



TYNEMARCH

Optimising Water Resource and Supply Systems

Practical systems to enable the water companies ensure an adequate reliability of supply, as well as further reduce operating costs, are now required more than ever.

The pressure to reduce operating costs often leads to the lowest cost resources being utilised first. However there is a danger that short-term cost saving practices can lead to difficulties in maintaining adequate supplies in the medium to long-term. The outcome may be considerably greater costs over the medium/long-term due to the intense use of expensive transfers. A lack of a common basis for system modelling between operations and planning may have led to some of the difficulties encountered by a number of companies in recent times.

Water resource managers must make prior judgements regarding the timing and utilisation of abstraction licences, typically over a period of up to 3 years into the future. The specific details of each licence can vary widely in complexity. For example some licences may be limited to cover only part of the year or several years. Some licences include higher limits for a given number of days per annum. The task of the water manager is made more complicated when new facilities are commissioned within the operational planning period or when licence conditions change as new restrictions are imposed.

The optimal utilisation of water resources thus poses the classic problem of balancing short-term and long-term multiple objectives. Finding the best solution is made more complicated by the need to take into account operational constraints such as the mixing of borehole sources with water quality thresholds. Further, in many systems the output of a water treatment works may be linked to river conditions or reservoir levels.

To date the most common approach to water resources allocation has been to develop spreadsheet models of the system, containing all the flow and volume equations, and to manually adjust the outputs until an operation regime is found which meets the demand. Whilst this may be feasible for simple systems, the complexities of larger systems described above often make this approach impracticable. Further, the proper consideration of changes in the system and its constraints over time is difficult to implement and maintain using spreadsheets. Finally and most importantly in the current regulatory climate, the solutions found by trial and error are very unlikely to be optimal.

An attempt has been made by other software to apply formal optimisation techniques but this has been restricted to single sequential time step optimisation with many time steps required to cover the whole period. This approach requires prior subjective judgements to be made regarding the timing of licence usage and the utilisation of storage over the whole period which are unlikely to be optimal. However, the most serious drawback of step-by-step optimisation is that short-term minimum cost solutions will be produced which may lead to greater long-term costs, or worse still an inability to satisfy demand.

MISER was developed to overcome the problems described above to enable water managers and resource planners to achieve reliable supplies at minimum cost under a variety of predicted low-flow/high demand scenarios, subject to time dependent operational constraints. The key advance in the method is the use of a single pass optimisation over the whole period of interest without prejudging the timing and utilisation of licences, control rules, treatment works etc. This allows MISER to be used by both water resources planners and operational managers ensuring consistency and compatibility between the two functions.

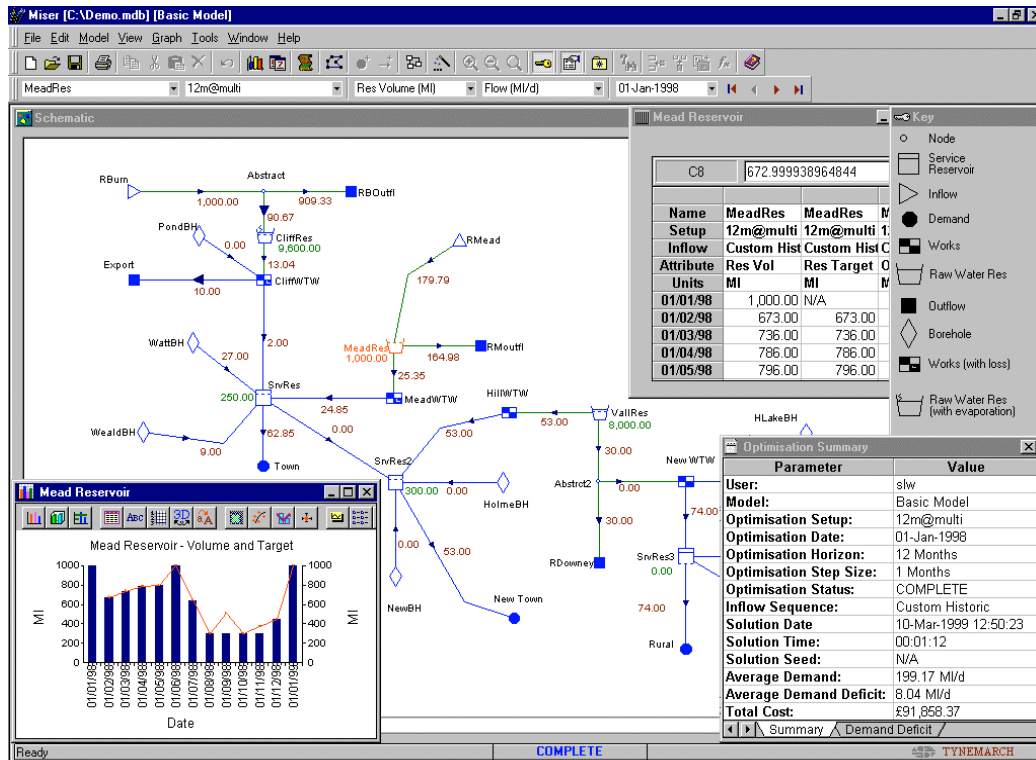
Type	Node	Node	Node	Node	Node	Node	Node
Name	MeadRes	MeadRes	MeadRes	MeadWTW	MeadWTW	MeadWTW	MeadWTW
Setup	12m@multi	12m@multi	12m@multi	12m@multi	12m@multi	12m@multi	12m@multi
Inflow	Custom Historic	Custom Historic	Custom Historic	Custom Historic	Custom Historic	Custom Historic	Custom Historic
Attribute	Res Vol	Res Target	Outflow	Shortfall	Cost	Outflow	Loss
Units	MI	MI	MI/d	as % of target	£/d	MI/d	MI/d
01/01/98	1,000.00	N/A	190.34		75.83	24.85	0.51
01/02/98	673.00	673.00	297.70	=(C8-B8)/C8*100	71.80	23.46	0.48
01/03/98	736.00	736.00	143.51	=(C9-B9)/C9*100	118.89	39.20	0.80
01/04/98	786.00	786.00	78.32	=(C10-B10)/C10*100	118.93	39.20	0.80
01/05/98	796.00	796.00	45.86	=(C11-B11)/C11*100	118.89	39.20	0.80
01/06/98	1,000.00	1,000.00	43.20	=(C12-B12)/C12*100	118.93	39.20	0.80
01/07/98	635.72	644.18	41.73	=(C13-B13)/C13*100	114.56	37.76	0.77
01/08/98	300.00	300.00	41.11	=(C14-B14)/C14*100	112.75	37.15	0.76
01/09/98	300.00	507.07	25.68	=(C15-B15)/C15*100	67.44	22.03	0.45
01/10/98	300.00	300.00	40.57	=(C16-B16)/C16*100	113.52	37.41	0.76
01/11/98	300.00	374.56	67.86	=(C17-B17)/C17*100	118.93	39.20	0.80
01/12/98	450.00	450.00	64.55	=(C18-B18)/C18*100	110.99	36.57	0.75
01/01/99	1,000.00	1,000.00					
		Sum of Shortfall		=SUM(E8:E18)			

Tabulated results with spreadsheet functionality

MISER has been in use for over a year by a number of the larger water suppliers in the UK for a variety of planning and operational applications. **Terry Kitson, Director of Asset Planning and Investment, Severn Trent Water Ltd** recently commented that MISER:

“is an invaluable tool in assessing the impact of climate change on water resource planning and operations”

The intuitive design of the MISER ‘drag-and-drop’ schematic interface, with its comprehensive set of components, has been appreciated the **Water Strategy Manager of Southern Water, Jon Crooke**. A rich tool set for the creation of schematics is provided and the layout can be configured to be roughly geographically representative. Model outputs such as flows, volumes and capacities can be displayed on the schematic and stepped through with time.



Easy to use drag-and-drop schematic interface

Another water supplier in the South of England has been using MISER for over a year and has found the use of a single powerful package has transformed their ability to analyse their water resource system, best illustrated by the following quotes:

“for the first time it <MISER> gives us the ability to simulate and optimise the water supply system as a single unit with realistic constraints on demand zones, infrastructure and resource availability”

“so far the focus of the MISER applications has been to examine the requirement for and the benefit of new water resource options. However it is being used increasingly in the operational planning of sources and for financial planning.”

Particular features proving to be extremely useful were quoted as follows:

“clear prioritisation of goals, e.g. to meet demands, if possible while keeping reservoirs above specified levels at minimum cost.”

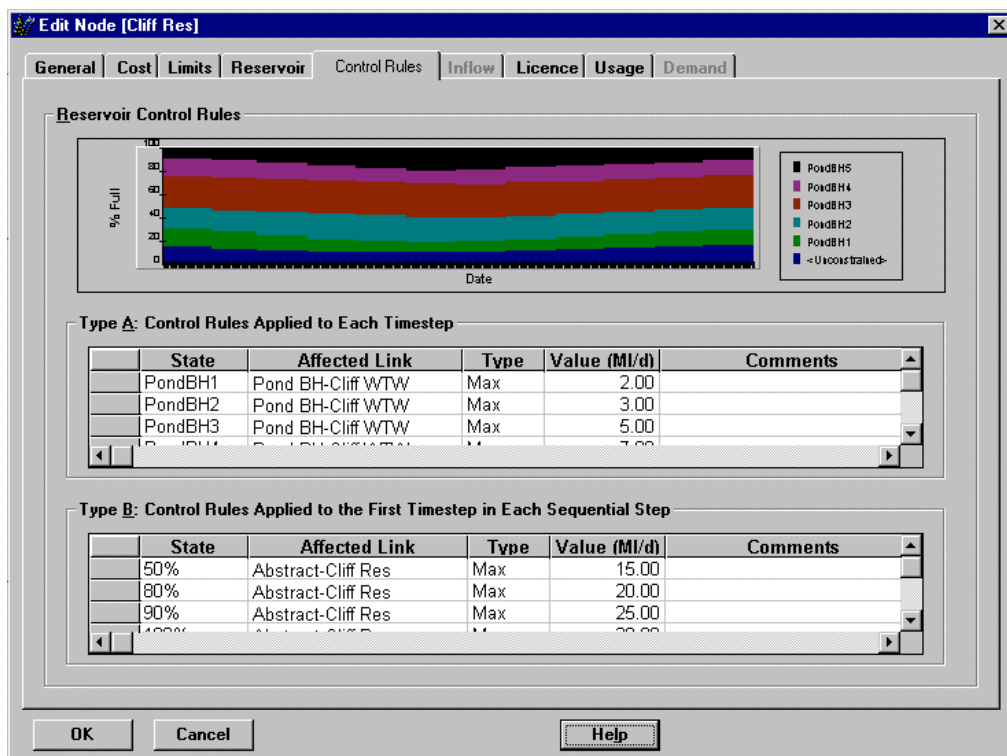
“the ability of the model to optimise over the whole of a drought period without having to specify control rules for the operation of sources”

“the ability of the model to automatically and optimally allocate the use of licences and reservoir storage through a year”

“the ability to simulate the behaviour of groundwater sources whose output is limited by low water levels during droughts.”

“sub-models can be created very easily for ‘what if’ analyses without changing the base model”

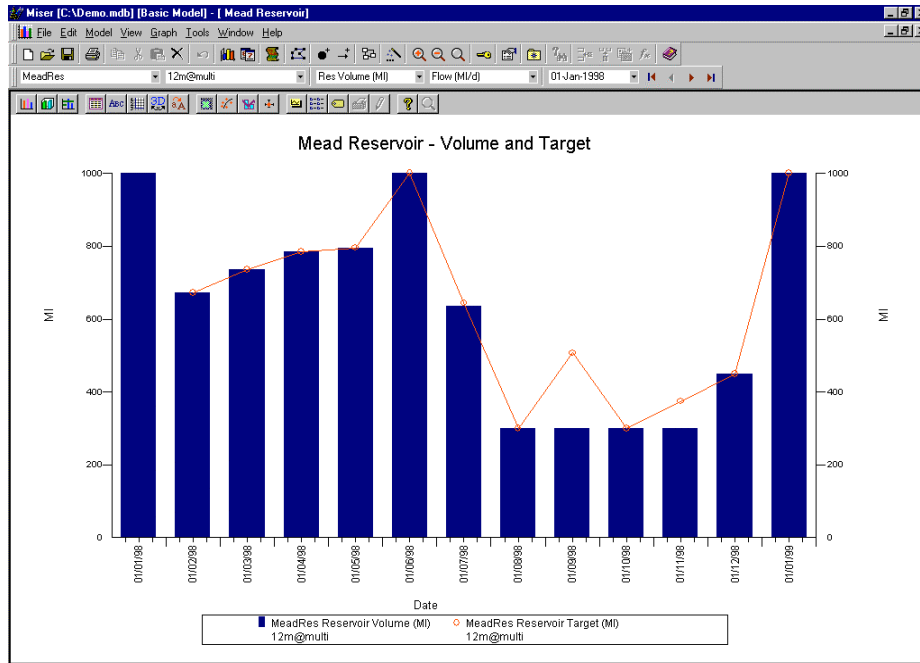
East of Scotland Water has been using MISER to analyse conjunctive use schemes with the objective of developing reservoir control rules to ensure reliability of supplies. **Severn Trent Water** have undertaken a similar application to derive new optimal reservoir control rules taking into account complex licences applying over different periods.



Reservoir control rules can be derived or specified

The derivation of optimal reservoir control rules also assists in identifying opportunities for reducing pumping costs. Simple pump scheduling, although almost always beneficial, will only optimise energy costs to meet predefined reservoir level profiles. If these are formulated subjectively without taking into account the full complexity of a system, then opportunities for saving costs may be lost unwittingly.

The capability of MISER to perform single-pass optimisations over the whole time horizon, taking into account all the various time-related aspects of the supply system, such as complex licences, dependencies etc., has been a key feature appreciated by all users. There is no need to predefine such operational strategies as control rules for reservoir operation or the usage of borehole sources over the optimisation horizon. These are determined automatically by the optimiser in a single-pass whole-horizon analysis.



Comparing simulated reservoir volumes and target values

The optimisation approach taken allows the specification of multiple goals to be considered within a single model run. The user can change the priority of the objectives so that the consequences of different strategies can be compared. For example the effect on the optimal operating strategy of the following alternative objective priorities might be of interest:

Objective Priority 1	Objective Priority 2
meet prescribed flows Minimise demand deficit Meet/get close to defined reservoir levels Minimise operating costs	meet prescribed flows minimise demand deficit minimise operating costs meet/get close to defined reservoir levels

MISER has set a new standard in the software available for the optimal management of water resource and supply systems and for the first time provides a common tool for resource planners and water supply managers to:

- plan the optimal utilisation of water resources according to explicit objectives and constraints, without the need for prior judgements on licence usage
- manage the conflict between short-term cost savings and long-term reliability of supply
- easily undertake ‘what if’ analyses to identify shortfalls against demand for a range of low flow, high demand scenarios
- rapidly evaluate the benefits of new sources or investments in system modifications¹

¹ ***This article was published in Wet News, Volume 5, Issue 8, 5 May 1999***