Jersey Water

Water Resources and Drought Management Plan

Appendix C. Water Source Yield Assessment

CONTENTS

JERSEY WATER RESOURCES AND DROUGHT MANAGEMENT PLAN

APPENDIX C. SOURCE WATER YIELD ASSESSMENT

1. INTRODUCTION

This appendix reports on the assessments undertaken to derive an estimate of the reliable source yield ("deployable output") of the Jersey Water raw water system as part of the development of the Water Resources and Drought Management Plan.

This appendix sets out:

- A summary of Jersey Water's raw water sources
- A review of available climate, hydrological and raw water supply data
- Analysis of historic drought periods from the Jersey rainfall data records
- A description of the methodological approach adopted for the source yield assessment
- Derivation of Jersey Water raw water source inflows
- Estimate of source yield and drought analysis.

2. SUMMARY OF RAW WATER SOURCES

The Jersey Water raw water sources and raw water storage assets, including reservoirs, pumped and gravity fed stream sources, boreholes and La Rosière desalination plant, that have been considered in this assessment of water source yield are summarised in Table C.1. The total gross raw water storage available to Jersey Water is **2705 million litres (Ml).**

The raw water supply system comprises of a series of interlinked raw water storage and impounding reservoirs. It consists of eight impounding reservoirs and their direct catchments, seven pumped surface water catchments, six boreholes and La Rosière desalination plant.

The impounding reservoirs are fed by a combination of indirect water sources and their direct catchments. They can be broadly split into four sub-systems: Val de la Mare; Water Works Valley (containing Handois, Dannemarche and Millbrook reservoirs); Grands Vaux; and Queen's Valley Figure C.1 shows the direct and indirect (pumped) stream catchments draining to these reservoirs (Figure C.1). There are no compensation flow release requirements at any of the impounding reservoirs to downstream water bodies.

There are also two small impounding reservoirs with a capacity of 9Ml each at La Hague and Les Mourier. Both are supplied by direct stream catchments. La Hague also receives water from Tesson borehole and the Little Tesson and Tesson streams. Water at La Hague can be pumped to Handois Reservoir or Val de la Mare Reservoir. Water at Les Mourier Reservoir can be pumped to Handois Reservoir or La Hague Reservoir. Water from the Val de la Mare, Grand Vaux and Queen's Valley systems are blended and used interchangeably in the raw water "header" tanks at Mont Gavey, which supplies Handois Water Treatment Works (WTW), and Beechfield, which supplies Augrès WTW. Mont Gavey and Beechfield tanks provide a short-term buffer storage to fluctuations in pump rates from the primary raw water pumping stations. The Val de la Mare system is the predominant supply to Handois WTW and the Grands Vaux and Queen's Valley systems are the predominant supplies to Augrès WTW.

There are five boreholes within the St. Ouen's wellfield; two of which are currently out of service due to the presence of contaminants from fire-fighting foam historically used at the airport. There is also a small borehole at Tesson. Little is known about these groundwater sources apart from their maximum pumping capacity and operational usage since 1995. It is not known how reliable these sources are during a notable drought although the yield of the St. Ouen's wellfield is previously quoted to have a reliable yield of 1.8 Ml/d . Under current operating conditions, taking account of the water quality constraints at the St Ouen's boreholes, the maximum reliable deployable output for the St. Ouen's boreholes and Tesson boreholes is assumed to be 0.3 Ml/d and 0.24 Ml/d, respectively.

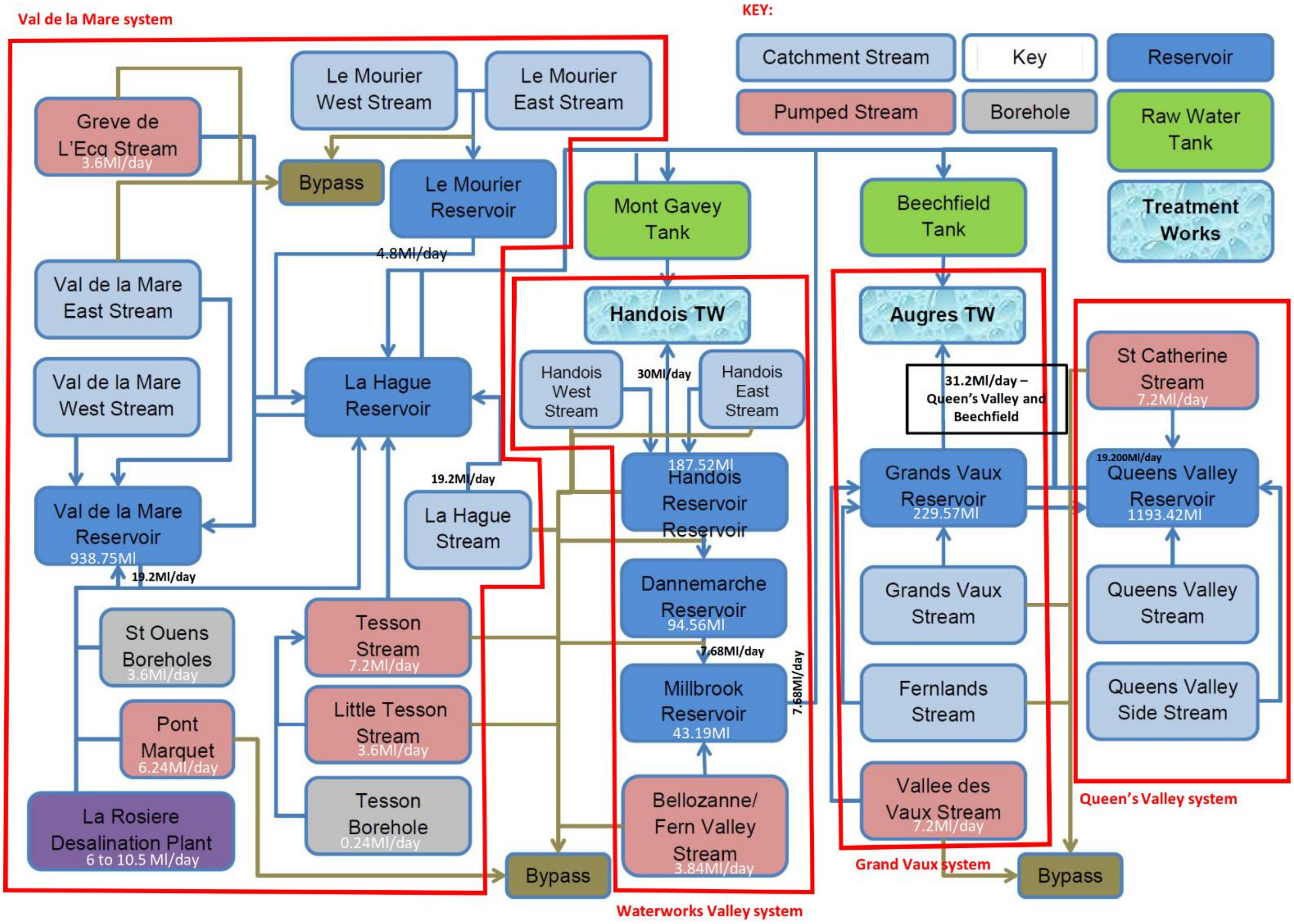
La Rosière desalination plant can supply either 5.4 Ml/d (one treatment stream) or 10.8 Ml/d (two treatment streams) and is used when the other water sources need supplementing, for either water quality or quantity reasons, to meet demand.

Raw water quality is a key concern for many water sources and can affect the availability and reliable deployable output of a source. Of particular concern is the presence of nitrates and algae, pesticides and herbicides from agricultural sources as well manganese.

Table C.1 Summary of Jersey Water's raw water sources

Source	Type	Catchment Area (km^2; if applicable)	Storage Capacity (Ml; if applicable)	Maximum Pump Capacity m3/hour	Maximum Pump Capacity Ml/day	Comments
Dannemarche	Reservoir	1.72	94.6	320	7.68	*Feeds Millbrook*
Grands Vaux	Reservoir	7.19	229.6	1300	31.2	*Feeds Queens Valley, Augres WTW and Mont Gavey*
Handois	Reservoir	2.51	187.5	1250	30	*Feeds Handois WTW and Dannemarche (spill)*
Millbrook	Reservoir	1.21	43.2	320	7.68	*Feeds Beechfield / Augres WTW, Mont Gavey / Handois WTW and Grands Vaux*
Queen's Valley	Reservoir	5.07	1193.4	800	19.2	*Feeds Augres WTW, Mont Gavey and Grans Vaux*
Val de la Mare	Reservoir	3.34	938.8	800	19.2	*Feeds La Hague, Mont Gavey and Handois / Beechfield*
La Hague	Reservoir	5.63	9.0	800	19.2	*Feeds Val de la Mare or Mont Gavey / Handois WTW*
Les Mourier	Reservoir	1.98	9.0	200	4.8	*Feeds Handois / Val de la Mare*
Fernlands	Indirect Catchment	2.34				*Feeds Grand Vaux*
Greve de Lecq	Pumped Stream Catchment	2.89		150	3.6	*Feeds Val de la Mare*
Pont Marquet	Pumped Stream Catchment	3.26		260	6.24	*Feeds Val de la Mare*
Little Tesson	Pumped Stream Catchment	2.72		150	3.6	*Feeds to Tesson stream.*
Tesson	Pumped Stream Catchment	3.89		300	7.2	*Feed La Hague*
Fern Valley	Pumped Stream Catchment	2.55		160	3.84	*Feeds Millbrook*
Vallee des Vaux	Pumped Stream Catchment	3.40		300	7.2	*Feeds Grands Vaux*
St Catherine	Pumped Stream Catchment	3.14		300	7.2	*Feeds Queen's Valley*
St Ouen's Bay (A1 to A5)	Borehole			150	3.6	*Feeds Val de la Mare. Current output is constrained to 0.3 Ml/d.*
Tesson	Borehole			10	0.24	*Feeds La Hague onwards. Current borehole output is constrained to 0.24 Ml/d.*
La Rosière	Desalination Plant				10.8	*Feeds Val de la Mare. Can provide either 5.4 Ml/d or 10.8 Ml/d*

Figure C.1 Raw Water Supply System Schematic[1].



[1] N.B. The links between the raw water assets shown in the schematic are indicative only.

3. WATER RESOURCE DATA AVAILABILITY

A review of water resource data availability identified the following meteorological, hydrological and raw water supply system data, as summarised below.

3.1 SUMMARY OF PREVIOUS STUDIES

The British Geological Survey (BGS) completed a study in 2000 on the water resources of Jersey and concluded that the volume of fresh water available to Jersey, both surface water and groundwater, is controlled by direct rainfall and by available storage between rainfall events, effectively creating a single interactive water body. BGS (2000) noted that the water body is currently stressed by a number of factors such as climate change, changing trends in land use, and an increase in demographic growth, which constrain the volumes of water available for consumption and the quality of that water. Early work on the water resource availability was carried out as part of various consultancy projects reviewing surface water availability in 1976 and 1986. During the 1990s an island annual "water balance" was calculated based on meteorological and hydrological data collected as part of the Trinity experimental catchment study by CEH Wallingford (The Trinity catchment lies within the Grand Vaux reservoir catchment). The BGS (2000) report presents the annual water balance for a 25-year period based on this monitoring, but does not comment on the hydrological yield of the public water supply as it existed then.

MWH (now Stantec) completed a water resources study for Jersey Water in 20062. During this study, a HYSIM rainfall-runoff simulation model was developed to generate daily historic inflow sequences for 16 source catchments for the historic period 1927 to 2007. The HYSIM model was calibrated using meteorological and hydrological data collected as part of the Trinity Experimental Catchment study and the BGS (2000) study.

The MWH assessment2 suggested that the 1990-1992 drought (estimated to have a 1 in 140 year return period) was the worst drought on the historic record with a raw water system yield of 11.11Ml/d (assessed using the HYSIM flow sequences and the MISER water resource model) for the 1927 to 2007 historic record period. Other drought events, in order of increasing return period, include: 1949-1950 (estimated at 1 in 50 year), 1976-1977 (estimated at 1 in 30 year), 1946 (estimated at 1 in 22 year) and 1956-1957 (estimated at 1 in 17 year).

3.2 METEOROLOGICAL AND HYDROLOGICAL DATA

A review of available data was undertaken as part of the development of the Water Resources

[2] MWH (2006). Jersey Water Resources Modelling Report. Report Ref 410_003544.

and Drought Management Plan to understand what information could be utilised to review and update the 2006 assessent of water source yield (or ”deployable output”). The following meteorological and hydrological information was identified:

- Rainfall:
    - Jersey Water monthly rainfall record from 1865 to 2005. There was no information regarding the source of this data. Jersey Water confirmed this was an amalgamated record from several unconfirmed rain gauges;
    - Jersey Water daily rainfall is recorded from 1995 to 2018 (and ongoing) for eight sites (Handois, Millbrook, Augrès, Val de la Mare, Queen’s Valley, Greve de Lecq and St. Catherine) across Jersey.
    - Jersey Meteorological Office holds daily rainfall for the Maison St. Louis Observatory in Jersey from 1st January 1894. There is a four-year break in daily records from 1921 to 1924 but monthly rainfall totals have been derived for this period from other sites.
    - Two third party providers of rainfall data are known to exist but were not included in this assessment. The data from one site, La Sergente, is known to be greater than 100 years in length and the other, The Elms, is owned by the National Trust.
    - Guernsey Meteorological Office – monthly cumulative rainfall totals from 1843 to 2015, together with daily rainfall totals from 1901 to 2015 and hourly rainfall totals from 1982 to 2015 for the island of Guernsey. It is noted that the rain gauge was moved from St. Peter Port to Guernsey Airport in 1946.
- Air temperature:
    - Jersey Water record daily air temperature data from 1994 to 2018 for two sites: Handois and Millbrook.
    - Jersey Meteorological Office holds daily maximum and minimum temperature data for the Maison St. Louis Observatory in Jersey from 1st January 1894. There is a four-year break in daily records from 1921 to 1924. Note that there is no long-term average temperature dataset for Jersey.
    - Guernsey Meteorological Office - monthly average temperature from 1843 to 2015, daily average temperature data from 1901 to 2015. The measurement location was moved from St. Peter Port to Guernsey Airport in 1946.
- Stream Flow:
    - Some stream flow data were collected in the mid 1990s from the Trinity catchment (part of the Grand Vaux catchment)**Error! Bookmark not defined.**; however, there are no long-term stream flow records available in Jersey. Jersey Water record level and flow rate over the abstraction weir for nine gravity-driven stream sources from 1995 to present day namely: Handois; St. Peter; Le Mourier; Grands Vaux Old and New weir; Pont Marquet; Queen’s Valley; La Hague; and St. Ouen.

- Groundwater Levels:
    - Groundwater levels at abstraction boreholes are recorded on an weekly basis from 1995 to present day.
- MWH 2006 Water Resource Assessment supporting data:
    - MWH provided Jersey Water with the HYSIM rainfall-runoff models for the 16 surface water source catchments including rainfall and potential evapotranspiration (PET) and the predicted flows for the period 1927 to 2007.
- Beyond that provided by MWH, there are no PET data available for Jersey.

3.3 WATER SUPPLY DATA

Jersey Water record the following operational data which are available from 1995 to present day. There are no operational data available before 1995, including periods of other known significant drought events pre-1995:

- Water Treatment Works (WTW) - daily treated water volume into supply ("distribution input") at Handois and Augrès. Daily volume output from La Rosière desalination plant is also recorded.
- Raw water abstraction – daily pumped stream and borehole abstraction and daily output from the raw water storage reservoirs. Daily weir level and flow rates are recorded for gravity fed stream sources.
- Raw water storage –daily water levels and storage for all reservoirs.

4. APPROACH TO SOURCE YIELD ASSESSMENT

The assessment of the reliable source yield ("deployable output") of the Jersey Water raw water supply system has been based on best practice guidance issued in 2014 by UK Water Industry Research Industry[3], adapted where necessary to take account of the availability and/or quality of data.

Following a comprehensive review of the available water supply data (spatial and temporal coverage and quality), the following approach was adopted to assess the water source yield of the Jersey Water raw water system:

- Historic drought analysis using Jersey Water's monthly rainfall data to inform whether to extend source catchment flow data for the yield assessment
- Extension of raw water source catchment flow data from 1927 to 2007 to 1901 to 2007 using the 2006 MWH HYSIM model parameters
- Evaluation of source yield using mass-balance storage models.

[3] UKWIR (2014). Handbook of Source Yield Methodologies. Report Ref: 14/WR/27/7.

The approach is described in more detail below.

4.1 DROUGHT ANALYSIS OF JERSEY WATER MONTHLY RAINFALL DATA

4.1.1 RAINFALL DATA

The assessment uses the monthly rainfall data from 1865 to 2014 provided by Jersey Water. However, the specific rain gauge(s) used to compile this long-term record were not available. Therefore, in order to confirm the quality of the data, double mass plot analysis was undertaken, whereby the cumulative Jersey monthly rainfall record was plotted against the cumulative rainfall from another reliable long-term data source, in this case rainfall data recorded at the Radcliffe Observatory in Oxford from 1853[4] and the Guernsey Meteorological Office rainfall data recorded from 1843 (as corrected). This analysis identifies anomalies in the Jersey rainfall record, known as a 'point of inflection' or change in gradient usually coincident with a change in location or measurement technique. Nevertheless, the assessment confirmed that the Jersey Water monthly rainfall record was suitable for further analysis without any adjustment.

4.1.2 APPROACH

Calculation of surface water source yield for Jersey Water focuses on assessing inflows to the company's raw water reservoir storage assets during the worst drought conditions on the historic record. In the previous water resource assessment (MWH, 2006), long-term flow records were generated for each water source catchment from 1927 to 2007. However, given the availability of a longer rainfall record for Jersey, it was considered prudent to examine this longer record for further drought events, including the known drought event of 1920-1922 in southern England and the Channel Islands, as this could affect the levels of service for water supply reliability offered by Jersey Water. Monthly rather than daily rainfall data were used because of the longer duration of the monthly records and the available raw water storage which provides resilience to short, sharp periods of rainfall deficiency that are identified in the daily rainfall records.

The Standard Precipitation Index (SPI)[5] method was adopted to assess the occurrence, intensity and magnitude of historic droughts – the SPI method is based on the probability of observed monthly rainfall (fitted to a gamma distribution), which is useful in that it allows quantification of the rainfall deficit over different timescales. The timescales considered in this assessment were selected in relation to the likely "critical period" of raw water storage depletion due to drought in Jersey with respect to water supply reliability. On this basis, timescales of 9 months, 12 months and 24 months were adopted. A "drought" is defined as

[4] https://data.gov.uk/dataset/historic-monthly-meteorological-station-data/resource/bf1fa5f4-1b85-4bc7-bc50-07c8d77f63e8
[5] http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf

any period when the SPI is negative and is less than -1.0 (representing greater than one standard deviation). The results are presented in Section 5.

4.2 EXTENSION OF SOURCE CATCHMENT FLOW RECORDS

The HYSIM[6] rainfall-runoff models used in the previous 2006 water resource assessment**Error! Bookmark not defined.** to generate daily historic flow data for the sixteen raw water source catchments from 1927 to 2007 were used for the extension of the daily historic flow series back to 1901. The approach is compatible with the UKWIR Handbook of Source Yield Methodologies[7]. The sixteen source catchments models used in this assessment are listed in Table C.2.

Table C.2: HYSIM raw water source catchment models

Raw Water Catchment	Sub-Catchment Area (km^2)
Greve de Lecq	2.89
Val de la Mare	3.34
Pont Marquet	3.26
Les Mourier	1.98
La Hague	5.63
Little Tesson	2.72
Tesson	3.89
Handois	2.51
Dannemarche	1.72
Millbrook	1.21
Fernlands	2.34
Fern Valley	2.55
Vallee des Vaux	3.40
Grands Vaux	7.19
St Catherine's	3.14
Queen's Valley	5.07

The HYSIM models use daily rainfall and PET, along with parameters that describe the catchment characteristics (e.g. catchment area, land-use cover) to generate a daily flow record. For the flow record extension, it is not necessary to amend the catchment parameters, but the rainfall and PET data required extension prior to 1927. It was necessary to extend the rainfall and PET for each of the sixteen source catchment HYSIM models to generate a catchment specific extended flow series. The approach to the rainfall and PET data record is described below.

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[6] http://www.watres.com/software/HYSIM/
[7] UKWIR (2014). Handbook of Source Yield Methodologies. Report Ref: 14/WR/27/7.

4.2.1 RAINFALL EXTENSION

Due to the availability of rainfall data to the study, daily rainfall data provided by the Guernsey Meteorological Office, and which commenced in 1901, were used as the basis of record extension of the Jersey source catchment rainfall records. The quality of the Guernsey rainfall data set was assessed using double mass analysis by comparing the cumulative Guernsey rainfall against the cumulative rainfall from a data set of known high quality, namely that of Radcliffe Observatory in Oxford. No data corrections were required for the 1901 to 1926 period of the Guernsey data set.

Guernsey rainfall data from 1901 to 1926 from this dataset was merged with each of the sixteen Jersey source catchment rainfall datasets and double mass analysis undertaken which identified a ‘point of inflection’, as expected, in 1927 at the point the datasets were merged. As a consequence of this, all data prior to 1927 has been corrected by applying a scaling factor equivalent to the divisor between the gradients pre- and post- 1927 from the double mass analysis for each of the sixteen source catchments. Subsequent double mass analysis on the corrected data confirmed that no further adjustments were required to provide a reliable rainfall record from 1901 to 2007 for the derivation of the extended flow series.

4.2.2 PET EXTENSION

The daily PET data series used in the 2006 assessment**Error! Bookmark not defined.** is common to all sixteen catchments and is a disaggregated value from monthly PET estimates. The monthly PET for the period 1927 to 2007 was calculated from an empirical relationship between monthly PET and mean monthly temperature recorded at Jersey airport between 1967 and 1991; however, the equation representing this relationship was not presented in the 2006 assessment**Error! Bookmark not defined.** and therefore an alternative approach was required to extend the PET data.

Due to the availability of data, mean monthly air temperature from Guernsey Meteorological Office was correlated against the derived monthly PET data set from 1927 to 2007 with the resulting linear regression equation having a R^2 value of 0.796 ($y = 7.8353x - 24.109$). This linear relationship was used to extend PET data back to 1901 in line with temporal extent of the Guernsey dataset.

4.3 ESTIMATION OF JERSEY WATER SOURCE YIELD

Four spreadsheet-based water balance and storage models were developed to assess the yield of the Jersey Water’s raw water sources grouped as follows:

- Val del la Mare Reservoir, stream intakes including La Hague, Les Mourier, Greve de L’Ecq, Pont Marquet, Tesson and Little Tesson, St. Ouen’s and Tesson boreholes and La Rosière desalination plant
- Waterworks Valley (Handois, Dannemarche and Millbrook reservoirs) and associated stream intakes including Bellozanne \ Fern Valley.

- Grand Vaux Reservoir and associated stream intake at Vallee de Vaux
- Queen's Valley Reservoir and associated stream intake at St. Catherine Stream.

The water sources included in each storage system are shown in Figure C.1. The models allow the simulation of historic storage between 1901 and 2007 based on the available storage capacity (see Table C.1), the extended flow data for the 16 source catchments and an assumed annual demand profile for water placed on the supply system.

For each of the four storage systems above, the model considers raw water storage and the surface water sources as a 'lumped' storage and source model rather than explicitly considering the individual storage reservoirs and sources (and the transmission links between them) separately. The model does, however, consider the maximum abstraction rate of each stream source (Table C.1) where this information is available. There are limitations in this approach, principally that the operational constraints between the lumped individual sources and storages may not be accurately reflected; however, it was considered that grouping the storage and supplying sources in the manner indicated in Figure C.1 accurately reflects the existing operational use of the raw water system. A further limitation of this approach is that raw water transfers (and their physical constraints) between the four storage systems need to be considered separately and source use between the four systems cannot be automatically optimised. However, given that the sources have similar characteristics (surface water reservoir catchment and pumped stream sources) and that the La Rosière desalination plant is considered the only reliable alternative available water source, this simplification of the raw water system is considered robust for the purposes of source yield assessment.

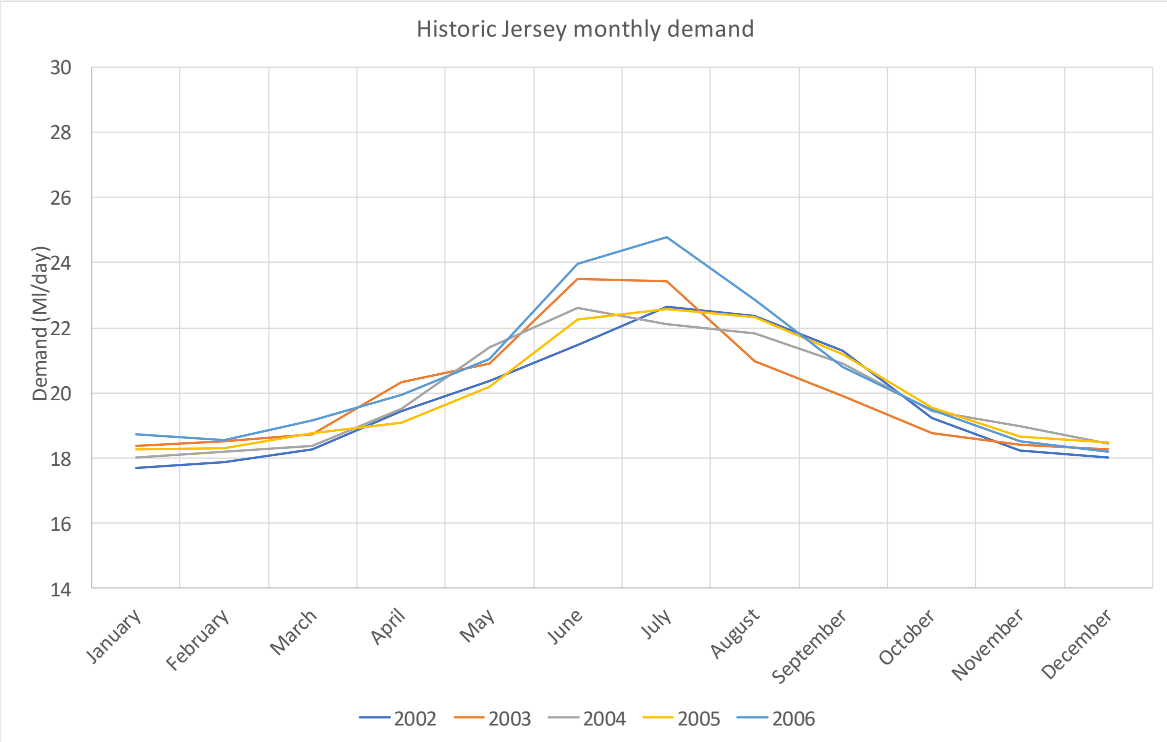
The four Jersey Water storage models were used to assess the yield of Jersey Water's sources by adjusting the demand in the model such that total storage falls to the minimum acceptable level (termed "Emergency Storage") once during the simulation period from 1901 to 2007.

In this assessment, the Emergency Storage is defined as a storage volume equivalent to 30 days' supply to meet normal unrestricted dry weather demand plus an allowance for "Dead Storage". It is assumed that in the event of a drought, La Rosière desalination plant would provide a reliable output of 10.8 Ml/d and therefore Emergency Storage is defined as 30 days' supply from all the water sources except for La Rosière.

Dead Storage is defined as an allowance for any siltation and/or the volume of water remaining at the bottom of the storage reservoirs that may not be capable of being abstracted and / or treated to potable standards during drought conditions. For water resource planning purposes, the Dead Storage has been assumed to be 5% of the total storage volume available in each reservoir.

The storage model uses a recent dry year demand profile 'shape' for 2006 (Figure C.2). This year was a known hot and dry period within the recent demand records kept by Jersey Water. Further details of the demand data and forecast can be found in Appendix E.

Figure C.2 Selected historic annual demand profile showing peak dry year profile in 2006



5. DROUGHT ANALYSIS OF RAINFALL

The outcome of the SPI assessment is summarised in Table C.3 and Figures C.3 and C.4. The SPI analysis for 9 month and 12 month durations highlights **single season** droughts, whilst the SPI analysis for a 24 month duration emphasises **multi-season droughts**.

The single, most intense drought for all timescales is the 1921 - 1922 drought (Table C.3, Figures C.3 and C.4). The 1976 drought for the 9 month duration SPI analysis is almost as intense as the 1921 - 1922 drought (Figure C.3 and Table C.3). Besides the 1921 - 1922 drought, there are a number of droughts that have a lesser, but similar intensity for the 12 month and 24 month duration SPI analysis. In contrast, the multi-year drought of 1988 - 1992 has the greatest drought magnitude for each timescale considered (Table C.3), including the 24 month duration.

To summarise, a number of historic drought events consistently appear significant in Jersey:

- 1921 - 1922
- 1949 - 1950
- 1976 - 1977
- 1988 - 1992

It is therefore recommended that any assessment of water resource availability and drought planning considers the 24-month drought risk period and includes the 1921 - 1922 drought to provide a robust assessment given the prevalence of this event in the analysis below.

Level of service considerations for water supply reliability also benefit from this long-term drought severity and duration understanding provided by the SPI approach.

Table C.3 Summary of top 5 (by intensity) drought periods in Jersey for a 9, 12 and 24 month timescale using the SPI method. Bold type highlights maximum drought magnitude.

SPI - 9 month (top 5 by intensity)

Drought Start Date	Duration (months)	Magnitude (Cumulative SPI)	Intensity (Min. SPI)
Jan-1921	18	39.6	3.99
Oct-1975	16	25.4	3.75
DeC.1879	10	17.2	2.97
Oct-1948	16	25.4	2.88
DeC.1988	45	**58.0**	2.56

SPI - 12 month (top 5 by intensity)

Drought Start Date	Duration (months)	Magnitude (Cumulative SPI)	Intensity (Min. SPI)
DeC.1920	22	45.3	3.84
Nov-1953	13	20.6	2.83
Jan-1949	15	24.9	2.82
Mar-1989	45	**62.**0	2.81
Jan-1976	15	24.4	2.68

SPI - 24 month (top 5 by intensity)

Drought Start Date	Duration (months)	Magnitude (Cumulative SPI)	Intensity (Min. SPI)
Feb-1921	32	62.2	3.28
Oct-1989	50	**78.1**	2.68
Mar-1949	20	28.0	2.24
Aug-1906	50	73.7	2.21
Jan-1997	21	26.4	2.14

Figure C.3. SPI index for Jersey monthly rainfall data of a 9 month duration

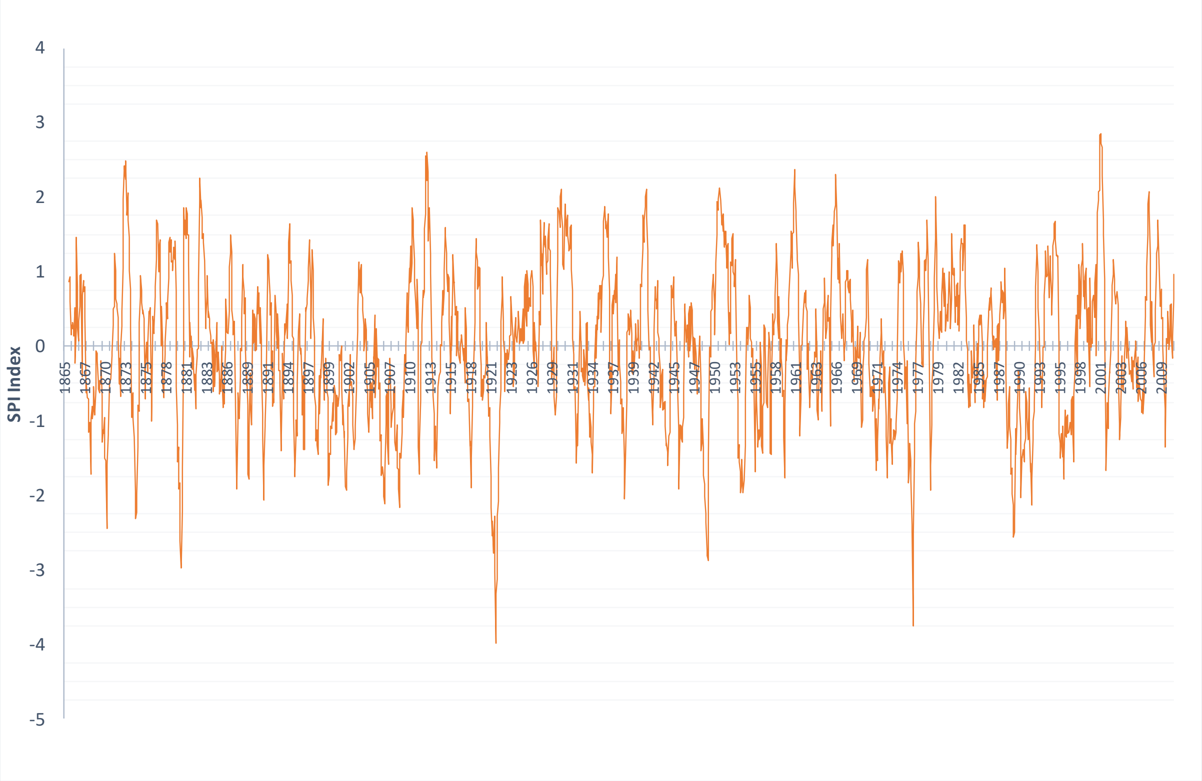
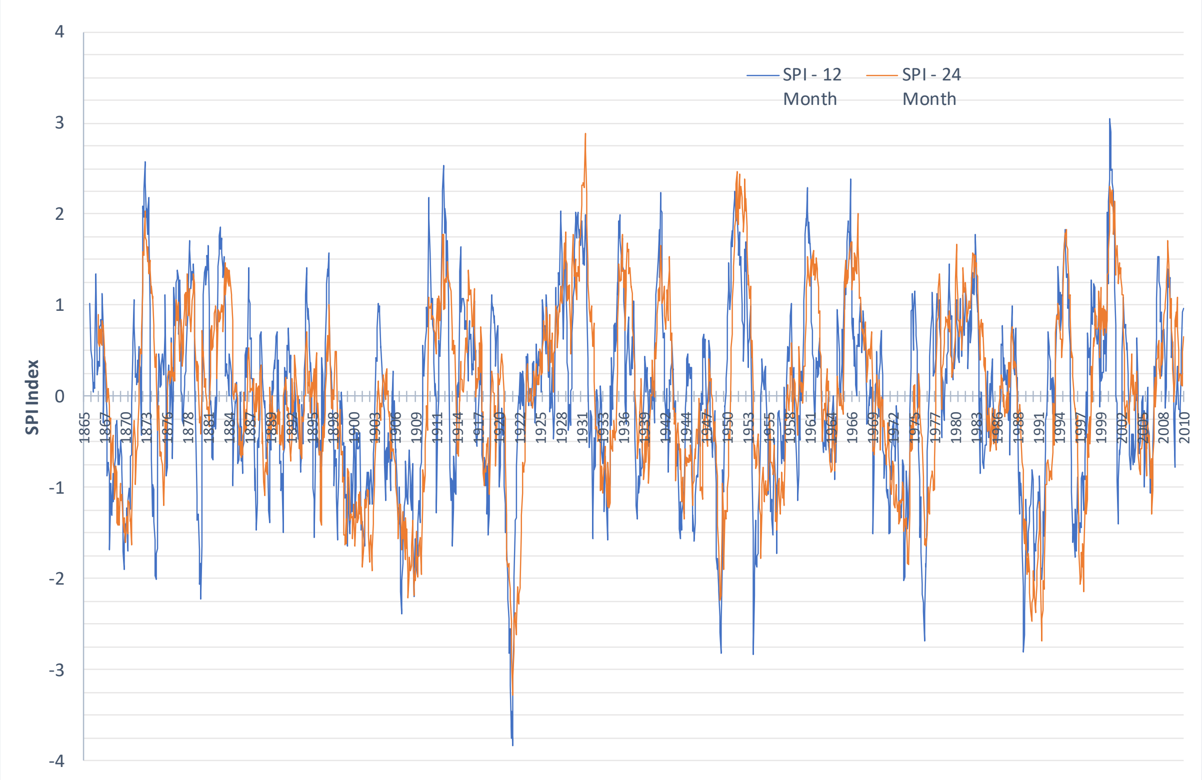


Figure C.4. SPI index for Jersey monthly rainfall data of a 12 month and 24 month duration



6. SOURCE YIELD ASSESSMENT

6.1 SUMMARY OF BASELINE SOURCE YIELD ASSESSMENT

Using the four storage models described above, the baseline yield of Jersey Water's raw water supply system is presented in Table C.4. The total baseline yield is calculated as 20.46 Ml/d; this is equivalent to a dry year annual demand that results in the predicted total Jersey Water reservoir storage reducing to the Emergency Storage level during the worst historic drought on record and occurs once in the simulation period of 107 years. The critical drought year where predicted reservoir storage reaches a minimum is 1992 for all the water resource systems except Grands Vaux where the critical drought year is 1990 (see Table C.4).

Table C.4 Baseline yield of Jersey Water's water resources

Water Resource System	Baseline Yield (Ml/d)	Critical Drought Year
Queen's Valley	2.60	1992
Grands Vaux	1.39	1990
Water Works Valley	1.62	1992
Val de la Mare	**14.85**	**1992**
Total	**20.46**	

6.2 DROUGHT ANALYSIS

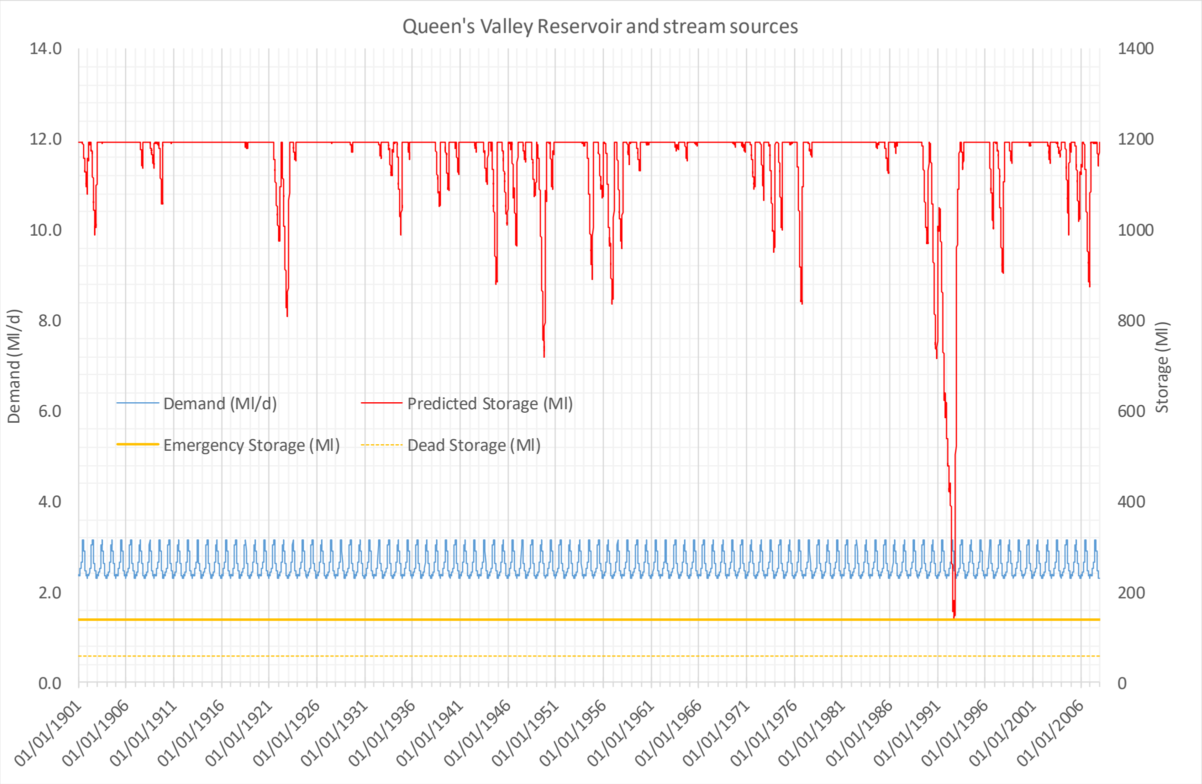
Table C.5 shows the key drought events in the total Jersey Water predicted reservoir storage simulation from 1901 to 2007 assuming all sources, including La Rosière desalination plant, are available at all times. The most significant drought in the period is that of 1991 / 1992 which begins in April 1991, reaches the Emergency Storage level in August 1992 and does not refill until December 1992. The approximate return period of this event is estimated at 1 in 191 years; the predicted minimum storage in all other drought events is significantly higher than in 1991 / 1992 and the drought durations are constrained to a single season. The 1991 / 1992 event is therefore an extreme drought with a return period approaching the 1 in 200 year drought scenario that water companies in England are required to plan for and maintain essential supplies to their customers (but with water use restrictions in place).

Figures C.5 to C.8 show the predicted reservoir storage for each of the four water resource sub-systems and Figure C.9 shows the total Jersey Water predicted reservoir storage from 1901 to 2007 with a repeat of the historic flow records.

Table C.5 Summary of notable droughts in combined Jersey Water total predicted reservoir storage

Drought Rank	Drought Start Date	Duration (to min. storage - months)	Minimum Storage (Ml)	Approx. Return Period (Years)[8]
1	April 1991	16	435	191
2	April 1990	6	1107	68
2	April 1949	6	1332	42
3	April 1976	6	1403	30
4	May 1922	5	1480	24
5	May 1944	5	1713	19

Figure C.5 Predicted raw water storage for the Queen's Valley system from 1901 to 2007 with demand at hydrological yield



[8] Based on Gringorten.

Figure C.6 Predicted raw water storage for the Grands Vaux system from 1901 to 2007 with demand at hydrological yield

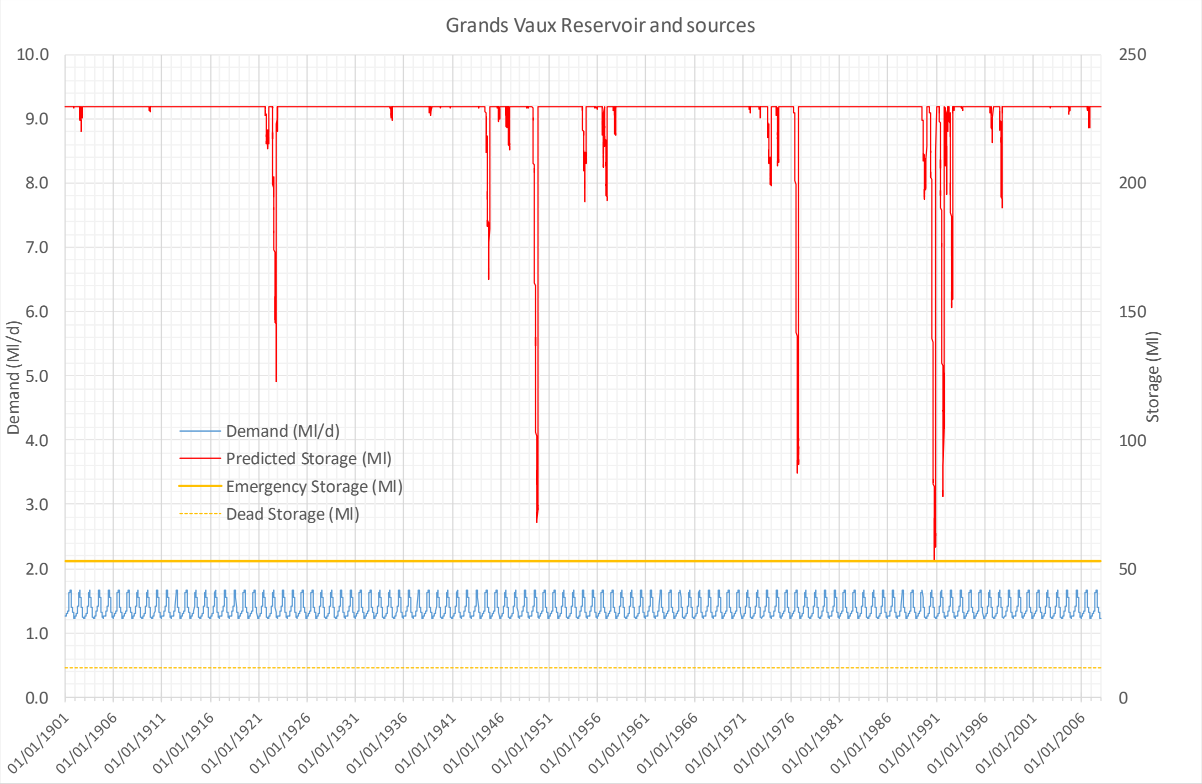


Figure C.7 Predicted raw water storage for the Water Works Valley system from 1901 to 2007 with demand at hydrological yield

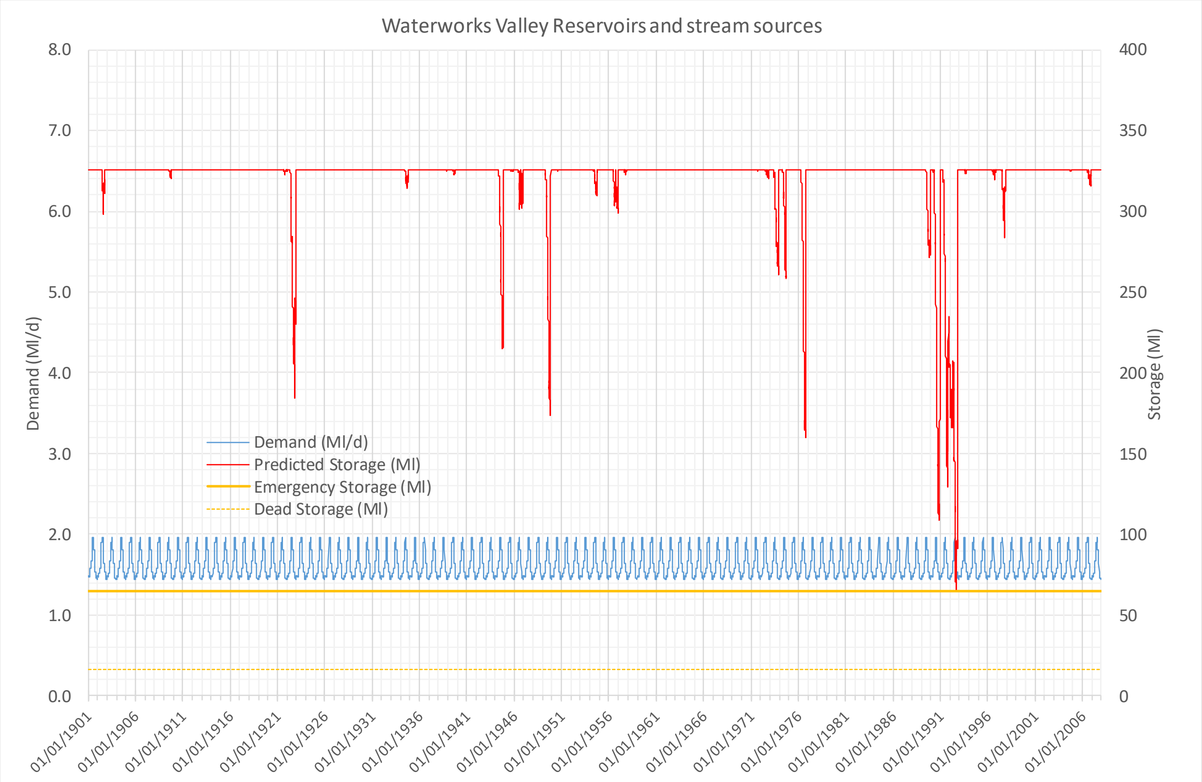


Figure C.8 Predicted raw water storage for the Val de la Mare system from 1901 to 2007 with demand at hydrological yield

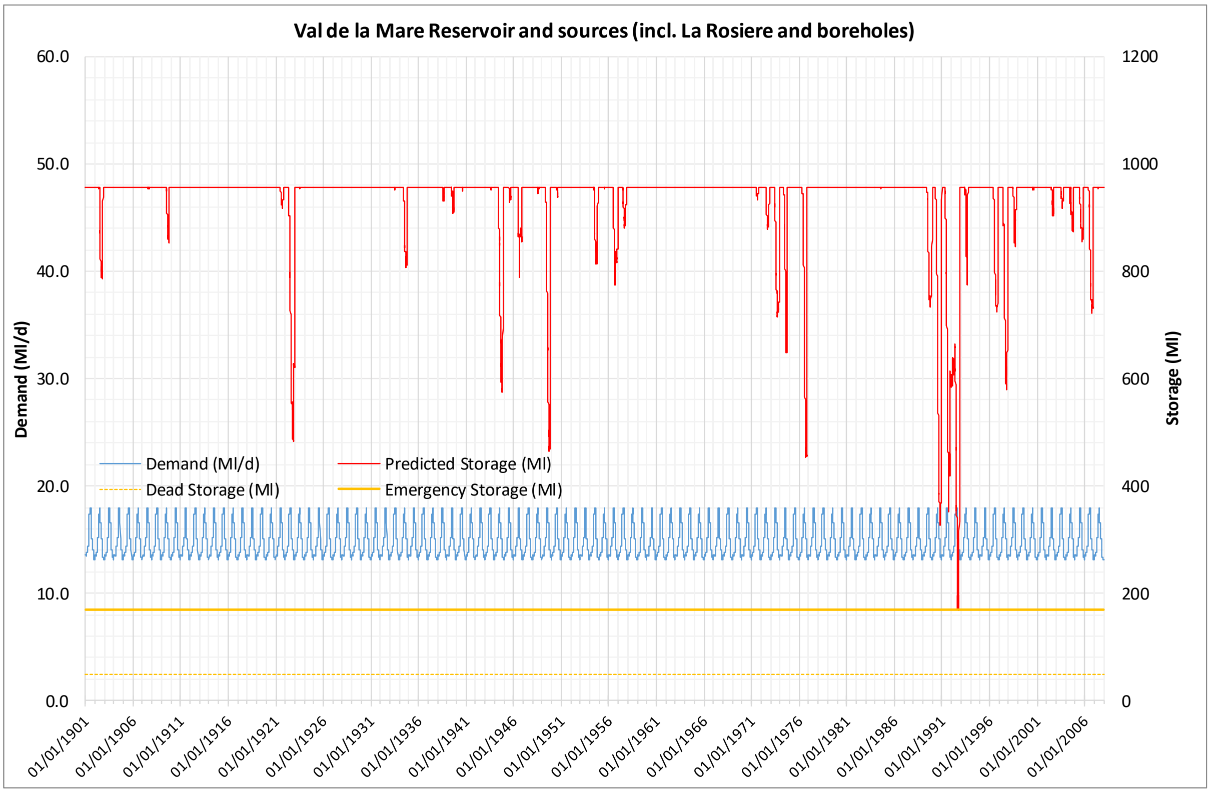


Figure C.9 Predicted Jersey Water total raw water storage from 1901 to 2007 with demand at hydrological yield