Appendix K
Surface Water Assessment

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K1.1 Overview

This Appendix presents technical information relating to the assessment of surface water for the McArthur River Mine Expansion EIS. The main EIS report provides complete background to the context and key environmental issues for surface water management, and information presented herein is limited to technical methods and data utilised to undertake the assessment of surface aspects of the project.

K1.2 Design Peak Flood Flow Estimates for the McArthur River

Estimates of design peak flood flows were required to assess existing flooding in the McArthur River and the impacts of the proposed realigned river and creek channels. For this EIS, estimates of design flood flows have been determined from studies undertaken by Kellogg Brown and Root (KBR, 2003) as part of investigations into the feasibility of the proposed works. The KBR flood estimates were determined utilising annual-series flood frequency analysis of observed floods at the DIPE stream gauging station (9070132 – MIM pump station) located immediately upstream of the mine. The flood frequency analysis was undertaken in accordance with procedures recommended in Australian Rainfall and Runoff (1987) which is widely accepted for this type of analysis.

An alternative method of estimating design peak flood flows (and hydrographs) utilising rainfall-runoff routing methods could not be applied with sufficient confidence for the McArthur River catchment. The main limitation is due to the sparsity of rainfall gauges in the catchment (which would be required for runoff model calibration), and uncertainty in design rainfall storm conditions to apply to the model (specifically the combined effect of uncertainty design rainfall intensities and application of rainfall areal reduction factors for the large catchment area).

The adopted design peak flood flow estimates (based on flood frequency analysis methods) are therefore considered the most reliable estimates for the project. It is important to note that:

- The KBR flood frequency estimates include the 2003 flood event which results in higher flood flow estimates from previous flood studies and reports.
- Estimates of floods for 100 year ARI (1% Annual Exceedance Probability - AEP) and 500 year ARI (0.2% AEP) should be utilised with caution as the estimates are likely to exceed the credible limit of extrapolation as defined in the recommendations of Australian Rainfall and Runoff – Book VI Extreme Floods (1999).

A flood frequency plot of the design flood estimates is presented in Figure K.1.

The flood frequency analysis results apply specifically to flood flows at the DIPE stream gauge. For estimates of flood flows at other locations along the McArthur River where the contributing catchment area (and flood magnitude) varies, the flood frequency estimates for the stream gauge location were scaled relating catchment area to peak discharge as shown in Equations 1 to 5 (KBR, 2003).

$$Q_{500\,yearARI} = 73.9A^{0.6} \quad \text{Eq. 1}$$

$$Q_{100\,yearARI} = 36.1A^{0.6}$$ Eq. 2

$$Q_{50\,yearARI} = 25.4A^{0.6}$$ Eq. 3

$$Q_{5\,yearARI} = 5.3A^{0.6}$$ Eq. 4

$$Q_{2\,yearARI} = 1.8A^{0.6}$$ Eq. 5

Where: Q = peak flow flow (m^3/s), and A = catchment area (km^2)

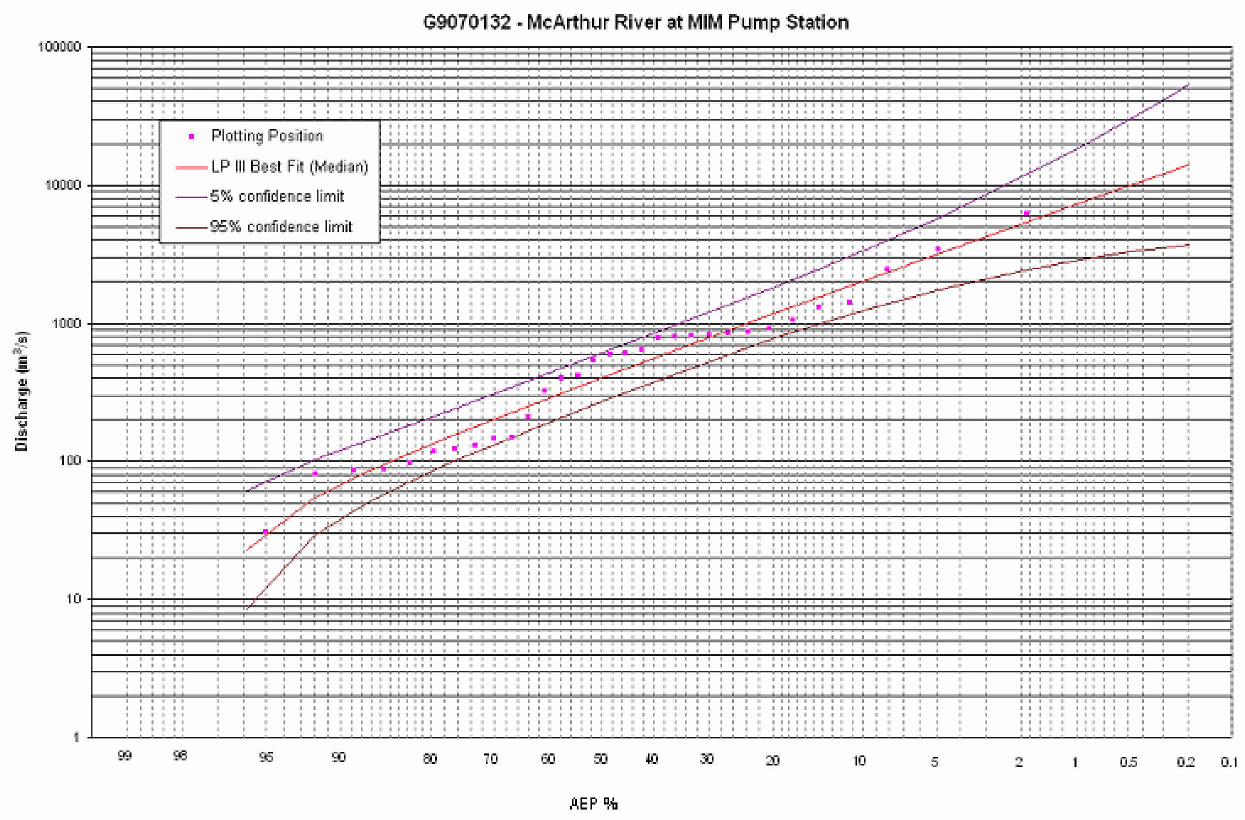
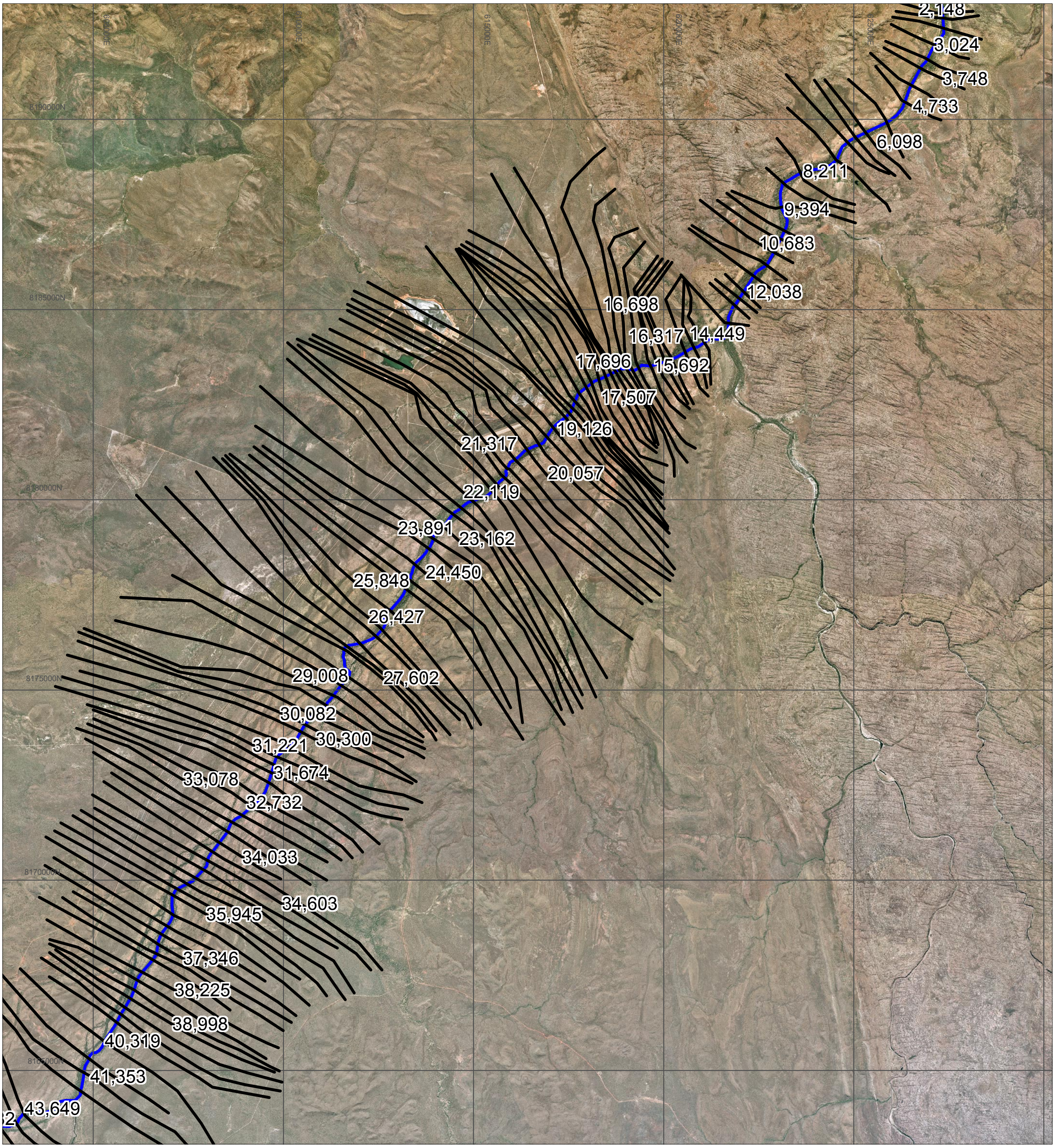


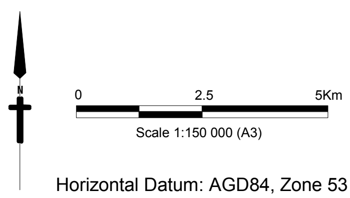
Figure K.1 McArthur River Flood Frequency Plot

K1.3 Mathematical Hydraulic Modelling

K1.3.1 Approach

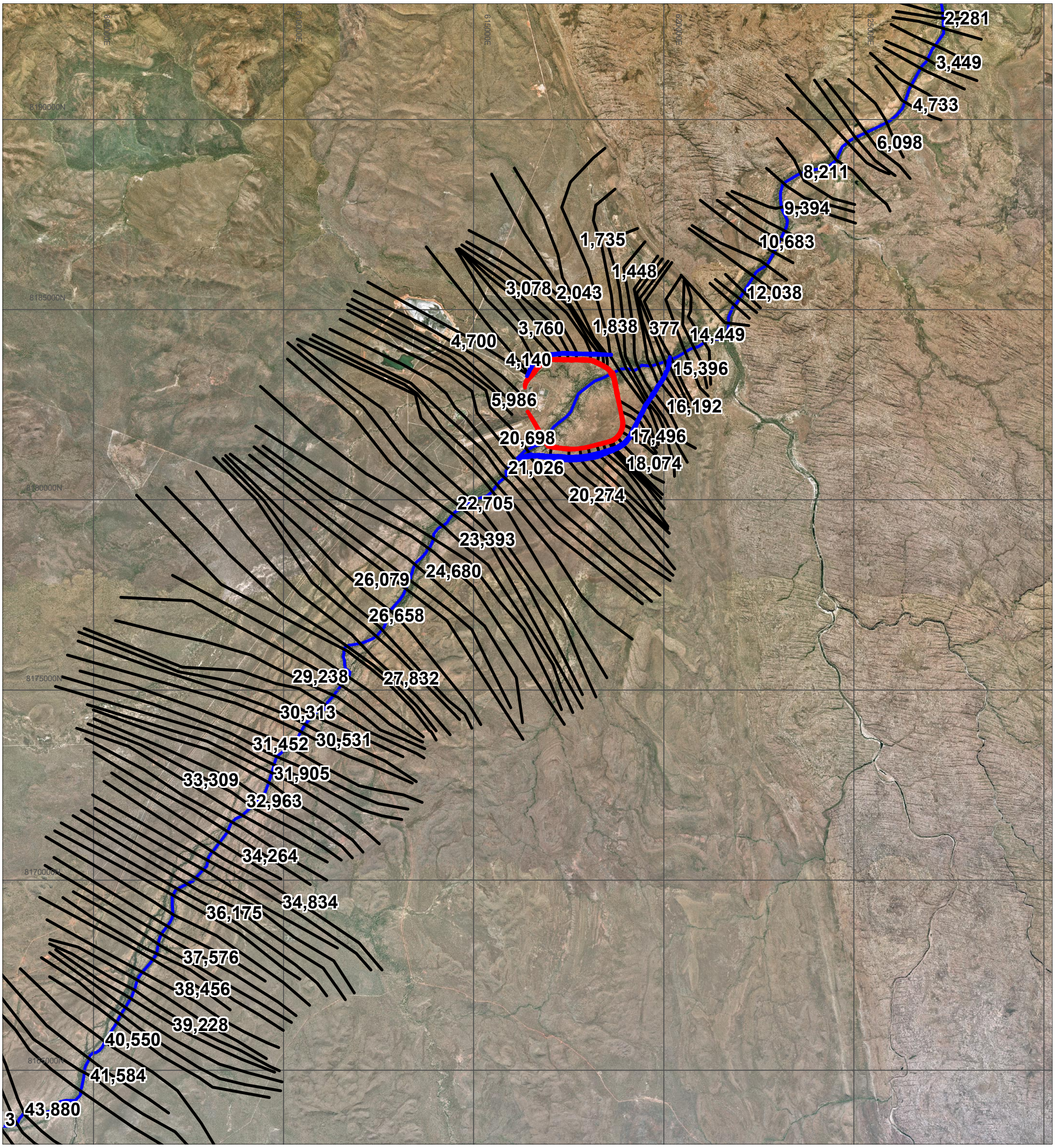
Mathematical hydraulic modelling of the McArthur River was undertaken to evaluate key hydraulic parameters of river flows for existing river conditions, and proposed works, in relation to flood levels, flow velocity, shear stress, stream power (as indicators of erosion potential in flood conditions), flow velocity for assessment of hydraulic requirements for fish passage, and sediment transport capacity (as indicators of sedimentation potential and broader geomorphologic characteristics).





Horizontal Datum: AGD84, Zone 53

xstrata / URS	McARTHUR RIVER MINE OPEN CUT PROJECT ENVIRONMENTAL IMPACT STATEMENT	**HEC-RAS HYDRAULIC MODEL CROSS-SECTION LAYOUT EXISTING CONDITIONS**
Drawn: VH	Approved: CMP	Date: 03-08-05
Job No: **42625552**	File No: 42625552-g-154.wor	Figure: **K.2** Rev: A **A4**



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Horizontal Datum: AGD84, Zone 53

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URS

McARTHUR RIVER MINE
OPEN CUT PROJECT
ENVIRONMENTAL IMPACT STATEMENT

HEC-RAS HYDRAULIC MODEL
CROSS-SECTION LAYOUT
OPEN CUT PIT MINE EXPANSION

Drawn: VH	Approved: CMP	Date: 03-08-05
Job No: **42625552**	File No: 42625552-g-155.wor	

Figure: **K.3** | Rev: A | A4

The mathematical modelling was undertaken utilising HEC-RAS software which accounts for steady-state, one-dimensional, gradually varied flow. HEC-RAS is produced and supported by the US Army Corp of Engineers, and widely accepted in Australia and internationally for this type of hydraulic analysis.

K1.3.2 Hydraulic Model Data and Extents

Topographic data to define the existing river waterway geometry in the HEC-RAS model was based on aerial photogrammetric survey (2001) supplemented with detailed ground-based surveyed cross-sections of the McArthur River in the vicinity of the mine.

The HEC-RAS model was developed to evaluate the variation of hydraulics in a broad reach of the river system and facilitate comparison of local reach hydraulics in the broader context. The model extended from 20 km downstream of the mine up to 25 km upstream of the mine.

For existing river conditions flood flows can break out of the main channel and flow into Barney Creek during large flood events (greater than 50 year ARI). In such flood conditions, there is no distinct flowpath divide between the main channel flood flow and flood flow along Barney Creek. The HEC-RAS model for existing flooding conditions was therefore developed with a single flowpath (reach).

For flood conditions after the mine expansion, the flood protection bund will provide a distinct flowpath divide between the main McArthur River channel flood flow and flood flow along Barney Creek for large flood events. The HEC-RAS model for the proposed conditions included split flow provisions for large flood events to account for the divided flood flow path.

The layout of the HEC-RAS model for existing conditions is presented in Figure K.2 and for proposed works is presented in Figure K.3. For reference to HEC-RAS model output plots presented in this EIS, the HEC-RAS model chainages can be correlated to the ‘design chainages’ for the new McArthur River channel works (shown in Figure 12.13 of the main EIS report) using Table K.1.

Table K.1
HEC-RAS Model Chainage to McArthur River Design Chainage Reference

HEC-RAS Model Chainage	Channel Design Chainage
15396	5254
15677	4973
15886	4764
16192	4457
16390	4260
16489	4160
16574	4076
16849	3801
17036	3614
17299	3351
17496	3154
17765	2884
17988	2662
18035	2615
18074	2576
18255	2394
18434	2216
18694	1955
18934	1715
19252	1398
19749	900
20274	376

K1.4 Hydraulic Model Calibration – Existing Conditions

The mathematical hydraulic model required hydraulic roughness values (Mannings' n) that represent the resistance to flow by channel bed/banks and floodplain features. Existing vegetation along the river banks has a substantial influence on hydraulic roughness, and the influence varies according to depth and magnitude of flow. Different hydraulic roughness factors were therefore determined for flood flow conditions and for low-flow conditions of interest to the assessment of hydraulics for fish passage.

K1.4.1 Flood Flow Hydraulic Roughness Values

The hydraulic roughness values for the HEC-RAS model for flood flows were determined by calibration of the model using the observed flood level measurements from the 7 January 2003 flood event at the DIPE McArthur River MIM Pump Station stream gauge (upstream of the mine) and the McArthur River

Mine gauge (downstream of the Glyde River Junction). An exact calibration match to observed flood levels was not attainable and preference was given to providing the best possible match at the upstream gauge. The limitations of the model calibration were considered to be likely due to possible errors in the observed flood levels, uncertainty in the high range of the upstream DIPE gauge rating curve and corresponding flow adopted for the 2003 flood, and uncertainty associated with the flow estimate at the downstream gauge due to unknown contribution of Glyde River flooding for 2003 flood event (note: downstream McArthur River Mine recorded is not gauged and does not have a rating curve).

The adopted hydraulic roughness values for flood flow conditions determined from the model calibration were n=0.080 for the main channel and n=0.075 for floodplain areas. The flood flow calibration results are summarised in Table K.2.

Table K.2 Calibration Results for 7 January 2003 Flood Event

Location	HEC-RAS Cross-section	Peak Flow (m^3/s)	Observed Level (mAHD)	Modelled Flood Level (mAHD)
DIPE Stream Gauge (MIM Pump 9070132) (upstream of mine)	20795	4,700	36.21	35.71
MRM Gauge (downstream of Glyde River)	12038	5,600	33.70	34.13

K1.4.2 Low Flow Hydraulic Roughness Values

The hydraulic roughness values for the HEC-RAS model for low flows (up to 100m^3/s) were determined by calibration of the model to rating curve water levels for the DIPE McArthur River MIM Pump Station gauge (Station 9070132, upstream of the mine). At low flows, the effect of vegetation and large woody debris has a substantially varying influence on hydraulic roughness depending on the depth of flow. Accordingly, low flow hydraulic roughness values were specifically determined for three flow cases (20, 50, and 100 m^3/s). The calibration results and adopted hydraulic roughness values are summarised in Table K.3.

Table K.3 Calibration Results for Low Flow Conditions

Flow (m^3/s)	DIPE Gauge 9070132 Rating Curve Level (mAHD)	Modelled Water Level (mAHD)	Channel Roughness Value Manning's 'n'
20	23.40	23.38	0.230
50	23.88	23.93	0.120
100	24.77	24.72	0.080

K1.5 Verification of Model Flow Velocities For Fish Passage Flows

The HEC-RAS model estimates of existing channel flow velocities for low flows of interest to hydraulic conditions for fish passage were verified with gauged flow velocity data obtained from DIPE for the stream gauge (9070132) located immediately upstream of the mine. DIPE has routinely undertaken gauged flow measurements at this gauging station since 1976. The data set included 98 measured flows and 13 measured flows were selected covering the range of flows from 20 to 100 m^3/s. The gauged flows and corresponding mean gauged flow velocities are presented on Figure K.4. The gauged flow velocities confirmed acceptable estimates of existing river channel low-flow velocities from the HEC-RAS model.

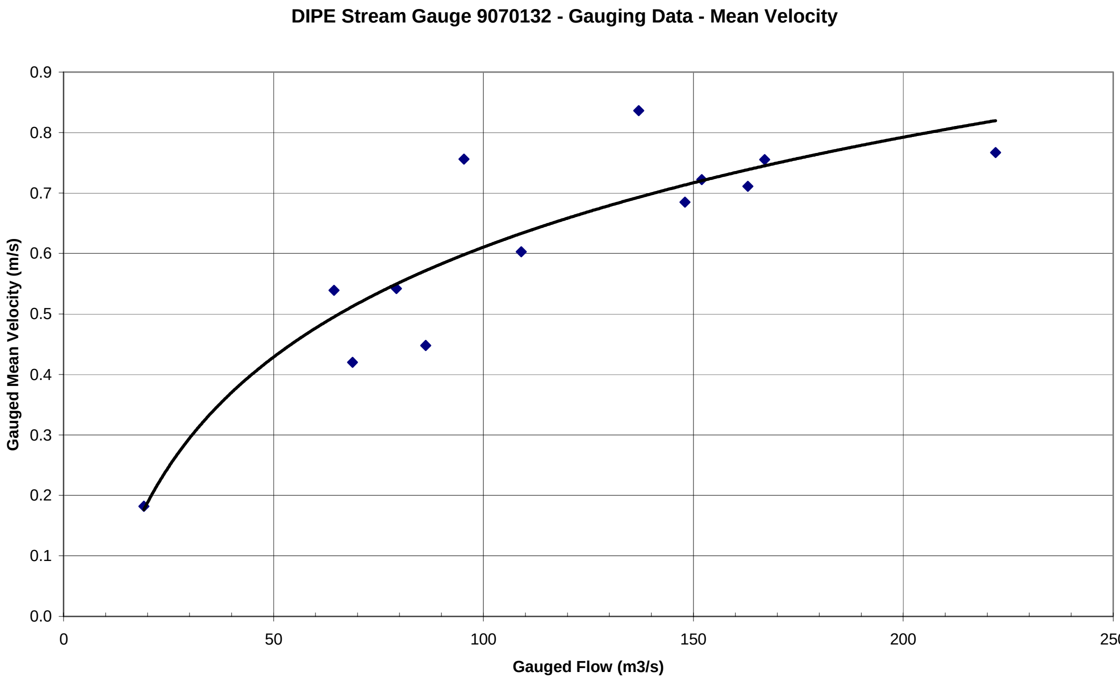

Figure K.4 Gauged Mean Flow Velocities at DIPE Stream Gauge

K1.6 Sediment Data for Sediment Transport Capacity Assessment

The HEC-RAS hydraulic model was utilised to undertake sediment transport capacity calculations to provide an indicator of sedimentation potential under existing river conditions and with the proposed channel realignment. The sediment transport capacity analyses were undertaken using Ackers-White equation and required parameters to define the particle size distribution of typical sediment that could be transported by McArthur River flow. The sediment particle size distribution was selected from a range of sediment particle size distribution tests of the typical McArthur River floodplain and channel soils sampled as part of the geotechnical investigations for the project feasibility (Golders, 2004). The sediment particle size distributions and adopted data (TPA09) for the sediment transport analyses is presented on Figure K.5.

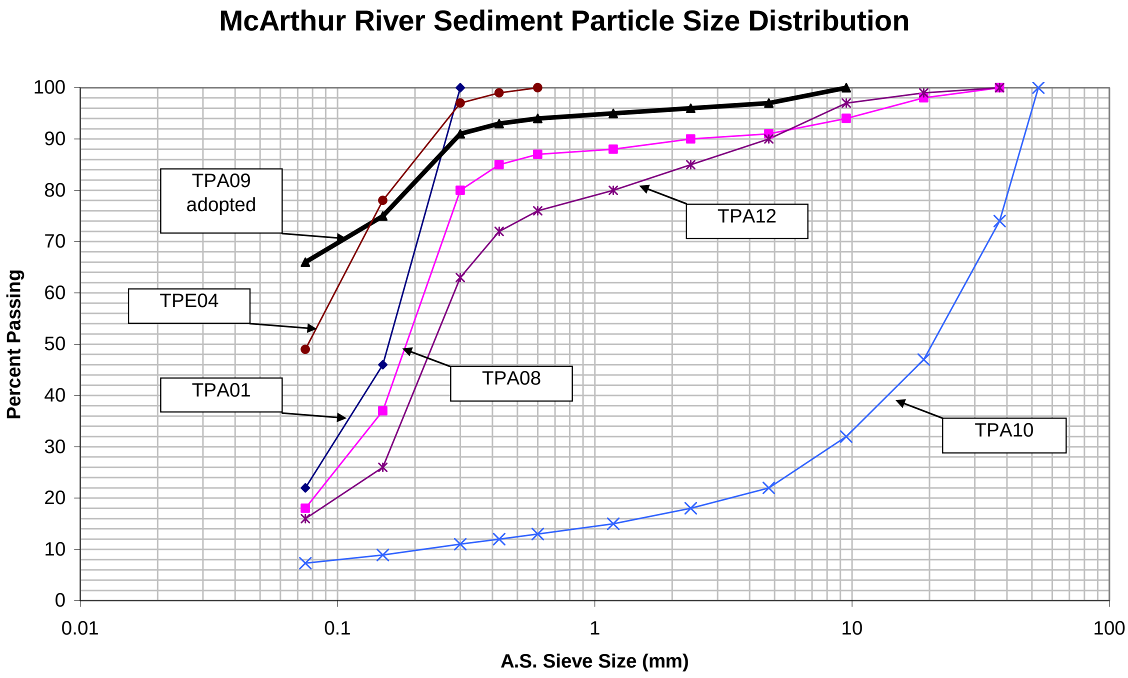

Figure K.5 Sediment Particle Size For McArthur River Channel / Floodplain Soils

K1.7 Hydraulic Model Results – Existing and Proposed

The hydraulic modelling results comparing existing river conditions and hydraulics with the proposed channel realignment and flood protection bund are presented as series of longitudinal profile plots in Figures K.6 to K.36 below. The plots are separated into specific hydraulic parameters and grouped according to flow cases as follows:

- 2 year ARI flood flow – Figures K.6 to K.10
- 5 year ARI flood flow – Figures K.11 to K.15
- 50 year ARI flood flow – Figures K.16 to K.20
- 100 year ARI flood flow – Figures K.21 to K.25
- 500 year ARI flood flow – Figures K.26 to K.30
- 20 m^3/s (fish passage flow) – Figures K.31 to K.32
- 50 m^3/s (fish passage flow) – Figures K.33 to K.34
- 100 m^3/s (fish passage flow) – Figures K.35 to K.36

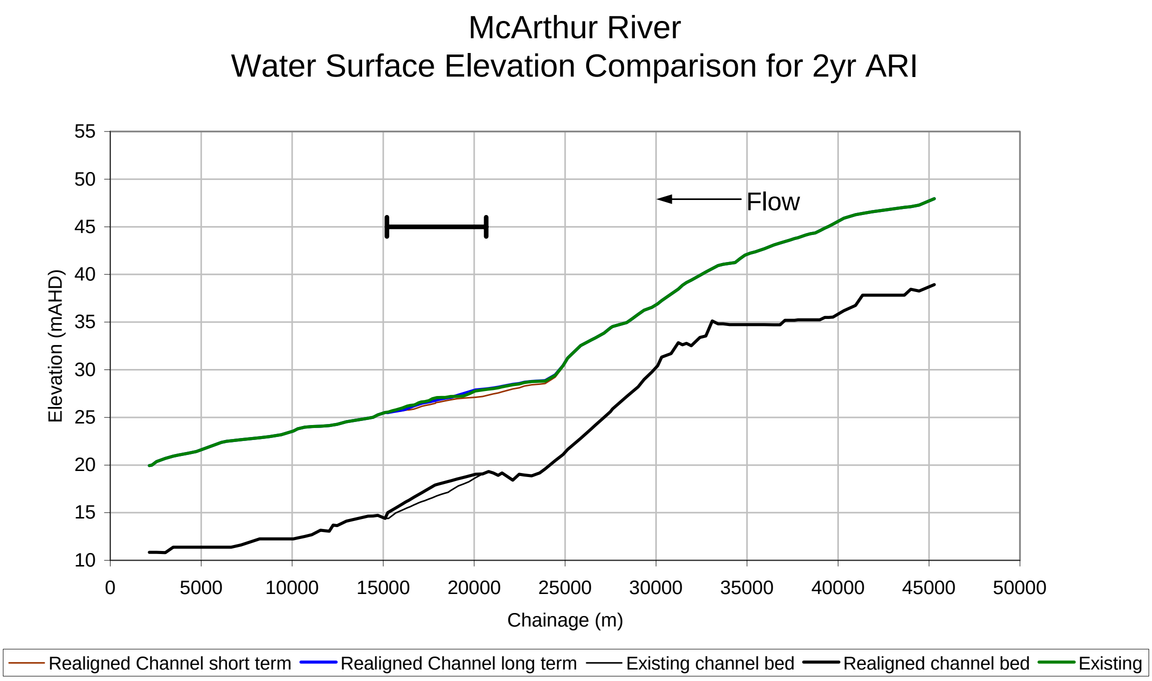

Figure K.6 Water Level– 2 year ARI flood event

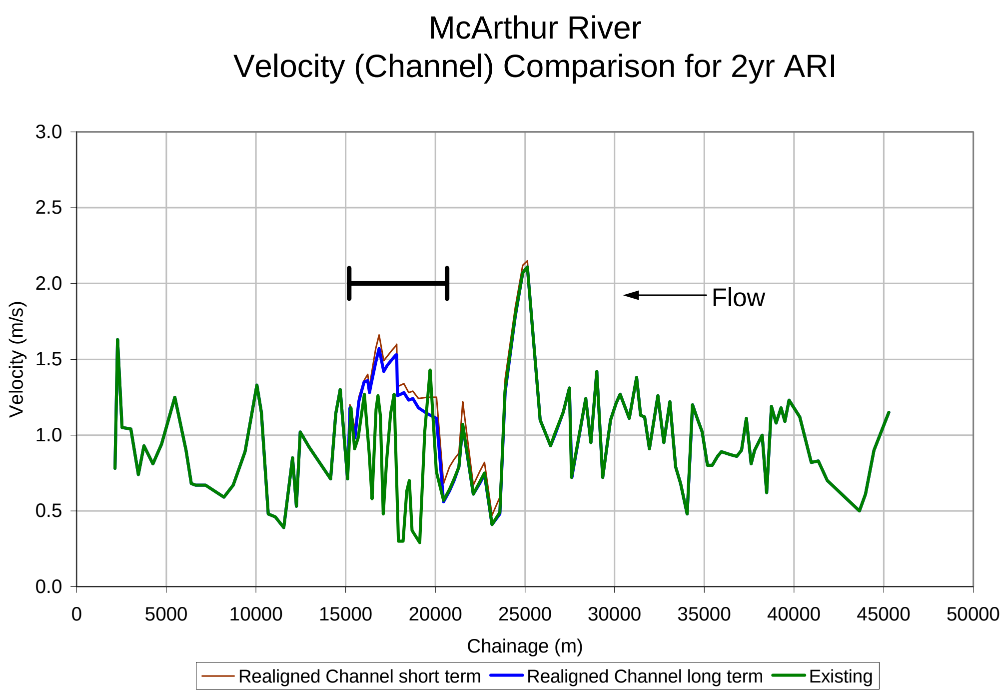

Figure K.7 Velocity – 2 year ARI flood event

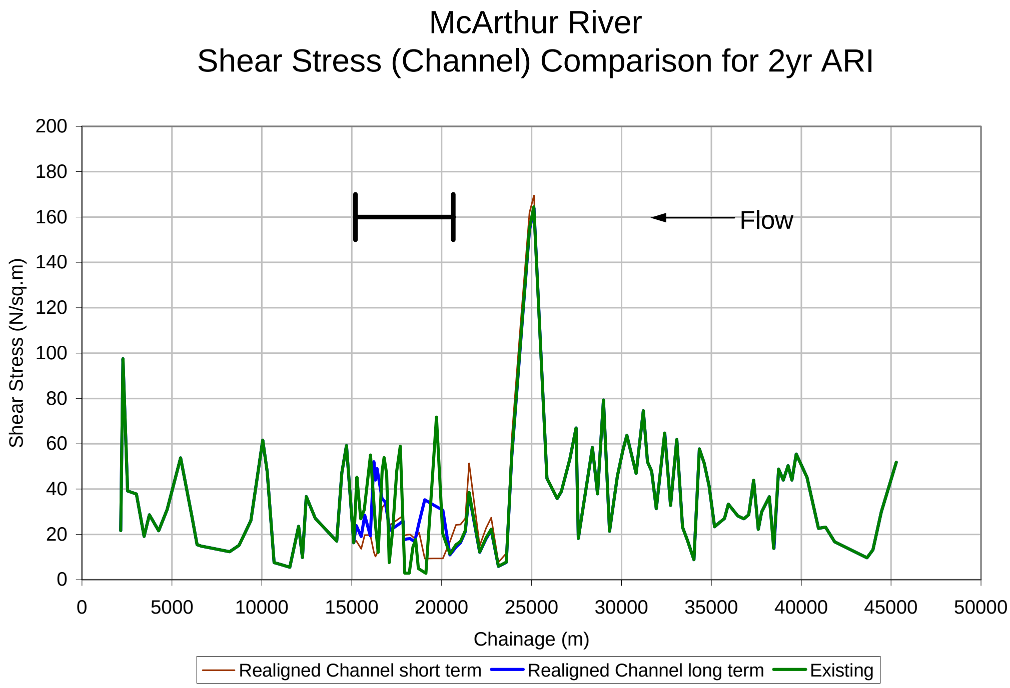

Figure K.8 Shear Stress – 2 year ARI flood event

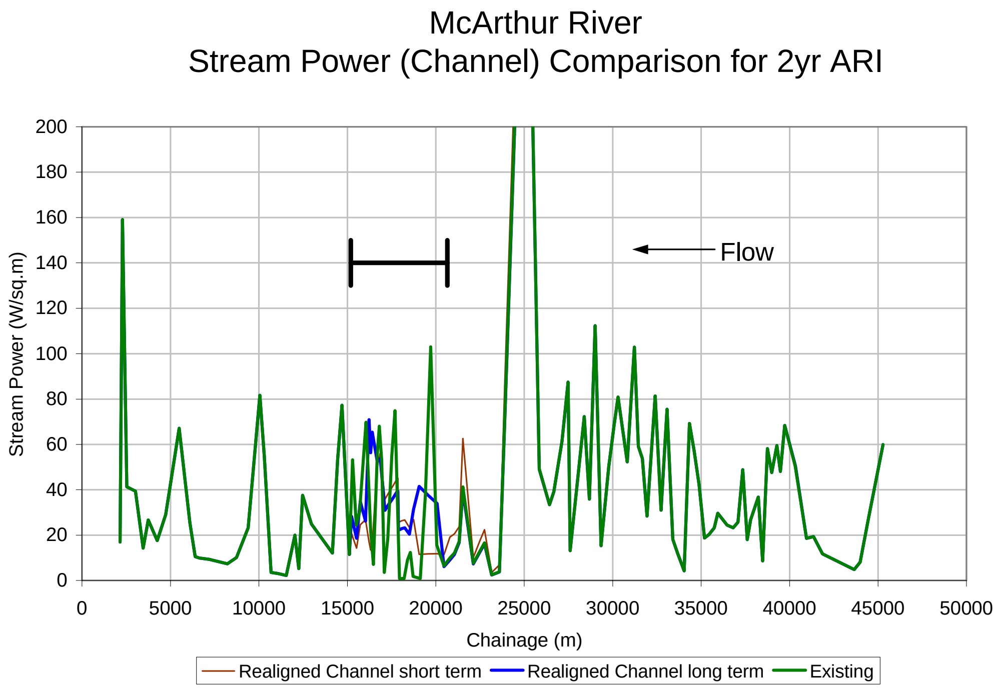

Figure K.9 Stream Power – 2 year ARI flood event

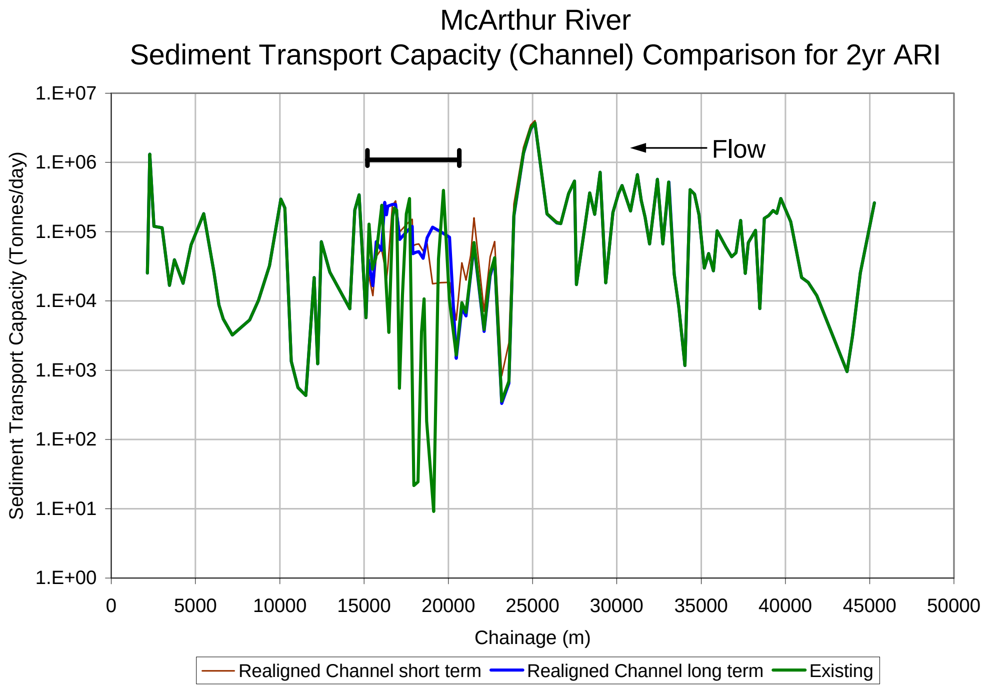

Figure K.10 Sediment Transport Capacity – 2 year ARI flood event

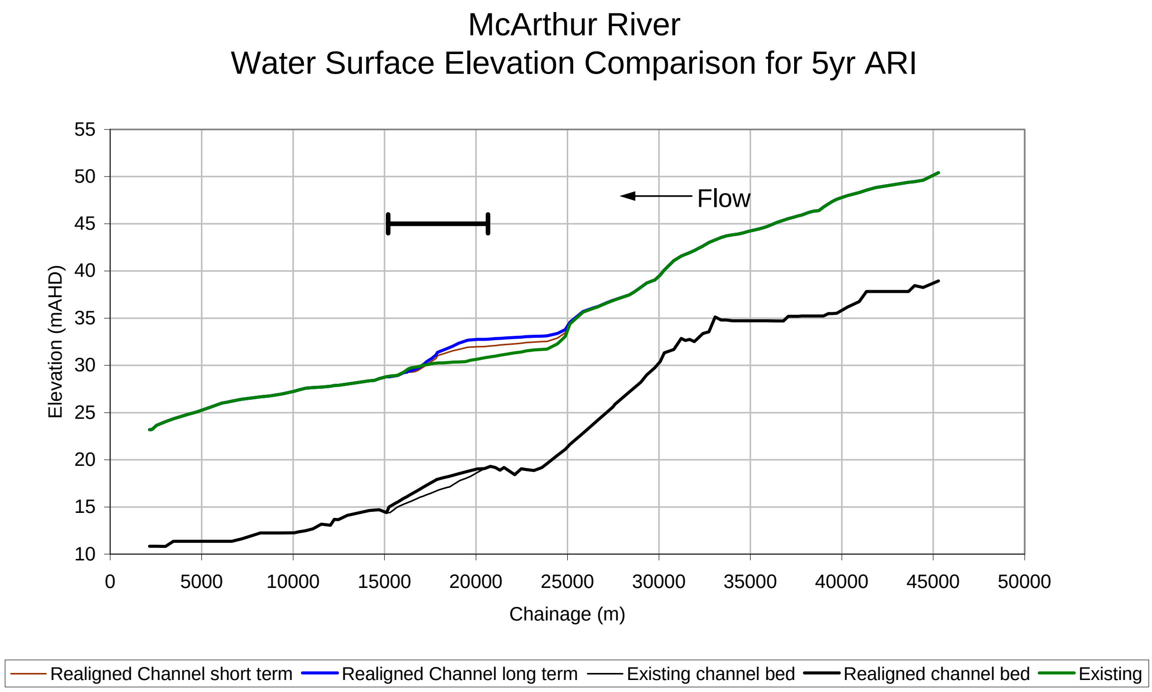

Figure K.11 Water Level – 5 year ARI flood event

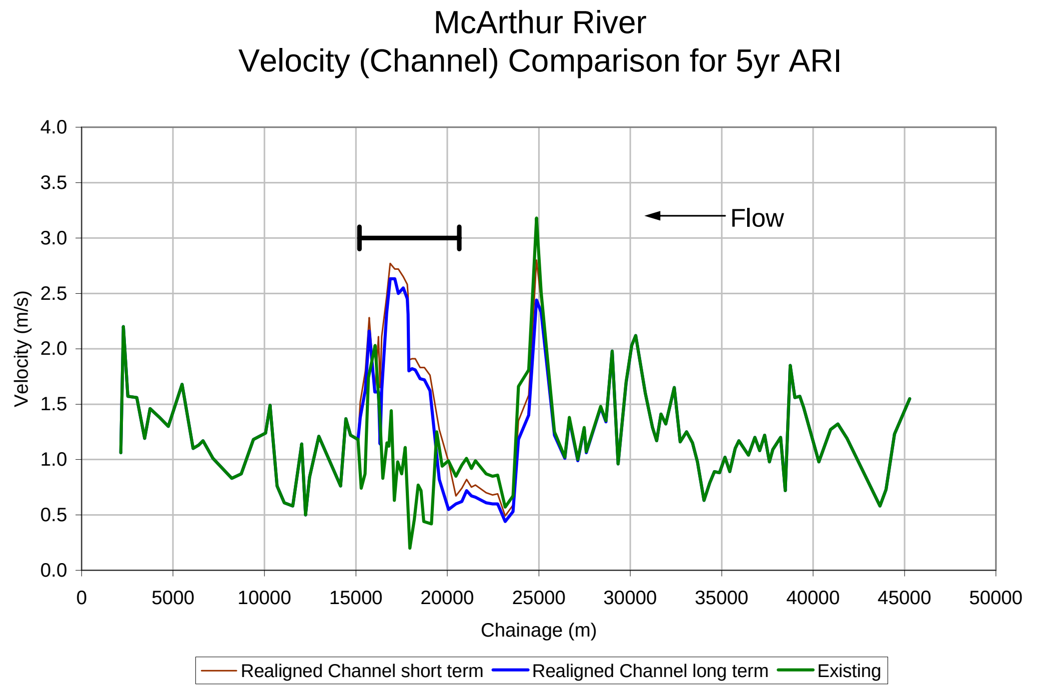

Figure K.12 Velocity – 5 year ARI flood event

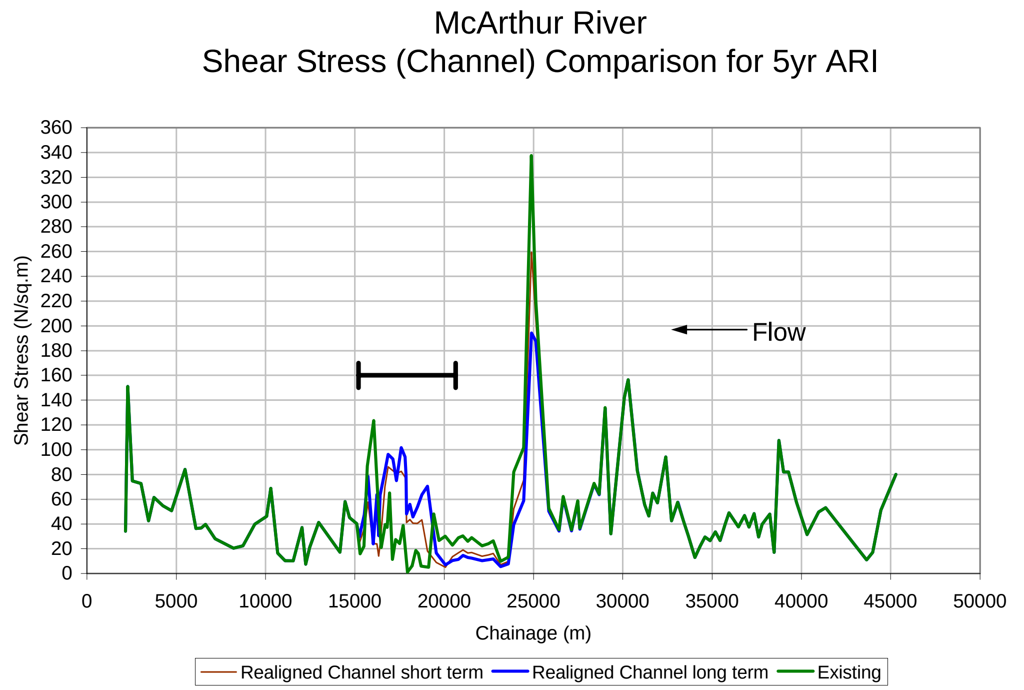

Figure K.13 Shear Stress – 5 year ARI flood event

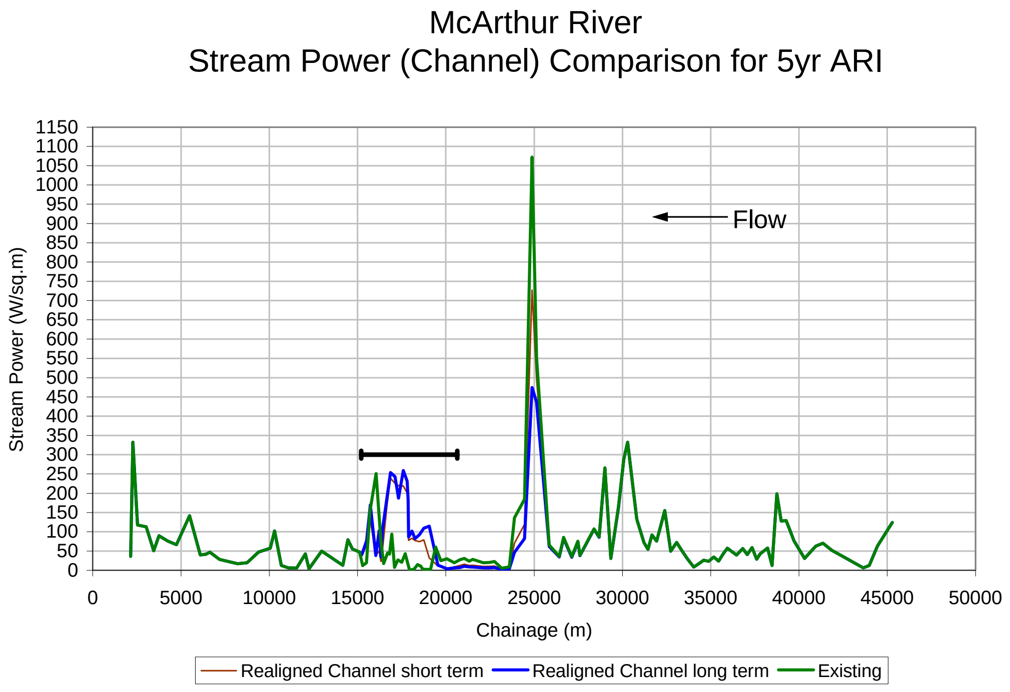

Figure K.14 Stream Power – 5 year ARI flood event

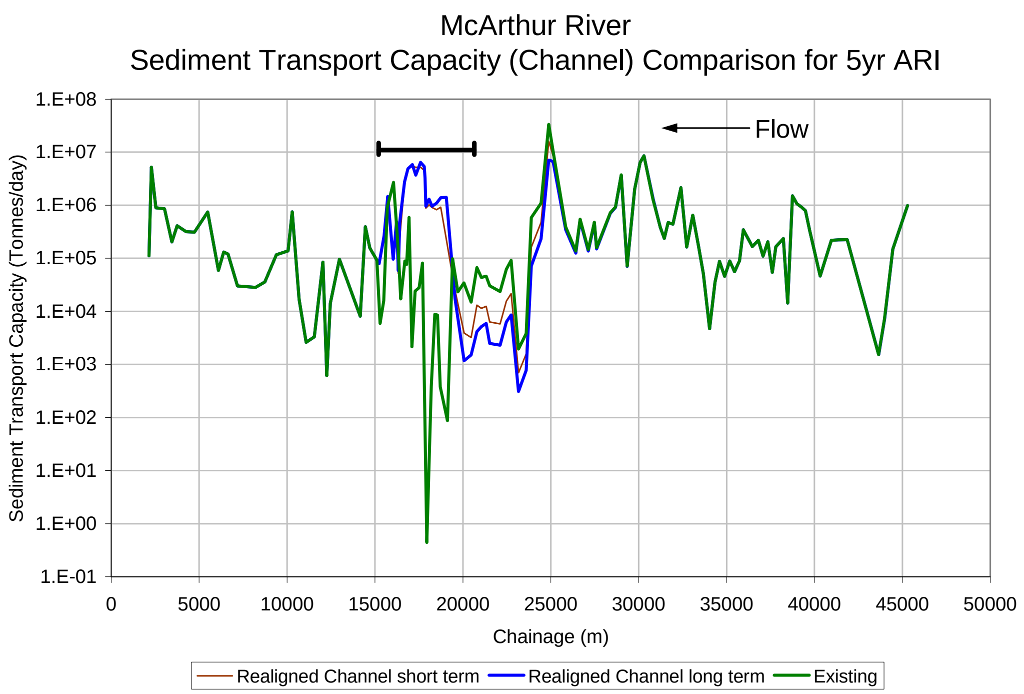

Figure K.15 Sediment Transport Capacity – 5 year ARI flood event

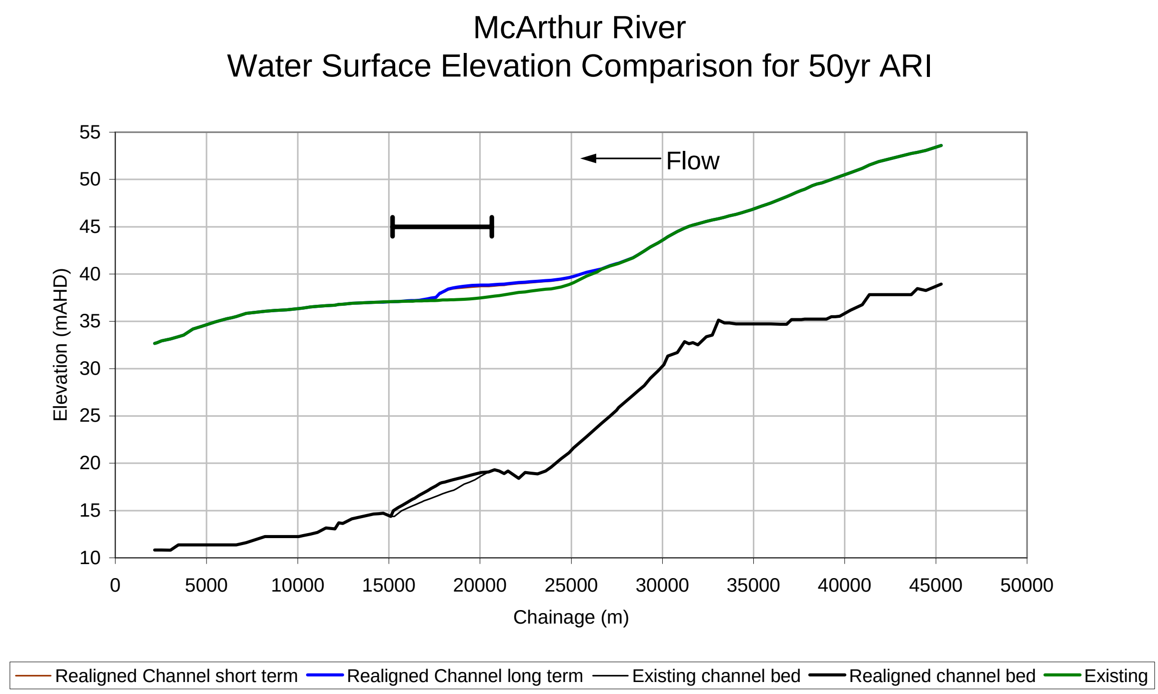

Figure K.16 Water Level – 50 year ARI flood event

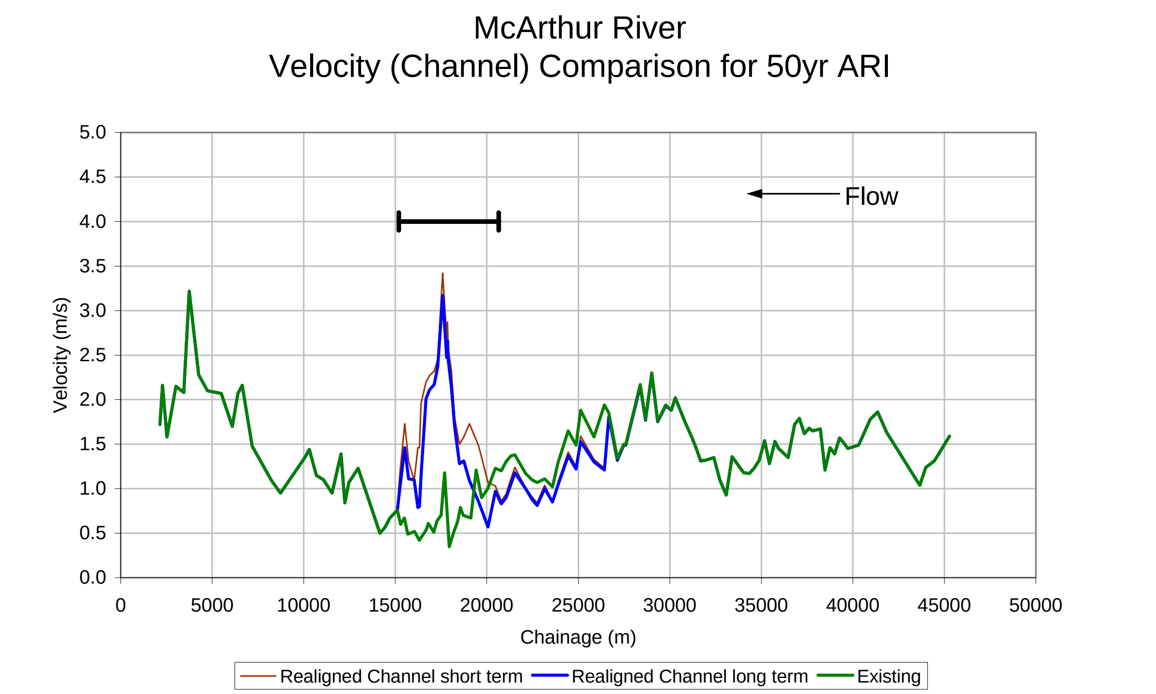

Figure K.17 Velocity – 50 year ARI flood event

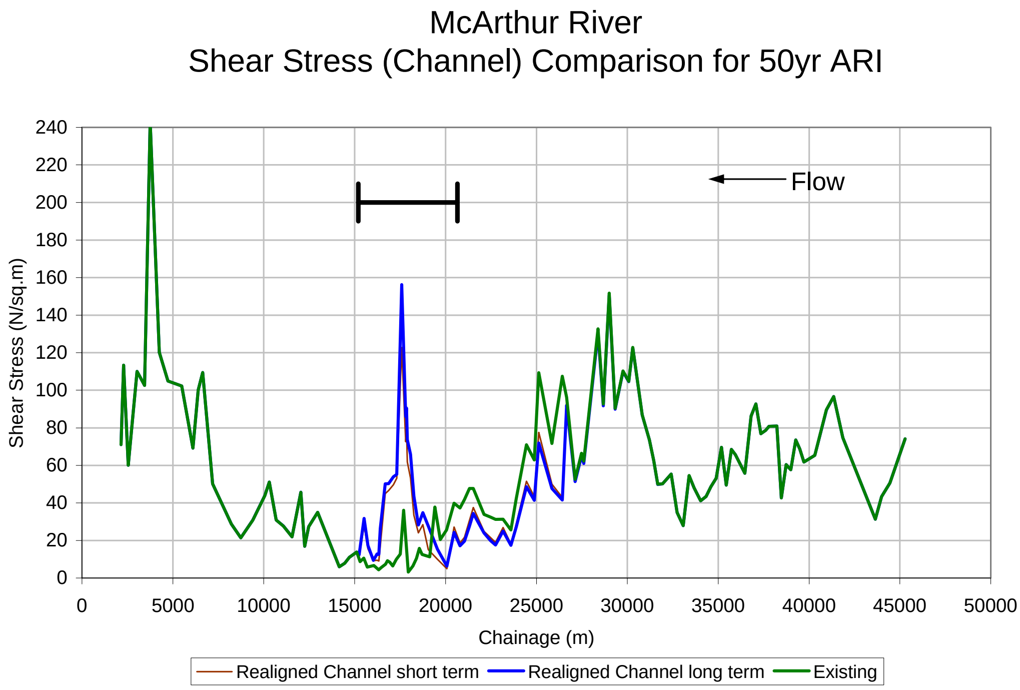

Figure K.18 Shear Stress – 50 year ARI flood event

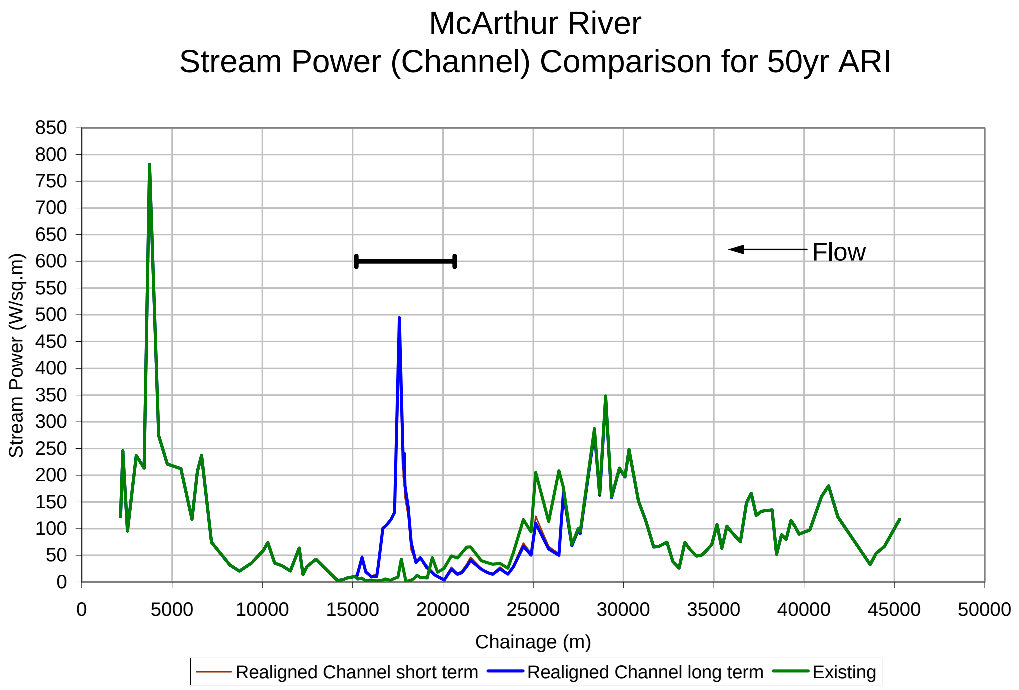

Figure K.19 Stream Power – 50 year ARI flood event

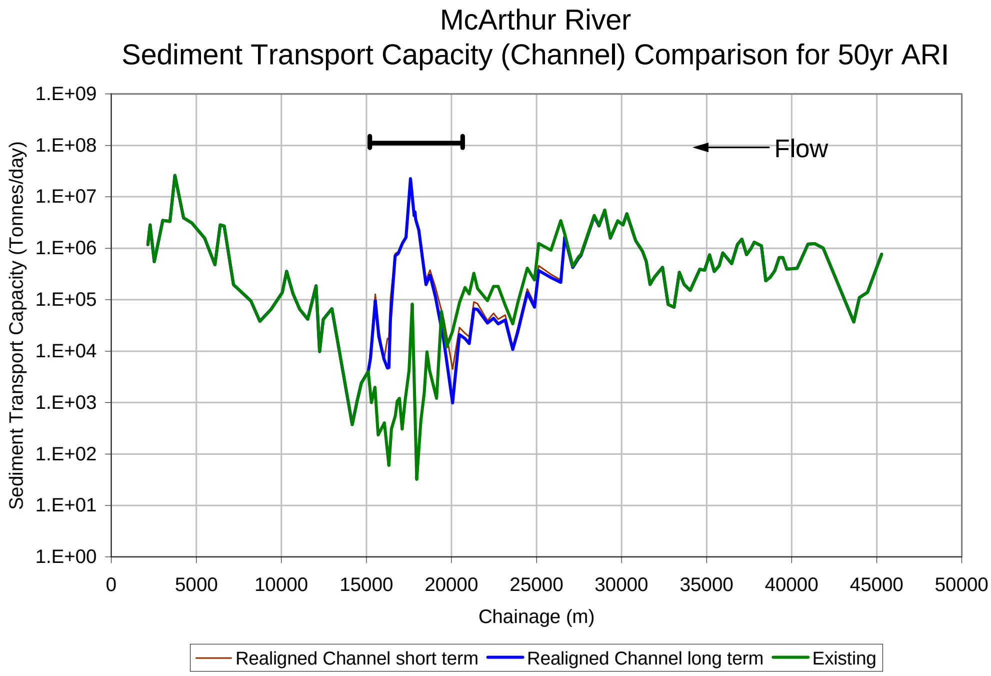

Figure K.20 Sediment Transport Capacity – 50 year ARI flood event

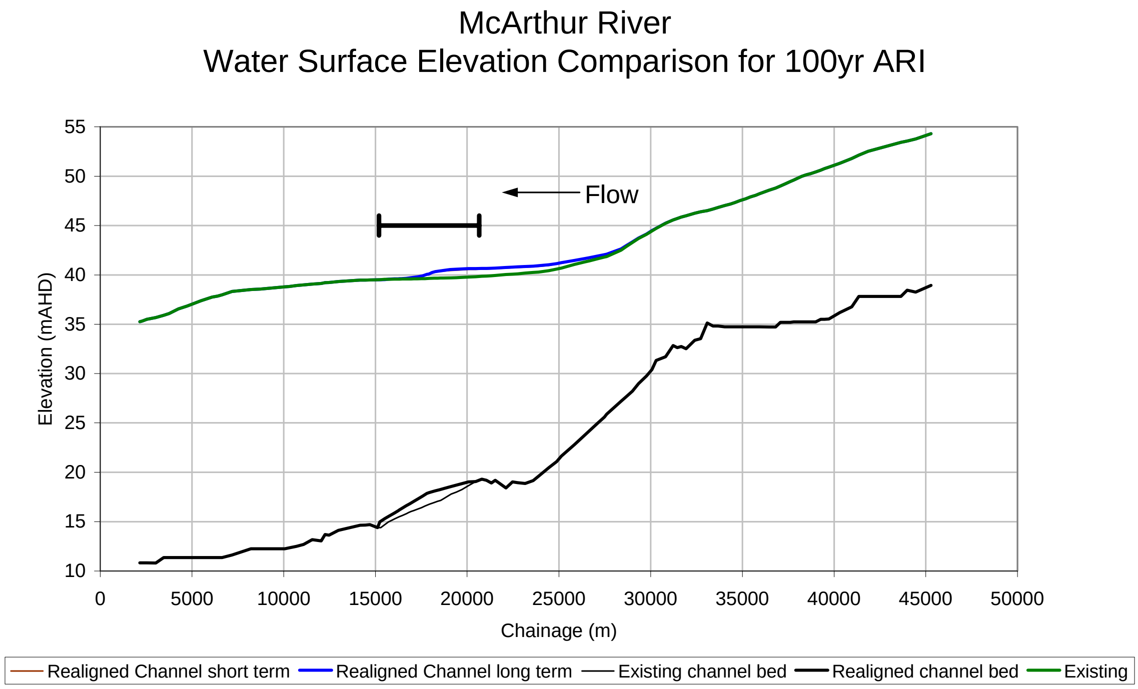

Figure K.21 Water Level – 100 year ARI flood event

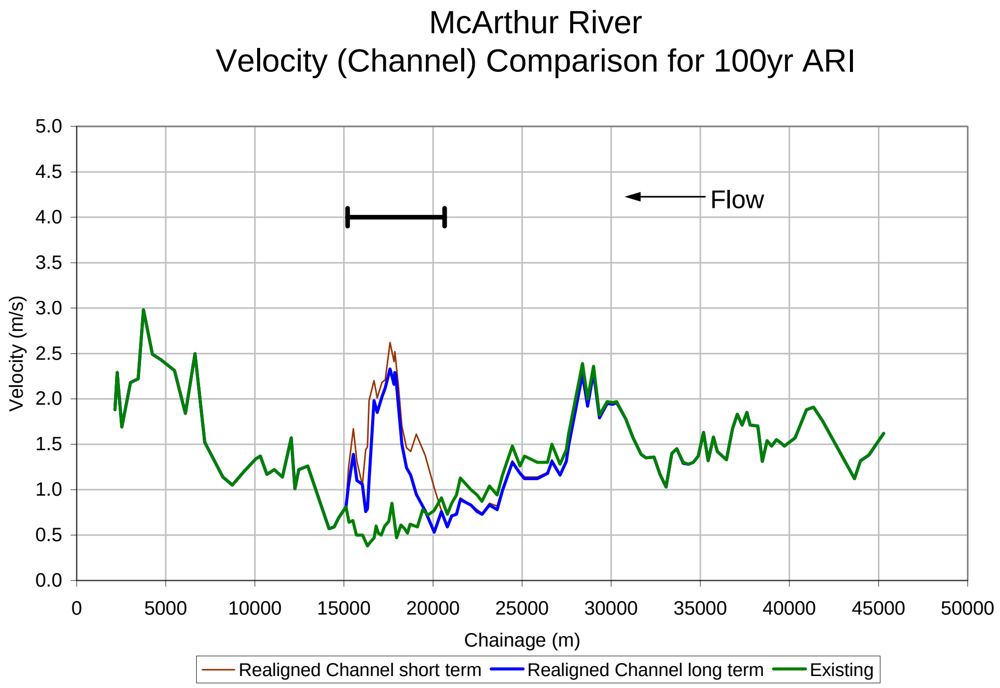

Figure K.22 Velocity – 100 year ARI flood event

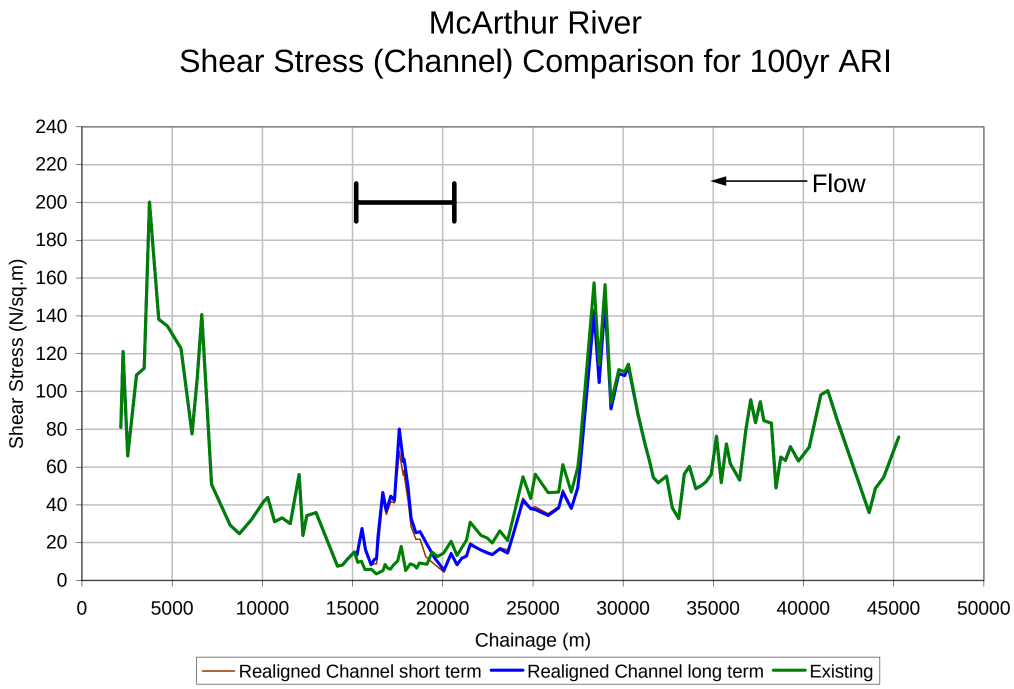

Figure K.23 Shear Stress – 100 year ARI flood event

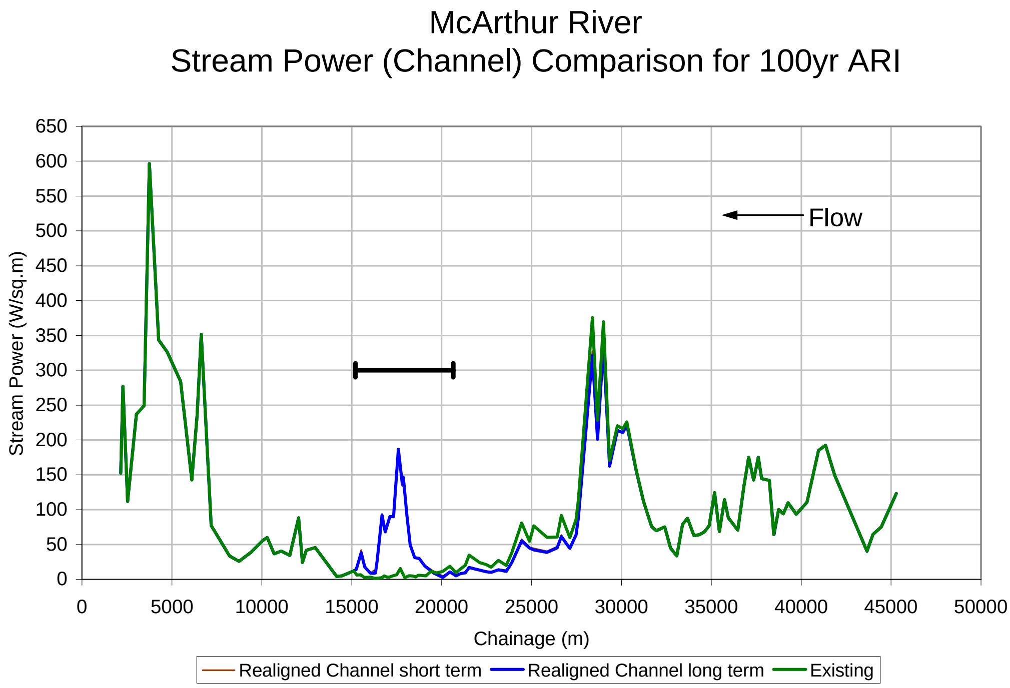

Figure K.24 Stream Power – 100 year ARI flood event

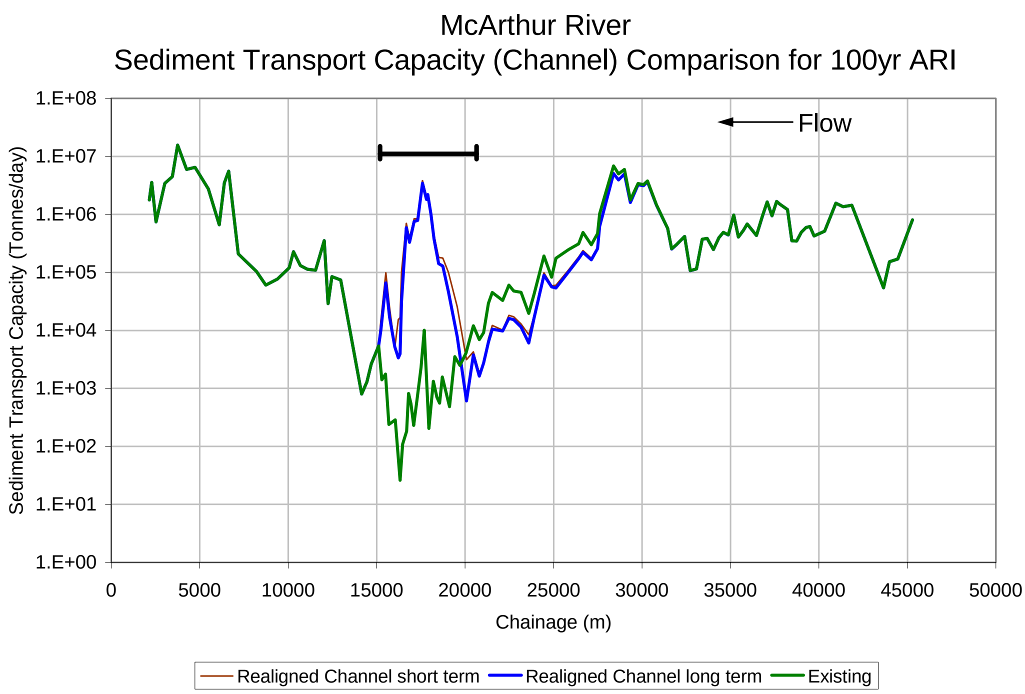

Figure K.25 Sediment Transport Capacity – 100 year ARI flood event

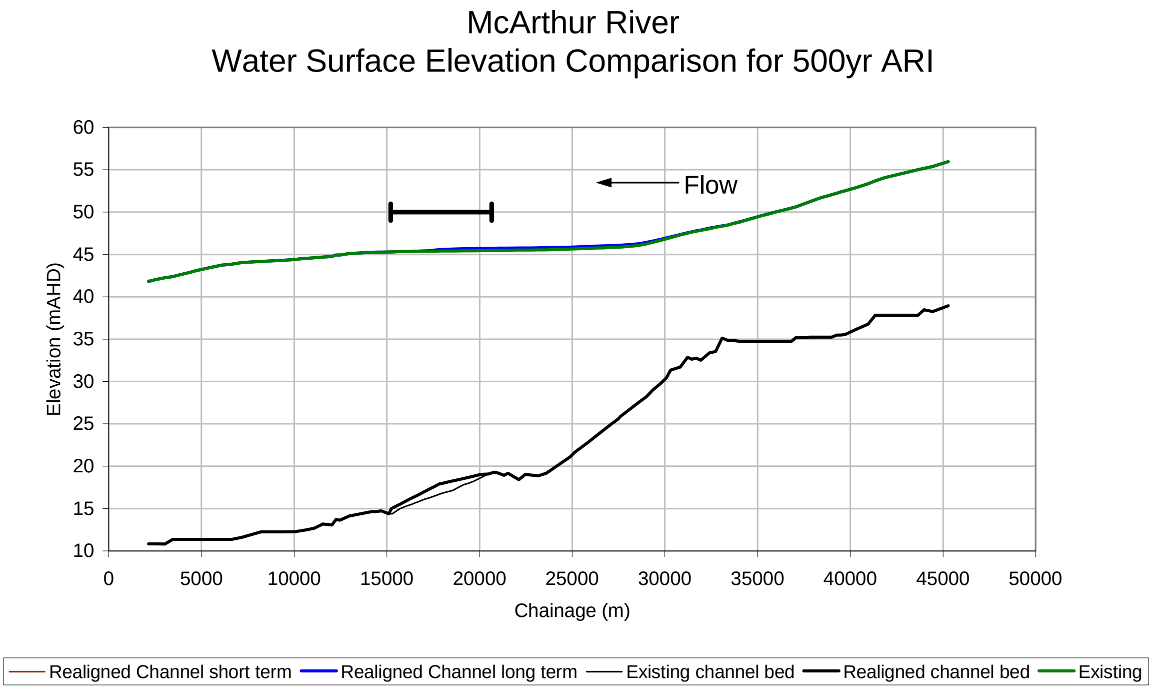

Figure K.26 Water Level – 500 year ARI flood event

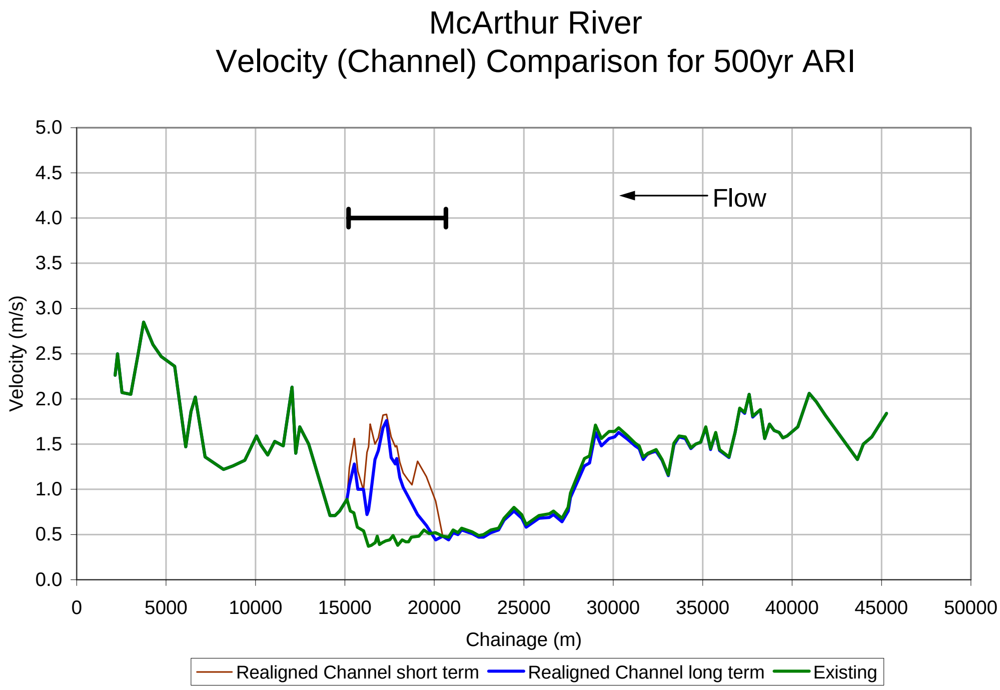

Figure K.27 Velocity – 500 year ARI flood event

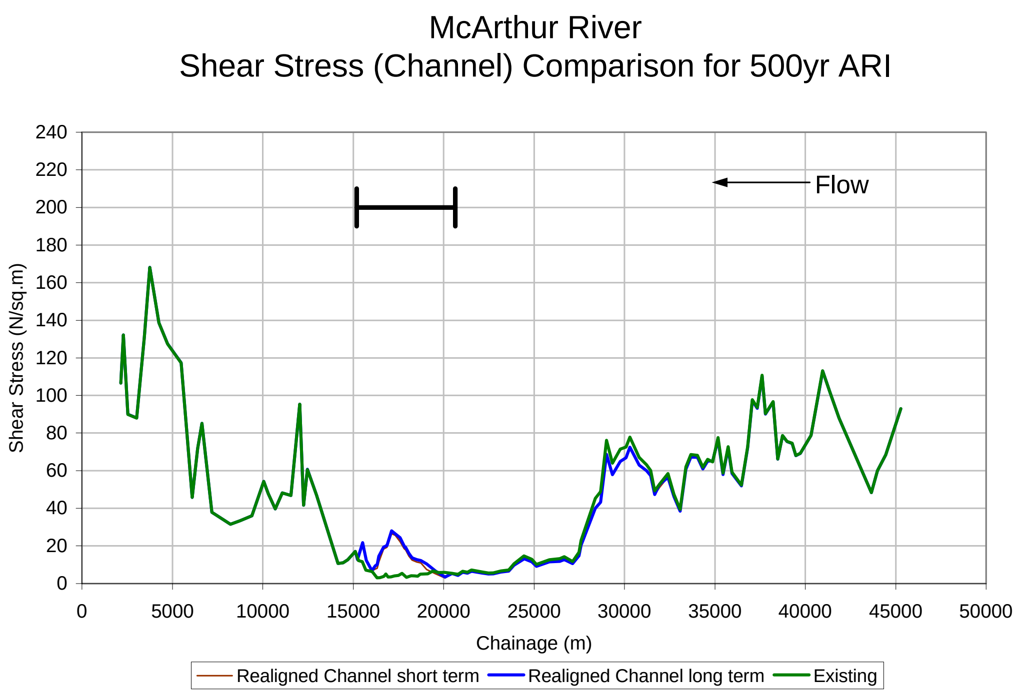

Figure K.28 Shear Stress – 500 year ARI flood event

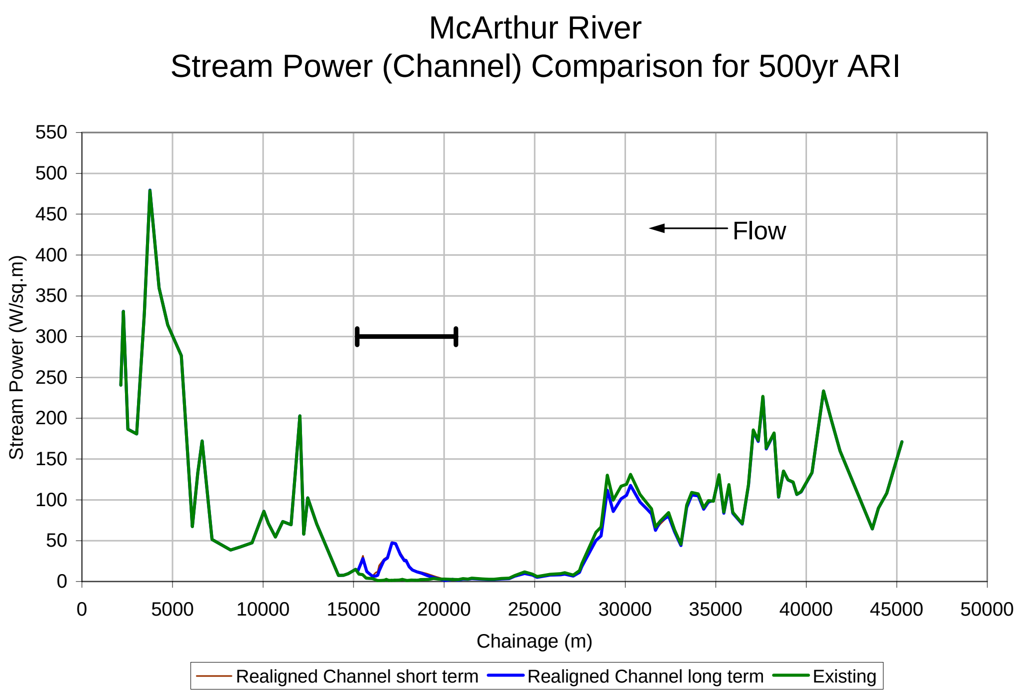

Figure K.29 Stream Power – 500 year ARI flood event

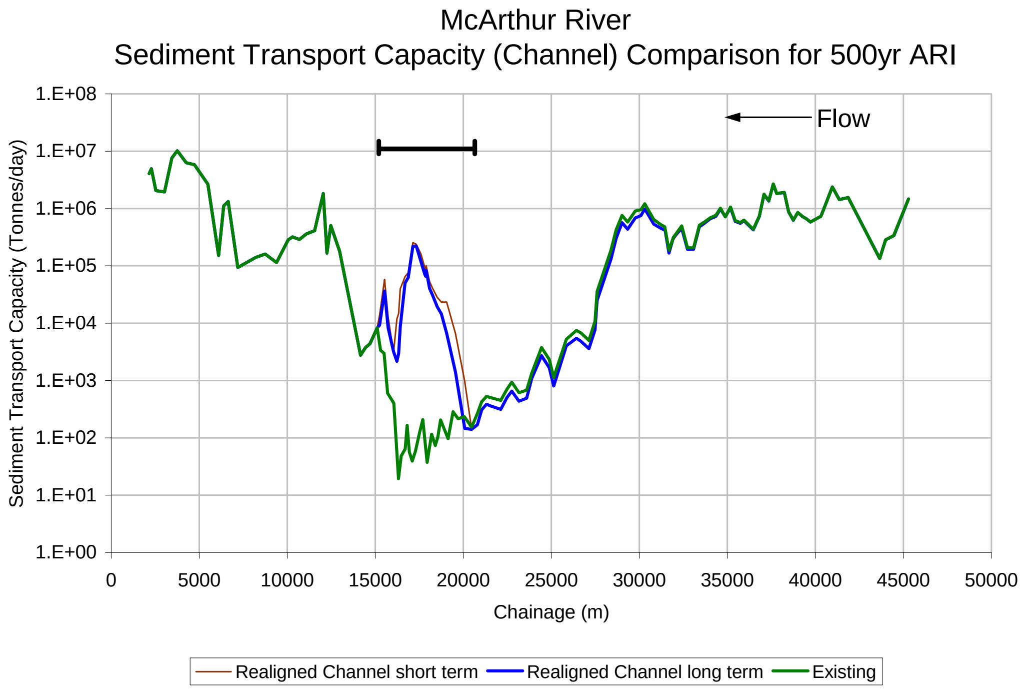

Figure K.30 Sediment Transport Capacity – 500 year ARI flood event

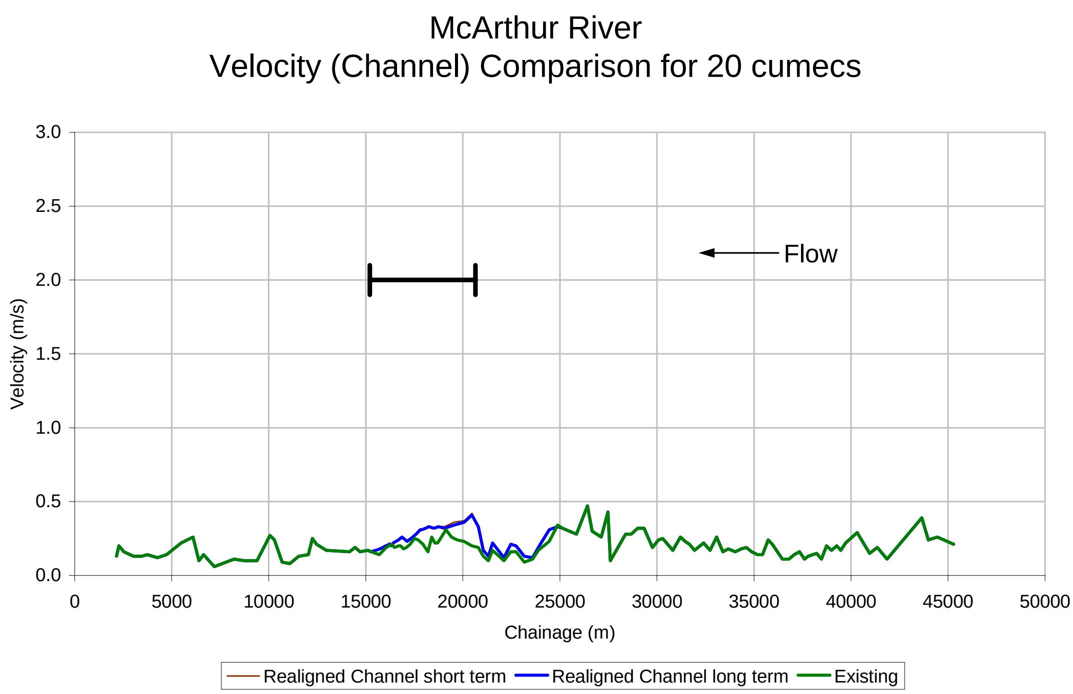

Figure K.31 Velocity – 20 m^3/s (Fish Flow)

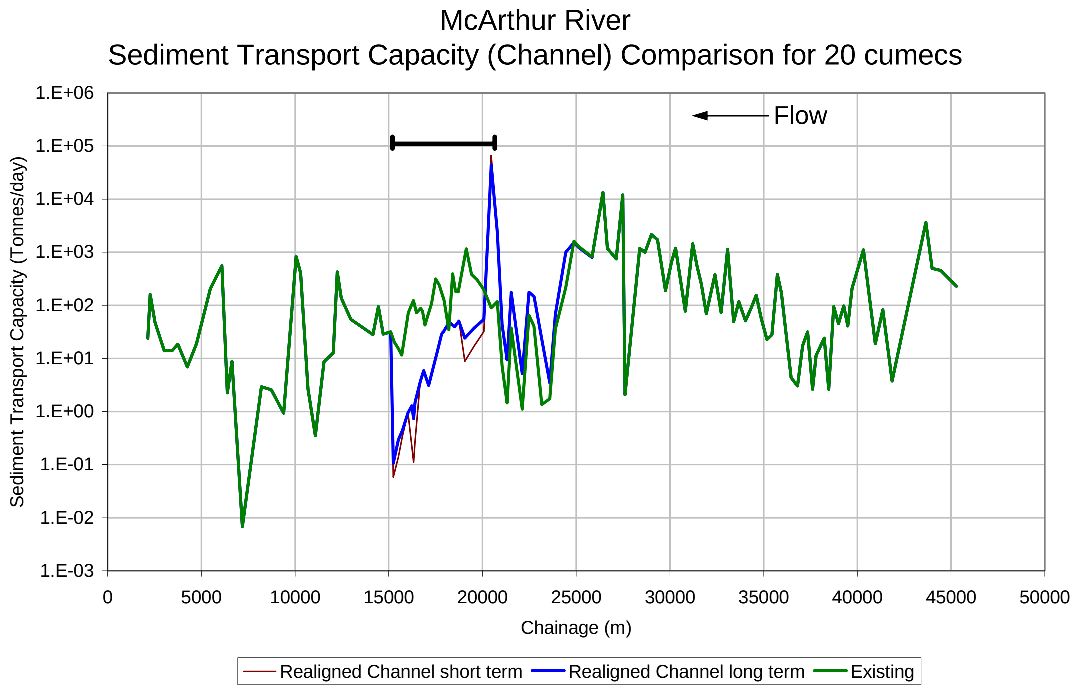

Figure K.32 Sediment Transport Capacity – 20 m^3/s (Fish Flow)

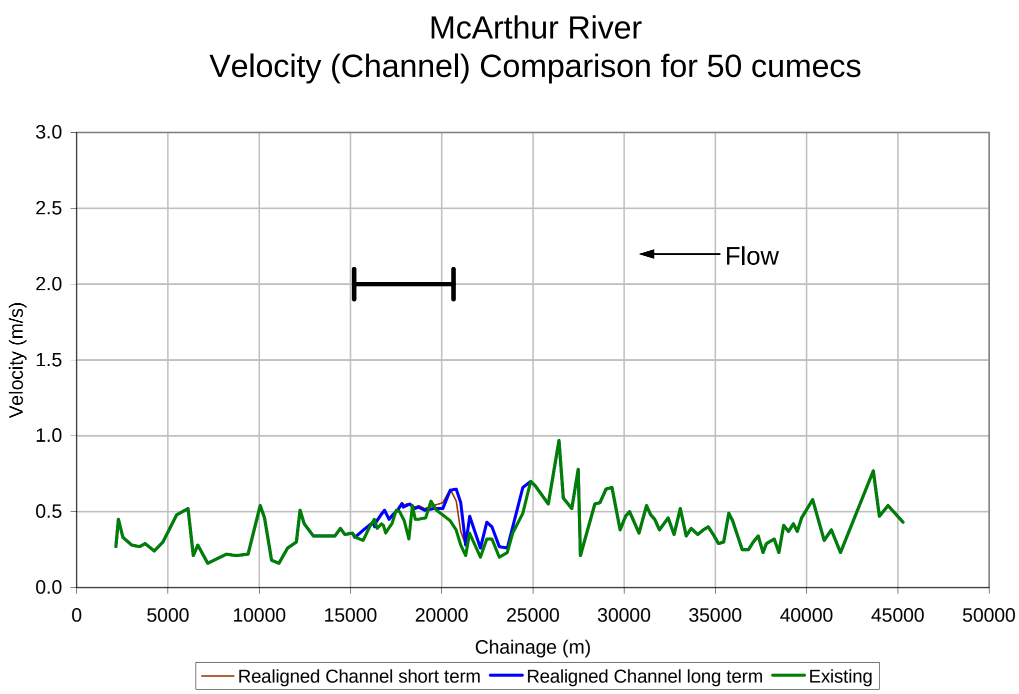

Figure K.33 Velocity – 50 m^3/s (Fish Flow)

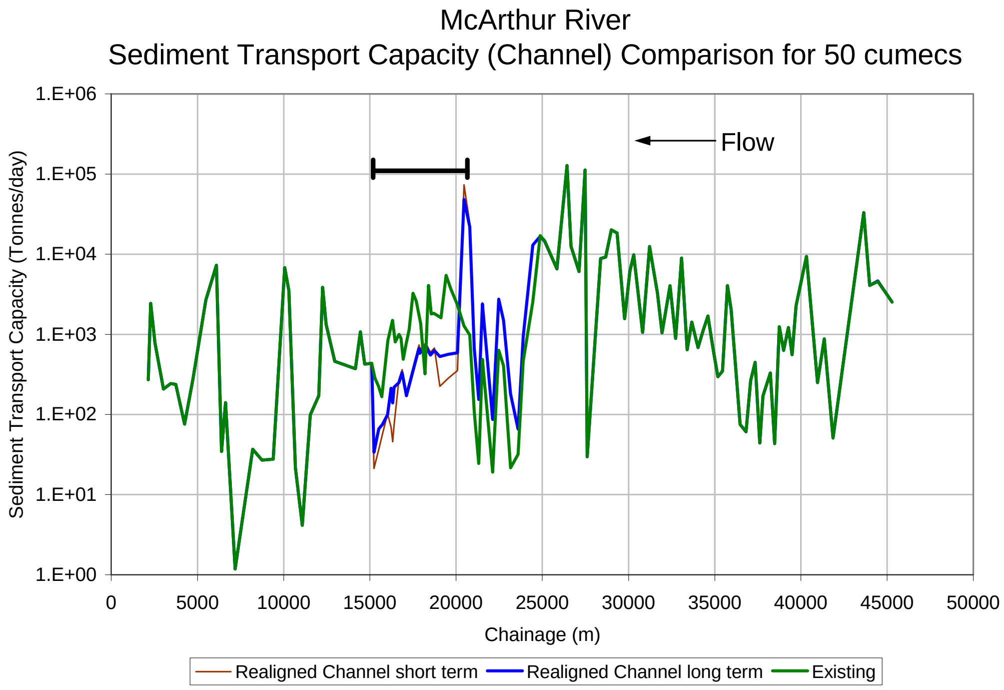

Figure K.34 Sediment Transport Capacity – 50 m^3/s (Fish Flow)

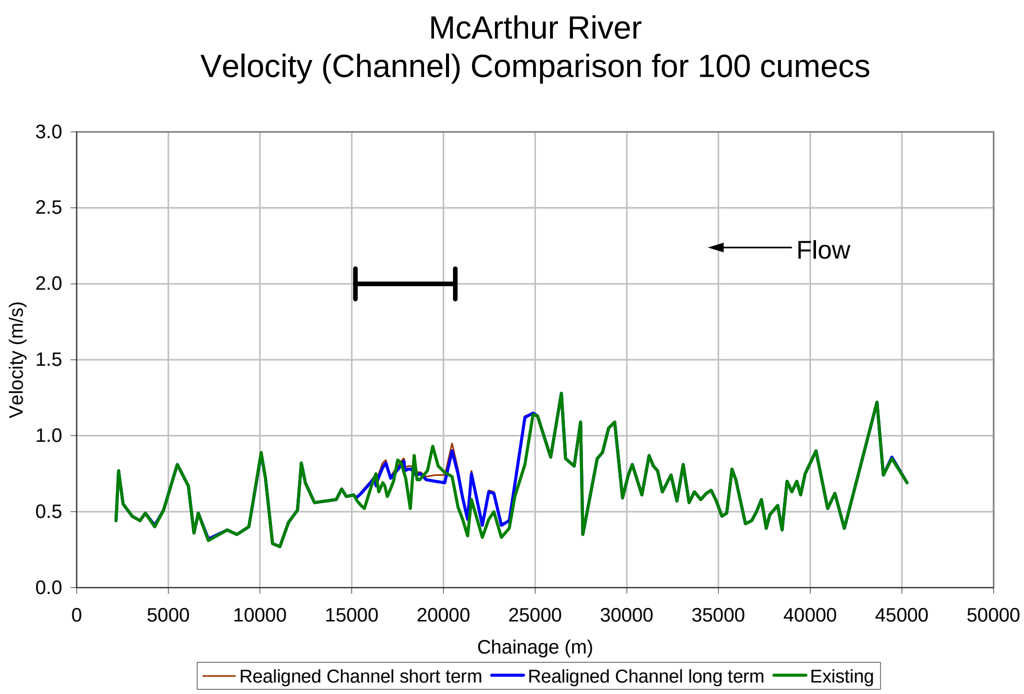

Figure K.35 Velocity – 100 m^3/s (Fish Flow)

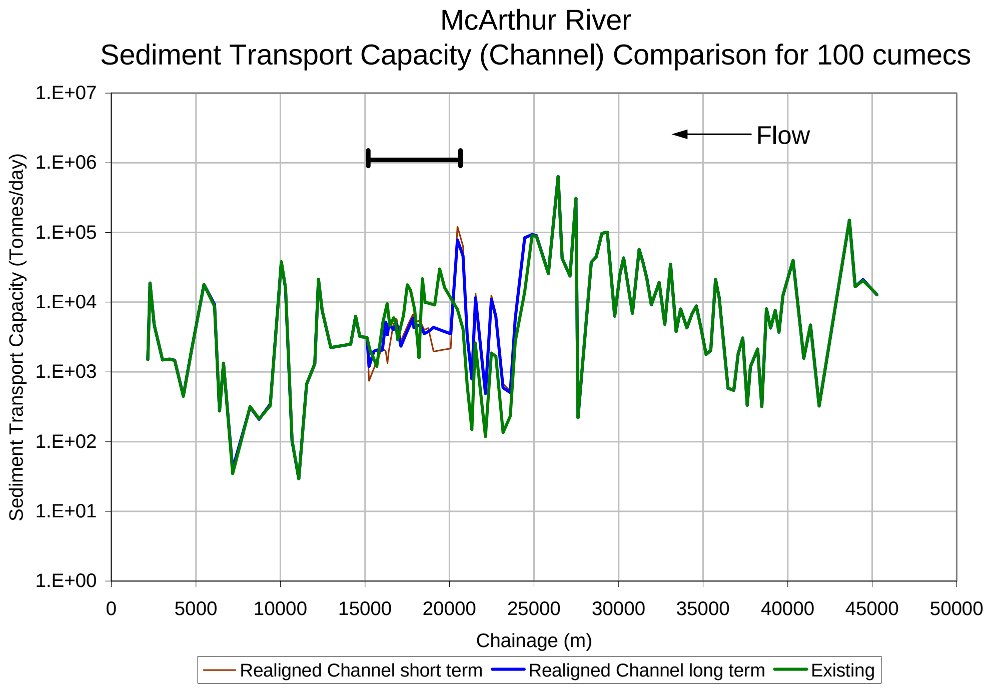

Figure K.36 Sediment Transport Capacity – 100 m^3/s (Fish Flow)

K1.8 Historical Cross-section Surveys of McArthur River Channel

Historical cross-section surveys of the McArthur River channel at the MIM Pump stream gauging station (9070132 upstream of the mine) were obtained from DIPE for a qualitative evaluation of recent historical changes to the river channel geometry and comparison to the qualitative geomorphologic assessment and quantitative hydraulic assessments. Overlay comparisons of the river channel cross-section are presented in Figure K.37 and confirm the EIS conclusions that the existing McArthur River channel near the mine is relatively stable.

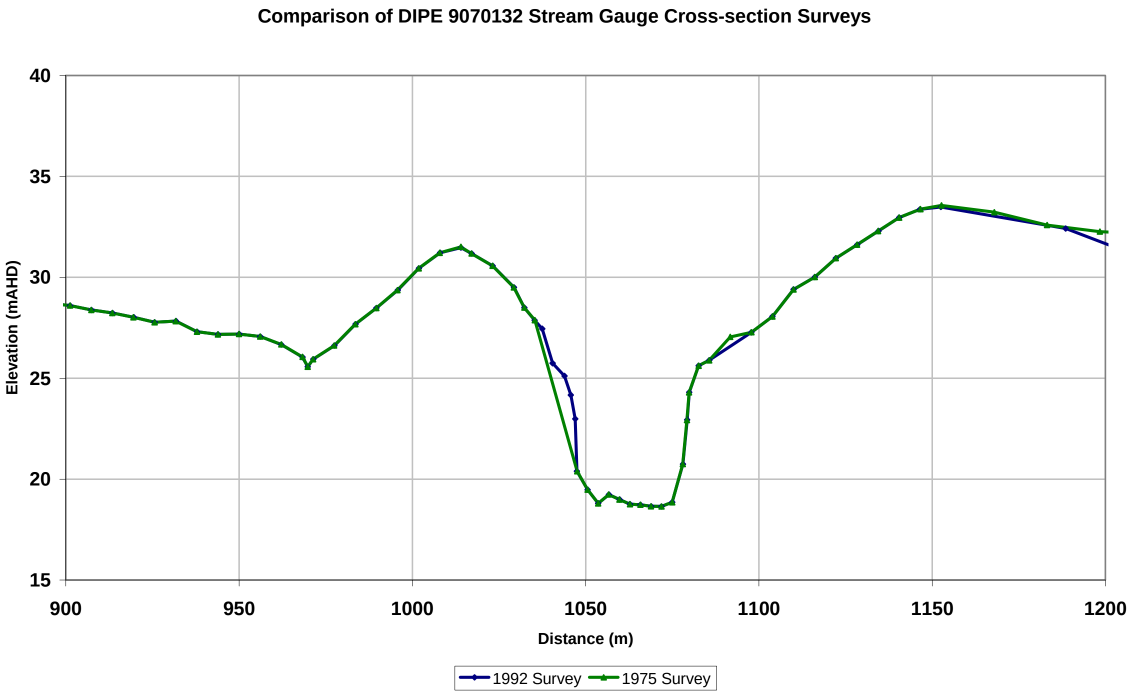

Figure K.37 Comparison of Historical McArthur River Channel Surveys