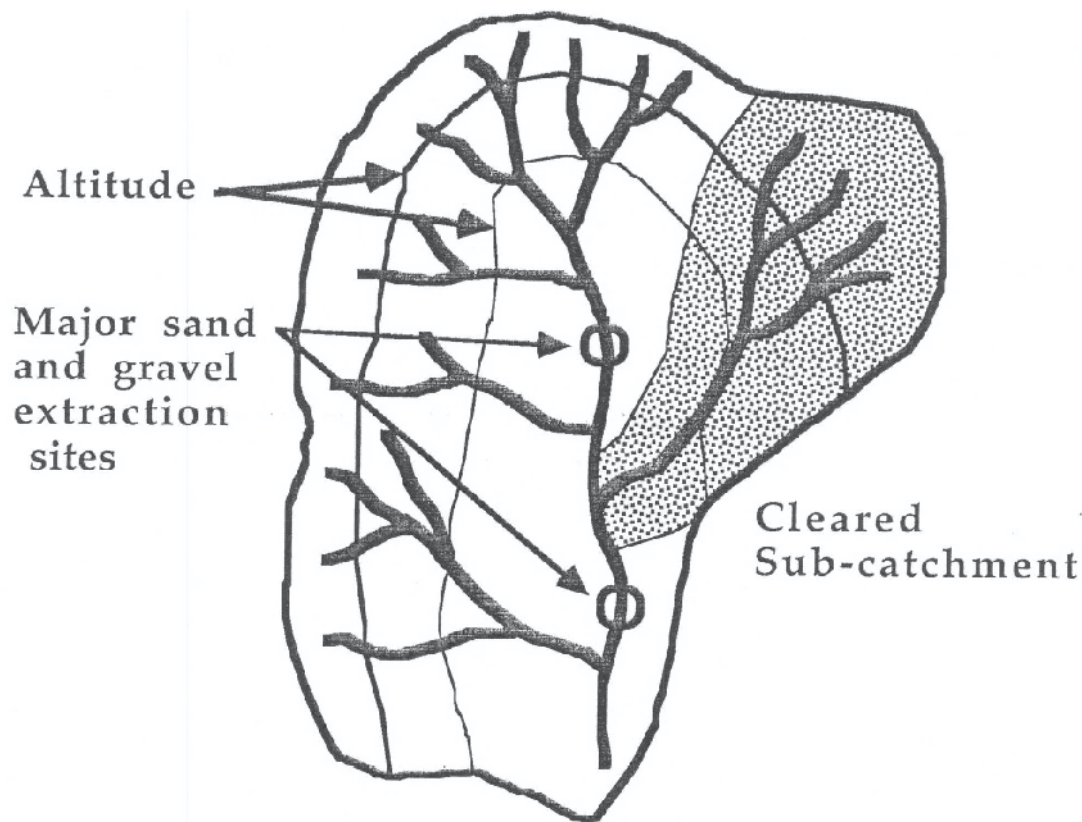
The first stage is then a mapping exercise directed at identifying the homogeneous stream sections. Key attributes controlling the natural physical and ecological features of the stream are used dependent on the availability of relevant sources of information. Some of the more attributes used to define boundaries for this sub-division are listed below in approximate order of importance for the project are :-

Sub-catchment Structure / Stream Order - the addition of each new tributary to the major channel changes the hydrology and also affects sediments channel morphology, channel habitat diversity (pools riffles runs etc.), substrates, bed and bank condition and the ecology of the stream. Stream order is generally recognised as an important attribute. Also any disturbances in upstream catchments will impinge on other river sections downstream in the stream network. Sub-section boundaries are therefore established at each tributary junction, up to a scale of about 1:100,000. The tributaries are similarly divided into sub-catchments and sub-section elements.



- **Natural and Artificial Barriers and Obstructions** - barriers are established at major artificial barriers such as dams and weirs; at natural barriers such as water falls, rapids, wetlands and swamps along the main channels; and at the locations of other barriers and obstructions. Dams and weirs act as sediment traps and alter the flow regimes and dynamics downstream. Section boundaries are therefore located at these structures. The entire reservoir, weir pool or natural lake is designated as one or more distinct sections because of the different habitat in these pools. Additional sub-section boundaries are located at the upstream limits of these lake and reservoir pools for each of the tributaries entering the reservoirs. These structures other natural barriers such as water falls and rapids restrict to fish movement and the passage of other animals often leading to changes in community structure upstream of the barriers.
- **Altitude, Catchment Slope and Stream Gradient** - Altitude itself is an important parameter affecting local climate and the of many plant and animal species. Catchment slope affects run-off dynamics and this influences channel morphology. Stream gradient is also of fundamental importance for stream classification as it affects flows, sediments and many other physical and biological features of streams.
- **Geology and Soils** - Again the geology and soils of the catchment and the geology

beneath the stream bed are important in affecting the channel morphology and other



Additional section boundaries are located using altitude, extent of clearing of the sub-catchments, site of major disturbance and other parameters.

- **Land Use, Vegetation type and Vegetative cover** - Sub-section boundaries should be established at major discontinuities in vegetation, for example conservation areas, forests, plantation areas, and boundaries of natural vegetation types.
- **Land System and Climatological Boundaries** - Land system and climatological boundaries can also be used to sub-section the streams.
- **Tidal Limit and Boundaries between Intermittent and Permanent Streams** - boundaries are also established at the tidal limits and between permanent and intermittent sections of rivers and streams.
- **Discharge points for Waste, Sites of Pollution & Disturbances** - additional section boundaries should be located at these points, for example at the location of waste discharge points, mining sites and sites for sand and gravel extraction.
- **Sites of Major Stream Diversion**- These diversions or water extraction sites also represent disturbances which will affect condition downstream. This applies whether or not the diversion or extraction is made from a weir or from a site without such a structure. Areas where a large amount of water is extracted by many users may be

designated even though a separate section boundary may not be justified at each extraction point.

- **Location of Major Discontinuities in Stream Habitat, Condition or River Management (Improvement) Activities** - this includes the location of channelization and bank protection works, fencing of riparian areas and major natural boundaries in stream condition or habitat type.
- **Aerial Photography and Reconnaissance** - plane or helicopter - Good quality, recent aerial photography is an excellent source of information for conducting the initial sub-division and inspections from the air may also be useful. However, it should be emphasised that the focus of the study is on the instream attributes, most of which cannot be seen or assessed remotely. The use of these techniques depends on the availability of materials and staff trained in their use. The time and financial resources required for aerial reconnaissance may be better used in expanding the reconnoitre survey and ground-level inspections, except perhaps in the larger catchments. This provides information at the scale needed for the sub-section rather than the broad scale overview. If the resources and trained staff are available aerial photography and flyovers should be used to provide the broader scale overview for initially sub-dividing the catchment.

6.6 Step 3 - Initial Allocation of Potential Sites

Using this preliminary information the sites can then be allocated to the homogeneous stream sections. This will be dependent on the resources available as this will limit the number of sites. The allocation will also depend on the resolution and priorities which have been set for various sub-catchments, areas and streams throughout the survey area. This allocation can then thereafter be based on the relative areas of the sub-catchments or the length of major streams present in each sub-section. Within sections the actual location of the sites will largely depend on access and the variability detected during the reconnoitre survey. However, after this the sites are generally allocated systematically at a proportional distance along the length of the stream in the section.

6.7 Step 4 - Reconnoitre Survey - one team of 2 covering 20-30 sites per day

Using the base map prepared by this initial sub-division a reconnoitre survey is conducted to further test the notion of homogeneity of the sections and to continue the sub-division process using visual assessment of the physical and ecological condition and habitats. A series of potential survey sites representative of the sections are also identified and photographed. Aerial photographs and light plane and helicopter flights would be useful to provide an overview, however the emphasis should be on the actual visual inspection of the sites at ground level because the survey is focused on the instream attributes and many of the relevant features can only be assessed at ground level. Once again this is essentially a map exercise with the potential sites being located onto the base maps. The 'Site Location' datasheet should also be filled out at this time. This saves considerable time during the actual survey as the datasheet can be used to quickly locate the site including directions of how to gain access to the site.

6.8 Step 5 - Training Workshop

A workshop is required to teach the staff about the procedures and the data to be collected. It is suggested that a 'hands-on', 'learn by doing' approach is the most appropriate.

6.9 Step 6 - Detailed Site Survey - teams of 2 people covering 6-12 sites per day

The detailed site survey is then conducted at the series of sites allocated for each section. Some sites may only be partially surveyed, with only a location and a set of photographs being taken. Additional sites may be added at this stage if justified in terms of increased variability on habitat or condition missed during the reconnaissance. The precise location of the sites may also be changed in order that the sites chosen are more representative of the conditions and habitats within the sections. Detailed surveys at the sites may also highlight the need to add additional section boundaries.

6.10 Step 7 - Sub-division of the Catchment at the Stream Boundaries

Sub-catchment boundaries are drawn on the base maps using the stream and river section boundaries and the topographic maps. The data sheets for the sub-catchment boundaries are then completed including the numbering codes and the location of the centroid for the element, the downstream limit on the major drainage line and other information. Each homogeneous stream section is then represented by one or more site at which detailed instream information has been collected and an area of land corresponding with its immediate local catchment. Ideally these sub-catchment boundaries are then digitised or scanned into a GIS system, which can then be used to obtain information on the catchment area, average elevation, major and minor stream lengths and other relevant information. Otherwise this information can be obtained manually. This will depend on the availability of digitised river and stream information, topography and other information for the area. The sub-catchment elements provide the link to interface between the instream data and the catchment data both in terms of the immediate sub-catchment areas and the cumulated sub-catchment elements through the drainage network.

6.12 Step 8 - Data entry and verification

The data recorded on the set of datasheets are then entered into the databases and verified. Additional non-survey data are added. Appropriate verification procedures should be adopted to ensure the data are accurately entered. The data sheets should be properly achieved to enable the data entered to be checked.

6.13 Step 9 - Archiving of Photographs and Data sheets

The photographic record and the data sheets themselves should be properly archived so as to provide an efficient bench mark for future studies, and for checking the accuracy of the data entered. Reference to the photographs will be very helpful in confirming the final condition classifications.

6.14 Step 10 - Data Analysis and Classification of Sections

Once the data entry has been completed the various data analysis, classification and report generating programs can be run and the results examined. The classification can then be revised and verified against other available information on the condition of the streams and rivers in the catchment and the relevance of the sectioning.

6.15 Step 11- Further Sub-sectioning

The analysis of the site data and the verification of the output may reveal that further sub-sectioning may be required. This can be done by reworking the base map and modifying the sub-sectional information. The sub-section numbering system allows for these additions to be made without having to re-number all the sub-sections.

6.16 Step 12 - Preparation of Final Reports and Data Summaries

The final reports and data summaries can then be prepared and interpreted.

6.17 Step 13. -Establishing Interfaces with Sources of Additional Catchment Information

For subsequent more detailed analyses including investigation of the sources and processes of problems relevant for integrated catchment management it will be necessary to establish links with other sources of information. A GIS system can be used for this purpose by making use of the sub-catchment and subsection boundaries. Alternatively separate linked databases can be established in DBASE IV or in other databases compatible with DBASE IV.

6.18 Summary of the Organisational Structure for the Project (details in the Implementation Manual).

Organisational Structure

Group	Representation	Roles and Responsibilities
State-Wide Implementation and Coordination Group	Head-Office Dept. Representatives or Inter-Regional Group	Coordination and establishment of priorities State-wide Program development and consistency in application Promotion of the project. Planning and organising the training programs. Liaise with and support for Regional and Catchment Implementation Groups Maintain links with ICM and various other Departments and groups.
Regional Implementation Groups	Regional Officers designated as representatives for the project within each Region.	Implementation of the project within Regions including joint efforts required for catchments extending into more than one region. Planning and organisation of the project within the regions. Liaison with the State-wide Group. Establishment and supervision of the Catchment Implementation Groups.
Catchment Implementation Groups	Regional Officers with representatives from Local Government, ICM and other local community groups	Planning and implementation of the project within each catchment. Collection and analysis of all existing relevant data.
Regional Catchment Survey Leaders	Regional Scientific Officer(s)	Organise and maintain equipment and other resources required for the survey. Day to day organisation. Data entry, verification and sub-sectioning. Preparation of reports and data summaries.
Regional Survey Teams	Regional Scientific and Technical Officers and others selected to conduct the survey.	Surveys and data collection for each catchment or sub-catchment

7. Survey Components and Data Sheets

7.1 Introduction

The components to be included in the "State of the Rivers" project were finalised after reviewing the literature and incorporating the ideas and comments obtained from the consultation phase of the project. A graphic approach was adopted for the design of the datasheets, which were also conceived to be self supporting and able to be used without reference to coding sheets. The traditional approach of using computer data entry sheets as the data sheets, supported by extensive coding sheets (e.g. that used for the datasheets accompanying the Australian Soil and Land Survey Handbook (McDonald et al. 1990)), is too complex and difficult to use in the shorter term. The State of the Rivers Project will involve many regional groups who will not have the advantage or years of experience in which to memorise the codes and procedures. New groups will have to be trained in each Region. These specific requirements justified the approach taken to eliminate coding sheets and the adoption of a graphic approach. As a result the datasheets appear a little cluttered at first, but this is quickly overcome after a short period of use.

The data parameters included for each component include raw data, partially derived data and a qualitative overall assessment items. These overall assessments are generally located at the end of the datasheet which should help to improve their reliability given that it is filled in after entry of all the individual items contributing to this overall assessment. It provides a rapid 'first-go' assessment of the condition in terms of the different components. These items can be later compared with the ratings derived more objectively from the raw data.

A photographic record is included as part of the site description. This provides not only a baseline for comparison with future follow-up surveys, but it should also be used to check and verify the condition ratings. The records of the photographs taken are therefore included as items in the database.

The data collected on each of the individual datasheets should not be seen as only being relevant for a single component. Many of the individual data items are relevant in many different ways (e.g. pool depth and bed substrate particle sizes for aquatic habitat assessment).

A description of each of the components is provided in the next sections including the following aspects:-

Introduction

Issues and Concepts Boundaries

Scope and Limitations Parameters

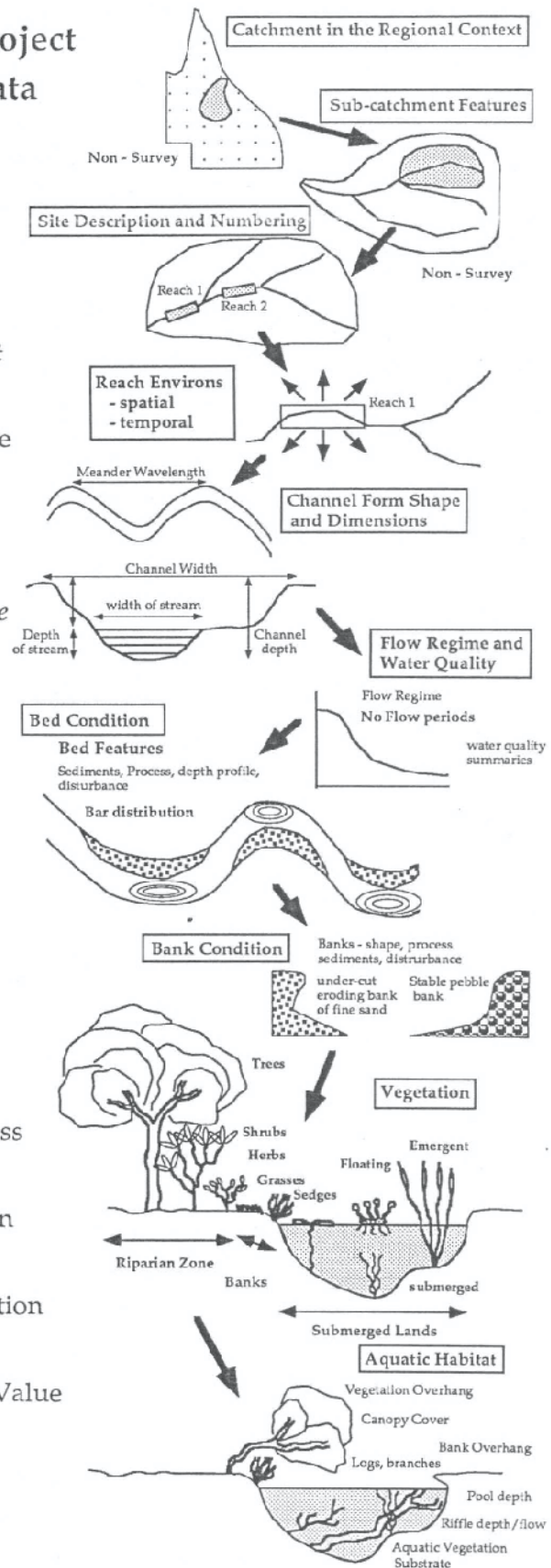
Target Outputs and Indicators

An overview of the components is provided on the next page.

State of the Rivers Project

Major Types of Data

1. Catchment in the Regional Context
* *climate, regional land system*
2. Sub-catchment Features
* *Land use, soils, geology, slope, gradient*
3. Site Description, Location, Drainage code
* *grid reference, AMTD, identifiers*
4. Reach Environs Information - Spatial
* *floodplain land use and type, channel pattern, land administration, disturbance*
5. Reach Environs Information - Temporal
* *conditions prevailing at the time of the survey*
6. Channel Form, Shape & Dimensions
7. Hydrology and Water Quality
* *Summaries derived from other sources*
8. Banks - Physical Condition & Process
9. Bed & Bars - Physical Condition & Process
10. Vegetation - Aquatic, Bank and Riparian
11. Aquatic Habitat Classification & Condition
12. Scenic, Conservation and Recreational Value



Date (dd/mm/yy) Recorder

STATE OF THE RIVERS --- SHEET 1 Sub-Section Element

Basin		Sub-section	
[] []	[] []	[] []	[] []
Unit Code			

Drainage Code

A	[] [] [] []	B	[] [] [] []	C	[] [] [] []	D	[] [] [] []	E	[] [] [] []	F	[] [] [] []	G	[] [] [] []	H	[] [] [] []
I	[] [] [] []	J	[] [] [] []	K	[] [] [] []	L	[] [] [] []	M	[] [] [] []	N	[] [] [] []	O	[] [] [] []	P	[] [] [] []
Q	[] [] [] []	R	[] [] [] []	S	[] [] [] []	T	[] [] [] []	U	[] [] [] []	V	[] [] [] []	W	[] [] [] []	X	[] [] [] []

Non-Survey

[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []	[] [] [] []
-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------	-----------------

Downstream Stream Section Boundary

Map Number		Grid Reference		Latitude		Longitude		GPS ? Other		Est. Position Error	
[] [] [] []	E	[] [] [] []	N	[] [] [] []	deg min sec	[] [] : [] []	deg min sec	[] [] : [] []	[] []	±	[] [] [] [] m
Map Scale		AMTD (from map)		Total U/S Distance (add AMTD's)							
[] [] [] []		[] [] [] []		[] [] [] [] [] [] [] [] [] []							

Centroid

Grid Reference		Latitude		Longitude		GPS ? Other		Est. Position Error			
[] [] [] []	E	[] [] [] []	N	[] [] [] []	deg min sec	[] [] : [] []	deg min sec	[] [] : [] []	[] []	±	[] [] [] [] m

b - Catchment Area (sq. km) Length of Major Tributary (km) Length of Minor Tributaries (km)

[] [] [] [] [] []	[] [] [] [] [] []	[] [] [] [] [] []
-------------------------	-------------------------	-------------------------

Elevation Information (from Map)

Elevation at Upstream Limit (m)	Elevation at Downstream Limit (m)
[] [] [] []	[] [] [] []
Maximum Elevation in section (m)	Average Stream Gradient (major tributary) (%)
[] [] [] []	[] [] [] []

Data from GIS

- Soils
- Geology
- Land System
- Bioregion
- Climatic region
- Land use
- Land cover
- Land tenure
- Slope
- Urbanisation

7.2.1 Introduction

7.2.2 Issues and Concepts

7.2.3 Boundaries

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7.2.4 Scope and Limitations

The parameters only relate to the location of the section, the drainage code (see 5.3.11), elevation data and average stream gradient. The area of the sub-catchment and the length of major and minor tributaries is also included for analysis purposes and for producing summaries of condition in terms of stream length. Other catchment information could be added to this database or derived from other sources using the sub-catchment boundaries and the GIS system.

7.2.5 Parameters

The parameters include the drainage code for the section; the location of the downstream limit and centroid for the section; the sub-catchment area; length of major and minor tributaries; and elevation (upstream and downstream limits, maximum and average for the section).

A suitable centroid can be produced by the GIS system or entered manually by choosing some convenient point. It is used for plotting purposes. Similarly the length of major and minor tributaries can be obtained from the GIS system or measured manually. The question of a suitable scale has yet to be resolved and this is somewhat dependent on the availability of the digitised streams and rivers for the GIS system. It is suggested that a scale of 1:100,000 or 1:50,000 would be appropriate. The terms "major" and "minor" simply refer to the major drainage channel within the sub-section and the tributaries of it. The size will obviously depend on the location of the section. The average stream gradient refers to the major drainage line. It can be determined from the difference in elevation at the upstream and downstream ends of the section and the length of the stream.

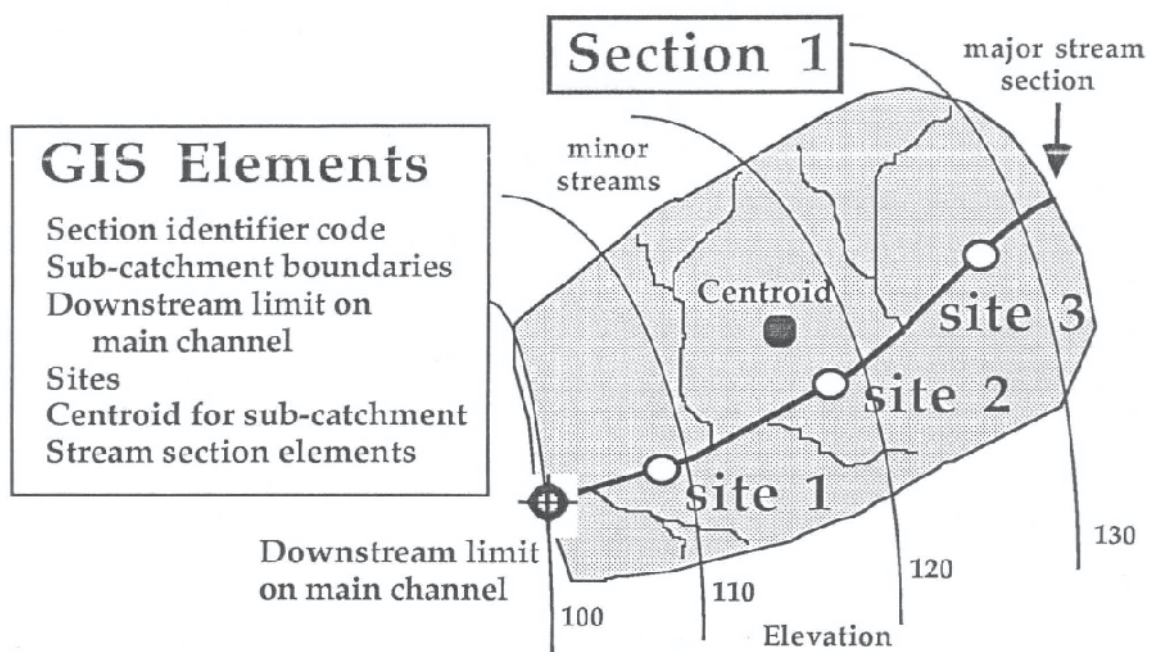


Figure 2 Data Sheet 2 Hydrology

STATE OF THE RIVERS -- SHEET 2 <i>Hydrology</i>				Date (dd/mm/yy) Recorder
Basin	Sub-section	Site	Tributary Name	
SITE CODE				
HYDROLOGY SUMMARY PARAMETERS				
p 61				
Water Flow Gauge Number Gauge Reading (m) Flow estimate (ML/day)		2 Time since last runoff Days since last bankfull discharge Days since last major flood Days since last major rainfall event		
3 General Local Conditions Wet Season Drier than normal Dry Season Wetter than normal Typical conditions				
Note : Various parameters could be derived from HYDSYS for existing stations e.g. High Flow Low Flow Flow Duration Analysis Seasonality Variability Statistics				

INSTREAM WATER QUALITY MEASUREMENTS - Note: this is optional		Time Measured						
	Surface	0	1	2	3	4	5	6
Physico-Chemical Data	Depth (m)							
	Water Temp(deg. C)							
	Dissolved Oxygen (mg/l)							
	pH							
	Conductiv. (EC us/cm)							
	Salinity (ppt)							
	Turbidity (NTU)							
	Secchi Depth (m)							
Flow (m/sec)								

7.3 Hydrology and Water quality

731 Introduction

The purpose of this datasheet is to establish an appropriate interface to the hydrological and water quality data through HYDSYS. Normally the gauging stations throughout the catchment are entered as special sites in the data base using the standard identification codes. This allows access to the flow records and water quality records in the form of suitable summary parameters. It also allows the flows at the time of the survey to be determined and compared with the flow pattern. Certain other estimates of the prevailing conditions are also made to establish flow and rainfall patterns at the time of the survey.

Water quality measurements are not normally taken during the survey, however provision is made for optionally recording such information. Such water quality comparisons across the entire catchment may prove very useful in establishing the variability of conditions and the adequacy of the water quality monitoring sites throughout the catchment. In future it may be possible to include water quality summary information in the database, perhaps in specific catchments, but the data currently available are inadequate for this purpose.

7.3.2 Issues and Concepts

Existing hydrological and water quality data (HYDSYS) will be used rather than collecting information during the survey. The key is to select appropriate hydrological summary parameters which are relevant for the condition assessment and for classification purposes. The simplest option is to use the existing facilities of the HYDSYS package such as low flow analysis, seasonality of flow, flow duration, and flow variability statistics. This needs to be further developed. The concept would be to apply one or more of these packages to the hydrological record at each gauging sites and then to enter a suitable set of summary statistics into the database. The other alternative would be to develop another form of hydrological classification which would be more relevant relating to high and low flow dynamics and the seasonality, variability and consistency of flows (e.g. for low flows - Zelenhasic & Salvai 1987; Nathan & McMahon 1990). Some measure of the extent of modification of the natural flow regime and the relationship between licensed diversions, actual diversions and the water yield to derive the 'exploitation rate or level' would also be helpful as this is an important aspect of assessing the condition of the stream. This also requires further development or application of existing models. These aspects could be easily incorporated for the stream gauges, but would be much more difficult for the ungauged sections. The more important hydrological aspects are:

1. Extent of modification of the natural flow regime.
2. High flow events - peak annual instantaneous discharge, bankfull discharge.
3. Low flow events - analysis based on low flow events, their frequency, size and duration.
4. Flow variability and consistency on a seasonal basis.

7.3.3 Boundaries

Only the gauging stations would normally be included, but there is scope for recording flow and water quality information for potentially all the sites.

7.3.4 Scope and Limitations

The information is obviously limited to the data collected at the gauging stations and the sampling regime. Some extrapolation will be required between stations. Water quality data has not yet been incorporated into the DPI's HYDSYS.

7.3.5 Parameters

The parameters are the gauge reference number, reading and estimated flow; the estimated number of days since the last bankfull discharge, the last major flood and the last major rainfall event. The general local condition prevailing at the time of the survey are also recorded. Flow regime and water quality summary parameters derived from HYDSYS can be added to the data sheet and database when this aspect has been finalised.

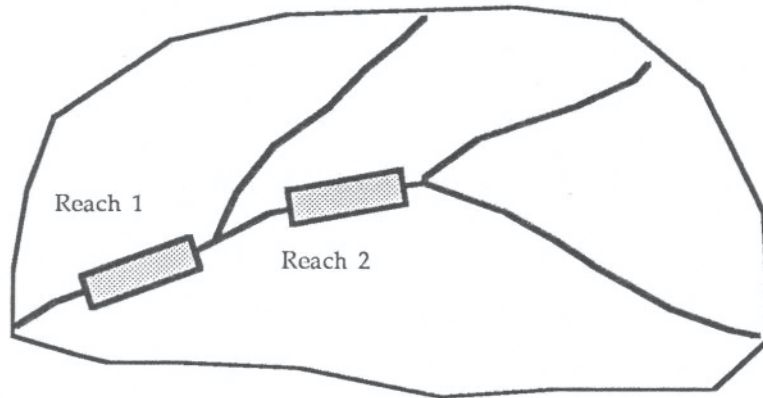
7.3.6 Targets outputs and indicators

Summaries of the hydrology and water quality can be used for classification purposes. The other data establishes the context of the sampling terms of the flow and rainfall records.

[illegible]

7.4.1 Introduction

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7.4.2 Issues and Concepts The following points are important :-

- The sites selected should be representative of the section.
- The site description and location reference should allow the site to be precisely located for follow-up surveys in the future.
- The AMTD for the site should be obtained from relevant maps, and also the total AMTD distance combining the main channel and tributaries should also be estimated.
- Several different types of site are recognised extending from Stream gauge locations, water quality sampling sites (from previous studies), and sites where only this sheet and a set of photographs have been taken.

7.4.3 Parameters

Location should be defined by grid reference, latitude and longitude using portable satellite navigation equipment (GPS). Position errors should be calculated based on the accuracy of the GPS equipment and its stated performance under the prevailing conditions. Both latitude/ longitude and grid references should be taken for checking purposes.

A standard set of photographs should be taken at each site (colour slides using wide-angle lenses) including the following aspects:

1. Reach environs
2. Upstream and downstream views
3. Lateral left and lateral right
4. Key features

A standard method for labelling and filing the slides has been established so that the photographic record is properly archived. Labels attached to each slide should include the following:-

- map coordinates and latitudes/longitudes for the site
- type of photograph
- site number
- date

Catchment area upstream of the site and whether or not the site is tidal are also recorded. Gauging stations locations are entered as special sites in the database.

7.4.4 Targets outputs and indicators

The location information should be adequate for enabling the exact location of the surveys to be determined for future follow-up work. The standard set of photographs for each site provide invaluable back-up for the survey and also are the foundation for setting a baseline for future follow-up surveys.

[illegible]

The diagram shows a plan view of a river channel. A central rectangular area is shaded with a stippled pattern and labeled "Reach 1". This reach is situated within a larger oval boundary. Arrows point outwards from the reach in six directions: straight up, straight down, and four diagonal directions (up-left, up-right, down-left, down-right). The river channel is represented by a line that enters from the left, passes through the reach, and exits to the right, with a slight meander.

The aim here is to record local information about the land immediately adjacent to the reach and information about the water flow and water level conditions prevailing at the time of the survey.

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stream. It includes information on:-

- local land use local disturbance
- local vegetation type
- floodplain features (billabongs etc.)
- local land tenure

The datasheet was adapted from that used by Anderson and Morison (1989) and Mitchell (1990). An overall shoreline vegetation disturbance rating (Anderson and Morison 1989) is also made in relation to the extent of clearing and replacement of vegetation by exotic species in the riparian zone and adjacent land (valley flat/floodplain and shoreline /riparian vegetation).

7.5.2 Issues and Concepts

The aim is to characterise the broad-scale features of the environs of the reach selected for the survey. Although the survey is focused on the stream and the riparian zone, it is also valuable to collect general information about the floodplain and valley-flat areas immediately adjacent to the reach. This information is difficult to obtain by other means. The concept is that the general condition of the floodplain lands has a large effect on the stream, and therefore needs to be assessed. The broad-scale channel pattern for the stream is also important for classification.

The major issues are :- land tenure, sedimentation rates and sources, vegetation cover, sources of disturbance.

7.5.3 Boundaries

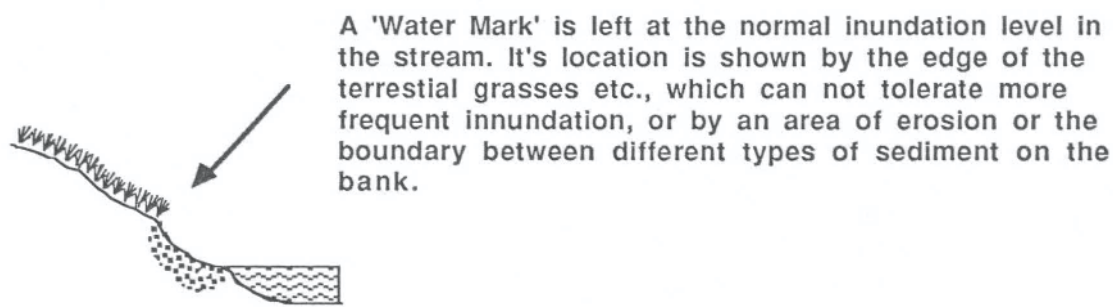
The survey is restricted to the Adjacent Land that is the land bordering the riparian zone and what can be readily seen on site.

7.5.4 Scope and Limitations

The assessment is in very general terms but is nevertheless important as such data is not readily available from other sources.

7.5.5 Parameters

Water level at the time of sampling - water level at the time of sampling is recorded in relation to the 'water mark'. The concept of a 'water mark' is used to provide a reference point for standardising the channel measurements and for defining the boundary between the lower and upper banks. A mark is left on the bank at the normal inundation level for the stream. It is delineated by either the edge of the terrestrial grasses and other vegetation which cannot tolerate more frequent inundation, or an obvious point of erosion or substrate differences along the bank. Its origin, definition and use is described in more detail by Anderson and Morison (1979). The concept was originally described by Woodyer (1968).



Adjacent land use classification - pasture, forest, crop-land etc.

Tenure of land - private, forestry, national park etc.

Channel pattern classification - Map scale and Local scale

Local meander wavelength

Width of the floodplain and valley flat

Local sources of disturbance - bridges, culverts, pumps, roads etc.

Floodplain features - anabranches, ox-bows, wetlands etc.

(Note: The categories were developed during the consultation with various personnel)

7.5.6 Targets outputs and indicators

Overall stream classification in terms of adjacent land tenure and use

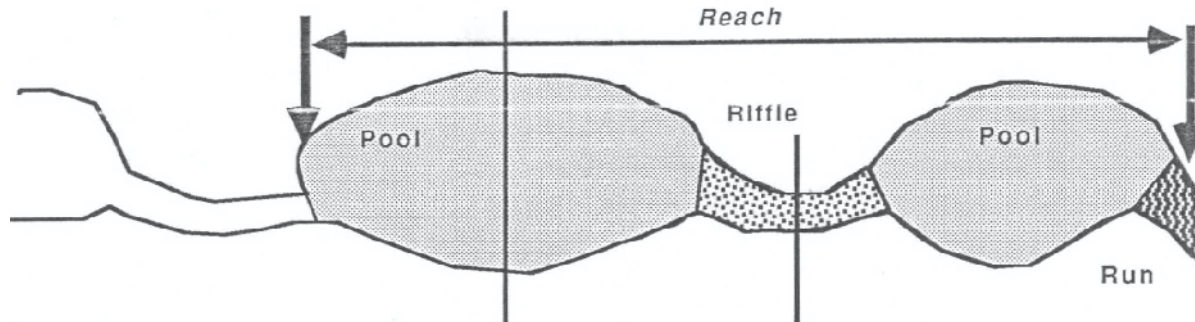
Links between instream parameters and floodplain characteristics

The overall disturbance rating is a very useful parameters integrating many aspects of the condition of the shoreline vegetation.

Figure 5 Data Sheet 5 Channel Habitat

STATE OF THE RIVERS — SHEET 5 Channel Habitat				Date (dd/mm/yy) Recorder																																																
Basin	Sub-section	Site	Tributary Name																																																	
1	2	3	4																																																	
Channel Habitat Types <table border="1" style="width: 100%; border-collapse: collapse; font-size: 0.8em;"> <tr> <td style="padding: 2px;">Height > 1m Gradient > 60 deg</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. height (m)</td> <td style="padding: 2px;">Est. Av. Gradient (deg.)</td> </tr> <tr> <td style="padding: 2px;">Stop Height < 1m Gradient 5 - 90 deg Strong Currents</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. height (m)</td> <td style="padding: 2px;">Est. Av. Gradient (deg.)</td> </tr> <tr> <td style="padding: 2px;">Depth > 0.3 m Gradient 3 - 5 deg Strong Currents Rocks break surface</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> <tr> <td style="padding: 2px;">Depth 0.1 - 0.3 m Gradient 1 - 3 deg Moderate Currents Surface unbroken but unsmooth</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> <tr> <td style="padding: 2px;">Depth < 0.1 m Gradient 1 - 3 deg Small Currents Surface unbroken and smooth</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> <tr> <td style="padding: 2px;">Depth > 0.3 m Gradient 1 - 3 deg Small but distinct & uniform current Surface unbroken</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> <tr> <td style="padding: 2px;">Depth > 0.5 m where stream widens or deepens and current declines</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> <tr> <td style="padding: 2px;">Depth < 0.3m a reasonable size (>20% of channel width) cut-off section away from the channel</td> <td style="text-align: center;"></td> <td style="padding: 2px;">% of section</td> <td style="padding: 2px;">Est. Av. length (m)</td> <td style="padding: 2px;">Est. Av. depth (m)</td> <td style="padding: 2px;">Est. Av. Width (m)</td> </tr> </table> Selecting a Reach Choose an appropriate Reach for the remaining assessment. It should:- 1. Preferably contain at least 2 complete pools and riffle / run habitats 2. The whole length of the reach should be visible at one location. 3. The pool should be the largest and deepest in the area. Sketch the reach showing the location and dimensions of the major habitat types. Measure the length width of each channel habitat type and take a transect across each type located at right angles to the shoreline and passing over the point of maximum depth in a pool (low flow area) and maximum flow / bed height for a run or riffle habitat. I.e. the transect where flows would be expected to be maximal. Total Length of reach (m) REACH DETAILS 3 Sketch the reach showing the channel pattern and the distribution of channel habitat types and key features. A cross-section profile showing the bank shape and vegetation types would also be helpful if there is time					Height > 1m Gradient > 60 deg		% of section	Est. Av. length (m)	Est. Av. height (m)	Est. Av. Gradient (deg.)	Stop Height < 1m Gradient 5 - 90 deg Strong Currents		% of section	Est. Av. length (m)	Est. Av. height (m)	Est. Av. Gradient (deg.)	Depth > 0.3 m Gradient 3 - 5 deg Strong Currents Rocks break surface		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)	Depth 0.1 - 0.3 m Gradient 1 - 3 deg Moderate Currents Surface unbroken but unsmooth		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)	Depth < 0.1 m Gradient 1 - 3 deg Small Currents Surface unbroken and smooth		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)	Depth > 0.3 m Gradient 1 - 3 deg Small but distinct & uniform current Surface unbroken		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)	Depth > 0.5 m where stream widens or deepens and current declines		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)	Depth < 0.3m a reasonable size (>20% of channel width) cut-off section away from the channel		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)
Height > 1m Gradient > 60 deg		% of section	Est. Av. length (m)	Est. Av. height (m)	Est. Av. Gradient (deg.)																																															
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Depth < 0.3m a reasonable size (>20% of channel width) cut-off section away from the channel		% of section	Est. Av. length (m)	Est. Av. depth (m)	Est. Av. Width (m)																																															

7.6 Channel Habitat



7.6.1 Introduction

An appropriate reach representative of the channel habitat types, instream physical and ecological condition is selected for survey. The aim of this datasheet is to classify the segments of the reach into the following broad channel habitat types:-

waterfall
cascade
rapid

riffle
glide
run
pool
backwater

These represent the broad range of aquatic habitats present and the diversity of sediments, flows, depths and general habitats present in the reach. This classification is important for both the physical and environmental condition of the stream. The classification follows Anderson and Morison (1989). The diversity of habitat types present in the area and their features and relative size and dimensions are also recorded. Ideally the reach should contain 2 meander wavelength and 2 complete pools and riffle/run habitats. The length of the reach selected for survey is recorded. Transacts are taken through each habitat type present at the deepest point in the pool and the shallowest point at the thalweg for riffles and runs. The distribution of the channel habitat types and the location of the transects are recorded using a sketch.

7.6.2 Issues and Concepts

The channel shape, dimensions and form are fundamental for the classification of streams and rivers for both physical and environmental purposes. The range of channel habitat types and the diversity of types present at any location are important ecological parameters.

7.6.3 Boundaries

The channel measurements are made from bank top to bank top for the two or more cross-sections taken within each survey reach. The focus of the surveys is on the extremes within each reach - the point of maximum depth and minimum flow (pools), and the point of minimum depth (highest bed height across the stream) and maximum flow (riffle or run section). Additional cross-sections should be taken at other channel habitat types within the reach. The extremes are chosen to establish the range of substrates, depths and channel parameters within the reach. Transects are taken across the wetted perimeter of the stream, and across the lower and upper banks on each side to the bank top.

7.6.4 Scope and Limitations

The cross-sections include relatively few points and this limits their application to broad-scale less detailed analysis of channel dimensions. No surveying techniques are used to establish height datum and the only reference points for comparison are the bank-top, the water mark and the water surface. This again limits their usefulness. More detailed information would take too long to obtain and would require knowledge and experience not generally available for the people to be involved in the survey. Cross-sections taken at stream gauges may be used to assess the accuracy of the information obtained. Despite these limitations the data obtained is invaluable for establishing the relative channel dimensions.

7.6.5 Parameters

Percent of the channel in each of the channel habitat types (pool, riffle, run, cascade, waterfall etc.)

channel dimensions at water level, at the 'water mark' (normal flow level) and at the top of the bank (bankfull level)
lower and upper bank slope
bed and bank sediments at several points across the cross-section depth at the cross section
and estimated average depth remnant pool volumes

Other Data Sources

Transects at gauging stations and from flood studies could be added to the database or used for historical comparisons.

7.6.6 Targets outputs and indicators

Channel dimensions and cross-sectional area at various flows (water level at time of survey, at the "water mark", at bankfull stage) Bank slopes and sediments
Bed profile and sediments
Percent of reach classified into each of the channel habitat types Remnant pool volumes
Transects establish base lines for future follow-up surveys

Figure 6 Data Sheet 6 Cross-Section

STATE OF THE RIVERS --- SHEET 6 --- Cross-Sections

Basin: Sub-section: Site: Section Number for This reach:

Page of Date (dd/mm/yy) Recorder

1 TYPE Pool ☐ Length of Type (m)
 Riffle ☐ Av. Width of Type (m)
 Run ☐ Av. Depth of Type (m)
 Glide ☐
 Cascade ☐
 Rapid ☐
 Backwater ☐
 Other

Sediment Classification
 Sediment classes are those of the SAA which are easier to estimate visually - estimate % of total inorganic volume occupied by each category. Estimate organics as % of total vol. Record presence of each type (esp. max. and min. sizes) and % vols for major fractions.
 Fine: ☐ Sand: ☐ Gravel: ☐ Cobble: ☐ Boulder/Rock: ☐
 0.1mm salt 0.5mm sugar grain 2mm raw sugar 5mm pea 10 cent coin 20mm tennis ball 60mm Head 300mm ?
 P. Organics = particulate organics - estimate as % of the total volume. Inorganic components are estimated from the inorganic fraction only (i.e. omitting the organics)

Bank Sediments
 Left: mm < 0.05, 0.06 - 0.5, 0.5 - 2, 2 - 5, 5 - 20, 20 - 60, 60 - 300, Bould > 300, P.Organics
 Right: mm < 0.05, 0.06 - 0.5, 0.5 - 2, 2 - 5, 5 - 20, 20 - 60, 60 - 300, Bould > 300, P.Organics

Bank Measurements
 Left Bank: Upper Bank height, Upper Bank width, Lower Bank height, Lower Bank width
 Right Bank: Upper Bank height, Upper Bank width, Lower Bank height, Lower Bank width

Cross-section readings across the bed (minimum of 3, maximum 15)
 Reading 1 to Reading 8: Dist (m), Depth (m), Flow (m/s), mm, pres. % by vol., pres. % by vol.

5 LEFT LOWER BANK
 Width (m), Height (m), Slope (deg.)

6 LEFT UPPER BANK
 Width (m), Height (m), Slope (deg.)

8 RIGHT LOWER BANK
 Width (m), Height (m), Slope (deg.)

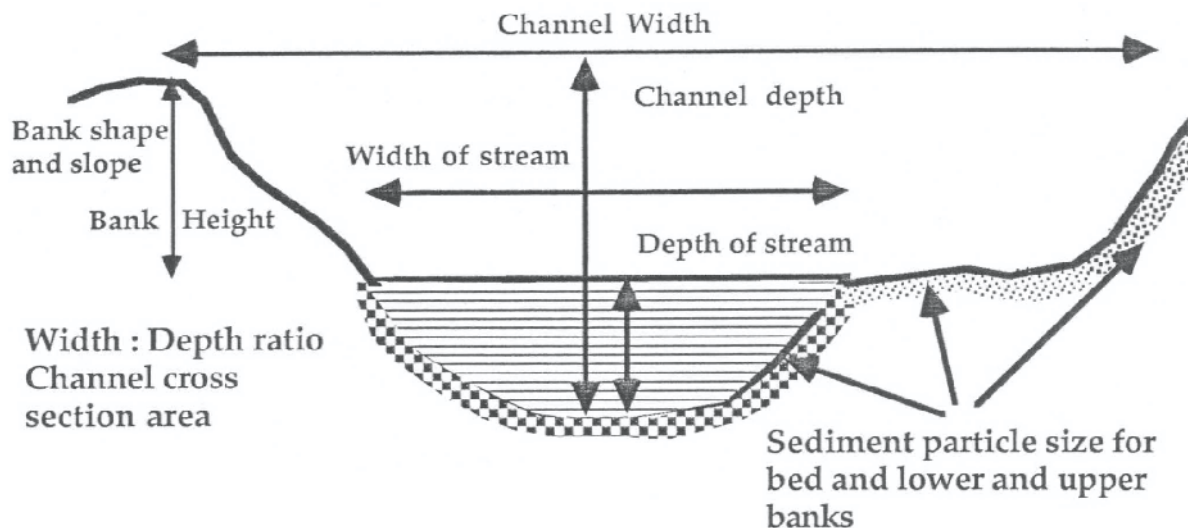
9 RIGHT UPPER BANK
 Width (m), Height (m), Slope (deg.)

11 Rock Outcrops
☐ Left Lower bank
☐ Left Upper bank
☐ Right Lower bank
☐ Right Upper bank
☐ Bed
☐ None

5 Total Width (m) at the water surface or where transect taken

6 Page No. for Extra Readings

7.7 Cross-sections



7.7.1 Introduction

Cross-sections are taken to provide a basic picture of the channel size, shape and form. A series of sediment samples are also taken at several points across the bed and also on the lower and upper beds banks. The particle-size composition of the sediments is determined by visual inspection using the estimated percentage contribution of each particle-size fraction to the total volume of inorganic materials present (Anderson and Morison 1989).

Channel shape, morphology and dimensions are fundamentally important for classifying the aquatic habitats in relation to physical and biological attributes. Stream invertebrate distribution and abundance is very much influenced by the type of substrate present and the relationship between flows depths and substrates. Bank and bed sediment particle size composition also dictate the response of the stream to various disturbances. The cross-sections also provide base-line information for follow-up surveys when changes in channel dimensions may be detected. They are also important for understanding the processes affecting the stability of the channel e.g. headward erosion of the bed.

The techniques and data sheet have been adapted from Anderson and Morison (1989). The sediment size classes are those of the Standards Association of Australia, Australian Standard 1726 - 1981, SAA Site Investigation Code (gravel = 2 - 60mm; sand = 0.06 - 2mm; and silt/clay = < 0.06 mm).

7.7.2 Issues and Concepts

Taking cross-sections in each of the channel habitats present provides information on the diversity of habitats and habitat parameters present. Focusing the cross sections at the point of maximum depth in pools and minimum depth at the thalweg in riffles and runs provides information on the range of bed sediments in the reach. Many of the attributes included on this data sheet are also important for other components e.g. pool depth for fish and invertebrate habitat, substrate particle size for aquatic habitat.

7.7.3 Boundaries

The channel assessment is made from bank top to bank top at two or more cross-sections within each survey reach. The focus of the surveys is on the extremes within each reach - the point of maximum depth and minimum flow (pools), and the point of minimum depth (highest bed height across the stream) and maximum flow (riffle or run section). Additional cross-sections should be taken at other channel habitat types within the reach. The extremes are chosen to establish the diversity and range of substrates, depths and channel parameters within the reach. Cross-sections are taken firstly across the wetted perimeter of the stream, and the measurements are continued up the lower and upper banks on each side of the stream to the bank top. The boundary between the lower and upper banks is set at the 'water mark'. The depth estimates are made at the time of the survey and they will therefore be dependent on the prevailing discharge at the time of the survey. However, calculating depths relative to the 'water mark' provides a simple way of standardising the depth and width measurements for the different channel habitats.

7.7.4 Scope and Limitations

The cross-sections are reliant on only a minimal set of measurements, 3-5 across the wetted perimeter, and 2 width and height measurements for each bank, in a small stream. There is scope for an unlimited number of measurements to be made, but time is the ultimate determinant of how much detail can be obtained. Approximately half the time for the survey at each site is already set aside for the cross-section measurements. The small number of measurements obviously restricts the use that can be made of the cross-section information. Nevertheless the measurements are invaluable for the broad scale comparisons between stream sections. There is simply no substitute for these measurements. The small number of measurements taken represents a compromise, because the cross-sections take a long time (about half the total time at each site). A portable echo-sounder is used for taking depths at sites too deep to wade. Some of these sites will be surveyed by boat, again using an echo-sounder. Sections of stream that are dry at the time of the sampling are still measured using the 'water mark' as the reference point from which to measure the "depths" as depths a tape stretch across the channel at the water mark. These measurements enable depths, widths, flows (an option) and substrate particle size composition to be compared in different channel habitat types and at different points across the channel. This information is of fundamental importance for classifying the instream habitat in terms of its macroinvertebrate and fish communities. Depths and widths can be compared for the channel (from the bank top), for the "normal" or "usual water" flow (from the water mark), and for the depth prevailing at the time of the survey (from water's surface).

7.7.5 Parameters

Channel dimensions along transects at water level, at the 'water mark' (normal flow level) and at the top of the bank (bankfull level /channel dimensions) for each type of channel habitat type present in the reach.

Sediment particle sizes , and estimates of the particulate organic matter for the lower and upper banks and bed sediments.

Lower and upper bank width, height and slope.

Depth at the cross section and estimated average depth.

7.7.6 Targets outputs and indicators

- Channel dimensions and cross-sectional area at various flows (water level at time of survey, at the "water mark", at bankfull stage)
- Pool, riffle, run habitat dimensions (diversity of depths and widths)
- Bank dimensions, slopes and sediments
- Bed profile and sediment distribution (diversity of sediment types present in the reach)
- Width : depth ratio
- Estimates of remnant pool volumes
- Transects establish base lines for future follow-up surveys to detect changes in channel form.

Figure 7 Data Sheet 7 Bank Condition

STATE OF THE RIVERS — SHEET 7 BankCondition

Basin: Sub-section: Site: Tributary Name:

Date (dd/mm/yy): Recorder:

The "Water Mark" is left at the normal inundation level in the stream. It's location is shown by the limit of the terrestrial grasses etc. which can only withstand short periods of inundation, or by an eroded area or boundary in the bank sediment types.

Assess the condition of the banks on the left and right side of the stream (facing downstream). Identify the major types of instability (eroding, slumping & aggrading) and mark the location where they occur on the lower and upper banks. Also record the slope and shape of the banks, and make an overall assessment of instability.

LEFT BANK

1 LOWER BANK 2 UPPER BANK

Record % of bank length: Stable: Bare of Veg:

LOCATION for instability: Eroding: Aggrading: Slumping:

11 LEFT BANK Slope (Rank types)

12 Artificial Bank Protection Measures

13 Levee Banks

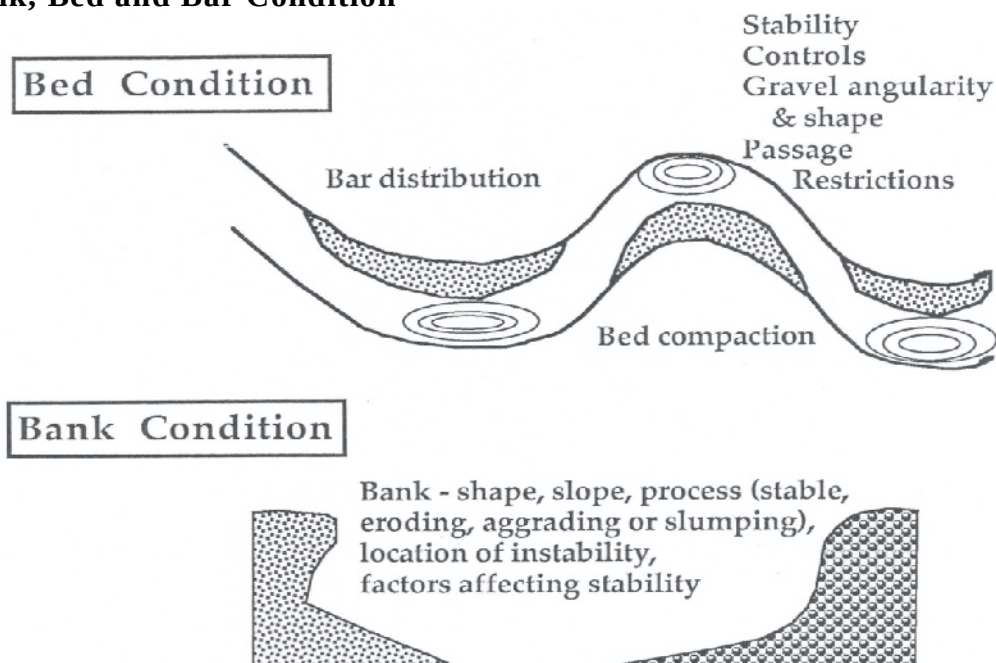
14 RIGHT BANK Slope (Rank types)

15 RIGHT BANK Shape (Rank types)

Rate the Overall Condition of the Left Bank: High: Mod: Low: Min:

Rate the Overall Condition of the Right Bank: High: Mod: Low: Min:

7.8 Bank, Bed and Bar Condition



7.8.1 Introduction

Two data sheets are used to assess the condition of the bed bar and banks. These data sheets were developed from those of Anderson and Morison (1989), those used for the study reported by Mitchell (1990), ideas of Geoff Eades, DPI, Water Resources Business Unit (personal communication) and SCRC (1991). The assessment is made in terms of the percentage of the length of bank or surface area of the bed, which is assessed to be stable or unstable (eroding, aggrading, slumping). The type of bar and its relative percentage of the total surface area of the bed are also assessed. The location of the instability (bends, obstacles etc.) and the local factors affecting stability are also assessed to help to identify the processes involved. Overall semi-subjective ratings of the condition of the bed and banks stability are also made. The suitability of the site for general fish passage and for specific barriers at the site is also assessed in relation to the stage at the time the survey is made and of the stage required for the barrier to be effectively by-passed or over-topped.

7.8.2 Issues and Concepts

The natural dynamics of river drainages and floodplains are dependent on the variable features of the catchment geomorphology, dominant soil types, vegetation cover, as well as climate, and the channel morphology and dimension and substrate features are all interrelated (Leopold & Maddock, 1953; Leopold et al., 1963; Richards 1982). Rivers in good physical condition have particular characteristics relating to the dynamic inter-relationship between discharge, flow, sediment carrying capacity and channel form (after Chorley et al. 1984; Richards 1982).

Figure 8 Data Sheet 8 Bed and Bar Condition

STATE OF THE RIVERS SHEET 8 Bed and Bar Condition

Basin Sub-section Site Tributary Name

Record the total % of bed surface along the reach protruding out of the water at the water mark and forming a bar. Identify its type, the features of the bed & gravel if present, the overall stability of the bed and the controls and factors affecting the stability of the bed.

1. BAR TYPE

Bars Absent

Point

Alternate / side irregular

Mid-channel island

Encroaching Vegetation

Around Obstructions

Channel bar plain

Low flow meander infilled channel

High flow deposits

2. BAR SIZE % of bed surface forming a bar

3. Gravel Features

Angularity: Very Angular, Angular, Sub Angular, Rounded, Well Rounded

Shape: Sphere, Disc, Blade, Rod

4. Gravel surface: Gravel covered by algae / silt, Gravel - 'clean'

5. Bed Compaction

Tightly packed, armoured

Packed, but not armoured

Moderate Compaction

Low Compaction

6. Factors Affecting Stability

Sand & Gravel extraction

Bed deepening

Bank Erosion

Channelisation

Cut-off of supply of alluvial materials

Mining

Agriculture or grazing

Sand & Gravel extraction

7. Controls: Stabilising the Bed

Bridge Ford or Culvert

Rock Outcrops

Fallen Trees

Bed stabilising structures

Other

None

8. Overall Bed Stability Rating

Unstable / Eroding ← Stable → Unstable / Aggrading

9. PASSAGE FOR FISH AND OTHER ORGANISMS

1. Score the general passage for the prevailing conditions (now) and for the stage equivalent to the water mark.

2. For Obstructions give type, height above water mark and stage when by-passed or over-topped.

No Passage

Very Restricted

Moderately Restricted

Partly Restricted

Good Passage

Wide no torrent Unrestricted

High dam weir, or waterfall

Cascade rapid or log jam

Low weir, pile culvert, ford, bridge

Single log, branch, pile, rock

Low feature easily by-passed

None

Other

These characteristics are :-

- a tendency to reach equilibrium channel form where channel-forming discharge and sediment loads are balanced;
- a vigorous riparian, aquatic and emergent vegetation promoted by a sequence of flows that allows germination and growth, and control of excessive build up of vegetation;
- a capacity to recover a pre-existing channel form after a large flood (resilience);
- characteristic channel patterns and relative stabilities for different particle size distributions of the sediment load, resulting in highly stable low sinuosity muddy channels and widely varying braided sand and gravel channels;

The normal pattern of dynamic equilibrium with irregular channel modifying episodes associated with of floods, and near bank-full discharges, may be altered, accelerated or shifted towards another direction by a range of human activities.

Major Problems - Streams and rivers are regarded as being in poor physical condition when there has been some perceived loss of amenity or value in one of the role expected of a natural stream because of one or more problems. Major problems in streams leading to their classification as degraded, being of poor condition and requiring some sort of management action are :-

- bank erosion - many causes

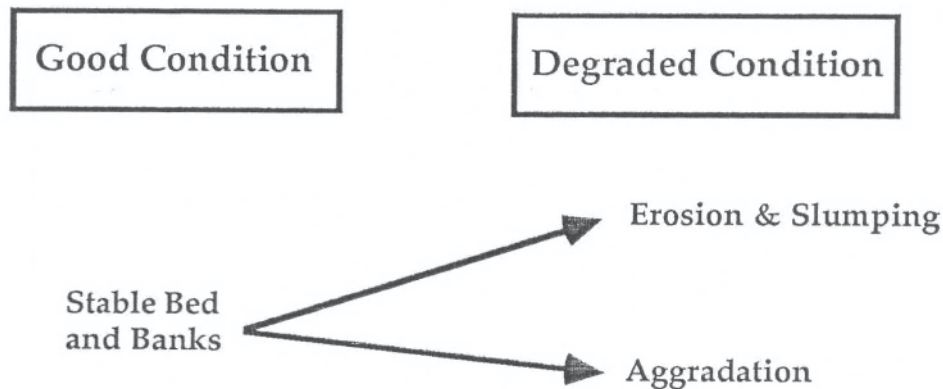
- channel breakaways and lack of confinement of the stream to its original channel
- active meandering leading to bank collapse, trees falling into the stream and loss of agricultural production
- deepening of the bed - gulying of upper tributaries often a cause of bank erosion
- aggradation of the bed - build up of silt, sands and gravels in the channel, reducing cross-section area, destroying habitat values and shallowing the channel leading to breakaways.
- off-channel scours and siltation
- flooding and waterlogging
- Infilling of the channel leading to loss of storage
- Water quality deterioration (adapted from SCRC 1991)

Major Concepts - The major concept for assessing the physical condition of the bed, bar and banks of streams is the notion that undisturbed streams will be in a more or less stable state of dynamic equilibrium (Dury, 1966; Richards, 1982; Heede 1986). Such stream are often referred to as 'graded' streams. The term grade was defined by Davis 1902 to describe the 'balance between erosion and deposition attained by mature rivers'. The stream continually adjusts to maintain equilibrium with its environment. Variations in the balance between sediment supply and sediment transport capacity either along the length of a stream or within a cross section can cause the stream to alter in one of the stream's six degrees of freedom:- slope, depth, width, planiform, bed form, or flow resistance, in order to return to an equilibrium or graded stream condition (SCRC 1991). Changes in the stream morphology or "condition" in the short, medium or longer term may occur either gradually, or suddenly through the impact of a major event such as a flood, or because the stream has approach a threshold situation which will send it along a different path when the next event occurs. These short, medium or long term changes can be triggered by various natural causes such as major floods, seasonal changes and climate changes (e.g. rainfall patterns).

The erosion rates in channels have been correlated with width, depth, curvature, channel slope, and amount of vegetation on the banks Odgaard (1987). However, medium term changes are often 'forced' by human activities creating a temporary dis-equilibrium in the channel, which then passes through 'transient states' in approaching a new equilibrium. The change in sediment transport is in this case a step-function or a threshold rather than a continuous trend. The concept of morphologic thresholds is important in understanding the processes responsible for incised channels (Schumm et al. 1984; Harvey and Watson (1986). Such man-induced changes include direct human effects through construction of dams and major diversions, channelization, river management works. They can also be produced indirectly through changes to runoff, sediment supply and transport characteristics through land use, urbanisation, forestry and various other land use changes. Urbanisation of catchments often leads to channel incision by increasing peak discharges and the duration of high flows (Booth 1990).

Alluvial channels can be classified according to their stability characteristics which can be thought of in terms of the total sediment load delivered to the channel. Deposition occurs when the calibre of the sediment exceeds the power of the river to transport it. Erosion occurs when the stream power rises enabling material to be moved from the channel banks or bed. In stable channels there is no progressive change in gradient dimensions or shape and the channel is in a steady state. Significant bed or bank erosion or aggradation are

therefore a signs of instability and degraded stream condition likely to affect there use and amenity values. Assessment of the physical condition of streams therefore involves assessing the extent to which streams have become unstable and are in a degraded condition.



Various direct and indirect human impacts on the stream and catchment have complex effects on the channel SCRC (1991). For example, runoff and sediment yield vary markedly with land use differences in catchments of similar lithology and climate. For example, runoff from pasture and crops may be 30 and 350 times those from undisturbed woodland. It has also been shown that increased bare area in an overgrazed basin caused a 30% increase in runoff, and a 45% increase in sediment yield. The clearing of bank vegetation may be linked to grazing or crop management, or it may itself lead to profound shifts in channel form and shape. Reduced vegetation cover

may increase discharge, increase the velocity (and erosion capacity) of a given discharge, and reduce bank resistance - all of which favour bed and bank erosion. Urbanisation leads to reduced infiltration, reduced storage, faster overland velocities and therefore the runoff regimes are 'flashier' with shorter lag times and times bases and with higher peak flows. Sediment yields from urban catchments are 2-200 times the natural yield. Channel cross-sections eventually enlarge to accommodate the increased urban flood peaks. Weirs and reservoirs act as sediment and water storages which causes channel adjustments downstream. This does not necessarily imply that the shift from the stable or graded condition towards a degraded condition is always caused directly or indirectly by human impact. It could be produced by major floods or it could occur through a long term natural change in channel morphology.

Identifying the time-frame as well as the process - The time frames for channel metamorphosis and change in response to changes in sediment load and flow regimes are complex. Bankfull discharge events are seen as the primary flows for shaping the channels but larger catastrophic flood flows are also important as is their timing in relation to the recovery period at lower discharges. The dynamics of the processes are therefore difficult to assess using single 'snap-shot' surveys. We are primarily interested in the dominant process at the time of the sampling - that is, whether the banks *are* eroding, or whether sediment is accumulating, forming bars and filling in the channel. What we observe will

obviously depend on the time that has elapsed since the last major flood or bankfull discharge. What we see during the survey may also change very rapidly in the future, and this capacity for changes has to be considered. The survey can be used as a baseline against which to assess future changes if follow-up surveys are made, but there is no baseline for the first survey. So in conducting the survey we are primarily interested in identifying the current active process. It may be relatively easy to say that the bank is eroded, i.e. that it is steep and devoid of vegetation and apparently unconsolidated. It may be more difficult to say when the erosion occurred, last week last month or last year or that the banks are *still* eroding or that they are now becoming stable after the last active phase of erosion. Local knowledge may be invaluable in this supported by aerial photographs etc. It may be possible to allow this information obtained by talking with the local land owners to be incorporated into the survey.

Major Processes of Channel Change - One major objective of the survey is to get some indication of the dominant process of channel change that is occurring as well as an estimation of the extent of instability. SCRC (1991) list the following major processes leading to instability of bed and banks:

- Deepening of the channel bed
- Aggradation of the Channel bed
- Over-supply or under-supply of particulate sediments
- Off-channel scours and siltation
- Channel metamorphosis
- Meander development and progression
- Channel avulsion
- Sources of sands and gravels

Some of the factors contributing to the expression of the these processes are:

Channel Form, Shape, Dimensions and Substrates

-Detailed data are collected at 2 or more cross-sections in the reach.

Bank vegetation

- The condition and structure of the bank vegetation, and floodplain vegetation is important as is the proportion of bare banks. These aspects are included in the vegetation survey.

Bed and Bar Stability

- Obviously very important and linked with bank condition.

Reach Environs

- Provides background in terms of the larger scale channel pattern and signs of remnant ox bow lakes abandoned channels, billabongs.

Understanding these processes and the indicators for them are therefore fundamental for any condition assessment and for identifying the likely causes and therefore the potential long term solutions to the problems. The major processes and the indicators for them are:

Channel Metamorphosis - process whereby a complete change in channel morphology occurs in response to changes in sediment load or flow regime often triggered by a large flood or sequence of floods which cause the crossing of a geomorphic threshold. The major problems are bank erosion channel deepening, channel aggradation, off-channel scars, siltation, flooding or waterlogging.

Indicators - a shift from meandering to braided form may be triggered by extra sediment supply. Historic background is required to discern the changes. It requires a thorough understanding of the processes to tackle it.

Meander Process - Erosion and deposition by meander processes has contributed to the formation and reworking of most alluvial floodplains. Within a meander bend secondary currents develop a helical motion tending to erode material on the outside of the bend and to deposit it on the inside forming a point bar. Through time the point bar moves downstream by erosion of material from its upstream face, and deposition at its downstream end. The most common problem caused by this is bank erosion on the outside of the bends, but it can also lead to overbank scour or overbank flooding if the meander erodes through the natural levee bank.

Indicators - Bank erosion is the most common indicator of meander processes. Supporting evidence is:-

- erosion most severe on outside of bend
- growth of an adjacent point bar downstream on the inside of the bend
- banks collapsing due to the development of a deep hole on outside of the bend
- bank failure by undermining of the toe of the bank and subsequent failure
- historical evidence - oxbow lakes, remnant courses and swales
- natural cut-offs forming across meander necks
- meander crowding at bridges, rocky outcrops etc.

Channel Avulsion - This refers to the process by which a stream channel is abandoned in favour of a new course within the floodplain. This typically occurs where a river channel has evolved to the point where its capacity is low relative to the flow regime ("perched" channel on the flood plain). Overbank flow scours a new course for a section of the stream. It can lead to major losses of floodplain land.

Indicators - It can be manifest as problems of erosion or deposition. Scouring of floodplain depressions during floods. Headwards erosion where floodwater enter the new channel, or erosion of gulches where floodwaters leave the channel are good indicators. It can also be indicated by deposition and vegetation encroaching into the channel.

Upstream Progressing Bed Deepening - This is the process by which deepening in the bed of the channel moves progressively upstream. It can be triggered by many human impacts causing an increase in flow magnitude, frequency or volume resulting from clearing, land use changes and drainage in the catchment, concentration of flow at bridges and culverts, channel alterations such as channelization or straightening, desnagging or constructing levee banks reducing floodplain storage. Degradation may also be triggered by a reduction in sediment supply by the construction of a dam or sand and gravel extraction works. The progressive channel deepening moving upstream leads to problems of channel deepening, bank

collapse and aggradation downstream.

Indicators - Discernable water falls, or upstream movement of a less obvious steeper section different bank heights between reaches upstream and downstream loss of "chain of pools" structure to a stream which has deepened. Steep raw banks and fallen timber associated with bank retreat bare bed stripped clean of alluvial material.

Localised Bank Erosion - Bank erosion is most often the result of one or more of the previous processes, but it can also develop locally in a way unrelated to the more general channel changes. It can be initiated by stream flow, unconsolidated bank materials, groundwater, drawdown, obstructions to flow, surcharge, channel deepening, clearing of bank vegetation, irrigation flows, overbank flows, recreational pressures through tracks, waves from boats, tracks etc.

Indicators -

Stream flow - almost always a factor through attrition or undermining, or mass failure through erosion of the toe.

Bank Material - look for seams or pockets of erosion prone material in the bank

Groundwater - seepage may lead to the attrition of fines

Drawdown - rapid drawdown leaves the bank saturated and with less strength

Obstructions to flow - fallen trees, willows etc. may divert flows into the banks

Surcharge - loads on top of the bank may lead to bank failure

Channel deepening - may initiate bank retreat as the bank adjusts its slope in response to decreasing toe levels, or it may allow undermining of protective works or vegetation.

Lack of vegetation - vegetation binds the soil structure, reduces the effects of waves and physically protects the soil by providing a barrier between soil and flowing water.

Vegetation Collapse - may trigger the erosion

Prolonged high summer water levels - may inhibit bank vegetation and prevent root development in the toe of the bank.

Recreational Pressures - tramping of the bank vegetation, or digging etc.

Overbank flows - water entering the river from the adjacent land may cause bank erosion at the point of re-entry, also water leaving the channel may do the same thing.

The various indicators can then provide a means to identify the major processes leading to the change in the physical condition of rivers and streams.

GENERAL INDICATORS OF DOMINANT PROCESSES

Isolated Metamorph	Channel Process	Meander Avulsion	Channel Incision	Channel Bank Erosion
Banks Eroding	÷	÷		÷
Erosion mostly on outside of bends		÷		÷
Steep raw banks all along channel			÷	÷
Erosion where high flows enter and leave the channel	÷	÷	÷	
Erosion through natural levees				÷
Bank bare and aggrading				÷
Bank heights decrease upstream				
Bank erosion at obstruction				
Bed Eroding and Scouring				
water falls in bed				÷
gravels loose and bright		÷		÷
bed rated as major erosion				÷
Bed Aggrading with New Clean Deposits		÷		÷
mobile point bars		÷	÷	
extensive bar deposits			÷	
islands and encroaching vegetation				÷
banks steep and lower upstream				
Floodplain Signs				
recent remnants of anabranches, ox-bows		÷	÷	÷
scouring of floodplain			÷	
depressions, chutes				÷
recent floodplain sand deposits				
natural levees and signs of perched streams				

Major Causes of Changes in Condition - The various causes of changes in condition and instability through these processes are (adapted from SCRC (1991):

- long term changes to the hydrologic or sediment regime of the catchment;
- catastrophic flood or a sequence of such floods. A catastrophic flood is one which exceeds the threshold which controls the equilibrium state of the channel, if such events recur before the channel has had time to recover the channel will change, both the size and return frequency of floods is important crossing a geomorphic threshold e.g. meanders progress then lead to sudden meander cutoff, or channel evasions will trigger changes in flood plains;

- complex response where stream shifts between various states progressively downstream, e.g. channel deepening will progress upstream leading to siltation downstream, ultimately as upstream progression slows and sediment supply is decreased, a new episode of incision may be triggered in the newly deposited materials;
- direct human interference
 - gravel extraction - causes a sediment sink, causing scouring or bank erosion
 - clearing vegetation - causes loss of binding of materials but also a loss of flow resistance
 - flood mitigation works - causes an increase the proportion of the flood flows carried by the channel leading to bed or bank erosion
 - desnagging may decrease hydraulic resistance and lead to scouring, but also removes protection from scouring
 - drainage of swamps can trigger channel deepening
 - river realignment may initiate further channel changes;
- indirect human interference such as wave action from boats, walking tracks along banks, waste and rubbish disposal into streams;
- catchment clearing and land use change modification, salinity, sediment runoff, etc.

7.8.3 Boundaries

The bank survey are conducted on the lower and upper banks (the boundary between them is at the "water mark"). Separate surveys are made for the left and right banks.

7.8.4 Scope and Limitations

The interpretation of the results is limited because of the inability to make a thorough geomorphological assessment using untrained staff. The emphasis should be made on obtaining both raw data which can be interpreted in various ways and used to develop derived ratings and semi-subjective ratings made by the recorder at the time of the survey.

7.8.5 Parameters

BANK SURVEY - Independent assessment to be made on the left and right banks and for the upper and lower banks

1. **Bank Slope and Shape Categories**- vertical, undercut, steep, convex, concave etc. .
2. **Bank Condition Assessment** - proportion of banks rated as "eroding", "aggrading" or stable".
3. **Location of Instability** - outside of bends, straight sections, linked with obstructions, floodplain scours - significant as it provides and indicator of the likely dominant process.
4. **Floodplain scours and deposits**
5. **Percent of Bank Devoid of Vegetation**- erosion or deposition will lead to

vegetation loss and instability.

6. **Bank Substrates** - key attribute as it relates to the erosion potential and links with the bed and bar substrates.
7. **General Condition Assessment** - semi-subjective assessment based on various parameters.
8. **Potential for Erosion**- semi-subjective based on substrates and consolidation.
9. **Checklist of Likely Causes of Instability** -List and ratings of likely causes - grazing, sand and gravel extraction, clearing of vegetation, seepage, roads and culverts, vegetation loss, vermin, pumps, human tracks, extent of usage and interference.

BED & BAR SURVEY

1. **Bed and bar substrates** - from cross-sections at point of maximum depth and maximum bed height.
2. **Gravel shape, consolidation and brightness** (algae covered or not)
3. **Bar type, location and percent of bed protruding as bar** - point, alternate, channel bench, channel bar plain (braided), infilled channel.
4. **Bed Condition Assessment** - Proportion of the bar rated as "eroding"(minor and major), "aggrading" (minor or major) or "stable".
5. **Sources of Instability and Controls** - checklist of obstacles acting to control aggradation and erosion (e.g. rocks, logs, bridges, culverts, fords etc.
6. **Sand and Gravel Resources** - derived from substrate classification and % of bed protruding as a bar in a reach of a defined length.

7.8.6 Targets outputs and indicators

BANKS

Raw Data

Bank slope, shape criteria --- erosion potential, stability etc.

Channel shape and dimensions -- indicators of processes

Bank stability --- % of banks eroding, aggrading, slumping and stable Percent of banks (upper banks) bare of vegetation--- from vegetation sheet Bank substrates

Floodplain sediment deposits

Semi Subjective Ratings

General Condition Assessment

Erosion Potential

Factors affecting bank instability

Derived Variables

Various assessments of the stability of the banks and the dominant processes.

BED AND BARS

Raw Data

Bed gradient -- derived from reach environs sheet

Channel shape and dimensions -- indicators of processes Bed stability rating --- bed "eroding", "aggrading", or "stable"

Bar type, position and size -- as a proportion of submerged bed area Bed and bar substrates -- type, shape, compaction

Semi Subjective Ratings

- General Condition Assessment

- Controls and factors affecting of bed stability

Derived Variables

- Various assessments of the stability of the banks and the dominant processes.

- Sand and gravel resources.

Figure 9 Data Sheet 9 Vegetation

STATE OF THE RIVERS --- SHEET 9 Vegetation

Basin Sub-section Site Tributary Name

Date (dd/mm/yy) Recorder

The Riparian Zone The Riparian Zone is the corridor of vegetation along the edge of a stream or river which is intimately linked with the stream both in providing leaf and branch litter to the stream and being affected by the extra moisture available. It is the distinct vegetation zone along the stream. Estimate its width (to a maximum of 50m). The strip chosen should be relatively homogeneous. Disturbed zones may be very narrow.

Riparian Zone - LEFT BANK
- from the water mark, up & over the bank to edge of stream affected vegetation

1 Width of Riparian Zone (m)

% Bare - no vegetation

Vegetation Cover of the Riparian Zone - overlaps allowed record presence for rare types % cover for abundant sp.

2 Type % Cover % Exotic spp.

Trees > 30 m
Trees 10 - 30 m
Trees < 10 m
Woody Shrubs
Vines
Rushes & Sedges
Herbs/ non-woody S
Grasses
Tree Ferns
Ferns / Bracken
Mosses
Mangroves
Salt Marsh
Palms

Local Sp. _____
Local Sp. _____
Local Sp. _____

3 Total % Weeds and exotic spp. in zone

Local Species Checklist - Recorded: Yes No

4 rare abundant rare abundant

Rainforest 1 2 Exotic grass Lomandra longifolia
Casuarina 1 2 Bunya Pine
Melaleuca 1 2
Callistemon 1 2
Exotic Pines 1 2
Willow 1 2
Poplar 1 2
Camphor laurel 1 2
Lantana 1 2
Rubber vine 1 2
Para Grass 1 2

The method of assessment is the percentage cover of the designated surface area for each zone. Refer to cover examples as a guide.

Trees = woody, > 2m, 1 stem
Shrubs = woody, < 2m / 1 stem or, > 1 stem
Herb = not woody, > 1 stem, short
Sedge & Rush = herbaceous, tufted perennial

9 All Aquatic Vegetation
- submerged bed, within the wetted perimeter of the stream

Visible depth (m) _____
Too turbid - pres only _____
% Bare - no vegetation _____
Tot % Weed & exotic sp. _____

10 Submerged / Floating leaf

Total Cover _____
Total % exotics _____
Filamentous algae _____
Marine / estuarine algae _____
Chara / Nitella _____
Vallisneria / strap like _____
Herb like forms _____
Myriophyllum _____
Elodea _____

11 Floating Vegetation

% Submerged lands _____
Total Floating _____
Total % Exotic Floating _____
Water Hyacinth _____
Azolla _____
Water Lilies _____
Local Sp. 1 _____
Local Sp. 2 _____

Assessment is made in terms of the % cover of the surface area for the zone specified for each type (submerged lands, banks or riparian verge)

5 % cover 10 % cover 15 % cover 25 % cover

6 % cover 75 % cover 90 % cover

12 Emergent Veg. % Submerged lands

Total emergents _____
Total % exotic emergents _____
Phragmites _____
Typha _____
Para Grass _____
Other Rushes & Sedges _____
Encroaching willows _____
Other Shrubs & Trees _____
Local Sp. 1 _____
Local Sp. 2 _____
Local Sp. 3 _____
Local Sp. 4 _____

Other species identified _____

Riparian Zone - RIGHT BANK
- from the water mark, up & over the bank to edge of stream affected vegetation

5 Width of Riparian Zone (m)

% Bare - no vegetation

Vegetation Cover of the Riparian Zone - overlaps allowed record presence for rare types % cover for abundant sp.

6 Type % Cover % Exotic spp.

Trees > 30 m
Trees 10 - 30 m
Trees < 10 m
Woody Shrubs
Vines
Rushes & Sedges
Herbs/ non-woody S
Grasses
Tree Ferns
Ferns / Bracken
Mosses
Mangroves
Salt Marsh
Palms

Local Sp. _____
Local Sp. _____
Local Sp. _____

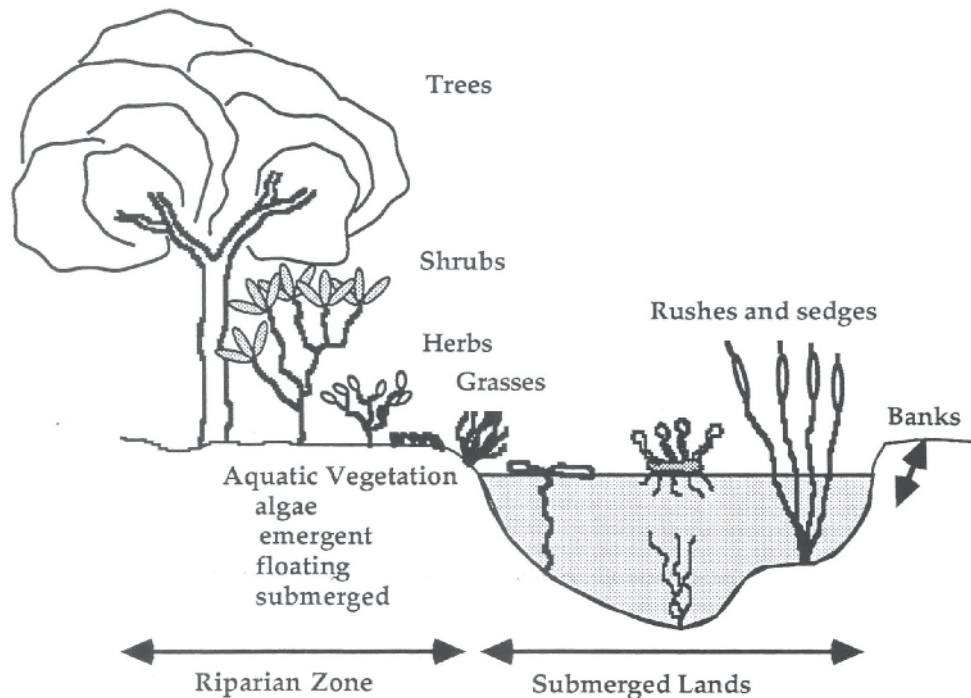
7 Total % Weeds and exotic spp. in zone

Local Species Checklist - Recorded: Yes No

8 rare abundant rare abundant

Rainforest 1 2 Exotic grass Lomandra longifolia
Casuarina 1 2 Bunya Pine
Melaleuca 1 2
Callistemon 1 2
Exotic Pines 1 2
Willow 1 2
Poplar 1 2
Camphor laurel 1 2
Lantana 1 2
Rubber vine 1 2
Para Grass 1 2

7.9 Vegetation



7.9.1 Introduction

Riparian and aquatic vegetation is recognised as one of the most important features for assessing the condition of streams. Both riparian vegetation (Harris 1988) and aquatic vegetation (Holmes 1989) have been used for stream classification. Riparian vegetation acts to:-

- Stabilise the banks
- Provide shade and shelter
- Provide leaf litter and other organic debris to the stream
- Provide a remnant wildlife corridor
- Provide for enhanced fish habitat
- Provide a buffer zone for intercepting sediments and nutrients.

Riparian and aquatic vegetation is assessed in terms of percentage cover for various growth forms and the cover and presence of key local native and exotic species. The percentage of each group which has been replaced by exotic species is also assessed. The methodology for the assessment was modified after Anderson and Morison (1989). Foliage structure and cover (foliage density) were used as the assessment methods because of the limited knowledge and experience of the survey staff. An optional checklist of locally and generally important species was included to allow extra data to be recorded if sufficient knowledge was available. The consultation phase was used to identify the checklist of general species which should be included permanently on the data sheet.

7.9.2 Issues and Concepts

The major objective is to assess the cover and condition of the aquatic and riparian vegetation within each reach surveyed in each stream section. Native riparian vegetation is a crucial factor which should be managed for diversity and structure (ground covers, understorey and overstorey); width (recognising that width suitable for protecting water quality may not be sufficient to sustain habitat); and longitudinal extent (ideally continuous for the drainage system) (Riding and Carter 1992).

The riparian zone provides a buffer strip between land use impact and the rivers and streams, removing sediments, nutrients and other pollutants in diffuse runoff (Odum 1990; Riding and Carter 1992). Understorey vegetation and groundcovers are necessary below the larger trees for buffering effectiveness. Therefore information regarding species composition, foliage structure, density, width, longitudinal extent, the extent of invasion or replacement by exotic species, and threats and protective measures such as fencing are the keys to assessing riparian vegetation. There are two ways of making the assessment:-

1. Uses a rating system to combine several of the attributes regarded as important and to directly assess condition or disturbance. For example, the 6 level disturbance classification used in the Wimmera River survey combined the extent of clearing of the riparian and valley flat vegetation and the extent of intrusion by exotic weed species.

2. The assessment is made in terms of percent cover of a defined area. The percentage of each area which is bare is also recorded. Various derived ratings and indices are derived from the raw data.

In developing the derived ratings several issues need to be considered

- There may be a need for a local or regional rating which accounts for fundamental differences in vegetation cover and type in different climatic regions throughout Queensland (e.g. rainforest vs channel country). Clearly the changes in condition may have to be assessed from a different baseline.
- The ratings are not necessarily directly proportional. For example, weeds and exotic species may mostly represent a disturbance. However, in some cases the weeds may be beneficial to some extent in that they act to stabilise the bed and banks- not as good as the native cover but better than no cover or simple grass cover. Further, both native and exotic vegetation may become a nuisance and degrade the habitat when they are present in very high densities. They may completely choke the water's surface and lead to eutrophication as well as changing the nature of the aquatic habitats by encouraging finer silts and clays to accumulate.

The final assessment is therefore not a simple matter, and the distribution and abundance of individual species may be important for integrated catchment management.

7. 9.3 Boundaries

Aquatic Vegetation -> *Wetted Surface Area* = submerged lands below the "water mark "

This is largely self-explanatory however the landward boundary will vary depending on the prevailing flow conditions - at low flow there may be a considerable margin of dry land between the water and the "water mark". At high flow the water mark may be submerged. It is therefore important to use the "water mark" boundary rather than the water's edge to provide a basic standard for comparison, independent of the flows at the time of the survey.

Bank Vegetation -> *Bank* = The marginal strip of land between the bank top and the "water mark"

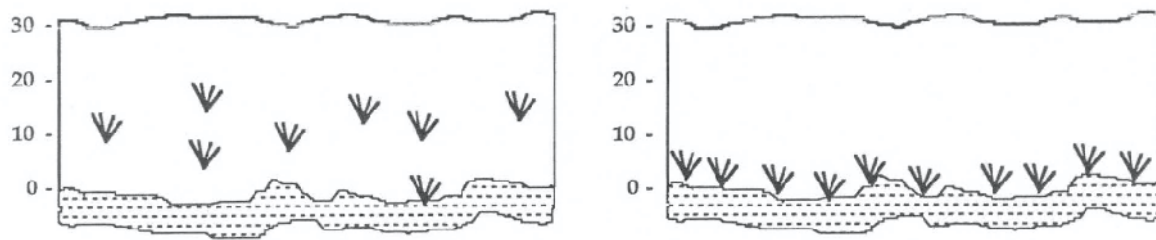
The bank could be included in the riparian zone, however it is a critical area in relation to erosion etc. and many plants only occur along the water's edge as a narrow strip and these plants would be under-estimated if they were assessed over the entire riparian zone.

Riparian Zone -> *Riparian Zone* = The strip of land containing distinctive vegetation along the margin of the stream '(1-100m wide).

The zone is defined by the person conducting the survey and its width estimated. If the zone cannot be clearly defined then the assessment should be made in a uniform strip 5m wide. The maximum possible width is 100 m.

It is difficult to derive a precise definition of a riparian zone, particularly for untrained staff. The definition of the boundaries for the riparian zone is therefore a problem. The general

perception of there being a strip of vegetation along the edge of the stream which is different from the rest of the vegetation in the landscape is generally obvious and recognisable by most people. The precise definition of its boundary is more difficult especially when it has been disturbed or partially cleared. The key attributes for assessment are the width of the zone, its longitudinal extent and the condition of its vegetation communities in terms of density (=cover) and invasion by exotic species. It is also clear that the width of this zone will vary markedly depending on location, the slope of the valley flat, soils and also the extent of disturbance. The options of setting a fixed width, or trying to define the width of the original undisturbed zone or exactly defining the width of the riparian zone in some other ways are impractical and would lead to errors. The untrained staff may be unreliable in applying these definitions. The strategy adopted was to simply record the width of the *remnant* strip of clearly distinguishable vegetation along the stream



The above example illustrates the problems with fixed width zones or with variable zones defined without using the vegetation. In both cases the percentage cover estimates would be the same despite the variation in distribution. Clearly a narrow densely vegetated margin (B) is functionally preferable to than a wide zone where the plants are sparsely distributed (A). Recording the riparian vegetation as B with strip 10m wide with a density of 50% than as A with a strip 25m wide with a density of 10% is more meaningful.

7.9.4 Scope and Limitations

- The instream surveys are limited to small reaches at specific location. No longitudinal survey data is collected but the data base should be designed to incorporate summaries from analysis of aerial photography.
- The focus of the survey is on the riparian and aquatic vegetation, not the vegetation on the adjacent flood plain or valley flat.
- It is assumed that the staff conducting the survey will not have the ability to identify the plant species beyond the more common native and weed species. For this reason the survey is focused on structural and life-form classification with assessment using percent cover rather than assessment of individual species.
- An optional checklist of species is included for both locally important species, or species which should be surveyed throughout Queensland. Photographs, keys are other simple forms of identification should be provided.

Classification and Types

CLASSIFICATION	TYPE	BOUNDARY
AQUATIC	Algae	Wetted surface
	Filamentous algae Rotted submerged vegetation Emergent Floating Rushes and sedges	bank
RIPARIAN	Trees > 25m Trees 10 – 25m Shrubs Herbs Vines Ferns Grasses Mosses Mangroves Salt marsh	Riparian Zone

7.9.5 Parameters

Assessment is made in terms of percentage cover of potential available habitat for the group. This is the easiest method of assessment by untrained staff.

Percent of Area Bare

Percent cover by each type, group or individual species

Percent of exotic species

Relative abundance of key native and introduced species in a checklist

7.9.6 Target Outputs and Indicators

- Percent of submerged lands, banks and riparian zone that is bare and without any vegetation.
- % bare in each zone
- Structure of riparian vegetation and cover by specific groups
- % cover by trees, shrubs, grasses etc.
- Relative abundance of selected key species in the checklist.
- Extent of invasion by exotic species
- % exotics or weeds in each zone

The condition of the riparian vegetation will be assessed by using a combination of the reduced cover compared with a regional or catchment standard (through clearing and grazing) and the extent of invasion or replacement by exotic species.

STATE OF THE RIVERS — SHEET 10

Aquatic Habitat

Date (dd/mm/yy) Recorder

Basin Sub-section Site Tributary Name

INSTREAM DEBRIS COVER

Assessment is made in terms of the % cover of the surface area for the zone specified for each type.

Water too turbid to estimate pres. only recorded

LEFT BANK

% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)

RIGHT BANK

% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)
% bank length type present	% bank length type present
Est. Av. width (m)	Est. Av. width (m)

Individual Log patches (record No.)

Log diam. > 250 mm % bad cover

Log diam. > 300 mm % bad cover

Log diam. > 300 mm % bad cover

Log diam. < 300 mm % bad cover

Branch pile < 50% dense patches % bad cover

Branch pile < 50% dense patches % bad cover

Branch pile < 50% dense patches % bad cover

Terraced knoives & twigs % bad cover

Macrophyte fragments % bad cover

Algal clumps and debris % bad cover

Large/deep Submerged Veg.

Freshwater % bad cover

Marine - zostera etc. % bad cover

Marine % bad cover

Emergent perennials > 0.5 m deep % bad cover

Tree Roots

Rock ledges/boulders/cobbles % bad cover

Perm. pool/hall/heap/rhaphis m. % bad cover

Man-made structures and debris

Combining all the assessment items and the general signs at the site, give it an overall rating for fish, invertebrates, birds & mammals

OVERALL AQUATIC RATING FOR ALL AQUATIC LIFE

VERY HIGH / PRISTINE
high diversity of depths and substrates
little or no disturbance
abundant and diverse cover
excellent vegetation cover

GOOD
good diversity of depths and substrates
little disturbance
diverse cover
excellent canopy & other veg. cover

POOR
low diversity of depths and substrates
moderate disturbances
low diversity of cover
poor canopy & other veg. cover

VERY POOR
no diversity of depths and substrates
high disturbance
no cover or low diversity
no canopy cover, other cover poor

Record the number of patches of each type present, and % cover or presence

5% cover 10% cover 15% cover 25% cover

1' = presence only record
99' = not assessed
0' = absent

50% cover 75% cover 90% cover

Canopy Cover

Vegetation Overhang

Bank Overhang

Instream cover by organic debris
- logs, branches, leaves and twigs

Cover by emergent and aquatic
vegetation, rocks and boulders

depth, width and area
of pools, ripples and runs

flow regimes

bed substrate diversity

Some of the attributes collected on the other sheets are important for assessing aquatic habitat. These include:-

- Channel habitats (pools, riffles and runs)
- Depth (Cross-sections)
- Bed Substrates (Cross-sections)

Cover of various types are also important for fish and invertebrates. Instream cover in the form of logs and branches provide shelter and attachment points, and also increases the diversity of flow and depth in the channel. Bank and vegetation cover also provide shade and shelter for the stream. The methods of assessment have been adapted from Anderson and Morison (1989) who developed their methods by reviewing overseas literature and the range of techniques used in Victoria. There is extensive literature on the relationship between fish population and habitat parameters (e.g. Platts, 1979; Hubert 1988; Kozel and Hubert, 1989; Meffe and Sheldon, 1988; Milner et al. 1985; Copp 1989; Platts and Nelson 1989; Hubert and Rahel 1989; Heede and Rinne 1990) though few such studies have been published in Australia (e.g. Davies 1988; Arthington et al. 1983). Likewise there is an extensive literature on the habitat requirements of macroinvertebrates in streams (e.g. Culp et al. 1983; Cushing et al 1983 Boulton and Lake (1990); Naiman et al. 1992) including attempts to predict invertebrate community types present in an area from stream measurements (Wright et al. 1984, 1989). Many of the references relevant for Queensland water are listed in Arthington (1992).

7.10.2 Issues and Concepts

The major objectives are to classify the aquatic habitat and to assess its condition. The focus is on the aquatic habitat for fish and macroinvertebrates. It is a physical assessment of the available habitat, rather than water quality or chemical aspects, or the specific requirements of particular species or communities.

- **Need for Classification** - Even with pristine habitats, the habitat assessment between different river systems such as a rainforest or a western Murray-Darling Basin river will be fundamentally different. The assessment of changes in condition therefore can only be made using a standard or reference. Ideally this would be an assessment from a pristine section within the same catchment or within the same region.
- **General habitat assessment- not specific for a group or species** - The assessment has to be suitable for use in all habitat types throughout Queensland, rather than relating to specific general habitats or the specific habitat requirements of particular species or groups . Generally the habitat requirements of Australian native species are not known well enough to stipulate specific requirements. However, the parameters collected should be adequate for making preliminary assessments in terms of the basic set of parameters known to be important for fish and invertebrates (e.g. depth, substrates, cover, flow and habitat diversity). Also the basic raw data collected should be adequate for deriving various ratings for specific species once their habitat requirements become known (e.g. depth requirements and spawning sites for Mary River cod).
- **Barriers to fish movement** - Natural and man-made barriers are important as they restrict movement, recruitment and they influence community structures. Ideally

stream section boundaries should be placed at the sites of major barriers. The surveys should include a method for classifying and rating the barriers (Bed and Bar Condition-datasheet). The key features are height, type, overtopping frequency and location in the catchment. General issues of movement and passage will also be provided from the transect information, and the channel habitat type classification in terms of pools, riffles, runs, cascades etc.

- **Temporal Issues** - The survey is only a single "snap-shot" and therefore only relates to conditions at the time the survey is carried out. There is a need for a method to standardise the assessments to relate to a standard inundation level.
- **Wildlife Habitat** - Ideally the survey should include an assessment of the habitat value of the area for birds, reptiles and mammals. This will not be specifically addressed but it should be satisfied by the general parameters used for the riparian vegetation, substrates and channel dimension surveys.

7.10.3 Boundaries

The assessment will be made within the reach boundaries using various boundaries such as the wetted perimeter, banks and channel boundaries at the water mark.

7.10.4 Scope and Limitations

- **Site Specific Survey** - The survey is site specific and therefore there is a need to ensure that the sites are truly representative of the habitat in the area. This can be accomplished through the reconnaissance surveys and by carefully selecting the sites within each section.
- **Visibility** - Many of the parameters have to be assessed visually. Many of the rivers are turbid and hence it may be difficult to make the assessment. This has to be allowed for by allowing the visible depth limit to be stated for the site and by allowing "presence only" to be recorded.

7.10.5 Parameters

The basic parameters are :-

canopy cover (Hawkins et al. 1982; Platts and Nelson 1989)

bank overhang from undercut banks and from vegetation (width and % of bank length)

instream cover

- organic debris - logs, log- jams, branches, branch piles, twigs and leaves (Bilby and Ward 1989; Carlson et al. 1990) - vegetation - aquatic and emergent

barriers to fish movement

- height of barrier
- type of barrier
- overtopping frequency

- weir locations and data about them including overtopping frequency

parameters derived from other components and sources

- channel classification and % of reach in each category (pools, riffles etc.)
- channel substrates in each of the major channel types (pools and runs/riffles)
- channel dimensions - depth and width within each of the channel types at different river stages

7.10.6 Targets outputs and indicators

a) Habitat Classification

A method for classifying habitats needs to be developed which should incorporate the following aspects:

1. Hydrology using HYDSYS output relating to the flow regime
2. Selected habitat parameters
3. Channel pattern and size i.e. floodplain, upland, large deep wide etc.
4. Stream order and size
5. Climate and region
6. Channel Habitat features i.e. pools, riffles, runs etc.
7. Altitude, gradient etc.

b) Condition Assessment

1. Flow regulation and extraction level - derived from HYDSYS
2. Selected habitat parameters used to derive single or combined ratings e.g. overhanging banks, overhanging vegetation, instream cover, substrates, pools of a given depth, etc.

Passage restrictions at low flow - barrier distribution and rating and channel depth

Figure 11 Data Sheet 11 Scenic, Recreation and Conservation Values

STATE OF THE RIVERS — SHEET 11 *Scenic, Reer & Conserv. Values*

Date (dd/mm/yy) / / Recorder

Basin Sub-section Site Tributary Name

Site code

1 Recreational Opportunity Type Allocate the site to ONE of the following types considering all aspects

	1 Natural 1. <i>Pristine Natural</i> Nature Reserve, Sanctuary	2 Natural 2. <i>Semi - Natural</i> Developed Reserve, Area, e.g. waterfall limited walking access	3 Natural 3. <i>Roaded- Natural</i> Camping Reserve, Rest Area. - structured sites with facilities	4 Rural 1. <i>Undeveloped Rural</i> Recreational settings in rural landscapes that are modified	5 Rural 2. <i>Developed Rural</i> Rural areas cleared for camping grounds, within rural towns	6 Urban 1. <i>Undeveloped Urban</i> Undeveloped urban parks and bushland kept semi-natural	7 Urban 2. <i>Developed Urban</i> Urban Parks and Sports grounds Walls along stream	8 Urban 3. <i>Highly Developed</i> Resort developments
Remoteness	3 km or more from all roads or tracks.	1 km or more from all roads.	not applicable	not applicable	not applicable	max of 500m to households	max of 500m to households	max of 2 km to households
Access	only by foot and 4 WD vehicle into the area	only by foot and 4 WD vehicle into the area, tertiary roads only	Moderate road access primary & secondary roads	good road access primary & secondary roads	accessible to all vehicles	low level access, primary road access	no limit to access	no limit to access
Human Impact & Development	no structures or exotic plants, pristine condition	only minor human influence, but small clearings O.K.	Moderate disturbance and development of facilities	natural setting but greatly modified	substantial modifications, rural residential	remnant bushland	modified open space	dominated by buildings etc.
Expected human contacts	rare, few other visitors	some contact with individuals but isolated	Moderate disturbance and some contact with groups	moderate contact on roads and trail sites	moderate to high interaction	Regular use by local residents	moderate to high density use	high density and frequent use
Facilities, regulations & structure	Little or none	some but subtle as formed tracks and signs	Minimal facilities, no powered sites etc.	Controls obvious, more complete facilities	barriers, signs & fences obvious	Remnant area with some restrictions	highly developed facilities	highly developed facilities

2 Recreation Types suitable for the area
Mark "1" for potential and "2" for actual use

☐ Barbecue and picnic	☐ Photography
☐ Bushwalking - camping	☐ Nature appreciation
☐ Bushwalking - day trips	☐ Swimming
☐ Camping - car access	☐ Water Skiing
☐ Canoeing / kayaking / rafting	☐ Bird Watching
☐ Dogs	☐ Other _____
☐ Shore Fishing	☐ Other _____
☐ Boat fishing - small boats	☐ Other _____
☐ Boat fishing - large boats	☐ Other _____
☐ Four Wheel driving	☐ Other _____
☐ Horse Riding	Comments: _____
☐ Motor bikes	_____
☐ Rowing	_____
☐ Sailing	_____

3 Scenic Value Assessment
Rate the site from 1 - 10 relative to other sites in the area

☐ Overall Scenic Value Rating
Rank the components for Scenic Value

☐ Inherent Natural Beauty (bushland setting)

☐ Inherent Physical Beauty (waterfalls etc.)

☐ Scenic Rural Setting

☐ Scenic Urban Setting

☐ Artistic merit or value

☐ Scenic value of a component e.g. tree etc.

☐ Other _____

4 Initial Conservation Value Assessment

☐ Rate the site as remnant habitat for *Aquatic Plant or Animal spp.*
1-10 _____

☐ Rate the site as remnant habitat for *Riparian Plant or Animal spp.*
1-10 _____

☐ Rate the value of the site as a wildlife corridor
1-10 _____

5

☐ Rank the Site (1-10) in terms of its quality as representative *Aquatic* Habitat for this type of site in this catchment.

☐ Rank the Site (1-10) in terms of its quality as representative *Riparian* Habitat for this type of site in this catchment.

7.11 Scenic, Recreational and Conservation Values

7.11.1 Introduction

A preliminary assessment of these values is made at each site. The sites are classified according to their recreational opportunity type (modified from that used for the Logan River Catchment Study), using remoteness, access, human contact and impact, and facilities available at the site. The suitability of the site for various types of recreation, and their scenic values are also assessed. A preliminary assessment of the conservation values of the sites is made in terms of ratings for the sites as remnant habitats for rare or endangered species of animals or plants, or as wildlife corridors.

7.11.2 Issues and Concepts

Scenic and recreational values are important for classifying streams in terms of their value for these activities. Conservation values are also important for integrated catchment management.

7.11.3 Boundaries

The assessment is made within the confines of the reach, riparian zone and adjacent lands.

7.11.4 Scope and Limitations

The data sources and assessment methods are only suitable for a very general assessment.

7.11.5 Parameters

- Scenic and recreational value assessments
- Known habitats of rare and endangered species (e.g. Mary River cod)
- Some parameters may be derived from the other components

7.11.6 Targets outputs and indicators

Ratings of the value of stream sections for their scenic, recreational and conservation values.

8. Database Design and Operation

It was decided that the database be developed on a personal computer (laptop preferred) using the DBASE IV program for the following reasons :

- The package could be used remotely and independently of a main frame GIS system, which would help to make the package as widely acceptable as possible. The package could be implemented on a wide variety of hardware both inside and outside of the DPI;
- Developing the package on a laptop model would make the package highly portable for demonstration purposes. This would help with promoting the concept to Regional staff and other potential users;
- BASE IV is the accepted database package for use in DPI;
- It helps to promote the idea that the system is "user friendly" and simple to use;
- DBASE IV can be directly interfaced with the DPI's GIS system;
- It is preferable to develop a simple system on a PC initially where it can be modified or even completely re-structured and modified during the development phase.

The other alternative of developing the package within the GIS system would offer additional power and sophistication in terms of analysis and output. While such a system may have to be developed to deal with the entire state, it would be better done at a latter stage of implementation of the project when all theoretical aspects have been finalised and any changes to the original concept have been made. It is simpler to deal with a smaller package during the development phase of the project.

8.1 Database Structure

Each of the 11 data sheets for the survey components form a separate database linked through the site code which provides a unique identifier for each basin, site, survey number (for replicate

surveys) and survey dates. The site code is a simple combination of the date, basin, sub-section, and site number. The site and section numbers are arbitrarily assigned during survey. The identification of the sub-section elements has been specifically designed to interface with the DPI's GIS system. Also the stream gauging sites in Queensland (HYDSYS) have been included as special sites with the full reference number to provide a link through HYDSYS to hydrology and water quality data.

The basic unit for data entry is a full set of records for each of the databases. This applies even when only some of the datasheet have been completed. This simplifies the programs, search routines and verification of the data entry. The programs supplied for data entry program routinely generates all datasheets, and there are codes on each sheet for indicating that no data was collected for a particular component. There are also a series of programs for editing and conducting various checks during data entry.

8.2 Data Entry

Data entry formats have been created for each of the datasheets which mirrors the basic layout of the datasheets.

8.3 Editing and Updating the Data

A series of data editing and data updating programs have been provided with the package. However, a basic understanding of the DBASE IV commands and menus is required to check and edit the data. Also this basic knowledge is required for conducting searches and analysis for the individual attributes collected during the survey. DBASE IV includes many sophisticated search routines which are ideal for this purpose.

8.4 Data Analysis and Reports

A number of data analysis and report programs have been provided as part of the package to generate data summaries on a site basis and for sites grouped into the sections. The sites and sub-sections can easily be grouped (permanently or temporarily) in other ways such as into the major sub-catchments or using elevation or other attributes. These reports provide the basic output for classifying the sites and sub-sections.

8.5 Grouping of Sites

A series of 9 group fields have been provided on each data sheet to enable the sites to be grouped in various ways, for example sites within major sub-catchments, or sites linked for other purposes. These groupings can be done manually or using various programs.

8.6 Condition Ratings

The data recorded for each of the components is used to produce a series of condition ratings for each component. These are scored as extents of degradation from a theoretical maximum rating of 100%. These ratings are produced from formulae which include weightings for each of the attributes relevant for compiling these ratings. There are a set of subjective ratings (derived from the subjective assessments made by the survey personnel at the time of the

survey), and objective ratings (derived from formulae using weighted contributions from various attributes). Both the formulae used and the weightings are explicit in the methodology, and they are also flexible to allow for changes to be made during the initial phases of the implementation of the methodology. It was recognised that these aspects can only be finalised after some surveys have been conducted and the results analysed and interpreted. An overall site and section rating can only be produced but it is intended that this be done in a way that allows for interpretation of the data rather than using a simple formula. Again this aspect can only be finalised after some surveys have been completed and analysed.

Once these ratings have been finalised it is important that the formulae are fixed and applied consistently in all areas of the state.

It was decided that the variation between catchments in terms of their natural pristine condition would be dealt with by scaling the final ratings rather than applying different formulae. This is a simpler approach which is clear and explicit. For example the final ratings assigned to stream sections in streams draining the Murray-Darling Basin may never, even when pristine, approach the 100% score given for riparian vegetation or aquatic habitat in terms of canopy cover in rainforest streams in the Wet Tropics areas along the coast. This will be accommodated by setting regional, catchment, or subcatchment standards such as at a remnant pristine site. All similar sites will be scaled upward using this reference so that the pristine rating in each area will be set at 100%. Both the original and scaled ratings will always be available to ensure that it is always clear how the ratings have been derived. This concept is fundamental to the consistent assessment of the physical and ecological condition of streams throughout Queensland using the State of the Rivers Methodology

8.7 Operational Manual

A basic operational manual for the DBASE IV system is included in the Implementation Report.

8.8 Implementation Manual

A second report has been published as an implementation manual for the State of the Rivers Project (Report 2. Implementation Manual)

9. Future Developments

In order to maintain consistency no major changes in the methodology should be permitted in terms of the basic set of core data. There is scope for further development of the optional data components and the addition of extra information relevant to a particular individual catchment or region. The major areas in which future developments are warranted are :-

- Modification of the condition rating formulae.

This can only be effectively done once some data has been collected.

- Transfer of the database, to anew database system in GIS

Once the project has been implemented and the GIS system has been further developed a transfer of the database into a relevant package within GIS itself may be warranted for conducting the state-wide assessments. The database size may become too large to be efficiently handled by DBASE IV.

- Development of an Instream Classification of Rivers and Streams
- Development of an Interface with the Hydrological and Water Quality Data Information using HYDSYS

Initially this could be done using the HYDSYS package but more work is required to select the data summary parameters and classification procedures to establish links with the hydrological record. Similarly it is important to establish links with the water quality monitoring and classification programs being set up in Queensland and those initially available through HYDSYS.

10. Pilot Study and Validation of the Approach and Methodology

10.1 Introduction

The Maroochy River was selected for the pilot study of the methodology. Its small size, close proximity to Brisbane, relatively complex range of river management issues and reasonably high population densities in rural area (rural residential and hobby farms) made it an ideal choice. The ready cooperation of the Regional staff and the local catchment group and Shire Council officers were of great benefit.

The actual pilot survey extended beyond what was originally intended in the sense that a complete survey of the whole catchment was conducted. Also full use was made of regional staff who were trained and fully involved in the survey. This provided an opportunity to test the whole procedure rather than just the approach, procedures and datasheets as had been originally intended.

Very few previous studies related to the State of the Rivers concept had been conducted in the Maroochy River catchment and therefore there were few opportunities to validate the outcome of the surveys or the condition assessments. Therefore the validation was restricted to the methodology itself in terms of the resources required, the effectiveness of the data base design, the time taken for each site and the general procedures. A separate report is to be produced analysing all the results from the Maroochy study in which the full findings from the project will be validated against other data sources. This will also provide an opportunity to fully develop and test the report programs and data summary procedures for the package. The results from the pilot study reported here should be regarded as only very preliminary draft findings to demonstrate the types of output possible from the package, rather than final output.

The survey itself was conducted over a three week period from 11 September 1992 to 2 October 1992. It involved the author, Glen Moller (Water Resources Unit, DPI, Brisbane) and five

officers from the Water Resources Unit, DPI, Gympie Office - Peter Boettcher, Greg Grainger, Bob Watson, Mark Perry and Helen Chambers. The data sheets were also trialed by members of the steering committee in the Maroochy River and at other sites in Brisbane. The steps and procedures undertaken for the pilot study are very similar to those recommended for the final survey method (see section 6.).

10.2 Introductory "State of the Rivers" Workshops

An introductory "State of the Rivers" seminar was held in Brisbane. While not specifically related to the pilot study the basic structure of this introduction to the methodology has been adopted for the implementation package. Some of the Regional officers, as well as Glen Moller attended this meeting and were introduced to the basic concepts of the methodology. The response to this seminar was generally good and such seminars or workshops should proceed the planning and surveys in each Region.

10.3 Planning and Scheduling

Following the selection of the Maroochy River as the site for the pilot survey the various base maps (topography, geology) and other information were gathered together. The Maroochy Shire Council was contacted and they provided various relevant reports

and maps. Their GIS system included some of the rivers and streams at a scale of 1:25,000. Topographic maps were available for almost all of the catchment at a scale of 1:25,000. The missing maps were generated by colour photocopying and enlarging 1:50,000 maps. A composite map of the whole catchment at a scale of 1:25,000 was generated. The survey was organised and scheduled and the various meetings arranged. In the pilot survey this component was somewhat rushed and more complete information could have been collected and processed, particularly historical information and data from relevant published and unpublished reports. Further contact could have been made with other local community groups and individuals if more time had been available.

10.4 Step 1. Preliminary Planning Workshop - 1 day

A one-day planning meeting was held at Nambour to plan and schedule the surveys and to gather the information needed for the initial sub-division of the streams and rivers into homogeneous sections. The aim of the workshop was to gather together the various local maps and data relevant for the study and to highlight important local issues and to plan the reconnaissance and full surveys. It also aimed to initially allocate the number of sites which could conceivably be surveyed in the time available to the sub-sections. This meeting involved the regional staff and two members of the local catchment management group.

Despite the shortage of time this meeting was very successful in highlighting the major differences in conditions throughout the catchment and providing a local perspective for the surveys. This provided an overview of access, types of sites, issues and problems in particular area, potential contacts and other information relevant for the initial sub-sectioning. Many of the boundaries for the sub-sections were finalised simply in terms of the local knowledge available. Local contacts in different areas of the sub-catchment were identified and the condition of local roads and tracks was also determined.

More time should be allocated to this aspect in the future. The workshop should involve local government representatives, land care and integrated catchment management group representatives and other interested agencies, groups and individuals who are potential users of the information and who may also provide information and assistance for the survey. The benefits of involving local Government representatives and members of local community groups should be emphasised as the local regional officers may not have detailed knowledge of the area to be surveyed, and these people have the local knowledge which is crucial for efficiently conducting the survey.

The information collected was used to start the process of sub-sectioning the rivers and streams and to allocating the sites available to the different sub-catchments.

10.5 Step 2. Preliminary Sub-division of Streams and Rivers - Map Exercise 1 day

The aim of this exercise was to take all the available information and maps to initially subdivide the streams and rivers into "homogeneous stream sections". The 1:25,000 series maps were used for this initial subdivision as these maps show some instream river characteristics such as the location of falls, large pools, fords, roads and tracks and other details important for the survey. The key attributes used to make this initial sub-division as a map exercise were:-

- Sub-catchment structure / stream order.
- Natural and artificial barriers and obstructions e.g. weirs, dams, waterfalls and rapids. The reservoirs were designated as separate sections.
- Altitude, catchment slope and stream gradient.
- Geology and soils
- Land Use, vegetation type and vegetative cover (native forest areas and National Parks
- Tidal Limit and boundaries between intermittent and permanent streams
- Source or discharge points for pollution or disturbances
- Sites of major stream diversions or stream flow alterations
- Location of major discontinuities of stream condition or river management activities

The sub-section boundaries were transferred directly onto the working maps.

10.6 Step 3 - Initial Allocation of Potential Sites

Using this preliminary information, the potential number of sites available were allocated to the sub-catchments based roughly on catchment size, but relatively more sites were allocated to the southern, more highly populated sub-catchments, such as Paynter, Petrie and Eudlo Creeks. It was estimated that about 120 sites could be surveyed in the non-estuarine parts of the catchment, with a further 30 sites in the estuarine areas (to be surveyed by boat). This estimate was based on a maximum effort of 6-8 sites per day for each team.

10.7 Step 4 - Reconnoitre Survey - 2 people for 4 days

A reconnoitre survey of the entire catchment was conducted by 2 staff over a four day period. Each of the previously identified sub-sections was inspected. The "homogeneity" of the sections was tested visually, and additional sections added where appropriate. Potential sites representative of the sections were inspected and selected.

Each site chosen was allocated a reference number and the 'Site Description' data sheet was completed including the set of standard photographs, the latitude / longitude (GPS) and grid reference and a sketch, location and description provided for the site. This was very important as it meant that only minimal effort was required to locate pre-selected sites during the full survey. A total of 127 sites in the non-tidal reaches of Eudlo, Acrobat, Paynter, Petrie, Coes, Chambers Gully, Rocky, Carol, Browns, York, Bunya Bunya, Ferntree, Tuckers, Doonan, Yandina and Coolum Creeks, and the South and North Maroochy Rivers. The location of the sites were transferred to the base map and to two working copies.

10.8 Step - 5 Training Workshop -1 day

A one day training workshop was held for the regional staff. Members of the catchment management group also attended. This comprised three hours of presentation and questioning, mostly directed at the details on the datasheets and the procedures. The use of various equipment (echo-sounders, inclinometers, GPS equipment) was also covered. However, the emphasis of the training was 'learn by doing' and the seminar

was followed by trial surveys of nearby streams. Questions and problems were dealt with by the experienced staff as the trial surveys were undertaken in pairs. The first two days of the actual full survey that followed were also seen as part of the training. Teams members were rotated and the more experience staff were on hand to deal with problems as they arose during these three days. These surveys were done at a lower speed to allow for this on-going training. The trial sites were selected to cover a range of natural and degraded conditions present in the local area.

10.9 Step 6 - Detailed Site Survey - 2 teams of 2 people for 11 days

The detailed site survey was then conducted at the series of sites allocated for each section. Some sites were only partially surveyed, with only a location and a set of photographs being taken. Additional sites were added at this stage to add needed detail, and to extend the survey into areas not previously covered by the reconnoitre. This included the sites in the tidal areas that were surveyed by boat, but not previously inspected.

Each day two survey teams of two people undertook the field work: one led by Dr. John Anderson and the other by Glen Moller, each supported by one staff member from the Gympie office. The 5 Gympie staff members involved rotated their participation in the survey allowing them to maintain their own work to a reasonable extent. They travelled to and from Nambour each day and this reduced the actual time for the surveys which generally were conducted from 0900 - 1700 hours each day. No time was lost due to bad weather. Occasionally other staff accompanied the teams as observers to learn about the methods.

Each team was equipped with a four-wheel drive vehicle, a set of 1:25,000 topographic maps with the sites marked on them, a Magellan GPS unit, 35 mm Camera and colour slide film, an inclinometer, a survey staff, an echo sounder, ropes and the 'Site Description' datasheets completed during the reconnaissance. Each team was assigned a set number of sites within a relatively small area of the catchment to minimise travelling time.

The 19 estuarine sites were surveyed over a 2 day period using a hired 4m dinghy and trailer equipped with a 9hp outboard motor.

10.10 Step 7 - Sub-division of the Catchment at the stream boundaries

The stream section boundaries, initially drawn as lines on the base map were extended to define the sub-catchment boundaries on the base maps.

10.11 Results of the Pilot Survey of the Maroochy Catchment

10.11.1 Site Number, Location and Coverage - A total of 192 sites were surveyed throughout the entire Maroochy catchment, 19 of which were in the estuary. The survey was restricted to areas with a defined channel and more or less permanent pools or flows. Of these sites, 7 were "photograph only" sites leaving 185 sites where a full survey was conducted. For the purposes of this preliminary summary the sites have been grouped as shown below.

Group	Sub-sections	Full Survey Sites
1.	Maroochy Estuary	19
2.	Doonan/Yandina/Coolum Creeks	21
3.	Smaller, lower tributaries -Ferntree, Tuckers Caboolture, Rocky, Martins Wappa etc.	24
4.	Paynter Creek	16
5.	Petrie Creek	28
6.	North Maroochy - main channel	14
7.	North Maroochy - lower tributaries - Browns, York, Gold, Running, Bunya Bunya	15
8.	Eudlo Creek	15
9.	South Maroochy River	33
10.	All Non-estuarine sites	166
ALL	All sites combined	185

10.11.2 Results - Preliminary Assessment -

These results are preliminary because the overall condition classification which is fundamental to the method have not been included here (the full analysis is the subject of a separate report). The summaries have only been prepared using a sub-division into the major tributaries rather than between tributaries which is the better approach. The initial assessment has also only been made in terms of the sites, rather than with the sites classified and grouped into homogeneous stream sections. The following preliminary analysis is therefore

restricted to a site summary within the sub-catchments. The condition assessment has been mostly restricted to the categories surveyed and only a very general overall assessment of condition has been made. The results are summarized in tables (see pages 114-116).

Reach Environs (Assessment based on the extent of clearing of the riparian and adjacent vegetation and the replacement of native vegetation by exotics)

Disturbance Cat.	% of sites
Pristine	5 %
Low disturbance	14%
Moderate disturbance	16%
High disturbance	15%
Very high disturbance	31%
Extreme disturbance	19%

Only 5% of the sites were classified as being pristine (mostly in the upper reaches of the smaller tributaries). The highly disturbed sites generally occurred in the cane

fields and in the lower urban sites of Petrie Creek, and Yandina/Coolum Creeks.

The least disturbed sites occurred in the South Maroochy, the North Maroochy tributaries such as Brown and York Creeks, and also in the estuarine areas. Generally the sites with better condition occurred in the upper reaches of the catchments (State Forest Areas). 65% of the sites were classified as having high to extreme disturbance which reflects the high proportion of the catchment which has been cleared. This percentage would be considerably lower on a catchment area basis because more of the sites were located in the lower ends of the catchments.

Nevertheless, the survey demonstrated that the reach environs of most sites had been disturbed, at least in terms of the vegetation adjacent to the riparian areas.

Bank Condition

Bank Processes Cat.	Av. % of bank	Instability Rating	
Bare	20%	Highly unstable	13%
Stable	70%	Moderately unstable	30%
Eroding	20%	Low instability	42%
Slumping	2%	Minimal instability	15%
Aggrading	3 %		

A total of 70% of all the banks surveyed were regarded as stable, 20% eroding and only 3% aggrading. 80% of the banks were covered with some vegetation which offered some protection from erosion, and about 60% of the banks were regarded as having low instability.

The least proportion of eroding banks occurred in Eudlo, South Maroochy, and the least

disturbed of the North Maroochy tributaries (Brown and York Creeks). In non-estuarine areas the banks had an average width, height and slope of 20m, 1.5m and 32° respectively. The bank sizes largely reflects the size of the river or stream.

63% of the sites had steep or vertical banks. The good general cover by riparian vegetation (see later section) has effectively protected the steep banks from erosion, and the reverse is probably also true, i.e. the steepness of the banks has allowed a remnant strip of riparian vegetation to remain despite the widespread clearing along the riverine margins and floodplain areas.

The strong linkage between the condition of the riparian vegetation and the condition of the banks was very obvious at many locations. Sites with very severe erosion and poor riparian vegetation often occurred immediately downstream of sites where the remnant tree line had protected the banks from erosion. Bank erosion was often listed as a cause of bed aggradation and bar build-up in the bed of the stream.

Bed and Bar Condition

Bed Stability Rating	% of sites
Severe Erosion	3 %
Mod. Erosion	13%
STABLE	58%
Mod. Aggradation	19%
High Aggradation	7%

60 % of the bed surveyed was classified as stable, with only 18% classified as being severely eroding or aggrading. There was little evidence of severe headward erosion at the sites surveyed and the dominant factors contributing to bed instability were bank erosion, and agriculture and grazing (stock and clearing of vegetation). The low incidence of bed erosion, despite the extensive clearing of the valley flat vegetation, was probably linked to the high occurrence of rock and coarser substrates in the bed. Only about 10% of the sites had bars present, and the average coverage of the bed was 27%. Petrie Creek had the highest percentage of sites listed as aggrading (50% of bed) and the more extensive bar deposits (40% of the bed).

Riparian and Aquatic Vegetation

Non estuarine sites (averages for sites)	
Width of Riparian Zone	17 m
% sites with width < 5m	31%
% sites with width >25m	16%
% zone bare	13%
% weeds	33%
% cover - medium trees	53%
% cover - submerged veg.	24%
% cover - floating vegetation	5 %
% cover - emergent vegetation	28%

The riparian vegetation was in quite good condition. The average percentage cover by moderate size trees (10-20m) was 40%. A narrow strip of remnant vegetation was present at most sites (only an average of 13% of the banks were bare). The average width of the riparian zone was 16m, but about 30% of the sites had widths less than 5m (the designated maximum width was 50m). Only 16% of the sites had widths > 25 m . Essentially the remnant riparian zone corresponds to the vegetation on the steep narrow banks (too steep to be cleared!!??). There was a high percentage invasion of the riparian zone by weeds (grasses, herbs, and trees such as camphor laurel etc.), nevertheless this remnant narrow strip was highly important in providing stability to the banks, shade and shelter in the stream and intercepting sediments and nutrients in runoff. The lowland smaller tributaries such as Caboolture Creek, Tuckers Creek, and also Petrie, Yandina, Coolum and Paynter Creeks had the narrower zones and the higher percentages of weed species present.

The cover by aquatic vegetation (submerged, floating and emergent) was relatively low due to the high proportion of rocky substrates and to the extensive canopy cover afforded by the trees along the banks. The increased occurrence of aquatic vegetation

was often seen in areas where the bank vegetation had been cleared allowing light to penetrate and bank erosion to partially fill the channel with sediment. It would be expected that aquatic vegetation would originally have been sparse in the area as most of the verge vegetation would have been rain forest or wet sclerophyll.

Pool Dimensions (see tables for details of other types not presented here)

Generally pools in the non estuarine areas of the catchment were relatively small (average length = 33m, width 7m and depth 0.77m). Providing somewhat restricted aquatic habitat. Substrates were dominated by rock and the courser size fractions (gravels, pebbles and cobbles). The deeper pools on average were in the estuary (av. 3.25m), Paynter Creek (av. 1.26m), Petrie Creek (av. 0.9m) and South Maroochy River (av. 0.75m).

Aquatic Habitat

All Sites (averages for sites)

Ratings	
Pristine	11%
Good	45%
Poor	24%
Very Poor	21%
% cover - rocky bed	16%
% cover - Canopy	57%
% cover - bank o/hang by veg.	18%

Only 11% of the aquatic habitat was regarded as being in pristine condition, but about 45% was in good condition, mostly because of the stable rocky bed throughout and the reasonable riparian zone. Cover by logs was low but this probably reflects the size of the stream. Rock substrates covered about 16% of the bed and the aquatic habitat was characterised mostly by coarser sediments. The canopy cover and vegetation overhang (<1m above the

surface) were both reasonable at 57% and 18% of the bank length, respectively.

Generally the conservation ratings for the aquatic habitat were low with 25% classed as only 1 out of 10, and 60% of sites rated as less than 5. This puts emphasis on conserving the more highly rated sites.

Recreational Opportunity Ratings

About 70% of the sites were rated as Rural 1., and only 11 % as Natural 1. These ratings generally reflected the high rate of clearing along the drainage lines in the catchment.

Overall Assessment

Generally, given the limitation of this preliminary study, the sites in the Maroochy catchment could be rated as moderate to poor. In some respects the rivers and streams are in somewhat better condition than would be expected given the extent of clearing in the catchment and the size and density of the population in the area. The natural attributes of steep banks, coarser bed sediments and rock outcrops along the bed and banks have acted to reduce the deterioration that would perhaps otherwise have occurred.

Protection, enhancement and restoration of the riparian vegetation would appear to be the key to maintaining or improving existing values. Replanting and replacing exotic species with native species and allowing rainforest corridors to regenerate would reduce bank erosion and enhance habitat values. The existing high quality vegetation should be protected and farmers and other land owners encouraged to protect and restore riparian vegetation along the banks.

Water quality is poor in many areas and this needs further attention.

The finding of this preliminary summary illustrate what could be achieved by conducting a complete analysis of the data and producing a final report. The final data set and all the classifications produced by these analyses could then be made available to the Local Council, the Integrated Catchment Management Group and other groups for further use in targeting areas requiring attention. The full analysis utilising the classification procedures will enable a more accurate and comprehensive assessment of the condition of the rivers and streams and an identification of the processes and actions required to maintain and enhance habitat values (a separate report on the condition of the Maroochy River and its tributaries is to be published).

Future follow-up surveys are needed to establish trend patterns and to assess the outcome of management initiatives to improve the condition of the rivers and streams in the Maroochy Catchment.

Summary Table 1. Note all counts are shown as actual sites - not percentages to enable groups to be added

		Disturbance of Environns					Banks										Total Number of sites							
		Process					Instability Rating			Size		Slope Categories												
Pristine	Low	Moderate	High	Very High	Extreme	% Bare	% Stable	% Eroding	% Slumping	% Aggrading	High	Moderate	Low	Minimal	Av. width	Av. height	Av. slope	Vertical	Steep	Moderate	Low	Flat		
All sites	9	26	29	27	58	36	20	70	20	2	3	47	100	151	60	4.5	1.8	32	101	146	84	46	17	185
All - non estu.	7	24	28	18	55	34	21	69	20	2	3	43	88	140	49	3.5	1.9	32	96	130	80	37	12	166
Estuarine	2	2	1	9	3	2	20	75	20	2	0	4	11	11	10	20	1.5	32	5	15	4	8	5	19
Yandina/Coolum	0	2	4	2	8	5	26	76	18	2	1	3	10	25	4	1.75	1.1	25	17	17	9	1	0	21
Small Tribs	2	4	4	3	6	5	26	58	28	1	4	8	11	19	6	3.4	3	27	11	19	8	5	6	24
Paynter Cr.	0	1	1	2	8	4	20	64	25	3	2	7	14	9	0	3	1.6	45	10	17	5	1	0	16
Petrie Creek	2	1	2	2	11	10	21	64	28	1	3	15	20	16	5	4.5	3.2	42	28	27	13	0	0	28
N. Maroochy	0	0	2	5	3	4	30	52	23	1	8	3	9	11	1	4	1.65	28	9	7	8	0	0	14
Browns, York etc	2	4	5	1	3	0	15	77	15	0	7	2	6	19	3	2.9	1.1	23	1	7	12	12	0	15
Eudlo Creek	1	4	2	0	6	2	14	73	11	3	3	0	7	12	19	1.9	1.2	40	7	12	8	0	4	15
S. Maroochy	0	8	8	3	10	4	15	82	13	2	1	5	11	29	21	4.5	1.6	30	13	24	17	18	2	33

Summary Table 2. Note all counts are shown as actual sites - not percentages to enable groups to be added

	Beds				Bars		Causes		Vegetation							Pool Dimensions			Total Number of sites			
	Severe Erosion	Mod. Erosion	Stable	Bed Stability Rating	Mod. Aggrad.	High Aggrad.	% with Bar	% Bed as Bar	Bank Erosion	Agricult / grazing	Width Rip. Zone	% width < 5m	% width > 25m	% zone bare	% weeds	% cover med trees	% submerged cover	% Floating cover		% emergent cover	Av. Length (m)	Av. Width (m)
All sites	5	23	104	35	13	10	27	63	104	17	31	10	13	33	53	28	5	28	68.5	20	1.13	185
All - non estu.	5	23	86	35	13	10	27	57	96	16	31	16	13	35	40	24	5	28	33.5	7	0.77	166
Estuarine	0	0	17	0	0	0	0	6	8	26	30	19	6	20	30	0	0	22	250	83	3.25	19
Yandina/Coolum	0	5	13	2	1	6	37	4	13	8	38	5	17	22	35	36	20	17	31.6	3	0.59	21
Small Tribs	0	4	14	4	2	11	26	9	12	12	38	14	21	60	50	29	4	29	29.4	6	0.64	24
Paynter Cr.	3	3	5	4	0	7	23	7	9	10	50	9	14	42	25	12	6	25	47	6.3	1.26	16
Petrie Creek	1	1	10	8	7	17	40	17	16	15	25	11	11	42	35	58	7	30	41	7.4	0.9	28
N. Maroochy	1	2	5	6	0	6	25	5	13	22	29	11	31	30	55	36	14	21	34	5.3	0.8	14
Browns, York etc	0	3	7	4	1	5	23	8	7	17	17	20	3	17	52	33	6	20	31	4.9	0.56	15
Eudlo Creek	0	3	5	4	1	10	15	4	8	12	40	13	8	30	39	27	6	53	30	14	0.71	15
S. Maroochy	0	2	27	3	1	8	14	3	18	22	24	32	5	23	45	21	6	24	28	8.4	0.75	33

Summary Table 3. Note all counts are shown as actual sites - not percentages to enable groups to be added

	Aquatic Habitat					Recreational Opportunity							Rating of Aquatic habitat for Conservation as Representative Habitat (1-10)										Total Number of sites			
	Ratings					% Rocky bed cover	% Canopy cover	% Veg o/hang																		
	Pristine	Good	Poor	Very Poor					Natural 1.	Natural 2.	Natural 3.	Rural 1.	Rural 2.	Urban 1.	Urban 2.	1.	2.	3.	4.	5.	6.	7.		8.	9.	10.
All sites	20	82	44	38	57	18	20	7	3	132	6	8	6	6	47	17	13	17	20	15	12	14	12	10	185	
All - non estu.	17	70	40	37	58	15	20	6	3	117	4	7	6	6	46	17	11	17	19	12	9	6	12	9	166	
Estuarine	3	12	2	1	13.1	58	46	0	1	0	14	2	1	0	1	0	2	0	1	3	3	7	0	1	19	
Yandina/Coolum	2	7	7	5	3	57	14	0	0	1	19	0	0	1	7	1	5	1	1	2	0	2	0	1	21	
Small Tribs	3	2	10	5	11	68	9	3	1	1	12	2	3	2	9	4	3	1	1	1	0	1	2	2	24	
Paynter Cr.	0	6	8	1	13	43	21	0	0	0	15	0	0	0	6	3	1	0	2	3	0	0	0	0	16	
Petrie Creek	2	10	5	11	8	46	16	5	0	0	18	0	0	0	13	5	3	0	2	1	2	0	1	1	28	
N. Maroochy	0	7	5	2	3	70	14	0	0	0	12	1	0	0	2	3	0	1	1	2	2	0	1	0	14	
Browns, York etc	3	7	1	4	27	64	13	3	1	0	11	0	0	0	1	3	0	2	1	2	1	2	3	0	15	
Eudlo Creek	1	7	5	2	4	54	13	0	1	1	12	1	0	0	1	3	3	3	3	1	0	0	1	0	15	
S. Maroochy	8	16	4	5	46	60	25	9	3	0	18	0	0	2	7	2	1	4	3	0	4	1	3	7	33	

10.12 Evaluation of the Pilot Survey and Validation of the Methodology

It was generally agreed that the pilot survey was very successful in all aspects. The results exceeded expectations in the sense that a complete survey of the Maroochy catchment was accomplished rather than the partial survey intended for the pilot. The pilot survey provides a means of evaluating, testing and validating various aspects of the methodology. A complete analysis of the results of the survey was never intended to be part of the development of the methodology and so this evaluation is concerned only with the methodology itself.

10.12.1 Planning and Initial Sub-sectioning - Regional Scientific Officer

The planning and full implementation of the package was not fully tested in the sense of having it completely run at the regional level. The planning, training and particularly the role of a Scientific Officer, or some other member of the Regional staff to undertake the initial sub-section of the streams and rivers was not tested in the trial. This involves analysing various maps and other sources of information and the inspection during the reconnoitre phase of the project. This requires some knowledge and experience in the classification of riverine habitats and conditions. For consistency in this aspect of the project and also in the interpretation of the datasheets some overlap in surveys would be desirable. Some preliminary participation of staff in surveys in other regions prior to attempting their own surveys would be very helpful. There is also a need for a State-wide Coordination group for the project to organise the training workshops and to provide the advice, checking and feedback needed to ensure consistency in application of the project.

10.12.2 Data Sheet Design and Use

The approach taken in designing of the datasheets - making extensive use of graphics and making the datasheets self-supporting and not reliant on coding sheets or other instructions was vindicated. The layout was a little cluttered and daunting at first, but once they had been used several times they were judged to be highly useable and easily understood despite the complexity wide range of information collected. A few minor changes were made 'on the run' to cover some omissions and clarifications, but no major changes were required.

The recorders varied in their background, training and experience which meant that they were more comfortable or more familiar with some components, and had more difficulty with others. For example some people were unfamiliar with vegetation, particularly the individual species. The provision of simple keys and photographs to aid in identification of the key species should be included in future surveys.

During the surveys each member of the group filled-in half of the sheets individually to save time, and then the cross-sections were undertaken together. There was a tendency for individuals to choose the datasheets with which they were the most familiar. There is no problem with this and it should be encouraged provided each recorder has an adequate understanding of every sheets. Swapping the teams around is also a good idea as helped to generate good team spirit and it provided some internal consistency as individuals exchanged ideas and problems.

No specific checks of consistency or replicate surveys of sites by different teams were

undertaken. This should be done in the future, but it was not justified as part of the pilot survey because of the range of other activities involved in developing the techniques and the training aspects. It would be better done at the end of a survey by a relatively experienced teams, perhaps groups that had been involved in more than one survey. This would provide a better indication of the consistency of the method once the training programs had been finalised and the techniques were more familiar to the staff coordinating the project.

10.12.3 Survey Procedures and Equipment

Generally all the equipment worked well and there were no problems with the procedures. The GPS equipment was very successful, and the only suggested improvement was the provision of better antennae to improve the resolution and accuracy. The units used were simple to operate and robust.

The use of a portable echo-sounder with the transducer attached to a 'kick-board' float proved to be a great time-saver at the deeper sites and avoided "getting wet". A larger boat with motor larger than 9 hp would have speeded-up the estuarine survey, but it was satisfactory. None of the freshwater sites required the use of a boat for survey and this reduced the time delays and effort which otherwise would have been required. The echo-sounder also proved invaluable in quickly locating the point of maximum depth for the cross-sections by boat and also at the deeper sites where no boat was used.

10.12.4 Computer Data Entry in the Field

This could be looked at as a future option, as the database certainly can be operated on laptop computers. However the potential savings in terms of data entry have to be weighed-up against the potential loss of days of records through failure of the equipment, and whether the equipment is robust enough for this type of survey. Presently the datasheets include sketches and other items which would be difficult to enter without sophisticated drawing packages.

10.12.5 Time and Resource Requirements

The survey rate exceeded expectations. An average of 8-10 sites were completed by each team with up to 12 sites being completed in any one day. This rate would be close to the maximum rate possible without working extremely long hours or compromising the quality of the data collected. Some small increase may have been possible without the daily travelling to and from Gympie. However, the travelling times between sites were short and access was generally good compared with what may be expected in other catchments. Therefore between 8-12 sites a day would seem to be a reasonable future target.

The surveys had originally been designed for spending an hour at each site, which allowing for travelling time gave a predicted minimal target of 6 sites for each team per day. The pilot survey showed that this could be increased to between 8-10 sites per day dependent on travelling distances between sites. This good result emphasised the importance of the reconnaissance in precisely locating the sites and describing how to find them quickly. The availability of 1:25,000 scale maps was also very important. In this aspect the survey exceeded

expectations.

10.12.6 Skill level of the Staff

The Regional staff had various backgrounds, qualifications and experience. All coped well with the method which again vindicated the survey design and showed that the method was suitable for being conducted by untrained regional staff after a short training program. This was one of the major objective of the design. Nevertheless, appropriate skills and backgrounds should be considered when selecting staff for the project. Officers with skill levels in soil mechanics (Farm Advisory Officer) had advantages in sediment analysis. Stream Control Officers showed a greater understanding of stream processes of erosion and accretion, and those with qualifications in environmental assessment were more skilled in plant identification. There is also merit in keeping the number of staff involved in the project small to increase the consistency and to minimize the training required. This needs to be offset by the obvious advantages of being able to 'spread the load' to enable other tasks to be completed.

10.12.7 Training Program

The adoption of a 'learn by doing' approach was again highly successful. The data sheets are difficult and laborious to describe. It is easier to learn by trying to fill them out. The availability of staff familiar with the project is obviously essential for this to be effective, and this perhaps warrants members of the coordinating group being present for this training. Also some preliminary participation by regional staff, particularly the environmental officers acting as leaders for the project in surveys outside their own region would be very helpful. The pairing of experienced personnel with the trainees, and changing the pairs were also very important. Provision of slide, graphics and an elaborate training manual are no real substitute for 'getting out there and giving it a go'.

10.12.8 Data Entry, and Preliminary Data Analysis and Reports

The data entry, data analysis and report generating programs were satisfactory for the pilot study. The preliminary output demonstrated the comprehensive data that is produced and the way the data can be used to assess the condition in terms of the various components.

11. References

- Anderson J.R. and Morison A.K. (1989). *Environmental flow studies for the Wimmera River, Victoria. Parts A-E*. A.R.I.E.R. Tech. Rep. Series No. 73-77, Department of Conservation and Environment, Victoria.
- Anon (1992) Environmental Indicators - A Literature Review. New South Wales Rivers and Estuaries Policy. State of the Rivers and Estuaries., (draft) Department of Water Resources, NSW.
- Arthington, A. H. (1992) Annotated Bibliography of Literature on the Condition of Queensland Streams and Rivers. Report to the Water Resource Commission, Brisbane, Queensland.
- Arthington, A.H., Milton D.A. and McKay, R.J. (1983) Effects of urban development and habitat alterations on the distribution and abundance of native and exotic freshwater fish in the Brisbane Region, Queensland. *Australian Journal of Ecology* 8: 87-101.
- Bailey, R.G. (1978) Description of ecoregions of the United States, Intermountain Region. United States Forest Service, Ogden, Utah. USA.
- Beck, M.B. and Finney, B.A. (1987) Operational water quality management: Problem context and evaluation of a model of river quality. *Water Resources Research* 23: 2030-2042.
- Bennison, G.L., Hillman, T.J. and Suter, P.J. (1989) *Macroinvertebrates of the river Murray Review of monitoring 1980-1985*. Murray-Darling Basin Commission.
- Bilby, R.E. and Ward J.W. (1989) Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Transactions of the American Fisheries Society* 118: 368-378.
- Blyth J.D. (1983) Rapid stream survey to assess conservation value and habitats available for invertebrates. Proceedings of a workshop: *Survey Methods for Nature Conservation*, Adelaide, Vol. 1 (Eds. Myers K., Margules C., and Mustoe I., CSIRO Adelaide.) pp. 343-375.
- Booth, D.B. (1990) Stream-channel incision following drainage-basin urbanization. *Water Resources Bulletin* 26:407-417.
- Boulton, A.J., Lake, P.S. (1990) The ecology of two intermittent streams in Victoria, Australia. I. Multivariate analyses of physicochemical features. *Freshwater Biology* 24:123-141.
- Carlson, J.Y. & Andrus, C.W. & Froehlich H.A. (1990). Woody debris, channel features, and macroinvertebrates of streams with logged and undisturbed riparian timber in North-eastern Oregon, U.S.A. *Can. J. Fish Aquat. Sci* 47:1-30.

Coats R., Collins L., Florsheim J. and Kaufman D. (1985) Channel change, sediment transport, and fish habitat in a coastal stream: effects of an extreme event. *Environmental Management* 9: 35-48.

Cooke, R.U. & Doornkamp (1974) *Geomorphology in Environmental Management: An Introduction*, Carendon Press, Oxford.

Copp, G.H. (1989) The habitat diversity and fish reproductive function of floodplain ecosystems. *Environmental Biology of Fishes* 26:1-27.

Cushing C.E., McIntire C.D., Cummins K.W., Minshall G.W., Petersen R.C., Sedell J.R., and Vannote R.L. (1983) Relationships among chemical, physical, and biological indices along river continua based on multivariate analyses. *Arch. Hydrobiol.* 98(3): 317-326.

Davies, P.E. (1988) Relationships between habitat characteristics and population abundance for brown trout, *Salmo trutta* L. and blackfish, *Gadopsis marmoratus*, Rich., in Tasmanian streams. *Australian Journal of Marine and Freshwater Research* 40: 341-59.

DCFL (1987) *Better Rivers and Catchments* The State of the Rivers Taskforce, Department of Conservation Forests and Lands, Victoria.

DCLM (1988) The Road, River and Stream Zone System in the Southern Forest of Western Australia. A Review. Department of Conservation and Land Management, Como, W.A.

Dury, G.H. (1966) The concept of grade. In: Dury, G.H. (ed.) *Essays in Geomorphology*. London, Heinemann pp 211-234.

DWR (1986) *The State of the Rivers and Streams in the Western Port Region*. Steering Committee for the Western Port Rivers Management Study, Department of Water Resources, Victoria.

Faith, D.P., Humphrey, C.L. and Dostine, P.L. (1991). Statistical power and BACI designs in biological monitoring: Comparative evaluation of measures of community dissimilarity based on benthic macroinvertebrate communities in Rockhold Mine Creek, Northern Territory, Australia. *Aust. J. Mar. Freshw. Res.* 42:589-602.

Fausch K.D., Karr J.R. & Yant P.R. (1984). Regional application of an index of biotic integrity based on stream fish communities. *Transactions of the American Fisheries Society*. 113:59-55.

Garman, D.E.J. (1983) Water Quality Issues in Australia. In: Department of Resources and Energy, *Water Quality Issues, Water 2000: Consultants Report No-7 AGPS*. Canberra.

Harrel Richard C., David Billy J. & Dorris Troy C. (1967) Stream order and species diversity of fishes in an intermittent Oklahoma stream. *Am. Midland Nat.* 78:428-436.

Harris, R.R. (1988) Associations between stream valley morphology and riparian vegetation as a basis for landscape analysis in eastern Sierra Nevada, California, USA. *Environmental*

Management 12:219-228.

Harvey, M.D., and Watson, C.C. (1986) Fluvial processes and morphological thresholds in incised channel restoration. *Water Resources Bulletin* 22: 359-368.

Hawkins C.P., Murphy M.L. & Anderson N.H. (1982) Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in cascade range streams of Oregon. *Ecology* 63: 1840-1856.

Heede B.H., & Rinne J.N. (1990) Hydrodynamic and Fluvial Morphologic Processes: Implications for Fisheries Management and Research. *North American Journal of Fisheries Management* 10: 249-268.

Heede, B.H. (1986) Designing for dynamic equilibrium in streams. *Water Resources Bulletin* 22: 351-357.

Holmes, N.T.H. (1989) British rivers: a working classification. *British Wildlife* 1: 20-36.

Huang, S-L., Ferng, J-J (1990) Applied land classification for surface water quality management: 1. Watershed Classification. *Journal of Environmental Management* 31:107-126.

Hubert, W.A. (1989) Relations of physical habitat to abundance of four nongame fishes in High-Plains streams: A test of habitat suitability models. *North American Journal of Fisheries Management* 9:332-340.

Hughes, R.M., Rexstad, E. and Bond, C.E. (1987) The relationship of Aquatic ecoregions, river basins and physiographic provinces to the ichthyogeographic regions of Oregon. *Copeia* 1987(2) 423-432.

Karr J.R., Yant P.R. & Fausch K.D. (1987) Spatial and temporal variability of the index of biotic integrity in three midwestern streams. *Transactions of the American Fisheries Society* 116: 1-11.

Karr, J.R. (1981) Assessment of the biotic integrity using fish communities. *Fisheries* 6: 21-26.

Karr, J.R. (1991) Biological integrity: A long neglected aspect of water resource management. *Ecological Applications* 1: 66-84.

Kozel, S.J. and Hubert, W.A. (1989) Testing habitat assessment models for small trout streams in the medicine Bow National Forest, Wyoming. *North American Journal of Fisheries Management* 9:458-464.

Kunert, C. & Macmillan, L. (1988) Conservation value and status of Victorian Rivers Part III The Wimmera River and its catchment. Royal Melbourne Institute of Technology April, 1988.

Larsen, D.P., Dudley, D.R. and Hughes, R.M. (1988) A regional approach for assessing

attainable surface water quality: An Ohio case study. *Journal of Soil and Water Conservation*. March -April 1988,171-176.

Larsen, D.P., Omernik, J.M., Hughes, R.M., Rohm, C.M., Whittier, T.R., Kinney, A.J., Gallant, A.L. and Dudley, D.R. (1986) Correspondence between spatial patterns in fish assemblages in Ohio streams and aquatic ecoregions. *Environmental Management* 10: 815-828.

Leopold, L.B., Wolman, M.G. and Miller, J.P. (1963) *Fluvial Processes in Geomorphology* W.H. Freeman and Company, San Francisco.

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

Macmillan L. A. (1983). A method for identifying small streams of high conservation status. Paper presented at 'Workshop on Survey Methods for Nature Conservation'. Adelaide University, 30 Aug - 1 Sept. 1983.

Matthews, W.J. (1986) Fish faunal breaks and stream order in eastern and central United States. *Environmental Biology of Fishes* 17:81-92.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1990) *Australian Soil and Land Survey - Field Handbook* Inkata Press, Melbourne.

Meffe, G.K. and Sheldon, A.L. (1988) The influence of habitat structure on fish assemblage composition in southern blackwater streams. *American Midland Naturalist* 120 225-240.

Milner M.J., Hemsworth R.J. & Jones B.E.(1985) Habitat evaluation as a fisheries management tool. *Journal of Fish Biology* 27 (Supplement A): 85-108.

Mitchell, P. (1990) *The Environmental Condition of Victoria Streams*. Department of Water Resources, Victoria. [Note: this includes reference to the unpublished procedures and datasheets developed by J. Tilliard of Ian Drummond and Associates for conducting the surveys]

Naiman, R.J., Lonzarich, D.G., Beechie, T.J. and Ralph, S.C. (1992) General principles of classification and the assessment of conservation potential in rivers. In: Boon, P.J., Calow, P and Petts, G.E. (1992) *River Conservation and Management* John Wiley & Sons, pp. 93-123.

O'Brien, W.T., A. M. McGregor and B.W. Crawshaw (1983) In-Stream Uses of Water in Australia. In: *Department of Resources and Energy, Instream and Environmental Issues*. *Water 2000: Consultants Report No.9* AGPS. Canberra.

Odgaard, A.J. (1987) Streambank erosion along two rivers in Iowa. *Water Resources Research* 23: 1225-1236.

Odum, W.E. (1990) Internal processes influencing the maintenance of ecotones. Do they exist? In: Naiman, R.J. and Decamps, H. (Eds) *The ecology and management of*

aquatic-terrestrial ecotones UNESCO, Paris; Parthenon publishing group - Man and the Biosphere Series No. 4 pp. 91-102.

Olsen, G. and Skidmore, E. (1991) *State of the Rivers of the South West Drainage Division* Publication No. 2/91. Western Australian Water Resources Council, Perth.

Omernik, J.M. (1987) Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77:118-125.

Pennak, R W. (1971) Toward a classification of lotic habitats. *Hydrobiologia*, 38:321-334.

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

Platts, W.S. & Nelson, R.L. (1989) Stream Canopy and its relationship to Salmonid biomass in the Intermountain West. *North American Journal of Fisheries Management* 9:446-457.

Poff, N.L. and Ward, J.V. (1990) Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management* 14:629-645.

Rabe F. W. & Savage N. L. (1979) A methodology for the selection of aquatic natural areas. *Biological Conservation* 15:291-300.

Rice, J. (1987) *Gippsland Water Resources: Environmental Issues Background Report*, South East Region Water Management Strategy, Department of Water Resources Victoria. Report No. 31.

Richards, K. (1982) *Rivers - Form and Process in Alluvial Channels*.. Methuen, London 358p.

Riding, T.D. and Carter, R. (1992) *The importance of riparian zone in water resource management*. Department of Water Resources, Parramatta, NSW.

Rohm C. M., Giese J. W. & Bennett C. C. (1987) Evaluation of an aquatic ecoregion classification of streams in Arkansas. *Journal of Freshwater Ecology* 47:127-140.

RWC (1987) *Guidelines for Catchment Management*. Standing Consultative Committee on River Management, Rural Water Commission of Victoria.

SCRC (1991) *Guidelines for Stabilising Waterways, 1991*. Prepared by the Working Group on Waterway" Management, for the Standing Committee on Rivers and Catchments, Rural Water Commission of Victoria.

Schumm, S.A., Harvey, M.D. and Watson (1984) *Incised channels: Morphology, dynamics and control*. Water Resources publications, Littleton, Colorado, 200pp.

Smart, M.M., Jones, J.R. and Sebaugh, J.L. (1985) Stream-Watershed Relations in the Missouri Plateau Province. *Journal of Environmental Quality* 14: 77-82.

Stanton, J.P. & Morgan, M.G. (1977) *The rapid selection and appraisal of key and endangered sites: The Queensland Case Study*. A report to the Department of Environment, Housing and Community Development.

Swanson, S., Miles, R. Leonard, S. and Genz, K. (1988) Classifying rangeland riparian areas: The Nevada Task Force approach. *Journal of Soil and Water Conservation* May-June 1988 259-263.

WAWRC (1990) Report on an Investigation into Scientific and Educational Values of
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Wetlands and Rivers in the Perth-Bunbury Region. Patrick Coffey of Mitchell McCotter and Associates, Western Australian Water Resources Council Publication No. 1/91, Perth.

WAWRC (1987) Environmental Significance of Wetlands in the Perth to Bunbury Region Volume 1. Main Report Western Australian Water Resources Council, Perth 1987.

Whittier, T.R., Hughes, R.M. , and Larsen, D.P. (1988) Correspondence between ecoregions and spatial patterns in stream Ecosystems in Oregon. *Can. J. Fish. Aquatic. Sci.* 45:1264-1278.

Woodyer, K.D. (1968) Bankfull frequency in rivers. *Journal of Hydrology* 6: 114-142.

Wright J.F., Moss D., Armitage P.D. & Furse M.T. (1984) A preliminary classification of running-water sites in Great Britain based on macro-invertebrate species and the prediction of community type using environmental data. *Freshwater Biology* 14:221-256.

Wright, J.F., Furse, M.T., Armitage, P.D. and Moss, D. (1989) Prediction of invertebrate communities using stream measurements. *Regulated Rivers: Research and Management* 4:147-155.