
A Guide to Aquator

6 Analyzers

Version 2.1

By Oxford Scientific Software Ltd.



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Analyzers

What is an Analyzer?



An Analyzer is an Aquator add-on which applies a specific analysis technique to an existing project.




An example is an Analyzer which carries out several runs of a model, each run with gradually increasing *Demand Centre* demands to determine the level of demand that causes the system to fail.

Optionally Analyzers can have *Properties*, *Parameters*, *States*, *Variables* and *Sequences*. These are added to the project's properties, parameters, states, variables and sequences collections, but may only be visible on the Analyzer's own setup form.

Additional Analyzers may be added to Aquator by third parties to undertake new types of analysis.

Standard Analyzers

Aquator Analyzers are:

-  Deployable Output – English & Welsh method
-  Deployable Output – Scottish method
-  River flow analysis (flow duration & low flow frequency)

Deployable Output – English and Welsh method



The purpose of this *Analyzer* is to determine the yield or *deployable output* (DO) of a water resources system using the

method used in England and Wales. The method 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.

This analyser allows the demand increment to be specified as well as the range of demands to be studied. Using the run dates already specified for the model, there is one model run for each overall demand, starting with the minimum demand.

Demand centres that are to have their demands scaled during the analysis are be specified. These demands are then scaled, keeping the same relative demand between individual demand centres so that the total is equal to that overall total for a particular model run. Specifying demand centres in this way allows for other demand centres to have their demand held constant for each of the model runs. These demand centres may be present in the model to represent other uses such as power stations or demands outside the resource zone.

Two methods of finding the deployable output are provided:

1. **Binary chop.** This method executes the model run with minimum demands first, followed by the run with maximum demands. If the first run does not fail and the last run does fail, the next model run is mid way between the minimum and maximum. If this third run fails, the second half of the demand range is eliminated from the analysis as it cannot contain the solution. If the third run does not fail, the solution must be in the upper range of demands. By applying this technique a solution is found faster on average than by the step by step method. However the binary chop has been known to find an incorrect solution under unusual circumstances when demand saving measures are in place. Here increasing the demand from a failed demand, can invoke more severe or lengthy demand saving, so that at the next demand increment there is no failure. The binary chop technique can find this higher demand and report it as the Deployable Output.
2. **Step by step.** This method executes the model run with minimum demands first, followed by successive runs with demands increased by the demand increment. The analysis is complete when failure occurs and the deployable output is the overall demand of the penultimate run.

Setting failure conditions - English and Welsh Method

Failures are defined at the component level. For example a demand centre has a parameter *Fail.If demand not met*. Setting this to True causes a failure when supply does not meet demand on any day and this will be detected by this analysis module. Similarly a reservoir has many possible ways of failing (e.g. empty or compensation flow not met) and these are defined in the reservoir's parameters. Reservoir groups can also trigger a failure in a number of ways. A river abstraction can also trigger a failure if a prescribed flow is not met.

In addition it is possible to trigger or remove failures using VBA on any component in the *AfterTerminateDay* event by setting the Status parameter. Trigger a failure by the following:

Status = aqtStatusFailure

Force a failure not to be counted by:

Status = aqtStatusOK

Thus there is a large degree of flexibility in defining what does and what does not constitute a failure.

Applying the analysis – English and Welsh Method

Unless there is a good reason to the contrary, the analysis is best undertaken on the longest possible simulation period. The run simulation period is defined in Aquator under menu **Setup -> Model..., States** tab.

If you have more than one demand centre, set up each of their parameters *General.Demand* and *General.Demand factor* to be in the correct ratio between demand centres. (The ratio between demands at demand centres is preserved for each model run undertaken during the analysis as the system wide, Overall demand is increased.) If you have full Demand sequence specified for any demand centre, this is ignored for this analysis and the *General.Demand* and *General.Demand factor* parameters used instead.

Decide on your failure criteria and set the appropriate parameters in the model components that can cause a failure. See *Setting failure conditions* for further information.

Select the **Tools -> Analyze** menu item and then **Deployable Output – English and Welsh Method**. The following form is displayed which controls the analysis:

In the above form the *Run Duration* frame shows the length of the model run period. This is defined by the project *Run start date* and *Run finish date* – see above.

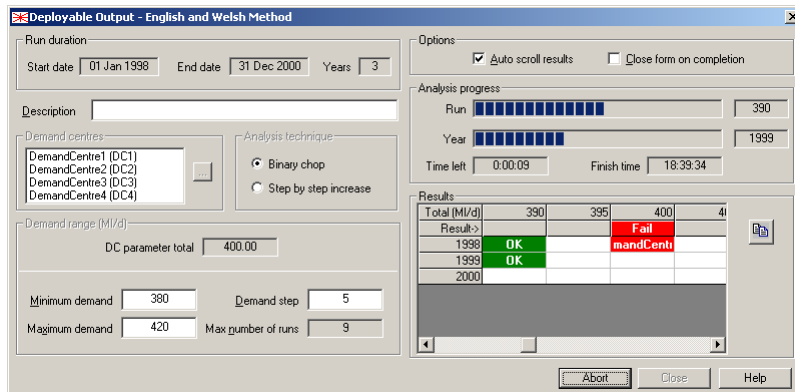
The Demand centre frame is used to define which demand centres are to be included in the run by run demand scaling process.

The analysis technique should be chosen as required. The section *Deployable Output – English and Welsh method* describes the advantages of each method.

The Demand Range frame allows the overall system demand specified for each model run. The DC Parameter *Total* value displayed on the form is the total of all demand centre demands as defined in their parameters and is for information only. The *Minimum Demand* is overall demand for the first model run. Subsequent model run uses an overall demand which is the *Minimum Demand* plus a number of *Demand Steps*. The *Max number of runs* value shows how many model runs will take place as the *Minimum Demand* is incremented to the *Maximum Demand*. In practice fewer runs might take place.

The *Close form on completion* check box in the Options frame determines whether the above form is closed automatically once the analysis is complete.

Having set up the analysis parameters, the analysis is carried out by clicking on the *Execute* command button. The form then changes to run mode:



In the above form the *Analysis progress* frame shows how the analysis is progressing and its estimated completion time.

The grid in the *Results* frame has one cell for each overall demand and year. It is possible to scroll through this grid as the analysis proceeds to study the result. Each time the model starts a new year and the Auto scroll check box is ticked, the cell in the grid relating to the current demand and year is made visible. The Copy command button:



copies the current content of the grid into the clipboard in a format suitable for pasting into Excel.

The *Abort* command button may be used to abort the analysis at any stage.

After the analysis is completed, the most relevant result set will be displayed in the project tree view. If the deployable output has been found, this will be the model run relating to the DO. If a solution has not been found, a result set is left so that it might be studied to determine a more suitable set of parameters.

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

An Analyzer can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
EnglishDO	Description

Group	Name
	Min demand
	Max demand
	Demand increment
	Analysis method
	Exit on completion

States

An Analyzer can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Analyzer.

Variables

An Analyzer can have more than one set of variables. Variables are possible daily outputs from the component and may be turned on and off.

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

There are no sequences for this type of Analyzer.

Deployable Output – Scottish Method



Deployable Output – Scottish method

The purpose of this Analyzer is to determine the yield or deployable output of a water resources system. The methodology has been determined by:

- West of Scotland Water
- East of Scotland Water
- North of Scotland Water
- SEPA (Scottish Environment Protection Agency)

Note that West, East and North of Scotland Water have now amalgamated into a single company – Scottish Water.

The analysis technique involves the following steps:

1. Run the model multiple times. Each model run has an incrementally increased *Overall demand*.
2. The number of *Days failure* is counted each year, (i), for the **N** years of the analysis.
3. The annual series of *Days failure* is ranked in ascending order of *Days failure* such that the lowest rank, **i = 1** is given to the lowest number of annual *Days failure* and the highest rank, **i = N** is given to the greatest number of annual *Days failure*.
4. A probability (and hence return period) is assigned to each of the annual *Days failure*.
5. A plot is produced with *Return period* on the x axis and *Days failure* on the y axis. This plot is characterised as follows:
6. There is one line on this plot for each level of *Overall demand*.
7. As *Overall demand* increases, its line will be at or above the lines for the next lowest *Overall demand*.
8. Each *Overall demand* line has a positive slope. This is because there are more *Days failure* at higher *Return period*.
9. From this plot is possible interpolate between *Overall demand* lines for the deployable output of the system. Here deployable output is defined as: *the overall demand at which the system fails no more than x days in an n year return period*. The method does not fix values of **x** and **n**; they are to be determined according to the requirements of the study and may vary from system to system. The definition of a failure is also study dependent.

It can be seen that the method is fixed in terms of the analysis technique to be applied, but open to flexibility of use by the choice of definition of failure, return period and the maximum number days failure per year. For example the Deployable Output of a system might be defined as follows: *The highest overall demand that can be met with a maximum chance of failure of two days at a one in fifty year return period*.

The statistical calculations are based on the method described in the *Low Flow Studies Report, Institute of Hydrology, January 1980, Report Number 1 (page 10)* and outlined here:

In Step 4 above, the exceedance probability of any of the annual *days failure*, $P_{(i)}$, is calculated as:

$$P_{(i)} = (i - 0.44) / (N + 0.12)$$

where:

i = rank (range: 1 to N)

N = length of simulation (years)

The return period, $T_{(i)}$, can be derived from the *exceedance* probability:

$$T_{(i)} = (1 - P_{(i)})^{-1}$$

In Step 5 above, the x axis (return period) is of type General extreme value (GEV). $T_{(i)}$ is converted to plotting position, $X_{(i)}$, using:

$$X_{(i)} = [1 - \exp(-kz_{(i)})] / k$$

where:

$$z_{(i)} = -\ln[-\ln\{(T_{(i)} - 1) / T_{(i)}\}]$$

The Weibull Distribution

The *Low Flow Studies Report* recommends the use of the *Weibull* form of the GEV ($k = 0.25$) to determine plotting position, $W_{(i)}$:

$$W_{(i)} = [1 - \exp(-0.25 * z_{(i)})] / 0.25$$

This analysis module allows uses a value of $k = 0.25$ by default, but this may be changed to any value in the range -0.25 to $+0.25$ to permit experimentation with different forms of the GEV.

Setting Failure Conditions - Scottish method

What constitutes a failure is defined at the component level. For example a demand centre has a parameter *Fail.If demand not met*. Setting this to *True* causes a *failure* when supply does not meet demand on any day and this will be detected by this analysis module. Similarly a reservoir has many possible ways of failing (e.g. empty or compensation flow not met) and these are defined in the reservoir's parameters. Reservoir groups can also trigger a failure in a number of ways. A river abstraction can also trigger a failure if a prescribed flow is not met.

In addition it is possible to trigger or remove failures using VBA on any component in the *AfterTerminateDay* event by setting the *Status* parameter. Trigger a failure by the following:

Status = aqtStatusFailure

Force a failure not to be counted by:

Status = aqtStatusOK

There is therefore a large degree of flexibility in defining what and what does not constitute a failure.

If more than one component reports a failure on any one day, this is treated as a single failure in the annual count of number of days failure. It is therefore not possible to have more than 366 days failure in any year. (For example a demand centre might report a

failure because demand was not met and reservoir report a failure because it was empty all on the same day – but this is counted as one day's failure).

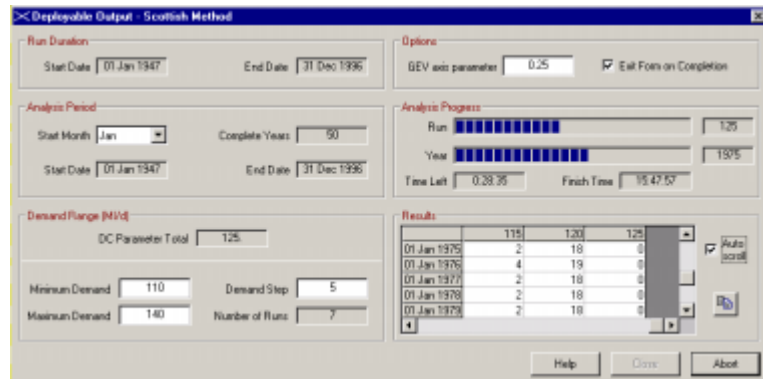
Applying the Analysis - Scottish method

1. Unless there is a good reason to the contrary, the analysis is best undertaken on the longest possible simulation period. (The longer the simulation period, the higher the return period the analysis estimates and the greater the accuracy for lower return periods. For example a simulation period of 10 years has a maximum 18 year return period event, whereas a simulation period of 75 years provides an estimate of the 134 year return period event.) The run simulation period is defined in Aquator under *Setup* menu, menu item *Model...*, *States* tab.
2. If you have more than one demand centre, set up each of their parameters *General.Demand* and *General.Demand factor* to be in the correct ratio between demand centres. (The ratio between demands at demand centres is preserved for each model run undertaken during the analysis as the system wide, *Overall demand* is increased.) If you have full *Demand sequence* specified for any demand centre, this is ignored for this analysis and the *General.Demand* and *General.Demand factor* parameters used instead.
3. Decide on your *failure* criteria and set the appropriate parameters in the model components that can cause a failure. See *Setting failure conditions* for further information.
4. Select the *Tools* menu, *Analyze* menu item and then *Deployable Output – Scottish Method*. The following form is displayed which controls the analysis:

The screenshot shows the 'Deployable Output - Scottish Method' dialog box. It contains the following fields and controls:

- Run Duration:** Start Date: 01 Jan 1947, End Date: 31 Dec 1996
- Options:** BEV axis parameter: 0.25, Exit Form on Completion
- Analysis Period:** Start Month: Jan, Complete Years: 50, Start Date: 01 Jan 1947, End Date: 31 Dec 1996
- Demand Range (M/d):** DC Parameter Total: 125, Minimum Demand: 110, Demand Step: 5, Maximum Demand: 140, Number of Runs: 7
- Analysis Progress:** Run, Year, Time Left, Finish Time
- Results:** (Empty)
- Buttons:** Help, Close, Execute

5. In the above form the *Run Duration* frame shows the length of the model run period. This is defined by the project *Run start date* and *Run finish date* – see 1 above.
6. The *Analysis Period* frame determines the analysis period. The analysis period is always less than or equal to the model run period. The analysis period starts on the first day of the month specified in the *Start Month* drop down list box and extends for as many complete years from that date as possible. This *Start Month* parameter therefore allows for the definition of a water year that is different to a calendar year (e.g. 1st October to 30th September). There must be at least 3 complete years for the analysis to proceed.
7. The *Demand Range* frame allows the overall system demand specified for each model run. The *DC Parameter Total* value displayed on the form is the total of all demand centre demands as defined in their parameters and is for information only. The *Minimum Demand* is overall demand for the first model run. The second model run uses an overall demand which is the *Minimum Demand* plus the *Demand Step*. Successive model runs have their overall demand increased by the *Demand Step* until the *Maximum Demand* parameter is reached. These values of overall demand are distributed amongst individual demand centres as described in 2 above. The *Number of Runs* value shows how many model run will take place between as the *Minimum Demand* is incremented to the *Maximum Demand*.
8. The *Options* frame allows the GEV parameter for the results plot to be specified. This should be set to 0.25 for a *Weibull Distribution* (see above) but must be in the range –0.25 to +0.25. The *Exit form on completion* check box determines whether the above form is closed automatically once the analysis is complete.
9. Having set up the analysis parameters, the analysis is carried out by clicking on the *Execute* command button. The form then changes to run mode:



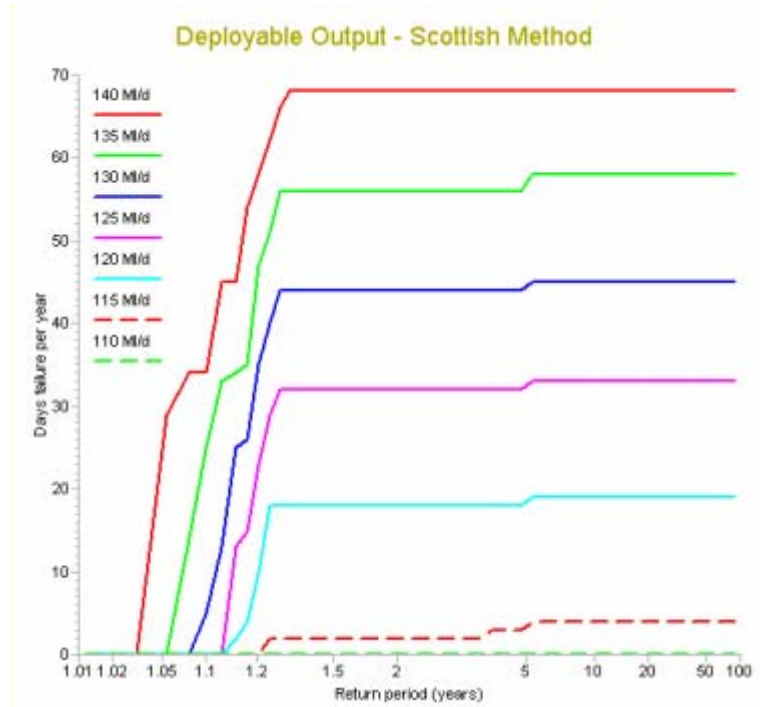
10. In the above form the *Analysis Progress* frame shows how the analysis is progressing and its estimated completion time.
11. The grid in the *Results* frame has one cell for each overall demand and year. Values in these cells show the number of *days failure* counted so far. It is possible to scroll through this grid as the analysis proceeds to study the result. Each time the model starts a new year and the *Auto scroll* check box is ticked, the cell in the grid relating to the current demand and year is made visible. The *Copy* command button, copies the current content of the grid into the clipboard in a format suitable for pasting into Excel.
12. The 'Abort' command button may be used to abort the analysis at any stage.
13. After the analysis is completed, the results are displayed as illustrated below:

Return period	110 ML/d	115 ML/d	120 ML/d	125 ML/d	130 ML/d	135 ML/d	140 ML/d
1.0 year	0	0	0	0	0	0	0
1.0 year	0	0	0	0	0	0	0
1.1 year	0	0	0	0	0	0	29
1.1 year	0	0	0	0	0	14	34
1.1 year	0	0	0	0	5	25	34
1.1 year	0	0	0	0	13	33	45
1.2 year	0	0	2	13	25	34	45
1.2 year	0	0	4	15	26	35	54
1.2 year	0	0	10	23	35	47	58
1.2 year	0	2	18	29	40	51	62
1.3 year	0	2	18	32	44	56	66
1.3 year	0	2	18	32	44	56	68

There is one column for each overall demand and one row for each return period. The values in the cells

represent give the number of days failure per year for a given overall demand and return period.

- After the analysis is completed, graphical results are displayed as shown below and a table of interpolated demands created under the *Deployable output* node in the *project tree view*.



Each line on the graph represents one level of overall demand.

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

An Analyzer can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
ScottishDO	Start month
	Min demand
	Max demand

Group	Name
	Demand increment
	GEV parameter
	Exit on completion

States

An Analyzer can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Analyzer.

Variables

An Analyzer can have more than one set of variables. Variables are possible daily outputs from the component and may be turned on and off.

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

There are no sequences for this type of Analyzer.

River flow analysis



This analyzer carries out standard hydrological analysis techniques on flow series. Two techniques are supported – Flow Duration analysis and Low Flow Frequency analysis.

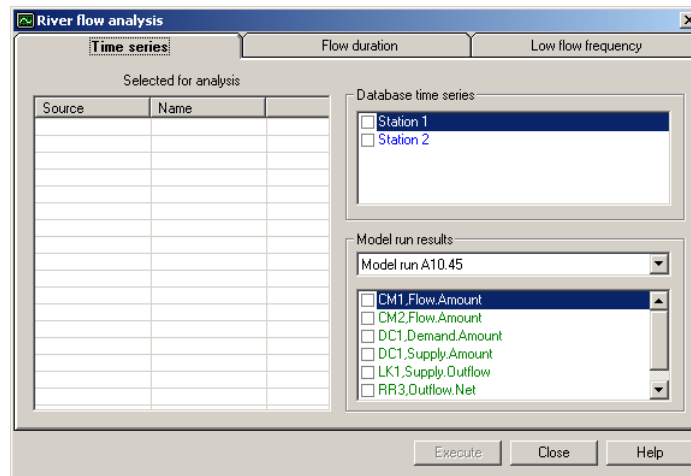
Flow frequency analysis has similar applications to flow duration analysis. They both help quantify the low flow regime of a river. However, because the frequency is expressed in terms of return period in years in the flow frequency technique, it is more suitable for describing rare events with return periods of 10 to 25 years. Consequently, it is important to note that the 90% exceedance probability on the flow duration curve is a more common event than the 90% exceedance probability (10 year return period) on the flow frequency curve.

In Aquator, both techniques can operate on time series data stored on the database and/or model run results.

In addition both techniques also support the analysis of more than one series at a time. For example it is possible to produce a single chart showing two or more flow duration curves for modelled flow generated from a number of model runs.

Results can be presented in a choice of units including Ml/d , m^3s^{-1} and non dimensional forms.

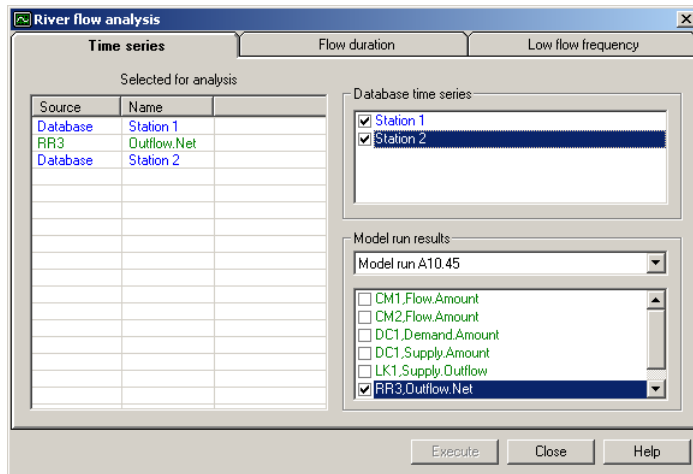
On selecting this analyzer the following form is displayed:



The selection of time series data to be included in the analysis is common for both the flow duration and low flow frequency techniques. At least one time series must be chosen for analysis on the “Time series” tab before either analysis can proceed.

Any flow series stored on the database can be included by checking the appropriate series in the upper right list box. Model run results can also be included by firstly selecting the correct model run from the drop down list and then checking the appropriate result variable in the lower right list box.

The following form shows three series selected, two from time series stored on the database (in blue) and one result series (in green).

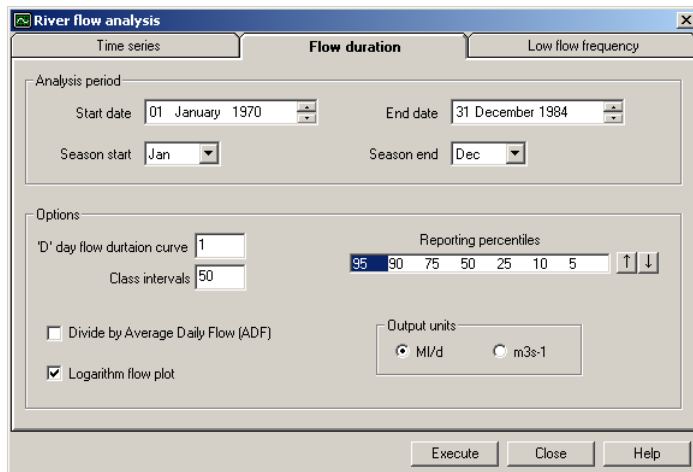


Having selected the data for analysis, proceed to the required analysis method by selecting the appropriate tab – “Flow duration” or “Low flow frequency”.

Flow duration analysis

Flow duration analysis gives the percentage of time a particular flow value is equalled or exceeded. For example a 95 percentile flow of $12.45 \text{ m}^3\text{s}^{-1}$, means that for 95% of the time the flow is at or above $12.45 \text{ m}^3\text{s}^{-1}$ (often called Q_{95}).

There are number of options that can be set for the analysis which control the calculations and the form of output. The following form shows the “Flow duration” tab where these parameters are located:



Analysis period

It is here that the period over which data are to be analysed is chosen. If no data exists on a particular day it is counted as a 'missing' value. Data could be missing from a time series stored on the database (as Aquator supports missing values) or, in the case of a model run result, the dates of the model run may not fully cover the analysis period chosen.

A seasonal flow duration analysis may be carried out by specifying start and end month to the season. Seasons can span the end of a calendar year by setting the start month of the season to a later month than the end month of the season (e.g. Oct – Mar covers the six months Oct, Nov, Dec, Jan, Feb & Mar).

Options

The analysis may be carried out on single daily values if 'D' day flow duration curve is set to 1. Alternatively this parameter can be set to values greater than 1 up to a maximum of 180. In this case successive, overlapping, periods of 'D' days are used in the analysis. For example if set to 5, the mean flow over days 1-5 is taken as the first time period; the mean flow over days 2-6 is taken as the second time period.

The number of class intervals is used during the calculations to categorise the flows. If set to 50, for example, the range of flows encountered (maximum – minimum) is divided by 50 and the number of flows in each interval counted. Class intervals are created on a logarithmic scale to help produce a more even distribution of flows in each interval. Setting the number of class intervals too small will reduce the accuracy of the analysis; setting it too large may result in less smooth flow duration curves.

The analysis calculates and reports the average daily flow (ADF) of the whole period of the analysis, taking into account any seasonal settings. The ADF may be used to standardise the analysis and produce the flow duration curves in non dimensional form. If this is required, check the 'Divide by average daily flow (ADF)' option.

The flow duration curve produced by the analysis has a probability x axis. Flow is shown on the y axis and can be linear or logarithmic. Check the 'Logarithm flow' option to produce a logarithmic plot. Many river flow sequences plot better (i.e. a straighter line) using the logarithm of flows. This is because log flows tend to be normally distributed.

The five reporting percentiles may be changed using the 'Reporting percentiles' control. An example of this would be if the 98 percentile flow was required rather than the 95 percentile flow. Finally the results can be presented in either Ml/d , m^3s^{-1} .

Analysis results

The analysis produces three types of output. The first is the flow duration table where each reporting percentile is shown for each series:

Flow duration table

Start date:	1 Jan 1970	Time interval (days) =	1
End date:	31 Dec 1984	Intervals in period =	5479
Series 1:	Station 1		
Series 2:	Station 2		

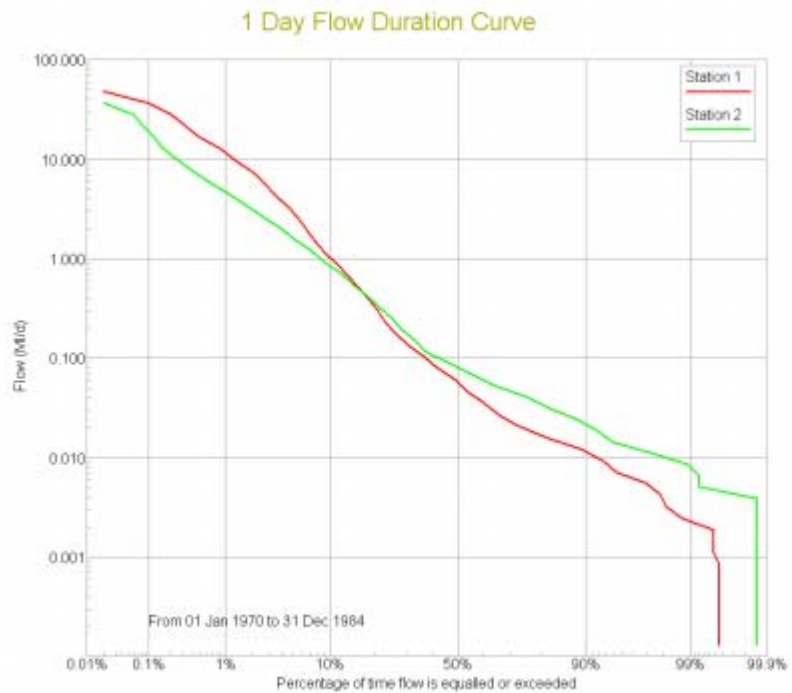
	Series 1	Series 2
Intervals with data	5309	5110
Intervals missing	170	369
Average daily flow	0.634	0.389
95 percentile (Q95)	0.007	0.013
90 percentile (Q90)	0.011	0.022
75 percentile (Q75)	0.019	0.041
50 percentile (Q50)	0.057	0.082
25 percentile (Q25)	0.204	0.260
10 percentile (Q10)	1.041	0.870
5 percentile (Q5)	2.941	1.616

Average daily flow units: ML/d
Percentile units: ML/d

The second form of output is the class interval data:

Interval	Class (ML/d)	% in class	Class (ML/d)	% in class
1	0.0000	100.0	0.0000	100.0
2	0.0001	99.5	0.0001	99.9
3	0.0002	99.5	0.0002	99.9
4	0.0002	99.5	0.0002	99.9
5	0.0003	99.5	0.0003	99.9
6	0.0004	99.5	0.0004	99.9
7	0.0005	99.5	0.0005	99.9
8	0.0006	99.5	0.0006	99.9
9	0.0008	99.5	0.0008	99.9
10	0.0011	99.5	0.0011	99.9
...
40	3.3306	4.4	2.6854	2.6
41	4.3499	3.4	3.4880	1.7
42	5.6813	2.7	4.5305	1.1
43	7.4200	2.1	5.8845	0.6
44	9.6910	1.3	7.6432	0.4
45	12.6570	0.9	9.9275	0.3
46	16.5308	0.5	12.8945	0.2
47	21.5901	0.3	16.7482	0.1
48	28.1979	0.2	21.7537	0.1
49	36.8281	0.1	28.2551	0.1
50	48.0995	0.0	36.6997	0.0

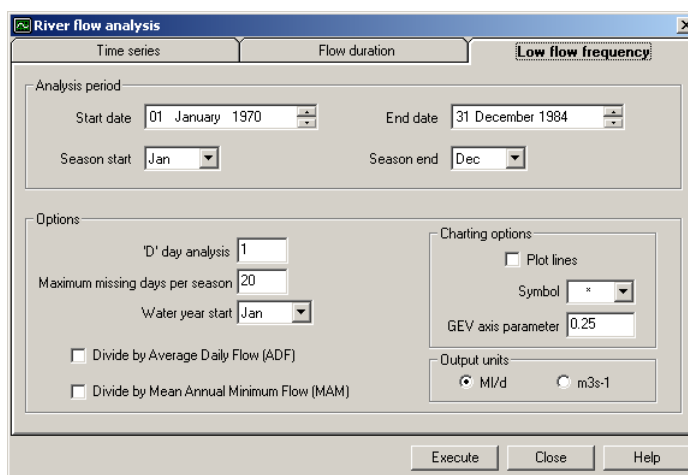
The third form output is the flow duration curve:



Low flow frequency analysis

Low flow frequency analysis provides the return period of low flow events. For example the one in ten year return period, 1 day, low flow might be estimated at $23.44 \text{ m}^3\text{s}^{-1}$. This means that on average, the minimum daily flow in a each year, is at or below $23.44 \text{ m}^3\text{s}^{-1}$ once every ten years.

There are number of options that can be set for the analysis which control the calculations and the form of the output. The following form shows the "Flow duration" tab where these parameters are located:



Analysis period

It is here that the period over which data are to be analysed is chosen. If no data exists on a particular day it is counted as a 'missing' value. Data could be missing from a time series stored on the database (as Aquator supports missing values) or, in the case of a model run result, the dates of the model run may not fully cover the analysis period chosen.

A seasonal low flow frequency analysis may be carried out by specifying start and end month to the season. Seasons can span the end of a calendar year by setting the start month of the season to a later month than the end month of the season (e.g. Oct – Mar covers the six months Oct, Nov, Dec, Jan, Feb & Mar).

Options

The analysis may be carried out on single daily values if 'D' day analysis is set to 1. Alternatively this parameter can be set to values greater than 1 up to a maximum of 180. In this case successive, overlapping, periods of 'D' days are used in the analysis. For example if set to 5, the mean flow over days 1-5 is taken as the first time period; the mean flow over days 2-6 is taken as the second time period.

The analysis looks at water years starting with the month specified in the 'Water year start' drop down list. Within each water year, data are used only from within the defined season. The year is discarded from the analysis if there are too many missing daily values in the season. This limit is set by the 'maximum missing days per season' parameter.

It is the minimum of the 'D' day flows that are found each season that are taken forward in the analysis. These minima may be converted to m^3s^{-1} or a non dimensional form by dividing by either:

- The Average Daily Flow (ADF) calculated from within the season
- The mean of the annual minima, Mean Annual Minimum (MAM)

The 'Charting options' parameters allow the format of the graphical output to be changed. Either or both lines and points may be drawn and the form of the x axis (GEV) changed. This should be set to 0.25 for a Weibull Distribution but must be in the range -0.25 to +0.25. (see below)

Method

The statistical calculations are based on the method described in the *Low Flow Studies Report*, **Institute of Hydrology**, January 1980, Report Number 1 (page 10) and outlined here:

The exceedance probability of any of the annual minima, $P_{(i)}$, is calculated as:

$$P_{(i)} = (i - 0.44) / (N + 0.12)$$

where:

i = rank (range: 1 to N)

N = number of years

The return period, $T_{(i)}$, can be derived from the exceedance probability:

$$T_{(i)} = (1 - P_{(i)})^{-1}$$

The x axis (return period) is of type General extreme value (GEV). $T_{(i)}$ is converted to plotting position, $X_{(i)}$, using:

$$X_{(i)} = [1 - \exp(-kz_{(i)})] / k$$

where:

$$z_{(i)} = -\ln[-\ln\{(T_{(i)} - 1) / T_{(i)}\}]$$

The Weibull distribution

The *Low Flow Studies Report* recommends the use of the *Weibull* form of the GEV ($k = 0.25$) to determine plotting position, $W_{(i)}$:

$$W_{(i)} = [1 - \exp(-0.25 * z_{(i)})] / 0.25$$

This analysis module uses a value of $k = 0.25$ by default, but this may be changed to any value in the range -0.25 to +0.25 to permit experimentation with different forms of the GEV (see above).

Analysis results

The analysis produces two types of output. The first is a table giving the low flows ranked and return periods assigned. There is one such table for each series analysed:

Low Flow Frequency Analysis

Series: Station 1

Start date: 1 Jan 1970 Time interval (days) = 1
 End date: 31 Dec 1984 Water year start = Jan

Seasonal analysis between Jan and Apr

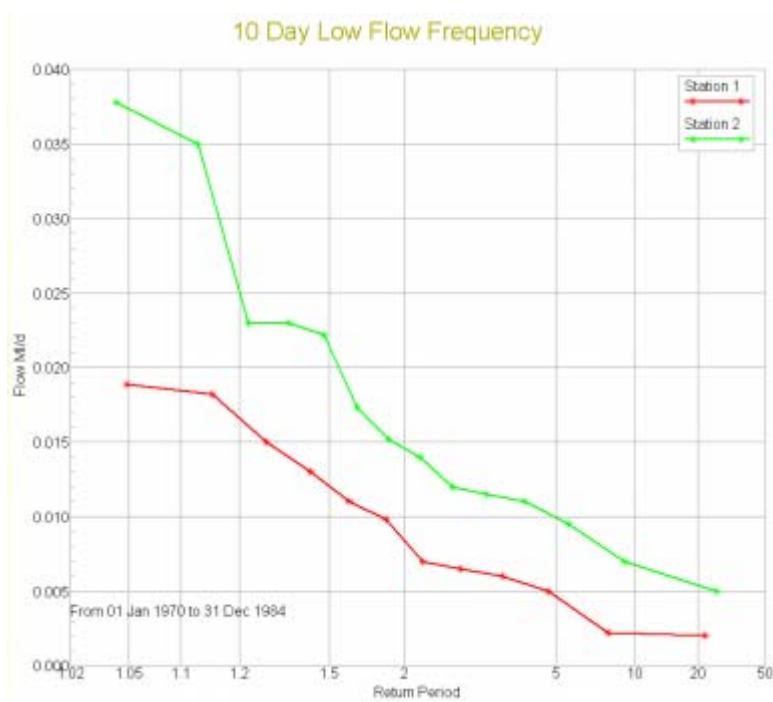
Water Year	Start Date	Rank	Flow	Return period	Exceedance Probability
1975	17 Apr 1975	1	0.027	1.0	0.040
1977	21 Apr 1977	2	0.019	1.1	0.110
1971	16 Apr 1971	3	0.017	1.2	0.181
1976	9 Jan 1976	4	0.015	1.3	0.252
1983	6 Feb 1983	5	0.013	1.5	0.323
1972	9 Jan 1972	6	0.013	1.6	0.394
1978	1 Jan 1978	7	0.013	1.9	0.465
1973	1 Jan 1973	8	0.011	2.2	0.535
1982	6 Jan 1982	9	0.010	2.5	0.606
1974	1 Jan 1974	10	0.009	3.1	0.677
1981	15 Jan 1981	11	0.006	4.0	0.748
1979	19 Jan 1979	12	0.002	5.5	0.819
1984	8 Jan 1984	13	0.001	9.1	0.890
1980	2 Jan 1980	14	0.000	25.2	0.960
1970			Insufficient data		

Flows in Ml/d

On average the minimum starts 30 days from start of water year

Average Daily Flow (ADF) = 1.068 Ml/d
 Mean Annual Minimum Flow (MAM) = 0.011 Ml/d

The second type of output is the low flow frequency plot:



Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

An Analyzer can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
River Flow Analysis FDC	Start date
	End date
	Season start month
	Season end month
	"D" day FDC
	Divide by ADF
	Percentiles
	Output units
	Plot log flows
	Classes
	River Flow Analysis LFF
End date	
Season start month	
Season end month	
Water year start month	
"D" day period	
Max days missing	
Divide by ADF	
Divide by MAM	
Output units	
GEV axis parameter	
Plot lines	
Plot symbol	

States

An Analyzer can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Analyzer.

Variables

An Analyzer can have more than one set of variables. Variables are possible daily outputs from the component and may be turned on and off.

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

There are no sequences for this type of Analyzer.

Properties

A *Property* is a value which has no hydrological significance. For example, the co-ordinates of a Component on the schematic and the colours used to render the Component's icon.

Parameters

A *Parameter* is a value for an Analyzer which affects its behaviour during a model run, but which typically does not change during a run, and often is not changed between runs. For example: the stage-area-volume curves of a Reservoir would not normally be altered frequently.

EnglishDO.Analysis method

Technique to be used to estimate the deployable output – Binary chop (numeric value = 1) or Step by step increase (numeric value = 2). See *Analysis definition*.

EnglishDO.Demand increment

The amount by which overall demand is increased for successive model runs. See *Applying the analysis*.

EnglishDO.Description

A user supplied line of descriptive text that describes the analysis.

EnglishDO.Exit on completion

Whether or not the form which controls the analysis is to be left visible after the analysis is complete. See *Applying the analysis*.

EnglishDO.Max demand

The maximum overall demand to apply to chosen demand centres. See *Applying the analysis*.

EnglishDO.Min demand

The overall demand to apply to chosen demand centres for the first model run in the analysis. See *Applying the analysis*.

River Flow Analysis FDC.Classes

The number of classes or intervals that the flow duration analysis should use. The maximum flow minus the minimum flow over the analysis period give the upper limit of the biggest class and lower limits of the smallest class. Classes are calculated on the logarithms of flows.

River Flow Analysis FDC."D" day FDC

Number of days flow to average to provide one value for analysis. For example if "D" is set to 5, the first flow value used in the analysis is the average flow over days 1, 2, 3, 4 & 5; the second flow value is the average flow over days 2, 3, 4, 5 & 6.

River Flow Analysis FDC.Divide by ADF

Present results in non dimensional form by dividing by the Average Daily Flow (ADF) as calculated within the defined season.

River Flow Analysis FDC.End date

End date for abstracting data for the flow duration analysis.

River Flow Analysis FDC.Output units

Results can be presented in either Ml/d , m^3s^{-1} .

River Flow Analysis FDC.Percentiles

The seven percentiles reported in the results. These are initially 95, 90, 75, 50, 25, 10 and 5.

River Flow Analysis FDC.Plot log flows

Set to True to plot the y axis as logarithms of flow. Typically the logarithms of river flows tend to be normally distributed. Therefore setting this parameter to True should produce plots with straighter lines.

River Flow Analysis FDC.Season end month

See start month below.

River Flow Analysis FDC.Season start month

Start month for a seasonal analysis. Season can be whole year by making start month the month after the end month (e.g. Start = Jan; End = Dec). Seasons can span end of year by making end month earlier than start month (e.g. season Nov, Dec, Jan, Feb, Mar is set by Start = Nov; End = Mar).

River Flow Analysis FDC.Start date

Start date for abstracting data for the flow duration analysis.

River Flow Analysis LFF."D" day period

Number of days flow to average to provide one value as a candidate for the minimum in a year. For example if "D" is set to 5, the first flow value used in the analysis is the average flow over days 1, 2, 3, 4 & 5; the second flow value is the average flow over days 2, 3, 4, 5 & 6.

River Flow Analysis LFF.Divide by ADF

Present results in non dimensional form by dividing by the Average Daily Flow (ADF) as calculated within the defined season.

River Flow Analysis LFF.Divide by MAM

Present results in non dimensional form by dividing by the Mean Annual Minimum (MAM).

River Flow Analysis LFF.End date

End date for abstracting data for the low flow frequency analysis.

River Flow Analysis LFF.GEV axis parameter

The General Extreme Value parameter (range -0.25 to +0.25). This affects the position of each return period on the x axis. Set to 0.25 for the Weibull distribution.

River Flow Analysis LFF.Max days missing

The maximum number of days that are allowed to be missing within the season before the year is excluded from the analysis.

River Flow Analysis LFF.Plot lines

Set to true to draw lines between the annual minima points on the chart.

River Flow Analysis LFF.Plot symbol

Select the type of symbol to use when plotting the annual minima. Can be none.

River Flow Analysis LFF.Output units

Results can be presented in either Ml/d , m^3s^{-1} .

River Flow Analysis LFF.Season end month

See start month below.

River Flow Analysis LFF.Season start month

Start month for a seasonal analysis. Season can be whole year by making start month the month after the end month (e.g. Start = Jan; End = Dec). Seasons can span end of year by making end month earlier than start month (e.g. season Nov, Dec, Jan, Feb, Mar is set by Start = Nov; End = Mar).

River Flow Analysis LFF.Start date

Start date for abstracting data for the low flow frequency analysis.

River Flow Analysis LFF.Water year start month

The analysis can use water years starting in any calendar month.

ScottishDO.Demand increment

The amount by which overall demand is increased for successive model runs. See *Method and applying the analysis*.

ScottishDO.Exit on completion

If checked, the analysis form is closed automatically when the analysis has finished executing. If not checked, the form remains to view the intermediate results on the grid or so that another analysis can be undertaken. The final analysis results are shown on the tree view in the project window.

ScottishDO.GEV parameter

The General Extreme Value distribution parameter. Set to 0.25 for a *Weibull Distribution*. See *Method and applying the analysis*.

ScottishDO.Max demand

The maximum overall system demand for any model run in the analysis. See *Method and applying the analysis*.

ScottishDO.Min demand

The overall system demand for the first model run in the analysis. See *Method and applying the analysis*.

ScottishDO.Start month

The start month for the water year to be used in the analysis. See *Method and applying the analysis*.

States

A *State* is a value for an Analyzer which affects its behaviour during a model run, and which typically does change during the run, and often is changed between runs. For example: the initial storage of a Reservoir on the first day of the run would typically vary from run to run.

Variables

A *Variable* is a value which is computed daily during a model run. This can include both predicted and observed values i.e. a sequence of observed storage linked to a Reservoir Component can be captured in a variable so that both observed and calculated storage can be plotted on the same chart.

Sequences

A *Sequence* is a requirement for daily data during a model run. Sequential data must be supplied to a Component in order for the Component to operate correctly. For example, a Reservoir requires a rainfall sequence to compute water added by precipitation each day.