DISCUSSION DOCUMENT

1984 REVIEW OF THE NORTHERN TERRITORY
HYDROLOGIC INFORMATION NETWORK: STAGE 1

Report for Stage 1 of Water Division Project No. 3041

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SYNOPSIS

A three-stage project has been established to review and upgrade the Northern Territory hydrologic (surface water) information network. This discussion document, forming Stage One of the project, has been prepared to provide a basis for comment on network philosophy and information requirements. Information collectors, analysts and users in the public water sector throughout the Northern Territory are invited to provide constructive comment.

The current setting of data collection, processing and analysis is described. Network design concepts are proposed for the Northern Territory. Proposals are made for station density, the design process, formalised reviews, data processing and analysis, and the funding framework.
SYNOPSIS

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CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1  It is concluded that the present hydrologic network in the Northern Territory is in need of major review. (Section 1.1).

Recommendation 1  It is recommended that there be two main classes of network; the resource inventory network to provide a quantitative understanding of the variability of hydrologic events areally and with time, and the project station network to provide information for present and imminent project needs (Section 3.1).

Recommendation 2  It is recommended that the station classification system based on the current main purpose of each station be adopted (Section 3.2).

Conclusion 2  It is concluded that hydrologic data networks should be an integration of stations collecting information on streamflow, water bodies, climate and catchment. Furthermore, these networks should be integrated with groundwater inventory networks (Section 3.5).

Recommendation 3  It is recommended that the hydrologic collection program include streamflow (discharge, water quality, sediment load, peak/low partial flows), water bodies, climate and catchment (Section 3.5).

Recommendation 4  For the resource inventory network, it is recommended that the network design team set the appropriate density of stations after considering local factors listed in Chapter 4.
(vi)

Conclusion 3  It is concluded that the network design team includes professional and technical staff based in Darwin, Katherine and Alice Springs; hydrologists who have the best working knowledge of hydrologic characteristics of the regions under consideration. This team must have access to advice from water planners and other users (Section 5.1).

Conclusion 4  It is concluded that the design of the project station network is straightforward, being based on the information requirements of the specific user (Section 5.2).

Recommendation 5  The recommended approach to examining the resource inventory network is to design the ideal network for the Northern Territory, and then to incorporate existing stations, where suitable, within the network. The recommended steps in this design process are set out in Section 5.2.

Conclusion 5  It is concluded that both the resource inventory and project networks must be reviewed at regular intervals to evaluate their effectiveness (Section 6.1).

Recommendation 6  It is recommended that, following establishment of the networks, brief annual reviews should be conducted jointly by the Senior Engineer Projects and the Principal Technical Officer. The timing of these reviews and their scope are detailed in Section 6.1.
It is recommended that, following this study, detailed network reviews (entailing data processing, analysis and application of new technology) be conducted at five-yearly intervals. The next such review is to be completed in 1990.

It is concluded that there is no simple test which indicates the length of operation of a station. Guidelines are given in Section 6.2; accuracy goals for the Northern Territory need to be established.

It is concluded that to have an effective hydrologic information system, data needs not only be collected but also processed, analysed and used (Chapter 7).

It is recommended that the records of all stations be processed and readily available on computer media and as hard copy within twelve months of the end of each water year (Chapter 7).

It is recommended that Water Division embark on a program of hydrologic analysis of data collected at each station, as part of the input to the five-yearly review (Chapter 7).

It is recommended that Water Division develop the ability to reliably fill-in missing record using modelling and correlation techniques appropriate to the various hydrologic regimes in the Northern Territory (Chapter 7).
Recommendation 11 It is recommended that as a general rule the funding of the construction and operation of project stations is to be met by the client (Section 8.3).

Conclusion 8 It is concluded that the Commonwealth is to fund the costs of operating national resource inventory stations, (currently 120 stations) with the Northern Territory to fund the remaining stations (Section 8.3).

Recommendation 12 It is recommended that the Commonwealth be approached to fund the construction of any new stations which will form part of the national resource inventory network. The Northern Territory will fund construction of new stations which form part of the local network (Section 8.3).
1. INTRODUCTION

1.1 Background

Information of varying length on the behaviour of Northern Territory rivers is available for 391 stream gauging locations. At 221 of these locations (including both resource inventory and specific project stations) water level recording and in many cases calibration are still being carried out. In addition, a network of 102 pluviographs (rainfall monitoring stations) is operated in conjunction with the stream gauging stations.

The hydrologic network has expanded considerably since the first stream gauging stations were commissioned in the early 1950's. In addition, stations have changed status, while project stations (including monitoring of effluent releases, tides, water quality and sediment transport) have been added. Often the information collected has been of use both for a specific project and for resource inventory purposes.

The hydrologic network has been reviewed periodically, the last review being by Kingston in 1980 (Reference 3). Since that review a number of events have occurred which, when combined, make the present appraisal of the network mandatory. These events include:

(i) National (Reference 8) and Northern Territory (Reference 10) studies which examined the Territory's water needs.

(ii) Arising from (i) the development within Water Division of five and twenty-year programs of water resource investigation and management. These programs helped clarify the hydrologic monitoring/data collection requirements.
(iii) The addition of more components to the network (for example water quality monitoring) but a reduction of in-house manpower resources to operate and maintain it. This has necessitated examining ways to streamline data collection and keep to a minimum the number of stations (by using multi-purpose stations for example); cost-effectiveness.

(iv) Preparation of a report on network design by the Australian Water Resources Council (AWRC) in 1982 (Reference 1). This latest, nationally-recognised approach differs from the approach used by Kingston (Reference 3).

(v) The digitising and computer storage of a large volume of data, and the rating of more stations, enabling review of the continuation of these stations.

1.2 Objectives

The objectives of this study are:

1. Review the network of resource inventory stations within the Northern Territory for the measurement of precipitation, streamflow, surface water quality and sediment load.

2. Review the operation of project stations, including those monitoring tides, surface water supply (bulk collection) and effluent release.

3. Make recommendations for change (if any) to the networks to meet the data requirements for the five-year and twenty-year programs of water resource investigation and management; prepare a program for implementing these changes.
1.3 Scope of this Document

This report, for Stage One of the hydrologic network review, takes the form of a discussion document. The document sets out the history of surface water data collection to show how the present monitoring points have been identified. It goes on to outline a framework for the design, density, practice and review of the Northern Territory's surface water network. The questions of information distribution and of 'who pays?' are addressed.

This document is being circulated for comment to a broad cross-section of the public sector of the water industry; data users including planners and designers in Water, Roads and Public Works Divisions; other government departments; investigations staff throughout Water Division; and staff who develop, operate and maintain the networks.

Stage Two of the study will include finalisation of the document on the philosophy of the Territory's surface water networks.

Stage Three will entail applying the above approach Territory-wide, resulting in a physical network which meets both Commonwealth and Territory data collection needs.
2. HISTORY OF THE HYDROLOGIC NETWORK
IN THE NORTHERN TERRITORY

Sketch notes on the history of the Northern Territory's hydrologic network are presented. Both resource inventory and project networks are discussed (as defined in Chapter 3).

2.1 Gauging Stations

2.1.1 Discharge and water levels

As pointed out in Chapter 1, 221 stations (the total of both the resources inventory and the project networks) are at present being operated, although information is available for 391 such stations. Kingston (Reference 3) has summarised the development of these networks, including the rationale in siting stations, the setting of priorities, and the economic benefits of the network. His report covers resource inventory stations and project stations (project investigations, project research, flood warning, tidal). His report does not include project operations stations (water supply bulk collection; effluent discharge) or statutory accounting stations. The classification system was based on that used in this report, but made complex in an attempt to classify multi-function stations. Recommendations which he made for upgrading of the networks were not followed through; the only growth in the network since 1980 has been in project stations.

2.1.2 Water quality

There is a loosely defined project network of stations to monitor surface water quality; stations in the Alligator Rivers Region, Rum Jungle Rehabilitation project, and at Mary Ann Dam fall into this category.
There has not been a resource inventory network to routinely measure water quality parameters. Kingston (Reference 3) recommended such a network be established, but to no avail. As pointed out in Chapter 3, a program for sampling key parameters at all resource inventory stations is being introduced in 1984/85.

Water quality baseflow surveys in major areas as recommended by Kingston (Reference 3) have been and are being conducted. Volume One of a series of reports (Reference 9) was released in 1983.

2.1.3 Sediment load

To date only project stations have been operated, notably in the Alligator Rivers Region, and to collect data as part of the investigation for a multi-purpose dam at Alice Springs. Most measurements have been of suspended sediment, although a small number of bed load measurements have been made.

The collection of this information, and future monitoring requirements are the subject of a programmed study in 1984/85: Project 4016 'Review of Sediment Yield of N.T. Rivers'.

2.2 Climate Stations

2.2.1 Rainfall

The Bureau of Meteorology has the responsibility for providing the general network of rainfall and climate data stations for Australia. However, this network is sparse. Water Division currently operates 102 pluviographs, with an additional number of daily-read rain gauges, where detailed monitoring of rainfall within gauged catchments is important.

10:REP3
These are operated for either resource inventory or for project purposes in conjunction with a stream gauge. Information is available for 169 such stations, as 67 are closed.

2.2.2 Other data

Water Division has operated other climate measuring equipment including evaporation pans for project purposes. There is no resource inventory network of such stations.
3. NETWORK DESIGN CONCEPTS

3.1 Why Have Networks?

The central question which should be asked when considering a study such as this is:

WHY ARE WE COLLECTING HYDROLOGIC INFORMATION?

The answer(s), will help clarify the purpose of the networks, and hence the design of the networks themselves.

The occurrence of hydrologic events is random both areally and in time. It is the variation of these events and their magnitude which is of importance; it is the variations which require study. A designed network is one which minimises the resources necessary to study these variations; its aim is the collection of data adequate to meet present and foreseeable needs, within an acceptable time frame and with a minimum of monitoring stations.

Network design concepts to be considered have been reported on in detail by Brown (Reference 2), Langbein (Reference 4), Moss (Reference 6) and others. It is not intended to 'reinvent the wheel' in this study, but to conform to recommended Australian practice as set out by the AWRC design document (Reference 1).

There are two main classes of networks; the multi-purpose network (resource inventory network) and the use-specific network (project stations). The resource inventory network has been described by Langbein (Reference 4) as a basic network to explain the regional hydrology; it looks to the future. The project network has been described by him as responding to present and imminent project needs; it provides point data; it serves the present.
3.2 Classification

To reduce subjectivity and hence more effectively design and review networks, a classification system is required which reflects the purpose of each station. The system is based on the current main purpose of each station, which is not necessarily that for which the station was originally established.

The classification system proposed is based on that considered appropriate by the AWRC (Reference 1) and which has been successfully applied to Western Australia (Reference 7). The classifications are shown on Table 3.2, and discussed in the remainder of this chapter.
### TABLE 3.2

**NETWORK DESIGN: CLASSIFICATION OF GAUGING STATIONS**

1. **RESOURCE INVENTORY NETWORK:**
   - Catchments to assess regional water resources and to monitor and understand time trends and spatial variations in the runoff characteristics.

   1.1 **PRIMARY STATIONS:**
      - **Bench Mark Stations:** Base stations to measure time variance.
      - **Mainstream Stations:** Selected primary stations with stable or protected catchments in which long term variations are attributable to climatic factors alone.
      - **Index Stations:** Generally catchments 1 000 km² which measure significant resources. (the number and location of these stations dictated by topography and drainage patterns.)

   1.2 **SECONDARY STATIONS:**
      - **Mainstream Stations:** Catchments 1 000 km² which measure runoff (quantity and quality) characteristics from significant variations in the physical environment - i.e. rainfall, landforms, vegetation and landuse.

2. **PROJECT NETWORK:**
   - Stations established for a specific purpose, to operate for periods determined by that purpose.

   2.1 **PROJECT INVESTIGATION STATIONS:**
      - Stations for specific investigations such as proposed damsites, groundwater recharge, diversions or flood control systems, or other water resources development or water quality investigation. (Either discontinued or reclassified at the end of the specific investigation.)

   2.2 **PROJECT RESEARCH STATIONS:**
      - Stations operated for research related to a specific project, including environmental stations in the Alligator Rivers Region, Rum Jungle Rehabilitation.

   2.3 **OPERATION STATIONS:**
      - Stations required for operating water storage or distribution systems, and for operating effluent release systems.

      (i) **System Flow Stations:** Stations recording regulated flows for compiling flow budgets or for analysis.

      (ii) **Current Use Stations:** Stations providing information for management and operation functions as distinct from flow recording purposes. (Records not kept.)
TABLE 3.2 (cont.)

**NETWORK DESIGN: CLASSIFICATION OF GAUGING STATIONS**

(ii) **Index Stations:** Catchments < 1,000 km² measuring runoff quantity and quality characteristics from particular types of landscape or landuse. Important to have a range of catchment sizes, including small catchments to provide storm runoff data from natural, agricultural and urban environments. Operate until an adequate estimate of the flow and quality characteristics can be obtained, either directly or by correlation.

(iii) **Partial Record Stations:** Stations recording either peak flows, low flows or water surface levels which can be used for flood or drought frequency studies.

(iv) **Landuse - Hydrologic Response Stations:** Small catchments measuring the effects on runoff (quantity or quality) characteristics of specific types of, or changes in, landuse or land treatment.

2.4 **STATUTORY ACCOUNTING STATIONS:** Stations providing water data for accounting purposes under legal or statutory agreements or obligations (probably operate indefinitely).

2.5 **FLOOD WARNING STATIONS:** Stations operating solely for flood warning purposes.

2.6 **TIDAL STATIONS:** Stations operating solely for monitoring tidal variation. Both indefinite and finite period stations.

**FOOTNOTES:**

(a) Multipurpose stations fulfilling more than one function should be listed in the classification in which they provide most value, not necessarily that for which they were installed.

(b) There are instances where more than one recording installation is required to determine the natural flow at a given locality.
3.3 Resource inventory network

The function of the resource inventory network is to provide information on the water resources of a region for general planning and design, to detect long term trends, and to provide information for the many unanticipated data demands. This network should be seen as a part of the national resource inventory network with attendant Commonwealth responsibilities. Although stations are established and operated at locations which may not be developed in the future, the selection of those locations should be in catchment types in which development is foreseeable. Such a selection, based on engineering judgement, should allow for the transfer of data to ungauged catchments with a high degree of reliability. In many respects then, the resource inventory stations can be viewed as 'project' stations.

As noted at the beginning of this chapter, the resource inventory network should be designed to provide a quantitative understanding of the variability of hydrologic events both areally and in time. This has been found to be most efficiently achieved by having a mix of primary and secondary stations (the terminology refers to the duration of the monitoring period, and not, as is sometimes thought, to the importance or value of the data obtained).

Primary stations operate for a very long period of time (or indefinitely), measuring variations with time. They provide the baseline data on climatic or environmental long term trends.

Secondary stations operate for a finite period to sample variations areally; when the station has enough record to allow satisfactory correlation with the primary network it is closed. The instrumentation from that station is then moved to sample a different catchment type or size. The duration of operation of these stations is discussed in chapter 6.
The combination of primary and secondary stations provides the most cost effective method of achieving both the long term monitoring and the widespread sampling necessary for water resources assessment. This is done with a minimum of stations operating at any one time.

The classifications of Bench Mark Stations (Primary Stations), and Partial Record Stations and Land Use Hydrologic Response Stations (Secondary Stations) are clearly explained in Table 3.2.

Mainstream stations usually measure the total resource of a basin or river system. As such these catchments are too large or complex to provide information about runoff characteristics which could be transferred accurately to other locations. The number and size of mainstream catchments is determined by regional topography and drainage patterns.

The number and location of index stations is related to environmental factors. The index catchments are selected to sample the hydrologic characteristics from significant variations in rainfall, landforms, geology, soils, vegetation and land use. To improve their usefulness for transfer of information to ungauged catchments, these index stations should be selected in a range of catchment sizes.

3.4 Project station network

Stations in this category are established and operated for a particular purpose or project. In most instances the data from these stations is not applicable to resource inventory/assessment, or improving the understanding of hydrologic processes. These stations are generally discontinued at the end of the specific project.
The classifications include stations for Project Investigation, Project Research, Operations, Statutory Accounting, Flood Warning, and Tidal. These are clearly described in Table 3.2.

3.5 Integration

The most cost effective way of monitoring the different variables required by planners, designers and others is to ensure that hydrologic data collection networks are integrated. The collection program should incorporate the following:

- streamflow
  - discharge (continuous)
  - water quality
  - sediment load (both suspended sediment and bed load)
  - peak flow/low flow partial records

- water bodies (lakes and reservoirs)
  - level
  - water quality

- climate
  - rainfall (daily, continuous)
  - evaporation
  - dewpoint and other data

- catchment
  - relief, geology, soils, natural vegetation
  - history (land use and vegetation condition)

As pointed out by the AWRC (Reference 1) the Bureau of Meteorology has the responsibility for providing the general network of rainfall and climate data stations for Australia.
However, the Bureau's network is sparse. Where detailed monitoring of rainfall within gauged catchments is important (either for resource inventory or for project purposes) it is up to the Northern Territory to carry out such monitoring.

The AWRC has stated that water quality assessment of surface waters should be fully integrated with the streamflow assessment program. As a result of the Water 2000 study (Reference 8) a program of sampling for key water quality parameters at all resource inventory stations is being introduced:

- pH and temperature (physical parameters)
- specific conductance (chemical parameters)
- turbidity (index of catchment erosion)
- and percent dissolved oxygen (to be introduced later, in 1985)

The stream gauging network should therefore reflect water quality data needs as well as water quantity and flood flow data needs.

Discussion to this point has centred on the hydrologic networks. It is obvious though that these networks should be integrated with groundwater monitoring networks, especially in large sedimentary basins or where water movement into or out of a groundwater system, such as along the Daly River, is important. Groundwater monitoring networks throughout the Northern Territory are either being established or under review during 1984/85. The hydrologic network design team must liaise with the groundwater network design/review teams to ensure networks are integrated efficiently.
4. NETWORK DENSITY

It is up to the network design team to set the appropriate density of stations for each region. This is done after considering various factors which include:

(i) the level of social and economic development, and the resulting required level of development of available water resources in the future.

(ii) the hydrologic variability of the region, and the amount of information (level of understanding) available now.

(iii) special regional characteristics or problems requiring hydrometric data.

Once the network has been designed, it is desirable to be able to check it against an independent guide to the minimum density of gauging stations appropriate to the region without causing undue economic loss or restricting future development. The AWRC (Reference 1) has modified the guidelines which were prepared by the World Meteorological Organisation (Reference 12), adapting them to Australian conditions. These Australian guidelines, discussed at length in Reference 1, are listed in Table 4; the zones to which they refer are shown in Figure 4. The network density or 'area per station' values used for the three climatic zones in the Northern Territory are to be entered in Table 4 when Stage 3 of this study is completed.

It is repeated that these broad guidelines are not a substitute for consideration of local and regional needs. They are not to be used as justification for the networks.
### TABLE 4  MINIMUM NETWORK DENSITY

<table>
<thead>
<tr>
<th>CLIMATIC ZONE FOR N T</th>
<th>AWRC GUIDELINES</th>
<th>VALUES ADOPTED FOR NORTHERN TERRITORY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mountains* and ranges</td>
<td>Flat Terrain</td>
</tr>
<tr>
<td>Tropical or humid zone (summer rain)</td>
<td>300 to 1000</td>
<td>1000 to 2500</td>
</tr>
<tr>
<td>Transitional zone (semi arid)</td>
<td>600 to 2000</td>
<td>2000 to 5000</td>
</tr>
<tr>
<td>Arid zone</td>
<td>3000 to 7000</td>
<td>7000 to 20 000</td>
</tr>
</tbody>
</table>

*Note: The Mountains and Ranges category refers to areas with much greater areal variability than the Flat Terrain Category.*
CLIMATIC TYPES
Köppen Classification (1936)

A Hot Moist Climates
B Dry Hot to Warm Climates
C Temperate Moist Climates
B Very Dry Hot to Warm Climates

Extract from climate map: Atlas of Australian Resources

FIGURE 2 Stream Gauging Network Density Zones
5. THE PROCESS OF NETWORK DESIGN

5.1 Design team

To satisfy most information needs surface water data must be collected over many decades (refer to Chapter 6). Because of the long lead time and associated costs, network design and review are important activities and not to be taken lightly. The design team must thus include hydrologists who have a good working knowledge of the hydrologic characteristics of the region under consideration. In the Northern Territory that means using the information and talents of engineers, scientists and technical staff based in Darwin, Katherine and Alice Springs; not just a small group of professionals based in Darwin. The design team must have access to advice from water planners and other potential uses.

5.2 Design process

The design of the project network is based on the information requirements of the specific user: station type, location, mode of operation and length of operation, as well as data processing and analysis are tailored to the client's requirements.

Design of the resource inventory network is based on the best current understanding of the factors which affect the hydrology of the region. Although this study is a major review rather than an initial design, the approach will be to design the ideal network and then to utilise existing stations, where suitable, within that network.

The steps in the design process include:

1. Compilation of relevant information in map form, including:
   - climate and rainfall distribution
- landform (geology, soils, topography)
- river systems and discharge patterns, based on the AWRC Drainage Divisions and River Basins (Figure 5.2)
- natural vegetation
- land use and land use history

2. Definition of regions considered to have similar hydrologic characteristics, by overlaying the above maps. These regions provide the guide to areal variability.

3. Identification of mainstream catchments by examining the major rivers and their likely behaviour. Gauging stations should be located at sites such as points of future development, at the start of the flood plain, at the head of the estuary.

4. Identification of index stations to sample environmental factors or hydrologic regions having a range of catchment sizes. The use of nested catchments should be considered to maximise information gained for the effort expended.

5. Identification of stations required to satisfy the data needs for any particular regional problem requiring solution such as salinity, or the hydrology of wetlands.

6. Examination of existing stations; assessment of their suitability in the network.

7. Consideration of practical problems involved in establishing and operating stations in the area being considered.
8. Check the network against the independent guide (Chapter 4) to the minimum density of gauging stations.

The final network should provide a balanced sampling of the major rivers and various hydrologic regions. This may involve the design team considering a number of designs which would be developed and compared until the most cost effective network is attained.

Of the network design/reviews conducted by the various States, that carried out by Western Australia in 1982 (Reference 7) most closely meets the study proposed for the Northern Territory. Many of the hydrologic regimes for Western Australia and the Northern Territory are similar, land use and likely development in the northern part of that State is similar, the level of and problems of data collection are similar, and that State has used the AWRC document (Reference 1) as the basis for its design. To obtain an idea of what is proposed for the approach to the Northern Territory resource inventory network, the Western Australia network for the Timor Sea Drainage Division (covering the Kimberley Districts) is included in Appendix 1.
6. NETWORK REVIEW

Both the resource inventory and the project networks must be reviewed at regular intervals to evaluate their effectiveness. Modifications need to be made where necessary. Unfortunately, there is no simple test which indicates that a station is adequately serving its purpose or that it should be closed.

A necessary starting point is that all data collected should be processed and analysed to determine the variability of the hydrologic characteristics with time and areally. Past reviews conducted on the Territory network (either ad hoc examinations or the formal review by Kingston in 1980) have been incomplete because they lacked this analysed data base. Even now a complete review cannot be conducted because much of the data backlog is still unprocessed and most stations are not fully rated.

However, data being collected now is being stored on the computer, and large in-roads are being made in the data backlog. Concurrently, both technical and professional staff are engaged in a defined program of station rating and rating and extension.

It is likely that much of the data will have been processed and analysed in five year's time. An objective should be to conduct a complete review in 1990, under the supervision of the Principal Engineer Surface Water. This review would also incorporate the effects of technological change which may influence operational costs and network design.

Meanwhile, brief annual reviews should be conducted, identifying inadequacies in the data base and evaluating individual stations by considering:

- percentage of data capture
- accuracy of the processed data
- reliability of the record
- consistency of the data collected with time
- ability of the station to perform its classified function
operating difficulties
- costs of operation

These annual reviews should be conducted jointly by the Senior Engineer Projects and Principal Technical Officer, using the staff resources available to them Territory-wide, in particular the Engineer 2 (Hydrology) and Senior Technical Officer Computations and Analysis. The reviews should be completed early in the calendar year (making use of the previous year's data and allowing time to have stations constructed or upgraded during the following dry winter months. The annual reviews should be incorporated in Water Division's project 1005 'HYDROGRAPHIC OPERATIONS'.

6.2 Duration of station operation

As indicated earlier, there is no simple test which indicates for how long a station should be operated. However, various researchers have calculated the minimum record length as a guide, for different purposes, in different hydrologic regimes and for varying accuracy goals.

In the resource inventory network, primary stations are defined as being of long term or indefinite duration. To illustrate this, McMahon (Reference 5) has calculated that the time to obtain sufficient information to specify the mean annual flow to within 10% accuracy in an average Top End stream is 40 years, whilst in central Australia this rises to greater than 150 years. If 5% accuracy is required, the times increase to 160 years and greater than 620 years respectively. More details are presented in Appendix 2. However, to specify the 1-in-10 year low annual flow (say for water supply design calculations) would require even longer record length. For the Adelaide River, the required record length allowing for an error of 10% is 150 years (compared to 25 years for mean annual flow).
As another example, the Water Resources Commission of New South Wales has adopted a compromise specification (Reference 11). Based on an examination of the coefficients of variation for that State (see Appendix 2), the historical record already available (larger and higher density than the NT), comparison with overseas achievements, and allowing what appears to be a reasonable length of record, the necessary length of record would vary from about 25 years in the Top End to 55 years in central Australia (for accuracy goals of 12% and 17% respectively).

For secondary stations, review will entail both the adequacy of the data collected and the need for further record. The duration of operation of these stations is dependent on obtaining good correlation of flows and water quality with a nearby primary station. As a guide, the length of operation of these stations is expected to be no greater than half that of nearby primary stations; far less if good correlation is obtained. When correlation of a suitable accuracy to simulate the long term flow (and water quality characteristics if necessary) is achieved, the secondary station should be closed under that classification. However, data collection may still be continued at that site if required, but under a different classification; for example a secondary station may be reclassified to a flood warning station.

In the project network, project stations should be closed once the data requirements have been met. However, some of these stations may be re-opened under another classification for other data needs; for example a project station collecting urban drainage design data, may, at the end of the project, be reclassified to an index secondary station in the resource inventory network.
7. **DATA PROCESSING AND ANALYSIS**

If we again ask the question posed in Chapter 3, "Why are we collecting hydrologic information?", it can be seen that hydrologic networks on their own are not enough. Brown (Reference 2) points out that a 'hydrologic information system' is required. Raw data has no use; it only become valuable when it has been processed, analysed and used.

Whilst the subjects of data processing and analysis are not explicit in this study's objective, they are related to the purpose of network design, operation and review, and so require some comment.

It is important that the following activities be maintained, or in some cases commenced, to ensure hydrologic data collection is efficient and cost effective.

1. The records of all stations should be processed and readily available on computer media and as hard copy within twelve months of the end of each water year. At present all stream gauging and tidal station records are being entered on computer storage within six months of the end of each year. Tables giving station details; daily instantaneous max. and min. stage; and max., min., and mean daily discharge (if rating curves have been prepared) are available. The first of the series of annual reports containing this information is being prepared, to be published in March 1985.

Computer software to enable the processing and presentation of related rainfall, water quality and sediment yield information is still to be developed, with targets of one, one and five years respectively.
2. As part of the major five yearly reviews, Water Division should carry out simple hydrologic analyses of the data collected at each station. Analyses can include:

- station-station correlations for which some computer software is already available in-house.

- catchment rainfall-runoff modelling studies using daily or monthly data. Computer software will shortly be available in-house.

- general hydrologic studies including flood frequency analysis updates, flow duration curves.

- general studies of water quality and sediment transport characteristics and trends.

3. Water Division needs to develop an ability to reliably fill-in missing record using modelling and correlation techniques appropriate to the various hydrologic regions. The regular application of these techniques will take up to ten years, depending on data availability.

4. Eventually, both uncorrected and corrected hydrologic information should be available for users.
8. FUNDING

8.1 Past funding arrangements

Prior to 1983/84 funding of the construction and operation of stations, and of data processing was shared between the Northern Territory and Commonwealth Governments. The funding of most project stations was the responsibility of the Northern Territory, although special project stations associated with environmental monitoring in the Alligator Rivers region were funded by the Commonwealth. Funding of national assessment (now resource inventory) stations was contributed to equally by the Northern Territory and the Commonwealth. The multi-use classification of stations clouded the funding issue.

In 1983/84 further complexities were introduced:

(i) Increasing recognition that project stations should be funded by the client; either construction alone (Palmerston Development Authority) or construction and operation (Rum Jungle Rehabilitation Project).

(ii) A reduction by 30% of the Commonwealth's contribution to the inventory network.

This network review/design, with its associated simplification of station classification, is the appropriate time to re-establish the funding framework.

8.2 Present costs

Since 1983/84 gauging station construction, major maintenance and upgrading, as well as access, have been carried out by contractors. Costs per station have ranged from approximately $10 000 to $40 000 depending on the work required and the location in the Northern Territory.
The average cost in 1983/84 to operate each station was $8,400. This cost includes six-weekly station inspections, minor maintenance, data processing, and allowance for professional and senior technical staff input.

8.3 Future funding

From July 1984 funding should be simplified to the following general framework:

(i) As a general rule the funding of the construction and operation of project stations is to be met by the client. Construction and operation are defined above; the construction costs will be site specific while the operation costs should be an average station cost for the Northern Territory. Exceptions to this proposal may need to be made in certain instances.

(ii) The Commonwealth has indicated that as of 1984/85 it will fund the operation costs of 120 resource inventory stations in the Northern Territory which are of importance to the national network.

(iii) It is proposed that the construction of new resource inventory stations which form part of the national network, particularly in areas of poor coverage such as in the Western Plateau and Lake Eyre Drainage Divisions also be funded by the Commonwealth. A precedent is being set in 1984/85, with the Commonwealth funding the construction of stations in the Pilbara and Kimberley regions in Western Australia.

(iv) The construction and operation of the remaining stations in the resource inventory network will be funded by Water Division. The final number will be finalised in Stage 3 of this study.
9. REFERENCES


5. McMAHON, T A: "Low flow and yield data requirements"; in Workshop on Surface Water Resources Data; Australian Water Resources Council; Canberra; 1983.


12 WORLD METEOROLOGICAL ORGANISATION; "Guide to Hydrological Practices", WMO No. 168 (Geneva); 1981.
APPENDIX 1

EXAMPLE: WESTERN AUSTRALIA RESOURCE INVENTORY NETWORK
TIMOR SEA DRAINAGE DIVISION

REPRINTED FROM REFERENCE 7 pp 38 to 49
5. TIMOR SEA DRAINAGE DIVISION (DIV VIII)

Within Western Australia, the Timor Sea Drainage Division covers the Kimberley Districts and comprises AWRC River Basins 801 to 809 inclusive. Although the region is estimated to have about 75% of the States' total surface water resources, it contains only about 1.4% of the State's population and water demands are low. Present water resource development is virtually limited to the Ord River irrigation scheme and the smaller Camballin scheme on the Fitzroy.

5.1 Characteristics affecting the hydrologic regime:

5.1.1 Climate:

The Division experiences a tropical climate with a distinct winter dry season which according to the Koppen classifications is described as a semi-arid monsoonal climate. Most of the rain falls between November to April and is fairly regular in occurrence but variable in amount. The average annual rainfall ranges from 1400 mm along the north-west coast to less than 400 mm in the transition zone along the desert margin in the south. Most of the rain results from thunder storms producing heavy, localized falls, but the occasional cyclone can generate widespread, intense falls to produce general flooding.

5.1.2 Topography and Landforms:

The landscape of the region falls naturally into three major physiographic divisions, named by Jutson (1934) as North Kimberley, Ordland and Fitzroyland. North Kimberley comprises the Kimberley plateau and its foreland of barrier ranges; it consists of Precambrian basalt and sandstone tablelands flanked to the south and east by mobile zones of intrusive and metamorphic rocks forming the King Leopold and Durack Ranges. Ordland consists mainly of an erosional surface or pediplain on Phanerozoic basalts, shales and limestones with many residual outcropping hills and ranges. Fitzroyland contains mainly Phanerozoic sedimentary rocks including limestones, dolomites and sandstones and forms the floodplains of the Fitzroy and Lennard River systems. Shallow, sandy, skeletal soils predominate throughout the region, but cracking clays occur on basalt country and on the lower slopes of the erosional and alluvial plains. Sandplains with dunes cover much of the Fitzroyland province, particularly in the west and south.

5.1.3 Drainage Patterns:

The drainage patterns and their density reflect the underlying geology. The Kimberley plateau is dissected by what was originally a superimposed radial drainage pattern that has since been modified by tectonic events and geological control. Generally, the plateau has a rectangular, joint controlled drainage pattern with a fairly low density. Valley forms range from wide, shallow V-shapes on the plateau top, to narrow U-shaped gorges where they dissect the rim.
then become wide and shallow, frequently with braided streamlines, on
the pediplains. The barrier ranges of the Kimberley foreland have a
trellis type drainage pattern of fairly high density with wide flat
valleys and steep, narrow interfluves, while the granite hills have a
high density, dendritic drainage pattern of narrow valleys. The
Ordland erosional plain has a dendritic drainage of moderate density
with generally wide shallow valleys except where the drainage is
superimposed on residual outcrops of resistant rocks. The Fitzroy
Plains have braided alluvial mainstreams with a few parallel or
dendritic pattern tributaries. The drainage density is low.

5.1.4 Natural Vegetation:

The natural vegetation of the Kimberley region consists of
savannah formations ranging from savannah-woodlands through low tree
savannah to open steppe. In the higher rainfall area of the north-west
it is mainly tropical tall-grass savannah with a tree layer of
bloodwoods and stringy barks forming a woodland on the sandstone
plateau, eucalypt-cabbage palm woodlands on the laterites and tall
grasslands with only scattered trees on the cracking clay plains. In
the medium rainfall area (400-700 mm) dense acacia thickets (pindan)
cover the sandplains, while snappygum-spinifex savannah occurs on the
rocky ranges and bloodwood-mitchell grass savannah on the clay plains.
Low tree spinifex steppe and short grass savannah occupy the desert
margin to the south. Small pockets of rainforest occur in the extreme
north and riverine gallery forests fringe the major stream lines. Some
of the natural vegetation has been cleared for irrigation schemes and
small areas disturbed by mining operations and services, but the major
impact on the vegetation has been from pastoral grazing and its
associated burning off programmes.

5.1.5 Landuse:

Irrigation schemes on the Ord and Fitzroy Rivers covering
11,000 ha and 2,500 ha respectively were developed in the mid 1960's.
These initially produced cotton, rice and sorghum, but since the mid
1970's have been producing oilseeds, fodder crops and rice for local
markets from much reduced acreages.

Mining operations started with the Halls Creek gold rush in
1885 and some fossicking continued for many years. There was some
small scale mining of silver and lead in the West Kimberleys and
copper in the East Kimberleys in the pioneering days, but modern
mining commenced in 1951 with the iron ore project on Cockatoo Island.
Reserves of bauxite have been proved but not yet developed on the
Mitchell Plateau and the most recent prospect is the Ashton diamond
venture.

The most important and widespread impact on the local
environment however, has been the pastoral industry. Sheep are run on
the short grass plains of the Fitzroy Valley and cattle throughout the
rest of the region, except for some very broken sandstone country in
the north. After nearly ninety years of virtually open range grazing
much of the river frontage has been severely overgrazed, particularly
in the Ord and Fitzroy River basins. Periodic burning off to destroy unpalatable grasses has altered the composition of the understory plants and encouraged the invasion of weed species in some areas.

5.2 Basis for the Network:

5.2.1 Network Density:

The Timor Sqa Drainage Division (Basins 801 to 809) covers an area of 282,110 km². Some 25% of this area has an average annual rainfall less than 500 mm and lies in the transitional zone described in section 2.2, while the remainder lies in the semi-arid monsoonal or tropical climate as described above. Nearly half the area (46%) is mountainous terrain of high or broken relief, but there is considerable homogeneity in the landforms.

Estimation of station numbers using the density values shown in Table 2.3, gives a range from 580 to 180 stations, with a median of 320. The lowest figure, derived from the lower density values, is considered the most appropriate for this network because:

- the highest rainfall (over 800 mm) occurs over the most homogeneous area with the least spatial variability
- most of the region lies outside Koppen's Zone of hot moist climate and within the zone of dry hot climate
- the high operational costs incurred in a region of difficult terrain with poor access must be consonant with the need for hydrologic data

Table 5.1 shows the distribution of the climate and topographical types listed by river basins, together with the number of stations calculated from the density values and the actual number of stations selected in the current 'skeleton' plan. The guideline total of 180 stations probably represents the optimum network, but the 105 stations selected in perhaps a more realistic compromise with present conditions as discussed below.

5.2.2 Mainstream Network:

Due to the configuration of the Kimberley plateau and the radial nature of the drainage patterns, the total surface water resources cannot be assessed by a few large mainstream gauging stations. The presence of Lake Argyle and the difficulties inherent in gauging wide, braided floodplain channels add to the complexity of the problem. In all, there are 27 separate 'resource catchments' which require individual stations to achieve a preliminary resource inventory, and a further 13 stations are considered necessary to obtain an understanding of the resources and their hydrological characteristics.
Of the 39 mainstream catchments selected, 20 have been classified as primary stations and 19 as secondary. In time, it is expected that a greater proportion could be reclassified to secondary status when adequate correlations have been achieved, due to the similarity of landforms on the sandstone plateaux.

5.2.3 Areal Sampling Network:

Although there is a broad correlation between the rainfall zones and the major vegetation types, there is sufficient complexity in the geology, soils and landforms to preclude any adequate definition of environmental or hydrological provinces for planning purposes. As with Division VII, the landscape has been represented by the nine landform types, depicted and described on Figure 5.1, which reflect in a simplified form the AWRC Relief and Landform units, and the physiographical provinces described by Beard (1979).

The distribution of the areal stations selected to sample these distinct landscapes is shown on Table 5.2, which reveals the preponderance of stations in the rocky upland 'source' areas and the dearth of definable catchments on the floodplains and coastal flats. The network, as enumerated, contains provision for these gaps to be filled by small catchments to be located by field investigation.

The geographical spread of areal stations achieved by sampling the landform units also achieves an adequate sampling of the rainfall distribution and the main vegetation zones. Some of the variations in floristic composition in response to soil types and special aspects of landuse, such as overgrazing, however, will have to be monitored by selected small catchments as these features are difficult to identify at map scale.

5.2.4 Catchment size distribution:

Catchment sizes for the nominated stations range from 25 km² to nearly 100 000 km², but provision is made for 14 additional small catchments. The distribution through the size range is depicted on Figures 5.2 and 5.3 which show a generally log normal distribution with a median value of 540 km². The large number of catchments in the 250-500 km² range reflect the naturally occurring size of 2nd and 3rd order streams on the sandstone plateau.

5.3 Special considerations affecting the Network:-

A network of 180 gauging stations as indicated by the density criteria would provide optimal sampling of the hydrologic characteristics of the Kimberley region with respect to both temporal and spatial variances. However, such a network would be difficult to justify and more difficult to operate in the present circumstances with a small population, low water demands and poor access.
The skeleton network enumerated in Table 5.3 is considered adequate to meet foreseeable needs for hydrologic data for study and design purposes and resource development such as water supply, irrigation and hydropower for the next 25 years. As it concentrates on the 'source' areas of runoff, the skeleton plan does not provide information on the flood plains, but this has proved almost impossible to obtain at the scales involved, with current technology.

Implementing and operating even the skeleton network in this remote region of difficult terrain and poor access will be costly and take some years to complete. A high proportion of the 29 existing stations require substantial rebuilding to upgrade their standard before a start can be made to expand the network. It is envisaged that this upgrading and expansion of the network to a total of 50 stations will be completed by 1995. Further expansion to the designed network of 105 stations may occur by 2010.
<table>
<thead>
<tr>
<th>BASIN</th>
<th>BASIN AREA (km²)</th>
<th>TRANSITIONAL ZONE</th>
<th>TROPICAL ZONE</th>
<th>CALCULATED FROM RAINFALL</th>
<th>RESIDUAL TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOUNTAINS</td>
<td>FLAT</td>
<td>MOUNTAINS</td>
<td>FLAT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1:1 200 km²</td>
<td>1:3 000 km²</td>
<td>1:5 000 km²</td>
<td>1:15 000 km²</td>
<td></td>
</tr>
<tr>
<td>AREA</td>
<td>AREA × STNS</td>
<td>AREA × STNS</td>
<td>AREA × STNS</td>
<td>AREA × STNS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>17 500</td>
<td>28 450</td>
<td>20 675</td>
<td>17 500</td>
<td>7</td>
</tr>
<tr>
<td>002</td>
<td>88 980</td>
<td>15 500</td>
<td>15 500</td>
<td>24 355</td>
<td>10</td>
</tr>
<tr>
<td>003</td>
<td>14 160</td>
<td>4 610</td>
<td>14 300</td>
<td>9 550</td>
<td>4</td>
</tr>
<tr>
<td>004</td>
<td>19 400</td>
<td>15 500</td>
<td>15 500</td>
<td>3 000</td>
<td>2</td>
</tr>
<tr>
<td>005</td>
<td>14 610</td>
<td>14 300</td>
<td>14 300</td>
<td>330</td>
<td>14</td>
</tr>
<tr>
<td>006</td>
<td>17 150</td>
<td>12 250</td>
<td>12 250</td>
<td>9 900</td>
<td>14</td>
</tr>
<tr>
<td>007</td>
<td>26 120</td>
<td>10 120</td>
<td>10 120</td>
<td>16 000</td>
<td>16</td>
</tr>
<tr>
<td>008</td>
<td>29 040</td>
<td>20 340</td>
<td>8 000</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>009</td>
<td>55 130</td>
<td>4 600</td>
<td>11 430</td>
<td>15 000</td>
<td>29</td>
</tr>
<tr>
<td>TOTAL</td>
<td>202 110</td>
<td>52 550</td>
<td>109 225</td>
<td>100 225</td>
<td>183</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>18.6%</td>
<td>30.7%</td>
<td>35.5%</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 5.2

DISTRIBUTION OF AREAL STATIONS THROUGH LANDFORM TYPES

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BASIN</td>
<td>801</td>
<td>802</td>
<td>803</td>
<td>804</td>
<td>805</td>
<td>806</td>
<td>807</td>
<td>808</td>
<td>809</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>TOTALS</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>11</td>
<td>12</td>
<td>8</td>
<td>52</td>
</tr>
</tbody>
</table>

**NOTE:** 52 STATIONS COMPRIS 2 BENCHMARK
27 PRIMARY AREAL
33 SECONDARY AREAL
52

(14 ADDITIONAL AREAL CATCHMENTS YET TO BE INVESTIGATED)
TABLE 5.3. TIMOR SEA DRAINAGE DIVISION (DIVISION VIII): DESIGNED HYDROMETRIC NETWORK

<table>
<thead>
<tr>
<th>BASIN</th>
<th>PRIMARY STATIONS (TIME VARIANCE)</th>
<th>SECONDARY STATIONS (SPATIAL VARIANCE)</th>
<th>TOTAL STATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BENCHMARK</td>
<td>MAINSTREAM</td>
<td>AREAL</td>
</tr>
<tr>
<td>801</td>
<td>002 - Fannie R</td>
<td>002 - Mt. Parry Ck</td>
<td>202 - Leopold R</td>
</tr>
<tr>
<td>802</td>
<td>005 - Fitzroy R</td>
<td>002 - Mt. Parry Ck</td>
<td>202 - Leopold R</td>
</tr>
<tr>
<td>803</td>
<td>001 - Lenyard R</td>
<td>001 - Up. Lenyard</td>
<td>- Banker R</td>
</tr>
<tr>
<td>806</td>
<td>001 - Mitchell R</td>
<td>003 - Crystal Ck</td>
<td>004 - Carson R</td>
</tr>
<tr>
<td>808</td>
<td>001 - Mid. Durack</td>
<td>002 - Bindaule Ck</td>
<td>- Low. Durack</td>
</tr>
<tr>
<td>TOTALS</td>
<td>2</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>

TOTAL HYDROLOGIC (SKELETON) NETWORK 105 - (Calculated from AWRC Guidelines: 183)

Primary Stations - 49
Secondary Stations - 56
Mainstream Stations - 39
Areal Stations - 66

105 105
### TIMOR SEA DRAINAGE DIVISION (DIVISION VIII)
#### LANDFORM TYPES DISTINGUISHED FOR NETWORK PLANNING

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Coastal Plains - Calcareous Sands, Limestone and Siliceous Pebbles</td>
</tr>
<tr>
<td>B</td>
<td>Flood Plains - Mostly Alluvial and Deltaic Deposits - Some Alien Sands</td>
</tr>
<tr>
<td>C</td>
<td>Lowland Sand Plain - Mostly Red Earth Sands - Some Dune Fields</td>
</tr>
<tr>
<td>D</td>
<td>Depressional Plains - Stone Pavements and Outwash Plains - Some Residual Hills and Ranges</td>
</tr>
<tr>
<td>E</td>
<td>Upland Sand Plain - Red Harbour Sands - Some Limestone and Alluvial Sands</td>
</tr>
<tr>
<td>F</td>
<td>Till land - Hills and Plains - Mostly on Sedimentary Rocks</td>
</tr>
<tr>
<td>G</td>
<td>Hills and Ridges - Broken Country on Granites and Gneisses</td>
</tr>
<tr>
<td>G'</td>
<td>Hills and Ridges - Broken Country on Granites and Metamorphic Rocks</td>
</tr>
<tr>
<td>H</td>
<td>High Plateau - Ranges and Tablelands and Steep Cut Gorges</td>
</tr>
<tr>
<td>J</td>
<td>High Ranges - Ranges and Hills Eroded by Rock Valleys</td>
</tr>
</tbody>
</table>

VIII TIMOR SEA DIVISION

1. Cape Leveque
2. V. Koonard River
3. Leveque River
4. Ati River
5. V. Belewen River
6. K. Kondor River
7. Ovij HUD River
8. Ovij HUD River
9. W. D. HUD
10. KEEPER-ER

![Map of TIMOR SEA DRAINAGE DIVISION](image)
TIMOR SEA DRAINAGE DIVISION (DIVISION VIII): CATCHMENT SIZE DISTRIBUTION WITHIN NETWORK
TIMOR SEA DRAINAGE DIVISION (DIVISION VIII): DISTRIBUTION OF 105 CATCHMENTS THROUGH SIZE RANGES

14 small catchments to be investigated
REFERENCES AND SOURCES : TIMOR SEA DIV VIII

1. BEARD J.S. (1979) Vegetation Survey of Western Australia, 1:1000 000 Series, Sheet 1, Kimberley, University of Western Australia Press, Nedlands.


APPENDIX 2 MINIMUM STREAMFLOW RECORD LENGTHS

This information has been obtained from a paper prepared by McMahon (Reference 5).

A2.1 Coefficient of variation

Coefficient of variation \( C_v = \frac{\text{standard deviation}}{\text{mean}} \)

Values for \( C_v \) within the Northern Territory (Figure A2.1) vary from:

(i) 0.5 to 1.0 in the Tropical Zone (with a sub zone of 0.5 to 0.75 in the Top End north of Katherine);

(ii) to an adopted value of 1.25 in both the Transitional and Arid Zones. The actual value of \( C_v \) is probably higher in these zones, but has not been calculated because of the paucity of data.

A2.2 Mean annual flow

From Table 7 of McMahon's paper, the minimum record length to specify the mean annual flow for various errors is:

<table>
<thead>
<tr>
<th>( C_v )</th>
<th>Minimum record length (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allowing 5% error</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>0.5 to 0.75 (Top End)</td>
<td>100 to 220</td>
</tr>
<tr>
<td>0.75 to 1.0</td>
<td>220 to 400</td>
</tr>
<tr>
<td>1.25 (Transitional and Arid Zones)</td>
<td>greater than 620</td>
</tr>
</tbody>
</table>
A2.3 Low annual flow

To specify the once in ten year low annual flow requires even longer record length, as shown in Table 8 from McMahon's paper.

For example, in the northern part of the Top End with a $C_v$ of 0.5 (say the Adelaide River), and allowing for an error of 10%, the required length of record from Table 8 is 150 years (compared to 25 years for mean annual flow).
FIGURE A2.1 Coefficient of Variation of Annual Flows

- Adopt coefficient of variation = 1.25
- Coefficient of variation > 1.5
### TABLE 7 (McMahon)

Minimum record lengths for given accuracy of mean annual runoff (years)

<table>
<thead>
<tr>
<th>Std. error of mean</th>
<th>Coefficient of variation of mean annual runoff $C_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td>annual flow</td>
<td>0.25</td>
</tr>
<tr>
<td>0.05 (5%)</td>
<td>25</td>
</tr>
<tr>
<td>0.1 (10%)</td>
<td>7</td>
</tr>
<tr>
<td>0.25 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>0.5 (50%)</td>
<td>-</td>
</tr>
</tbody>
</table>
### TABLE 8 (McMahon)

Minimum record lengths for given accuracy of once in ten year low annual flow (years)

<table>
<thead>
<tr>
<th>Std. error of 1/10 year low annual flow</th>
<th>Coefficient of variation of mean annual flow $C_v$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>0.05 (5%)</td>
<td>35</td>
</tr>
<tr>
<td>0.1 (10%)</td>
<td>9</td>
</tr>
<tr>
<td>0.25 (25%)</td>
<td>1</td>
</tr>
<tr>
<td>0.5 (50%)</td>
<td>-</td>
</tr>
</tbody>
</table>