

WQ2000: DEVELOPMENT OF AN INTERACTIVE SURFACE WATER QUALITY INFORMATION AND EVALUATION SYSTEM FOR SOUTH AFRICA

FINAL REPORT

to the

WATER RESEARCH COMMISSION

by

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WRC Report No: 950/1/04

ISBN: 1-77005-111-2

February 2004

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ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission and is entitled: "WQ2000: development of an interactive surface water quality information and evaluation system for South Africa"

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The financing of the project by the Water Research Commission and the contribution of the members of the Steering Committee are gratefully acknowledged.

This project was only possible with the co-operation of many individuals and institutions. In this regard the authors wish to record their sincere thanks to Mr B Woolf-Piggott Department of Water Affairs and Forestry and Mr AK Bailey, Stewart Scott Incorporated.

ABBREVIATIONS

CMA Catchment Management Agency

DWAF Department of Water Affairs and Forestry

GIS Geographic Information System

GNP Gross National Product

RDP Reconstruction and Development Programme

USS User Support System

VRSAU DWAF Vaal River System Analysis Update study

WMA Water Management Area

WMS Water Management System. DWAF model and database

WQ2000 Water Quality 2000 model. The modelling system that is the subject of this

report

WQT Hydro-salinity water quality model (RB Allen and CE Herold, 1988)

WR90 Water Resources 90 database and manuals (Midgley et. al., 1994)

WSAM Water Situation Assessment Model (MD Watson and CB Schultz, 2000)

EXECUTIVE SUMMARY

INTRODUCTION

Much of South Africa is water stressed resulting in the continual need to develop water resources. Increasing reliance has to be placed on effluent return flows. Pollutant loads are also added by mining and industrial development, with evaporative concentration of salts in impoundments and irrigation schemes. This, together with the general aridity of much of the country, has lead to increasing salinity problems. Meaningful evaluation of water resource development schemes therefore requires assessment of water quality. Salinity has long been recognised as the most intractable and economically important water quality problem.

For the past two decades the tools have been in place to integrate salinity into the water resource planning process. However, high cost and time restraints have prevented this from taking place in all but the biggest development schemes. Even in these instances water quality evaluation has tended to be addressed only once the most favoured options have been chosen on quantitative criteria.

This raises the need for a tool that will enable planners to make rapid low cost, but realistic, initial assessments of water quality impacts at the earliest planning stage. The WQ2000 interactive system is aimed at providing just such a planning tool.

The initial focus was on developing and testing the system for the Vaal River catchment. This would be followed by refinement of the methodology and extension to include the remaining South African hydrological regions.

WQ2000 allows the user to:

- · Rapidly assess the salinity implications of anticipated developments
- Provide support for more detailed assessments
- Overview the salinity status of resources
- Support extension of the WRC's Water Resource 90 (WR90) resource quantity assessment to other Southern African countries
- Provide input to the DWAF's Water Situation Assessment Model (WSAM).

Three project phases are envisaged:

- Phase 1: Development of and testing of methodology
- · Phase 2: User testing and model refinement
- Phase 3: Extension to remainder of South Africa.

MODEL LAYOUT

The WQ2000 model layout is shown in Figure 1.

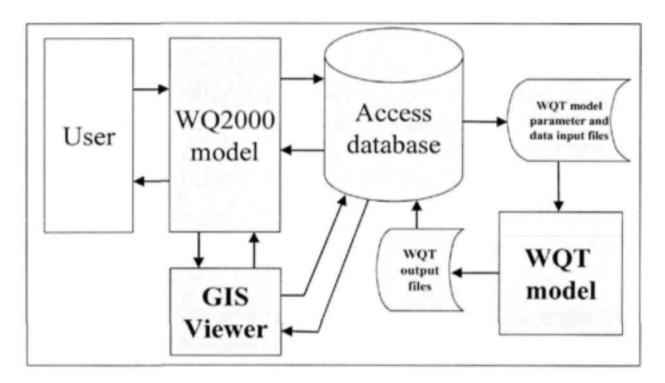


Figure 2.1: WQ2000 Model structure

WQ2000 provides the interface between the user, a database containing a large amount of data for each quaternary catchment, the monthly-time step WQT hydro-salinity model and the DWAF's GIS Viewer.

This enables the user to run the WQT model for a selected quaternary catchment and view the results for four different conditions:

- Virgin conditions for the specified quaternary catchment
- · Virgin conditions for the entire cumulative system
- Developed conditions for the specified quaternary catchment
- Developed conditions for the entire cumulative system.

The user can elect to use default present day values, or to modify them via the user-friendly screen interface.

The GIS Viewer provides a means to present the results for a number of quaternaries.

HYDRO-SALINITY MODEL

The WQT hydro-salinity model represents the catchment system by means of user defined sub-system elements connected by flow routes. The following five discrete WQT sub-model elements are used in WQ2000:

- Catchment salt washoff sub-model
- Channel reach sub-model
- Irrigation sub-model
- Junction sub-model
- Reservoir sub-model.

The selected quaternary catchment is represented by two catchments, namely the quaternary catchment itself and the upstream catchment area.

MODEL CALIBRATION

The following factors prompted the selection of the Vaal River catchment as the study area:

- Strategic importance of the catchment
- Severe water quality problems
- Availability of an extensive database and recent calibration of the WQT model
- Familiarity of researchers with catchment
- Initiatives to extend the DWAF's WSAM model to include salinity
- The comprehensiveness of the study area.

DATA PREPARATION

A large amount of data had to be prepared for inclusion in the WQ2000 model. The default values reflected in the menu sheets are drawn from this data.

Three basic types of data are stored. These comprise:

- Quaternary catchment physical data
- WQT model parameter values
- Monthly data files.

The default values can be changed to reflect new or planned catchment developments. Permissible changes can be made to:

- Paved urban area
- Irrigation area supported by farm dams and opportunistic irrigation area
- Irrigation area from main stem river supported from upstream major dams
- Wetland area
- Channel bed loss
- Catchment runoff proportions upstream of minor and major dams
- Major or minor dam full storage capacities and full storage areas
- Dam basin shape
- Effluent and mining quantity and quality
- Inflow from inter-basin water transfer
- · Water requirement from minor and major dams
- Compensation release from the major dam
- WQT catchment salt washoff module calibration parameters.

Any number of such changes can be made simultaneously for the selected quaternary catchment, and can be changed again in subsequent runs. Simulated quaternary catchment outflows can be stored as defined files. Such defined flows are used In subsequent runs for downstream quaternaries, obviating the need to re-simulate all the upstream quaternaries.

The main data sources used to populate the WQ2000 database include:

WR90:

WRC Water Resources 90 reports and database

WSAM:

DWAF Water Situation Assessment model

VRSAU: DWAF Vaal River System Analysis Update study.

MODEL CAPABILITIES

Standard runs: WQ2000 allows simulation of time series of monthly flows and TDS concentrations for any selected quaternary catchment for natural or present day development conditions using the standard default values. The model then automatically generates a result summary that contains the following information for natural and present day conditions with and without the effect of inflows from upstream catchments:

- Quaternary outflow TDS concentration (average, median, 95 and 98 percentiles and flowweighted average)
- Quaternary average outflow volume
- Catchment runoff before alteration by channel and reservoir storage, irrigation, point inflow or abstraction (average volume and TDS concentration)
- Average TDS concentration in major dam and flow-weighted average TDS concentration of spillage.

User defined changes: One or more of the default parameter values may be changed. This powerful feature allows the user to play the "what if?" game. For example, the effect of a new dam, changed effluent discharge or effluent quality may be tested.

Mapping: WQ2000 allows the user to generate, display and print maps.

MODEL LIMITATIONS

WQ2000 is intended primarily to provide a rapid assessment of the expected salinity implications of a planned development, or to prepare an overview of the regional salinity status. This is a powerful and flexible tool. However, it does have limitations that need to be observed.

- System simulation: WQ2000 is not a large system simulation model. In particular it is not
 intended to simulate month by month variations in water release between dams in highly
 regulated river reaches involving more than two major dams.
- Feedback loops: WQ2000 does not cater for feedback loops.
- Detailed evaluation: In many instances the standard WQ2000 system layout will be sufficiently accurate to yield the final results required to support the investigations.
 However, more detailed evaluation of some development options may require a custom made system layout to more accurately describe the catchment features.

USER MANUAL

A user manual has been prepared. This is available in electronic form via the WQ2000 help menus.

FURTHER DEVELOPMENT

Two types of further development are proposed. These comprise extension of the WQ2000 model to include the rest of South Africa and improvements aimed at increasing the versatility the system.

Envisaged enhancements include:

- Graphical display: Inclusion of routines to plot time series and duration curves of monthly flow, TDS concentration and TDS load.
- Comparison with water quality targets: Tabular and graphical comparison of simulation results with water quality standards and user modifiable water quality targets.
- Imigation model parameters: Inclusion of menu tabs to adjust WQT irrigation module parameter values.
- Future time horizons: Provision of scenarios of future development conditions and routines to calculate appropriate starting catchment and irrigation area salt storages.
- Other water quality variables: Extension to include other water quality variables.
- System modelling: Setting up of a large-scale coarse system model to simulate the monthly releases from the major system dams.

CONCLUSIONS

The main conclusions are as follows:

Attainment of project aims: The WQ2000 model has been successfully developed and applied to the Vaal River catchment. The study area includes both highly developed and undeveloped catchment areas. In many instances model calibrations were interpolated to cover large incremental catchments.

Model uses: WQ2000 provides a powerful means to rapidly assess catchment water quality using a sophisticated monthly time step hydro-salinity model, without the user needing any indepth knowledge of the WQT model or its calibration. WQ2000 can be used to:

- Obtain a rapid overview of the current water quality status
- Obtain present day (or natural) WQT model calibration parameter values.
- Rapidly test a wide variety of development options, including:
 - Change in urban area
 - Change in irrigated area
 - Change wetland area
 - Introduce new dams, or change the sizes of existing dams
 - Change mine pumpage flow rate and concentration
 - Add new effluent sources or alter flow rate and TDS concentration
 - Alter water importation flow rate and salinity
 - Change or introduce channel bed loss (usually associated with mining)
 - Change water demand on minor dams or major dams
 - Change the major dam minimum water release.
- Compliment to WR90: WQ2000 is a valuable complement to the existing WR90 and could serve as a useful prototype for its proposed extensions.

RECOMMENDATIONS

The following recommendations arise from the project:

Application of WQ2000: The WQ2000 model should be put to use by DWAF, consultants and Water Board practitioners as soon as possible. This will permit taking account of water quality at all levels of scheme development. The speed and ease of use of WQ2000 makes it feasible to carry out water quality assessments for even the smallest schemes and at the very earliest stages of project development.

Identification and solution of problems: It is anticipated that use of the model may reveal some shortcomings. It is strongly recommended that such problems are brought to the attention of the developers so that appropriate correction can be made. Provision should be made to issue a new distribution CD-ROM after one year's use and to set up a Web Site where new revisions can be posted.

Model improvements: Model enhancements that have already been identified should be implemented at an early stage. These include:

- Graphical display of monthly time series and TDS duration curves
- · Comparison of simulation results with water quality targets
- Future time horizon development scenarios and routines to calculate starting catchment and irrigation area salt storages
- Irrigation model parameter adjustment
- Inclusion of other water quality variables (after geographical extension of the existing system)

Extension to rest of South Africa: The WQ2000 model database should be extended to cover the remaining Water Management Areas (WMAs).

Recommended program: A phased approach is recommended:

- Phase 1: Model development This is the initial development phase, which has been completed with this report and its products.
- Phase 2: Model testing and enhancement A one-year phase is envisaged.
- Phase 3: Extension to remainder of Country
 It is anticipated that this would require 2 to 3 years. It could best be co-ordinated with the revision of WR90.

1. INTRODUCTION

1.1 Background and motivation

Large portions of South Africa can be described as water stressed and are expected to become more so in the future. This will result in the need to further develop water resources. Since much of the country is semi-arid, increasing reliance will also have to be placed on effluent return flows. These, together with pollutant loads emanating from mining and industrial development and evaporative concentration of salts in impoundments, will inevitably lead to further salinity problems that will degrade the value of the nation's vital water resources. The stage has already been reached where an evaluation of water quality is essential in evaluating alternative water resource development options. A case in point is the highly developed Vaal River catchment, where salinity already plays a major role in both the planning and operation of the Vaal River system.

If the Reconstruction and Development Programme (RDP) initiative and the drive to build the national economy are to succeed, it will become essential to develop available water resources to their optimum potential. As has already proved to be the case for existing intensively developed catchments, the increasing level of development will inevitably give rise to potential pollution problems. Sustained development will therefore require early anticipation of water quality problems, which if not properly countered could lead to inappropriate development of water resources (that may later have to be abandoned or remedied at great expense). It is therefore essential to consider both the short and long-term water quality implications of every land use or water resource development project, irrespective of its size.

In the case of large-scale development options, the resources are generally available to carry out the requisite water quality studies. However, the budgets available for the numerous smaller projects that will be required (such as RDP developments, the raising or construction of new municipal dams, etc.) will be much more constrained. Moreover, it is unreasonable to expect all of the consultants or other parties handling many such studies all over the country to have the technological expertise required to carry out the requisite complex water quality modelling studies. The danger then, is that due consideration of water quality impacts (if considered at all) will not receive sufficient attention until the more detailed feasibility or design stage, by which time urban development or dam sites have already been pre-selected. Discovery of water

quality problems at this late stage can be very costly, since by then money would already have been spent on more detailed planning, design and foundation investigations. The dilemma posed is that it is equally costly to carry out expensive water quality modelling studies for all of the alternative sites and options at the prefeasibility stage. Another problem is that limited available financial and expert professional resources will be wasted through duplication of effort when different studies are carried out. Time constraints may also rule out conventional detailed water quality studies.

This raises the need for a tool that will enable planners to make rapid low cost, but realistic, initial assessments of water quality impacts at the earliest planning stage. The newly developed interactive system described in this report is aimed at providing just such a planning tool.

1.2 Aims

The project is being pursued in two phases. This report deals with Phase 1, which had the following aims:

- Develop the structure for an interactive water quality information and evaluation system for South Africa to complement the manuals and databases produced in the WRC's "Surface Water Resources of South Africa 1990" (Midgley, et. al, 1994).
- Develop and/or adapt the basic methodology, algorithms and presentation formats required for each section of the system.
- Prepare the first segment of the system, for the Vaal River catchment (i.e. "C" region).
- Demonstrate the applicability of the methodology and algorithms for a data poor catchment.

The focus of this phase is on salinity.

This would be followed by refinement of the methodology and extension to include the remaining South African hydrological regions. The extension of the methodology to other water quality variables would also be considered. The potential of including other water quality models in the system would also be assessed at this stage. This would be particularly relevant in the case of other water quality variables.

1.3 Products

The products of the research project include:

- A methodology and basic structure for an interactive surface water salinity information and evaluation system for South Africa.
- A system for making first-order projections of the effect of expected (or planned) changes in land use and/or water resource development.
- An interactive electronic water quality system for the Vaal River catchment for rapid initial assessment of the salinity of surface water resources. This includes options for generating a clear and concise overview of the most relevant water quality characteristics of surface water resources of the Vaal River catchment, and for estimating the impacts of land use and water resource development.
- An electronic data base containing the basic information for the test catchment, including the parameter data files and model parameter values and monthly data files for the WQT hydro-salinity model (Allen and Herold, 1988) for each calibrated sub-system and the ability to disaggregate this to the quaternary catchment level.

1.4 Applications

The following benefits can be derived from the research products:

1.4.1 Rapid assessment of salinity

WQ2000 provides a means for water resource planners and other practitioners to make a rapid low cost assessment of the key characteristics of the salinity of a water resource (both before and after construction of the necessary dams). This will permit decision makers to take better account of water quality implications in the earliest planning stages, allowing a more rational selection of options to be examined in greater detail. This in turn should result in significant cost savings (at the planning, design and subsequent operational phases).

Similar benefits should accrue from being able to make a rapid assessment of the impact of proposed effluent discharge or land use development. This could assist both developers and regulatory authorities in anticipating and prioritising problems requiring further investigation.

1.4.2 Support for more detailed assessments

The accompanying electronic database provides more specialised users with a ready means of generating sets of data files and water quality model parameter files that can be used to run the WQT hydro-salinity model for more complex systems, should the need for more detailed investigation be identified.

1.4.3 Salinity status of resources

The new system opens the possibility of providing decision-makers (and the general public) with the means of generating a "State of the Nation" review with respect to the salinity of surface water resources. As such it will be an invaluable supplement and extension to the WRC's widely acclaimed WR90 set of South African surface water resource manuals (Midgley et. al, 1994).

1.4.4 Extension of WR90 to other Southern African countries

It is understood that the WRC is negotiating with US Aid for funding to carry out such an extension, which would include water quality, as well as water resources. The methodology and structure developed for the WQ2000 system provides an excellent tool for the extension of the WR90 manuals to other Southern African states, since it takes the initial concept of fixed manuals one step further to an interactive electronic database.

1.4.5 Input to WSAM

The basic water quantity version of the Department of Water Affairs and Forestry's (DWAF's) Water Situation Assessment Model (WSAM) is currently at an advanced stage of development (Watson and Schultz, 2000). Work is now being undertaken to develop water quality routines. The initial focus is on salinity assessment, with particular reference to the Vaal River catchment (Schultz, 2002).

The research products provide a ready means of generating some of the essential water quality information required as input to WSAM.

1.5 Approach

Three project phases are envisaged:

- Phase 1: Development of methodology, preparation of generic algorithms, user interfaces and database for salinity for the first segment of the database covering the Vaal River catchment.
- Phase 2: User testing and model refinement.
- Phase 3: Preparation of segments covering the remainder of South Africa, with possible extension to other relevant water quality variables.

1.5.1 Phase 1: Initial development for Vaal River

The main emphasis of the initial development is on salinity, which is the most problematic water quality variable.

The model produces results at a quaternary level, both for the local catchment off the main stem of the river and for the main stream affected by upstream catchments.

The original concept required the analysis of a range of catchment development conditions and the development of regional algorithms that can be used to approximate the impact of catchment development on water quality. This approach would have entailed dividing the catchment into representative regions, pre-processing the output data for each region for a range of development conditions, determining

appropriate algorithms and storing the relevant data for each region or quaternary. The user would then select a quaternary of interest, specify an effluent inflow volume and TDS concentration, dam size, water demand and importation flow and concentration. The model would then have used the pre-developed algorithms and look up tables of algorithm values to determine the quaternary salinity results.

At an early stage many advantages were recognised of an alternative approach. The alternative, which was adopted, involves making use of the WQT monthly time-step hydro-salinity model (Allen and Herold, 1988) to simulate a monthly time series of flow and salinity for the unique conditions specified by the user.

Hence, instead of preparing and storing a set of algorithms and look-up tables for each region, the system instead incorporates files of regional WQT model calibration parameters and naturalised monthly catchment runoffs for virgin and present day conditions. This information is derived from model calibrations carried out for the Vaal River System Analysis Update (VRSAU) study. Physical data (e.g. catchment area, MAP, monthly evaporation and wetland area) for each quaternary is also stored along with present day development status (e.g. major and minor dam characteristics, urbanisation, irrigation area and monthly crop factors). A standardised system layout comprising the local quaternary plus the upstream quaternaries is used. Allowance is made for wetland and streambed losses, major dams and farm dams, irrigation supported by farm dams and opportunistic irrigation, irrigation from the main stem river, effluent point discharge, water importation, water abstraction and pre-calculated inflow from upstream catchments. The system elements are described in greater detail in Chapter 3.

The user selects the quaternary of interest. He can then elect to use default values that have been pre-prepared to represent present day conditions. The user can also elect to set up a customised database for the current quaternary and upstream catchment comprising his own changes to one or a number of development characteristics and even WQT model parameters. The model is then run for the selected conditions and the results are presented for both virgin and altered conditions (present day defaults or user-specified values). Typical changes that the user may wish to test include the introduction of a new dam, altered abstraction or effluent flow or TDS concentration, changed irrigation areas or water importation.

Results are primarily expressed in the form of a report for both virgin and altered conditions, comprising the simulated salinity at selected key points. The advanced user also has the option of storing the prepared WQT parameter, monthly input and output data files for later use. Options for mapping prepared values are also available.

The methodology that has been developed places a powerful sophisticated analysis tool in the hands of users. Such users no longer need to be specialist modellers to successfully use the system. Although much of the capability of the monthly time step WQT hydro-salinity model is utilised (with some extended features), the system has been set up to operate seamlessly and invisibly. The long time delay involved in setting up the system layout and the required recourse to specialist modellers is therefore obviated. This enables the water quality consequences of a wide range of options to be assessed rapidly and at low cost. In many such instances these analyses would simply not have been carried out due to lack of resources (funding, specialist manpower and time).

1.5.2 Phase 2: Model testing and refinement

Phases 2 and 3 are not addressed in the current research study.

The WQ2000 database contains data for a large number of quaternary catchments. Many variables and parameter values are used to describe the natural and developed characteristics of each catchment. It is therefore anticipated that some anomalies may have to be addressed. The first year's use of the model by DWAF and involved consultants should prove to be the best means of identifying such issues.

Some desirable model enhancements have been identified during the initial development stage. Ideally these should be implemented before embarking on Phase 3.

1.5.3 Phase 3: Geographical extension

Phase 3 is to be a national effort that will involve more than one organisation. It would most likely involve a number of consulting firms. In particular, the participation of some or all of the firms involved in the DWAF's Provincial Situation Analyses is anticipated. It is quite feasible to proceed with coverage of the entire country after completion of Phase 1, since the necessary hydrological data (i.e. from WR90) and water quality

data (the DWAF's various water quality databases and the information proceeding from the Provincial Situation Analyses) is in place. Moreover, large areas of the country have already been covered by studies that have included (or soon will include) calibration of the WQT model. These include the Vaal, upper Crocodile, Orange, Fish-Sundays and upper Olifants River catchments.

Model refinements that may be considered include:

- · Graphical output of results
- Extension to other water quality variables.
- Adaptations of the output data to more specifically meet the input data needs of the water quality component of WSAM. These needs are not yet fully apparent as the WSAM water quality algorithms are still being defined.

2. MODEL LAYOUT

2.1 WQ2000 model structure

The WQ2000 model layout is shown in Figure 2.1.

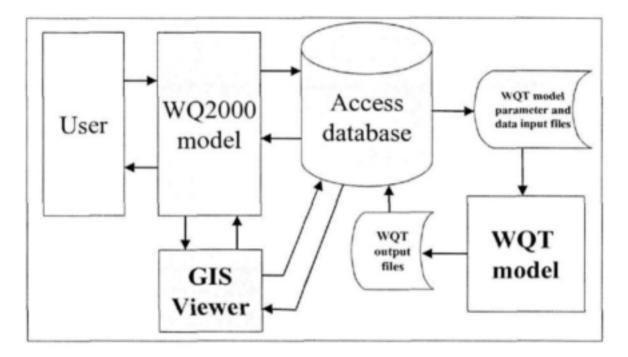


Figure 2.1: WQ2000 Model structure

2.2 Model description

2.2.1 WQ2000 model

The WQ2000 model provides the interface between the user and the underlying Access database, the WQT monthly time-step hydro-salinity model, the GIS Viewer and the input and output text files. This model is written in Delphi and the user navigates through the system via a series of user-friendly input screens. In response to user instructions, default values for the chosen quaternary catchment and its upstream catchment can be altered. Instructions are then given to run the model, generate reports and view graphics.

On running the model, WQ2000 prepares the appropriate input data files and initiates execution of the WQT model for four different conditions:

- Virgin conditions for the specified quaternary catchment (i.e. for that portion of the quaternary catchment off the main river channel with no influence from upstream catchments)
- Virgin conditions for the entire system (including the influence of upstream catchments)
- Developed conditions for the specified quaternary catchment (default present-day conditions or as customised by the user)
- Developed conditions for the entire system.

WQ2000 then reads the relevant output answer files for each simulation and extracts or computes the required output variables. Such output typically comprises arithmetic or flow-weighted mean TDS concentrations and percentile values at key points for the four conditions listed above. Key points of interest include the catchment outlet, TDS concentrations in the major reservoir and in the reservoir spillage.

Options are provided to view and print plots of selected stored WQT model parameters or results for a number of quaternaries. This is done by means of the DWAF GIS Viewer (Wolff-Piggott and Olivier, 2001). The database contains pre-prepared quaternary information for the four bulleted conditions (virgin and developed conditions for each quaternary dependent and independent of the upstream catchment) for default conditions.

In instances were the default values have been modified, the user can elect to store the customised values in the project database. This preserves them for further use by preventing them from being over-written when next the model is run for another quaternary catchment. By this means the user can build up a project database incorporating new customised values reflecting the latest catchment developments.

Appendix A describes the various input screens presented to the user. These screens show some typical default values that can be adopted or modified by the user. It also shows the type of results that can be generated.

2.2.2 Access database

Original default base data for natural and present day conditions for each quaternary are stored in an MS Access database. This comprises files of monthly catchment runoffs for paved and pervious catchment surfaces and rainfall data for the period October 1925 to September 1995. Catchment characteristics, major and minor reservoir, irrigation, present day abstraction and effluent data is stored for each quaternary catchment, together with the relevant WQT model parameter values. WQT model catchment washoff module parameter values are stored for each larger subsystem for which the model was calibrated during the VRSAU study (rather than for each quaternary catchment). This pre-prepared default data is stored in the directory C:\WQ2000\Base data.

The WQ2000 model uses this information to prepare input data files for use by the WQT model. Certain of the results from a WQT model run can also be stored in the Access database for use by the GIS Viewer.

The WQ2000 model does not provide the user with any options for altering the original default data. This data serves as the template for creating a user project database, which initially is populated with data identical to that in the default database. Any user-defined modifications can be stored in the project database. The user can elect to build up his own new default project database that reflects known catchment developments that have occurred since the original default database was issued. After one or more project databases have been created, any of them (including the original default database) can be used as the foundation for developing a new scenario.

For example, over a period of time the user may have built up a new default database called C:\WQ2000\Changed default, which has been added to as new catchment changes have occurred. He may then wish to test some options involving the introduction of a new effluent source. A new project file C:\WQ2000\New effluent 1 might then be created reflecting the proposed changes. On running this option the results summary may show unacceptable salinity at some downstream point in the system. Another run (with a new directory called C:\WQ2000\New effluent standard) might then be created to store the test results. The user might then elect to carry out a number of runs until an effluent TDS concentration is found that leads to acceptable downstream conditions. At this stage he may decide to store the results in the directory

C:\WQ2000\New effluent standard. This directory would then contain the default data from directory C:\WQ200\changed default, with changes made to reflect the new effluent flow data and the effluent concentration data that was found to result in acceptable downstream conditions. At a later stage, once the new effluent discharge works becomes operational, the new information could be entered into directory C:\WQ2000\Changed default, which would then reflect the new status quo.

Periodically, when the base data and model calibrations are updated, a new base data directory could be issued.

User requests for mapping result variables or model parameter values are satisfied using the data stored in the Access database.

2.2.3 WQT model

The WQT monthly time step hydro-salinity model is used to simulate monthly flows and total dissolved salts (TDS) concentrations at key points in a standard system used to represent the selected quaternary of interest and the upstream catchment. The WQT model is discussed in greater detail in Chapter 3.

2.2.4 GIS Viewer

The DWAF has developed a GIS viewer. This viewer is used in the Water Situation Assessment Model (WSAM) (Wolff-Piggott and Olivier, 2001). The GIS viewer is used as a stand-alone feature in WQ2000, which allows the user to access the GIS Viewer to present plots of simulation results or WQT model parameter values for user selected quaternaries. The results are presented by shading each quaternary according to the magnitude of the selected value. Small Pie Charts can also be plotted in each quaternary to represent the magnitudes for up to three more selected variables.

If the mapping request includes quaternaries affected by new data information (i.e. if new values for that quaternary or upstream quaternaries have been specified but the run results not yet stored) then the WQT model will automatically execute for all affected quaternaries to generate new results before displaying the plot.

Appendix A provides an example of a typical application of the GIS Viewer. This is sufficient to allow the user to display model results and model parameter values. The GIS Viewer has many more features, which allow the user to (for example) change the colour gradients used in the plots. Details of these features are not provided in this report. The user is referred to dedicated literature sources for a detailed description of the more advanced features of the GIS Viewer (Wolff-Piggott and Olivier, 2001).

2.2.5 Text data files

Each time a quaternary is selected WQ2000 calculates and displays the catchment characteristics, model parameter values and development data for the quaternary and upstream catchment sub-systems.

On issuing the command to run the WQT model, all the parameter files, monthly catchment runoff, rainfall, abstraction, mine pumpage (where applicable), water importation, upstream inflow and effluent discharge quantity and salinity text files are generated from the database information for each affected quaternary. The WQT model is then run for natural and present day conditions and the ensuing monthly text files are generated for hydrological conditions from October 1925 to September 1995.

The following file types are stored:

- Generated WQT model input data files (parameter plus monthly files)
- WQT model executable code
- Generated WQT model output files.

Table 2.1 shows the directories where the WQT model files are stored.

Table 2.1: WQT model file location

| Directory | Condition | | |
|---------------------------|---|--|--|
| C:\WQ2000\Natural | Quaternary with inputs from upstream catchment for natural (undeveloped) conditions. | | |
| C:\WQ2000\Naturaf\Nousout | Quaternary with no influence from upstream catchment for natural conditions. | | |
| C:\WQ2000\Current | Quaternary with inputs from upstream catchment for present day (developed) conditions. | | |
| C:\WQ2000\Current\Nousout | Quaternary with no influence from upstream catchment for present day conditions. | | |

3. HYDRO-SALINITY MODEL

The WQT hydro-salinity model (Allen and Herold, 1988) is used to simulate monthly flows and TDS concentrations. A more detailed description of the model is presented in the above reference.

The WQT model represents the catchment by means of user defined sub-system elements (called NODES) connected by flow channels (called ROUTES) to form a model system. The following six discrete sub-model elements (nodes) are available:

- · [SW] Catchment salt washoff sub-model
- [CR] Channel reach sub-model
- [RR] Irrigation sub-model
- [JN] Junction sub-model
- [RV] Reservoir sub-model
- [DC] Demand centre sub-model.

The two-digit code used to describe each node type is enclosed in square brackets. All but the last type of node is used in the standard WQ2000 system. Each node is designated a number. Each route is also assigned a unique number.

3.1 WQT Model structure

3.1.1 Network file

The system network file defines the manner in which the nodes are connected to form the model system. It also defines the weights assigned to each flow route, which in turn affects the order in which upstream reservoirs are called on to meet downstream water demands.

Figure 3.1 shows the system network used to describe a quaternary catchment in WQ2000.

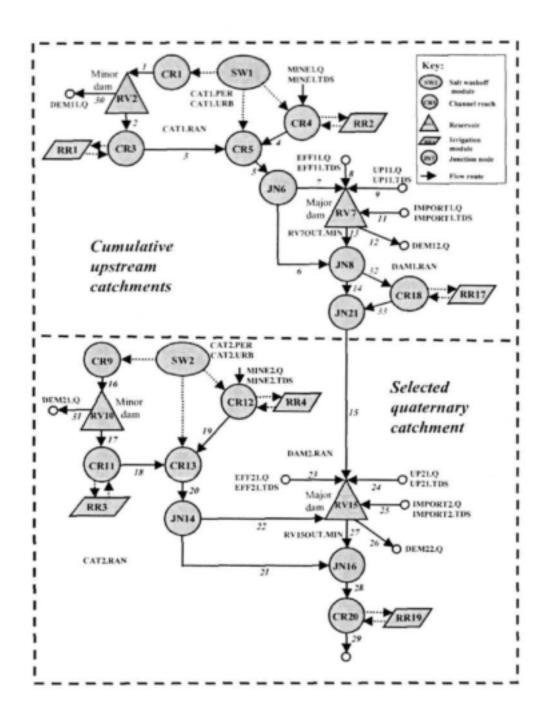


Figure 3.1: WQT model system network

Catchment boundaries have been represented in Figure 3.1 by heavy dashed lines. These show that each quaternary catchment is represented by two catchments. The lower half of Figure 3.1 represents the quaternary itself, while the upper half represents the aggregated upstream quaternaries.

Local quaternary catchment washoff processes are represented by node SW2, with part of the runoff being routed to channel nodes CR9, CR12 and CR13. Time series of monthly runoff from pervious and urbanised portions of the catchment are fed as input to SW2, along with calibrated model parameter values. SW2 generates time series of monthly TDS concentrations and TDS loads corresponding with the catchment runoffs.

The portion of the catchment runoff entering channel reach CR9 is discharged via route 16 to reservoir RV10, which represents the accumulated minor dams located in the quaternary catchment. These usually comprise small farm dams but can also include small dams operated by local authorities or industries that are located off the main stem river (i.e. that are not supported from upstream dams.) A monthly abstraction file (DEM21.Q) file represents abstraction from the minor dam (via route 31). Water is spilled from the minor dam or released to support downstream irrigation via route 17. The rainfall file CAT2.RAN provides a monthly time series of rainfall on the reservoir.

Channel reach CR11 serves merely as a means of supplying water to irrigation node RR3, which represents all quaternary irrigation that is supported by farm dams. Return flows from RR3 and unused spillage from RV10 enters channel reach CR13 via route 18.

Channel reach CR12 supplies water to irrigation node RR4, which represents unsupported (i.e. opportunistic) quaternary irrigation. Provision is also made for this node to receive monthly flow and TDS input from mining sources within the quaternary catchment. Bed losses can also be specified for this channel reach. Return flows from RR4 and unused catchment runoff and mine discharge enter channel reach CR13 via route 19.

Besides serving as recipient for outflows from channel reaches CR11 and CR12 and a portion of the runoff from catchment salt washoff module SW2, a wetland area can also be defined for channel reach CR13. Monthly rainfall data required for the wetland evapotranspiration calculations is provided by file CAT2.RAN. Part of the outflow from CR13 (via route 20) is passed downstream of the major reservoir (RV15) via route 21, the remaining flow entering the reservoir via route 22.

RV15 represents a major reservoir on the main stem of the river passing through the quaternary. For this purpose a major reservoir is defined as one that can be supported from other major dams located in the upstream catchment (i.e. from reservoir RV7). RV15 receives flow from the upstream system via route 15. Monthly effluent flow and TDS concentration derived from files EFFF21.Q and EFF21.TDS enter the reservoir via route 23. Water importation (files IMPORT2.Q and IMPORT2.TDS) enters via route 25. Inflow from pre-defined upstream catchments directly adjacent to the quaternary catchment enters via route 24 (files UP21.Q and UP21.TDS). Outflow from the reservoir is by abstraction via route 26 (file DEM22.Q) and by spillage or release via route 27. A minimum outflow from the dam (file RV15OUT.MIN) is specified to approximate the calls for water from downstream quaternaries. A separate file of monthly rainfall (DAM2.RAN) is assigned to the major reservoir, since a dam near the quaternary outlet can have rainfall characteristics that differ from those of the catchment (file CAT2.RAN).

Junction node JN16 merely combines the flows from routes 21 and 27 and routes them downstream via route 28.

Channel reach CR20 facilitates channel irrigation via RR19. RR19 represents irrigation from the main stem channel that is supported by upstream major dams. Typically this would include major government irrigation schemes or smaller riparian irrigation benefiting from compensation releases from upstream dams.

The sub-system above the quaternary is similar to that used for the quaternary itself. In this instance the model parameters and monthly flow files are cumulated (and where appropriate area or flow-weighted) from the data for the upstream quaternary catchments. This upstream subsystem extends upstream only until a stored outflow is encountered. In such instances the pre-calculated stored monthly inflow (files UP11.Q and UP11.TDS) are used to represent the net output from all upstream quaternary catchments.

When run for the quaternary alone, the system above route 15 is cut off and the flow via route 15 is set to zero.

For natural conditions all dams, irrigation and urban areas are assumed not to exist and all importations, effluent disharges, abstractions and minimum outflows are set to zero.

3.1.2 System command file

The system command file defines the locations of input and output file directories and the order in which nodes are to be calculated. To facilitate running the WQT model in the background for various conditions a new version of the WQT model (WQT1) has been created and compiled.

This version of the model also allows present day conditions to be simulated for several years of hydrology (in this case from October 1925 to September 1995) without excessive growth in catchment storage and salt export.

WQT1 has an additional type of run control file of the form: nnn.KR5, where nnn is a name up to 8 characters long. This file essentially contains all the user instructions that are normally entered manually when the WQT model is run. No knowledge of this file (or any other WQT model file) is required to run WQ2000. All of the necessary files have either been prepared and are included in the distribution CD-ROM or are calculated by the model each time a new quaternary is selected or parameter modified.

A description of this additional user instruction file is included in Appendix A.

3.2 Modules

The six types of model node are described in the following sections.

3.2.1 Salt washoff module

The catchment salt washoff module simulates the gradual accumulation of soluble solids within a catchment, their storage and subsequent release during runoff events. Account is taken of both pervious and paved urban catchment surfaces. For pervious surfaces the model simulates the movement of salt via direct runoff, infiltration, interflow, sub-surface storage and groundwater flow. Provision is made for the growth of paved urban surfaces and diffuse source salt recharge. Linear or exponential

interpolation can be specified between years for which unit salt recharge rates are specified.

Input data comprises model parameter values and files of monthly catchment runoffs from pervious and paved portions of the catchment. The model does not directly simulate the hydrological process. Instead empirical algorithms are used to estimate the proportion of the specified pervious runoff volume that arose from direct surface runoff, the remainder being assumed to have passed through the soil moisture and/or groundwater storage. Herold and Kakebeeke (1991) provide fuller descriptions of the model and Allen and Herold (1988) describe the empirical routines and equations used in the model.

WQ2000 allows the user to both view and change salt washoff module parameter values, although changes to the calibration parameter values should be attempted only by experienced modellers who are thoroughly conversant with the WQT model. Most commonly the user is expected to alter the default urban area to match updated information or to test the likely impact of a planned development.

3.2.2 Channel reach module

The channel reach sub-model simulates the movement of water and salt through a river reach. The upstream end of the river reach may accept input from up to five source routes. It can also accept a portion of the catchment runoff and salt washoff from an associated catchment salt washoff module. Files of monthly discharges and salt concentrations from mine de-watering may also be specified. Account is taken of riverbed loss and evapotranspiration loss from wetlands. Allowance is made for growth in wetland area, with linear or exponential growth interpolation between years for which areas are specified. The accumulation of salt in wetlands during periods when potential net evaporation loss exceeds the upstream inflow is also accounted for, with the release of such salts during subsequent flood events. Each channel reach has one downstream outflow route.

An irrigation module may also be associated with the channel reach, to represent riparian irrigation. The irrigation demand is abstracted from the channel and the return seepage discharged to the channel sub-model outflow route. Input data comprises model parameter values and files of monthly mine pumpage flow and TDS concentration and monthly rainfall (expressed as percentage of mean annual precipitation (MAP), catchment runoffs from pervious and paved portions of the catchment and inflows from upstream portions of the system or external inputs to the system.

In the WQT model mine pumpage is dealt with separately from normal effluent discharge. This is because the demand centre module allows the quality of normal effluent to be dependent on that of the supply water. Since mine pumpage originates from deep underground, its quality is assumed to be independent of the supply water quality. Although the demand centre module is not used in WQ2000, the distinction between mine water discharge and other effluent point sources has been maintained.

WQ2000 allows the user to view and change the following items:

- Proportion of associated salt washoff module runoff entering channel reaches CR9 and CR12
- Mine pumpage volume and TDS concentration (idealised as applying to CR12)
- Bed loss (applied to CR12)
- Catchment wetland area (applied to CR13).

3.2.3 Irrigation module

The irrigation sub-model simulates the accumulation of salt within irrigated lands and its release via return seepage. The irrigated land is modelled as a two layered system. Allowance is made for additional flushing during wet periods.

The following processes are simulated:

- Canal transmission losses
- Annual maximum permissible water allocation
- Multiple crops (up to 20 may be specified)
- Additional return flow during wet periods
- Losses to relatively inaccessible deep-seated ground water. (This is particularly important for arid areas where the groundwater table is located below the receiving stream invert level.)
- Addition of salts via agricultural lime, gypsum or fertiliser

- · Growth or reduction of irrigated area with time
- · Growth or reduction of maximum permissible annual water allocation
- · Variable effective rainfall reduction factors (as function of rainfall intensity)
- Return seepage from two sub-surface zones and via surface spillage from canal ends.

The irrigation module must be associated with a catchment salt washoff module. As the irrigated area increases, land (and the salt it contains) is transferred to the irrigation model. As irrigated land is take out of service, the land (and its associated salt) is transferred back to the catchment salt washoff model. Linear or exponential interpolation can be used to calculate irrigation areas for years between those for which areas are specified. Constant irrigation areas are used in WQ2000 (zero for natural conditions, or the default or user modified area for present day conditions).

The irrigation model can be defined as dependent on a channel reach, or as an independent node with its own water supply and return seepage routes.

When the water supply is curtailed the assumption is that the area of land under irrigation is reduced, with part of the land lying fallow. Normal catchment soil evapotranspiration is assumed to apply to fallow areas, until such time as the water availability allows irrigation of the full area to resume. The salt balance is maintained.

The irrigation model input comprises model parameters and a file of monthly rainfall data (expressed as percentage of MAP values).

WQ2000 allows the user to view and alter the irrigated areas for RR3 (irrigation supported by farm dams), RR4 (opportunistic irrigation) and RR19 (irrigation from the main stem river). The user can view, but not modify, the cumulative areas applicable to the upstream catchment (i.e. for RR1, RR2 and RR17). If the upstream irrigation areas need to be modified, it is necessary to first make and store the changes for each individual affected upstream quaternary catchment.

3.2.4 Reservoir module

The reservoir sub-model simulates the monthly water and salt balance of a dam. Input comprises runoffs from upstream nodes, which can comprise internally calculated inflow from the upstream system (such as via routes 15 and 22) or external inputs

such as effluent discharge (route 23), stored upstream inflow (route 24) and inter-basin water importation (route 25). Calculated outflows comprise water abstraction (route 26) and spillage and release (route 27).

Account is taken of evaporation loss, rainfall, abstraction and release and spillage driven by inflows to the reservoir. Complete mixing within the reservoir is assumed. This is a reasonable assumption for most reservoirs and the relatively long monthly computational time step.

The water and salt balance equations have been set up in such a manner that the reservoir can be included as part of a dependent salt feedback loop. This facilitates the recycling of salt when water abstracted from the dependent reservoir is supplied to a demand centre, which in turn returns salt-enriched effluent to tributaries draining back into the reservoir. This feature is not used in WQ2000 (see Section 3.2.6).

WQ2000 allows the user to view and alter the full storage capacity, full storage area and the power factor, B, in the equation used to link the two for the minor reservoir (RV10) and major reservoir (RV15):

Having specified parameter value B, the model calculates value A from the specified reservoir full storage area and full storage capacity:

A =
$$e^{(in(FSA)-B in(FSC))}$$
 (3.2)
where:
FSA = full storage area (km²)
FSC = full storage capacity (10⁶ m³)

The user may also view and adjust the mean annual abstraction (route 31) from the minor reservoir (RV10).

WQ2000 allows the user to view and adjust the following average flows to and from the major reservoir (RV15):

- Effluent discharge to reservoir (via route 23)
- Inter-basin water importation (via route 25)
- Minimum release (via route 27)
- Water demand (via route 26)

Only the flow is specified for routes 26 and 27, since the model will calculate the corresponding TDS concentration month by month, depending on the upstream inflows, rainfall and evaporation.

The average upstream inflow via route 24 can be viewed, but cannot be re-defined by the user. This is because any defined inflow via route 24 is dependent on the stored output from previous simulations of upstream quaternaries. The values for each monthly flow and TDS concentration contained in files UP21.Q and UP21.TDS will be unique, defined by the characteristics and inputs to each upstream catchment.

3.2.5 Junction node

The junction module simply mixes together the inflows from up to five upstream routes and routes the outflow to up to five downstream routes.

A later enhancement (Herold and Kakebeeke, 1991) allows for blending, whereby the inflow through preferential routes is adjusted to prevent the outflow TDS concentration from exceeding a defined blending target. Constraints on the capacity of flow routes can also be set. This feature is not required in WQ2000 and is not available in WQT1.

3.2.6 Demand centre module

The demand centre sub-model simulates the supply of water to meet specified monthly gross water demands and the return of effluent, enriched with salt added during use. The effect of monthly climatic variation on the percentage return flow is simulated. Provision is made for the direct recycling of effluent, with or without

desalination. The demand centre may form part of a larger dependent feedback cycle that spans a number of system elements including one dependent reservoir. Each demand centre may accept inputs from up to five source routes, each of which may be independent, or part of the dependent feedback cycle. Up to five return flow routes may also be specified. The simulated monthly effluent discharge and salt load is apportioned to each of the return flow routes.

The standard WQ2000 model system layout does not include any demand centre nodes. This is because feedback loops typically span several quaternary catchments, all of which would need to be included in the system (see Section 7.2).

3.3 Model changes

The main changes to the WQT model are discussed below. These changes are incorporated in the new model WQT1, which is used by the WQ2000 model.

3.3.1 Starting condition re-initialisation

The primary purpose of the WQT model was to calibrate the salinity parameters for historical conditions. Under these circumstances the accumulation of salts stored in the catchment over time as development took place did not affect the results as the model is calibrated against actual historical conditions. However, at any given time the catchment salt storages (and hence the catchment net salt export) lags behind the input rate arising from catchment development by a few decades. This is because most of the diffuse source salt generated in the catchment enters the soil and groundwater storage, which contributes to a gradual increase in storage and catchment export.

Hence, if an industrial development were to (say) double the rate at which diffuse source salts are introduced to the catchment, in the first year the catchment export via runoff would only be elevated by a few percent. Typically it would take 40 to 50 years before the catchment salt export also doubles and a new state of dynamic equilibrium between input, storage and export is established.

Hence, if a simulation of present day conditions is required for a range of hydrological conditions experienced over the last 70 years, then for the above example it would be quite wrong to start from present catchment storage states and simply run the seventy

years of naturalised hydrology through the model. This would result in a simulated trend in export salt concentration over the first 40 to 50 years of hydrology, with the concentration about double the present day condition for the last 20 years. However, for present day conditions the average TDS should not rise by more than a few (say 2 or 3) percent. This problem is overcome in WQT1 by first setting catchment storages to the ending values (i.e. end of September 1995) obtained from the calibration of historical conditions. The model is then run forward for the next year using the first year of naturalised hydrology (i.e. October 1925 to September 1926). The catchment storages are then re-set to the original starting condition and again run using the next year's hydrology (i.e. October 1926 to September 1927). This is repeated 70 times until the present day conditions have been represented by each of the available naturalised hydrological years from 1925/26 to 1994/95.

WQT1 is a modified version of WQT that allows the above procedure to be carried out automatically. A switch is also provided that allows a historical progression to be simulated. (i.e. the starting storages are set only once at the beginning of the simulation and are allowed to build up as the simulation proceeds through the available hydrological record). This option is the same as the working of the original WQT model and is appropriate for the calibration of the observed historical record.

DWA Report PC000/00/9390 (Stewart Sviridov & Oliver, 1991) provides a fuller description of the effect of catchment storage.

3.3.2 Print suppression

The WQT1 model allows suppression of all the normal dialogs and manual user instructions. Instead a set user instructions are contained in a user instruction file that is read in by WQT1. Three such user instruction files are included in the directory C:\WQ2000\Current to facilitate simulation of the system for present day conditions for the quaternary catchment for off-channel (i.e. no inflow from upstream quaternaries) and for the case when quaternary concentrations and flows are influenced by upstream inflows. Three similar files are contained in directory C:\WQ2000\Natural to control the simulations for natural conditions.

3.3.3 Splitting route output

The system network in Figure 3.1 does not show that the system is actually simulated in stages. This is done to prevent the downstream dam from calling on upstream minor dams to meet supply deficits. Hence, in Figure 3.1 dam RV7 may not call on dam RV2. RV15 should also be prevented from calling on RV10.

This is accomplished by breaking the system just before Junction node JN6 and just before Junction node JN14. A new subroutine has been added to WQT1. This facilitates splitting the output from Junction nodes in the proportions designated by the user. This is used to split the flow from Junction node JN6 to routes 6 and 7 and from JN14 to routes 21 and 22.

4. MODEL CALIBRATION

4.1 Choice of study catchment

The Vaal River catchment has been chosen as the study area. The factors prompting its selection to prove the WQ2000 model include:

- Strategic importance
- Water quality problems
- Extensive database
- Familiarity
- WSAM development
- · Comprehensiveness of study area

Figure 4.1 shows the general layout of the Vaal River catchment.

4.1.1 Strategic importance

The Vaal River system embraces the most strategic water resource in South Africa. This catchment is richly endowed with natural resources, including the famous Kimberley diamond mines and a number of highly productive gold mines.

The largest urban centres include the vast Pretoria-Witwatersrand-Vereeninging (PWV) complex, which is located largely within Gauteng. The Gauteng urban and industrial complex alone produces about half of South Africa's GNP. Other centres include Bloemfontein, Kimberley, Klerksdorp, Welkom, Secunda, Harrismith, Phuthaditjhaba and Ermelo. The economic dominance of the region acts as a population magnet. Hence these centres are notable for rapidly developing informal settlements, with concomitant demand for higher levels of service and pressure on receiving water quality.

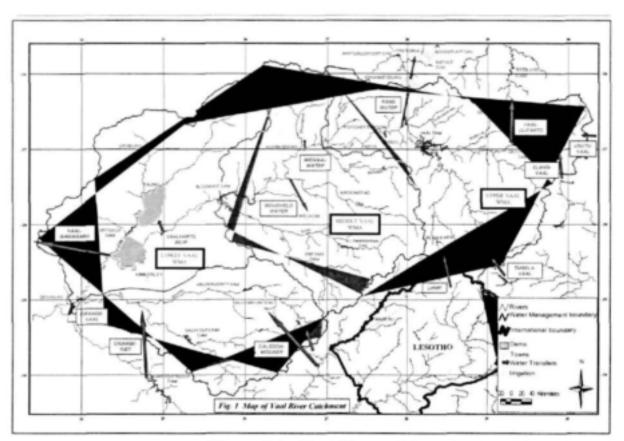


Figure 4.1: Vaal River catchment

Abundant local coal reserves support mines the in the Ermelo and Vereeniging areas, the largest underground coal mining complex in the world, which feeds the vast Sasol 2/3 oil-from-coal, fertiliser and explosives complex at Secunda. Other coal mines are associated with the large Tutuka, Majuba and Lethabo power stations.

The catchment contains the 37 000 ha Vaalharts irrigation scheme, and irrigation schemes along the Riet and Vet Rivers. Riparian irrigation takes place along the major river courses. The wetter portions of the catchment are also characterised by extensive dry land farming.

Aside from local developments, the Vaal River serves as the hub for the supply of water to surrounding regions. Major recipient areas include the Mpumalanga coalfields containing roughly two-thirds of the known coal reserves of Africa and supporting a number of major power stations, the rich Rustenburg platinum-mining areas and the developments in the greater Pretoria area.

4.1.2 Water quality problems

This catchment is also subject to serious water quality problems. Salinity has long been recognised as a particularly severe problem in the Vaal River system.

Substantial pollution loads are derived from underground mining, decanting from defunct mines (mostly coal at this stage) and generated by urban and industrial activities. The high cost of water importation has led to an increasing reliance on effluent re-use, which adds to the potential pollution problem. Growing pollutant input loads, together with cascading water use down the Vaal River, feedback cycles and evaporative concentration, have led to a steady build up of the concentration of intractable salts and other pollutants, which can only be removed at high cost. Consequently water quality has played an important role in both the development and management of water resources.

Salinity is the most dominant water quality problem in the Vaal River system. In any assessment of this problem the impact of the Vaal Barrage catchment stands out. Based on information generated in the VRSAU study (Herold and Rademeyer, 2001), during the 20 years up to September 1995 this catchment contributed nearly half of the salt load of the entire Upper Vaal Water Management Area, from only 16% of the catchment area. The salt load export per unit area from developed portions of this catchment was more than 20 times higher than that of the relatively undeveloped Vaal Dam catchment. About 40% of the export load was associated with non-point sources.

Salinity hotspots are also evident in many other developed regions within the Vaal River catchment and in downstream river reaches. These include the Freestate Goldfields (Herold et. al., 1996), Northwest Province and Evander Gold Mine mining areas, coal mining areas in the upper Vaal and Waterval River catchments (Herold and Taviv, 1992), arid urbanised areas at Bloemfontein and irrigation areas in the Riet River Settlement, at Vaalharts and Douglas. The accumulation of salts in irrigated lands poses a long-term concern (Herold and Bailey, 1996). The most severely affected downstream areas include the entire length of the Vaal River below Vaal Dam, the Klip, Blesbokspruit, Suikerbosrand, Riet, Mooi, Sand, lower Vet, Harts, Modder and Riet Rivers.

Initial findings also indicate a high potential for long-term salinization of the water resources of the Upper Vaal catchment due to the deposition of sulphate rich gasses emitted to the atmosphere by the mammoth Mpumalanga power stations and petrochemical industries (Herold et. al., 2001).

Salinity problems impose severe costs on users of the Vaal River system (Heynike, 1987 and Urban-Econ, 2000). Hence water quality is a significant factor in the planning and operation of the water resources (Herold and van Robbroeck, 1988).

4.1.3 Extensive database

The water resources and salinity regimes of the Vaal River catchment have already been studied extensively, resulting in the accumulation of a large database. Key studies include the DWAF's Vaal River Salinity Study (VRSS) (Herold, 1993), the Vaal River System Analysis (VRSA) and the Vaal River Situation Analysis Update (VRSAU). The DWAF and various other parties (especially water boards) also have extensive databases on salinity related water quality variables for this catchment. The widely used monthly time step WQT hydro-salinity model (Allen and Herold, 1988) was calibrated for the entire Vaal River catchment as part of the VRSA (Herold, 1988). The calibrations have since been revised as part of the VRSAU (Herold, 1999; Herold and Carden, 1999; Herold and Taviv, 1998; Ninham Shand, 1999).

Nutrients and eutrophication studies have also covered large portions of the catchment,

with lesser coverage and less extensive databases for other water quality variables such as faecal coliforms, metals and radionuclides.

4.1.4 Familiarity

The authors have been intimately involved with numerous salinity and water resources studies in the Vaal River catchment since 1978. Hence they are in a good position to appreciate the nuances of this complex catchment. They also have comprehensive inhouse expertise and experience in both the development and application of a range of water quality models and the development of interactive user interfaces and data base development.

4.1.5 WSAM development

From its initial concept (Pitman et. al., 1998) the intention was to include salinity assessment in the WSAM model, which was originally known as the National Water Balance Model. The first phase of the DWAF's WSAM model has been developed for water resources. Attention is now being placed on salinity assessment, with particular focus on the Vaal River catchment (Schultz, 2002). For this to succeed the WSAM developers will require relevant salinity input data. This data has to be derived from more detailed hydro-salinity modelling studies. Much of this essential information can be derived from output from the WQ2000 model simulations.

4.1.6 Comprehensiveness of study area

The Vaal River catchment includes the most highly developed areas in South Africa, as well as data scare rural areas. This catchment encompasses a comprehensive range of land uses. The diversity and complexity of the Vaal catchment should ensure that the system that is developed could handle most eventualities.

All of the above factors make the Vaal River the obvious choice for a study catchment to develop and test this interactive water quality evaluation system.

5. DATA PREPARATION

A large amount of data had to be prepared for inclusion in the WQ2000 model. The data included in the model is discussed in the following sections.

5.1 File structure

The model directory layout is shown in Figure 5.1.

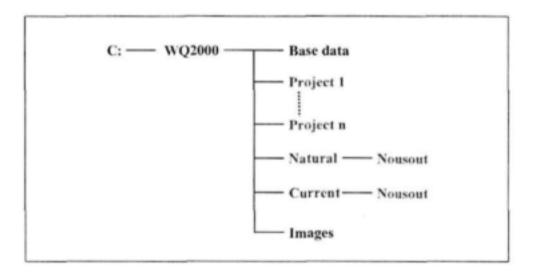


Figure 5.1: WQ2000 directory structure

The directories shown in black contain the original data files supplied on the distribution CD-ROM. These files should not in any way be interfered with.

Those shown in red are project directories set up in response to user commands. They can also be removed via the WQ2000 menus. Files within these directories should also not be tampered with. Changes to the project data should be made via the menu options provided in WQ2000.

Each time the model is run for a new quaternary catchment, WQ2000 sets up all the files needed to run the WQT1 model in directories C:\WQ2000\Natural and C:\WQ2000\Current and their extensions (shown in blue). Many of the files in these directories are overwritten whenever a new run is carried out. The answer files generated by WQT1 are also stored in these directories.

It is highly inadvisable for the user to directly modify the WQ2000 directory structure or any of the files that it contains. Valid changes should only be made via the WQ2000 menu dialogs.

The contents of each directory are described below:

5.1.1 WQ2000

Directory C:\WQ2000 contains the model executable code and help files. WQ2000 is written in Pascal.

5.1.2 Base data

Directory C:\WQ2000\Base data contains the original MS Access database, which is populated with the data required to generate the files needed to run the WQT1 model for natural and present day conditions for all 195 quaternary catchments comprising the Vaal River catchment. A large amount of data is stored in this database. For each quaternary catchment a text data file has to be provided for the 27 nodes of the system network shown in Figure 3.1. A network linkage file is also required, as well as command files to run the system for natural and present day conditions with and without the influence of upstream runoff.

This directory also contains a number of text files of monthly pervious and urban catchment runoff for the period October 1925 to September 1995 for catchments that have been calibrated in previous studies. Each calibrated catchment typically spans several quaternary catchments, although some are down to quaternary size. Monthly rainfall files are also included. The distribution CD-ROM also contains pre-prepared monthly quaternary runoff files for natural and present day conditions for each quaternary catchment.

WQ2000 does not provide any means of altering the files contained in this directory. Nor should they be interfered with using any other type of text editor or database model.

5.1.3 Project databases

The first time WQ2000 is used the user is asked to name a project directory. Initially this directory will be identical to the default database (C:\WQ2000\Base data). All modifications to the database can be stored in one or more project directories named: C:\WQ2000\Project name, where project name is any chosen alphanumeric name that meets with the normal Windows file naming convention.

5.1.3.1 Supported changes

Permissible changes that can be specified for any number of quaternary catchments include:

- paved urban area
- irrigation areas (supported by farm dams, opportunistic or supported from the main stem river below the major Dam)
- wetland area
- channel bed loss
- catchment runoff proportions upstream of minor and major dams
- · major or minor dam full storage capacities and full storage areas
- dam basin shape
- effluent and mining input
- inflow from inter-basin water transfer
- water demand
- · minimum release from the major dam
- various catchment salt washoff model calibration parameters (Changes to these values should be made only by experienced model users.)

Any number of such changes can be made simultaneously for the selected quaternary catchment, and can be changed again in subsequent runs. These changes can be added sequentially to the same project database, or any number of new project databases can be created. Each time a new project database is created, any one of the existing databases can be used as the template to provide the starting conditions. (I.e. the original Base data provided with the distribution CD-ROM can be used, or any other project database that the user has previously created.)

5.1.3.2 Defined outflows

Any defined catchment outflows that are created and stored will also be added to the active project database. For example, the model calibrations carried out during the VRSAU study treated the entire Wilge River catchment above Frankfort Weir as a single entity (with the exception of the Sterkfontein Dam (C11D quaternary) catchment, which was calibrated separately). This is a large catchment comprising 28 quaternary catchments. The user may elect to run the model for (say) quaternaries C83A to C83J and consolidate the output from the Liebenbergsvlei River catchment as two stored files of monthly flow and TDS concentration at the outlet of quaternary C83J. This means that when a downstream quaternary is simulated the model will not need to include these quaternaries. The defined outflow from C83J will be used instead.

This feature is particularly useful if the user wants to prevent quaternary water demands from being supported from part of the upstream system. For example, under normal operation Grootdraai Dam is not used to support Vaal Dam, since the strategic power stations and Sasol plant supplied from Grootdraai Dam require a higher assurance of supply than the rest of the Vaal River system. The Vaal River catchment upstream of Vaal Dam can therefore be treated as a separate system with defined flow and TDS files stored at quaternary C12L. Similarly the results for the Liebenbergsvlei River and the tributaries entering the Wilge River can be simulated and stored as defined inflows. Leaving the outflows from the quaternaries between and including Sterkfontein Dam and Vaal Dam undefined (i.e. quaternaries C81D, C81E, C81K, C82C, C82G, C82H, C83J, B83M and C22F*) will result in the upstream catchment including Sterkfontein Dam, excluding Grootdraai Dam, Saulspoort Dam and a number of municipal Dams. Hence the system layout would allow calls to be made on Sterkfontein Dam to meet water shortfalls at Vaal Dam, but would not permit calls on dams upstream of the quaternaries for which defined flows have been saved.

Any changes made to a quaternary catchment upstream of a defined outflow will necessitate recalculation of the defined flow and TDS files. In the above example if a change is introduced (say) to quaternary C83F, then quaternaries C83F, C83G and C83H will need to be re-simulated before new defined outflow files can be created at the bottom of C83H.

5.1.3.3 Results storage

Results of the simulation of individual quaternary catchments may also be stored in the project database (but without defining them as fixed outflow files). This facilitates regional mapping using the GIS Viewer (see section 6.3.2).

5.1.4 Natural simulation directory

The data and command files required to run the WQT1 model for natural (i.e. undeveloped) catchment conditions are stored in the directory C:\WQ2000\Natural. The system is simulated twice for natural conditions. The first simulation is for the entire system shown in Figure 3.1. This includes the cumulative impact of inflows from all quaternaries located upstream of the quaternary selected by the user. The answer files generated by WQT1 are stored in this directory.

The second simulation is for the selected quaternary alone. This is analogous to the situation in the catchment remote from the main stem river channel passing through the quaternary. In this instance the monthly inflow from the upstream catchment is cut off with the inflow via route 15 being set to zeros. The answer files generated by this simulation are temporarily stored in the directory C:\WQ2000\Natural\Nousout (where Nousout is an abbreviation for "no upstream outflow").

Many, but not all, of the files residing in directory C:\WQ2000\Natural are overwritten each time WQT1 is run for new quaternary catchment. However, the user should not edit or delete any of these files, as some files are common to all quaternaries and are not regenerated when a new quaternary run is executed. Hence they are required to remain in these directories. The initial set up from the distribution CD-ROM will populate these directories with all the requisite files. All file management should be left to the WQ2000 model, which sets up the required files in response to the user's menu selections.

Provision is made in WQ2000 for the user to copy the WQT1 model input and output data files generated for each quaternary (i.e. the contents of directories C:\WQ2000\Natural and C:\WQ2000\Natural\Nousout) to another directory specified by the user. Once this has been done the advanced user may make any desired changes to the files in the new directory without endangering the functioning of WQ2000.

The above two paragraphs are equally applicable to the present day simulation directory discussed in the following section.

5.1.5 Current simulation directory

The data and command files required to run the WQT1 model for present day catchment conditions are stored in the directory C:\WQ2000\Current. The first simulation is for the entire system shown in Figure 3.1. This includes the cumulative impact of inflows from all quaternary catchments located upstream of the quaternary selected by the user. The answer files generated by WQT1 are stored in this directory.

The second simulation is for present day conditions for the selected quaternary alone.

The answer files generated by this simulation are stored in the directory

C:\WQ2000\Current\Nousout.

Present day conditions generally refer to the state of development as at the end of September 1995, which corresponds with the closing date for the VRSAU calibrations used to populate the WQ2000 database. This date certainly applies to all WQT washoff model calibrations. However, in instances when recent developments are known to invalidate the September 1995 data, more up to date information has been used. This applies primarily to more recent changes in effluent discharge and abstraction data, which can have a much more immediate impact than gradual changes in diffuse source catchment salt export or growth in urban area.

For example up to September 1995 there was no significant discharge to the Blesbokspruit from Grootvlei Gold Mine (Quaternary C21E). However, in the years prior to this, pumping from the underground workings at Sallies Gold Mine (located in the C22C quaternary) had ceased. Polluted underground water made in the vicinity of Sallies mine then began to migrate towards Grootvlei Mine, which was gradually filing up to the current working level. During 1995 Grootvlei Gold Mine resumed pumping at an increased rate of between 80 and 150 MI per day at a TDS concentration of 3000 to 4000 mg/l. This is obviously a very significant input that cannot be ignored. The mine pumpage data used in WQ2000 therefore reflects the more recent status quo.

The current data obtained from WSAM also reflects a range of recent conditions, depending on the latest data available at the time when the database was last set up. Data from WSAM was also used as a source of data in WQ2000. The term "present day" is therefore somewhat loose, but generally refers to the five-year period leading up to 2000.

5.1.6 Images database

The directory C:\WQ2000\Images contains files of GIS overlays used by the GIS Viewer. These files are used when various map generation and viewing options are selected. These image files should not be tampered with.

5.2 Data types

The data types included in the WQ2000 database are outlined in the following sections.

5.2.1 Quaternary physical data

This includes catchment specific data such as gross and effective area, physical linkages to upstream quaternary catchments, wetland area, mean annual precipitation, monthly effective rainfall factors, mean annual and monthly Symons pan evaporation, mean conversion factors from Symons pan to A-pan evaporation and to lake evaporation, monthly crop factors, mean monthly wetland evaporation factors and natural mean annual runoff (MAR).

Physical information related to the present level of development is also included, such as paved urbanised area, increase in MAR due to urbanisation, irrigation areas, irrigation canal losses, major and minor dam capacities and full storage areas.

5.2.2 WQT model parameter values

WQT model calibration parameters are included for each node in the model network for each quaternary catchment.

5.2.3 Monthly data files

A number of monthly data files are also required. These include rainfall data, pervious and urban catchment runoff (for input to the salt washoff model nodes) and prepared flow and TDS outflows for selected quaternary catchments. The WQT model also requires files of monthly flow and TDS concentration for mine pumpage, effluent discharge, water importation, minimum release from major dams and abstractions from both major and minor dams. These files are prepared by WQ2000 as fixed present day rates from the default values. The user can modify any of these values to suit known catchment changes or to test new development options.

5.3 Data sources

The data items required by WQ2000 and the primary data sources for each are summarised in Table 5.1. The last column indicates which parameter values the user may change.

Table 5.1: Data descriptions and sources

| Description | Units | Source ¹ | User ⁶ Change |
|--|--------------------------------|------------------------|-----------------------------|
| Natural catchment physical data: | | | |
| Quaternary gross area | km ² | WR90 | yes |
| Quaternary effective area | km ² | WR90 | |
| Quaternary linkages | - | WR90 / WSAM | |
| Wetland area | km ² | VRSAU | yes |
| Catchment mean annual precipitation (MAP) | mm | WR90 / WSAM | |
| Monthly effective rainfall factors | - | VRSAU | |
| Mean monthly evaporation (Symons pan) | mm | WR90 | |
| Monthly Symons pan to A-pan factors | - | WR90 | |
| Monthly Symons pan to lake evaporation factors | - | WR90 | |
| Monthly crop factors | - | VRSAU | |
| Monthly wetland evapotranspiration factors | - | VRSAU | |
| Natural mean annual runoff (MAR) | 10 ⁶ m ³ | WR90 / WSAM | |
| Developed catchment physical data: | | | |
| Paved (impervious) urban area | | VRSAU / WSAM | yes |
| MAR (urban increase) | 10 ⁶ m ³ | VRSAU / WSAM | |
| Monthly channel bed loss | 10 ⁶ m ³ | VRSAU | yes |
| Irrigated areas supported by farm dams | km ² | VRSAU / WSAM | yes |
| Unsupported Irrigated areas | km ² | VRSAU / WSAM | yes |
| Irrigated areas supported by main stem river | km ² | VRSAU / WSAM | yes |
| Proportion of catchment runoff upstream of farm dams | - | Inferred from VRSAU | yes |
| Proportion of catchment runoff upstream of opportunistic irrigation areas | - | Inferred from VRSAU | yes |

| Description | Units | Source ¹ | User ⁶ Change |
|---|--------------------------------|------------------------|-----------------------------|
| Proportion of net catchment runoff below major dam | - | Inferred from VRSAU | yes |
| Reservoir data: | | | |
| Major dam MAP | mm | VRSAU | |
| Major dam full storage capacity (FSC) | 10 ⁶ m ³ | VRSAU / WSAM | yes |
| Major dam full storage area (FSA) | km ² | VRSAU / WSAM | yes |
| Minor dam FSC | 10 ⁶ m ³ | VRSAU / WSAM | yes |
| Minor dam FSA | km ² | VRSAU / WSAM | yes |
| Dam basin factor (power B in equation: area = A · storage ^B | - | WR90 / WSAM | yes |
| Major dam starting storage | 10 ⁶ m ³ | VRSAU | |
| Major dam starting TDS concentration | mg/l | VRSAU | |
| Minor dam starting storage | 10 ⁶ m ³ | VRSAU | |
| Minor dam starting TDS concentration | mg/l | VRSAU | |
| Calibration factors for each irrigation node (RR3, | RR4 & R | R19): 2 | |
| Maximum water allocation | 10 ⁶ m ³ | VRSAU | |
| Supply canal water loss | % | VRSAU | |
| Supply canal salt loss | % | VRSAU | |
| Irrigation efficiency factor | - | VRSAU | |
| Irrigation return flow factor | - | VRSAU | |
| Proportional return flow from upper soil storage zone | - | VRSAU | |
| Proportional return flow from lower soil storage zone | - | VRSAU | |
| Deep percolation salt concentration factor | - | VRSAU | |
| Proportion of salt loss to deep groundwater | - | VRSAU | |
| Salt load applied during first year | t/ha | VRSAU | |
| Salt load applied during subsequent years | t/ha | VRSAU . | |
| Initial salt storage in upper soil zone | mg/l | VRSAU | |
| Initial salt storage in lower soil zone | mg/l | VRSAU | |
| Upper zone soil moisture storage capacity | mm | VRSAU | |
| Lower zone soil moisture storage capacity | mm | VRSAU | |
| Irrigation soil moisture storage target | mm | VRSAU | |
| Irrigation soil moisture initial storage | mm | VRSAU | |
| Salt washoff model calibration parameters: 3 | | | |
| Initial pervious zone salt storage | t/km² | VRSAU | yes |
| Initial impervious urban zone salt storage | t/km² | VRSAU | yes |
| Initial subsurface salt storage | mg/l | VRSAU | yes |
| Pervious zone monthly salt recharge rate | t/km² | VRSAU | yes |
| Impervious urban zone monthly salt recharge rate | t/km² | VRSAU | yes |
| Pervious zone salt washoff efficiency | mm ⁻¹ | VRSAU | yes |
| Impervious urban zone salt washoff efficiency | mm ⁻¹ | VRSAU | yes |

| Description | Units | Source ¹ | User ⁶ Change |
|--|--------------------------------|--------------------------------------|-----------------------------|
| Initial interflow / groundwater flow estimate | mm | VRSAU | yes |
| Minimum interflow / groundwater flow estimate | mm | VRSAU | yes |
| Antecedent runoff decay factor | - | VRSAU | yes |
| Proportion of surface flow via interflow | - | VRSAU | yes |
| Proportion of salt washoff infiltration | - | VRSAU | yes |
| Subsurface storage depth | mm | VRSAU | yes |
| Monthly flow and TDS concentration data: | | | |
| Pervious catchment runoffs | 10 ⁶ m ³ | VRSAU | |
| Impervious urban catchment runoffs | 10 ⁶ m ³ | VRSAU / pre calculated 4 | |
| Catchment rainfall (as percentage of MAP) | % | VRSAU | |
| Major dam rainfall (% MAP) | % | VRSAU | |
| Defined catchment outflow volume (natural) | 10 ⁶ m ³ | Pre calculated | yes 7 |
| Defined catchment outflow TDS (natural) | mg/l | Pre calculated | yes 7 |
| Defined catchment outflow volume (present day) | 10 ⁶ m ³ | Pre calculated | yes 7 |
| Defined catchment outflow TDS (present day) | mg/l | Pre calculated | yes 7 |
| Mine pumpage volume (to node CR12) | 10 ⁶ m ³ | Calculated by WQ2000 ⁵ | yes |
| Mine pumpage TDS (to node CR12) | mg/l | Calculated by WQ2000 5 | yes |
| Effluent discharge volume (to node RV15) | 10 ⁶ m ³ | Calculated by WQ2000 5 | yes |
| Effluent discharge TDS (to node RV15) | mg/l | Calculated by WQ2000 ⁵ | yes |
| Importation volume (to node RV15) | 10 ⁶ m ³ | Calculated by WQ2000 ⁵ | yes |
| Importation TDS (to node RV15) | mg/l | Calculated by WQ2000 ⁵ | yes |
| Minimum release from major Dam (route 27) | 10 ⁶ m ³ | Calculated by WQ2000 5 | yes |
| Water demand from major dam (route 26) | 10 ⁶ m ³ | Calculated by WQ2000 ⁵ | yes |
| Water demand from minor dam (route 31) | 10 ⁶ m ³ | Calculated by WQ2000 ⁵ | yes |

NOTES: 1 The main data sources are:

WR90- Water Resources 90 reports and database (Midgley et. al, 1994b)

WSAM- Water Situation Assessment model (Watson and Schultz, 2000)

VRSAU- Vaal River System Analysis Update (Herold, 1999; Herold and Carden, 1999; Herold and Taviv, 1998 and Ninham Shand, 1999)

- 2 A fuller description of the WQT model calibration parameters is given by Allen and Herold (1988). WQ2000 does not provide for the user to view or update the irrigation model calibration parameter values.
- 3 WQ2000 allows the user to view and modify the salt washoff model parameter values. Further description of the parameters is given in the popup menus in the WQ2000 model. However, explanations of the model calibration processes are not provided. Further information can be obtained from (Allen and Herold, 1988 and Stewart Sviridov & Oliver, 1991). Default calibration parameter values are provided in WQ2000 for both natural and present day conditions.
- 4 Many quaternary catchments do not yet have any significant urbanisation. Hence they did not have calibrated urban runoff files. In order to allow the user to specify the option of introducing urbanisation, urban runoff files were created from simulations of the WRSM90 model (Pitman and Kakebeeke, 1991) for a fixed paved area of 10 km². WQ2000 then scales this unit runoff file according to the default or user specified urban area.
- 5 These monthly files are not provided in the WQ2000 database. Instead they are calculated from the default or user specified average values.
- 6 Parameter values that can be changed by the user from the WQ2000 menu are denoted by "yes" in this column.
- The user can choose to store files of simulated monthly outflows from upstream quaternaries. Defined quaternary outflows can also be removed. However, the user cannot directly change the defined monthly flows and TDS concentrations. These must be calculated by the model using the default or user modified values specified for upstream quaternary catchments. If any of the values are changed for any quaternaries upstream of a point where defined files have been specified, then all of the intervening quaternary catchments will first be recalculated to redefine new stored outflow files.

MODEL CAPABILITIES

The following sections outline the capabilities of the model.

6.1 Standard runs

The WQ2000 model allows simulation of time series of monthly flows and TDS concentrations at key points in the system network (see Figure 3.1) for any selected quaternary catchment for natural or present day development conditions using the standard default values provided with the distribution CD-ROM. Two cases are simulated for each state of development, namely the cumulative condition with inflows from upstream quaternaries taken into account, and the off-channel condition with no input from upstream catchments.

After selecting a quaternary catchment, the user can choose to run the model using the supplied default values. The model then automatically generates a result summary, which contains all the run data (to identify the summary sheet) and the run results.

The result summary contains the following information for natural and present day conditions with and without the effect of inflows from upstream catchments:

- Average outflow TDS concentration (via route 29)
- Median outflow TDS concentration (via route 29)
- 95 percentile outflow TDS concentration (via route 29)
- 98 percentile outflow TDS concentration (via route 29)
- Flow-weighted average outflow TDS concentration (via route 29)
- Average catchment runoff volume (runoff from node SW2 before alteration by channel and reservoir storage, irrigation, point inflow or abstraction)
- Average catchment runoff TDS concentration (runoff from node SW2)
- Average TDS concentration in major dam (node RV15)
- Flow-weighted average TDS concentration of spillage from major Dam (via route 27)
- Mean annual outflow from quaternary (via route 29).

6.2 User defined changes

6.2.1 Modify features

Once a quaternary catchment has been selected, the user may change one or more of the default parameter values. This facilitates adjusting the default values to reflect known catchment changes (such as growth in urban area, the introduction of new dams or changes in effluent discharge or water abstraction).

A particularly powerful aspect of this facility is that it allows the user to play the "what if?" game. If a new dam, effluent discharge or changed effluent quality is under investigation, the WQ2000 menu interface allows the user to make the necessary changes and run the model. The results summary can then be viewed to determine the water quality changes that would arise. The proposed change can then be adjusted and the results viewed successively until acceptable outflow water quality results are obtained.

The last column of Table 5.1 indicates the variables that can be modified by the user in WQ2000. WQ2000 provides menu windows for those values that can be modified (see Appendix A).

6.2.2 Calibration changes

Provision is made to modify WQT salt washoff node parameter values. However, it is strongly recommended that only users who are well conversant with the WQT model should attempt to modify calibration parameter values.

This is because care has to be taken to balance the model parameter salt generation rates with the starting storage values. Since catchment lag times are typically 4 to 5 decades long, failure to take proper account of initial storage states can lead to significant error in simulated salt export (Stewart Sviridov & Oliver, 1991).

6.3 Mapping

WQ2000 allows the user to generate, display and print maps.

6.3.1 GIS Viewer

The DWAF GIS Viewer (Wolff-Piggott and Olivier, 2001) allows the user to display and print maps showing chosen quaternary features.

When the Map option is selected, the user first selects the quaternaries to be plotted. The user can select individual quaternaries to be included, or all of the quaternaries upstream of and including a selected quaternary catchment.

The GIS Viewer allows the shading of each quaternary catchment according to a colour gradient representing the selected quaternary feature. The user can also select up to a further 3 features for plotting in each quaternary. These additional values are represented in the form of a pie chart, as it is impractical to shade each quaternary catchment more than once.

The GIS Viewer automatically selects shading gradients and colours. It also provides means of changing the shading ranges, colours and adding more overlays (such as urban areas and rivers). These features are not discussed in this report. The user can access them via the GIS Viewer features, or refer to the authors of the GIS Viewer for more information on the GIS Viewer (Wolff-Piggott and Olivier, 2001).

6.3.2 Regional maps

In the basic option the GIS Viewer shades each quaternary catchment for the selected region (i.e. set of chosen quaternaries) for a selected feature for present day conditions. The features that can be represented include salt washoff model parameter values and the results generated for each quaternary catchment.

For example, the user may elect to view the generated average TDS concentration of the runoff from each quaternary in the Grootdraai Dam catchment. The GIS Viewer will then shade each of the quaternaries C11A to C11L to represent the average TDS concentration of the runoff. This can be done using default conditions, or for the modified condition after altering some of the default values.

If simulations have already been carried out for all of the selected quaternaries, then the GIS Viewer will immediately proceed to prepare and display the plot. Otherwise, WQ2000 will first carry out simulations for each quaternary for which results have not yet been generated. The distribution CD-ROM contains results for all of the quaternaries of the Vaal River catchment for default values. Once user changes are made, the results for all downstream quaternaries are invalidated, and these will then have to be regenerated before GIS Viewer plots can be generated. This can be quite time consuming if a large number of quaternaries are involved. For larger regions that have not been simulated since making upstream changes it may be advisable to allow the regeneration of results to run overnight when the PC is not in use.

7. MODEL LIMITATIONS

WQ2000 is intended primarily to provide a rapid assessment of the salinity implications that can be expected to arise from a planned development, or to prepare an overview of the regional salinity status. While this is a powerful and flexible tool that makes use of many of the features of the WQT monthly time step catchment simulation model, it does have limitations that need to be observed.

7.1 System simulation

WQ2000 is ideal for rapidly assessing the impacts of developments in relatively uncomplicated regions. However, it is not a large system simulation model.

Provided the system comprises no more than 2 major dams, with the lower dam calling for water from the upstream dam, it can be handled with reasonable confidence. For example, the entire C1 region (upper Vaal River) should yield valid results, since the Grootdraai Dam operation is largely independent of Vaal Dam.

The entire Upper Vaal catchment down to Vaal Dam could also be simulated with reasonable results, but less confidence, provided determined result files are stored for the output from Grootdraai Dam. In this instance simulation of the C11F* catchment (which represents Vaal Dam) would call on Sterkfontein Dam as required to meet water deficits at Vaal Dam. However, the simulated call on Sterkfontein Dam would suffer from the limitation that WQ2000 allows specification of only an average outflow from the downstream major reservoir (i.e. Vaal Dam). This means that climatically driven monthly variation in the demand on Vaal Dam by the downstream system will not be replicated.

If an intermediate quaternary on the Wilge River between Sterkfontein Dam and Vaal Dam is selected (say C82C), then the downstream "major" dam (see Figure 3.1) will by definition be in this quaternary. Since the downstream Vaal Dam would not be included in the standard model system, there will not be any mechanism for drawing water from Sterkfontein Dam. Hence the simulation of in-stream conditions will be inaccurate (although the simulation of off-stream conditions should still be valid for this quaternary).

Hence the cumulative results for regulated river reaches will not take proper account of upstream releases made to satisfy downstream water requirements. This limitation is relevant to the following river reaches:

- Wilge River: All quaternaries directly between Sterkfontein Dam and Vaal Dam (i.e. quaternaries C81D, C81E, C81K, C82C, C82G, C82H, C83J, C83M, C22F*)
- Vaal River between Vaal Dam and Vaal Barrage (quaternaries C22F and C22K)
- Middle Vaal River between Vaal Barrage and Bloemhof Dam (quaternaries C23B, C23C, C23, C24B, C24J, C25C, C25F and C91A*)
- Lower Vaal River between Bloemhof Dam and the Orange River confluence (quaternaries C91A, C91B, C91D, C91E, C92A, C92B and C92C).

WQ2000 is not designed to handle the simulation of conditions along multiple dam regulated river reaches. A system model set up for the larger catchment should rather be used in such circumstances. WQ2000 will still yield valid results for the off-channel portion of each of the above quaternaries.

7.2 Feedback loops

The standard WQ2000 system (Figure 3.1) does not make use of the WQT Demand Centre module. Hence WQ2000 does not cater for feedback loops. This is because the most significant feedback loop occurs in the Vaal Barrage catchment, but this feedback cycle spans more than one quaternary catchment. (The Vaal Barrage catchment includes 17 quaternary catchments.) Hence the feedback loop would have to be broken at each quaternary catchment boundary. To work correctly a feedback loop must fit within a single system that is run as an integral whole. Hence the WQ2000 model cannot be used to simulate the effect of the Vaal Barrage catchment feedback loop. In any event, the current system-operating rule means that this feedback effect is effectively seldom in operation. This is because for most of the time very little of the effluent returned to Vaal Barrage is recycled back to users in the Vaal Barrage catchment (Herold and Rademeyer, 2000). Feedback loops elsewhere in the Vaal River catchment are insignificant.

Modelling of feedback loops requires setting up a custom made system layout, such as that used in the VRSAU to represent the Vaal Barrage sub-system (Herold, 1999).

7.3 Detailed evaluation

In many instances the standard WQ2000 system layout will be sufficiently accurate to yield the final results required to support the investigations. However, more detailed evaluation of some development options may require a custom made system layout to more accurately describe the catchment features. In such cases WQ2000 can still be used to deliver a coarse approximation to rapidly assess the water quality implications of a range of options. Thereafter a more detailed system would need to be set up to evaluate the most favoured options.

8. USER MANUAL

A user manual is given in Appendix A. The manual is also available in electronic form via the WQ2000 help menus.

FURTHER DEVELOPMENT

Two types of further development are proposed. These comprise extension of the WQ2000 model to include the rest of South Africa and improvements aimed at increasing the versatility the system. These are discussed further in the following sections.

9.1 Extension to rest of South Africa

The basic modelling software has been developed and successfully tested and applied to the most complex and highly developed areas of South Africa. The Vaal River test catchment includes two complete water Management Areas (WMAs) (the Upper and Middle Vaal WMAs) and substantial portions of two other WMAs (the Lower Vaal and upper Orange WMAs).

The success in applying the model to this area indicates that it can be expected to work just as well for the remaining WMAs of South Africa. The WQ2000 software has already been developed. The remaining task is to populate the database for the remaining catchments of the country. To facilitate this, a calibrated monthly time step hydrological database is already available on a quaternary basis for the entire country from the WRC's WR90 project (Midgley, et. al, 1990). The DWAF's WSAM model (Watson and Schultz, 2000) also provides quaternary scale coverage of the country and serves as a source of present day catchment development data. The WQT hydrosalinity model has also been calibrated for some of the most strategically important portions of the country.

The most logical course of action is to extend the WQ2000 database to first include those catchments for which the WQT model has already been calibrated. These include the upper Crocodile River, Orange River, upper Olifants, Orange and Fish-Sundays catchments and portions of the Western Cape. Other studies may well have extended the WQT modelling to more catchment areas.

The WQT model can be calibrated for a coarse coverage of relatively widely dispersed sampling points for the remaining areas. This would allow extension of the WQ2000 database coverage to the whole of South Africa. This is considered more practical than attempting to calibrate the model to the same level of detail as used in previous catchment studies (such as the VRSAU study).

The WRC is presently investigating the feasibility of updating the WQ90 manuals to include the latest 12 years of hydrology. Various improvements to the hydrological modelling are envisaged. The intention is also to include a level of water quality analysis in the revision. WQ2000 provides an ideal vehicle for this. The WQ2000 software could easily be adapted as a vehicle to support the creation of a much more powerful interactive electronic water quantity and water quality evaluation system.

9.2 Model improvements

Users could benefit from various enhancements to the WQ2000 model. These are discussed below.

9.2.1 Graphical display

The present version allows production of quaternary result summary sheets and a map showing the results for selected parameters or outputs for each quaternary. The user can also examine the monthly flow, TDS concentration and TDS load time series text files produced by each run of the WQT model. These time series can then be manipulated with the user's own software to produce time series or duration curve plots.

Such plotting routines are not readily available to most potential users. These could be incorporated in WQ2000 to permit the viewing of selected plots.

9.2.2 Comparison with water quality targets

The inclusion of tables of water quality standards and user modifiable water quality targets would allow comparison with the results to determine the percentage time and degree to which targets would be violated by each option. These comparisons could be tabulated or presented in graphical form for the quaternary under consideration. Regional results could also be presented. (For example, the quaternaries for which the water quality target is violated could be colour coded.)

9.2.3 Metadata

Metadata is required to document the sources of the default data the key assumptions used. A change list is required to track the changes made to the default values.

9.2.4 Protect changes to WQT catchment washoff module

At present WQ2000 provides a series of tabs containing default values that the user can change. The last two of these are for changes to the WQT catchment salt washoff module. In view of the skill and experience required before attempting such changes to these model calibration parameter values it is recommended that access to these tabs are moved and should appear only after further selections have been made. A warning and disclaimer should also be displayed before this option becomes available.

9.2.5 Irrigation model parameters

At present WQ2000 does not provide a means for the user to modify the WQT model irrigation parameter values. This facility was not included to reduce the degree of knowledge of the WQT model required by the user. Menu tabs to allow adjustment of these parameter values could be included.

9.2.6 Future time horizons

At present WQ2000 allows the user to evaluate natural or present day conditions. Menus are also provided to alter variables to represent anticipated future development conditions. However, a useful feature would be to include scenarios of future development conditions (e.g. projected urban areas at 10 year intervals, or annual growth rates). The user could then select a time horizon (say 2015) and the model would then interpolate the appropriate urban area, catchment salt recharge rate, water demand and effluent flow. The appropriate starting catchment and irrigation area salt storages could be calculated from the calibrated present day WQT model parameter values.

9.2.7 Other water quality variables

The basic structure of WQ2000 can be extended to include the modelling of water quality variables other than TDS. The next logical progression might be to include a breakdown of the major economically important salts comprising the TDS (such as sodium, chloride, sulphate and fluoride). This could make use of the same WQT model. The main disadvantage is that the model has not yet been calibrated for individual salts. Hence the results of previous studies cannot be drawn upon to populate the model. (Although, the plan to implement fluoridation of water supplies may well lead to calibration of WQT for fluoride for more developed catchment areas.)

WQ2000 could also be extended to include biodegradable variables (such as nitrates, ammonia and COD) or variables with more complex pathways through the environment (such a phosphate and metals, in which deposition and re-suspension play important roles). However, the in-stream decay processes controlling such variables tend to occur at a smaller spatial scale that quaternary catchment size. Simulation of concentrations at the quaternary catchment outlets therefore might not be sufficiently meaningful to represent the more severe conditions arising nearer to the points of discharge of pollution sources.

9.2.8 System modelling

In Section 7.1 it is indicated that WQ2000 cannot accurately accommodate simulation of in-stream conditions along regulated river reaches. This is because downstream system elements would have to be included to model the month by month quantities of water that have to be released through the quaternary catchment to meet downstream water requirements. This limitation could be overcome by setting up a large-scale coarse system model for the larger system. This could be used to simulate the monthly releases from the major system dams, which could in turn provide the monthly water release data required as input to the selected quaternary catchment.

This approach is beyond the scope of the present study. It would also increase the computation time, since a system model similar to that used in the VRSAU study would first have to be run for the larger system before the quaternary catchment could be simulated. Moreover, there is little scope for further water resource development along such regulated watercourses. Any such evaluation would almost certainly have to be carried out using system-modelling techniques. WQ2000 is not intended to fulfil this purpose.

10. CONCLUSIONS

10.1 Attainment of project aims

The WQ2000 model has been successfully developed and applied to the Vaal River catchment. The WQT model calibrations carried out for the VRSAU study upon which WQ2000 is based included both highly developed and undeveloped catchment areas. In developed regions the model calibrations cover areas incorporating as few as one quaternary catchment. In other areas the calibrated gauges command incremental catchments that include several quaternary catchments. (For example the incremental catchment above Frankfort weir (gauge C8H001) includes 18 quaternary catchments covering an area of 15 498 km².) Hence the model is well able to interpolate data for large catchments located between sparsely distributed calibration points.

10.2 Model uses

WQ2000 provides a powerful means to rapidly assess catchment water quality for both natural and present day conditions for the off-channel case or taking into account the inflow from upstream catchments. These assessments make use of a sophisticated monthly time step hydro-salinity model, without the user having to have any in-depth knowledge of the WQT model or its calibration.

WQ2000 can be used to:

- Obtain a rapid overview of the current water quality status, using the GIS Viewer features.
- Obtain present day (or natural) WQT model calibration parameter values. These
 can be taken from the WQ2000 menu, or can be derived in the form of text files
 that can be used directly as input to the WQT model from the prepared data files
 generated by the model. Parameter values can be obtained for the selected
 quaternary catchment and for the upstream catchment, which is the weighted
 aggregate for a number of upstream quaternary catchments.

- Rapidly test a wide variety of development options. This is the most powerful application of WQ2000. The most common options that can be tested include one or more of the following:
 - Change in urban area
 - Change in irrigated area
 - Change wetland area
 - Introduce new dams, or change the sizes of existing dams
 - Change mine pumpage flow rate and concentration
 - Add new effluent sources or alter flow rate and TDS concentration
 - Alter water importation flow rate and salinity
 - Change or introduce channel bed loss (usually associated with mining)
 - Change water demand on minor dams or major dams
 - Change the major dam minimum water release.

The user is also able to change the calibration parameters used in the WQT model Salt Washoff module. This is recommended only for advanced WQT model users.

This range of choices allows for the testing of a large variety of catchment development and management options.

The user may build up a project database incorporating the development changes affecting the region of concern that have occurred since the default database was last updated.

• WQ2000 has been designed for ease of use. As such it is ideal for rapid testing of the salinity implications of a planned new development. This represents a valuable compliment to the existing WR90 manuals, which is in many respects much more versatile than WR90. The proposed extensions to WR90 (the WR2000 proposal) are expected to greatly increase the power of WR90 by making it a more interactive system. WQ2000 could serve as a useful prototype for the WR2000 development.

11 RECOMMENDATIONS

11.1 Application of WQ2000

The WQ2000 model for the Vaal River catchment should be put to use as soon as possible. In the first instance it should be of use to the following organisations:

- DWAF Directorate of Planning
- DWAF Directorate of Water Quality Management
- DWAF Regional Offices
- CMAs (once established)
- · Consulting firms
- Water Boards

It is particularly important that those involved in the planning of water resources (i.e. those who make use of WR90 and WSAM) also take account of water quality at all levels of scheme development. The speed and ease of use of WQ2000 makes it feasible to carry out water quality assessments for even the smallest schemes and at the very earliest stages of project development.

This is a significant breakthrough, since now water quality implications can be sifted long before the most favoured quantity based schemes have been identified. Salinity implications can therefore be taken into account in a more integrated manner, rather than being considered only at a much later stage, when some of the best options may already have been rejected or when water quality implications may introduce a whole range of new options.

11.2 Identification and solution of problems and enhancements

It is anticipated that use of the model may reveal some shortcomings. A large number of quaternaries, with many variables per quaternary are involved. It is therefore possible that users may identify anomalies. It is strongly recommended that such problems be brought to the attention of the developers so that appropriate corrections can be made.

A budget should be made available to cover the cost of such amendments for the first year of operation. At the end of this period a new CD-ROM can be distributed. Alternatively a Web Site can be set up where new revisions can be posted.

Use of the model may also reveal desirable enhancements. A means of collating and assessing these suggested enhancements is also desirable.

11.3 User Support System

Steps 11.1 and 11.2 need to be supported. This can best be achieved by setting up a User Support System (USS). This should incorporate:

- Model testing
- Presentations to potential users
- · Workshops (to form the basis for evaluation of the system)
- · Preparation of training material and a training course
- · Recording of skills base (i.e. those who have undergone suitable training)
- · Central assimilation of identified user problems and their correction
- Notification of identified problems and distribution of updates via a web page.

A system similar to that being prepared by the DWAF for WSAM could serve as an excellent model for the envisaged USS. Such a system requires the resources of a stable established organisation. The DWAF appears to be well suited for this role.

11.4 Model improvements

Certain model enhancements have already been identified. These should be implemented at an early stage, before extending the modelling to other catchments. These include:

11.4.1 Graphical display

Routines to allow the display of monthly time series and TDS duration curves should be included.

11.4.2 Water quality targets

Tables of TDS targets should be included in the database. These default values could be based on the SA Water Quality Guidelines (Department Of Water Affairs and Forestry, 1996). The user should be able to select the appropriate guideline (e.g. for domestic use, or irrigation use.) or set a user-defined target (which may, for example, represent a local interim target). The guideline target should be plotted on the graphical display. Provision should also be made to determine the percentage exceedance of the target value.

11.4.3 Metadata

The inclusion of metadata recommended to document the sources of the default data, the assumptions used and to track changes made.

11.4.4 Protect changes to WQT catchment washoff module

It is considered desirable to hide the tabs for changing the WQT catchment salt washoff module calibration parameter values, accompanied by suitable warnings of the consequences of inappropriate changes.

11.4.5 Future time horizons

Modifications should be made to incorporate development information for future time horizons in the default database, and allowance made for the user to select a future year for evaluation. Options should also be provided to modify the default projections. This will entail the development of a routine to calculate the appropriate starting catchment and irrigation area salt storages from the calibrated present day WQT model parameter values.

11.4.6 Irrigation model parameters

Provision should be made for the user to view and change the WQT irrigation module parameter values. These too should be hidden from general use with appropriate warnings when this option is invoked.

11.4.7 Other water quality variables

Although expansion to other water quality variables is feasible, it is recommended that this not be attempted until after the salinity model has been extended to the rest of the South African catchments.

11.4.8 System modelling

Extension of the WQ2000 model to incorporate system modelling is not recommended.

11.5 Extension to rest of South Africa

The WQ2000 model database should be extended to cover the remaining WMAs.

This can best be achieved by first including those catchments to which the WQT model has already been applied. In the first instance model calibrations are already available for such areas. These also represent areas of recognised importance where water quality plays a significant role.

Coarse scale WQT model calibration can be carried out for the remainder of the country and the database extended accordingly.

Extension of WQ2000 to other catchments could be co-ordinated with the revision of WR90. The benefit stemming from this would be the lengthened and improved hydrological record, which would permit use of the last 12 years of water quality data, which in many instances would almost double the useable water quality record.

11.6 Recommended program

A phased approach is recommended.

Phase 1: Model development This is the initial development phase, which
has been completed with this report and its products.

- Phase 2: Model testing and enhancement A one year phase is envisaged during which tasks 11.1 to 11.4 would be carried out.
- Phase 3: Extension to remainder of Country This comprises task 11.5. It is anticipated that this would require 2 to 3 years. It could best be co-ordinated with the revision of WR90.

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APPENDIX A

USER MANUAL

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New Users

New users should read

Introduction
System Requirements
Installation
About WQ2000 Projects
Tutorial

The general operation of WQ2000 is described under

Quaternary Information - Help Summary GIS Viewer Quaternary Hierarchy Diagram

More information is available under the following topics:

Navigating data tables
Glossary
Tips on using WQ2000
File Maintenance
Rebuilding Upstream Quaternary Data
Troubleshooting & Error messages
Program Technical Information
Running the WQT Model Manually
Support

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Introduction

WQ2000 was developed under WRC Project 950 – WQ2000: Development of an Interactive Surface Water Quality Information and Evaluation System for South Africa.

WQ2000 serves as a user interface for viewing quaternary parameters from the WQ2000 database, for running the WQT model, displaying the results in a summary report, and for representing the data on a map using the DWAF GISViewer.

System Requirements

Also see:

WQ2000 Help contents

Installation

The minimum system requirements for installing and running WQ2000 are:

- A personal computer with Windows NT Version 4 Service Pack 3, Windows 95/98 or compatible version.
- 70MB hard disk space for program and initial data files
- * 100MB free hard disk space for temporary files while running the applications
- * Super VGA screen, minimum 800 x 600 resolution.

- 64MB RAM.
- CD-ROM (only required for drive for installation)

Installation

Also see:

WQ2000 Help contents System Requirements

Read the ReadMe.txt file on the WQ2000 Setup CD for last minute changes not applied to the Help file or manual.

To install the WQ2000 software and data files:

- Insert the WQ2000 Setup CD-ROM into the CD drive. The CD AutoRun Index screen should appear automatically.
- Select Setup WQ2000, and follow the prompts on the screen.
- Should the DWAF GISViewer not already be installed on your PC, select Setup DWAF
 GISViewer from the CD AutoRun screen, and follow the Setup prompts on the screen. The
 GIS Viewer is part of the WSAM application (Water Situation Assessment Model). Refer to
 the GISViewer User Manual should you need more information.
- Unless the GISViewer is already configured for a default layout, copy the file WQ2000.gvf from \GISViewer directory on the Setup CD to C:\Program Files\DWAF\GISViewer\GISViewer, or wherever the GISViewer is installed. Alternatively search for the file PCFast.gvf to locate to directory for this file.
 - Start the GIS Viewer (Windows Start | Programs | DWAF GisViewer | GisViewer), and select menu option Tools | Options. On the Start-up page, select Use custom *.gvf file and browse for the WQ2000.gvf file copied in step 4 above. Click OK, and exit GISViewer.
- Continue to Startup up WQ2000 for instructions on creating your first WQ2000 project.

Should you experience any problems executing WQ2000, please see the Troubleshooting and Support sections in the Help file. More detail about the installation is available under the Program Technical Information section in the Help file.

Note: WQ2000 interfaces with the DWAF GISViewer. The development of the GISViewer however is not part of this project. The GISViewer is supplied on the WQ2000 Setup CD courtesy of DWAF. For upgrades and support contact DWAF directly.

UNINSTALLING WQ2000

To remove a WQ2000 installation from the computer:

- Make a backup of all projects you may want to archive
- Select Windows Start | Settings | Control Panel | Add/Remove Programs, select WQ2000 and click Add/Remove.
- The above steps will only remove files stored on the hard drive by the Setup program.
 Projects created afterwards have to be deleted manually. Use Windows Explorer, and delete the C:\Program Files\WQ2000 directory with all it's sub-directories and files.

Tutorial in Using WQ2000

Also see:

WQ2000 Help contents

This tutorial should help the user to get acquainted with all the important features of WQ2000. In this tutorial we wish to see what the effect of introducing an upstream mine discharge would be on the average TDS concentration of quaternary C11E, and to display the data graphically on a map.

Start-up up WQ2000

If not already installed, refer to the installation instructions

To start the WQ2000 program, select Start on the Windows task bar, and select Programs | WQ2000 | WQ2000.

When WQ2000 starts up, it displays the Open WQ2000 dialog, where a project to work with should be selected. By default the previous project used will be selected. Immediately after installation no project exists, and only the Create a new project option will be available. Click OK after selecting an option.

The Create New Project dialog appears. Enter a new project name, e.g. MyTest. Leave the default source project as Base Data, and click OK.

The new project is now created and opened. The current project name is shown in the WQ2000 title bar. The Quaternary Selection page will be shown.

Selecting a quaternary

On the Quaternary Selection page we need to specify the quaternary to work with. As we want to introduce a mining discharge to a quaternary upstream of C11E, we need to know which quaternaries supported by WQ2000 are upstream of it. To find out, select menu option Map | Quaternary Hierarchy Diagram.

Enter C11E as the root node, and click Update.

A message will be displayed mentioning the number of quaternaries found. Click OK.

The hierarchical diagram displays the logical structure upstream of C11E. Let's say we want to introduce the mine discharge to C11B.

Close the dialog to return to the Quaternary Selection page.

For our exercise we want to compare the status quo with the altered condition for C11B (the quaternary where the change takes place) and further downstream at quaternary C11E.

One can either enter the quaternary number in the Quaternary field, or select it from the map. For interest sake, click Select Quaternary from Map.

A map displaying all the CMA's is displayed.

Click on Upper Vaal. Always click close to the centre of the area of interest. The centre closest to the clicked point will be selected, regardless of the boundaries displayed.

The quaternary map for the Upper Vaal will be displayed. Click the Zoom In button and click on the map to enlarge it.

Click the Select button, and click on C11B (just below C11A). The selected quaternary's name is displayed in the field on top of the screen.

Click OK. The Quaternary Selection page is displayed again, and the parameters for C11B are loaded.

Displaying status quo results

Click the Next button at the bottom of the screen until the Outputs page is displayed.

Click Display Summary Information. The WQT model will be executed, and after which the Summary Information Report will be displayed. An example of such a report is given in Appendix B.

For the present day case the summary results report shows the cumulative average TDS concentration to be 230 mg/l, with a concentration of 666 mg/l being exceeded for 95% of the time.

Now click on the Selection tab and enter quaternary C11E. Click the Outputs tab. Click Display Summary Information to execute the WQT model and display the results for quaternary C11E.

The default cumulative average TDS concentration for C11E is 116 mg/l and the value exceeded 95% of the time is 127 mg/l.

Editing parameter values

Again select quaternary C11B by clicking on the Selection tab and entering C11B.

Click the *Physical Data 2* tab to display the second page containing values for the quaternary. The left-hand column displays values for the selected quaternary. The right hand column displays the calculated sum for all upstream quaternaries. These values are not editable, and appear in grey.

Notice that the quaternary name and the data value set, Present Day or Naturalised, is displayed above the page tabs. Click on Present Day. Naturalised data will now be displayed.

Notice that some fields in the left-hand column are now also disabled (greyed). This is because these fields are not applicable for naturalised conditions.

Click Naturalised Values to return the display to present day values again.

Move the mouse pointer to one of the data fields, and keep it there for a moment. A description for the field will pop up. To disable this feature, click the question mark button at the bottom of the screen.

The same descriptions are also available in the help screens. The relevant help text for the displayed screen is called up by pressing F1.

A number appears to the left of some field captions. This number relates to a position on the system diagram. Click the System Diagram button to display this diagram. (Click the + button to enlarge the image.) Close the diagram screen.

We want to introduce a mine discharge to this quaternary. Change the 1st field from the top of the screen from 0 to 10000, representing a flow rate of 10000 m³/day (equivalent to 10 Ml/day). Change the 2nd field from the top of the screen from 0 to 4000 mg/l.

Notice that the fields turn yellow. This is to indicate that this field's value is different form the stored value. To reset to the stored value, double click the field.

Displaying new results

The other tab pages display more parameters for the current quaternary. Click on the Outputs tab to display the Outputs page.

Click Display Summary Information. The WQT model will be executed for quaternary C11B, after

which the Summary Information Report will be displayed.

Notice that the new mine discharge data is reflected in the first column. The reported average TDS concentration for quaternary C11B has now increased to 992 mg/l and the 95% exceedance level to 2587 mg/l. This is not our final answer yet, as we want to see the effect on C11E.

Click the print button on top of the screen should you wish to print the report.

You may now repeat the above steps to edit more data, and display the summary report to see the effect.

Once all changes are made, click the Save button at the bottom of the screen.

Select the Selection page again, select quaternary C11E, go to the Output page, and click Display Summary Information. This will display the answer we were looking for.

Notice that the new mine discharge data for quaternary C11B is now reflected in the 3rd column, as it is now in the upstream catchment. The reported average TDS concentration for quaternary C11E has now increased to 173 mg/l and the 95% exceedance level to 196 mg/l. These increases are much smaller than at C11B. This is due to considerable dilution from the water imported to quaternary C11C (from Heyshope Dam) and quaternary C11E (from Zaaihoek Dam).

Displaying the map

We now intend to display a map representing the new TDS values graphically.

Only saved data is displayed on the map. If there are any changed values that should be rendered, click the Save button before proceeding.

Select menu option Map | GIS Viewer. The Map Selection dialog will be displayed.

Indicate the quaternaries to be displayed: Click Select all quaternaries upstream of... and enter C11E.

Select up to four items from the second field. A selection is made by typing a "Y" either of the last two columns, under the heading Q for the off-channel case for the selected quaternary, or C for the cumulative case taking account of discharges from upstream quaternaries. In this example choose them all for the cumulative case: Average TDS Concentration (TDS), Median TDS concentration (T50), 95 percentile TDS concentration (T95) and 98 percentile TDS concentration (T98). A maximum of four selections is permitted.

Press the drop down menu in the third field to display the four fields that you have checked. Select one of them (in this case Average TDS concentration) as the variable value used to shade each quaternary catchment. The remaining three selected items will automatically be used to display on pie or bar charts on the map.

In this example the last check box will be greyed out and become unavailable. If three or less items had been selected this box would have become accessible. If checked, the variable selected for shading the quaternary catchments would also have been included in the pie chart.

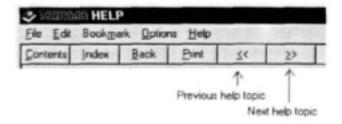
Finally click OK and confirm your answer by pressing Yes in the pop-up window.

The WQT model will be executed for quaternaries effected by changes since their previous calculation only.

Once all calculations are done, the GISViewer will be displayed.

Always close the GISViewer before activating it again from WQ2000.

One last note:

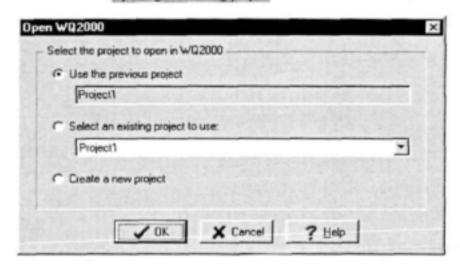


Use the browse buttons on the help screen to display help topics sequentially. (Sorry for mentioning this - but many users don't know how to turn a page in a help file.)

About WQ2000 Projects

Also see:

WQ2000 Help contents Creating a new WQ2000 Project Opening an existing project



The WQ2000 Setup includes data for the available quaternaries for up to September 1995. Normally you would like to make changes to this data to reflect known changes since 1995 to the network. You may also want to make changes to the data in order to run the WQT model for different scenarios in what-if analysis.

WQ2000 isolates the initial base data as supplied with the Setup CD from any changes, by copying all the base data files to a project directory on the hard disk. Changes made are then stored in the user's project directory. Different projects (i.e. project directories) can be created for different scenarios. Each project is stored in a separate directory on the computer's hard disk.

No changes are allowed to the 1995 base data directly - this only serves as a source for new projects. It is however recommended that a present day base data project is created. The user should apply all known changes to the network since 1995 to this project. When creating a new project for what-if analysis, the user should then clone the present day base data instead of the original 1995 base data.

A project is created by selecting the File | New menu option in WQ2000. When creating a new project, the user can select to clone any existing project. The default will be to copy the 1995 base data supplied with the Setup CD to the new user specified project directory.

The current project name is shown in the WQ2000 title bar.

To rename a project, exit WQ2000, and use Windows Explorer to rename the project directory.

To delete a project, select menu option File | Delete Project.

To archive a project, or to copy a project from one computer to another, one simply need to copy the directory.

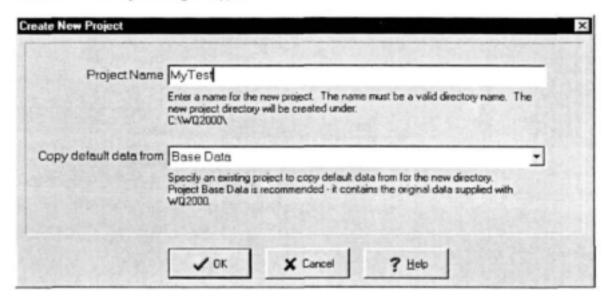
Creating a New WQ2000 Project

Also see:

WQ2000 Help contents About WQ2000 Projects Opening an existing project

To create a new WQ2000 project, select menu option File | New Project.

The Create New Project dialog will appear.



Enter a name to identify the new project in the *Project Name* field. This name will be used as a directory name ("folder name") on the hard disk; hence it should only contain valid directory name characters. The path for the new directory, which is the WQ2000 program directory, is shown underneath the field for reference.

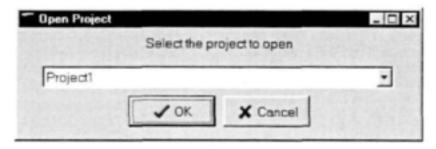
Specify an existing source project in the *Copy default data from* field. The default is the Base Data project, which contains the 1995 data supplied with Setup. To include data changes from a previous project, select the previous project as source.

Click OK to create the new project directory and to copy the data files to it. The new project will automatically be selected as the new working project in WQ2000; i.e. the previous project will be closed.

Opening An Existing WQ2000 Project

Also see:

WQ2000 Help contents About WQ2000 Projects Creating a new WQ2000 Project



To open an existing project, select menu option File | Open Project.

Select a project name from the list of available projects, and click OK.

The current project will be closed, and the new project will be opened. The new project will be the default project the next time WQ2000 is started.

Using the database Navigator

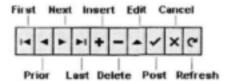
Also see:

Help contents

The database Navigator is activated when the user selects the Edit Effluent Data button in the Physical Data 1 page.

The Navigator component (a database navigator) is used to move through the data in a database table, and perform operations on the data, such as inserting a blank record or posting (saving) a new or changed record. It is used in conjunction with the data controls, such as the edit fields or the data grid, which gives the user access to the data, either for editing the data, or for simply displaying it.

The database navigator consists of multiple buttons.



When the user chooses one of the navigator buttons, the appropriate action occurs on the table the navigator is linked to. For example, if the user clicks the Insert button, a blank record is inserted in the dataset.

This table describes the buttons on the navigator:

| Button | Purpose |
|--------|---|
| First | Sets the current record to the first record |
| Prior | Sets the current record to the previous record |
| Next | Sets the current record to the next record |
| Last | Sets the current record to the last record |
| Insert | Inserts a new record, and sets the data set into Edit state, and enable the Cancel and Post buttons |
| Delete | Deletes the current record and makes the next record the current record |
| Edit | Puts the data set into Edit state so that the current record can be modified, and enable the Cancel and Post buttons |

Post Writes changes in the current record to the database

Cancel Cancels edits to the current record, restores the

record display to its condition prior to editing, and

turns off Insert and Edit states if they are active

Refresh Redisplays the current record from the dataset,

thereby updating the display of the record on the

screen

File Maintenance

Also see: WQ2000 Help contents

This option is accessed by selecting File | File Maintenance from the menu.

It is recommended to execute File Maintenance after manual manipulation of the data files.

The data used by the WQT model is stored in a database, together with a number of external data files. The experienced user can add and remove external data files, but then needs to update the database accordingly. The File Maintenance option assists in checking for missing or unknown files.

When activated, File Maintenance will prompt if it should check for outflow files (generic file names OUT2.Q & OUT2.TDS) for each quaternary. Quaternary outflow files are always stored as sets of four files: a .Q and a .TDS file for each of Natural and Present day conditions. If one of these files is missing, the remaining files will be deleted, and the flag in the database indicating their existence will be cleared. If a set of four files is found, the flag will be set in the database.

The next prompt asks if it should check for missing monthly data files. All missing files (files mentioned in the database but that do not appear on the project directory) will be reported. Similarly all files found on the project directory that are not mentioned in the database are reported. No files are created or deleted.

Rebuilding Upstream Quaternary Data

Also see: WQ2000 Help contents

This option is activated by selecting menu option File | Rebuild Upstream Data.

Upstream data for all quaternaries will be recalculated. These calculations may take a few hours, depending on the processor speed.

User changes are only allowed to quaternary data. Upstream data for a quaternary is calculated automatically by WQ2000, and should not be edited. Due to the time required for calculations, the results of upstream calculations are stored, and the calculations are only repeated after changes for affected quaternaries.

When changes to a quaternary are saved, WQ2000 flags the downstream quaternaries as outdated. Before running the WQT model, WQ2000 first recalculates all outdated upstream data for each of the quaternaries of the current quaternary, and then clears the flag(s).

When advanced users make changes are made by advanced without using WQ2000; the flags indicating the upstream data is outdated might not be set correctly. The Rebuild Upstream Data should always be called after manual changes to the database.

This option is unavailable if there are any unsaved changes.

Quaternary Information - Help Summary

Also see:

WQ2000 Help contents

WQ2000 presents water quality parameter data at quaternary level. The WQ2000 database contains more than a thousand parameters for each quaternary. 36 of the most important parameters that can be edited by the user are displayed on the quaternary information screen. This screen is divided into seven pages, each accessible by either clicking the page's tab at the top of the screen, or by clicking the Next and Back buttons at the bottom of the screen.

The pages are:

- Quaternary Selection page for selecting the quaternary of interest
- Physical Data page 1, page 2 and page 3 physical network data
- Parameter page 1 and page 2 salt washoff model parameters
- Outputs Options to run the WQT model and to report <u>summary information</u> for the quaternary.

The data displayed on these pages are from the current project file. The project name is displayed in the title bar on top of the screen. See <u>About WQ2000 Projects</u> for more detail.

Most of the fields displayed on the physical data pages are numbered. These numbers refer to the numbers on the system diagram, which indicates the position in the network diagram each parameter applies to. See <u>System Diagram</u> for more detail.

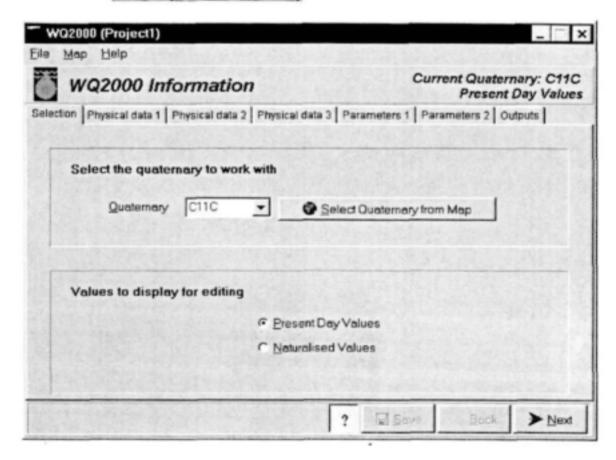
Values for the quaternary can be edited on the physical data and parameter pages - see <u>Editing Field</u>
<u>Values</u> for mode detail.

Quaternary Selection

Also see:

WQ2000 Help contents

Quaternary Information Summary



The Quaternary Selection page is the first page on the WQ2000 screen. Click the Selection tab to call up this page. It is used to select the quaternary of interest.

There are four ways of specifying the quaternary:

- Enter the quaternary number directly in the Quaternary field.
- Select it from the list displayed when the arrow button in the field is pressed.
- To select the quaternary from a CMA map, click the Select Quaternary from Map button. See Quaternary Selection Map for more detail.
- The selected quaternary number is displayed next to Current Quaternary. If this number is clicked, the quaternary selection map is also displayed.

It is not always clear from the map which quaternary is downstream from which. The <u>Quaternary Hierarchy Diagram</u> can be used to identify the upstream position quaternaries for each quaternary. The WQ2000 database contains data for each quaternary in the Vaal River catchment. Further extensions are expected to provide coverage for the entire country. This diagram can also be used to identify which quaternaries are available.

Quaternary Selection Map



The quaternary of interest needs to be specified on the Quaternary Selection page. To assist in selecting the quaternary, the Select Quaternary from Map button can be clicked to display the selection map.

Initially a map displaying all the CMA's is displayed.

The general procedure is (a) to select a CMA. A map of all the quaternaries in the CMA is then displayed. (b) Select a quaternary in the CMA, and (c) click OK. The data for the quaternary will then be loaded, and the quaternary number will be displayed on the quaternary selection page.

Selecting an area: A CMA or quaternary can be selected by either selecting it from the combo field above the map, or by clicking on its name on the map. Always click close to the centre of the area of interest. The centre closest to the clicked point will be selected, regardless of the boundaries displayed. The name of the clicked area will appear in the combo field. The Select button must always be depressed to be able to select an area.

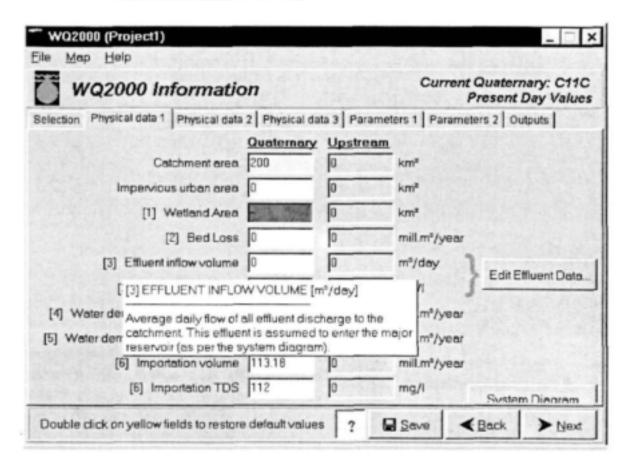
Zooming: The zoom option can be used to enlarge or reduce the image scale. Zooming has no effect on the amount of detail displayed. The image can only be enlarged three levels, and it can only be reduced to it's original size. When zooming out from a quaternary map already at it default scale; the CMA map will be displayed. To zoom in or out, click the appropriate button, click on the area of interest the required number of times, and click the Select button to select an area.

Editing Field Values

Also see:

WQ2000 Help contents

Quaternary Information Summary



The detail described here applies to the Physical Data and Parameter pages. These screens display values for the selected quaternary. The left-hand column displays values for the quaternary itself, and the right hand column displays the calculated sum for all upstream quaternaries. The upstream values are not editable, and appear in grey.

The quaternary name and the data value set, Present Day or Naturalised, is displayed above the page tabs. By clicking on the quaternary name another quaternary can be selected. By clicking on the data set name the displayed values alternate between Present Day and Naturalised.

When naturalised data is displayed, some fields in the left-hand column are also disabled (greyed). This is because these fields are not applicable to naturalised conditions.

To display descriptions for the fields displayed, either (a) press F1 to display the help text for the current page, or (b) enable the pop-up help. To enable pop-up help, click the "?" button at the bottom of the screen. It is pressed by default. Move the mouse pointer to one of the data fields, and keep it there for a moment. A description for the field will pop up. The same descriptions are also available in the help screens.

A number appears to the left of some field captions. This number relates to a position on the system diagram. Click the System Diagram button to display this diagram.

When data in any of the fields is edited, it will be validated. A warning message will be displayed if

the value is outside a specified range for the specific field. A warning can be ignored, but if a field is displayed in red, either a valid value has to be entered, or the Escape key has to be pressed to restore the original value.

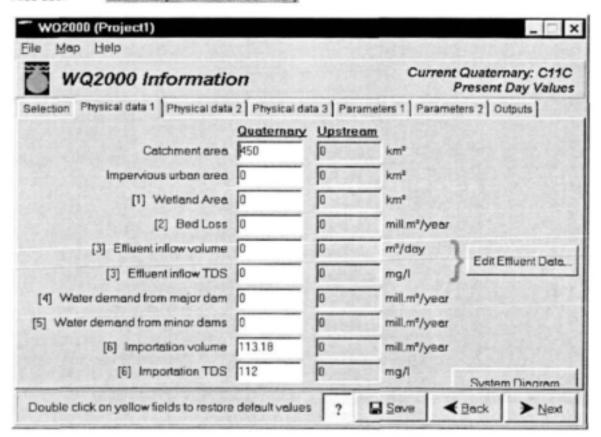
The background of a field turns yellow when it is edited. This is to indicate that this field's value is different form the stored value. To reset to the stored value, double click the field.

To save changes, click the Save button at the bottom of the screen. The values for all yellow fields will be written to the project's database, and the fields will be reset to white.

Changed values don't have to be saved before the model can run. The model will use the changed values even if they are not saved.

Physical Data Page 1

Also see: Quaternary Information Summary



The Physical Data page 1 is the second page on the WQ2000 screen. Click the Physical Data 1 tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

The following fields are displayed on the page:

Quaternary

The quaternary of interest selected via the previous screen.

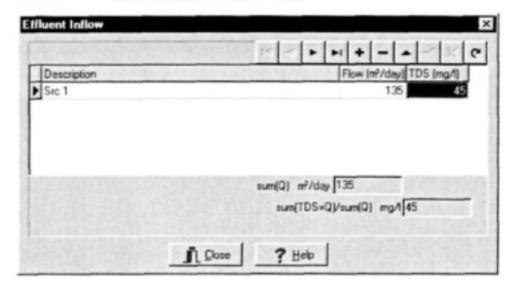
| Upstream | | The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries. |
|-------------------------------|--------------------------------------|---|
| Catchment area | km² | Effective catchment area of the quaternary or portion thereof to be modelled. |
| Impervious urban area | km² | The catchment area that is impervious. This represents the paved portion of urbanised areas that is effectively connected to the surface water drainage system. Aside from interception losses, the rainfall on this portion of the catchment contributes to direct surface runoff, with no infiltration into the soil. |
| [1] Wetland area | km² | The surface area of wetlands (vieis) within the catchment. |
| [2] Bed loss | 10 ⁶ m ³ /year | The estimated annual loss of water into the bed of channels and wetlands. This excludes the net evaporation loss from channel or wetland surfaces, which is calculated separately by the model. |
| [3] Effluent inflow volume | m ³ /day | Average daily flow of all effluent discharge to the catchment. This effluent is assumed to enter the major reservoir (as per the system diagram). |
| [3] Effluent inflow TDS | mgЛ | Flow-weighted average TDS concentration of effluent discharged to the catchment |
| [4] Major dam water demand | 10 ⁶ m ³ /year | Annual water abstraction requirement from the major dam (as per the system diagram). |
| [5] Minor dam water demand | 10 ⁶ m ³ /year | Annual water abstraction requirement from the minor dam (as per the system diagram). |
| [6] Importation volume | 10 ⁶ m ³ /year | Annual inter-basin transfer of water to the catchment. |
| [6] Importation TDS | mg/l | TDS concentration of water imported to the catchment. |

The Effluent Inflow fields cannot be edited on this screen directly. Click the Edit Effluent Data button to display the Effluent Discharge Values dialog for entering these values. Unlike other user editable fields, effluent inflow values are immediately saved after being edited, and the field will not become yellow. The displayed value cannot be restored to the original saved value.

Editing Effluent Discharge Values

Also see:

Quaternary Information Summary



The Effluent Inflow fields cannot be edited on Physical Data page 1. Click the Edit Effluent Data button to display the Effluent Discharge Values dialog for entering these values.

This dialog allows for entering effluent inflow from different sources. Refer to Navigator for instructions on using the database navigator for data manipulation.

The fields on this dialog are:

Description

Description of effluent point source.

Inflow volume m3/day Average daily flow of all effluent discharge to the point source. This effluent is assumed to enter the major reservoir (as per the system diagram).

Inflow TDS

ma/l

Flow-weighted average TDS concentration of effluent point source.

The total flow (Q) and flow-weighted average TDS concentration (TDS xQ)/(Q) for the quaternary will be calculated from all the entered point sources and written to the database and Physical Data page 1.

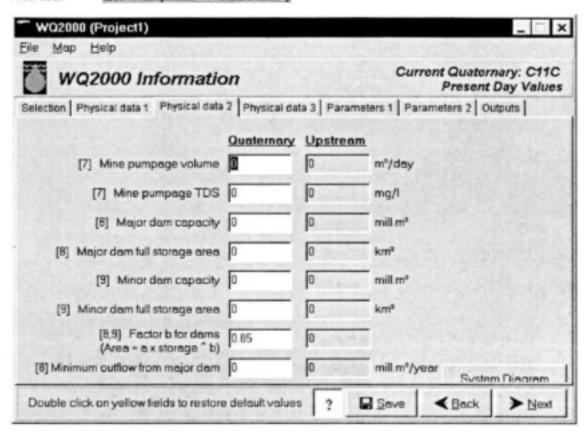
Unlike other user editable fields, effluent inflow values are immediately saved after being edited, and the field on the Physical Data page will not become yellow, as is the case with other fields that can be reset to their original value.

When user entered data is deleted, the total effluent inflow and concentration will be adjusted to represent the remaining entered values. If all records are deleted, the total will be zero.

Physical Data Page 2

Also see:

Quaternary Information Summary



The Physical Data page 2 is the third page on the WQ2000 screen. Click the *Physical Data 2* tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

The following fields are displayed on the page:

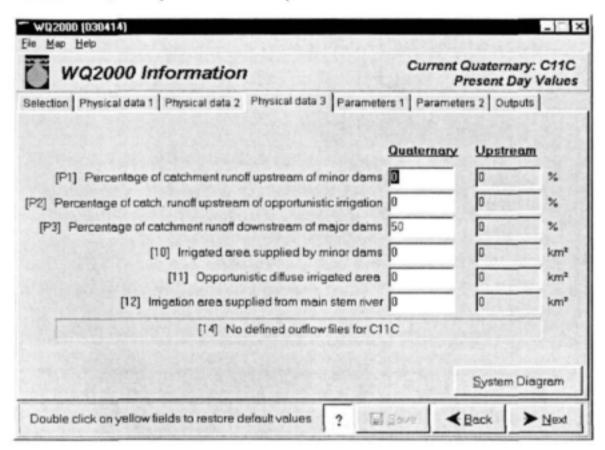
| Quaternary | | The quaternary of interest selected via the previous screen. |
|----------------------------|--------|---|
| Upstream | • | The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries. |
| [7] Mine pumpage volume | m³/day | Mine water discharge to the catchment. The salinity of this water is independent of the |

| | | water supply from surface water, since this water is assumed to be pumped from underground. |
|--|--------------------------------|---|
| [7] Mine pumpage TDS | mg/l | Average TDS concentration of mine pumpage water discharge. |
| [8] Major dam capacity | 10 ⁶ m ³ | Full storage capacity of the major dam. The major dam is taken as being on the main stem of the river and supported from upstream major dams (see the system diagram). Minor dams do not support this dam. |
| [8] Major dam full storage area | km² | Surface area of major dam when 100% full. |
| [9] Minor dam capacity | 10 ⁶ m ³ | Full storage capacity of the combined minor dams. Minor dams are as taken being off the main stem of the river and are not supported by any other dams. Nor do they support downstream dams. These dams mostly comprise farm dams and small dams used to supply water to towns and industries. Minor dams have been aggregated into one effective "minor dam". This is an accepted hydrological modelling practice that has been adopted since many such dams are typically dispersed through each quaternary catchment. Modelling them as a single effective dam provides a reasonable representation of the cumulative effect of such dams on catchment runoff. |
| [9] Minor dam full storage area | km ² | Combined surface area of minor dams when 100% full. |
| [8,9] Factor b for dams: (Area = a x storage ^b) | | Factor used to estimate the dam surface area for any storage state. Factor a is calculated internally from the specified full storage capacity (FSC) and full storage area (FSA) specified above as: a = FSA x FSC ⁶ |
| [8] Minimum outflow from major dam | mill.m³/year | Minimum monthly release from the major dam. This is typically the dam compensation release. It can also represent the flow need to meet downstream water requirements. This is only an approximation, since the downstream system requirement will change from month to month in response to climatic variation and dam storage state. When this effect is important it is strongly recommended that a more detailed system analysis is undertaken. |

Physical Data Page 3

Also see:

Quaternary Information Summary



The Physical Data page 3 is the fourth page on the WQ2000 screen. Click the *Physical Data 3* tab to call up this page. It is used to display and edit physical data values used to run the WQT model for the selected quaternary of interest.

Numbers in front of the field titles refer to the position on the system diagram.

The following fields are displayed on the page:

| Quaternary | | The quaternary of interest selected via the previous screen. |
|---|---|---|
| Upstream | | The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries. |
| [P1] Proportion of catchment runoff upstream of minor dams | % | The proportion of the catchment runoff that is assumed to enter upstream of minor dams (see system diagram). This is an estimated average for all the aggregated minor dams. |

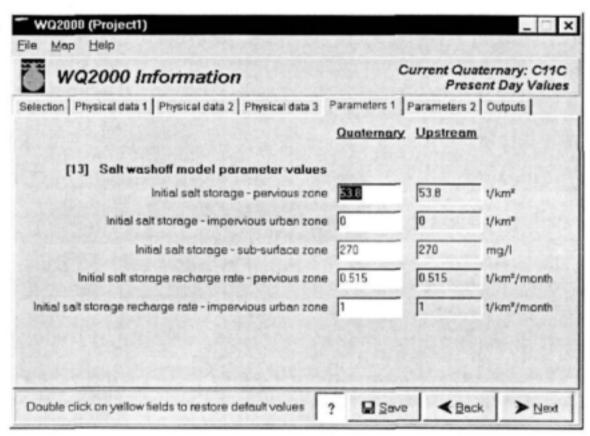
| [P2] Percentage of catchment runoff upstream of opportunistic irrigation | % | The proportion of the catchment runoff that is assumed to enter upstream of diffuse irrigation areas that are not supplied by minor dams (see system diagram). Such irrigation areas are not supplied from the main stem channel, and hence cannot be supported from upstream major dams. |
|--|-----|---|
| [P3] Percentage of catchment runoff downstream of major dams | % | The proportion of the catchment runoff remaining after interception of minor dams and diffuse irrigation that enters the system below the major dam (see system diagram). |
| [10] Irrigated area supplied by minor dams | km² | Irrigation area located directly below minor dams and is supplied from them (see system diagram). |
| [11] Opportunistic diffuse irrigation area | km² | Opportunistic catchment irrigation direct from local streams that is not supplied by minor dams (see system diagram). These irrigation areas are not adjacent to the main stem river and are not supported by major dams. |
| [I2] Irrigation area supplied from main stem river | km² | Irrigation area adjacent to the main stem river that can be supported from upstream major dams (see system diagram). This irrigation is assumed to be located downstream of the major dam. |

Parameters Page 1

Warning!

Only users skilled in the use of the WQT model (Allen and Herold, 1988) should attempt to change the model calibration parameters. Calibration requires attention to a number of important factors. Failure to follow the procedures properly will lead to a unbalanced calibration, which will lead to misleading results. Further information is given in Department of Water Affairs report P C000/00/9490 (Stewart Sviridov & Oliver, 1990).

Also see: Quaternary Information Summary



The Parameter Data page 1 is the fifth page on the WQ2000 screen. Click the *Parameters 1* tab to call up this page. It is used to display and edit salt washoff values used to run the WQT model for the selected quaternary of interest. A description of these values is given by Herold and Allen in DWAF report P C000/00/7086: Vaal River System Analysis, Water quality modelling, Volume A: Water quality calibration model, Pretoria, 1988.

The following fields are displayed on the page:

The quaternary of interest selected via the previous screen.

The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been.

specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries.

Initial salt storage - pervious zone

t/km²

t/km²

mg/l

Calibrated WQT model parameter defining the starting salt storage per unit area for the pervious portion of the catchment. (Parameter SWSSP in the WQT model.)

Initial salt storage impervious urban zone

Calibrated WQT model parameter defining the starting salt storage per unit area for the impervious portion of the catchment. (Parameter SWSSU in the WQT model.)

Initial salt storage sub-surface zone

Calibrated WQT model parameter defining the starting salt storage concentration in the hydrologically active portion of the soil. (Parameter SWSSG in the WQT model.)

Initial salt storage t/km2/month recharge rate pervious zone

Calibrated WQT model parameter defining the initial rate at which the salt storage in the pervious portion of the catchment is replenished. (Parameter SWSSRP in the WQT model.) The pervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, part of which enters direct surface runoff, the remainder infiltrating

to the sub-surface salt storage.

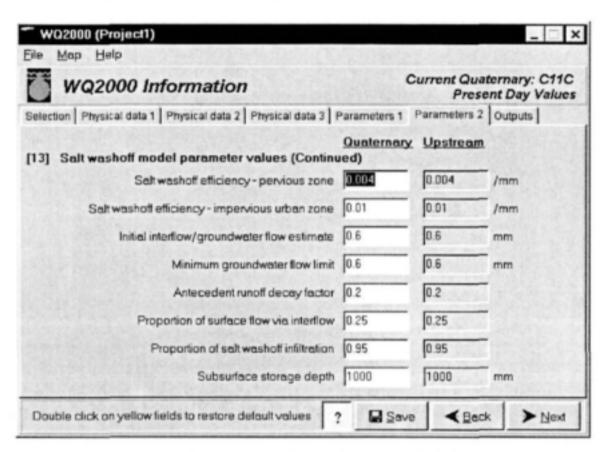
Initial salt storage t/km²/month recharge rate urban zone

Calibrated WQT model parameter defining the initial rate at which the salt storage in the impervious portion of the catchment is replenished. (Parameter SWSSRU in the WQT model.) The impervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, all of which enters direct surface runoff.

Parameters Page 2

Also see:

Quaternary Information Summary



The Parameter Data page 2 is the sixth page on the WQ2000 screen. Click the Parameters 2 tab to call up this page. It is used to display and edit salt washoff values used to run the WQT model for the selected quaternary of interest. A description of these values is given by Herold and Allen in DWAF report P C000/00/7086: Vaal River System Analysis, Water quality modelling, Volume A: Water quality calibration model, Pretoria, 1988.

The following fields are displayed on the page:

| Quaternary | | The quaternary of interest selected via the previous screen. |
|---------------------------|------------------|---|
| Upstream | | The sum of all quaternaries upstream of the selected quaternary, but downstream of quaternaries for which monthly flow and TDS concentration output files have been specified. These values are calculated internally by the model based on the information specified for each upstream quaternary. The user can only change these values by specifying new values for upstream quaternaries. |
| Salt washoff efficiency - | mm ⁻¹ | Calibrated WQT model parameter defining the efficiency with which salts are washed from the |

pervious zone

pervious area salt store in response to rainfall. (Parameter SWEP in the WQT model.) The amount of the stored salt washed out each month follows the decay equation:

Where:

Wper = salt load washed from pervious storage (t/km²)

Sper = salt load in pervious storage (t/km²)

R = rainfall (mm)

Salt washoff efficiency – impervious urban zone mm⁻¹

Calibrated WQT model parameter defining the efficiency with which salts are washed from the impervious area salt store in response to rainfall. (Parameter SWEU in the WQT model.) The amount of the stored salt washed out each month follows the decay equation:

Where:

Wurb = salt load washed from impervious storage (t/km²)

Surb = salt load in impervious storage

(t/km2)

R = rainfall (mm)

Initial interflow / groundwater flow estimate mm

Calibrated WQT model parameter giving the initial estimate of the surface runoff derived from sub-surface flow from groundwater and interflow. (Parameter SWEQG in the WQT model.)

Minimum groundwater flow limit mm

Calibrated WQT model parameter defining the minimum subsurface flow. (Parameter SWEQG in the WQT model.) Hence if the monthly catchment runoff is less than SWEQG, then the entire flow is assumed to be surface flow.

Antecedent runoff decay factor Calibrated WQT model parameter defining the proportion of the previous month's sub-surface flow that is carried forward to the current month. (Parameter SWRDF in the WQT model.)

Proportion of surface flow via interflow Calibrated WQT model parameter defining the proportion of the current month's surface runoff (after subtracting the subsurface flow carried forward from the previous month) attributed to sub-surface flow. (Parameter SWPAF in the WQT model.) Proportion of salt washoff infiltration Calibrated WQT model parameter defining the proportion of the salt washed out of the pervious surface salt store that infiltrates to the subsurface storage zone. (Parameter SWPAF in the WQT model.)

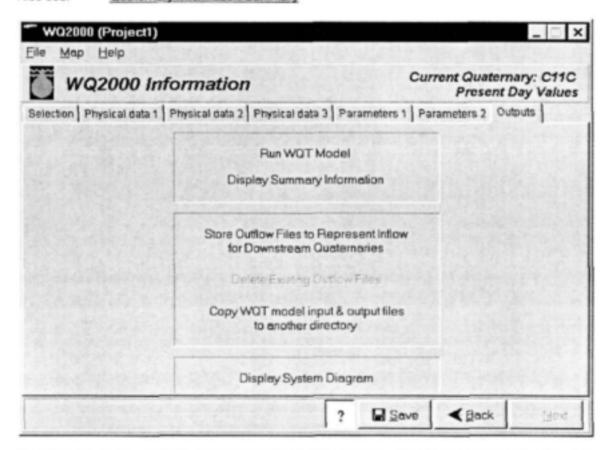
Subsurface storage depth mm

Calibrated WQT model parameter defining the water depth of the catchment subsurface storage zone. (Parameter SWHGW in the WQT model.) This is an empirical model parameter used to simulate the slow lagged response of the combined vadoze zone and the hydrologically significant active portion of the groundwater.

Model Outputs

Also see:

Quaternary Information Summary



The Model Outputs page is the last page on the WQ2000 screen. Click the Outputs tab to call up this page. It is used to run the model and use the processed results as described below.

The options on this page are the following:

 Run WQT Model: This option simply runs the WQT model for the selected quaternary, using the changes made on the previous pages. The changes do not have to be saved before the model will use them. No output is displayed. WQ2000 first processes all upstream quaternaries if necessary. It then creates the parameter files for this quaternary, and then runs the model. The model is actually executed six times for different sections and phases of the network.

On completion a message will display "Done". If an error occurs, an error message will be displayed, and processing will terminate. All model parameter input and output files are left as is until they are recreated for another run of the model.

- Display Summary Information: The <u>Summary Information</u> report is displayed. An example
 of a Summary Information Report is given in Appendix B. If the WQT model has not already
 run, the above procedure will be executed automatically. In most cases this will be the only
 option the user will need to select on this page.
- Store Outflow Files: Stores the result of the previous run of the WQT model. OUT2.Q and OUT2.TDS represent these files on the advanced system diagram.

Outflow files represent inflow into the downstream quaternary, from the current quaternary and all quaternaries above it. When processing the downstream quaternary, WQ2000 does not have to process any quaternaries above the point where it finds an outflow file. This can save a considerable amount of processing time.

For some quaternaries more accurate measured results are available than those simulated by the model. If these files are copied as outflow files to the project directory, they will automatically be detected by the File Maintenance option, and will then be used by WQ2000 to produce more accurate results.

If data for a quaternary with a saved outflow file, or a quaternary upstream of it, is changed, the saved outflow files downstream of it will automatically be replaced by the new calculated files.

The Quaternary Hierarchy Diagram option can be used to see which quaternaries have saved outflow files. All these quaternary names are preceded by "<<<".

- Delete existing outflow files: This option deletes saved outflow files for the selected quaternary. This option is only available if there are saved files for the quaternary.
- Copy WQT Model files: This option is used to copy model input and output files to another directory for future use. Every time the model is run, existing files in the model directory are replaced with new files for the selected quaternary, including its changes (edited values).

Model directories should not be confused with project directories. Project directories contain the WQ2000 database and files for all quaternaries. A model directory only contains parameter files for the current quaternary, and WQT model program files.

There are two model directories: one for present day values, and another for naturalised values. This option only copies one of these two at a time. Select this option again to copy the other set of files as well.

The default destination directory is C:\WQ2000\User\QQQQPPPP where QQQQ will be the quaternary number and PPPP will either be Nat or Pday, depending on the data set selected, e.g. C:\WQ2000\Data\C11APDay.

Data from the present day and naturalised directories should not be copied to the same destination, as some files will be overwritten.

Refer to Running the model manually for more information about the model.

Display System Diagram: The <u>System Diagram</u> is displayed. This option has the same function as the *System Diagram* buttons on the previous screen pages.

Summary Information

Also see:

Quaternary Information Summary

The Summary Information report option is available from the Model Output page on the WQ2000 screen, and applies to the current selected quaternary.

The report presents results from the WQT model, as well as some of the input parameters used to get these results. All changes made by the user are shown on the report, even if they were not saved at the time the report was produced. This allows the user to easily identify what assumptions were made to produce the results.

The parameters presented on the report are the following:

| Qual | ternary | Present | day |
|--------|-------------|---------|-------|
| 121100 | DOLL HOSELY | riesein | LAGRA |

Results from simulation for present day catchment development conditions. The results in this column are for those portions of the catchment that are not influenced by inflow from upstream quaternary catchments. Represented by the bottom half of the system diagram with no inflow from upstream quaternary catchments [15] or major dams [16]. Water importation direct to the quaternary [6] is included.

Quaternary Natural

Results from simulation for natural (virgin) undeveloped catchment. The results in this column are for those portions of the catchment that are not influenced by inflow from upstream quaternary catchments. Represented by the bottom half of the system diagram with no inflow from upstream quaternary catchments [15] or major dams [16]. Water importation direct to the quaternary [6] is included.

Cumulative Present day

Results from simulation for present day catchment development conditions. The results in this column are for the entire system, including the influence of inflows from upstream quaternary catchments.

Cumulative Natural

Results from simulation for natural (virgin) undeveloped catchment. The results in this column are for the entire system, including the influence of inflows from upstream quaternary catchments.

Physical Data (Inputs)

These values are the same as on Physical Data pages 1 to 3 on the input screen.

Catchment area (km2)

Effective catchment area of the quaternary or portion thereof to be modelled.

Impervious paved area (km²)

The catchment area that is impervious. This represents the paved portion of urbanised areas that is effectively connected to the surface water drainage system. Aside from interception losses, the rainfall on this portion of the catchment contributes to direct surface runoff, with no infiltration into the soil.

[1] Wetland Area (km²)

The surface area of wetlands (vieis) within the catchment.

[1] Bed Loss (10⁶m³/year) Specified annual loss of water into the bed of channels and wetlands. This excludes the net evaporation loss from channel or wetland surfaces, which is calculated separately by the model. Specified average daily flow of all effluent discharge to the catchment. [3] Average effluent inflow volume (m3/day) This effluent is assumed to enter the major reservoir (as per the system diagram). [3] Average effluent Flow-weighted average TDS concentration of effluent discharged to the inflow TDS concentration catchment (mg/l) [4] Water demand from Annual water abstraction requirement from the major dam (as per the major dam (10⁶m³/year) system diagram). [5] Water demand from Annual water abstraction requirement from the minor dam (as per the minor dams (10°m3/year) system diagram). Specified annual inter-basin transfer of water to the catchment. [6] Importation (10°m3/year) [6] Average water Specified average TDS concentration of water imported to the importation TDS quaternary catchment (route [6] of system diagram). concentration (mg/l) [7] Mine pumpage Specified mine water discharge to the catchment. The salinity of this (m³/day) water is independent of the water supply from surface water, since this water is assumed to be pumped from underground. [7] Mine Pumpage TDS Average TDS concentration of mine pumpage water discharge. concentration (mg/l) [8] Major dam storage Full storage capacity of the major dam. The major dam is taken as capacity (106m3) being on the main stem of the river and supported from upstream major dams (see the system diagram). Minor dams do not support this [8] Major dam surface Surface area of major dam when 100% full. area (km²) [9] Minor dams storage Full storage capacity of the combined minor dams. Minor dams are as capacity (10⁶m³) taken being off the main stem of the river and are not supported by any other dams. Nor do they support downstream dams. These dams mostly comprise farm dams and small dams used to supply water to towns and industries. Minor dams have been aggregated into one effective "minor dam". This is an accepted hydrological modelling practice that has been adopted since many such dams are typically dispersed through each quaternary catchment. Modelling them as a single effective dam provides a reasonable representation of the cumulative effect of such dams on catchment runoff. Combined surface area of minor dams when 100% full. [9] Minor dams surface area (km²) [8,9] Factor b for dams: Factor used to estimate the dam surface area for any storage state. (AREA = ax)Factor a is calculated internally from the specified full storage capacity STORAGE^b) (FSC) and full storage area (FSA) specified above as: a = FSA x FSC^b

[8] Minimum outflow from major dam (10⁶m³/year) Minimum rate at which water is released from the major dam. A constant discharge rate is assumed.

[P1] Proportion of catchment runoff upstream of minor dams The proportion of the catchment runoff that is assumed to enter upstream of minor dams (see system diagram). This is an estimated average for all the aggregated minor dams.

[P2] Proportion of catchment upstream of unregulated irrigation The proportion of the catchment runoff that is assumed to enter upstream of diffuse irrigation areas that are not supported by minor dams (see system diagram). Such irrigation areas are not supplied from the main stem channel, and hence cannot be supported from upstream major dams.

[P3] Proportion of catchment downstream of major dams The proportion of the catchment runoff remaining after interception of minor dams and diffuse irrigation that enters the system below the major dam (see system diagram).

[10] Irrigated area supplied by minor dams (km²) Irrigation area located directly below minor dams and is supplied from them (see system diagram).

[11] Opportunistic diffuse irrigated area (km²) Diffuse catchment irrigation direct from local streams that is not supported by minor dams (see system diagram). These irrigation areas are not adjacent to the main stem river and are not supported by major dams.

[12] Irrigation area supplied from main stem river (km²) Irrigation area adjacent to the main stem river that can be supported from upstream major dams (see system diagram). This irrigation is assumed to be located downstream of the major dam.

SW module parameters (Inputs) [13]

WQT model Salt Washoff module parameter values used in the simulation.

Initial salt storage – pervious zone (t/km²) Calibrated WQT model parameter defining the starting salt storage per unit area for the pervious portion of the catchment. (Parameter SWSSP in the WQT model.)

Initial salt storage – impervious urban zone (t/km²) Calibrated WQT model parameter defining the starting salt storage per unit area for the impervious portion of the catchment. (Parameter SWSSU in the WQT model.)

Initial salt storage subsurface zone (mg/l) Calibrated WQT model parameter defining the starting salt storage concentration in the hydrologically active portion of the soil. (Parameter SWSSG in the WQT model.)

Initial salt storage recharge rate - pervious zone (t/km²/month) Calibrated WQT model parameter defining the initial rate at which the salt storage in the pervious portion of the catchment is replenished. (Parameter SWSSRP in the WQT model.) The pervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, part of which enters direct surface runoff, the remainder infiltrating to the sub-surface salt storage.

Initial salt storage recharge rate - urban zone (t/km²/month) Calibrated WQT model parameter defining the initial rate at which the salt storage in the impervious portion of the catchment is replenished. (Parameter SWSSRU in the WQT model.) The impervious area catchment store is increased by this amount each month. A portion of the salt is washed from the store by rainfall, all of which enters direct surface runoff.

Salt washoff efficiency – pervious zone (1/mm) Calibrated WQT model parameter defining the efficiency with which salts are washed from the pervious area salt store in response to rainfall. (Parameter SWEP in the WQT model.) The amount of the stored salt washed out each month follows the decay equation:

Where:

Wper = salt load washed from pervious storage (t/km²)

Sper = salt load in pervious storage (t/km2)

R = rainfall (mm)

Salt washoff efficiency – urban impervious zone (1/mm) Calibrated WQT model parameter defining the efficiency with which salts are washed from the impervious area salt store in response to rainfall. (Parameter SWEU in the WQT model.) The amount of the stored salt washed out each month follows the decay equation:

Wurb = Surb x
$$(1 - e^{-SW \in U^*R})$$

Where:

Wurb = salt load washed from impervious storage (t/km2)

Surb = salt load in impervious storage (t/km2)

R = rainfall (mm)

Initial interflow/groundwater flow estimate (mm) Calibrated WQT model parameter giving the initial estimate of the surface runoff derived from sub-surface flow from groundwater and interflow. (Parameter SWEQG in the WQT model.)

Minimum groundwater flow limit (mm) Calibrated WQT model parameter defining the minimum subsurface flow. (Parameter SWEQG in the WQT model.) Hence if the monthly catchment runoff is less than SWEQG, then the entire flow is assumed to be surface flow.

Antecedent runoff decay factor Calibrated WQT model parameter defining the proportion of the previous month's sub-surface flow that is carried forward to the current month. (Parameter SWRDF in the WQT model.)

Proportion of surface flow via interflow Calibrated WQT model parameter defining the proportion of the current month's surface runoff (after subtracting the subsurface flow carried forward from the previous month) attributed to sub-surface flow. (Parameter SWPAF in the WQT model.)

Proportion of salt washoff infiltration Calibrated WQT model parameter defining the proportion of the salt washed out of the pervious surface salt store that infiltrates to the subsurface storage zone. (Parameter SWPAF in the WQT model.)

Subsurface storage depth (mm) Calibrated WQT model parameter defining the water depth of the catchment subsurface storage zone. (Parameter SWHGW in the WQT model.) This is an empirical model parameter used to simulate the slow lagged response of the combined vadoze zone and the hydrologically significant active portion of the groundwater.

Upstream inflow

[15] Defined upstream inflow volume (10⁶m³/year) Mean annual inflow from upstream quaternaries. This is the average of the defined monthly flows that have been stored from previous model runs. [15] Defined upstream inflow TDS concentration (mg/l) Flow-weighted mean TDS concentration calculated from file of defined monthly values.

Results

[14] Average TDS concentration (mg/l)

Simulated average TDS concentration outflow from the catchment (via route [14] in system diagram).

[14] Median TDS concentration (mg/l)

Median TDS concentration of simulated monthly outflow from catchment via route [14] in system diagram. Monthly TDS concentration exceeded for 50% of the time.

[14] 95 percentile TDS concentration (mg/l) Simulated monthly TDS concentration in catchment outflow via route [14] exceeded for 5% of the time.

[14] 98 percentile TDS concentration (mg/l) Simulated monthly TDS concentration in catchment outflow via route [14] exceeded for 2% of the time.

[14] Flow-weighted average TDS concentration (mg/l) Simulated flow-weighted average TDS concentration of outflow from the catchment (via route [14] in system diagram). Calculated as Sum (Q*C)/Sum (Q), where Q = monthly flows and C = monthly TDS concentrations.

[13] Average catchment runoff volume (10⁶m³)

Average annual runoff from the selected quaternary catchment. This includes urban runoff, but excludes the effects of irrigation, dams, mine pumpage and effluent discharge, abstractions, wetlands, bed loss and water importation.

[13] Average catchment runoff TDS concentration (mg/l) Simulated average TDS concentration of the washoff from the selected quaternary catchment (i.e. WQT model Salt Washoff module [13] salt export concentration.)

[8] Average TDS concentration in major dam (mg/l) Average simulated TDS concentration in the quaternary major dam. (I.e. arithmetic average of simulated monthly TDS concentrations in dam.) This value represents the concentration experienced by a user drawing water from the dam at a constant rate.

[8] Flow-weighted average TDS concentration of spillage from major dam (mg/l) Flow-weighted average simulated TDS concentration of the water spilled from the dam. This is generally lower than the arithmetic average concentration, since during flood events large volumes of water are spilled from the dam at diluted concentrations.

[14] MAR (10⁶m³)

Simulated mean annual outflow from catchment (via route [14] in system diagram).

System Diagram

Also see:

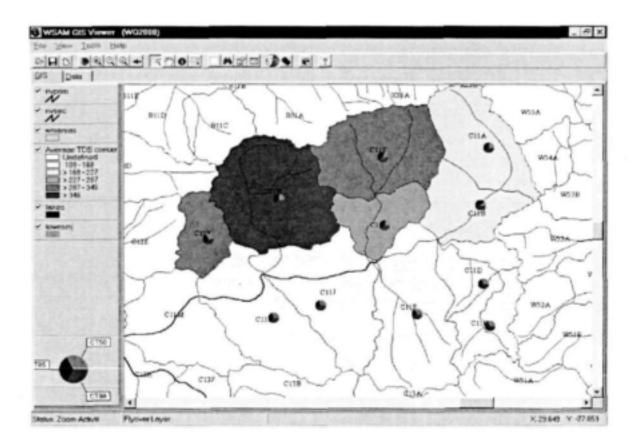
Quaternary Information Summary

The system diagram provides a schematic presentation of the network.

This screen is displayed by clicking System Diagram on any page on the WQ2000 screen, except on the Selection page. The diagram is presented in Appendix C in the user manual.

Most of the fields displayed on the physical data pages are numbered. These numbers refer to the numbers on the system diagram, which indicates the position in the network diagram each parameter applies to.

GIS Viewer



The GISViewer is used to display quaternary maps, presenting up to four numerical values per quaternary for comparison between the quaternaries. The first value is used to shade the quaternaries, while the next two or three values are used to display a pie or bar chart per quaternary.

To use the GISViewer, select WQ2000 menu option Map | GIS Viewer. The GIS Map Selection dialog is displayed, where the quaternaries and fields to display are selected. From this dialog the GIS Viewer is activated to display the required result. Quaternaries must be entered as a comma or space separated list. The Select all quaternaries upstream of... button can be used for automatic entering of the quaternaries for a part of the network.

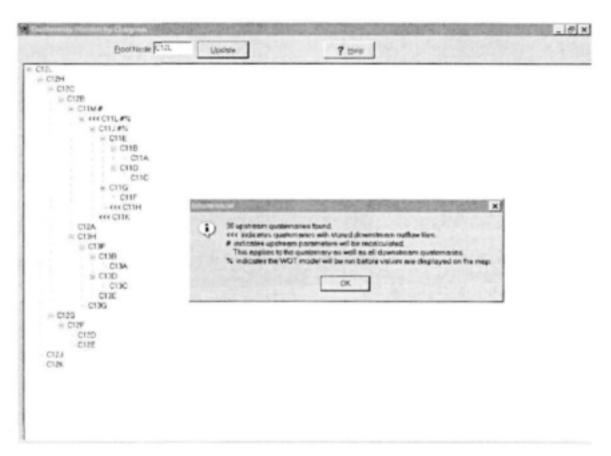
If no quaternaries are displayed, refer to the WQ2000 Setup instructions for loading a default layout in GISViewer for WQ2000.

The GIS Viewer was developed by the DWAF and is used in the DWAF's WSAM application (Water Situation Assessment Model). Refer to the GISViewer User Manual should you need more information.

WQ2000 communicates with the GISViewer through the Windows Clipboard. Any data already in the clipboard will be replaced when activating the GISViewer. The user is free to use the clipboard for whatever purpose after the GISViewer is displayed. NOTE: It is important to exit the GIS Viewer before activating it again from WQ2000.

GISViewer is provided with a number of maps (layers), including a Quaternary, CMA, Primary River, Secondary River and Provinces layers. To start GISViewer manually select Windows Start | Programs | DWAF GisViewer | GisViewer. When starting GISViewer this way there is no link between WQ2000 and GISViewer.

Quaternary Hierarchy Diagram



Select menu option Map | Quaternary Hierarchy Diagram to display the screen.

This option has the following purposes:

- It is not always clear from a less detailed map, as is provided with WQ2000 for quaternary selection, which quaternary is upstream of which. This can be clearly determined from this screen.
- The WQ2000 database does not contain data for each quaternary in the country. This diagram can also be used to identify which quaternaries are available.
- This option can be used to see which quaternaries have saved outflow files. All these quaternary names are preceded by "<<<".

Enter the most downstream quaternary for the area of interest, in the Root Node fields, and click Update. A message will be displayed mentioning the number of quaternaries found. Click OK.

The hierarchical diagram of the logical structure upstream of root node will then be displayed.

Running the WQT Model Manually

It is not the intention to describe the use of the WQT model in this manual. This section however describes how the model is run in the context of WQ2000.

WQ2000 uses a specially prepared version of WQT called WQT1. The version is set to execute without interrogating the user via the normal WQT model interactive dialog. Instead WQT1 reads the user instructions from prepared text files.

To run the WQT1 model outside WQ2000:

- Two similar directories on the hard disk are used for running the WQT1 model: one for naturalised data, and the other for present day data. The files in these directories are identical, except for the parameters in these files.
- * The option: "Copy WQT model input & output files to another directory" can be used to copy the files to another directory to protect them against being overwritten when the model is run again from within WQ2000. This option can only be used after the model has run, because the input files are only created when the model is run.
- The input and output parameter files are described in the WQT model documentation.
- The second and third lines in the .CMD files indicate the directories where the files are stored, and should be changed as applicable.
- The WQT1 model creates/replaces all .ANS files.
- Run the model from the MS DOS command prompt. When running the WQT1 model, a .KR5 network configuration input file must be specified as command line parameter, e.g. C:\>WQT1 WQ1.KR5.
- To run the model to include upstream influences:

Run WQT1 with WQ1.KR5

Edit file WQRV15.DAT and change line 5 (Line 5(a)) to:

15 " "

Run WQT1 with WQ2.KR5

To run the model to exclude upstream influences:

Run WQT1 with WQ1.KR5

Edit file WQRV15.DAT and change line 5 (Line 5(a)) to:

15 'dummy.q' 'dummy.q'

Run WQT1 with WQ3.KR5

- When running the WQT1 model with WQ3.KR5, it overwrites the output created by WQ2.KR5. To overcome this, the WQ3.KR5 output files will be written to a NoUsOut ("NO UpStream influence OUTput") subdirectory of the current directory, e.g. to C:\WQ2000\NATURAL\NOUSOUT. The input files are all taken from the current directory (C:\WQ2000\NATURAL in the previous example). This is accomplished by setting the 3rd line in WQ3.CMD to the NoUsOut directory.
- All of the data files that are created by WQ2000 are fully compatible with the original WQT model. Hence an advanced user who has the executable code for the original WQT model can simply use the data files as input as normal. The original WQT model executable code

and detailed instructions on its use are not included on the WQ2000 distribution CD-ROM.

Troubleshooting

Unable to run WQ2000 after Setup

WQ2000 requires ADO for access to the database. ADO is part of Microsoft Data Access Components (MDAC). MDAC is part of Windows 2000 and Windows XP, but needs to be installed separately for Windows 95 and 98. MDAC is also installed by various other applications. If WQ2000 gives an error message during start-up, it probably means that MDAC is not installed on the PC.

MDAC Version 2.1 can be found on the \Extras\ADO directory on the Setup CD. Refer to ReadMe_MDAC.doc on the CD for mode detail.

Support

Also see:

Troubleshooting

For support in using WQ2000, or for reporting any problems or comments, please contact:

Dr Chris Herold

Telephone:

(011) 706-8524

E-mail:

heroldcm@global.co.za

For support in using the GIS Viewer, contact DWAF.

Glossary

Allen, RB and Herold, CE (1988) Vaal River System Analysis, Water Quality Modelling, Volume A: Water Quality Calibration Model. Report P C000/00/7086, Department of Water Affairs and Forestry, Pretoria, South Africa.

Stewart Sviridov & Oliver (1991) Vaal River Water Quality Management Study, Calibration procedures for the monthly time step hydro-salinity model. Report P C00/00/9490, Department of Water Affairs and Forestry, Pretoria, South Africa.

Tips

Backup!: Remember to make regular backups of the data. If the database gets corrupted, EVERYTHING can be lost, and often nothing can be recovered!

Feedback: Users' comments on this program will be highly appreciated. Please let us know about any problems, defects or advice. See the <u>Support</u> section for contact numbers.

File Maintenance: Menu option File | File Maintenance should be executed regularly to refresh some tables.

Print Screen: To print a screen dump from Windows is not as simple as just pressing the *Print Screen* key as in DOS. Press *Print Screen* to copy a bitmap image of the entire screen to the clipboard, or press *Alt - Print Screen* to copy a bitmap image of the active window to the clipboard. Then call up any word processor, eg. Word Perfect or Word. Position the cursor where the image should be inserted, and press *Ctrl-V* or select menu option *Edit* | *Paste*, to load the image into the document. The image can then be printed from that application.

Program Technical Information

Also see:

Quaternary Information Summary

WQ2000 is a 32-bit program that will run on Windows NT Version 4 and Windows 95 or later.

The WQ2000 database is in MS Access 97 format. Monthly data files are ASCII files in the format described for the WQT model.

Refer to System Requirements for installation requirements.

Program Directories involved:

The following programs and files are installed in the default directories indicated:

C:\WQ2000

WQ2000 program files

C:\Base Data

Default project data files

C:\WQ2000\Current

WQT Model with present day data

C:\WQ2000\Natural

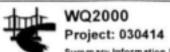
WQT Model with naturalised data

Other directories can be specified for C:\WQ2000 during installation.

While running WQ2000, mode directories may be created as specified by the user.

APPENDIX B

SUMMARY INFORMATION REPORT



Summary Information Report: Quaternary C11C

Page 1 Date: 2003/04/15

| Rescription | Quaternary Present day | | Upstream Present day | Upstream |
|--|---------------------------|---------|-------------------------|----------|
| Physical Data (Inputs) | | | | |
| Catchment area (km²) | 450 | 450 | 0 | |
| repervious paved area (km²) | 0 | | 0 | |
| Vetland Area (km²) [1] | 0 | 0 | 0 | |
| led Loss (mil.m²/year) [1] | 0 | 0 | 0 | |
| verage effluent inflow volume (mil.m²/year) [3] | 0 | - | 0 | |
| verage effluent inflow TDS concentration (mg/l) [3] | 0 | - | 0 | |
| Vater Demand from major dam (mill.m²/year) [4] | 0 | | 0 | |
| Nater Demand from minor dams (mill.m²/year) [5] | 0 | - | 0 | |
| (verage water importation volume (mit.mf/year) [6] | 113.18 | | a | |
| (verage water importation TDS concentration (mg/l) [6] | 112 | | 0 | |
| Ane pumpage (mil.mf/year) [7] | 0 | | 0 | |
| Ane pumpage TDS concentration (mg/l) [7] | 0 | | 0 | |
| Asjor dam storage capacity (mil.m²) [8] | 0 | | 0 | |
| fajor dam surface area (km²) [8] | 0 | | 0 | |
| Anor dams storage capacity (mil.m²) [9] | 0 | | 0 | |
| Anor dams surface area (km²) [9] | 0 | | 0 | |
| actor b for dams (AREA = a * STORAGE*b) [8,9] | 0.85 | | 0 | |
| Animum volume outflow from major dam (mill m/year) [8] | 0 | | 0 | |
| roportion of catchment runoff upstream of minor dams [P1] | 0 | 0 | 0 | |
| roportion of catchment runoff upstream of opportunistic irrigation [P2] | 0 | 0 | 0 | |
| roportion of catchment runoff downstream of major dams [P3] | 0.5 | 0.5 | 0 | |
| rrigated area supported by minor dams (km²) [10] | 0 | | 0 | |
| Opportunistic diffuse irrigated area (km²) [11] | 0 | | 0 | |
| rigated area supplied from main stem river (km²) [12] | 0 | | 0 | |
| alt Washoff Module Parameters (Inputs) [13] | | | | |
| nitial salt storage - pervious zone (t/km²) | 53.6 | 57.9 | 53.8 | 57 |
| ntial salt storage - impervious urban zone (t/km²) | 0 | 0 | 0 | |
| nitial salt storage - sub-surface zone (mg/l) | 270 | 273 | 270 | 2 |
| nitial salt storage recharge rate - pervious zone (t/kmf/month) | 0.515 | 0.52 | 0.515 | 0. |
| nitial salt storage recharge rate - impervious urban zone (t/km²/month) | 1 | 1 | 1 | |
| Salt washoff efficiency - pervious zone (/mm) | 0.004 | 0.004 | 0.004 | 0.0 |
| Salt washoff efficiency - impervious urban zone (/mm) | 0.01 | 0.01 | 0.01 | 0. |
| nitial interflow/groundwater flow estimate (mm) | 0.6 | 0.6 | 0.6 | |
| Animum groundwater flow limit (mm) | 0.6 | 0.6 | 0.6 | |
| Antecedent runoff decay factor | 0.2 | 0.2 | 0.2 | (|
| roportion of surface flow via interflow | 0.25 | 0.25 | 0.25 | 0. |
| Proportion of salt washoff infiltration | 0.95 | 0.95 | 0.95 | 0.9 |
| Subsurface storage depth (mm) | 1 000 | 1 000 | 1 000 | 10 |
| Jostream Inflows | | | | |
| lumber of defined inflows [15] | - | | 0 | |
| everage defined upstream inflow volume (mil.m²/year) [15] | - | | 0 | |
| Average defined upstream inflow TDS concentration (mg/l) [15] | - | | 0 | |
| lesults | | | Cumulative | |
| verage TDS concentration (mp/l) [14] | 113.03 | 181.74 | 113.03 | 181. |
| Aedian TDS concentration (mg/l) [14] | 115.135 | 172.265 | 115.135 | 172.2 |
| 5 percentile TDS concentration (mg/l) [14] | 119.651 | 278.252 | 119,651 | 278.2 |
| 6 percentile TDS concentration (mg/l) [14] | 123.416 | 281.258 | 123.416 | 281.2 |
| low-weighted average TDS concentration (mg/l) [14] | 110.259 | 106.92 | 110.259 | 106. |
| verage upstream inflow volume (mil.mf/year) [15] | | | 0 | |
| low-weighted average upstream inflow TDS concentration (mg/l) [15] | | - | | |
| verage catchment runoff volume (mil.m²/year) [13] | 37.14 | 37.14 | 37.14 | 37. |
| verage catchment runoff TDS concentration (mg/l) [13] | 175.05 | 177.63 | 175.05 | 177. |
| and a second sec | 35.37 | 0 | 35.37 | |
| verage TDS concentration in major dam (mg/l) [8] | | | | 4 (0.00) |
| | 7) [8] 111.02 | 106.452 | 111.02 | 106.4 |

APPENDIX C

SYSTEM DIAGRAM

