Appendix A
Deployable output

A.1 Non-technical summary

Atkins was appointed by Northern Ireland Water (NI Water) in March 2009 to prepare the Company's Water Resources Management Plan (WRMP) for the period 2010 to 2035 (WRMP 2010). The new WRMP replaces the current Water Resource Strategy (WRS) prepared by Ferguson McIlveen[1] and updated by Scott Wilson in January 2007[2]. The main supply-side component of the WRMP is deployable output (DO). This is calculated using a standard methodology that requires the use of behavioural models of the water resource system. This Appendix describes the construction of water resource system models for the calculation of DO.

None of the models or input data sets used for Water Resource Strategy (WRS) 2002 was available. New water resource models have therefore been constructed. The models have been developed using the Aquator water resource modelling application. The 2010 supply system has been configured to five Water Resource Zones (WRZs) based on information and data collated from a variety of sources and through collaboration with both NI Water staff and the Atkins Trunk Mains Modelling (TMM) team.

There are few direct measurements of reservoir inflows and flows at river intakes. A bespoke method for determining flow time series for use in the water resource system model was therefore developed for the WRMP 2010. The methodology employed utilises gauged flow data provided by the Rivers Agency along with software developed for Northern Ireland Environment Agency by Wallingford Hydrosolutions Ltd.

The overall DO for Northern Ireland was calculated as 773.6 Ml/d until 2015 falling to 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. The individual WRZ results as follows:

- North WRZ 106.2 Ml/d (56.2 Ml/d excluding PPP transfers);
- West WRZ 88.2 Ml/d;
- Central WRZ 31.1 Ml/d (12.1 Ml/d excluding PPP transfers);
- East WRZ 329.5 Ml/d (149.5 Ml/d excluding PPP transfers); and
- South WRZ 218.6 Ml/d and 204.5 Ml/d beyond 2015 (71.6 Ml/d excluding PPP transfers).

Overall, it seems that there is little change in the total DO for Northern Ireland with the WRMP 2010 DO value around 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of PC10 schemes.

The models were configured to investigate the potential impacts of changes in flow regime from climate change. The river flow series in the model were perturbed in accordance with the UKWIR UKCP09 Rapid Assessment. Looking across the whole of Northern Ireland, the 50th percentile scenario showed virtually no change from the baseline. Under the 5th percentile perturbations there was a DO reduction of just below 27 Ml/d (3.5%) simulated. Under the 95th perturbations simulated DO was increased by 23 Ml/d (3.0%).

The work described in this Appendix provides a robust basis for the DO values to be used in the supply/demand balance elements of the WRMP. The approach makes best use of available data and techniques. The analysis can be updated as and when improved data

[1] Ferguson McIlveen (2003) Water Resource Strategy 2002-2030
[2] Scott Wilson (2007) WRS Review of Recent Published Data - Revision B

and information becomes available, for example using longer (pre 1975) flow time series generated from rainfall-runoff models.

A.2 Background

Atkins has updated all aspects of the NI Water supply demand balance for the new WRMP. The update has been in accordance with the standard planning guidance issued by the Environment Agency for water companies in England and Wales for the PR09 Business Plan submissions and amendments issued by DRD.

The supply demand balance analysis includes:

- Reassessment of deployable output (DO) from the Company's existing sources;
- Preparation of new demand forecasts;
- Reassessment of target headroom to allow for uncertainty; and
- Outage allowances for existing and future sources.

A detailed options appraisal was undertaken as part of the WRMP process to identify the least cost planning solution for NI Water over the planning period. Atkins has also undertaken a Strategic Environmental Impact Assessment (SEA) for the Draft WRMP.

In addition to the preparation of the WRMP and undertaking a SEA, the scope of Atkins' work includes for the development of a trunk mains model (TMM) for the Northern Ireland network. When complete this will allow a better understanding of the hydraulic capacity of the system and hence the potential for transfers between areas of surplus and areas of deficit both within Water Resource Zones (WRZ) and between WRZs.

The preparation of a WRMP follows a standard approach set out in guidelines based on a programme of R&D projects funded by UKWIR and the Environment Agency to develop practical methodologies. The methodologies have been reviewed and where necessary updated over time to take account of new techniques and analytical tools, greater computing power, and more data.

The fundamental supply-side building block for the supply/demand balance is the estimation of deployable output (DO); other measures of source yield such as "safe yield" or "reliable yield" do not form part of the current WRMP process. The value of DO represents the output of a source (or group of sources) that can be achieved under specific design conditions. For surface water sources, the calculation of DO is based on behavioural analysis using flow time series that are as long as possible. The DO of a source is a measure of what the source can produce under the hydrological conditions of the worst drought on record. Under more favourable hydrological conditions, a given source may be able to deliver more than the DO, up to limits determined by the capacity of the treatment works and/or abstraction licence conditions.

None of the models or input data sets used for WRS 2002 was available for WRMP 2010. New water resource models have therefore been constructed using the Aquator water resource modelling application. The models have been configured to represent the current supply system. Model construction has used information and data collated from a variety of sources and through collaboration with both NI Water staff and the Atkins TMM team. In addition to assessing the current supply system, the models have been used to test scenarios related to climate change and will be used to assist the optioneering process. At the end of the WRMP it is the intention that the models will be handed over to NI Water to allow future scenarios to be tested if such a requirement arises.

This Appendix details the reasons for opting to use a water resources model, the decision to use Aquator, the model build process and the model setup and execution of DO and scenario model runs. At each stage of the Appendix recommendations are given for possible future improvements with later plans, which are commonly linked to further data becoming available for inclusion in the models. This Appendix should always sit alongside the models to provide the basis for a comprehensive audit trail which is a critical element of any long-term modelling exercise.

A.3 Introduction to Aquator

Whilst it is possible to determine the DO of individual sources without the aid of a computer model, such a tool is essential when looking at conjunctive use across a Water Resource Zone[3] (WRZ). There are a number of appropriate software packages that are commercially available but Aquator has been chosen as the most suitable one for WRMP 2010. It has been used for a number of years by various water companies in the UK as a high level strategic water resources planning tool. It provides an intuitive and flexible platform for simulating all elements of a WRZ and, importantly, allows future supply system modifications to be incorporated into the model environment with ease.

The following information is taken from the Oxford Scientific Software website (the developers of Aquator) and the Aquator User Manual. A brief history, a description of the features of the model and an introduction to the DO analyser which has been be used to complete the supply forecast for the WRMP is provided.

- **History**: The first version of Aquator was developed for use by the then Scottish Water Companies now Scottish Water and the Scottish Environment Protection Agency (SEPA). It was delivered to these organisations early in 2001 as part of the Surface Water Yield Project undertaken by Water Resource Associates. Since then Aquator has been adopted by other water companies, environmental organisations and consulting engineers worldwide.
- **Features**: Aquator is a state of the art simulation package that enables one to construct a representation of any water supply system on-screen by dragging and dropping components from the toolbox onto the schematic area. Each component encapsulates a built-in set of operating rules. As Aquator seeks to satisfy the daily demand, these rules are automatically enforced no matter how complex the system. While obeying these rules Aquator implements a multi-pass strategy for supplying water. These passes enable Aquator to calculate leakage, to satisfy minimum flow requirements, and to supply at lowest cost when water is plentiful but otherwise supply according to resource state.
- **DO analyser**: The main function of Aquator in relation to WRMP 2010 is the DO analyser which is used to calculate the DO of each of the WRZs. Aquator has analysers for both the English & Welsh and Scottish methods of determining DO. The English & Welsh method, which is applicable to WRMP 2010, involves setting a minimum and maximum overall demand in a resource zone and increasing the demand incrementally until failure is encountered. The DO of the system is defined as the overall demand that is one increment below the demand causing a failure.

[3] A Water Resource Zone is the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.

A.4 Model build

A.4.1 Introduction

The following sections of the Appendix outline the construction phase of the Aquator models that were developed to simulate water supply in each of the five WRZs in Northern Ireland. The boundaries of the five WRZs used for WRMP 2010 were identified using information from the previous WRS, and through collaboration with the Atkins TMM team. The WRZ boundaries have been presented and discussed at various progress, Project Steering Group and technical meetings with NI Water staff. The agreed boundaries are shown Figure A.1.

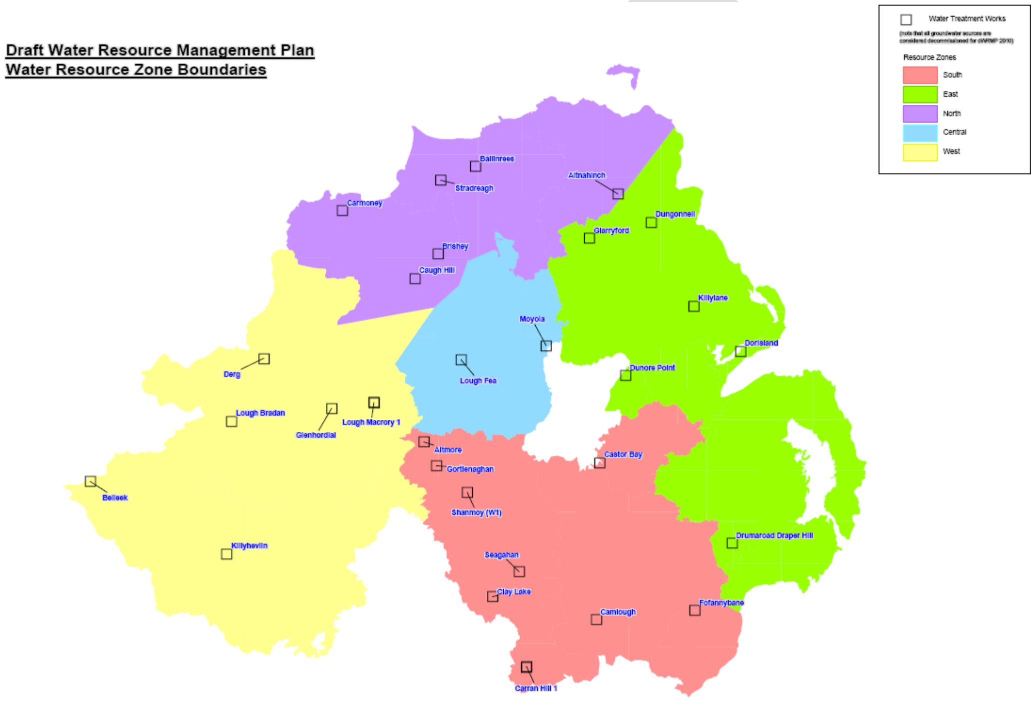

Figure A.1 – WRMP 2010 WRZs: North WRZ in purple shading; West in yellow; Central in blue; East in green; and South in red

As with all computer modelling exercises, the most important success factor is the amount and the quality of data that can be provided to feed into the model build. Therefore, prior to commencing model development, a comprehensive data collation phase was undertaken with data requests to NI Water and the Northern Ireland Rivers Agency. The data collated were used to feed into the model structure (section A.4.2) and as model input data (section A.4.3) which were used to set the physical constraints in the model, for example reservoir storage capacities, as well as providing boundary conditions, for example the amount of flow entering the WRZ in rivers. The knowledge and expertise of the Atkins TMM team was also employed at various stages of the Aquator model build.

A.4.2 Model structure

Introduction

As is the case for all high level strategic tools, deciding on an appropriate level of simplification of the real system on the ground is a critical step in the model build. In this supply forecast this is mainly based on:

i. Professional judgement of what is suitable for a DO assessment;

ii. Looking back to how DO has been determined in Northern Ireland in previous years; and,

iii. Ensuring that the work is consistent with the amount and quality of data that have been provided in the data collation phase.

Provenance

In the initial stages of the model build four schematics were put together with the Aquator software in a format suitable for DO assessment. These were based on information in the WRS 2002 (text in section A.5.2, Table 4.1 and various maps from WRS 2002). The schematics were grouped according to a previous divisional structure used at that time. Each component was checked against a GIS mapping layer of the water supply network produced by NI Water on 22/12/2008 and provided as background material with the tender for the WRMP.

These schematics (Figures A.3 to A.7) were then issued to a number of key personnel within NI Water who were asked to comment on the schematics in relation to the current situation on the ground, especially in the geographical areas of which they held particular expertise. The original schematics then were updated to take account of this new information. The schematics were also rearranged into the five new WRZs (North, West, Central, East and South) as set out for the WRMP 2010 and reissued to NI Water for final checks.

In the final step of the model structuring process, each schematic was verified with the Atkins TMM team. This was to ensure that the distribution network set out in Aquator was an appropriate representation of the real one. Although Aquator necessarily involves a large degree of simplification of the distribution system, it is still important to ensure that overall movements of water around the WRZ are representative.

All PC10 funded schemes are included in the models and following the recommendations of WRS 2002 all groundwater sources are assumed to be out of service for WRMP 2010. Any assets which have been identified as being ‘out of service’ or abandoned have not been removed from the original schematics. However they have been disabled in the model and are represented with a line through the component name. Assets known to be operated under the PPP have ‘PPP’ inserted into the component name. Aquator demand centre components (yellow circles in the model schematics) are still included based on the 2002 WRS resource zone names as they remain the most appropriate means of apportioning demand across each WRZ.

In addition to the model structures shown in the section below, a further set of models were constructed to give an unconstrained view of the WRZ, where all sources are linked to one central demand centre. In this approach DO results are not limited by pipeline capacity constraints and so provide a useful indication of supply potential in the WRZ. These four model schematics (the central WRZ is already connected in this respect) are included in section A.8.1 in and more explanation of this approach is given in section A.5.1

Schematics

This section provides schematics for each WRZ model, Figure A.2 provides a guide to the component symbols shown in the schematics, (North WRZ in Figure A.3 West WRZ in Figure A.4; Central WRZ in Figure A.5; East WRZ in Figure A.6; and South WRZ in Figure A.7), exported directly from Aquator, and

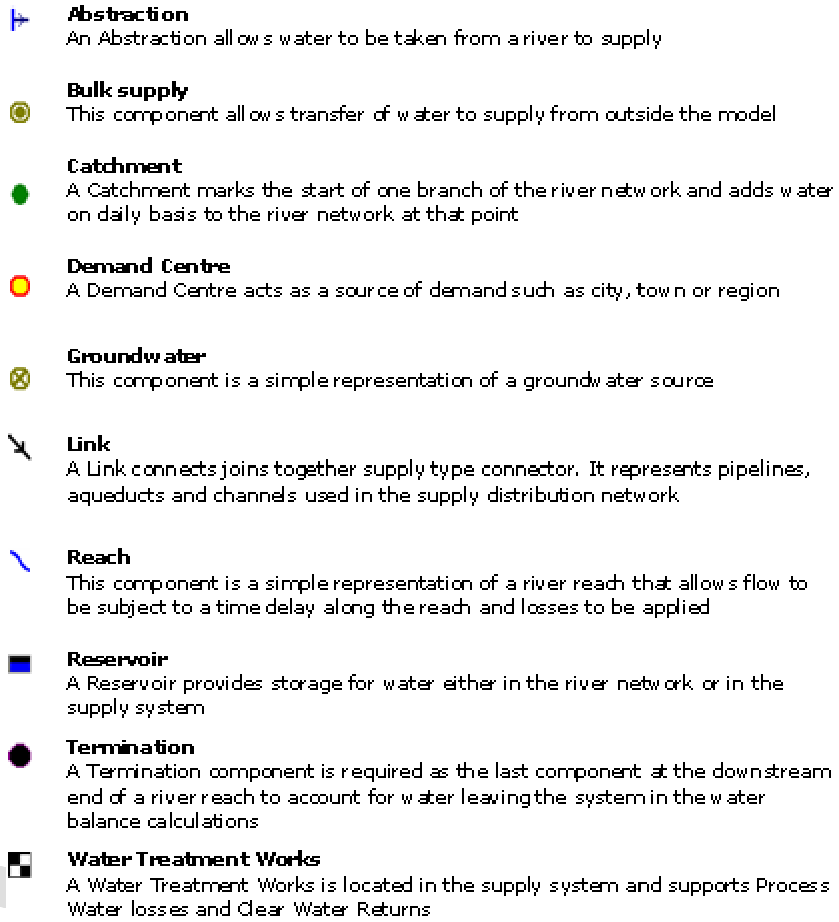

Figure A.2 – Key to Aquator model components symbols

North WRZ Schematic

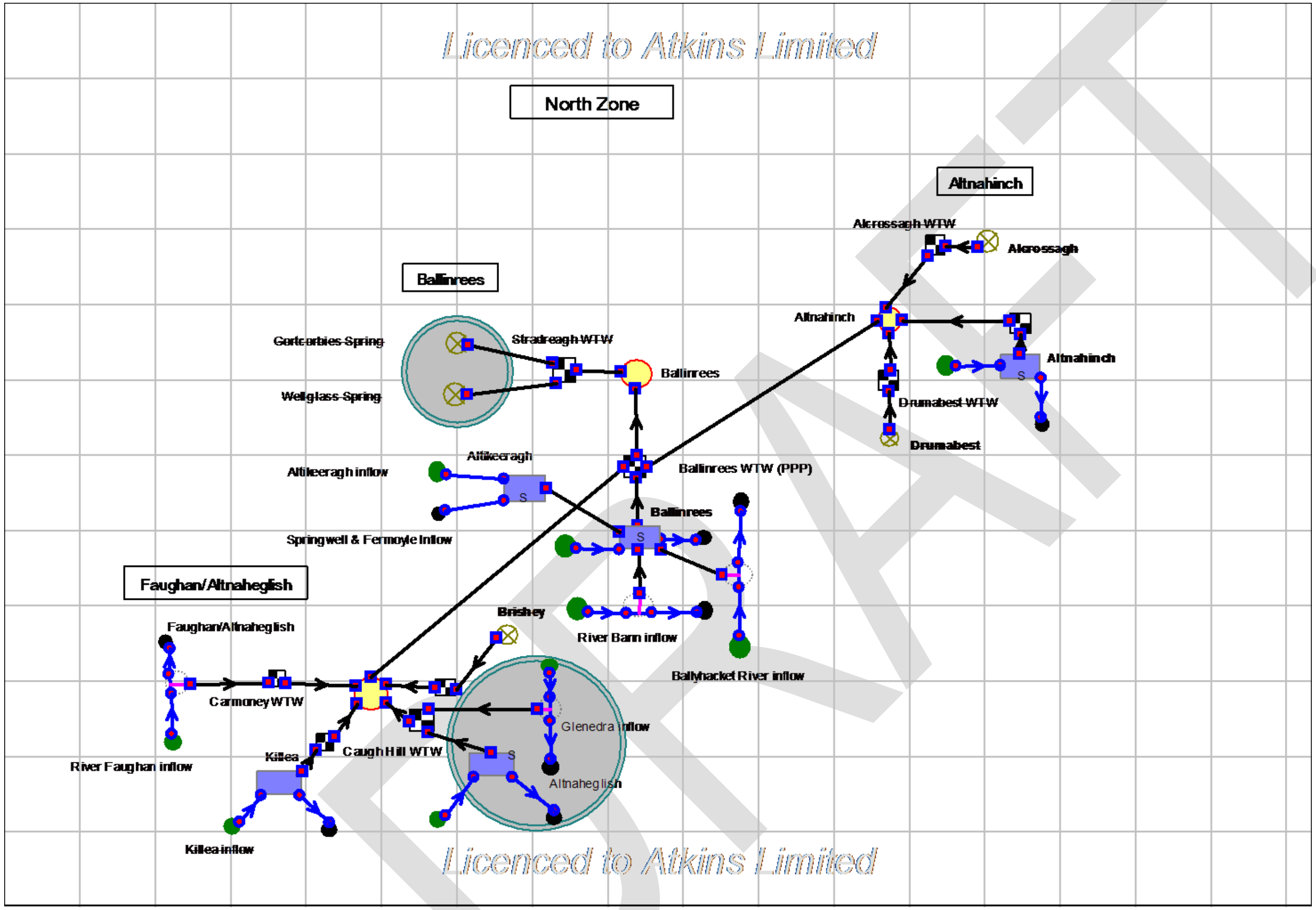

Figure A.3 – North WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

West WRZ Schematic

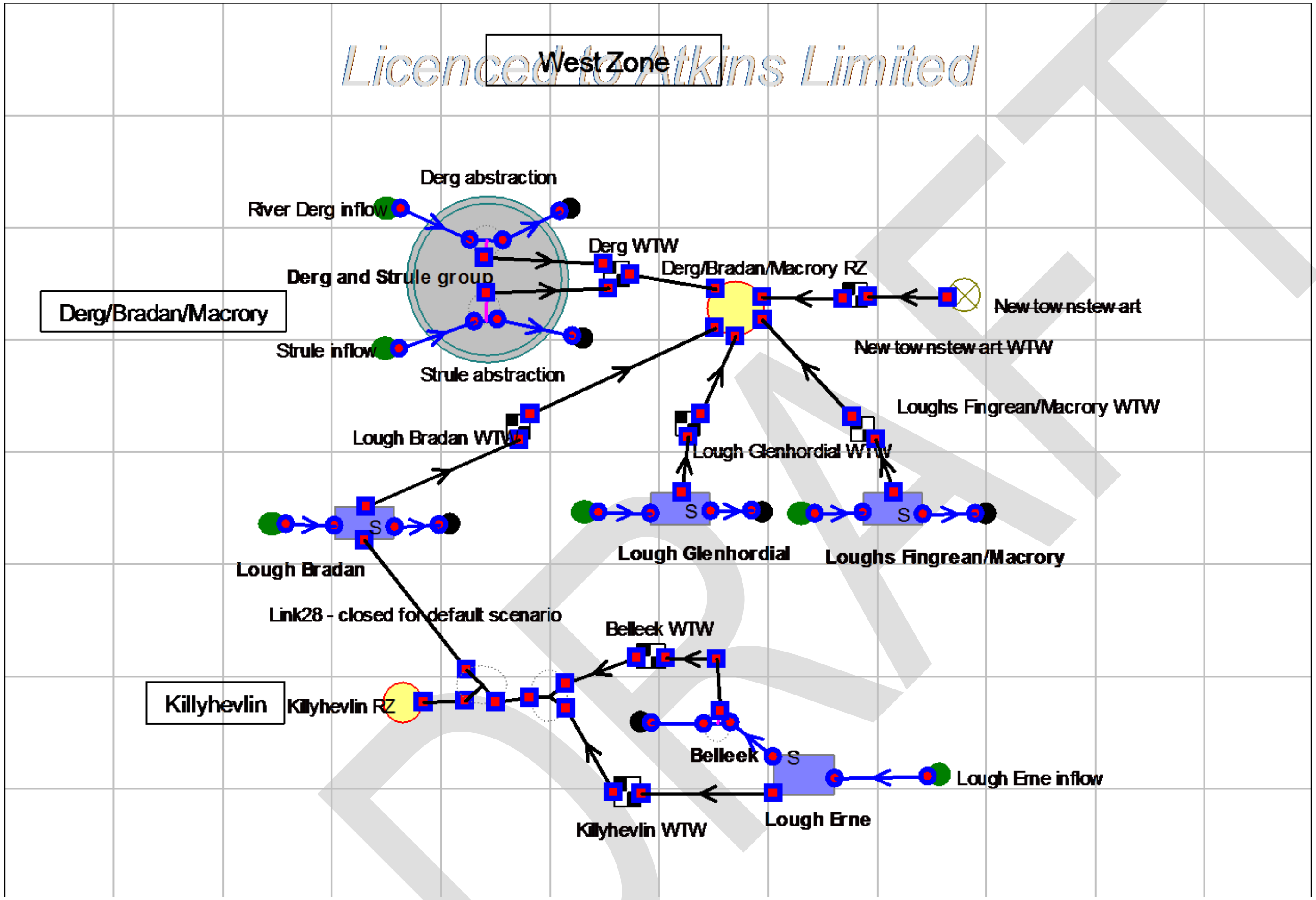

Figure A.4 – West WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

Central WRZ Schematic

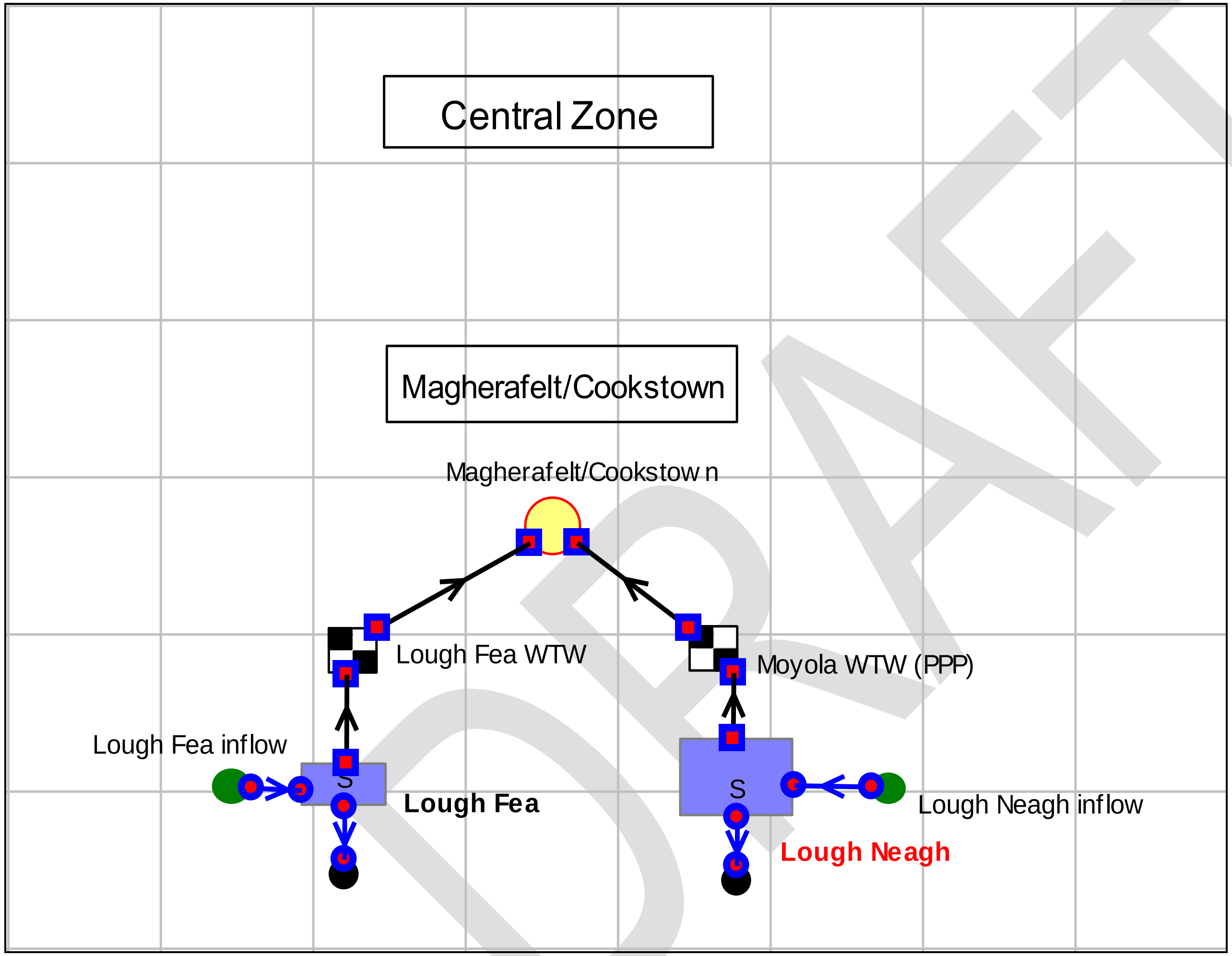

Figure A.5 – Central WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

East WRZ Schematic

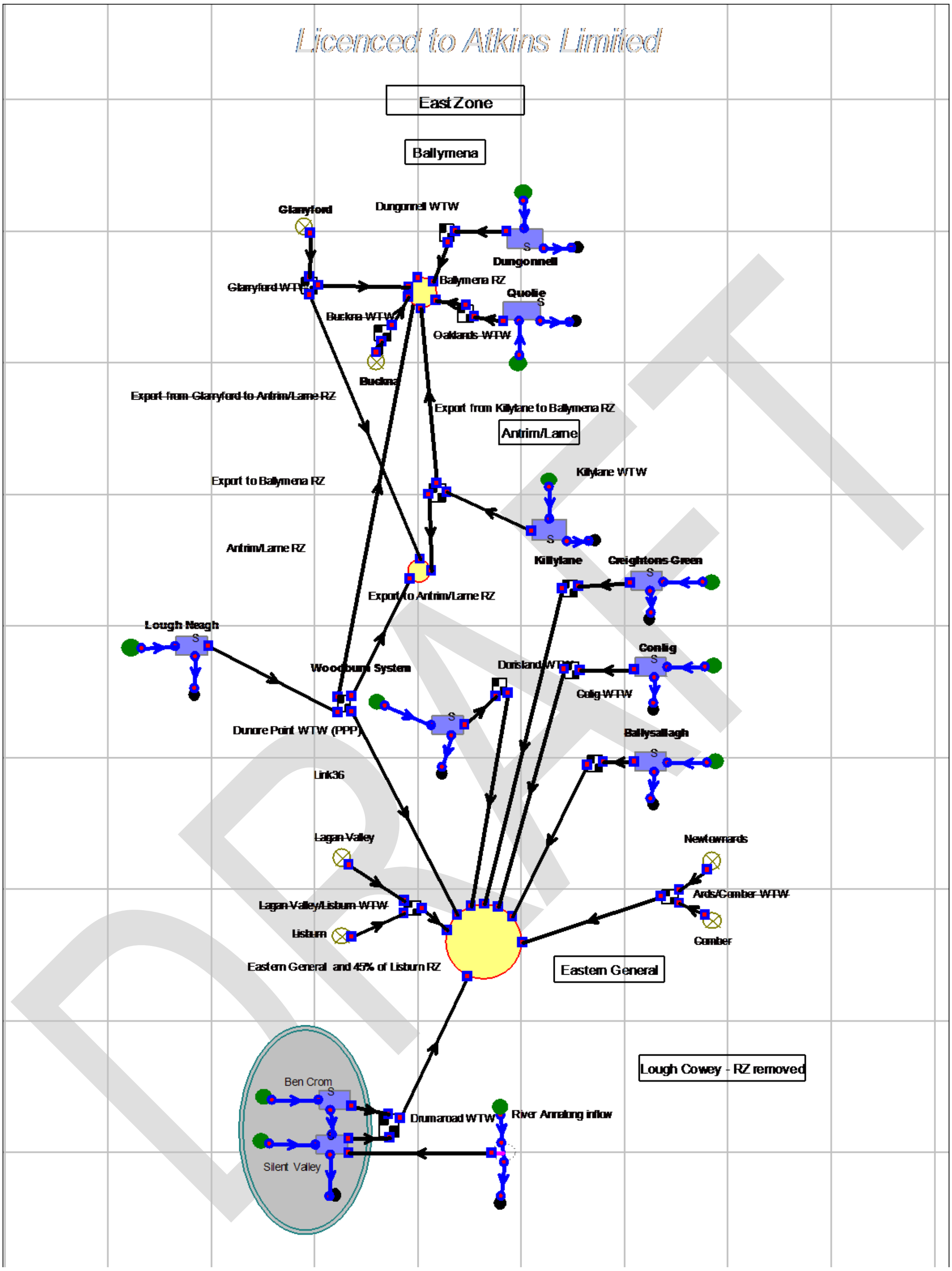

Figure A.6 – East WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

northern ireland water

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South WRZ Schematic

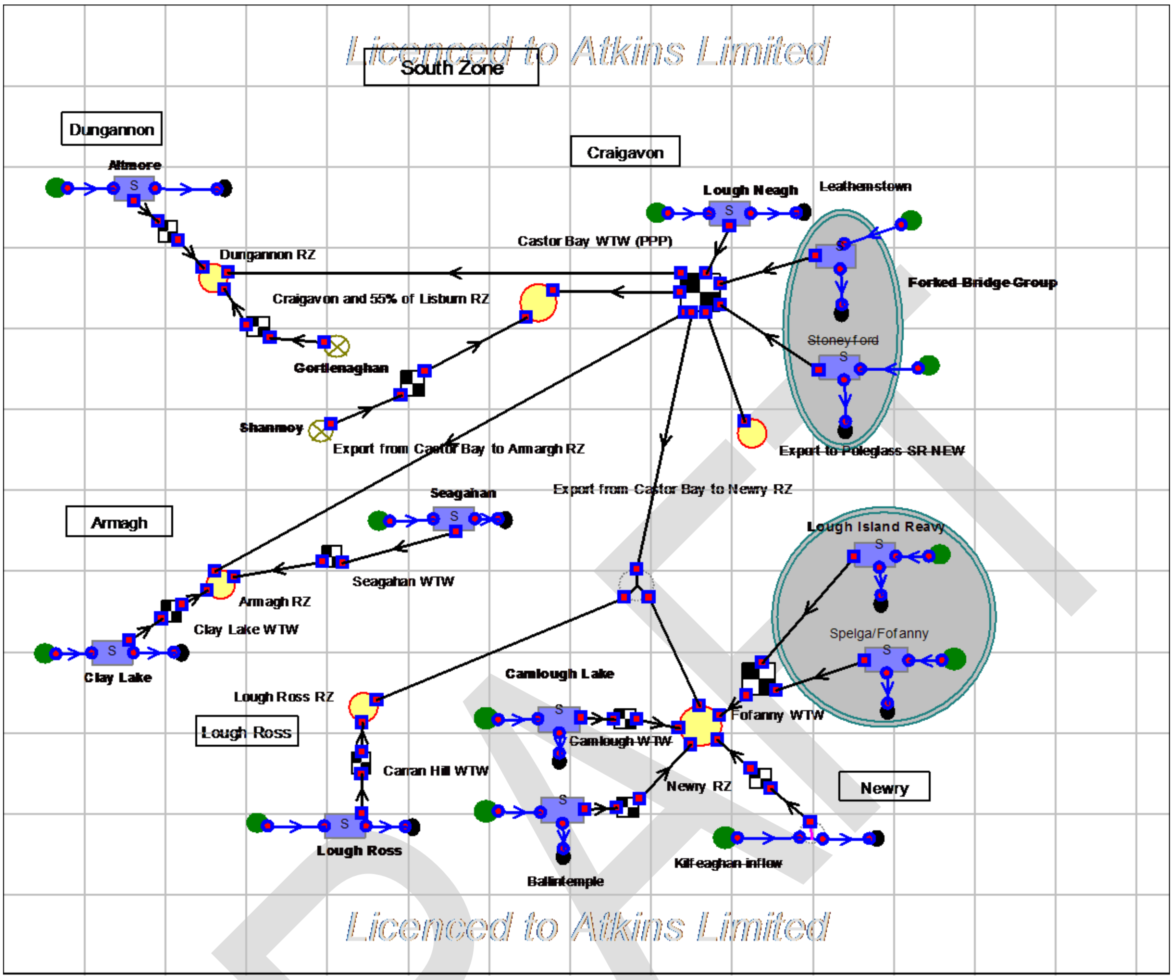

Figure A.7 – South WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

Recommendations for improvement

There are a number of cross-WRZ transfers currently in operation in Northern Ireland. These transfers are not included in the current model structures as they have been developed for determining DO on an individual WRZ basis. However, it would relatively simple to model these transfers, either by merging separate WRZ models together (straightforward in Aquator) and adding in new links between sources and the relevant demand centres, or by incorporating transfers as an bulk imports into the WRZ with an assumption of some normal level of use. This is beyond the scope of work required for the WRMP.

As noted in the Provenance section above, the distribution network in Aquator is always a simplification of the real network. The level of detail in the current model setup is appropriate for use in WRMP 2010. However, if in future modelling work a more in-depth analysis of any particular area is required then the distribution system can be easily expanded to include more pipes and more complex operational rules. It is important to note that this will still be a limited physical representation of the system and not comparable to the TMM.

Similarly, the river system in the models can be expanded to allow a more comprehensive simulation of hydrology across the WRZ. This can be useful for a variety of purposes, for example examining the environmental impact downstream of river abstractions.

A.4.3 Input data

Data collation

Initially a full Aquator data request form was issued to NI Water and this is shown in section A.8.2. However, it became apparent that it would not be possible for NI Water to fulfil all of these requirements within the timescale set out for data collation. Therefore, the list was condensed to a shorter 'critical list' which was viewed as the minimum required for an appropriate DO assessment. It was still not possible for NI Water to provide all of these data, however, it was possible to replace those that were missing (noted in italics below) with data from an alternative source or with data that were derived as part of this investigation.

- Impounding reservoirs
  - storage capacity
  - inflow record – *not available so determined using LFE software* (*Catchment Hydrology*)
  - observed storage records
  - important operational rules – *not available so models optimised manually (section* A.5.2*)*
  - storage control curves - *not available so models optimised manually (section* A.5.2*)*
  - compensation releases
- Boreholes
  - confirmation of whether still in service
  - yields
- Abstraction licences
  - daily and annual quantities
  - minimum and environmental flow conditions
- Infrastructure (link mains and Water Treatment Works [WTW])
  - Critical capacities constraints (e.g. between the source (impounding reservoir, river, borehole etc.) and the water treatment works); i.e. is there a critical capacity limitation relating to the intake structure, pumping station or link (pipe, channel etc.) that will constrain the volume of water that is able to reach the works in addition to any licence constraints?
  - Treatment works capacities
- River and stream flows above each intake (flows into impoundments covered under impounding reservoirs)
  - Mean daily flow time series - obtained from Rivers Agency for all 106 gauges

The following sections describe the data collated during this period, along with the processing required to produce the input data for each element of the Aquator models used to determine DO.

Abstraction licences

Digital copies of all Northern Ireland abstraction licences, associated maps and abstraction licence applications were provided. The information from all the licences (which were issued in 2007) was translated into to a format suitable for Aquator and the current organisation of WRZs as shown in Table A.1. Only daily licences conditions were provided and there are no minimum flow conditions.

WRZ	Source	Daily Licence quantity (Ml/d)	Notes
North	Glenedra River / Altnaheglish	40	Licence covers both intakes (also covers Kerlins Burns but this is not modelled separately in Aquator and is combined with Altnaheglish)
	Altnahinch	14.5	
	Ballinrees / River Bann	50/40	The licence application separates out the component intakes (e.g. Ballyhacket River 25 Ml/d) but the actual licence just quotes 50 Ml/d overall with a maximum of 40 Ml/d of this coming from the River Bann
	River Faughan	55	
West	Belleek	2.5	
	Loughs Fingrean / Macrory	18.5	
	River Derg and River Strule	26.6	Only a draft licence at this stage. Current full licence is 15 Ml/d on River Derg alone.
	Lough Bradan	16	
	Lough Erne (Killyhevlin)	44	
	Lough Glenhordial	8	
Central	Lough Fea	17	
	Lough Neagh (Moyola)	20	
East	Woodburn system	50	
	Silent Valley, Ben Crom and Annalong River	115	In the licence document the licensed amount is 155 Ml/d. However, this includes 40 Ml/d which was pumped from Lough Island Reavy (South WRZ) so this has been subtracted from the licence quantity.
	Dungonnell	14.5	
	Lough Neagh (Dunore Point)	189	
	Killylane	16.1	

WRZ	Source	Daily Licence quantity (Ml/d)	Notes
South	Lough Neagh (Castor Bay)	154	The application requests 183 Ml/d. The amount sought for Castor Bay in the 2005 abstraction licence application was 155 Ml/d
	Camlough Lake	5	Camlough is decommissioned in 2015
	Clay Lake	10	The licence application only requests 5 Ml/d
	Lough Island Reavy	22	The licence allows 40 Ml/d to be abstracted from the Lough, but also states that only 22 Ml/d can be pumped to Fofanny the remainder to Drumaroad (Silent Valley – East WRZ). The full 40 Ml/d can be pumped to Drumaroad within the licence but there is no infrastructure to deliver this at present).
	Lough Ross	9.5	
	Seagahan	20	
	Spelga/Fofanny (+ Lough Island Reavy)	52	This is part of combined licence with Lough Island Reavy which also has a separate individual licence of 22 Ml/d

Table A.1 – Abstraction licence conditions

(based on licences re-issued in 2007 and licence application documents)

Demand centres

It is important that the Aquator models contain current information on demand across each of the WRZs. Demand values are attached to each demand centre (DC) so that as Aquator scales up demand across the WRZ (during a DO run) it can do so proportionally with respect to the demand centres. In this case, demand corresponds to post MLE (Maximum Likelihood Estimation) distribution input average values from the 2008-09 Water Balance. As this was based on a total of 21 WRZs it was necessary to combine some areas to produce values for the 15 demand centres included in the Aquator models. It was also necessary to split the Lisburn area across the East and South WRZs (Eastern General and Craigavon demand centres) as shown in Table A.2.

WRZ	Demand Centre	Demand (Ml/d)	Notes
North	Faughan/ Altnaheglish	45.04	
	Altnahinch	13.69	
	Ballinrees	17.62	
West	Derg/Bradan/ Macrory	37.22	
	Killyhevlin	25.68	
Central	Magherafelt/ Cookstown	26.70	

WRZ	Demand Centre	Demand (Ml/d)	Notes
East	Antrim/Larne	30.34	
	Ballymena	24.32	
	Eastern General	236.96	Includes Belfast, Carrick, Lough Cowey, Ards, Lisburn (45%) and Downpatrick
South	Newry	53.28	Includes Newry and Mournes (originally Mournes had some overlap with Eastern General but currently fully included in the South WRZ)
	Craigavon	94.74	Includes Craigavon, Lisburn (55%) and Craigavon SE
	Lough Ross	6.43	
	Armagh	18.33	
	Dungannon	5.20	
Total		**635.56**	

Table A.2 – Demand values applied to each demand centre in the Aquator models

(based on post MLE values from 2008-09 Water Balance)

Links

Links (black arrows) in Aquator are used to join together components of the supply system. They can represent pipelines, aqueducts or channels. As Aquator is a simplification of the real supply system, each link often represents a number of actual pipes on the ground. In the Aquator models developed here many links have no maximum capacity set. This is because the WTWs to which they are connected have maximum capacities which control flow through the distribution system. However, in some cases, particularity where links are transferring water from one area of a WRZ to another and where WTWs have multiple outputs, the application of capacity constraints to links can have a significant effect on model operation and hence DO results. Therefore, a lot of effort has been expended in assigning appropriate maximum capacity constraints to certain links.

Again it is important to stress that each of these links does not necessarily represent an individual pipeline – it is more convenient to think of the links as a general movement of water between areas across the supply network. Table A.3 gives a list of all links to which maximum capacities have been applied along with the reasons behind the limit. In addition to links in current operation, all new links which have approved funding under PC10 have also been included. If a link has been investigated but it did not prove possible to attach a reliable capacity the link was left as unrestricted. The reasons for this are noted against the link in Table A.3.

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
North	Ballinrees WTW	Ballinrees DC	35	This relates to the capacity of the main supplying Coleraine, Castlerock and Garvagh. In practice it would be difficult for the distribution network to utilise more than 30 Ml/d. There are several trunk mains from the works into the Ballinrees demand centre but the capacity of these are not known at this stage so 35 Ml/d is a reasonable capacity to use.
	Ballinrees WTW	Faughan/Altnaheglish DC	15	Known physical constraint on Ballinrees to Limavady and Londonderry Transfer[4]
	Ballinrees WTW	Altnahinch DC	10	Set to PPP contracted volume but physical capacity also known to be 10 Ml/d (determined during testing on project handover)
West	No link capacities applied			
Central	No link capacities applied			
East	Killylane WTW	Ballymena DC	3	Established during field tests and modelling carried out by Mouchel Parkman in 2009. The low capacity is due to low pressure problems on the main. There are proposals to upgrade this main but as there is no valid justification at the moment the link is restricted to 3 Ml/d.
	Dunore Point WTW	Ballymena DC	22	Established during field tests and modelling carried out by Mouchel Parkman in 2009
	Dunore Point WTW	Antrim and Larne DC	Unrestricted	The main from Dunore Point to Larne has a known capacity of 11 Ml/d. However, in the Aquator demand centre Larne is combined with Antrim and there are multiple inputs to Antrim making it impossible to assign a reliable overall flow capacity to this link.

[4] Capita Symonds (2008)

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
	Dunore Point WTW	Eastern General DC	160	The Dunore Point to Belfast link was completed in 2008 with a design flow capacity of 140 Ml/d. However, further upgrades were applied during construction taking the capacity to 160 Ml/d. This was established during field tests and modelling carried out by Mouchel Parkman in 2009
South	Castor Bay WTW	Dungannon DC	30	Castor Bay to Dungannon strategic transfer project tender document
	Castor Bay WTW	Craigavon and Lisburn DC	Unrestricted	The Castor Bay to Forked Bridge strategic transfer (29 Ml/d) is represented by this link but so are a number of other connections. When combined the overall capacity is above that of Castor Bay WTW and hence not restrictive. However, there is a complicated network of links in this area and it's not possible to assign one single constraint
	Castor Bay WTW	Jerretspass PS	18	Castor Bay to Newry Phase 1 PC10 scheme (capacity determined by Atkins TMM test). Phases 2 and 3 (taking capacity to 38 Ml/d) are very likely to go ahead but will be reviewed at PC13 so are not included in the baseline model
	Jerretspass PS	Lough Ross DC	5	PC10 and PC13 capacity. There is a design capacity of 9.8 Ml/d for the proposed main from Jerretspass to a new SR at Tullyhappy. This SR will then feed about 5 Ml/d into Newry distribution and then about 5 Ml/d into the Lough Ross area. The information available would indicate that 1 Ml/d can pass to Lough Ross through an existing system but there is uncertainty over the performance of the existing system once the new system is in place, so the capacity of the link is set to 5 Ml/d.

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
	Jerretspass PS	Newry DC	18	There is a 450mm downstream main via gravity and a 12" DI main via the pumps at Jerretspass into the Newry demand centre so Atkins TMM team don't envisage any other restriction than the amount of water that can pass along link 1 from Castor Bay. For PC13 the capacity of this link is been increased to 33 Ml/d.
	Castor Bay WTW	Armagh DC	10	The Castor Bay to Dungannon strategic transfer project tender document gives a value of 6.7 Ml/d as a current supply amount for this link. However, it is known that there is some surplus in capacity in this area so the maximum has been set to 10 Ml/d
	Lough Island Reavy Reservoir	Fofanny WTW	20	There is an actual infrastructure constraint on the pipe between Lough Island Reavy and Fofanny WTW.

Table A.3 – Supply network link capacities

Reservoirs

All significant impounding reservoirs were included in the Aquator models although some were combined together as one component, for example those of the Woodburn system. The most important parameter attached to the reservoir components was storage capacity but there were also a few compensation flow conditions that have been applied at the reservoir outlets. The determination of reservoir inflows is described in Catchment hydrology.

Storage capacity

The Aquator reservoir component storage volume parameter was set based on 'Maximum Usable Storage' values provided by NI Water for WRMP 2010 and shown in Table A.4.

Water Resource Zone	Reservoir	Aquator Storage Volume (Ml)
North	Altnaheglish	2227
	Ballinrees	1209
	Altnahinch	1250
	Altikeeragh	185

Water Resource Zone	Reservoir	Aquator Storage Volume (Ml)
West	Loughs Fingrean/Macrory	1282 (combined)
	Lough Glenhordial	92
	Lough Bradan	950
	Lough Erne	Assumed infinite storage relative to demands
Central	Lough Fea	1696
	Lough Neagh	Assumed infinite storage relative to demands
East	Lough Neagh	Assumed infinite storage relative to demands
	Lough Island Reavy	9092
	Woodburn System	8193
	Silent Valley	12913
	Ben Crom	7721
	Killylane	1327
	Dungonnell	942
South	Spelga/Fofanny	3932
	Camlough Lake	3300
	Lough Neagh	Assumed infinite storage relative to demands
	Lough Ross	No information provided so set to 20000
	Clay Lake	1467.6
	Seagahan	2453

Table A.4 – Reservoir storage capacity

Compensation flow conditions

Compensation flow requirements were provided for three reservoirs in the same NI Water table as the storage capacity values. These were applied to the relevant Aquator models and are shown in Table A.5. The compensation condition at Altnahinch is specifically stated in the abstraction licence but this is not the case for the Dungonnell or Spelga/Fofanny ones.

Water Resource Zone	Reservoir	Compensation flow condition (Ml/d)
North	Altnahinch	3.21
East	Dungonnell	0.454
South	Spelga/Fofanny	2.27

Table A.5 – Reservoir compensation flow conditions

Catchment hydrology - reservoir inflows & river flows

Introduction

As flow is not recorded at the majority of river intakes or reservoir inflows a bespoke method for determining hydrological model inputs was devised for the WRMP 2010. Aquator requires a time series of daily flow values at each of its catchment components (green circles in the model schematics shown in Figure A.3 to Figure A.7) which are located above each reservoir (blue rectangles) in the model schematics and at the start of each river reach (blue lines in the model schematics). The methodology employed utilises gauged data provided by the Rivers Agency along with software developed for Northern Ireland Environment Agency by Wallingford Hydrosolutions Ltd, and is described in the following sections. For the purpose of WRMP 2010, Lough Neagh and Lough Erne are considered as infinite supplies (abstractions are limited only by infrastructure constraints and licence conditions) and hence catchment inflows have not been calculated.

Data

Data available on the Rivers Agency's WISKI database were downloaded, checked by an experienced hydrologist and comments on the quality of the data with respect to this study were made. In addition, the Northern Ireland Environment Agency supplied information on the quality of recorded flows and the reasons why particular gauging stations were included or rejected for use in Low Flows Enterprise software. Reasons for rejection included artificial influences on the flow regime (abstractions or discharges) and insufficient record length. The information provided was used in the hydrological assessment. The available data are summarised in Table A.14.

Software

The Low Flows Enterprise (LFE) software was used to provide Flow Duration Curves (FDCs) at each of the licensed intake locations. Mapping information added to the software included the WISKI gauging stations, Licensed Intakes (taken from the Northern Ireland paper licences) and 1:50,000 scale OSNI maps. The software also included flow gauges selected by CEH Wallingford and the intakes from Northern Ireland Water GIS layer. No artificial influences on the flows or impoundments were included.

Approach

The aim of the hydrological analysis was to estimate mean daily flows from 29/12/76 to 11/07/09 (as this represented the full period of gauging station data available from Rivers Agency) at each of the Licensed Intakes shown in Table A.15 in section A.8.3. To do this the following method was developed:

- The LFE software was used to delineate a catchment (catchments maps are included in section A.8.3) draining to each of the Licensed Intakes. The software is able to use either a digital (using an inflow grid from the CEH-Wallingford Digital Terrain Model to identify watersheds) or analogue (defining the area contributing to a catchment by an association of grid squares to the nearest reach of river) boundary. Generally a digital boundary was used unless the software was unable to find a digital climb thread (it should be noted that the analogue catchment outlets were generally located downstream of the Licensed Intakes). Boundaries were checked using OSNI mapping and amended where necessary. Detailed notes for the delineation of each catchment are given in section A.8.3 (Table A.16).

- For each catchment, similar gauged catchments were selected based on the Region of Influence (ROI) methodology which uses catchment characteristics that can be obtained for any ungauged catchment in the UK. These are called Region of Influence gauging stations, five were selected and ranked based on their distance in 'HOST space' from the Licensed Intake catchment, with rank 1 being the nearest (or most similar).
- Flow statistics were generated and the catchment boundaries saved. The flow statistics were generated using the ROI gauges and included annual mean flow, annual runoff, Base Flow Index, annual and monthly flow duration statistics for the natural flow regime (FDCs). Where available, geographically local data gauges were used to improve the estimation of these statistics.
- If it was necessary to use an analogue catchment downstream of the intake site, then the FDCs created were adjusted using area weighting.

A bespoke excel tool was created which contained data processing functions for estimating the flow time series for each Licensed Intake as follows:

- The annual FDC for the Licensed Intake site, the five ROI gauges and the recorded flow time series were imported into the Excel spreadsheet. For the ROI gauge ranked 1, the flow recorded each day was compared to the FDC for the gauge and the percentage time this flow is exceeded was noted. This was then related to the flow statistics obtained for the intake site from LFE to create a mean daily flow time series at the intake site. In Table A.6, for example, if the flow recorded at GS1 (203029) is 4.17 m3/s (flow exceeded 5% of the time), the corresponding flow at the intake site is 0.264 m3/s (flow exceeded 5% of time). If flow data for the particular date is not available then GS2 (203097) was used, then GS3 etc. until a complete time series from 29/12/76 to 11/07/09 was produced. In some cases it was necessary to replace ROI gauge 5 with a different gauge if insufficient flow data was available; gauges geographically close to the intake site were used to do this.

This methodology is illustrated graphically in Figure A.8 and with each aspect shown in full detail in section A.8.2.

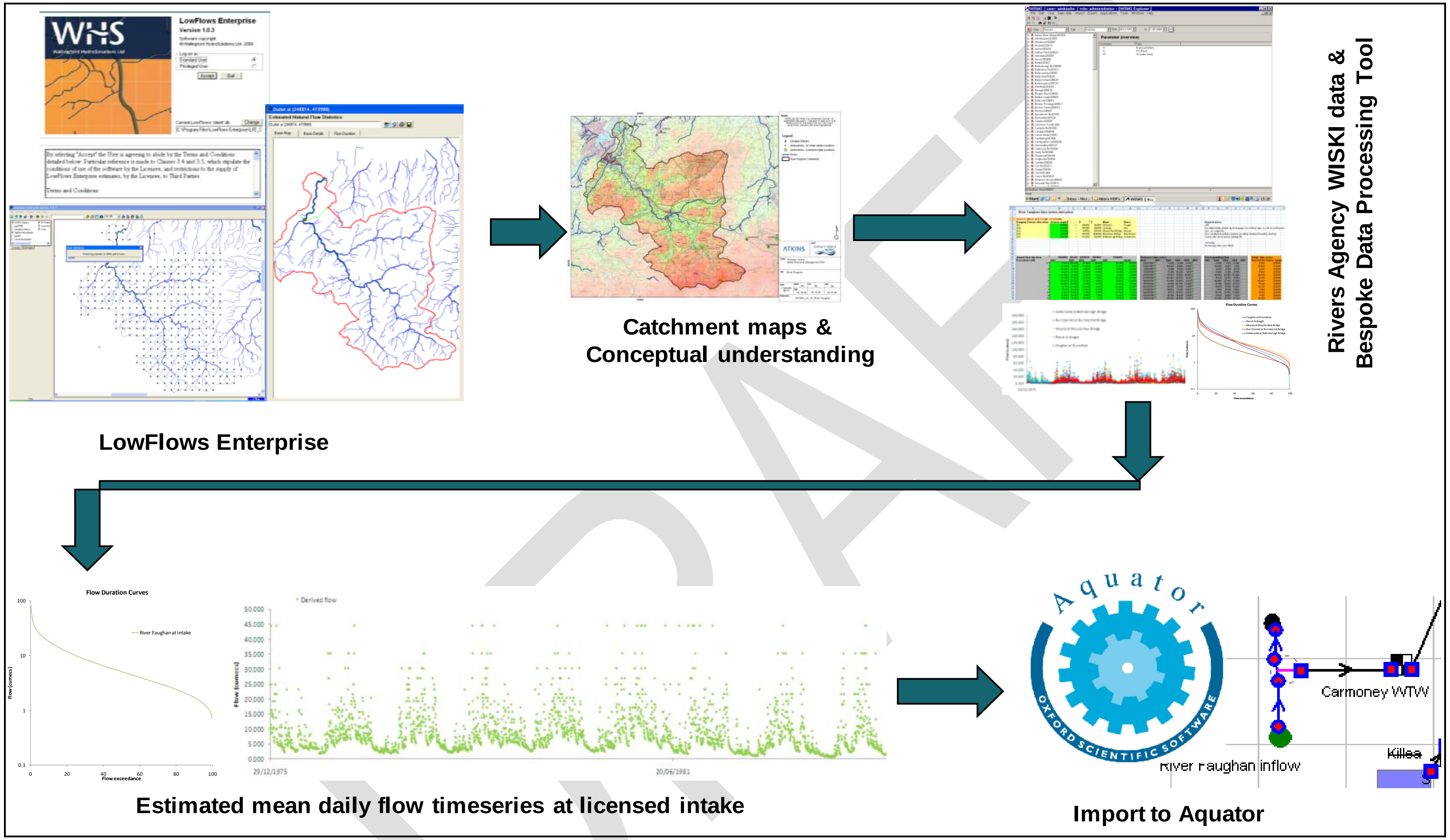

Figure A.8 – Graphical illustration of the methodology for the determination of catchment hydrology

Annual flow duration	ROI gauge 1	ROI gauge 2	ROI gauge 3	ROI gauge 4	ROI gauge 5	Intake
Exceedance (%)	203029	203097	203046	203093	203033	
0.1	23.620	66.120	4.296	177.700	47.330	0.988
1	8.656	39.260	2.286	106.800	23.480	0.505
2	6.514	30.400	1.761	80.420	18.020	0.390
3	5.333	24.600	1.491	70.970	14.740	0.328
4	4.631	21.150	1.342	62.430	12.420	0.290
5	**4.170**	19.170	1.243	57.320	11.070	**0.264**
6	3.888	17.450	1.150	53.340	9.872	0.244
7	3.635	15.700	1.073	50.070	9.112	0.226
8	3.384	14.310	1.000	46.590	8.422	0.210
9	3.207	13.320	0.935	44.030	7.831	0.197
10	3.073	12.530	0.880	41.830	7.309	0.187

Table A.6 – Example of flow duration curve sampling

Checking of the flow time series

As stated above, the gauged data from WISKI was checked and comments on the data were made. The time series were also plotted and examined for erroneous data, for example improbably high or low values (e.g. greater than 1,000 m^3/s or more), were removed.

An additional check was carried out at a gauged site: Martin's Bridge on the River Callan. This gauging station was chosen because it is not including in the LFE software and, according to the Hydrometric Register, the influence of abstractions and discharges is minimal. The methodology was followed as if the site was ungauged, and the flows calculated were compared with the recorded flows. Figure A.9 shows the results of this test for 1981. There is a generally good agreement between the two sets of flows.

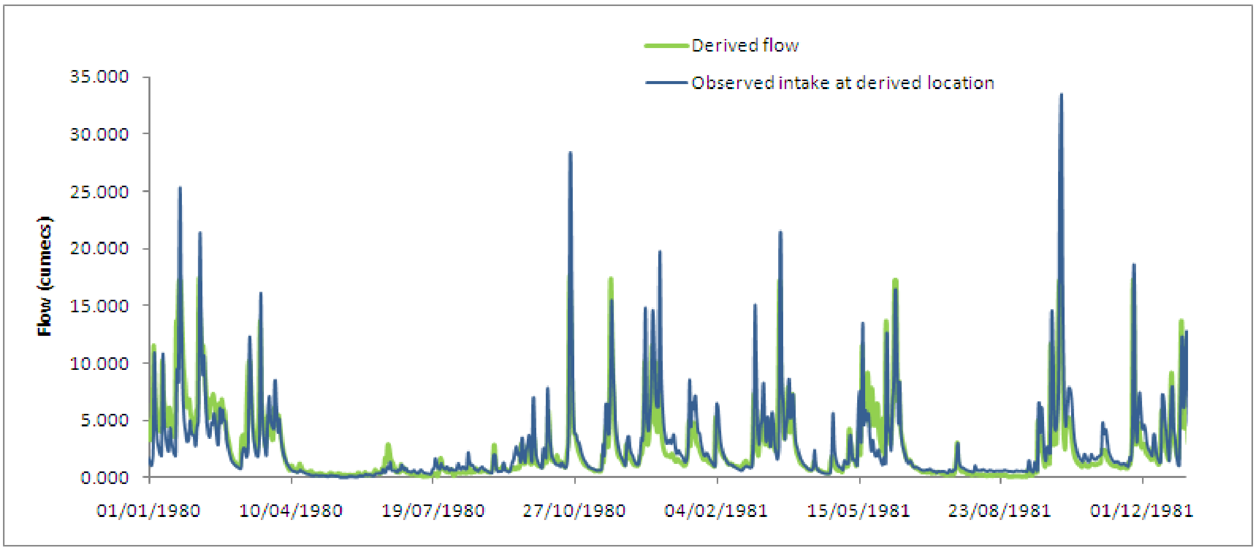

Figure A.9 – Recorded and Derived Flow at the Martin's Bridge gauging station during 1981

Limitations

The checks performed on the incoming data and the flows generated, illustrated that the method reliably produced flow time series for each of the Licensed Intakes. However, there were a few limitations and these are listed below:

- The length of the overall flow record is relatively short at 33 years (29/12/76 to 11/07/09);
- Not all the gauging stations have recorded data for the whole period of record and therefore the time series may be generated from more than one of the ROI gauges. When the record switches from one gauge to another the flows may show a relatively large increase or decrease. The time series were checked and no significant increases or decreases were found;
- The time series created will never be greater than the Q0.1 flow, which is the flow which is exceeded 0.1% of the time; and,
- The LFE software contains no abstractions, discharges nor impoundments.

Water treatment works

Physical capacity

During the data collation phase a number of sources of information regarding physical capacities of water treatment works (WTW) were provided. These included Water Service Works Overview sheets produced in 2005, NI Water GIS layers and AIR09 pumping station capacities. However, the most important source of information was a table assembled by the NI Water Water Supply Team for the purposes of WRMP 2010. This table provided values for each of NI Water's WTWs for both normal production and delivery capacity. These delivery capacity values were used to populate the Aquator models.

Whilst most data provided related to maximum flow capacity, the Water Service Works Overview sheets also stated a minimum flow capacity for some WTWs. Where possible, these have been incorporated into the Aquator models. For the PPP scheme WTWs a separate table was provided outlining flow capacities at the various delivery points for each WTW. Table A.7 shows all maximum and minimum WTW capacities applied in the models.

WRZ	Water Treatment Works	Minimum flow (Ml/d)	Source	Maximum capacity (Ml/d)	Source
North	Altnahinch	-	-	10.3	WRMP 2010
	Ballinrees	-	-	50.0	PPP capacity table
	Carmoney	-	-	35.0	WRMP 2010
	Caugh Hill	8	Water Service 2005 Works Overview	24.0	WRMP 2010
West	Belleek	-	-	2.0	WRMP 2010
	Killyhevlin	-	-	35.0	WRMP 2010
	Lough Bradan	-	-	12.3	WRMP 2010
	Lough Glenhordial	-	-	6.0	WRMP 2010
	Loughs Fingrean/Macrory	-	-	12.0	WRMP 2010
	Derg			25.0	WRMP 2010
Central	Lough Fea	-	-	12.1	2002 WRS
	Moyola	-	-	19.0	PPP capacity table
East	Dorisland	25	Water Service 2005 Works Overview	46.0	WRMP 2010
	Drumaroad	-	-	116.0	WRMP 2010
	Dungonnell	-	-	11.0	WRMP 2010
	Dunore Point	-	-	180.0	PPP capacity table
	Killylane	-	-	12.0	WRMP 2010
South	Camlough	-	-	5.0	WRMP 2010
	Castor Bay	-	-	147.0	PPP capacity table
	Fofanny	18	Earthtech Project Profile Sheet	44.0	WRMP 2010
	Clay Lake	-	-	5.0	WRMP 2010
	Lough Ross/ Carran Hill	-	-	6.8	WRMP 2010
	Seagahan	-	-	13.0	WRMP 2010

Table A.7 – WTW flow capacity constraints

Production losses

Using 2009 estimated abstraction and measured delivery volume data provided by Dalriada (delivered through NI Water) it was possible to calculate typical losses for the PPP scheme WTWs. Therefore, a loss value of 2.44% was applied to each of these WTWs during modelling.

Data were also provided which allowed a loss value of 10% to be applied to Drumaroad WTW. All other NI Water WTWs were given a default loss value of 5% based on Atkins' experience of works in England.

Is it is important to note that where abstraction licence capacities are identical to WTW delivery capacities, for example at Ballinrees WTW, then the delivery capacity will be reduced as it is not possible to abstract additional water to compensate for losses.

Recommendations for improvement

The data provided for WRMP 2010 have facilitated a full and appropriate assessment of DO in each of the five WRZs. In any modelling exercise it is always possible to improve the accuracy of any outputs by increasing the volume and quality of input data. In this particular modelling exercise the most significant omission was the supply system operating rules, in particular the control curves for reservoirs. With these incorporated into the models it would be possible to base the DO assessment more on actual representation of operational practices and less on hypothetical model optimisation (section A.5.2) It would also be possible to use the models to explore how the different sources might be operated under non-drought conditions.

A.5 Deployable output

A.5.1 Introduction

For surface water systems, the DO is defined as the constant rate of supply that can be maintained from the water resources system except during periods of restriction. The DO values determined with the Aquator models are taken through to the supply demand balance where they will be converted to Water Available for Use (WAFU) through the application of an outage allowance.

With the exception of the Central WRZ, which only has one demand centre (DC), two separate Aquator models were developed to assess DO for each WRZ. The first model type incorporates multiple demand centres representing distinct supply areas (initially based on the 15 resource zones used for WRS 2002) and a simplified representation of the trunk main distribution system with some maximum capacity constraints included. The second model type has only one central DC to which all sources are connected with links that have no capacity constraints. The results from this second model type are intended to provide an estimate of the unconstrained DO of the WRZ. In this case unconstrained is a hypothetical condition in which there are no internal transfer capacity constraints. Therefore water can be moved freely around the WRZ and all demand anywhere in the WRZ has equal accessibility to all supplies.

The Aquator inbuilt DO analyser was employed to measure the DO of each constrained and unconstrained WRZ model. Aquator has two DO analysers that follow the guidance in the English & Welsh and Scottish methods of determining DO. The English & Welsh method, which is applicable to WRMP 2010, involves setting a minimum and maximum overall demand in a resource zone and increasing the demand incrementally until failure is encountered. The DO of the system is defined as the overall demand that is one increment below the demand causing a failure. All reservoirs are set to 100% storage at the start of the run (29/12/1975). Unplanned outages from events such as pollution, poor raw water quality, and power failure are not included in the DO assessment but are included later in the supply demand balance.

A.5.2 Model optimisation

In the absence of any operational rules such as reservoir control curves it was necessary to exert some additional control on the models to ensure that they would behave sensibly during the determination of DO. The main aims of the optimisation carried were to:

a) Ensure that demand was fulfilled at each of the demand centres in the WRZ on any given day unless there was insufficient water across the WRZ to do so; and

b) Ensure that for conjunctive use the sources most sensitive to low-flow conditions were used least preferentially in order to maintain the highest level of storage and hence the best protection to supplies during dry periods.

In addition to this general optimisation, as mentioned above the models were also optimised so that the non-NI Water WTWs operated under the PPP scheme were used most preferentially. This is because these Dalriada WTWs are contracted to supply their full amounts to NI Water at any time requested and also because they are all connected to large sources with very little chance of failure due to hydrological conditions (with exception to Ballinrees WTW, they are all connected to Lough Neagh which, for the WRMP 2010 supply forecast, is assumed to be infinite relative to demands). Under the design condition for the supply demand balance, the PPP schemes will be expected to deliver at the contracted volumes.

There are two main types of parameter that have been adjusted during optimisation; the minimum flow parameter (units of Ml/d) and the cost of supply parameter (units of £/Ml). Neither parameter was set on the basis of known costs or known physical constraints at this stage; this was purely done to achieve sensible model behaviours as described above. The minimum flow parameter was adjusted on a number of links and WTWs. When the parameter was set above zero the model aimed to supply water from this link or WTW at this level or higher for as long as there is sufficient demand to support such a movement of water. This is an effective means of moving water from certain sources in a preferential fashion but in some cases it can lead to the model behaving in an unrealistic manner with respect to fulfilling demand across a number of demand centres. For this reason it was used in combination with the cost of supply parameter which was also adjusted on a number of links and WTWs. This parameter allows a cost to be added to supply and hence reduces the preferentiality at which sources are used. Using a number of different costs across a WRZ is a particularly effective optimisation technique.

With manual optimisation the model setup is only generally valid for one set of conditions. For a DO run, the critical period with respect to total demand in the WRZ is determined using the DO analyser. The model is then run in normal time series mode up to the failure date. The total demand is set to the same level as the demand that caused the failure in the DO analyser. If the model does not appear to behave sensibly (for example demand is not satisfied at one demand centre whilst another connected demand centre has surplus supply available) then some of the above parameter changes are made and the DO analyser is repeated to determine the new demand that can be met. This iterative process continues until the model is fully optimised.

There are a number of drawbacks to this method. Firstly, every time that model conditions are changed, for example when looking at conditions anticipated under climate change (section A.6.2) or examining the effects of adding new infrastructure during the optioneering process (section A.6.3), the models must be re-optimised which can be a time consuming process. Secondly, the models are optimised to behave most effectively for just one set of conditions. It is therefore unlikely that real operational rules would be able to achieve the same level of supply under that one set of conditions, resulting in a lower DO.

Finally, the models now contain parameter settings that are no longer based on actual processes occurring in the field. Therefore it is imperative that the audit trail which sits alongside the models clearly states which parameters have been set for model optimisation and which have been set to represent reality.

Despite these issues, this type of optimisation is necessary and appropriate in the absence of real operational rules and a satisfactory automatic optimisation procedure. It should be noted that one such application may become available in a future version of Aquator in which case it will likely be possible to apply this to the NI Water models retrospectively.

The model optimisation that has been applied is shown for the DO runs in Table A.8 and Table A.9 in the 'Model optimisation required' row. The additional optimisation required in the climate change runs is shown in section A.8.4. At the time of writing the optioneering model runs have not been completed but details of optimisation carried out will be provided along with the model run results.

A.5.3 Results

The following tables give the results of the DO determination for each WRZ along with the constraints linked to the failure to meet higher demand and the model optimisation that was required (North, West and Central in Table A.8 and South and East in Table A.9). The tables contain the following information:

- Actual demand centre demand – based on 2008-09 average distribution input figures.
- WRMP 2010 WRZ DO – multi demand centre model.
- WRMP 2010 Unconstrained WRZ DO – single demand centre model.
- Demand factor – the ratio of DO to 2008-09 distribution input.
- Model optimisation requirements – measures taken to control model operation where no information had been provided on NI Water operating rules, for example reservoir control curves. The optimisation applied is not intended to replicate NI Water operating manuals, but only to achieve sensible behaviour in the model.
- Failure year – the critical year in which resources are most constrained by hydrology or licence/ asset constraints and hence the period over which DO is defined.
- Critical demand centre – the demand centre at which resources are most constrained and hence where DO is defined.
- Cause of failure – an explanation of the events that determine the condition under which DO is calculated.
- Failure analysis – some additional work to investigate the sensitivity of results to changes in hydrology and also the temporal extent of the failures that determine the DO results.
- Assets constraints – the relevant WTW and link capacities, along with the corresponding licence conditions.

<table>
<tr><th>WRZ</th><th colspan="3">North</th><th colspan="2">West</th><th>Central</th></tr>
<tr><th>Demand Centre (DC)</th><th>Altnahinch</th><th>Ballinrees</th><th>Faughan/ Altnaheglish</th><th>Derg/ Bradan/ Macrory WRZ</th><th>Killyhevlin WRZ</th><th>Magherafelt/Cookstown</th></tr>
<tr><th>Actual Demand (2008-09 post MLE Distribution Input (DI)) (Ml/d)</th><th>13.69</th><th>17.62</th><th>45.04</th><th>37.22</th><th>25.68</th><th>26.70</th></tr>
<tr><td>WRMP 2010 WRZ DO (Ml/d)</td><td colspan="3">106.2</td><td colspan="2">88.2</td><td>31.1</td></tr>
<tr><td>Demand factor</td><td colspan="3">1.391</td><td colspan="2">1.402</td><td>1.165</td></tr>
<tr><td>Model optimisation required</td><td colspan="3">1. Assign cost of £10/Ml to all WTWs apart from Ballinrees to force preferential use of PPP.
2. Add minimum flow of 35 to Ballinrees WTW to Ballinrees DC link to prevent above costs from causing a failure at Ballinrees DC.
3. Add cost of £5/Ml to link between Caugh Hill WTW and Faughan DC to promote use of Faughan River intake and protect Altnaheglish storage (important to prevent early failure).
4. Add minimum flow of 10Ml/d to the link between Ballinrees WTW and Altnahinch DC to prioritise the DC with the more serious hydrology constraints</td><td colspan="2">1. Add a £10/Ml cost to Lough Bradan WTW as this is the most hydrologically challenged source. This source still causes the failure in the DO run so no further optimisation required.</td><td>1. Added cost of £10/Ml to Lough Fea WTW to ensure full use of PPP Moyola (not required for DO run anyway but may be useful for CC)</td></tr>
<tr><td>Failure year</td><td colspan="3">1984</td><td colspan="2">1984</td><td>1975</td></tr>
<tr><td>Critical demand centre</td><td colspan="3">Altnahinch</td><td colspan="2">Derg/Bradan/Macrory</td><td>WRZ</td></tr>
<tr><td>Cause / observations</td><td colspan="3">Altnahinch reservoir empties on 20/09/1984. The model supplies a continuous 10Ml/d from Ballinrees to the Altnahinch DC. Increasing the capacity of this link would appear to be key to increasing overall WRZ DO but there isn't too much more that can be extracted anyway, based on current asset constraints</td><td colspan="2">Lough Bradan empties on 19/09/1984. This is despite all other sources being used in preference over the full run. At this point Killyhevlin DC is receiving 36Ml/d out of a possible 37Ml/d so there's not much scope for inter-zonal transfers in improving overall DO. This is highlighted in the unconstrained run DO.</td><td>Asset constraints</td></tr>
<tr><td>WRMP 2010 Unconstrained WRZ DO (Ml/d)</td><td colspan="3">116.8</td><td colspan="2">89.1</td><td>31.1</td></tr>
<tr><td>Demand factor</td><td colspan="3">1.530</td><td colspan="2">1.530</td><td>1.165</td></tr>
<tr><td>Model optimisation required</td><td colspan="3">1. Minimum flow of 50Ml/d assigned to Ballinrees WTW to force full supply.
2. Cost of £10/Ml added to Altnahinch WTW to preserve the source with the highest hydrology constraints</td><td colspan="2">1. Add a £10/Ml cost to Lough Bradan WTW as this is the most hydrologically challenged source. This source still causes the failure in the DO run so no further optimisation required.</td><td>1. Added cost of £10/Ml to Lough Fea WTW to ensure full use of PPP Moyola (not required for DO run anyway but may be useful for CC)</td></tr>
<tr><td>Failure year</td><td colspan="3">1984</td><td colspan="2">1984</td><td>1975</td></tr>
<tr><td>Cause</td><td colspan="3">Altnahinch reservoir empties on 19/09/1984.</td><td colspan="2">Lough Bradan empties on 18/09/1984. This is despite all other sources being used in preference over the full run.</td><td>Asset constraints</td></tr>
<tr><td>Failure analysis</td><td colspan="3">1. If not hydrologically constrained would expect a WRZ DO of 113.2Ml/d based on this ratio between demands on each DC and the maximum that can be supplied to Altnahinch based on infrastructure constraints.
2. If not hydrologically constrained would expect an Unconstrained WRZ DO of 118.1Ml/d based on the WTW capacities and specified losses (i.e. DO run is just 1.3Ml/d down at Altnahinch rest at full capacity)
3. Licence is also constraining Ballinrees as 50Ml/d limit on abstraction is then subject to 2.44% losses
4. DO failure is just for one day if the run is extended beyond the initial failure. The model can meet higher demands as a WRZ DO with very few failures; achieved a maximum asset delivery of 113.2Ml/d with 22 failure days all essentially in one block around September 1984. We may want to check flows at that time, but the hydrograph looks OK - just a prolonged dry spell.</td><td colspan="2">1. If not hydrologically constrained would expect a WRZ DO of 90.6Ml/d based on this ratio between demands on each DC and the maximum that can be supplied to Killyhevlin based on infrastructure constraints.
2. If not hydrologically constrained would expect an Unconstrained WRZ DO of 92.3Ml/d based on the WTW capacities and specified losses (i.e. 3.2 Ml/d down).
3. DO failure is just for 3 days if the run is extended beyond the initial failure. The model can meet higher demands as a WRZ DO with relatively few failures; but to achieve a maximum asset delivery of 90.6Ml/d there would be 32 failure days all primarily in August and September in the 1980s.</td><td>1. Not hydrologically constrained so WRZ DO matches some of infrastructure delivery capacities.
2. Apparently some issues around how readily Moyola could be extended if needed as an option so could be more focus on Lough Fea if options needed for additional supply in Central Zone. A quick check suggests that the hydrology would (just) support full use of the Lough Fea licence (17Ml/d) if the works capacity was increased.</td></tr>
<tr><td>DC WTW capacities (Ml/d)</td><td>10.3 at Altnahinch WTW</td><td>50 at Ballinrees WTW (PPP)</td><td>35 at Carmoney WTW, 24 at Caugh Hill WTW</td><td>25 at Derg WTW, 12.3 at Lough Bradan WTW, 6 at Glenhordial WTW, 12 at Fingrean/Macrory WTW</td><td>2 at Belleek WTW, 35 at Killyhevlin WTW</td><td>12.1 at Lough Fea WTW, 19 at Moyola WTW (PPP)</td></tr>
<tr><td>DC licence constraints (Ml/d)</td><td>14.5 at Altnahinch Reservoir</td><td>50 at Ballinrees Reservoir, 40 at River Bann</td><td>55 at River Faughan, 40 at Altnaheglish Reservoir and Glenedra (group)</td><td>26.6 at Derg/Strule, 16 at Bradan, 8 at Glenhordial, 18.5 at Fingrean/Macrory</td><td>2.5 at Belleek, 44 at Lough Erne</td><td>17 at Lough Fea, 20 at Lough Neagh</td></tr>
<tr><td>Link capacities (Ml/d)</td><td colspan="3">Ballinrees WTW to Ballinrees DC 35, Ballinrees WTW to Faughan/Altnaheglish DC 15, Ballinrees WTW to Altnahinch DC 10.</td><td>None applied</td><td>None applied</td><td>None applied</td></tr>
<tr><td>Notes</td><td colspan="3">Ballinrees can only deliver 48.8 because licence is 50 - 2.44% loss</td><td>The River Strule abstraction has now been added and the licence updated.</td><td>Lough Erne is assumed an infinite resource</td><td>Lough Neagh is assumed an infinite resource</td></tr>
</table>

Table A.8 – WRMP 2010 DO results; North, West and Central WRZs

WRZ	East			South				
Demand Centre (DC)	**Antrim/Larne WRZ**	**Ballymena WRZ**	**Eastern General WRZ (with 45% of Lisburn)**	**Newry WRZ**	**Craigavon WRZ (with 55% of Lisburn)**	**Lough Ross WRZ**	**Armagh WRZ**	**Dungannon WRZ**
Actual Demand (2008-09 post MLE Distribution Input (DI)) (Ml/d)	**30.34**	**24.32**	**236.96**	**53.28**	**94.74**	**6.43**	**18.33**	**5.20**
WRMP 2010 WRZ DO (Ml/d)	329.5			218.6 (204.5 after 2015)				
Demand factor	1.130			1.228 (1.149 after 2015)				
Model optimisation required	1. Add 100% control curve-fill (not normal curve) to Silent Valley to encourage maximum filling of the reservoir from the River Annalong intake. 2. Add cost of £10/Ml to Dorisland and Drumaroad WTWs to encourage full use of PPP. This was not applied to Dungonnell and Killylane as it meant that these sources were grossly under-utilised. Therefore, a cost of £1/Ml was applied to these WTWs. 3. Add minimum flow of 9Ml/d to link between Dungonnell WTW and Ballymena DC to encourage use of own source over PPP water thus sending more PPP water towards E General. 9 found by trial and error as too high a number causes failure at Ballymena (not enough flow from PPP) 4. Add minimum flow of 8Ml/d to link between Killylane Reservoir and Killylane WTW to encourage use of own source over PPP water thus sending more PPP water towards E General. The 8 is set by trial and error to prevent over-utilisation of Killylane Reservoir. 5. Add minimum flow of 33Ml/d to link between Dorisland WTW and Eastern General DC to balance use of Dorisland and Drumaroad			1. Assign cost of £10/Ml to all WTWs apart from Castor Bay to force preferential use of PPP. 2. Add minimum flow of 5 Ml/d to link between Clay Lake WTW and Armagh RZ to minimise use of Castor Bay water 3. Add minimum flow of 13 Ml/d to link between Seagahan WTW and Armagh RZ to minimise use of Castor Bay water 4. Add minimum flow of 10 to link between LIR and Fofanny WTW to balance use of LIR and Spelga/Fofanny (not that relevant at this demand but may need further optimisation for option runs) 5. Add minimum flow of 16 Ml/d (17 Ml/d after 2015) to link between Jerretspass PS and Newry demand centre to balance use of water from Jerretspass PS between Lough Ross and Newry demand centres.				
Failure year	1978			1975				
Critical demand centre	Eastern General			Newry				
Cause / observations	Silent Valley and Ben Crom reservoirs become empty on 15/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure. In relation to other WTWs, they are both utilised as little as possible throughout the run.			Asset constraints at Newry both before and after decommissioning of Camlough in 2015. However, this could easily have been Lough Ross with slightly different optimisation which has the same access to Castor Bay water.				
WRMP 2010 Unconstrained WRZ DO (Ml/d)	334.2			224				
Demand factor	1.146			1.259				
Model optimisation required	1. Add costs of £10/Ml to all WTWs apart from PPP to encourage PPP use. Increase to £20/Ml for Drumaroad and Dorisland; the most hydrologically challenged sources. 2. Apply minimum flow of 88Ml/d (trial and error) to link between Drumaroad WTW and E General DC to balance utilisation between Drumaroad and Dorisland.			1. Add minimum flow to Castor Bay of 127Ml/d to force use 2. Add 100% control curve to Spelga/Fofanny to balance use with LIR 3. Add cost of £10/Ml to Clay Lake to preserve the most hydrologically challenged source. 4. Add minimum flow of 44Ml/d to the link between Fofanny WTW and DC to force full use of Fofanny				
Failure year	1978			1991				
Cause	Woodburn Reservoir becomes empty on 13/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Silent Valley/Ben Crom could cause the failure. In relation to other WTWs, they are both utilised as little as possible throughout the run.			Clay Lake empties on 30/10/1991 despite other sources being used preferentially for the duration of the run.				
Failure analysis	1. If not hydrologically constrained might expect an Unconstrained WRZ DO of 364.6Ml/d based on the licences, WTW capacities and specified losses (i.e. 30Ml/d down), but we know that 16Ml/d could reliably come from LIR, which is not in this model and there are constraints within the zone (see below) as well a hydrological ones. 2. DO failure is just for 3 days if the run is extended beyond the initial failure, with a demand of 329.8Ml/d. The model can meet 343Ml/d as a WRZ DO with 'only' 179 hydrological failures in late summer and autumn of many years. Any attempts to increase the WRZ DO beyond this point are limited by delivery constraints to the Ballymena DC where the DI ratio combined with capacity limits in the model mean that no greater demand can be met (it may be worth looking at sensitivity to DI if hydrological constraints are mitigated).			1. If ignore failures on Lough Ross, WRZ can achieve 196.3Ml/d so not just constrained by Lough Ross and it is the Newry DC that then constrains further water use. Running at a capacity limit of 225.1Ml/d produces 490 failure days generally in late summer and autumn and in most years. Increasing the link from Castor Bay looks to be the best option here maybe achieving about 220Ml/d.				
DC WTW capacities (Ml/d)	12 at Killylane WTW, 1 80 at Dunore Point WTW (PPP), 46 at Dorisland WTW	11 at Dungonnell WTW, 12 at Killylane WTW, 180 at Dunore Point WTW (PPP)	180 at Dunore Point WTW (PPP), 46 at Dorisland WTW, 140 at Drumaroad WTW	44 at Fofanny WTW, 5 at Camlough WTW (decomm'd in 2015), 147 at Castor Bay WTW (PPP)	147 at Castor Bay WTW (PPP)	6.8 at Carran Hill WTW	5 at Clay Lake WTW, 13 at Seagahan WTW, 147 at Castor Bay WTW	147 at Castor Bay WTW (PPP)
DC licence constraints (Ml/d)	16.1 at Killylane, 50 at Woodburn, 189 at Lough Neagh	14.5 at Dungonnell, 16.1 at Killylane, 189 at Lough Neagh	189 at Lough Neagh, 50 at Woodburn, 115 group licence for Silent Valley, Ben Crom and Annalong River	22 at Lough Island Reavy (paper licence states 22 to Fofanny but 40 to Drumaroad- no link at present, 52 at Spelga/Fofanny and LIR group) , 5 at Camlough Lake (decomm'd in 2015), 154 at L. Neagh	154 at Lough Neagh	9.5 at Lough Ross	10 at Clay Lake, 20 at Seagahan, 154 at Lough Neagh	154 at Lough Neagh
Link capacities (Ml/d)	Killylane WTW to Ballymena WRZ 3, Dunore Point to Ballymena WRZ 22, Dunore Point to Eastern General 160			Castor Bay to Dungannon WRZ 30, Castor Bay to Armagh WRZ 10, Castor Bay to Jerretspass PS 18, Jerretspass PS to Lough Ross DC 5, Jerretspass PS to Newry DC 18. Also added link of 20 between LIR and Fofanny to enforce Stuart Walsh view that LIR can supply 20 this way (licence 22)				
Notes	Lough Neagh is assumed an infinite resource		Drumaroad losses set to 10% based on information from Stuart Walsh	Storage capacity of Lough Ross set to 20000 Ml as had no info. In 2015 Camlough is decomm'd	Lough Neagh is assumed an infinite resource			Altmore now disabled

Table A.9 – WRMP 2010 DO results; South (before and after decommissioning of Camlough in 2015) and East WRZs

Based on the constrained modelled view of WRZ, i.e. according to the English & Welsh guidance, the overall DO for NI Water is 773.6 Ml/d until 2015 and 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. A summary of the DO assessment in each WRZ is given below.

North WRZ

The DO for the North WRZ is 106.2 Ml/d which is equivalent to 1.4 times the 2008-09 post MLE Distribution Input (i.e. the DO is 1.4 times higher than the average demand met in those years). The DO is determined by Altnahinch reservoir emptying in September 1984. If there were no hydrological constraints, i.e. DO was only constrained by assets in place across the WRZ, then the result would be increased to 113.2 Ml/d.

With the unconstrained model, where all sources are connected to one central demand centre, DO is increased to 116.8 Ml/d which again is determined by Altnahinch reservoir emptying in September 1984. Removing the hydrological constraints to leave only the asset constraints would further increase DO to 118.1 Ml/d.

With the current model setup a continuous 10 Ml/d is supplied from Ballinrees to Altnahinch. Increasing the capacity of this link would appear to be the key to increasing overall WRZ DO.

West WRZ

The DO for the West WRZ is 88.2 Ml/d which is equivalent to just over 1.4 times the 2008-09 post MLE Distribution Input. The DO is determined by Lough Bradan emptying in September 1984. If there were no hydrological constraints then the result would be increased to 90.6 Ml/d.

With the unconstrained model DO is increased to 89.1 Ml/d which again is determined by Lough Bradan emptying in September 1984. Removing the hydrological constraints to leave only the asset constraints would further increase DO to 92.3 Ml/d.

This DO is achieved with all other sources being used in preference over the full run. In terms of inter-WRZ connectivity, the Killyhevlin demand centre is receiving 36 Ml/d out of a possible 37 Ml/d so there's not much scope for moving inter-zonal transfers to Derg/ Bradan/ Macrory demand centre in improving overall DO. This is highlighted in the unconstrained run DO.

At this time the licence application for the Strule PC10 scheme is still being considered (although like all PC10 schemes it is included in the baseline DO). It is known that under very low flow conditions the draft licence limits could result in a worst-case reduction in yield from the Derg and Strule from 26.6Ml/d to 8Ml/d during the lowest flow conditions predicted[5]. A lack of interconnectivity in the WRZ means that at times of minimum flow conditions, there are no alternative sources of supply to make up any short term deficits caused by reduced abstraction from the Strule. The available flow record suggests that low flow conditions that could severely restrict abstraction only arise about 1% of the time, but these events could last for up to 3 weeks.

Discussions between NI Water and NIEA have reached an agreement whereby in the event of such water scarce periods arising, the output from the Derg WTW could be maintained by following normal drought planning procedures under Article 4.6 of the WFD. It is therefore appropriate for NIW to consider mitigating the risks to public water supply within the Derg area during drought periods, although such measures are outside the scope of the Water Resources Management Plan process. Further consideration is included in Section 9.4 of the main report.

[5] 8Ml/d represents the maximum abstraction level from the Strule that would meet the UKTAG requirements at all times of the flow record.

Central WRZ

The DO for the Central WRZ is 31.1 Ml/d which is equivalent to just less than 1.2 times the 2008-09 post MLE Distribution Input. At present there are no hydrological constraints and the result for this WRZ with a single demand centre is determined only by asset constraints and not hydrological constraints.

East WRZ

The DO for the East WRZ is 329.5 Ml/d which is equivalent to just over 1.1 times the 2008-09 post MLE Distribution Input. The DO is determined in the Eastern General area by Silent Valley[6] and Ben Crom reservoirs emptying in November 1978. However, the model is optimised to balance storage between Silent Valley/ Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure.

With the unconstrained model, where all sources are connected to one central DC, DO is increased to 334.2 Ml/d which this time is determined by the Woodburn system emptying in November 1978 (again this could easily have been Silent Valley and Ben Crom). Removing the hydrological constraints to leave only the asset constraints would further increase DO to 364.6 Ml/d.

South WRZ

The DO for the South WRZ is 218.6 Ml/d which is equivalent to about 1.3 times the 2008-09 post MLE Distribution Input. In 2015 the Camlough source (5Ml/d consistent with the previous safe yield assessment) is planned to be decommissioned which leads to a decrease in DO to 204.5 Ml/d. This DO reduction of 14.1 Ml/d is larger than the supply capacity of Camlough which is 5 Ml/d due to the conjunctive nature of the model[7]. The capacity of the link between Castor Bay and Newry is 18 Ml/d and means that additional water from Castor Bay cannot be moved towards the Newry DC to compensate for the loss of the Camlough supply to the Newry demand centre.

Both before and after the loss of Camlough in 2015, DO is determined by asset constraints at Newry. However, the model is optimised to share water from Castor Bay between the Newry and Lough Ross DC's. With slightly different optimisation, Lough Ross could easily cause the failure. Using the unconstrained model, DO is increased slightly to 224.0 Ml/d which is determined by Clay Lake emptying in October 1991. After 2015, with the loss of Camlough, DO in the unconstrained model is 219 Ml/d.

A.5.4 Looking back to WRS 2002

Table A.10 shows a comparison of the WRMP 2010 DO results with the WRS 2002 DO assessment. Overall, it seems that there is little change in the total DO for Northern Ireland. The WRMP 2010 unconstrained DO is about 25 Ml/d higher than the WRS 2002 DO of 771 Ml/d; the WRMP 2010 constrained DO is about 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. From 2015, with the decommissioning of Camlough, overall DO would be reduced to 759.5 Ml/d (unconstrained 790.2 Ml/d); i.e. below the WRS 2002 total.

On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of approved sources. There is the opportunity to transfer water between the South and East WRZs but how and indeed whether this should contribute to individual WRZ DO results has still to be established.

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[6] Table A.1 shows that while the licensed amount that can be abstracted from Silent Valley is 155 Ml/d, this includes 40 Ml/d to be pumped from Lough Island Reavy (South WRZ) so this has been subtracted from the licence quantity in the East WRZ calculations

[7] Where there is more than one demand centre in a single zone model, the demands are increased proportional to one another in following a standard DO assessment approach. This means that yield changes for single sources can have affects on DO that are greater or less than the direct change in source yield

WRMP 2010 WRZ	Sub-Zone Demand Centre (based on WRS 2002 WRZs)	WRS 2002 DO (Ml/d)		WRMP 2010 WRZ DO (Ml/d)	WRMP 2010 Unconstrained WRZ DO (Ml/d)	Comments
North	Altnahinch	17.0	101.2	106.2	116.8	A number of groundwater sources have been decommissioned since the WRS 2002
	Ballinrees	25.0				
	Faughan/ Altnaheglish	59.2				
West	Derg/ Bradan/ Macrory	32.0	68.9	88.2	89.1	The WRMP 2010 incorporates the planned River Strule abstraction but all groundwater sources have been decommissioned
	Killyhevlin	36.9				
Central	Magherafelt/ Cookstown	29.3	29.3	31.1	31.1	
East	Antrim/ Larne	33.9	418.9	329.5	334.2	The boundary between the WRMP 2010 South and East WRZs has divided some of the WRS 2002 WRZs, with Lough Island Reavy and a portion (55%) of Lisburn area demand moving into the South WRZ. The current model setup does not include transfers from Lough Island Reavy to Drumaroad WTW (16 Ml/d safe yield - calculated prior to WRMP 2010, 10 Ml/d normal summer use), or from Castor Bay to the East WRZ (no information provided by NI Water but could be around 20 Ml/d into the Eastern General DC). There are a number of sources that have been decommissioned since the WRS 2002, as well as Forked Bridge WTW.
	Ballymena	26.2				
	Lough Cowey	3.8				
	Eastern General	355.0				

WRMP 2010 WRZ	Sub-Zone Demand Centre (based on WRS 2002 WRZs)	WRS 2002 DO (Ml/d)		WRMP 2010 WRZ DO (Ml/d)	WRMP 2010 Unconstrained WRZ DO (Ml/d)	Comments
South	Newry	53.0	152.4	218.6 (204.5 beyond 2015)	224 (219 beyond 2015)	The Craigavon demand centre now incorporates 55% of the Lisburn area demand (100% in Eastern General for WRS2002)
	Craigavon	67.6				
	Lough Ross	6.8				
	Armagh	21.0				
	Dungannon	4.0				
Total DO (Ml/d)		**770.7**		**773.6 (759.5 beyond 2015)**	**795.2 (790.2 beyond 2015)**	

Table A.10 – Comparison of WRMP 2010 DO results with the WRS 2002 DO assessment

A.5.5 Recommendations for improvement

In comparison with the assessment completed by many water companies in England the length of record used to determine DO here is relatively short at 1975 to 2009. The longer the record used the more chance that there is of encountering drought conditions and the higher the resilience of the DO determined by analysis is likely to be to future droughts. As recordings of river flow generally started later in Northern Ireland than England, in order to start the analysis before 1975, it would be necessary to infer river flow from rainfall records which are likely to go back further. The best method for this is to construct rainfall-runoff models which would be calibrated against post 1975 river flow records. This would require an extensive programme of hydrological work to collect and quality control the basic hydrometric data, and to develop, calibrate and validate appropriate rainfall-runoff models. Another benefit of using a longer record is that it increases the value of statistical analysis.

At the outset of the WRMP 2010 programme there was an expectation that NIEA would have been able to advise NIW on the scope and timetable of its programme of work to review existing abstraction licences and hence the possible location and magnitude of sustainability reductions. However, at the time of writing NIEA has not provided any further information to NIW for consideration in the Draft WRMP. Therefore the Aquator model includes current licence conditions only; there are no constraints built into the model to prevent abstractions from removing all flow up to the licence limit.

A.6 Scenarios

A.6.1 Introduction

Once the baseline DO had been determined the focus of modelling shifted towards looking at future scenarios which need to be investigated for WRMP 2010. These include the anticipated effects of climate change and the investigation of new supply options during the optioneering process.

A.6.2 Climate change

Introduction

The models were configured to investigate the potential impacts of anticipated changes that could be brought about in Northern Ireland due to climate change. The river flow series in the model were perturbed in accordance with the UKWIR UKCP09 Rapid Assessment. As explained in section A.5.2, the models required some further optimisation and this is outlined, along with full detail model outputs in Table A.17.

Methodology

The update of previous flow meteorological and flow factors for UKCP09 – referred to as the 'UKWIR UKCP09 Rapid Assessment' – provides a revised set of monthly and seasonal flow factors based on the updated projections. The factors are produced for 183 catchments in the UK, and for the 2020s.

The more complex approach within the UKWIR methodology would require rainfall-runoff models to convert perturbed precipitation and PET time series into associated flow perturbations. Without these models for Northern Ireland, it is necessary to use the more simple method, perturbing river flow series instead. UKWIR flow factors[8] are provided for five catchments in Northern Ireland:

- Six Mile Water at Antrim;
- Claudy at Glenone Bridge;
- Burn Dennet at Burndennet;
- Camowen at Camowen Terrace; and
- Fairywater at Dudgeon Bridge[9].

As these catchments do not cover all of the required area of Northern Ireland, it was necessary to examine key meteorological, geographical and hydrological characteristics of the catchments draining to these gauging stations, with each of the supply catchments; thus enabling the flow factors to be transferred (i.e. applied) to other catchments. This is a way of estimating the flow factors in the absence of hydrological models and without detailed examination of the UKCP09 projections (in a similar manner to the UKWIR Rapid Assessment).

The data comparison uses the following four factors:

- Region of Influence (ROI) stations (top 5);
- Hydrometric Area (location);
- Rainfall; and
- Base Flow Index (BFI).

The ROI data was derived from the LFE software, which provides a variety of information on each catchment, from which a gauged catchment can be selected for use as a proxy. This software is the same as has been used already to generate daily time series for Aquator catchment inflows. Each catchment of interest was scored, based on the four factors, in its similarity to the catchments for which flow factors were available. The outcome of this and the factors applied are presented in section A.8.4, but an example for Six Mile Water is included here in Figure A.10. The perturbations to the baseline flow series for each supply catchment provide a quantified estimate of the impact of climate change on river flows for the 2020s timeslice.

[8] Von Christierson, B., Wade, S. and Rance, J. 2009. Assessment of the significance to water resource management plans of the UK Climate Projections 2009, UKWIR, London.
[9] Fairywater was not included in the assessment as it is mislabelled as ‘Scotland’ in the UKWIR Rapid Assessment spreadsheets and was thus overlooked. This fifth catchment could be included in any subsequent assessment.

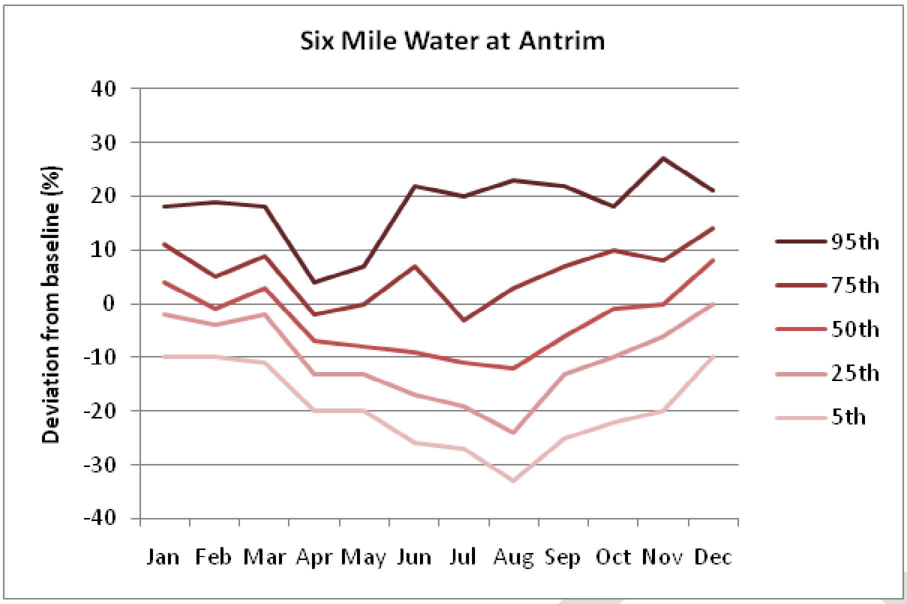


Figure A.10 – Flow factors for Six-Mile Water at Antrim

Results

The absolute changes to DO are shown in Table A.11 for the three climate changes scenarios investigated with the Aquator models (5th, 50th and 95th percentile) and Table A.12 gives the results in percentage terms. Looking across the whole of Northern Ireland, the 50th percentile scenario showed virtually no change from the baseline. Under the 5th percentile perturbations there was a DO reduction of just below 27 Ml/d (3.5%) simulated. Under the 95th perturbations simulated DO was increased by 23 Ml/d (3.0%).

In percentage terms the biggest individual WRZ reduction in DO seen under the 50th percentile projections was a 0.9% decrease in DO simulated in the North WRZ. For the 5th percentile projection there was a 5.8% reduction in the North zone, and at the 95th percentile, the largest increase in DO simulated was a 5% increase in the East WRZ.

WRZ	Deployable output (DO) Result (Ml/d)	Climate Change Scenario DO Results (Ml/d)			Notes
		5th Percentile	50th Percentile	95th Percentile	
North	106.2	100.0	105.2	111.3	Altnahinch reservoir is always critical with supplies running out at the same time in each scenario.
West	88.2	86.8	88.0	89.5	Lough Bradan is always critical with supplies running out at the same time in each scenario.
Central	31.1	31.1	31.1	31.1	Hydrological conditions do not become limiting under any of the climate change scenarios.

WRZ	Deployable output (DO) Result (Ml/d)	Climate Change Scenario DO Results (Ml/d)			Notes
		5th Percentile	50th Percentile	95th Percentile	
East	329.5	314.4	328.1	346.1	DO responds to changing hydrological conditions across the WRZ under the climate change scenarios.
South	218.6 (204.5 after 2015)	215.1 (200.4 after 2015)	218.6 (204.5 after 2015)	218.6 (204.5 after 2015)	The DO for this WRZ is determined by the isolated Lough Ross demand centre. If this is removed from the analysis, the remaining DO under all scenarios but one is 189.2 Ml/d. This value is determined by asset constraints but for the 5th percentile climate change scenario the additional hydrological constraints are such that they Spelga/Fofanny reservoirs to empty in 1977 and DO is further reduced to 185.1 Ml/d.
NI Total	**773.6 (759.5 after 2015)**	**747.4 (732.7 after 2015)**	**771.0 (756.9 after 2015)**	**796.6 (782.5 after 2015)**	

Table A.11 – Climate change run results showing revised DO values under the 5th, 50th and 95th percentile climate change scenarios

WRZ	Climate Change Scenario DO Results (Ml/d)			Range (%)
	5th Percentile	50th Percentile	95th Percentile	
North	94.2%	99.1%	104.8%	10.6%
West	98.4%	99.8%	101.5%	3.1%
Central	100.0%	100.0%	100.0%	0.0%
East	95.4%	99.6%	105.0%	9.6%
South	98.4% (98.0% after 2015)	100.0% (before and after 2015)	100.0% (before and after 2015)	1.6% (2.0% after 2015)
Total	**96.6% (96.5% after 2015)**	**99.7% (before and after 2015)**	**103.0% (before and after 2015)**	**6.4% (6.6% after 2015)**

Table A.12 – Climate change impact on baseline DO

A.6.3 Optioneering

These Aquator models form a strong basis for the high level strategic testing of new options for supply in the optioneering process (section 8).

A.7 Conclusions

A number of Aquator models have been built to represent the five WRZs of Northern Ireland. The structure of each model was initially based on the WRS 2002 and updated using the expertise of key NI Water personnel and the Atkins TMM team. An extended data collation period was undertaken to assemble model input data. There were difficulties in collating the full data set required for Aquator but enough data were either collected or derived for an appropriate assessment of DO using Aquator's inbuilt English & Welsh method DO analyser.

The overall DO output for Northern Ireland was determined as 773.6 Ml/d until 2015 and 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. The individual WRZ results are as follows:

- North WRZ – 106.2 Ml/d (116.8 Ml/d if transfers are unconstrained within the WRZ);
- West WRZ – 88.2 Ml/d (89.1 Ml/d if unconstrained);
- Central WRZ – 31.1 Ml/d (no different if unconstrained);
- East WRZ – 329.5 Ml/d (334.2 Ml/d if unconstrained); and
- South WRZ – 218.6 Ml/d and 204.5 Ml/d beyond 2015 (224 and 219 Ml/d if unconstrained).

The results from the unconstrained models (all sources linked to one central DC) suggest that there is most scope for increasing DO by increasing connectivity of the distribution system in the North WRZ.

Comparison of the results from this analysis with WRS 2002 shows that there is little change in the total DO for Northern Ireland. The WRMP 2010 unconstrained DO is about 25 Ml/d higher than the WRS 2002 DO of 771 Ml/d; the WRMP 2010 constrained DO is about 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of approved sources.

The models have also been used to determine the potential impacts of anticipated changes to river flows patterns due to climate change. On a Northern Ireland wide basis the largest simulated changes only showed a 3.5% change to the baseline DO values. At individual WRZ level this was only increase to a maximum impact of just under 6%. However, it is important to state that there could be a much greater effect on DO if minimum flow conditions were applied to river abstractions.

At the time of writing the models are set to test options set out for the optioneering process.

The work described in this Appendix provides a robust basis for the DO values to be used in the supply/demand balance elements of the WRMP. The approach makes best use of available data and techniques. The analysis can be updated as and when improved data and information becomes available, for example using longer (pre 1975) flow time series. In any modelling exercise it is always possible to improve the accuracy of any outputs by increasing the volume and quality of input data. In this particular modelling exercise the most significant omission was the supply system operating rules, in particular the control curves for reservoirs which were not available for use in WRMP 2010. With such information incorporated into the models it would be possible to base the DO assessment on actual representation of operational practices and less on hypothetical model optimisation (section A.5.2). It would also then be possible to use the models to explore different operating procedures under average and wet (rather than drought) hydrological conditions.

A.8 Additional information

A.8.1 Unconstrained model schematics

The following schematics represent the unconstrained version of each WRZ (North WRZ in Figure A.11; West WRZ in Figure A.12; East WRZ in Figure A.13; and South WRZ in Figure A.14), where all sources are connected to a single demand centre (explained in section A.5.1). There is no schematic for the Central WRZ which is already structured in this way.

North Zone

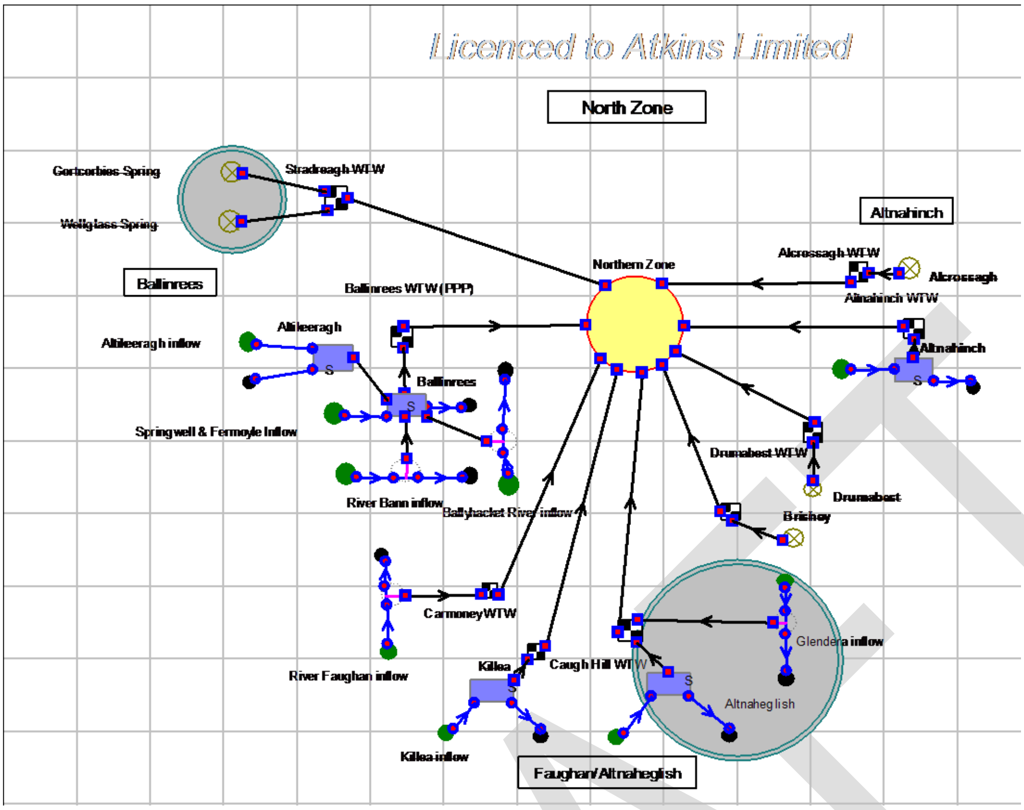


Figure A.11 – North WRZ unconstrained model schematic

West Zone

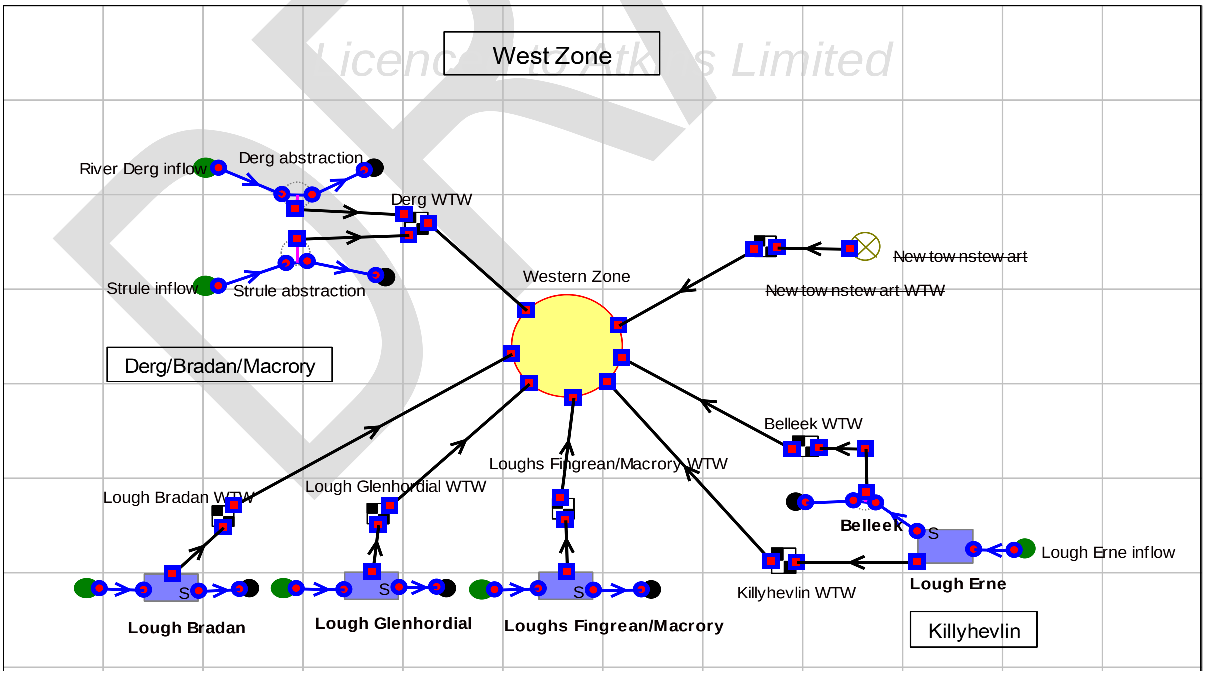


Figure A.12 – West WRZ unconstrained model schematic

East Zone

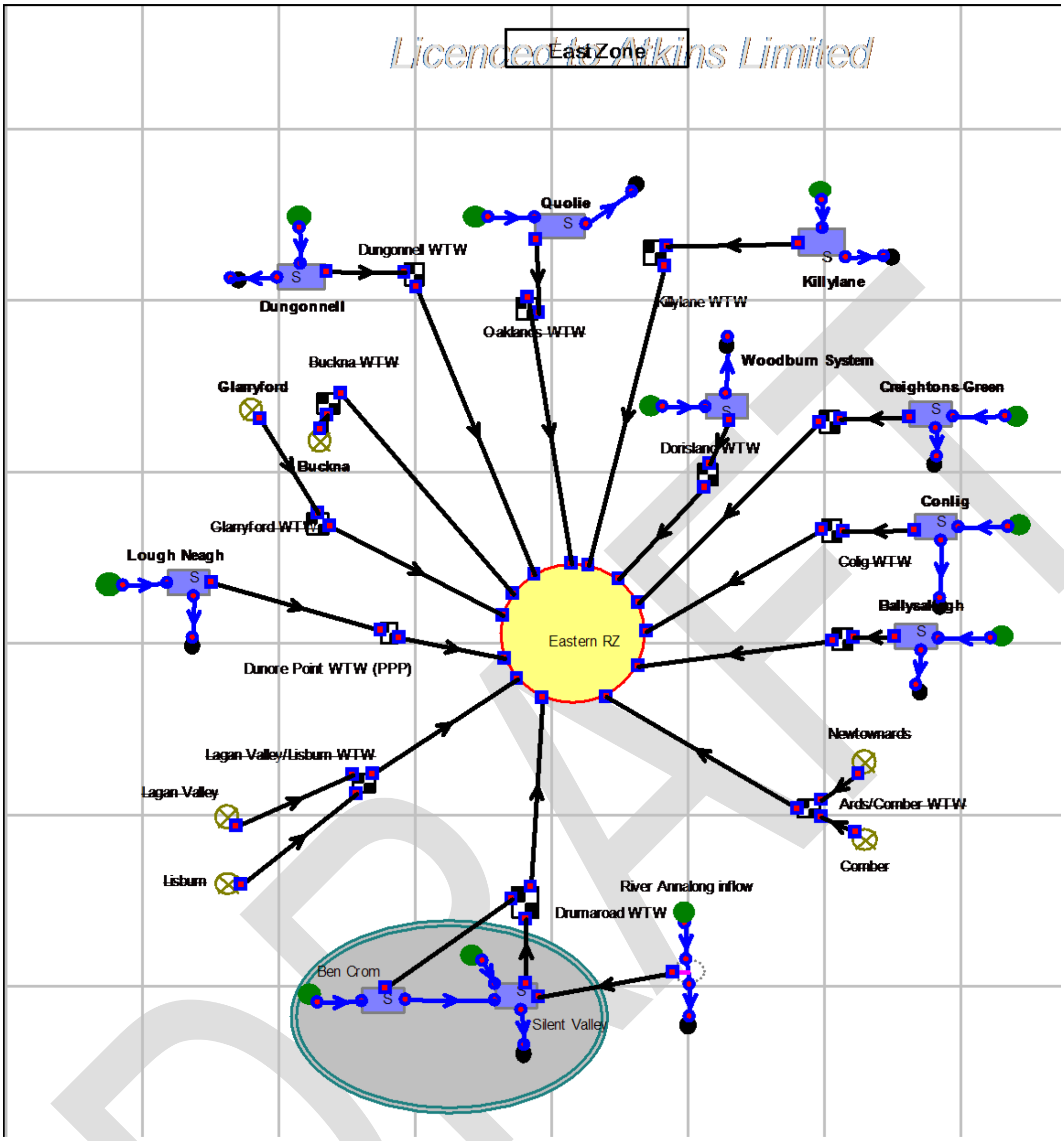


Figure A.13 – East WRZ unconstrained model schematic

South Zone

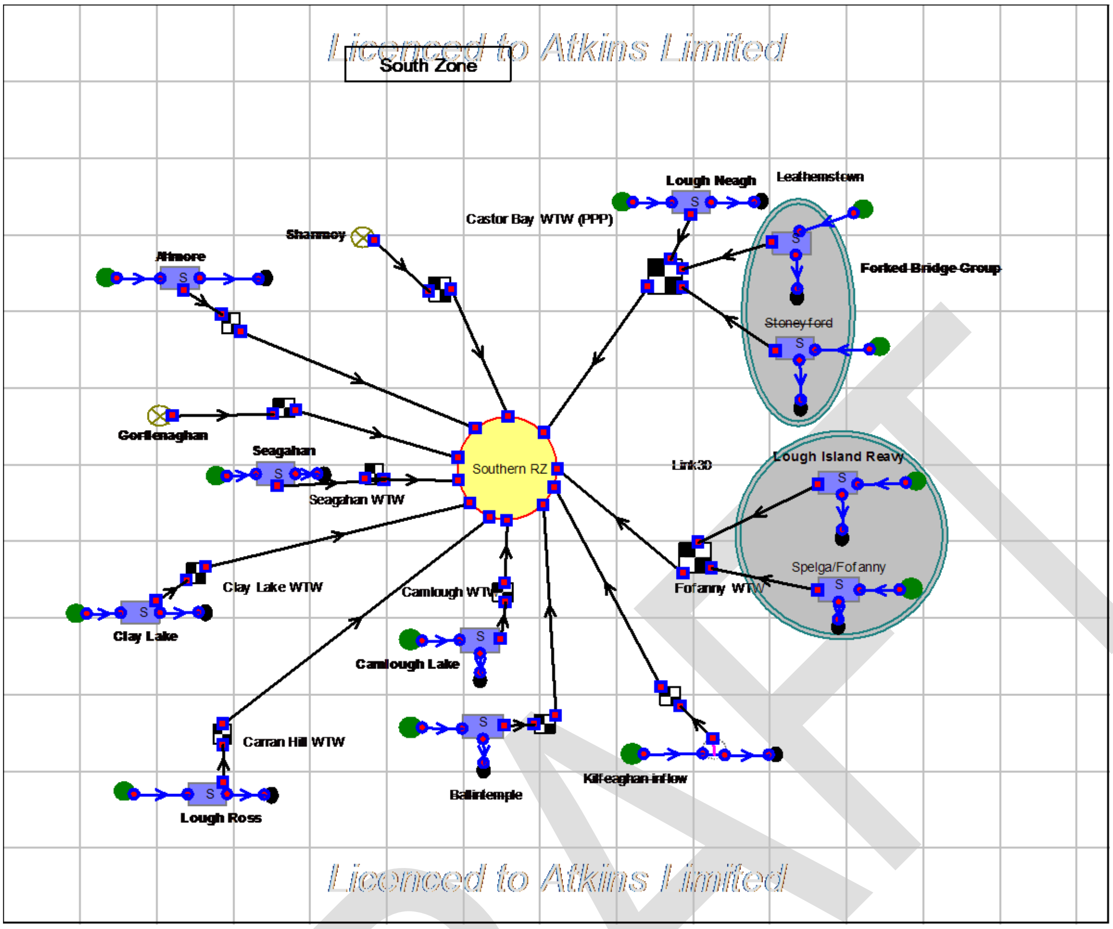


Figure A.14 – South WRZ unconstrained model schematic

A.8.2 Data request list

Expected data requirements for the Aquator modelling

Note that 'time-series' can refer to a single value, time series (daily, weekly, monthly or annual), or a fixed profile (daily, weekly, monthly or annual) to be used each year

Blenders (mixes water in supply to meet minimum quality standards)

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Sources	Component name or ID	
Blend method (fraction or determinand based)	Drop-down selection	Not likely required – only if significant blending operations exist
Fraction	Percentage distribution	
Determinand levels	Values	

Bulk supplies

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Amount	Time-series	Definitely required
Must use entire amount?	Yes/no	

Catchment

Parameter	Format / Data type	Likelihood of requirement
Flow	Time-series	Definitely required but may come from outside NI Water

Discharge

Parameter	Format / Data type	Likelihood of requirement
Flow	Time-series	Not likely required

Gauging stations

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Flow constraint	Time-series	Not likely required
Flow	Time-series	

Groundwater abstractions

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Efficiency	Percentage	
Daily maximum abstraction	Time-series	Definitely required
Monthly maximum abstraction	Time-series	
Minimum flow	Time-series	

Groundwater abstraction licences

Parameter	Format / Data type	Likelihood of requirement
Individual or group?	Drop-down selection	
Type of licence	Drop-down selection	
Enforced?	Yes/no	Definitely required
Amount	Time-series	
Start month	Drop-down selection	

Links (supply system pipes, aqueducts etc.)

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Bi-directional?	Yes/no	
Maximum flow - forward	Time-series	
Maximum flow - reverse	Time-series	Definitely required – some help may be available from Atkins Network Modelling Team
Minimum flow - forward	Time-series	
Minimum flow - reverse	Time-series	
Licence constraints?	Constraint component name or ID	

Pumping stations

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Minimum flow	Time-series	Not likely required
Maximum flow	Time-series	
Monthly maximum flow	Time-series	

Reservoirs

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	Definitely required
Compensation	Time-series	Definitely required
Additional outflow	Time-series	Not likely required
Hydropower	Time-series	Not likely required
Irrigation	Time-series	Not likely required
Flood drawdown	Time-series	Not likely required
Level Area Storage	Array of single values	Required if available
Abs. emergency level	Single value	Required if available
Rel. emergency level	Percentage	Required if available
Abs. dead water level	Single value	Required if available
Rel. dead water level	Percentage	Required if available
Control curves (time series or profile of storage)	Time-series	Definitely required
Rainfall	Time-series	Required if available
Evaporation	Time-series	Required if available
Observed levels or storage	Time series (daily, weekly, monthly or annual) to be used each year	Definitely required

Reservoir licences

Parameter	Format / Data type	Likelihood of requirement
Individual or group?	Drop-down selection	
Type of licence	Drop-down selection	
Enforced?	Yes/no	Definitely required
Amount	Time-series	
Start month	Drop-down selection	

River reach

Parameter	Format / Data type	Likelihood of requirement
Abstraction	Time-series	Not likely required
Discharge	Time-series	

Surface water abstractions

Parameter	Format / Data type	Likelihood of requirement
Operational?	Yes/no	
Flow constraint	Time-series	
Daily maximum abstraction	Single value, time series (daily) or fixed profile (daily) to be used each year	Definitely required
Monthly maximum abstraction	Single value, time series (monthly) or fixed profile (monthly) to be used each year	

Surface water abstraction licences

Parameter	Format / Data type	Likelihood of requirement
Individual or group?	Drop-down selection	
Type of licence	Drop-down selection	
Enforced?	Yes/no	Definitely required
Amount	Time-series	
Start month	Drop-down selection	

Water treatment works

Parameter	Format / Data type	Data availability / source / contact details
Operational?	Yes/no	Definitely required
Minimum flow	Time-series	Required if available
Daily maximum flow	Single value, time series (daily) or fixed profile (daily) to be used each year	Definitely required
Monthly maximum flow	Single value, time series (monthly) or fixed profile (monthly) to be used each year	Definitely required
Losses	Percentage	Required if available

Table A.13 – Data request list

A.8.3 Hydrological analysis

WISKI gauging stations and quality checks

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
203017	Dynes Bridge	Upper Bann	Record ok	28/12/1978	05/07/1994	1082
203039	Tullynewy Bridge	Clogh	Record ok	19/12/1983	08/07/2009	91
203043	Shanmoy	Oona Water	Record ok	11/11/1986	11/07/2009	12
205033	Woodburn East	Woodburn	Record ok	07/06/2000	11/07/2009	0
203024	Gambles Bridge	Cusher	Record ok	29/12/1975	11/07/2009	8
205029	Feeny	Lagen	Record ok	30/09/2004	31/12/2008	0
203947	Flat Vee Weir	Four Mile Burn	Record ok	06/10/1977	12/08/1986	479
204001	Seneirl	Bush	Record ok	29/12/1975	02/07/2009	81
203024	Gambles Bridge	Cusher	Record ok	29/12/1975	11/07/2009	8
203019	Glenone Bridge	Claudy	Record ok	29/12/1975	11/07/2009	1443
205015	Grandmere Park	Cotton	Poor Data Set in 1980-1990 where flows need adjusting	01/03/1987	11/07/2009	163
206002	Jerretts Pass (River)	Jerretts Pass	Record ok	02/01/1980	11/07/2009	47
203096	Kilraghts	Breckagh Burn	Record ok	26/03/1996	31/12/2008	0
203063	Leap Bridge	Glenavy	Record ok	23/05/2001	11/07/2009	91
203619	Lough Neagh Inflow	Lough Neagh	Record ok	30/08/1995	02/01/2001	8
203010	Maydown Bridge	Blackwater	Record ok	29/12/1975	11/07/2009	1
203097	Moyallan	Upper Bann	Poor Data Set in 2000 and 2002 where flows need adjusting	19/08/1990	16/08/2008	15
205004	Newforge	Lagan	Record ok	28/12/1977	11/07/2009	0
205110	Park Centre	Clowney	Record ok	23/09/1988	03/01/2001	209
236053	Ratoran	Pubble	Record ok	27/06/1994	31/12/2007	0
205102	Townsend Street	Farset	Record ok	30/12/1987	08/04/2002	743
203041	Tullybryan	Ballygawley Water	Record ok	05/11/1980	11/07/2009	278
236052	Rawbridge	Corlough	Record ok	28/06/1994	11/07/2009	11
235052	Rockstown	County River	Record ok	27/11/2002	30/06/2009	0
203050	UUC	Ballysallyblag h	Record ok	02/06/1993	08/07/2009	0
205309	Lusky Mill	Blackwater (Down)	Record ok	31/12/1975	07/01/1982	1
203090	Recorder F	Braid	Record ok	29/12/1975	18/03/2007	8788
205031	Woodburn West	Woodburn	Record ok	19/05/2000	11/07/2009	8

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
205005	Ravernet	Ravernet	Poor Data Set in 1999 where flows need adjusting	27/12/1979	06/07/2009	224
203046	Rathmore Bridge	Rathmore Burn	Record ok	31/12/1983	31/12/2008	0
203052	Pollands Bridge	Upper Bann Tributary	Record ok	31/12/1999	02/07/2009	1219
205105	Orangefield	Knock	Record ok	30/09/1983	02/06/2009	114
206015	Ohares, Castlewellan	Burren	Poor Data Set in 1999 where flows need adjusting	17/10/1994	31/12/2007	20
202005	Muff Glen	Muff	Record ok	15/02/1995	11/07/2009	0
205108	Rosepark	Knock	Record ok	03/07/2003	30/06/2009	62
203020	Moyola New Bridge	Moyola	Record ok	29/12/1975	11/07/2009	796
203040	Movanagher	Lower Bann	Record ok	25/06/1980	27/06/2009	2921
205023	Meaghlough Road	Carryduff	Record ok	29/12/1988	29/06/2009	3316
204007	Altnahinch	Bush	Record ok	21/09/2000	02/06/2009	15
202007	Altnaheglish	Roe	Record ok	27/09/2001	31/03/2009	0
205032	Woodburn Central	Woodburn	Record ok	19/05/2000	04/07/2009	2
203028	White Hill	Agivey	Record ok	15/03/1976	11/07/2009	280
205012	Watsons Bridge	Annahilt	Record ok	31/12/1980	26/09/1984	0
236058	Tilery Bridge	Arney	Record ok	01/02/1999	11/07/2009	183
203045	Springmount	Engine Burn	Poor Data Set	31/12/1981	29/12/1987	1388
203093	Shane's Viaduct	Main	Record ok	30/12/1983	11/07/2009	0
203038	Rocky Mountain	Rocky	Record ok	25/12/1985	02/07/2009	332
201304	Stonebridge	Strule	Record ok	22/12/1986	16/10/1997	0
203023	The Moor Bridge	Torrent	Record ok	01/01/1980	11/07/2009	1025
22565	#N/A	#N/A	#N/A	11/08/2004	05/08/2008	0
236009	Thompsons Bridge	Swanlinbar	Record ok	24/02/1987	07/03/1995	1
203025	Martin's Bridge	Callan	Record ok	29/12/1975	11/07/2009	7
203620	Lough Neagh Outflow	Lough Neagh	Record ok	25/06/1980	11/07/2009	2921
206009	Tipperary Wood	Shimna	Record ok	17/10/1994	11/07/2009	0
203012	Ballinderry Bridge	Ballinderry	Record ok	30/08/1995	11/07/2009	5
203018	Antrim	Six Mile Water	Record ok	29/12/1975	11/07/2009	0
203027	Ballee	Braid	Record ok	01/01/1980	11/07/2009	0
236005	Ballindarragh Bridge	Colebrooke	Record ok	30/12/1986	11/07/2009	0
202001	Ardnagle	Roe	Record ok	29/12/1975	11/07/2009	0
203013	Andraid	Main	Record ok	21/12/1982	31/12/1990	1105

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
236051	Ballycassidy	Ballinamallard	Record ok	16/04/1991	11/07/2009	1
201015	Ballymagory	Glenmorgan	Record ok	29/08/1995	11/07/2009	0
203029	Ballyclare	Six Mile Water	Record ok	03/01/1980	01/01/2000	1493
205036	Dromore Street	Ballynahinch	Record ok	17/10/2001	02/07/2009	12
203033	Bannfield	Upper Bann	Record ok	29/12/1975	11/07/2009	24
205010	Banoge	Lagan	Record ok	27/12/1983	25/07/1994	0
204004	Glendurn	Beaghs Burn	Poor Data Set in 1996 and 1998 where flows need adjusting	19/11/1995	11/07/2009	1226
206007	Bonnys	Tullybranigan	Record ok	19/10/1994	11/07/2009	0
201007	Burndennet Bridge	Burn Dennet	Record ok	29/12/1975	11/07/2009	15
205024	Burrendale	Burren	Record ok	01/03/1989	25/06/1994	0
201005	Camowen Terrace	Camowen	Poor Data Set in 1976 where flows need adjusting	29/12/1975	01/07/2009	1
201006	Campsie Bridge	Drumragh	Record ok	29/12/1975	11/07/2009	27
206004	Carnbane	Bessbrook	Record ok	13/12/1983	03/07/2009	285
205109	Loop Bridge	Loop	Record ok	29/12/1986	30/06/2009	3904
203044	Looblands	Ballinaloob	Record ok	10/09/1981	07/01/1988	0
236056	Larkhill	Garvary River	Poor Data Set in 1976 where flows need adjusting	16/08/1995	11/07/2009	138
205011	Kilmore	Annacloy	Record ok	22/11/1979	11/07/2009	12
236006	Killhevlin	Erne	Record ok	24/09/1984	11/07/2009	100
203091	Kernoghan	Devenagh Burn	Record ok	29/12/1976	05/11/1981	927
206005	Hockey Club	Newry	Record ok	13/06/1994	18/06/2009	819
205022	Gransha Road	Ward Park Stream	Record ok	31/12/2003	04/12/2008	104
202006	Gortenny	Castle	Poor Data Set in 1999 where flows need adjusting	27/02/1995	27/05/1999	142
203026	Glenavy	Glenavy	Record ok	02/01/1980	02/01/2001	8
203098	Galgorm (formerly Gallahers)	Main	Record ok	26/09/1984	11/07/2009	1075
203055	Flume 4	Fourmileburn	Record ok	31/12/1976	30/12/1979	0
203053	Flume 3	Fourmileburn	Record ok	18/12/1979	31/12/1985	0
203054	Flume 2	Fourmileburn	Record ok	17/01/1979	31/12/1985	3
203051	Flume 1	Fourmileburn	Record ok	18/12/1979	31/12/1985	0
205111	Fire Authority	Blackstaff	Record ok	01/11/2001	15/05/2007	626
202004	Eglinton	Muff	Record ok	19/12/1994	11/07/2009	6
205101	Easons	Blackstaff	Record ok	11/10/1983	04/04/2001	156

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
203092	Dunminning - Lower	Main	Poor Data Set in 1984, 1999 and 2000 where flows need adjusting	24/08/1983	11/07/2009	59
201002	Dudgeon Bridge	Fairy Water	Poor Data Set in 2000 where flows need adjusting	29/12/1975	11/07/2009	782
201010	Drumnabuoy House	Mourne	Record ok	17/06/1982	31/12/2008	0
236007	Drumrainy Bridge	Sillees	Record ok	22/09/1981	11/07/2009	14
205008	Drummiller	Lagan	Record ok	27/12/1977	11/07/2009	82
203911	Dromona (Kennaways)	Main	Record ok	29/12/1975	18/11/1980	0
201008	Castlederg	Derg	Record ok	29/12/1975	11/07/2009	0
203042	Cidercourt Bridge	Crumlin	Poor Data Set in 1999 and 2001 where flows need adjusting	29/12/1982	11/07/2009	3
202002	Drumahoe	Faughn	Poor Data Set in 1999 where flows need adjusting	27/08/1976	11/07/2009	31
203049	Clady Bridge	Clady	Record ok	19/12/1983	11/07/2009	5
203011	Dromona	Main	Record ok	08/09/1980	11/07/2009	1154
205020	Comber	Enler	Record ok	29/12/1983	11/07/2009	8
203022	Derrymeen Bridge	Blackwater (Armagh)	Record ok	04/01/1983	06/07/2009	4993
205025	Delamont Bridge	Delamont	Record ok	27/09/1989	02/07/2009	3150
203021	Currys Bridge	Kells Water	Poor Data Set in 2000-2002 where flows need adjusting	29/12/1975	11/07/2009	77
203035	Craigs	Aghill Burn	Record ok	21/12/1982	15/09/1992	2
201009	Crosh	Owenkillew	Poor Data Set in 2001 where flows need adjusting	14/02/1980	11/07/2009	24

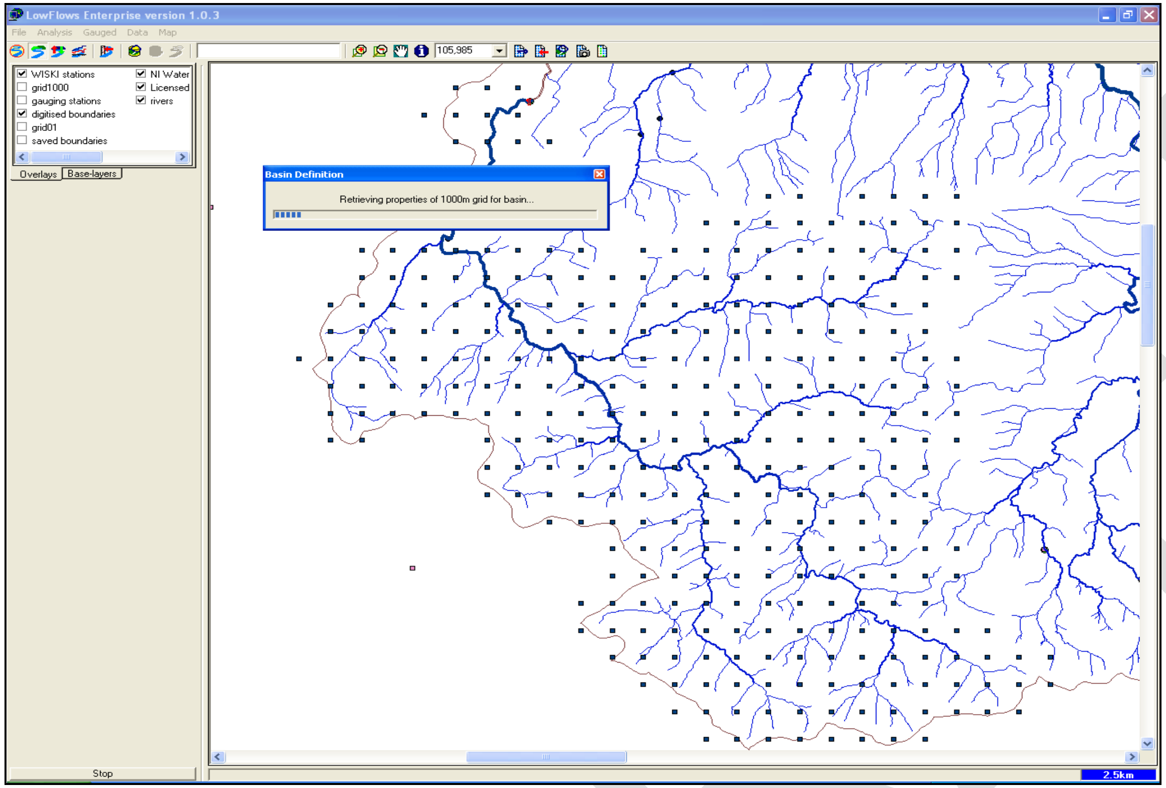
Table A.14 – WISKI gauging stations and record checks

Licensed abstraction intakes

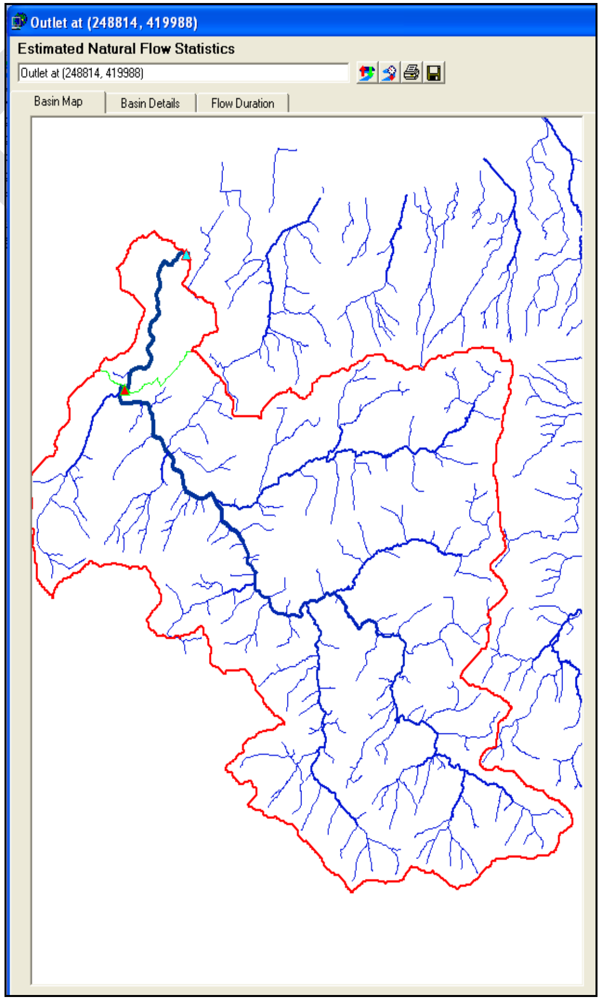
Local Name	Easting	Nothing	Source	Licence Name
Altmore Reservoir	267313	367499	Reservoir	Altmore
Cappagh Reservoir	269122	366943	Reservoir	Altmore
Altnahinch Impounding	312100	423500	Reservoir	Altnahinch
Springwell No 1	277148	428037	River	Ballinrees
Springwell No 2	277094	427899	River	Ballinrees
Springwell No 3	277074	427627	River	Ballinrees
Fermoyle	277286	428992	River	Ballinrees
Altikeeragh No 1	275478	430096	River	Ballinrees
Altikeeragh No 2	274474	430914	River	Ballinrees
Altikeeragh No 3	273925	431142	River	Ballinrees
Ballyhacket	274423	432692	River	Ballinrees
River Bann	286201	430098	River	Ballinrees
Lough Erne Belleek	194530	358640	Lough	Belleek
Camlough	302920	325854	Lake	Camlough
River Faughan	248880	420000	River	Carmoney
Lough Ross	288000	315700	Reservoir	Carron Hill Lough Ross
Glenedra River	268410	402380	River	Caugh Hill
Kerlins Burn	265310	403490	River	Caugh Hill
Altnaheglish	269650	403490	River	Caugh Hill
Clay Lake	283852	332806	Reservoir	Clay Lake
Gentle Owen Lake	283608	330035	Lake	Clay Lake
River Derg	232473	386169	River	Derg
Beltoy Water Course	341340	394423	River	Dorisland
Bellyvallagh Course	337720	393820	River	Dorisland
Frenchpark Conduit	339260	389750	River	Dorisland
Lough Mourne	341600	392380	Reservoir	Dorisland
Copeland	342810	391400	Reservoir	Dorisland
North Woodburn	337090	391140	Reservoir	Dorisland
Up South Woodburn	336660	388740	Reservoir	Dorisland
Mid South Woodburn	337280	388890	Reservoir	Dorisland
Low South Woodburn	337770	389120	Reservoir	Dorisland
Dorisland	338600	388100	Reservoir	Dorisland
Annalong	334800	323280	River	Drumaroad
Annalong	334820	323210	River	Drumaroad
Ben Crom	331470	325540	River	Drumaroad
Silent Valley	330840	321840	Reservoir	Drumaroad
Collin Burn	321800	418400	River	Dungonnell
Lough Garve 1	320800	417900	River	Dungonnell
Lough Garve 2	320487	417870	River	Dungonnell
Inver River	321968	419118	River	Dungonnell
Dungonnell IR	319268	417140	Reservoir	Dungonnell
Spelga	326600	327300	Reservoir	Fofanny
Fofanny	328603	329122	Reservoir	Fofanny
Slievemeel	329425	329300	Watercourse	Fofanny
Glenhordial Burn	248250	375650	River	Glenhordial
Crosh	249550	376350	River	Glenhordial
Camowen	247360	371220	River	Glenhordial
Glenhordial	248090	375250	Reservoir	Glenhordial
Lough Erne Killyhevlin	224710	342250	Lough	Killyhevlin
Donaghy's	330858	399497	Reservoir	Killylane
Crosswater 2	330187	401155	Reservoir	Killylane
Crosswater 3	329390	401308	Reservoir	Killylane

Local Name	Easting	Nothing	Source	Licence Name
Curraghmacall Stream 2	226050	374160	Stream	Lough Bradan
Curraghmacall Stream 1	225900	374440	Stream	Lough Bradan
Scraghey Burn	224280	372560	River	Lough Bradan
Lough Bradan	225950	371440	Reservoir	Lough Bradan
Lough Lee	225800	376240	Reservoir	Lough Bradan
Whitewater	278400	389600	Reservoir	Lough Fea
Sruhannaclogh	277900	389400	River	Lough Fea
Sruhanpollakeeran	276900	389100	River	Lough Fea
Lough Fea	276400	386500	Reservoir	Lough Fea
Muddoch	328470	332680	River	Lough Island Reavy
Moneyscalp	331480	334020	River	Lough Island Reavy
Lough Island Reavy	329230	333830	Reservoir	Lough Island Reavy
Bauck Hill	259350	378250	River	Loughmacrory
Loughanadarragh	256760	377770	Lough	Loughmacrory
Loughnepeast	256540	377480	Lough	Loughmacrory
Lough Carn	257460	378890	Lough	Loughmacrory
Stradowan No 1	253450	379750	River	Loughmacrory
Stradowan No 2	253450	379850	River	Loughmacrory
Glencolpy	253450	381050	River	Loughmacrory
Cornagillagh Bridge	254050	380650	River	Loughmacrory
Lenagh Bridge	254050	381850	River	Loughmacrory
Lough Fingrean	257220	377720	Reservoir	Loughmacrory
Lough Macrory	257550	376450	Reservoir	Loughmacrory
Seaghan Dam	326600	327300	Reservoir	Seaghan
Leathenstown Reservoir	321440	372444	Reservoir	Forked Bridge
Andersons	321949	370457	River	Forked Bridge
Stoneyford River Pumping Station	322005	370487	River	Forked Bridge
Stoneyford Reservoir	321475	369899	Reservoir	Forked Bridge
Dornans Intake	321056	372361	River	Forked Bridge

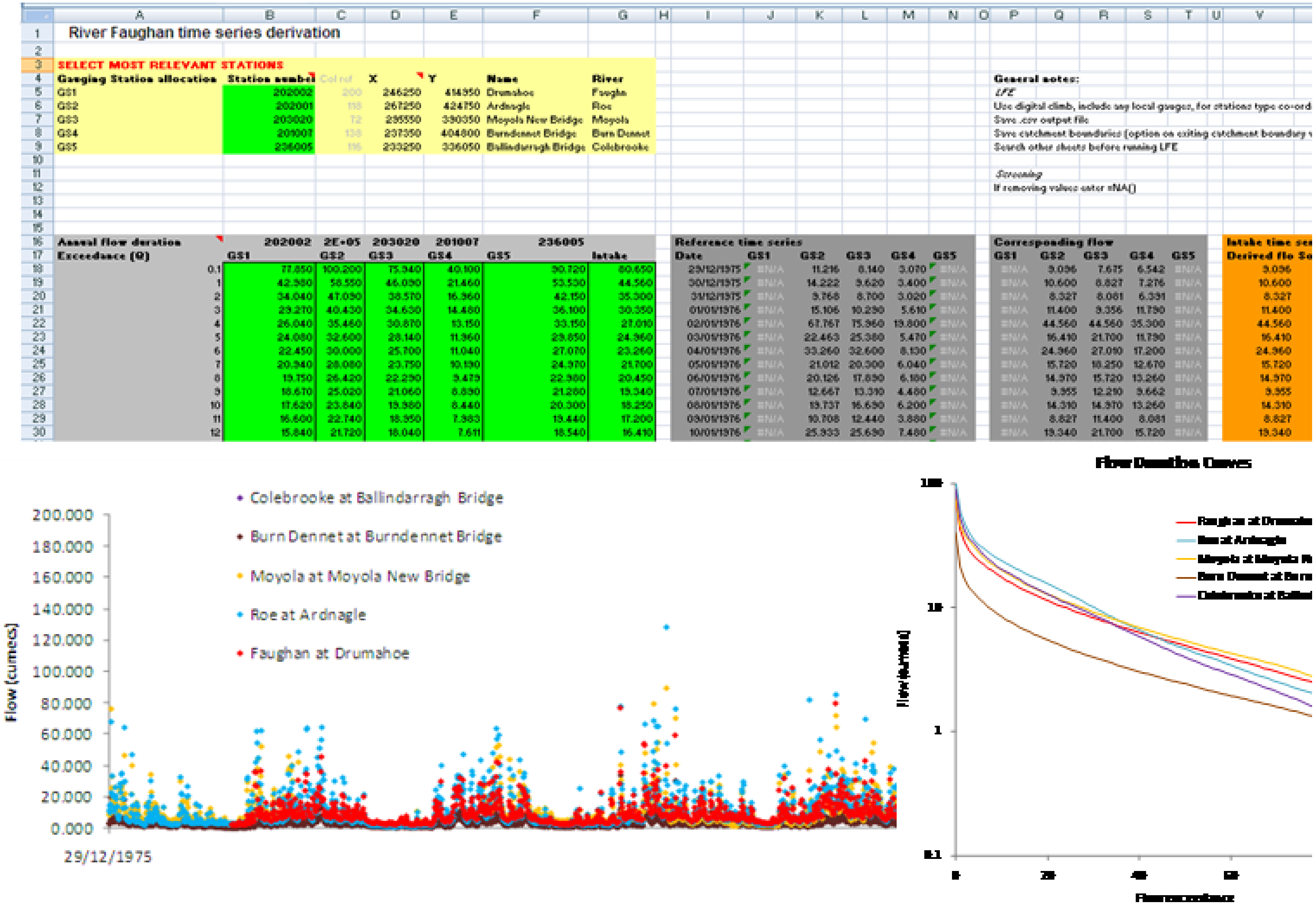
Table A.15 – Licensed abstraction intakes



a) An example of delineation using LFE software



b) LFE sotfware showing catchment boundary with a local gauging station just upstream



River Faughan time series derivation

SELECT MOST RELEVANT STATIONS

Gauging Station allocation	Station number	Col ref	X	Y	Name	River
GS1	202002	200	246250	414350	Drumahoe	Faughan
GS2	202001	118	267250	424750	Ardnagle	Roe
GS3	203020	72	295550	390350	Moyola New Bridge	Moyola
GS4	201007	138	237350	404800	Burndennet Bridge	Burn Dennet
GS5	236005	116	233250	336050	Ballindarragh Bridge	Colebrooke

General notes:
LFE
Use digital climb, include any local gauges, for stations type co-ord
Save .csv output file
Save catchment boundaries (option on exiting catchment boundary v
Search other sheets before running LFE

Screening
If removing values enter #NA()

Annual flow duration	202002	2E+05	203020	201007	236005	
Exceedance (Q)	GS1	GS2	GS3	GS4	GS5	Intake
0.1	77.850	100.200	75.940	40.100	90.720	80.650
1	42.980	58.550	46.090	21.460	53.530	44.560
2	34.040	47.090	38.570	16.360	42.150	35.300
3	29.270	40.430	34.630	14.480	36.100	30.350
4	26.040	35.460	30.870	13.150	33.150	27.010
5	24.080	32.600	28.140	11.960	29.850	24.960
6	22.450	30.000	25.700	11.040	27.070	23.260
7	20.940	28.080	23.750	10.190	24.970	21.700
8	19.750	26.420	22.290	9.479	22.980	20.450
9	18.670	25.020	21.060	8.890	21.280	19.340
10	17.620	23.840	19.980	8.440	20.300	18.250
11	16.600	22.740	18.950	7.983	19.440	17.200
12	15.840	21.720	18.040	7.611	18.540	16.410

Reference time series					
Date	GS1	GS2	GS3	GS4	GS5
29/12/1975	#N/A	11.216	8.140	3.070	#N/A
30/12/1975	#N/A	14.222	9.620	3.400	#N/A
31/12/1975	#N/A	9.768	8.700	3.020	#N/A
01/01/1976	#N/A	15.106	10.290	5.610	#N/A
02/01/1976	#N/A	67.767	75.960	19.800	#N/A
03/01/1976	#N/A	22.463	25.380	5.470	#N/A
04/01/1976	#N/A	33.260	32.600	8.130	#N/A
05/01/1976	#N/A	21.012	20.300	6.040	#N/A
06/01/1976	#N/A	20.126	17.890	6.180	#N/A
07/01/1976	#N/A	12.667	13.310	4.480	#N/A
08/01/1976	#N/A	19.737	16.690	6.200	#N/A
09/01/1976	#N/A	10.708	12.440	3.880	#N/A
10/01/1976	#N/A	25.933	25.690	7.480	#N/A

Corresponding flow					Intake time ser
GS1	GS2	GS3	GS4	GS5	Derived flo So
#N/A	9.096	7.675	6.542	#N/A	9.096
#N/A	10.600	8.827	7.276	#N/A	10.600
#N/A	8.327	8.081	6.391	#N/A	8.327
#N/A	11.400	9.356	11.790	#N/A	11.400
#N/A	44.560	44.560	35.300	#N/A	44.560
#N/A	16.410	21.700	11.790	#N/A	16.410
#N/A	24.960	27.010	17.200	#N/A	24.960
#N/A	15.720	18.250	12.670	#N/A	15.720
#N/A	14.970	15.720	13.260	#N/A	14.970
#N/A	9.355	12.210	9.662	#N/A	9.355
#N/A	14.310	14.970	13.260	#N/A	14.310
#N/A	8.827	11.400	8.081	#N/A	8.827
#N/A	19.340	21.700	15.720	#N/A	19.340

c) Bespoke excel spreadsheet containing data from ROI gauged catchments used to estimate flow time series

Figure A.15 – Catchment delineation maps and estimate flow time series

North WRZ	Notes
River Faughan	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Altnaheglish and Kerlins Burn	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Glenedra River	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Ballyhacket	In area 202 although rest of intakes for same licence are in area 203.
River Bann	Comprises most of area 203 including Lough Neagh, but LFE does not yet represent impoundments
Altikeeragh No.1, Altikeeragh No.2, Altikeeragh No.3	Could not generate correct boundary in LFE, so seems too large and overlapping with Altikeeragh2
Springwell No.1, Springwell No.2, Springwell No.3 and Fermoyle	Some issues with defining small catchments. Also Springwell 2 and 3 using gauges still needing screening
Altnahinch Impounding	Catchment definition runs too far downstream below the intake but may not be too great an error. Have used the local GS at Altnahinch but this was not one of the LFE GS so should check why it was omitted
West WRZ	**Notes**
River Derg	Digital used. Derg gauge used as local gauge.
Curraghmacall Stream 1&2, Scraghey Burn, Lough Bradan, Lough Lee	Curraghmacall Stream 2 digital area 3.26km^2, analogue 1.66km^2, both saved, digital used. Curraghmacall Stream 1 digital used. Scraghey Burn used digital. Lough Bradan digital 3.22km^2, analogue 5.15km^2, used digital but weighted by are as catchment area into reservoir approx 1.4km^2. Lough Lee digital 0.82km^2 (just downstream of lake), analogue 1.88km^2, digital used. For Lough Lee needed to replace ROI gauges 4 and 5 to get a complete time series, so 204001 replaced 201010 at 4th and 201002 replaced 203028 at 5th.
Glenhordial Burn, Crosh, Camowen, Glenhordial	Crosh analogue area almost twice as big as digital, used digital. Nearest WISKI station upstream at Camowen. Camowen nearest WISKI stations Camowen Terrace (201005) and Campsie bridge (201006). Glenhordial: digital area 6.23km^2, analogue 0.34km^2, used digital, cannot see WISKI station nearby.
Bauck Hill, Loughanadarragh, Loughnepeast, Lough Carn, Stradowan No1&2, Glencolpy, Cornagillah Bridge, Lenagh Bridge, Lough Fingrean, Lough Macrory	Bauck Hill digital used, but additional station 201008 added as ROI gauge 5 to obtain complete time series. No WISKI station nearby. Loughnepeast, Lough Fingrean and Lough Macrory are all included in the Lough Macrory catchment, digital at Lough Macrory used for these. Lough Carn saved as digital and analogue, used digital for calculations (the digital one selected is further downstream than Licence site) but adjusted FDC by 0.84/1.4 (0.84 is approx area at the Licence site). Stradowan 1 and 2 upstream of Cornagillah so just used Cornagillah digital for all 3. Glencolpy digital area 2.17km^2, analogue 3.03km^2. used digital as point seemed closer to the intake grid reference. Lenagh Bridge message that could not find climb thread in digital, used analogue instead, but adjusted analogue by 0.6/0.96 (area weighting, approx area at License point is 0.6km^2).

East WRZ	Notes
Collin Burn, Lough Garve 1, Lough Garve 2, Inver, Dungonell	Collin Burn 206001 ranked 5th ROI gauge, but no data available therefore used 203021. Lough Garve 1&2 couldn't select digital for either, used analogue which is downstream and weighted FDC by area, both included 206001 ranked 4th ROI gauge (for which no data is available), moved 203028 from 5th to 4th and added 203021 as 5th ROI GS. Inver used digital. Dungonell digital not representative, used analogue which is only a little way downstream.
Donaghy's, Crosswater1, Crosswater 2	Donaghy's digital seems fine. Crosswater2 and Crosswater3 digital boundaries cross a drainage path, but boundaries don't overlap so overall flow probably OK. Analogue site is further downstream of licence sites so used digital.
Lough Neagh	Assumed infinite.
Bellyvallagh, Frenchpark, Lough Mourne, Beltoy Copeland, North Woodburn, South Woodburn, Dorisland	Bellyvallagh used digital, but not enough data to produce time series so replaced 203019 with 203018 as 5th ROI GS. North Woodburn used digital. South Woodburn all on same river reach so only one inflow, analogue used and weighted by area, not enough data to produce time series so used 203018 instead of 203019 as 5th ROI GS. Lough Mourne and Beltoy upstream of Copeland, Copeland flows only required. Dorisland analogue used but weighted by area (0.16/0.983)
Silent Valley	Just downstream of Ben Crom, but separate inflow required for Aquator. This was obtained by subtracting Ben Crom from the Silent Valley flows. Digital used.
Ben Crom	Digital used.
Annalong	Nearly in the same location so just one inflow created. Digital used.
Central WRZ	**Notes**
Lough Fea, Whitewater, Shruhannaclogh, Shruhapollakeeran	Whitewater digital 5.29km^2, analogue 7.12km^2, used digital (looks like the analogue point is quite a lot further downstream). Sruhanpollakeeran: digital 0.43km^2, analogue is further downstream 1.87km^2, digital boundary upstream not same as analogue but if you were to draw the boundary manually looks like it would be the same size roughly as the digital. Lough Fea climb thread could not be found in digital, analogue used, catchment area drawn manually 4.1km^2, FDC adjusted by area weighting (4.1/7.34). For Sruhapollakeeran and Shruhannaclogh the 5 ROI gauges did not provide a complete time series, therefore gauge 201007 added in as the 5th GS for both.
Lough Neagh	Assumed infinite.
South WRZ	**Notes**
Altmore Reservoir, Cappagh Reservoir	Altmore is upstream of Cappagh on the same river, therefore Cappagh used for both. Digital used and boundary looks OK.
Clay Lake, Gentle Owen Lake	Clay Lake analogue area = 7.9km^2, not possible to select digital, but analogue is downstream of licence point so adjusted FDC by area weighting (5.9/7.9). Gentle Owen Lake is in a different catchment (and hydrometric region) so water must be transferred from Gentle Owen Lake to Clay Lake. Not possible to select digital boundary so used analogue and adjusted FDC by area weighting (0.56/2.25), manual area draining to Gentle Owen Lake is approx 0.56km^2.
Lough Neagh	Assumed infinite.
Lough Ross	Analogue didn't include all the area draining to the lake so used digital. Selected point just downstream of the lake so captured all inflows. 206001 first ROI gauge, however no data available, 203025 added in at 5 to provide complete time series.

Seagahan Dam	All fine.
Camlough Lake	Digital boundary looks odd and crosses a drainage path. Used analogue and adjusted using area weighting. Approx manual area at licence point is 2.3km^2 and analogue area is 3.02km^2, so adjusted by 2.3/3.02. 206001 is ROI gauge 1 but no data available, therefore 203033 added in at 5 to provide complete time series. NB only selected catchment at the upstream inflow to the lake since this is the licence location shown on the map; if the abstraction is for the whole lake then the catchment area will be larger.
Spelga, Fofanny and Slievemeel	Spelga, local gauge found but not used because generated negative value for mean flow. At Fofanny there seems to be a bypass channel round the reservoir. Just took the location at the dam. Slievemeel used digital (both analogue and digital saved).
Muddoch, Moneyscalp and Lough Island	The catchments are difficult to define, however an analogue catchment downstream of the reservoir was chosen and used for all the licence points.
Leathenstown Reservoir and Dornan's Intake	Dornan's Intake downstream of Leathenstown reservoir. Dornan's flows only used.

Table A.16 – Catchment delineation notes and comments

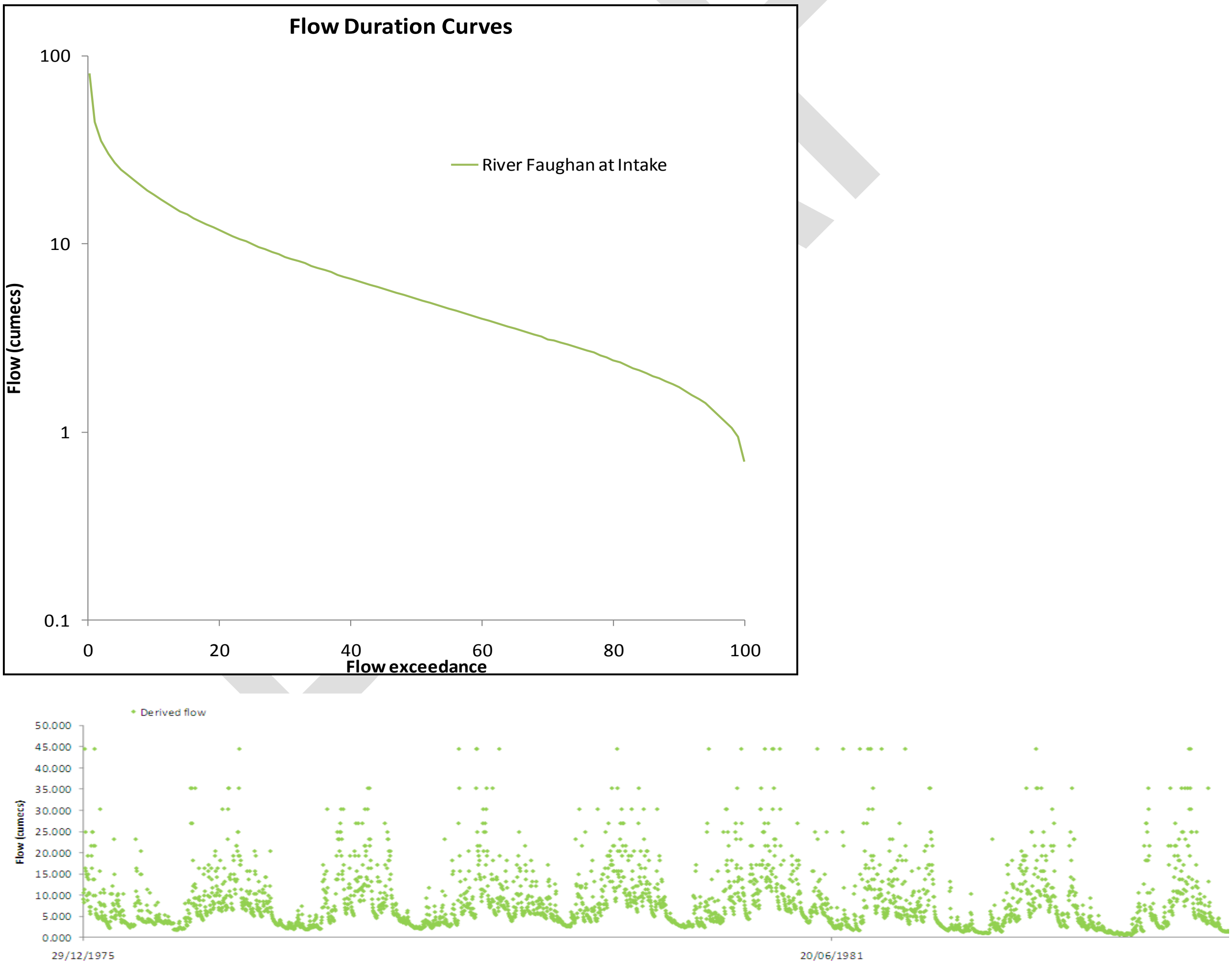


Figure A.16 – Example of flow duration curves and times series generated at each Licensed intake

A.8.4 Climate change

Climate change Flow factors

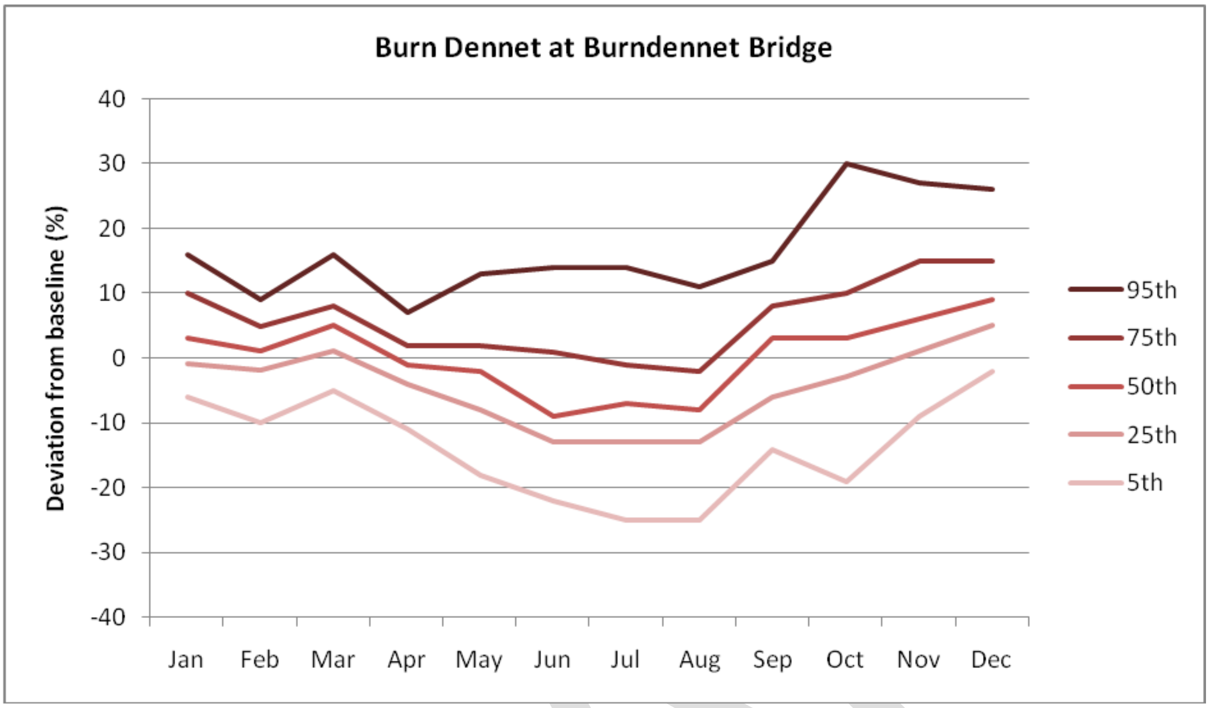


Figure A.17 – Flow factors for Burn Dennet at Burndennet Bridge

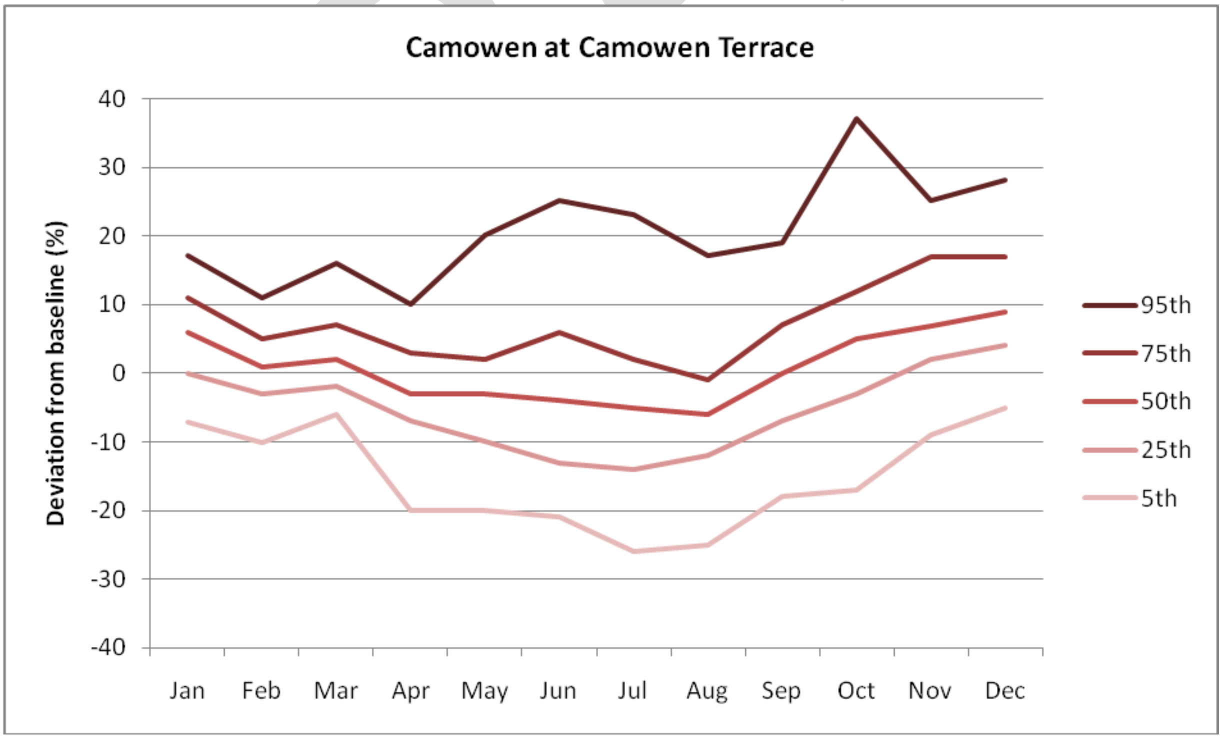


Figure A.18 – Flow factors for Camowen at Camowen Terrace

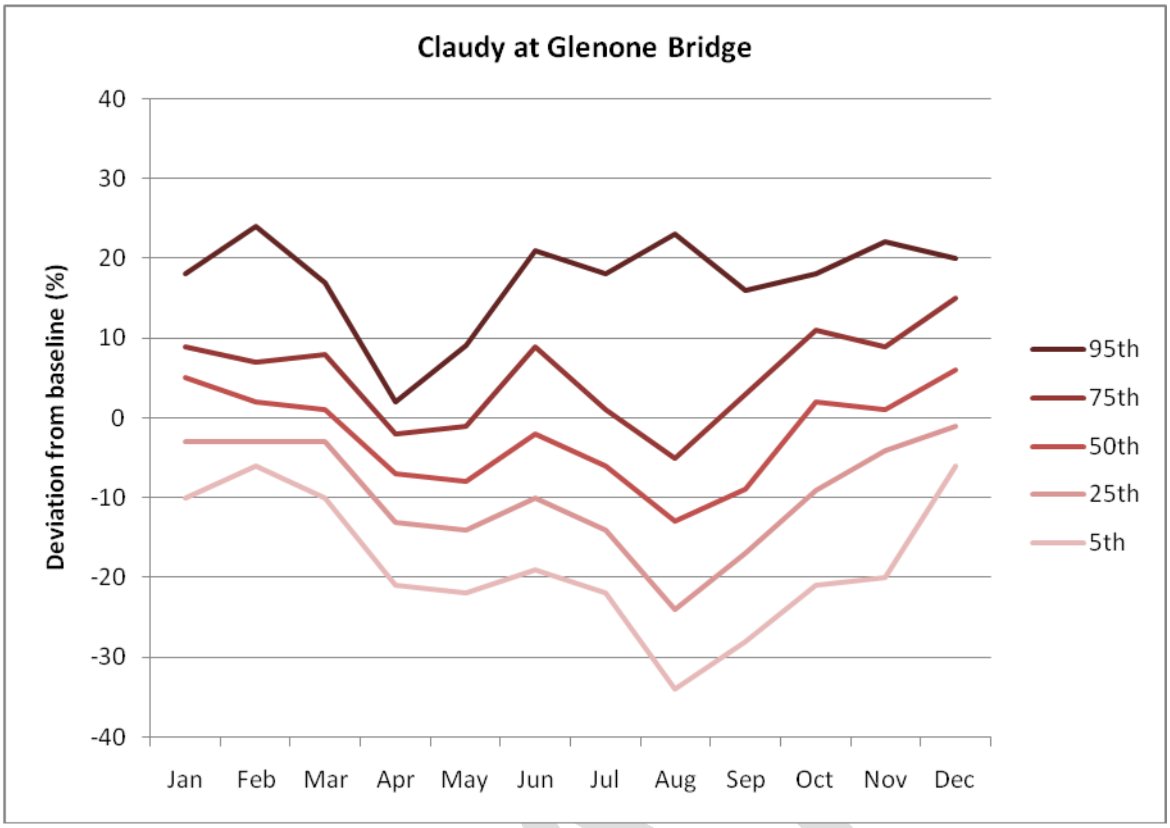


Figure A.19 – Flow factors for Claudy at Glenone Bridge

Simulation details and results

			5th Percentile Climate Change Runs						50th Percentile Climate Change Runs						95th Percentile Climate Change Runs					
WRZ	**Demand Centre**	**Demand (2008-2009 post MLE DI) (Ml/d)**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**	**RZ DO (Ml/d)**	**Dem and fact or**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**
North	Altnahinch	13.69	100	1.310	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahinch	Same failure date and conditions as non-CC run	105.2	1.37 8	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahinch	Same failure date and conditions as non-CC run	111.3	1.458	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahin ch	Same failure date and conditions as non-CC run
	Ballinrees	17.62																		
	Faughan/Altna heglish	45.04																		
West	Derg/Bradan/ Macrory RZ	37.22	86.8	1.380	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Bradan /Macrory	Same failure date and conditions as non-CC run	88.2	1.39 9	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Brada n/Macrory	Same failure date and conditions as non-CC run	89.5	1.423	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Br adan/Ma crory	Same failure date and conditions as non-CC run
	Killyhevlin RZ (DC1)	25.68																		
Central	Magherafelt/C ookstown (DC5)	26.70	31.1	1.165	None	1975	Hydrological conditions still not limiting		31.1	1.16 5	None	1975	Hydrological conditions still not limiting		31.1	1.165	None	1975	Hydrological conditions still not limiting	
East	Antrim/Larne RZ (DC8)	30.34	314.4	1.0781	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell WTW to Ballymena DC - reduced to 7 Ml/d 2) Killylane Reservoir to Killylane WTW - retained at 8 Ml/d 3) Dorisland WTW to Eastern General DC - reduced to 30 Ml/d	1978	Eastern General	Silent Valley and Ben Crom reservoirs become empty on 23/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure. Dungonnell can supply more water at this time but increasing its utilisation means that it fails later in the record and ultimately reduces DO	328.1	1.12 5	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell WTW to Ballymena DC - reduced to 7 Ml/d 2) Killylane Reservoir to Killylane WTW - reduced to 7 Ml/d 3) Dorisland WTW to Eastern General DC - increased to 34 Ml/d	1978	Eastern General	Silent Valley and Ben Crom reservoirs become empty on 15/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure.	346.1	1.187	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell and Killylane minimum flow controls retained from non-CC model - no further water can be moved away from the Ballymena and Antrim/Larne DCs 2) Dorisland WTW to Eastern General minimum flow removed to protect the over-utilised Woodburn system 3) Add minimum flow of 105 Ml/d (currently max supply just less than 105 Ml/d) to link between Drumaroad WTW and Eastern General to minimise use of Woodburn	2005	Eastern General	The Woodburn System becomes empty on 17/10/2005 despite optimisation to maximise preferential use of other sources
	Ballymena RZ (DC7)	24.32																		
	Eastern General RZ (DC2)	236.96																		

			5th Percentile Climate Change Runs						50th Percentile Climate Change Runs						95th Percentile Climate Change Runs					
WRZ	**Demand Centre**	**Demand (2008-2009 post MLE DI) (Ml/d)**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause / observations**
South	Newry RZ (DC5)	53.28	215.1 (200.4 after 2015)	1.209 (1.126 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link. 2) Increase minimum flow on link between Jerretspass PS and Newry demand centre to 16.5 (17.5 after 2015) to re-balance supply with Lough Ross	1977 (1975 after 2015)	Newry (Lough Ross after 2015)	218.6 (204.5 after 2015)	1.228 (1.149 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link.	1975	Newry	Not hydrologically constrained in baseline so increasing water in catchment has not effect. Failure could easily be in Lough Ross demand centre with slightly different optimisation	218.6 (204.5 after 2015)	218.6 (204.5 after 2015)	1.228 (1.149 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link.	1975	Newry	Not hydrologically constrained in baseline so increasing water in catchment has not effect. Failure could easily be in Lough Ross demand centre with slightly different optimisation
	Craigavon RZ (DC4)	94.74																		
	Lough Ross RZ (DC3)	6.43																		
	Armagh RZ (DC2)	18.33																		
	Dungannon RZ (DC1)	5.20																		

Table A.17 – Climate change run results (5th, 50th and 95th percentile) and model optimisation

Appendix B – Outage

B.1 Introduction

The WRP Guideline (produced by the Environment Agency for England and Wales) recommends that companies follow the principles set out in the operating methodology section of the report Outage allowances for water resources planning (UKWIR 1995) to determine their outage allowance. However, the WRPG also notes that the degree to which a company explores outage will vary according to need and circumstance. The Guideline thus notes that the minimum approach is for a company to justify outage allowances in relation to the likelihood of events occurring, given the magnitude, duration and timing of actual outage circumstances, as supported by recorded data.

In the glossary of the WRP Guideline, outage is defined as:

> *A temporary loss of deployable output. (Note that an outage is temporary in the sense that it is retrievable, and therefore deployable output can be recovered. The period of time for recovery is subject to audit and agreement. If an outage lasts longer than 3 months, analysis of the cause of the problem would be required in order to satisfy the regulating authority of the legitimacy of the outage).*

The UKWIR (1995) methodology notes that outages may occur from either planned or unplanned events.

Unplanned outages are caused by an unforeseen or unavoidable events affecting any part of the source works and occurring with sufficient regularity that the probability of occurrence and severity of effect may be predicted from previous events or perceived risk. The methodology provides a definitive list of events that could be considered as unplanned outages:

- Pollution of sources;
- Turbidity;
- Nitrates;
- Algae;
- Power failures; and
- System failures.

Planned outages arise from maintenance, inspection, refurbishment, and repair of source works. These outage events would not generally be considered where the loss of deployable output (DO) resulting from such regular maintenance issues was already taken into account in the calculation of DO for the source works in question. The company would not generally undertake major planned maintenance during periods or prolonged dry weather when reservoir storage has been drawn down and rivers are experiencing low flows.

B.2 Outage assessment

B.2.1 Data gathering

In the previous Water Resource Strategy (WRS 2002), the assessment of outage was based on discussions with each of the four Water Service Divisions in existence at the time, but no historic outage data was available. A nominal outage allowance of 3% of distribution input was assumed. It is understood that this was an allowance for unplanned outage only. No comment was made regarding planned outages.

Unplanned outage would normally be assessed using both observed outage from historical data and expected outage based upon interviews. Ideally there would be sufficient historical data to allow calculated outage values to be simply checked by operations staff to ensure that they were still consistent with the present state and expected future state of the source works.

A meeting was arranged with key NI Water staff to try to develop an understanding of outage, identify sources most at risk from specific outage events, and where possible to quantify these risks in terms of frequency, magnitude and duration of event. In an effort to provide a robust update to the estimation of outage for this WRMP, Atkins developed a pro forma to capture outage events. The staff interviewed were:

- Charles Gallagher – Head of Water Supply
- Gordon Nicholl – Business Unit Manager for Water Supply

During this meeting each source works was assessed in terms of risk of unplanned and planned outage events. The results are included in Table B.2 in section B.4. This summary represents relative risk at each source works. The key points to note from the meeting were:

- Production capacity estimates are based on the "20 hours rule" – i.e. if the works is shut for 4 hours, it can be run at a higher rate for 20 hours to catch up any lost capacity. As a result, <u>planned outages are assumed to be zero</u>.
- The supply system is, out of necessity, run with minimal outage as there is insufficient security in the system. So any outage event must be dealt with immediately. Therefore, even if data/information of historic outage events is available, the level of <u>overall unplanned outage would be expected to be low</u>.
- All sources have back-up power generators, so there are no "power failure" outage events.
- It was not possible to derive more detailed quantification of outage events than the relative risk assessment included in Table B.2 in section B.4. Therefore, <u>no estimates of frequency, duration or magnitude of outage events were made</u>.
- Water treatment works production capacity (July 2009) figures are based on estimates of safe yield (WRS 2002), plus allowances for safety factors. The safety factors make some allowance for uncertainty, outage, etc. However the NI Water staff noted that it was not possible to disaggregate and separate out each component making up the general safety factor.

However, there was little historical outage data available to support the assessment. The only data available was from Upwards Reports, which detail issues at WTWs. These were available from July 2008 to November 2009. They were assessed as the primary means to gather information on historical outage events.

The Upwards Reports data has been collated and entered into the outage pro forma for each source works. The results suggest that over a period of approximately 17 months, there was a total of nearly 17 days of outage events at the source works, as summarised in Table B.1 below.

Source works	Total outage duration days (Jul 2008 – Nov 2009)	Approximate outage (days / year)
Carmoney	2.8	2.0
Moyola	8.0	5.6
Clay Lake	0.2	0.1
Dunore	0.5	0.4
Derg	0.5	0.4
Castor Bay	0.5	0.4
Camlough	1.2	0.8
Killyhevlin	0.1	0.1
Altnahinch	1.2	0.8
Lough Macrory	1.1	0.8
Dorisland	0.2	0.1
Foffany	0.2	0.1
Seagahan	0.2	0.1
Total days outage	16.7	11.8

Table B.1 – Summary of Upwards Report unplanned outage events, Jul 2008 to Nov 2009

However whilst the Upwards Report data provides an indication of outage events experienced over approximately 17 months, they provide no indication of the magnitude of the impact.

B.2.2 Planned outages

No data was available regarding planned maintenance, inspection, refurbishment, and repair of source works. However, planned outages were discussed at the outage meeting with NI Water staff. They stated that the production capacity estimates are based on the "20 hours rule" – i.e. if the works is shut for 4 hours, it can be run at a higher rate for 20 hours to catch up any lost capacity. Thus, planned outages are already considered in the WTW capacity estimates. If an allowance for planned outages were to be included this would result in double counting. Therefore planned outage is assumed to be zero.

B.2.3 Unplanned outages

Due to the lack of suitable historic data, and the difficulties of operations staff in quantifying potential outage risks through interviews, the assessment again has to be based on expert judgement. However, recommendations for improved data collection for the future assessment of outage events have been made.

PPP source works are assumed to act effectively like bulk imports, as these are contracted amounts of water. Therefore, no allowance has been made for potential outages at these source works.

B.3 Conclusions

An attempt to collect relevant outage data was made through interviews with key operational staff aided by a pro forms developed to capture information and judgements in a robust and auditable manner. Potential data capturing historical outage events was also investigated, of which the only relevant available source were the Upwards Reports, but these were only available since July 2008, and did not capture information on magnitudes of impact.

Due to the lack of suitable historic data, and the difficulties of operations staff in quantifying potential outage risks through interviews, the assessment has again been based on expert judgement. However, approaches for improved data collection for future assessment of outage events have been considered.

The operations staff interviewed stated that the supply system is run with minimal outage as there is insufficient security in the system. So any outage event must out of necessity be dealt with immediately. Therefore, they felt that overall unplanned outage would be expected to be low – in the region of 1%-2%. Planned outages are already allowed for within WTW capacity estimates, so no additional allowance for these has been made.

Therefore, the outage allowance used for this Draft WRMP is 2% of deployable output, based on expert judgement. This is relatively low by comparison with many water companies in England and Wales, however, it is felt to represent a reasonable estimate in the context of the operating conditions experienced in Northern Ireland. The total deployable output of NI Water sources (i.e. excluding PPP schemes) is approximately 378 Ml/d (section A.1). Thus the assumed 2% allowance for outage equates to approximately 7.54 Ml/d.

B.3.1 Recommendations

In order to increase confidence in the estimates of outage for future planning purposes, and given the difficulties operational staff had in trying to quantify potential outage events, consideration should be given to the development of a data collection system.

Currently, the outage allowance is relatively low, although is felt to represent the conditions experienced in Northern Ireland – i.e. operations staff must currently ensure that outages are minimised and any events resolved in a short period of time, as there is insufficient security and resilience within the supply system. However, as steps are taken to improve the resilience of the system, the issue of outage may become more critical to the planning process. Therefore it will be necessary to base future outage allowances on reliable data sets.

Improved data collection will also facilitate a move towards a probabilistic determination of outage, so that an allowance may be chosen at which the company understands the risk that it may be exceeded in any given year. For instance, if the outage value is taken from the 95th percentile of cumulative probability, then there would be a 5% chance that the level of outage that actually occurs would be greater than this value.

Data capture systems

A data capture system could follow the template currently used in the Upwards Reports (an example of which is below), but perhaps with a section to estimate the magnitude of the impact in Ml/d terms, as well as the duration. For ease with outage assessment, events could also be classified under one of the definitive categories of unplanned outages.

Standard Upwards Report

Event type/classification:	*Carmoney Water Treatment Works*	Report N°.:	*1*
Event category:	*2*		
Basis for categorisation;	*Received a telephone call form NIEA to inform plant staff that there was white foam covering over the full width of the River Faughan intake at Cloghole road. This is a possible detergent used for the oil spill clean up from last week on the river. Oil pollution in River Faughan last week resulted in plant shutdown of Faughan PS and Carmoney WTW for 36 hours. May give rise to local public or media interest.*		
Name of Reporter:	*Shaun Kelly*		
Date and time of Event:	*15/11/009*	*14.00*	
Report Date and time:	*15/11/09*	*16.30*	
Functional Area:	*Water Supply & Networks*		
Site Name/Location:	*Carmoney WTW, Londonderry*		
Asset Name:	*Faughan PS & Carmoney WTW*		

Event Details:

- *Plant operational staff were informed of white foam in the river by at approx. 14.00 hrs and as a precaution shut down the pumping station and treatment works immediately.*
- *NIEA staff to check river for source of pollution including site where oil pollution occurred last week.*
- *Water Supply on site to establish extent of pollution. Carried out manual checks for Ammonia, phosphates & taste & odour tests through out the treatment plant & nothing was detected*
- *White foam is clearly visible in the river below the Weir gates where the water is turbulent.*
- *Water Supply staff currently investigating whether any pollution has got into the works but no visible signs of foam anywhere in the works.*
- *A boom has been installed at the works intake to deflect river flow away from the works.*
- *Monitoring of the river intake ongoing.*
- *Current storage level at Carmoney sufficient for24-30 hour's min. Rezoning not required at this time*
- *NIEA have contacted ENVA who were used to clean up the oil spill last week to check if any detergent was used in the clean up. ENVA were adamant that no detergent was used by them.*
- *Scientific staff will be on site shortly to conduct checks in the Raw Water and through out the works.*
- *Plant will remain shutdown while further analysis of the river and plant takes place.*

Population Affected including potential:	*No customers are affected at present.* *WTW currently produces about 25 ML/day to about 100,000 population.*

Action Taken:

- *Supply and scientific staff on site to ascertain extent of problem*
- *Approximately 24 -30 hours storage in the system.*
- *Telemetry & Networks have been informed of the problems*

Estimated time of restoration:	*As a precaution Treatment works has been shut down. Hopefully plant will be started up at 08:00hrs tomorrow with the guidance of scientific section*
Information passed to the following:	*A Law, B McKee, C Gallagher, M Wright, M Mailey, G McKeague, G Murphy, D Devaney*
Line to take:	• *NI Water is monitoring the situation and will take all necessary action to protect and maintain supplies to customers.* • *Final water quality is not affected.*

Figure B.1 – Example of current Upwards Report

An alternative, although similar system, could make use of the pro forma already developed as part of this assessment. For any legitimate outage event, the pro forma could be completed and issued to a designated member of staff responsible for data collection, and then entered into a data base to allow easy access to the data in future assessments.

Sourceworks:		**Date of Review:**	26/11/2009				
Source type:	**Water Treatment Works**	**NIW Staff:**					
		Atkins Staff:					
UNPLANNED OUTAGE							
Event Group	**Outage Event**	**Data available (identify source)**	**Estimated return period (years)**	**Duration (days)**	**Outage (days/year)**	**Proportion (%) of treatment affected**	**Comments**
Pollution of Source	Contamination risk						
	Accidental spills						
	Pollution of nearby river						
	Algae						
	Cryptosporidium/Giardia						
	Nitrates / agriculture (e.g. pesticides)						
	Turbidity - operational / air						
	Turbidity - rain induced						
Power failure	Loss of Supply - rural & no generator						
	Loss of Supply - urban						
System failure	Flooding - fluvial						
	Flooding - drainage						
	Flooding - pipe burst						
	Control Failure (e.g. telemetry)						
	Disinfection problems (incl UV failure)						
	Ortho-Phosphate control problems						
	Pump failure (including multiple failures)						
	Age related (general M&E/ICA)						
	New process (microfiltration etc)						
	Complex process (iron removal etc)						
	Burst main (raw water transfer to WTW)						
	Catastrophic failure (e.g. fire)						
	Operator Error						
	Other works failures						
		Total days outage experienced		0.0			
PLANNED OUTAGE							
Event Group	**Outage Event**	**Data available (name source)**	**Estimated return period (years)**	**Duration (days)**	**Outage (days/year)**	**Proportion (%) of treatment affected**	**Comments**
Planned	Inspections						
	Maintenance						
	Repair						
	Refurbishment						

Figure B.2 – Example of outage pro forma

Another approach could be to conduct regular analysis of water into supply data from each source works. This could be done, for example, on a monthly basis. Occurrences of significant decreases of water into supply could be followed up with the operations manager to understand the reason for the variation, and determine if it is due to a legitimate outage event or not. If so, the approximate magnitude could be determined from the data. At the time of inquiry with the operations manager, the approximate duration of the outage event could also be assessed. Note that not all reductions in output would be due to outage events, and it may also be possible to maintain supply through increased output from alternative sources or storage (and then catch up to replace “lost” storage from covering the outage event).

B.4 Outage records

B.4.1 Unplanned outage risks

Add a tick (✓) to the top-left section of box to indicate if the type of outage has been experienced historically. Add a tick in the bottom-right (using spaces to align) to indicate if data might be available. An example is here:	✓ / ✓

Production Source	Head WTWs	Unplanned Outage						
		Source pollution	Turbidity	Nitrates	Algae	Power failures	System failures	Comments
Altnahinch Impounding Reservoir	Altnahinch	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure
Lough Erne	Belleek	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Camlough Lough	Camlough	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
River Faughan	Carmoney	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	High risk system failure surrently, but upgrade now underway
Lough Ross	Carran Hill	× / ×	× / ×	× / ×	✓ / ×	× / ×	✓ / ×	Low risk system failure
Altnaheglish Impounding Reservoir	Caugh Hill	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Glenedera River	Caugh Hill	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure. Low risk source pollution
Clay Lake Impounding Reservoir	Clay Lake	× / ×	× / ×	× / ×	✓ / ×	× / ×	✓ / ×	medium risk system failure (due to membrane plant)
River Derg	Derg (Tievenny)	✓ / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Woodburn Combined Impounding Reservoirs	Dorisland	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure

Production Source	Head WTWs	Unplanned Outage						Comments
		Source pollution	Turbidity	Nitrates	Algae	Power failures	System failures	
Silent Valley/Ben Crom Impounding Reservoirs River Annalong	Drumaroad	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Dungonnell Impounding Reservoir	Dungonnell	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Fofanny/Spelga Impounding Reservoirs	Fofanny	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Lough island Reavy	Fofanny	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Glenhordial Impounding Reservoir	Glenhordial	× / ×	✓ / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure. Low risk turbidity
Lough Erne	Killyhevlin	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure (due to process issues)
Killylane Impounding Reservoir	Killylane	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure. Low risk source pollution
Lough Bradan Impounding Reservoir	Lough Bradan	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	High risk system faliure surrently, but scheme is in capital programme
Lough Fea Impounding Reservoir	Lough Fea	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Lough Macrory/Lough Fingrean Impounding Reservoirs	Lough Macrory	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Seagahan Impounding Reservoir	Seagahan	× / ×	× / ×	× / ×	✓ / ×	× / ×	× / ×	No system failure risk subject to successful comissioning. Low risk of algae
Ballinrees & Altikeeragh Impounding Reservoirs Rivers Bann and Ballyhacket	Ballinrees							PPP
Lough Neagh	Castor Bay							PPP
Lough Neagh	Dunore Point							PPP
Stoneyford and Leathemstown Impounding Reservoirs	Forked Bridge							PPP
Lough Neagh	Moyola							PPP

Table B.2 – Summary of unplanned outage risks at each source works