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Strategic Framework for National Water Resource Quality Monitoring Programmes

Department of Water Affairs and Forestry
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Executive Summary

This report provides an overarching Framework for National Water Resource Quality Monitoring Programmes. The Department of Water Affairs and Forestry developed the framework to ensure that national water resource quality monitoring programmes that comply with the requirements of the National Water Act (Act No. 36 of 1998) are implemented. This framework is to serve as a basis for reviewing the design of current programmes and for designing new programmes. A description is also given of the roles and responsibilities of the different tiers of water management institutions with respect water resource quality monitoring. The framework should, in particular, clarify how NATIONAL monitoring programmes fit into the bigger scheme of water resource quality monitoring. The strategy also addresses the issue of establishing the capacity required to develop and maintain programmes and to provide some generic guidelines for designing monitoring programmes.

The three topics that are included in the framework are relatively independent and, therefore, are addressed in the report as three independent parts, namely Part 1: A Strategic Framework for Water Resource Quality Monitoring; Part 2: Generic Design Guidelines for Water Resource Quality Monitoring Programmes and Part 3: Capacity Building to Support Water Resource Quality Monitoring.

Part 1: A Strategic Framework for Water Resource Quality Monitoring

The fundamental point of departure of the overarching framework for water resource quality monitoring in SA is that all water resource quality monitoring should be information user-centric. In other words, all monitoring should be justified by serving specified information users with the water resource quality information they need to perform their management functions. The first building block of the framework consists of defining the three core functions of monitoring, namely:

- Data acquisition,
- Data management and storage, and
- Information generation and dissemination.

All of these functions are supported by an IT support infrastructure. The next overlay on the framework is the three portfolios of monitoring programmes that are the responsibilities of the three tiers of water resource governance in SA, namely:

- A portfolio of National Monitoring Programmes led and maintained by the Department of Water Affairs and Forestry's Policy and Regulation branch.
- A portfolio of regional or catchment Monitoring Programmes which are the responsibility of Catchment Management Agencies and the Operations branch of the Department of Water Affairs and Forestry.
- Portfolios of local Monitoring Programmes that are the responsibility of local institutions and / or water users.

There is, however, huge scope for the sharing of infrastructure and resources between the three tiers of monitoring as well as between different monitoring programmes within a particular tier. A key requirement is also that the data collected at different tiers are consistent and comply with minimum quality requirements. These benefits and requirements will only be achieved if an effective governance system exists for water resource quality monitoring within and across the different tiers of monitoring.

One of the biggest obstacles in the rationalisation of water resource quality monitoring is the absence of a standardised terminology concerning water resource quality monitoring amongst the institutions and stakeholders involved in it. The beginnings of a standard terminology for water resource monitoring and management in SA is proposed.

Part 2: Generic Design Guidelines for Water Resource Quality Monitoring Programmes

The second part of the report addresses guidelines for the design of new water resource quality monitoring programmes or revisiting the design of existing programmes. The principles embedded in the proposed design guidelines are those of an integrated design, in other words tightly integrating the design of each of the core functions of a monitoring programme, namely, the data acquisition, data management and storage, and information generation and dissemination functions.

It also adopts the information user-centric design approach, namely, that the design starts with establishing who the primary information users are, and what their information needs are. These information needs from then on dictate the design starting with the information generation and dissemination function, followed by the data management and storage function and finally the data acquisition function. The guidelines were also given a SA nuance based on local experience.

Part 3: Capacity Building to Support Water Resource Quality Monitoring.

Whenever water resource quality is discussed, the issue of the severe lack of capacity comes to the fore. In this part of the document, the scope of capacity building is addressed and the many ways in which it can and should be addressed are highlighted. The scope of capacity building includes creating an enabling environment with appropriate policy and legal frameworks; institutional development, including community participation, awareness raising, human resources development (including motivation and commitment) and strengthening of managerial systems. Specific interventions range from training that enhance the skills, abilities and knowledge base of individuals to reforming policies, laws and institutions that hinder sustainability. Capacity building should go beyond the traditional top-down approach of enhancing skills and knowledge through training and provision of technical skill. It must focus on enhancing the quality of the outcomes of the monitoring programmes, and the resultant decision making in all aspects of water resources monitoring, from planning to practical actions. In addition to the transfer of technology and technical capability, capacity building should foster collaboration among institutions, and build both human and social capital. Capacity building should, therefore, not be considered as an action to be done in addition to designing and implementing monitoring programmes but, rather, monitoring programmes should be designed and implemented in such a way as to increase the human and social capital that underpin and ensure the effective utilisation of the information being generated. Many examples and guidelines for achieving this are provided in this part of the report.

In as much as the strategic framework defines the three core functions of monitoring, the capacity building component defines the efficiency mechanisms that are necessary to ensure sustainability of the monitoring programmes. These are: (a) Skills development and training; (b) Institutional collaboration and coordination; (c) Research and development; (d) Design improvement and upgrading; (e) Public participation; and (f) Funding. Rather than being viewed as discrete from the core functions of a monitoring programme, the efficiency mechanisms should be seen as interdependent components of one system.

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Part 1: A Strategic Framework for Water Resource Quality Monitoring

1.1 Background

1.1.1 Need for Monitoring

An old and well-proven management principle states, "If you can't measure it, you can't manage it". This principle applies as much to water resource management as it applies to managing any other kind of human endeavour. This principle is recognised explicitly in Chapter 14 of the National Water Act (NWA, Act No. 36 of 1998) (DWAF, 1998) that requires monitoring of water resource quality to be an integral part of water resources management in South Africa. The NWA mandates the Minister of Water Affairs and Forestry to establish national monitoring systems that monitor, record, assess and disseminate information regarding, amongst many other things, the quality of water resources.

Although the NWA refers to monitoring systems in the plural, it does not specify exactly, from a systems design perspective, what these national monitoring systems should be, or provide all the other details required to specify, design and implement such monitoring systems. The National Water Resources Strategy (NWRS) recognises that no single monitoring programme can lead to a comprehensive expression of the "state of the water environment". The need for implementing and maintaining different monitoring systems to provide information on different aspects of water resource quality is confirmed by the reality that several water resource quality monitoring programmes exist currently both in DWAF and in several other institutions involved in water resources management.

During implementation of the requirements of the NWA, DWAF is reviewing both the water resource quality monitoring that is currently being done as well as the institutional roles and responsibilities with respect to water resource quality monitoring. A strategic framework for water resource quality monitoring is a key requirement for guiding and directing this transformation process. The development of such a framework is the main focus of this study.

1.1.2 What is meant by "monitoring" water resource quality

For many people, and not only in South Africa, the phrase "water resource quality monitoring" means collecting and storing data related to the quality of water resources. Since the early 1970's, those conducting and funding long term monitoring, identified one of their biggest problems being the "data-rich but information-poor syndrome". In other words, their monitoring activities usually tend to generate large volumes of data that apparently find little application in the practice of water resource management. However, at the same time they faced continuous complaints from water resource planners and managers about the lack of relevant water resource quality information to support their planning and management information needs. This lack of relevant information is bad enough, but is compounded by the fact that at the same time masses of data were and still are being collected requiring significant time, effort and cost, seemingly without the expected benefits being derived from it.

The “data-rich but information-poor syndrome” led several countries (USA, Europe, New Zealand, and to some extent, South Africa) to fundamentally rethink the purpose of water resource quality monitoring, and consequently the process being used to design monitoring programmes. As a result , a user-centric approach was adopted towards the design of monitoring programmes. In the user-centric approach, the purpose of monitoring was therefore redefined as: “Delivering the management information about water resource quality they require, to water resource managers, planners and other stakeholders”. This statement of the purpose of monitoring may sound obvious. However, its implications for the design and maintenance of monitoring programmes are profound. Previously the design of monitoring programmes was dictated mainly by the consideration of how much water resource quality data (sites, frequency, attributes) could be collected with the available resources and infrastructure. So monitoring involved the execution of two core functions, namely data acquisition and data management and storage. The shift in focus to the user-centric approach currently being used to design monitoring programmes required that the scope of monitoring be extended to include a third, but crucial, core function in addition to the other two namely information generation and dissemination. The three core functions are:

- Data acquisition.
- Data management and storage.
- ***Information generation and dissemination.***

The information user-centric approach also recognises that water resource management approaches and practices change with time. Therefore, in order to remain relevant, monitoring programmes need to be reviewed from time to time to confirm that they still meet their users’ information requirements and be revised if necessary.

1.1.3 The demands for monitoring created by integrated water resource management

Integrated water resource management is a corner stone of the new approach to water resources management adopted in SA and required by the NWA. Integration has to happen in several different dimensions, e.g. integration of the different components of the hydrological system (surface water, groundwater, estuaries, and wetlands) and integration between statutory, economic, social, and resource quality objectives when making decisions about resource utilisation. Water resource quality information users, who now have to make decisions and take actions that conform to the requirements of integrated water resources management, require both more resource quality information, and often also, more sophisticated information concerning water resource quality (also refer to Part 3: Capacity Building).

1.1.4 The implications for monitoring of changes in the institutional set-up for water resource management

An important principle underpinning the South African approach to water resources management is that the national government, through the Minister and the Department of Water Affairs, acts as the custodian of South Africa's water resources. However, it also recognises that people at all levels in society should participate in planning and decision-making about the use of water resources in order to ensure that social, economic and environmental needs are met. This led to a three-tier water management system being implemented in SA. The first tier is represented by the Policy and Regulation Branch of the national department of Water Affairs and Forestry (DWAF P&R). The second tier is represented by the Operations Branch (Cluster & Regional Offices) of the Department of Water Affairs and Forestry (DWAF Operations/Ops) as well as the to be established Catchment Management Agencies (CMAs). At the third tier, one finds a number of different local institutions and organisations, organisations such as water boards, industries and local authorities. It is recognised that establishing these institutions and building their capacity and infrastructure to function effectively may take a long time. Therefore, while the new water management institutions, such as CMAs, are being established, DWAF Ops is being restructured to perform, in the interim, the water management functions on behalf of these new institutions.

Up to now, with the exception of two or three major Water Boards, practically all water resource quality monitoring in SA was funded and executed by DWAF. Although DWAF Ops staff handled most of the actual data acquisition, a few DWAF P&R Units performed virtually all the data management and storage and information generation and dissemination functions. These DWAF P&R Units were also responsible for designing and maintaining most of the resource quality monitoring programmes. Therefore, the bulk of water resource quality information currently being produced in SA is obtained from monitoring programmes operated by DWAF P&R.

The new institutional set-up for water resource management in SA has profound implications for how water resource quality monitoring in SA will be conducted from now on:

- Many of the water resource management functions previously performed by DWAF, as a central government department, are now to be performed by CMA's and other water management institutions (or DWAF Ops acting on their behalf). As a result, these institutions now also become primary users for most of the water resource quality information that was until now only required by DWAF for performing its water resource management functions.

- CMA's and other water management institutions are expected to operate the monitoring programmes required to produce the water resource quality information they need for performing their functions. In short, it means that in future DWAF will no longer be responsible for virtually ALL water resource quality monitoring as in practical terms it currently is.

- DWAF P&R's principle role in future is likely to be to provide the strategic context for water resources management in SA as described in the NWRS (DWAF, 2002) and, as the principle custodian of SA's water resources, perform an oversight function concerning the adherence of other water management institutions to the NWRS. Therefore, in future DWAF P&R's (as a central government department) need for water resource quality information is likely to be reduced to:

    - Information required for International / National level water resources strategic and development planning.
    - Information required for performing its custodianship role, in other words, auditing performance to a set of strategic resource quality objectives agreed with the different water management institutions.
    - Information it has to provide to other national government departments, e.g. DEAT to enable them to perform their roles such as in reporting from time to time on the State of the Environment.
    - Information it has agreed, in terms of international agreements, to provide, e.g. for South Africa's participation in the WWAP, SADC, UNEP / GEMS Water Monitoring Programme.

1.1.5 Guidelines for the design of national water resource quality monitoring programmes

The generic guidelines for the design of resource quality monitoring programmes are dealt with Part 2 of this report. By its very nature the information contained in the guidelines chapter applies to any kind of water resource quality monitoring programme. It can therefore be used for the design of all types of resource quality monitoring programmes, not only ***national*** programmes as is the case for the strategic framework proposed here.

1.1.6 Need for convergence on terminology related to water resource quality monitoring

Different groups of people currently involved in the broad field of water resource quality monitoring use different terminology. This leads to much confusion if one does not clarify one's own use of terminology sufficiently for others to map their own way of using terminology on it. The overarching framework for national monitoring programmes for water resource quality monitoring, as proposed in this document, could be a first step towards a greater convergence and eventually a consensus on the terminology related to water resource quality monitoring used in South Africa.

It is recommended that the reader, before going beyond this point in this document, at least briefly scan through the *Appendix (Section 1.3): Notes on Concepts / Terminology*. Thereafter, as the usage of certain terms becomes more pertinent to a particular section of the document, the reader should study the relevant parts of the Appendix more carefully.

1.2 A strategic framework for water resource quality monitoring

1.2.1 Introduction

Water resource quality monitoring is a complex endeavour. Monitoring programmes can be viewed from many different perspectives, and as a consequence, people involved in the design and management of monitoring programmes often describe them in many different ways.

Monitoring programmes are currently categorised in SA according to:

- The types of water resource quality attributes addressed, e.g. hydrological monitoring, microbiological monitoring, inorganic chemical monitoring, etc.
- The type of water resource quality problem addressed, e.g. toxicity monitoring, eutrophication monitoring, radioactivity monitoring, etc.
- The type of water resource being monitored, e.g. surface water, groundwater, estuaries, etc.
- The geographic scale, e.g. national (where the word "national" has a geographic interpretation of SA-wide geographic coverage), regional, catchment, etc.
- Institutional responsibility, e.g. national (where the word "national" usually has the interpretation that it is the monitoring which is the primary responsibility of DWAF P&R rather than a regional or local water management institution), regional monitoring (the responsibility of DWAF Ops), catchment monitoring (the responsibility of CMA's), monitoring by Water Boards, etc.
- The primary information objectives of the monitoring programme, e.g. status & trend monitoring, monitoring for the purpose of impact assessment, monitoring for the purpose of compliance assessment, monitoring for quality assurance purposes, etc.
- The scope of monitoring, e.g. some would refer to "monitoring" as only the data acquisition component of a monitoring programme while others would understand the word "monitoring" to describe the complete process consisting of the three core functions of monitoring namely: data acquisition; data management and storage; and the generation (which includes assessment) and dissemination of information.

There are a few important observations to be made concerning these descriptions or categorisations, namely:

- It is obvious that none of these categorisations or descriptions of water resource quality monitoring programmes are mutually exclusive. In other words a particular monitoring programme can for example be described as a hydrological monitoring programme, a surface water monitoring programme, a national programme (both in the geographic and institutional sense), and a status and trend-monitoring programme.

- None of them are necessarily a better description or categorisation than the other. It depends on what the purpose of the description and the audience.

- In addition, the different groups of people (often in different organisational units or different organisations) involved in the design, implementation and operation of monitoring programmes have developed their preferred ways of describing and categorising the monitoring programmes they are responsible for.

If the people responsible for monitoring programmes use different ways to describe and categorise such programmes, and have done so for a long time, it means that their unique understanding and institutional memory about their monitoring programmes is locked up in the terminology they use. This can lead to problems such as:

- Misunderstanding, poor coordination and even conflict between different groups involved in water resource quality monitoring.
- Monitoring programmes described in such different ways often create the impression that different programmes are unique, when in reality there are opportunities for exploiting possible synergies, for reducing duplication of effort and for sharing resources.

One has to recognise that water resource quality information is needed at different levels of spatial and temporal resolution depending largely on the nature of the management function for which the information is required. For example, the information required for developing and revising the NWRS (DWAF, 2002) would usually be at a much coarser temporal and spatial resolution than the information required to determine whether a specific effluent discharge meets the conditions of the licence under which it is allowed to be discharged (Figure 1.1).

Despite these differences in resolution, there still is significant opportunity for sharing resources, infrastructure and data or information produced at a particular level across the other levels.

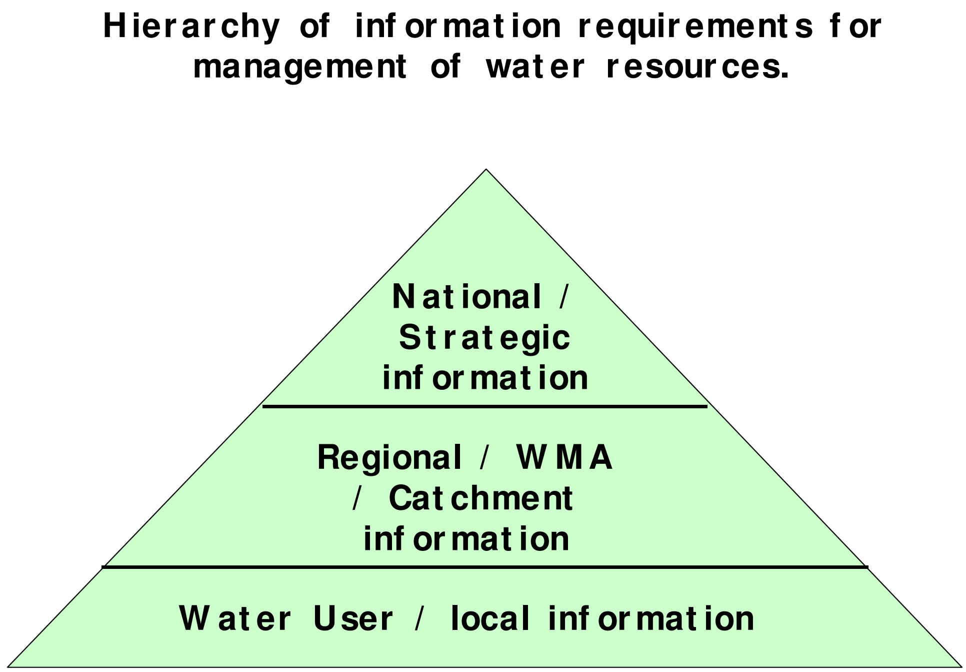

Figure 1.1 Diagram to illustrate that different information requirements exist at different water management levels ranging from the most detailed information (on spatial and temporal scales) required at the local level and less detailed information required at the national / strategic level

1.2.2 The need for a strategic framework for water resource quality monitoring

The awareness of the need for a more integrated and coordinated approach to water resource quality monitoring has existed for quite some time. Several years ago DWAF initiated the definition and development of a comprehensive water resource quality "Monitoring Assessment Information System" (MAIS). For details on the MAIS strategy see:
http://www.dwaf.gov.za/iwqs/wrmais/MAISPhase2FinalReport.pdf
Moreover, for details on the proposed implementation of MAIS see:
http://www.dwaf.gov.za/IWQS/wrmais/MAIS-project-inception.pdf.

The implementation of the NWA and the establishment of the required water management institutions are now proceeding rapidly. A strategic framework for monitoring water resource quality is, therefore, urgently needed to enable DWAF and the other water management institutions to:

- Ensure that the provision of all the water resource quality information necessary for integrated water resource management is adequately addressed. As such, the framework endeavours to outline the types of monitoring programmes required to produce the information needed for integrated water resource management from the strategic / national level.

- Serve as a basis for clarifying the roles and responsibilities of all the stakeholders involved in providing the required water resource quality information for managing water resources from the strategic / national to the local level.

- Serve as a basis for redesigning / restructuring / rationalising existing water resource quality monitoring programmes.

- Ensure that water resource quality monitoring programmes currently being planned or developed are in line with the requirements of the NWA, the NWRS and the other requirements of DWAF.

- Support effective and coordinated governance of water resource quality monitoring at all levels (local, catchment, strategic / national) and by all the institutions involved in water resource management. Governance also needs to address the interfaces between the different national government departments that are stakeholders in water resources management, e.g. DEAT, NDH, NDA, DMEA, etc.

The framework also takes cognisance of some important realities to be faced by any redesign, restructuring or rationalisation of water resource quality monitoring in SA:

- Water resource quality monitoring is generally expensive, often requires sophisticated technologies and depends on access to specialists with scarce skills.

- There are likely to be significant overlaps between both the objectives and the operational components of water resource quality monitoring programmes required to produce information at the local, catchment and national / strategic level.

1.2.3 The proposed strategic framework for water resource quality monitoring

The strategic or overarching framework is based on a functional view of monitoring and endeavours to standardise terminology. The functional view was originally proposed in the inception report produced for the MAIS project, Phase 3, see: http://www.dwaf.gov.za/IWQS/wrmais/MAIS-project-inception.pdf. Some of those concepts are briefly summarised here but the reader is encouraged to refer to the inception report for the full development of many of the concepts used here.

The model is shown in Figure 1.2. Its main features are a number of monitoring programmes that all have the same functional components:

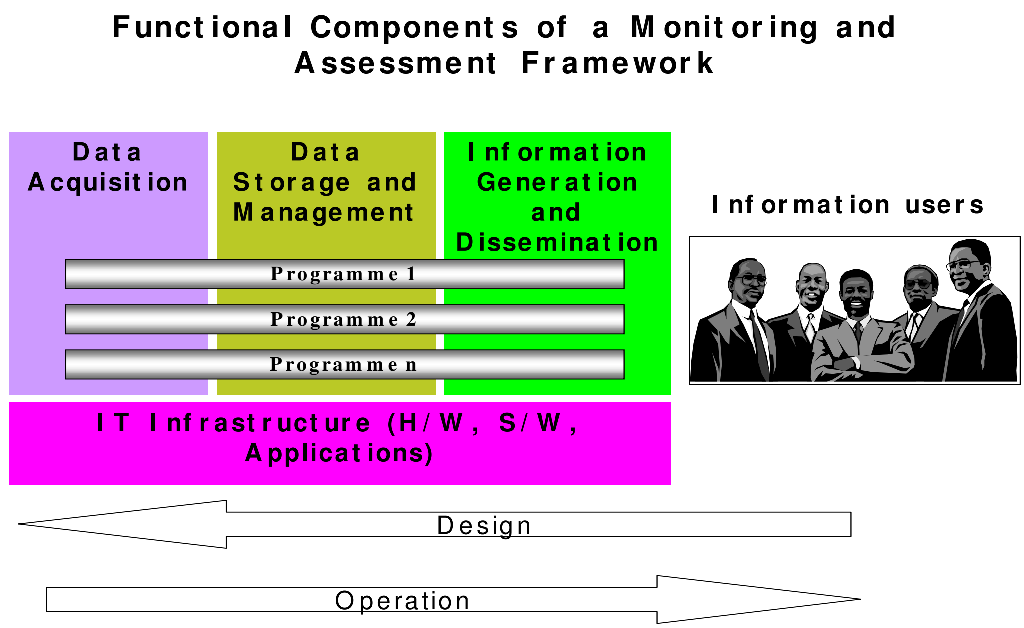

Figure 1.2 Functional model for water resource quality modelling as proposed in the MAIS inception report

Different monitoring programmes are likely to be able to share, to a significant degree, the same logistics and technical infrastructure required to perform their data acquisition function. Similarly, various monitoring programmes should, to a large degree, be able to share the same data management and storage infrastructure. The major distinction between different monitoring programmes should, therefore, be in the types of information products they produce in response to the requirements of information users.

The framework, based on a functional description of monitoring, is also, as shown in Figure 1.2, information user centric. In other words, the design of any monitoring programme has to start with vigorously specifying what information requirements it is designed to satisfy. From there, the data acquisition and data management and storage components are designed.

Any selection of monitoring programmes within this functional framework can now be grouped as a coherent portfolio for management and organisational design purposes, and shown as overlays on the three core functions.

The functional framework presented in Figure 1.2 applies to any water resource quality monitoring programme, irrespective of geographic scale or institution responsible and not only the National Monitoring Programmes. It was also pointed out earlier that the word “national” with respect to monitoring programmes is sometimes used in at least two different ways, i.e.:

- A geographic sense, in other words "national" means coverage by the programme of all the relevant water resources within the borders of South Africa.

- An institutional sense, in other words "national" means the water resource quality monitoring programmes for which DWAF P&R assumes the primary responsibility (even if some of the monitoring functions, such as data acquisition, are contracted out to other institutions).

The geographic coverage of a monitoring programme is a very design specific issue that deals with the number and location of monitoring points on the basis of a number of considerations. It is, therefore, not very useful to use it in that context for the purpose of defining a *strategic framework* for monitoring programmes.

The institutional interpretation of the word "national", on the other hand is a useful concept for defining a *strategic framework* for monitoring programmes because it could be used to clearly define the institutional responsibility for different portfolios (groupings) of monitoring programmes, such as national programmes, regional (cluster) programmes, CMA programmes, Water Board programmes, etc. Therefore it is proposed that, in addition to the functional model, the strategic framework also incorporates the concept of portfolios of monitoring programmes based on the water management institutions primarily responsible for a given portfolio of programmes.

Strategic Framework for Monitoring and Assessment based both on Functional Components and the Institutional Responsibility for Different Portfolio's of Programmes

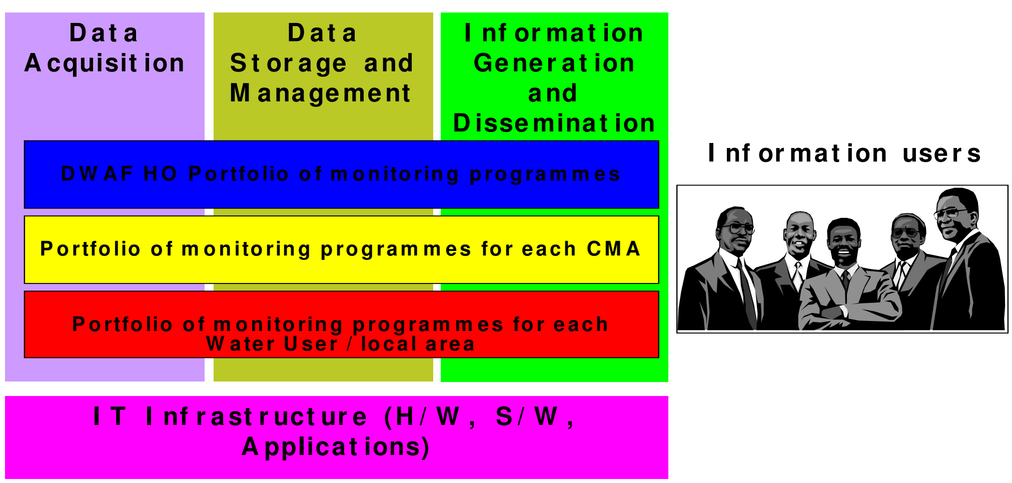

Figure 1.3 Strategic framework for water resource quality monitoring expanded to include portfolios of monitoring programmes, based on the different tiers of water management institution responsible for each portfolio of programmes

Graphically, the framework will now look like the model displayed in Figure 1.3. It now becomes a matter of policy and negotiation between the different water management institutions, operating from the local to the strategic level, to decide which monitoring programmes belong in which portfolio. Decisions about the allocation of monitoring programmes to different portfolios are not trivial. The implications are that from that point onwards, the institution having the primary responsibility for a particular portfolio would be responsible for the funding and management of all the monitoring programmes in such a portfolio.

The strategic framework for water resource quality monitoring described here should become the framework for all water resource quality monitoring from the local to the strategic / national tier.

1.2.4 The portfolio of national water resource quality programmes

As the principal custodian of SA water resources, DWAF P&R's role in future is likely to be the provision of the strategic context for water resources management in SA (NWRS) and to perform an oversight function concerning the adherence of other water management institutions to the NWRS. Therefore, in future DWAF P&R's needs for water resource quality information is likely to be reduced to:

- Information it has agreed to provide in terms of international agreements, e.g. for South Africa's participation in the UNEP / GEMS Water Monitoring Programme , Incomati Maputo Tripartite Agreement, etc.
- Information required for international and national level water resources strategic and development planning.
- Information required for performing its custodianship role, in other words, auditing performance to resource quality objectives set at strategically selected monitoring sites.
- Information provided to other national government departments, e.g. to DEAT for State of the Environment reporting.

The portfolio of national water resource quality monitoring programmes proposed in Table 1 below is defined as those for which DWAF P&R (in its role as the national government department that has been designated to be the custodian of SA water resources) assumes primary responsibility. In other words, it will act as the lead agent for the portfolio of water resource quality monitoring programmes aimed at delivering the information products required to satisfy the information requirements listed above. A few important considerations guided the selection of programmes to be considered for the portfolio of national programmes, i.e.:

- If the geographic coverage of a given monitoring programme in this portfolio (e.g. the current hydrological or inorganic chemical monitoring programmes) is for SA as a whole, then the resolution would typically be limited to pre-identified key monitoring stations per each hydrological unit or ecoregion that has significance from a DWAF P&R (strategic) perspective, e.g.:
    - Pre-identified catchments for surface water.
    - Pre-defined list of aquifers for ground water.
    - Pre-defined list of wetlands (e.g. RAMSAR listed).
    - Pre-identified estuaries (by DEAT and DWAF RDM).
    - Appropriate Ecoregion scale for aquatic ecosystem health.

- If the geographic coverage of a given programme in this portfolio is not SA-wide but is based on pre-selecting priority areas, either on the basis of the risk posed or the significance of the water resource itself, then the resolution would simply be determined by the design of the programme. Examples of this are the current microbiological and toxicological monitoring programmes.

- The information user-centric approach to the design of monitoring programmes requires that each monitoring programme in the portfolio of such programmes is preferably defined around a coherent set of information products related to a specific set of water resource quality ***management*** issues or problems. As a result, all of the proposed programmes focus on a management issue (salinity, health risk, water yield) rather than a discipline (e.g. chemical, microbiological, hydrological).

- The proposed portfolio of monitoring programmes also moves away from the current practice of defining separate monitoring programmes for different hydrological units e.g. surface water, rivers, groundwater, estuaries, etc. It adopts the principle of combining all the monitoring, across all hydrological units (surface water, groundwater, estuaries, wetlands, etc.), required to address a particular water resource quality management issue in one programme. So each of the programmes listed in Table 1 would include the monitoring of surface, water, groundwater, wetlands, estuaries, etc.

The first column of Table 1 shows each new proposed programme and the second column roughly maps these onto existing monitoring programmes (or those in the design stage). To further illustrate what the scope of a particular programme may be, the last column shows a sample of attributes that would typically be included in such a monitoring programme.

The programmes listed in Table 1 are not presented as a definitive set of national programmes, but rather to demonstrate the application of the proposed strategic framework to what should become the portfolio of national programmes. One of the implications of applying the proposed strategic framework to formulate a portfolio of national programmes is that current programmes need to be redesigned. For example, where the monitoring is currently being done in separate programmes, e.g. groundwater quality monitoring and surface water monitoring for inorganic chemicals, these should now be considered to be merged. Redesigning programmes in order to achieve the proposed mergers will require significant effort and will in the process need to consider many technical, logistical and scale issues. These challenges are, however, no reason to either avoid or unduly delay the process. Also, there would be cases where the current programmes have significant gaps in terms of addressing all of the required hydrological components (surface water, groundwater, wetlands, estuaries), and should, therefore, be expanded to include monitoring other resource types where relevant.

Note that DWAF P&R may in future only be responsible for funding water resource quality monitoring programmes making up its portfolio of national programmes. The funding of other portfolios of monitoring programmes (see next section) would become the responsibility of the relevant water management institution at the different tiers of water resource management.

Table 1 Proposed portfolio of water resource quality programmes for which DWAF P&R should assume primary responsibility, mapped onto existing monitoring programmes.

Proposed DWAF P&R Monitoring Programme	Mapping onto current Monitoring Programmes	Typical Attributes Included in the proposed programme
National water resource yield (quantity) monitoring programme (includes atmospheric conditions related to yield)	National Hydrological (including flow, rainfall, reservoir, evaporation) & Geohydrological monitoring programmes	Rainfall, flow, evaporation, reservoir level, borehole level, etc.
National flood warning monitoring programme (local flood monitoring programmes should become part of the portfolios of regional or catchment monitoring programmes)	National flood monitoring and various local flood monitoring programmes, e.g. Orange-Vaal etc.	Only during potential flood conditions: Rainfall, flow, reservoir levels, etc. Subsequent to extreme flood events a range measurements to characterise the event.
National salinity monitoring programme	National inorganic chemical & groundwater quality monitoring programmes	EC, TDS, Ca, Mg, Na, Cl, HCO_3, SO_4, pH, Alkalinity, Hardness, SAR, etc.
National eutrophication monitoring programme	National eutrophication & part of the inorganic chemical monitoring programme	N- Species, P-species, chlorophyll, algal species, algal toxins
National faecal pollution of water monitoring programme	National microbiological & groundwater quality monitoring programmes	Microbiological indicators, indicators of status of sanitation infrastructure
National toxicity monitoring programme	National toxicity, groundwater & part of the inorganic chemical monitoring programmes	Toxic metals, NH_4 (because NH_3 isn't measured directly) plus other variables needed to calc NH_3, organic toxins, etc.
National radioactivity monitoring programme	National radioactivity & groundwater quality monitoring programmes	Water borne radioactive species
National aquatic ecosystem health monitoring programme	National River Health monitoring programme – to be expanded	Indicators of aquatic ecosystem health. Not limited to water phase only.
National acidification monitoring programme (could include relevant atmospheric conditions)	National inorganic chemical programme & monitoring groundwater from mines and acid mine drainage	pH, SO_4, Metals, NO_x species
National reservoir sedimentation monitoring programme	Reservoir survey programme	Bathymetry of reservoirs
National waterweeds monitoring programme??	May be done by CMA rather than DWAF P&R tier.	Types, presence, extent of water weeds
National alien vegetation monitoring programme (Working for Water)??	May be the responsibility of DEAT rather than DWAF P&R	Impact of clearing alien vegetation on water resource quality may be observed in the status and trend of water resource yield.

1.2.5 Portfolios of water resource quality monitoring programmes to be the responsibility of other water management institutions

Because the definition of portfolios of water resource quality monitoring programmes for other (than national / DWAF P&R) water management institutions will in future become their responsibility, neither firm nor detailed proposals are made for them. However, below are presented some preliminary ideas about the portfolios of water resource quality monitoring programmes that could or should become the responsibility of such institutions. The purpose of presenting these ideas is primarily to put the proposed portfolio of national water resource quality monitoring programmes in context.

CMAs (or DWAF Ops as their substitutes or extensions) and other local management institutions are likely to assume primary responsibility for the following types of monitoring programmes:

- Status and trend monitoring of local catchments to evaluate the achievement of Reserve and Resource Quality Objectives at the catchment scale. The required resolution would typically be much finer than that used by the national programmes. The list of monitoring programmes would include, at a catchment scale, several of the programmes listed in Table 1.
- Programmes to assess compliance of water users to water licence conditions or general authorisations.
- Programmes assessing impacts of proposed water uses for the purpose of issuing licenses or designing other water management interventions.
- Programmes generating the information needed for determining the achievement of the Ecological Reserve.
- Process control monitoring, e.g. for water releases from a reservoir.

Third tier institutions such as Water Boards (WB), local authorities as well as industries, from a resource quality perspective, would assume primary responsibility for monitoring:

- The quality of their intake water for process control purposes.
- In those cases where they perform certain water resource quality management functions, the monitoring required as outlined for CMA’s above.
- Status and trends of local aquifer systems under control of the WUAs.
- Management attributes (water use) of all legal water users.

Types of monitoring programmes that are likely to be operated at the different tiers of water resource quality management are summarised in Figure 1.4 below.

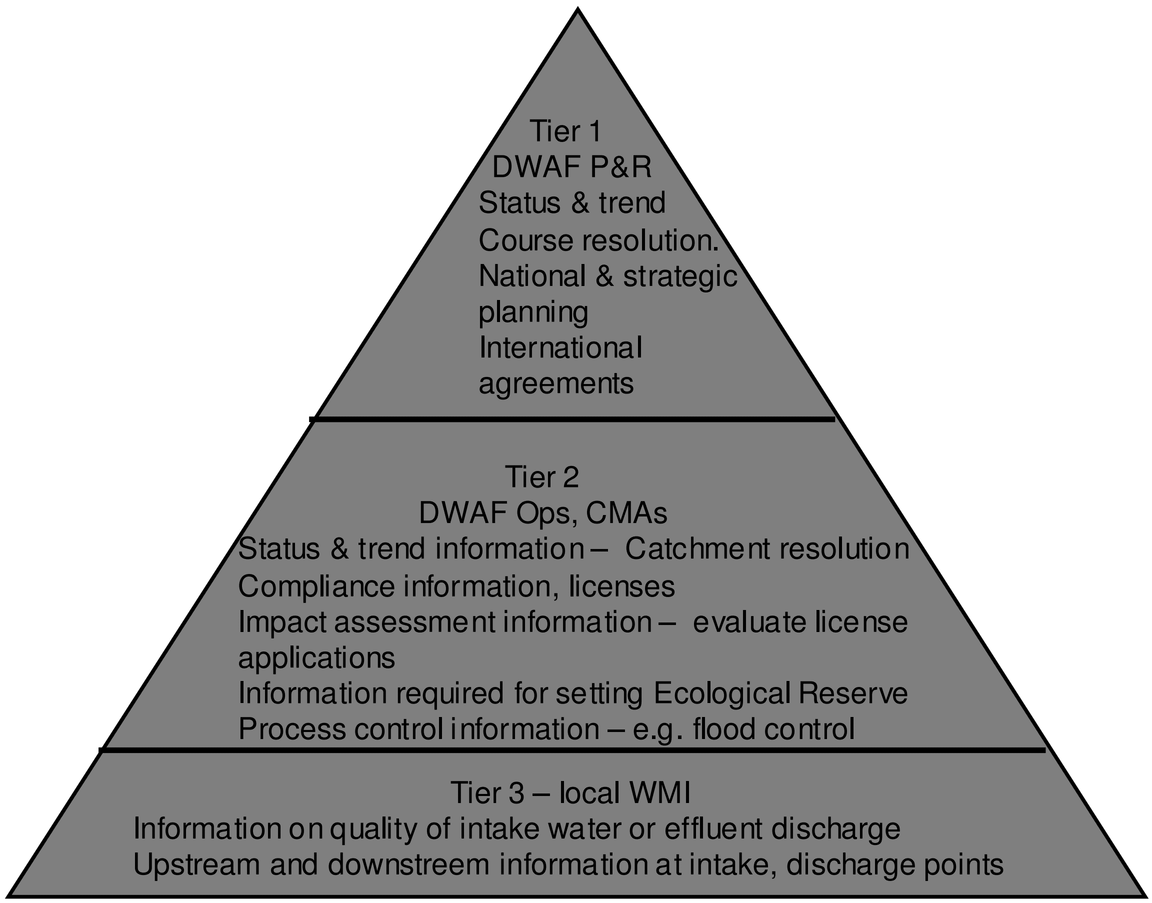

Figure 1.4 Examples of types of monitoring programmes included in monitoring programme portfolios aligned to the three different levels of information requirements

1.2.6 Implications for governance of water resource quality monitoring

A key success factor for effective monitoring of water resource quality as prescribed in the NWA will be effective governance of the overall process. The governance process must coordinate and share resources, infrastructure, data and information across the various water management institutions involved. To ensure information delivery at the three management tiers in Figure 1.4, the governance process must:

- Adopt common standards for the performance of data acquisition, data management and storage, and information generation and dissemination.

- Implement common quality assurance criteria across the different tiers at which monitoring is performed.
- Effectively share scarce and difficult to maintain resources, such as the IT infrastructure supporting monitoring functions, i.e. data acquisition, data management and storage and information generation and dissemination.
- Support ongoing research and development of technologies (methods, standards, instrumentation, etc.) required to maintain cost-effective monitoring programmes. This should be done at the DWAF P&R tier.
- Coordinate all the relevant activities of stakeholders (inside and outside DWAF) involved in water resource quality monitoring.

Such a governance mechanism (Figure 1.5) has already been proposed in the MAIS Strategy submitted to and accepted by DWAF in May of 2000 (see Figures 1.5 & 1.6 as well as the MAIS strategy document at http://www.dwaf.gov.za/iwqs/wrmais/MAISPhase2FinalReport.pdf).

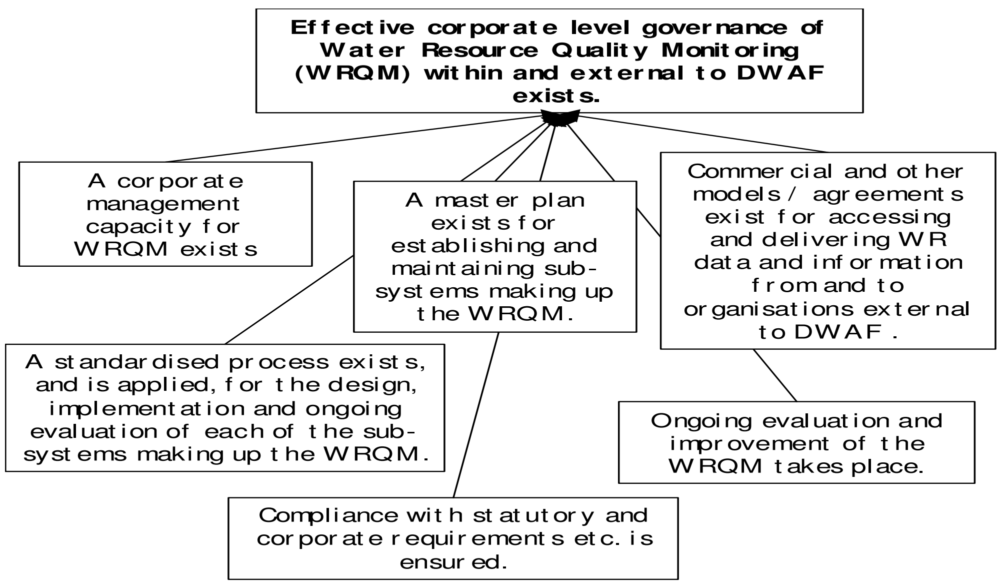

Figure 1.5 A diagram showing governance requirements for resource quality monitoring proposed in MAIS strategy in 2000

In the context of the MAIS strategy, the strategic framework for water resource quality monitoring is the next level of detail reflecting the greater clarity that now exists about the transformation of DWAF compared to what was known in 2000.

Establishing an overarching / strategic framework (Figure 1.6), based on a consensus between the main role players managing water resource quality monitoring programmes, is regarded as a significant next step in bringing to realisation the MAIS strategy. It would have the following benefits:

- Standardisation of the terminology used to describe monitoring programmes, thereby reducing misunderstanding and the apparent uniqueness of various programmes.
- A common framework that all the water resource quality monitoring programmes operated by DWAF and other water management institutions can fit into.
- Better governance and coordination of monitoring within DWAF and between DWAF and other water management institutions.

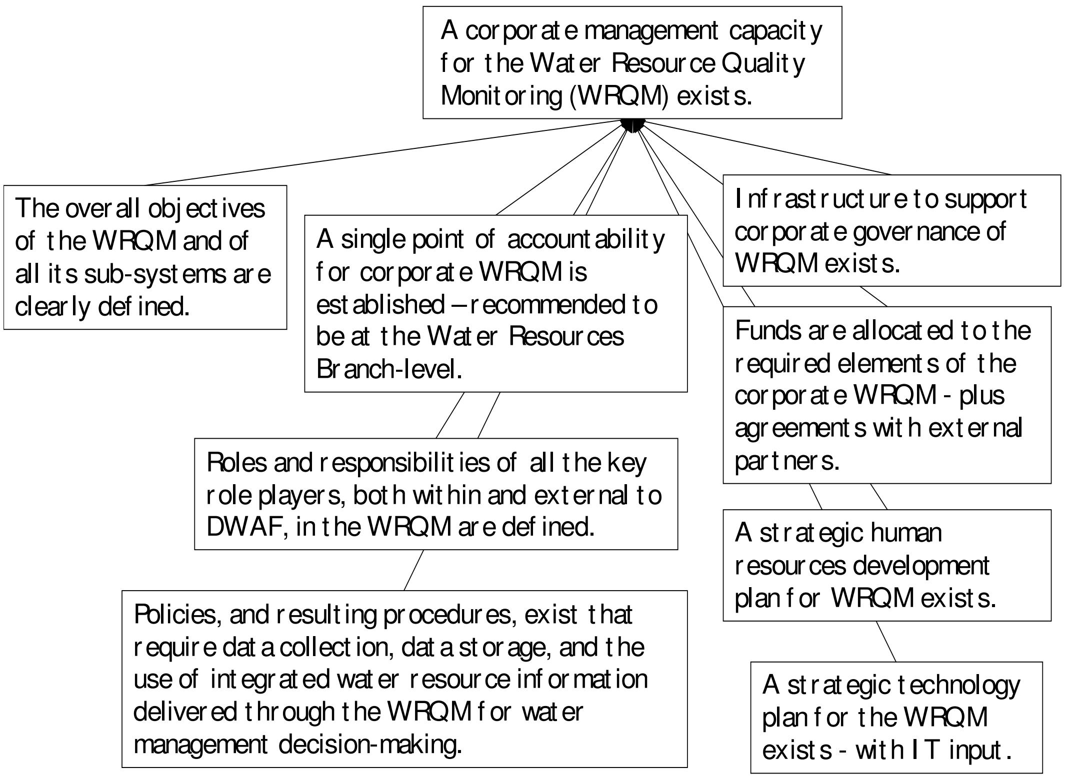

Figure 1.6 A diagram showing the infrastructure and capacity required for establishing corporate (DWAF) governance

As is the case with most other water resource management functions, water resource quality monitoring in SA also needs to be restructured and redesigned so that it aligns with the principles embodied in the NWA, the NWRS and the new institutional set-up for water resource management. A critical requirement for such a redesign and restructuring will be that it takes place in an orderly fashion and does not result in potentially disastrous losses in water resource quality information.

The governance role outlined for DWAF P&R with respect to water resource quality monitoring will require for it to maintain a certain minimum infrastructure, for example:

- A central water resource quality laboratory infrastructure (e.g. chemical, biological (inclusive of microbiology, hydrobiology and toxicity), hydrological, geo-hydrological laboratories and workshops) in order to support DWAF P&R's role with respect to quality assurance, R&D and assessment of new methodologies for covering each of the three core monitoring functions.
- A centralised IT infrastructure and systems.

1.2.7 Implementation and transitional issues raised by the proposed strategic framework for national resource quality programmes

Implementing the strategic framework would fundamentally affect many roles and responsibilities within the CD: Water Resources Information Management, and there will also be implications for many current users of the information that it disseminates. It would have to deal with many issues related to the transition from the current situation to what is proposed in this framework. Some of these issues are highlighted here:

1.2.7.1 Monitoring Programme Manager

Within the context of the proposed framework, each of the Monitoring Programmes (national as well as other programmes) needs to have a person assigned to it as the Monitoring Programme Manager (MPM). From an accountability point of view, a given Monitoring Programme should have only one Programme Manager. However, a Programme Manager could be responsible for more than one Monitoring Programme if each programme had a fairly low workload associated with it. Each MPM would be responsible for:

- The design of new programmes and the periodic review of existing programmes across the three core functions.
- Sustained resourcing of the programme, with respect to infrastructure (IT, equipment), financial resources and people. The resourcing function would typically involve concluding and maintaining agreements with other entities within and outside DWAF to perform certain functions (according to pre-defined standards) such as data acquisition, data management and storage, etc. on an agency basis. It would also entail maintaining a core staff for the programme itself to perform functions such as:
    - The development of methods and standards for performing functions and the training of those who have to perform the functions.
    - Technology assessment and review.
    - Auditing of functions performed by agencies.
    - Information generation and dissemination.

Regular review of the utilisation of disseminated information, in other words how it is used, if there are changes in the information requirements and responding to these by either modifying the information generation and dissemination function or even reviewing the design of the programme.

1.2.7.2 Overlaps between monitoring programmes

One has to accept that there will be a degree of overlap between monitoring programmes, both between programmes falling in the same portfolio (e.g. National Monitoring Programmes) and between monitoring programmes in different portfolios (e.g. National Monitoring and CMA Monitoring Programmes) as well as between monitoring done by different government departments, e.g. DWAF and DEAT or DWAF and DME. The nature of the overlap may also be any one or a combination of:

- The same monitoring point.
- The same resource quality constituent.
- The frequency of sampling or measurement of a given water resource quality attribute.

Far from being obstacles or threats, these overlaps are significant opportunities to share the infrastructure and resources of the various water management institutions and government departments.

In such situations, the MPMs of the respective programmes are expected to negotiate with their counterparts who will be performing each of the core monitoring functions for that monitoring station and how the data / information derived from it will be shared. However, having made an agreement with another agency (whether it is within DWAF or not) to perform a certain function at a given standard is not enough to ensure that it will be done! Each MPM has to continuously monitor the performance of such "outsourced" functions to ensure that they actually happen.

One would expect the more monitoring programme-specific requirements to exist around in the information generation and dissemination function, because this is where matching the information products with specific user requirements occurs. It is, therefore, also where specific discipline-oriented knowledge and experience is required (e.g. hydrology vs. biology) in order to produce valid information products. Despite the discipline-specific knowledge and experience required, there are also a number of ways in which the information generation functions of the different monitoring programmes can share generic information generation processes and tools such as mathematical modelling, GIS, graphics and statistical applications.

Here are a few examples of dealing with overlaps for national monitoring programmes:

1. *Proposed National Salinity Monitoring Programme*. After its redesign, it is unlikely to include resource quality constituents such as the various nitrogen species, or phosphate species, or fluoride, or boron etc. Does this necessarily mean DWAF P&R would stop monitoring these attributes? No! Nitrogen and phosphorous species are attributes related to the National Eutrophication Monitoring Programme and, therefore, the monitoring sites, chemical species to monitor, and the frequency of data acquisition should form part of the design of

that programme. In addition, one particular nitrogen species, namely ammonia, is a potential toxicant for aquatic life. It should, therefore be monitored as part of the National Toxicity Monitoring Programme or the Health of Aquatic Ecosystems Monitoring Programme. The same arguments apply to fluoride, boron and phosphorus species. The point is that it may happen that some of the water resource attributes that are currently being monitored in the inorganic chemical monitoring programme will not find a place in the redefined National Monitoring Programmes – each of which would have been designed by starting with information requirements of information users. In that case, their monitoring should be discontinued. ***The important point is – there can NO LONGER be any justification for simply continuing monitoring water resource quality attributes on the basis of "we have done it up to now" – or "people sometimes ask for such data."***

2. *Inorganic Chemical Monitoring Programme*. A whole infrastructure already exists for the data acquisition and data storage and management functions for all the attributes currently included in the inorganic chemical monitoring programme. If these attributes are now going to be apportioned between several different National Monitoring Programmes – does that mean we have to duplicate that infrastructure? The answer is NO! We are in fact striving to maximise the use of the same infrastructure by the different monitoring programmes. So, all the programmes that in future will deal with the attributes currently forming part of the inorganic chemical monitoring programme will continue to use the same infrastructure – which by mutual agreement could continue to be managed by the MPM for the new National Salinity Monitoring Programme. This MPM in turn would have agreements with several regional offices, laboratories etc. to do parts of the data acquisition function. In fact such sharing of infrastructure should not only be done with respect to the monitoring of attributes that currently belong to the inorganic chemical monitoring programme, but also the monitoring of any other attributes which could possibly be dealt with by the same infrastructure – even if the infrastructure must be expanded or the skills of people currently performing different functions within that infrastructure be extended.

3. *The Information Generation And Dissemination Function*. In some cases, we have a group of people who service enquiries for information from the inorganic chemical monitoring programme. If that is reduced to a National Salinity Monitoring Programme should they then only service enquiries for salinity related attributes. In the case of delivering information to information users it becomes more critical for people representing the different National Monitoring Programmes to become directly involved, if even only authorising the release of the data / information. There are two reasons for this: 1) to ensure that the data or information is used correctly, in other words, the user understands what the information can and cannot be used for, and 2) to remain aware of information requirements of information users. The programme designer may not have been aware of some of these user requirements during the design phase of the programme and being alerted to such requirements could lead to these being included in a future revision of the programme. Even though the information generation and dissemination function is likely to be quite programme-specific, it could still allow for significant sharing of the same infrastructure and skills. It

would be useful to share a core capability for doing statistical, graphical and GIS analyses, methods for effectively presenting information as well as using the intra- and internet for disseminating information. All of these are required for the generation and dissemination of information products.

1.2.7.3 Dealing with transition

In the current situation, where many of the issues around primary responsibility for implementing and maintaining different portfolios of monitoring programmes are unresolved, **DWAF P&R and DWAF Ops must adopt the principle that they will not halt any monitoring currently being done by DWAF unless it is**:

- The specific outcome of a re-design or rationalisation of a programme, or
- The programme has been transferred to another water management institution that has both
  - Accepted the primary responsibility for it.
  - Demonstrated it has the competency and the capacity for maintaining the programme.

1.2.7.4 A shared IT Infrastructure

Using the proposed strategic framework for describing and categorising different monitoring programmes would enable DWAF P&R and other water management institutions to benefit from sharing infrastructure and human resource capacity to perform certain core monitoring functions. This would be of great benefit, as almost all of the monitoring programmes in DWAF P&R, and possibly also DWAF Ops, the CMAs and Water Boards, could share the same IT platform and infrastructure for performing many tasks related to:

- Data acquisition
- Data management and storage
- Information generation and dissemination (e.g. assessment tools such as statistical methods, mathematical models, etc.).

DWAF P&R should go out of its way to promote the concept of every water management institution involved in water resource quality monitoring sharing the same IT infrastructure. It should take the initiative by rapidly establishing such an infrastructure and offering the use of it on attractive terms to other water management institutions.

1.3 Appendix: Notes on concepts / terminology

Water resource quality is a complex and wide ranging field for which an equally complex terminology has been developed over the years by various groups, both in SA and abroad, involved in studying and managing it.

This document does not set out to propose a terminology that everyone involved in water resource quality management in SA is expected to use henceforth. Rather, as a first step in starting an extensive process of consensus building amongst all of the role players, it sets out to very clearly explain how terminology is used so that users can map their own current use of terminology onto it.

1.3.1 Water Resource Quality

Refers to ALL the physical, chemical, biological and ecological attributes of the resource. It specifically considers the resource as a whole and therefore includes all the RESOURCE attributes, not only the attributes related to the water component of the resource. In the context of this definition of water resource quality there is no need to separately state "aquatic ecosystem health" because it is simply a specific set of water resource quality attributes.

1.3.2 Water Resource Quality Attribute

The quality of a water resource can be described in many different ways, e.g. one can state the temperature of the water, the slope of a stream section, the depth of water at a particular point, the number and type of algae present, the concentrations of a range of inorganic chemicals, etc. In this document and the proposed framework ALL the different ways that water resource quality can be described, no matter whether or not the description is quantitative (can be expressed in numbers) or qualitative (expressed in words), are considered to be water resource quality ATTRIBUTES. For interest's sake, if you look up the word "attribute" in a UK English thesaurus, some of the listed synonyms are: characteristic; trait; feature; aspect, element, part. From all of these options the word "attribute" does seem to be the preferred one, although it might be a personal choice. Other synonyms for attribute used in SA are: CONSTITUENT, DETERMINAND and VARIABLE.

1.3.3 Water Resource Quality Variable

The word "VARIABLE" is used here as a synonym for "ATTRIBUTE" when the author wants to emphasise the fact that the measured value of a particular attribute can vary with space and time and that one often needs to describe an attribute in terms of its statistical properties, such as its mean or median, standard deviation or skewness coefficient, in order to give a comprehensive picture of its status in the resource in question.

1.3.4 Grouping of Water Resource Quality Attributes / Variables

No single monitoring programme can deal with all of the information requirements related to the many different water resource quality attributes. The resource quality attributes are, therefore, often grouped or categorised, for monitoring purposes, in different ways, e.g. according to:

1. An academic discipline, e.g. inorganic chemical attributes.
2. Association of a group of attributes with a certain type of water resource quality problem, e.g. eutrophication, toxicity.
3. Apparently an academic discipline, but based on an underlying assumption of a relationship between the discipline and a water resource quality problem, e.g. microbiological attributes which in reality are a very small number of attributes which serve as indicators of human health risks associated with faecal contamination of water resources.

4. Apparently an applied discipline, but also based on an underlying assumption of the relationship between a set of attributes and a vitally important area of concern in water resource management, such as hydrology which primarily deals with attributes related to the quantity and water yield aspects of surface water. The underlying management issues, however, are the availability of water, the reliability of supply, and the risks of floods and droughts.
5. Apparently a grouping of water resource quality attributes, but in reality all the possible attributes of concern in a particular water resource unit, e.g. groundwater quality, wetlands quality, etc.

The current situation presents some obvious inconsistencies in how water resource quality attributes are grouped for the purposes of monitoring. In the strategic framework, specific proposals make the definition of monitoring programmes, and therefore the grouping of water resource quality attributes for this purpose, more consistent.

1.3.5 Monitoring & Assessment

“Monitoring” and “assessment” of water resource quality are sometimes referred to as if these are separate activities implying that hierarchically they are at the same level, e.g. as used in the NWA. Some confusion probably arises because people understand both of these terms in different ways.

To ensure that clarity exists when a strategic framework for monitoring is discussed or used, as the following definitions are proposed:

- **Monitoring:**

  The word “monitoring” is always used as the descriptor of a specific group of three core, interconnected functions, starting with data acquisition, followed by data management & storage, and concluding with information generation and dissemination.

  Therefore, if one wants to refer to the execution of only one or two of the three core functions, say the data acquisition function only, then the word “monitoring” should NOT be used. In such cases, it is proposed that the description of the function itself, as in the example above, “data acquisition” should rather be used.

  Whilst it is proposed that DWAF accepts the above description of monitoring, it is acknowledged that the choice of ***3 core functions is arbitrary.*** One could also define 4 functions and that the 3rd function can be divided into 2 steps, i.e. data processing and knowledge assessment as the 1st step and knowledge correlation and synthesis and information generation as a distinct 2nd step. This makes it 4 functions, not 3. The WRC has for instance referred to elements of the last function as technology transfer in a sense. However, what is important here is not ***the number of steps*** but ***the scope of the functions.*** “Monitoring” includes all the functions or steps starting with data acquisition through to the delivery of information products (which requires some degree of assessment) to information users.

- **Assessment:**

The word "assessment" of water resource quality is used in at least two different ways:

1. The value addition activities performed by the owners of the monitoring programmes in converting data into information products, e.g. interpreting, comparing data to a standard, calculating a trend, etc.
2. The activities performed by the users of information in adding their experience and knowledge of their subject area to the information they have received, often from many different sources, in order to make a decision or perform an action.

In the context of this framework, the first interpretation of the word "assessment" is already part of the information generation function and, therefore, need not, and should not be stated separately as in "monitoring & assessment" because it only then leads to confusion.

The second interpretation of the word "assessment" no longer forms part of any monitoring programme but is part of what users do with the information products that they receive from monitoring programmes. Again, by using the phrase "monitoring and assessment" it creates confusion about the roles and responsibilities of those people responsible for monitoring programmes and those responsible for using the information, namely the information users.

Therefore, in conclusion, in this framework the word monitoring is used on its own and as such it includes the kind of assessment required to generate standard information products from data. Refer to the MAIS inception report for a thorough discussion of the issues concerning the boundary between monitoring programmes and the users of information produced by monitoring programmes (http://www.dwaf.gov.za/IWQS/wrmais/MAIS-project-inception.pdf).

1.3.6 Data to Information – the value addition chain

Most people involved in the generation and use of water resource quality information understand the concept that one starts somewhere with the acquisition of raw data and ends somewhere with something called information. The example below briefly illustrates the concept: One can start with taking a reading of the water height at a particular point in a river at a particular time. Knowing what the water height is, however, has little value unless it can be translated into a flow rate, for example by using a calibration table for water height against flow rate for that particular section of the river. Again knowing the flow rate at one particular point at a particular instant in time has limited value. So one would like to take many measurements over time and also at different points in a river basin and then summarise these as, for example, mean daily, monthly or even annual flows in order to understand the flow characteristics of a river system. The next level of value addition could be to patch flow records in order to fill in periods during which measurements could not be taken, or to calculate extreme values with a given return period.

Although few people have difficulty accepting the concept of a continuous chain of value addition along the course of which data is converted to information, there is usually little agreement on cut-off points between "data" and "information". Trying to make this distinction is fruitless because the difference is in the eye of the beholder. For example, an experienced river basin systems modeller could easily consider a time series of patched, naturalised mean daily flows for a given monitoring station as "raw data", i.e. one of the inputs used in the model to generate information on the water yield of the river basin. For someone else, the same record could be considered to be the information required to make a resource management decision.

The definition of monitoring given above specifies that one of the core functions of monitoring is "information generation and dissemination". However, if there were no unique definition of what can be considered to be information then how would one be able to design a monitoring programme? The only rational approach that can be followed in the information user-centric design approach is to:

1. Accept that the information products produced by a given monitoring programme are the outcome of a negotiated agreement between the information providers (operators of the monitoring programme) and the information users (clients of the monitoring programme). One must also accept that the definition of the information products can change with time as the needs and sophistication of information users changes.
2. Understand that information users, once they have received the agreed information products delivered by a monitoring programme, will in their use of that information add their own specific insight, experience and tacit knowledge as well as other kinds of information received from other sources to reach a decision or take an action. To distinguish between the outcomes delivered by the value addition process of a monitoring programme from the value addition done by information users, we state that:
    a. A ***monitoring programme*** *produces* ***information*** *products.*
    b. Using the outputs of monitoring programmes as some of their inputs, ***information users*** *produce* **complex knowledge** *products.*

1.3.7 Monitoring programme

As stated above, monitoring always consists of three core functions:

- data acquisition
- data management and storage
- information generation and dissemination.

We have also distinguished the outputs from monitoring, namely *information products*, from what information users produce by using such information products as their inputs, namely *complex knowledge products*.

A monitoring *programme* is defined as a management mechanism which addresses the three core functions, data acquisition, data management and storage, and information generation and dissemination, in order to deliver a coherent set of information products. Such a set of information products is tailored to meet an agreed water resource management information requirement specified by a pre-identified group of information users. The three core functions making up a monitoring programme are briefly elaborated below (from MAIS inception report: DWAF, 2001):

- *Data acquisition*
  - Acquisition of data through DWAF P&R central facilities or from other organisations,
  - Liaison with other organisations to influence their monitoring or data transfer standards, and
  - Measurements, sample collection, or analysis executed by CMAs or other water management institutions would form core activities.

- *Data storage and management*
  - Control of maintenance, security, access to data,
  - Enforcement of corporate specification for data formats,
  - Provision of access through whichever media is most appropriate,
  - Preparation and delivery of standard data on a regular basis, and
  - Other similar activities.

- *Information generation and dissemination*
  - Converts data to information,
  - Distributes information to users in required formats using agreed media (hard copy, electronic, Internet, etc.),
  - Arranges with DATA STORAGE AND MANAGEMENT to store processed information,
  - Preparation and distribution of reports,
  - Modelling,
  - Statistical analysis,
  - Patching of missing data, and
  - Other similar activities.

The phrase "management mechanism", for describing a monitoring programme, was carefully chosen because a monitoring programme need not map one to one on the way a particular organisation involved in monitoring is structured (its organogram). What is important is that a monitoring programme must have a person responsible and accountable for its design, maintenance and performance – here referred to as the owner or manager of the monitoring programme. Typically it would be someone involved in performing the information generation and dissemination function because it is the adequate performance of this core function that justifies the existence of a monitoring programme and defines the content of the other two core functions. It is quite likely that many of the activities involved in the other two core functions might be performed by different parts of the same organisation or even by different organisations. The arrangements for ensuring smooth functioning of the programme can be of many forms, e.g. dual reporting responsibilities as in a matrix management structure, an outsourced model or even by appointing staff or contractors in different parts of the country but reporting directly to the monitoring programme manager.

A few management principles need to be embedded in the design of monitoring programmes as a management mechanism:

1 The programme manager must be the single point of accountability for the performance of the programme, in other words how well it meets the pre-agreed information requirements of its information users.
2 The programme manager must have the required authority to make decisions and take actions and have access to the resources needed to have all three of the core functions adequately performed.

From a particular water resource information user's perspective, one will seldom find that the information products produced by a single monitoring programme can meet all their information requirements. Monitoring programmes are, therefore, typically designed to deliver a coherent set of information products that were agreed up front with information users, to meet a specific sub-set of their information requirements.

1.3.8 Portfolio of monitoring programmes

Water resource quality monitoring programmes can be grouped according to the following criteria, e.g.:

1. In the strategic or overarching framework described here for national water resource quality monitoring programmes, according to the institution assuming the primary responsibility for a specific group of programmes.
2. One can also use the type of information products produced as a basis for defining portfolios of monitoring programmes, e.g.:
    - ***Compliance*** monitoring programmes where the word compliance refers to compliance with specific water use license conditions or general authorisations. The word compliance is assumed to mean monitoring that can lead to law enforcement.
    - ***Performance (audit)*** monitoring programmes where performance refers to comparisons of water resource quality to predetermined resource management objectives such as the Reserve and Resource Quality Objectives.
    - ***Status and Trend*** monitoring programmes which provide long term information (5 yrs or more) primarily on ***what*** the water resource quality is and how it is changing over time.
    - ***Impact Assessment*** monitoring programmes which provide information on ***why*** the water resource quality is what it is and why it is changing over time or is

expected to change over time. They are usually shorter term than status and trend monitoring programmes.

- ***Surveys.*** These monitoring activities are typically once off, irregularly performed, or regularly performed with intervening periods of several years. An example of such monitoring is the regular surveying, spaced several years apart for any given reservoir, of the siltation of reservoirs.

1.3.9 Monitoring System

In the context of the definitions already given for monitoring, monitoring programmes, and portfolios of monitoring programmes, a monitoring system would simply be a grouping of monitoring portfolios according to some logical criteria. It was previously proposed, in the MAIS project (DWAF, 2001), that the Department of Water Affairs and Forestry should take the lead in establishing a ***Water Resource Quality Monitoring System*** by involving all the other institutions involved in water resource quality management. In other words, the criterion used for defining such a system would be that it includes all the portfolios of monitoring programmes aimed at providing information products ***related to water resource quality***. Such a system would, for example, be separate from a Water Services Monitoring System or a Forestry Monitoring System.

1.3.10 Information system

The term "information system" is often used both in a narrow and in a broad context. Some people use the term to describe the information technology sub-component (hardware, networks, software, data bases, etc.) involved in data acquisition, data management and storage, and information generation and dissemination. Others would use it synonymously with how a monitoring programme is defined above, namely, including the information technology elements but also all of the other functions required for data acquisition, data storage and management, and information generation and dissemination.

The NWA specifically refers to information systems. However, in the context of the definition of monitoring, monitoring programmes, portfolios of monitoring programmes and monitoring systems above, use of the term "information system" is redundant. For those who have used it in the broad sense, it is proposed that the term monitoring programme (or monitoring portfolio, or monitoring system) is used instead. For those who used it in the narrow sense (IT technology) it is simply one of several sub-components of a monitoring programme.

1.3.11 Water Management Institutions

- **Department of Water Affairs and Forestry:** As defined by the latest structural diagram of the Department – in other words every one reporting eventually to the Director General of the Department.
- **DWAF P&R:** Those parts of the Department with the responsibility (in the context of this document) *for water resource quality management functions* at the *national (SA-wide) level related to policy and regulations*.
- **DWAF Ops (includes concept of clusters), Catchment Management Agencies (CMAs) and certain Water Boards:** Those parts of water management institutions, whether they are currently part of DWAF or not, who are responsible for water resource quality management functions at a regional or catchment (as defined in the context of the CMAs).

Part 2: Generic Monitoring Programme Design Guidelines

2.1 Introduction

Once the need for a specific monitoring programme has been identified, such a programme has to be designed according to the design framework for monitoring programmes outlined below.

The design guidelines provided here are based on a few underlying principles:

- A systems approach to monitoring programme design which recognises that a monitoring programme consists of several core functions that have to integrated to form a whole.An information user-centric approach to the design of monitoring programmes.The guidelines are also structured according to the functional model proposed earlier in the Strategic Framework for national water resource quality monitoring programmes. The design guidelines are divided into phases (representing each of the core functions – refer to Figure 1.2, copied from Part 1 above for ease of use) and each phase is divided into a number of steps.

The design guideline phases and steps are also listed in the typical sequence in which they will need to be dealt with during the design and implementation of a monitoring programme. However, one must realise that designing a monitoring programme is an iterative process and it is unlikely that a design will be completed by making just one pass through the phases and steps. Particular issues may crop up in a later phase or step requiring the designers to return to a previously completed phase or step in order to resolve it.

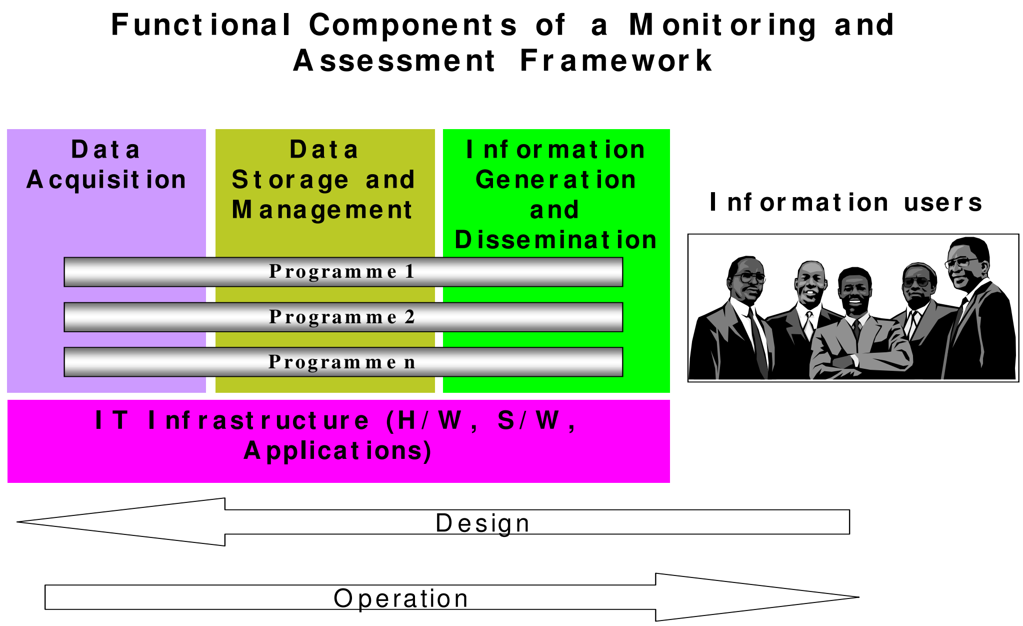

Figure 1.2 Functional model for water resource quality modelling as proposed in the MAIS inception report.

2.2 Phase 1: Information Generation and Dissemination

2.2.1 Step 1: Identify the primary users of the information

The user-centric design approach starts with the identification of the primary users of the information products to be delivered by the monitoring programme, irrespective of whether it is being designed for the first time or being redesigned.

This step sounds deceptively simple but it is often one of the most complex steps to perform. Since monitoring programmes are usually defined as delivering a coherent set of information products addressing a particular set of resource quality management problems or issues (see the list of proposed national programmes, Table 1 page 22), the users of the information provided are seldom nicely grouped in a single Directorate within P&R function of DWAF. If it is a typical water resource quality management issue, one will find people in different functions, e.g. strategic planning, water resources development planning, resource directed measures, source directed measures etc. involved in one way or another dealing with the problem or issue. Similarly, one would find DWAF P&R, DWAF Ops / CMAs and other water management institutions dealing with the problem or issue as well. Sometimes if the problem or issue happens to be very topical at the time, one may also find such a topic being addressed by research funders such as WRC and others. Journalists and the general public may also be interested in the topic and demand information on one aspect or another.

The problem in identifying users is seldom about identifying ***potential*** ones, it is more likely to be about deciding which ones amongst the many potential users are the really important ones that one should pay most attention to. Therefore, the concept of ***primary*** users is introduced here. The identification of primary information users, in the case of National Resource Quality Monitoring Programmes, should be done on the basis that they meet at least one or more of the following selection criteria:

- They perform a DWAF P&R function.
- They cannot perform their function adequately without having access to the information products to be / currently being produced by the National Resource Quality Monitoring Programme in question.
- If it were not for meeting the requirements of the above users performing the above functions, it would be hard to justify the establishment and maintenance of the programme in question.

There are also ***secondary*** users such as the general public, schools, students at tertiary education institutions, researchers etc., who could also benefit from having the information available. However, this fact cannot be used as the main or only justification for establishing and maintaining a monitoring programme. At most it could be offered as a desirable spin-off from a programme already clearly justified on the basis of it satisfying the information requirements of its primary users.

It is important to make a note here about whether "Consultants / Contractors" should be considered as information users at all, and if so, whether they should be treated as primary or secondary users. It all depends on what the consultants use the information for. In many cases the units in DWAF who are responsible for performing certain water resource quality management functions do not have sufficient capacity to be able to do all of the work they have to do, and in such cases extend their capacity by appointing external consultants. In such cases, these consultants are simply an extension of DWAF and should be considered as primary information users. They often, through being employed by DWAF, have had the most experience or at least the most recent experience in using information for a given purpose and can, therefore, make very valuable inputs into defining the information products required.

Even if we know that we have to focus on the primary users of the information produced by a current monitoring programme or to be produced by a new monitoring programme, we still need to select the specific individuals whom we need to interact with. Here one must recall that in the context of the Strategic Framework for national monitoring programmes, one of the features of a national monitoring programme was that it delivers a set of information products addressing a specific management problem / issue such as eutrophication, faecal pollution of water resources, salinity, etc. from a resource quality perspective. Any of these problems usually requires a multi-functional approach to dealing with them. One would, for example, look at the information required to deal with the problem at a strategic planning level, and try to identify one or two people who currently perform that function and discuss with them their information needs. Similarly one would look at the people performing planning functions, people who are responsible for ensuring performance to resource quality objectives, etc.

2.2.2 Step 2: Identify the information products required by the primary information users

As scientists, engineers and technologists involved in the various aspects of monitoring water resource quality, we are usually very good at addressing the "how to" questions. However, the questions around *why* we need to monitor and how the information produced by monitoring programmes will be used is seldom adequately addressed.However, failing to adequately address the question of: "Why do we need to monitor?" or "What is the purpose of monitoring?" results in many water quality monitoring programmes suffering from the "data rich but information poor" syndrome. This next step is, therefore, crucial in the design of monitoring programmes.

Once the primary information users, in the case of national monitoring programmes representing the various DWAF P&R functions that should be involved, have been identified, one needs to design, with their input and consensus, the information products that they would be receiving. In this process a number of separate issues need to be addressed:

1. What are the management decisions / actions that they need to take that require *resource quality related* information to be delivered by the monitoring programme as input to their decision-making process? This is probably the most crucial question because the answer to it will determine the very nature of the information to be produced and, therefore, the rest of the design of the programme. Monitoring is usually done by or enforced by government, therefore understanding the legal and policy framework underlying monitoring is crucial to formulating, at least, broad monitoring goals. Monitoring programme designers should, therefore, familiarise themselves with the legal and policy framework as far as it relates to the management issues being addressed by the information to be delivered by the programme.

   To illustrate this concept, let us use the example of eutrophication as a water resource management issue. The question one asks would typically be: "What typical decisions and actions concerning eutrophication does the user need information for?" Their response could be any or more of the following hypothetical examples:

   a. Users have to decide in which catchments to implement special source control measures to reduce eutrophication related water quality problems experienced in dams. For this they need to know what the current eutrophication status of reservoirs is and also whether it is deteriorating over time. As the programme designer, your first question would be: Is this information that should be produced by a national programme – say for eutrophication related resource quality? You would evaluate the request for information against the following criteria:

      i. Is it required for the purpose of performing a DWAF P&R function In the example given above, clearly YES;
      ii. Is the request for resource quality related information – in the example YES;
      iii. Is the request for status and trend information – in the example YES;
      iv. Is the information related to eutrophication as a management issue – in the example YES.

Therefore, the information requested should be considered as a strong candidate as an information product to be produced by a National Eutrophication Monitoring Programme.

b. There may be some other information users who need to make decisions related to, for example, the impact of eutrophication on the health of aquatic ecosystems. Here one would have to carefully consider which national programme could best provide the required information, e.g. the National Eutrophication Monitoring Programme or the National Aquatic Ecosystems Health Monitoring Programme. The outcome of that decision would determine in which programme's design this particular information need will be addressed.

2. Once the designer knows the nature of the information required and how it is to be used, the rest of the questions deal more with the technicalities of producing the required information. The questions and the ensuing discussion now start to focus on:
    a. What resource quality attributes are significant (e.g. in the example above, what attributes would be used for determining eutrophication status)?
    b. Whether they should be reported individually or combined into some form of an index, etc.?
    c. What constitutes a significant difference with respect to the management issues being addressed? Here one should watch out that what may be a *statistically* significant difference may not be significant from a *management perspective*. However, the reverse argument does not apply often! To further pursue this argument it may be necessary to debate the whole issue about when risk minimisation is appropriate or not and issues around the "no regrets" approach to resource quality management which is a big topic in itself.
    d. The format in which the information is needed (e.g. a table or graph displaying measured status against some standard or resource quality objective, etc.)?
    e. How frequently it is needed (and should be updated), etc.?

3. The geographic coverage of the programme needs to be decided. At this stage all that needs to be established is whether:
    a. The programme should have a broad (SA wide) geographical coverage, and if so, whether there are other issues around political or organisational boundaries (e.g. all WMAs should be covered or all Provinces should be covered etc.) that should also be considered.
    b. The programme should focus on selected areas only, typically selected on the basis of their significance. Significance is usually determined by a combination of priority (financial, social, health, etc.) given to the resource and the likely risk of impacts.

4. A final note of caution to the programme designer when interacting with information users is to be as clear as possible about what information the programme being designed will NOT be producing. Users are sometimes so pleased to at least have someone listening and seeming to be willing to respond to their dire needs for information that there is a tendency to try and have all their needs satisfied through your programme. Be very aware of the scope and mandate of your programme and DO NOT venture outside it unless the issue was formally considered and the scope of the programme expanded as a result of it.

2.2.3 Step 3: Design the information Generation Protocols

Now that the designer knows the different kinds of information products to be produced by a programme, the generation of these information products has to be designed in detail.

One of the best ways to perform such a design is to follow the rapid prototyping approach:

1. For each information product identified:

    a. Make a "mock up" of the information product.
    b. Then ask the question as to what input is required to produce it (both data and methods of analysis).
    c. Assess the feasibility of obtaining the data required and performing the analyses to generate the proposed information products.
    d. Then use actual test data or, if this not available, hypothetical data to test whether the specified information products can be produced.

2. It is good practice to have, at least, a sample of the different information users who said they needed such information evaluate the "mock ups" in order to verify that they can be used in the decision-making processes they were intended to be used for. *Remember that the message to the users at this stage of the process is not that you WILL be able to produce the information specified but rather that you are still investigating the feasibility of producing it.*

3. Make the modifications to the "mock ups" as requested by the users (repeat step 1), have these evaluated by the users (repeat step 2) until a consensus is reached on the information products required and the feasibility of the national programme to produce it.

2.3 Phase 2: Design the Monitoring Network

At this stage of the design process it should already be clear what the proposed geographic scope of the programme is.

Knowing who the primary information users are, what information products they require and what they need the information for, you should now strive to obtain a ballpark annual operating budget for the programme. It may seem premature, but you do need a ballpark number, e.g. is it 1, 10 or 100 million Rand per annum? This number is important because, despite all the design criteria that may be applied to design the network, it is pointless to come up with a design that is completely off the scale of what is financially available.

Network design deals primarily with three issues, namely:

- What resource quality attributes to include in the programme.
- Location of data acquisition points (definition of points at a macro scale).
- How frequently data should be acquired.

Each of these is discussed briefly below.

2.3.1 Select and finalise the water resource quality attributes to be included in the monitoring programme

2.3.1.1 Introduction

By this stage in the design process, the designer should already have a good idea of which resource quality attributes must be included in the monitoring programme. The fundamental question of "Which water quality attributes are of concern?" with respect to the information requirements of the information users will already have been considered to some degree in the design of the Information Generation Protocols.

Careful selection of the water quality attributes to be included in the monitoring programme is of crucial importance because:

- They have a direct impact on the ability of the programme to deliver the information products it was designed for.
- They have a direct impact on the cost of the monitoring programme. It is not only the operating cost that is important but also the initial capital cost of establishing the programme. For example if you need to build a concrete weir across a river to measure a particular attribute (e.g. flow), the initial capital outlay will be orders of magnitude higher than if you could measure the attribute by taking a sample of water to analyse the electrical conductivity (EC).
- Once a choice has been made – it cannot / should not easily be changed.

This step in the design should, therefore, cause the designer to move away from the typical current practice of selecting the resource quality attributes to be included in a monitoring programme based on the:"Lets measure everything we can with our available infrastructure" approach!

Some of the factors to consider in deciding which resource quality attributes to include in a monitoring programme are:

1. Information needed.
2. Significance of physical processes.
3. Logistics of data acquisition.
4. Institutional aspects.
5. Financial implications.
6. Continuity of records.

Each of these are discussed briefly below:

2.3.1.2 Information needed

A key issue is to precisely determine what information is required when finalising the selection of water resource quality attributes to include in a monitoring programme. For example, do we want to know whether water is contaminated with Cholera bacteria vs. do we want to know whether there is a risk of the water being contaminated with Cholera? In the first case you would have to include the presence of Cholera bacteria as a resource quality attribute. In the second case all you need to include is the presence of an indicator organism of faecal pollution (e.g. *E. coli*) as a resource quality attribute. The cost and logistics for the monitoring programme may be greatly affected by such a choice.

2.3.1.3 Significance of physical processes:

An understanding of the physical-bio-geo-chemical processes affecting resource quality is a key consideration in deciding on which water resource quality attributes to include when designing a monitoring programme, e.g.:

- Understand if the behaviour of an attribute, such as the concentration of a chemical, physical or biological attribute in water, is dictated by a transport or a yield limited process.
- The bio-availability of attributes, e.g. plant nutrients or heavy metals, for uptake by aquatic organisms.Attributes characteristic of typical waste products produced by different man-made processes and which often end up in water resources.

2.3.1.4 Relationships between attributes

The relationships between different water quality attributes is of great significance because these may allow us to derive information about attributes not being monitored or those that can only infrequently be monitored from other attributes that are being monitored, or can be monitored more frequently or more easily.

The most common statistical method used to quantify relationships between water resource quality attributes is linear regression. Other ways are to use the more sophisticated multiple regression techniques or to use mathematical models to describe the relationships.

2.3.1.5 Logistics / feasibility of data acquisition

Some of the issues to consider when selecting resource quality attributes are:

- Whether data acquisition of a particular attribute can be done by direct measurement, recording and transmission of data to a central location (e.g. temperature, flow, EC) or whether some or all the steps have to be done manually.
- Feasibility of obtaining representative samples; sample stability; the need for preservation for the attribute being considered.
- Availability / accuracy / precision / cost / skill / infrastructure requirements for chemical / biological / physical analytical methods for the attribute being considered.

2.3.1.6 Institutional and statutory considerations

In the selection of resource quality attributes to include in a monitoring programme, one may find situations in which the degree to which good science would dictate your choice of attributes being constrained by law or policy. This happens typically when law or policy prescribes either the attributes, the data acquisition points or the frequency of measurement.

In cases where there is a conflict between what law / policy and what good science dictates, one should at least investigate the feasibility to get alignment, but when all else fails law and policy would probably supersede.

2.3.1.7 Financial implications

Monitoring programme designers cannot be oblivious to the financial implications of the number and type of resource quality attributes they select to be included in a monitoring programme. The more attributes that are included in a programme the greater the cost. In addition, including a particular attribute that has special data acquisition requirements, e.g. sampling and analytical requirements, may have a drastic impact on the costs of a programme. The trade off then becomes how much additional information is gained for the additional cost incurred.

2.3.1.8 Continuity of records

In most cases at least one of the information requirements associated with national resource quality monitoring programmes will be that the information is needed for detecting trends in resource quality attributes. If a particular attribute has been measured for a long time already, and it is now being considered to replace it with another attribute, it may by prudent to:

Continue monitoring the previous attribute in order to maintain records of resource quality that are long enough for reliably detecting trends.In certain cases, where there is a good enough relationship between the attribute being considered for discontinuing and the new one, one should make provision for a transition period during which both are measured for a long enough period to establish the relationship between them before discontinuing the previous one.

2.3.2 Selecting the data acquisition (sampling) sites

The location of data acquisition sites is a critical step in the monitoring programme design process. If monitoring is not done at the correct locations, it can fatally compromise the ability of a monitoring programme to deliver the information required and thereby meet its objectives! Therefore, as with all the monitoring programme design steps, knowing the monitoring objectives of a given monitoring programme and constantly keeping them in mind is a key requirement for the proper location of monitoring sites.

Currently in SA, far too little attention is given to correctly locating resource quality monitoring sites, mostly for a number of historical reasons:

- The oldest national monitoring network is the one that was designed for hydrological monitoring. At the time it was designed, the overriding information requirement was to estimate the water yield from catchments in order to decide where and what size reservoirs to build.
- The availability of flow gauging structures and the whole data acquisition infrastructure and logistics that went with it, made the National Hydrological Monitoring Programme a very attractive template on which to superimpose the location of data acquisition points for subsequent new monitoring programmes, such as the National Chemical Monitoring Programme.There was another assumption, particularly related to chemical water resource quality attributes, namely that the information generated would only be useful if it is used in conjunction with the corresponding discharge information from the same point. In essence the assumption was that one would have to calculate

chemical loads as a resource quality attribute in order for the information to be useful. This is certainly a valid information requirement for certain specialised management purposes, but is definitely not the case for many others. If we are mainly interested in resource status and trend information, as is suggested for national programmes, then having the corresponding discharge information available is not necessarily a requirement. Therefore, considerations of logistics and convenience have often over-ridden any other considerations with respect to deciding on the location of data acquisition sites for attributes other than discharge.

The location of data acquisition sites have been dealt with at two scales, namely the macro-location of sites (data acquisition stations) and the micro location of data acquisition points at a given station.

2.3.2.1 Macro scale location of data acquisition stations

The major factors to consider when locating data acquisition points at a macro scale are:

- The type of water body in which the data acquisition station is to be located, e.g.:

    - Rivers vs reservoirsSurface vs groundwater

  Therefore, some understanding of the typical physical behaviour of different types of water bodies is necessary in deciding on the siting of data acquisition points.
- It is important to take into account that the implications (financial, infrastructure and logistics) of every additional data acquisition station decided upon can differ greatly for different types of resource quality attributes. For example, if the attribute of concern is:

- A discharge, and one assumes the classical method of using a gauging weir for measuring discharge then there is significant capital expenditure as well as construction time involved.
- A chemical attribute, and one assumes sampling and analyses at a central laboratory then the most significant issues may be the logistics of getting the samples to the laboratory and the costs associated with the analysis of the samples.

- Representing political jurisdictions, e.g. Provinces, institutional considerations, e.g. Water Management Areas, etc.

- The type of resource quality attribute of concern, e.g.:

    - Conservative attributes, e.g. one can make the assumption that the principle of "conservation of mass" applies to understanding / modelling the behaviour of the attribute in the water environment.
    - Non-conservative attributes, e.g. one cannot make the assumption that the principle of "conservation of mass" applies to understanding / modelling the behaviour of the attribute in the water environment.

As is the case with serial correlation (see next section), a key assumption underlying the calculations done to estimate the statistical properties of a population of observations for a given water resource quality attribute is that the observations are INDEPENDENT! In the case of regional statistical properties, it requires that the value we observe at one sampling station has no influence over the value we are likely to observe at the next sampling station. If the sampling stations are correlated, then the assumption of independence is no longer valid – in other words if we observe a particular value at a sampling station then we are likely to observe a value of similar magnitude at another sampling station. That is, observations from different sampling stations are correlated with one another – also known as spatial correlation. If spatial correlation is present it introduces redundancy in the data. The data, therefore, APPEARS to contain more information about / more reliability in estimating statistical properties of the underlying population than what is really the case.

Despite the potential constraints introduced by spatial correlation present in data collected at different data acquisition stations in the same region, it is seldom used in monitoring programme design. The reasons being that the other considerations often override, and possibly also that regional statistics (e.g. the mean Ca concentration at sampling stations in a given geographic region) are seldom required as important information products.

2.3.2.2 The micro-scale location of the data acquisition (sampling) points

Once the designer has decided the macro location of the data acquisition stations, it also needs to be decided where, precisely, to locate the data acquisition points at a particular station. The data acquisition points at a given data acquisition station may be different for different water resource quality attributes. Issues to be considered are:

- Mixing, in cases where the quality of the resource could differ locally, e.g. horizontally across a river or with depth in a reservoir.
- Ability to reach the station and the specific data acquisition point – also considering issues of personal safety.
- Stability of the site / features of the site.
- Type of resource quality attribute.
- Likelihood of protection against vandalism or reasons for loss of a site.

The available budget (often split into capital and operating components) for a monitoring programme determines the scope of the monitoring programme. The scope includes the number of data acquisition stations and points as well as the frequency of data acquisition (which is dealt with in the next section). So one will most probably be required to do a few iterations between determining the desired number of data acquisition stations and points, and determining the data acquisition frequency in order to come up with the optimum design for both of these in the context of the available budget.

2.3.3 Frequency of Data Acquisition (sampling frequency)

The frequency of data acquisition (sampling frequency) often receives a lot of attention, most probably because it is one of the design features that can be changed more easily than others, such as location of data acquisition stations, or the selection of resource quality attributes.

The frequency of data acquisition has a direct impact on the amount of information that can be generated for a given data acquisition effort / budget.

The following statistical issues need to be considered when deciding on the appropriate data acquisition frequency:

- The amount of information that can be obtained, the reliability of statistical estimates and the accuracy of these estimates tend to increase with increasing the number of observations made, in other words the frequency of data acquisition.
- However, this relationship is constrained by auto - / serial-correlation present in a time series of observations. Serial-correlation puts a limit to the data acquisition frequency. If data is collected at a frequency that introduces serial-correlation in the data, then we enter the situation where the relationship between increasing the frequency of making observations leading to increased reliability of statistical estimates breaks down. Expressed in another way, if we increase the frequency of making observations beyond this threshold we will incur the cost of monitoring – which is quite significant – without gaining any additional information! You will need some historical data or have to make

some assumptions about the statistical properties of the resource quality attributes of concern. If you do not have historical data to use, and the implications of the assumptions you make are significant, you may first have to do some surveillance monitoring in order to obtain the information required to estimate data acquisition frequencies more reliably. The duration of the surveillance monitoring will be dictated by case-specific considerations, e.g. if the attribute varies significantly over seasons, one may want to capture at least one seasonal cycle.

There are other issues, in addition to the statistical ones, to consider when deciding on the sampling frequency:

- Logistical and cost considerations. The logistics of data acquisition may put some constraints on what you eventually select as the frequency of data acquisition.

- If we use the above considerations and apply the appropriate statistical procedures for estimating the required sampling frequency, it is quite likely that we will come up with different frequencies for different resource quality attributes. The reason being that the variances associated with the different attributes will not be the same. However, in many cases it will be impractical to do data acquisition at the same station at different frequencies!In such cases one has to decide on some basis to select a common frequency:
    - Choose the highest frequency and accept that there will be some redundancy present in the data for those attributes that require a lower data acquisition frequency. This must be accounted for in the information generation procedures in order to avoid assigning higher than justified reliabilities to the statistical information generated.
    - Choose a frequency that is weighted for the relative importance of the different resource quality attributes. This is somewhat like taking the middle road, in other words the data acquisition frequency will be lower than desired for some attributes, just right for some, and too high for some.
- In many cases of having to determine data acquisition frequencies, one is actually constrained by a predetermined data acquisition frequency – usually a frequency selected for a particular attribute (which is not part of your programme) to serve the needs of other national or regional monitoring goals. However, the cost of setting up the additional data acquisition infrastructure to serve the needs of your monitoring programme may simply not justify the incremental increase in the reliability of the information derived. In such cases, you should at least go through the exercise of calculating the incremental loss of information as a result of a reduced data acquisition frequency before accepting the situation as is!
- The whole of the preceding analysis of determining data acquisition frequencies is based on the underlying assumption that some, or the most important, information products to be provided by the monitoring programme are based on estimates of the statistical properties of the resource quality attributes of concern. This may not always be the case. Certain information products may require different (not statistically-based) approaches to determining data acquisition frequencies, e.g.:
    - Compliance monitoring may have a frequency pre-determined by law / regulation / license condition.
    - Impact assessment monitoring may require sampling frequencies not constrained by the assumption of independence of subsequent observations.

- Process control monitoring may require data acquisition frequencies determine by process requirements.

2.4 Phase 3: Design the Operational Requirements for the Programme

In this part of the design document, one has to describe the detailed operational requirements for IMPLEMENTING each of the core functions making up a water resource quality monitoring programme. This should ideally be done in such detail and with such clarity that the programme design team could hand over this document to someone who was not involved in the design at all and they should have a high probability of successfully implementing the programme.

The operational requirements have to be designed and documented in such a way that adequate end-to-end quality assurance is built into all of the processes forming part of the three core functions making up the monitoring programme, namely, data acquisition, data management and storage, and information generation and dissemination.

It is recommended that one or more of the internationally / nationally recognised standard protocols for end-to-end process quality assurance is adopted as a template guideline for documenting the operation requirements of the programme. Templates to consider are: ISO 9001:2000 (SABS, 2000).

This task may not be as daunting as it seems. Most monitoring programmes will be making use of some existing infrastructure for performing some of the processes, e.g. as part of the data acquisition function, the process of having water samples analysed by a laboratory to determine chemical, biological or physical attributes. By simply specifying / selecting a SANAS accredited laboratory to perform such analyses means that such a laboratory already complies with all the operational requirements and in the programme design one could simply reference their documentation. The same would apply to any other part of the programme where the operations will be performed by an accredited organisation.

However, certain parts of the end-to-end process may not currently meet the required operational specifications / accreditation. In such cases, the programme design team would need to fill in the gaps. As mentioned before, rather than starting with a clean slate, consider using existing templates. These can be the generic ones mentioned above, or even better, ones that have been developed specifically for water resource quality monitoring programmes (e.g. consider the work done at Umgeni Water).

A sample list (not a complete checklist!) of the topics to be addressed in the operational design of a water resource quality monitoring programme is provided below.

2.4.1 Information Generation and Dissemination

The specification of information users, their requirements and the information products to be delivered to satisfy these requirements, would already have been completed as described in Section 2.2. This would also include the selection of the methods and / or models to analyse and present the information products as well as the media / formats for disseminating the information.

What needs to be documented here are the processes to be followed, e.g. what needs to be done, by whom and when (e.g. daily, weekly, monthly, quarterly, annually, etc.). In the case of specified statistical methods, mathematical models or graphical analyses to be used for generating information products, one should specify requirements such as:

- The method, and if appropriate the software to use for applying the method.
- The preparation of the input data, including any data verification and adjustments to be done, such as patching missing values and dealing with zero or non-detect measurements.
- Output verification.

The operational requirements must specifically make provision for regular verification that the information products being produced by the programme are used, and for the purpose that they were designed for.

In documenting the operational requirements associated with the information generation and dissemination function, the design team must be constantly aware of the agreed boundary between information products to be produced by the monitoring programme, and complex knowledge products to be produced by the users of the information. The operational requirements must be limited to those required for producing and disseminating the information products delivered by the monitoring programme being designed.

2.4.2 Data management and storage

Operationally, most of the data management and storage processes required for national water resource quality monitoring programmes would make use of the available DWAF IT infrastructure and systems. These provide a reliable operational platform. For more information on the IT systems currently being used for and being planned for water resources data management and storage see http://www.dwaf.gov.za/iwqs/wrmais/RainbowProject-Final%20Reportver5-4.doc

The monitoring programme design team should liaise and agree with the people managing the IT structure for the IT infrastructure and support required for the programme being designed. After this, the people providing the IT infrastructure and support would have their own operational requirements so that these need not be developed by the monitoring programme design team.

Most of the operational requirements to be developed by the design team would relate to procedures and processes that will ensure valid data being received by the IT infrastructure and also processes and procedures for extracting data from the system.

2.4.3 Data acquisition

The operational requirements for performing all the processes involved in this core function consistently and reliably are probably the most challenging part of operating a monitoring programme.

The geographic scope of most national water resource quality monitoring programmes will require that data acquisition be done in virtually all parts of South Africa. It will also involve making use of infrastructure and human resources belonging to a wide range of institutions, each with their own way of doing things.

Other than is the case with accredited laboratories or DWAF's centralised IT infrastructure, the monitoring programme design team cannot assume, other than in a few exceptions, that formalised / accredited systems exist for managing the data acquisition processes in these institutions. Therefore, the design team will have to develop the required operational procedures and processes as well as the mechanisms for quality assurance for the consistent performance of the processes.

These processes have to ensure the integrity of the data acquisition process from the point where a sample is taken / measurement is made to the handover of the data to the data management and storage function.
Some of the key issues to be addressed are:

- Ensuring that samples are taken (or measurements are made) at the right place (data acquisition station and point) and at the right time, and at the right frequency.
- In the case of *in-situ* measurements, that the structures / instruments are properly calibrated and maintained. In the case of samples, that the samples are properly treated, transported and that they reach the laboratory in time.

- That the data is transmitted reliably from the instrument (*in-situ* measurement) or laboratory to the data storage and management infrastructure. That is, Quality Assurance (QA) for all of the above exists.

The broader QA principals and system requirements of ISO 9001: 2000 (Quality management System) should be followed to allow for a complete QA management system. As ISO 9001: 2000 (SABS, 2000) is a generic standard, it is recommended that the more specific principals set out in "Quality Assurance in Environmental Analyses" (Clark, 2000) be used as a basis for ensuring that all aspects relating quality control in water resource monitoring have been addressed. It is also important that the ISO 17025 requirements for sampling be adhered to.

Part 3: Capacity Building

3.1 Introduction

3.1.1 Background

The Capacity Building Framework for monitoring of water resource quality provides a common, consistent and complementary approach to capacity building as a guide to all those involved in monitoring of water resources. While it is initially focused on supporting the DWAF P&R National Monitoring Programmes (first tier), it also provides a potential framework for other institutions involved in monitoring, which amongst others include:

- [already mentioned above.]DWAF OPS, Clusters, Regional Offices (second tier),
- CMAs,
- Local (third tier) water management institutions, and
- Other regional (e.g. SADC) monitoring bodies, private sector organisations and members of the public.

3.1.2 What is capacity building?

Capacity building within the context of water resource quality monitoring is generally defined as a range of activities by which individuals, groups and organisations improve their skills and knowledge to achieve sustainable water resources management. This definition is inadequate as it refers to only one component of capacity building, and that is skills and knowledge. In its broadest sense, capacity building includes creating an enabling environment with appropriate policy and legal frameworks; institutional development, including community participation, awareness raising, human resources development (encompassing motivation and commitment) and strengthening of managerial systems. Specific interventions range from training that enhances the skills, abilities and knowledge base of individuals to reforming policies, laws and institutions that hinder sustainability.

Capacity building should go beyond the traditional top-down approach of enhancing skills and knowledge through training and provision of technical skill. It must focus on ***enhancing the quality of the outcomes of the monitoring programmes, and the resultant decision making*** in all aspects of water resources monitoring, from planning to practical actions. In addition to the transfer of technology and technical capability, capacity building should foster collaboration among institutions, and build both human and social capital.

3.2 The rationale for capacity building

A number of management problems in water resource quality monitoring have been identified and these include:

- a lack of managerial and incentive measures,
- a lack of personnel required for operation and maintenance,
- a lack of associated research and development activities,
- a lack of co-ordination among water management institutions and agencies, and
- a shortage of funds.

This framework, therefore, seeks to ensure an improvement in water resource quality monitoring. In order to achieve long-term water resources management outcomes, investments in people are as critical as investments in practical works, laboratories and related technology. The long-term success of the national monitoring programmes would, therefore, depend on the degree to which the responsible authorities are able to make informed decisions that result in sustainable water resources management and ongoing economic viability.

Water resource quality monitoring may be complex relative to other environmental monitoring processes. The instruments required are significantly more sophisticated, expensive, and difficult to operate. Their maintenance requires much higher degrees of knowledge and expertise, and the type and level of manpower required to collect, analyse, and manage water quality data should match these requirements. DWAF P&R, therefore, needs a multidisciplinary team of professionals which would be able to carry out the activities listed above, the financial resources for acquiring the expertise, as well as acquiring and maintaining the equipment. The equipment could range from laboratory facilities, laboratory supplies, and proper sample transportation facilities.

A lack of co-ordination and communication between institutions has led to the current disparity between monitoring programmes of various institutions. That is, data collected by one institution has not been easily available to other institutions/departments. Such practices have contributed to some frustrations and tensions among the institutions concerned. Equally, the absence of co-ordination has often contributed to the development of incompatible methods, software, and data systems used in monitoring, resulting in inconsistent data results.

It is thus essential that all major institutions involved in water resource quality monitoring contribute meaningfully in the development of any new framework for monitoring the water quality of the resource. The framework should facilitate the sharing of data available between the various institutions as well as the potential users of that data.

3.3 Capacity building as a key investment for national monitoring programmes

Water resource quality management challenges occur at a broad spatial and temporal scale; and they are complex. Furthermore, they are likely to involve difficult trade-offs between alternative uses and users at local, regional and national level. Individuals within communities and within Government require the skills, knowledge and will to respond effectively to new water resource quality challenges, and adopt an integrated approach in their quest for long-term management solutions.

It would, therefore, be essential for DWAF P&R, in partnership with other institutions, to build on previous initiatives so as to assist water resource quality managers and users to deal with water quality challenges. The *status quo* could be reversed if investments are made through strategic capacity building programmes, which would result in long-term benefits for all.

DWAF P&R should endeavour to maximise the effectiveness of the investments they make in water resource management by ensuring that the monitoring programmes yield high quality outputs. The investment would be enhanced by promoting the commitment of DWAF P&R staff and related institutions by involving them through all the stages of water resource quality monitoring, planning and implementation. DWAF P&R must also review and change their own processes to work more effectively with the broader community, both locally and internationally.

3.4 The Guiding Principles of Capacity Building

The principles of capacity building (as specified below) should be reflected in the development of capacity building components for departmental strategic plans as they will guide the implementation of this framework. Therefore, DWAF P&R as the lead agent should ensure that:

- Key stakeholders are targeted to meet the priority water resource quality monitoring outcomes of the country,
- Priority issues are clearly defined,
- Partnerships between key stakeholders and relevant institutions are encouraged,
- Existing capacity, local expertise and knowledge is valued and considered before undertaking any new initiatives,
- Sharing of resources, experience and expertise, both locally and internationally is provided for,
- There is trust and mutual reciprocity amongst the key stakeholders and implementers of the framework,
- There is adherence to the stipulated methods so that there is consistency in outcomes,
- Encompass 'learning by doing' and other appropriate learning styles,
- Local community expertise and knowledge is valued and utilised,
- Information is made accessible to the entire community (general public),
- Information is based on access to accurate scientific and technical information, and
- It contributes towards building human and social capital.

Outcomes and significant change will only be evident in the longer term and they will not be achieved overnight. It is, therefore, important to identify short-term goals which have to be practical actions that will contribute to the long-term monitoring goals. Although short-term targets are a means to an end, rather than an end in themselves, they will form the foundation upon which sustainable water resources management would be achieved. Important short-term outcomes/targets for capacity building relate to:

- Awareness creation on water resources quality management,
- Proper training in order to influence positive attitude, behaviour and practices in water resources quality management,
- Information and knowledge sharing,
- Development of the necessary skills and competencies,
- Institutional support and collaboration, and
- Appropriate funding.

3.5 The goal and expected strategic activity areas of the capacity building framework

The main objective of the capacity building component of this Framework is to encourage:

Informed and improved decision-making, which should lead to the implementation of these decisions in such a manner that sustainable management of water resources is attained.

The capacity building framework must address the needs of all the following functional components of a monitoring programme:

- Data acquisition,
- Data storage and management, and
- Information generation and dissemination.

These functional components, on their own, are not sufficient for operating a monitoring programme. They have to be accompanied by the following efficiency mechanisms:

- Design and upgrading of monitoring programmes,
- Research and development,
- Co-ordination, communication and information sharing,
- Public participation and improved public relations,
- Skills development and training, and
- Appropriate funding.

The various components of a sustainable water resource quality monitoring programme, together with support mechanisms such as institutional change and communication, should be seen as interdependent components of a holistic implementation package (Figure 3.1). These support mechanisms should not be pursued in isolation from one another if efficient and effective water quality monitoring is the desired end goal. It is the combination of enhancing the *ability to act* through provision of knowledge and skills, and fostering *motivation to act* through awareness raising and the provision of facilitation and support that should lead to effective reform in water quality monitoring. In order to move towards sustainable water resources management in general and the proposed portfolio of water resource quality programmes in particular, DWAF P&R requires new approaches and ways of thinking, which should lead to developing a variety of skills, institutional structures, and planning methods and procedures. Details of each one of the elements of the proposed framework are discussed below.

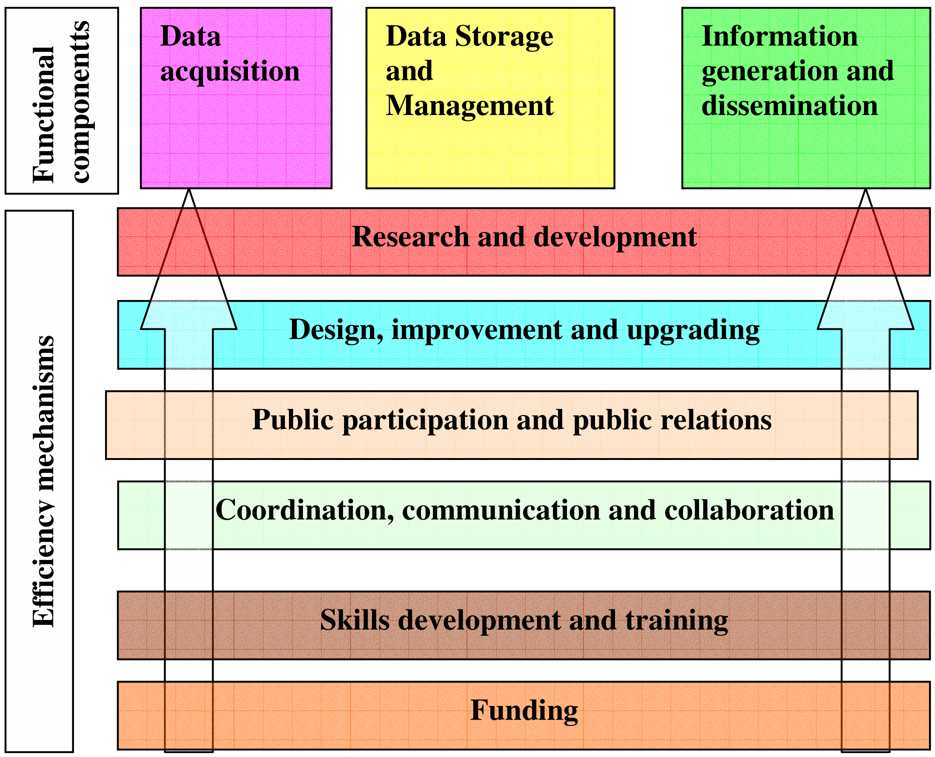

Figure 3.1 Functional components of a monitoring programme, showing mechanisms for improving the efficiency of capacity building

3.6 Design of monitoring programmes

Principles of the design of monitoring programmes with respect to DWAF P&R monitoring programmes are well articulated in the Monitoring and Assessment Information Strategy (MAIS) Phase 2 final report. The following section will look at the efficiency challenges facing a design process for a new programme or upgrading of an existing programme specifically. DWAF P&R would require experts who would be able to design the proposed monitoring programmes, and to establish associated policies and monitoring. Design skills are necessary to update the programmes, since the proposed framework requires higher levels of integration. The functionality of every design has to be evaluated against the objectives of the programme and will have to be improved at different intervals according to changes in technology.

The increasing complexity of water quality issues such as public health, agriculture, food production, or micro-contaminants, require new and different types of data reporting in addition to the data historically collected in water quality monitoring programmes that was an indication of chemical attributes, such as major ions, and bacterial indicators. Chapter 2 of this document describes the information user-centric approach to the design of monitoring programmes, defined around a coherent set of information products related to a specific set of water resource quality management issues or problems. This requirement calls for a multi-disciplinary approach that extends beyond water resource quality expertise so as to be able to include economic and social development understanding in the framework.

3.6.1 Data acquisition

Data acquisition is probably the most established of the functional components of monitoring within DWAF P&R and other institutions. This does not mean that data acquisition activities are optimal and do not require any interventions. Problems exist in the area of field instrumentation, laboratory equipment, methods of analysis, skills of personnel, attitude and commitment towards work, co-ordination and communication.

One of the proposals on the portfolio of monitoring programmes (Chapter 2) is that monitoring currently undertaken through separate programmes but looking at similar indicators (e.g. inorganic chemicals), should be merged. Furthermore, the merging of the programme would require much higher levels of co-ordination of data acquisition activities. The monitoring programme co-ordinator or programme manager will have to build a team with diverse skills. Sample collectors must be well trained in sampling since any improper sampling will lead to meaningless results and misdiagnosis at that sampling point. Sample collectors must be able to handle and operate equipment used for surface water as well as ground water analysis processes if the analysis has to be carried out at the point of sampling. The lowest level of decentralisation in the hierarchy of monitoring activities would be in the area of data acquisition where collaboration efforts among institutions involved in monitoring will be highest. It is expected that there will be more institutions involved in data acquisition than in management and storage and in information generation and dissemination.

Laboratory accreditation must be given priority, as monitoring results lead to decisions that affect people and organisations. Accreditation or lack thereof tends to over-ride a pollution issue where there are disputes with water users over water pollution. Where the cost of accreditation becomes prohibitive, the department must go into partnerships with laboratories run by other public or private sector institutions. If a monitoring programme, regardless of what tier it operates at, wants to make use of laboratories other than those at DWAF P&R national laboratories, such laboratories will have to demonstrate compliance with standards set by DWAF in order for them to be used as service providers in performing the data acquisition function.

3.6.2 Data management and storage

After acquisition, many data sets require processing for format conversion and quality assurance. Formats used to store and disseminate water resources quality data may differ from one institution to the other, or within the same institution as is currently the case in DWAF P&R. The Department must have the ability to convert data to common, readily useable formats and compel all other users to use that desired format or compatible formats. The history and condition of the incoming data sets and its management will need expert examination, since it would influence the level of quality assurance attained in management decisions.

Small data sets can be managed effectively and efficiently in simple desktop applications such as spreadsheets or text files. However, when data sets are large, and have to be shared by different users, as is the case in DWAF P&R, it becomes more efficient to store the data in a functional Information Management System. Such a system requires intelligent design, taking into account the characteristics of the data as well as the needs of the end users. The system should have a high security level so that existing data is not altered by unauthorised individuals.

Management of time-series data presents a special challenge to the water resources manager. Voluminous time-series data require highly sophisticated information systems. Making an information system useful requires the development of data management interfaces that can move data into and out of commonly-used analytical tools, such as GIS, spreadsheets, statistical packages, and visualisation tools, for use by water resources managers and decision makers. When a system is complex, it stands the risk of not being used by those in need of the information.

Monitoring programmes, therefore, have implications on the skills, the systems and governance issues pertaining to data analysis, storage and management. Skills that are required and are scarce are those of experts in Information Technology and Project Management. Problems relating to the development of databases and other information systems that may not necessarily be compatible are well documented in the MAIS Phase 2 report. These problems need to be addressed by this framework.

3.6.3 Information management (generation, dissemination and usage)

Previously, issues related to data acquisition and data management and storage dictated the design and operation of monitoring programmes, however, the current shift towards the user-centric approach dictates that more attention be given to information management (generation, dissemination and use). This component of monitoring requires skills in data interpretation and appropriate packaging for use by managers and decision makers. There can be a disjuncture between the information needs of users and the data collection and management effort by monitors. This problem is caused by an emphasis on data collection by water monitoring institutions. It is this disjuncture that needs to be addressed by this framework, ensuring a smooth transition in operations between data collection and information usage.

A necessary activity within a reform and re-organisation programme is an educational process directed at major users of information in order to reduce the demand for irrelevant information and to more closely align data needs with more modern types of data available as well as data interpretation. Utilisation of modern and cost-effective monitoring techniques will be unsuccessful unless users understand how these techniques can improve their ability to manage water quality. Central to the development of information products and complex knowledge products is integration of data and information from a range of monitoring programmes. The MAIS Phase 3 inception report refers to information products and complex knowledge products that have to be delivered to various water resources managers for them to be able to perform their functions. Thus, the individuals employed in the functional areas of management and decision-making require much more sophisticated expertise and other support that would enable them to request data or information relevant to their needs.

3.6.4 Research and development

Water resource quality managers and users must be able and willing to access the necessary information, data and science (biophysical, social and economic) to make sound water resources management decisions. This information can be used to build knowledge of environmental systems, facilitate the development of long-term practical models, undertake social impact assessments, evaluate alternative options and contribute to day-to-day management decisions. Research and Development should focus on bridging the gap in areas where other relevant information required in decision-making may not be available. It is important to ensure that this information is packaged in a way that meets the needs of decision makers seeking to implement sustainable water resource management, thereby turning information into knowledge.

Applied research and development is needed in several areas of water resource quality monitoring. These needs include the development of indices, methods for collecting and using ancillary data, modelling complex systems and ecosystems, measuring and assessing ecological health, and sampling and analysing toxic constituents at affordable costs. Additionally, methods are needed to design and operate monitoring for non-point sources of pollution and variables that are difficult to quantify. Technology is needed to improve field-based instrumentation, laboratory equipment, computer technology for analysis and the presentation of results. Achieving the national water resources monitoring goals will require sustained support for applied interdisciplinary research and development to address these and other knowledge gaps.

The Water Research Commission, the CSIR, the former IWQS (now RQS) and various universities have been involved in research over a long period of time. Much has been produced but the information is often not easily accessible. Internal publications of the various institutions have not been widely disseminated. Documents are not easily accessible to other researchers, decision makers and the general public and as such a strategy for information dissemination is required. Such information must be in a format that is user friendly and acceptable to the broader public, while still addressing the specific requirements of the primary user. There must be a more formalised alignment with international best practice, with due consideration for the country’s needs and challenges. Potential areas of activity include:

- *Research into new / improved water resources management practices;*
- *Research into the impediments of change to more sustainable WRM practices;*
- *Identification of new areas of monitoring, international best practice and adaptation;*
- *Identification of bio-physical, social and economic data and research gaps;*
- *Collection of information and undertaking research to fill those gaps;*
- *The development of decision support and negotiation tools for complex decision making;*
- *Improving community and government awareness of the availability of existing information and data resources;*

- *Facilitating involvement of the broader community, government agencies, universities and others in data collection and research (institutional collaboration);*
- *Development of mechanisms for identifying, valuing and making use of local knowledge;*
- *Supporting the development of consistent and reliable frameworks for water resource quality monitoring;*
- *Developing new approaches to extension and adoption of new or improved methods for data acquisition and information generation;*
- *Packaging information so that it is accessible to users;*
- *Organise high profile conferences for information dissemination; and*
- *Collect baseline data for target setting and monitoring and evaluation.*

3.6.5 Co-ordination and liaison

Developing proper institutional arrangements for water quality monitoring remains a challenge in many developing countries, and South Africa is no exception. Government departments involved in collecting water quality data include those responsible for water, health, agriculture, and the environment. In addition, municipalities and various industries collect water quality data for their own internal purposes and for compliance reporting. A significant percentage of these data collection efforts are planned and designed without adequate consultation and co-operation with the potential partners. Consequently, there is often considerable duplication and inconsistencies in the data collected, and major gaps may go unnoticed. In some areas, water quality laboratories may be underused, improperly equipped and the data thereof not properly co-ordinated, and they may not have a sufficient complement of trained people to ensure proper quality control and quality assurance. Experiences from other countries indicate that a functional and cost-effective national water quality monitoring programme can exist only when there is close collaboration between the various institutions concerned. However, it has been recognised that it has not been easy to organise inter-departmental co-ordination in the past, and it is an effort that would require a commitment from all of the institutions concerned in order for the monitoring programme to succeed.

A **coordination** mechanism in the form of a committee or task team is required in order to liaise with other organisations, firstly, to influence their monitoring standards and data transfer, and secondly, to reduce duplication and begin to address gaps where they exist.

DWAF P&R is currently going through a period of major devolution of authority and decentralisation of water management activities. Part of the philosophical change is the acceptance that government cannot and should not necessarily provide all services to the public. Within the water resources quality programme there is an acceptance of the need to examine alternate ways of doing business, including use of the private sector as a means of reducing costs and of reducing in-house demand for scarce human resources.

Decentralisation by its very nature requires the co-ordination of activities among responsible institutions, which in essence requires the institutions to collaborate and complement each other. An intensive communication drive is required to facilitate the collaboration between and co-ordination among institutions so as to encourage a flow of information among and between institutions. Communication will not happen unless there is a deliberate effort to communicate. Dedicated personnel should be made available to oversee monitoring programmes and should be accountable for the quality of data captured. Senior managers in

DWAF P&R must work closely with this unit and provide the desired institutional support as some of the decisions taken would be based on the availability and quality of the data obtained through the monitoring programme.

International collaboration is not currently a strategic activity for institutional strengthening, but occurs as an operational obligation (NWA) i.e. assessment of water quality at a point of exit from SA. International visits are *ad hoc*., with no targeted strategy. There are many obstacles to be overcome in order to achieve effective international collaboration as became apparent when SA, Swaziland and Mozambique embarked upon establishing a working agreement, called the INCOMAPUTO Agreement (Magda Ligthelm: 012-336 8648; TCH@dwaf.gov.za). As is the case with other SA institutions, collaboration concerning monitoring water resource quality should be considered a strategic objective and built into international agreements.

Potential areas of strategic activity include:

- *The provision of community support networks, accompanied by instilling the principles of monitoring, and interfacing with stakeholders;*
- *Provision of technical support for regional structures in developing and implementing water resource quality monitoring plans;*
- *Leadership development programmes within the community regarding water resource quality monitoring;*
- *Community motivation initiatives such as recognition of accomplishments and information sharing forums; i.e. with the farming communities (or WUA's) that are participating in monitoring activities;*
- *Mechanisms for engaging water users and other stakeholders such as local governments and industry associations (accreditation and use of the private sector); and*
- *Establishment of a National Monitoring Council to support monitoring activities and provide strategic direction for monitoring in the country.*

3.6.6 Public participation and public relations

Individuals within the communities and the general public must be made aware of water resource quality issues, and understand the link between these issues and the long-term sustainable reliance on the resource by the community. In this way the general public is able to influence decisions on water resource quality matters that affect them. When the level of awareness of water resource quality issues is raised, it is hoped that individuals will seek to understand more (the WHY aspects), and be motivated to support and participate in the assessment, planning, implementation and evaluation of solutions (the HOW aspects).

Internationally, the trend has been the use of voluntary monitors in water quality monitoring. Volunteers collect data from water that otherwise may not be assessed, and they increase the amount of water quality information available to decision-makers at all levels of government. In the absence of proper training, quality assurance and direct management of volunteer monitors the quality of data they collect would be compromised. It is, therefore, proposed that data from volunteer monitoring programmes must be kept separate from that of the formal DWAF P&R monitoring programmes. However, provision must be made for the storage and management of such data and dissemination of information generated from it.

The main challenge will be to improve the quality of outcomes of the volunteer efforts. The volunteer programmes must also be used for information dissemination, public awareness and local user education. However, it should be noted that the volunteers could generally report on gross pollution / spillage incidents (based on methods they can use without intensive training), and therefore act as "alarms or give the amber light" hence facilitating further investigation.

Links should be established between volunteer monitors and water resource quality monitoring at all levels of government to encourage co-operative planning, training, and data exchange between volunteer groups and government. Consistent quality assurance guidance should be developed for volunteer monitors to help them document their methods and quality assurance protocols. Standard, simple and easy to use field monitoring methods should be developed. These should be the indicator methods. The effectiveness of volunteer monitoring depends very much on the simplicity of the monitored attributes. Use of these methods cannot be mandatory because of differing needs, goals, capabilities, and resources of volunteer programmes. Nation-wide training on laboratory, field, and quality-assurance methods for volunteers should be promoted. Such training helps to encourage consistency in methods, increases the level of quality assurance for volunteer information, and promotes the exchange of ideas and the development of advanced methods.

Potential areas of activity include:

- *Awareness raising activities through community based organisations (e.g. WUA's, Forums) and local events;*
- *Formal advertising and marketing activities in regions;*
- *Engagement of primary and secondary educational institutions in increasing awareness of scholars with regard to water resource quality issues;*
- *National monitoring conferences and workshops;*
- *User education programmes; and*
- *Engagement of the Parliamentary Portfolio Committee on Water.*

3.6.7 Skills development and training

Sustainable WRM requires that available knowledge be translated and implemented and as a result, monitors, analysts and their managers and users should have the necessary skills to undertake the implementation of these activities. A variety of skills exist within DWAF P&R, research institutions and in some communities. However, there has not been an effort to try and match the skills with the needs of the monitoring programmes. While the skills requirements might be related, the existing skills may not fit the requirements of the new monitoring programmes.

Priority must be given to human resources development through continuous education, in-service training, career development, and short-and long -term training. This will require the preparation of a human resources development and training plan by the directorates involved in monitoring (on the job training) in consultation with Directorate HRD (who fund tertiary education bursaries). The human resources development plans for monitoring programmes must be incorporated within the broader strategic human resources development strategy of the department. Monitoring programmes must be kept abreast of developments even after the establishment of CMAs, and the delegation of the monitoring responsibility should be closely regulated.

It is desirable that every manager or co-ordinator of a monitoring programme should have adequately trained staff in the programme. Some of the skills acquired may be relevant for more than one monitoring programme and it would add value if such skills are used across programmes. There is a valid argument that some skills are highly specialised for specific tasks. Such skills must be identified and treated as special cases, where necessary.

Entry-level staff require on the job training to be able to perform their monitoring tasks. It seems that both the length and intensity of training are increasing as a result of the more sophisticated nature of current monitoring activities and equipment. This is putting a strain on DWAF P&R's training budget, as well as the time taken off for training which impacts on the quality and consistency of monitoring. DWAF P&R cannot afford to maintain the *status quo* and has to find ways and means of recruiting relatively more 'hands on' individuals. DWAF P&R is not in a position to compete with the private sector in terms of recruitment mainly because of low salary levels in government and as such a two-pronged strategy is suggested. Firstly, the Department should consider reviewing the current staff recruitment and retention strategy, especially the remuneration and entry levels for scientists and technologists as this is a highly specialised field. Secondly, DWAF P&R should strengthen the existing national water training institutes and provide them with the necessary support in order to identify, encourage, promote, and organise human resources activities and training needs. This will include a review, modification, and co-ordination of training programs in the water sector to ensure that they are consistent with the national strategy.

DWAF P&R has to encourage co-ordination between universities and the water sector to review their curriculum according to the needs of water resources management. In spite of the attention given to university education in the area of water resources, most of the university programmes in South Africa are oriented toward the engineering aspects of water, and very few courses are given in other areas such as water law, legislation, analysis of water systems, linear programming, GIS, and management. Furthermore, the basic sciences that are taught at universities are not necessarily meant to provide a specialisation in water, but rather are general sciences such as chemistry, physics and biological sciences. Only a few South African universities provide studies of aquatic sciences or limnology. A large component of training of water specialists, therefore, is expected to take place while on the job. The possibilities of accreditation of the training by the relevant SETA must be investigated.

Other than a shortage in scientific skills, DWAF P&R has to address the challenge of the shortage of technologists. There is a need for technologists in all areas of monitoring and this would only be improved if the low entry-level salaries are reviewed and incumbents have clearly defined carrier paths.

Potential areas of activity include:

- *Development of tools for the identification of skills and knowledge gaps;*
- *Development of new, and modification of existing training materials;*
- *Strategic delivery of training based on identified skills and knowledge gaps and strategic partnerships with training institutions, industry etc.; and*
- *Extension of skills development into user communities.*

3.6.8 Funding

Adequate funding is a key component of any water resource quality monitoring programme. Monitoring programmes become costly as a result of the need for equipment (both laboratory and field), operation and maintenance of such equipment, chemicals, salaries, and the process of information dissemination. Since the ready availability of the requisite resources and facilities is invariably constrained, the cost-effectiveness of any system proposed must be very carefully considered. Beyond cost effectiveness, there must be proper budgeting for all activities. The current budgets of the various monitoring programmes are not a true reflection of the cost of monitoring. The budgets are presented in terms of the analytical costs, coordination and administration. Staff remuneration is typically budgeted for elsewhere. The various monitoring programmes budget for some training, while the Directorate HRD also budgets for some. For example, the Directorate:HRD caters for the training (bursaries) at tertiary level, therefore, not training specific to any monitoring programme, hence that is done per programme. Moreover, there is a certain level of overlap between the tasks carried out by the various programmes.

Potential areas of strategic activity include:

A detailed process of costing of the salary component of the new monitoring programmes;
The cost of the required equipment (operation and maintenance);
The cost of training of staff;
The cost of information dissemination and community awareness;
The cost of transport and courier services; and
Strategic rationalisation of resources with partner institutions (sharing of monitors, equipment, labs and information).

3.6.9 Implementation structures: Governance

DWAF P&R remains fully responsible for the implementation of this framework. However, there are other institutions such as CMAs, WUAs and Water Boards that have been mandated by law to take over some of the water management responsibilities from DWAF P&R. The Department, while building internal capacity, should extend the benefits of this framework to other institutions.

Some of the recommendations and proposals made in this framework affect stakeholders, and therefore they should be implemented after broad consultations with stakeholders. A lot of compromises by all parties involved will have to be considered. Stakeholders may begin to question DWAF P&R on some of the proposals, hence the process of implementation must be open and transparent.

It will be necessary to establish an institutional structure that will support the implementation of the framework, and also a National Monitoring Council (an independent high-level body charged with oversight of the national monitoring interests). Such a structure is accepted in many countries where there are large programmes dealing with water resource quality monitoring. Membership on the National Council would include representation by the private sector, volunteer monitoring organisations, and government agencies at all levels. Establishment of such a structure serves a variety of purposes including, but not limited to:

- The development of guidelines and tools to provide technical support and serve as a forum for collaborative programme planning development and implementation. The viewpoints of business, academia, farmers' groups, Water User Associations and volunteers are critical to the successful implementation of the strategy.
- The assumption of broad responsibility for promoting implementation of a nation-wide monitoring strategy and co-ordinating collaboration among the various institutions involved in monitoring.
- The facilitation of monitoring and assessment programmes to fulfil their intended initial purpose and support national compatibility and information sharing where purposes overlap.
- Oversee all aspects of water resource quality monitoring.
- Issue guidelines to promote consistency in aspects related to water resource quality monitoring. These guidelines would address the comparability of field and laboratory methods, recommended minimum sets of parameters for specific monitoring purposes, environmental indicators, quality assurance programmes, metadata requirements, data management and sharing, and reader-friendly formats for reporting information to decision makers and the public.
- Encourage, through a communication strategy, the adoption of these guidelines by relevant institutions involved in water resource quality monitoring.
- Co-ordinate the development of a nation-wide training effort to help ensure that appropriate individuals acquire the knowledge and skills needed to carry out monitoring responsibilities.

3.7 Monitoring and Evaluation

Given that water resource quality monitoring outcomes are only achievable over the long term, monitoring the achievement of intermediate outcomes is critical in assessing the impact of short-term investments in monitoring programmes. Capacity building activities are key mechanisms through which these intermediate outcomes can be realised. Monitoring and evaluation of the effectiveness of these activities in bringing about the desired change should be an integral component of developing and implementing a capacity building plan. Monitoring and evaluation are the key mechanisms for:

- Reporting activities against expenditure;
- Assessing the success of various capacity building initiatives and revising the approach towards capacity building accordingly; and
- Revising progress towards targets, and based on this information, reviewing the level to which targets are realistic and achievable in the given time frame.

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The information contained in this report reflects the views of the authors on the issues addressed and as such the authors accept the full responsibility for these. However, our views were influenced over the years and more recently by information both published and expressed in discussions with many people involved in water resources management in general and monitoring specifically. It is impossible to reference every source here, therefore, the list of references provided below should be viewed more as an entry point to some published material and people involved in the field for the reader who wants to pursue some of the topics raised above.

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Informative Web Sites:

http://www.environmentalintegrity.org/

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