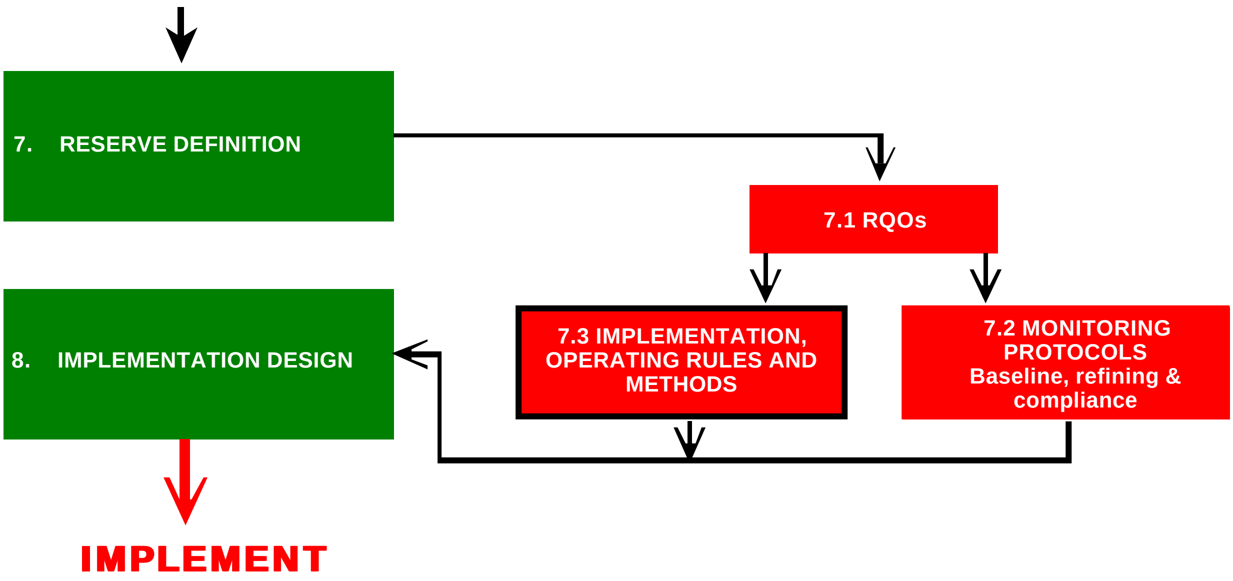
8. IMPLEMENTATION DESIGN *(7 & 8)*



8.1 RESERVE DEFINITION

A Management Class (MC) consists of various categories which are not necessarily compatible - i.e. Ecological category, Basic Human Need category, Domestic Use category, Irrigation category, Recreation category etc. When a recommendation regarding the Management Class is made by DWAF, all the consequences of supplying the Reserve and the various users must be considered. In certain circumstances, it could be decided that due to socio-economic considerations and resulting policy decisions, the ERC associated with the MC might not ultimately be the recommended ERC. This would be a decision taken for political and/or socio-economic reasons.

This phase of the Reserve process takes place **after a decision has been made regarding the Management Class**. Various Reserve and operating scenarios, each with a different ERC will have been identified at this point. One of the Reserve scenarios becomes the Ecological Reserve which must now be defined in context of the Management Class, i.e. the Management Class dictates the Ecological Reserve.

8.2 FROM DEFINITION TO DESIGN

8.2.1 Resource Quality Objectives

Resource Quality Objectives (RQO) are defined objectives for flow, quality, biota and habitat to achieve the ERC component of the Management Class (MC). The flow and quality components of the RQOs have already been defined for each Reserve scenario. Some aspects of biota and habitat RQOs would already have been identified during the definition of the Reserve scenarios. This would require further exploration at this stage to ensure that they are is quantitative and measurable objectives.

As RQOs are not part of the TOR, methods to define RQOs are not provided.

8.2.2 Monitoring protocols

Monitoring protocols must be defined to measure compliance, i.e. whether the RQOs are being achieved. The monitoring should consist of two phases, the baseline collection phase and compliance monitoring. A process to revise and update Reserves based on the results on the monitoring is of the utmost importance. Components that should be monitored are amongst others hydrology, hydraulics, geomorphology, vegetation, fish, aquatic invertebrates, water quality. The complexity of the monitoring will depend on various aspects and the design of the monitoring protocol must consider this. Monitoring also do not form part of this TOR and is therefore not discussed further.

8.2.3 Design of operating rules and methods

The planning stage of implementation effectively involves integrating the Reserve requirements together with all the other demands on the system into a water resource management design. Part of this process should account for the aspirations of the relevant stakeholders, which is a very important component of any Reserve implementation, but will not be discussed in detail in this section as they are covered in chapter 7.

For systems that are dominated by reservoir storage, the planning phase implies establishing the yield and the design of the reservoir operating rules. For systems without major storage, this may involve making decisions about the issuing of abstraction licenses or permits to undertake flow reduction activities such as afforestation.

Design: Reservoir Situations

Typically, the final phase of an Intermediate or Comprehensive Reserve determination (i.e. one where a relatively detailed investigation has been used) is a scenario-planning phase where conflicts between the Reserve and other demands on the system are considered and, where possible, resolved (Chapter 7).

One issue that occurs quite frequently is related to the release of irrigation requirements into the natural channel followed by their gradual removal over a stretch of river by a number of irrigators. As the irrigation water is frequently required during the dry season, this can lead to a reversal of the seasonal distribution of low flows in the river reaches below the reservoir. Artificial flows, which are in excess of natural and which have very low variability, are unlikely to satisfy a Reserve scenario without substantial ecological consequences. The only solution to providing the irrigation water and satisfying a Reserve would be through engineering works (pipelines or canals) that allowed the irrigation water to be distributed without using the natural channel; a rather expensive option.

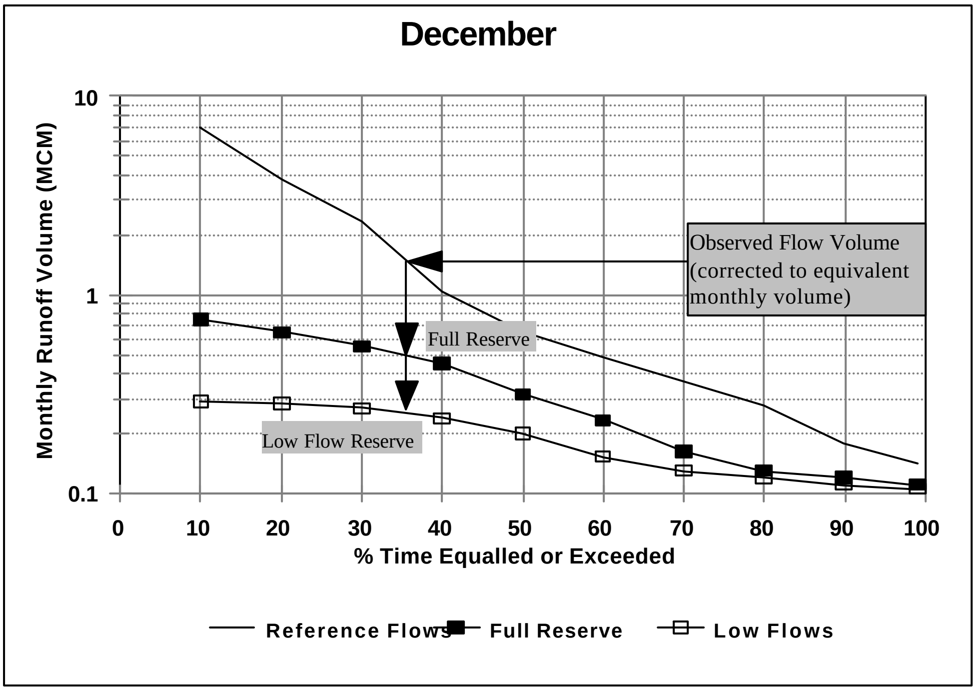
One of the main constraints in reservoir situations is the capacity of the outlet works to make releases to satisfy the high flow requirements of the Reserve, while a related issue is whether or not some of the high flow requirements will be met by natural spills from the dam. It is necessary to consider both of these issues during the planning phase, and a monthly time-scale yield model can provide some of the necessary information. Such a model can indicate whether the patterns of spill volume are sufficient to meet the high flow volumetric requirements and a knowledge of the capacity of the outlet works will suggest whether sufficient flexibility in the operation of the dam exits to make the required peak flow releases. However, a monthly model is incapable of providing the required information to address issues related to synchronising releases with downstream tributary inflows and the hydraulic routing of releases to achieve peak flow objectives downstream. The implementation design phase for situations where there is no, or very limited, high flow release capacity and where there is capacity are therefore quite different and are discussed separately.

No, or limited, high flow release capacity.

In these cases the design of the implementation approach becomes relatively simple and most of the methods are already available. The operating rules for releases consist of the final assurance tables (but ignoring the high flow requirements) established for the Reserve after the scenario planning has been completed. It is then necessary to identify a 'Reference Flow' site that can provide suitable, near real-time, trigger signals for the releases. This site should reflect relatively natural flow variations and could be based on a streamflow gauge, water balance calculations of reservoir inflow volumes, or a near real-time simulation of catchment runoff. The main point is that time series of flow volume data need to be generated at intervals of between 10 days and 1 month and that a representative set of 1-month flow duration curves can be established prior to operation. The operational design then consists of three steps (Figure 8.1):

- Determine the observed volume over the time interval.
- Establish the % exceedence value of this flow from the relevant monthly flow duration curve for the 'Reference Flow' site.
- Use the % point value to look up the required release for the next cycle (10 to 30 days) in the Reserve assurance table.

Figure 8.1 Illustration of the use of a 'Reference Flow' site and Reserve assurance curves to quantify a Reserve requirement.



The use of a 10 day cycle allows some intra-month variation in releases to be achieved and only involves the addition of some simple calculations to interpolate between the Reserve requirements of two calendar months.

Adequate high flow release capacity

These situations become more complex as allowance must be made for high flow releases which can only be based on trigger signals that are available at a time resolution of 1 day or less. The requirements for the 'Reference Flow' site are therefore more stringent and the methods of analysing the flows observed from the site, more complex. Hughes et al. (1997) developed a model (IFR Model) that allows a daily time series of Reserve requirements to be simulated from a daily time series of reference flows, given values for the main flow components of the BBM table, as well as values for their % assurance. The model has since been updated (particularly the high flow release rules and procedures) and can operate as a design tool for determining assurance rules, or as an implementation tool. The assurance rules can be calibrated in a relatively flexible way such that restrictions on the selection of a 'Reference Flow' site are minimised. However, it is still necessary to select a site which reflects similar climate influences on the resulting flow regime that would be expected at the Reserve site under relatively natural conditions. The 'Reference Flow' site must also be able to provide daily flow information to the reservoir operator on a real-time basis.

The model can be calibrated during the design and planning phase by making use of a historical flow time series for the 'Reference Flow' site. The operational use of the model simply involves the regular updating of the 'Reference Flow' daily flow time series, after which the model generates the Reserve requirements. The low flow component of the model is relatively simple and has been demonstrated to give acceptable results. The high flow component is far more problematic and currently operates on rate-of-rise criteria and several other factors that determine whether a suitable trigger event is likely to be imminent at the 'Reference Flow' site. This measure of likelihood is then used, together with the Reserve specifications for high flows, to determine whether to recommend a high flow release and at what level. While the model appears to generate satisfactory results when applied to historical time series, there are several other issues that have to be considered in the design of an implementation scheme.

The most water-efficient method of making releases from a reservoir to satisfy downstream Reserve objectives is to supplement tributary inflows. This is a straightforward objective to achieve in terms of low flows and could be designed using a monthly yield model given adequate information about future water resource developments in the tributaries and the main river. However, to synchronise high flow releases with events occurring in tributary streams will be a much more difficult task and one that will only be worth undertaking if the water savings are likely to be substantial. Any method of triggering high flow releases will have to rely upon some type of forecasting approach, none of which are likely to be foolproof. The IFR model approach of estimating the likelihood of a suitable trigger event from the initial rate-of-rise offers a solution that might prove to be as good as any other practical approach. A sophisticated streamflow and rainfall monitoring system coupled to a forecasting model might be possible, but it is unlikely that the costs involved could be justified in most cases.

Where the Reserve has been determined at a site that is distant from where the reservoir releases are to be made, it will be necessary to account for attenuation of the released high flows. It is unlikely that sophisticated hydraulic channel routing methods will be appropriate in most cases, largely due to the excessive data requirements. It is more likely that some form of calibrated storage-routing model will be appropriate and that the calibration could be based on test releases.

There appear to be many examples where existing dams have some capacity to release high flows, but that capacity is not large enough to satisfy the Reserve requirements. While there are methods available to establish when releases should be made and how large they should be, there do not seem to be established procedures for making a decision about whether to meet the Reserve or to suffer the ecological consequences of not meeting the Reserve. The highest flow components of the Reserve are usually included to satisfy the geomorphological objectives of maintaining the channel form. If that objective is not achieved, then unfortunately many of the other flow requirements may not achieve their stated objectives, as the relationships between flow and habitat are likely to change. Having made such a statement, it should also be pointed out that the relationships between channel form and the high flow regime of South African rivers are not very well understood. This makes it difficult to quantify the high flow requirements of the Reserve with a reasonable degree of confidence. The costs of dam construction (or alteration) to incorporate outlet works with the capacity to release high flows are very high (an additional R46 million or 9% of the total dam cost to extend the Skuifraam Dam outlet works from 30 $m^3 s^{-1}$ to 160 $m^3 s^{-1}$). Perhaps these two factors together explain why it remains a difficult task to finalise the design of the high flow component of a Reserve implementation.

Design: No Regulating Mechanisms

This type of situation is found where the main types of development are streamflow reduction activities such as afforestation, abstraction from small farm dams and run-of-river abstractions from the main stream. One of the most urgent requirements for implementation 'design' is the need to account for the Reserve during the process of issuing licenses for new abstraction or afforestation permits. As these water resource development activities are not really capable of regulating flow (although see some comments later), the technicalities of interpreting a Reserve design for implementation purposes should be relatively simple. The Institute for Water Research has developed a prototype 'model' that can be used to assess the Reserve requirements relative to present day conditions for small to moderate sized catchments. The model also provides decision support information to regional DWAF staff to assist in the process of issuing new permits.

The model (Figures 8.2 and 8.3) requires a monthly time series of natural flows (possibly obtained from WR90 – Midgley et al., 1994) and a text file of Reserve assurance rules. It also requires information about existing and license applications for afforestation, farm dams (storage volume, catchment area, annual abstractions including evaporation and seasonal distributions of abstractions), as well as run-of-river abstractions (seasonal distributions and annual abstractions for four assurance levels). The model calculates the calendar month duration curves for the natural flow data and makes use of the CSIR estimation methods (Scott and Smith, 1997) to adjust them to account for streamflow reductions due to present day afforestation. A simple water balance model is then applied to estimate the present day effects of small farm dams and the run-of-river abstractions at different assurances are used to further reduce the duration curves to a representation of present day conditions.

Fig 8.2 Screen images of some of the information input components for the simple Reserve implementation model designed for small to medium catchments with no major regulating mechanisms.

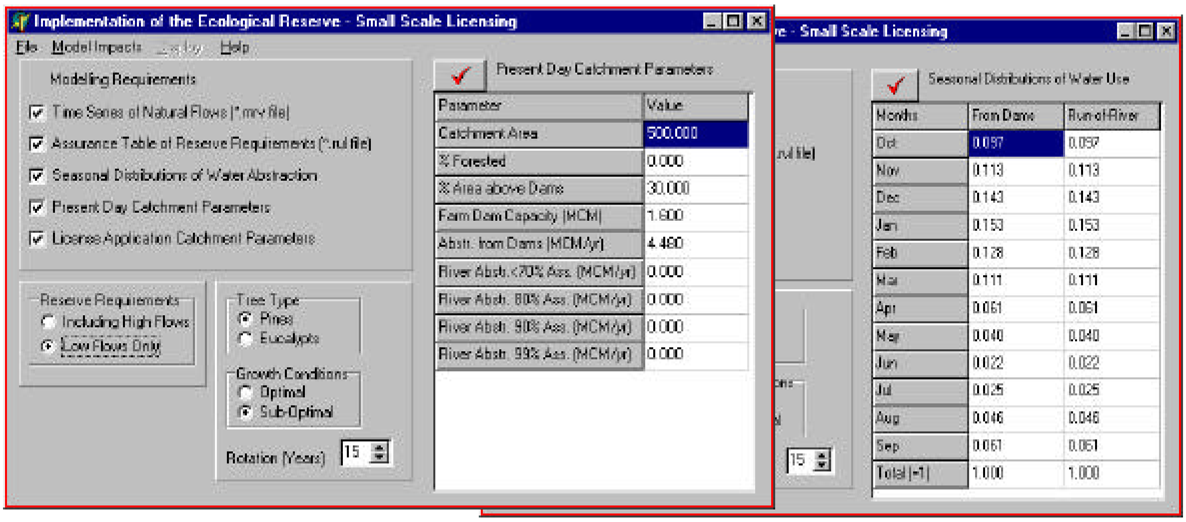
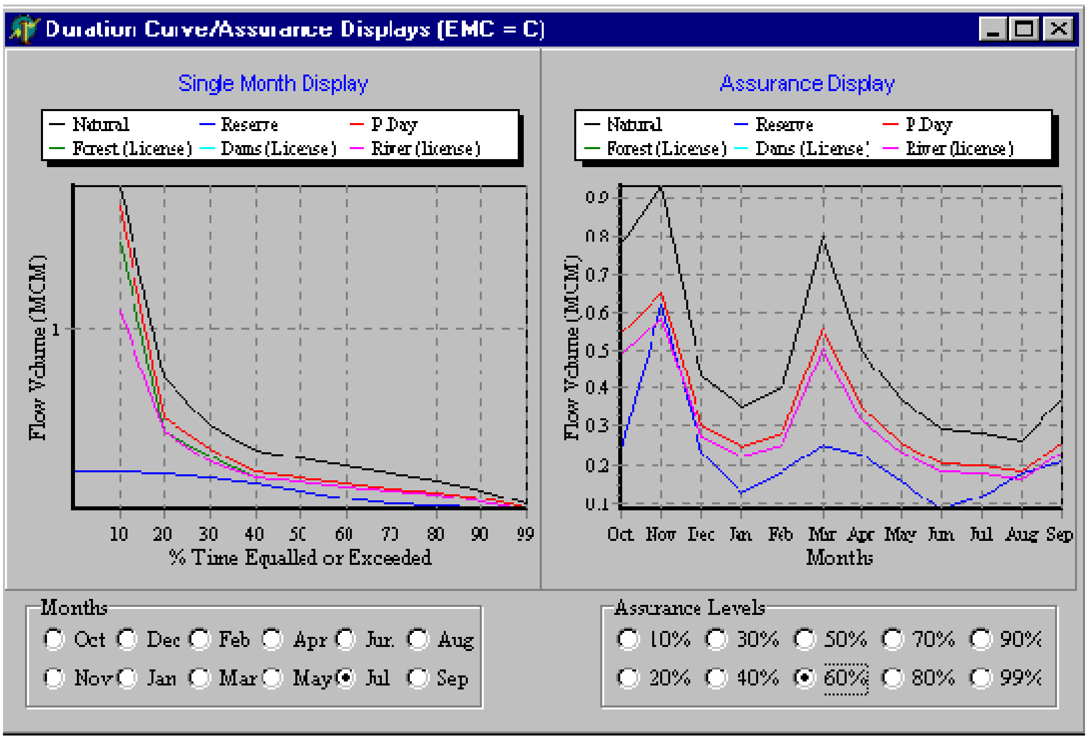


Fig 8.3 Screen image of the results display component for the simple Reserve implementation model designed for small to medium catchments with no major regulating mechanisms.



The information on license applications for the three types of development are then applied in the same way to generate three additional duration curves for future possible conditions. The results are displayed (Figure 8.2) as sets of curves for a selected calendar month and as flow volumes for selected % points for all calendar months. It is then a simple process to identify to what extent present day, or future conditions may violate the Reserve requirements.

An allowance has been made in the model to make use of the full Reserve requirements, or to use only the low flow requirements. This feature has been included as many of the developments referred to are less likely to have an impact on isolated high flow events than on base flows. Including the high flow requirements may therefore confuse the issue and indicate violations of the Reserve that are more an artifact of the use of monthly volumes (rather than daily flows) in the model. However, it is possible that a large number of farm dam developments could have an impact on high flow events, particularly those that have relatively low peaks and occur frequently. The option to include the high flow requirements is still therefore necessary. The model uses very simplistic methods of estimating the development impacts, which are considered appropriate, given the lack of precision in the information that is likely to be available.

The model has yet to be assessed by potential users (DWAF Regional Offices and future Catchment Management Agencies) and it is therefore too soon to tell whether or not the relatively simplistic approach is adequate, or whether additional detail is necessary. However, even in its existing format, the model should be useful for identifying the potential problems (from a Reserve point of view) of issuing permits for different types of water resource developments, as well as suggesting some amelioration measures that could be implemented to resolve problems. Possible amelioration measures might include the reduction of run-of-river abstractions at high assurance, or the allowance for farm dams to make compensation releases.

While the model presents a possible approach for the DWAF Regional Offices (or CMAs) it only becomes practical if the information requirements can be satisfied. While the Reserve determination methods are compatible, it appears that the information on current water use is frequently not available. This situation has largely arisen from the fact that prior to the Water Act of 1998 it was not necessary to license abstractions and there is therefore frequently little accurate quantitative information available. If existing abstractors are asked to quantify their historical water use, in preparation for licensing in terms of the new Act, it is quite possible that they would exaggerate to try and secure future water availability.

Operational Stage

The previous section has illustrated that there are techniques available that can be used in designing an implementation approach to managing water resources that incorporates the Reserve. However, it is one thing to design a management approach and another to actually put it into practice. From a purely technical point of view the major requirement is the ability of the water resource manager to obtain real-time observations of stream flows from the 'Reference' site that was used to design the implementation scheme. If the scheme is not being operated for high flows then 'real-time' effectively translates into once every 10 days or so. If high flows are to be managed, then 'real-time' becomes daily, or even more frequent. Neither of these two requirements is excessively onerous given the technical capabilities of modern hydrometeorological observation systems.

The issues related to the operational phase are therefore more concerned with the willingness to adapt past management methods to accommodate the Reserve and with problems related to enforcing compliance. There was a large emphasis in the previous water law on private ownership and therefore private management. The emphasis is now on public management of water resources and it is only under such a system that the implementation of a concept such as the Reserve can be considered tenable. However, it must also be recognised that it will take a long time for some water consumers to become familiar with, and accept, new water resource management practices. Licensing abstractions, and placing restrictions on water use during droughts, is only going to be worthwhile if checks are carried out to ensure that the terms of licenses are not being violated. This inevitably means an extension of the responsibilities of DWAF (or CMAs) to include policing and checking that abstractors are not violating the terms and conditions of their licenses.

One of the critical requirements appears to be the need for more widespread public understanding of the long-term benefits of implementing the Reserve and the fact that it is designed to ensure sustainable use of our water resources. Without adequate 'buy-in' and participation from the broad range of water users, it will be an almost impossible task for DWAF to operationalise the Reserve. It is considered that the CMAs of the future and Community Water Forums have a major role to play in this regard.