St George System

St George Model Results to Support Basin Plan Requirements

Water Planning and Coastal Sciences

December 2018

Queensland Government

Prepared by

Queensland Hydrology
Water Planning and Coastal Sciences
Science and Technology Division
Department of Environment and Science
GPO Box 2454
Brisbane Qld 4001

Citation

DES (2018), St George System – St George Model Results to Support Basin Plan Requirements, Queensland Department of Environment and Science, Brisbane.

December 2018

Contents

List of tables

List of figures

1 Introduction

The St George Model was developed using the modelling platform developed by the Department of Environment and Science. A detailed background to the data used, methodology, calibration and validation of the model development is documented in *St George Model Calibration (NRM, 2002).* A description of the model can be found in *St George Model Manual (2018)*.

1.1 Current model

In preparing a water resource plan (WRP) and a resource operations plan (ROP) under the *Water Act 2000* (Qld), Queensland develops a hydrologic model to test management scenarios. The current plans, viz. the Water Resource (Condamine Balonne) Plan 2004 (current WRP) and the Condamine and Balonne resource operations plan July 2015 (current ROP), uses the Integrated Quantity Quality Model (IQQM) for the catchment models.

The current ROP model for the Condamine–Balonne also forms the basis for the audited Cap model which supports Cap Reporting requirements under the Murray–Darling Basin Agreement and in the transition to the Basin Plan Section 71 reporting. Note that the current ROP and Cap models use different simulation periods but are otherwise the same.

In the ROP and Cap models, the St George Water Supply Scheme was represented as a separate model using an in-house platform that represents the continuous sharing rules as well as the event management rules operating in this system. A description of the model can be found in *St George Model Manual (2018)*.

1.2 Proposed Model

Queensland has developed a model for the St George System as part of the review of the current WRP and ROP and for the proposed Water Plan package being developed to comply with Basin Plan requirements. This ROP model is based on the old modelling platform and uses the flows from the Middle Condamine SOURCE model and provides the inflows and control files for the Lower Balonne Distributary model. It differs from the current model on the following points:

- It incorporates changes to the allocations since the development of the current model and separately models the allocations purchased by CEWH.
- The model also represents the new environmental management rules proposed in the Generation 2 WRP.
- The water allocations for zone LB2 downstream of the ST George gauge (422201F) have been transferred from the St George model to the Distributary model.

1.3 Basin Plan Requirements

The Basin Plan prescribes requirements that Queensland needs to address to meet accreditation.

The key requirements that need to be addressed by the model are:

1. BDL – Baseline diversion limit of a SDL resource unit. The Baseline diversion limits are determined based on development conditions as specified in Schedule 3 of the Basin Plan. In general, the BDL is a sum of:
   - take from water courses
   - take from regulated river
   - take by floodplain harvesting
   - take by commercial plantation
   - take from basic rights.

   The model provides a component of the take identified in Schedule 3 is the long-term annual average limit on the quantity of water that can be taken from the watercourse and from regulated rivers. The other forms of take are considered in the Water Accounting Methods Report (NRM, 2016).

2. SDL – Sustainable diversion limit of the Water Resource Plan area. The SDL is the long-term average sustainable diversion limit from an SDL resource unit as defined in Schedule 2 and 4 of the Basin Plan. Clause 10.10 of the Basin Plan specifies that the Water Resource Plan must set out the method for determining the maximum quantity of water that the plan permits to be taken for consumptive use during a water accounting period. This method may include the modelling. For the Condamine–Balonne SDL resource unit, Queensland prepared the IQQM Model to meet this requirement. As there are no SDL adjustment measures proposed for the Condamine–Balonne, the difference between BDL and SDL is achieved by Commonwealth water recovery. To simulate SDL in the model, the Commonwealth's water entitlements would have to be treated as inactive (i.e. not used for consumptive take).

3. Annual Actual Take – Determination of annual actual take must be specified. As per clause 10.15 of the Basin Plan, the determination of the quantity of water, actually or estimated, taken for the consumptive use by each form of take from each SDL resource unit will be determined after the end of a water accounting period. The method used to estimate the quantities should be same as used to determine BDL and SDL.

4. Environmental Water – Determination of the environmental water requirements of environmental assets and ecosystem functions. Clause 8.51, sub-section (1) and (2) of the Basin Plan list a number of measures to determine the environmental water requirements of an environmental asset and states that a method to estimate them may include a conceptual model.

5. SDL Adjustment Proposals – Models are an important tool for evaluating the SDL adjustment proposals. Chapter 7 of the Basin Plan states that the Authority can propose adjustments to the surface water SDLs if certain additional changes in infrastructure are proposed through the implementation of 'supply measures' and 'efficiency measures'.

Sections 10.22, 10.49 and 10.50 of the Basin Plan specify requirements that the WRP Package meet:

a) Section 10.22 states that a water resource plan must describe what was done to comply with the requirements mentioned in Part 4, Chapter 10 of the Basin Plan.

b) Section 10.49 states that:
   - A water resource plan must be based on the best available information.

- The water resource plan must identify and describe the significant sources of information on which the water resources plan is based.

c) Section 10.50 states that:
"A water resource plan must identify any significant method, model or tool that has been used to develop the water resource plan."

This report covers the requirements outlined above.

2 St George Model

The St George System Model was developed by an in-house modelling platform. A detailed background to the data used, methodology, calibration and validation of the model development is documented in *St George Model Calibration (NRM, 2002).* A description of the model can be found in *St George Model Manual (2018).* Figure 1 shows the model's extents.

.

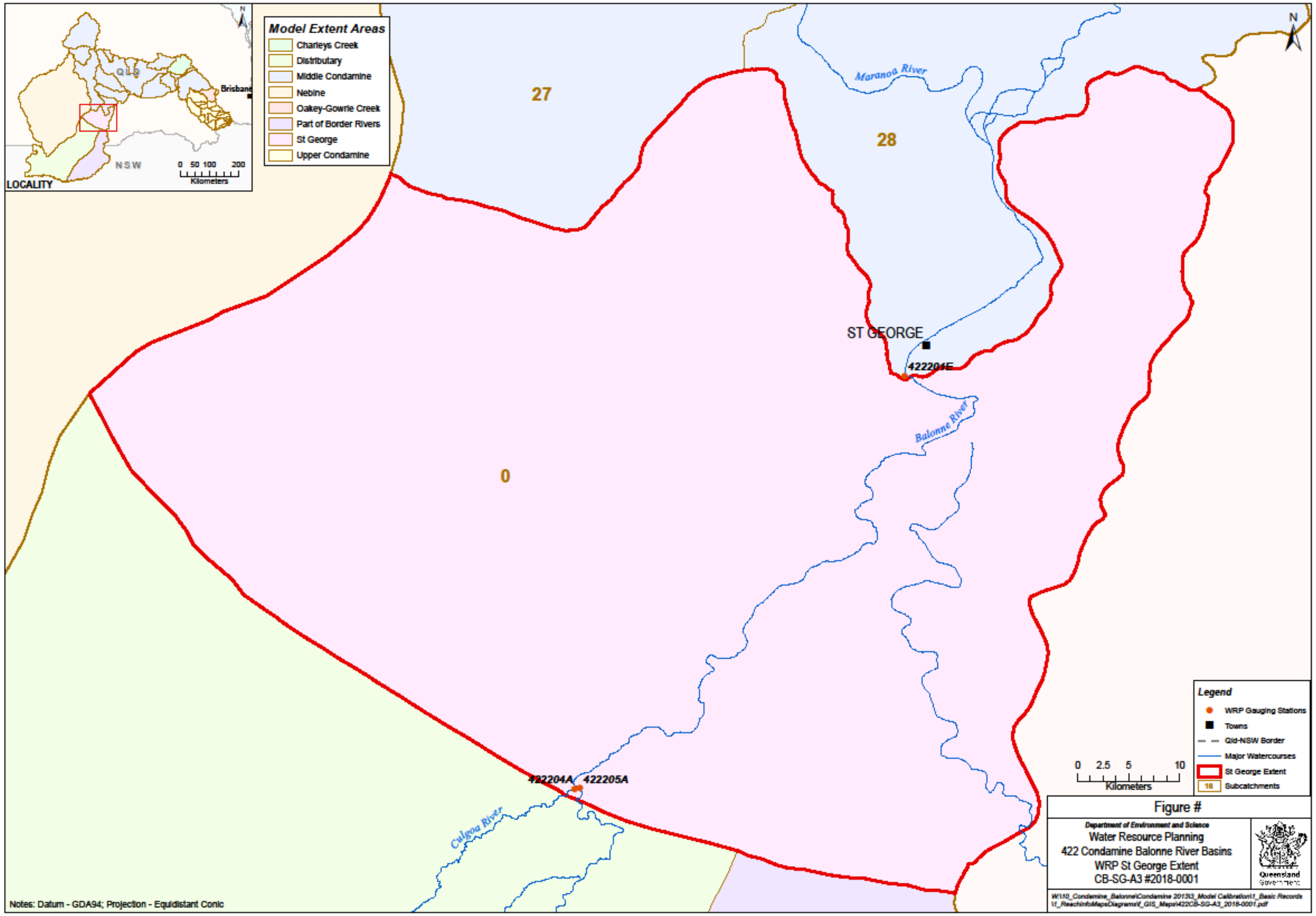

Figure 1 Model Extents

3 Model Scenarios

In this section, the model scenarios are described. The details of the model scenarios are described in Table 1.

Table 1 Detail of the Model Scenarios

Case Number	Model Name	Description	Simulation Period
1710D	Current Cap Model	This model was developed to underpin the first generation Water Resource Plan (WRP, 2014) and Resource Operation Plan (ROP, 2008) and was later extended to cover the Basin Plan Period.	1895–2017
1811E	Current Cap Model Adjusted for Trades	This model was the Current Cap Model modified to reflect the trades up to June 2017	1895–2017
1902H	New Draft WP Model	This model was developed to underpin the second generation Water Resource Plan representing all of the Water Allocations and licences in the basin reflecting trades up to November 2018.	1889–2013

All of the model scenarios cover a period greater than the Basin Plan (1895–2009) so they are able to fulfil the Plan's requirements. All results in this report are provided for the Basin Plan period.

These scenarios were used to simulate the extractions (BDL) under the Resource Operation Plan for the St George System.

The model simulated the flows and extractions by water allocations.

3.1 Current Cap Model (Case 1710A)

A current Cap Model case (case 1710D) was simulated using the current St George Cap model. The inflows to the model were estimated using the current Middle Condamine ROP model. A full description of the Cap case can be found in Chapter 4 of DERM (2012).

3.1.1 Storage Details and Assumptions

Details of the storages in the St George Water Supply Scheme are given below. Details of the on-farm storages were determined during the Gen 1 ROP certification process. In the St George model, the dam and weirs were represented by a single storage with a storage area curve adjusted to reflect the usual operation of the storages.

Table 2 St George Water Supply Scheme On-stream Storages

Storage	Full Supply Volume (ML)	Dead Storage Volume (ML)	Required Level (ML)
Beardmore Dam	81,700	3	-
Jack Taylor Weir	10,270	1,670	8,080
Moolabah Weir	2,580	440	2,580
Buckinbah Weir	5,120	780	5,120
Total	99,670	6,010	-

3.1.2 Management System

The St George model simulates the continuous sharing water sharing rules for the supplemented users as described in the ROP. The model also accounts for the transmission losses in supplying water to the different groups of users.

The water harvesting announcements are made in the model using the inflows into the dam when the dam is full and overflowing. A file of these flows is created by the model for use in the Distributary model to ensure consistency between the two models.

The model also simulates the event management rules defined in the current WRP using a control file, which is created by analysing the results of simulations that are used to check flow-through events and Narran filling under pre-development conditions. The same control file is used in the Distributary model.

3.1.3 High Priority Demand

The high priority demands in the system are Sunwater’s Distribution Loss, which is held in the Sunwater share along with medium priority distribution loss. The town water supply is a medium priority demand.

Table 3 St George High Priority Demand

Description	Nominal Volume (ML/a)	Zone
WA 1233 Sunwater Distribution Loss	390	LBS01
WA 1326 Sunwater Distribution Loss	2,610	LBS02

3.1.4 Medium Priority Demand

The medium priority demand was combined into shares based on their location and assigned a share on the basis of the formula in the ROP. The Nominal Volumes and share volumes are summarised below.

Table 4 St George Water Supply Scheme Medium Priority Demand

Share	Location	Nominal Volume (ML/a)	Share Volume (ML)
1	Zone LBS-01 Ponded Area	9,951	10,244.7
2	Zone LBS-01 St George Main Channel	19,414	19,987.0
4	Zone LBS-02 Buckinbah Main Channel	29,888	32,389.6
6	Zone LBS-02 Thuraggi Channel	4,851	5257.0
7	Zone LBS-03 Downstream of Jack Taylor Weir	4,615	5939.0
9	Zone LBS-04 Downstream of Jack Taylor Weir	3,130	4,028.0
55	Bulk Share (Not Used)	0	0
56	Sunwater Share	9,721	12,726.2
57	Town Water Supply	3,000	3,088.5

The monthly patterns used for the medium priority demand and town water supply are shown below.

Table 5 Monthly Demand Pattern for Medium Priority Demand (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
19.9	17.7	6.8	1.1	0.2	0.5	0.2	3.2	16.9	5.1	4.7	23.7

Table 6 Monthly Demand Pattern for Town Water Supply (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	15	12	5	3	3	3	3	3	8	15	15

3.1.5 Unsupplemented Demand

The unsupplemented demands in the St George System can be found in Attachment 10C of the ROP (2008) along with the overland flow licences in Attachment 12. The water harvesting thresholds used in the model have been adjusted to reproduce the announcement system which is based on the inflows to Beardmore Dam when the dam is overflowing. The model thresholds are given in Appendix B.

The on-farm storages were based on information collected during the certification process undertaken for the ROP (2008). The crop demand was specified using a monthly crop demand file created using the IQQM crop model, the St George rainfall and evaporation. The average monthly crop demand is given in Table 7.

Table 7 Average Monthly Demand Pattern for Water Harvesting Demands (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23.4	21.6	6.4	1.3	0.1	0.0	0.0	2.0	13.3	6.4	4.6	20.9

3.2 Current Cap Model Adjusted for Trades(Case 1811A)

The model is the same as the Current Cap Model, except that the allocations that have had a change in conditions have been adjusted to reflect the change in conditions. The allocations are the same as in the new Draft WP Model described below. The main difference is the inflows are from Case 1811A for the Middle Condamine model and the rainfall, evaporation and crop demand from the current Cap model have been used. The event management rules from the current Cap model were also used.

3.3 New Draft WP Model (Case 1902H)

The new Draft WP St George model used the flows estimated using the Middle Condamine SOURCE ROP Model (Case 1811F). The recovered water in this section has been separated from the original allocations and have been represented as individual allocations.

3.3.1 Storage Details and Assumptions

The storages in the new St George ROP model are given in Table 2.

3.3.2 Management System

The new Draft WP St George model uses the same management rules as the current ROP model, except for the Narran filling rule. This model simulates the new rule proposed in the Draft WP, which uses the flow at the St George gauge trigger the reduction in water harvesting rather than the Narran Lake filling under pre-development conditions.

3.3.3 High Priority Demand

The town water supplies are described in Table 3Table 2.

3.3.4 Medium Priority Demand

The medium priority demand was combined into shares based on their location and assigned a share on the basis of the formula in the ROP. The new model takes into account trades that have occurred since the first model was established. The Nominal Volumes and share volumes are summarised Table 8.

Table 8 St George Water Supply Scheme Medium Priority Demand

Share	Location	Nominal Volume (ML/a)	Share Volume (ML)
1	Zone LBS-01 Ponded Area	9,326	9,600.7
2	Zone LBS-01 Ponded Area from LBS-02	213	230.8
3	Zone LBS-01 Ponded Area from LBS-03	507	652.4
4	Zone LBS-01 Ponded Area from LBS-04	310	398.9
5	Zone LBS-01 St George Main Channel	20,044	20,634.4
6	Zone LBS-02 Buckinbah Main Channel	29,888	32,387.7
7	Zone LBS-02 Buckinbah Main Channel from LBS-03	15	19.3
8	Zone LBS-02 Thuraggi Channel	4,638	5,025.9
9	Zone LBS-03 Downstream of Jack Taylor Weir	4,093	5,266.9
10	Zone LBS-04 Downstream of Jack Taylor Weir	2,820	3,628.8
55	Bulk Share (Not Used)	0	0
56	Sunwater Share	9,721	12,725.8
57	Town Water Supply	3,000	3,088.4

The monthly patterns used for the medium priority demand and town water supply are shown in Table 5 and the monthly pattern for the town water supply is shown in Table 6.

3.3.5 Unsupplemented Licensed Data

Details of the allocations in the model can be found in the spreadsheet called ‘Lower Balonne WMA - from RCS-Rev_2018_11.xlsx’. The water harvesting allocations with a Multi-Year Volumetric Limit (YVL) were represented with large demand, while the allocations with an Instantaneous Volumetric Limit (IVL) were presented by the storages supplied during the certification process with the capacity restricted to the IVL. The model water harvesting thresholds are shown in Appendix B.

3.4 Current Without Development Case (Case 1710B)

For the Current Without Development case, the Beardmore Dam inflows calculated by the Middle Condamine Case 1710B were used as the St George gauge inflows to the Distributary Without Development Case 1710B.

3.5 New Without Development Case (Case 1811C)

For the new Draft WP Without Development case, the Beardmore Dam inflows calculated by the Middle Condamine Case 1710B were used as the St George gauge inflows to the new Draft WP Distributary Without Development Case 1811C.

4 Reconciliation with Murray–Darling Basin Plan Schedule 3

The Basin Plan places limits on water extractions within the SDL resource units. The model 1811F is proposed to estimate the available water, specifically the take from watercourses for water allocations and licences. This will support the Water Accounting Methods proposed in the Water Accounting Methods Report (NRM, 2016) for the other forms of take and classes of water access right. For the details on these proposed methods, see the report cited above.

The following section provides the comparison and of the long-term diversions between the various model scenarios, using the Basin Plan simulation period 1895–2009. Table 9 provides a comparison between the long-term diversions of the water allocations in the model scenarios while Table 10 presents the mean annual flow at the St George gauge ((422201F).

Table 9 Long-Term Diversions for the Various Models (1895–2009)

Demand	Current Cap Model (1710D) (GL)	Current Cap Model Adjusted for Trades (GL)	New Draft WP Model (1902H) (GL)
Supplemented Demand	78	78	75
Unsupplemented Demand	69	68	70
Total	147	146	145

It should be noted that the LB2 water harvesting allocations downstream of Jack Taylor Weir have been transferred to the Distributary model and have not been included in the comparison above.

The reason for the decrease in the modelled diversions was caused by the change in the flows. Figure 2 shows a comparison of the flow duration curves for the inflows to Beardmore Dam from the current ROP model with the inflows from the new SOURCE ROP model. The decrease in the flows of less than 1,000 ML/day caused a reduction in the supplemented diversions. The small increase in the flows greater than 1,000 ML/day increased the water harvesting diversion, but the increase was not enough to compensate for the decrease in the supplemented diversions.

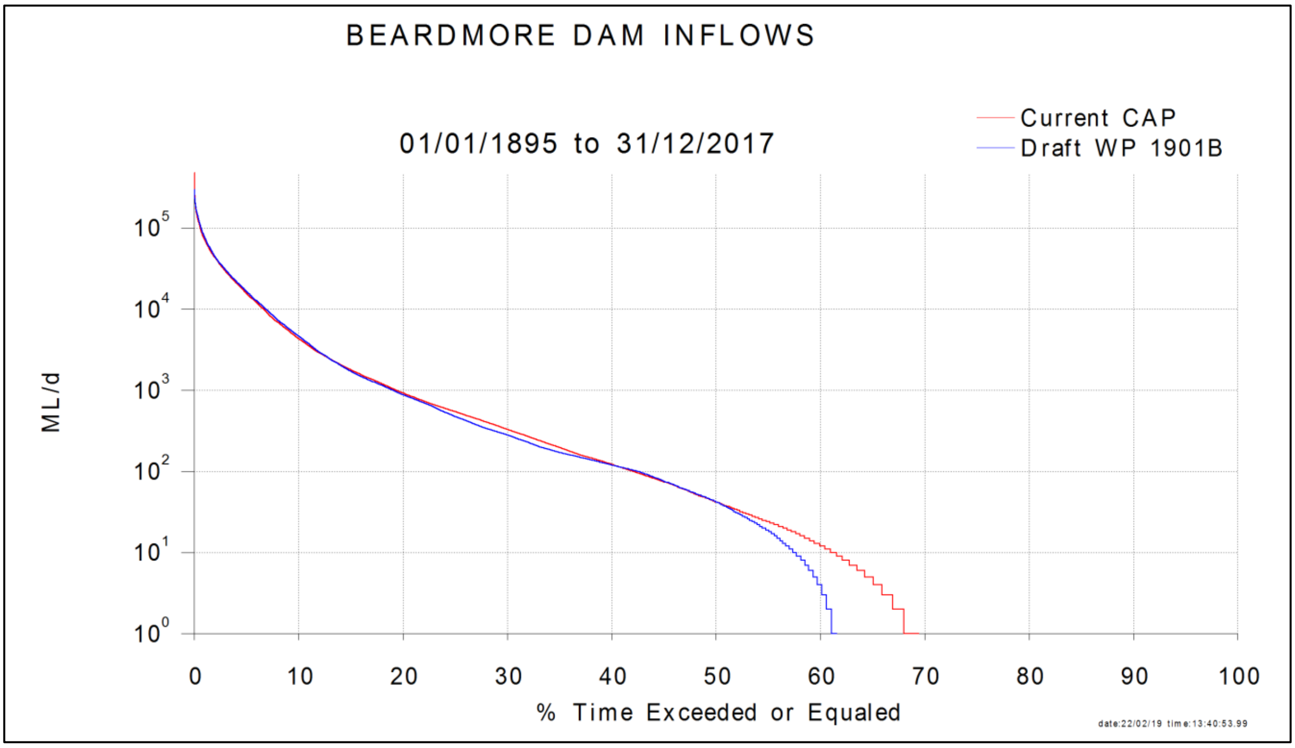

Figure 2 Comparison of Beardmore Dam Inflows

The long-term flows estimated at the St George gauge (422201F) are presented below for both the cases with and without development. There was nearly an 8 per cent increase in the flows predicted at the St George gauge for the 1895 to 2009 period of simulation under the development conditions with the new SOURCE model flows.

Table 10 Long-Term Flows at St George Gauge (422201F) for Development Cases (1895–2009)

Location	Current ROP (1710D) (GL)	New ROP (1812A) (GL)
St George Gauge (422201F)	888	960

Table 11 Long-Term Flows at St George Gauge (422201F) for Without Development Cases (1895–2009)

Location	Current ROP (1710D) (GL)	New ROP (1811F) (GL)
St George Gauge (422201F)	1,281	1,302

A general discussion of the reasons for the difference between the results of the models is given in Appendix A.

5 Conclusion

The new model for St George System has benefited from additional information that has become available to update the legislative models that support the Queensland Water Resource Planning process and Murray–Darling Basin Plan requirements. The models have benefited from:

- new climatic and streamflow data
- updated methodology
- longer simulation period and better representation of climatic variability.

The Basin Plan has a simulation period from 1895 to 2009 which differs from both the current Resource Operation Plan (2006) and the new Resource Operation Plan (2016), causing some of the variation in the diversion figures between Basin Plan and State Plan. When a consistent period is applied, it is possible to compare take from watercourses by allocations for the two plans, as shown in Table 9Table 12. The CEWH entitlements in the St George system have been modelled separately. As these allocations are same as the other allocations in the system, they have been modelled as extracting their full entitlement.

Table 12 Long-term mean annual diversions from watercourses under water allocations and licences: comparison of model 1710D and 1811F

Mean annual diversions (1895–2009)	Current Cap Model (1710D)	Draft WP Model (1902H)
Total	147 GL	145 GL
CEWH entitlements only	14 GL	15 GL

As can be seen in Table 12, the Draft WP Model (1812A) estimates of mean annual diversions are slightly lower than the estimates provided by the Current Cap Model (1710D) model. The main difference between the two models is the different inflows from upstream resulting from improved methods of estimating flows from rainfall using Sacramento rainfall-runoff models that have been calibrated using calibration techniques. There were also some slight differences caused by the different modelling platforms that have been discussed in more detail in Appendix A and DES (2018).

The new model demonstrates Queensland’s commitment to improve on the previous model’s robustness and defensibility. All future models will build on the new model and use the latest information, methodologies and technology available at the time when the next new model is developed.

6 References

DES (2018), *Differences Between the Source and IQQM Modelling Platforms*. Department of Environment and Science.

Department of Natural Resources and Mines (2016), *Water Accounting Methods Paper for Warrego-Paroo-Nebine Water Resource Plan, State of Queensland, February 2016.*

DERM (2012), *Condamine-Balonne Cap Model Description*, Department of Environment and Resource Management.

DES (2018), *St George Model Manual SGCS35,* Department of Environment and Science, Brisbane.

NRM(2002) St George Model Calibration Draft Report prepared by Natural Resources and Mines Queensland.

ROP (2008). *Condamine and Balonne Resource Operations Plan December 2008 Amended July 2017 (Revision 5)*. Department of Natural Resources and Mines, State of Queensland.

WRP (2004), *Water Resource (Condamine and Balonne) Plan 2004*. State of Queensland.

Appendix A – Methodology and Data Differences

Methodology and Data Differences 1995 to 2013

The IQQM developed for the first Water Resource Plan was completed in 1998 with a simulation period from 1922 to 1995. The period of simulation was extended from 1895 to 2006 for the CSIRO Sustainable Yield Study and was then extended to 2009 for the Murray–Darling Basin Plan modelling. The Sacramento models developed in the 1990s were used to extend the period of simulation back to 1895.

In 2013, a new set of models was developed for the Condamine–Balonne using the SOURCE platform. These models used an extended data set, which included new gauging stations, as well as new methods for model calibration. Consequently, the flows in the SOURCE models are different from the flows in the original models.

There are also differences between how the SOURCE and IQQM models perform certain processes, which can give different simulated diversions and flows especially in complex systems.

An attempt was made to isolate the differences between the two modelling platforms by setting up an IQQM mode with the same flows and routing and loss parameters as the SOURCE model. It was found that most of the differences could be attributed to the differences in the flows.

A general discussion of the main points of difference between the two models is given below.

Rainfall and Evaporation

Different rainfall and evaporation data were used. Some of the rainfall stations used in the original model have been closed, so it was necessary to use another near-by station in the SOURCE model. SILO patched point data, which is recorded station rainfall infilled with SILO data drill (grid) data at that location, was used.

In the Sacramento modelling, new techniques were used to select rainfall stations in the calibration. Stations were chosen that gave the best agreement between the modelled and measured streamflow.

In the SOURCE modes, evaporation data from the Warwick site were used for all of the catchment even though it is located in the northern section. This site had the best metrological data for the estimation of the lake and potential evaporation in the catchment. It was best to use this data rather than data extrapolated from this site. The evaporation at Warwick would be fairly similar to evaporation in these catchments and any errors are unlikely to have a large effect on the model.

Flow Data

Recorded flow data used to develop the original IQQM and the SOURCE models has varied in a number of ways:

- Different and additional gauges used.
- Longer records with flows associated with more extreme weather conditions.
- Rating changes. This will change earlier flow records if the rating curves change.
- Data may have been extracted differently. Variations include use of different time offsets and different conversion calculations used to generate flow data from levels.

In the original IQQM, stream gauges on the main stream were mainly used for estimating flows. In the SOURCE model, more tributary gauges and new gauges were used to improve the estimation of the flows.

Sacramento Calibrations

The latest Sacramento models are different to the original ones. They use different catchment areas, rainfall, evaporation and flow data (residuals were developed on numerous different modelling assumptions and for different time periods and, in some cases, flow data were extracted differently).

The main difference was the use of the FORS method to determine both catchment parameters and the rainfall stations. This methodology resulted in better agreement between the modelled and measured flows. The Sacramento models were calibrated over a longer calibration period that included a major drought and record floods, which should improve the ability of the model to predict these events.

Use of Historical Diversions in Flow Calculations

There are very few measured diversions in this catchment. The derived inflows can only be accurately adjusted if daily diversion data is available. As this data was not available, it was considered better to not include them in the estimation of inflows.

Flow Adjustment Explained (using DMM)

Once the full length inflow sequences for the whole model were included, further adjustments were made to the Sacramento parts of them to obtain a better match between the model and the long-term recorded flow data in the catchment. The program DMM was used to make the adjustments.

DMM is an adjustment process applied across multiple reaches. It is used to adjust Sacramento data in multiple reaches upstream of a long-term gauge, to bring the modelled and recorded flows into alignment. Recorded head water inflows and calculated residual inflows are not adjusted.

DMM first calculates the difference between modelled and recorded flows at the downstream gauge being adjusted to. The differences are caused by inaccuracies in Sacramento inflows due to inaccurate spatial and temporal rainfall and evaporation representation, and also by the averaging of lag and routing, and losses. DMM adjusts the Sacramento parts of the inflow sequences to produce sequences which together with the calibrated model’s assumptions, will result in better alignment of the modelled and gauge flows at the long-term gauges. It does multiple iterations to converge towards a best set of adjusted inflows and then the user decides which iteration’s inflows give the best result overall. The program usually modifies Sacramento data by scaling in proportion to the differences between the modelled and measured flow at a downstream gauge. If there is gauged flow but no modelled flow, the program distributes the measured flow over the upstream sub-catchments using a scaling factor based on the catchment area of the sub-catchments weighted by the mean annual rainfall on the sub-catchment.

DMM can be applied to align the model to multiple long-term gauges. In this case the adjustment is done to the next long-term downstream gauge and the adjusted inflow data is then excluded from adjustments to gauges further downstream.

The final residual reach inflows are used in the model validation and model simulation runs.

Appendix B – St George Model Water Harvesting Thresholds

ROP Threshold (ML/day)	St George Model Threshold (ML/day)
1,200	1,910
1,500	2,010
2,000	3,374
2,500	3,415
3,000	5,098
3,500	5,132
4,000	5,554
5,000	6,299
6,000	7,189
7,000	8,546
8,000	14,832
10,000	17,020
12,000	18,196
14,000	19,906
16,000	21,403
18,000	23,523
20,000	25,669
22,000	27,749
24,000	29,797
26,000	31,837
28,000	33,877
30,000	35,917
32,000	37,947
34,000	39,946
36,000	41,947
38,000	43,947
40,000	45,947
42,000	47,947
44,000	49,946
46,000	51,946
48,000	53,947
52,000	57,947
56,000	61,947
60,000	65,947