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TABLES

FIGURES

14. SURFACE WATER

14.1. Description of environmental values – hydrology

This section addresses Section 3.4.1 of the ToR and describes the existing hydrologic regime of the Dawson River, its tributaries and other river systems, including downstream systems, subject to potential water related impacts as a result of the Project.

14.1.1. Regulatory framework

The Project is located in the southern end of the Fitzroy Basin, in the upper Dawson River. Water resources in the Fitzroy Basin are managed under a number of pieces of legislation, policies and strategies, the most significant (for the Project) are listed below:

- Water Act 2000;
- Water Resource (Fitzroy Basin) Plan;
- Fitzroy Basin Resource Operations Plan (2004) (amended July 2009, Revision 2); and
- Central Queensland Regional Water Supply Strategy.

These are described below, with other legislation relevant to the Project discussed in Section 1.10.

14.1.1.1. Water Act 2000

The *Water Act 2000* specifies that all rights to the use, flow and control of water in Queensland are vested in the State. The Water Act provides for a:

- sustainable management framework for the planning, allocation and use of water resources;
- regulatory framework for service providers covering asset management, customer standards, and dam safety;
- governance regime for statutory authorities that provide water services; and
- regulation of works and other activities undertaken in watercourses.

The *Water Act 2000* is primarily implemented by DERM.

14.1.1.2. Water Resource (Fitzroy Basin) Plan

Water Resource Plans (WRPs) are subordinate legislation to the *Water Act 2000*. They are developed in order to provide a strategic framework for the allocation and sustainable management of water, at a catchment scale.

The Fitzroy Basin Water Resource Plan was originally finalised in 1999 and was the first in Queensland. It aims to provide a balance between current environmental needs, consumptive uses, and future water resource development. A WRP is valid for a period of ten years, after which time the plan is reviewed by DERM. The Fitzroy WRP was under review at the time of drafting the EIS and therefore the 1999 WRP plan has been used in the assessment of potential impacts and associated compliance. The revised WRP was approved on 8 December 2011.

The modelling undertaken for the EIS will be revised using the model developed for the new WRP and compliance with the *Water Resource Plan (Fitzroy Basin) Plan 2011* (WRP) will be assessed prior to project approval.

The WRP establishes two key sets of objectives:

- Environmental Flow Objectives (EFOs); and
- Water Allocation Security Objectives (WASOs).

The EFOs set out a series of mandatory and non-mandatory flow objectives for key locations in the Basin. The EFOs for the Fitzroy Plan cover a range of flow conditions including Seasonal Base Flow, a First Post-Winter Flow Event and Medium to High Flow Events. The WASOs provide a level of security for supplemented and unsupplemented water entitlement holders. In the Fitzroy Basin water is available as high priority and medium priority supplemented water, i.e. it is supplied from a water storage, or as unsupplemented water, which is accessed via run of river flows.

The WRP specifies the use of the Integrated Quantity Quality Model (IQQM) developed by DERM for the assessment of water resource development within the Fitzroy Basin (where practicable).

14.1.1.3. Fitzroy Basin Resource Operations Plan (ROP) 2004 (amended July 2009, Revision 2)

The ROP is a plan prepared under the provisions of the *Water Act 2000* to implement a WRP for certain water in all or part of the plan area. The Fitzroy Basin ROP implements the Fitzroy Basin WRP. While the WRP sets out the strategic goals for water resource management in the plan area, the ROP defines the rules that govern the allocation and management of water in order to achieve the WRP outcomes.

As part of the ROP, areas of the Basin are identified which are able to provide future water allocations, over and above existing surface water entitlements. This ‘unallocated’ water reflects a potential future water source which can be provided while still meeting the WRP objectives. The ROP identifies the following ‘unallocated’ water available for future release:

- up to 300,000 ML of mean annual diversion from the Isaac/Connors and Lower Fitzroy River systems;
- up to 40,000 ML of mean annual diversion from the Comet/Nogoa/Mackenzie River system; and
- up to 11,500 ML of mean annual diversion from the upper Dawson River.

The ROP also identifies 190,000 ML of unallocated medium priority water from the Dawson River (as provided in the WRP), specifically associated with Nathan Dam.

14.1.1.4. Central Queensland Regional Water Supply Strategy

Water planning in the Fitzroy Basin also exists under the Central Queensland Regional Water Supply Strategy (CQRWSS). This was developed in 2006 by DERM, in conjunction with other State Government Departments, Authorities and Local Government. The development of the CQRWSS was initiated by the Central Queensland Regional Water Supply Study and in response to the prolonged drought in Central Queensland, which highlighted the need for a whole of government regional strategic water supply plan to provide for current and future water needs. The Strategy addresses the key issues of:

- urban growth and industrial development;

- entitlements in some existing water supply systems in the region are at or approaching full usage;
- some existing water supply schemes are performing below water users' requirements; and
- meeting requirements of the urban, industrial coal mining and agriculture from 2005-2020 with predicted shortfalls.

The Strategy aims to outline the equitable and timely solutions to the urban, industrial/mining and agricultural water needs of the Central Queensland region. Nathan Dam was identified in the CQRWSS as the preferred medium to long term water supply solution to meet future water demands in the Dawson-Callide sub-region.

It should however be noted that the CQRWSS is a planning document and does not have a legislative basis.

Other relevant water management policies include the National Water Initiative (2004) and the COAG Water Reform Agenda (1994). These both address reform of water management at a national level and are described in Section 1.10.

14.1.2. Assessment methodology

14.1.2.1. Streamflow reporting

For this study there are five primary streamflow reporting sites that have been used; three within the Dawson River catchment and two on the Fitzroy River. The reporting sites are listed below and are shown in Table 14-1
Figure 14-1:

- Dawson River at Nathan Gorge – 8 km downstream of the dam site and representing WRP EFO node 5A;
- Dawson River at Theodore – downstream of the Theodore Weir and representing WRP EFO node 4;
- Dawson River at Beckers – upstream of Don River confluence with Dawson River and downstream of Neville Hewitt Weir. Representing WRP EFO node 2;
- Fitzroy River at Eden Bann Weir – WRP EFO node 1; and
- Fitzroy River Barrage – WRP EFO node 0.

The dam site is located upstream of the Nathan Gorge gauge at AMTD 315.3 km, with a catchment area of approximately 23,185 km^2.

Table 14-1 Streamflow reporting sites

Catchment	Station Number	WRP EFO node	River	Location	AMTD (km)	Catchment Area (km^2)
Dawson River	130320	5A	Dawson River	Nathan Gorge	307.2	23,308
	130305	4	Dawson River	Theodore	193.6	28,503
	130322	2	Dawson River	Beckers	71.0	40,500
Lower Fitzroy	n/a	1	Fitzroy River	Eden Bann Weir	143.0	135,750
	n/a	0	Fitzroy River	Barrage	59.6	139,000

It should be noted that the Nathan Gorge reporting site (EFO node 5A) is located within the Gyranda Weir impoundment area. Flows reported at this location represent inflows at this point and do not include consideration of the volume stored in Gyranda Weir.

Several methodologies have been used in the assessment of the existing surface water environment and the potential impacts of the dam. Water resource modelling, using IQQM, was undertaken in order to assess streamflow and water usage, as well as compliance with the WRP specified WASOs and EFOs. Recorded gauge data has also been used to characterise the current flow regime.

To assess potential flood impacts for the dam and surrounds, hydrologic and hydraulic modelling has been undertaken, using *URBS* and *MIKE 11*. The flood modelling assessed the peak flood volumes and peak flood levels for historical flood events as well as a range of design events.

14.1.2.2. Water resource modelling (IQQM)

The DERM IQQM is a hydrologic model that simulates the catchment's response to climate conditions over a historical period. This model was originally developed and calibrated as part of the Water Allocation and Management Plan (Fitzroy Basin) 1999 (WAMP), now known as the Fitzroy Basin WRP. The IQQM uses a historic simulation period of 96 years from 1900 to 1995. At the time of preparing this EIS it was mandatory that WRP related assessments were conducted against this simulation period.

As part of the WRP review the modelled simulation period will be extended by DERM to 2008. This data will be used for the detailed design phase of the Project. In the mean time, a preliminary extended data series (to 2008) was made available to SunWater by DERM.

Three scenarios are discussed here with respect to IQQM modelling: Pre-development, Full Entitlement and 'With Dam'. The development of the Pre-development and Full Entitlement scenarios, including the nature of the model and the assumptions adopted, is documented in the *Fitzroy Basin Water Allocation and Management Planning: Technical Reports* (DNR, 1998).

The Pre-development scenario represents flows within the system with all dams and water infrastructure removed from the model and with no water extracted from the system. This provides information on the flow regime of the system prior to any water resource development and is used to represent the natural condition of the catchment.

The Full Entitlement scenario incorporates all water resource development within the catchment which existed at the time the model was developed, i.e. all dams, weirs, off stream storages, associated water infrastructure and all water entitlements. It assumes full utilisation of all existing water entitlements regardless of the actual degree of utilisation. This provides information on the committed entitlements and represents the approved level of water resource use in the catchment. The Full Entitlement model is the base case for the assessment of the impacts of approved levels of development against the WRP specified objectives.

In order to understand the likely flow regime after the dam is operational, as compared to the flows in the river under the current levels of development, an additional model is required. The Full Entitlement model was therefore adjusted to include the dam and its draft proposed operational strategy. This case is referred to as the 'With Dam' scenario. It is not possible to use actual utilisation of entitlements because these vary from year to year and farm to farm. So, to ensure an ecologically conservative modelling approach for predictive purposes, full entitlement use remains incorporated.

14.1.2.3. Flood modelling

Potential flood impacts were assessed through the analysis of historical flood records, hydrologic modelling and hydraulic modelling.

Historical flood records were assessed through a flood frequency analysis of flooding records at Taroom, Glebe and Theodore gauging stations. This provided an estimate of the size of flood events for a range of return periods, based on recorded flood levels. From the flood frequency analysis, the 1956 flood, which was the largest on record at the time of the assessment, was estimated to be between a 1 in 100 and 1 in 150 Annual Exceedance Probability (AEP) event. At the time of preparation of this document (summer 2010/2011) significant flooding occurred in the Fitzroy River basin, including in the Dawson River catchment. However, information relating to the magnitude of the flooding was not available from the relevant agencies. The recent flooding information will be incorporated into future flood modelling, undertaken for the detailed design phase of the Project.

Design rainfalls were determined using the methodologies outlined in Australian Rainfall & Runoff (SunWater, 2008). For AEPs up to the credible limit of extrapolation (1 in 2000), design rainfalls were derived using the CRC-FORGE methodology. Design hydrology inflows were then determined using the *URBS* model. *URBS* is a continuous/event based rainfall runoff routing model, primarily used for operational flood forecasting and design flood estimation. The *URBS* model was used to predict design flood flows for a range of (AEPs) at the dam site. These flows give an indication of the size of existing floods at the dam site, which can be used to understand the potential flood operations of the dam.

The *URBS* model was also used to estimate the Probable Maximum Flood (PMF), which the dam spillway will be designed to pass. The PMF is an extremely rare flood event, and is the most severe flood that can reasonably be expected to occur.

Flood flows and levels were estimated using *MIKE11*, a 1D hydraulic modelling software package. The model extends along the Dawson River for a distance of approximately 90 km, from the confluence of Juandah Creek and Dawson River (beyond the upstream extent of the backwater for a Probable Maximum Precipitation Design Flood (PMPDF) event) to Nathan Gorge. The hydraulic model was calibrated against three recorded flood events, February 1956, January 1996 and August 1998. The model was then verified using the May 1983 event.

The hydraulic modelling assesses two scenarios: the existing environment (no dam) and the developed case (with dam). Modelling undertaken for the developed case assumed that the dam was at FSL at the beginning of a flood event. The catchment was also ‘wetted up’ prior to running the model; this reduced the level of instream losses. These assumptions help to provide a conservative assessment of flood impacts.

For these studies, flooding was assessed at the following sites along the Dawson River; Taroom (AMTD 384.6 km), Theodore (AMTD 230.1 km), Nathan Gorge (close to the dam wall site, AMTD 307.2 km) and Beckers (AMTD 71.0 km). Additional reporting sites were Eden Bann Weir (AMTD 143 km) and Barrage (AMTD 59.6 km) on the Fitzroy River.

14.1.3. Catchment description

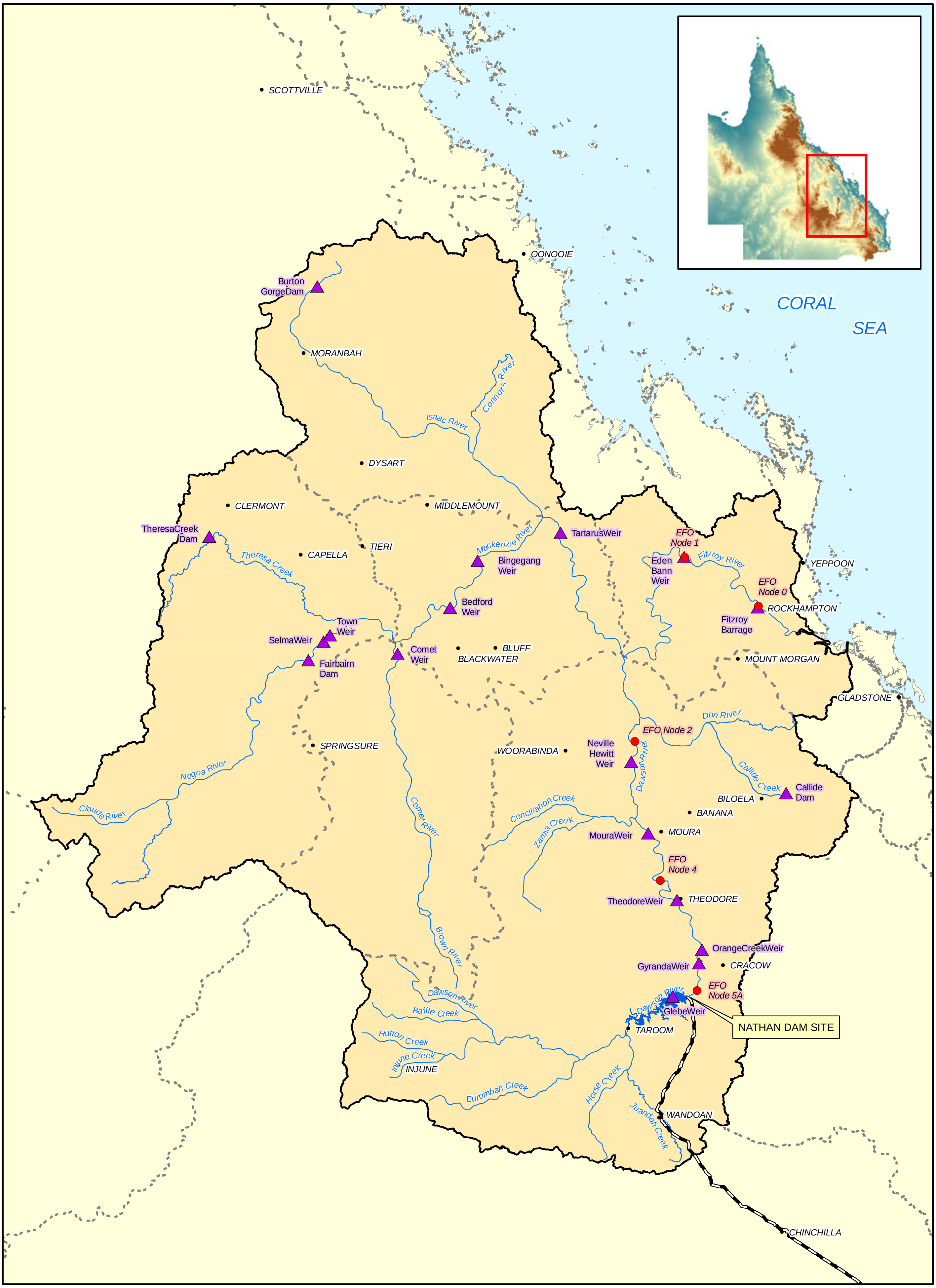
This section describes the existing surface water environment of the Dawson River and Fitzroy catchment, in terms of local streams and rivers, rainfall, existing usage, surface water flow and flooding. The sub-catchments crossed by the pipeline are addressed in Section 14.1.7, including those within the Condamine River catchment.

An overview of the catchment, including watercourses, towns, existing water storages and the water supply pipeline is presented in Figure 14-1.

The Dawson River is located in the southern corner of the Fitzroy Basin. The Fitzroy Basin has a total catchment area of approximately 142,600 km^2 and consists of six major sub-catchments: Isaac-Connors, Mackenzie, Dawson, Nogoa, Comet and Fitzroy.

The dam site is located on the upper Dawson River at AMTD 315.3 km, measured along the river from the confluence of the Dawson River and Fitzroy Rivers, and is 35 km directly north east of Taroom. From the dam site, the Dawson River flows north, joining the Fitzroy River near Duaringa, AMTD 310.3 km from the Fitzroy River mouth. The dam site is therefore approximately 626 river kilometres from the river mouth. The Nathan Dam catchment has a total area of approximately 23,185 km^2, which is approximately 16% of the total Fitzroy Basin.

As detailed in Section 10.1.3, within the Dawson River catchment there are environmentally sensitive areas including artesian springs (boggomosses), wetlands and the Lake Murphy Conservation Area, which is listed in the Directory of Important Wetlands. The location of boggomoss sites, wetlands and area of inundation from Nathan Dam is shown in Figure 14-2. Environmentally sensitive areas are discussed in detail in Chapter 10.



LEGEND

- Town
- EFO Node
- Weir Locations
- Proposed Pipeline
- Major Watercourses
- Full Supply Level (185.3 m AHD)
- Fitzroy Basin
- Catchment Boundaries

Projection: GDA94

Figure 14-1

0 20 40 80
Kilometres

N

Scale 1:3,000,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Fitzroy Basin drainage characteristics

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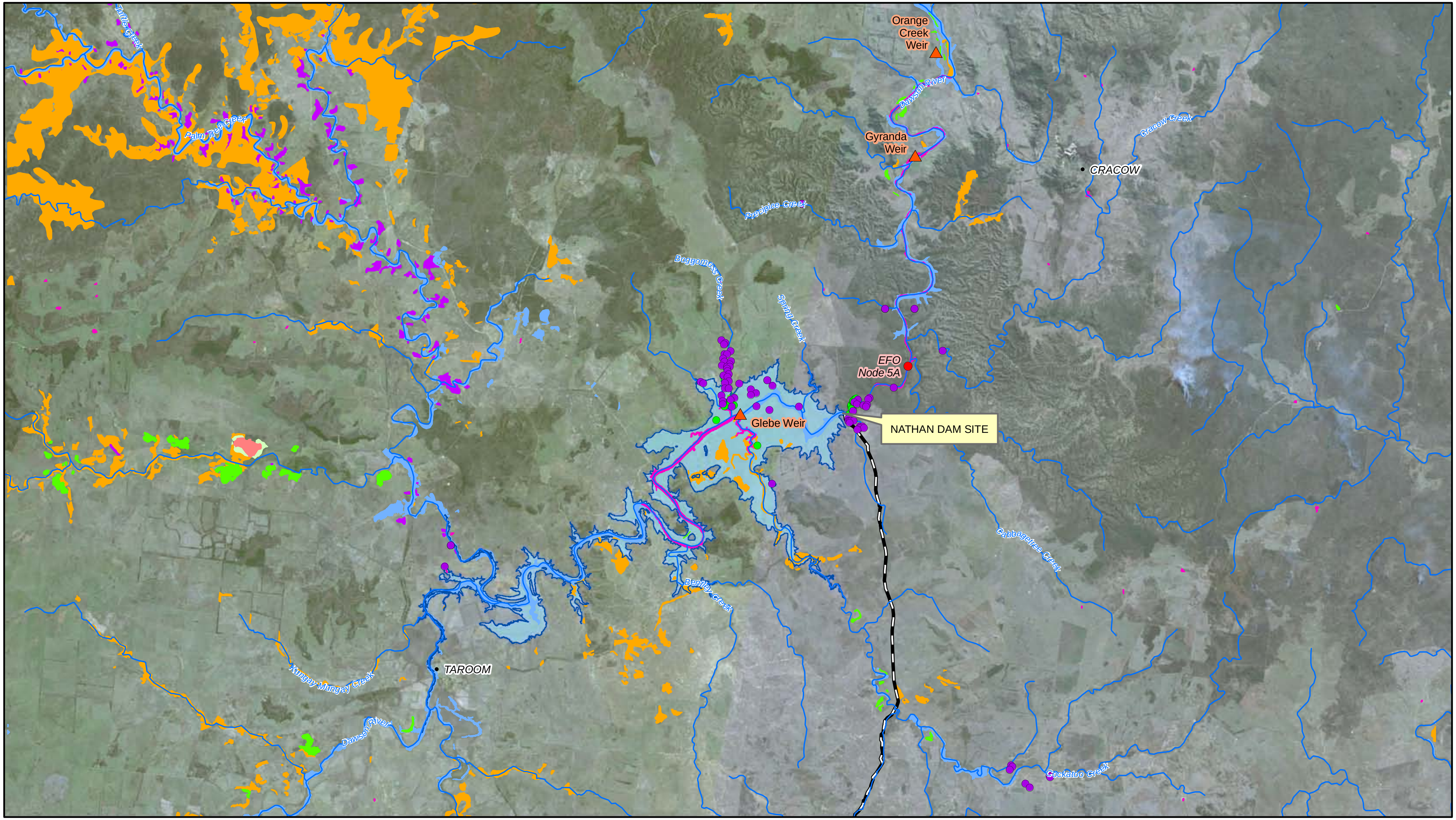

LEGEND

- Town
- Fensham (2005) GAB Spring Sites
- Chenoweth (2008) GAB Spring Sites
- EFO Node
- Weir Locations
- Proposed Pipeline
- Watercourse
- Full Supply Level (183.5 m AHD)

Wetland Systems

- Coastal/ Sub-coastal floodplain grass, sedge and herb swamps
- Coastal/ Sub-coastal floodplain lakes
- Coastal/ Sub-coastal floodplain tree swamps (Melaleuca/ Eucalypt)
- Coastal/ Sub-Coastal non-floodplain tree swamps (Melaleuca/Eucalypt)
- Coastal/ Sub-Coastal non-floodplain (spring) swamps
- Coastal/ Sub-coastal non-floodplain soil lakes
- Artificial/ highly modified wetlands)
- Riverine

Projection: GDA94 Zone 56

Figure 14-2

0 2 4 8
Kilometres

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Scale 1:400,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Area of inundation and Boggomoss sites

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14.1.3.1. Nathan Dam catchment

There are approximately 64 creeks and rivers flowing into the Dawson River, with the major tributaries upstream of the dam site being Baffle Creek, Eurombah Creek, Hutton Creek, Horse Creek, Palm Creek and Juandah Creek. The major tributaries downstream of the dam site are the Don River, Callide Creek, Castle Creek, Mimosa Creek (including Conciliation Creek and Zamia Creek), Banana Creek and Bone Creek. The majority of these are shown in Figure 14-1.

There are a number of tributaries which drain directly into the Nathan Dam water storage, these are detailed in Table 14-2 and are shown in Figure 14-2.

Table 14-2 Catchments draining into the Nathan Dam water storage

Catchment	Catchment Area (km^2)
Spring Creek	43
Spring Gully / Boggomoss Creek	110
Bentley Creek	348
Palm Tree Creek	5,196
Blackboy Creek	79
Cockatoo Creek	1,030
Juandah Creek	4,830

A description of the surrounding landscape character, including landform and land use, is provided in Chapter 5.

14.1.3.2. Historic rainfall and evaporation

A description of the climatic conditions including a summary of historic rainfall and evaporation within the Dawson River catchment has been provided in Section 3.1. The key findings in regards to climatic conditions in the catchment are:

- the area is characterised by warm summers (December through February) and relatively cool winters (June through August);
- rainfall across the catchment varies seasonally, with higher rainfall occurring in late spring and summer;
- mean annual rainfall does not vary significantly across the Nathan Dam catchment or along the pipeline and is in the range of 600-700 mm;
- evaporation in the region is high and varies seasonally, with higher evaporation occurring in late spring and summer. Mean monthly evaporation , exceeds mean monthly rainfall for each month; and
- rainfall and runoff are highly variable and the catchment has experienced frequent periods of drought and flooding.

14.1.4. Surface water flow patterns

This section describes the existing surface drainage patterns within the Dawson River catchment.

The major tributaries upstream of the dam site (Baffle Creek, Eurombah Creek, Hutton Creek and Juandah Creek) rise to the south west of the dam site, in the southern most region of the Fitzroy Basin. Downstream of the dam site the major tributaries of the Dawson River either lie to the east (the Don River and Callide Creek) rising from the Calliope Range, or the tributaries lie to the west (Conciliation Creek and Zamia Creek) rising from the Expedition Ranges.

Flows in the Fitzroy Basin are highly seasonal, with the majority of flows occurring from December to April. High flow events generally occur in late summer/early autumn.

A description of the geomorphic features of the Dawson River is provided in Section 14.4.

14.1.4.1. Gauged streamflow

This section presents recorded streamflow data at gauge sites along the Dawson River. The gauge data has been used to characterise the current flow regime. The Nathan Dam catchment consists of mainly cleared farming land, where approximately 30% of the catchment is undisturbed. Land clearing, land use change and water resource development have taken place progressively and the impact of this is reflected in the recorded gauge data.

The closest streamflow gauge to the dam site is the Nathan Gorge gauge, approximately 8.1 km downstream of the dam. This gauge recorded daily streamflow data between 1954 and 1986 (with missing data between 1958-1963 and 1975-1978). The streamflow record (Figure 14-3) shows that flow has generally occurred in large pulses, with significant periods of low flow between events. The 25^{th}, 50^{th} and 75^{th} percentile of daily streamflow over the gauge record is 9 ML/d, 39 ML/d and 216 ML/d, while the peak recorded flow was 368,240 ML/d in February 1956. This indicates that there is a large variety in the flow range, although generally flow is quite low.

Due to the high variation in the flow range it is difficult to present a hydrograph which will provide an adequate understanding of the overall flow range, i.e. there are periods of very high and very low flows.

The closest gauging station upstream of the dam is the Glebe Gauge, which is approximately 14.1 km upstream of the dam site. Figure 14-4 shows the gauged annual flow at Glebe from 1920-2002. Glebe Weir was constructed in 1971 and records after this point represent inflows to the weir. The record shows considerable climatic variability, with low annual flows occurring in the 1960's. High flow periods have also occurred, particularly in the mid 1950s and late 1980s.

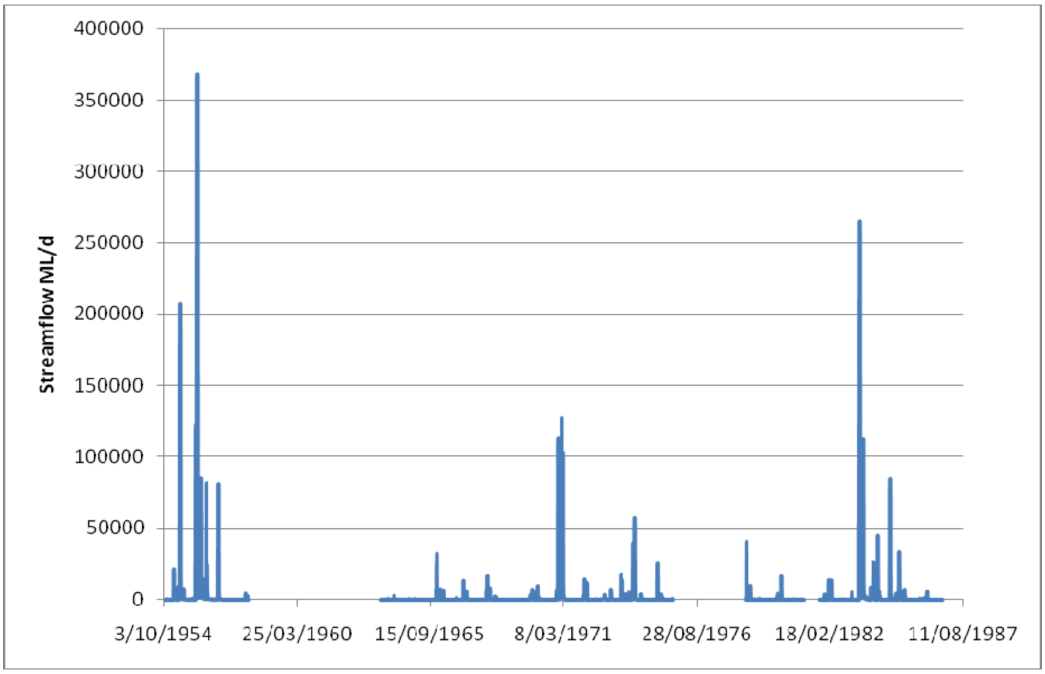


Figure 14-3 Gauged daily flow at Nathan Gorge (GS 130320)

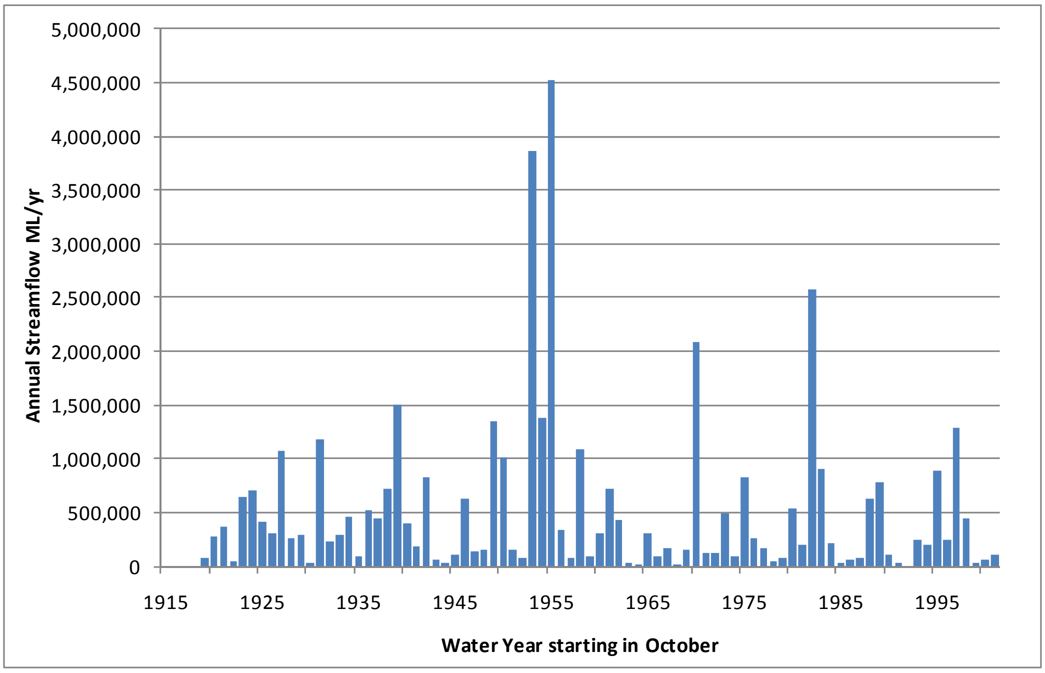


Figure 14-4 Gauged annual flow at Glebe (GS 130303)

Table 14-3 presents annual flow statistics for key gauge sites in the Fitzroy Basin. This table presents a combination of closed and operational gauges. Gauge data is provided by DERM and is generally available up to the last two to three years. More recent data is undergoing processing and is not yet available.

It should be noted that a gauge record may contain periods of missing data and that not all of the gauges cover the same period of time. Some caution should therefore be used when comparing statistics, particularly minimum and maximum values, as periods of extreme weather may differ between the sites.

Table 14-3 Fitzroy catchment gauge flow statistics

River	Location	Gauge no.	AMTD (km)	Period of Record	Mean Annual Flow (ML/a)	Minimum Annual Flow (ML/a)	Maximum Annual Flow (ML/a)	Median Annual Flow (ML/a)
Dawson River	Taroom	130302	384.6	1911-2006	358,920	2,940	2,880,780	204,580
	Glebe	130303	330.1	1919-2002	514,540	0	4,528,170	261,460
	Nathan Gorge	130320	307.2	1954-1986	736,850	3,220	4,574,020	217,000
	Theodore	130305	230.1	1924-2002	621,270	0	4,727,750	310,940
	Beckers	130322	71.0	1964-2006	755,110	500	4,618,250	325,820
	Boolburra	130301	16.1	1910-1978	1,160,260	2,980	5,533,930	838,430
Isaac River	Yatton	130401	43.0	1962-2007	1,980,850	9,970	16,633,300	568,610
Nogoa River	Fairbairn Dam	130216	685.6	1973-2002	212,940	0	1,352,070	0
Mackenzie River	Coolmaringa	130105	376.0	1971-2007	3,526,740	200,460	19,741,360	1,811,580
Fitzroy River	Riverslea	130003	276.0	1922-2007	4,724,360	96,120	23,874,300	2,710,450
	The Gap	130005	142.1	1964-2007	4,316,750	88,170	22,918,060	2,708,440
	Yaamba	130001	108.8	1914-1974	5,185,150	0	36,563,450	2,593,860

Source: DERM (2010) – note that data from years with a significant number of missing days has not been included in this analysis

14.1.4.2. Modelled flow statistics

As the gauge record incorporates a gradual increase in development levels over time, two modelled scenarios are used to assess the overall change from natural conditions. These are the Pre-development and Full Entitlement scenarios (Section 14.1.2.2). Table 14-4 presents the mean annual flow (rounded to the nearest 100) for the Pre-development and Full Entitlement scenarios at the reporting sites discussed in Section 14.1.2.1. The modelling is based on a historic simulation period of 96 years, from 1900 to 1995 (the WRP simulation period), and operates under the assumption of 100% utilisation of current water entitlements (full entitlement modelling). As such, results in Table 14-4 will differ from those presented in Table 14-3.

Table 14-4 Fitzroy catchment modelled flow statistics

River	Location	AMTD (km)	Mean Annual Flow (ML/a)		% Reduction
			Pre-development Scenario	Full Entitlement Scenario	
Dawson River	Nathan Gorge	307.2	571,500	548,700	4%
	D/S Theodore	230.1	664,900	589,600	11%
	Beckers	71.0	1,011,900	895,700	11%
	End of Dawson River	0	1,504,600	1,316,600	12%
Fitzroy River	Eden Bann Weir (inflow)	143.0	5,264,600	4,654,800	12%
	Barrage (inflow)	59.6	5,445,800	4,787,400	12%
	Estuary*	0	5,445,800	4,686,800	14%

*Flows at the Estuary represent freshwater inflows only

The cumulative impacts of development have reduced the mean annual flow in the catchment by 4% to 12%, with generally higher impacts in the lower reaches of the Basin.

Modelled flow duration curves for the reporting sites are presented in Figure 14-5 to Figure 14-11 for both the Pre-development and Full Entitlement scenarios. The flow duration curves demonstrate the percentage of time that the streamflow equals or exceeds a particular discharge during the simulation period. Flow duration curves can be used as an indicator of how flow might be expected to vary at a location over an extended period of time and are useful when comparing the overall changes in flow regime between different scenarios.

The modelled flow duration curves show that the flow regime in the Dawson River is highly impacted by existing water resource development and flow regulation. The most upstream reporting station, Nathan Gorge (Figure 14-5) shows that low flows have been heavily impacted, and that the river regularly experiences periods of no flow under current levels of approved development (Full Entitlement scenario), while under the Pre-development scenario, water was flowing in the river 98% of the time. The change in the low flow regime is primarily due to extraction at Glebe Weir and the fact that environmental flow releases are not made from Glebe Weir, apart from the first post winter flow release. Downstream at Theodore and Beckers the low flow range is better maintained through a combination of Seasonal Baseflow releases, release of orders down the river and the re-supply of downstream weirs (from Theodore) or tributary inflows (Beckers).

Further downstream along the Dawson River all flows, with the exception of infrequent high flow events, have been significantly reduced in the Full Entitlement scenario, as shown in Figure 14-6 and Figure 14-7. In Figure 14-7 at Beckers, the impact of flow regulation can be seen on low flows which are artificially maintained within the river over the simulation period, while in the Pre-development scenario, flows are only present for 86% of the simulation period.

At the downstream end of Dawson River, shown in Figure 14-8, it can be seen that the Full Entitlement scenario is similar to the Pre-development scenario. This is due to inflows from the Don River, which has a relatively undeveloped catchment. This reduces the impact of the development within the Dawson catchment on flows into the Fitzroy River.

Flow duration curves for the Fitzroy River downstream of Dawson River are shown in **Figure 14-9** to **Figure 14-11**, with the Fitzroy End of System flows representing the freshwater flows into the estuary. The flow duration curves presented for the Fitzroy River reflect moderate levels of impact, although a high degree of regulation is evident in the low flow range at Eden Bann Weir and at the end of the Fitzroy River. This is primarily due to the extractions from the water storages and the influence of local waterharvesters.

Figure 14-11 shows a significant step in the flow duration curve calculated at the end of the Fitzroy River due to the influence of the Barrage fish ladder operations. The fish ladder is operational when the storage volume is greater than 73122 ML, releasing 18 ML/d down the fish ladder. This creates the flat tail of the flow duration curve.

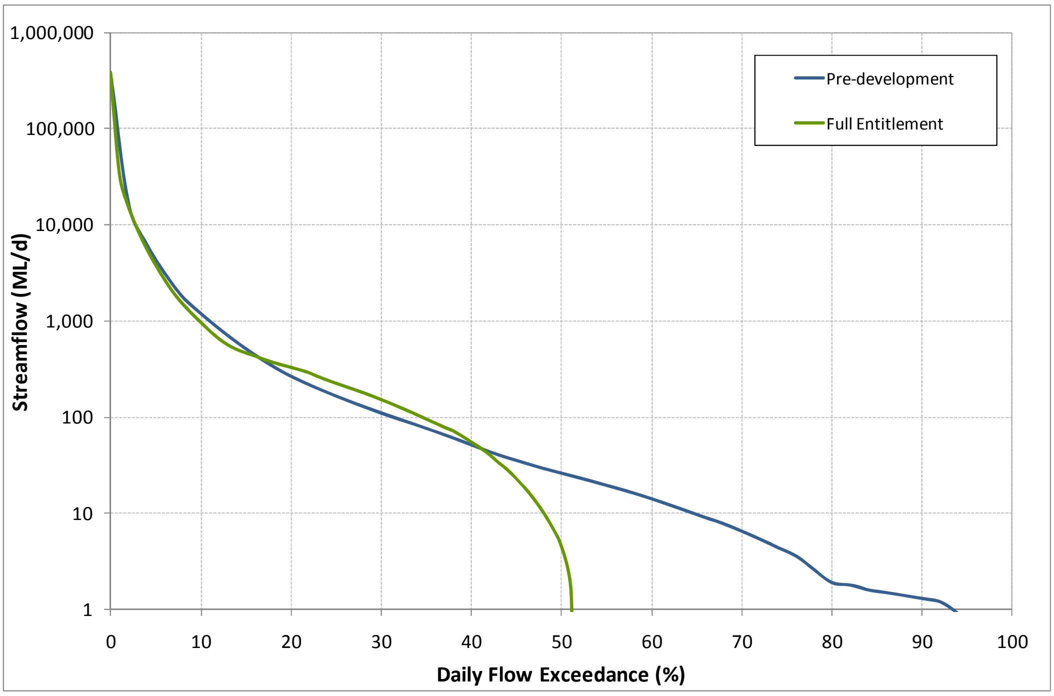


Figure 14-5 Dawson River at Nathan Gorge daily flow duration curve

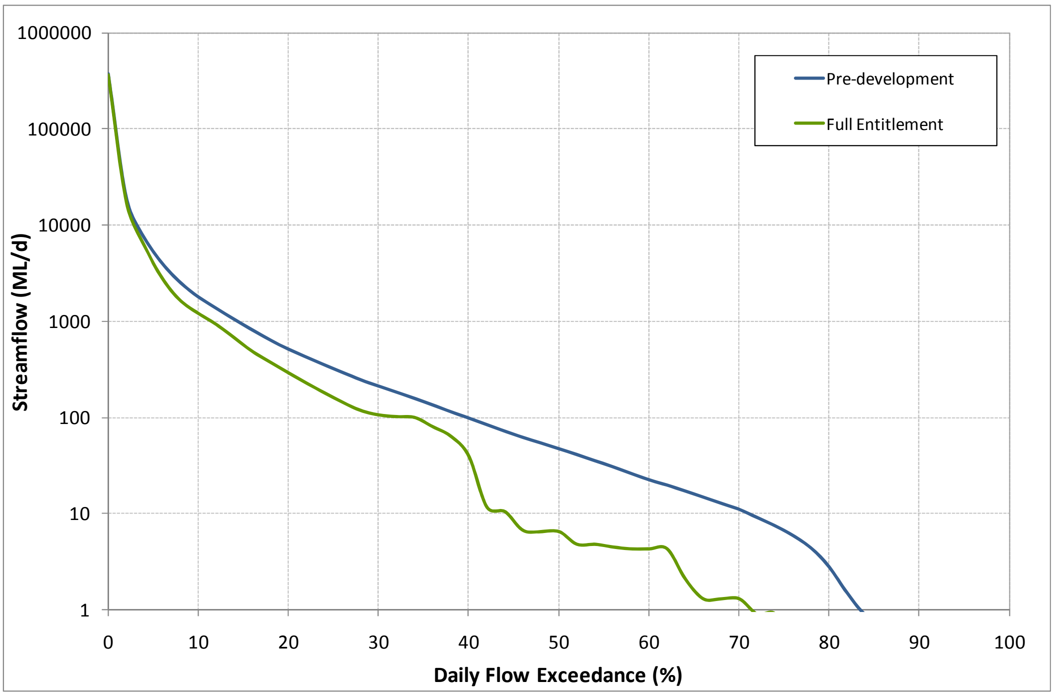


Figure 14-6 Dawson River D/S Theodore daily flow duration curve

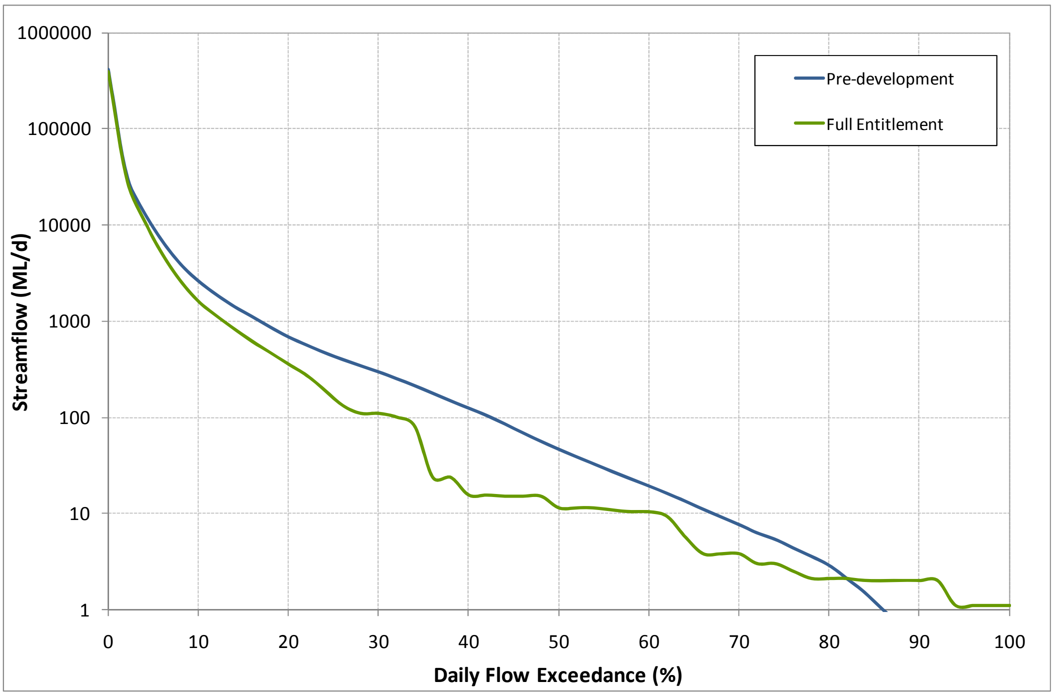


Figure 14-7 Dawson River at Beckers daily flow duration curve

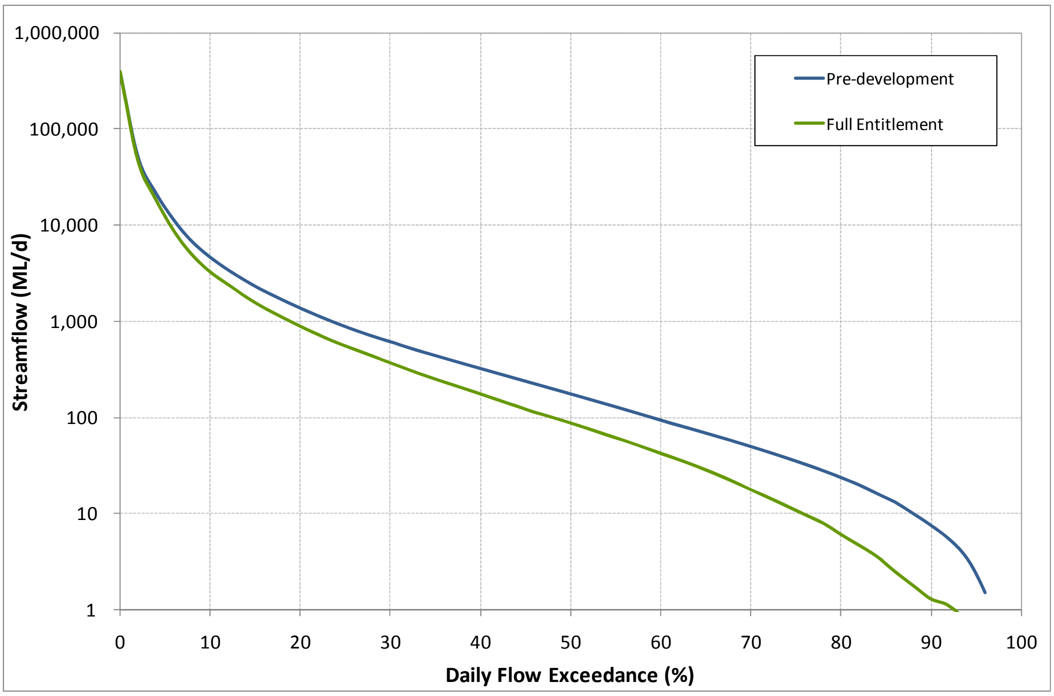


Figure 14-8 End of Dawson River flow duration curve

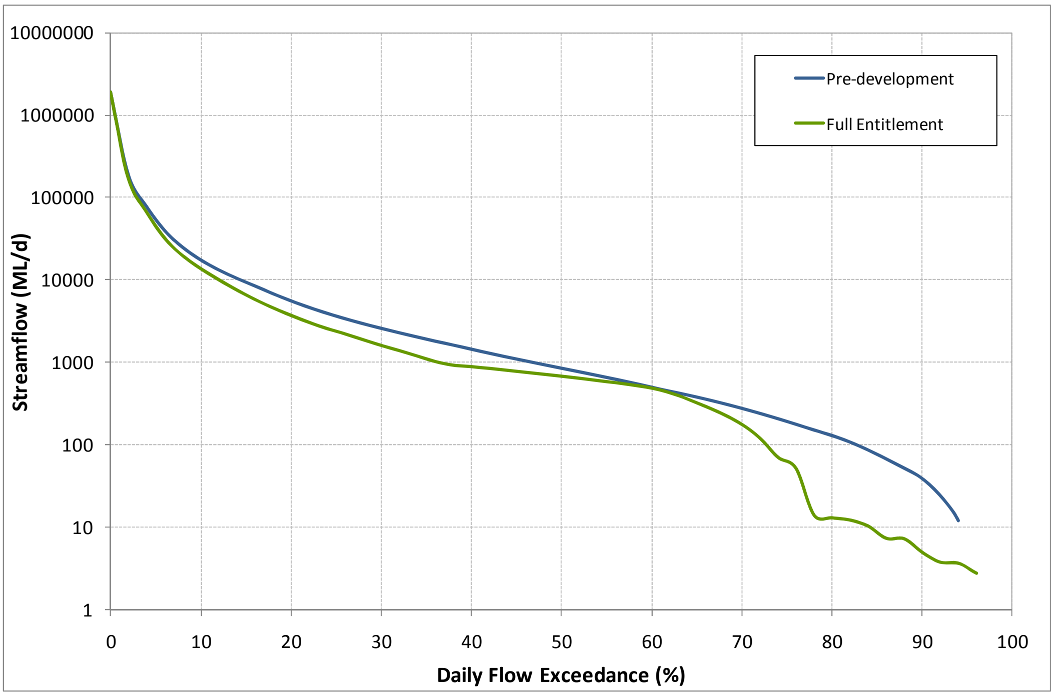


Figure 14-9 Fitzroy River inflow to Eden Bann Weir daily flow duration curve

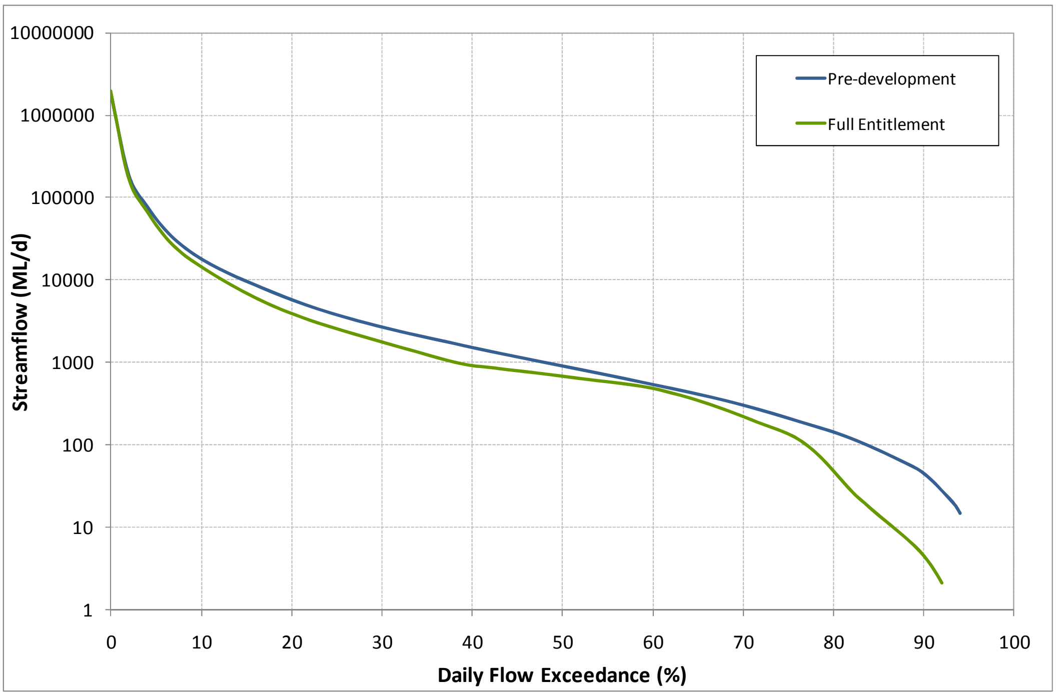


Figure 14-10 Fitzroy River inflow to Barrage daily flow duration curve

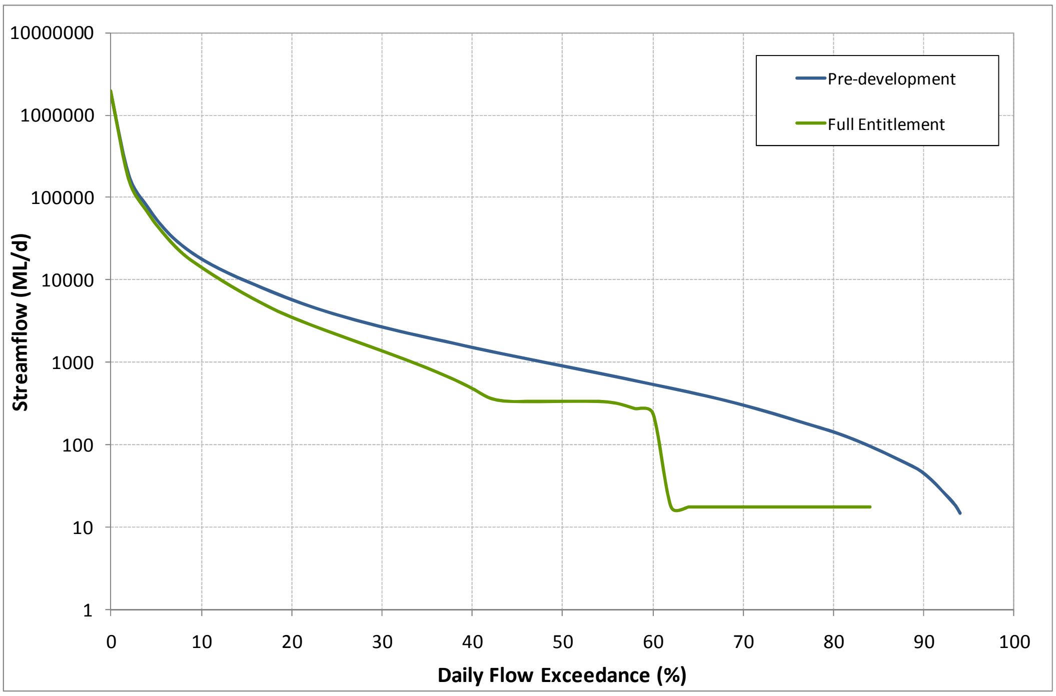


Figure 14-11 Fitzroy River at end of system daily flow duration curve

14.1.4.3. *Environmental flow objectives*

The impact of the current levels of water resources development on key flow statistics was assessed against the WRP EFOs; seasonal baseflow, first post winter flow and medium to high flows.

Reporting against WRP EFOs has been presented using the colour coding in Table 14-5.

Table 14-5 Colour code for model results

Colour Code	Description
(dark green)	All WRP Objectives Achieved
(light green)	WRP Mandatory Objectives achieved – but Non-Mandatory Objectives not Achieved
(red)	WRP Mandatory Objectives failed
(grey)	Not applicable

Assessments were made at the following WRP reporting nodes:

- Dawson River at Nathan Gorge – WRP node 5A;
- Dawson River at Theodore– WRP node 4;
- Dawson River at Beckers – WRP node 2;
- Fitzroy River at Eden Bann Weir – WRP node 1; and
- Fitzroy River at Barrage – WRP node 0.

Table 14-6 presents the seasonal baseflow results (non-mandatory) for the Full Entitlement scenario, under existing development conditions. This shows that the base flow objective is not met in September to December for node 2 (Dawson River at Beckers) and node 0 (Fitzroy River at Barrage).

Table 14-7 presents the first post winter flow event performance indicators (mandatory), for the existing management scheme (upper and lower sub-schemes, with existing development). The performance indicators are achieved at all locations.

Table 14-8 and Table 14-9 present the mandatory and non-mandatory medium to high flow event objectives for the Dawson and Fitzroy River WRP nodes 2 and 0, respectively for the existing management scheme. All medium to high flow event objectives are met at both locations.

Table 14-6 Non-mandatory seasonal base flow results for the Full Entitlement scenario

Node	Location	Seasonal Base Flow performance indicator objective target (Optional)	Seasonal Base Flow Performance Indicator Objective		
			Jan – April	May – Aug	Sep - Dec
5A	Dawson River at Nathan Gorge	0.8-1.2	0.9	0.9	1.2
4	Dawson River at Theodore	0.8-1.2	0.8	0.9	0.9
2	Dawson River at Beckers	0.8-1.2	0.8	0.8	0.7
1	Fitzroy River at Eden Bann Weir	0.8-1.2	0.9	1.0	0.9
0	Fitzroy River at Barrage	0.8-1.2	0.9	0.8	0.7

Table 14-7 Mandatory first post-winter flow event performance indicators for the Full Entitlement scenario

Performance Indicator for FPWF objective	Mandatory Values	Dawson River			Fitzroy River	
		Node 5A (Nathan Gorge)	Node 4 (Theodore)	Node 2 (Beckers)	Node 1 (Eden Bann Weir)	Node 0 (Barrage)
Number of first post-winter flows	≥ 80%	92%	89%	92%	96%	94%
Number of flows within 2 weeks of predevelopment event	≥ 50%	71%	66%	73%	66%	63%
Number of flows within 4 weeks of predevelopment event	≥ 70%	73%	70%	81%	76%	74%
Average flow volume	≥ 70%	-	-	-	-	89%
Average peak flow	≥ 70%	90%	81%	85%	80%	-
Flow Duration (2 times base flow)	≥ 70%	92%	87%	86%	95%	94%
Flow Duration (5 times base flow)	≥ 70%	91%	84%	80%	84%	92%

Table 14-8 Mandatory and non-mandatory medium to high flow event objectives for Dawson River for the Full Entitlement scenario

Performance Indicator for medium to high flow objective	Non-Mandatory Values	Mandatory Values	Dawson River		
			Node 5A (Nathan Gorge)	Node 4 (Theodore)	Node 2 (Beckers)
Mean Annual Flow	≥ 74%	≥ 69%	Not Applicable		88%
Median Annual Flow	≥ 50%	≥ 50%			80%
Floodplain zone statistics	≥ 70%	≥ 69%			84%
Upper Riparian zone statistic or Bank full statistic	≥ 85%	≥ 80%			91%
In-Channel riparian zone statistic	≥ 75%	≥ 75%			86%
Channel Morphology statistic	≥ 65%	≥ 60%			81
Fish species diversity statistic (APFD)	≤ 3	≤ 3			1.0

Table 14-9 Mandatory and non-mandatory medium to high flow event objectives for Fitzroy River for the Full Entitlement scenario

Performance Indicator for medium to high flow objective	Non-Mandatory Values	Mandatory Values	Fitzroy River	
			Node 1 (Eden Bann Weir)	Node 0 (Barrage)
Mean Annual Flow	≥ 74%	≥ 77%	Not Applicable	86%
Median Annual Flow	≥ 50%	≥ 50%		74%
Marine and Estuarine Process Statistic	-	≥ 80%		90%
Floodplain zone statistics	≥ 70%	≥ 70%		75%
Upper Riparian zone statistic or Bank full statistic	≥ 85%	≥ 80%		85%
In-Channel riparian zone statistic	≥ 75%	≥ 75%		84%
Channel Morphology statistic	≥ 65%	≥ 65%		85%
Fish species diversity statistic (APFD)	≤ 3	≤ 3		2.1

14.1.5. Flooding

This section describes historical flooding in the Fitzroy Basin and the upper Dawson River catchment, including peak levels and flood frequency. It also presents modelled flood levels at key locations for a range of events for the existing environment.

14.1.5.1. Historical flooding - regional

Flooding in the Fitzroy region typically occurs in summer or early autumn, in association with tropical cyclones or intense monsoonal depressions. These weather systems can produce very high rainfall over a short period of time.

Due to the size of the catchment and each of its major tributaries the Fitzroy Basin frequently experiences flooding following high rainfall events, particularly in the lower catchment. Major floods in the Lower Fitzroy can result from rainfall events occurring in either the Dawson or the Connors-Mackenzie catchments, although flooding in the Rockhampton area can also occur from heavy rainfall in the local area below Riverslea (BoM, 2010).

The Lower Fitzroy is partly protected from flooding by “The Gap”, a narrow valley above Eden Bann Weir. This area constricts downstream flood flows, acting as a detention basin with flood waters backing up behind The Gap to form a large lake.

The Bureau of Meteorology (BoM) holds flood records for the Fitzroy Basin dating back to the mid 1800s. At the Rockhampton gauge (GS 130910) flood records begin in 1859, with the highest recorded flood occurring in January 1918 and reaching 10.11 metres gauge height. Flooding in January 2011 reached a peak of approximately 9.20 m at Rockhampton, while flooding in February 2008 reached 7.50 m.

The Bureau of Meteorology (2009) defines the severity of flooding according to the impacts to the local area or directly downstream. Major flooding is defined as flooding which inundates a large area, isolating towns and cities, disrupting transport corridors and potentially causing the evacuation of properties. Moderate flooding inundates low lying areas and may require the evacuation of stock and properties. Minor flooding causes the closure of minor roads and low level bridges.

Figure 14-12 shows the annual flood peaks at the Rockhampton gauge for the past 150 years (note that this figure does not include the 2011 flood event).

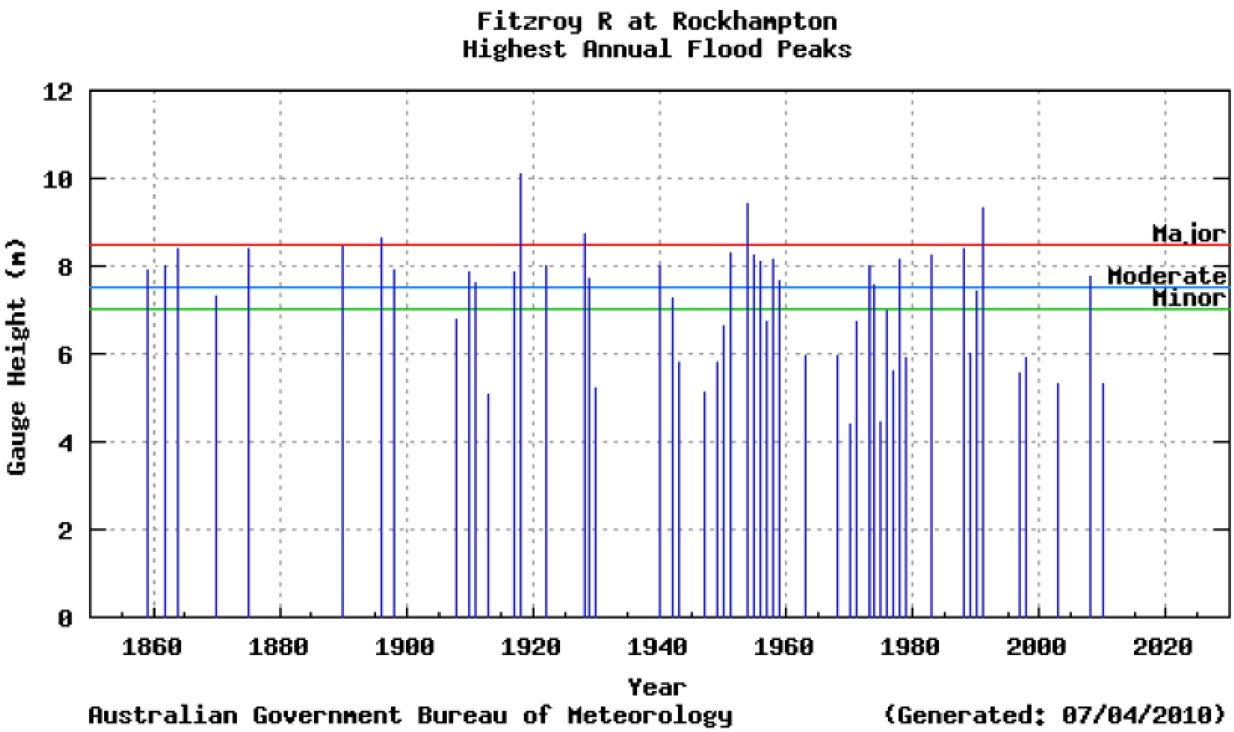


Figure 14-12 Annual flood peaks – Fitzroy River at Rockhampton (BoM, 2010)

Figure 14-13 and Figure 14-14 show the peak annual flows at the Taroom and Theodore gauges, upstream and downstream of the dam site (DERM, 2010; BoM, 2010). The peak annual flows for Beckers Gauge (one of the streamflow reporting sites) are shown in Figure 14-15. These records capture the majority of significant flood events that have occurred in the catchment. The major, moderate and minor flood levels are shown for each site. It can be seen from Figure 14-13 that almost 50% of floods recorded at Taroom have been classified as a major flood.

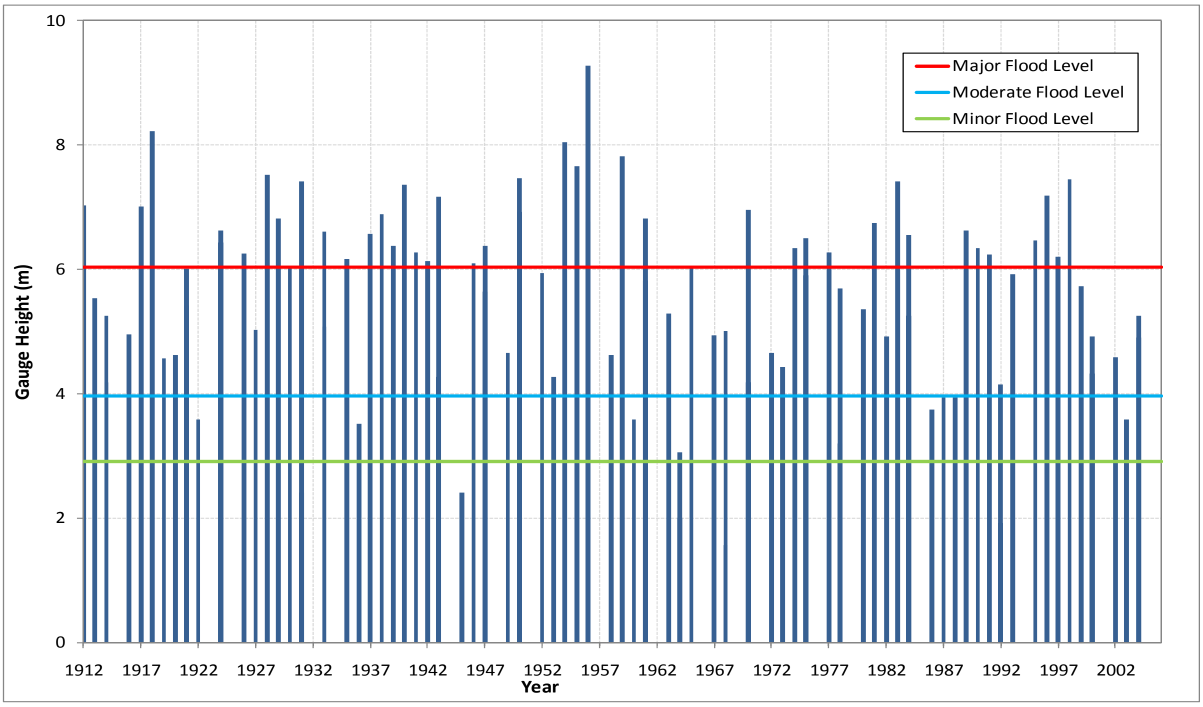


Figure 14-13 Annual flood peaks – Dawson River at Taroom Gauge (GS 130302)

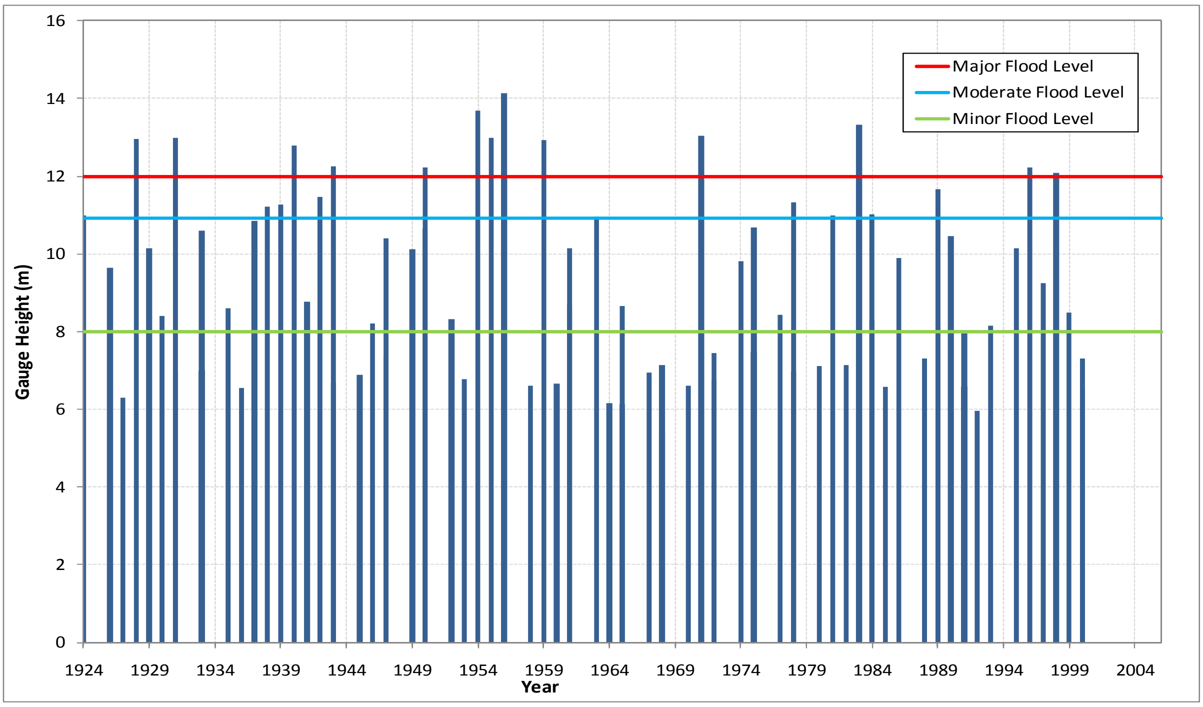


Figure 14-14 Annual flood peaks – Dawson River at Theodore Gauge (GS 130305)

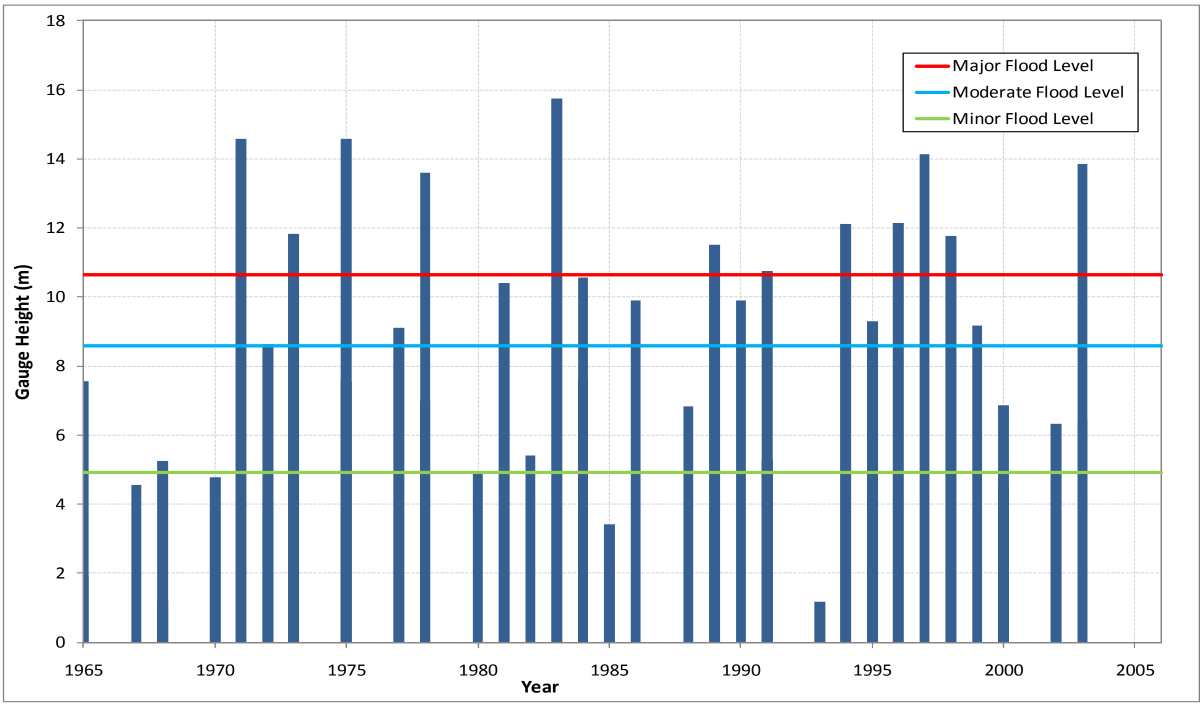


Figure 14-15 Annual flood Peaks - Dawson River at Beckers Gauge (GS 130322)

Figure 14-16 to Figure 14-19 show recorded flood hydrographs for the January-February 2010 tropical cyclone Olga, which resulted in flooding across the Fitzroy catchment (BoM, 2010b). These figures present hydrographs for the Dawson River, at Taroom, Woodleigh (downstream of Theodore), Beckers and Newlands (downstream of the Don River confluence). The hydrographs show the recorded rainfall and river level at the gauge over a period of weeks.

The catchment upstream of the Taroom gauge is quite large, and while no rainfall was recorded at the Taroom gauge during this event, the river level recorded a major flood generated from rainfall in the upper catchment. This flood peak is seen to travel through all of the gauges downstream of Taroom, with localised rainfall contributing to the flood level at some locations. The hydrographs along the Dawson River show a slow mitigated response to rainfall, indicating that the catchment may have high initial losses during rainfall events.

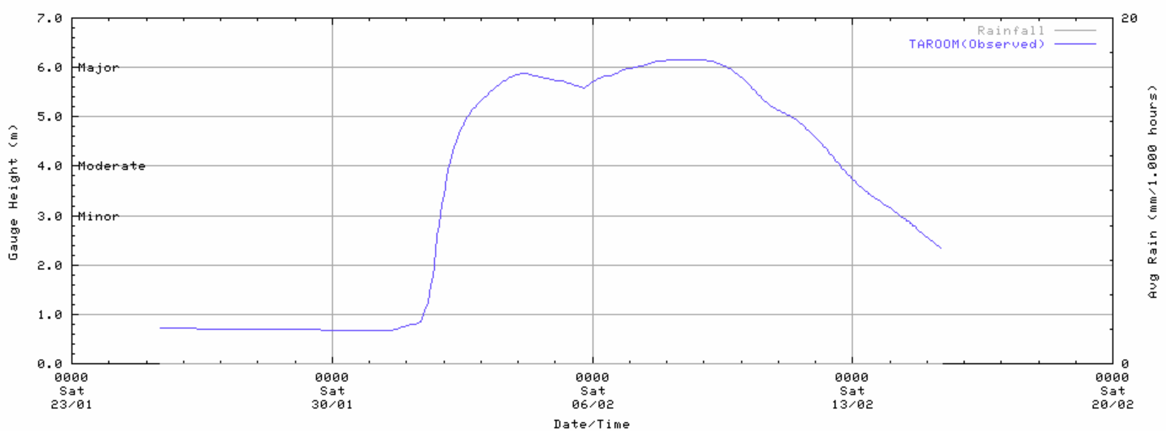


Figure 14-16 January 2010 flood hydrograph – Dawson River at Taroom (BoM, 2010b)

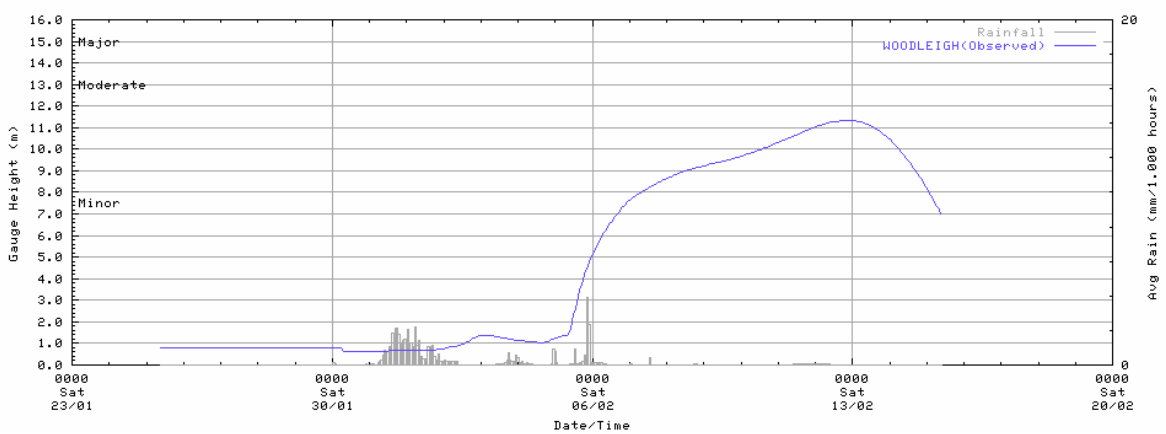


Figure 14-17 January 2010 flood hydrograph – Dawson River at Woodleigh (BoM, 2010b)

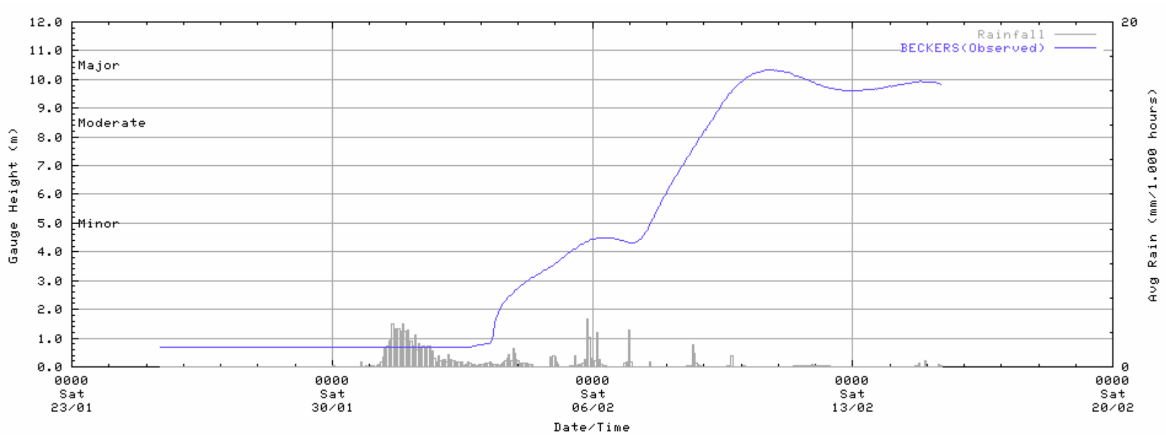


Figure 14-18 January 2010 flood hydrograph – Dawson River at Beckers (BoM, 2010b)

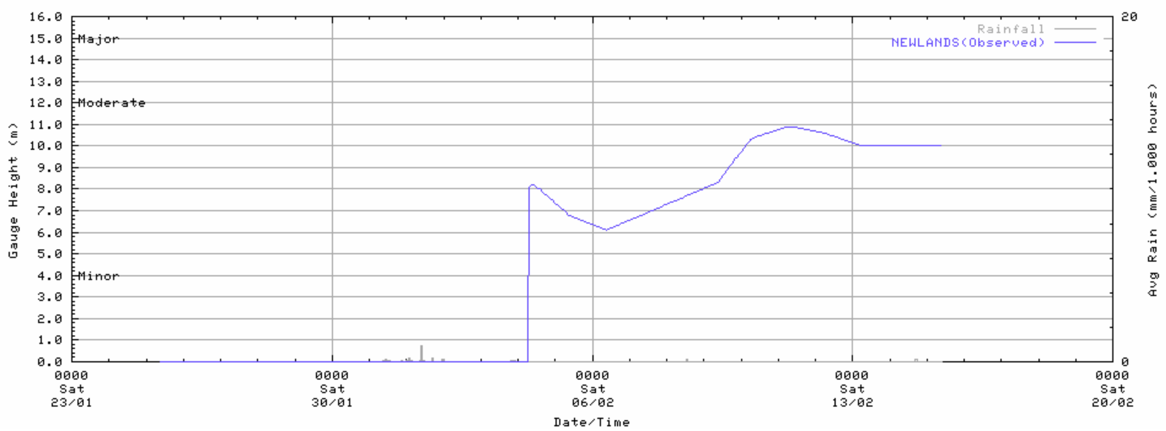


Figure 14-19 January 2010 flood hydrograph - Dawson River at Newlands (BoM, 2010b)

Table 14-10 presents the peak flood depth across the Fitzroy Basin during the seven major flood events which have occurred in the past century. Figures are for flood depth at the gauge site.

Table 14-10 Historic flood depth (gauge height) in the Fitzroy Basin (m) (BoM, 2010)

River	River Height Station	Flood Event						
		Jan 1918	Feb 1954	Jan/Feb 1978	May 1983	Jan 1991	Jan 2008	Feb 2008
Funnel Creek	Waitara	-	10.67	11.90	7.35	13.60	11.10	10.10
Connors River	Connors Junction	-	-	15.98	13.75	17.30	-	-
	Cardowan	-	17.37	16.38	9.95	17.10	14.80	15.05
Nogoa River	Emerald	-	14.12	12.97	12.00	-	15.36	-
Mackenzie River	Yakcam	-	-	23.15	20.12	13.80	20.55	12.83
	Bingegang	-	-	17.23	16.0	12.35	15.80	8.55
	Tartrus	-	17.48	16.60	14.90	18.10	16.20	15.69
Dawson River	Taroom	6.71	8.15	4.08	7.46	6.24	6.07	3.85
	Theodore	-	13.64	11.27	13.24	7.98	-	-
	Moura	-	-	10.46	12.09	6.60	8.00	-
	Baralaba	-	15.52	2.68	4.60	9.45	-	-
	Newlands	-	18.16	16.28	14.63	15.29	9.05	6.55
Mimosa Creek	Karamea	-	10.26	8.10	9.98	9.12	-	-
Don River	Rannes	-	8.28	10.17	9.60	9.55	-	6.45
Fitzroy River	Riverslea	31.48	28.60	23.15	22.89	27.97	21.93	21.68
	Yaamba	17.32	16.59	14.75	14.97	16.65	14.25	14.15
	Rockhampton	10.11	9.40	8.15	8.25	9.30	7.50	7.75

14.1.5.2. Historical flooding - local

SunWater has undertaken flood assessments of the dam, including areas upstream and downstream of the dam wall. This included hydrologic analysis and modelling of the Nathan Dam catchment and hydraulic modelling of the area surrounding the dam site. These investigations are reported in the following:

- Nathan Dam – Design Flood Hydrology (2008); and
- Nathan Dam Preliminary Design – Hydraulic Modelling Study (2010).

For these studies, local flooding was assessed at key sites along the Dawson River; including Taroom, Theodore, Glebe and Beckers gauging stations.

Recorded peak gauge heights and peak flows on the Dawson River are presented in Table 14-11. It should be noted that the flood levels presented in Table 14-10 and Table 14-11 may differ slightly as they are derived from different gauges (i.e. BoM flood gauge or DERM streamflow gauge) and may include slight differences due to location or instrumentation. The DERM gauge data is adopted for analysis of peak discharge.

Table 14-11 Recorded peak flood gauge heights and flows in the Dawson River (DERM, 2010)

Event	Taroom Gauge		Theodore Gauge		Beckers Gauge	
	Peak Gauge Height (m)	Peak Flow (m^3/s)	Peak Gauge Height (m)	Peak Flow (m^3/s)	Peak Gauge Height (m)	Peak Flow (m^3/s)
Feb 1954	8.05	1,990	13.68	3,030	-	-
Feb 1956	9.27	3,920	14.14	4,250	-	-
May 1983	7.42	1,730	13.33	2,200	15.75	3,130
Jan/Feb 1991	6.24	720	7.95	310	10.74	840

Flood frequency analyses were undertaken from streamflow records at key gauging stations, with record lengths between 70 and 90 years. The flood frequency analyses indicated that the 1956 flood, the largest on record (at the time of the assessment) was estimated to be between a 1 in 100 and 1 in 150 Annual Exceedance Probability (AEP) event (SunWater, 2010c). A summary of the flood frequency analyses is presented in Table 14-12.

Table 14-12 Dawson River flood frequency analyses (SunWater, 2008)

AEP (1: …)	Peak Flow (m^3/s)		
	Taroom	Glebe	Theodore
5	1,000	1,300	1,200
10	1,400	1,800	1,700
20	1,800	2,400	2,200
50	2,400	3,600	3,200
100	3,000	4,700	4,000

The January 2011 flood event peaked at 14.7 m at Theodore (BoM, 2011), exceeding the 1956 record. Due to the timing of this event and the availability of data from the event it has not been incorporated in the flood frequency analyses discussed above. However, recent flooding will be incorporated into future flood modelling, undertaken for the detailed design phased of the Project.

14.1.5.3. Design flooding

Table 14-13 presents the adopted design flood flows on the Dawson River at the dam site for a range flood events. These flows give an indication of the size of existing floods at the dam site, which can be used to understand the potential flood operations of the dam. The 1 in 100 AEP flood level generated by these flows is used to determine the location of infrastructure and for land acquisition purposes.

Table 14-13 Design flow estimates – Nathan Dam site (pre-dam) (SunWater, 2010c)

AEP (1: …)	Critical Duration (hr)	Peak Flow (m^3/s)
5	12	1,490
10	72	1,890
20	72	2,520
50	72	3,040
100	72	3,670
PMPDF	120	20,800

Table 14-13 also presents an estimate for the Probable Maximum Precipitation Design Flood (PMPDF), this is an extremely rare flood event and is the largest flood that can reasonably be expected to occur. The notional AEP of the PMP at the dam site is 1 in 43,000. The critical duration of the design storms generally ranged from 12 to 72 hours, while the PMPDF had a critical duration of 120 hours.

The estimation of the Probable Maximum Flood (PMF) is conducted as part of the dam safety assessment. This is used to determine the size of the spillway required in order to meet Queensland Dam Safety and ANCOLD guidelines. As a result of the design standards adopted and the standards of construction and maintenance required under the Queensland Dam Safety Regulations, the risk of failure of dam and subsequent loss of life will be very low.

14.1.6. Current water resource development

This section describes the current levels of water resource development in the Dawson catchment, including existing water users, storages, water products and supply schemes.

14.1.6.1. Existing water storages

The storages within the Fitzroy Basin are detailed in Table 14-14.

Approximately 10.9 km upstream of the Project site there is an existing storage, Glebe Weir, which has a full supply volume of 17,700 ML. This weir will be submerged once the dam is completed. There are no instream storages upstream of Glebe Weir, although there are multiple small storages along the Dawson River downstream of the Project site, as detailed in Table 14-14.

Table 14-14 Existing water storages in the Fitzroy Basin

Sub-catchment	Structure	River	AMTD	Full Supply Volume (ML)	Dead Storage Volume (ML)	Length of River Inundated (km)
Isaac Connors	Burton Gorge Dam	Isaac River	280.3	19,264	1,926	
	Teviot Creek Dam	Teviot Creek	31.0	24,000	2,400	
Dawson	Glebe Weir	Dawson River	326.2	17,700	430	30.3
	Gyranda Weir	Dawson River	284.5	16,500	2,120	26.5
	Orange Creek Weir	Dawson River	270.7	6,140	2,320	13.8
	Theodore Weir	Dawson River	228.5	4,760	750	16.0
	Moura Offstream Storage	Dawson River	156.9	2,820	140	NA
	Moura Weir	Dawson River	150.2	7,700	600	12.6
	Neville Hewitt Weir	Dawson River	82.7	11,300	2,120	30.3
Nogoa Mackenzie	Fairbairn Dam	Nogoa River	685.6	1,301,000	12,300	51.9
	Selma Weir	Nogoa River	668.7	1,180	25	11.3
	Bedford Weir	Mackenzie River	548.8	22,900	3,290	43.3
	Bingegang Weir	Mackenzie River	489.2	8,060	1,400	28.2
	Tartrus Weir	Mackenzie River	429.5	12,000	2,530	33.5
	Theresa Creek Dam	Theresa Creek	112.8	9,735	500	
Callide	Callide Dam	Callide Creek	80.1	136,370	2,880	
	Callide Weir	Callide Creek	61.1	506	6	
	Kroombit Dam	Kroombit Creek	68.8	14,600	30	
Fitzroy	Eden Bann Weir	Fitzroy River	143.0	35,900	9,650	42.2
	Fitzroy Barrage	Fitzroy River	59.6	81,300	21,900	65.9

14.1.6.2. Existing operations

Within the Fitzroy Basin, supplemented water is delivered through five water supply schemes; these are described in **Table 14-15**, and shown in **Figure 14-20**. Unsupplemented water is accessed during high stream flow conditions (waterharvesting) within the Dawson Valley Water Management Area.

Table 14-15 Fitzroy Basin supplemented water supply schemes (DNRW, 2008 & 2009)

Water Supply Scheme	Operator	ROP/iROL	Water Allocation/ Interim Water Allocation (ML/yr)		
			High Priority	Medium Priority	Medium Priority A
Dawson Valley	SunWater	Fitzroy ROP	5,579	36,797	19,456
Nogoa Mackenzie	SunWater	Fitzroy ROP	44,398	190,925	-
Callide Valley	SunWater	iROL	4,311	443	-
Lower Fitzroy	SunWater	Fitzroy ROP	25,520	3,101	-
Fitzroy Barrage	Fitzroy River Water	Fitzroy ROP	50,483	11,610	-

The dam will form part of the Dawson Valley Water Supply Scheme. This Scheme is currently operated by SunWater under a Resource Operations Licence (ROL) issued by DERM.

The current Dawson Valley Water Supply Scheme extends 338 km along the Dawson River from the upstream limit of Glebe Weir to the downstream limit of the Boolburra waterhole, approximately 18 km upstream of the Fitzroy River junction (DNRW, 2009). This water supply scheme has been divided into two sub-schemes;

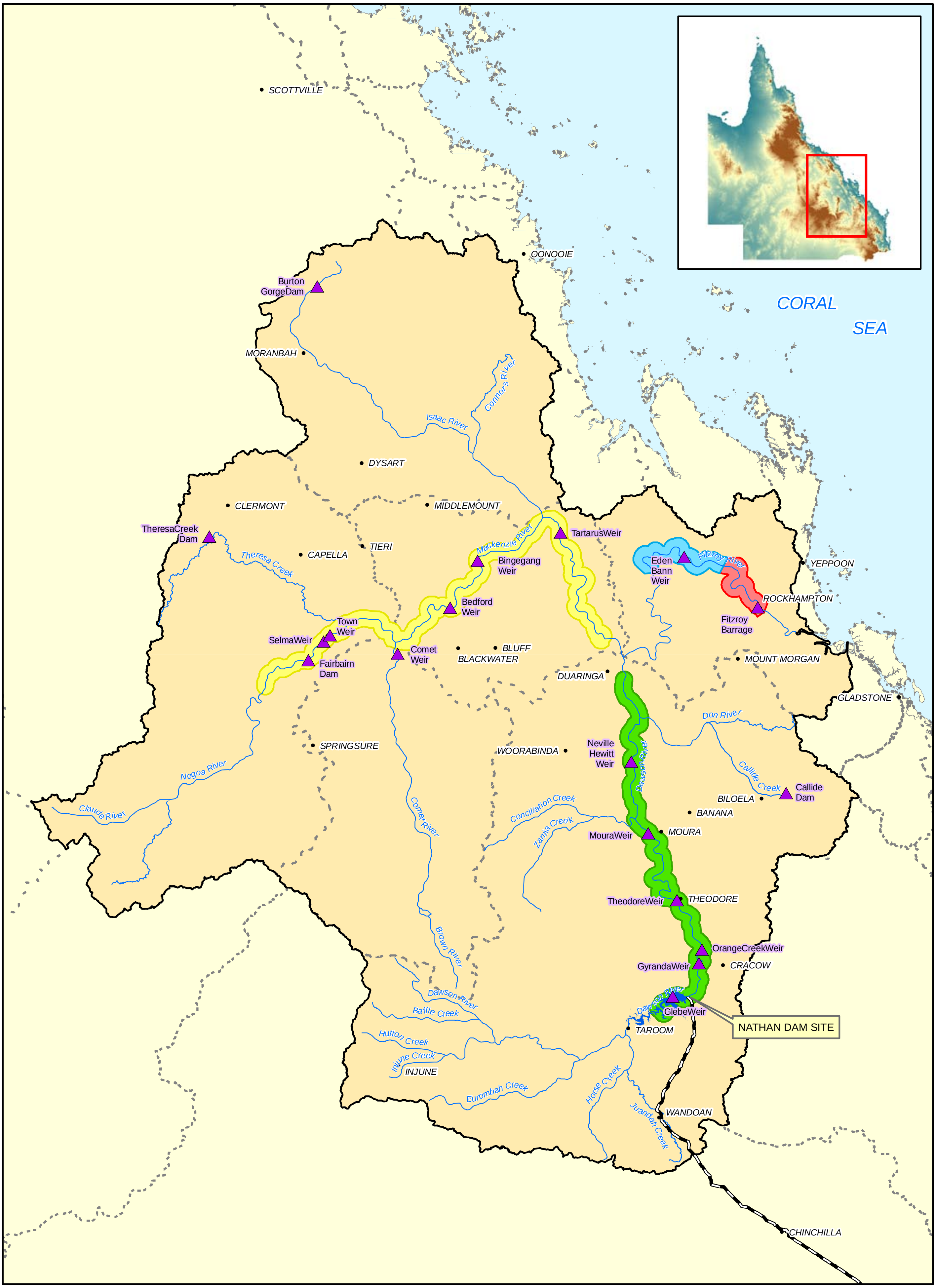
- the upper Dawson sub-scheme, from the Glebe weir, Gyranda, Orange Creek, Theodore, Moura weirs, and Moura Offstream Storage to the upstream limit of Neville Hewitt weir; and
- the lower Dawson sub-scheme, from the upstream limit of the Neville Hewitt weir to the downstream end of the Boolburra waterhole.

The two sub schemes are currently operated independently. Releases are not made from storages in the upper sub-scheme to supply water orders or maintain storage levels in the lower sub-scheme.

The Dawson River, downstream of Glebe Weir, is a highly regulated river, as demonstrated by the flow duration curves in Figure 14-6 and Figure 14-7. The regulated reach covers a total length of 338.1 km with the total impounded extent from existing storages is 138.5 km, or approximately 41% of the regulated reach. With the dam in place this will increase to 49% of the regulated reach.

The upper Dawson River, above the upstream limit of Glebe Weir, is unregulated and is approximately 270 km long. The river rises in the Carnarvon Range, on the other side of the range from the headwaters of the Comet River.

The Dawson Valley Water Management Area extends 356 km from the Glebe Weir to the Fitzroy River Junction. This management area overlaps the Dawson Valley Water Supply Scheme.



LEGEND

- Town
- Weir Locations
- Proposed Pipeline
- Major Watercourses
- Full Supply Level (185.3 m AHD)
- Fitzroy Basin
- Catchment Boundaries

Supplemented Water Supply Scheme

- Nogoa Mackenzie
- Dawson Valley
- Lower Fitzroy
- Fitzroy Barrage

Projection: GDA94

Figure 14-20

0 20 40 80
Kilometres
N

Scale 1:3,000,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Fitzroy Basin supplemented water supply schemes

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14.1.6.3. Existing water users

While existing water use in the Dawson catchment is dominated by irrigated agriculture and stock and domestic supplies, there is also demand to meet urban town water supply, power generation and large scale industrial and mining requirements (DNRW, 2006).

The *Central Queensland Small Communities Water Study: Community Demands Report* (PB, 2008) identified a significant demand for future urban water supplies within the Dawson River catchment. Many communities in this region are currently, or have recently been, under water stress and cannot expand without further water supplies. Water demand in the region is primarily driven by the population growth associated with new mining activity.

Within the Dawson River catchment Taroom is the largest town, with a current population of approximately 700. Taroom and the other smaller towns in the region are detailed in Table 14-16. This table details the projected 2010 and 2050 population from 2001 census data, with the reported annual water usage for 2005/2006 and the projected increase in demand required to meet the projected growth in population. It should be noted that the Wandoan Coal Mine project was not included in the future demand assessment as there was some uncertainty of it proceeding at the time of assessment (PB, 2008).

Table 14-16 Existing and projected town water use in the Dawson River catchment

Town	Primary Water Supply Source	Existing (2006)		Projected 2010		Projected 2050	
		Population	Annual Demand (ML/a)	Population	Annual Demand (ML/a)	Population	Annual Demand (ML/a)
Wandoan	Juandah Creek, Great Artesian Basin	443	173	462	180	611	238
Taroom	Dawson River, Great Artesian Basin	662	219	703	232	1,046	346
Theodore Moura Banana Baralaba	Dawson Valley Water Supply Scheme: ▪ Theodore Weir ▪ Moura Weir ▪ Neville Hewitt Weir	3,174	1,220	3,436	1,493	6,484	2,858

Source: PB (2008)

The towns of Taroom and Wandoan have two independent water supply sources (surface water and groundwater), so water supply to these towns is considered to be low risk. The report identified that the towns of Banana, Baralaba, Moura and Theodore are rapidly expanding, and that they are currently using their full allocations with no spare entitlements to provide for growth. It was noted that the Dawson Valley Water Supply Scheme can be unreliable during prolonged droughts when high priority water is restricted, and medium priority water is not available (PB, 2008). At the time of the future demand assessment, Banana Shire Council had been unsuccessful in attempts to secure an additional high priority allocation of 400 ML/a for towns within the DVWSS (PB, 2008). The projected demand for this group of towns is an additional 100 ML every four years and is shown in Figure 14-21.

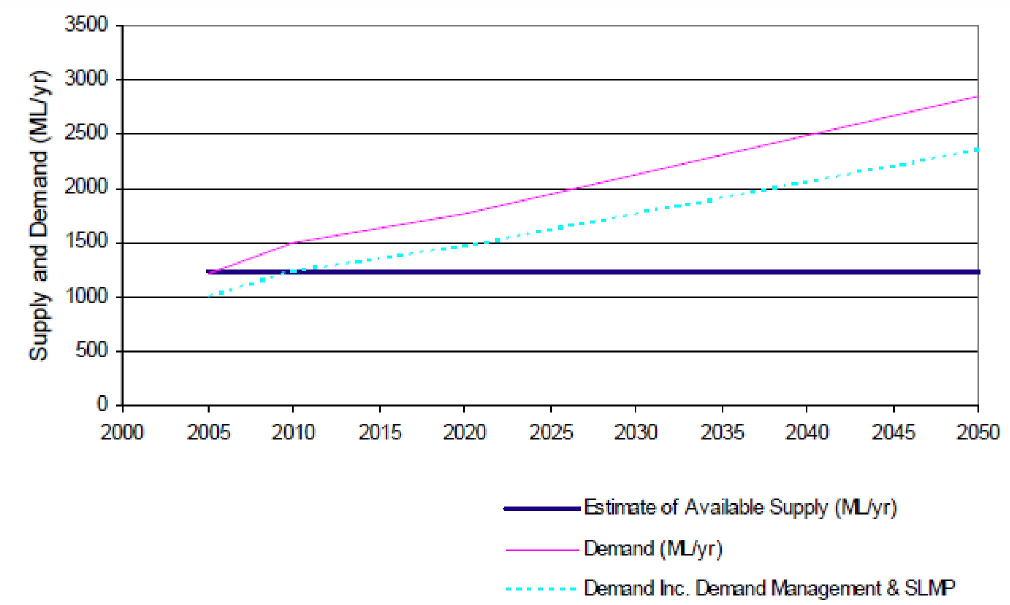


Figure 14-21 Banana, Baralaba, Moura and Theodore demand projections (PB, 2008)

(n.b. SLMP stands for system leakage management plan)

In addition to this study, Sunwater commissioned Psi-Delta to do a market demand survey targeting SunWater customers and existing allocation holders. The projections from this study were similar with a predicted requirement of 1,900 ML/a for Western Downs Regional Council and 1,100 ML/a for the Banana Shire Council. Further information on this study is provided in Section 1.3.2.2.

Apart from the water associated with the dam, there is an allowance within the ROP for the release of an additional 11,500 ML of mean annual diversions from the upper Dawson River to support future development within the catchment. This water would be based on unsupplemented flows, which are highly seasonal and irregular, and would provide a low reliability of supply (DNRW, 2008).

14.1.6.4. Current access to water resources

Water resources within the catchment are accessed by a range of different users, for a variety of purposes. This includes urban (town water supply), industrial, irrigation, and stock and domestic use.

Water products are available as either supplemented or unsupplemented water entitlements. Supplemented water entitlement holders are supplied with water from water storages. Unsupplemented water entitlement holders access river flow on an opportunistic basis. Supplemented water is available in the Dawson catchment as either high priority, medium priority or medium priority A. These products have different associated levels of security of supply. Access to water can be measured against the WASOs, or in the case where these are not applicable the mean annual diversion (MAD) may be adopted as in indicator.

The WRP specifies WASOs for supplemented users in the Dawson Valley, Nogoa Mackenzie, Lower Fitzroy and Fitzroy Barrage Water Supply Schemes and for unsupplemented users in the Nogoa Mackenzie and Fitzroy Water Management Areas and for sections of the Comet River and Dawson River.

For supplemented users in the Dawson River and Lower Fitzroy the WRP specifies a median monthly reliability of 95-100% for high priority users and 82-88% for medium A and medium priority users (although the ROP maintains a 20% differential of announced allocations for medium priority A).

There are three performance indicators specified for unsupplemented water, these focus on the number of days of water harvesting opportunity, as follows:

- 30th Percentile Year – the number of days that water would have been taken in the 30th percentile wettest year in the simulation period (for a given site, purpose and flow conditions);
- 50th Percentile Year – the number of days that water would have been taken in the 50th percentile wettest year in the simulation period (for a given site, purpose and flow conditions); and
- 75th Percentile Year – the number of days that water would have been taken in the 75th percentile wettest year in the simulation period (for a given site, purpose and flow conditions).

The WRP specifies the minimum number of days of water harvesting opportunity for the 30th, 50th and 75th percentile years.

WASOs are not specified for unsupplemented users on the Dawson River, downstream of the dam site. For this investigation these users have been reported against their modelled mean annual diversion. This information is presented as an illustration of the existing level of approved development in the catchment for this water resource group.

Levels of surface water use in the Fitzroy Basin have been estimated using the Full Entitlements model (as described in Section 14.1.2.2). Results have been reported against WRP WASOs and are presented using the colour coding specified in Table 14-5.

Table 14-17 presents a summary of the medium and high priority WASOs for supplemented user groups in the Dawson River and Lower Fitzroy catchments. The WRP objectives are achieved for the Dawson River and Lower Fitzroy schemes.

Table 14-18 presents the number of days of waterharvesting opportunity for the Lower Fitzroy unsupplemented irrigators (mandatory WASO). These WRP objectives are achieved for all irrigator groups.

Table 14-19 presents the mean annual diversions for the unsupplemented irrigators groups (rounded to the nearest hundred ML).

Table 14-17 Mandatory medium and high priority WASOs for the Full Entitlement scenario

Mandatory Water Allocation Security Objectives		Median Monthly Reliability (%)	Full Entitlement (%)
Dawson River			
Upper Dawson River	High Priority	95-100	100.0
	Medium Priority	82 - 88	83.0
Lower Dawson River	High Priority	95-100	100.0
	Medium Priority	82 - 88	90.0
Lower Fitzroy			
	High Priority	95-100	99.5
	Medium Priority	82 - 88	97.0

Table 14-18 Mandatory unsupplemented WASO: days of water harvesting opportunity (Lower Fitzroy) for the Full Entitlement scenario

Unsupplemented Irrigator Groups	Days of Waterharvesting opportunity					
	WRP Objectives			Full Entitlement scenario		
	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year
Class 5A	72	45	22	72	72	44
				72	72	44
				72	72	44
				72	72	44
				72	72	40
Class 5B	42	35	21	42	39	34
Class 6C	102	98	95	129	127	116
				122	113	98
				128	126	115
				125	116	101
Class 7D	70	58	47	116	107	88
				116	105	87

Table 14-19 Unsupplemented irrigator groups - mean annual diversions for the Full Entitlement scenario

Unsupplemented Irrigator Groups	Full Entitlement scenario (ML/a)
Dawson River	
Regulated Reach (Nathan Dam to Dawson River confluence)	66,900
Unregulated Reach and Tributaries	7,300
Lower Fitzroy	
Regulated Reach (Dawson River confluence to Fitzroy Barrage)	56,000
Unregulated Reach and Tributaries	10,300

14.1.6.5. Distribution

Within the Dawson Valley Water Supply Scheme, there are no existing water supply pipelines. Figure 2-5 shows the preferred route of the pipeline from Nathan Dam to Dalby.

14.1.7. Pipeline

Water from the dam required to meet demand in the Surat Basin will be pumped via a pipeline approximately 260 km long, extending as far as Dalby. Details of the pipeline are provided in Chapter 2, and the route for the pipeline is shown in Figure 2-5.

The preferred pipeline route includes approximately 20 stream crossings, of both major and minor streams. Within the Dawson catchment these streams include Price Creek, Cockatoo Creek, Bungaban Creek, Bullock Creek, Stableyard Creek, Roche Creek, Juandah Creek and others. The pipeline also crosses the Condamine catchment, crossing streams including Dogwood Creek, Charleys Creek, Cooranga Creek and Jimbour Creek.

Although the larger streams crossed by the pipeline may be perennial the smaller watercourses will flow intermittently or are ephemeral. These streams support a number of farmers who generally use small volumes of unsupplemented water, predominantly for irrigation, and stock and domestic purposes.

Gauge data is only available for four of the streams crossed by the pipeline; annual statistics are presented for these gauges in Table 14-20. The pipeline crosses Charleys Creek close to the gauge site; however the other three gauges are located at some distance from the pipeline crossings. As such the statistics for these three gauges are only intended to be indicative of likely flows.

The pipeline crosses Juandah Creek approximately 10.5 km upstream of GS 130344A, where the upstream catchment is in the order of 700 km^2. The pipeline crosses Dogwood Creek approximately 31 km upstream of GS 422202B, where the upstream catchment is approximately 1600 km^2. The pipeline crosses Jimbour Creek approximately 32 km downstream of GS 422339A, where the catchment is in the order of 1000 km^2. Flows at these locations are likely to be intermittent.

Table 14-20 Gauge flow statistics: creeks crossed by the pipeline

Gauge no.	Location	Catchment Area (km^2)	AMTD (km)	Period of Record	Mean Annual Flow (ML/a)	Minimum Annual Flow (ML/a)	Maximum Annual Flow (ML/a)	Median Annual Flow (ML/a)
130344A	Juandah Creek at Windamere	1678	62.8	1973-2006	45,800	200	215,400	18,200
422202B	Dogwood Creek at Gilweir	3010	107.9	1945-2006	74,600	0	559600	32,400
422339A	Jimbour Creek at Bunginie	235	49.2	1972-1992	4,000	100	16,400	2,200
422343A	Charleys Creek at Chinchilla	3461	19.0	2003-2006	21,800	16,700	27,800	20,800

Source: DERM (2010)

14.2. Potential impacts and mitigation measures - hydrology

This section addresses Section 3.4.1.2 of the TOR. The Project is described in detail in Chapter 2 and information pertinent to this section is summarised below.

The dam will be located at AMTD 315.3 km along the Dawson River, approximately 70 km downstream of the Taroom Township. The dam will be ungated and constructed with an earth and rockfill embankment spanning 1,240 m, and a Full Supply Level (FSL) of 183.5 m Australian Height Datum (AHD). The storage capacity of the dam at FSL will be approximately 888,312 ML, with a minimum operating volume (MOV) of 34,502 ML and the surface area of the reservoir at FSL will be approximately 13,508 ha (excl. Islands). When the dam is operational it will increase the system yield with approximately 66,011 ML/a of high priority entitlements.

Current design of the dam includes two outlets; outlet one for regular releases and the first post winter flow event (valve capacity of 3,890 ML/d) and outlet two for releases to assist the floodplain flow objectives (flap gates in spillway with a capacity of 19,870 ML/d). Outlet one is operational from MOV (EL 170.0 m AHD) to FSL (EL 183.5 m AHD) while outlet two is operational from EL 177.0 m AHD to EL 190 m AHD.

14.2.1. Construction

This section describes the potential impacts of the construction stage on surface water hydrology, and the mitigation measures which will be used to minimise or negate these impacts.

14.2.1.1. Dam and surrounds

Construction of the dam wall will take place over three years and the critical period during which the dam construction is most susceptible to inclement weather will be in the wet season, generally between November and March. It is anticipated that the construction of the earth and rockfill dam will be carried out over two dry seasons with the placement of the earth and rockfill ceasing over the wet season. Additional detail is provided in Chapter 2.

Downstream flows in the Dawson River will be maintained throughout the construction process, with Glebe Weir continuing to fulfil its role as the uppermost storage of the DVWSS. A diversion channel will be constructed to divert water around the works. This will maintain the water access of existing downstream users as well as downstream environmental flows during the construction period. The diversion channel will become the permanent outlet conduit for the dam following construction.

Coffer dams will be constructed at both ends of the flow diversion channel, to store water upstream and safely divert flows through the channel, to catch site runoff downstream for treatment or use and to prevent backflow of diverted water from downstream. Provisions will be made to ensure site stability in the event the upstream coffer dam is over-topped and the site is flooded.

The construction sequence is such that no interruption to natural flows in the river will occur prior to closure of the dam at the commencement of storage. During construction, all flood events will have to be either passed around the works or safely through the works. The earth and rockfill style of dam will allow for safe overtopping by major flood waters during construction when protected by concrete on the downstream face, with minimal risk of damage to the construction works. Changes to upstream and downstream flooding are expected to be negligible during the construction phase.

A dewatering program may be undertaken to draw down the water table in the vicinity of the dam foundation, in order to excavate and construct in dry conditions. It is anticipated that dewatering bores will be located around the excavation with some drilled to depths above the sandstone foundation and others below it. Dewatering is expected to occur over a period of approximately 50 days. The groundwater discharged from the bores will be pumped into a sedimentation pond on the left bank of the river and reused for dust suppression, haul roads watering and rehabilitation or progressively released back into the river under a water quality management plan. The long term impact of the dewatering program on local hydrology and groundwater levels is expected to be negligible (groundwater impacts are discussed in detail in Chapter 15).

Excavation material from the diversion channel may be used in the construction of the coffer dams or will be hauled to stockpile for later reuse or disposal. Stockpiles will be located and managed such that potential impacts to water resources are minimised. Permanent disposal of materials may be in the form of shallow mounds that can be landscaped and stabilised complementing the existing landscape, or backfilled within the diversion channel or excavation or within the water storage area. Excavation and placement of fill are therefore not expected to cause any noticeable changes to local drainage patterns or hydrology.

Potential water quality impacts during construction are discussed in Chapter 16.

14.2.1.2. Pipeline

The primary potential impacts of construction of the pipeline on surface water resources include:

- disturbance of riparian soils and vegetation at watercourse crossings;
- damage to the streambed and changes to the morphology of the watercourse ;
- potential changes to overland flow paths related to mounding above the pipeline or to the relative level of access tracks;
- water contamination through pollutant leakage or spills, sewage or greywater disposal from construction camps, or through trench dewatering; and
- over extraction of water for use during construction;

These issues are addressed in Chapters 2, 6, 16 and below.

The majority of the pipeline will be buried, although there is one section of pipeline (approximately 45 km) which is dominated by shallow stony topsoils and underlain by low to medium strength rock from about 1m in depth. At this stage it is unknown whether or not this material can be successfully excavated. Sections of pipeline in this area are therefore likely to be placed above ground, although the pipeline will be buried in any sections of the area that will allow trenching to the required depth. Above ground sections would be supported by concrete piers that suspend the pipeline approximately 300 mm above the natural surface level, allowing overland flow to continue unimpeded. In most instances the pipeline would be buried as deep as practical (up to the typical trench depth associated with the type of pipe installed), with a low backfill mound placed over the pipeline to obtain the minimum required cover. This may result in minor changes to existing drainage patterns; however appropriate gaps will be placed to allow for water movement, with particular attention to natural discharge points.

Although the larger watercourses crossed by the pipeline may contain permanent water the smaller watercourses flow intermittently or are ephemeral. As such, works in these areas will be scheduled for the dry season when most crossings are expected to be dry. At this stage, it is assumed all watercourse crossings will be by trench, minimising the width of clearing of the riparian zone as much as possible. Once construction is completed the channel will be returned to its natural condition. This approach will minimise any long term impacts to the downstream flow regime.

If a crossing does contain water then the trench area will be isolated by coffer dams. It may be necessary to dewater the trench using pumps, discharging the water downstream. A secondary low level coffer dam may need to be constructed to act as a sediment basin depending on the environment downstream and the suspended sediment concentration of the discharge water. The works will include the provision to transfer flows from upstream of the works to the downstream channel without passing though the disturbed construction site.

In most stream beds the pipe will be encased in concrete. It is not essential that the trench be fully dewatered in order to place the concrete, which can be achieved under water. On completion of works any coffer dams will be removed slowly and the stream bed and banks reinstated to their original profile. The stream bed and watercourse morphology will be returned to its existing condition.

Excavated material will be stockpiled away from gully heads, active creek banks, bank erosion or other unstable areas. Sedimentation fences and bunds will be used to contain excavated material during construction.

Although the natural flow regime at watercourse crossings may be interrupted for a short period of time during the construction phase it is anticipated that there will be no changes after the pipeline has been finalised.

A range of management strategies will be developed prior to construction commencement in order to mitigate the potential impacts of the pipeline construction. These will be detailed in:

- an Erosion and Sediment Control Plan; and
- a Surface Water Management Plan, including a Flood Management Plan.

Water quality matters are addressed in Chapter 16. The Draft EMP is presented in Chapter 29.

14.2.1.3. Associated infrastructure

- Roads

Two new roads will be constructed and six existing roads will be modified or upgraded, as shown in Figure 2-6 and discussed in Chapters 2 and 21. The new roads will be built to provide construction access to the dam site, access to the future recreation area, and new routes for inundated areas. Where roads are inundated by the storage they will either be relocated or closed. Retained roads will be raised or realigned as necessary, in order to maintain or improve current flood immunity.

New culverts will be constructed on all road realignments and new roads. Culverts will be sized to maintain existing local drainage patterns.

Flood causeways will be constructed on Glebe Weir rd at Spring Creek and on Cracow rd at Bentley Creek, a bridge will also be required on Cracow rd at Cockatoo Creek.

All roadworks will be to the standard applicable to the designation, e.g. local government or Main Roads, and will satisfy requirements for fish passage, where applicable.

Roads are discussed in detail in Chapters 2 and 21.

- Resource extraction areas

During construction several resource extraction areas will likely be utilised as detailed in Chapter 2. These areas, as well as any stockpile areas, will be managed to control sediment runoff during rainfall events. Excavated material will be stockpiled away from gully heads, active creek banks, bank erosion or other unstable areas. Stockpiles will be managed so that impacts on local drainage and surface water flows will be minimal.

- Decommissioning of Glebe Weir

Glebe Weir and its associated infrastructure will be inundated by the Nathan Dam water storage however; Glebe Weir will continue to serve its role in the Dawson Valley Water Supply Scheme until Nathan Dam commences to store water and can take over that role. A decommissioning plan has been prepared, in line with current practices established by ANCOLD. Decommissioning will involve completely abandoning the storage, with its removal to the extent that it no longer retains water. While this is best achieved by complete removal of the wall and reinstatement of the bed and banks, in the case of Glebe Weir, it is appropriate to only partially remove the structure.

14.2.2. Surface water flow under operations

Modelling of the dam operations and hydrologic impacts was carried out using the IQQM for the current Fitzroy Basin ROP. It is acknowledged that DERM has updated the Fitzroy Basin WRP . This could potentially have impacts on the existing Dawson catchment model, particularly with respect to environmental flow objectives and the modelling of existing users. It is anticipated that changes will be made to the location and licence details of existing users, particularly unsupplemented irrigators and waterharvesters. As a result of this, the conclusions presented below may require revision prior to the projects approval.

The objective of the modelling presented below was to develop hydrologic models for the Full Entitlement scenario (representing existing approved levels of development in the catchment) and the 'With Dam' scenario (with Nathan Dam) incorporating an operational strategy. The models were then used to assess the performance and impacts of the dam under current climate conditions, projected Climate Change, during the recent climatic period (1995-2008 which is not included in the ROP model) and for the Cumulative Impacts scenario (incorporating other currently proposed water resource development within the Fitzroy Basin). This modelling will be revised as the Project progresses and when the new WRP becomes available.

14.2.2.1. Preliminary operational strategy

In May 2010 SunWater completed a preliminary yield assessment for Nathan Dam. This scenario made some operational changes to the management of the Dawson Valley Water Supply Scheme, as well as the addition of Nathan Dam. The primary change was to unite the upper and lower Dawson sub-schemes into a single water supply scheme.

The operational strategy for the Dawson Water Supply Scheme adopted for the EIS includes:

- new high priority water products supplied by Nathan Dam;
- existing medium priority water products currently supplied by Glebe Weir will be supplied by Nathan Dam;
- other existing medium and high priority water products in the DVWSS will be supplied as per their current arrangements;
- environmental releases:
  - seasonal base flow (SBF) releases from Theodore, Moura and Neville Hewitt Weirs and Nathan Dam;
  - first post winter flow (FPWF) releases from Gyranda, Theodore, Moura, and Neville Hewitt Weirs and Nathan Dam;
  - maintenance of low flows directly downstream of Nathan Dam;
  - fishway operation at Nathan Dam; and
  - turtleway release at Nathan Dam.
- The operational strategy will be refined as the Project progresses and design and management strategies are finalised.

New water products supplied from the dam are currently intended to be entirely high priority supply. Demand assessment for the dam business case has identified a total potential demand which exceeds the supply, with the bulk of this water supplied to mining clients, although some water is reserved for urban use. The majority of new clients are located to the south of the dam and will be supplied through a pipeline. However, several new clients are located north of the dam site and will be supplied from Nathan Dam via the downstream weirs.

Modelling was undertaken to assess the supply of these demands, with priority given to demands within the Dawson catchment. The allocatable yield was optimised against the downstream EFOs, WASOs and management strategies, resulting in a total additional HP available yield of 66,011 ML/a, distributed as follows:

- 47,700 ML/a supplied via pipeline, direct from Nathan Dam;

- 750 ML/a supplied from Gyranda Weir;
- 400 ML/a supplied from Theodore Weir;
- 7,092 ML/a supplied from Moura Weir;
- 2,269 ML/a supplied from Neville Hewitt Weir, and
- 7,800 ML/a extracted at Duaringa (from the Boolburra Waterhole) and supplied from Neville Hewitt Weir.

The modelled demand distribution described above is not necessarily the potential maximum yield, but is dependent upon the location and volume of the clients downstream of the dam, the capacity of the pipeline, the target reliability for MP and HP users and the adopted environmental release strategy. As the Project progresses the demand distribution described above may change, depending on the final location of new clients and the amount of water they sign up for.

The high priority supply from the dam has been assumed to have a constant demand pattern as the water is intended for industrial use, which has little variation of demand during the year. This is also in line with modelling of urban supplies in the region and is considered appropriate given the likely urban or industrial use of the water.

The management strategy developed for the yield modelling scenario is to supply high priority customers at 100% reliability while the existing medium priority customers are supplied at 88% reliability.

Under the proposed operational strategy there are impacts to some of the waterharvesters downstream of the dam. Compensation will be provided to existing users who are negatively impacted by the Project. Compensation could be delivered through a range of measures, such as financial compensation or provision of an alternative water product. Several compensation flow release strategies were investigated for the EIS, however these were found to be inefficient and were not pursued further at this stage. Compensation strategies will be considered in more detail in later stages of the Project, after the new WRP is released and in conjunction with local irrigator groups.

Due to aquatic species in the reach downstream of the dam (particularly Fitzroy River turtles) it is important to maintain existing low flows in this area. As the downstream reach is highly affected by the operation of Gyranda Weir, at FSL the weir backs up to approximately 4 km downstream of the dam, the low flow release strategy is focussed on the area immediately downstream of the dam.

To achieve this, two commonly used environmental indicators; flows of 10 cm and 30 cm depth, have been adopted. The 10 cm flow provides an indicator of riffle flows, while the 30 cm flow provides an indicator of stream connectivity and fish movement opportunity. For this investigation the rating at Nathan Gorge was used to determine the relevant flows. Flow depths of 10 cm and 30 cm are equivalent to flows of 9.0 and 48.5 ML/d respectively. The operational strategy encompasses a low flow environmental release which mirrors the dam inflows, up to a maximum release of 50 ML/d.

The seasonal baseflow release of 50 ML/d is made from the dam when inflows are above 50 ML/d, the dam is above 150,000 ML and a first post winter event is not occurring. It was found that additional releases were not required from September to December (inclusive) as there were already sufficient releases made during this period (for other purposes) to satisfy baseflow requirements. The seasonal baseflow release is essentially covered by the low flow environmental release, however it is still included as operational parameters may change.

A first post winter flow release strategy was adopted which releases the first high flow event into the dam between the period 1 October and 30 April, as stipulated in the WRP. The event is triggered by flows into the dam of 900 ML/d. Inflows to the dam are then released for 21 days, capped at a maximum of 3,890 ML/d (the maximum capacity of outlet one). As first post winter flow releases are already incorporated in the operations of other storages on the Dawson River, these have not been changed.

The post winter flow and seasonal baseflow releases are conditional on the dam being above a trigger volume of 150,000 ML. When the dam is below this volume post winter flow and seasonal baseflow releases are not made, however the low flow release is still made and the fishway and turtleway are still operated. The trigger volume represents approximately 1.5 years of supply plus dead storage and a small allowance for losses. This represents a preliminary estimate of a suitable restriction trigger and may change as the Project progresses.

The current concept for the fishway is a bi-directional fish lift employing a 7000 litre hopper. This conveys fish both upstream and downstream by means of a cableway across the dam embankment. For the purpose of this investigation the requirement of the fishway operation has been met by the low flow release strategy, which is not restricted by the dam storage level until the dam drops below the minimum operating volume.

The turtleway is proposed as a constructed channel between the dam pondage and the downstream river, requiring a small trickle flow to facilitate turtle movement. Modelling of the turtleway was based on a release of up to 2 ML/d (mirroring inflows to the dam). This is sufficient flow to allow approximately 10 to 20 cm of flow in a 1-2 m wide channel, depending on the final design adopted. Turtleway releases are made in addition to fishway releases and occur during the natural movement periods of January to February (inclusive) and August to November (inclusive). Design of the turtleway will be refined as the Project progresses with potential alterations to flow periods based on advice from agencies and relevant experts.

14.2.2.2. Flow regime

The following section presents statistics describing the flow regime of the Pre-development, Full Entitlement (current development) and 'With Dam' scenarios.

Key findings can be summarised as follows:

- There will be a range of impacts on the flow regime along the Dawson River due to the operation of Nathan Dam. The impacts of the dam decrease with distance downstream from the dam, as flow from additional tributaries enters the river. Downstream of the Boolburra waterhole (approximately 297 km downstream of the dam) the flow regime has returned to close to what it was under the Full Entitlement scenario.
- Impacts to the flow regime directly downstream of the dam (at Nathan Gorge) can be categorised as follows:
- Low flows – the low flow range (0 to 50 ML/d) will return to near pre-development levels due to the low flow release strategies adopted;
- Medium flows – the medium flow range (50 to 30,000 ML/d) will be moderately reduced in the ranges of 50 to 200 ML/d and 1,500 to 30,000 ML/d. The flow range between 200 to 1,500 ML/d will be slightly advantaged;
- High flows - the high flow range (flows over 30,000 ML/d) will not change significantly; and
- Overall flow volume – the overall flow volume (on an annual basis) will decrease.

- The Project will have minimal impacts on flow regimes in the Fitzroy River, downstream of the Dawson River.

Table 14-21 and Table 14-22 present the mean and median annual flow for the Pre-development, Full Entitlement and 'With Dam' scenarios. The 'With Dam' scenario shows a reduction in mean annual flows along the Dawson River, however, this impact decreases at downstream locations. The median annual flows are more significantly affected than the mean because more small to medium flows are taken into storage while larger flows will overtop the dam.

Table 14-21 Fitzroy catchment modelled mean annual flow statistics

River	Location	Pre-development Scenario (ML/a)	Full Entitlement Scenario (ML/a)	With Dam Scenario		
				(ML/a)	% change from Pre-development	% change from Full Entitlement
Dawson River	Nathan Gorge	571,500	548,700	395,300	-31%	-28%
	D/S Theodore	664,900	589,600	443,700	-33%	-25%
	Beckers	1,011,900	895,700	742,500	-27%	-17%
	End of Dawson River	1,504,600	1,316,600	1,156,500	-23%	-12%
Fitzroy River	Eden Bann Weir (inflow)	5,264,500	4,654,800	4,499,700	-15%	-3%
	Barrage (inflow)	5,445,800	4,787,400	4,641,100	-15%	-3%
	Estuary*	5,445,800	4,686,800	4,540,400	-17%	-3%

*Flows at the Estuary represent freshwater inflows only

Table 14-22 Fitzroy catchment modelled median annual flow statistics

River	Location	Pre-development Scenario (ML/a)	Full Entitlement Scenario (ML/a)	With Dam Scenario		
				(ML/a)	% change from Pre-development	% change from Full Entitlement
Dawson River	Nathan Gorge	283,300	260,800	113,300	-60%	-57%
	D/S Theodore	348,700	269,600	121,100	-65%	-55%
	Beckers	521,200	395,800	245,000	-53%	-38%
	End of Dawson River	782,800	590,900	516,500	-34%	-13%
Fitzroy River	Eden Bann Weir (inflow)	2,775,900	2,138,700	2,085,900	-25%	-1%
	Barrage (inflow)	2,849,800	2,195,800	2,118,700	-26%	-4%
	Estuary*	2,849,800	2,102,200	2,019,400	-29%	-4%

*Flows at the Estuary represent freshwater inflows only

Figure 14-22 to Figure 14-28 compare the modelled flow duration curves for the three scenarios along the Dawson and Fitzroy Rivers. In several of the figures the Full Entitlement line is not visible; this is because it is overlain by the With Dam scenario.

The modelled flow duration curves show that directly downstream of the dam at Nathan Gorge, and at the majority of downstream locations on the Dawson River in the 'With Dam' scenario, the flow regime will more closely simulate natural flows than the Full Entitlements scenario for low flow periods. This includes all flows with a daily flow exceedance of greater than 41% at Nathan and at similar exceedances downstream. This is due to flows released for Low Flow, Fishway and Turtleway operation, the seasonal baseflow release and flows released to maintain downstream storage volumes.

At Beckers the flow duration curve shows elevated low flow (25 ML/d) for approximately 30% of the simulation period. This is due to the supply of new HP water at Duaringa, downstream of Beckers. This water is extracted before the end of the Dawson River, with the flow duration curve moving towards pre-development conditions.

Low to medium flows, in the 50 to 200 ML/d range, are moderately impacted in the 'With Dam' scenario at Nathan Gorge. However, downstream of Nathan Gorge flows in this range are not as highly impacted. This flow range is substantially increased downstream of Theodore, primarily due to the seasonal baseflow release and releases to Moura Weir from Theodore Weir.

Medium to high flows, in the 1,500 to 30,000 ML/d range, are moderately impacted in the 'With Dam' scenario. This range generally covers flushing flows through to half bankfull flows in this reach. This is particularly evident at Nathan Gorge as these flows are generally captured by the dam; however, these impacts decrease at downstream locations. Flows above 30,000 ML/d usually occur as part of a large flood event, when the dam receives enough inflow to fill. The larger flows therefore pass through the storage with minimal loss of volume.

By the end of the Dawson River (Figure 14-25) the flow regime has moved closer to pre-development conditions in the 54-94%ile flow range, although a slight decrease is evident in the mid to high range. This is primarily due to inflows from the Don River catchment. The impacts of the dam on flows in the Lower Fitzroy River (Figure 14-26 to Figure 14-28) are minor, mainly due to inflows from the larger Nogoa-Mackenzie catchment.

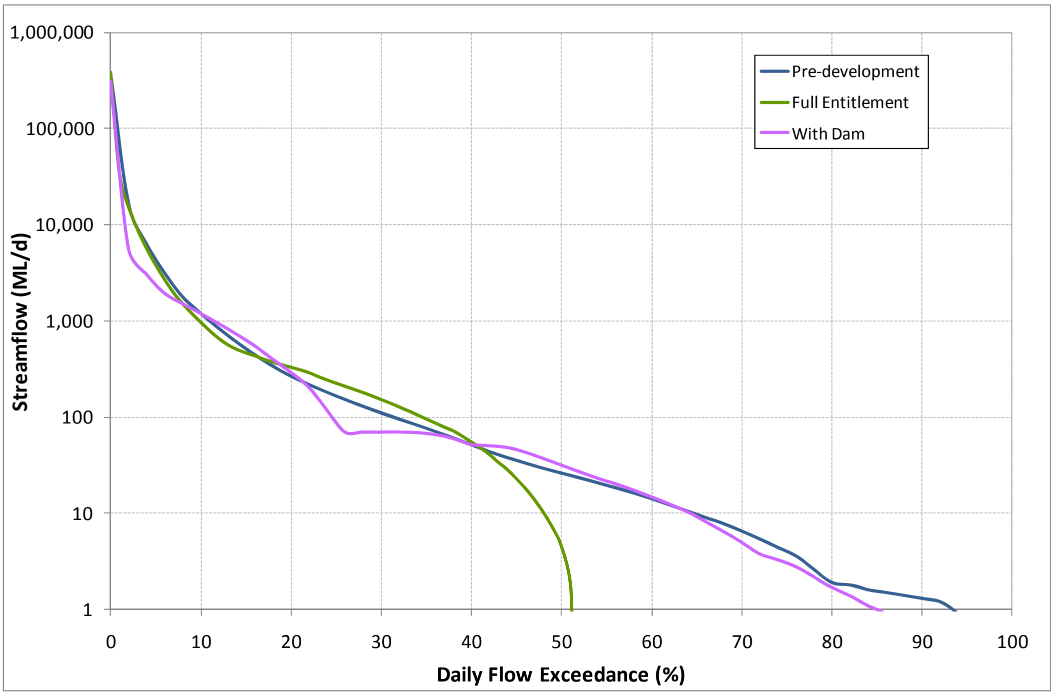


Figure 14-22 Dawson River at Nathan Gorge daily flow duration curve (with dam)

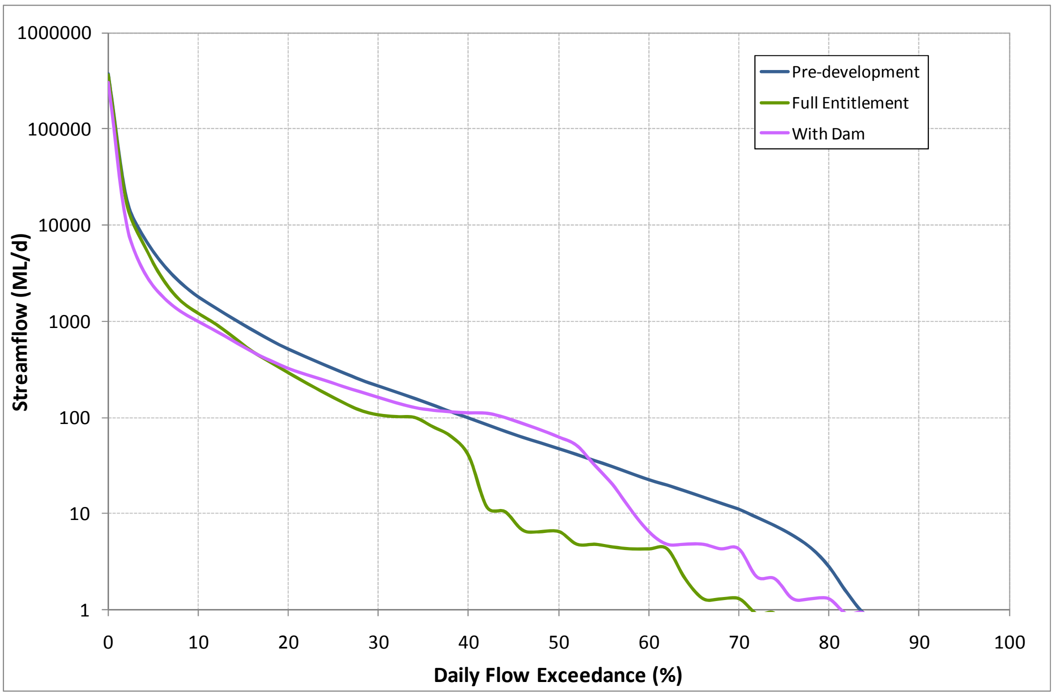


Figure 14-23 Dawson River D/S Theodore daily flow duration curve (with dam)

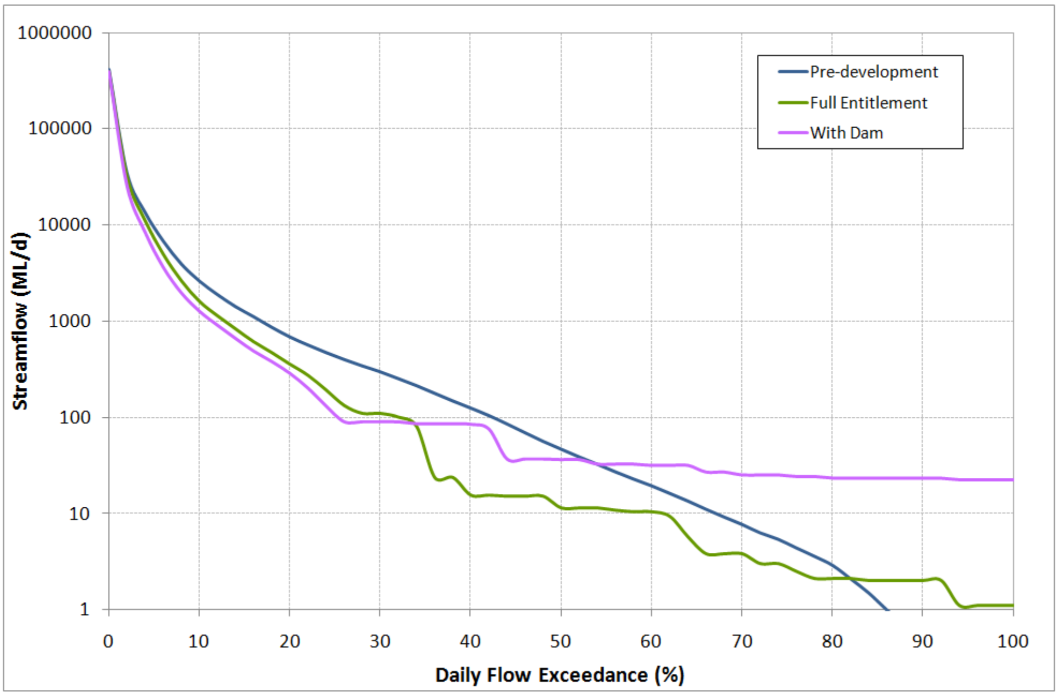


Figure 14-24 Dawson River at Beckers daily flow duration curve (with dam)

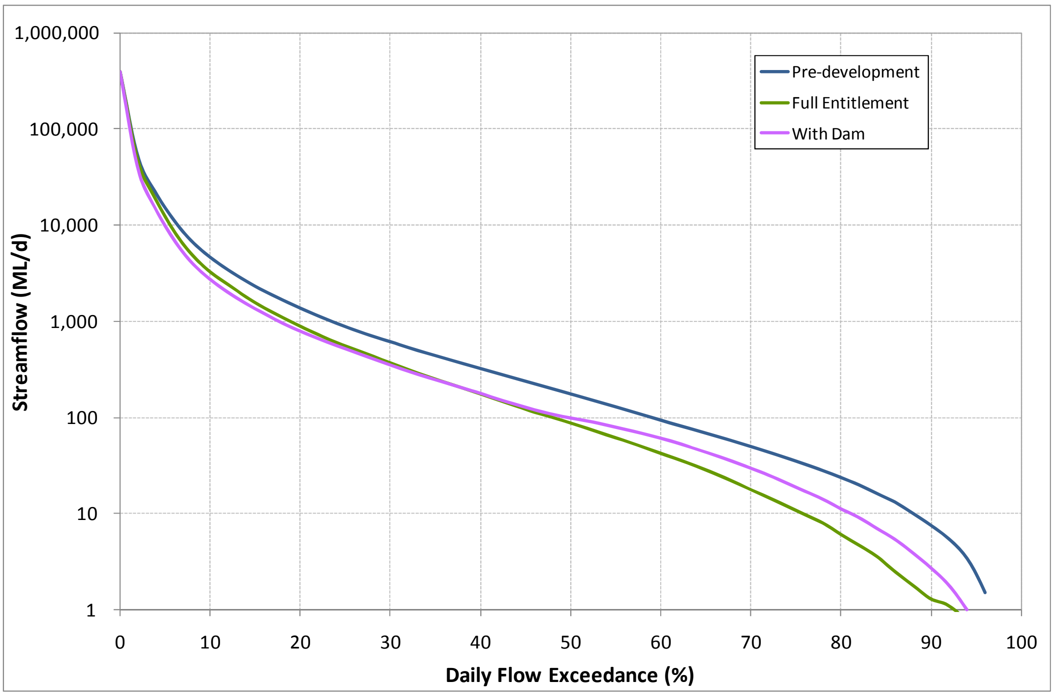


Figure 14-25 End of Dawson River daily flow duration curve (with dam)

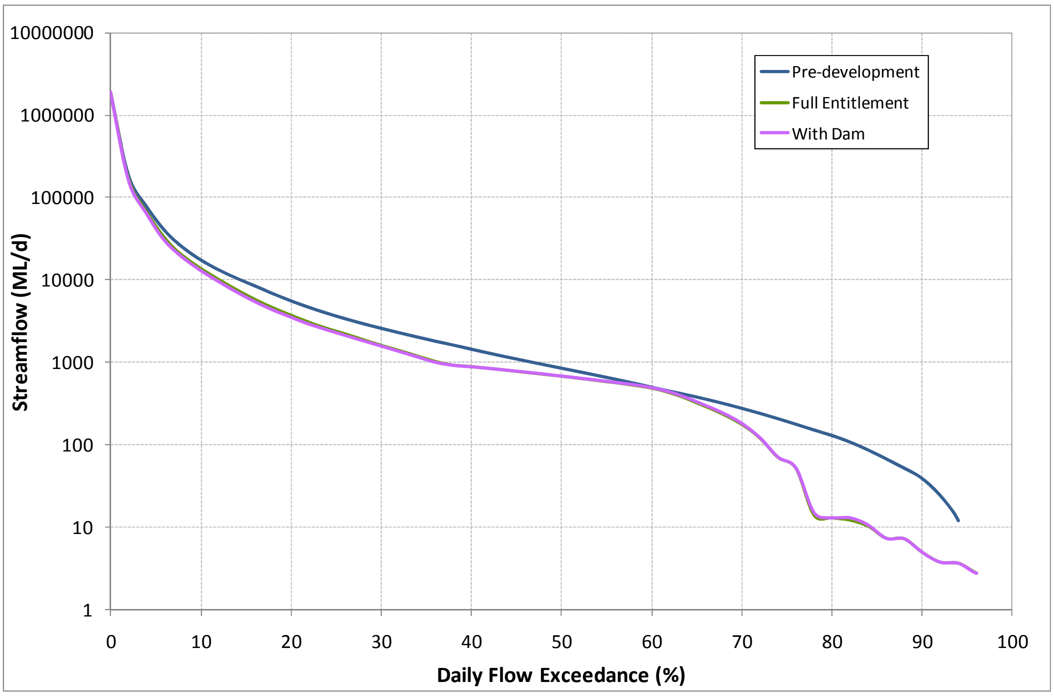


Figure 14-26 Fitzroy River inflow to Eden Bann Weir daily flow duration curve (with dam)

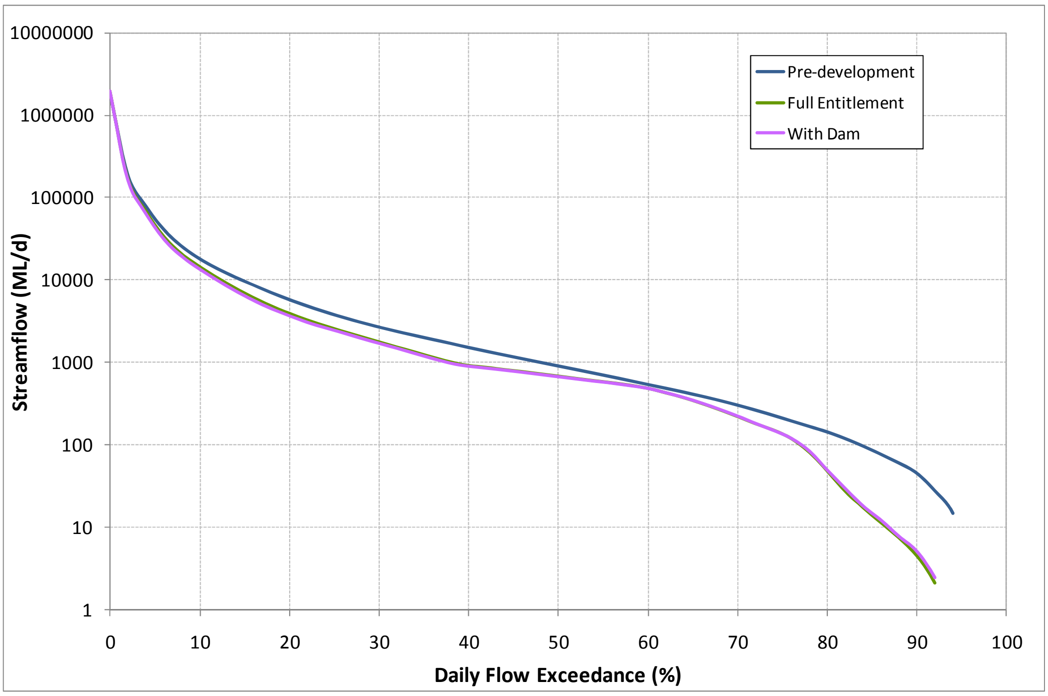


Figure 14-27 Fitzroy River inflow to Barrage daily flow duration curve (with dam)

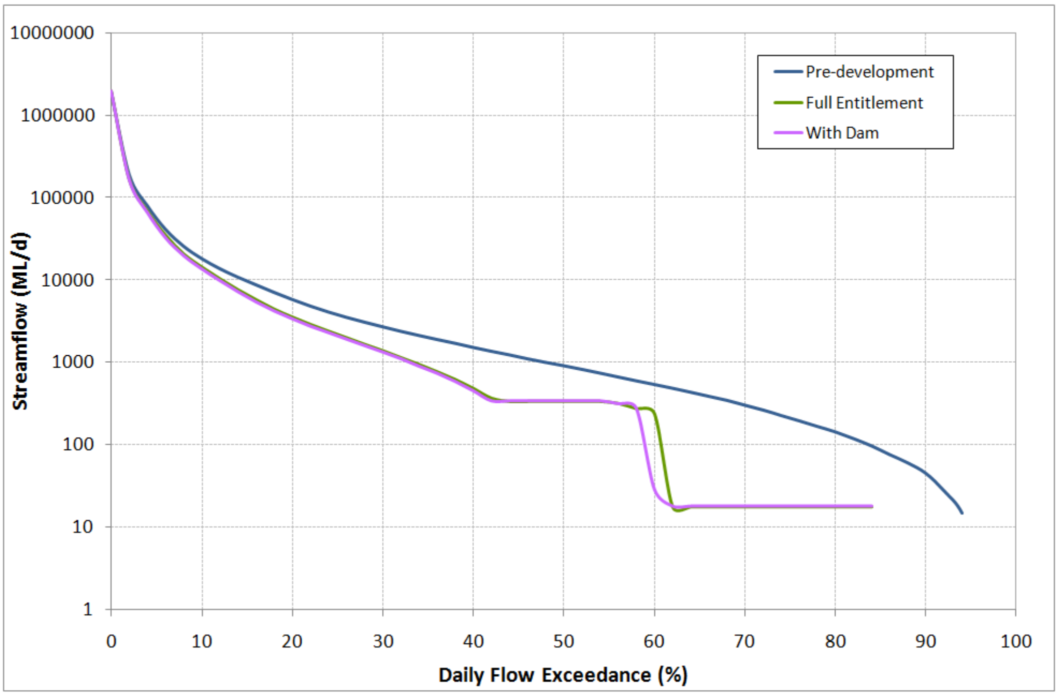


Figure 14-28 Fitzroy River at end of system daily flow duration curve (with dam)

14.2.2.3. *WRP objectives*

The impact of the dam has been assessed against the WRP EFOs and WASOs. Reporting against WRP EFOs and WASOs has been presented using the colour coding in Table 14-5.

Environmental flow objectives

Table 14-23 presents the seasonal baseflow results (non-mandatory). This shows that the baseflow objective is not met in September to December at two locations under the Full Entitlement scenario and at three locations under the 'With Dam' scenario. By comparing equivalent cells, the baseflow statistics are seen to improve in six cases, are the same in seven cases and worse in two. The latter are both due to the oversupply of water below the dam, caused by regulated releases from the dam and other water storages. As the non compliance relates to an oversupply the issue can be investigated in later stages of the Project, when other release and compensation strategies have been finalised.

Table 14-24 and Table 14-25 present the first post winter flow event performance indicators (mandatory) for the Dawson and the Lower Fitzroy Rivers. These indicators were achieved for all locations, under both scenarios. On the Dawson River (Table 14-24) by comparing equivalent cells, the first post winter flow event performance indicators are seen to improve in six instances, are the same in one instance and worse in 11. At Nathan Gorge and Theodore the timing of the events improves, although the number of events and duration decrease. At Beckers the number of events increases, while the timing and average peak flow decreases slightly. However, it should be noted that these indicators generally pass the objective by a substantial margin.

The overall impact to the first post winter flow indicators on the Fitzroy River is less than on the Dawson River. By comparing equivalent cells (Table 14-25), the first post winter flow event performance indicators are seen to improve in three instances, are the same in four instances and worse in five. The number of events does not change, there is a small decrease in the average peak flow (Eden Bann Weir) and average flow volume (Barrage), and the event duration is similar. There are some changes to timing however, with the number of events within two or four weeks of the pre-development event decreasing at Eden Bann Weir and increasing at the Barrage. Again, it should be noted that these indicators generally pass the objective by a substantial margin.

Table 14-26 and

Table 14-27 present the mandatory and non-mandatory medium to high flow event objectives for the Dawson and Lower Fitzroy Rivers for WRP Nodes 2 and 0 (medium to high flow event objectives have not been specified for Nodes 5, 4 and 1). There are three occurrences at Node 2 and one occurrence at Node 0 for the 'With Dam' scenario where the non-mandatory objectives are not met; however the mandatory objectives are all met for both locations under both scenarios. By comparing equivalent cells, the medium to high flow event are decreased in 14 instances and improved in one. The changes at Node 2 are much reduced by Node 0, mainly due to inflows from the Nogoa-Mackenzie catchment, although the Don River catchment also contributes substantial flows and would ameliorate the changes to medium and high flow events downstream of Beckers.

Table 14-23 Non-mandatory seasonal base flow results for the Full Entitlement and 'With Dam' scenarios

Node	Location	Non-Mandatory Values	Seasonal Base Flow Performance Indicator Objective		
			Jan – April	May – Aug	Sep - Dec
Full Entitlement					
5A	Dawson River at Nathan Gorge	0.8-1.2	0.9	0.9	1.2
4	Dawson River at Theodore	0.8-1.2	0.8	0.9	0.9
2	Dawson River at Beckers	0.8-1.2	0.8	0.8	0.7
1	Fitzroy River at Edan Bann Weir	0.8-1.2	0.9	1.0	0.9
0	Fitzroy River at Barrage	0.8-1.2	0.9	0.8	0.7
'With Dam' Scenario					
5A	Dawson River at Nathan Gorge	0.8-1.2	1.0	1.0	1.3
4	Dawson River at Theodore	0.8-1.2	1.0	0.9	1.6
2	Dawson River at Beckers	0.8-1.2	0.9	0.8	0.9
1	Fitzroy River at Eden Bann Weir	0.8-1.2	0.9	1.0	0.9
0	Fitzroy River at Barrage	0.8-1.2	0.9	1.0	0.7

Table 14-24 Mandatory first post-winter flow event performance indicators for the Full Entitlement and 'With Dam' scenarios for Dawson River (Node 5, Node 4 and Node 2)

Performance Indicator for FPWF objective	Mandatory Values	Node 5 (Dawson River at Nathan Gorge)		Node 4 (Dawson River at Theodore)		Node 2 (Dawson River at Beckers)	
		Full Entitlement	With Dam Scenario	Full Entitlement	With Dam Scenario	Full Entitlement	With Dam Scenario
Number of first post-winter flows	≥ 80%	92%	91%	89%	84%	92%	93%
Number of flows within 2 weeks of predevelopment event	≥ 50%	71%	81%	66%	67%	73%	71%
Number of flows within 4 weeks of predevelopment event	≥ 70%	73%	82%	70%	72%	81%	76%
Average peak flow	≥ 70%	90%	83%	81%	70%	85%	78%
Flow Duration 2 times base flow for 4 day tolerance	≥ 70%	92%	82%	87%	81%	86%	86%
Flow Duration 5 times base flow for 4 day tolerance	≥ 70%	91%	80%	84%	76%	80%	81%

Table 14-25 Mandatory first post-winter flow event performance indicators for the Full Entitlement and 'With Dam' scenarios for Fitzroy River (Node 1 and Node 0)

Performance Indicator for FPWF objective	Mandatory Values	Node 1 (Fitzroy River at Eden Bann Weir)		Node 0 (Fitzroy River at Barrage)	
		Full Entitlement	With Dam Scenario	Full Entitlement	With Dam Scenario
Number of first post-winter flows	≥ 80%	96%	96%	94%	94%
Number of flows within 2 weeks of predevelopment event	≥ 50%	66%	64%	63%	71%
Number of flows within 4 weeks of predevelopment event	≥ 70%	76%	74%	74%	78%
Average peak flow	≥ 70%			89%	88%
Average flow volume	≥ 70%	80%	79%		
Flow Duration 2 times base flow for 4 day tolerance	≥ 70%	95%	95%	94%	94%
Flow Duration 5 times base flow for 4 day tolerance	≥ 70%	84%	83%	92%	93%

Table 14-26 Mandatory and non-mandatory medium to high flow event objectives for Node 2 (Dawson River at Beckers)

Performance Indicator for medium to high flow objective	Non-Mandatory Values	Mandatory Values	Full Entitlement	With Dam Scenario
Mean Annual Flow	≥ 74	≥ 69	88%	73%
Median Annual Flow	≥ 50	≥ 50	80%	50%
Floodplain zone statistics	≥ 70	≥ 69	84%	69%
Upper Riparian zone statistic or Bank full statistic	≥ 85	≥ 80	91%	84%
In-Channel riparian zone statistic	≥ 75	≥ 75	86%	80%
Channel Morphology statistic	≥ 65	≥ 60	81%	65%
Fish species diversity statistic (APFD)	≤ 3	≤ 3	1.0	2.7

Table 14-27 Mandatory and non-mandatory medium to high flow event objectives for Node 0 (Fitzroy River at Barrage)

Performance Indicator for medium to high flow objective	Non-Mandatory Values	Mandatory Values	Full Entitlement	With Dam Scenario
Mean Annual Flow	≥ 74	≥ 77	86%	83%
Median Annual Flow	≥ 50	≥ 50	74%	71%
Marine and Estuarine Processes Statistic	-	≥ 80	90%	88%
Floodplain zone statistics	≥ 70	≥ 70	75%	88%
Upper Riparian zone statistic or Bank full statistic	≥ 85	≥ 80	85%	84%
In-Channel riparian zone statistic	≥ 75	≥ 75	84%	81%
Channel Morphology statistic	≥ 65	≥ 65	85%	81%
Fish species diversity statistic (APFD)	≤ 3	≤ 3	2.1	2.4

Water allocation security objectives

The Fitzroy Basin WRP specifies WASOs for supplemented users throughout the Basin and for unsupplemented users in the Nogoa Mackenzie and the Fitzroy Water Management Areas, and the Dawson and Comet Rivers. WASOs are not specified for unsupplemented users in the Dawson catchment, downstream of the dam site. For this investigation unsupplemented users in the Dawson catchment (downstream of Nathan Dam) have been reported against their modelled mean annual diversion. This is not intended to imply a level of compliance but is rather intended to illustrate the level of potential impacts.

Table 14-28 presents a summary of the medium and high priority WASOs for supplemented user groups in the Dawson River and Lower Fitzroy catchments. In the Full Entitlement scenario, the Dawson River is divided into two independent sub-schemes, as per current arrangements, and in the 'With Dam' scenario the Dawson River is managed and reported under one sub-scheme. This is due to the new operational arrangements proposed by the proponent which are intended to increase the efficiency of the scheme operations. The WRP targets are achieved for each group under both the Full Entitlement and "With Dam" scenario.

All high priority users achieve the same reliability of supply and mean annual diversion under both scenarios, while some of the medium priority users will experience a reduction and some will experience an increase. Overall mean annual diversions for MP users will increase by approximately 1260 ML/a, with an increase of 1450 ML/a in the upper sub-scheme and a reduction of 180 ML/a in the lower sub-scheme. This represents an overall increase of 3% of mean annual diversions. Impacts to MP users in the Dawson management zones are summarised in Table 14-29. This table demonstrates that MP users in zones I (Med A), D, C and B are negatively impacted by the Project, experiencing a reduction of 2% to 3% of mean annual diversions. However, the irrigators in all other zones experience an increase in mean annual diversions of 7% to 8%. These impacts are not directly due to the construction of the dam but are more to do with the revised operational rules of the water supply scheme.

Table 14-30 presents the number of days of waterharvesting opportunity for the Lower Fitzroy unsupplemented irrigators (mandatory WASO). Under the Full Entitlement and 'With Dam' scenarios all the objectives are achieved. Comparing equivalent cells shows that there are increases in the number of days of waterharvesting opportunity in six instances, the same in 14 instances and decreases in 16. However, it should be noted that these indicators generally pass the WRP objective by a substantial margin. Waterharvesters on the Lower Fitzroy are expected to experience an overall reduction of approximately 380 ML/a, or 1% of existing diversions. The groups that are impacted are the class 5A and class 5B irrigators who have high passing flow thresholds associated with their licences (5A: 2592 ML/d, 5B: 4320 ML/d). This reflects the impact to medium to high flows described in the *Environmental Flow Objectives* section above.

Table 14-31 presents the mean annual diversions for the unsupplemented irrigators groups downstream of the dam. (Irrigators on tributaries and upstream of the dam are not reported as they are not affected by the Project.) The unsupplemented irrigators are grouped according to their passing flow thresholds and the management zone they are located in.

The unsupplemented irrigators in the Dawson catchment experience an average reduction of 10% of their mean annual diversion. The groups that are impacted are the waterharvesters with high passing flow thresholds associated with their licences, either 15 or 30 cumecs. This reflects the impact to medium to high flows described in the *Environmental Flow Objectives* section above. Essentially, high flow events will still occur but they will often have a lower peak flow and may occur for a shorter duration, allowing less opportunity for waterharvester access. Generally the waterharvesters experience a reduction of days of pumping opportunity of one, two and three days in the 30%ile, 50%ile and 75%ile years respectively.

Compensation strategies were tested for these irrigators however these were found to be inefficient in terms of the amount of water released from the dam compared to the benefit to the impacted waterharvesters. Appropriate compensation strategies will be developed at later stages of the Project, after the new WRP is released and in conjunction with local irrigator groups.

Table 14-28 Mandatory medium and high priority WASOs

Mandatory Water Allocation Security Objectives		Median Monthly Reliability (%)	Full Entitlement (%)	With Dam Scenario (%)
Dawson River				
Upper Dawson River	High Priority	95 - 100	100.0	
	Medium Priority	82 - 88	83.0	
Lower Dawson River	High Priority	95 - 100	100.0	
	Medium Priority	82 - 88	90.0	
Dawson WSS (One Subscheme)	High Priority	95 - 100		100.0
	Medium Priority	82 - 88		88.0
Lower Fitzroy				
	High Priority	95 - 100	99.5	99.5
	Medium Priority	82 - 88	97.0	97.0

Table 14-29 Medium priority irrigation (Dawson River) – mean annual diversions

Sub-scheme	Management Zones	AMTD (km)	Licence Volume	Full Entitlement		With Dam Scenario			
				Mean Annual Diversion	Monthly Reliability	Mean Annual Diversion	Monthly Reliability	Change to Mean Annual Diversion	
			(ML/a)	(ML/a)	(%)	(ML/a)	(%)	(ML/a)	(%)
Upper Dawson	Dawson M	326.2 – 356.5	1,160	907	83.1	975	88.2	+ 68	+ 7%
	Dawson K	270.7 – 311.0	800	626	83.1	677	88.2	+ 51	+ 8%
	Dawson J	242.0 – 270.7	7,550	5,897	83.1	6,335	88.0	+ 438	+ 7%
	Dawson I	228.5 – 242.0	2,075	1,620	83.1	1,753	88.0	+ 133	+ 8%
	Dawson I - Med A		16,060	13,856	88.7	13,591	88.0	- 265	- 2%
			3,405	2,937	88.7	2,880	88.0	- 57	- 2%
	Dawson H	167.0 - 228.5	6,524	5,095	83.1	5,434	88.1	+ 338	+ 7%
	Dawson G	150.2 – 167.0	9,238	7,219	83.1	7,816	88.0	+ 597	+ 8%
	Dawson E	107.0 – 133.0	2,720	2,123	83.1	2,268	88.2	+ 146	+ 7%
Lower Dawson	Dawson D	82.7 – 107.0	4,264	3,734	89.6	3,612	88.0	- 123	- 3%
	Dawson C	48.0 – 82.7	1,892	1,641	89.5	1,597	88.0	- 44	- 3%
	Dawson B	18.37 – 48.0	683	595	89.2	578	88.1	- 18	- 3%
	Total		56,371	46,250		47,513		+ 1,263	+ 3%

Table 14-30 Mandatory unsupplemented WASO: days of waterharvesting opportunity (Lower Fitzroy)

Unsupplemented Irrigator Groups	Days of Waterharvesting opportunity								
	WRP Objectives			Full Entitlement			With Dam Scenario		
	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year
Class 5A	72	45	22	72	72	44	72	72	41
				72	72	44	72	72	41
				72	72	44	72	72	40
				72	72	44	72	72	41
				72	72	40	72	72	35
Class 5B	42	35	21	42	39	34	42	39	31
Class 6C	102	98	95	129	127	116	129	128	123
				122	113	98	123	117	106
				128	126	115	128	128	122
				125	116	101	126	120	107
Class 7D	70	58	47	116	107	88	117	107	90
				116	105	87	116	107	89

Table 14-31 Unsupplemented irrigators (Dawson River) – mean annual diversions

Management Zones	Flow Threshold	Full Entitlement	With Dam Scenario		
		Mean Annual Diversion	Mean Annual Diversion	Change to Mean Annual Diversion	
		(ML/a)	(ML/a)	(ML/a)	(%)
Dawson M	15/30 cumecs	300	345	45	15%
Dawson K	15/30 cumecs	902	670	-232	-26%
Dawson J	15/30 cumecs	9,193	8,442	-751	-8%
Dawson J + I	-	940	940	0	0%
Dawson I	15/30 cumecs	2,174	1,731	-444	-20%
Dawson H	15/30 cumecs	9,261	7,383	-1,878	-20%
Dawson J + H	1 cumec	2,586	2,586	0	0%
Dawson G	15/30 cumecs	5,972	4,581	-1,391	-23%
Dawson F	15/30 cumecs	1,160	873	-287	-25%
Dawson E	15/30 cumecs	5,105	4,807	-298	-6%
Dawson E + D	1 cumec	5,897	5,897	0	0%
Dawson H + E + D	-	2,713	2,713	0	0%
Dawson D	15/30 cumecs	6,906	6,188	-717	-10%
Dawson C	15/30 cumecs	2,289	2,059	-230	-10%
Dawson B + A	15/30 cumecs	9,832	9,143	-688	-7%
Dawson C+A	-	1,600	1,600	0	0%
Dawson A	-	108	108	0	0%
Total		**66,939**	**60,067**	**-6,872**	**-10%**

14.2.2.4. Extended simulation period modelling

As part of the EIS assessment, DERM has extended the existing IQQM simulation period to include the period 1995-2008. This was done in order to assess the impact of the recent climatic conditions from 1995-2008 on the catchment and the dam.

At the time of preparing this EIS, it should be noted that the data for the extended simulation period was still undergoing development and calibration. As such, the modelling based on this data can be used to indicate catchment behaviour, but is not suitable to assess the WRP EFOs and WASOs. The results presented here represent a preliminary assessment based on data available at the time of publishing. Further calibration of this extended model has been completed as part of the finalisation of the WRP 2011 and will be assessed prior to approval of the project.

Table 14-32 presents a comparison of the mean and median annual flows for the “With Dam” scenario at key reporting locations, for the WRP Simulation period and the Extended Simulation period. These results show that the extended simulation period has generally reduced the mean annual flow by between 4% and 6% across the Dawson River catchment, compared to the WRP simulation period. The median annual flow shows a greater range of impact (-2 to -

9%), primarily due to the influence of the dam operations, i.e. more small to medium flows are taken into storage while larger flows will overtop the dam. It should be noted that since 2007 the region has experienced a number of significant floods and the dry period seen in the 2000-2007 record has been somewhat reversed.

Table 14-32 “With dam” scenario – mean and median annual flow for the WRP simulation period (1900-1995) and the extended simulation period (1900-2008)

River	Location	WRP Simulation Period	Extended Simulation Period	% change
Mean Annual Flows (ML/a)				
Dawson River	Nathan Gorge	395,300	371,200	-6%
	Theodore	443,700	422,300	-5%
	Beckers	742,500	711,000	-4%
	End of Dawson River	1,156,500	1,106,200	-5%
Median Annual Flows (ML/a)				
Dawson River	Nathan Gorge	113,300	106,600	-6%
	Theodore	121,100	113,000	-7%
	Beckers	245,000	241,000	-2%
	End of Dawson River	516,500	474,100	-9%

Figure 14-29 shows the storage trace for the dam under the WRP simulation period and the extended simulation period. The extended simulation period captures the drought experienced from 2000-2007. The critical period for the dam operations occurs within both simulation periods in 1969, where the dam falls to a very low level for approximately 2 months, approaching its minimum operating volume.

Figure 14-30 shows a more detailed view of the dam critical period and the extended simulation period. During the extended simulation period the dam volume remains at low levels from 2003 to 2007, but the storage does not drop as low as the critical period in 1969.

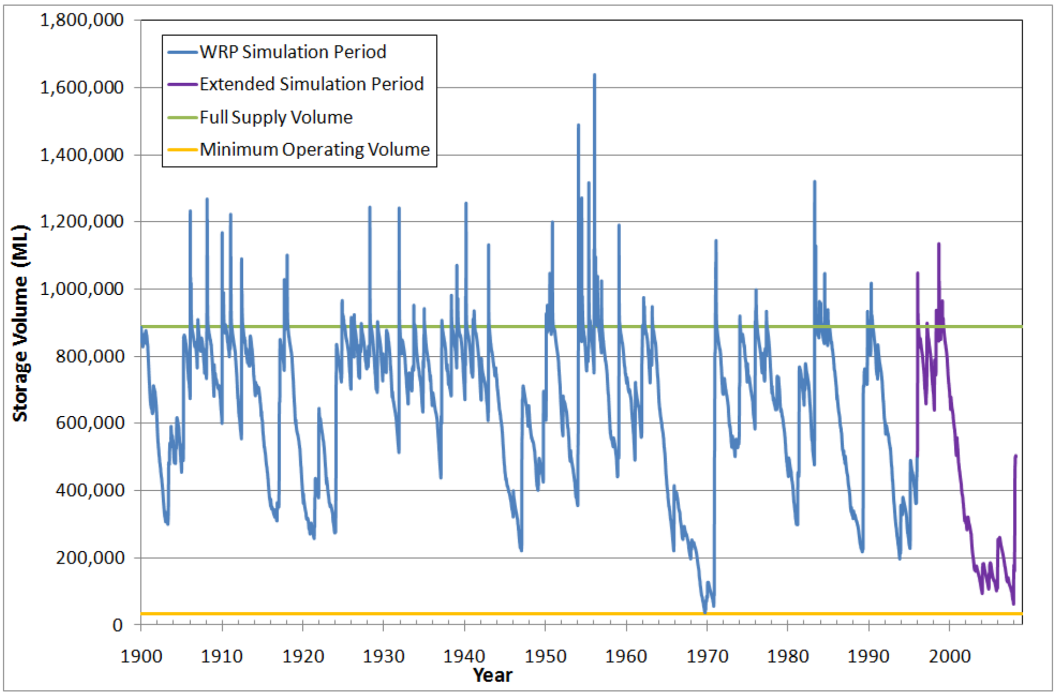


Figure 14-29 Nathan Dam modelled storage trace – WRP simulation period and extended simulation period (1900-2008)

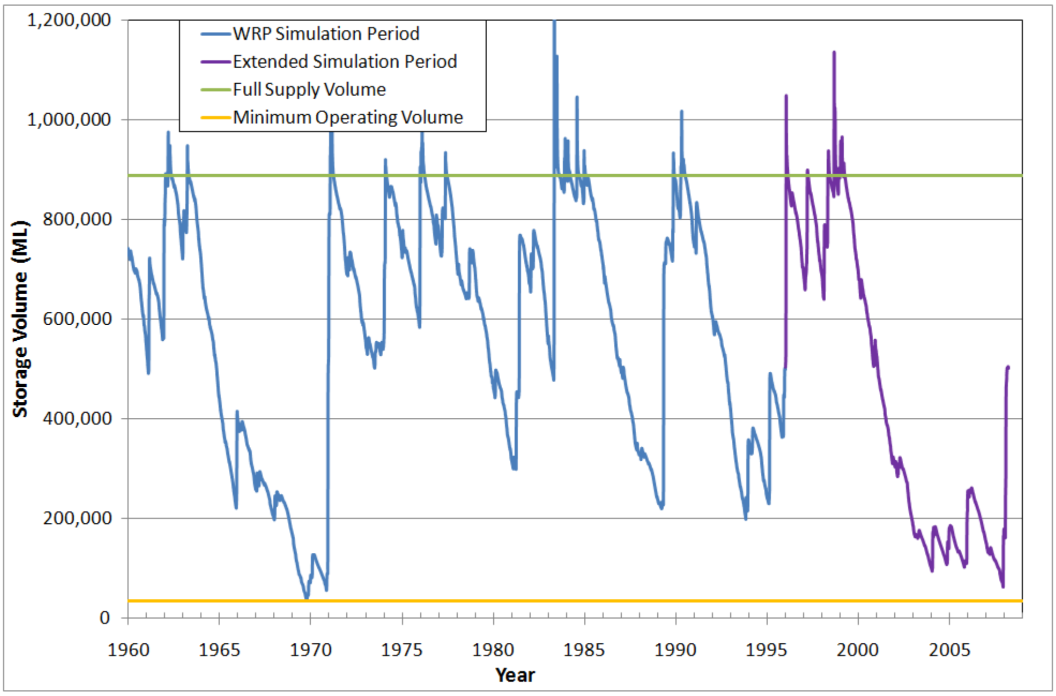


Figure 14-30 Nathan Dam modelled storage trace – WRP simulation period and extended simulation period (1960-2008)

Figure 14-31 presents a daily storage exceedance curve for the dam considered under the WRP simulation period and the extended simulation period. The storage exceedance curve is nearly identical for approximately 50% of the time; beyond this point the graph shows that the extended simulation period is slightly drier than the WRP simulation period. Although the average dam volume is lower during this period, the storage does not fail.

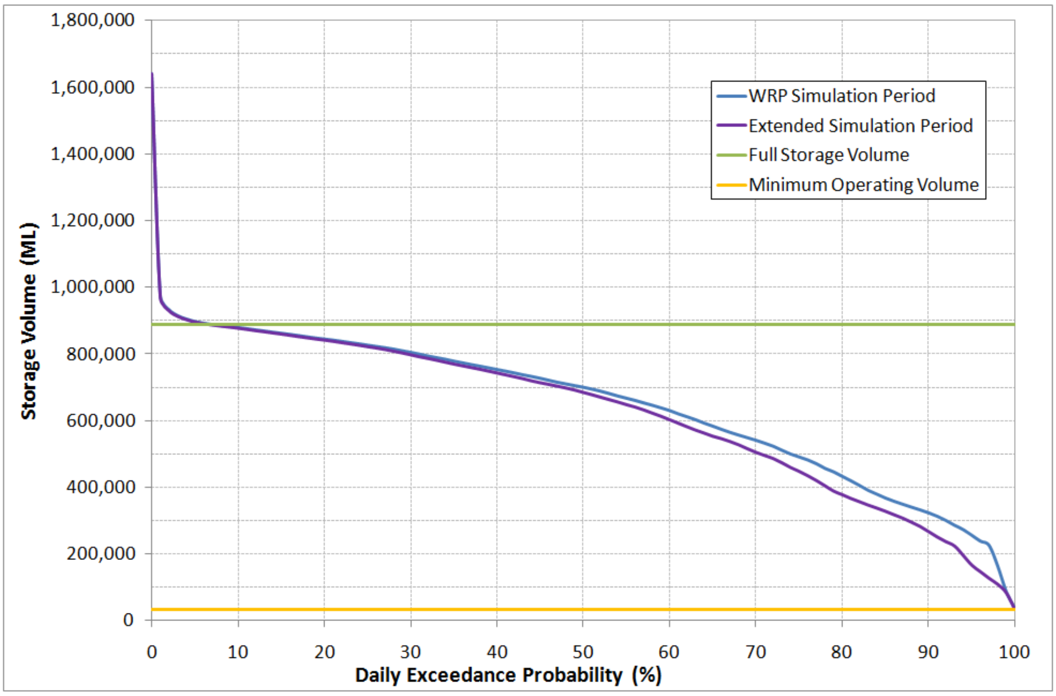


Figure 14-31 Nathan Dam modelled storage exceedance curve – WRP simulation period (1900-1995) and extended simulation period (1900-2008)

Figure 14-32 presents the daily flow exceedance curve at the Nathan Gorge gauge site, directly downstream of the dam comparing the pre-development, full entitlement WRP period and extended simulation periods. This shows that the extended simulation period does not have a significant impact on the daily flow regime directly downstream of the dam, as the operating strategy can be maintained despite the drought.

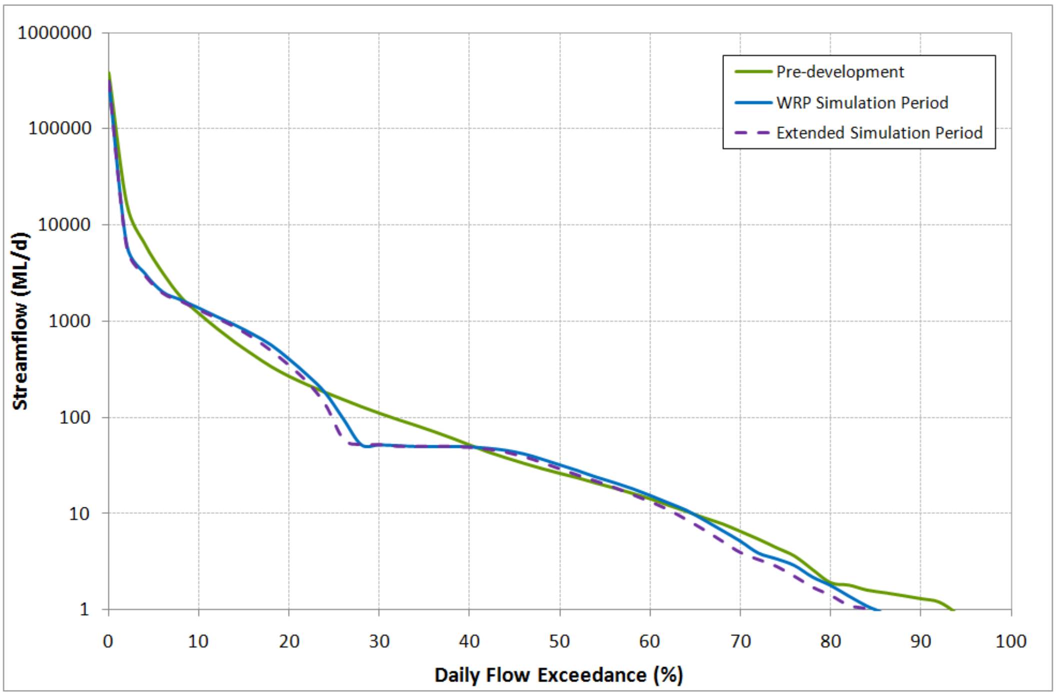


Figure 14-32 Nathan Gorge daily flow duration curve - WRP simulation period (1900-1995) and extended simulation period (1900-2008)

14.2.2.5. Time to fill analysis

An analysis was performed on the probability of the dam reaching certain storage volumes. This assessment was carried out using daily IQQM modelling of 85 ten year periods with a rolling start year (1900, 1901….1985). The initial storage volume for the dam was set to zero for each of the ten year periods, starting in January. The dam was modelled using the preliminary operational strategy (Section 14.2.2.1).

An assessment was then made of the length of time it took for the storage to reach certain volumes. Key volumes for the assessment were the minimum operating volume (34,502 ML), trigger for first post winter flow (FPWF) and seasonal baseflow (SBF) releases (150,000 ML) and full storage volume (888,312 ML).

Results of this assessment are presented in Figure 14-33. The graph presents the 10^{th}, 50^{th}, 99^{th} and 99.9^{th} percentile probability of filling within a ten year period. The 50^{th} percentile results show the median outcome while the 10^{th}, 99^{th} and 99.9^{th} percentile results provide an envelope of probability.

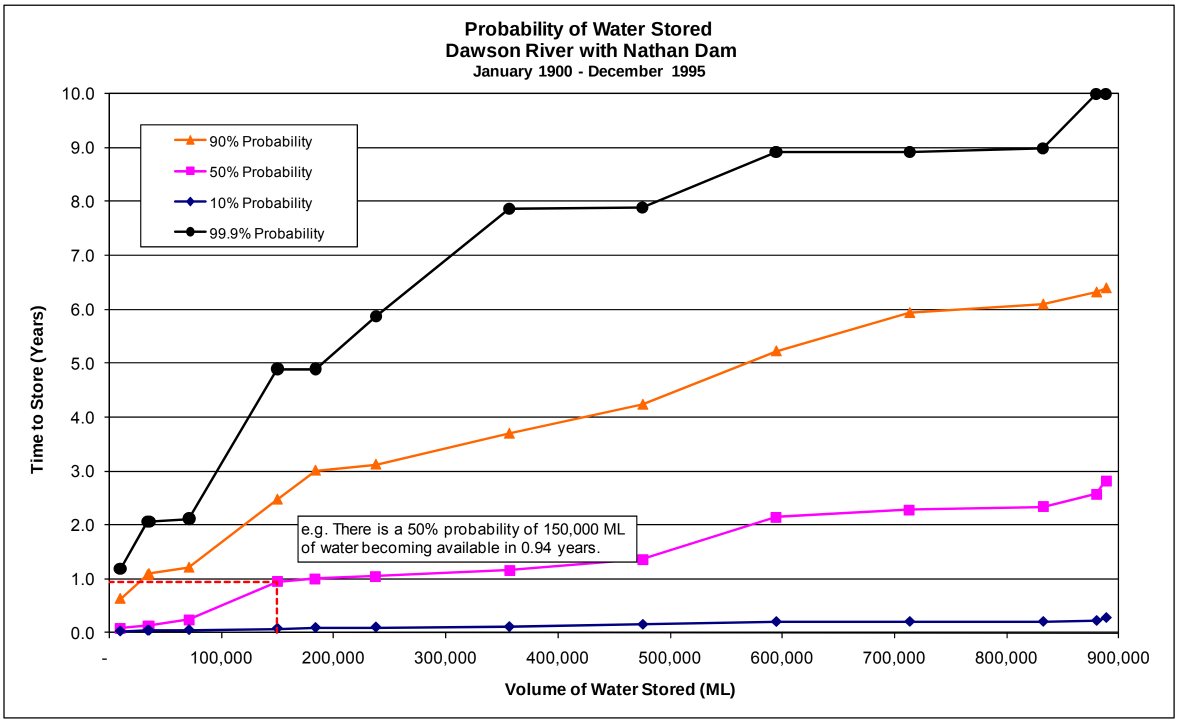


Figure 14-33 Nathan Dam time to fill analysis

The 99.9th percentile results show a distinct jump in the time taken for the storage to fill from MOV (two years) to the FPWF and SBF release trigger of 150,000 ML (five years). This reflects the probability of the dam becoming operational during a dry period, with very low inflows to the dam. Alternatively, the 10th percentile results simulate the probability that the dam will become operational during a wet period, where the dam would likely fill within approximately three months.

Results for the key storage volumes are summarised in Table 14-33. These results show that there is a 50% probability of exceeding the minimum operating volume within two months, reaching the FPWF and SBF release trigger within one year and full storage volume within three years.

Table 14-33 Nathan Dam - probability of reaching key storage volumes

Key Storage Volumes	**Volume (ML)**	**Time to Store (Yr)**			
		10% Probability	**50% Probability**	**90% Probability**	**99.9% Probability**
Minimum Operating Volume	34,502	0.04	0.12	1.07	2.06
FPWF and SBF Release Trigger	150,000	0.08	0.94	2.47	4.89
Full Storage Volume	888,312	0.28	2.82	6.39	9.99

Modelling for the time to fill analysis was based on the operational strategy discussed in Section 14.2.2.1. This means it has been assumed that the additional demands from the dam were available from day one. As such, the information presented for this analysis represents a worst case scenario in terms of maximum extractions during the filling phase and the time taken to reach key storage volumes. The release of new allocations to meet additional demands will be a staged process consistent with market conditions.

During the detailed design phase a final operational strategy will be developed. This will include a transitional operational strategy which will describe how the dam will be operated in the period between starting to store water and reaching a nominal operating volume. The transitional operational strategy will maintain water access for downstream users and key environmental flows but will otherwise aim to fill as quickly as possible. The detailed filling strategy for the dam will be developed in later stages of the Project, once the design details of the dam are finalised and the new WRP model becomes available.

14.2.2.6. Climate change

A sensitivity analysis was undertaken in order to demonstrate the potential range of impacts under climate change conditions. For this analysis the 2050 climate change projection under the highest emissions scenario (A1FI) was adopted. This emissions scenario assumes a high reliance on fossil fuels and most closely follows current actual emissions levels. The 2050 projection represents a timeframe which is close enough to have some certainty around the estimates but still allows enough time for climate change impacts to develop. Estimates for timeframes beyond 2050 contain too much uncertainty to provide a useful forecast of likely future conditions. Modelling of estimates for timeframes prior to 2050 was felt to add little value to the assessment as the impacts would be superseded by the 2050 modelling. The 2050 projection therefore represents the highest estimate of impact that we may have some confidence in.

Because of the uncertainty in climate change predictions, three cases were modelled in order to demonstrate the range of potential impacts. The median case (50^{th} percentile) is the most likely future case, while the 90^{th} percentile and the 10^{th} percentile cases represent the confidence limits of the estimates.

Climate change data development

Data for the climate change modelling was supplied by DERM and was developed using the following methodology (DERM, 2009).

Scaling factors for evaporation and rainfall were supplied by the Queensland Climate Change Centre of Excellence (QCCCE). The factors were supplied as monthly percentage changes for each sub-catchment in the Fitzroy Basin and for each of the adopted General Circulation Models (GCMs) shown in Table 14-34. GCMs are mathematical models representing physical processes in the atmosphere, ocean, cryosphere and land surface (IPCC, 2010). They are used to simulate the response of the global climate as the result of changes to solar conditions or physical parameters, such as greenhouse gas concentrations. The GCMs listed in Table 14-34 were selected by QCCCE as the most appropriate models for the prediction of climate change impacts on rainfall in Queensland (DERM, 2009).

Table 14-34 General Circulation Models used for the Fitzroy Basin assessment (DERM, 2009)

General Circulation Models
Mark 3.0 SRES A2
Mark 3.5 SRES A2
GFDL_cm2_1 SRES A2 *
IAP_FGOALS1_0_g_SRES A1B
MIROC3_2_hires_SRES A1B
MIROC3_2_medres_SRES A1B
MIUB_echo_g_SRES A2 *
MPI_ECHAM5_SRES A2 *
NCAR_CCSM3_0 SRES A2
UKMO_HADCM3 SRES A2 *
UKMO_HADGEM1 SRES A2 *

* GCMs with only monthly rainfall change factors (that is, no predicted evaporation change).

Climate change impacts are generally influenced more by changes in rainfall than evaporation. The GCMs for this study were therefore selected by ranking the mean annual rainfall predicted by each model. The climate change models which provided the median, 90th and 10th percentile rainfall were selected to show the best indication of uncertainty.

The GCMs for the 10th and 90th percentile cases were found to be consistent across the Fitzroy Basin; however the median case differed for the Nogoa Mackenzie and the Dawson-Callide catchments.

Climate change scaling was applied to lake evaporation and potential evapotranspiration, but did not affect seepage or adjustments for local catchment inflows. The adopted monthly Climate Change percentage adjustments for rainfall and evaporation are supplied in Appendix 14-A.

Climate change streamflows were generated using Sacramento rainfall-runoff models and the adjusted rainfall and evaporation series. Representative Sacramento models were selected for each of the four Fitzroy sub-catchments in order to determine the influence of climate change in that catchment. Streamflows were generated using climate change rainfall and evaporation then compared to flows generated using historical data.

Climate change sensitivity modelling

The three climate change cases were run for both the Full Entitlement and "With Dam" scenarios. The results from the Full Entitlement climate change modelling were used to quantify changes to flow characteristics created by the predicted changes to rainfall and evaporation. These flow characteristics, when compared to Full Entitlement flow characteristics, provide an indication of the sensitivity of the river systems to the climate change estimates, under existing infrastructure and development.

The results from the “With Dam” climate change case were used to quantify changes to flow characteristics created by the dam. Table 14-35 presents a comparison of mean annual flow at key locations in the Dawson River catchment for the “With Dam” scenario. Under the median climate change case mean annual flow is reduced by 15% to 22% across the catchment. The 90th and 10th percentile climate change cases have a high impact on flow within the Dawson River, ranging approximately -57% to + 59%.

Table 14-35 Mean annual flow in the Dawson River catchment - under projected 2050 climate change impacts (with dam scenario)

	Mean Annual Flow (With Dam Scenario)			
			% change	
	Current Climate (ML/a)	Median Climate Change (ML/a)	Median Climate Change	10th and 90th Percentile range
Dawson River at Nathan Gorge (Node 5a)	395,300	311,500	-21%	-56% to +54%
Dawson River at Theodore (Node 4)	443,700	345,900	-22%	-57% to +59%
Dawson River at Beckers (Node 2)	742,500	603,700	-19%	-52% to +56%
End of Dawson River	1,156,500	985,300	-15%	-45% to +51%

Table 14-36 presents a comparison of median annual flow at key locations in the Dawson River catchment for the “With Dam” scenario. Under the median climate change case median annual flow is reduced by 9% to 19% across the catchment. The 90th and 10th percentile climate change cases have a high impact on flow within the Dawson River, ranging approximately -54% to +107%.

Table 14-36 Median annual flow in the Dawson River catchment - under projected 2050 climate change impacts (with dam scenario)

	Median Annual Flow (With Dam scenario)			
			% change	
	Current Climate (ML/a)	Median Climate Change (ML/a)	Median Climate Change	10th and 90th Percentile range
Dawson River at Nathan Gorge (Node 5a)	113,300	103,000	-9%	-35% to +42%
Dawson River at Theodore (Node 4)	121,100	98,600	-19%	-40% to +73%
Dawson River at Beckers (Node 2)	245,000	198,700	-19%	-54% to +107%
End of Dawson River	516,500	435,200	-16%	-50% to +59%

The climate change cases were not assessed against WRP objectives. This is because the climate change cases are based on likely impacts at 2050, well outside the WRP timeframe. WRPs are valid for a period of ten years, after which they are revised, incorporating more recent flow data, and changes to catchment development, infrastructure and management. It is anticipated that climate change estimates will be introduced to the WRP process in 2012.

Figure 14-34 to Figure 14-37 present the daily flow exceedance curves for Dawson River at Nathan Gorge, Theodore, Beckers and the end of Dawson River. These graphs show the impact of the dam and regulated supply on the overall flow regime under current climate conditions as well as the three climate change cases.

Overall, the catchments behaved as expected under the climate change cases, and the adopted operational strategies are appropriate. The climate change cases presented a range of possible future climates, from 'wet' to 'dry'. The current climate was generally found to fall between the 50th percentile and the 10th percentile climate change cases, i.e. at the wetter end of the scale.

Under the Climate Change scenarios impacts seem to be more pronounced in the lower flow ranges at Nathan Gorge and Theodore. This is most likely due to the influence of the dam operations. At Beckers and at the end of the Dawson River the impacts seem to be more evenly distributed through the flow range.

At Beckers the flow duration curve shows elevated low flow (25 ML/d) for approximately 30% of the simulation period. This is due to the supply of new HP water at Duaringa, downstream of Beckers. This water is extracted before the end of the Dawson River, with the flow duration curve moving back towards pre-development conditions.

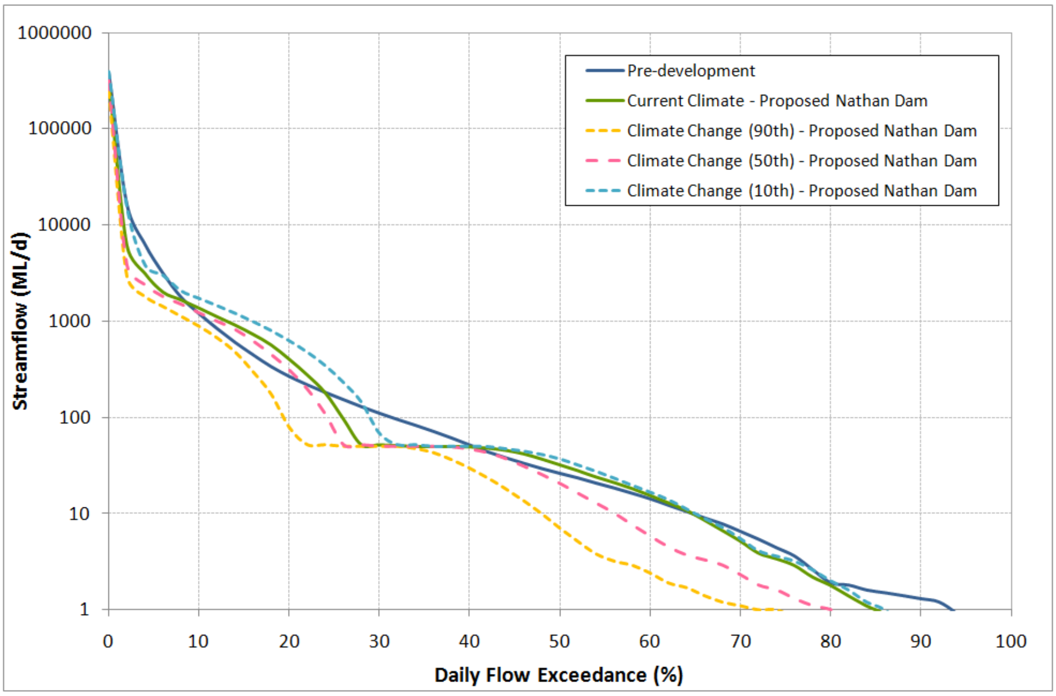


Figure 14-34 Daily flow exceedance curve - Dawson River at Nathan Gorge

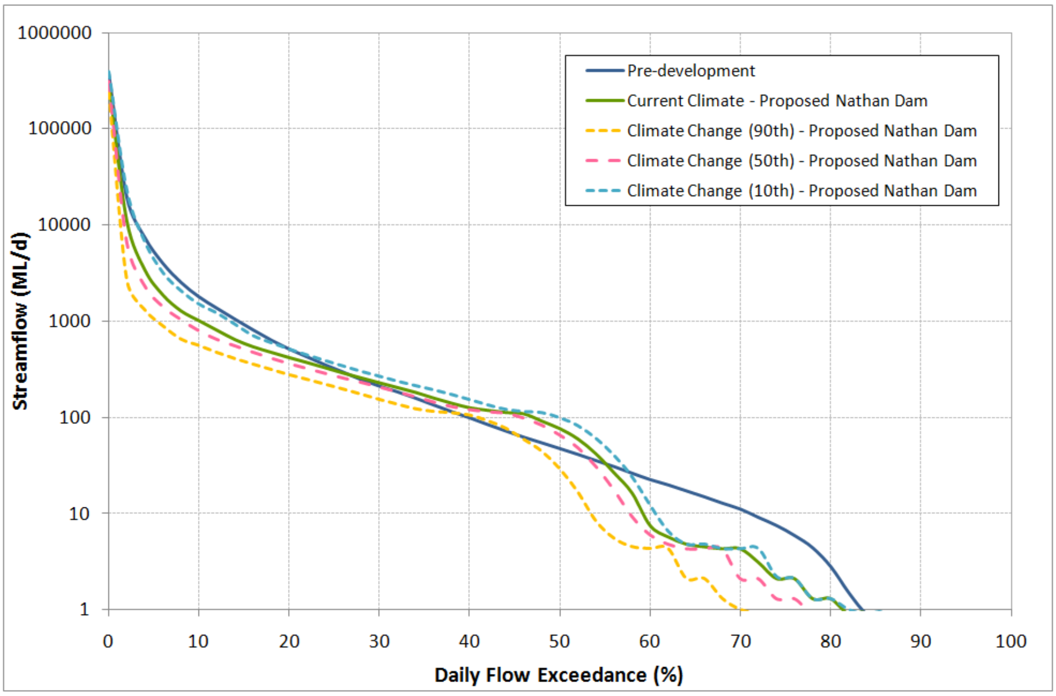


Figure 14-35 Daily flow exceedance curve - Dawson River at Theodore

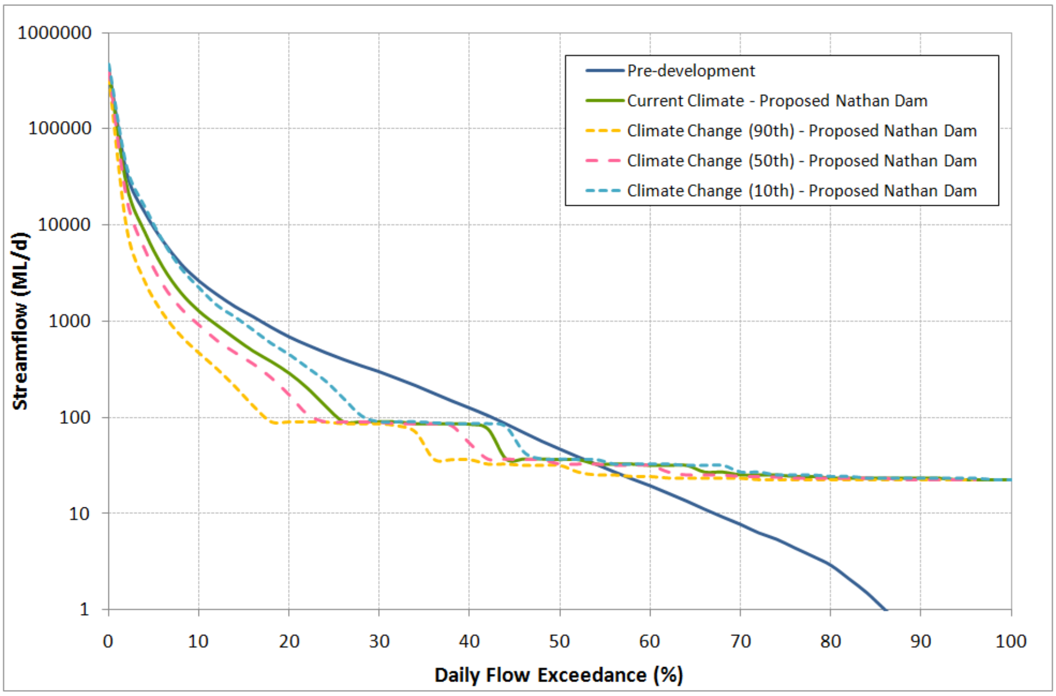


Figure 14-36 Daily flow exceedance curve - Dawson River at Beckers

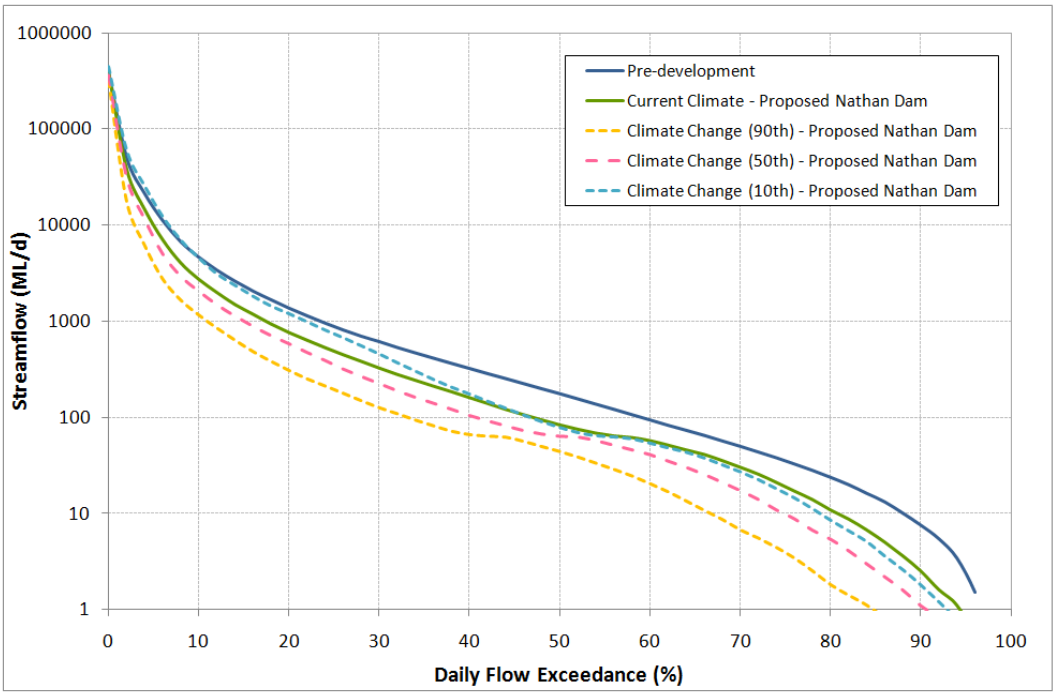


Figure 14-37 Daily flow exceedance curve - End of Dawson River

14.2.2.7. Level of service analysis

A level of service (LOS) analysis is intended to evaluate the frequency, duration and severity of water restrictions which would be experienced under defined water restriction rules. The LOS approach is outlined in the following papers:

- Framework for Analysing Surface Water Availability in South East Queensland: Technical Report (QWC, 2005); and
- Guidelines for Analysing Rural Water Supply System Performance (SunWater & DNRMW, 2006).

New water supplied from the dam is intended to be HP only, with no restrictions placed on the HP supply, apart from the dam's minimum operating volume.

A LOS analysis was carried out for the new HP supply (as a single supply) for the current climate and potential climate change scenarios, with the results presented in Table 14-38 to Table 14-40. The following model scenarios were assessed:

- current climate (as per the current ROP model);
- 10th percentile climate change scenario (wet conditions)
- 50th percentile climate change scenario (most likely future conditions)
- 90th percentile climate change scenario (dry conditions)

The HP supply was assessed against the following criteria:

- Normalised mean annual diversion (%) – The mean annual diversion over the simulation period expressed as a percentage of the nominal volume.
- Normalised median annual reliability (%) – The median of all the annual diversions expressed as a percentage of the nominal volume.
- Normalised median monthly reliability (%) – The median of all the monthly diversions expressed as a percentage of the nominal volume.
- Minimum resulting contingency volume – The minimum volume in the storage during the simulation period above the minimum operating volume (if no failures occur).
- Level of water availability (LOWA) – The volume of diversions as a percentage of the nominal volume, used as a level of service indicator.
- Annual frequency of equalling or exceeding each level of water availability – The percentage and number of years that are supplied at or above the specified level of water availability.
- Long-term percentage duration of time* less than or equal to specified levels of water availability – The number and percentage of days where the supply is less than or equal to the specified level of water availability. (*Note that the period of model analysis is 95 years, or 34,698 days).
- Maximum duration of periods less than or equal to specified levels of water availability (days) – The maximum consecutive number of days with supply less than or equal to the specified level of water availability.

The results presented in Table 14-38 to Table 14-40 show that the storage provides a high reliability of supply, achieving 100% median monthly and median annual reliability for all scenarios. The normalised mean annual diversion is also 100% under the current climate and 10th percentile climate change scenarios. However, this is reduced to 99.6% in the 50th percentile climate change scenario and 97.8% in the 90th percentile climate change scenario (where the 90th percentile climate change scenario represents the driest future climate change scenario modelled by the QCCCE).

Contingency storage may be used to address water demands as a result of climatic fluctuations, demand growth, climate change and variability (QWC, 2005). Under the current climate scenario and the 10th percentile climate change scenario the minimum volume in the dam is 35,787 ML and 213,715 ML respectively. This is above the minimum operating volume of 34,502 ML and represents a potential contingency volume for dam operators (albeit a small one under current climate conditions). Under the 50th and 90th percentile climate change scenarios the storage falls below the minimum operating volume and there is therefore no contingency volume presented for these scenarios.

Under the current climate scenario and the 10th percentile climate change scenario, the level of water availability (LOWA) is 100% of the nominal volume on both an annual and daily basis.

However, under the 50th and 90th percentile climate change scenarios the annual frequency of equalling or exceeding the specified LOWA levels alters. For example, under the 50th percentile climate change scenario 100% of the nominal volume is supplied in 96.8% of years (92 years), while 90% of the nominal volume is supplied in 98.9% of years (94 years) and 50% of the nominal volume is supplied in 100% of years (95 years). This implies that over the 95 year period assessed in 92 years 100% of the nominal volume is supplied, for two years between 100% and 90% is supplied, and for one year between 90% and 50% is supplied (Table 14-39).

For the 50th percentile climate change scenario, there are 171 days where diversions are equal to or less than 90% of the nominal volume, with the longest individual spell at or below 90% of the nominal volume lasting 155 days. There are 161 days with diversions equal to or less than 50% of the nominal volume, 41 days with diversions equal to or less than 10% of the nominal volume and 12 days where the diversion requirements are not met at all (0% LOWA).

Under the 90th percentile climate change scenario 100% of the nominal volume is supplied in 93.7% of years (89 years), with 90% of the nominal volume also supplied in 93.7% of years (89 years), 50% of the nominal volume is supplied in 98.9% of years (94 years) and 10% of the nominal volume is supplied in 100% of years (95 years). This implies that over the 95 year period assessed in 89 years 100% of the nominal volume is supplied, for five years between 50% and 90% is supplied, and for one year between 50% and 10% is supplied (Table 14-40).

For the 90th percentile climate change scenario, there are 948 days where diversions are equal to or less than 90% of the nominal volume, with the longest individual spell at or below 90% of the nominal volume lasting 477 days. There are 907 days with diversions equal to or less than 50% of the nominal volume, 277 days with diversions equal to or less than 10% of the nominal volume and 239 days where the diversion requirements are not met at all (0% LOWA).

Table 14-37 LOS assessment results for current climate scenario

Normalised Mean Annual Reliability (%)	Normalised Median Annual Reliability (%)	Normalised Median Monthly Reliability (%)	Minimum Resultant Contingency Volume (ML)	Level of Water Availability (LOWA)	Annual Frequency of Equalling or Exceeding LOWA	Long-term percentage duration of time* less than or equal to LOWA	Maximum duration of periods less than or equal to LOWA (days)
100.0%	100.0%	100.0%	1,285	100% nominal volume	100.0% 95 years	100.0% 34,698 days	34,698
				90% nominal volume	100.0% 95 years	0.0% 0 days	-
				50% nominal volume	100.0% 95 years	0.0% 0 days	-
				10% nominal volume	100.0% 95 years	0.0% 0 days	-
				0% nominal volume	100.0% 95 years	0.0% 0 days	-

* Period of model analysis 34,698 days (95 years)

Table 14-38 LOS assessment results for the 10th percentile climate change scenario

Normalised Mean Annual Reliability (%)	Normalised Median Annual Reliability (%)	Normalised Median Monthly Reliability (%)	Minimum Resultant Contingency Volume (ML)	Level of Water Availability (LOWA)	Annual Frequency of Equalling or Exceeding LOWA	Long-term percentage duration of time* less than or equal to LOWA	Maximum duration of periods less than or equal to LOWA (days)
100.0%	100.0%	100.0%	179,213	100% nominal volume	100.0% 95 years	100.0% 34,698 days	34,698
				90% nominal volume	100.0% 95 years	0.0% 0 days	-
				50% nominal volume	100.0% 95 years	0.0% 0 days	-
				10% nominal volume	100.0% 95 years	0.0% 0 days	-
				0% nominal volume	100.0% 95 years	0.0% 0 days	-

* Period of model analysis 34,698 days (95 years)

Table 14-39 LOS assessment results for the 50th percentile climate change scenario

Normalised Mean Annual Reliability (%)	Normalised Median Annual Reliability (%)	Normalised Median Monthly Reliability (%)	Minimum Resultant Contingency Volume (ML)	Level of Water Availability (LOWA)	Annual Frequency of Equalling or Exceeding LOWA	Long-term percentage duration of time* less than or equal to LOWA	Maximum duration of periods less than or equal to LOWA (days)
99.6%	100.0%	100.0%	-	100% nominal volume	96.8% 92 years	100.0% 34,698 days	34,698
				90% nominal volume	98.9% 94 years	0.5% 171 days	155
				50% nominal volume	100.0% 95 years	0.5% 161 days	146
				10% nominal volume	100.0% 95 years	0.1% 41 days	41
				0% nominal volume	100.0% 95 years	0.0% 12 days	12

* Period of model analysis 34,698 days (95 years)

Table 14-40 LOS assessment results for the 90th percentile climate change scenario

Normalised Mean Annual Reliability (%)	Normalised Median Annual Reliability (%)	Normalised Median Monthly Reliability (%)	Minimum Resultant Contingency Volume (ML)	Level of Water Availability (LOWA)	Annual Frequency of Equalling or Exceeding LOWA	Long-term percentage duration of time* less than or equal to LOWA	Maximum duration of periods less than or equal to LOWA (days)
97.8%	100.0%	100.0%	-	100% nominal volume	93.7% 89 years	100.0% 34,698 days	34,698
				90% nominal volume	93.7% 89 years	2.7% 948 days	477
				50% nominal volume	98.9% 94 years	2.6% 907 days	466
				10% nominal volume	100.0% 95 years	0.8% 277 days	181
				0% nominal volume	100.0% 95 years	0.7% 239 days	140

* Period of model analysis 34,698 days (95 years)

Figure 14-38 displays the Nathan Dam storage trace for the current climate and the three modelled climate change cases. The figure shows that the dam is drawn down more frequently and severely under the 90th percentile (dry) case.

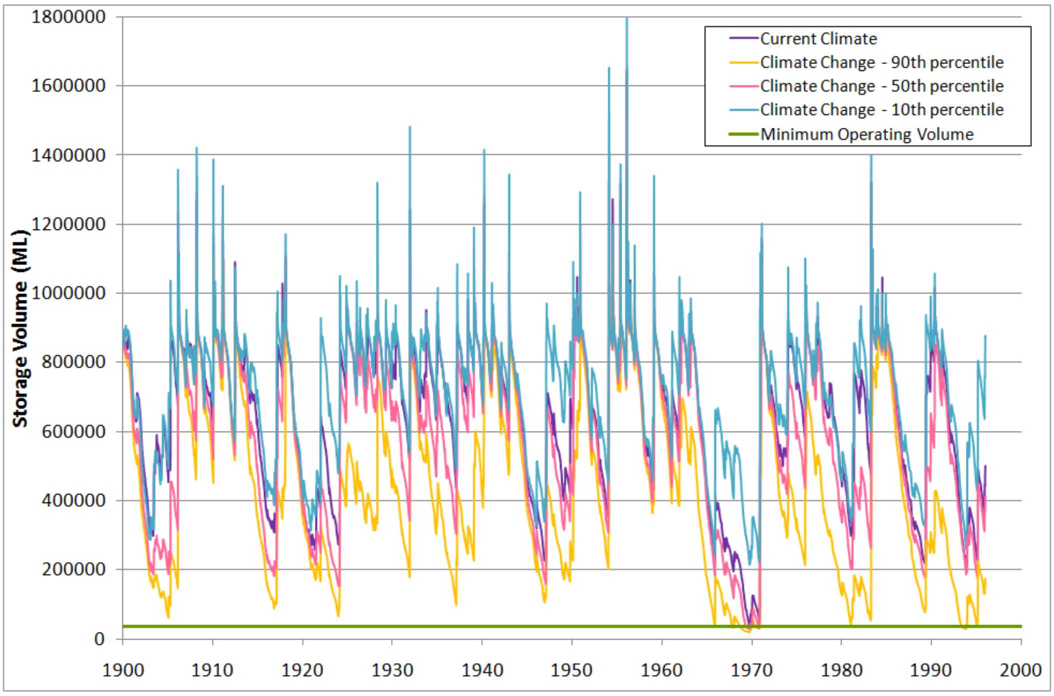


Figure 14-38 Nathan Dam modelled storage trace – current climate and potential climate change scenarios

These results also show that the dam level does not drop below the MOV (34,502 ML) under current climate conditions, nor under the 10th percentile climate change case. However, for the 50th and 90th percentile climate change cases the dam volume drops below the MOV for 0.5% and 2.6% of the time, respectively.

Overall, the statistics presented above show that the storage provides a high level of reliability, and a very low risk of storage levels falling below the MOV.

14.2.3. Flooding

This section describes the impacts that the dam may have on flooding. This includes a discussion of the potential backwater effects upstream of the dam as well as an assessment of any potential flood effects downstream.

Hydraulic modelling was assessed for the Pre Dam and Post Dam scenarios for a range of design floods, including the 1 in 100 AEP design flood events and the PMF for the Post Dam scenario. These assessments have defined the required minimum extent of upstream land acquisition and the maximum flood level at the dam site. (The methodology used for this assessment is described in Section 14.1.2.3)

For the Post Dam scenarios, it was assumed the dam was initially at Full Supply Level. This is a conservative assumption as the dam is calculated to be at FSL approximately 7% of the time; hence it is likely that actual flood levels will be lower than predicted here.

The 1 in 100 AEP (Q100) flood level is used to define the flood buffer around the storage area and will inform the land acquisition strategy, as discussed in Section 2.4.1.1. The flood buffer aims to achieve objectives related to water quality, safety and protection of infrastructure while minimising impacts on productive land use and disruption to existing landowners.

The design and operation of the dam will be optimised during the detailed design process in accordance with the *Queensland Dam Safety Management Guidelines* (DNRM, 2002). Flood extents provided here are preliminary and indicative; they are not intended to be a design tool and are provided as an indication of relative impacts only.

The results of the flood modelling are presented to 0.1 m increments. This is standard practice, given the data available and the nature of the assessment undertaken. However, it is important that possible errors involved in the process and therefore the ultimate accuracy of the outputs is acknowledged. The objective of this section is to compare the Pre and Post Dam model results, in order to assess the relative impact of the dam. The difference between the scenarios can be estimated with greater precision than absolute flood levels because the results from both scenarios are based on the same input data, with its incumbent errors.

However, the absolute flood level predicted by either individual scenario, and therefore how it is depicted on a map, is affected by all the errors and inaccuracies of the input data along with the accuracy of the local topographic data (in this case +/- 0.7 m or +/- 0.15 m, depending on the area). Given the accuracy of the topographic data the prediction of the absolute level of a modelled Q100 event is likely to have an accuracy of +/- 0.25 m.

14.2.3.1. Upstream flooding

At FSL the dam will inundate several upstream reaches and tributaries, reducing the travel time of flood waters, compared to existing conditions. Peak flows for the Post Dam scenarios are therefore slightly higher and occur earlier than under existing conditions, although the critical duration does not change. Peak inflows at the dam site are shown in Table 14-41 for the pre and post dam scenarios for a range of design events.

Table 14-41 Peak flows at Nathan Dam site

AEP (1: …)	Peak Inflow (m^3/s)		Peak Outflow (m^3/s)	Time to Peak (hr)		Peak Water Level (m AHD)
	Pre Dam	Post Dam	Post Dam	Pre Dam	Post Dam	Post Dam
5	1490	1650	1010	102	76	185.4
10	1890	2060	1410	117	89	185.9
20	2520	2760	1990	123	92	186.4
50	3040	3330	2480	129	97	186.8
100	3670	4030	3100	134	100	187.3
1000	5140	5940	4460	125	88	188.4

Flood routing was carried out using the proposed spillway configuration in order to determine the inundation levels for a range of flood events. The spillway rating curve accounts for factors such as depth of approach, downstream apron interference and degree of submergence. Detailed topographic assessment was used to determine the storage capacity and surface area relationships with respect to the reservoir level.

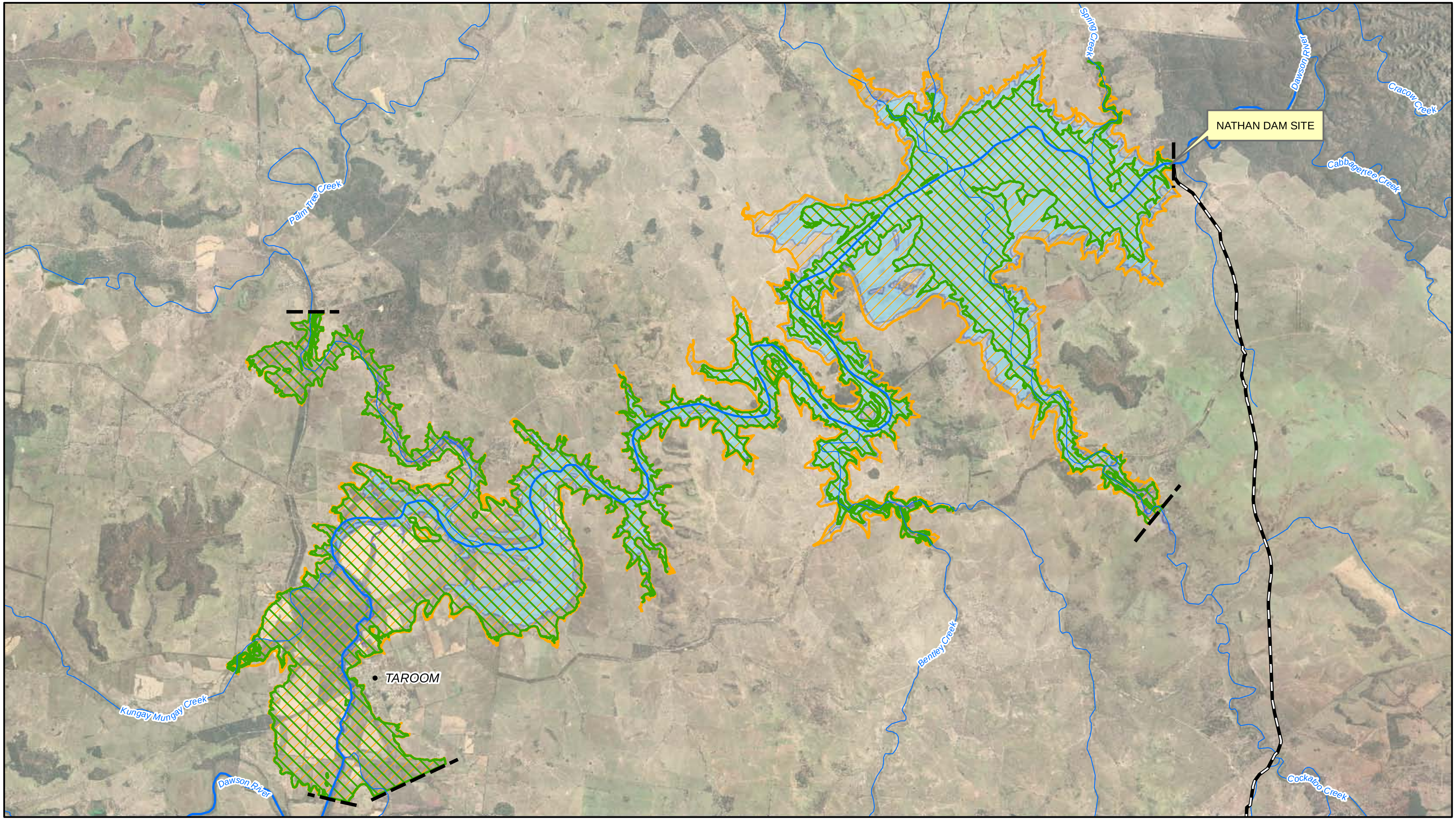
The results of the flood routing were used in conjunction with the storage characteristics to determine the reservoir storage capacity and surface area for the peak water surface level reached during the floods assessed. These results are shown in Table 14-42 for the dam at FSL and for the 1 in 100 AEP and the 1 in 1000 AEP.

Table 14-42 Reservoir area and storage capacity for Nathan Dam at FSL, 1 in 100 AEP and 1 in 1000 AEP (SunWater, 2010)

Flood Condition	Peak Reservoir Level (m AHD)	Reservoir Storage Capacity (ML)	Reservoir Area (ha)
No Flood and Reservoir at FSL	183.5	888,312	13,514
1 in 100 AEP	187.3	1,542,600	21,600
1 in 1000 AEP	188.4	1,795,500	24,400

Backwater effects from the dam will cause some localised flooding impacts in the areas surrounding the water storage. Figure 14-39 shows the extent of the reservoir at FSL and the 1 in 100 AEP flood level. A comparison of the modelled 1 in 100 AEP flood with and without the dam produces the flood margin used in the land acquisition process. If properties are purchased in their entirety then the exact location of the flood margin becomes less critical.

Properties affected by flooding upstream of the dam are presented in Figure 7-3. This shows that there is one residence below FSL, within the water storage area, and two residences between FSL and the Q100 flood level, located in Taroom. These residences will not be habitable as they will no longer meet housing safety criteria. There are also a number of properties where the residence is above the Q100 flood level although the property is affected by FSL. SunWater will negotiate easements for these properties so that further development or construction will not expose the residents to flood risk.



LEGEND

- • Town
- Proposed Pipeline
- Extent of Flood Mapping
- Dawson River
- Watercourse
- Full Supply Level (183.5 m AHD)
- 1 in 100 AEP with No Dam
- 1 in 100 AEP with Dam

Note:
The flood extent shown on this map does not include areas where there is no difference in peak flood levels between the pre and post dam scenarios.

Projection: GDA94 Zone 56

Figure 14-39

0 1 2 4
Kilometres

N

Scale 1:200,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Nathan Dam - inundation extent at FSL and the 1 in 100 AEP

Flooding at Taroom

Of particular interest in this study was determining the impact caused by the dam on flood levels at the township of Taroom. For the 1 in 100 AEP event the difference in peak water level pre and post dam is +0.6 m, although both flood peaks are below the town development limit of EL 190.1 m AHD.

Two residences in Taroom are located between FSL and the Q100 flood level and will not be habitable, as they will no longer meet housing safety criteria. While all other residences are located above the Q100 flood level several are on property which is either affected by the FSL or Q100 levels. SunWater will negotiate easements for these properties so that further development or construction will not expose the residents to flood risk.

Table 14-43 presents the peak flood levels from the upstream extent of the model (approximately 18 km upstream of Taroom) to the dam site for the 1 in 100 AEP for the pre and post dam scenarios, showing an increase of peak flood level due to the dam. The difference in peak flood level between the two scenarios increases heading downstream to the dam site, as would be expected.

Table 14-43 Peak flood levels for the 1 in 100 AEP – pre and post dam (SunWater, 2010)

	AMTD (km)	Peak Flood Level (m AHD)		Difference in Peak Flood Level (m)
		Pre Dam	Post Dam	
Upstream boundary of model	403.0	197.2	197.2	0
Juandah Creek Confluence	388.1	189.2	189.7	0.5
Taroom Bridge	385.5	189.1	189.7	0.6
Taroom Township	384.7	189.1	189.7	0.6
Bundalla Road Crossing	365.4	188.1	189.2	1.2
Bentley Creek Confluence	342.8	181.2	187.6	6.4
Glebe Weir	326.2	177.5	187.4	9.9
Dam Site	315.3	176.9	187.4	10.5

Flooding at the Leichardt Highway Bridge

The Leichardt Highway Bridge at Taroom has a deck elevation of 188.5 m AHD. This provides the bridge with immunity from approximately a 1 in 20 AEP flood event under existing conditions. However, the approaches to the bridge have a lower flood immunity and the bridge is therefore unusable during more frequent flood events. An example of this is shown in Figure 14-40, which presents flooding at the bridge in March 2010, approximately equivalent to a 1 in 12 AEP.

Figure 14-40 Flooding at the Leichardt Highway Bridge at Taroom (March, 2010)

Table 14-44 presents the peak flood levels at the Leichardt Highway Bridge at Taroom for the 1 in 5 AEP to the 1 in 1000 AEP. The dam makes no appreciable difference to the 1 in 5 and 1 in 10 AEP. For larger flood events the dam will increase the depth of flooding at the bridge. However, as the approach to the bridge would be cut this is not considered to be a significant impact. Flood durations are expected to increase by up to one day.

Table 14-44 Peak flood levels at the Leichardt Highway Bridge at Taroom – pre and post dam

AEP (1: …)	Peak Flood Level (m AHD)		Difference in Peak Flood Level (m)	Bridge Inundation (m)	
	Pre Dam	Post Dam		Pre Dam	Post Dam
5	187.8	187.8	0.0	-	-
10	188.0	188.1	0.0	-	-
20	188.4	188.5	0.1	-	-
50	188.7	189.0	0.3	0.2	0.5
100	189.1	189.7	0.6	0.6	1.2
1000	190.6	191.3	0.8	2.1	2.8

Flooding at Stoney Crossing

There is an existing ford across the Dawson River at Stoney Crossing, at the south west end of North Street, Taroom. The ford has an elevation of approximately 181.5 m AHD and is regularly cut during high flow events. On average the ford is cut six times per year, with the event lasting an average of 10 days. This equates to the ford being unpassable for approximately 16% of the time.

Once the dam is operational the ford will be affected by the storage level. It is estimated that the storage level will overtop the ford for approximately 57% of the time.

14.2.3.2. Downstream flooding

Hydrologic and hydraulic modelling of the Dawson River catchment above the Water Storage with and without the dam has been previously been undertaken (Department of Natural Resources 1997, SunWater, 2008, SunWater, 2010). Flooding was assessed for a range of design floods with AEPs (Annual Exceedance Probability) ranging from 1 in 5 up to the PMF.

The PMF is defined as “the limiting value of the flood that can reasonably be expected to occur”. Modelling of the design flows for the PMF indicates that the PMF event would result in a peak surface water level of EL 200.1 m AHD within the water storage. The dam is designed to have sufficient discharge capacity to safely pass the PMF so that if such an event occurs, the downstream community will not be subject to additional risk due to the dam being in place.

The estimated maximum inflows and outflows for a selection of these flood events are shown in Table 14-45. These figures show that the dam significantly reduces the peak discharge of downstream flood flows.

Table 14-45 Estimated flood routing results for a range of AEPs (SunWater, 2010b)

AEP (1: …)	Pre Dam	Post Dam		Critical Duration (hr)	
	Peak Inflow (m^3/s)	Peak Inflow (m^3/s)	Peak Outflow(m^3/s)	Pre Dam	Post Dam
5	1,490	1,650	1,010	12	12
50	3,040	3,330	2,480	72	72
100	3,670	4,030	3,100	72	72
1,000	5,140	5,940	4,460	72	72
PMF		25,280	18,965		120

Peak flood levels directly downstream of the dam will be reduced, particularly in the minor to moderate flood range. The dam is ungated so can exercise little control over flood flows. However, the dam will act as a detention basin for flood flows, increasing the duration of downstream flood events but generally lowering the peak flood levels. There is no significant infrastructure on the Dawson River directly downstream of the dam site. The closest residences within the flood model are situated above the existing 1 in 100 AEP flood level. However, there are several farm buildings in the area which may be below the existing flood level. As flood levels are reduced, the impact on these structures is positive.

The downstream frequency of overbank flows or floodplain inundation will decrease once the dam is in place. This will primarily affect the reach directly downstream of the dam, further downstream the impact of the dam will be mitigated through tributary inflows. The impact to wetlands and floodplains is discussed in detail in Chapter 12.

Modelling undertaken for the developed case assumed that the dam was at FSL at the beginning of a flood event. This assumption helps to provide a conservative assessment of flood impacts. However, if the dam was not full at the beginning of a flood event the downstream reduction in flood level would be increased, resulting in significantly lower flood levels.

Flooding at Theodore

Flooding in the region of Theodore will be significantly changed by the presence of the dam. In general, the peak flood level and inundated area will be reduced once the dam is operational. Impacts will be most noticeable for more frequent flood events, e.g. the 1 in 10 AEP, as these will be the events that are mainly captured or reduced by the dam. A summary of the estimated flood levels for the 1 in 100 AEP, pre and post dam, is presented in Figure 14-42.

Table 14-46 Peak flood levels at Theodore – pre and post dam (SunWater, 2010b)

AEP (1: …)	Peak Flood Level (m AHD)		Difference in Peak Flood Level (m)	Time to Peak (hr)		Difference in Time to Peak (hr)
	Pre Dam	Post Dam		Pre Dam	Post Dam	
10	141.9	141.0	- 0.9	159	181	22
20	142.8	142.1	- 0.7	159	179	19
50	143.3	142.7	- 0.6	164	179	15
100	143.8	143.3	- 0.5	176	180	4

Currently flood events such as the 1 in 10 AEP or larger take around seven days to reach their peak water level and then recede over approximately 10 days. Post dam the peak water level will be reached slightly later but will recede over a longer period, taking approximately two to three weeks to return to baseflow levels. For example, Figure 14-41 presents the expected impact to the 1 in 10 AEP event at Theodore.

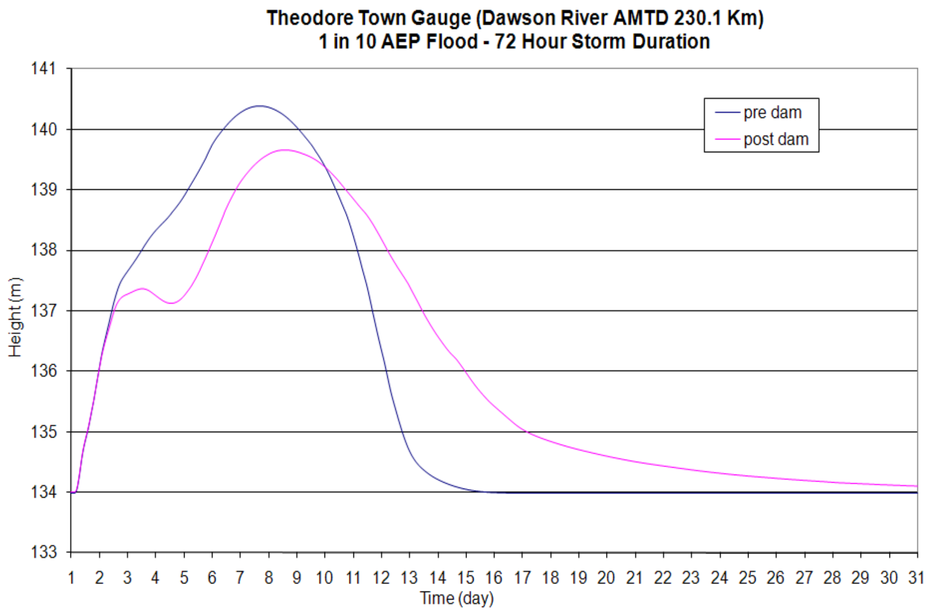
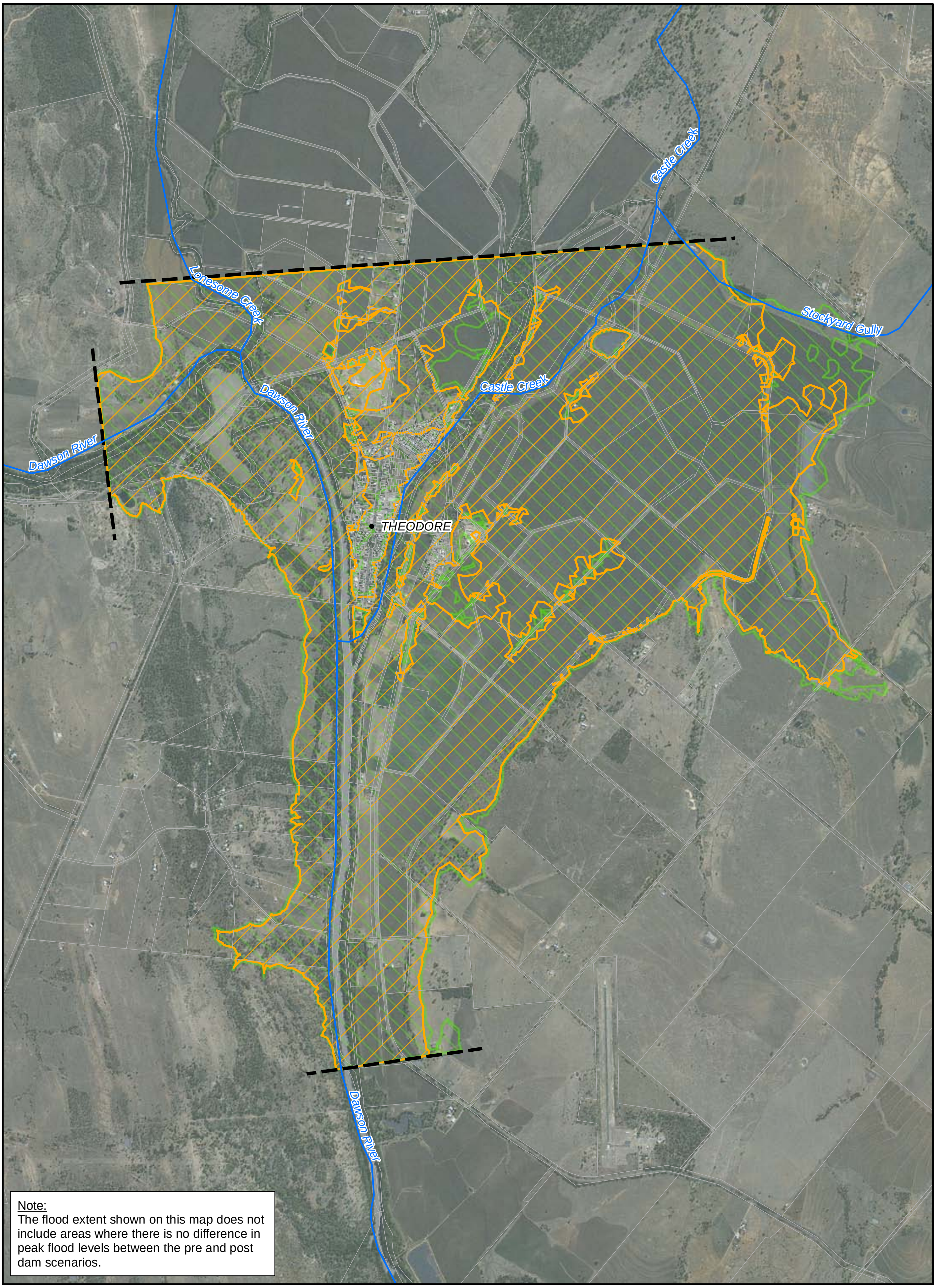


Figure 14-41 Flood hydrograph at Theodore for the 1 in 10 AEP



Note:
The flood extent shown on this map does not include areas where there is no difference in peak flood levels between the pre and post dam scenarios.

LEGEND

- Town
- Proposed Pipeline
- Extent of Flood Mapping
- Watercourse
- Cadastre
- 1 in 100 AEP with No Dam
- 1 in 100 AEP with Dam

Projection: GDA94 Zone 56

Figure 14-42

0 250 500 1,000
Metres
N
Scale 1:40,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Flood extent at Theodore for the 1 in 100 AEP (pre and post dam)

14.3. Cumulative risk

A Cumulative Impacts scenario was modelled in order to represent the infrastructure currently proposed for the basin: Connors River Dam, Nathan Dam and Lower Fitzroy Weirs (comprising Eden Bann Weir Stage 3 and Rookwood Weir Stage 2 in a staged development). Each of these developments is in the early approvals phase and requires a full business case to be developed and approved before they can proceed. It is not assured that they will all progress.

Modelling of the Cumulative Impacts scenario for the Dawson catchment is based on the "With Dam" scenario (see Section 14.2.2). The results for the Dawson catchment have therefore not been separately reproduced below but have been used to feed into the downstream models.

The Isaac Connors and Nogoa Mackenzie catchments were modelled with the Connors River Dam Full Storage Volume (FSL) at EL 169.1 m AHD, Full Storage Volume (FSV) of 373,662 ML and Minimum Operating Volume (MOV) of 14,863 ML. These catchments are modelled using the preliminary operational strategy developed for the Connors River Dam EIS. This is not a final operational strategy and is expected to change as the Project progresses. These results have been included to provide a complete overview of impacts to the Fitzroy catchment, although results from the Isaac Connors and Nogoa Mackenzie catchments are not influenced by the Nathan Dam case modelling.

Proposed development in the Lower Fitzroy consists of Eden Bann Weir Stage 3 and Rookwood Weir Stage 2 (each with 2.0 m gates). This is estimated to provide an additional 76,000 ML/a of high priority water and is modelled using a preliminary operational strategy which aims to maintain the Fitzroy Barrage at the current nominal operating level of EL 3.38 m AHD, but draws down Eden Bann and Rookwood Weirs at an even rate.

The Lower Fitzroy models include preliminary operational strategies only and therefore does not include compensation strategies for unsupplemented irrigators, low flow environmental release strategies or any other strategies to address flow issues specifically related to those projects. These are expected to be developed as the Projects progress. As such, there is future scope to address WRP compliance, amongst other issues. The scenarios presented here give a preliminary assessment of the likelihood that all of the infrastructure can be developed in a sustainable manner and it is not intended that a full compliance presentation be undertaken at this stage.

14.3.1.1. Environmental flow objectives

The performance of the Cumulative Impacts scenarios was assessed against the WRP environmental flow objectives: seasonal baseflow, first post winter flow and medium to high flows. These include mandatory and non-mandatory objectives. Assessments were made at the following WRP reporting nodes:

- Isaac River at Yatton – WRP node 9;
- Mackenzie River at Tartrus – WRP node 8;
- Fitzroy River at Eden Bann Weir – WRP node 1; and
- Fitzroy River at Barrage – WRP node 0.

(Section 14.2.2 shows the Dawson Catchment EFO results.)

Table 14-47 presents the seasonal baseflow results (non-mandatory). These results show that the baseflow objectives are mainly altered during Sept-Dec under the cumulative impacts scenario. However, the Lower Fitzroy model is preliminary and therefore does not include compensation strategies for unsupplemented irrigators or low flow environmental release strategies. It is expected that these effects can be adequately addressed by the future development of appropriate strategies.

Table 14-48 presents the first post winter flow event performance indicators (mandatory). These indicators were achieved for the Isaac and Mackenzie River for both scenarios, and along the Fitzroy River for the existing scenario at all locations, however, under the cumulative impacts scenario there were three exceptions. The number of flows within four weeks of the predevelopment event statistic does not pass the mandatory objective at either of the Fitzroy River nodes, and the average peak flow statistic does not satisfy the mandatory objective at Eden Bann Weir. However, it is anticipated that these effects can be adequately addressed by the future development of appropriate strategies.

Table 14-49, Table 14-50 and Table 14-51 present the mandatory and non-mandatory medium to high flow event objectives for WRP nodes 9, 8 and 0, respectively. (Medium to high flow event objectives have not been specified for node 1, Eden Bann Weir.) These objectives are met for all three locations and under both scenarios, with one exception. The upper riparian zone statistic does not pass the non-mandatory objective at Fitzroy Barrage under the cumulative impacts scenario, but does meet the mandatory objective.

Overall, the impacts of the Cumulative Impacts scenario are moderate and will be able to be managed through a combination of environmental flow releases and management rules. These will need to be developed as the proposed infrastructure is approved and finalised.

Table 14-47 Non-mandatory seasonal base flow results for the Full Entitlement and Cumulative Impacts scenarios

Node	Location	Non-Mandatory Values	Seasonal Base Flow Performance Indicator Objective		
			Jan – April	May – Aug	Sep - Dec
Full Entitlement					
9	Isaac River at Yatton	≥ 0.9	1.0	0.9	0.9
8	Mackenzie River at Tartrus	0.8-1.2	0.9	0.8	0.8
1	Fitzroy River at Eden Bann Weir	0.8-1.2	0.9	1.0	0.9
0	Fitzroy River at Barrage	0.8-1.2	0.9	0.8	0.7
Cumulative Impacts Scenario					
9	Isaac River at Yatton	0.8-1.2	1.0	0.9	0.9
8	Mackenzie River at Tartrus	0.8-1.2	0.9	0.8	0.7
1	Fitzroy River at Eden Bann Weir	0.8-1.2	1.0	1.2	1.3
0	Fitzroy River at Barrage	0.8-1.2	0.9	0.8	0.7

Table 14-48 Mandatory first post-winter flow event performance indicators for the Full Entitlement and Cumulative Impacts scenarios

Performance Indicator for FPWF objective	Mandatory Values	Isaac River	Mackenzie River	Fitzroy River	
		Node 9 (Yatton)	Node 8 (Tartrus)	Node 1 (Eden Bann Weir)	Node 0 (Barrage)
Full Entitlement					
Number of first post-winter flows	≥ 80%	92%	100%	96%	97%
Number of flows within 2 weeks of predevelopment event	≥ 50%	90%	76%	65%	75%
Number of flows within 4 weeks of predevelopment event	≥ 70%	92%	85%	75%	81%
Average flow volume		-	-	-	89%
Average peak flow	≥ 70%	87%	76%	80%	90%
Flow Duration (2 times base flow)	≥ 70%	100%	96%	95%	97%
Flow Duration (5 times base flow)	≥ 70%	100%	88%	84%	97%
Cumulative Impacts Scenario					
Number of first post-winter flows	≥ 80%	92%	100%	95%	91%
Number of flows within 2 weeks of predevelopment event	≥ 50%	87%	70%	59%	60%
Number of flows within 4 weeks of predevelopment event	≥ 70%	89%	82%	65%	66%
Average flow volume		-	-	-	86%
Average peak flow	≥ 70%	77%	76%	68%	-
Flow Duration (2 times base flow)	≥ 70%	96%	96%	95%	91%
Flow Duration (5 times base flow)	≥ 70%	97%	92%	83%	91%

Table 14-49 Mandatory and non-mandatory medium to high flow event objectives for Node 9 (Isaac River at Yatton)

Performance Indicator for Medium to High Flow Objectives	Non-Mandatory Values	Mandatory Values	Full Entitlement scenario	Cumulative Impacts Scenario
Mean Annual Flow	≥ 74	≥ 74	99%	95%
Median Annual Flow	≥ 50	≥ 50	98%	91%
Floodplain zone statistics	≥ 70	≥ 70	100%	96%
Upper Riparian zone statistic or Bank full statistic	≥ 85	≥ 85	102%	89%
In-Channel riparian zone statistic	≥ 75	≥ 75	100%	80%
Channel Morphology statistic	≥ 65	≥ 65	99%	82%
Fish species diversity statistic (APFD)	≤ 3	≤ 3	0.2	1.2

Table 14-50 Mandatory and non-mandatory medium to high flow event objectives for Node 8 (Mackenzie River at Tartrus)

Performance Indicator for Medium to High Flow Objectives	Non-Mandatory Values	Mandatory Values	Full Entitlement scenario	Cumulative Impacts Scenario
Mean Annual Flow	≥ 74	≥ 74	88%	86%
Median Annual Flow	≥ 50	≥ 50	80%	75%
Floodplain zone statistics	≥ 70	≥ 70	90%	90%
Upper Riparian zone statistic or Bank full statistic	≥ 85	≥ 85	97%	91%
In-Channel riparian zone statistic	≥ 75	≥ 75	89%	76%
Channel Morphology statistic	≥ 65	≥ 65	89%	82%
Fish species diversity statistic (APFD)	≤ 3	≤ 3	1.7	1.9

Table 14-51 Mandatory and non-mandatory medium to high flow event objectives for Node 0 (Fitzroy River at Barrage)

Performance Indicator for Medium to High Flow Objectives	Non-Mandatory Values	Mandatory Values	Full Entitlement scenario	Cumulative Impacts Scenario
Mean Annual Flow	≥ 74	≥ 77	86%	81%
Median Annual Flow	≥ 50	≥ 50	74%	63%
Marine and Estuarine Processes Statistic	-	≥ 80	90%	85%
Floodplain zone statistics	≥ 70	≥ 70	75%	88%
Upper Riparian zone statistic or Bank full statistic	≥ 85	≥ 80	85%	83%
In-Channel riparian zone statistic	≥ 75	≥ 75	84%	85%
Channel Morphology statistic	≥ 65	≥ 65	85%	79%
Fish species diversity statistic (APFD)	≤ 3	≤ 3	2.1	2.5

14.3.1.2. Water allocation security objectives

Table 14-52 presents a summary of the medium and high priority WASOs for supplemented user groups in the Lower Isaac Connors, Nogoa Mackenzie and Lower Fitzroy catchments. The WRP targets are achieved for each group under both the Full Entitlement and Cumulative Impacts scenario. Under the Cumulative Impacts scenario the reliability of Medium Priority entitlement increases in the Lower Fitzroy. This is due to the increased water storage capacity of Eden Bann and Rookwood Weirs. The performance of the supplemented water products will be balanced through later optimisation.

Table 14-52 Mandatory medium and high priority WASOs - Full Entitlement and Cumulative Impacts scenarios

Mandatory Water Allocation Security Objectives	WRP Target Median Monthly Reliability (%)	Full Entitlement scenario (%)	Cumulative Impacts Scenario (%)
Isaac Connors			
High Priority – Connors River Dam	≥ 95	-	99.5
Nogoa Mackenzie			
High Priority	≥ 95	100.0	100.0
Medium Priority	82-88	93.6	93.7
Lower Fitzroy			
High Priority	≥ 95	99.5	99.8
Medium Priority	82 - 88	97.0	99.0

Table 14-53 presents the number of days of waterharvesting opportunity for the Nogoa Mackenzie unsupplemented irrigators (mandatory WASO). These WASOs are achieved for all irrigator groups, under both scenarios.

Table 14-54 presents the number of days of waterharvesting opportunity for the Lower Fitzroy unsupplemented irrigators (mandatory WASO). The objectives are achieved for each group under both the existing and cumulative impacts scenario.

Table 14-55 presents the mean annual diversions for the unsupplemented irrigators groups in the Nogoa Mackenzie and Lower Fitzroy catchments. The mean annual diversions have generally been maintained at their existing levels under the cumulative impacts scenario due to the combination of environmental releases and compensation strategies. However, in the Lower Fitzroy model, there is a 7% reduction for unsupplemented irrigator groups along the regulated reach. It is anticipated that these effects can be adequately addressed by the future development of appropriate strategies for the Fitzroy River.

Table 14-53 Mandatory unsupplemented WASO: days of waterharvesting opportunity (Nogoa Mackenzie)

Unsupplemented Irrigator Groups	Days of Waterharvesting opportunity								
	WRP Objectives			Full Entitlement scenario			Cumulative Impacts Scenario		
	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year
Class 1A	26	24	20	26	26	26	26	26	26
				26	26	26	26	26	26
				26	26	26	26	26	26
				26	26	26	26	26	26
Class 1B	23	21	15	23	23	23	23	23	23
				23	23	23	23	23	23
Class 4C	80	70	60	87	81	72	87	81	72

Table 14-54 Mandatory unsupplemented WASO: days of waterharvesting opportunity (Lower Fitzroy) – Full Entitlement and Cumulative Impacts scenarios

Unsupplemented Irrigator Groups	Days of Waterharvesting opportunity								
	WRP Objectives			Full Entitlement			Cumulative Impacts Scenario		
	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year	30%ile Year	50%ile Year	75%ile Year
Class 5A	72	45	22	72	72	44	72	70	30
				72	72	44	72	70	30
				72	72	44	72	69	29
				72	72	44	72	70	29
				72	72	40	72	64	29
Class 5B	42	35	21	42	39	34	42	38	25
Class 6C	102	98	95	129	127	116	129	129	122
				122	113	98	123	117	106
				128	126	115	128	128	121
				125	116	101	127	120	107
Class 7D	70	58	47	116	107	88	117	106	88
				116	105	87	116	106	87

Table 14-55 Unsupplemented irrigator groups: mean annual diversions - Full Entitlement and Cumulative Impacts scenarios

Unsupplemented Irrigator Groups	Full Entitlement scenario (ML/a)	Cumulative Impacts Scenario	
		(ML/a)	(% change)
Isaac Connors			
Regulated Reach (Connors River Dam to Mackenzie River)	9,244	9,331	+ 1%
Unregulated Reach and Tributaries	14,912	14,912	0%
Nogoa Mackenzie			
Regulated Reach (Fairbairn Dam to Tartrus Weir)	63,914	63,895	0%
Unregulated Reach and Tributaries	60,517	60,517	0%
Lower Fitzroy			
Regulated Reach (Dawson River confluence to Fitzroy Barrage)	56,072	52,348	-7%
Unregulated Reach and Tributaries	10,278	10,131	-1%

14.3.2. Impact assessment and residual risks

The methodology used for risk assessment is discussed in Section 1.8.

This section assesses the risks relevant to surface water resources and summarises the mitigation measures proposed to minimise those risks. It is not anticipated that any significant risks relevant to surface water resources will remain after mitigation.

The risk assessment is of the Project as described in Chapter 2, in which SunWater has already incorporated a range of risk reduction and mitigation measures. Table 14-56 presents the assessment of residual risks after mitigation.

Based on this assessment, the following conclusions can be made:

- the risk of impacts to existing users and the environment during construction through changed river flows is low and will be managed by the inclusion of a channel to divert flows around the construction site;
- the risk of impacts to existing users and the environment during operations through changed river flows is medium and will be managed through the dam operational strategy and a compensation strategy for users;
- the possibility of changes to stream bed profiles and local drainage patterns is low and will be managed through appropriate construction management techniques, plans and procedures;
- given the potential impact of climate change on the region, the dam represents an additional, valuable resource to buffer potential climate change impacts on regional water supply security; and
- based on this risk assessment, the risks relevant to surface water resources can be effectively managed and the residual risks are acceptable.

Table 14-56 Surface Water Risk Register

Hazard Area: Dam and surrounds (Construction)

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Reduced flow levels and volumes downstream of the dam.	Construction of dam	Potential to reduce the water access of existing water users and key environmental flows	During construction flows will be diverted around the construction site via a diversion channel	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Dam and surrounds (Operations)

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Reduced flow levels and volumes downstream of the dam.	Impoundment phase of dam.	Potential to reduce the access of existing water users and reduce or change the timing of key environmental flows	A transitional operational strategy will be developed which will set out operational rules for environmental and other releases during the dam filling phase.	Minor	Unlikely	Low			Minor	Unlikely	Low
Upstream Flood Impacts.	Potential backwater effects from operation of dam.	Potential to increase the flood risk to existing infrastructure and residences.	Land purchase strategy and flood management strategy.	Minor	Unlikely	Low			Minor	Unlikely	Low
Reduced flow levels and volumes downstream of the dam.	Operation of dam.	Potential to reduce the access of existing water users to unacceptable levels.	A compensation strategy will be developed for effected water users.	Moderate	Unlikely	Medium			Moderate	Unlikely	Medium

Hazard Area: Dam and surrounds (Operations)

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Reduced flow levels and volumes downstream of the dam.	Operation of dam.	Potential to reduce or change the timing of key environmental flows, e.g. reduction of frequency and volume of flow between the river, floodplains and associated waterbodies	An environmental flow strategy will be developed to manage key environmental flows. Land use restrictions	Minor	Likely	Medium			Minor	Likely	Medium

Hazard Area: Pipeline and associated infrastructure (Construction)

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Changed local drainage patterns.	Pipeline construction activities in stream beds.	Stream channel changes.	Design, Project EMP and restoration work after construction.	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Pipeline and associated infrastructure (Operations)

Hazards	Factors	Impacts	Project Description Controls & Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Changed local drainage patterns.	Pipelines located above ground	Alteration to local drainage patterns and instream flows	Pipeline trenched wherever practicable, if trenching is not possible the pipeline will be elevated to facilitate flows or culverts will be installed where required.	Minor	Unlikely	Low			Minor	Unlikely	Low

14.4. Summary - hydrology

This section has assessed the potential impact of the Project on existing water resources and existing water users in the Fitzroy Basin. This assessment showed that the adopted preliminary operational strategy combined with the proposed mitigation measures will reduce all identified risks to an acceptable level. This will be achieved through a combination of environmental and compensation release strategies, financial compensation and management plans. The preliminary operational strategy will be refined as the Project progresses. However, climate change risk is a factor for which mitigation is not entirely within SunWater's control. The Project is a regional benefit with respect to buffering the effects of climate change.

14.5. Description of environmental values – fluvial geomorphology

14.5.1. Methodology

This section addresses the geomorphic aspects inferred from TOR item 3.4.1.1 and includes:

- a description of the fluvial geomorphology under pre-development, current and full entitlement scenarios; and
- a discussion of the changes in the parameters from pre-development to current conditions and the corresponding changes that may be anticipated in sediment processes in the catchment, including delivery to the coastal and near-shore environment.

14.5.1.1. Dam and surrounds

For the purposes of describing the existing environment and undertaking the impact assessment, the Dawson River and its tributaries were divided into three zones:

- upstream – all rivers / streams upstream of the FSL;
- water storage – all rivers / streams within the FSL; and
- downstream – all rivers / streams downstream of the dam wall.

The method used to describe the existing environment for the dam and surrounds constituted the following broad steps:

- a desktop review of the current topography of the dam and surrounds, based around current aerial imagery and topographic maps;
- a review of literature describing the current geomorphic condition of the Dawson River, based largely on ACARP (2002), Galloway (1967), State of the Rivers Report (DPI, 1995) and Water Allocation and Management Plan (Fitzroy Basin) 1999 (WAMP); and
- site assessments – assessment of geomorphic condition at various sites. This involved the selection of a representative number of sites in the three zones described above. There were two types of sites in the assessment:
  - visual observation sites that established an understanding of the scale and diversity of geomorphic features within the three zones; and

- monitoring assessment sites that provided a reach-based assessment of baseline condition and stability, which in turn, informed the impact assessment and recommendations for future geomorphological monitoring.

At each stability monitoring assessment site, a standard proforma was used to record data of relevance to channel stability. The proforma was developed from the work of Thorne (1998), Rapp and Abbe (2003) and Simon *et al.* (2007) and encompassed descriptive data (e.g. bed and bank material) and assessments of a variety of geomorphological characteristics and processes and vegetative characteristics to determine bank, bed and overall channel stability. Each site was given an overall channel stability score (Figure 14-43). Sites with values of 10 or less are generally indicative of stability, values of 11-15 are indicative of moderate stability, values of 15-20 indicate moderate instability, whereas values of 20 or greater are indicative of severe instability.

Sites were generally selected according to their accessibility and were thus generally located upstream from bridge crossings or at locations adjacent to roads. This selection process may have resulted in some bias to geomorphic condition assessments due to their proximity to infrastructure. A description of sites is listed in Table 14-57 and their locations are shown in Figure 14-44.

1. Primary bed material

Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay
0	1	2	3	4

2. Bed/bank protection

Yes	No	(with)	1 bank protected	2 banks
0	1		2	3

3. Degree of incision (Relative ele. Of "normal" low water; floodplain/terrace @ 100%)

0-10%	11-25%	26-50%	51-75%	76-100%
4	3	2	1	0

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

0-10%	11-25%	26-50%	51-75%	76-100%
0	1	2	3	4

5. Streambank erosion (Each bank)

	None	fluvial	mass wasting (failures)
Left	0	1	2
Right	0	1	2

6. Streambank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

7. Established ripirian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	2	1.5	1	0.5	0
Right	2	1.5	1	0.5	0

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	2	1.5	1	0.5	0
Right	2	1.5	1	0.5	0

9. Stage of channel evolution

I	II	III	IV	V	VI
0	1	2	4	3	1.5

10. Composition of adjacent side slope (circle)

	N/A	Bedrock	Boulders	Gravel-SP	Fines
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

11. Percent of slope (length) contributing sediment

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

12. Severity of side-slope erosion

	None	Low	Moderate	High
Left	0	0.5	1.5	2
Right	0	0.5	1.5	2

Figure 14-43 Proforma used to assess overall channel stability (Simon *et al.* 2007)

Table 14-57 Sites visited near dam site and surrounds

Zone	Site Number	Site Description	Site Assessment
Upstream	US1	Juandah Creek	Monitoring
	US2	Palm Tree Creek	Monitoring
Water Storage	IZ1	Dawson River u/s of Taroom	Monitoring
	IZ2	Dawson River at Bundulla Road	Monitoring
	IZ3	Cockatoo Creek	Monitoring
	IZ4	Dawson River immediately upstream of Glebe Weir	Visual
	IZ5	Dawson River immediately downstream of Glebe Weir	Monitoring
	IZ6	Dawson River approximately 1 km downstream of Glebe Weir	Monitoring
Downstream	DS1	Dawson River immediately downstream of dam site	Monitoring
	DS2	Dawson River in Gorge	Visual
	DS3	Precipice Creek	Monitoring
	DS4	Dawson River at Gyranda Weir	Visual

14.5.1.2. Pipeline

The method used to describe the existing environment for the pipeline and associated infrastructure included a review of literature, aerial photography and site assessments. A reach-based geomorphic assessment was considered the most appropriate method. This provided general stream characteristics and channel process descriptions.

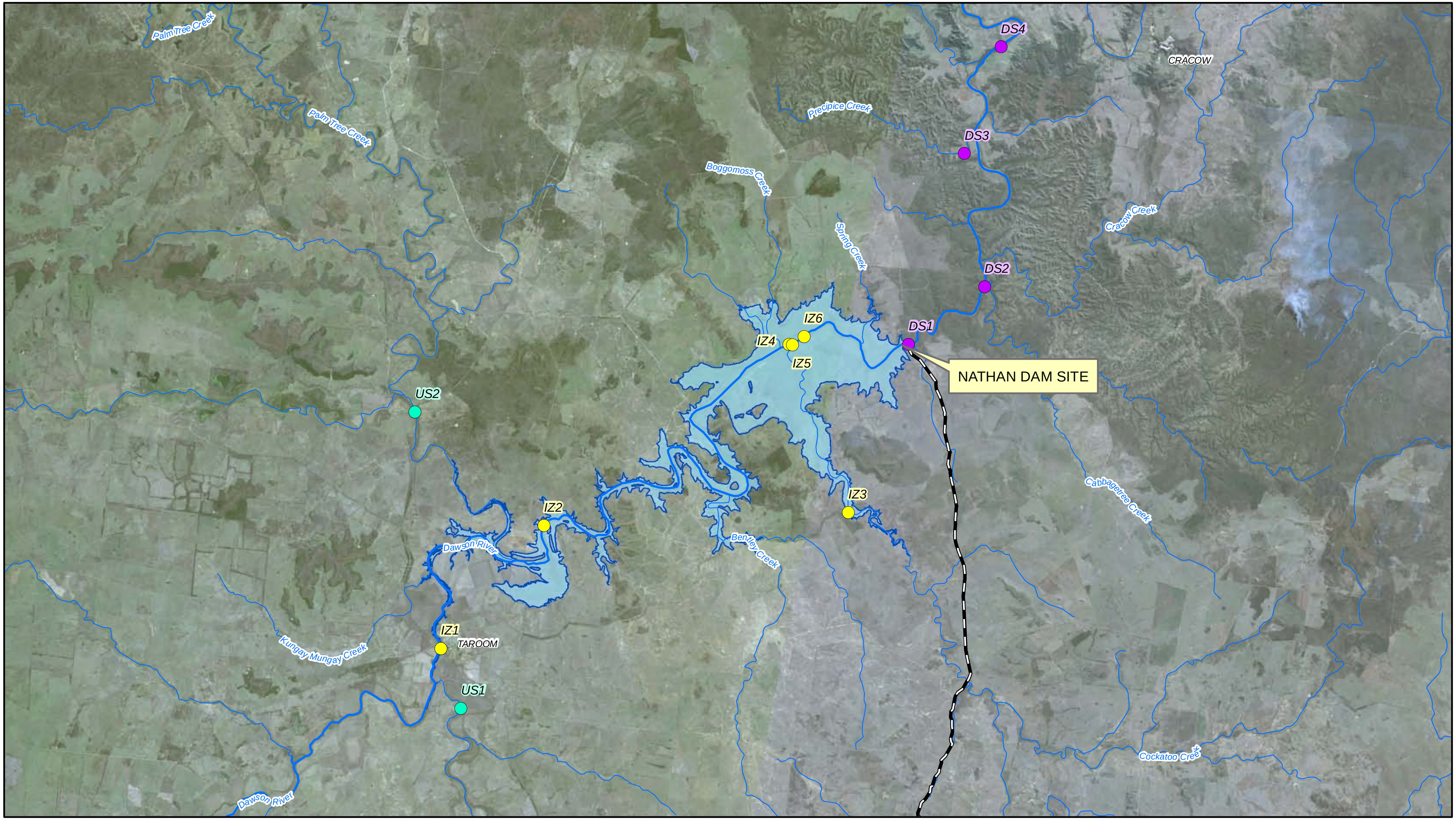
14.5.2. Dam and surrounds

14.5.2.1. Geomorphic overview

The Dawson River commences in the Great Dividing Range, west of Injune, Queensland. The headwaters of the Dawson River are in the Jurassic Sandstones and Mudstones, producing a sediment yield comprised largely of fines (suspended load and wash load) and a smaller proportion of gravels and cobbles (Gunn, 1977).

Landforms of the northern and western parts of the Nathan Dam catchment, including the upper reaches of the Palm Tree Creek catchment are characterised by rolling to steep hills with a number of plateau surfaces. These hills are associated with resistant quartz sandstones (Gunn, 1977).

Landforms of the central, southern and eastern parts of the Nathan Dam catchment are generally gentler and range from undulating and rolling low hills to occasional steep low hills and steep hills. The steeper landforms are more common towards the headwaters of streams. Flat to gently undulating plains of appreciable extent are generally restricted to areas along the Dawson River.



LEGEND

- Proposed Pipeline
- Dawson River
- Watercourse
- Full Supply Level (183.5 m AHD)

Assessment Sites

- Downstream Site
- Inundation Zone Site
- Upstream Site

Projection: GDA94 Zone 56

Figure 14-44

0 2 4 8 Kilometres

N

Scale 1:350,000 (at A4)

SKM SunWater Making Water Work

NATHAN DAM AND PIPELINES EIS

Geomorphic assessment site locations

Geological history

By the Upper Cretaceous, the Dawson River catchment upstream of Nathan Gorge was almost entirely one of broadly undulating plains cutting across gently dipping Jurassic and Cretaceous beds. A deep weathering profile was associated with this land surface but only truncated remnants of the lower zones remain (Wright, 1968). This land surface was dissected by the end of the early Tertiary, probably as a result of uplift, and the main elements of the present drainage pattern came into being. Dissection was deep and extensive lower plains developed in what are now the southern parts of the Glebe Weir catchment. Later in the Tertiary, the newly-created lowlands were masked by terrestrial deposits and some basalt flows with fans and aprons at the foot of the ranges and deep weathering continued (Wright, 1968).

Processes were complex during the latter part of the Tertiary and the Quaternary but four main stages have been recognised in the Dawson River area (Wright, 1967):

- dissection of the Tertiary weathered surface and ensuing deposition;
- dissection and reworking of deposits;
- drainage rejuvenation, terrace and floodplain development; and
- later stage drainage rejuvenation and further terrace and floodplain development.

Incision associated with the last stage is continuing, but younger, lower level, floodplains are forming along the main streams. These are evident upstream of the dam site as the level to gently undulating plains adjacent to the Dawson River from approximately 318 km AMTD to 335 km AMTD and along Cockatoo and Boggomoss Creeks. These floodplains developed as a result of the constriction that Nathan Gorge places on the Dawson River. The Nathan Gorge constriction slows flood flows upstream and results in over-bank flooding and deposition of finer materials. Similar floodplains occur upstream of approximately 361 km AMTD and these extend well upstream of Taroom (Shields, 1997). These floodplains may result from constriction of the river by adjacent sandstone hills between approximately 348 km and 361 km AMTD or from the Nathan Gorge constriction.

Post European settlement history

The pre-European form of the rivers within the region was described by Ludwig Leichhardt (Leichhardt 1847) and Thomas Mitchell (Mitchell 1848). Leichhardt visited the Dawson River and Palm Tree creek, and described many of the key geomorphic features including the occurrence of instream vegetation, gullies, anabranches and swamps, and chain of ponds.

Since European settlement, regional rivers, including the Dawson River, have been impacted by anthropogenic activities such as water regulation, agriculture, mining and resource industries, extractive industries, infrastructure, crossing construction, clearing, grazing and recreation. There has also been development of the region’s water resources and construction of dams and weirs, including on the Dawson River. These are outlined below:

- Glebe Weir is located approximately 10.9 km upstream of the dam site on the Dawson River and has a full supply volume of 17,700 ML;
- five water storages are located downstream of the Project site on the Dawson River (Gyranda Weir, Orange Creek Weir, Theodore Weir, Moura Weir and Neville Hewitt Weir); and

- two water storages are located between the junction of the Dawson and Fitzroy Rivers (near Duaringa) and the sea (Eden Bann Weir and the Fitzroy River Barrage) (DNR 1998a).
- These structures affect the flow of water and sediment in the catchment, as will be discussed in later sections.

14.5.2.2. Present geomorphic features of the Dawson River

Overview

Dawson River is characterised by a range of alluvial features including terraces, abandoned channels and anabranches. This indicates that the river is dynamic and has periodically shifted course and created and occupied different channels over recent geologic time. Within close vicinity of the dam site, the extent of these features is somewhat limited by the surrounding geology, with bed and bank rock outcropping observed. However, examples of anabranches, benches and terraces are still present.

The contemporary Dawson River is confined and entrenched within a broader valley floor that is comprised of older alluvial terraces and bedrock controls. The river is characterised as having a complex channel type with a channel-in-channel physiography (Figure 14-45). A single channel or series of channels carries flows most of the time, whilst the larger 'macro-channel', acts as a restrictive floodplain, outside of which floods have very infrequent and limited influence. There is notable diversity in channel patterns along the Dawson River. Channel patterns range from a single meandering channel, with occasional flood runners developed on the floodplain to multi-channelled braided/anabranching and anastomosing channel patterns. These changes in river character may relate to changes in valley width, and the influence that has on channel and floodplain forming processes.

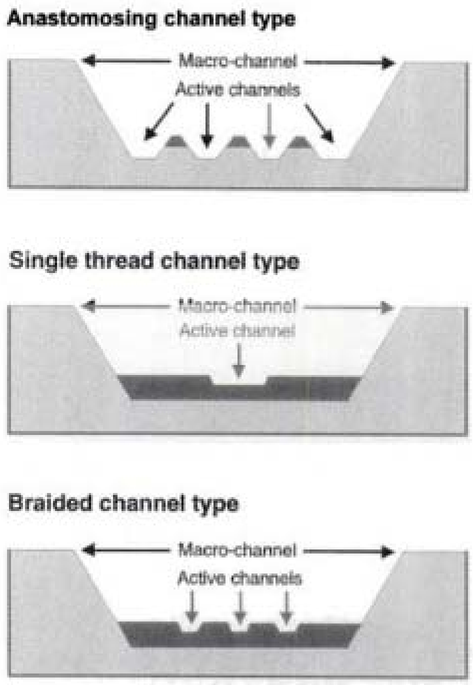


Figure 14-45 The macro-channel and channels that flow within it (Rountree *et al.,* 1999)

It is speculated that the primary multi-channelled channel pattern on the Dawson River forms via the sub-division of channels through the deposition of an in-channel ridge (Tooth and Nanson, 1999, 2000; Wende and Nanson, 1998). Based on the work of the above authors, Judd (2005) proposed that this formation of multiple channels through the construction of ridges is likely to be limited to river systems that exhibit some or all of the following characteristics:

- a low energy environment that will not erode the vegetation or subsequent sediment depositing in the bed of the stream;
- the stability of in-channel sediment deposits is more dependent on vegetation than the cohesion of sediment; and
- the stream is ephemeral, and thereby allows vegetation to establish on the bed of channels.

In the context of the impact of the proposed dam, the continuity of supply of coarse, non-cohesive sediments is also likely to be important to retaining the multi-channel pattern.

- A common feature is the instream bench, which has also been described by ACARP (2002) as a feature of channels in the Bowen Basin. Benches occur along one or both sides of the channel forming a low vegetated false bank line several metres from the true boundary of the channel. Benches are temporary sediment storages and often form once a flood begins to recede. Vegetation is often stripped from benches during flood events and much of the bench is temporarily removed. This results in a short term increase in channel width (ACARP, 2002).
- Terraces are former floodplain levels that develop as the river incises over geologic time. They are more permanent features than benches, and tend to become inundated only during major floods. A number of terraces can exist at a given point on the river. Typically, two or three terrace levels were observed along the Dawson River and this is indicative of progressive incision into the landscape over geological time. River bed levels can also vary over shorter time frames and at a local scale, with episodic erosion (cut) and deposition (fill) cycles following floods. Ongoing incision of rivers has also been noted at a regional scale (Finlayson, 1992).

The majority of the sites inspected along the Dawson River conformed to the complex channel type, with a channel-in-channel physiography as described earlier. The Dawson River through and downstream of the dam reservoir area meanders within both alluvial and sedimentary rock landscapes. Meandering within alluvial landscapes is a very common fluvial process but it is less common in areas of rock exposure. The parallelism of a number of the meander features suggests structural control on river location through features such as coarse joint patterns in the sedimentary rocks.

There is a change in the channel form of the Dawson River just downstream of Taroom. The change occurs at the downstream end of a substantial waterhole known as *The Wide* at approximately 383 km AMTD. Adjacent topography suggests that a rock bar at the downstream end of the waterhole may be the cause of this change in form though there is no rock exposure in the river bed. Through and upstream of this waterhole, the river is generally characterised by a single, well-defined channel 50 to 100 m wide and up to 10 m deep with a single low flow channel in the bed. There is usually an extensive, level, alluvial plain on one or both sides of the river and the channel meanders within this.

From the downstream end of this waterhole, *The Wide*, and into the upstream parts of Nathan Gorge, the Dawson River is characterised by a broad low-level floodplain approximately 200 m to 350 m wide between banks from approximately 8 m to 15 m high. The clayey confined floodplain is dissected by a series of anastomosing channels (anastomosing is a term used to describe channels that bifurcate, branch and rejoin irregularly) with some isolated waterholes. Only one, or occasionally two, of these channels carry low flows and the nature and maturity of the vegetation adjacent to these channels and on the confined floodplain suggests that the channels are relatively permanent. This lower-level floodplain apparently represents the younger inner floodplains identified along parts of the main rivers of the Dawson – Fitzroy system (Wright, 1968a).

The broad Dawson River stream bed is vegetated, principally with forest red gum, coolabah, and occasional river oak, and the low flow channel is fringed with tea tree. Banks above the broad bed are generally vegetated with forest red gum, coolabah and occasional river oak and poplar box. A range of native and naturalised grasses generally give complete ground cover except in high shade areas and in ephemeral channels and waterholes. This native vegetation cover resists erosion during normal flood events but would be stripped during large floods.

Nathan Gorge is a well-known geomorphic feature in the Dawson River area. The Dawson River has eroded a deep, channel through a landscape where the surface geology is dominated by the relatively resistant Precipice Sandstone, resulting in formation of the gorge landform. The section of the Dawson River through the gorge is structurally controlled by joint planes and faulting in the Precipice Sandstone. As outlined in Section 14.5.2.1 the Dawson River has been impacted by anthropogenic activities such as water regulation, agriculture, mining and resource industries, extractive industries, infrastructure, crossing construction, clearing, grazing and recreation. These effects, as reflected in the State of the Rivers report (DPI 1995), include increasing sediment loads in stream waters, an increase in erosion and aggradation and decreased diversity of channel habitat type.

Catchment erosion and sediment transport

There is little doubt that the rate of landscape erosion in the Dawson River catchment has increased since European settlement. Mapping data presented on the Australian Natural Resource Atlas website (ANRA, 2008), based on results of a regional SedNet sediment model, show a notable increase in the rate of hillslope erosion since European settlement in the Dawson River catchment. More recent SedNet modelling by Dougall *et al.* (2006) indicated that throughout the Fitzroy River basin, hillslope erosion was the most important source of sediment to both the stream network and the coast (Figure 14-46).

Neil *et al.* (2002) reported that the export of sediment and the mean suspended sediment concentration from the Fitzroy River basin were the highest for all Queensland coastal catchments for both natural and disturbed conditions and that the increase factor for sediment yield for 'natural' compared to 'existing' was also highest (at approximately 4). Neil *et al.* (2002) also reported that the Fitzroy River basin had one of the lowest percentages of land use classified as 'pristine' for Queensland coastal catchments. In terms of sediment contribution made from different sub catchment areas, the Dawson River also contributes a comparatively small proportion of sediment to the overall basin than other sub catchment areas (Figure 14-46).

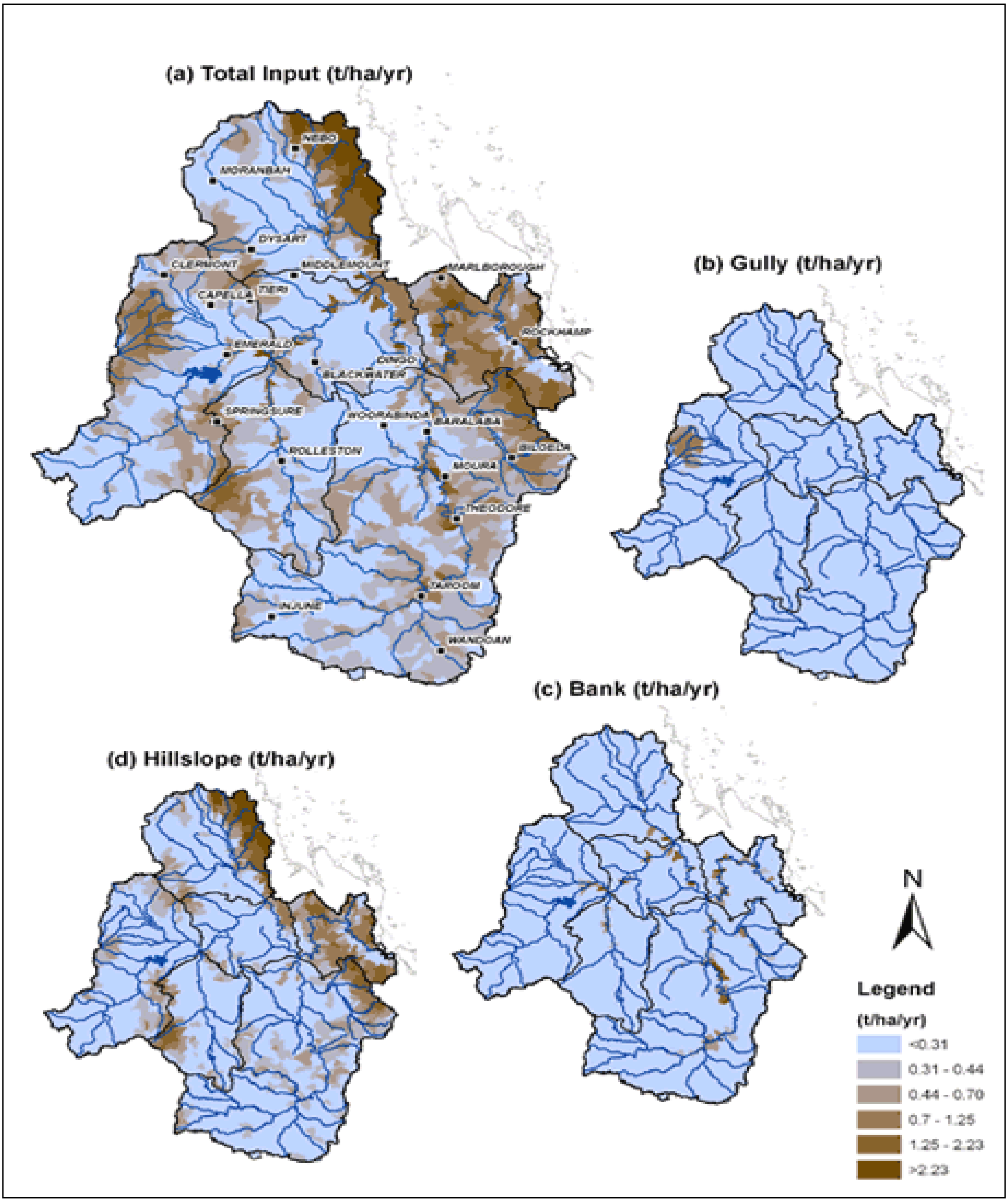


Figure 14-46 Estimated sediment contribution to coast for the Fitzroy River basin (from Dougall *et al.* (2006))

The State of the Rivers report (DPI, 1995) provides a general assessment of the condition of reach environments for the Dawson River catchment. A summary of condition ratings for a range of river condition attributes is provided in Table 14-58. The river is generally described as in good to moderate condition with stable to moderately stable bed and banks. It should be noted that these assessments are highly subjective in nature and were completed over 15 years ago.

Table 14-58 Condition assessment of reach environments of the Dawson River

Reach	Environs	Bank stability		Bed and bar stability		Overall condition	Diversity
		Rating	Active Process	Rating	Active Process		
Upstream of water storage	Moderate	Quite stable	Eroding	Moderately stable	Eroding	Good	Very poor to poor
Water storage	Moderate to Good	Quite stable	Aggrading	Stable to Moderately stable	Eroding	Moderate	Very poor
Downstream of proposed Nathan Dam	Very good	Stable	Eroding	Moderately stable	Unclassified	Good	Very poor

Site assessment

Table 14-59 lists the stability assessment results. The majority of sites were assessed as either moderately stable or moderately unstable, despite the highly stable nature of the greater terraced macro-channel. This slight biasing to unstable ratings can be attributed to the generally mobile nature of the bed and within channel features (bars, benches etc) within the Dawson River catchment. Two sites with severe instability ratings were located in the section of river downstream of Glebe Weir. The stability ratings are discussed further below.

Table 14-59 Stability assessments for the monitoring study sites

Site Number	1. Primary bed material	2. Bed/bank protection	3. Degree of incision	4. Degree of constriction	5. Stream bank erosion	6. Stream bank instability	7. Established riparian cover	8. Occurrence of bank accretion	9. Stage of channel evolution	10. Composition of adjacent side slope	11. Percent of slope contributing sediment	12. Severity of side slope erosion	Overall channel stability	Stability Rating
US1	4	1	3	0	2	0	3	3	0	0	0	0	16	Mod. Unstable
US2	4	1	3	0	2	0.5	2.5	2.5	2	0	0	0	17.5	Mod. Unstable
IZ1	4	1	2	0	0	0	1	3	0	0	0	0	11	Mod. Stable
IZ2	4	1	3	0	1	0	2	2	0	0	0	0	13	Mod. Stable
IZ3	4	1	3	0	0	2	2	4	0	1	0	0	17	Mod. Unstable
IZ5	4	1	3	3	2	4	2	4	4	0	0	0	27	Severe instability
IZ6	4	1	3	0	2	3.5	2	4	4	2	1	1.5	28	Severe instability
DS1	4	1	3	0	2	0	1	1	0	2	2	1	17	Mod. Unstable
DS3	3	1	3	0	1	0	1.5	2.5	0	0	0	0	12	Mod. Stable

Upstream

At Juandah Creek (US1), the channel conforms to the complex channel type, and includes terraces, a main flow channel with vegetated bench (Figure 14-47 a and b) and a secondary flood channel (Figure 14-47 c). This secondary flood channel may at one time have been the former channel of the creek. Its course meanders across the eastern boundary of the broad floodplain (approximately 2.5 km wide), whilst the main channel provides a straighter alignment down the valley. Elevated flood runners were also noted across the floodplain (Figure 14-47 d). Stock access is an existing impact at this site.

Palm Tree Creek (US2) has a more confined floodplain (< 1 km wide), with a 25 m wide and 7 m deep meandering channel with narrow benches and steep banks (Figure 14-48 b, c and d). Processes of bank erosion leading to lateral migration were evident (Figure 14-48 a). The top of the banks and adjacent floodplain were well vegetated. Occasional large woody debris (LWD) were observed spanning the length of the channel (Figure 14-48 d).

a) Main channel bench

b) Vegetated bench

c) Flood runner

d) Meander cutoff, secondary flood channel

Figure 14-47 Geomorphic features of Juandah Creek

a) Bank erosion and lateral migration

b) Meandering channel

c) Bench

d) LWD and steep banks

Figure 14-48 Geomorphic features of Palm Tree Creek

Water Storage

The Dawson River, at sites assessed within the water storage area, generally conformed to the complex channel type, with a channel-in-channel physiography. At Bundalla Road crossing (IZ2), the river comprises a series of anabranching channels, separated by vegetated bars/islands and areas of active floodplain (Figure 14-49 a, b and c). At any one time flow is restricted to one or two of the anabranching channels. During high magnitude flood events, the entire floodplain and its system of anabranching channels is engaged. The tributary site on Cockatoo Creek is a partially bedrock confined meandering channel (Figure 14-49 d).

The Dawson River downstream of Glebe Weir was assessed as exhibiting severe instability at two locations (IZ5 and IZ6). The first site (IZ5) is located immediately downstream from the Glebe Weir. Flows are being channelled down one anabranch via a V-notch weir/chute (Figure 14-50 a and b) engineered to allow more consistent gauging of downstream flows. This has meant under low and some medium flow conditions, flows are no longer distributed across multiple anabranch channels. Bed incision, bank erosion and channel widening is occurring along this anabranch. As the bed of this anabranch has lowered through bed incision, this has had the effect of disconnecting adjacent anabranches that are now sitting high on the floodplain (Figure 14-50 c and d).

The second site (IZ6) is located approximately 1 km downstream of Glebe Weir. By this point, continued bed and bank erosion has led to the formation of a single meandering channel, with a bankfull width of 30 m wide and depth of 8 m. The channel is migrating laterally from one side of the floodplain to the other, with erosion effectively scouring out an older alluvial terrace (Figure 14-50 f). As the single meandering channel has formed and incised its bed, it has left a number of perched anabranching channels. Further study of aerial photography shows that this newly formed meandering channel extends approximately 8 km downstream from Glebe Weir. The transformation in channel form from an anabranching to a meandering channel is known as channel metamorphosis. This represents the crossing of a geomorphic threshold, with the meandering channel form being a product of the changed flow and sediment transport regime that has developed since construction of Glebe Weir.

a) IZ2 - Dawson River - Anabranch with low flow

b) IZ2 – Dawson River - Anabranch

c) IZ2 – Dawson River - Vegetated island

d) IZ3- Cockatoo Creek

Figure 14-49 Geomorphic features of Dawson River at Bundulla Road and Cockatoo Creek

a) IZ5 – Dawson River. Weir channelling flow into anabranch

b) IZ5 – Dawson River, Small weir downstream of Glebe Weir that channels flow into anabranch.

c) IZ5 – Dawson River. Bank erosion

d) IZ5 – Dawson River. Perched anabranch

e) IZ6 – Dawson River. Main channel

f) IZ6 – Dawson River. Erosion of terraces

Figure 14-50 Geomorphic features of Dawson River downstream of Glebe Weir

Downstream of the proposed dam wall

Three sites on the Dawson River downstream of the proposed dam wall location were visited. The first site was located immediately downstream of the dam wall (DS1). At this location the Dawson River is confined by the surrounding Precipice Sandstone which forms steep slopes down to the river. The river has an anabranching channel form, with multiple channels separated by vegetated longitudinal bars and areas of active floodplain (Figure 14-51a, b). The inclination of the trees, accumulations of woody debris and hummocky relief over the floodplain attest to the significant flows that fill the floor of the valley at this location (Figure 14-51c, d).

a) DS1 – Dawson River. Longitudinal vegetated bar separating two anabranches.

b) DS1– Dawson River. Flood runner/anabranch running along edge of floodplain

c) DS1 – Dawson River. Flood debris.

d) DS1– Dawson River. Hummocky relief over floodplain

Figure 14-51 Geomorphic features of Dawson River, immediately downstream of dam site

Price Creek is a right hand tributary immediately downstream of the proposed dam wall (DS3). The creek is entrenched within surrounding bedrock controls and alluvial terraces (Figure 14-52). The bed of the creek has incised down to the Precipice Sandstone. The steep rock walls on both sides of the Dawson River that characterise Nathan Gorge commence immediately downstream of the Price Creek junction and the depth of incision increases with distance downstream. The second site assessed on the Dawson River was within Nathan Gorge, immediately upstream of the confluence with Cabbage Tree Creek (DS2). The floor of the Gorge at this site was flooded as a result of the backing up of water behind Gyranda Weir.

a) Price Creek. Channel entrenched within surrounding bedrock and alluvial terraces

b) Price Creek. Bench in foreground

Figure 14-52 Geomorphic features of Price Creek, immediately downstream of dam site

The third site assessed on the Dawson River was at Gyranda Weir (DS4). The weir was at FSL at the time of the assessment, with water inundating the channel and floodplain of the Dawson River (Figure 14-53 d). Tributaries that drain into the Dawson River upstream of Gyranda Weir are also inundated by the weir pool (Figure 14-53 b and c). Precipice Creek enters the Dawson River approximately 8 km upstream of Gyranda Weir (DS3). This creek is transporting coarse sand material as bedload (Figure 14-53 a). It is likely that much of this material is being deposited along sections of the lower creek where inundation occurs (Figure 14-53 b).

a) DS3 – Precipice Creek. Sand bed.

b) DS3 – Precipice Creek. Tailwaters from Gyranda Weir

c) Unnamed creek backflooded by tailwaters from Gyranda Weir

d) DS4 – Dawson River. Looking upstream from Gyranda Weir.

Figure 14-53 Typical Geomorphic features of Precipice Creek

No field geomorphic assessments were completed of the Dawson River downstream from Gyranda Weir. Instead, a description of the existing environment for this section of river has been developed based on a review of literature and aerial photography. The Dawson River downstream of Gyranda Weir can be divided into a series of segments, with the downstream end of each segment defined by a weir pool and its associated weir (as shown in Figure 14-1).

The river is highly regulated, with long sections of river periodically inundated due to the attenuation of water behind the downstream weir. However, upstream of each weir pool, there are sections of river where flows are not impacted by the downstream weir. The characteristics of these sections of river vary, but generally display similarities to that documented further upstream, ranging from a single meandering channel, with occasional flood runners developed on the floodplain to multi-channelled braided/anabranching and anastomosing channel patterns.

A continuous weir pool exists between Gyranda Weir and Orange Creek Weir. There are also a number of secondary channels that traverse the floodplain through this section of river. Some of these may be former courses (palaeochannels) of the Dawson River, which have been abandoned as the channel has shifted its position to another area of the valley. It is expected that the ability of the present river to encounter similar movements in channel position is reduced as a result of the regulation of flows in this section of river.

Downstream of Orange Creek Weir there is a 27 km section of channel which does not experience attenuation of flows from Theodore Weir. The river ranges in pattern from a single meandering channel, to multi-branched anabranching and anastomosing forms. Long elongated pools are also present, the occurrence of these features being attributed to large bankfull and overbank flows, that have sufficient stream power to scour the channel, forming and maintaining the dimensions of the pool. These pools are likely interspersed by hydraulic controls, such as riffles, rock bars and runs.

Similarly, downstream of Theodore and Neville Hewitt Weir, the river varies in form from a single meandering channel, to multi-branched anabranching and anastomosing form, until the Dawson River meets the Fitzroy, where the channel adopts a more defined meandering channel form. Elongated pools continue to be present at varying intervals along the river. An extensive arrangement of palaeochannels and flood runners lie preserved across the floodplain.

14.5.2.3. Present geomorphic values of the Dawson River

From a geomorphic perspective, values were defined as fluvial landforms, or the processes that created them, which provide ecological habitat and promote channel stability. In particular, four values are discussed in more detail below:

- macro-channel morphology;
- pools;
- assemblages of large woody debris; and
- flood channel and off-stream wetlands.

Macro-channel morphology

The diversity of the macro-channel was noted as a value. As previously described, the macro-channel typically contained a variety of topographic features, anabranches, flood runners/secondary flood channels, assemblages of large woody debris, depressions and benches. The geomorphic features of the macro-channel are maintained by regular flood ‘resetting’ events.

Pools

The extensive instream perennial pools that occur along the length of the Dawson River were noted as values. The pools tended to be separated by channel constrictions or obstructions and instream vegetation. Maintenance of the pools would occur via flushing flood flows.

Assemblages of large woody debris

Abundant large woody debris was observed at many of the sites that were visited. These affect the morphology of the channels by causing sediment accumulation resulting in bar formation. They also alter flood channel hydraulics to create scours and depressions, and temporarily dam water in shallow depressions to form post-flood temporary pools.

Flood channel and off-stream wetlands

Three broad groups of wetlands were observed:

- localised features that occur within the flood channel and on terraces. These are likely to range from temporary features that form in depressions following flood events, to more permanent features that intercept groundwater levels. These wetlands are referred to as "Riverine" type as described by Queensland Wetland Mapping (EPA 2005);
- Lacustrine wetlands (EPA, 2005). These are deepwater habitats situated in a topographic depression or a dammed river channel. This includes the waterbodies that are formed by Glebe and Gyranda Weir; and
- Palustrine wetlands (EPA, 2005). These are more generally known as vegetated swamps and springs. They are characterised by the dominance of persistent emergent vegetation. A number of these are present in the areas around Boggomoss Creek and Price Creek.

Existing impacts on Dawson River

Impacts of land use change

Development of the catchment since European settlement, mainly for agriculture and industry, has resulted in a number of impacts to Dawson River and its tributaries, as described below:

- increased sediment yield to the rivers. The amount of sediment in the river channels has increased across the Fitzroy Catchment Basin. Instances of gully erosion were observed (Figure 14-54 a). This increased supply of sediments into channels has probably contributed to infilling of pools and smothering of bed habitat;
- impacts of existing crossings. Localised degradation of bank and bed stability was noted at a number of road and infrastructure crossings; and
- construction of low level crossings and causeways. These are localised impacts causing direct, but minor physical disturbance of the bed and banks (Figure 14-54 b)

a) Gully erosion b) Erosion downstream of culvert

Figure 14-54 Impacts of landuse change

Impacts of sand and gravel extraction

Sand and gravel extractions were not observed during field inspections but these industries are known to exist in the catchment. These activities can have a disturbing influence on channel stability as they tend to decrease the supply of available sediments to downstream areas, causing erosion problems, although this is dependent on the rate of replenishment.

Impacts of water resource infrastructure

The Dawson River, downstream of Glebe Weir, is a highly regulated river, as demonstrated by the flow duration curves in Figure 14-6 and Figure 14-7. The regulated reach covers a total length of 338.1 km, whereas the total impounded extent from existing storages is 138.5 km, or approximately 41% of the regulated reach. With the dam in place this will increase to 49% of the regulated reach. There are seven existing storages on the Dawson River; six located downstream of the proposed dam, with Glebe Weir located within the water storage. As described earlier, Glebe Weir has had a significant impact on the geomorphology of the Dawson River downstream of the weir where it then meets the. Gyranda Weir headwaters located 15 km downstream. These existing water storages will have also reduced geomorphic variability both within and downstream of the weir walls with bar and associated vegetation encroachment occurring downstream of the walls.

14.5.3. Pipeline

The pipeline crosses a number of intermittent streams draining in an east to west direction, including Price Creek, Pigeon Creek, Cockatoo Creek, Bungaban Creek, Roche Creek, Juandah Creek, Dogwood Creek, Charleys Creek, Cooranga Creek and Jimbour Creek.

14.5.3.1. Present geomorphic features of the watercourses crossed by the pipeline

This assessment has been completed based on a review of aerial photography of the pipeline alignment. A field assessment of these waterways has not been carried out. A limited number of ground photographs of the watercourses at road crossings and broad description of their condition was made available for this study.

The morphology of the creeks typically comprises a meandering channel form, with a singular channel winding across a broader floodplain. Roche creek and Juandah creek are two exceptions to this. The morphology of these two creeks varies along their course from a single channel to two or more channels. Where the pipeline crosses these two creeks, two channels of comparable size to one another are formed on opposite sides of the valley floor.

14.5.3.2. Present geomorphic values of watercourses crossed by the pipeline

Based on the analysis undertaken, it is considered that these watercourses will contain similar features to those that have already been identified in the Dawson River catchment as described in Section 14.5.2.3. These included a macro-channel morphology, pools, assemblages of large woody debris, flood channel and off-stream wetlands.

Existing impacts on watercourses

Impacts of land use change

As in the case of the Dawson River catchment, development in catchment areas of watercourses crossed by the pipeline has resulted in a number of impacts, as described below:

- increased sediment yield to creeks. This is likely to have increased as a result of clearing of vegetation cover in catchment areas, thinning of riparian vegetation cover along watercourses and increased stock access to waterways; and
- impacts of existing crossings. Localised degradation of bank and bed stability was noted downstream of low level road crossings and culverts (Figure 14-55).

a) Eroded drain in the road reserve adjacent to Nathan Road

b) Streambank erosion in Bungaban Creek downstream of the Nathan Road crossing

Figure 14-55 Impacts of landuse change

14.5.4. Associated infrastructure

Chapter 2 describes the detail of the associated infrastructure related to this Project. Several of these have direct relevance to fluvial geomorphology of the streams within the region. Potential impacts upon the receiving environment related to construction and operation of the infrastructure being planned are described in Section 14.6.4. However, the existing environmental values associated with areas potentially impacted by the infrastructure are similar to those described in Sections 14.5.2 and 14.5.3 as the waterways potentially affected display a similar range of features to those discussed in these sections. Of specific note are:

- the complex channel type that characterises tributaries of the Dawson River catchment with a channel-in-channel physiography, and features such as benches, off-river channels, flood runners and terraces. Some of these features are also likely to occur in watercourses along the pipeline;
- the anabranching channel form present immediately downstream of the dam, with multiple channels separated by vegetated longitudinal bars and areas of active floodplain; and

- relatively steep, bare eroded banks and sparse riparian vegetation along incised streams, particularly downstream of road crossings.

14.6. Potential impacts and mitigation measures – fluvial geomorphology

This section describes the potential impacts of the dam, pipeline and associated infrastructure with regard to the geomorphological values previously defined.

14.6.1. Methodology

This section addresses the geomorphic aspects inferred from TOR item 3.4.1.2 and includes:

- the impacts of construction of each of the Project components on the fluvial geomorphology;
- potential impacts on fluvial geomorphology resulting from changes in flood frequency and magnitude;
- impacts from flood regime change on floodplain connectivity;
- determination of the effect of the proposal on sediment transport; and
- the impact of sedimentation on dam storage volumes and bed profiles.

An assessment of nutrients has been undertaken in Section 16.1.4.4.

14.6.2. Dam and surrounds

14.6.2.1. Potential construction impacts

Chapter 2 details the full description of the extent and nature of construction activities. Those activities that may cause sediment-related impacts are described in detail in Table 14-60 and summarised below:

- construction and operation of the on-site office, construction camp and associated infrastructure;
- construction and operation of the diversion channel and associated coffer dams;
- foundation excavation and preparation;
- construction of spillway, plunge pool and excavated channel downstream of the dam;
- removal of coffer dams;
- construction of roads/access tracks for transport of material to / from construction footprint.

Impacts generated from the above activities are likely to be of a site-specific and short-term nature and related to the generation of sediment and slurry and concomitant increased turbidity resulting from:

- washing of the foundation;
- runoff from stockpiles, coffer dams, site office, camp and associated infrastructure;
- erosion of banks and / or bed of diversion channel;
- disturbance to banks and bed during construction of the dam wall and abutments; and
- occurrence of a larger than 1 in 1 AEP event during construction.

Any release of sediment is likely to be composed largely of finer material (clays and silts), although some larger material (sands, gravels) may be entrained in larger flow events. During larger flow events, fine sediment plumes may occur downstream but would be short lasting and mix with existing entrained sediment. Coarser sediment would likely be transported downstream in slower-moving pulses. These pulses would have minimal impact on the overall sediment budget but may have localised impacts on bed habitat. These issues are more relevant to water quality than fluvial geomorphology.

14.6.2.2. Potential operation impacts

Upstream and within the impoundment

The construction of the dam will result in the formation of a channel-reservoir system upstream of the dam wall. This channel-reservoir is comprised of two parts – a larger lake and a section of river upstream of the lake where back flooding occurs along the Dawson River and incoming tributaries. Water levels within the channel-reservoir system are dynamic, fluctuating in response to incoming flows, evaporation losses, extractions and downstream releases. As water levels change in response to these variables, this will have an influence on the extent of the area inundated upstream of the dam. These characteristics may have several potential impacts on channel and floodplain morphology, as described below:

- drowning of hydraulic habitats within the water storage. As discussed previously, the majority of the river reach that will be impounded by the proposed Nathan Dam has been either drowned or severely altered by Glebe Weir. As such, the majority of the hydraulic habitats within the water storage are already severely impacted. Further, no significant geomorphic features were identified within the water storage area. The impact is therefore considered to be minor;
- smothering of geomorphic features by sediment deposition within the 'back flooding' sections outlined above. Brune's reservoir trap efficiency method was used to calculate that the proposed Nathan Dam has a trap efficiency of 99%. It is likely that all the coarse sediment and the majority of the suspended sediment will be trapped by the dam. Using sediment modelling work undertaken by Dougall *et al.* (2006), sediment storage allowances for the dam after 50 and 100 year periods were calculated at 31,128 ML (at EL 169.7 m AHD) and 62,257 ML (at EL 171.8 m AHD) respectively, constituting 2.89% and 5.77% of full supply capacity (0.06% / year). This was based on an average sediment supply value of 0.38 t/ha/yr (total: 81,000 tonnes and 629,000 m^3) (derived from Dougall *et al.* (2006)). The majority of this sediment will be deposited in the 'back flooding' sections where inflows initially meet the dam backwater and will include both floodplain (fine sediment) and channel (coarse sediment) deposition. Given that no significant geomorphic features were identified within the storage area, this impact is likely to be minor. Further, inflows during periods where the dam water level is low may remobilise this sediment and transport it further into the dam;
- sedimentation within the periodically inundated backwater areas may result in the creation of new substrate areas that provide conditions favourable for vegetation establishment and growth. The changes to the watering regime may have the effect of changing the abundance and diversity of riparian vegetation. Studies completed in the backwater area of the Ord River, upstream of Lake Argyle in north-west Australia showed a progressive encroachment of vegetation into the channel environment (Sandercock, 2004). As vegetation grows, the additional hydraulic roughness created by vegetation favours further deposition and the creation of new areas upon which plant establishment can occur; and

- water storage area shoreline erosion. Figure 14-29 shows the Nathan Dam modelled storage trace over the WRP simulation period and extended simulation period (1900-2008). It shows considerable variation in water level over the modelled period. These fluctuations in water level (and associated fluctuations in pore-water pressures) may result in increased erosion of areas of shoreline particularly susceptible to erosion (i.e. areas with erodible margin sediment &/or sparse vegetation). The action of waves and human/livestock activities may also exacerbate shoreline erosion. This can be managed using vegetation buffers on areas of steep bank and/or erodible soil types, managed access for both humans and recreation and stock, and restrictions on recreational boating speeds. However, some erosion of the shoreline is likely given the ponded water acting on landscapes that have not formed under these hydraulic conditions and the long fetch created for wind waves on such a large body of water.

Downstream of the impoundment

For ease of explanation, the section of river downstream of the dam is divided into several shorter reaches approximately demarcated by the EFO Nodes (Figure 14-1). The reaches are outlined below:

- *Nathan Gorge (EFO Node 5a)* – the proposed Nathan Dam to Gyranda Weir;
- *Theodore Reach (EFO Node 4)* – Gyranda Weir to EFO Node 4;
- *Beckers Reach (EFO Node 2)* – EFO Node 4 to EFO Node 2;
- *Lower Dawson* – EFO Node 2 to the Dawson-Mackenzie confluence; and
- *Fitzroy River* – This includes the reaches between the Dawson-Mackenzie confluence and the mouth and incorporates Eden Bann Weir (EFO Node 1), the Fitzroy Barrage (EFO Node 0) and the Fitzroy River estuary.

Section 14.2.2 provides a detailed assessment of downstream hydrological impacts resulting from the operation of the Nathan Dam. The following is a summary of those hydrological impacts related to geomorphic characteristics and processes:

- Flow regime impacts of the dam are greatest immediately downstream of the dam, with the magnitude of change decreasing with increasing distance downstream from the dam. This is generally consistent for all hydrological parameters of relevance to geomorphology. However, due to the extensive existing water infrastructure, there are anomalies in certain reaches downstream of the dam (e.g. elevated low flow at EFO Node 2 for approximately 30% of the simulation period due to increased supply demand downstream of EFO Node 2). These patterns are discussed further in Section 14.2.2;
- The seasonality of the flow regime is not greatly changed as a result of the dam. However, there are considerable reductions in the variability of flow experienced. An assessment of seasonal and monthly variation in mean daily discharge was undertaken for the pre-development, full entitlement and post-dam scenarios. This showed little variation between scenarios in terms of seasonal variation, but indicated reductions in variability of flow over the summer months of January and February between scenarios, which is typically the period of the year when the highest flows are experienced. However, this assessment was based on mean daily discharge, which does not reveal the magnitude of flood events that are impacted. The analysis has also only been carried out on the section of river immediately downstream of the Nathan Dam, which is where the greatest change in flows arising from the construction of the dam is expected to occur. As per the first bullet point, these impacts would reduce in a downstream direction;

- As indicated in Section 14.2.2, there is a greater shift to a continuous low flow regime under the Post Dam scenario which is consistent with the proposed low flow strategy;
- Significant reductions in the frequency of half bankfull and bankfull flows will be experienced in the Post Dam scenario. There is a 50% reduction at Nathan Gorge, immediately below the dam and 30% reduction at Theodore. The reduction in frequency of half bankfull flows is reduced to 10% at Beckers Reach, whilst the frequency of bankfull flows remains unchanged;

Impacts on geomorphic characteristics and processes (e.g. sediment transport, erosional, depositional and habitat maintenance processes) are largely influenced by the hydrological regime and, as such, are likely to reflect the magnitude and patterns of those hydrological impacts discussed above. As such, they are likely to be greatest immediately downstream of the dam (Nathan Gorge reach) and diminish in a downstream direction. Impacts will be negligible in the Fitzroy River, downstream of the Dawson River. As with the hydrological impacts, however, geomorphic impacts will also be partially influenced by the existing weirs. Impacts should be limited within the existing weir pools, whereas uninundated reaches, particularly those immediately downstream of the dam and those downstream of Orange Creek Weir, will be most at risk of being impacted.

Potential impacts during operation may include:

- Downstream changes in sediment load. The construction of the water storage on the Dawson River would result in the trapping of all incoming coarse grained sediment behind the reservoir and the majority of fine material. It is only during periods when a flood occurs and the reservoir is full with flows running over the spillway that there may be some transfer of a small proportion of fine sediments to the downstream reaches. Downstream reaches would therefore experience a marked reduction in sediment load, the amount being proportional to the rate of sedimentation upstream of the storage. This impact would diminish in a downstream direction with the input of flow and sediment from tributaries and other sources (catchment and bank erosion);
- Clearwater scour. This may be expected within the 2 km reach downstream of the dam (*Nathan Gorge* reach) due to the sediment trapping effect of the dam. The extent of this scour may be limited by bedrock outcropping along the channel. Geotechnical studies at the dam wall show that the bed is comprised of a mixture of sands and clay to a depth of approximately 10 m, overlaying a sandstone base. Armouring of the bed is unlikely to occur due to the lack of coarse gravels and cobbles in the bed. Significant vertical scour may therefore be expected to occur. This impact is expected to be somewhat ameliorated by the input from Price Creek immediately downstream of the dam. Clearwater scour also has the potential to impact on the ability of the low flow release strategy to meet its objectives of achieving set flow levels. As the channel incises and widens, a greater volume of flow will in turn be required to achieve a particular flow level;
- Channel type shift. The reaches immediately downstream of the dam currently consist of a series of anabranching channels (DS1). It is expected that with the combined effect of a reduction in the frequency of bankfull, minor and moderate floods, the reduction in sediment supply and clearwater scour, the channel planform within this reach may shift from an anabranching morphology to a single-thread meandering channel. Given the fine-grained nature of the bed and bank materials, incision and widening (bank erosion) is anticipated along the meandering channel. The current intention to design a plunge pool on the downstream side of the dam so that flows from the spillway will pass directly into an excavated channel downstream of the dam embankment will likely accelerate this channel planform shift. However, the greater channel should remain stable given that this reach is located within a gorge. This impact

is likely to extend until the Gyrandra Weir pool is reached (approximately 2 km downstream from the Nathan Dam wall).

The erosion may be buffered through the encroachment of vegetation on the river banks, although a reduction in cease to flow events will also reduce opportunities for vegetation to colonise the bed and create ridges that divide the channel and maintain the anabranching form. However, Glebe Weir appears to have had little effect on the downstream anabranching pattern, although Glebe Weir is a smaller instream structure and would have a much lower impact on downstream sediment conveyance than the proposed Nathan Dam. Considering the surrounding landscape, the stability of the greater channel will not be affected;

- There is likely to be similar, but greatly diminished, impacts further downstream in unregulated reaches.
- Bank erosion. In conjunction with the above shifts in channel type, bank erosion associated with regulation of flows (notch erosion) and the clarity of the water is likely to occur downstream of the dam. This should be minor in most reaches, except for those with particularly erodible material and / or little riparian vegetation cover. Outcropping rock in the Nathan Gorge reach is likely to ameliorate this impact to some degree, although erosion is still likely to occur in the anabranching channels within the greater channel. This impact is likely to extend until the Gyrandra Weir pool is reached (approximately 2 km downstream from the Nathan Dam wall);
- Sedimentation in pools. Given the reduction in the magnitude and frequency of bankfull, minor and moderate floods, changes to the dimensions of the channel are expected. The ability of the channel to transport sediments supplied from incoming tributaries will also be reduced. This could result in problems of sedimentation in existing pools. The ability of these pools to maintain their channel dimensions, is also comprised by the reduction in the frequency of formative bankfull flows. With a reduction in the frequency of minor and major overbank flows, this will result in lower potential for the scour and creation of new secondary channels across the floodplain. This will occur throughout the Dawson reaches, but its severity will diminish in a downstream direction and should be negligible by the Dawson-Mackenzie confluence;
- Bar and associated vegetation encroachment. Regulated rivers often experience encroachment of vegetation because the stability of the substrate is increased (with reduced flows) and an absence of large floods that are effective in removing vegetation. Exposed bars and benches with shallow water tables form good sites for vegetation establishment. Encroachment of vegetation across the floodplain, secondary channels and anabranching channels is anticipated as a result of the reduction in magnitude and frequency of floods. This encroachment of vegetation may also assist in mitigating the impacts of clearwater scour downstream of the dam. However, the reduction in cease to flow periods is also expected to reduce opportunities for vegetation to colonise the bed, which is important for the creation of vegetated ridges that divide the flow, maintaining and creating anabranching channel patterns;
- Changes to hydraulic habitat. Given the likelihood of increased sedimentation and associated bar/vegetation encroachment, there is potential for smothering of riffle/run habitat in unregulated reaches, particularly those downstream of Orange Creek Weir in the Theodore Reach. However, given the low flow release strategy highlighted in Section 14.2.2, this impact would likely be minor, particularly considering the existing regulation resulting from instream infrastructure. However, given the limited instream hydraulic habitat mapping available, it is suggested that monitoring sites are established within unregulated reaches of the river;

- Reduced sediment supply to coast. Given that Section 14.2.2.2 shows that there is very little discernible difference in the flow regime between the full entitlements and post-dam scenarios within the Fitzroy River reaches, it is unlikely that sediment supply will be greatly affected. While all coarse and most fine sediment will be trapped by Nathan Dam, contributions from tributary inflow, hillslope erosion and channel erosion will ameliorate this impact. Further, Dougall *et al.* (2006) showed that the Dawson River contributes a comparatively small proportion of sediment to the overall basin compared with other sub catchment areas (Figure 14 46); and
- Flow Regime Change. The Fitzroy Basin WRP uses several environmental flow objectives to assess the compliance of water resources development with the WRP. While most objectives are indirectly related to channel morphology, of most relevance are the following medium – high flow objectives:
  - Channel morphology statistic – the annual peak daily flow volume in the simulation period with an annual probability of exceedance of 50%; and
  - Flood plain zone statistic – the number of flows that inundate flood plain habitats.
- The Nathan Dam will meet the mandatory (and some non-mandatory) medium to high flow event objectives at the applicable nodes (node 2 and 0) (Table 14-26 and Table 14-27).
- However, there are no channel morphology or flood plain zone statistics for the nodes closest to the dam, where these statistics would be less likely to be met. As described above, the downstream frequency of bankfull and overbank flows or floodplain inundation will decrease once the dam is in place, particularly in the reach directly downstream of the dam.

14.6.2.3. Mitigation measures

Through the implementation of the mitigation measures described below and in Chapter 2, sediment-related and fluvial geomorphological impacts are expected to be mostly minor.

The proposed mitigation measures during construction include:

- optimisation of spillway profile and energy dissipation arrangements downstream of the dam through physical hydraulic modelling so that erosion is minimised; and
- development of a sedimentation and erosion control plan as outlined in Chapter 6. This is important to ensure minimal smothering of downstream hydraulic habitats and to minimise likelihood of bank instabilities associated with runoff.

In situ construction monitoring is recommended at the geomorphic monitoring sites listed in Table 14-57 and at additional sites along the 2 km section of river immediately downstream of the dam wall and within the reach immediately downstream of Orange Creek Weir. Assessments should include both visual and proforma-based assessment of geomorphic stability to assess impact on both channel integrity and sediment entrainment that, at a minimum, assesses:

- bed and bank stability, including the presence of any active erosion / failure or deposition;
- slope (longitudinal bed and bank);
- vegetation presence and contribution to stability (riparian and aquatic);

- LWD presence and potential for further jams;
- channel capacity;
- bed and bank sediment types;
- bed consolidation; and
- cross-sections should be established.

The proposed mitigation measures during operation include:

- continued monitoring of geomorphic assessment sites for potential change that adheres to the above guidelines. This should include those construction monitoring sites outlined above;
- mapping of hydraulic habitats within the unregulated reaches immediately downstream of the dam wall and immediately downstream of Orange Creek Weir;
- bed and bank stabilisation as required in the area immediately below the dam should vertical scour or notch erosion be observed;
- establishment of vegetation buffers on areas of steep bank and/or erodible soil types along the water storage area shoreline, managed access for both humans and recreation and stock, and restrictions on recreational boating speeds in the water storage area;
- investigate options for targeted sand and gravel extraction in the upstream reaches of the water storage area to remove excess material; and
- further optimisation of the flow release strategy during detailed design stage of the Project, including exploring the possibility of distribution of releases across a number of anabranches, rather than into a single excavated channel.

14.6.3. Pipeline

14.6.3.1. Potential construction impacts

Impacts during this phase are likely to be of a short-term and localised nature and of minor consequence. They will be largely related to the following key construction activities (Chapter 2):

- clearance of vegetation from construction areas;
- removal and stockpiling of top soil;
- pipe laying, backfilling and rehabilitation; and
- trench excavation.

Potential impacts are generally related to the clearance of vegetation from stream banks and other within-channel features such as bars and benches, thereby resulting in increased exposure to flows. Potential impacts may include:

- localised increases in Total Suspended Solids (TSS) and bed sedimentation in receiving watercourses caused by construction within channels during flows or within waterholes, noting that the intention is to conduct works in the dry season in higher risk areas;

- increased soil erosion and sediment delivery to channel from erosion of soil stockpiles, exposed pipeline construction strips and other cleared areas, particularly during intense storm events in areas of erodible/dispersible soils;
- bank mass failures resulting from construction activities at creek crossings. These are a particular concern within the incised stream types, as they typically consist of high, steep banks that are particularly prone to mass failures; and
- increased delivery of sediment to channel from banks resulting from the disturbance of highly erodible soils.

14.6.3.2. Potential operation impacts

Sediment-related and fluvial geomorphological impacts relating to operation of the pipeline are expected to be negligible due to the rehabilitation discussed in Chapter 2 and Section 14.6.3.3. However, potential impacts may include:

- exposure of the buried pipeline at stream crossings due to scour, causing local bed and bank erosion; and
- continued elevated TSS in receiving watercourses resulting from sediment-laden runoff from the pipeline construction strip and associated continued bed sedimentation.

14.6.3.3. Mitigation measures

Considering the ephemeral or intermittent nature of most of the watercourses within the region, most impacts related to increased delivery of sediment to the channel can be mitigated by avoiding construction during wetter months, as currently planned. As per design standards, mitigation measures planned to be implemented include:

- minimising the amount of open trench at any one time;
- rapid backfilling and stabilisation (e.g. compaction and light rock armouring) of pipeline trench at riverbanks;
- limit the clearance of riparian vegetation to the width required to safely accommodate the pipeline construction strip;
- ensuring the pipeline approach to waterbodies is kept as close to right angles as possible to limit disturbances to the banks;
- employing fine-scale assessment of pipeline crossings to minimise disturbance of particularly erosive soils and to avoid established riparian vegetation and dry-season waterholes;
- implementing good industry-practice management of instream activities. This includes limiting construction to drier months and limiting the duration of watercourse construction activities;
- implementing good industry practice erosion and sediment control measures at / near watercourse crossings, as necessary and maintain these until soil stabilisation has been completed;
- prohibiting soil stockpiling adjacent to waterbodies;
- ensuring waterbody crossings are monitored following major rainfall events to identify erosion / deposition; and
- ensuring potential bed scour depths at pipeline crossings are calculated prior to determining the depth that the pipeline will be buried to ensure the pipeline is not exposed.

14.6.4. Associated infrastructure

Associated infrastructure may have impacts on the receiving fluvial geomorphology environment.

14.6.4.1. Potential construction impacts

Potential impacts may include:

- localised increases in TSS and bed sedimentation in receiving watercourses caused by construction within or within close vicinity of channels and / or poor erosion and sediment controls associated with construction of all associated infrastructure listed above;
- increase in bank erosion (gullying) due to potentially inadequate drainage control, particularly in association with the construction of roads and clay extraction areas;
- increased soil erosion and sediment delivery to channel from erosion of soil stockpiles, particularly during intense storm events in areas of erodible soils;
- bank mass failures resulting from construction activities at creek crossings; and
- increased susceptibility of bars and benches within the complex stream types, resulting from vegetation clearance and profiling of banks.

14.6.4.2. Potential operation impacts

Potential operation impacts related to the majority of the afore-mentioned associated infrastructure are likely to be negligible.

14.6.4.3. Mitigation measures

As described in Section 14.6.3.3, most impacts can be mitigated by avoiding construction during wetter months and by designing the drainage associated with the infrastructure to appropriate standards.

14.6.5. Impact assessment and residual risks

The methodology used for risk assessment and management is discussed in Section 1.8.

This section assesses the risks relevant to fluvial geomorphology and summarises the mitigation measures proposed to minimise those risks.

Unmitigated and mitigated consequence and likelihood ratings for the identified hazards are shown with explanatory notes in Table 14-60. The risk assessment is of the Project as described in Chapter 2, in which SunWater has already incorporated a range of risk reduction and mitigation measures.

Based on this assessment, the following conclusions can be made:

- The Dawson River, downstream of the propose dam is already a highly regulated river which has influenced geomorphic process. The regulated reach covers a total length of 338.1 km while the total impounded extent from existing storages is 138.5 km, or approximately 41% of the regulated reach. With the dam in place this will increase by 8%.

- A reduction in the frequency of flood events and variability instream flow is likely. When combined with reduction in sediment loads, it is anticipated that this will lead to a change in channel planform for the 2 km section of river downstream from the dam, as described above. These impacts may be offset through ongoing monitoring of channel changes, bed and bank stabilisation as required and further optimisation of the flow release strategy.
- With respect to downstream geomorphic processes there will be significant changes to the magnitude and frequency of flood events downstream of the dam and weirs. While the magnitude of flow changes decreases with increasing distance from the dam, the changes in flow magnitude and frequency will impact on the ability of the river to maintain its geomorphological processes and form. The reduction in cease-to-flow periods will also limit the potential for vegetation to colonise the bed, which is an important component that contributes to the formation of vegetated ridges and maintenance of an anabranching channel form. The reductions in frequency of bankfull flows will lead to contraction of the overall channel width. Sedimentation issues are likely to arise in pools as a result of the reduction in frequency of flows up to and exceeding bankfull capacity. The potential for new secondary flood channels to form across the floodplain will be reduced due to the reduction in the magnitude and frequency of overbank flows.
- While sediment supply downstream may be reduced, this is not considered significant at the scale of the Fitzroy Basin and may be slightly beneficial because current rates of sediment delivery and transport are much higher than pre-development conditions; and
- Although some localised erosion and sedimentation impacts may occur, overall the risks to fluvial geomorphology are low to medium. Mitigation options (where feasible) are presented in Table 14-60.

Table 14-60 Fluvial geomorphology risk register

Hazard Area: Dam and surrounds (Construction)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Increased TSS and bed sedimentation in channels and water bodies	Discharge of construction sediment likely under wet conditions.	Will occur from construction of dam with localised effects on water quality and habitat.	Development of a sediment and erosion control plan, including limiting construction to the dry season	Minor	Unlikely	Low			Minor	Unlikely	Low
Increase in bank erosion (gullying) due to inadequate drainage control from exposed areas.	May occur when wet weather occurs during construction.	Uncontrolled runoff from construction areas adjacent to watercourses may cause erosion and piping failures at river banks.	Development of a sediment and erosion control plan, including limiting construction to the dry season	Minor	Possible	Medium			Minor	Possible	Medium
Within channel sediment build-up in water storage, particularly within the upstream reaches, resulting from dam backwater effects.	Construction of the dam.	Sediment deposition in Dawson River and tributaries in reaches affected by dam backwater will reduce hydraulic habitat variability.		Minor	Absolute	Medium	Investigate options for targeted sand and gravel extraction to remove excess material.	Moderate	Minor	Possible	Medium

Hazard Area: Dam and surrounds (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectivenes s	Residual Risk		
Shoreline and subsurface erosion processes within water storage	This effect will depend on the overall erodibility of the shoreline.	Erosion of shorelines due to wave action causing minor slips and localised/temporary turbidity increases.	Development of a sediment and erosion control plan that adheres to best practice – may include rock protection in selected areas, revegetation and dam usage restrictions.	Minor	Possible	Medium			Minor	Possible	Medium
Drowning of hydraulic habitats within the water storage leading to reduction in geomorphic variability	Will occur as storage fills.	Drowning of geomorphic/hydraulic features will occur on a local scale, but these will not be unique features.		Minor	Absolute	Medium			Minor	Absolute	Medium

Hazard Area: Dam and surrounds (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectivenes s	Residual Risk		
'Clearwater' scour and associated bank erosion along 2 km section of river downstream of dam due to sediment trapping by dam.	Extent of this effect will depend on bed and bank rock outcropping, and the interaction between clearwater flows from the dam, the calibre of downstream bed sediments, and extent of Gyranda headwater	Channel changes downstream from Glebe Weir indicated that scour may be significant downstream of Dam. Bed and banks are also comprised of highly erodible fine alluvial sediments. Vegetation encroachment may offset potential erosion impacts.	Optimisation of spillway profile, energy dissipation arrangements downstream of the dam through physical hydraulic modelling so that erosion is minimised. Monitoring of geomorphic assessment sites and treatment of erosion as required.	Moderat e	Likely	High	Optimisation of flow release strategy downstream of dam Bed and bank stabilisation, where required	Significant	Moderate	Possible	Medium

Hazard Area: Dam and surrounds (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
Channel changes downstream from dam and weirs	Flow characteristics predicted to change significantly in the Dawson River immediately downstream of dam and weirs. As a whole this effect (if occurs) will be localised.	Reduced rate of channel change, contraction of overall channel width, sedimentation of pools, changes to hydraulic habitat and stabilisation of mobile fluvial features.	Optimisation of spillway profile, energy dissipation arrangements downstream of the dam through physical hydraulic modelling so that erosion is minimised. Monitoring of geomorphic assessment sites and treatment of erosion/aggradation as required.	Moderate	Likely	High	Optimisation of flow release strategy downstream of dam and weirs Mapping of hydraulic habitats within the unregulated reaches immediately downstream of the dam wall and immediately downstream of Orange Creek Weir	Significant	Moderate	Possible	Medium
Reduced sediment supply to estuary and coast	The Dawson River dam will be located a significant distance from the coast and the river system is already heavily regulated between the dam and the coast.	Any reduction in sediment supply to coast will trend towards a more natural condition.		Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Dam and surrounds (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
Reduction in connectivity with floodplain and associated water bodies due to reduction in flooding extent	Flow characteristics are not predicted to change significantly in the Dawson River as a whole.	A reduced frequency of flow and sediment transfer between the river and floodplain water bodies.		Minor	Unlikely	Low			Minor	Unlikely	Low
Notch erosion resulting from reduced variability of flows near the Dam	Flow characteristics are not predicted to change significantly in the Dawson River as a whole.	An increased rate of bank erosion due to reduced variability of flows.		Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Pipeline (Construction)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Increased TSS and bed sedimentation in channels and water bodies	Discharge of construction sediment likely under wet conditions.	Will occur from construction of pipeline with localised effects on water quality and habitat.	Soil erosion and sedimentation management plan to be developed and implemented for all construction sites.	Minor	Unlikely	Low			Minor	Unlikely	Low
Bank mass failures in incised stream types due to pipeline construction.	More likely to occur under wet/high flow conditions before crossings are rehabilitated.	Trenching may cause localised erosion or larger scale bank failure leading to localised habitat damage in certain stream types due to erodible/non-cohesive bank material.	Design standards Soil erosion and sedimentation management plan to be developed and implemented for all construction sites.	Minor	Unlikely	Low			Minor	Unlikely	Low
Increase in bank erosion (gullying) due to inadequate drainage control from exposed areas.	May occur when wet weather occurs during construction.	Uncontrolled runoff from construction areas adjacent to watercourses may cause erosion and piping failures at river banks.	Soil erosion and sedimentation management plan to be developed and implemented for all construction sites.	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Pipeline (Construction)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Exacerbated erosion of within channel bars and benches where vegetation has been removed (particularly complex stream types).	Erosion expected to occur if flows occur during construction period and for some months after before vegetation re-establishes.	Clearance of vegetation from in-channel sediment features (e.g. bars) at pipeline creek crossings will make them more susceptible to erosion at a local scale.	Soil erosion and sedimentation management plan to be developed and implemented for all construction sites.	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Pipeline (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
Scour of buried pipeline at creek crossings.	Scour depths would typically be in the order of 2 – 4 m below bed level.	General scour of sandy-bed creeks may undermine buried pipe at creek crossings. This may cause localised scour and erosion.	Design standards including establishing bed scour depths prior to construction	Minor	Possible	Medium		Significant	Minor	Unlikely	Low

Hazard Area: Pipeline (Operation)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
Increase in bank erosion (gullying) due to inadequate drainage control from exposed areas	May occur when wet weather occurs during construction.	Uncontrolled runoff from construction areas adjacent to watercourses may cause erosion and piping failures at river banks.	As far as practical works will be undertaken during dry weather conditions. Should wet weather prevail appropriate sediment and erosion control measures will be implemented.	Minor	Unlikely	Low			Minor	Unlikely	Low
Bank mass failures resulting from construction activities at creek crossings	More likely to occur under wet/high flow conditions before crossings are rehabilitated.	Trenching may cause localised erosion or larger scale bank failure leading to localised habitat damage in certain stream types due to erodible/non-cohesive bank material.	As far as practical works will be undertaken during dry weather conditions. Should wet weather prevail appropriate sediment and erosion control measures will be implemented.	Minor	Unlikely	Low			Minor	Unlikely	Low

Hazard Area: Associated infrastructure (Construction)

Hazards	Factors	Impacts	Project Description Controls and Standard Industry Practice	Risk with Controls			Additional Mitigation Measures	Mitigation Effectiveness	Residual Risk		
				C	L	Current Risk			C	L	Mitigated Risk
Increased TSS and bed sedimentation in channels and water bodies	Discharge of construction sediment likely under wet conditions.	Localised effects on water quality and habitat.	As far as practical works will be undertaken during dry weather conditions. Should wet weather prevail, appropriate sediment and erosion control measures will be implemented.	Minor	Unlikely	Low			Minor	Unlikely	Low
Increased soil erosion and sediment delivery to channel from erosion of exposed surfaces	May occur when wet weather occurs during construction.	Uncontrolled runoff from construction areas adjacent to watercourses may cause erosion and piping failures at river banks.	As far as practical works will be undertaken during dry weather conditions. Should wet weather prevail appropriate sediment and erosion control measures will be implemented.	Minor	Unlikely	Low			Minor	Unlikely	Low

14.7. Cumulative risks

From the perspective of the Fitzroy River Basin, the cumulative impacts associated with the dam, pipeline and associated infrastructure are minimal. The impacts of the modelled Cumulative Impacts Scenario on WRP environmental flow objectives are not excessive and will be able to be managed through a combination of environmental flow releases and management rules. These will need to be developed as the proposed infrastructure is approved and finalised.

On a local scale, cumulative impacts may be more significant depending on exact location and nature of the disturbance. However, local effects are more likely to be short-term and overall the risk is considered low.

14.8. Summary – fluvial geomorphology

This section has assessed the potential impact of the Project on fluvial geomorphology in the Dawson River and wider Fitzroy River Basin. This assessment showed geomorphic processes for the Dawson River will be maintained in upper catchment areas, where the dam has no impact. In the water storage area and areas downstream, the changes to the flow regime are such that they will result in considerable adjustments to geomorphological processes. This will impact on the condition and distribution of geomorphic values present in these reaches. There is the potential to mitigate these risks through the optimisation of the flow release strategy downstream of the dam and weirs.