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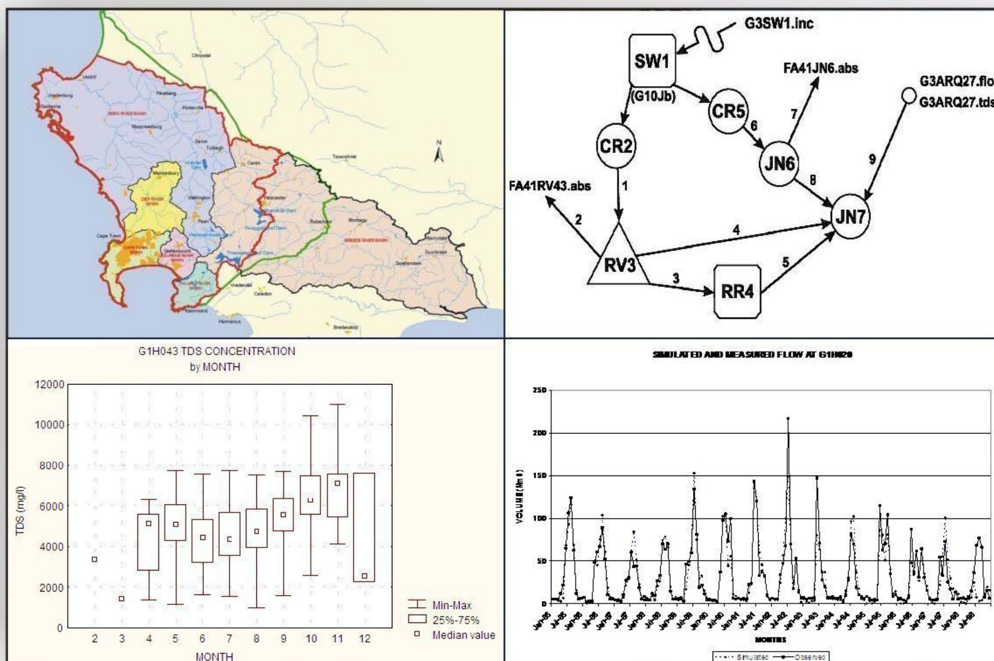
Department of Water Affairs and Forestry

Directorate: National Water Resource Planning

The Assessment of Water Availability in the Berg Catchment (WMA 19) by means of Water Resource Related Models

Report No.6 : Water Quality

Volume 3 : Update Monthly FLOSAL Model to WQT



FINAL **August 2008**

Submitted by:

Ninham Shand (Pty) Ltd

in Association with

Umvoto Africa (Pty) Ltd

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DEPARTMENT OF
WATER AFFAIRS AND FORESTRY

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THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

REPORT No. 6 : WATER QUALITY

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APPROVAL

DWAF REF NO.	:	P WMA19/000/00/0408
CONSULTANTS	:	Ninham Shand in association with Umvoto Africa
AUTHORS	:	W Kamish and J N Rossouw
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STUDY TEAM : Approved for Ninham Shand

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REPORT No	REPORT TITLE	VOLUME No.	VOLUME TITLE
1	Final Summary Report		
2	Rainfall Data Preparation and MAP Surface		
3	The Assessment of Flow Gauging Stations		
4	Land Use and Water Requirements	Vol 1	Data in Support of Catchment Modelling
		Vol 2	Invasive Alien Plant Mapping
		Vol 3	Water Use and Water Requirements
5	Update of Catchment Hydrology	Vol 1	Berg River
		Vol 2	Upper Breede River
		Vol 3	Peripheral Rivers
6	Water Quality	Vol 1	A Literature Review of Water Quality Related Studies in the Berg WMA, 1994 - 2006
		Vol 2	Updating of the ACRU Salinity Model for the Berg River
		Vol 3	Update Monthly FLOSAL Model to WQT
7	(Report No Not Used)		
8	System Analysis Status Report		
9	Groundwater Model	Vol 1	Overview of Methodology and Results
		Vol 2	Data Availability and Evaluation
		Vol 3	Regional Conceptual Model
		Vol 4	Regional Water Balance Model
		Vol 5	Cape Flats Aquifer Model
		Vol 6	Langebaan Road and Elandsfontein Aquifer System Model
		Vol 7	TMG Aquifer, Piketberg Model
		Vol 8	TMG Aquifer, Witzenberg – Nuy Model
		Vol 9	Breede River Alluvium Aquifer Model
10	Berg and Mhlathuze Assessment Studies (Refer to Report No.1)		
11	Applicability of the Sami Groundwater Model to the Berg WAAS Area		

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

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Update Monthly FLOSAL Model to WQT

EXECUTIVE SUMMARY

INTRODUCTION

The water quality model (WQT) is a monthly time-step model describing salt generation, accumulation and transport in the catchment, using parameters with physical meaning to simulate catchment salt wash-off and the effects of irrigation and impoundments. The model developed to integrate with the Water Resources Planning Model (WRPM), is defined as a network of routes connecting a variety of node types or sub-model elements, each node or feature representing a specific feature in water quality modeling.

Calibration of the WQT model takes place by iteratively calibrating the model parameters until the simulated TDS loads and/or concentrations match the corresponding observations as closely as possible at calibration points (water quality and flow gauging sites) in the system. The parameters governing the salt wash-off and irrigation sub-models are calibrated in particular, these being the two most active elements in accumulating and releasing TDS in the catchment.

For this study the WQT model was configured from the origin of the Berg River to the gauging station G1R003 (Misverstand Dam).

RESULTS

The WQT model was configured from the origin of the Berg River to Misverstand Dam (G1R003) and was calibrated at nine gauging stations. A summary of results is presented in the following table.

Gauge		Flow (Mm^3/month)		Concentration (mg/l)		Load (ton/month)	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
G1H020	Mean	28.91	25.40	59.74	90.07	1612	1662
	Std. Dev.	35.13	30.80	14.68	30.80	1958	2056
G1H037	Mean	2.13	2.17	103.9	176.90	169	175
	Std. Dev.	2.32	2.92	58.6	121.8	219	234
G1H041	Mean	2.13	2.17	103.90	176.99	169	174
	Std. Dev.	2.32	2.92	58.60	121.77	219	234
G1H036	Mean	35.32	35.39	112.93	214.33	3719	4080
	Std. Dev.	46.37	45.26	38.56	146.23	5073	5276
G1H008	Mean	5.70	7.14	107.23	121.80	595	696
	Std. Dev.	8.26	10.40	34.98	28.34	900	808
G1H043	Mean	0.45	0.59	2003	3109	1222	1451
	Std. Dev.	1.26	0.92	2452	1324	3067	2394
G1H013	Mean	49.76	45.28	148.69	503.58	7919	8618
	Std. Dev.	67.61	61.80	59.04	579.11	11592	12902
G1H035	Mean	3.93	3.20	1566	3311	5630	5607
	Std. Dev.	10.40	5.32	1055	2810	15924	8493
G1R003	Mean	Not calculated	48.72	Not calculated	995	Not calculated	14072
	Std. Dev.		66.8		1732		20189

THE ASSESSMENT OF WATER AVAILABILITY IN THE BERG CATCHMENT (WMA 19) BY MEANS OF WATER RESOURCE RELATED MODELS

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ABBREVIATIONS

Text	Definition
DWAF	Department of Water Affairs and Forestry
HIS	Hydrological Information System
TDS	Total dissolved solids
WQT	Water Quality TDS model
WRPM	Water Resources Planning Model
WRSM	Water Resources Simulation Model

MODEL PARAMETER CODES

RRHSL	Lower soil moisture storage capacity
RRHSU	Upper soil moisture zone storage capacity
SWGMB	Nominal minimum groundwater flow
SWSSRP	Pervious zone salt recharge rate

CHAPTER 1: WQT MODEL CONFIGURATION

1.1 INTRODUCTION

1.1.1 Background

The water quality model (WQT) is a monthly time-step model describing salt generation, accumulation and transport in the catchment, using parameters with physical meaning to simulate catchment salt wash-off and the effects of irrigation and impoundments. The model developed to integrate with the Water Resources Planning Model (WRPM), is defined as a network of routes connecting a variety of node types or sub-model elements, each node or feature representing a specific feature in water quality modeling. The six basic elements or sub-models defined in the WQT calibration model are given in **Table 1.1**.

Table 1.1 WQT Sub-models

Sub-model	Code	Simulates
Catchment Salt Wash-off	SW	Accumulation and release of solids on catchment
Channel Reach	CR	Movement of water and salt along river reach
Irrigation Block	RR	Accumulation and release of solids on irrigation land
Demand Centre	DC	Water supply with enriched return flow
Junction	JN	Combining/mixing/distributing of routes
Reservoir	RV	Monthly water and salt balance of dams

Calibration of the WQT model takes place by iteratively calibrating the model parameters until the simulated TDS loads and/or concentrations match the corresponding observations as closely as possible at calibration points (water quality and flow gauging sites) in the system. The parameters governing the salt wash-off and irrigation sub-models are calibrated in particular, these being the two most active elements in accumulating and releasing TDS in the catchment.

For this study, the WQT model was configured from the origin of the Berg River to the gauging station G1R003 (Misverstand Dam). The Sout River tributary confluences with the Berg River downstream of Misverstand Dam, but no flow or water quality monitoring occurs here and therefore it was not included in this study.

Figure 1.1 shows the location of the flow gauging stations at which grab sample water quality data was available for calibration purposes.

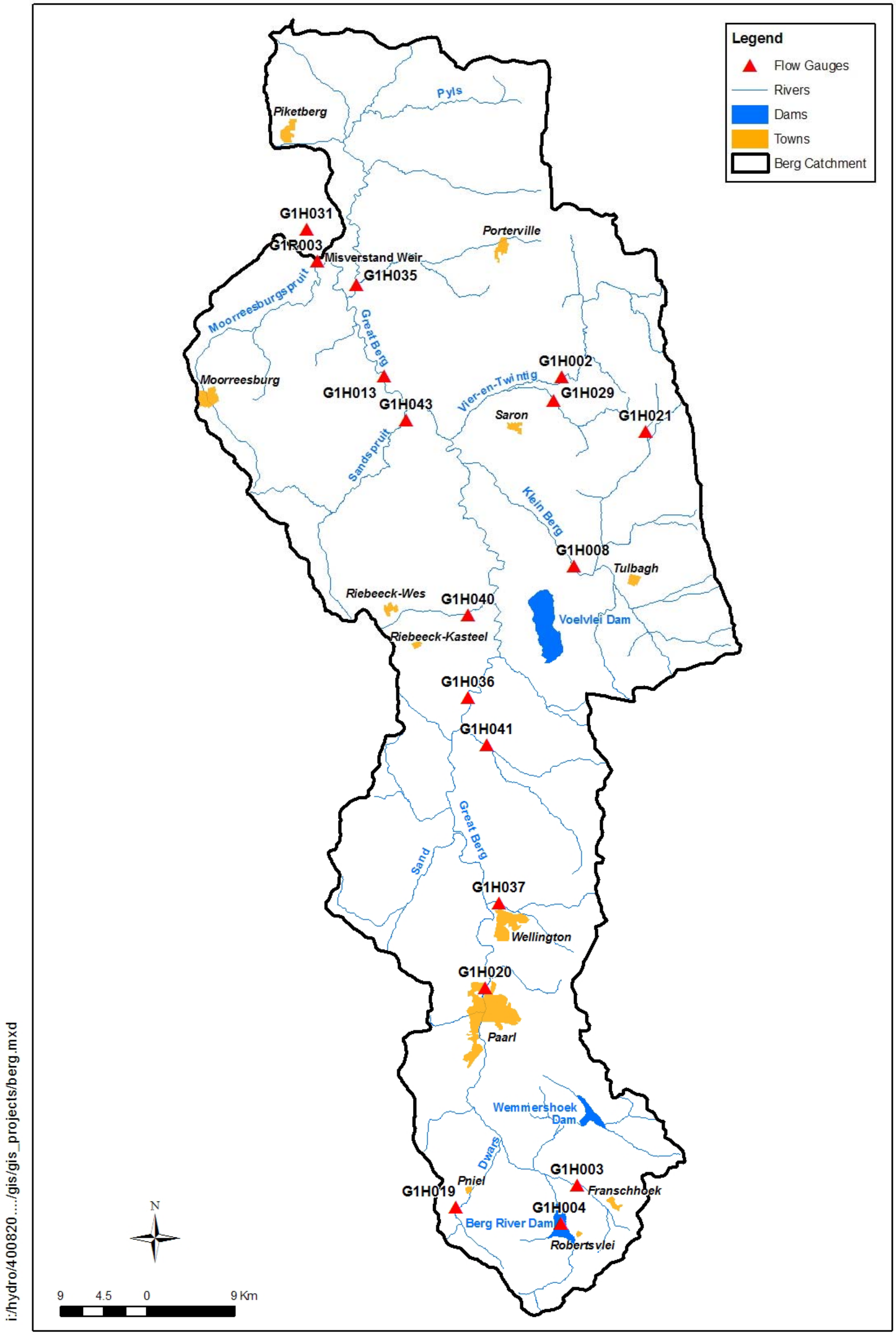


Figure 1.1 Layout of the Berg River catchment

CHAPTER 2: CALIBRATION PROCESS

The main source of recorded water quality data in the study area was the Hydrological Information System (HIS) database of the Department of Water Affairs and Forestry (DWAF).

In general, it was observed that flow measuring started earlier than water quality monitoring. At some stations flow measurements commenced as early as 1920 while water quality monitoring only commenced in the early 1970s. Water quality samples were at best collected on a weekly basis, but in some cases several months of gaps may exist in a water quality record. Monitoring of mainstream flow is usually done on a more regular basis than tributary inflow. Refer to **Figure 1.1** for the location of the available gauging stations in the catchment.

2.1 AVAILABLE GAUGING STATIONS

Table 2.1 summarises the relevant information regarding the gauging stations that were used to calibrate the G10 catchment for salinity. This information includes the river or tributary on which the gauge is located, the quaternary catchment(s) upstream of the gauge and the name of the WQT network in which the gauge is located.

Table 2.1 Information Regarding the Calibration Gauges

Gauge	Location	Quaternary catchments	WQT Network
G1H020	Berg River at Daljosafat	G10A, G10B, G10C	G1B
G1H037	Krom River	Within G10D	G2A-A
G1H041	Kompanjies River	Within G10D	G2A-A
G1H036	Berg River at Vleesbank	Within G10D	G2A-B
G1H008	Klein Berg River	G10E	G2B
G1H043	Sandspruit	Within G10J	G1H043
G1H028	Twenty Four Rivers	G10G	G3A
G1H013	Berg River at Drieheuwels	G10F	G3A
G1H035	Matjies River	Within G10J	G3B
G1R003	Misverstand Dam	G10G	G3B

The gauging stations at G1H043 and G1H028 were not calibrated for flow in the hydrological component of the study and consequently, quaternary catchments G10J (Krom River portion), G10G and G10F were collectively calibrated at gauging station G1H013. In terms of salinity, however, the salt load from the Sandspruit (G10J) is substantial, while that of the Twenty Four Rivers is low due to the excellent quality. In either case, the use of regional calibration parameters would be an inaccurate approach when describing the salt generation processes in these catchments.

Historically (DWAF, 1993) it has been shown that between gauging stations G1H036 and Misverstand Dam (see **Figure 1.1**), the biggest TDS loads are contributed by the Matjies River

(G1H035) and the Sandspruit (G1H043). A typical annual TDS load input to the Berg main stem is depicted in **Figure 2.1**.

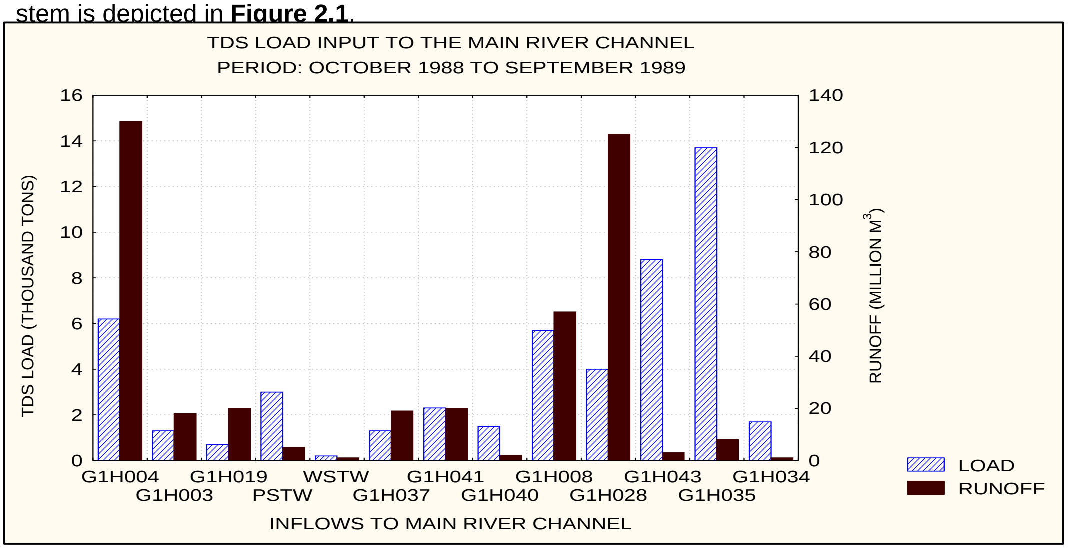


Figure 2.1 TDS load and runoff for tributaries of the Berg (after DWAF, 1993)

From **Figure 2.1** it can be seen that the flows contributed by the Matjies River (G1H35) and Sandspruit (G1H43) are small in comparison to their loads, indicating that high concentrations could be expected in these rivers.

2.2 DATA PREPARATION

Calibration of the WQT model was done using either a flow gauging station or reservoir as observation point, calibrating on TDS load or concentration, respectively.

In the case of flow gauging stations, monthly files of observed flow ($10^6 m^3$), flow weighted mean observed TDS (mg/l) and monthly TDS loads were generated for each calibration point. The following is an abbreviated description of the method used:

- Daily flow files were obtained from the HIS database and then aggregated to monthly files.
- Monthly grab sample TDS data was arranged against instantaneous flow data and a best-fit inverse logarithmic relationship was derived. This relationship was then used to infill the TDS grab sample data. This process is then moved forward one sample at a time. In all cases, the observed TDS values “anchor” the infilled time series.
- Daily TDS and flow data were then multiplied to obtain daily salt loads and the resulting aggregated monthly loads were divided by the aggregated monthly flow to obtain a flow weighted average monthly TDS.

It was noted that large gaps in the water quality record resulted in daily TDS values that remained almost constant during the infilling process and this in turn resulted in false monthly flow weighted TDS values that were not representative of reality. Close attention was given to this phenomenon to ensure that realistic estimates of the flow weighted average monthly TDS were produced.

For this task, the duration of the infilled monthly flow-weighted observed records was not extended beyond what was available from previous studies. Instead, calibrations were only performed over a representative time period, i.e 1985 – 1998 where possible, such that estimates of the values for the salt generation parameters may be obtained. It is expected that an extension of the infilled monthly flow-weighted observed record would not change the calibrated values of the salt-generation parameters significantly.

At gauging stations, model calibration was primarily aimed at reproduction of monthly loads calculated by the above process.

CHAPTER 3: WQT NETWORK CONFIGURATIONS

The network configurations for the WQT model were based on the networks that were used in the hydrological component of this study. Due to the practical limitation of 30 routes per configuration, certain configurations had to be split with the outflow from the upstream configuration being appropriately transferred downstream. Consequently, the WRSM2000 networks were split into smaller networks in order to accommodate the limitations of the WQT model. The network configurations are depicted in **Figures 3.1** to **3.10.**

Table 3.1 summarises the computational order of the sub-networks and indicates the names of the output files from the upstream networks which need to be transferred to the downstream networks.

Table 3.1 Sequence of the WQT Networks and Input Files

Sequence	Upstream Network	Downstream Network	Output Files	
			Flow File	Salinity File
1	G1A	G1B	G1ARQ27.FLO	G1ARQ27.TDS
2	G1B	G2A-B	G1BRQ25.FLO	G1BRQ25.TDS
3	G2A-A	G2A-B	G2ARQ24.FLO	G2ARQ24.TDS
4	G2A-B	G3A	G2ARQ15.FLO	G2ARQ15.TDS
5	G2B	G3A	G2BRQ15.FLO	G2BRQ15.TDS
6	G1H043	G3A	G1H043.FLO	G1H043.TDS
7	G3A	G3B	G3ARQ27.FLO	G3ARQ27.TDS
8	G3B	none	none	none

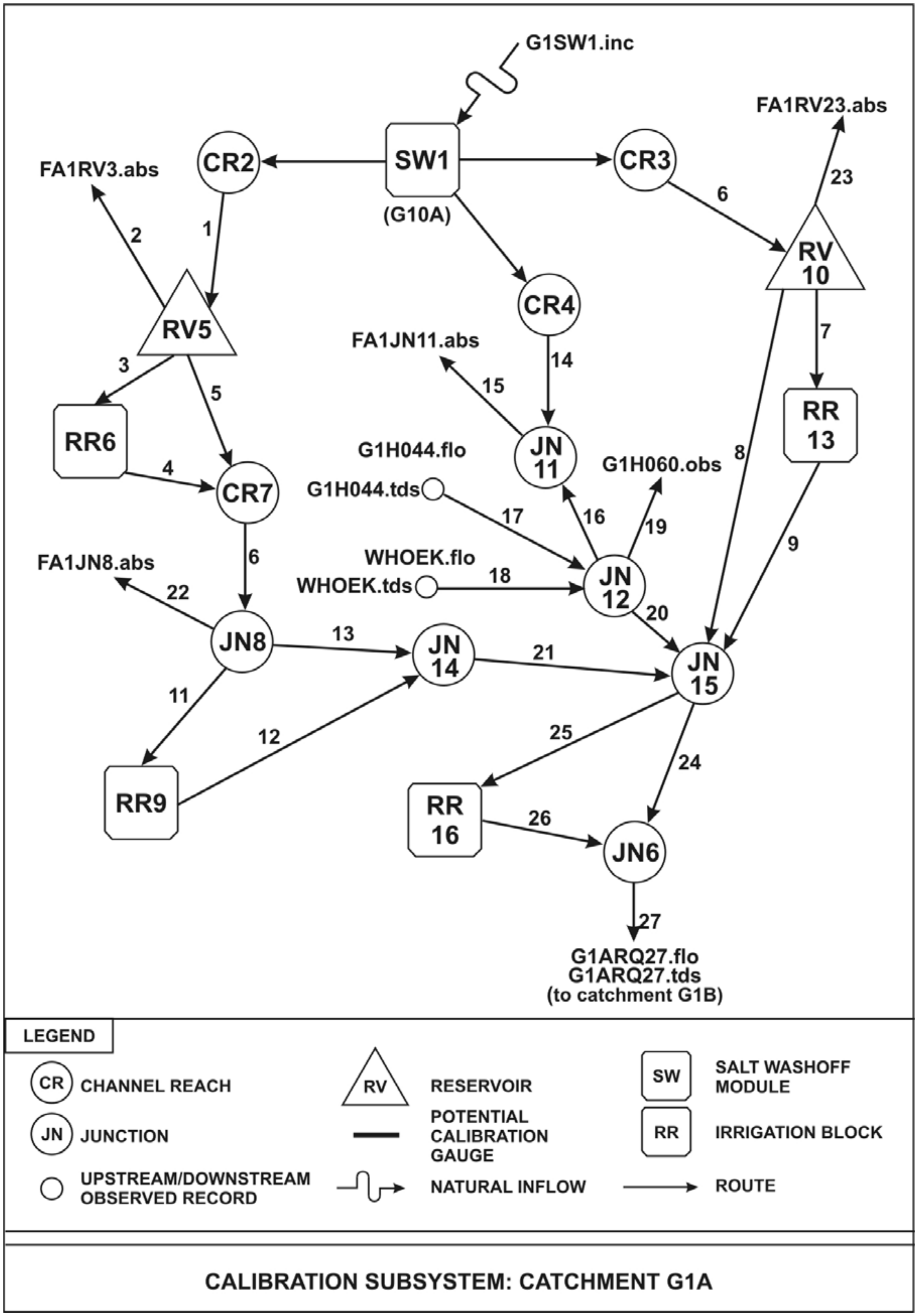


Figure 3.1 WQT configuration for calibration at G1H020 (Section 1)

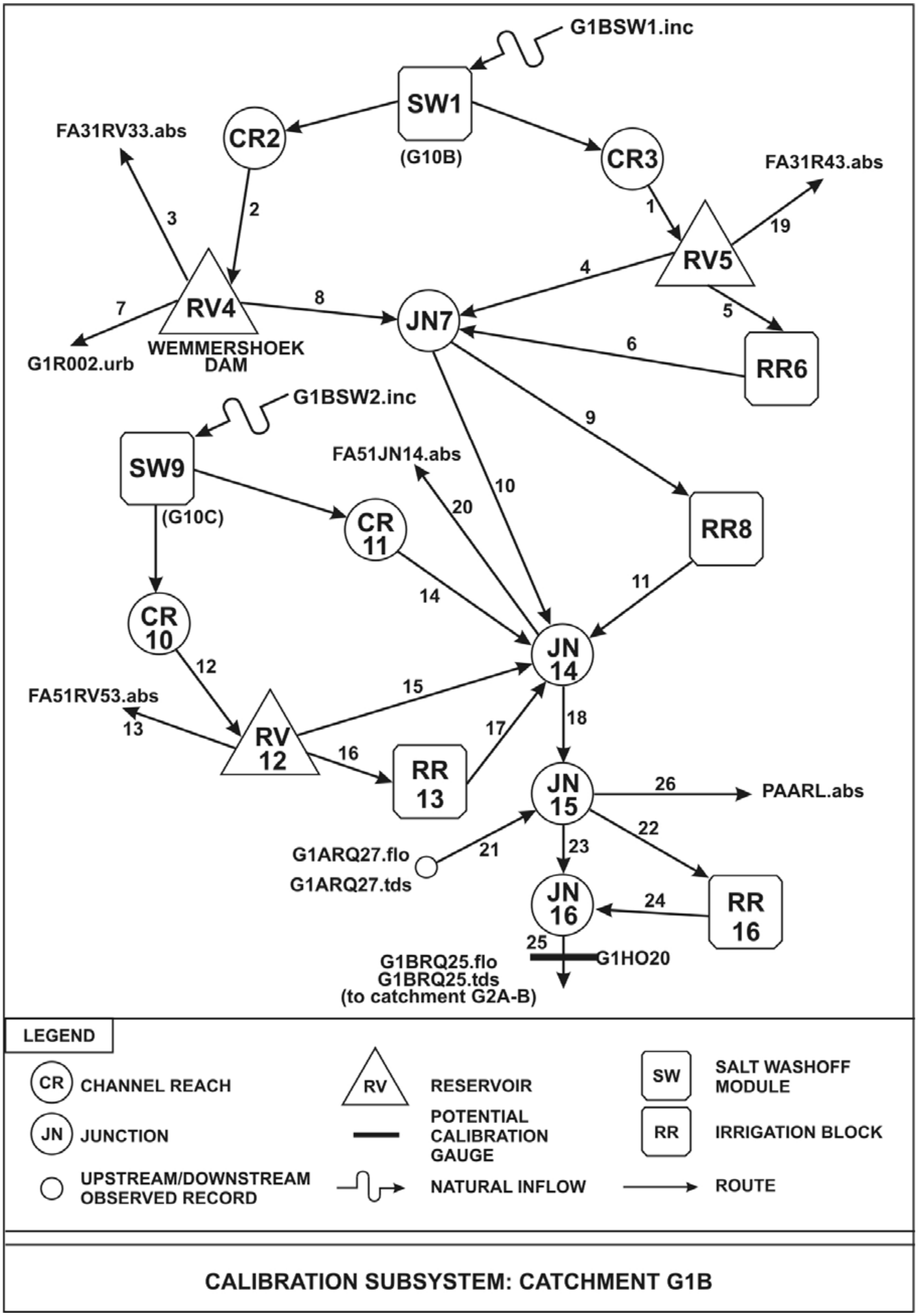


Figure 3.2 WQT configuration for calibration at G1H020 (Section 2)

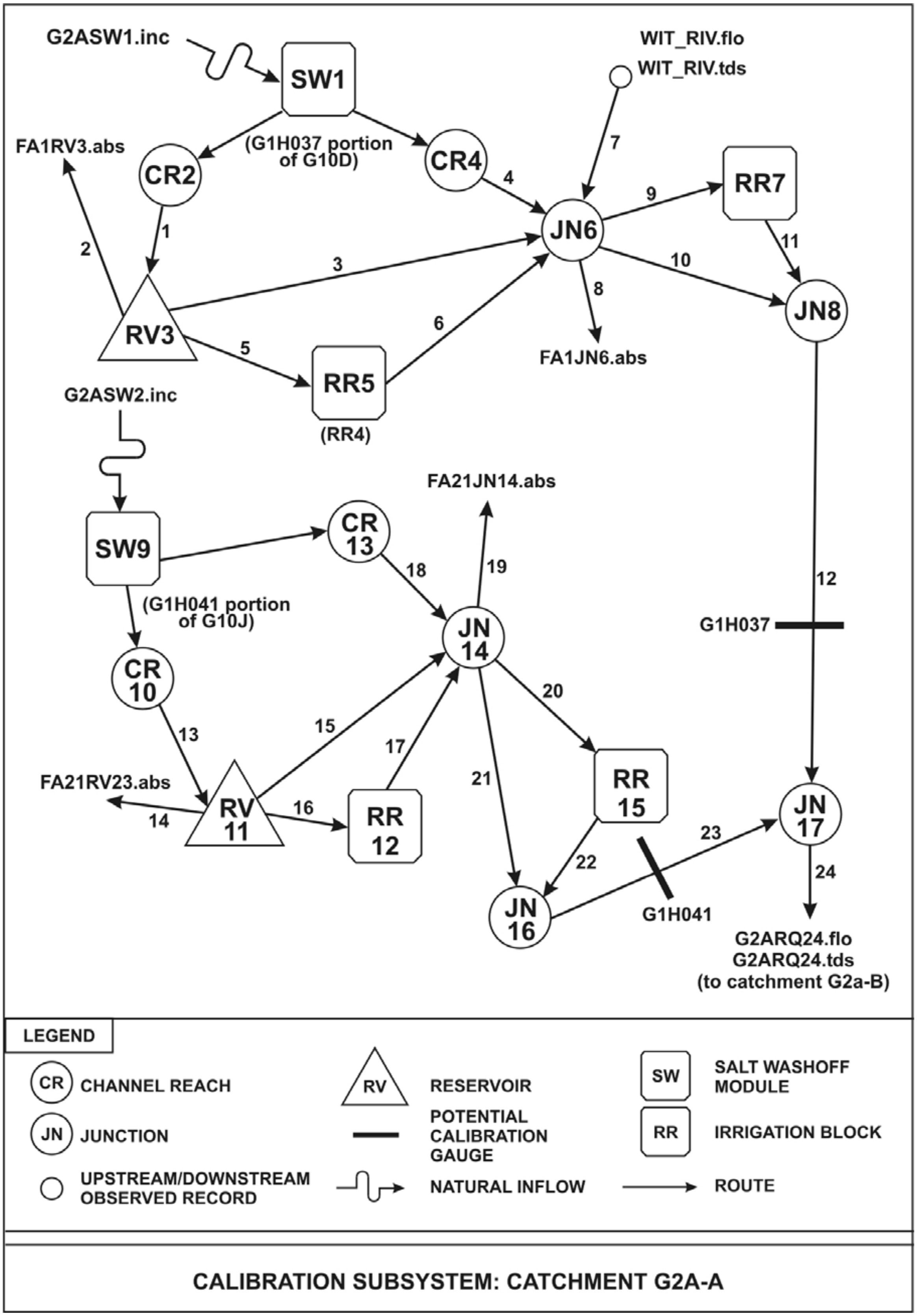


Figure 3.3 WQT configuration for calibration at G1H037 and G1H041

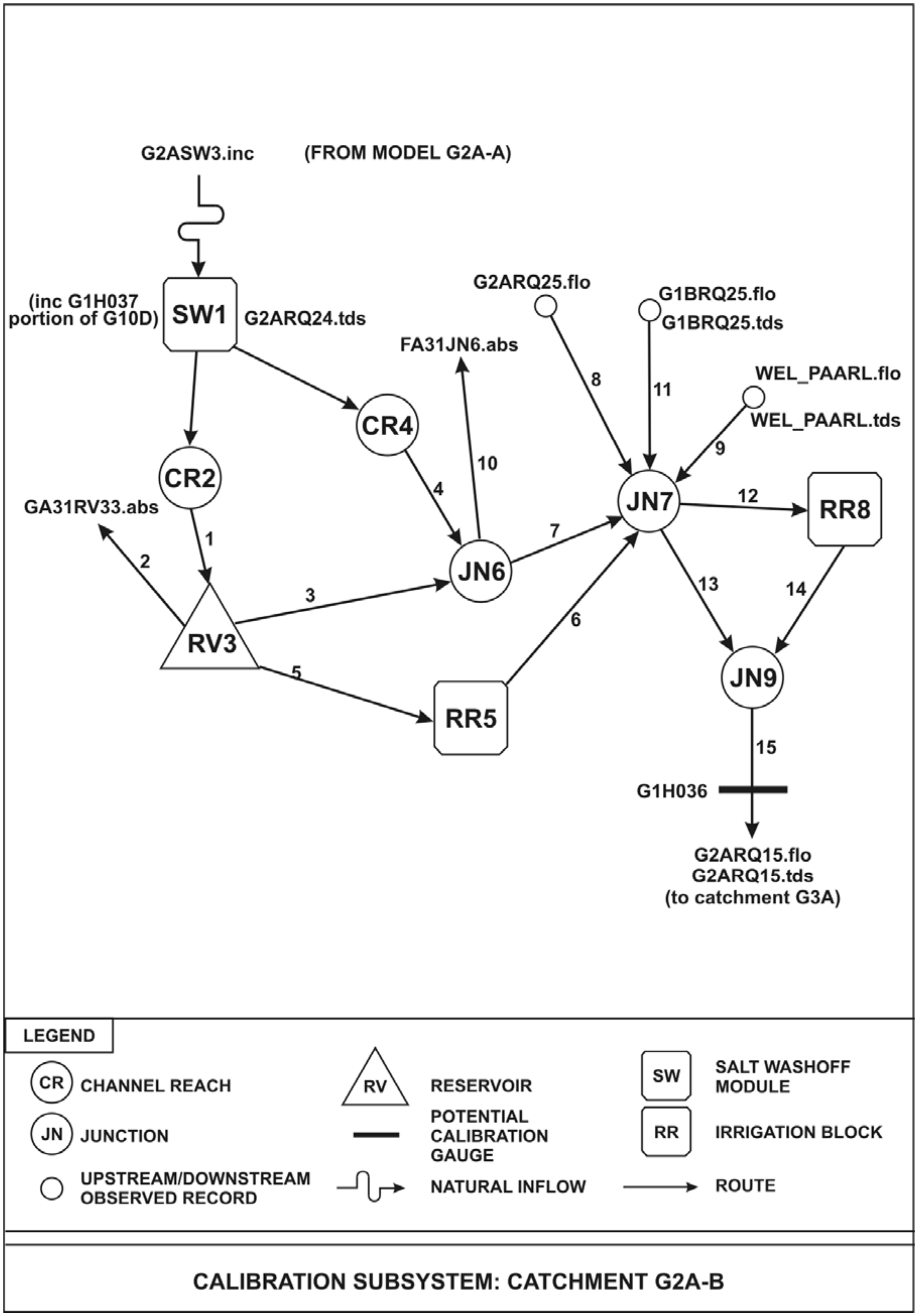


Figure 3.4 WQT configuration for calibration at G1H036

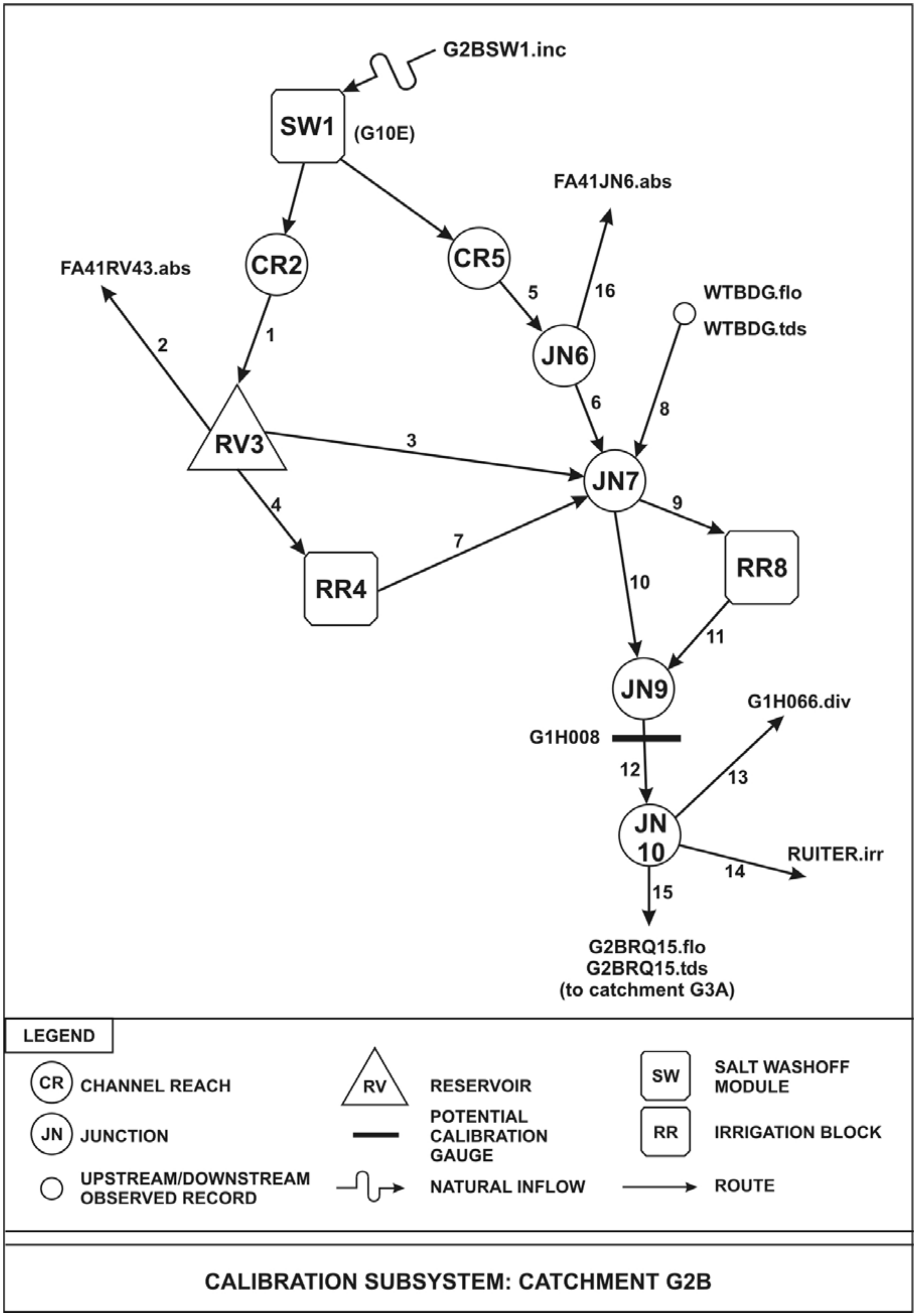


Figure 3.5 WQT configuration for calibration at G1H008

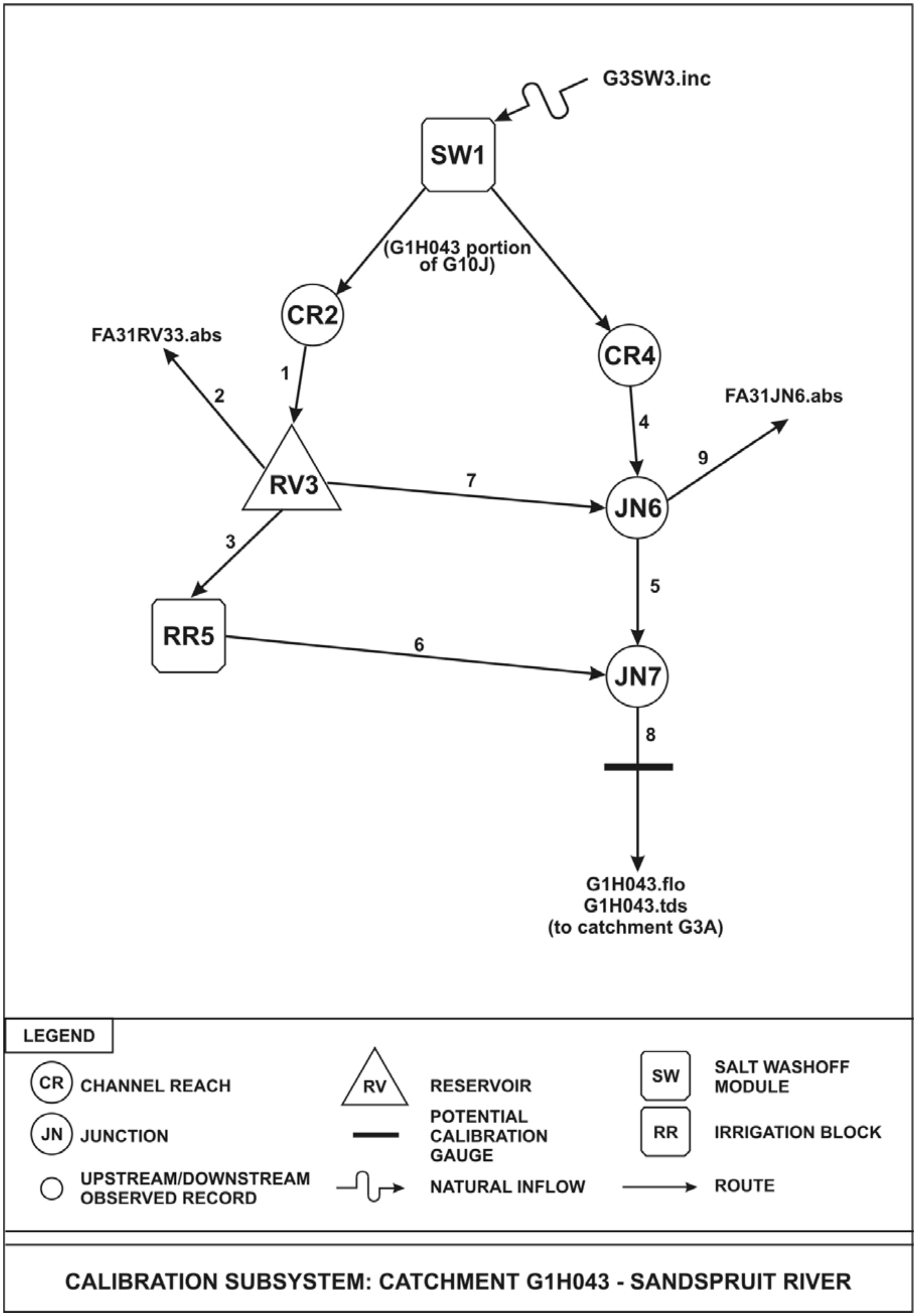


Figure 3.6 WQT configuration for calibration at G1H043

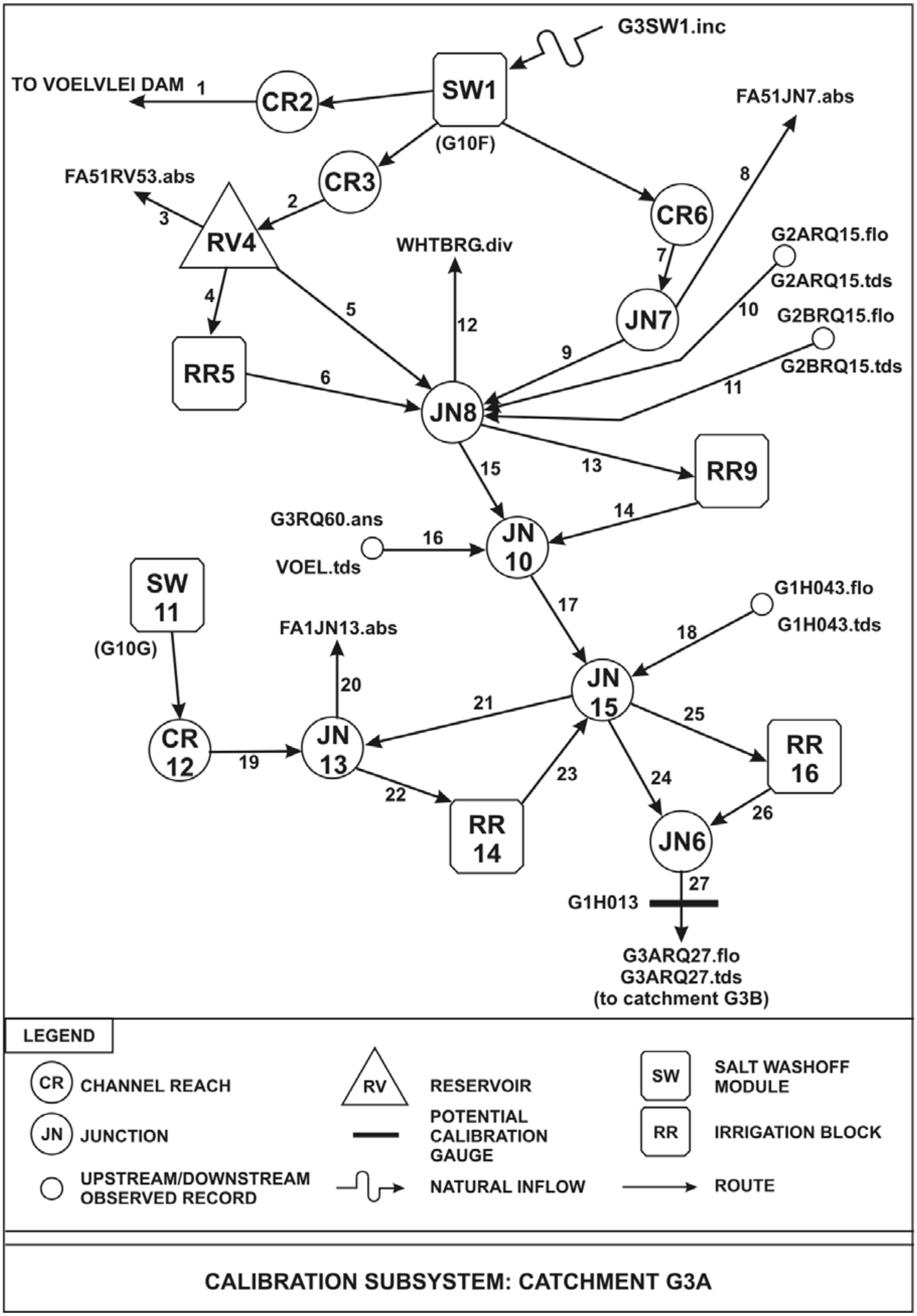


Figure 3.7 WQT configuration for calibration at G1H013

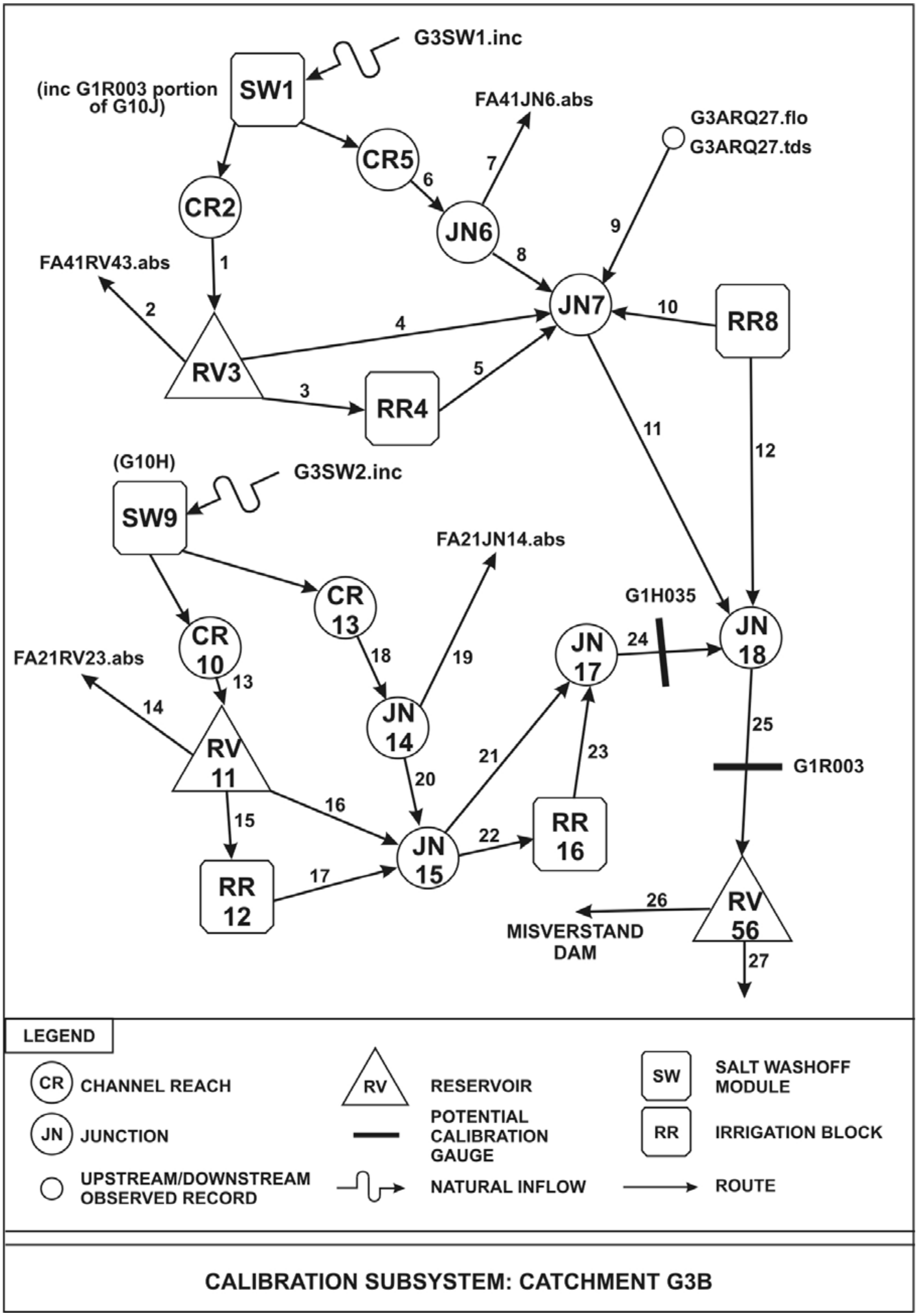


Figure 3.8 WQT configuration for calibration at G1R003

CHAPTER 4: CALIBRATION RESULTS

The following section discusses the calibration of the various sub-catchments. Since some calibration sub-catchments contain more than 30 routes, it is necessary to split the calibration into smaller sub-divisions. The process for calibrating the sub-catchment is, however, the same as for a smaller catchment.

The results of the model calibration depends on the quality and accuracy of the input data to model as well as the water quality data created from the grab sample record. The following could influence the accuracy of the WQT calibration results:

- The value of RRHSU was assumed at 40% of the root depth, i.e. 1000 mm, while RRHSL was assumed to be the total soil depth, i.e. 2500 mm.
- Estimates of the SWGMB parameter (the monthly flow rates below which all catchment outflow is assumed to be baseflow, i.e. from groundwater), were assumed to be the minimum of the average natural flow (based on the method prescribed in the WQT manual).
- Subtracting the monthly salt loads of the specified inflow from the monthly load at the observed point and dividing this by the catchment area, yielded the initial estimate of SWSSRP. It was accepted that this is the highest possible value for this parameter, since the effects of irrigation are already included in the observed record.
- The lack of suitable observed water quality data points is not ideal for calibration purposes.

In all cases, the goodness-of-fit of the model was based on the observed and simulated means and standard deviations of either loads or concentrations as well as the visual correspondence of the two sets of time series.

4.1 CALIBRATION AT G1H020 (BERG RIVER AT DALJOSAFAT)

Analysis of the TDS grab sample record for the period 1965 to 2002 shows that the average, maximum and minimum recorded TDS concentrations at gauge G1H020 (Berg River at Daljosafat) were 60 mg/l, 264 mg/l and 5 mg/l, respectively. The observed data and the modelled discharge, concentration and load results for G1H020 are presented in **Table 4.1**.

Table 4.1 G1H020 Calibration Results

Calibration Period	1985 - 1994	
	Observed	**Modelled**
Discharge (million m^3/month)		
: Average	28.91	25.40
: Std Dev.	35.13	30.80
Concentration (mg/l)		
: Average	59.74	90.07
: Std Dev.	14.68	65.00
Load (t/month)		
: Average	1612.18	1662.07
: Std Dev.	1958.59	2056.87

4.2 CALIBRATION AT G1H037 (KROM RIVER AT WELLINGTON)

Analysis of the TDS grab sample record for the period 1979 to 1992 shows that the average, maximum and minimum recorded TDS concentrations at G1H037 (Krom River at Wellington) were 95 mg/l, 692 mg/l and 36 mg/l, respectively. The seasonal variation of the TDS values is depicted in **Figure 4.1** which is typical of what is expected from a semi-arid region with slightly higher TDS concentrations during the summer months. This occurs as a result of the irrigation return flows and the evapo-concentrating effect and comparatively lower TDS values during winter, and as a result of good quality run-off. Furthermore, water from the Wit River (in the Breede River catchment) was assumed to be imported to the catchment at a constant monthly flow rate of 0.22 Mm^3/month.

The observed data and the modelled discharge, concentration and load results for G1H037 are presented in **Table 4.2**.

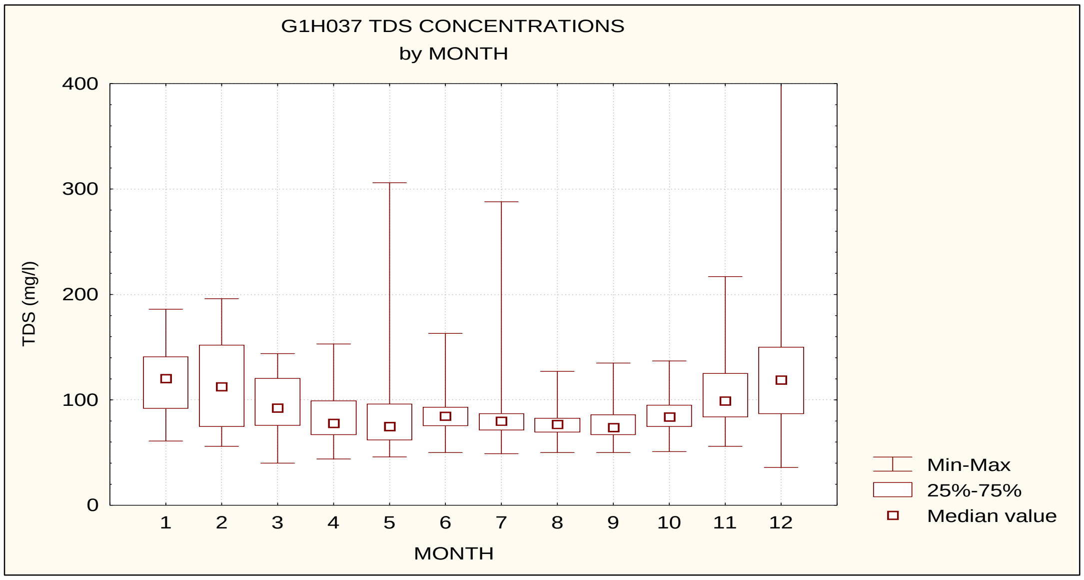


Figure 4.1 Seasonal distribution of TDS concentrations at gauging station G1H037

Table 4.2 G1H037 Calibration Results

Calibration Period	1985 - 1992	
	Observed	Modelled
Discharge (million m^3/month)		
: Average	2.13	2.17
: Std Dev.	2.32	2.92
Concentration (mg/l)		
: Average	103.90	176.99
: Std Dev.	58.60	121.77
Load (t/month)		
: Average	168.77	174.75
: Std Dev.	219.07	234.19

4.3 CALIBRATION AT G1H041 (KOMPANJIES RIVER AT DE EIKEBOOMEN)

Analysis of the TDS grab sample data at gauge G1H041 (Kompanjies River at De Eikeboom) for the period 1979 to 2002 shows that the minimum, average and maximum TDS concentrations were 39 mg/l, 164 mg/l and 5 499 mg/l, respectively. It is more than likely that the highest recorded value is inaccurate and should not be regarded as representative of the TDS concentrations at this gauge. The seasonal distribution of the TDS concentrations at the gauge is depicted in **Figure 4.2**. As is typical of this part of the Berg River catchment, the higher TDS concentrations occur during the summer months with the lower TDS concentrations occurring in the winter months.

The observed data and the modelled discharge, concentration and load results for G1H041 are presented in **Table 4.3**.

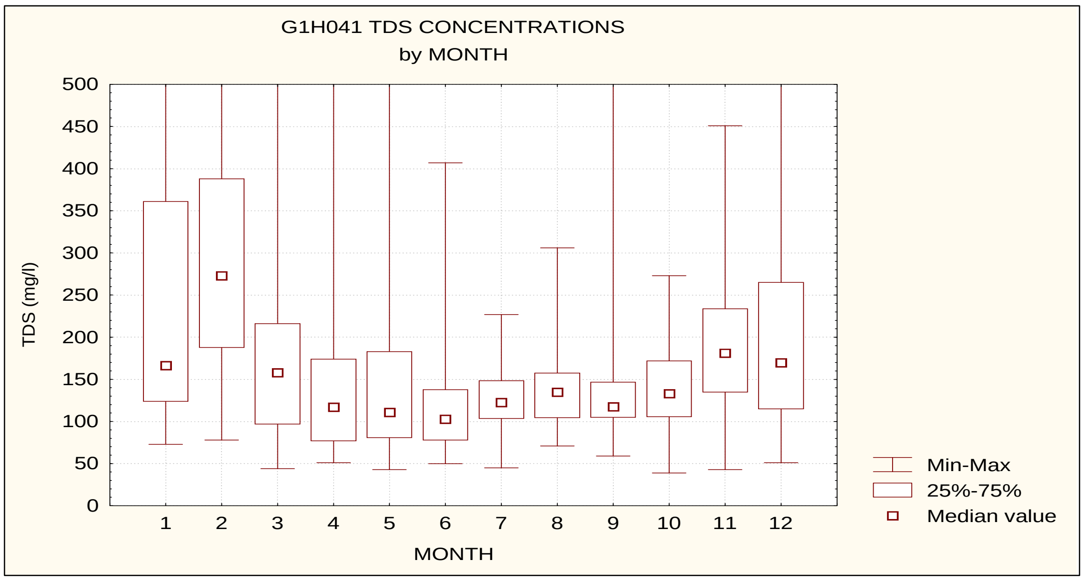


Figure 4.2 Seasonal distribution of TDS concentrations at gauge G1H041

Table 4.3 G1H041 Calibration Results

Calibration Period	1985 – 2004	
	Observed	**Modelled**
Discharge (million m^3/month)		
: Average	2.13	2.17
: Std Dev.	2.32	2.92
Concentration (mg/l)		
: Average	103.90	176.99
: Std Dev.	58.60	121.77
Load (t/month)		
: Average	168.77	174.75
: Std Dev.	219.07	234.19

4.4 CALIBRATION AT G1H036 (BERG RIVER AT VLEESBANK)

Analysis of the TDS grab sample data at gauge G1H036 (Berg River at Vleesbank) over the period 1978 to 2002 shows that the minimum, average and maximum TDS concentrations were 35 mg/l, 123 mg/l and 418 mg/l, respectively. The seasonal distribution of the TDS concentration at gauge G1H036 (see **Figure 4.3**) shows that no marked increase in TDS is experienced over the winter months with 75% of the observed TDS values in winter being less than 150 mg/l.

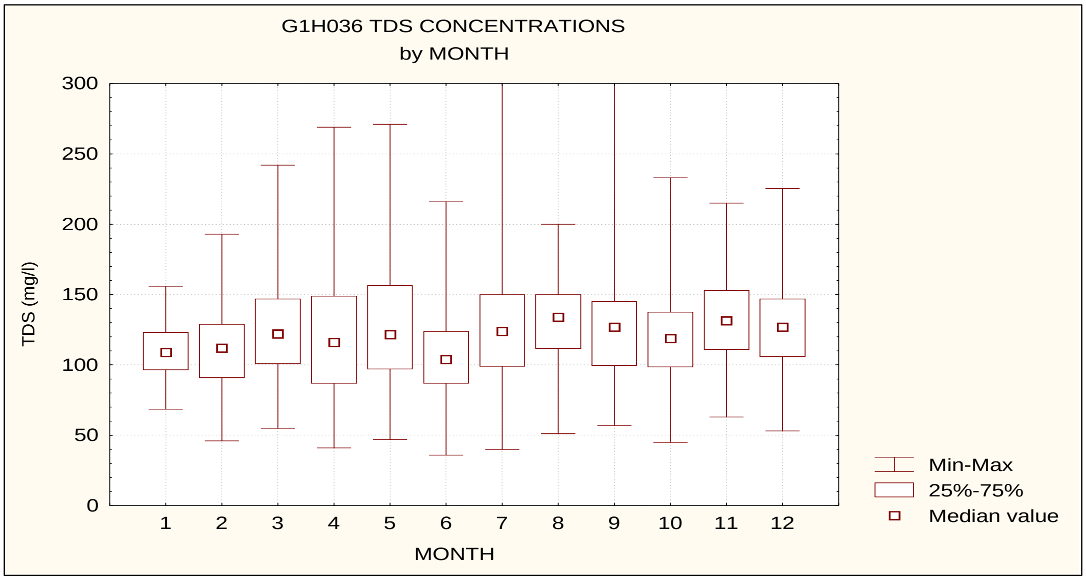


Figure 4.3 Seasonal distribution of TDS at gauge G1H036

The observed data and the modelled discharge, concentration and load results for G1H036 are presented in **Table 4.4**.

Table 4.4 G1H036 Calibration Results

Calibration Period	1985 – 2004	
	Observed	Modelled
Discharge (million m³/month)		
: Average	35.32	35.39
: Std Dev.	46.37	45.26
Concentration (mg/l)		
: Average	112.93	214.33
: Std Dev.	38.56	146.23
Load (t/month)		
: Average	3719.83	4080.65
: Std Dev.	5073.61	5276.65

4.5 CALIBRATION AT G1H008 (KLEIN BERG AT NIEUWKLOOF)

Analysis of the TDS grab sample for gauge G1H008 (Klein Berg at Nieuwkloof) over the period 1976 to 2002 shows that the minimum, average and maximum TDS concentrations were 17 mg/l, 102 mg/l and 321 mg/l, respectively. The seasonal distribution of the TDS concentration at gauge G1H008 (see **Figure 4.4**) shows that no marked increase in TDS is experienced over the winter months with 75% of the observed TDS values in winter being less than 150 mg/l. The calibration results at gauging station G1H008 are shown in **Table 4.5.**

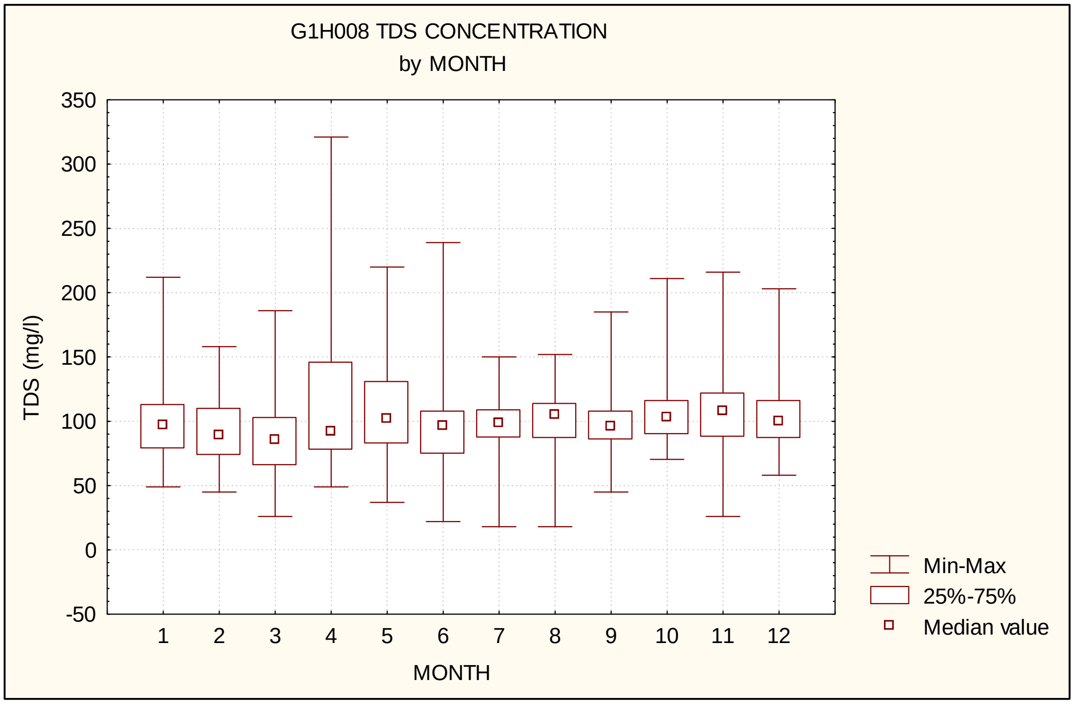


Figure 4.4 Seasonal variation of TDS concentration at gauging station G1H008

Table 4.5 G1H008 Calibration Results

Calibration Period	**1985 – 2004**	
	Observed	**Modelled**
Discharge (million m³/month)		
: Average	5.70	7.14
: Std Dev.	8.26	10.40
Concentration (mg/l)		
: Average	107.23	121.80
: Std Dev.	34.98	28.34
Load (t/month)		
: Average	595.20	696.84
: Std Dev.	900.98	808.46

4.6 CALIBRATION AT G1H043 (SANDSPRUIT AT VRISGEWAAGD)

As mentioned previously in the report, the catchment gauged by G1H043 (Sandspruit at Vrisgewaagd) produces naturally high TDS concentrations during the winter months when previously dissolved salts are mobilised. Analysis of the grab TDS sample record spanning the years 1980 to 1997 showed that the minimum, maximum and mean TDS concentrations of the run-off produced in this catchment were 1 005 mg/l, 10 989 mg/l and 5 039 mg/l, respectively. The seasonal distribution of TDS concentrations is depicted in **Figure 4.5**. It should be noted that, contrary to expectation, the TDS concentration increases over the winter months, implying that high TDS loads can be expected from this catchment.

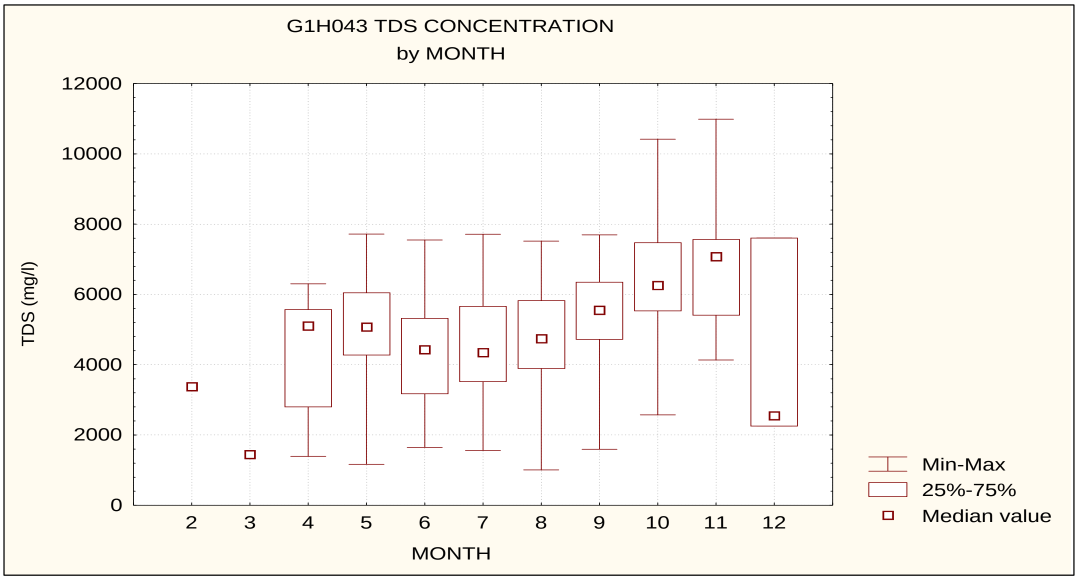


Figure 4.5 Seasonal variation of TDS concentration at gauging station G1H043

The observed data and the modelled discharge, concentration and load results for G1H043 are presented in **Table 4.6**.

Table 4.6 G1H043 Calibration Results

Calibration Period	1985 – 2001	
	Observed	Modelled
Discharge (million m^3/month)		
: Average	0.45	0.59
: Std Dev.	1.26	0.92
Concentration (mg/l)		
: Average	2002.97	3109.03
: Std Dev.	2451.95	1324.23
Load (t/month)		
: Average	1221.69	1451.34
: Std Dev.	3066.52	2393.90

4.7 CALIBRATION AT G1H013 (BERG RIVER AT DRIEHEUWELS)

Previous studies (Fourie and Görgens, 1977 and DWAF, 2005) have shown that two peaks in TDS concentration occur in the Lower Berg River with the winter peak probably being caused by the mobilisation of salts from the downstream catchment. In the analysis of the TDS grab samples at gauge G1H013 (Berg River at Drieheuwels) for the period 1965 to 2002 it was shown that the minimum, average and maximum TDS concentrations at this gauge were 18 mg/l, 142 mg/l and 1 170 mg/l, respectively. The seasonal distribution of the TDS concentrations is shown in **Figure 4.6**.

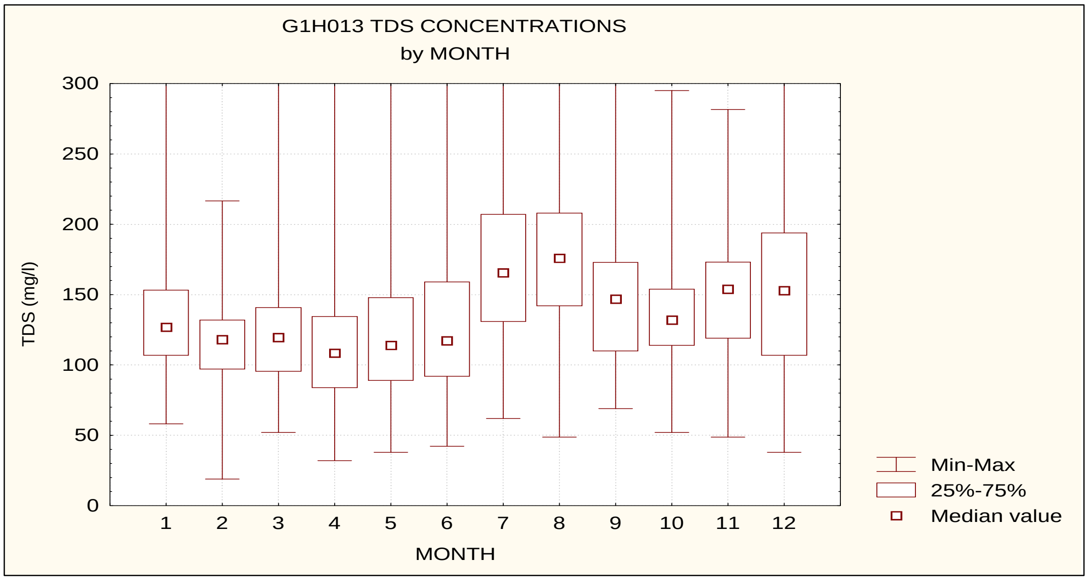


Figure 4.6 Seasonal distribution of TDS concentration at gauge G1H013

The observed data and the modelled discharge, concentration and load results for G1H013 are presented in **Table 4.7**.

Table 4.7 G1H013 Calibration Results

Calibration Period	1985 – 2004	
	Observed	Modelled
Discharge (million m³/month)		
: Average	49.76	45.28
: Std Dev.	67.61	61.80
Concentration (mg/l)		
: Average	148.69	503.58
: Std Dev.	59.04	579.11
Load (t/month)		
: Average	7919.47	8618.84
: Std Dev.	11591.55	12902.03

4.8 CALIBRATION AT G1H035 (MATJIES RIVER AT MATJIESFONTEIN)

According to Bath, the largest salt load contribution to the Berg River mainstem is from the Matjies River (G1H035) (DWAF, 1993). Analysis of the TDS grab sample record for the period 1971 to 2002 showed that the minimum, average and maximum TDS concentrations were 25 mg/l, 1 814 mg/l and 5 669 mg/l, respectively. The seasonal distribution of TDS concentrations at gauge G1H035 is depicted in **Figure 4.7**, which shows that more than 75% of the winter grab samples had TDS concentrations of over 1 000 mg/l, while at least 25% of the observations had concentrations above 2 000 mg/l.

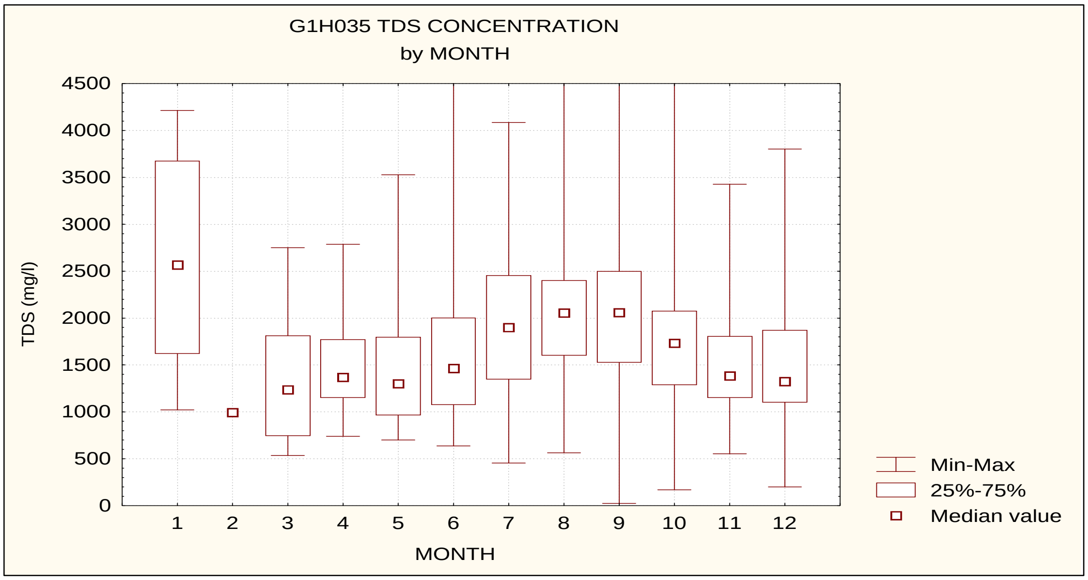


Figure 4.7 Seasonal distribution of TDS concentration at G1H035

The observed data and the modelled discharge, concentration and load results for G1H035 are presented in **Table 4.8**.

Table 4.8 G1H035 Calibration Results

Calibration Period	1985 – 2002	
	Observed	Modelled
Discharge (million m^3/month) : Average : Std Dev.	 3.93 10.40	 3.20 5.32
Concentration (mg/l) : Average : Std Dev.	 1561.44 1054.96	 3310.68 2810.17
Load (t/month) : Average : Std Dev.	 5630.19 15924.29	 5607.53 8492.80

4.9 CALIBRATION AT G1R003 (BERG RIVER AT MISVERSTAND DAM)

Analysis of the TDS grab sample record for G1R003 (Berg River at Misverstand Dam) for the period 1977 to 2002 showed that the minimum, average and maximum TDS concentrations were 22 mg/l, 197 mg/l and 615 mg/l, respectively. The seasonal distribution of TDS concentrations at gauge G1R003 is depicted in **Figure 4.8**, which shows that more than 75% of the winter grab samples had TDS concentrations less than 300 mg/l and that 500 mg/l was seldom exceeded.

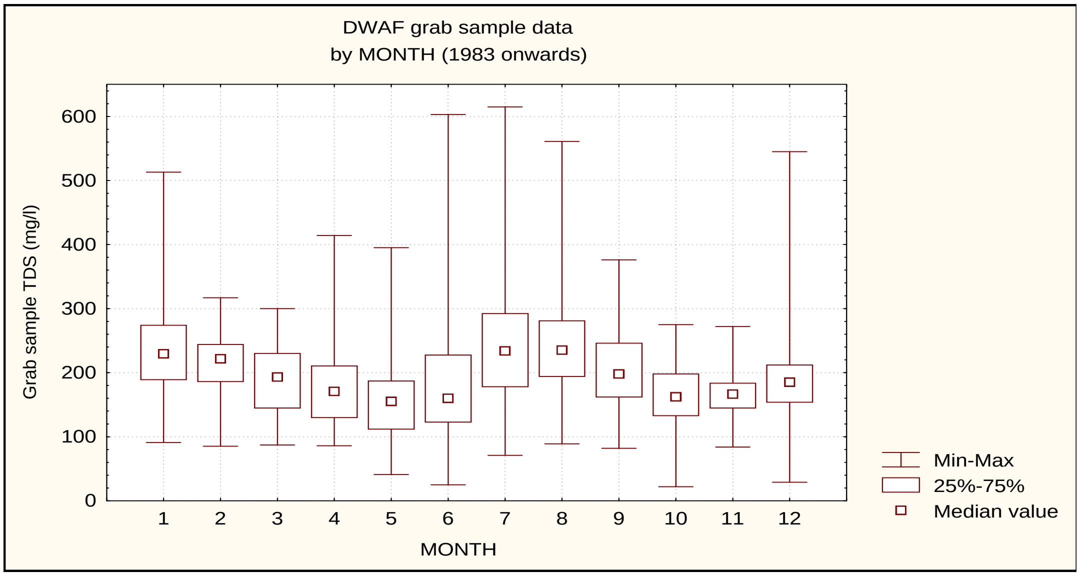


Figure 4.8 Seasonal distribution of TDS concentration at gauge G1R003

The simulated discharge, concentration and load results for G1R003 are presented in **Table 4.9**. No observed data was prepared for this gauge since the simulated values are applicable to the inflows to the dam and would not be representative of the inlake concentrations, which would be subjected to the dilution effect.

Table 4.9 G1R003 Calibration Results

Calibration Period	1985 – 2004
	Modelled
Discharge (million m^3/month)	
: Average	48.72
: Std Dev.	66.80
Concentration (mg/l)	
: Average	995
: Std Dev.	1732
Load (t/month)	
: Average	14072
: Std Dev.	20189

CHAPTER 5: COMPARISON OF ACRU*SALINITY* AND WQT SIMULATIONS

Details of the configuration of the ACRU*Salinity* model is documented in a separate report entitled *The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models: Report 6 Water Quality: Volume 2 Update Daily ACRU Catchment and Salinity Models (Berg)* (DWAF,2007). This report presents the simulated daily streamflow and salinity concentrations at selected gauges in the catchment.

Since ACRU*Salinity* is a daily hydrosalinity model while WQT is a monthly model, the simulated outputs of the two models cannot be compared directly. It should be noted, however, that the intended application of the outputs from the two models are entirely different. Outputs from ACRU*Salinity* were specifically aimed at informing short-term operational decision making, e.g. conditional abstraction of water at Misverstand Dam to offset the effects of water quality, because the model is capable of capturing the fast-response exhibited by both streamflow and salinity.

The monthly WQT model, on the other hand, provides averaged values of salinity related parameters, obtained after the calibration process, which are directly transferable to the Water Resources Planning Model (WRPM) where it could be used to estimate the medium-to-long term implications of increased irrigation on salinity, for example.

REFERENCES

Department of Water Affairs and Forestry, South Africa. 1993. *Water Quality, Volume I : General*. Prepared by A J Bath of Ninham Shand Inc. in association with BKS Inc. as part of the Western Cape System Analysis. DWAF Report No.P G000/00/2891.

Department of Water Affairs and Forestry, South Africa. 2005. *Review of Observed and Simulated TDS Patterns at Misverstand Dam, Berg River*. Prepared by W Kamish of Ninham Shand (Pty) Ltd.

Department of Water Affairs and Forestry, South Africa. 2008. *The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models : Update Daily ACRU Catchment and Salinity Models (Berg)*. Prepared by Ninham Shand (Pty) Ltd in association with Umvoto Africa on behalf of the Directorate : National Water Resource Planning. DWAF Report No. P WMA19/000/00/0407.

Fourie, J M and Görgens, A H M. 1977. *Mineralization studies of the Berg River (1974 to 1976)*. A research report of the National Institute for Water Research of the Council for Scientific and Industrial Research.

APPENDIX A

SALT WASH-OFF SUB-MODULE PARAMETERS

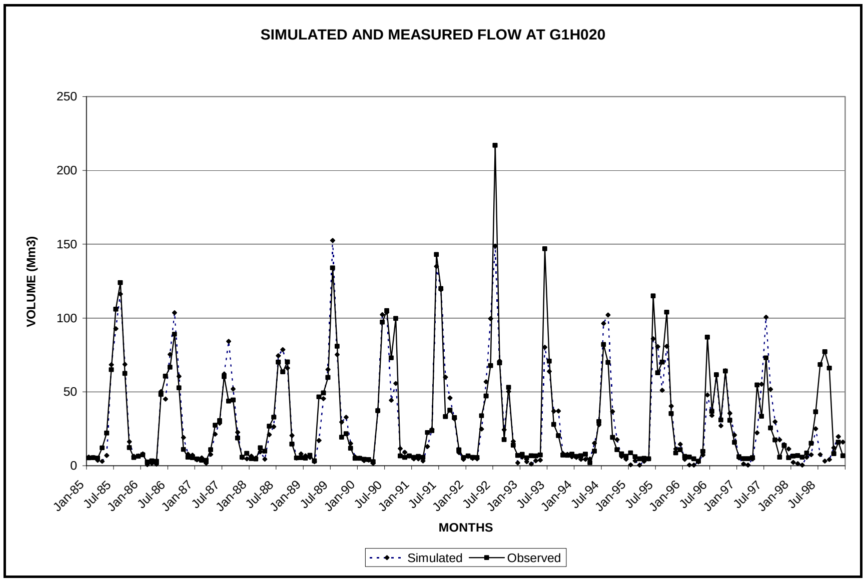
APPENDIX A - SALT WASH-OFF SUB-MODULE PARAMETERS

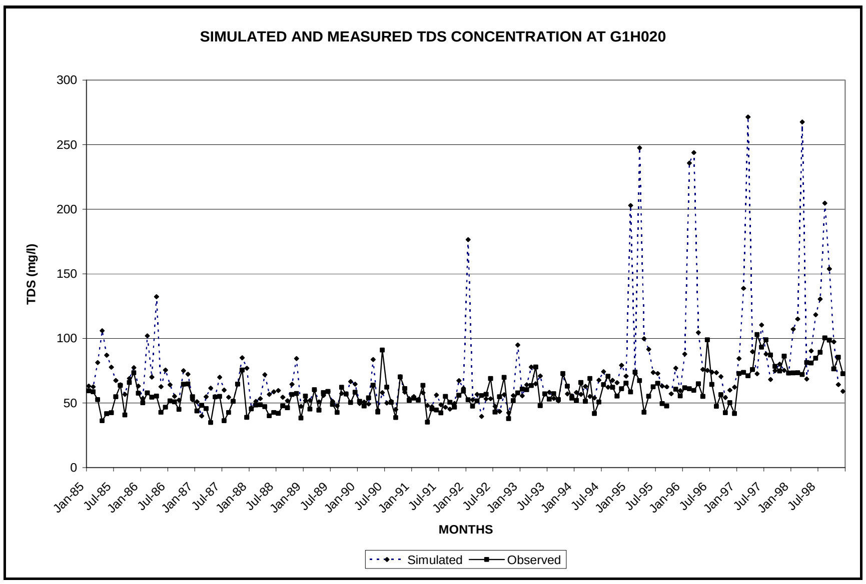
SUB-SYSTEM	G1A	G1B		G1C	G2A-A	
CATCH. AREA	185.9	145.8	348.2	185.9	80.7	125.7
MODULE No.	sw1	sw1	sw9	sw6	sw1	sw9
SWQG	0.2	0.2	0.2	0.2	0.2	0.2
SWSSP	4.19	16.41	7.14	134.4	11.36	15.18
SWSSU	0	0	0	0	0	0
SWSSG	86.52	91.63	124.96	2171.27	167.19	253.8
SWSSRP	1.97	1.97	0.97	1.12	1.42	1.29
SWSSRU	0	0	0	0	0	0
SWGMB [1..12]	3.41	6.81	1.15	0.107	2.12	0.65
SWRDF	0.3	0.3	0.3	0.3	0.3	0.3
SWPAF	0.2	0.2	0.2	0.2	0.2	0.2
SWEP	0.005	0.005	0.005	0.005	0.005	0.005
SWEU	0.05	0.05	0.05	0.05	0.05	0.05
SWPI	0.95	0.95	0.95	0.95	0.95	0.95
SWHGW	300	300	300	300	300	300

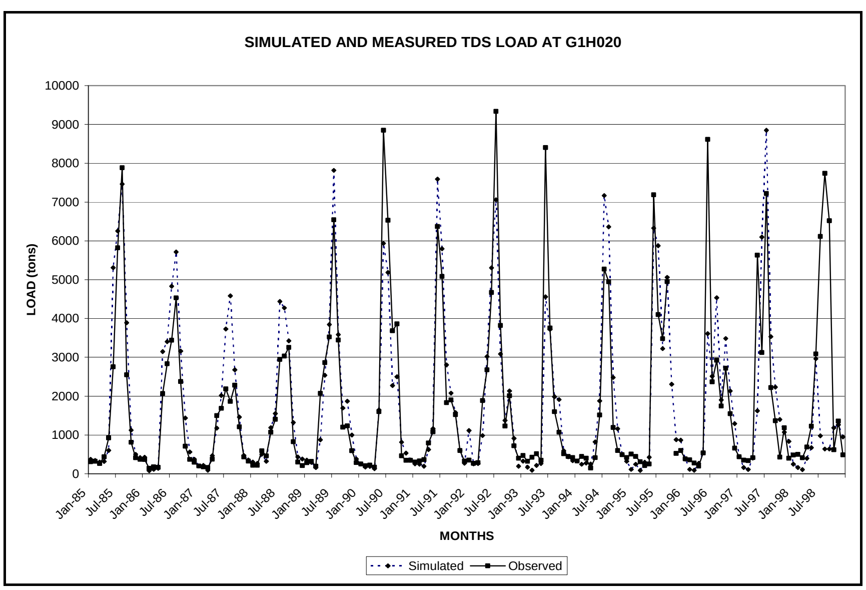
SUB-SYSTEM	G2A-B	G2B	G1H43	G3A		G3B	
CATCH. AREA	513.7	438.3	533.1	557.3	186.8	374.8	737.7
MODULE No.	sw1	sw1	sw1	sw1	sw11	sw1	sw9
SWQG	0.2	0.2	0.2	0.2	0.2	0.2	0.2
SWSSP	0.87	14.56	274.37	221.08	3.28	86.2	360
SWSSU	0	0	0	0	0	0	0
SWSSG	14.44	244.58	3940.44	3412.65	63.29	822	6120
SWSSRP	0.71	1.12	6.55	2.63	0.39	0.49	7.95
SWSSRU	0	0	0	0	0	0	0
SWGMB [1..12]	0.85	0.55	0.06	0.07	0.54	0.24	0.055
SWRDF	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SWPAF	0.2	0.2	0.2	0.2	0.2	0.2	0.2
SWEP	0.005	0.005	0.005	0.005	0.005	0.005	0.005
SWEU	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SWPI	0.4	0.4	0.4	0.4	0.4	0.98	0.95
SWHGW	300	300	300	300	300	300	300

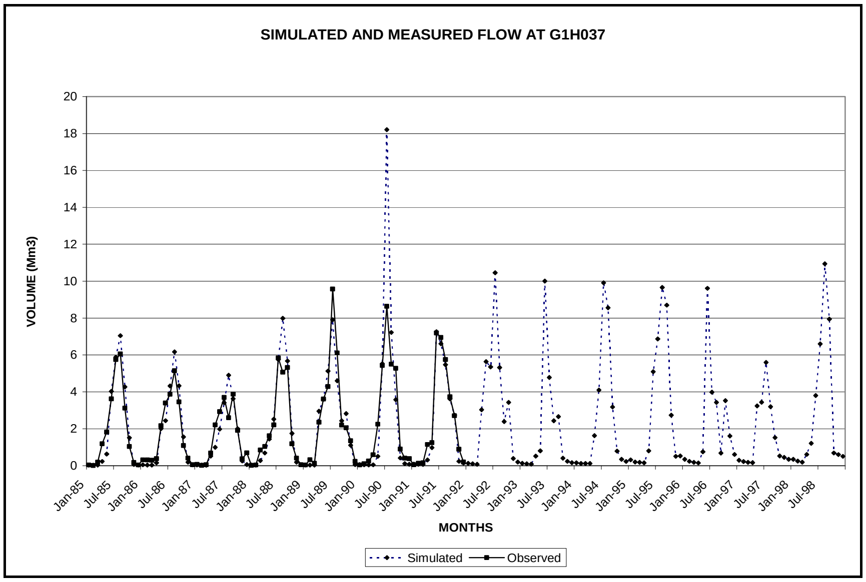
APPENDIX B

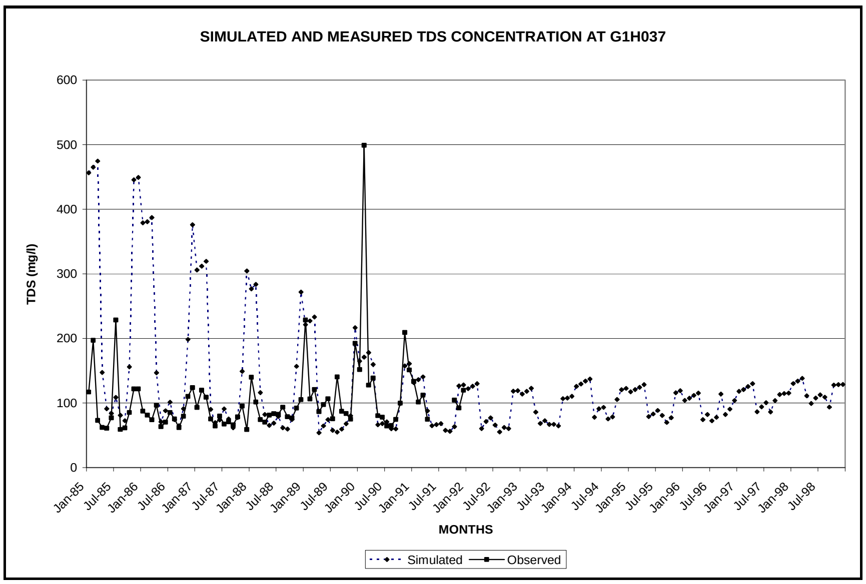
CALIBRATION GRAPHS

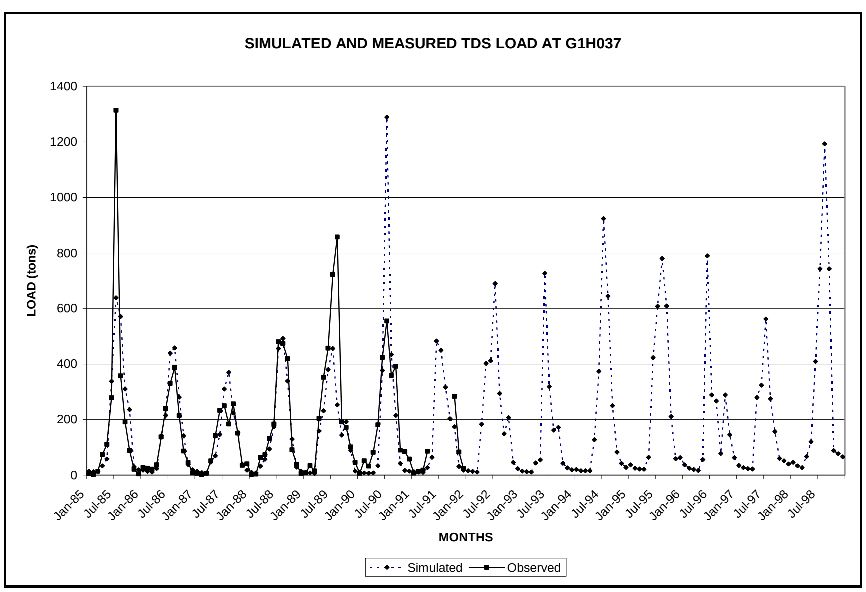

SIMULATED AND MEASURED FLOW AT G1H020
VOLUME (Mm3)
MONTHS
Simulated
Observed

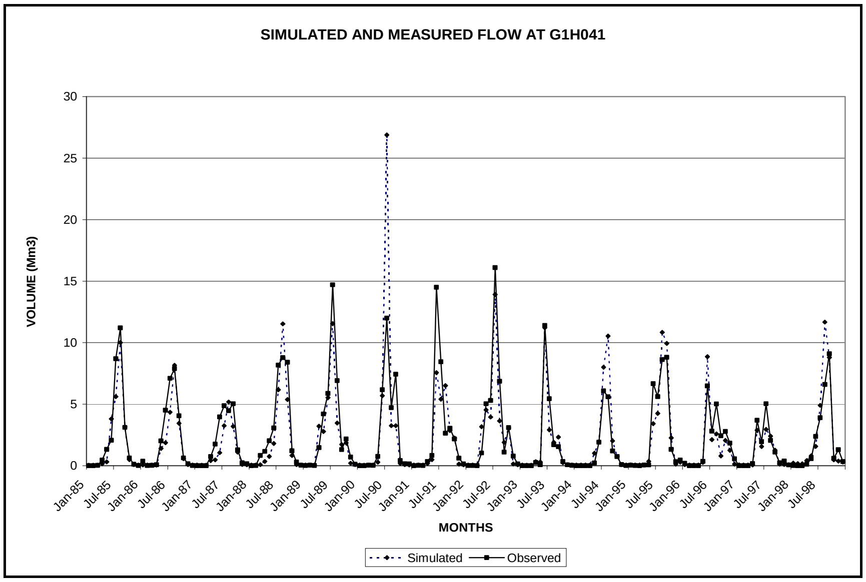

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H020
TDS (mg/l)
MONTHS
Simulated
Observed

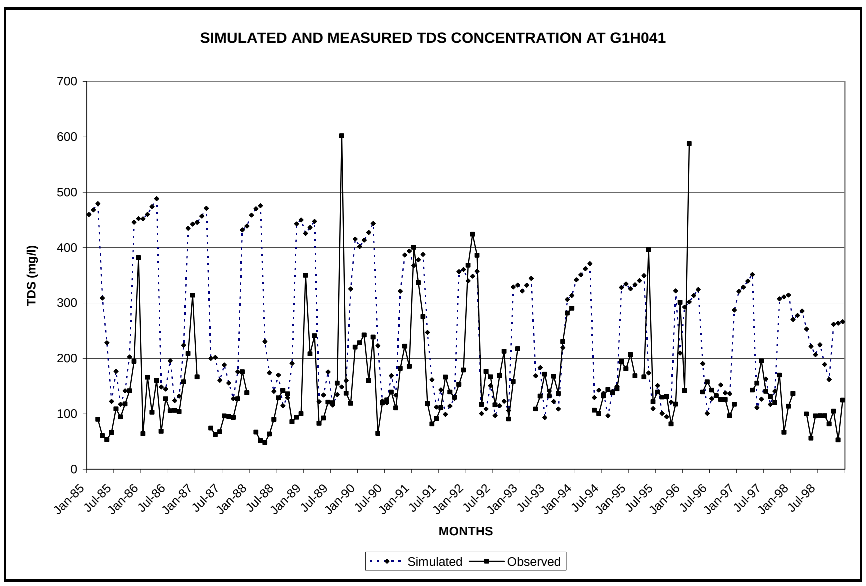

SIMULATED AND MEASURED TDS LOAD AT G1H020
LOAD (tons)
MONTHS
Simulated
Observed

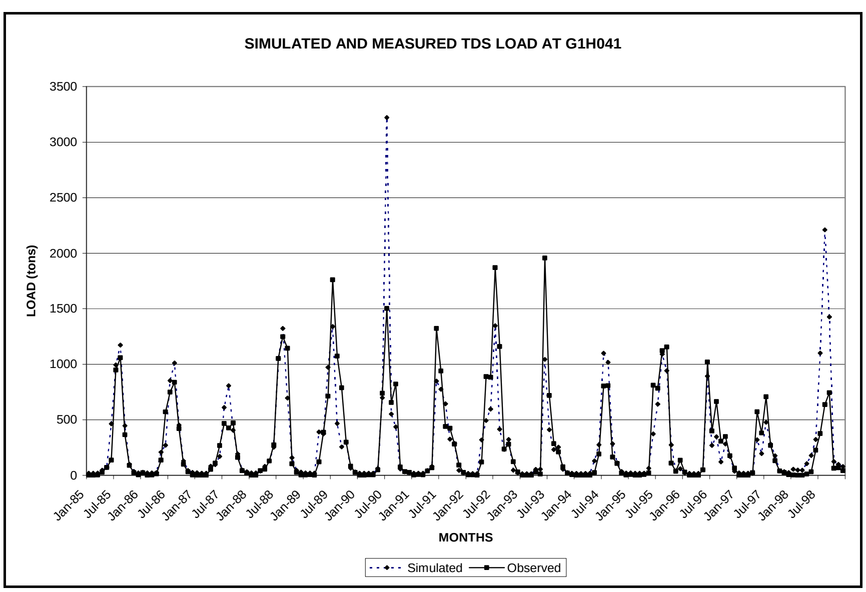

SIMULATED AND MEASURED FLOW AT G1H037
VOLUME (Mm3)
20
18
16
14
12
10
8
6
4
2
0
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

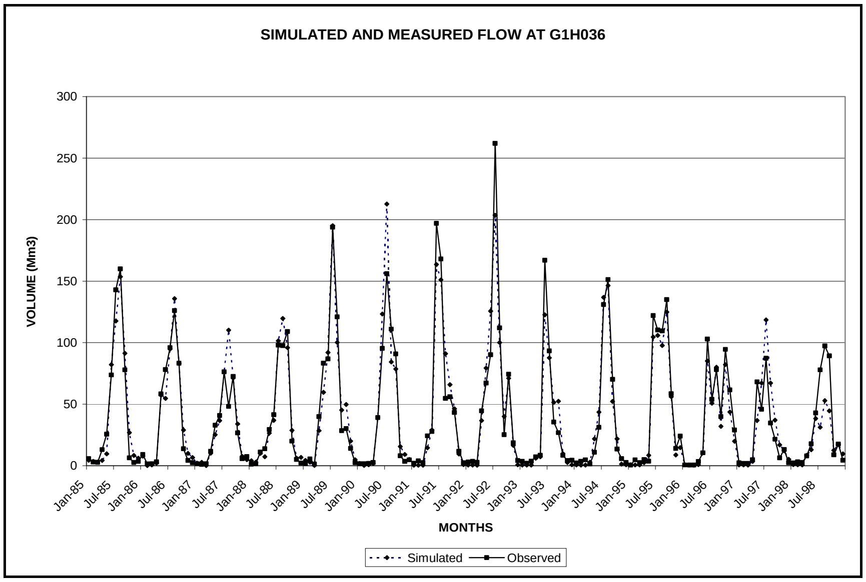

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H037
TDS (mg/l)
600
500
400
300
200
100
0
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

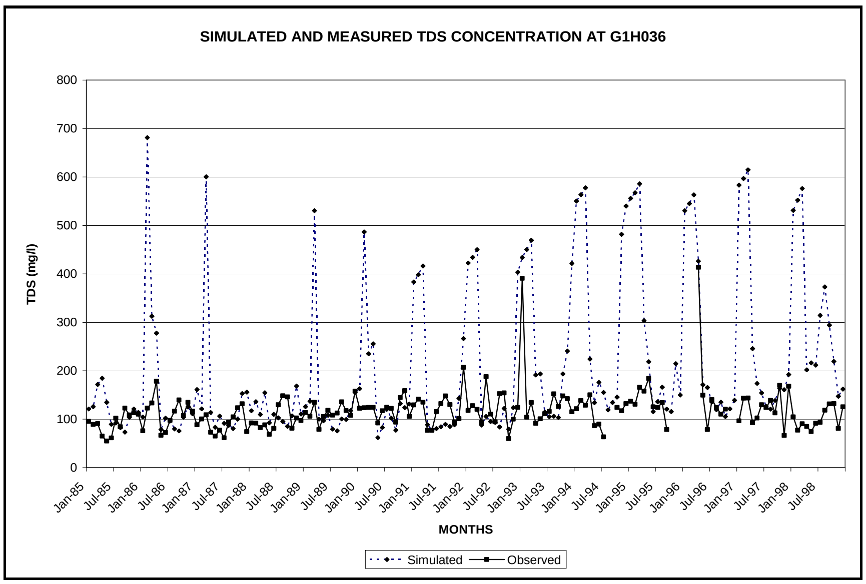

SIMULATED AND MEASURED TDS LOAD AT G1H037
LOAD (tons)
1400
1200
1000
800
600
400
200
0
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

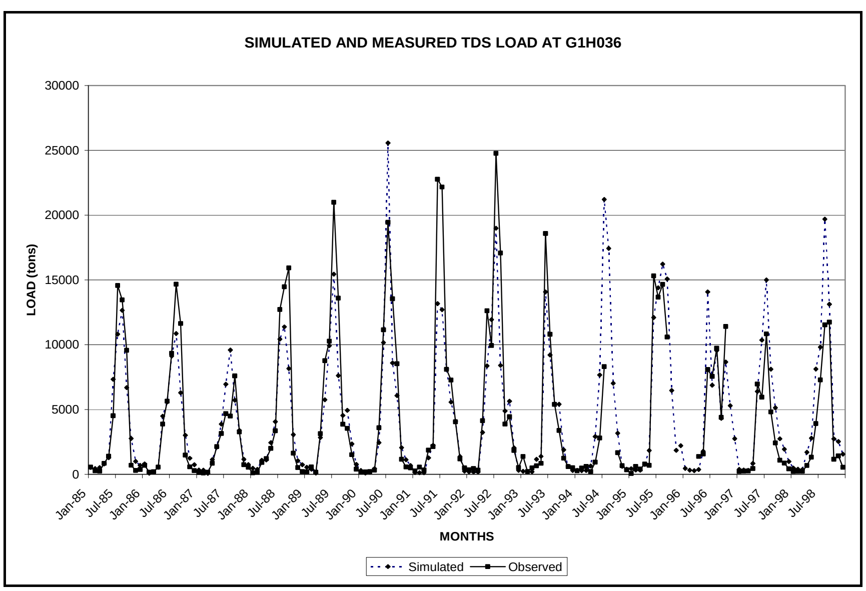

SIMULATED AND MEASURED FLOW AT G1H041
VOLUME (Mm3)
0
5
10
15
20
25
30
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

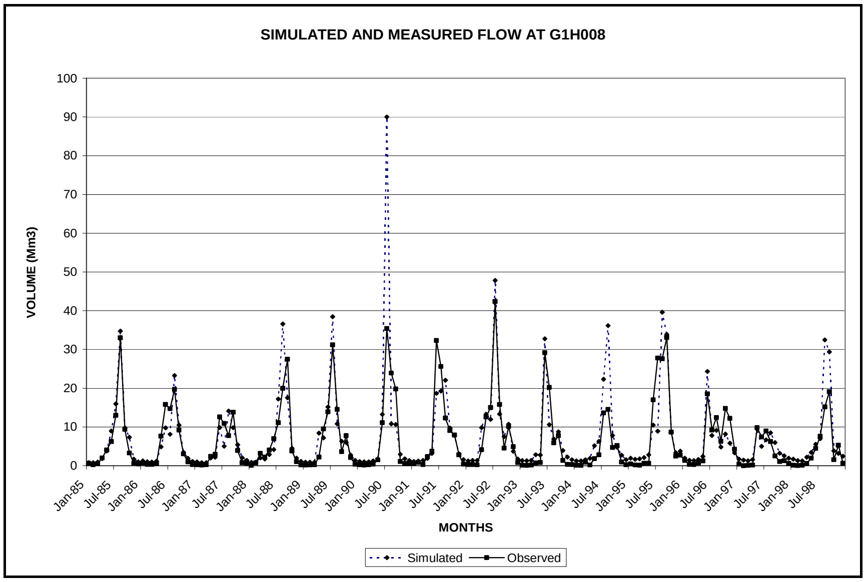

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H041
TDS (mg/l)
0
100
200
300
400
500
600
700
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

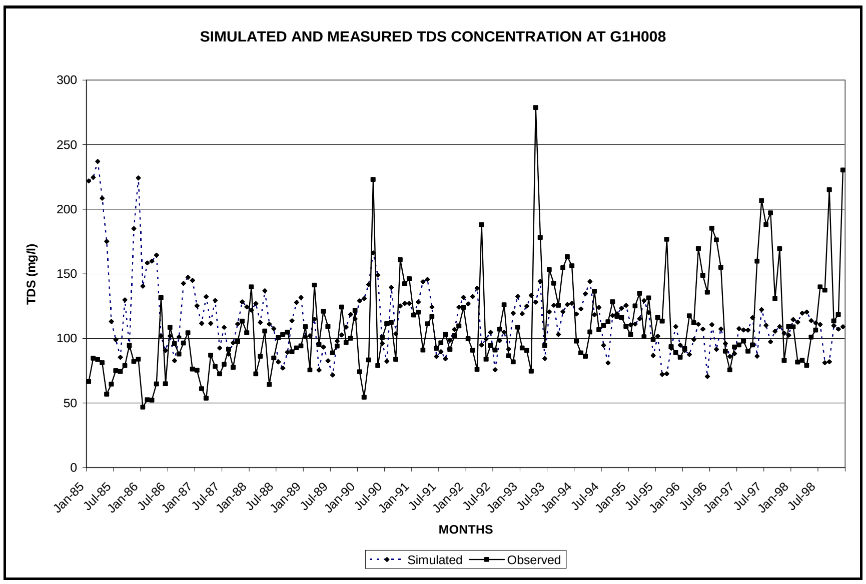

SIMULATED AND MEASURED TDS LOAD AT G1H041
LOAD (tons)
0
500
1000
1500
2000
2500
3000
3500
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

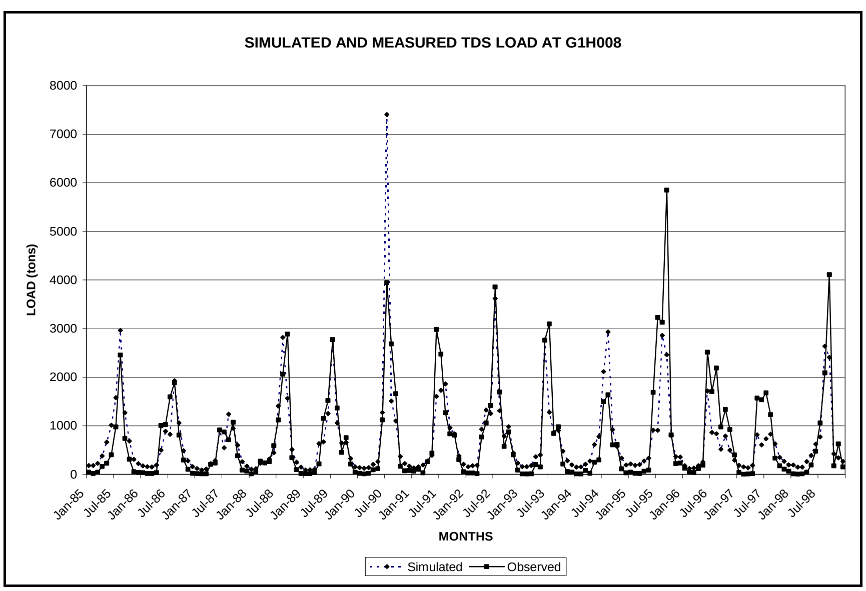

SIMULATED AND MEASURED FLOW AT G1H036
VOLUME (Mm3)
MONTHS
Simulated
Observed

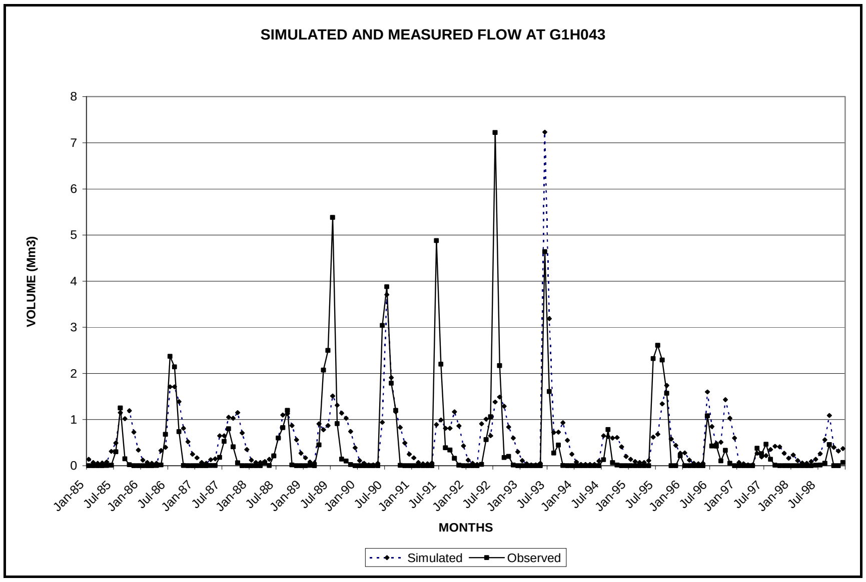

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H036
TDS (mg/l)
MONTHS
Simulated
Observed

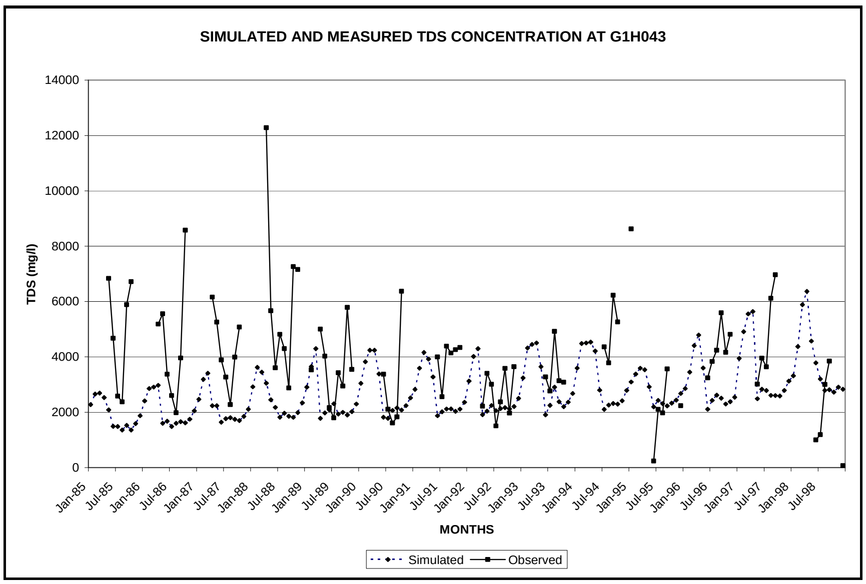

SIMULATED AND MEASURED TDS LOAD AT G1H036
LOAD (tons)
MONTHS
Simulated
Observed

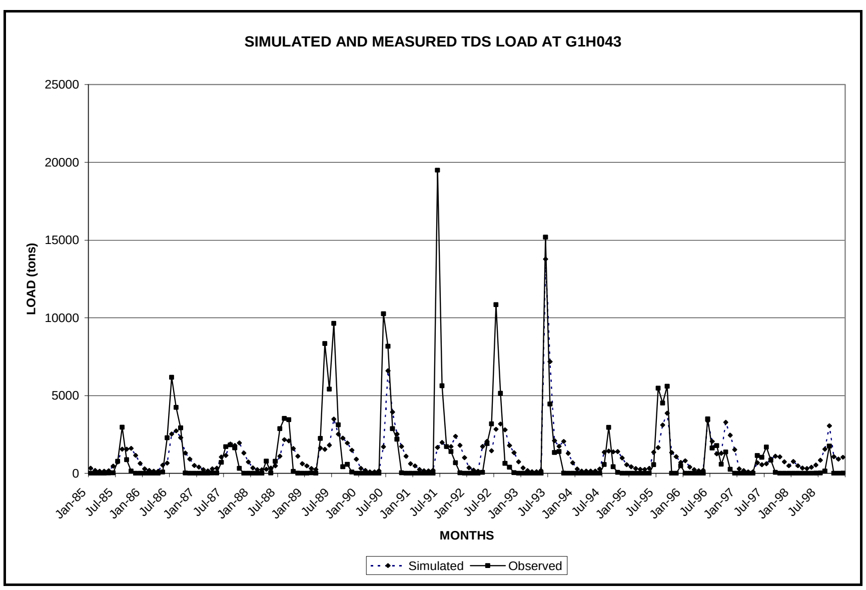

SIMULATED AND MEASURED FLOW AT G1H008
VOLUME (Mm3)
MONTHS
Simulated
Observed

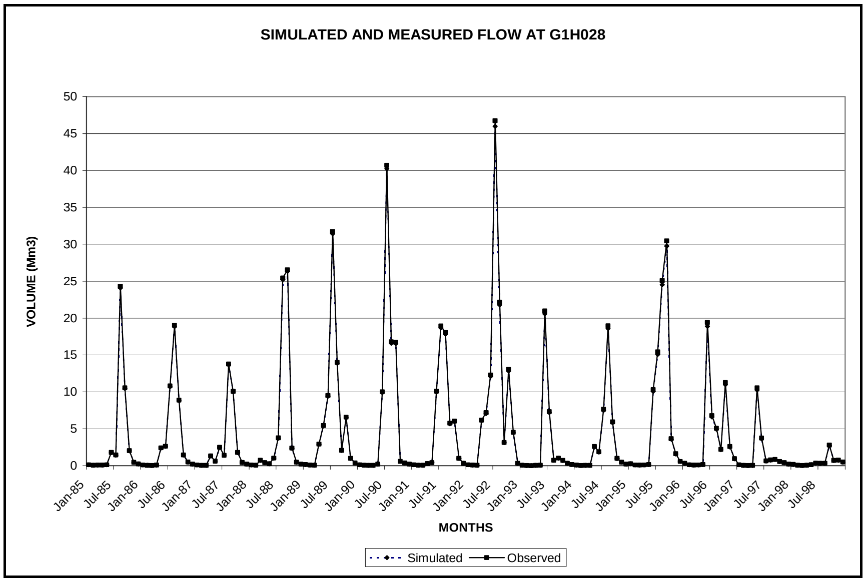

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H008
TDS (mg/l)
MONTHS
Simulated
Observed

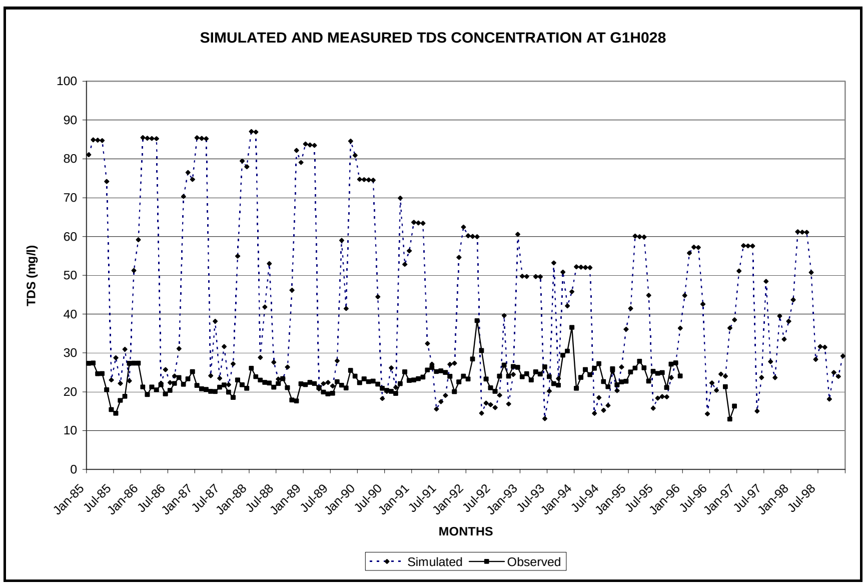

SIMULATED AND MEASURED TDS LOAD AT G1H008
LOAD (tons)
MONTHS
Simulated
Observed

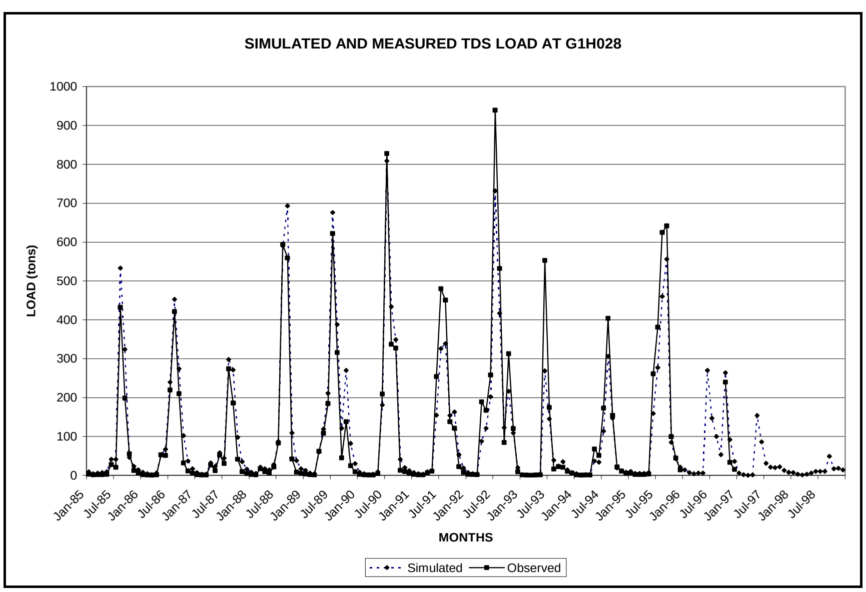

SIMULATED AND MEASURED FLOW AT G1H043
VOLUME (Mm3)
0
1
2
3
4
5
6
7
8
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

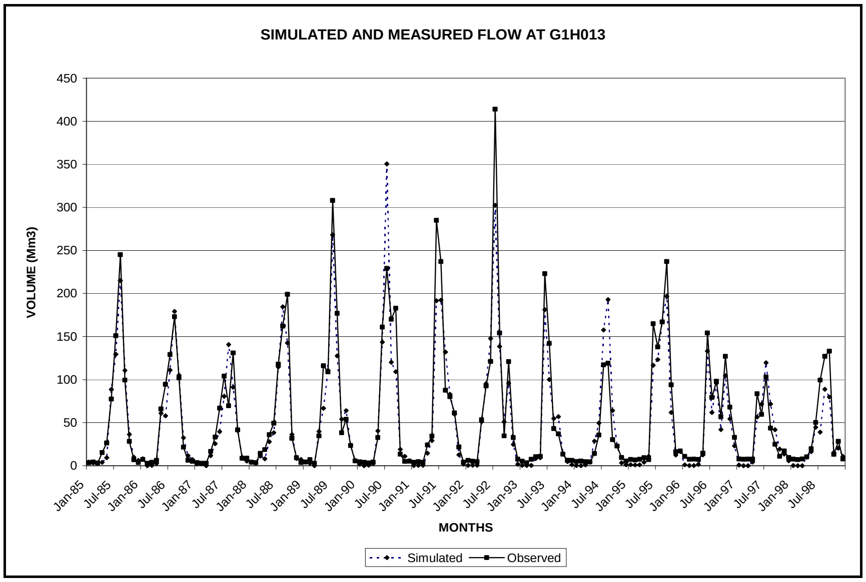

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H043
TDS (mg/l)
0
2000
4000
6000
8000
10000
12000
14000
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

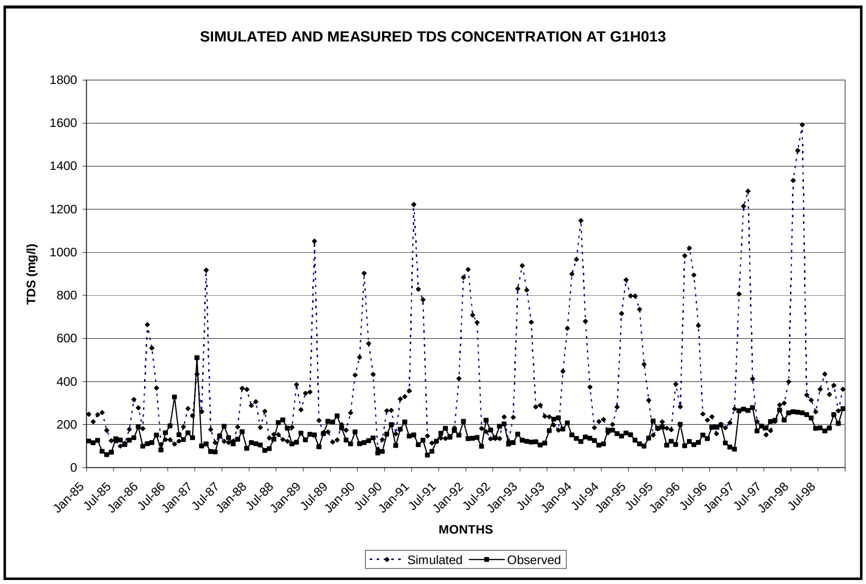

SIMULATED AND MEASURED TDS LOAD AT G1H043
LOAD (tons)
0
5000
10000
15000
20000
25000
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

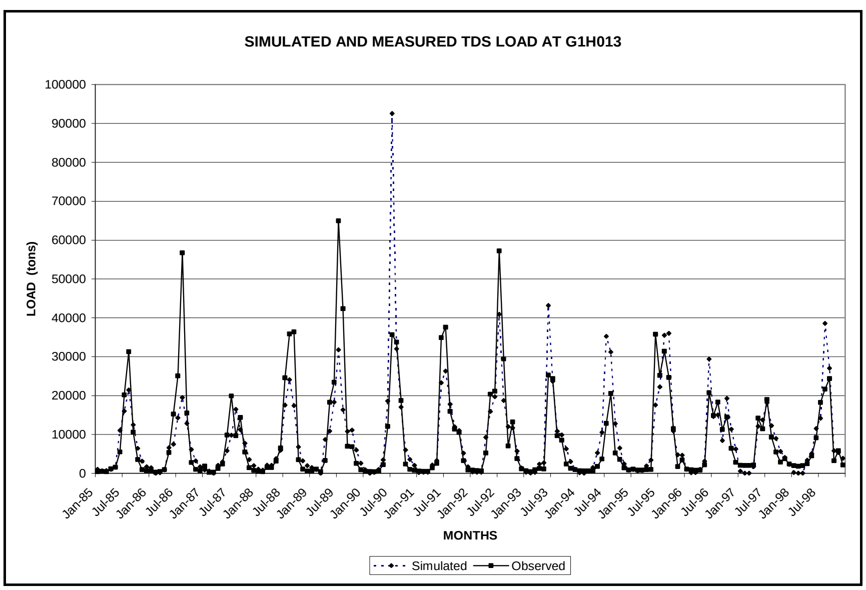

SIMULATED AND MEASURED FLOW AT G1H028
VOLUME (Mm3)
0
5
10
15
20
25
30
35
40
45
50
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

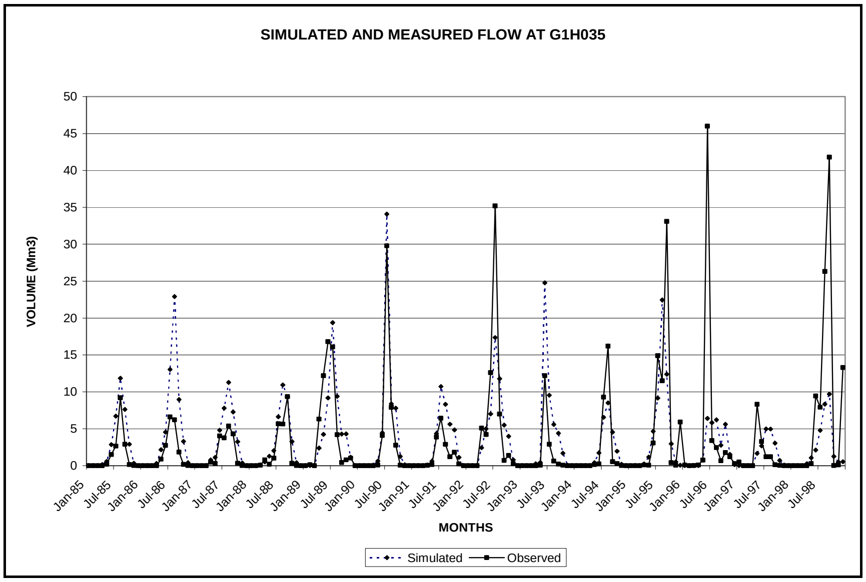

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H028
TDS (mg/l)
0
10
20
30
40
50
60
70
80
90
100
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

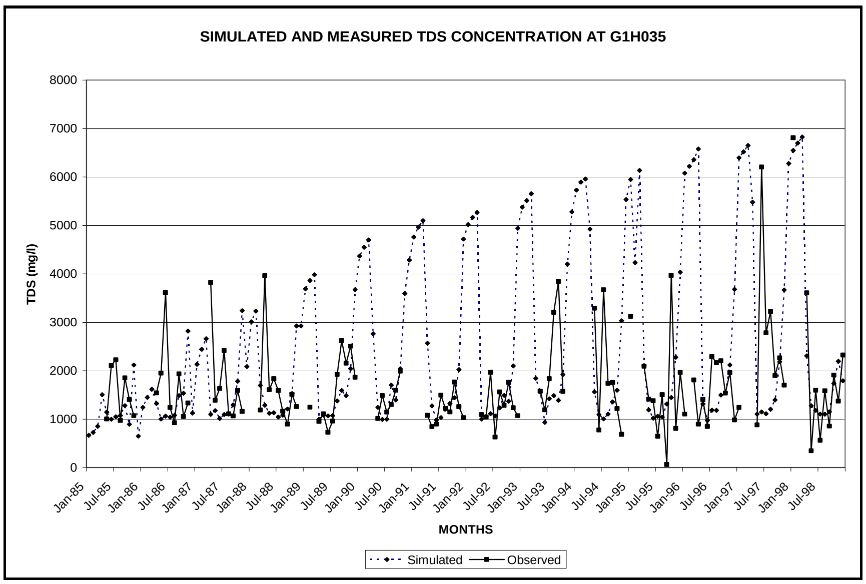

SIMULATED AND MEASURED TDS LOAD AT G1H028
LOAD (tons)
0
100
200
300
400
500
600
700
800
900
1000
Jan-85
Jul-85
Jan-86
Jul-86
Jan-87
Jul-87
Jan-88
Jul-88
Jan-89
Jul-89
Jan-90
Jul-90
Jan-91
Jul-91
Jan-92
Jul-92
Jan-93
Jul-93
Jan-94
Jul-94
Jan-95
Jul-95
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
MONTHS
Simulated
Observed

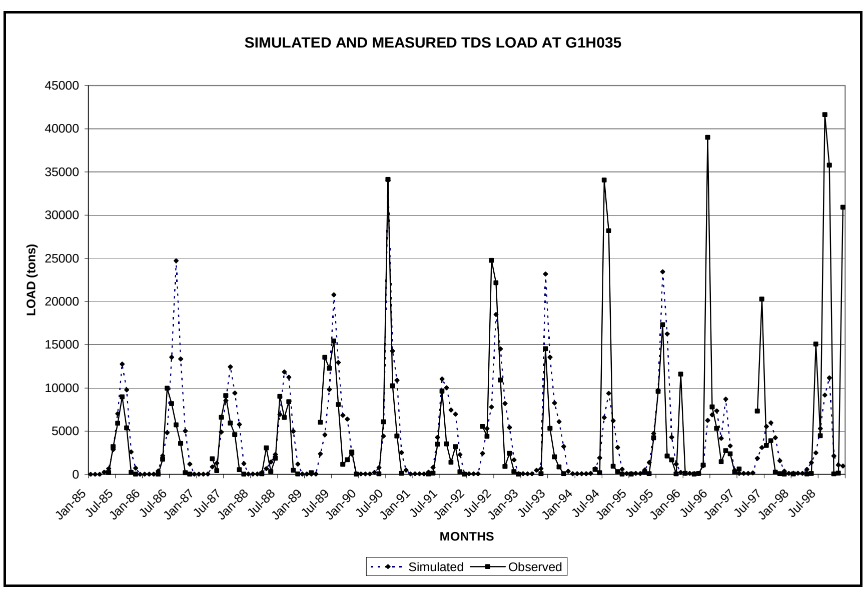

SIMULATED AND MEASURED FLOW AT G1H013
VOLUME (Mm3)
MONTHS
Simulated
Observed

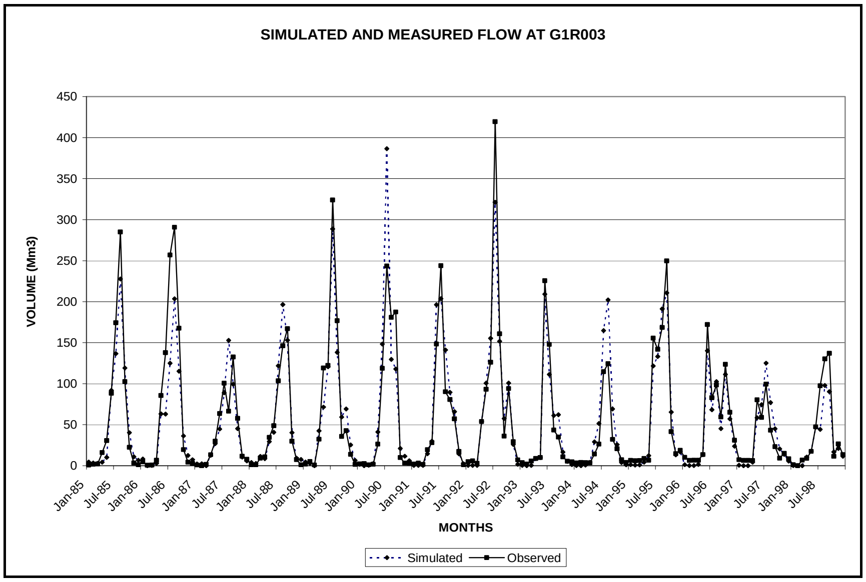

SIMULATED AND MEASURED TDS CONCENTRATION AT G1H013
TDS (mg/l)
MONTHS
Simulated
Observed

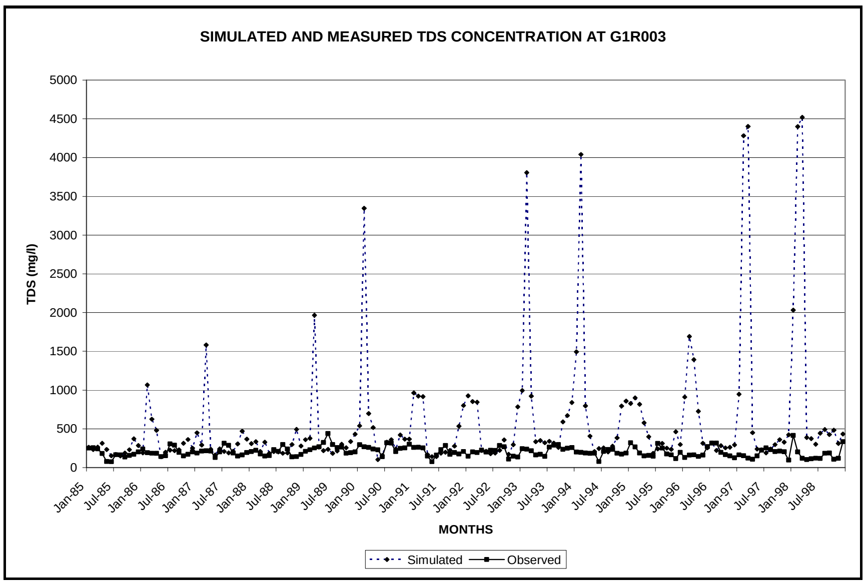

SIMULATED AND MEASURED TDS LOAD AT G1H013
LOAD (tons)
MONTHS
Simulated
Observed

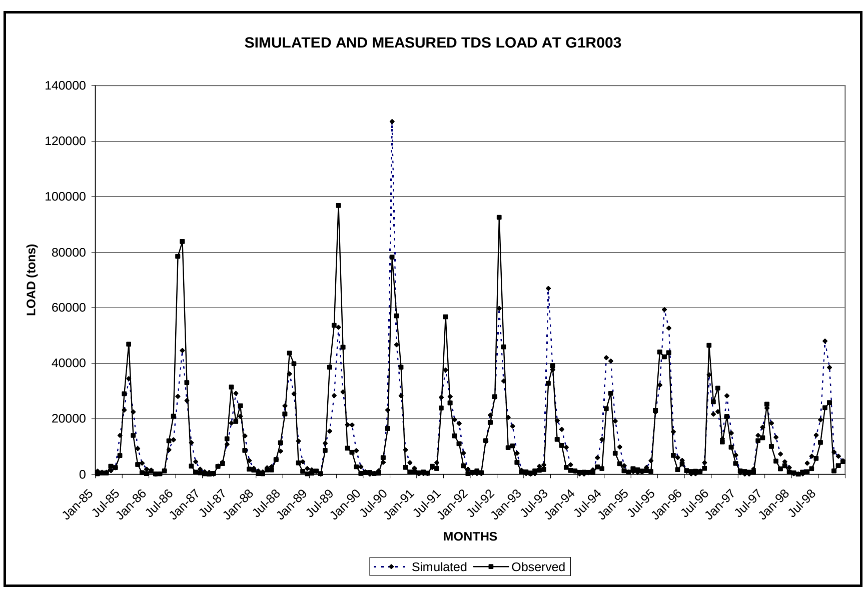

SIMULATED AND MEASURED FLOW AT G1H035
VOLUME (Mm3)
MONTHS
Simulated
Observed


SIMULATED AND MEASURED TDS CONCENTRATION AT G1H035
TDS (mg/l)
MONTHS
Simulated
Observed


SIMULATED AND MEASURED TDS LOAD AT G1H035
LOAD (tons)
MONTHS
Simulated
Observed


SIMULATED AND MEASURED FLOW AT G1R003
VOLUME (Mm3)
MONTHS
Simulated
Observed


SIMULATED AND MEASURED TDS CONCENTRATION AT G1R003
TDS (mg/l)
MONTHS
Simulated
Observed


SIMULATED AND MEASURED TDS LOAD AT G1R003
LOAD (tons)
MONTHS
Simulated
Observed