Technical Note

Project:	Hampshire Abstraction Inquiry	**To:**	Nigel Hepworth, Jessica Fletcher, Siobhan Mason
Subject:	Overview of Aquator Model	**From:**	Ben Piper
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Purpose of this Technical Note

This Technical Note summarises key aspects of the SWS 2017 Aquator model as used to inform the draft Drought Plan and the Hampshire Inquiry. It is included as Appendix A to the Statement of Common Ground – Modelling.

Contents

1. Introduction to the SWS Western Area Aquator Model

1.1. Background

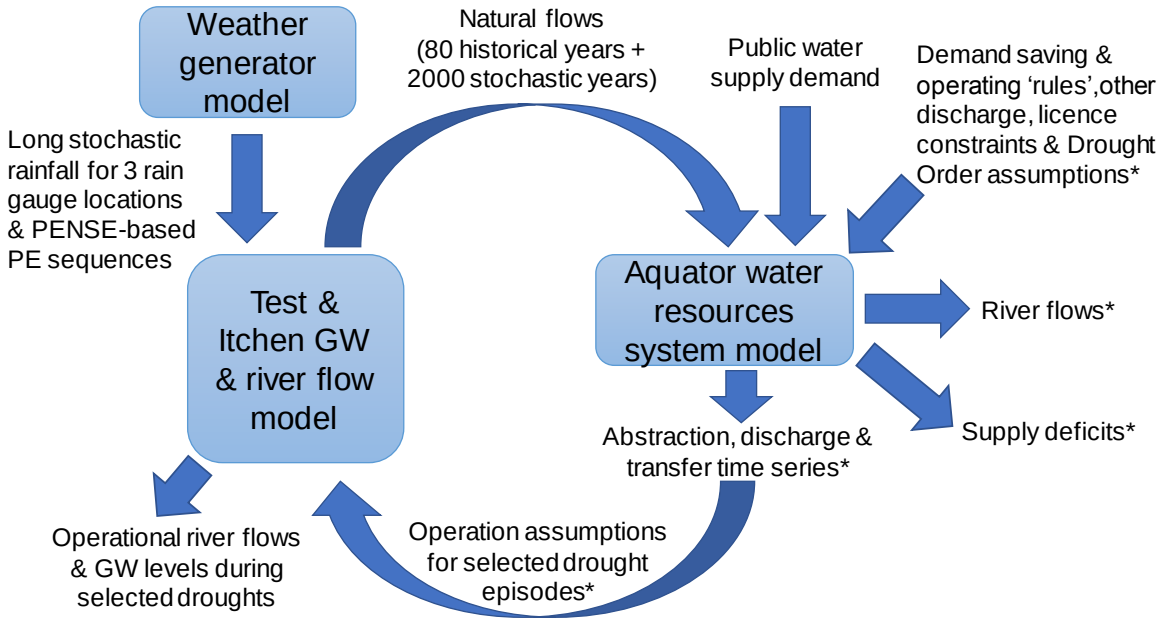
Aquator is an industry-standard water resources modelling application that is used by SWS to inform its Water Resource Management Plan (WRMP) and Drought Plan. The 2017 version of the SWS Western Area Aquator model was developed by SWS from an earlier version of the model. For the 2017 version, the previous Hampshire South Water Resource Zone (WRZ) has been subdivided into four separate WRZs:

- Hampshire Rural;
- Hampshire Winchester;
- Hampshire Southampton East; and
- Hampshire Southampton West.

The SWS 2017 version, with the associated inflow and demand timeseries, was provided to Atkins for specific tasks to inform supporting work for the Hampshire Inquiry and the draft Drought Plan. Since the model was provided to Atkins, some refinements have been required to address specific additional issues raised by SWS.

Aquator includes a conceptual representation of SWS's water resource system, its sources and the demands that need to be met, together with timeseries of river inflows, abstraction licence conditions and operational rules. These are used to provide baseline conditions against which the performance of the system under different abstraction licence and operational scenarios can be compared.

The inputs and outputs from the model, and its relationship to the Test and Itchen groundwater model (T&I GW model – from which the inflow timeseries have been derived) are summarised in Figure 1.



*Model runs use predictive scenario abstractions, discharges, licence conditions, demand constraints and drought order availability rules, assuming current public supply demands (e.g. with 'drought orders' or 'without drought orders'). Predicted environmental impacts come from the differences between runs (e.g. 'with drought orders' minus 'without drought orders')

Figure 1 Aquator model – inputs and outputs

1.2. What Aquator does, and doesn't do

Aquator is a water resource simulation model that performs water balance calculations on a daily timestep in response to sets of abstraction licence conditions and operational rules. The model seeks to meet demands across the four WRZs of Hampshire South using SWS own sources. During dry periods, the modelled residual flow on the River Itchen at Allbrook & Highbridge may fall to pre-determined Drought Trigger Levels (DTLs) (which can be changed for different scenario runs). If these levels are breached then this triggers drought interventions which include percentage reductions in demand (associated with Temporary Use Bans (TUB) and eventually Non-Essential Use (NEU) Bans) and the activation of alternative resources (for example bulk supply from Portsmouth Water).

If these demand-side measures, combined with the Portsmouth Water bulk supply, are no longer able to satisfy demands, then deficits are recorded. Alternative scenarios include

supply-side drought orders, which assume relaxation of abstraction licence conditions and therefore permit additional abstraction, and hence reduction in residual flows downstream.

Hydrological analysis for previous WRMPs and Drought Plans showed that the Deployable Output (DO) of the Testwood Water Supply Works (WSW) was constrained by the current abstraction licence and not hydrology. The changes to the abstraction licence proposed by the Environment Agency under its Section 52 powers would have an immediate impact on DO. The Section 52 abstraction licence conditions have therefore been included in the SWS 2017 Aquator model.

Each Aquator scenario run produces daily timeseries of abstraction, river flows at key points in the river system, demands met, the level of demand restrictions, and any deficits. These outputs can be interrogated and summarised to inform water resource planning and other decision making. The outputs are analysed for the following periods:

- Historic Climate (HC) – simulated years 2718 to 2797 (corresponding to 1918 to 1997); and
- Stochastic Climate (SC) – simulated years 2800 to 4799.

It is important to stress that Aquator is not an operational model – it responds to pre-defined rules that govern the conditions under which abstraction is permitted. The rules are necessarily simplifications of the operating procedures that may be followed in practice.

1.3. Key assumptions in the SWS Western Area Aquator 'reference condition' model

The key assumptions in the 'reference condition' model are:

- Abstractions from the River Test are limited by the proposed Section 52 licence condition for Testwood, including a Hands off Flow (HoF) for the River Test total outflow of 355 Ml/d;
- Abstractions from the River Itchen are limited by the Itchen sustainability reductions, in particular a HoF of 198 Ml/d at Allbrook and Highbridge and a HoF of 194 Ml/d at Riverside Park;
- Drought interventions are triggered and modelled according to a set of DTLs at Allbrook & Highbridge. For the reference condition these include demand-side measures to impose customer restrictions;
- Portsmouth Water's abstraction at Gaters Mill provides 15 Ml/d to its customers; and
- Internal transfers from Southampton West to Southampton East WRZs occur to a maximum of 24 Ml/d, starting when abstraction from the River Itchen sources are no longer sufficient to stay above the HoF of 198 Ml/d at Allbrook and Highbridge and/or the HoF of 194 Ml/d at Riverside Park.

1.4. Assumptions in the SWS Western Area Aquator Scenario Runs

Bulk supply from Portsmouth Water

The bulk supply from Portsmouth Water is triggered when residual flows at Allbrook & Highbridge breach the Level 1 restriction threshold. The supply is taken at a constant rate of 15 Ml/d and is used in preference to abstraction from SWS own sources.

The supply continues as long as Level 1 conditions persist and for a period of up 30 days thereafter to allow for recovery from low-flow condition that ensures the supply does not switch on and off in response to short-term variations in modelled residual flow.

Implementation of Drought Orders

A range of Drought Orders have been identified to relax abstraction licence conditions so that additional supplies can be mobilised to meet restricted demands and to avoid deficits. A typical sequence (that can be varied between different Scenario Runs) would follow the sequence below:

1. Allow abstraction at Testwood that would take the residual flow at the Test Tidal Limit below the S52 HoF of 355 Ml/d; then
2. Activation of SWS Candover drought order scheme; then
3. Allow abstraction at Gaters Mill that would take the residual flow at Riverside Park below the Stage 4 HD Review of Consents Site Action Plan HoF of 194 Ml/d; and finally
4. Allow abstraction from SWS Lower Itchen sources (SWS Otterbourne groundwater & surface water, and Twyford) that would take the residual flow at Allbrook & Highbridge below the Stage 4 HD Review of Consents Site Action Plan HoF of 198 Ml/d.

2. Conceptualisation of demands

Aquator represents SWS's demands on its Hampshire South water resource system through a total of 19 Demand Centres (DC) together with a transfer to the Isle of Wight via the Cross-Solent main and a dedicated industrial supply.

The demand that needs to be satisfied comprises the forecast demand plus an allowance for leakage and other losses; this value is called Distribution Input (DI). A daily profile is applied to give the DI that abstraction from SWS's own sources, transfers through the existing network represented in the model, and when these are not sufficient to maintain demands activating the bulk supply from Portsmouth Water and then the implementation of Drought Orders to relax abstraction licence conditions.

For the purposes of the Aquator modelling undertaken to date, 2015/2016 demands have been used.

The Supply Demand Balance on which WRMPs are based include allowances for outage, with climate changes and other uncertainties included in a Target Headroom allowance. Aquator is concerned with system performance, rather than long-term planning, so the demand timeseries input to Aquator do not include such uncertainties.

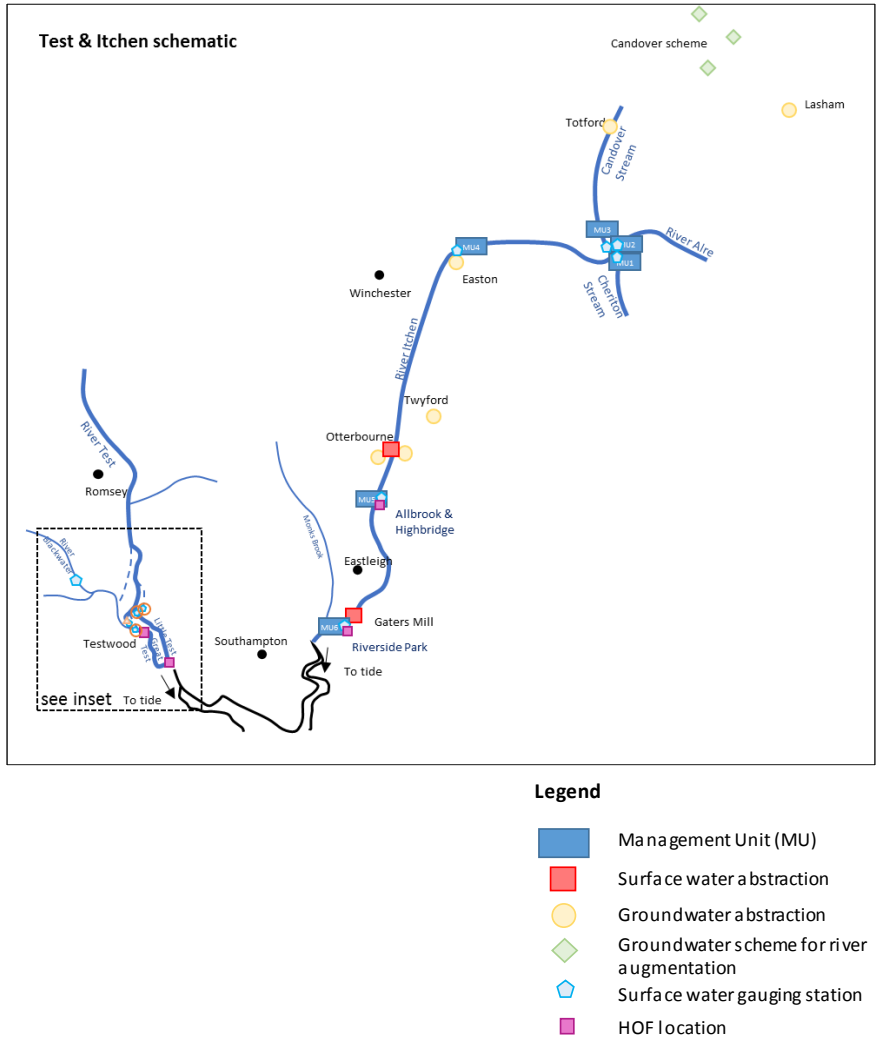
A summary of the average DI for each of the DCs that make up the four WRZs is given in Table 1.

Table 1 – Average Distribution Input (DI) modelled in each WRZ

Water Resource Zone	DI (Ml/d)
Hampshire Rural	7.43
Hampshire Winchester	19.70
Hampshire Southampton West	30.02
Hampshire Southampton East	86.83
Hampshire WRZ DCs: sub-total	143.98
Southampton West – Industrial supply	10.00
Southampton West – Cross-Solent main to IoW	12.00
Overall Hampshire WRZL total	163.98

3. Conceptualisation of the river system

Conceptualisation of catchments of the River Itchen and the River Test for Aquator is based on Management Units (MU) and/or Assessment Points (AP) respectively (Figure 2). The daily inflow timeseries are derived from Run 163 (Naturalised) of the T&I GW model.



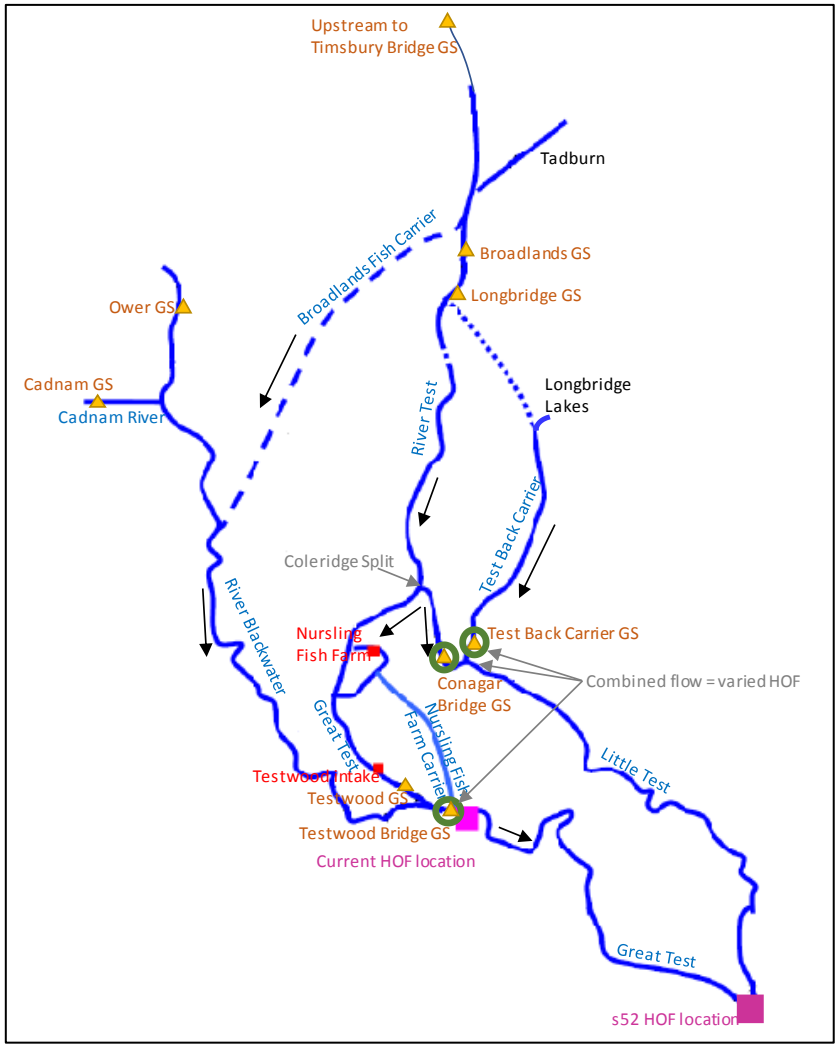


Figure 2 Schematic of River Test and River Itchen inflow points represented in Aquator

3.1. River Test

The locations of the inflow points to the Aquator representation of the River Test are:

- River Test at Timsbury (AP14);
- Tadburn Lake;
- Longbridge Lakes;
- Cadnam; and
- Ower.

3.2. River Itchen

The locations of the inflow points to the Aquator representation of the River Itchen are based on Management Units (MU) used for River Itchen Sustainability Study (RISS, undertaken in AMP4 from 2002). Inflows at the following points are used:

- Cheriton Stream (MU1);
- River Alre (MU2);
- Candover Stream (MU3);
- River Itchen to Easton (MU4);
- River Itchen from Easton to Allbrook & Highbridge (MU5);
- River Itchen from Allbrook & Highbridge to Riverside Park (MU6); and
- Monks Brook a small right bank tributary that joins the Itchen downstream of the Riverside Park gauging station but upstream of the Tidal Limit at Woodmill Pool.

3.3. Flow diversions

The key flow diversions represented in Aquator are on the River Test:

- Broadlands Fish Carrier (BFC); and
- Great Test/Little Test flow split.

It has been assumed that the Coleridge Award (2/3 : 1/3) is adhered to.

3.4. Discharges from Wastewater Treatment Works (WwTW)

The representation of discharges from SWS's WwTW is summarised in Table 2.

Table 2 - WwTW discharges represented in Aquator

Location	Assumed discharge (Ml/d)
River Itchen – discharges to groundwater	
Morestead Road	7.91
Alresford	0.77
River Itchen – discharges to surface water only	
Harestock	4.31
Eastleigh (Chickenhall)	20.00
River Test – discharges to surface water only	
Romsey	4.90

The values shown are not based on consented Dry Weather Flow (DWF) but rather recent actual DWF. Note that tributary inflows are allowed for in the flow timeseries given in Section 3.1 (River Itchen) and in Section 3.1 (River Test).

4. SWS water resource system

4.1. SWS sources

The conceptualisation in Aquator of each of SWS's sources includes:

- Licensed quantities (Annual, peak day, and for some sources monthly limits);
- Estimates of source DO for both average and peak conditions (Table 3) and any profile throughout the year as required; and
- For the Testwood in the Hampshire Southampton West WRZ and the Lower Itchen groundwater and surface water sources in the Hampshire Southampton East WRZ the maximum quantities authorised in the abstraction licence (Table 4).

Table 3 - SWS Source Deployable Output (DO)

Source	WRZ	ADO (Ml/d)	PDO (Ml/d)	GW factor
Horsebridge	Hampshire Rural	1.50	1.50	60%
Timsbury		13.00	13.60	60%
Barton Stacey	Hampshire Winchester	1.12	1.82	60%
Totford		4.55	4.54	60%
Easton		18.17	27.30	100%

Table 4 – Maximum output available from SWS's Testwood and Lower Itchen sources

Source	WRZ	Average (Ml/d)	Peak (Ml/d)
Testwood	Hampshire Southampton West	80.00	80.00
Twyford	Hampshire Southampton East	18.50	22.80
Otterbourne groundwater		48.00	53.50
Otterbourne surface water		44.46	45.00

Supplies from the groundwater sources are represented as a flat profile over a nine-month period equivalent to the average DO (ADO) and a flat "top hat" profile equivalent to the peak DO (PDO). The model uses a lumpy groundwater factor, which means that a percentage of the groundwater abstracted from the aquifer is assumed to be taken from the adjacent river and hence reduces flow by a given percentage. Abstraction from the Easton, Twyford, Twyford Moors and Otterbourne groundwater sources are assumed to reduce flows in the Itchen by 100% of the water abstracted. For the other sources, the "lumpy groundwater" assumption is assumed.

The aggregate abstraction available from SWS's Lower Itchen sources (Twyford, Otterbourne groundwater and Otterbourne surface water) is the maximum of DO or the difference between upstream inflow and the HoF.

If a Drought Order has been implemented, then abstraction that reduces the residual flow below the HoF is permitted.

4.2. Internal water resource system links

The main water resource system links represented in Aquator are shown in Table 5.

Table 5 - Interzonal transfers

Name	Route	Maximum capacity (Ml/d)
Gover Road	Southampton West to Southampton East	6.9
Rownhams WBS	Southampton West to Southampton East	2.5
Woodside Transfer	Southampton West to Southampton East	14.6
Sandy Lane WBS	Hampshire Rural to Southampton East	1.1
Olivers Battery WBS	Southampton East to Hampshire Winchester	7.5

5. Model outputs

Each Scenario Run produces timeseries of daily variables; these include the following types of variable that are used for post-processing:

Demands

- Demands requested;
- Demands satisfied;
- Shortfalls;
- Drought intervention level (if any); and if triggered
- Percentage reduction in demand applied to SWS DCs.

Residual Flows

- Downstream of the Otterbourne abstractions at Allbrook & Highbridge gauging station;
- Downstream of the Portsmouth Water abstraction at Gaters Mill at Riverside Park gauging station; and
- At the River Test Tidal Limit.

Abstractions

- Abstraction from each of SWS sources;
- Bulk supply from Portsmouth Water;
- Groundwater abstraction from the SWS Candover drought order scheme;
- Additional abstraction at Testwood when HoF relaxed under Drought Order;
- Additional abstraction at Portsmouth Water Gaters Mill when HoF relaxed under Drought Order; and

- Additional abstraction at SWS Lower Itchen sources when HoF relaxed under Drought Order.

6. Comments on use of Aquator

The conceptualisation of the Hampshire water resource system in Aquator requires simplifications and assumptions relating to the natural river network and groundwater system, the water resource system, and operational rules. Aquator is used for water resource planning, rather than for system operations.