APPENDIX B:

SOURCE CATCHMENTS & RECEIVING WATER QUALITY MODELLING REPORT

A part of BMT in Energy and Environment

Moreton Bay TWCMP Source Catchment and Receiving Water Quality Modelling Summary

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Moreton Bay TWCMP: Source Catchment and Receiving Water Quality Modelling Summary

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1 INTRODUCTION

1.1 Study Objectives

This report presents the construction, calibration process, execution of and the scenario analysis with the coupled catchment and receiving water quality modelling structure used in support of the Total Water Cycle Management Plan (TWCMP) for Moreton Bay Regional Council (MBRC). This modelling scheme was established to assess the following study objectives:

- Quantify existing catchment loads (Total Nitrogen, Total Phosphorous and Suspended Solids) from the MBRC area;
- Assess the existing impacts of these catchment loads on receiving water quality in Moreton Bay and the associated estuaries;
- Establish sustainable loads coming from the MBRC areas; and
- Evaluate the potential impacts of land use management plans and the Total Water Cycle Management Plan on the receiving water quality in Moreton Bay and associated estuaries.

1.2 Model Framework

In order to assess the potential impacts associated with land use development and water management in the MBRC area, an integrated modelling framework was implemented to assess the following key catchment and receiving water quality processes:

- Lot scale water balance modelling – the eWater CRC Urban Developer model was adopted (see Appendix A of the TWCMP report);
- Catchment flows and pollutant loads – the eWater CRC Source Catchments model was adopted (see Section 2 of this report) to simulate flows and pollutant loads used to inform the receiving water quality modelling. Future development scenarios incorporated the TWCMP, flow and load reductions using MUSIC and Urban Developer and integrated with Source Catchments;
- Whole of Moreton Bay and associated estuarine hydrodynamics and water quality – a customised version of the Healthy Waterways Partnership Receiving Water Quality Model (referred to herein as *RWQM V2*) was adopted (see Section 3 of this report) utilising flows and pollutant loads from Source Catchments as boundary conditions for existing and future scenarios*.*

A conceptual diagram illustrating how results from these varying modelling packages were interfaced is provided in Figure 1-1.

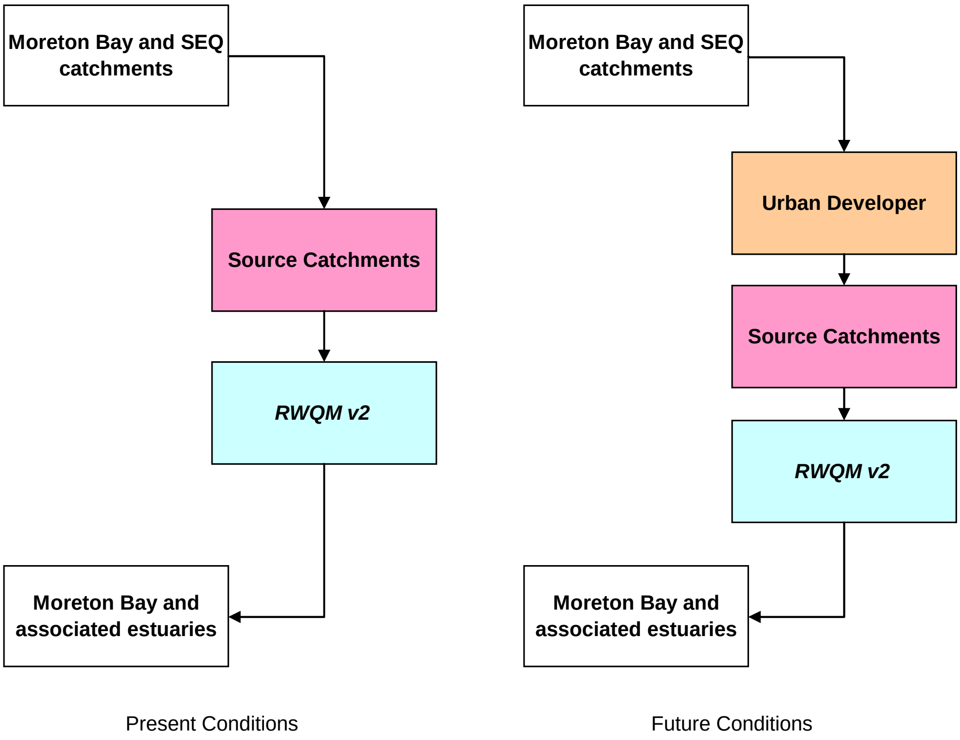


Figure 1-1 Integrated Modelling Conceptual Diagram

2 CATCHMENT MODELLING

2.1 Overview

Source Catchments was used in this study to define the catchment derived flows and associated loads of diffuse pollutants entering Moreton Bay and its contributing estuaries.

The Source Catchment modelling framework was developed by the eWater CRC (Argent et al 2008a, 2008b), a federally funded Cooperative Research Centre combining Australia's pre-eminent research organisations, State Government water regulators and industry practitioners. Details of the Source Catchments data requirements and model construction methodology are described in the following sections, together with a description of the model calibration performance. This section also presents the mean annual loads generated by the MBRC catchments and the major river catchments including a discussion of these results..

2.2 Source Catchments Model

The Source Catchments model developed for the Moreton Bay Catchment and contributing estuaries as applied by this project has been built upon many years of previous catchment investigation in the South East Queensland (SEQ) by BMT WBM staff and other local researchers (BMT WBM 2010a). Figure 2-1 shows an example screenshot of the catchment model and outputs.

The hydrologic model (i.e. rainfall to runoff) used within Source Catchments for this study was the SIMHYD daily runoff model. SIMHYD is a conceptual rainfall-runoff model that estimates daily stream flow based on daily rainfall and evapotranspiration data (Chiew and Siriwardena 2005). The SIMHYD model incorporates 7 hydrologic parameters, and 2 additional parameter that address pervious and impervious areas. The pollutant export modules used for this study were event mean concentrations (EMC) for simulating export rates during storm events and dry weather concentrations (DWC) for simulating exports rates during dry periods. Data sets used to build the model are described below.

2.2.1 Subcatchment Map

A subcatchment map of the Moreton Bay catchment area was developed from the existing SEQ model (BMT WBM 2010) and adapted to integrate with the hydrodynamic *RWQM V2* model. Additional catchment delineation was performed using a BMT WBM Digital Elevation Model (DEM) of the SEQ region. This task allowed for flows and loads of individual catchments that drain to Moreton Bay to be captured discreetly for the *RWQM V2*. The majority of these catchment delineations occurred in the Caboolture and Pine River catchments for which the *RWQM V2* has numerous inputs at those locations. The Moreton Bay Regional Council catchments were derived from the previous Moreton Bay Regional Council Catchment Water Quality Model report (BMT WBM 2010b).. The final subcatchment map is shown in Figure 2-2.

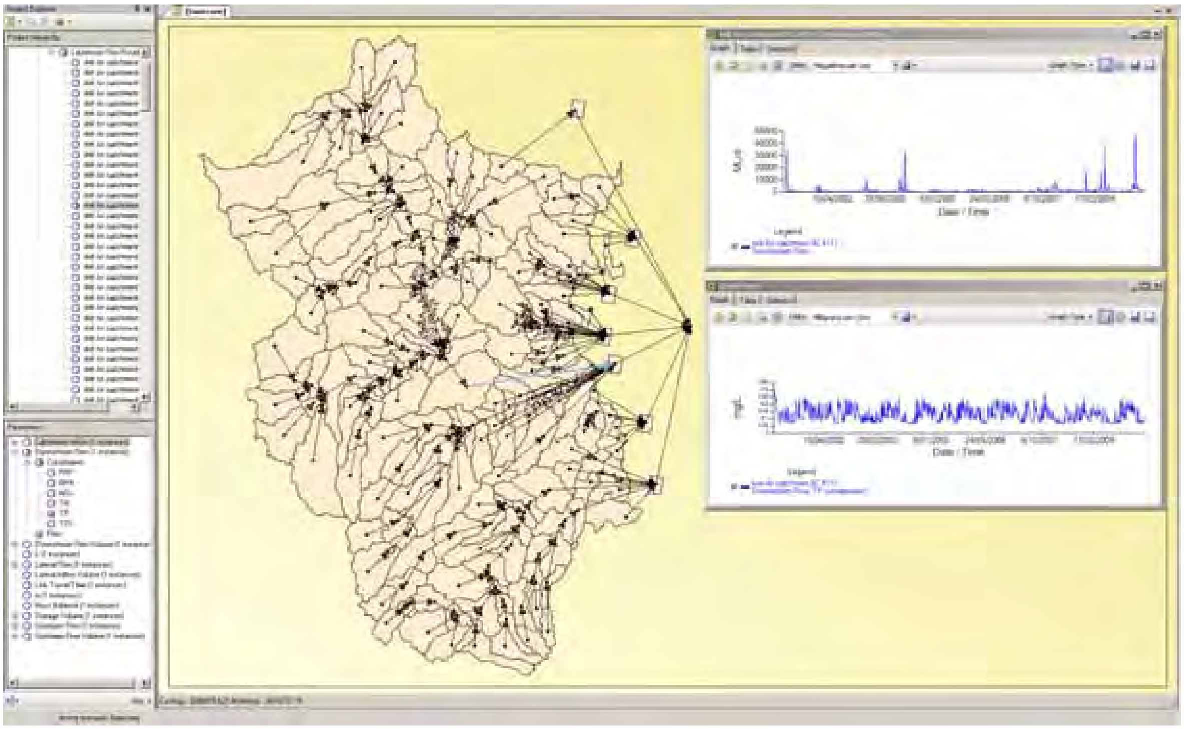
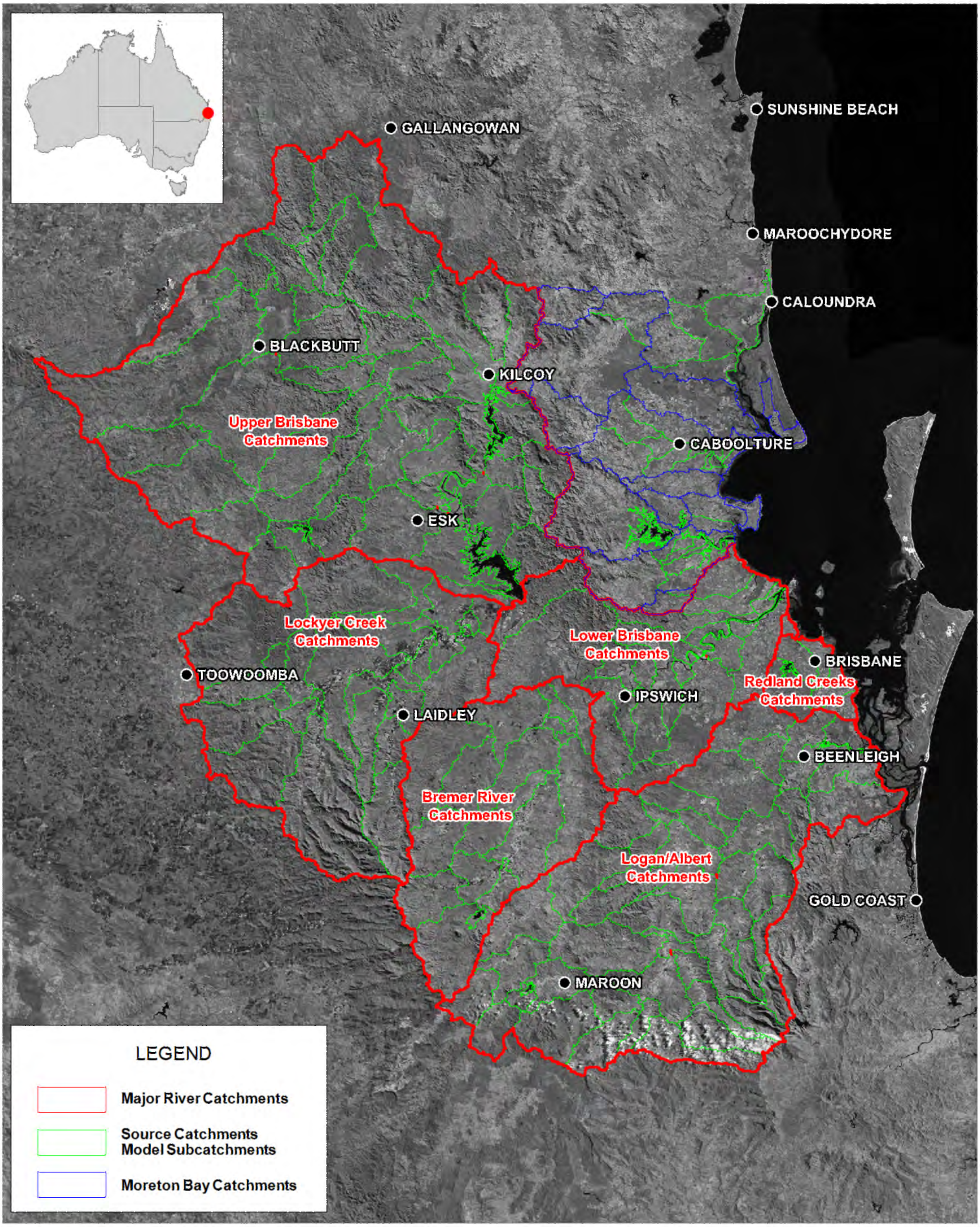


Figure 2-1 MBRC Catchment Model

2.2.2 Land Use

Land use is an important data requirement of Source Catchments and is a key driver of flows and diffuse load predictions. In the case of the model developed for this study, the land use mapping data for the MBRC catchments was obtained from Council on the 26 May 2010 and is based on the Digital Cadastral Database (DCDB). Land use within this dataset was grouped into 19 broad categories containing 65 specific categories. In order to make the modelling more efficient, this dataset was modified to reduce the total number of land uses from 65 down to 8 based on similar hydrological configurations for the region. For the areas outside of the MBRC catchments, the most recent (2006) regional land use mapping data for SEQ was obtained from the Department of Environmental and Resource Management (DERM).

The combined land use sets were classified by functional units for the purpose of catchment modelling for efficiency because similar land use designations have similar hydrologic and pollutant export characteristics. The land use categorisation into functional units is presented in Appendix A. The functional units for the entire catchment are illustrated in Figure 2-3. The origins of the hydrologic and pollutant export parameters are described in Section 2.3 and Section 2.4, respectively. A summary of the total areas per functional unit is provided in Table 2-1.



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Model Subcatchment Boundaries

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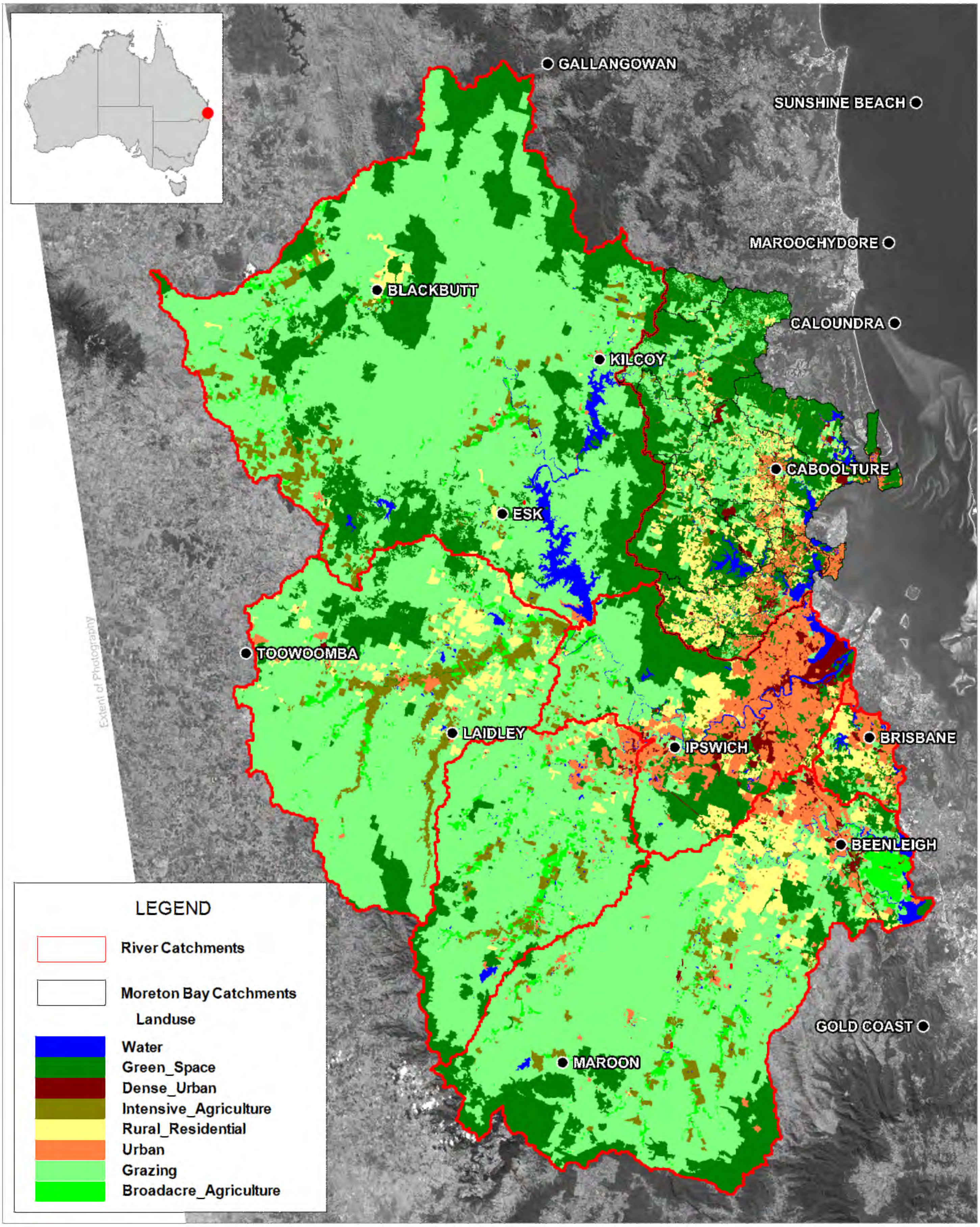

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MBRC and SEQ Source Catchments Functional Unit

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Table 2-1 Functional Units Area (km²)

Catchment	Broadacre Agriculture	Dense Urban	Grazing	Green Space	Intensive Agriculture	Rural Residential	Urban	Water	Total
Bribie Island	0.0	1.4	0.3	30.5	0.0	0.2	9.0	0.9	42.3
Brisbane Coastal Creeks	0.0	0.5	5.1	17.0	0.3	1.3	14.3	0.1	38.5
Burpengary Creek	0.0	6.0	12.9	23.5	0.0	20.9	17.1	3.6	83.9
Byron Creek	0.0	0.0	2.6	3.8	0.0	0.0	0.1	0.0	6.6
Caboolture River	0.0	15.8	99.2	114.5	0.4	74.5	36.2	7.8	348.3
CIGA	0.0	0.1	27.9	9.3	0.0	2.4	1.2	0.0	40.9
Hays Inlet	0.0	5.4	2.1	25.1	1.3	11.3	27.1	6.2	78.4
Lower Pine River	0.0	8.4	10.5	109.5	2.8	101.7	55.8	14.8	303.6
Mary River	0.0	0.0	30.2	55.3	1.7	0.7	1.2	0.1	89.2
Neurum Creek	0.0	0.0	53.3	70.3	1.5	1.8	2.3	0.8	130.2
Pumicestone Creeks	0.0	2.9	50.1	140.2	1.1	13.0	10.8	13.6	231.8
Redcliffe	0.0	1.9	0.3	2.8	0.0	0.1	14.7	4.9	24.7
Sideling Creek	0.0	3.1	7.8	17.9	0.2	18.9	2.7	1.1	51.6
Stanley River	0.0	0.9	178.1	251.9	3.2	17.6	12.4	3.2	467.2
Upper Pine River	0.0	1.9	48.2	192.9	7.6	77.7	10.0	17.7	355.9
MBRC Total	**0.0**	**48.1**	**528.7**	**1064.5**	**20.1**	**342.0**	**214.9**	**74.7**	**2293.1**
Bremer River	92.2	6.1	1395.0	182.7	75.5	28.3	73.3	13.3	1866.4
Lockyer	78.2	5.9	2133.4	293.9	216.6	171.7	34.9	11.0	2945.6
Logan-Albert	157.3	33.2	2482.4	698.6	150.9	280.6	167.9	48.8	4019.8
Lower Brisbane	19.3	120.2	524.9	423.2	27.7	154.2	500.1	59.4	1829.0
Redlands	0.8	7.7	26.2	66.3	10.3	67.4	83.8	14.9	277.2
Upper Brisbane	96.5	5.7	4256.7	1786.5	229.2	135.5	31.1	178.5	6719.6
Remaining Total	444.3	178.7	10818.6	3451.2	710.1	837.7	891.1	325.9	17657.6
Total	**444.3**	**226.9**	**11347.3**	**4515.8**	**730.2**	**1179.7**	**1106.0**	**400.6**	**19950.7**

2.2.3 Climate – Rainfall and Evaporation

Rainfall and evapotranspiration data are fundamental to the development and execution of catchment modelling. Gridded daily rainfall and potential evapotranspiration (PET) data sets for the entire South East Queensland catchments provided via the DERM SILO database were used in this study (DNRW 2010). The data encompassed the period from 1/1/1980 to 31/5/2009.

Annual average rainfall patterns derived from this data set are illustrated in Figure 2-4 for two catchments, the Pumicestone creeks catchments and the upper Bremer River. Annual average potential evapotranspiration data are shown in Figure 2-5 for the same catchments. As demonstrated by these figures, there can be wide variability in rainfall and PET across the modelled domain, hence the importance of having spatially varying gridded climate data.

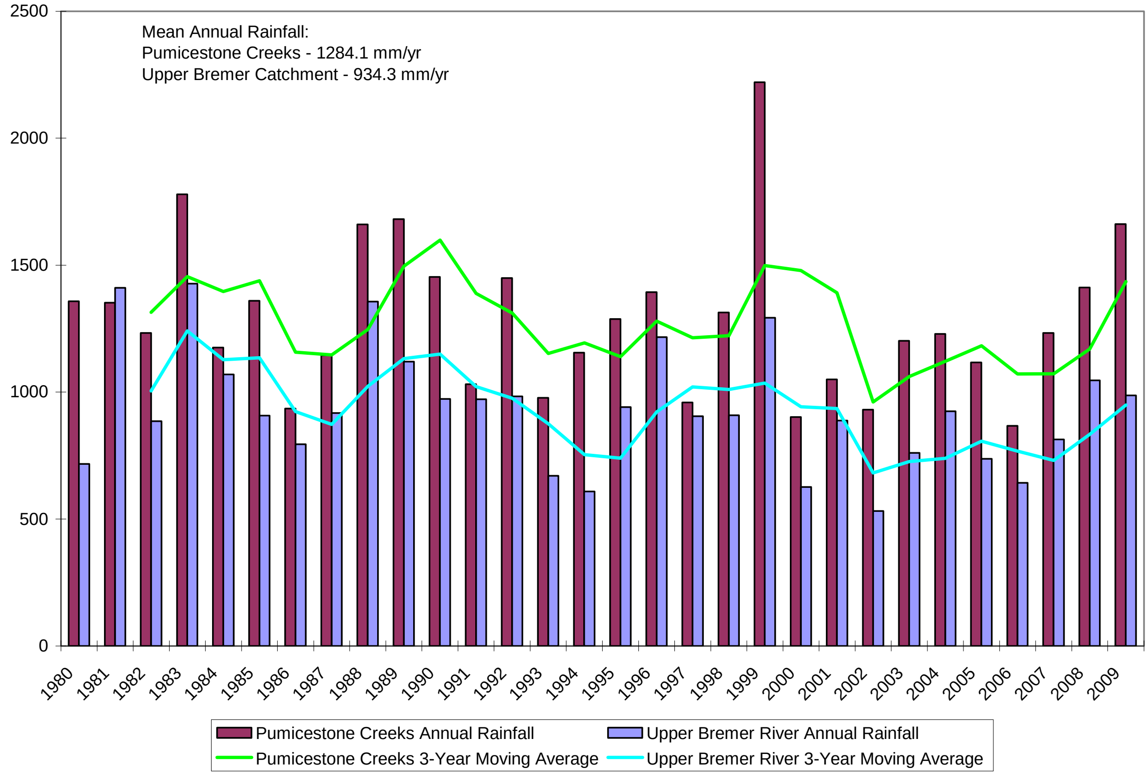


Figure 2-4 SILO – Total Yearly Rainfall Data – South East Queensland Average

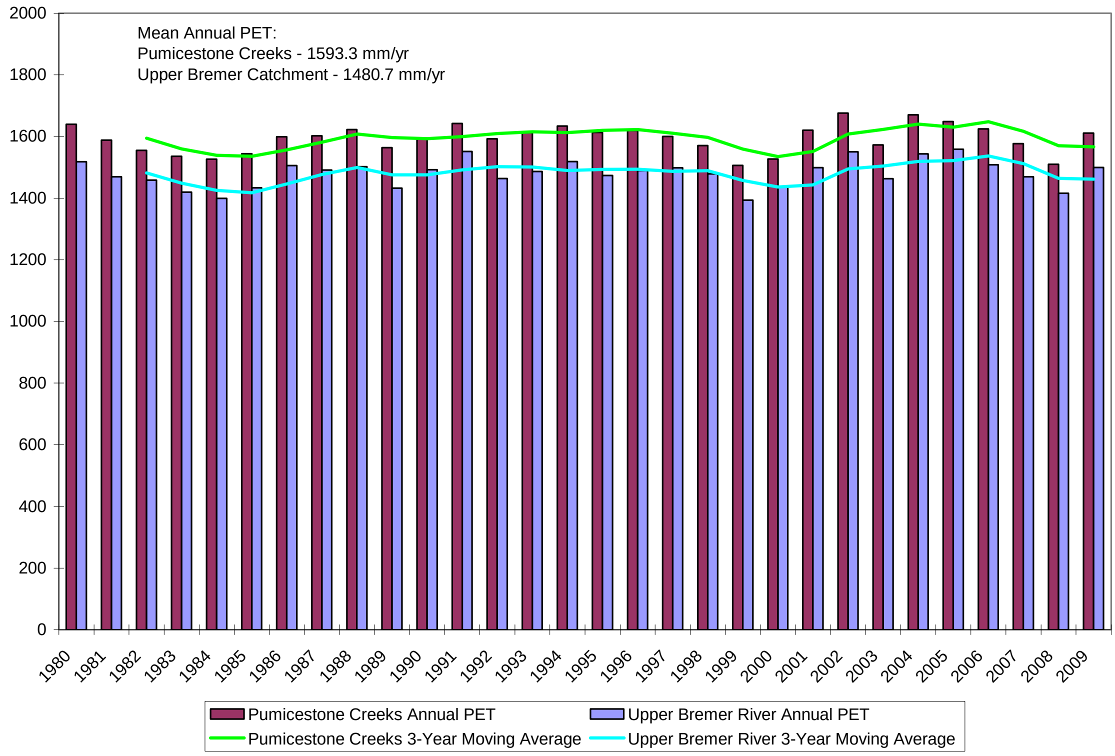


Figure 2-5 Total Yearly Potential Evaporation – South East Queensland Average

2.2.4 Water Storages, Withdrawals and Point Sources

Water storages for this Source Catchment model consisted of the Wivenhoe Dam and the North Pine Dam. In both cases rules for determining storage volume, level and spill amounts were unavailable for this study. As an alternative, daily flows from the Wivenhoe Tailwater gauging station were sourced from DERM (2011) for the period of May 1986 through to June 2010. The data were input directly within the *RWQM V2* to representing discharge from the Dam. Figure 2-6 shows the locations of these dams and the withdrawal locations.

The best available daily flow data for the North Pine Dam was the historical average monthly release volumes extracted from the previous Source Catchment model (known as EMSS). These monthly volumes were distributed into daily release volumes and repeated annually for the period of the study. Table 2-2 shows the monthly release volumes.

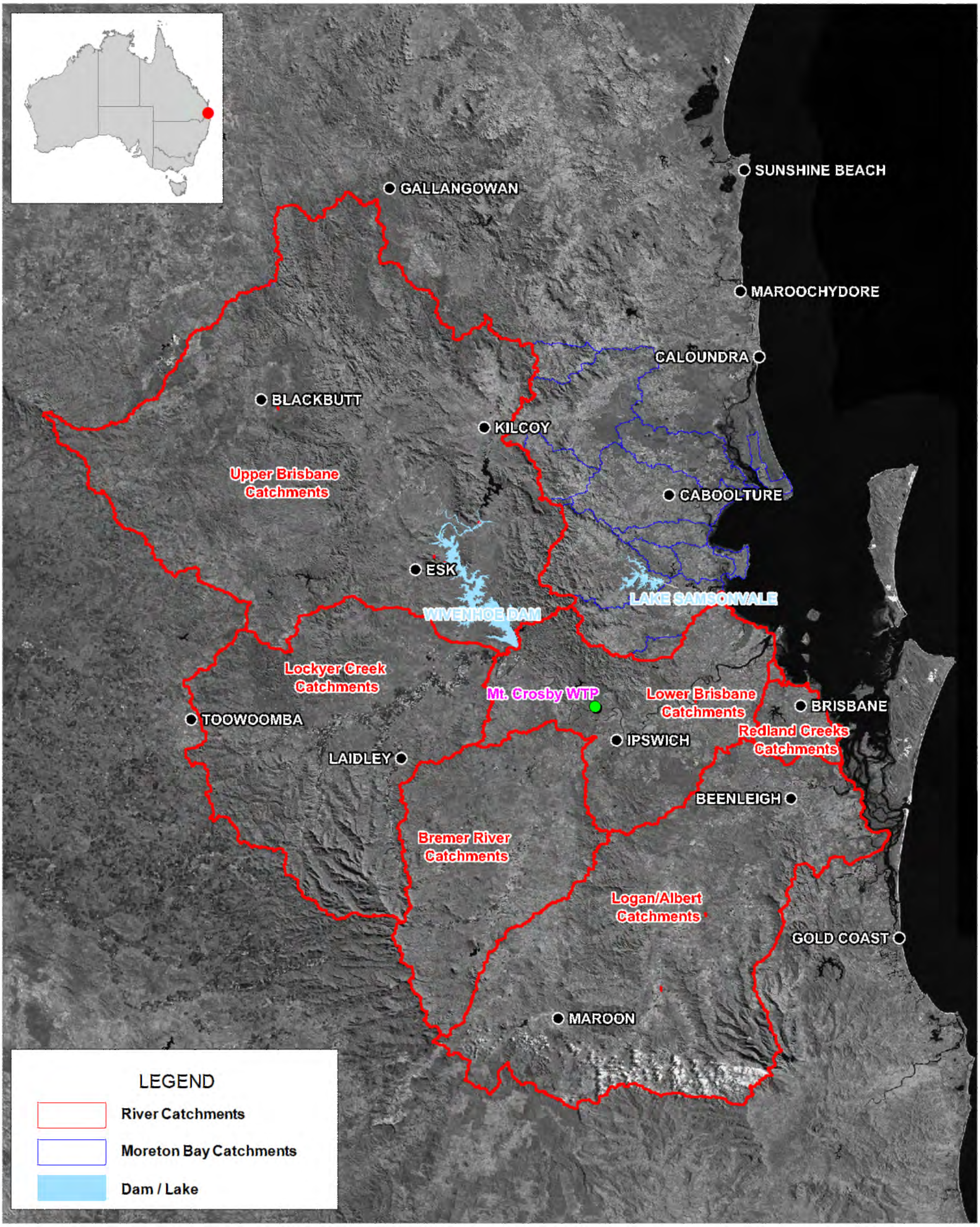
Similarly, no historical daily data were available for system withdrawals at these Dams. The withdrawals for the Mt. Crosby water treatment plant (WTP) at Wivenhoe Dam was based on previous knowledge of the operations of the plant and were estimated at two-thirds of the flows released from the dam with a maximum of 1,000 megalitres per day (MLD). That is, if on a particular day flows were greater than 1,000 MLD, only 667 MLD was withdrawn. Withdrawals for the North Pine Dam occur prior to discharge of water from the dam and were therefore not included in the model.

Lake Kurwongbah was not included in the analysis due to the lack of available daily release data. Due to the size of this storage it is not anticipated this will have any significance on the modelling.

Point sources (e.g., municipal sewage treatment plants and industrial process water discharges) were not used in the Source Catchments model. Point sources were however included in the receiving water quality model.

Table 2-2 North Pine Dam Monthly Releases and Withdrawals

Month	Release ML/month
January	4526
February	5432
March	13237
April	9180
May	6107
June	4860
July	4061
August	3906
September	5160
October	5704
November	4680
December	5239



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Modelled Storages and Withdrawals

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2.3 Source Catchments Hydrologic Calibration

Calibration of the hydrologic model was conducted on 10 gauges in the SEQ region using the Parameter Estimation Tool (PEST) developed by John Doherty and Watermark Numerical Computing (WNC 2005). PEST is a process that varies each SIMHYD parameter for each gauged region and for each functional unit to arrive at a least-squares best fit parameter set of the modelled data compared to the observed gauge data.

The 10 gauges represent the most downstream locations of the catchment model that interface directly with the *RWQM V2* described in Section 3. Figure 2-7 shows the locations of the 10 gauges used for calibration. The catchments above the Wivenhoe Dam were calibrated, however, because actual historical flows were used in the model immediately downstream of the Dam, the calibration of those catchments is not reported here.

There are no gauges downstream of the Wivenhoe Dam on the Lower Brisbane River to which the model could be calibrated. The hydrologic parameters of the nearest geographic neighbour catchment for which a calibration had been performed were therefore substituted for those catchments. Each gauge region, therefore, was calibrated separately to that region’s observed gauge data. Table 2-3 summarises the hydrologic parameterisation of the Caboolture River as an example. For further discussion of these refer to Chiew and Siriwardena (2005).

Table 2-3 Hydrologic Parameterization - Caboolture River, Example

SIMHYD Parameter	Broad Agriculture	Dense Urban	Grazing	Green Space	Intensive Agriculture	Rural Residential	Urban
Baseflow coefficient	0.083	0.305	0.083	0.735	0.083	0.401	0.305
Impervious Threshold (mm)	1.000	0.652	1.000	1.000	1.000	0.725	0.725
Infiltration coefficient	356.3	200.6	356.3	170.4	356.3	181.2	200.6
Infiltration shape	3.886	1.514	3.886	0.543	3.886	2.173	1.514
Interflow coefficient	0.065	0.341	0.065	0.407	0.065	0.311	0.341
Pervious fraction	1.000	0.961	1.000	1.000	1.000	1.000	1.000
Recharge coefficient	0.125	0.665	0.125	0.517	0.125	0.434	0.665
Rainfall interception storage capacity (mm)	2.165	2.297	2.165	5.000	2.165	4.432	2.297
Soil moisture storage capacity (mm)	226.3	184.0	226.3	500.0	226.3	56.2	184.0

The calibration process accounted for daily flows, monthly volumes and total volume as the means of arriving at the most suitable set of SIMHYD parameters. The process involved minimising the error between the observed and modelled daily, monthly, and total flow volumes. Ultimately, the calibration performance was assessed both quantitatively and quantitatively as described in the following subsections.

2.3.1 Quantitative Performance

Quantitative performance measures were used to provide lumped measures of average errors in representing observed data. The statistical performance of the hydrological parameterisation process was measured through the following two performance statistics:

1 Nash-Sutcliffe efficiency (NSE) coefficient: The NSE coefficient is commonly used to assess the predictive power of hydrological models. An efficiency of 1 corresponds to a perfect match of modelled discharge to the observed data. An efficiency of 0 indicates that the model predictions

are only as accurate as the mean of the observed data. An efficiency of less than 0 occurs when the observed mean is a better predictor than the model. The NSE coefficient were calculated on the daily and monthly flow volumes using the following equation (from Moriasi *et al*, 2007):

$$\mathrm{NSE} = 1 - \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n} \left(Y_i^{obs} - Y^{mean}\right)^2} \right]$$

2 Total volume percent bias (PBIAS): The average tendency of modelled data to be greater or less than the corresponding observed data. PBIAS is calculated on total modelled and observed volumes for the using the following equation (from Moriasi *et al*, 2007):

$$\mathrm{PBIAS} = \left[\frac{\sum_{i=1}^{n} \left(Y_i^{obs} - Y_i^{sim}\right) * (100)}{\sum_{i=1}^{n} \left(Y_i^{obs}\right)} \right]$$

Table 2-4 summarises the performance of the hydrologic model based on these indicators and Table 2-5 provides some general guidance in assessing these indicators. It should be noted that the performance ratings are for monthly time step values, whereas the model was calibrated to daily and total values, including monthly values. It is likely that these performance ranges are different for different time steps, though no literature was found to provide further guidance. Bolded entries in Table 2-4 indicate values outside of the range of the satisfactory ratings given in Table 2-5.

Table 2-4 Hydrological Calibration Model Performance

Gauge	No. of Observations		Daily NSE	Monthly NSE	Total Volume (GL)		PBIAS (%)
	Daily	Monthly			Model	Gauge	
142001A	11107	361	0.709	0.926	1177	1004	**17%**
142202A	10790	361	0.718	0.929	1409	1358	4%
143033A	10862	361	0.639	0.943	154	204	**-24%**
143107A	6774	132	0.620	0.861	413	408	**-16%**
143108A	9265	132	0.578	0.693	286	410	**-40%**
143113A	10890	361	**0.498**	0.818	322	357	-10%
143210B	4855	263	0.687	0.907	252	276	-9%
143303A	11073	361	0.652	0.938	1678	1729	-3%
145014A	11012	361	0.686	0.928	7001	7523	-7%
145196A	6617	264	0.652	0.925	4652	4598	1%

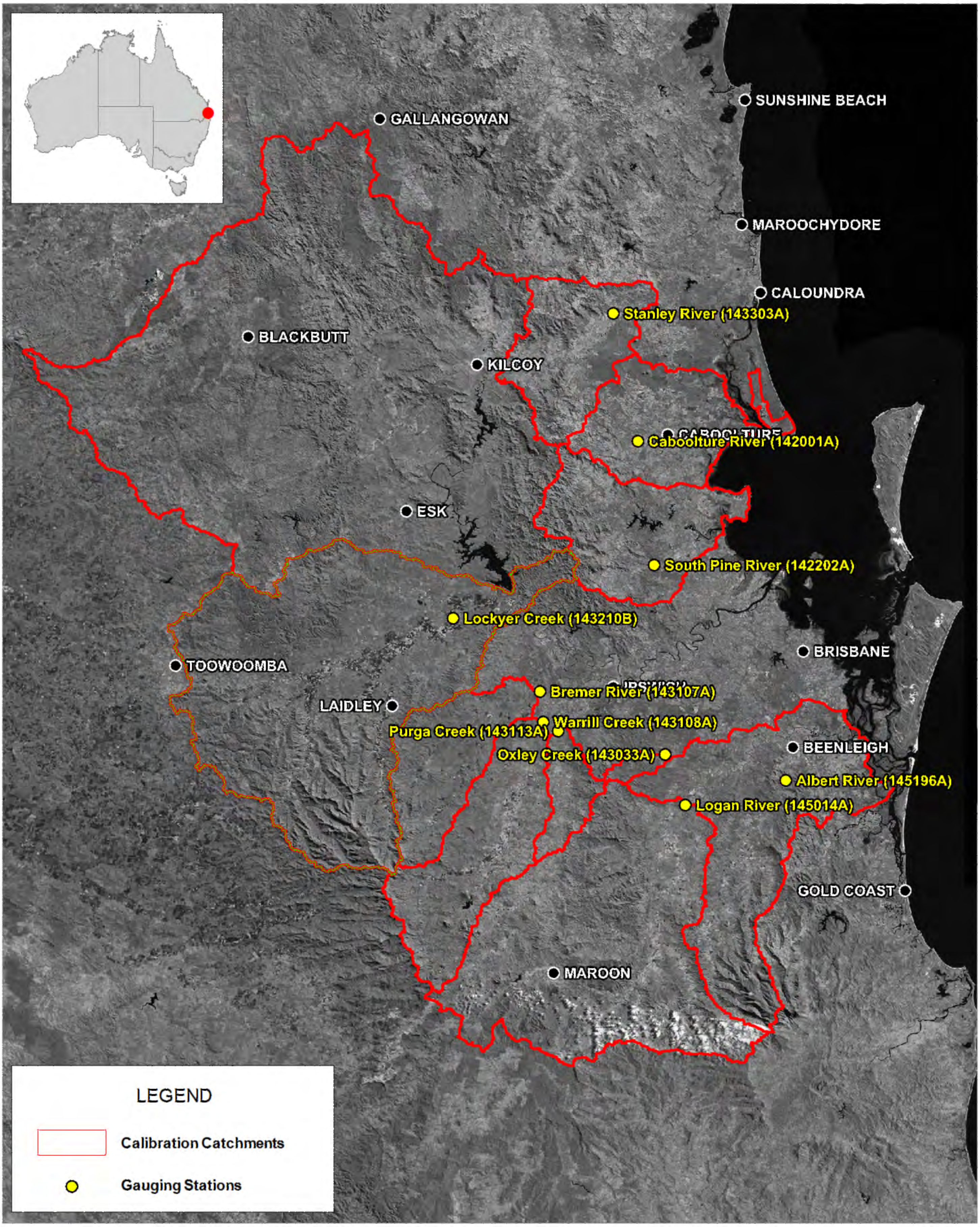
Table 2-5 General Performance Ratings for Recommended Statistics for a Monthly Time Step (adapted from Moriasi *et al* 2007)

Performance Rating	PBIAS (%)	NSE
Very Good	PBIAS < ±10	0.75 < NSE ≤ 1
Good	±10 ≤ PBIAS < ±15	0.65 < NSE ≤ 0.75
Satisfactory	±15 ≤ PBIAS < ±25	0.5 < NSE ≤ 0.65
Unsatisfactory	PBIAS ≥ ±25	NSE ≤ 0.5

While in some instances, some of the model performance indicators are outside of the recommended value ranges given in Table 2-5, it should be noted that these are indicators for models with a monthly time step, not a daily or total volume time step. Additionally, those catchments for which performance indicators are outside of the recommended value ranges, the other performance indicators of that catchment are generally satisfactory or higher. For example, while the daily NSE of the catchment above gauge 143113A is slightly less than 0.5, the monthly NSE and total volume PBIAS are very good and good respectively.

2.3.2 Qualitative Performance

A qualitative assessment of the model performance, daily time series plots of observed and modelled flows for a 3-year period from 1/7/2005 to 31/6/2008 were plotted for the Caboolture, South Pine River, and the Logan River, shown in Figure 2-8, Figure 2-9, and Figure 2-10 respectively. These plots show that the model replicates the behaviour of the catchments in response to climatic conditions. Overall, the model is capturing the peak flows rates and the model is able to represent the flood recession after the peak flows occur. This feature is important in capturing the total loads coming from the catchments for storm events. Additionally, the monthly and total volume performance indicators show that over time, runoff is accurately being modelled and includes both storm events and baseflow.



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Calibration Regions and Gauges

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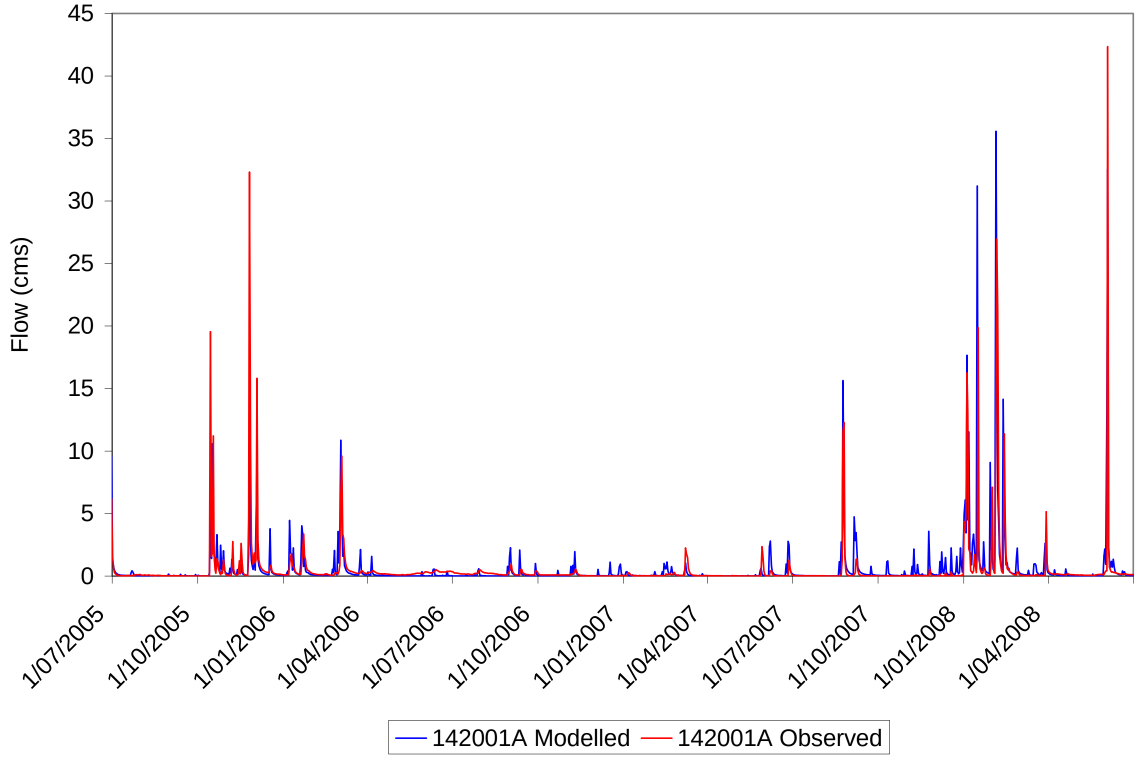


Figure 2-8 Representative Time Series Data, Measured and Modelled – Caboolture Gauging Station, 142001A

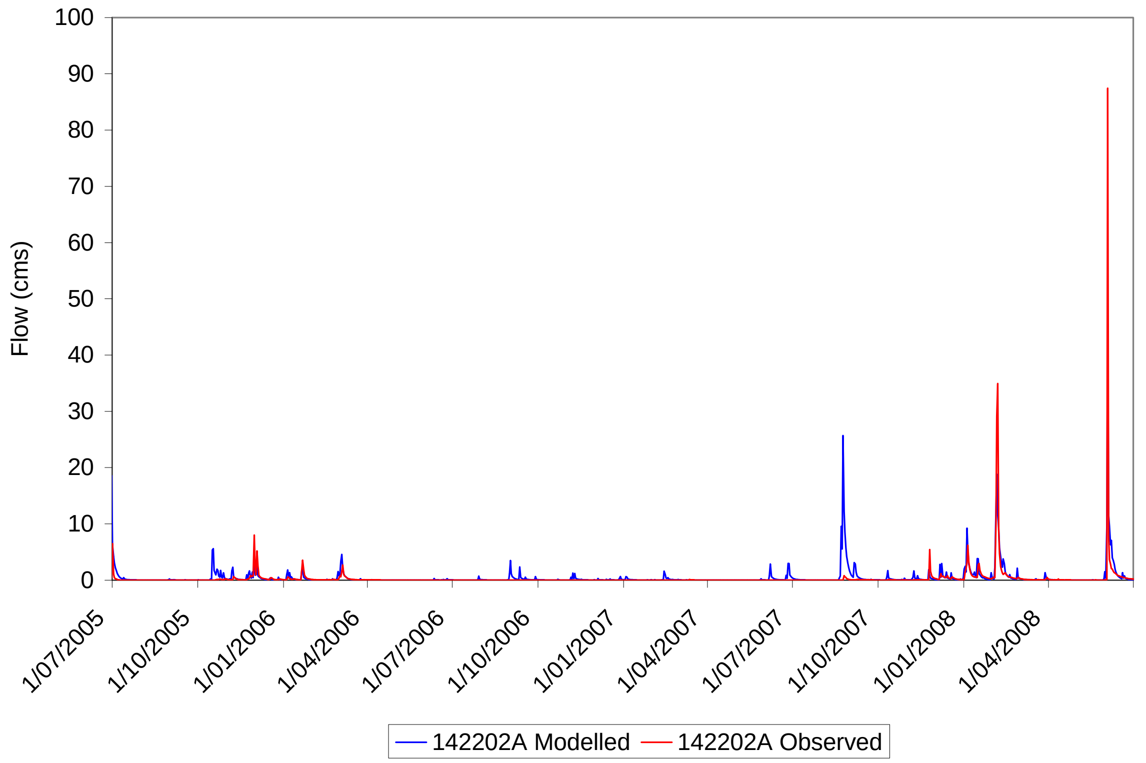


Figure 2-9 Representative Time Series Data, Measured and Modelled – South Pine River Gauging Station, 142202A

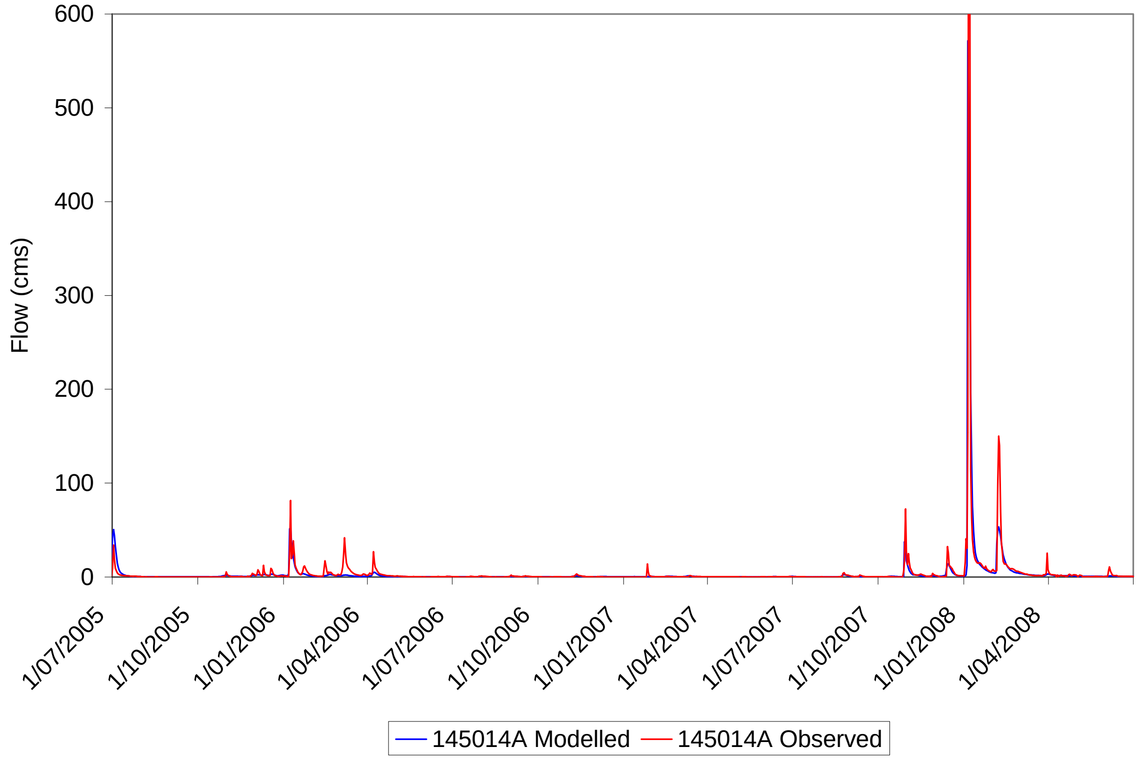


Figure 2-10 Representative Time Series Data, Measured and Modelled – Logan River Gauging Station, 145014A

2.4 Water Quality

Water quality parameterisation used for this study was the Event Mean Concentration (EMC) and Dry Weather Concentration (DWC) pollutant export process. Literature values have been used to derive and allocate EMC/DWC values for each land use represented by the model and these were applied across the entire catchment area. The data used was based on Chiew and Scanlon (2002) but updated through several sources including SEQWater, DERM and WBM as discussed in the original WBM MBRC catchment modelling report (BMT WBM 2010c). These values are given in Table 2-6.

Table 2-6 Water Quality Export Rates

	DWC (mg/L)			EMC (mg/L)		
Functional Use	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**
Green Space	7	0.4	0.03	20	1.5	0.06
Grazing	10	0.7	0.07	260	2.08	0.3
Broadacre Agriculture	10	0.7	0.07	300	1.95	0.321
Irrigated Agriculture	10	0.7	0.07	550	5.2	0.449
Rural residential	10	0.7	0.07	130	1.6	0.28
Urban	7	1.5	0.11	130	1.6	0.28

Pollutant export from storage releases were determined by taking long-term mean concentrations during baseflow periods from water quality monitoring stations downstream of the storage releases.

Table 2-7 Storage Pollutant Concentrations

Storage Name	Constituent		
	TSS (mg/L)	TN (mg/L)	TP (mg/L)
Wivenhoe Dam[a]	7.2	0.49	0.03
North Pine Dam[b]	4.0	0.56	0.06

[a] Source: DERM 2011, gauge 143035A

[b] Source: EHMP 2011, EHMP site 806

2.5 Existing Average Annual Loads

Following completion of the Source Catchment model construction and calibration process, the model was executed to determine the existing flows and loads into Moreton Bay and its estuaries from the contributing catchments. These loads are summarised in Table 2-8 below.

The flows and loads generated by this calibrated catchment model are consistent with previous catchment modelling performed for the MBRC (BMT WBM 2010b). The Caboolture River catchments produce the greatest amount of pollutants, even though the Stanley River catchments produce the greatest mean annual flows. This is likely because of the land use characterisations of the two catchments, with the Stanley River containing a greater proportion of green space, and the Caboolture River containing more rural residential and urban areas. The Caboolture and Upper and Lower Pine catchments contribute 51% of the total flows from the MBRC catchments, and 59%, 54%, and 58% of TSS, TN, and TP loads respectively. Overall, the MBRC catchments contribute approximately 44% of total flows of the entire catchment, and 27%, 36%, and 32% of TSS, TN, and TP loads respectively.

Table 2-8 Average Annual Existing Flows and Loads

Catchment	Q (GL/yr)	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Bribie Island	11.0	363	12.3	1.1
Brisbane Coastal	11.4	953	17.7	1.9
Burpengary	24.6	1,983	33.4	4.2
Byron Creek[a]	2.0	192	3.1	0.3
Caboolture	114.2	11,242	159.7	19.8
CIGA	13.5	2,102	21.7	2.8
Hays Inlet	22.3	1,563	33.4	3.7
Lower Pine River	86.9	5,718	119.6	13.3
Mary River	32.5	1,346	32.1	2.6
Neurum Creek[a]	42.9	2,103	44.1	3.9
Pumicestone Passage	60.3	4,120	75.4	7.1
Redcliffe	7.3	485	11.3	1.4
Sideling Creek	15.5	1,387	21.9	2.6
Stanley River[a]	167.6	7,796	172.8	15.2
Upper Pine River	96.8	8,741	145.5	14.1
MBRC Total	**709**	**50,093**	**904**	**94**
Bremer River	121	20,722	216.4	27
Lockyer Creek	86	13,317	143.4	17.6
Logan/Albert Rivers	616	103,922	1,043.70	135.9
Lower Brisbane	282	23,430	376.8	52
Redlands Creeks	76	10,233	126.9	17
Wivenhoe	40	4,946	188.9	14.1
Remaining Total	**1,220**	**176,571**	**2,096.0**	**263.5**
Total	**1,929**	**226,664**	**3,000**	**357**

[a] Bryon Creek, Neurum Creek, and Stanley River drain to the Upper Brisbane Catchment

2.6 Discussion

The calibration of the Source Catchments hydrologic model is generally robust, with good results associated with the North and South Pine Rivers and the Caboolture River. This is important because receiving water quality in these areas is part of the focus for this study. Some calibration measures are slightly outside of the range suggest acceptability, however the other calibration measures for these regions is good.

The model results from the calibrated hydrologic model combined with the established water quality export rates are substantiated by the previous MBRC catchment modelling study. These outcomes suggest that the catchment model predictions are sufficient for the purposes of this study.

It should be noted that uncertainties within the modelling framework and the forcing data used to parameterise and calibrate them, including pollutant export rates, may influence the results and introduce the level a variability and uncertainty to the modelling. This may in turn influence the annual and sustainable loads determinations discussed in subsequent sections.

Pollutant export rates used to parameterise the catchment model were based on several recent studies for the SEQ region and represent median values from all of the sites involved. This means that the same values were used catchment wide. For example, the Green Space (i.e., fully forested) event mean concentration (EMC) for TSS used in the model represents a median value of 20 mg/l and was applied uniformly across the catchment model. These studies also indicated a degree of variability in the parameters (e.g., between 8 mg/L and 90 mg/L) that is not represented in the catchment model. While this variability may be present in the Moreton Bay catchments, there is insufficient data to spatially attribute variable pollutant export rates across the region. Therefore, the median values have been used. This approach is consistent with the majority of catchment modelling activities undertaken in Australia.

Further information on this matter, the degree to which these rates may vary, and more details regarding the uncertainties in the model are discussed in Appendix D.

3 *RWQM V2* RECEIVING WATER QUALITY MODELLING

This section presents the development and application of the Receiving Water Quality Model Version 2, (*RWQM V2*) including the calibration and validation of the hydraulic and water quality components of the model.

The previous draft of this report (BMT WBM 2011) addressed some of the technical issues pertaining to the calibration and validation of the *RWQM V2* model. These issues have been addressed and resolved to the greatest practical extent. The model was established as generally stable and has since performed well with the employment of a few work-arounds as necessary. Additionally, the necessary sewage treatment plant (STP) data were sourced to encompass the period chosen for scenario assessment.

3.1 Model Background

RWQM V2 was developed, calibrated and validated previously (refer to WBM, 2005) on behalf of the Healthy Waterways Partnership (HWP) and other key SEQ stakeholders. It is a two-dimensional, depth-averaged model which is based on heritage code from the Resource Management Associates (RMA) finite element model, originally developed by Professor Ian King. In development of *RWQM V2*, significant enhancements to the water quality algorithms were undertaken by scientists at the HWP and what was then Queensland's EPA.

In this application, BMT WBM has excised the large scale model which encompasses Moreton Bay from Pumicestone Passage to the Logan-Albert catchments, and as far east as Moreton and Stradbroke Islands. Of interest, this model was developed and initially calibrated by BMT WBM for the HWP in 2005 as a regional model.

This version of the Moreton Bay *RWQM V2* model includes both 1- and 2-dimensional elements, with 1-dimensional elements consisting of the Brisbane, Bremer, Logan and Albert River, as well as Pumicestone Passage. The North and South Pine, and Caboolture Rivers, are 2-dimensional up to the model domain boundaries to capture more accurately the hydrodynamics and water quality simulations in those waterways. Figure 3-1 illustrates the configuration and model mesh of the Moreton Bay *RWQM V2* model.

3.2 Model Data Sets and Model Configuration

3.2.1 Bathymetry

The model domain encompasses a widely varying bathymetry, from shallow narrow river estuaries to wider, deeper oceanic waterways. The Digital Elevation Model (DEM) used to create the marine and estuarine waterways is regularly used and updated in modelling activities. For the Moreton Bay modelling, the most recent bathymetry was used in the *RWQM V2 and* this bathymetry is illustrated in Figure 3-2.

3.2.2 Boundary Conditions

The Moreton Bay *RWQM V2* model has three tidal forcing boundaries shown in Figure 3-3:

- Northern Boundary – from the north end of Pumicestone Passage to the northwest tip of Moreton Island;
- Middle Boundary – the waterway between Stradbroke and Moreton Islands connecting Moreton Bay and the Coral Sea; and
- Southern Boundary – the waterway immediately south of Stradbroke Island.

The tidal forcing conditions were generated synthetically at the northern tidal boundary using tidal constituents from Mooloolaba (Station 011008A) and at the middle and southern boundaries using tidal constituents from the Gold Coast Seaway (Station 045044A). Representative time series of these boundaries are shown in Figure 3-3. These were also compared to measured Maritime Queensland Safety tables for verification; those tides are also included in Figure 3-3. The synthetic boundary conditions used in the *RWQM V2* provided the most consistent tidal pattern.

3.2.3 Catchment Inflows

Results from the Source Catchments model described earlier in Section 2 were extracted and used to define the catchment inflows and associated diffuse source pollutant loads to the *RWQM V2*. The locations of these inflows are shown in Figure 3-5.

3.2.4 Meteorological Forcing

Relevant meteorological (e.g. wind speed and direction) and other salient atmospheric (e.g. solar radiation) forcing data were also required for *RWQM V2* execution. The data were obtained from BOM Meso-LAPS modelling simulation results available to BMT WBM from other studies we are currently conducting in SEQ. Meso-LAPS is a fine scale version of the BOM Limited Area Prediction System (LAPS) software. It should be noted however, the *RWQM V2* doesn't incorporate these parameters, with the exception of wind used in the hydrodynamic calculations.

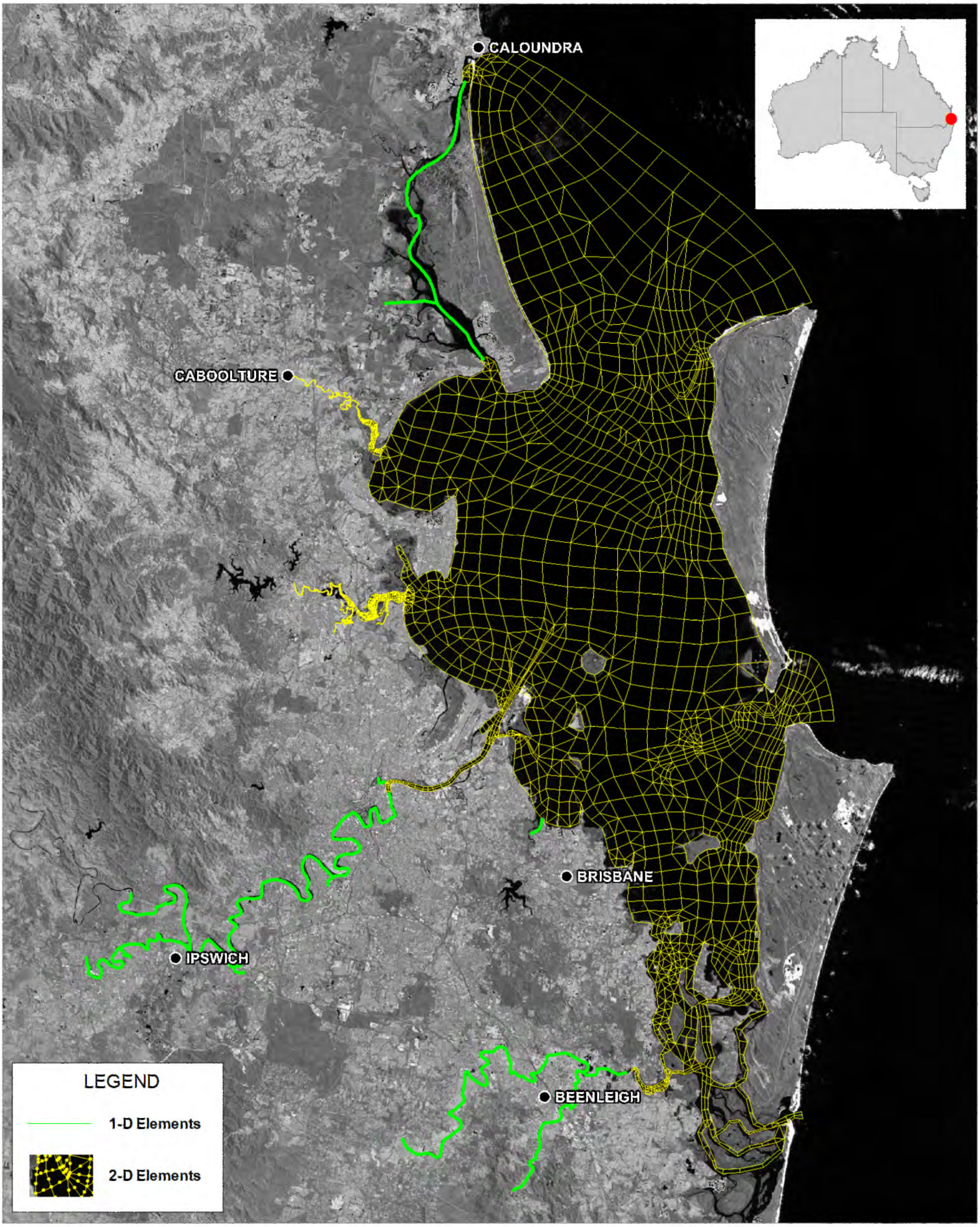
3.2.5 Point Sources Loads

Thirty-one point sources were included in *RWQM V2* model, including STP and industrial discharges. Yearly STP data were included as a time series in the model based on historical information. Figure 3-6 shows the location of all point source contributions to the *RWQM V2* model.

It should be noted that point sources were input into the model without near field modelling and prior dilution as a result of dispersion achieved by diffusers or outfalls. As such, the *RWQM V2* results of this study with respect to STP flows and loads are conservative because they do not account for entrainment of receiving water distributed across the region of where dispersion is expected to occur.

3.2.6 Initial Conditions

Initial conditions, specifically related to start-up of the water quality model and were established by initialising the model with constant average EHMP values across the model domain. The *RWQM V2* was simulated for a warm up period of three months prior to the model true starting period (i.e. commencement of results interrogation).



Title:
Moreton Bay Model Mesh

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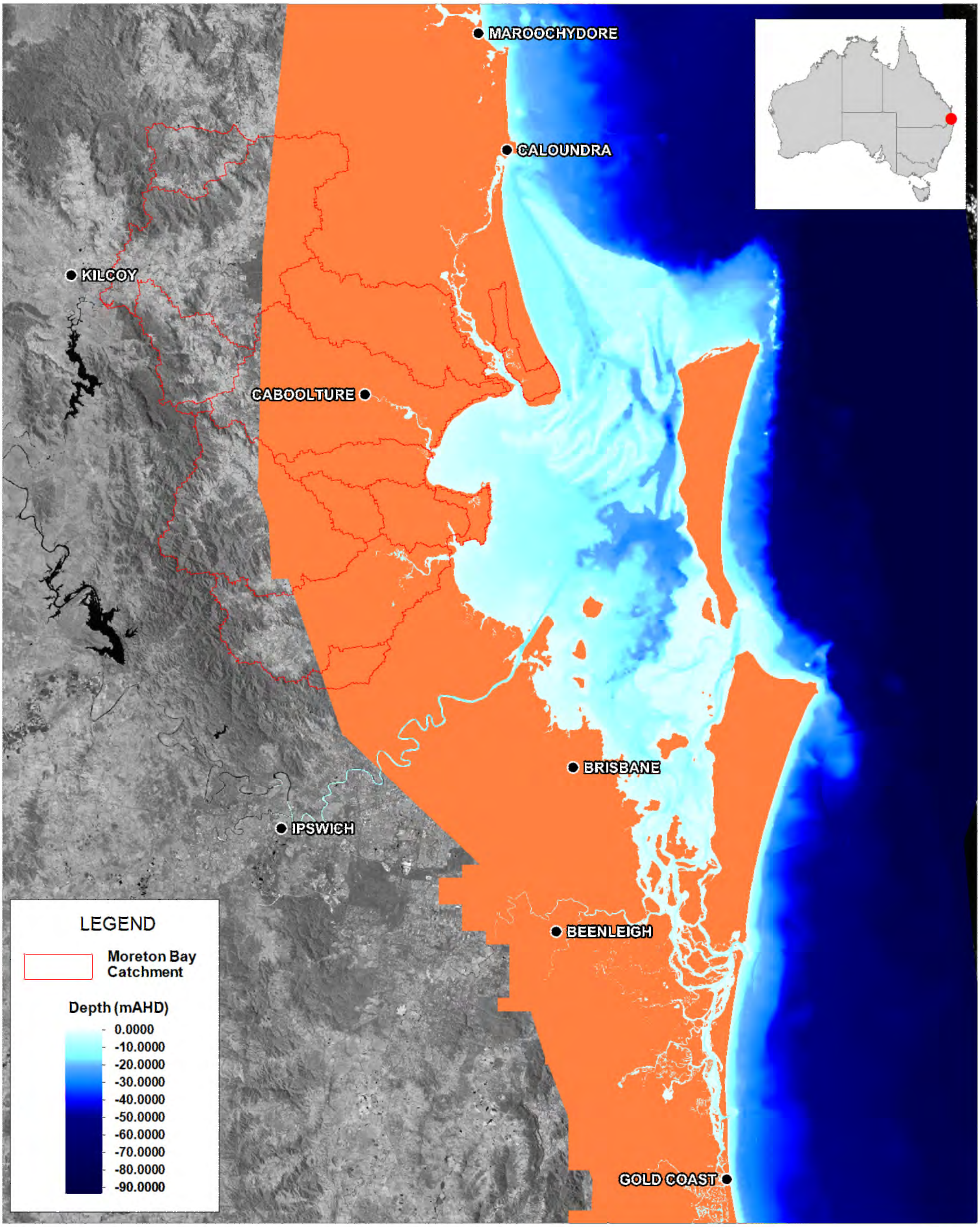

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Moreton Bay Bathymetry Data

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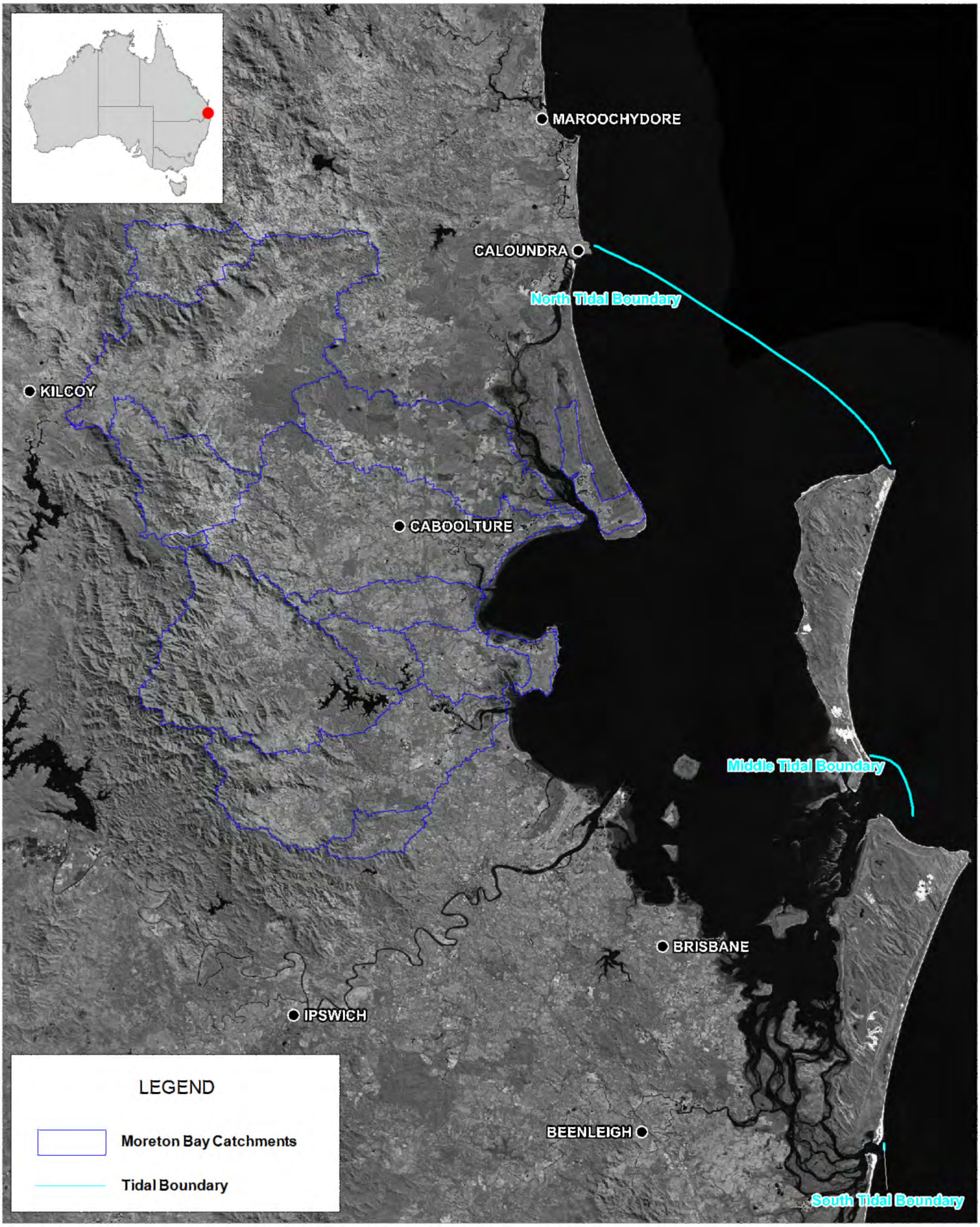

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Model Boundary Conditions

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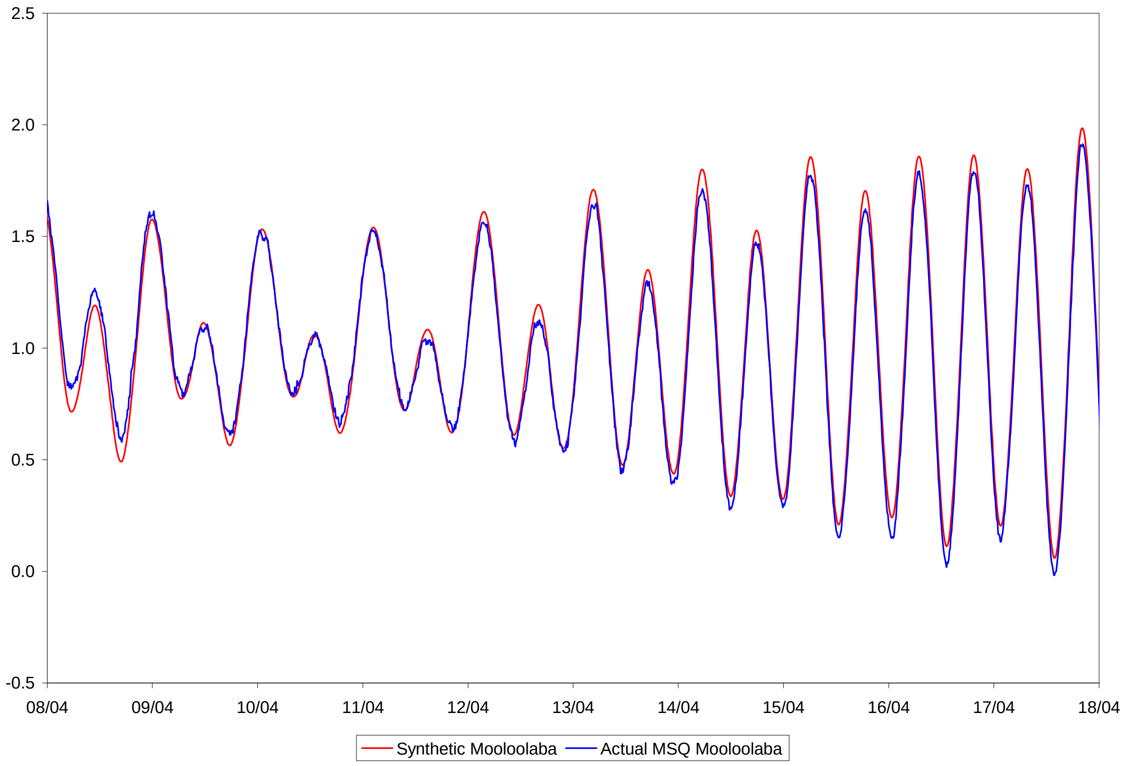


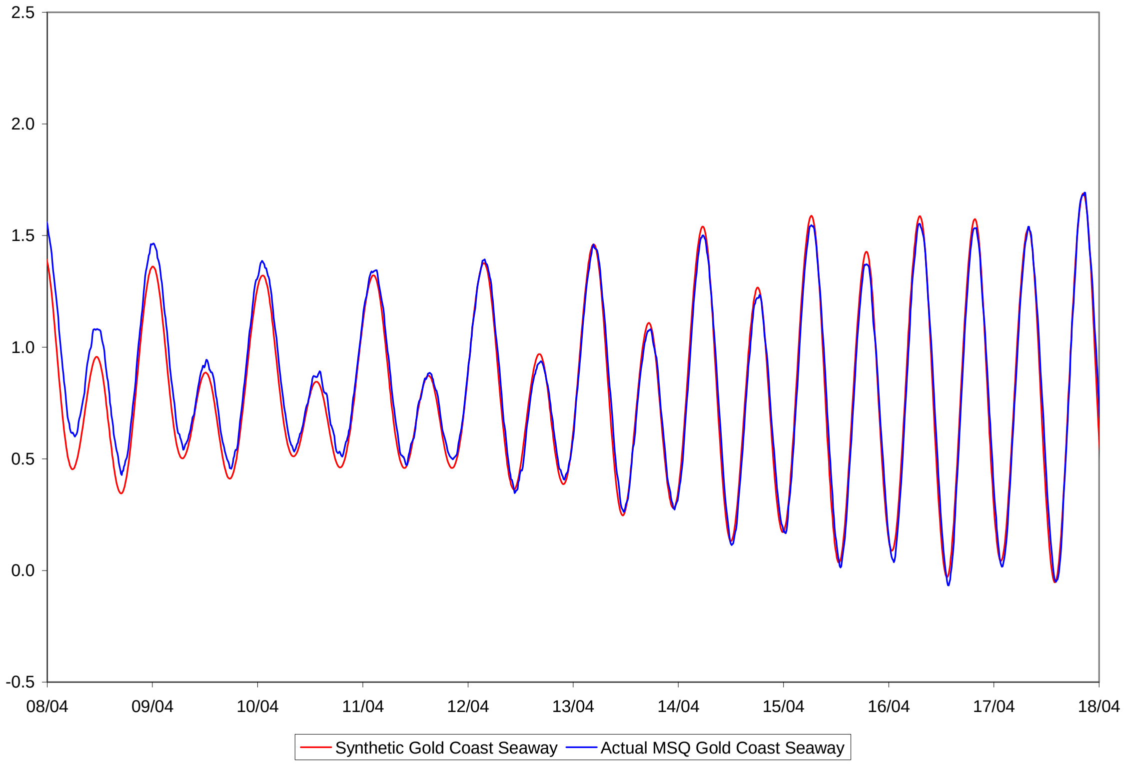
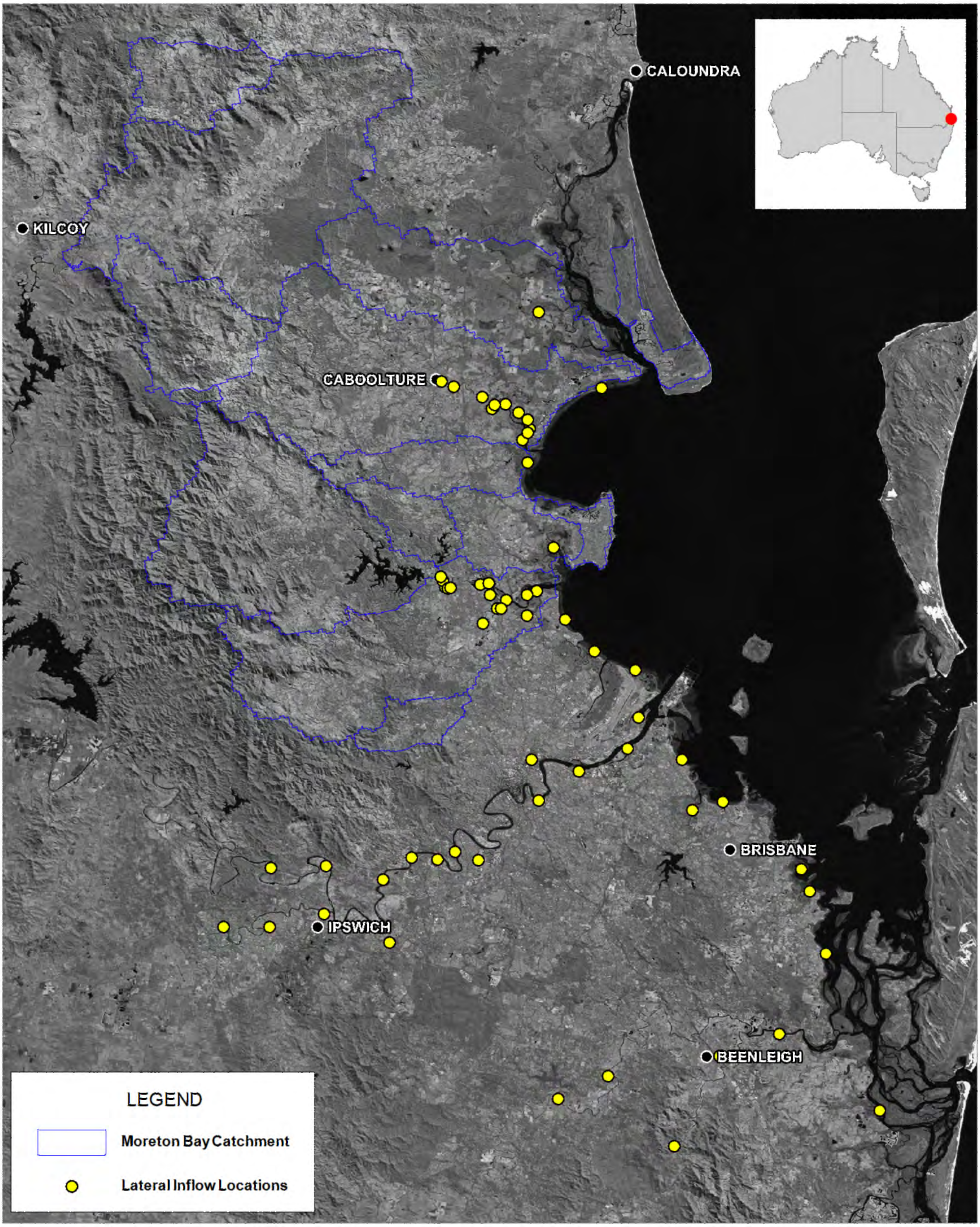


Figure 3-4 Tidal Forcing Boundary Conditions, Example Maloolabah and Gold Coast Seaway



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Inflow Locations

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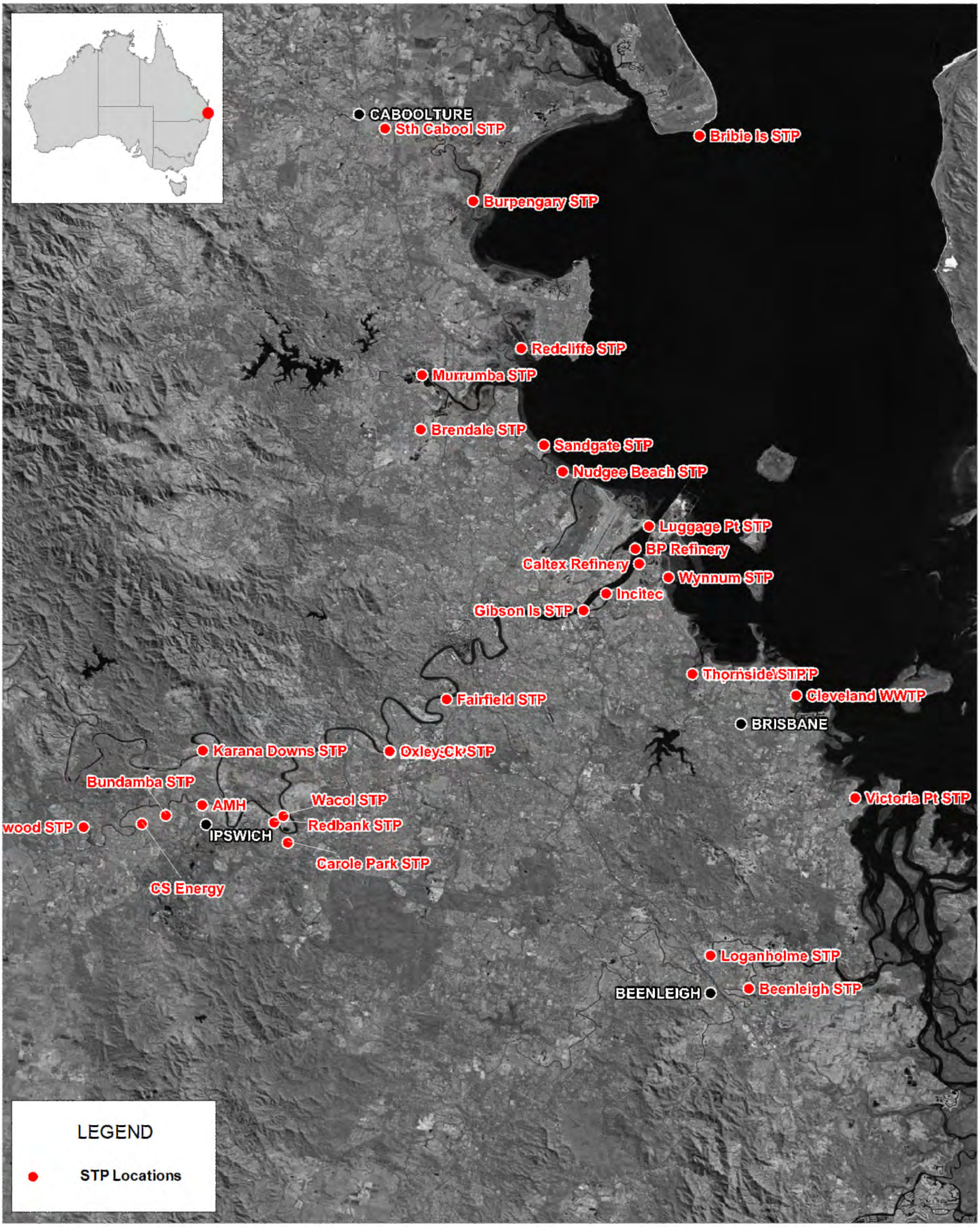

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Point Source Locations, STPs and Discharges

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3.3 Model Calibration and Validation

The performance of the *RWQM V2* model was assessed by comparing modelled and predicted water levels for hydraulic verification and water quality results with available EHMP data. The hydraulic verification of the model did not involve detailed parameterisation of hydrodynamic components of RWQM V2, rather a verification that the hydrodynamic module captured the tidal characteristics in Moreton Bay in general and at specific locations. The periods of verification for the hydrodynamic module were April 2007 for the North and South tidal boundaries, and 23/05/2005 and 9/05/2005 at specific locations within the river estuaries.

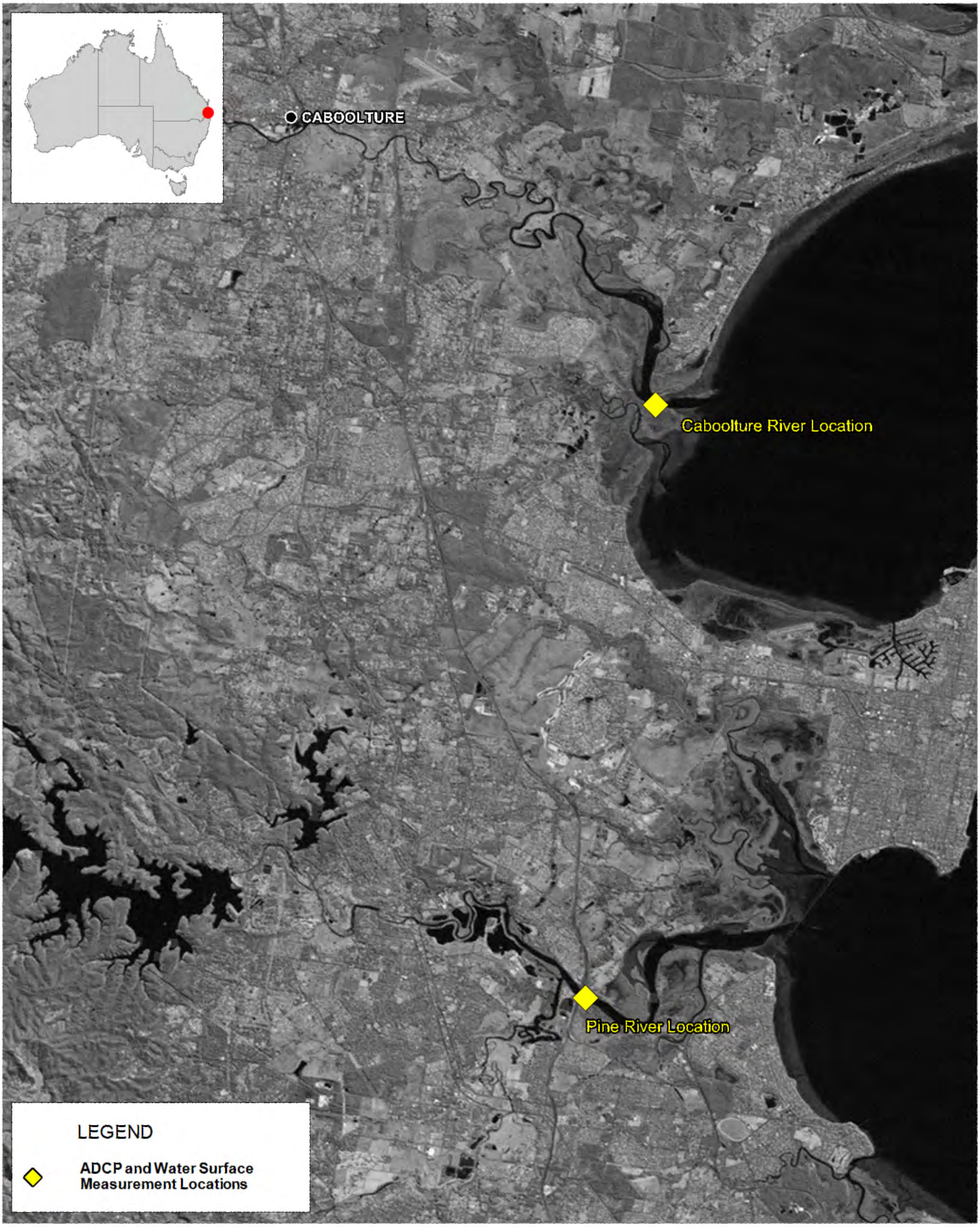
A one-year period (from 1/7/2005 to 30/6/2006) during relatively dry conditions was chosen for water quality model calibration. This period was chosen to establish and verify the internal processing dynamics of the model over a stable period. Conversely, the model validation was conducted over a relatively wet period from 1/7/2007 to 30/6/2008.

3.3.1 Hydraulic Verification

The model's hydrodynamic performance was assessed by comparing the modelled tidal elevations at the tidal boundaries to the forced model boundary conditions. Examples of these comparisons are shown in Figure 3-8 and Figure 3-9, each representing the period of one month in 2004. The model reproduced the tidal flood and ebb maximums and minimums to within +/- 3.0 mm and the phase is accurately modelled at each of the locations.

To further demonstrate the model's hydrodynamic robustness, particularly within the study areas of interest, modelled flows and tidal elevations were compared to measured values in the Caboolture and Pine River estuaries. The locations where the data were collected are shown in Figure 3-7. Tidal and flow data in the Caboolture River were collected over a 14-hour period on 23/5/2005. Tidal and flow data in the Pine River were collected downstream of the Gympie Arterial/Bruce Highway bridge during a 14-hour period on 9/5/2005. Water level measurements were made using fully submersible Greenspan Model PS310 or CTD350 instruments at 15-minute intervals. Depth sensors were calibrated in metres of fresh water to which a density correction was applied to convert depths in metres of salt water.

Tidal current measurements were collected using an Acoustic Doppler Current Profiler (ADCP), which were then converted to flows. The ADCP was mounted to a 5.5m aluminium hulled commercial survey vessel owned by BMT WBM. The vessel recorded transects at each location capturing the area of the cross section and the velocity in the channel to give the total discharge for the cross section. Figure 3-10 and Figure 3-11 show the comparison of water surface elevation and flows in the Caboolture and Pine Rivers respectively. For measured versus modelled flow rates of the Caboolture and Pine Rivers, the Nash Sutcliffe coefficients, *E*, are 0.92 and 0.87, respectively.



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ADCP and Water Surface Elevation Measurement Locations in Caboolture and Pine Rivers

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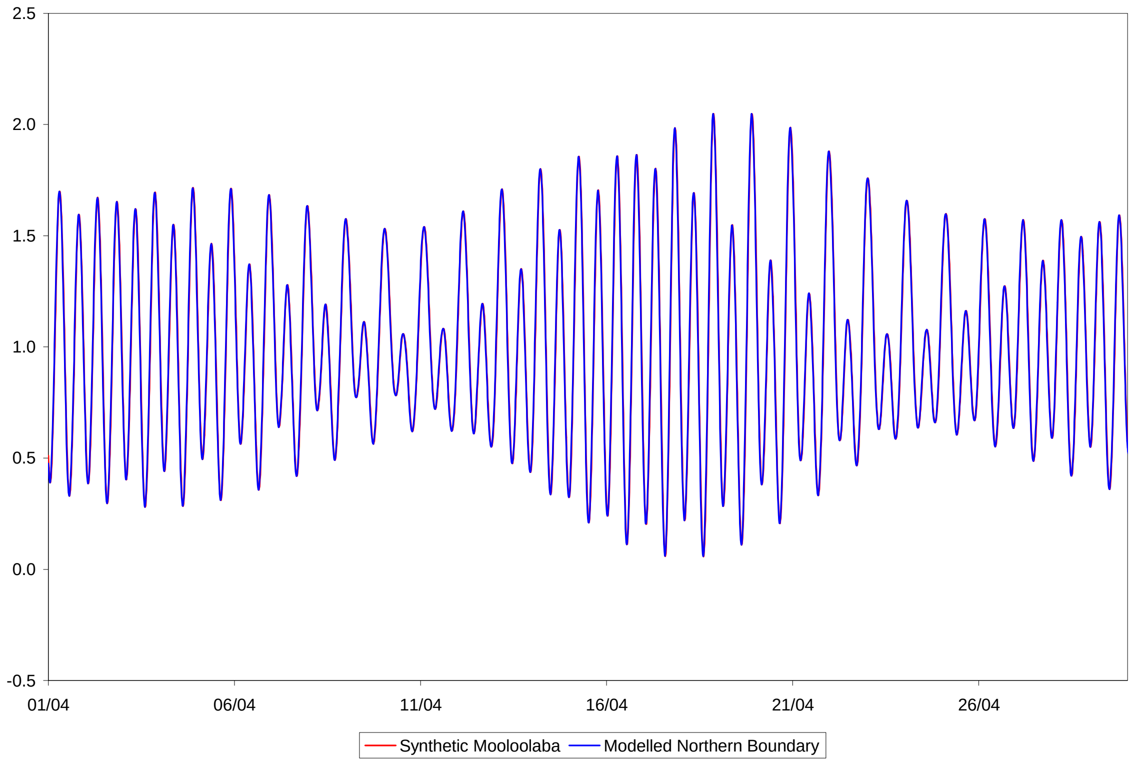


Figure 3-8 North Model Boundary Tidal Verification

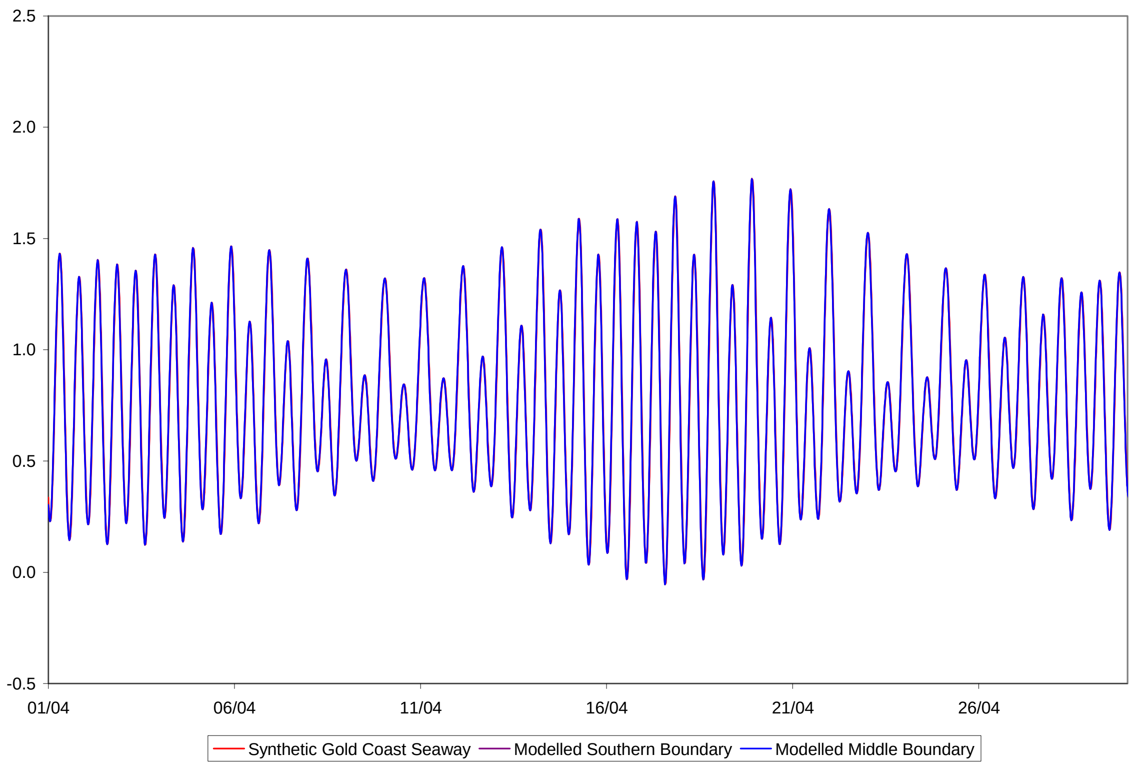


Figure 3-9 Middle and South Boundary Tidal Verification

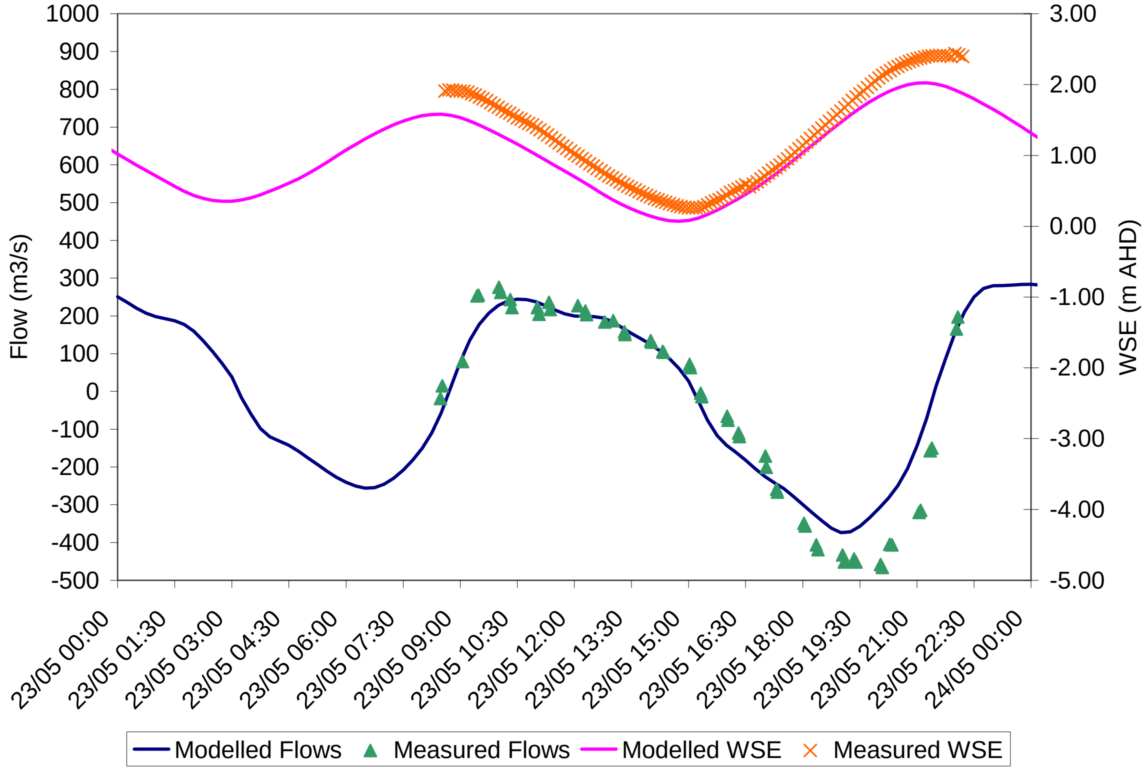


Figure 3-10 Flow and Water Surface Elevation Comparison in the Caboolture River

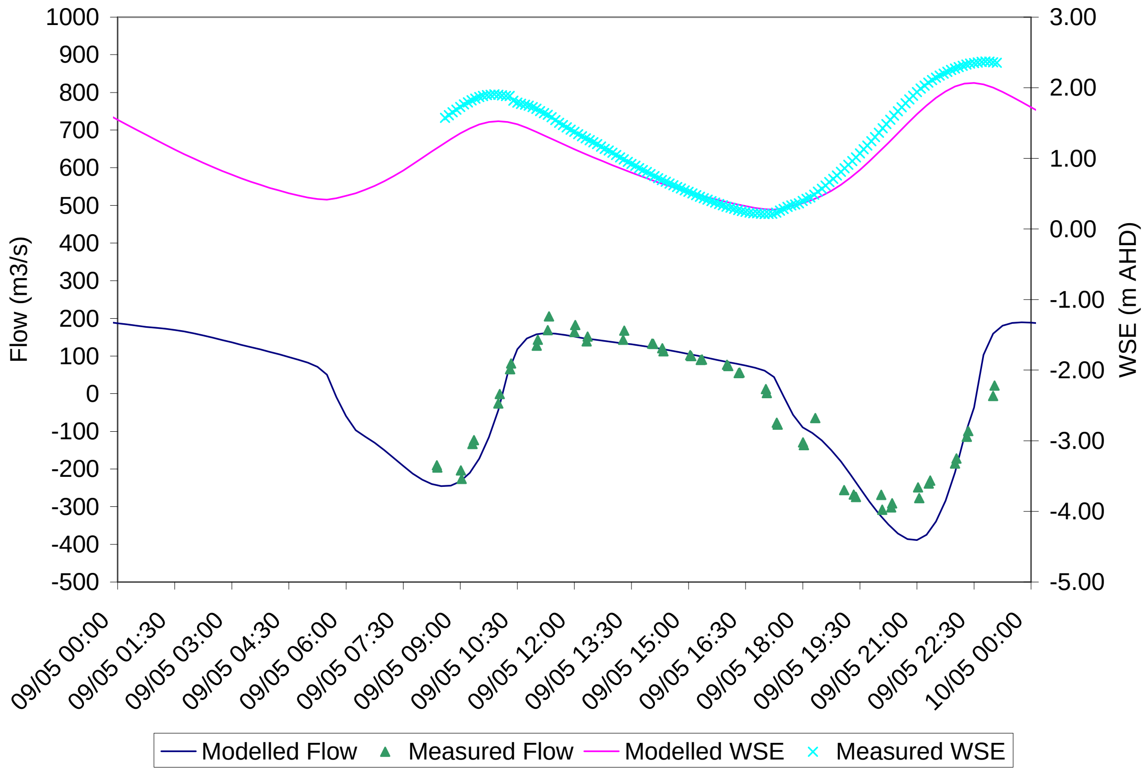


Figure 3-11 Flow and Water Surface Elevation Comparison in Pine River

3.3.2 Water Quality Calibration and Validation

The model was calibrated to a period of dry conditions (this period being 1/7/2006 to 30/6/2007) and validated to a period of predominantly 'wet' conditions (this period being 1/7/2007 to 30/6/2008). This approach was adopted as it lends considerable support to the coupled catchment-receiving water quality model system and it demonstrates the model's ability to reliably simulate a wide suitable range of geographic, seasonal and climatic conditions within Moreton Bay.

Calibration essentially entailed comparison of model predictions with monthly EHMP data, with commensurate expertise based adjustments to relevant water quality model process coefficients until suitable model results were obtained. Key literature (e.g. Wu-Seng 1993) was used to inform any model coefficient modifications. For model validation, these model process coefficients were kept constant and only boundary/inflow conditions were changed to suit the different time period and hydrologic and climatic conditions.

Calibration and validation results are presented in Appendices B and C respectively, with discussion of the calibration and validations presented below. Constituents presented for consideration are those that were used in the TWCMP analysis being TN, TP, TSS and salinity, which was used to calibrate the advection-dispersion characterisation of RWQM V2. Figure 3-12 shows the location of each EHMP site relative to their respective waterways.

Due to the relevance of certain waterways to the Moreton Bay catchments and water quality, only some of the EHMP sites are presented herein. In particular, calibration and validation reporting has been presented in the appendices for the Brisbane and Bremer Rivers, the Logan and Albert Rivers, and Moreton Bay beyond Bramble and Deception Bays. Additionally, due to the nature of the configuration of Pumicestone Passage in the model, only the lower EHMP sites have been included in the appendices. This is discussed in more detail below.

It is noted the Source Catchments and *RWQM V2* represents suspended sediments, however, water quality objectives for the waterways examined in this study address turbidity. As such, a conversion factor of 2.55 was used to estimate turbidity from suspended sediment concentrations.

3.3.3 Discussion

3.3.3.1 Hydraulic Verification

As the *RWQM V2* model was repurposed from an originally calibrated model, the hydraulic verification process showed that the hydraulic model replicated water surface elevations in both phase and amplitude well in comparison with the synthetic tidal conditions. Similarly, the modelled data compares well with of the flows and water surface elevations for the cross sections in Caboolture and Pine River, with presenting Nash-Sutcliffe coefficients.

3.3.3.2 Water Quality Calibration and Validation

Whilst a robust calibration process was undertaken, water quality parameters set in the previous study were largely maintained with only minor adjustment for a few constituents. With respect to the water quality calibration, the following key items are discussed below:

- The original WBM 2005 calibration was over a dry period (i.e. the year 2000 – the same year as used in the original Queensland's EPA calibration) so this study represents the first attempt to apply the *RWQM V2* over a wet period for validation. This is justification for the required parameter adjustment undertaken here, in addition to that required due to the more extensive EHMP data available and the influence of the upgraded catchment model used here compared to that used by WBM 2004.
- The Manning's *n* factor was spatially varied and adjusted appropriately to arrive at a calibration of advection-dispersion (AD) within the model.
- The EHMP data, while providing a good spatial coverage within Moreton Bay and the river estuaries, are biased with regard to time, as evidenced in most of the calibration and validation figures. That is, EHMP data are routine monthly samples, not event-based sampling, and each sample may or may not correspond to any particular event. Hence some events for which the model predicts high flows and pollutant loads, are not necessarily captured by EHMP measurements.
- The EHMP data to which the model was calibrated also have some limitations due to measurement uncertainties. Although it is difficult to associate a definite value to these sampling and/or laboratory analysis errors, typical literature values of 10 to 30% cumulative probable uncertainty were used for nutrients, under typical conditions (Harmel *et al* 2006).

Overall, this calibration is deemed satisfactory for the purposes of this study. In general, satisfactory agreement between the recorded EHMP data and the model results was achieved both for the calibration (dry) and the validation (wet) periods, to an extent appropriate for the purposes of this study. Although other limitations of the *RWQM V2* are discussed in WBM 2005 (and the results presented herein should be viewed in the context of that discussion) the long track record and current calibration status of the model used in this study are such as to make it the best model available at this time for application in this investigation.

It should be noted that the *RWQMV2* modelled suspended sediments (TSS) rather than turbidity, while EHMP data and QWQG values are based on turbidity (and TSS). In order to address this, the modelled TSS concentrations were converted to turbidity concentrations (in NTU) by multiplying TSS by a factor of 2.55. This relationship was derived from TSS-turbidity data from the Mt. Crosby Weir from over more than 50 years of measurements). This relationship was employed for all estuaries considered in this study, primarily because no data exists that relates the two units systems in the other rivers.

Additionally, there are some associated uncertainties in the characterisation of the *RWQMv2* that would likely introduce uncertainty into the results of this study. Due to the calibration and validation process by which the model was determined to perform reasonably well over both wet and dry periods, it is not anticipated these uncertainties would introduce a significant amount of uncertainty in the results. The manner in which the scenarios was assessed against the water quality objectives and the sustainable load targets (Sections 4.3 and 4.4) is aimed at limiting the uncertainty of the results as well (See Section 4.5.2).

Refer to Appendix D of this report for summary of the *RWQMV2* modelling uncertainty.

Caboolture River

The advection-dispersion calibration of the Caboolture River was good with the model capturing the response of the estuary with accurate salt recovery throughout the estuary after storms. Salinity in the uppermost EHMP site was lower than the EHMP data, primarily for the calibration, however, it should be noted the inflows coming in from the catchment had no salinity, and only during dry periods did the model demonstrate any appreciable salt recovery at this site.

The water quality calibration was good for nitrogen with the model accurately reflecting the monitoring data. Turbidity and phosphorus were slightly lower than the EHMP data for periods of little or no rain, however, the model generally captured the behaviour of the receiving water with respect to catchment storm inflows and respective pollutant loads.

Pine River

The AD calibration of the Pine River showed the model represents the salt flushing and recovery well, with all but one site (the uppermost site of the North Pine River) recovering at the rate that matched well with EHMP data..

Overall, phosphorus and turbidity were accurately represented in the model, with nitrogen predicted higher than the EHMP data near the Murrumba STP, and lower than EHMP in other locations lower in the estuary. It is likely the STP had a significant influence on pollutant concentrations in Pine River.

Bramble and Deception Bays

The Bramble and Deception Bay calibrations for advection-dispersion and water quality are generally acceptable, with the model demonstrating the system response within each Bay to catchment inflows and pollutant loads.

The behaviour of the broader oceanic water quality trends relating to Moreton Bay were captured though phosphorus and nitrogen appeared low in Deception Bay.

Pumicestone Passage

Pumicestone Passage was evaluated, as much as was practical, at the 4 southernmost EHMP sites in the estuary. The catchment inflows to Pumicestone Passage consisted of those from Glass Mountain Creek, Elimbah Creek, Ningi Creek, and Bribie Island. All of these inflows enter the model at one location near E01302. The model in this location is one-dimensional, which limits the ability to fully assess fate and transport of constituents within the estuary.

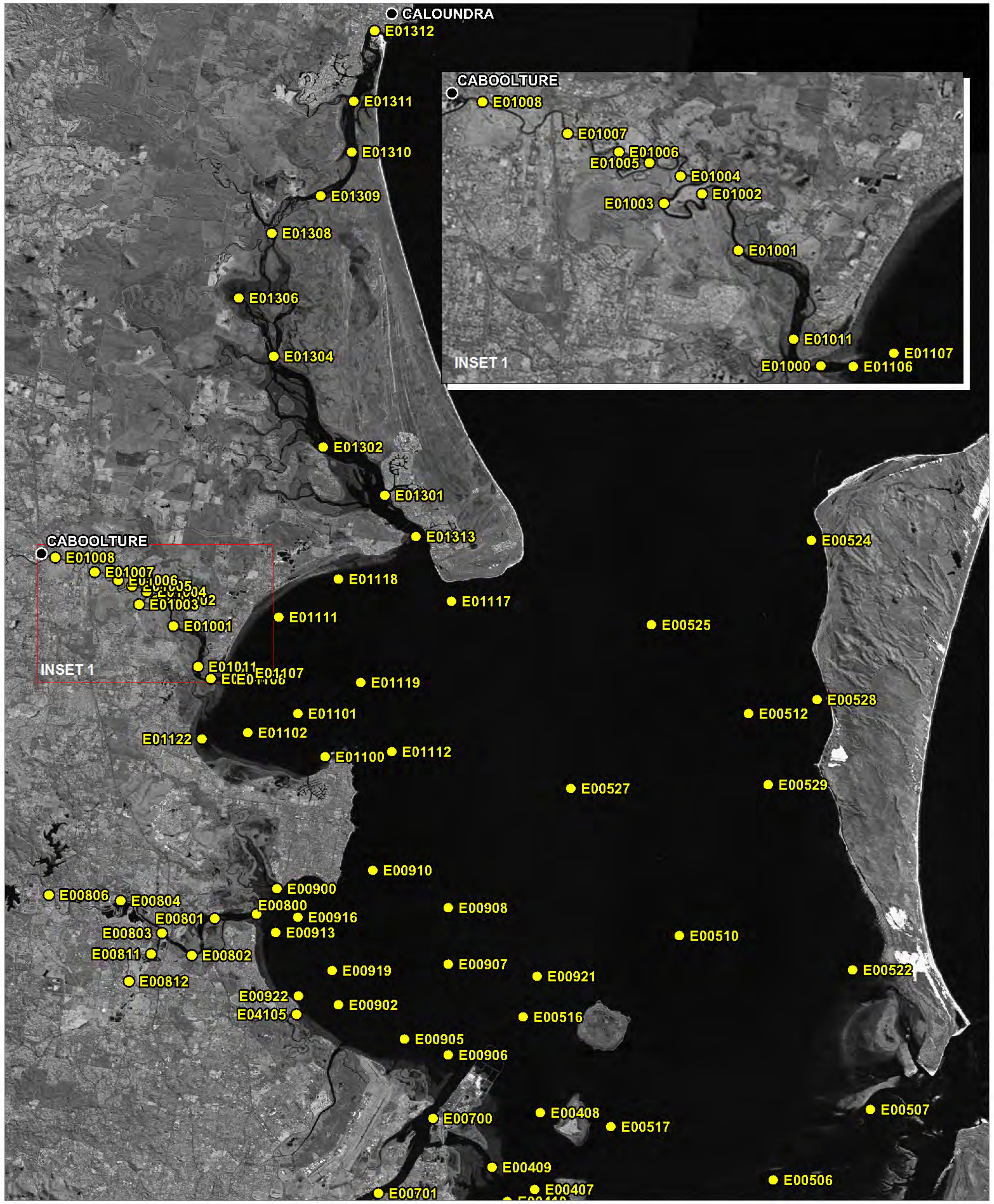
The AD calibration of model for Pumicestone Passage shows the limited configuration of the mesh in that area. The model consistently predicts lower than measured salinity as the mesh at that location is one-dimensional and all of the catchment inflows occur at one location, near the E01302 site rather than being geographically distributed.

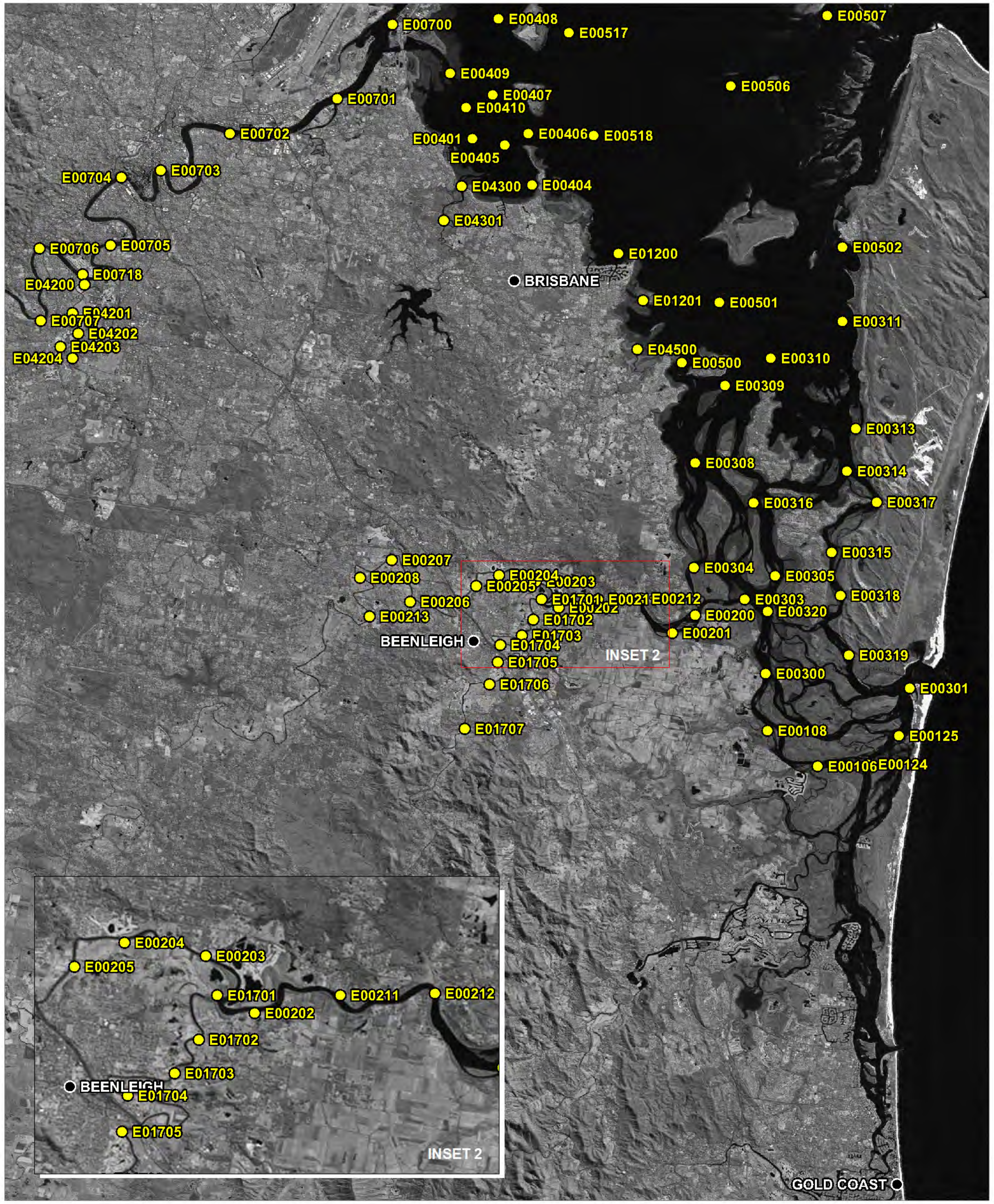
Low phosphorus and turbidity generally reflect the concentrations of those constituents in the catchment inflows, however nitrogen is predicted to be higher than the measured values.

Remaining Waterways

The remaining waterways demonstrated a generally good representation of advection-dispersion and water quality in their respective waterways.

The upper reaches of the Brisbane and Bremer Rivers show higher concentrations of nitrogen than EHMP data, however, this is likely because of influence of STPs within the area, and the sensitivity of the model to these direct inputs. Similar to Pumicestone Passage, the model mesh of the Brisbane and Bremer Rivers at these locations is one-dimensional and is therefore limited in its ability to model pollutant fate and transport as well as the locations represented two-dimensionally..





LEGEND

● EHMP Locations

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EHMP Locations

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BMT WBM

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4 SCENARIO ASSESSMENT

The development of each of the scenarios described in this section was to enable a rigorous and quantifiable assessment of the effects of various potential land use configurations (within the MBRC catchments) upon the water quality within Moreton Bay and its estuaries. As such, this section of the report presents the results from the catchment and receiving water quality modelling for all relevant scenario assessments.

The structure of this section presents the following:

1 Section 4.1 provides a brief discussion of the application of future land use from the existing 2010 existing conditions land use.

2 Section 4.2 provides the process by which the typical year was selected for assessing each of the management scenarios.

3 Section 4.3 outlines the water quality objectives that formed the basis of the water quality assessments.

4 Section 4.4 describes the determination of the 'sustainable load' within each waterway.

5 Section 4.5 describes the land use management scenarios applied in both Source Catchments and *RWQM V2* and if those scenarios meet the 'sustainable load' or other conditions/objectives within each waterway.

4.1 Future Land Use

Future land use was applied to the MBRC administrative area only to isolate the impacts of the catchment loads from these areas. Future land use changes included all future development and was sourced from land use data provided by MBRC and is shown in Figure 4-1.

The future MBRC land use areas included the Caboolture Identified Growth Area (CIGA) area the total areas are summarised in Table 4-1. The changes in land use per catchment are summarised in Table 4-2.

4.2 Selection of Typical Annual Rainfall Conditions

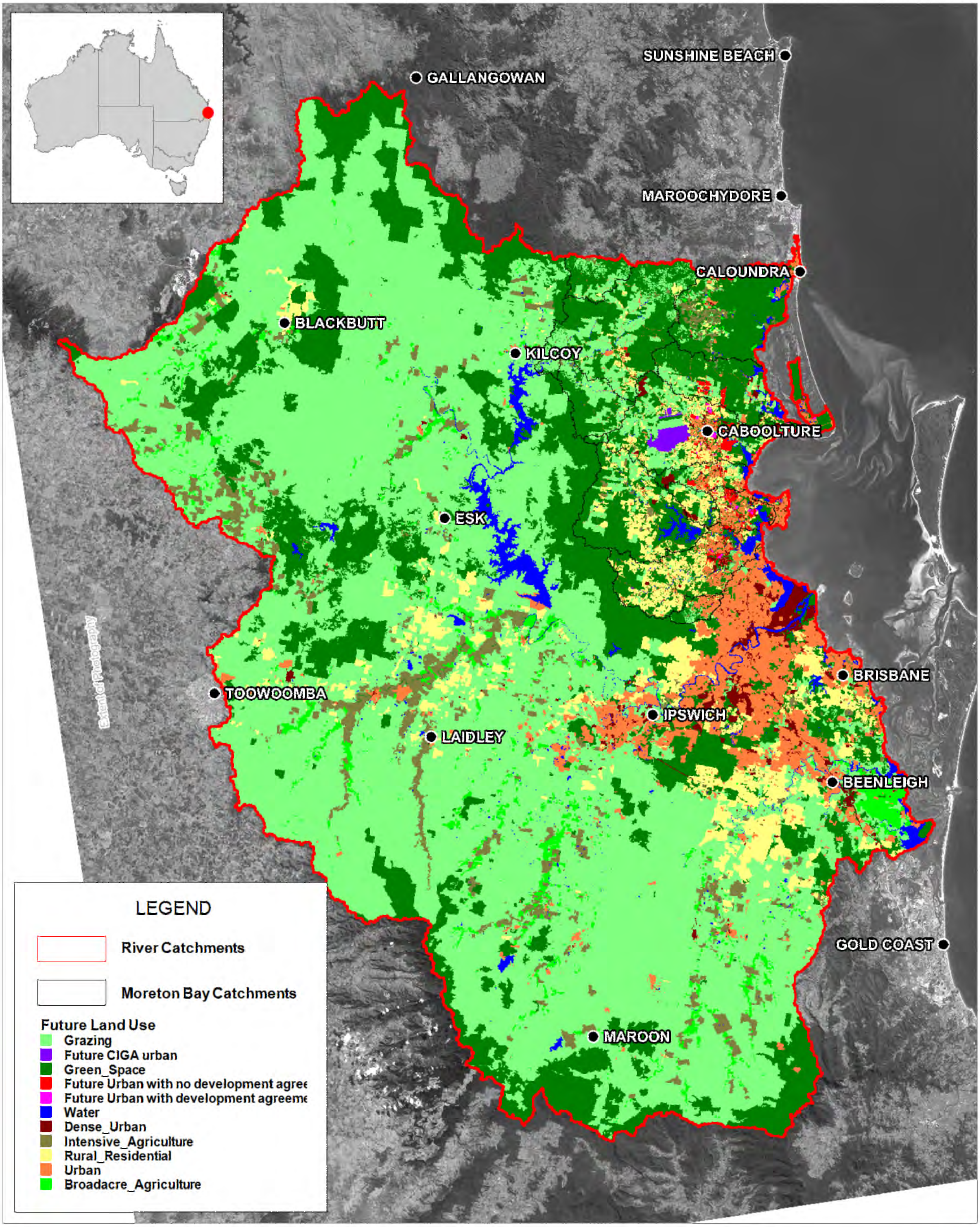
In each case, the coupled modelling system (i.e. Catchment and Receiving Water Quality Models) described earlier in this report (refer to Section 1.2) was modified and simulated as required for a typical one-year period. The typical period adopted was from 1/07/2005 to 30/06/2006 which provided a period where monitoring data (i.e. EHMP data) was available and any potential water quality impacts due to land use change would be representative of near-average conditions.

The aim of this task was to ensure that sustainable loads simulations were not biased by one or two large inflow events, but rather encompassed periods characterised by typical long term rainfall patterns.

4.2.1 Rainfall Dataset

Daily rainfall records were extracted from the Source Catchments model (refer to Section 2) at nine selected catchments across the study area as shown in Figure 4-2 below. The rainfall data extracted originated from the gridded SILO data that was available from January 1950 to May 2010.

It should be noted that the EHMP receiving water quality data was available over the entire study area during the period of late 2002 to October 2010. As result, the following 'typical' annual rainfall selection analysis was focused within this period with the intent of identifying a year that had supporting EHMP data.



Title:

Future MBRC and SEQ Source Catchments Functional Units

Figure: 4-1

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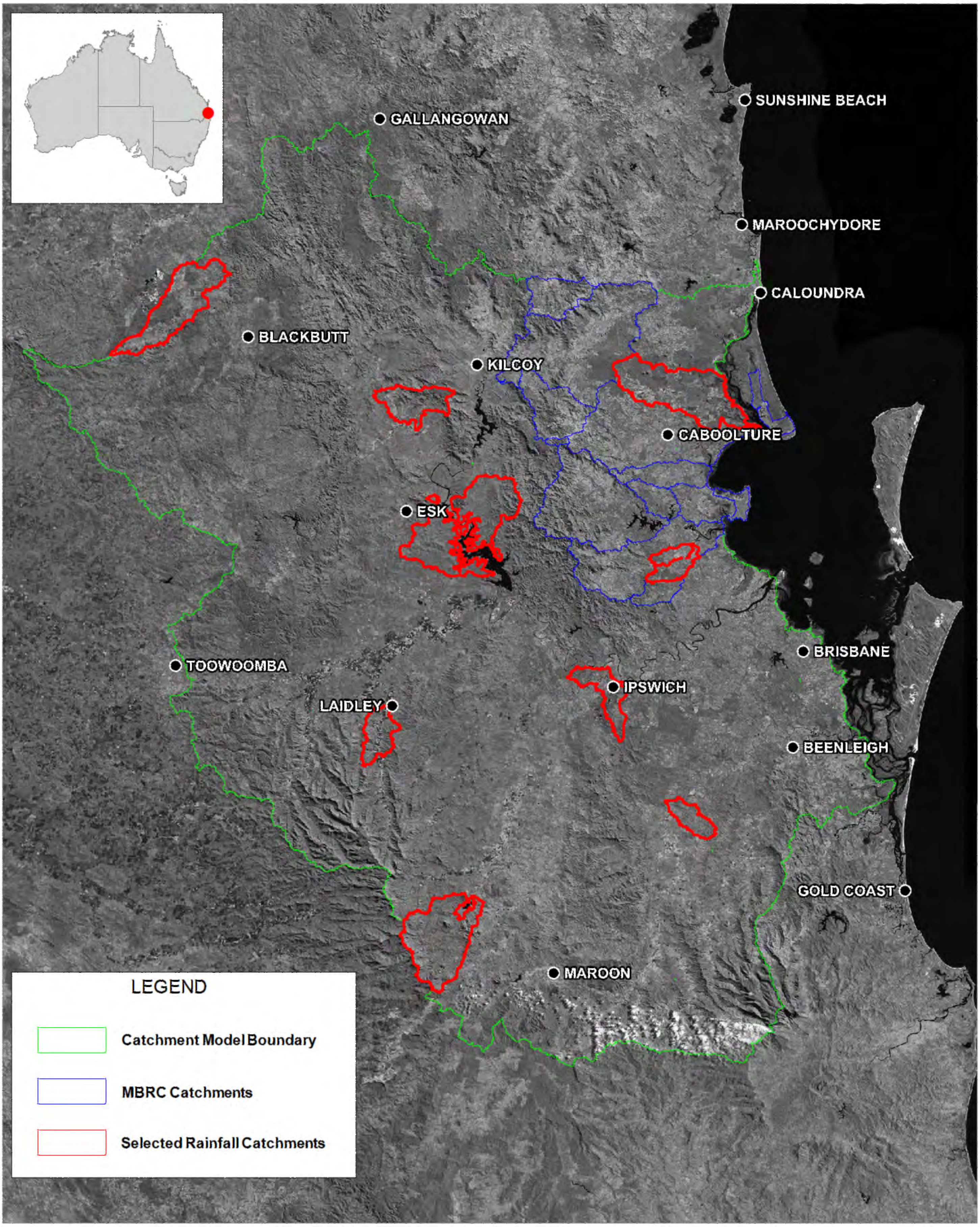
Table 4-1 Future Land Use Area and Change from Present Land Use (km^2)

Catchment	Broadacre Agriculture	Dense Urban	Grazing	Green Space	Intensive Agriculture	Rural Residential	Urban	Future with DA	Future with no DA	Future CIGA	Water	Total
Bribie Island	0.0	1.4	0.3	29.3	0.0	0.2	8.9	0.5	0.8	0.0	0.9	42.3
Brisbane Coastal Creeks	0.0	0.5	5.1	16.8	0.3	1.3	14.3	0.0	0.2	0.0	0.1	38.5
Burpengary Creek	0.0	6.0	11.5	20.5	0.0	20.7	17.0	0.0	4.6	0.0	3.5	83.9
Byron Creek	0.0	0.0	2.6	3.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0	6.6
Caboolture River	0.0	15.6	92.9	104.7	0.4	74.3	36.1	3.7	12.8	0.0	7.8	348.3
CIGA	0.0	0.0	8.3	2.9	0.0	0.0	0.0	0.0	0.0	29.6	0.0	40.9
Hays Inlet	0.0	5.4	1.3	15.2	1.2	11.0	26.9	1.6	9.7	0.0	6.2	78.4
Lower Pine River	0.0	8.4	10.5	109.5	2.8	101.7	55.8	0.0	0.0	0.0	14.8	303.6
Mary River	0.0	0.0	30.2	55.3	1.7	0.7	1.2	0.0	0.0	0.0	0.1	89.2
Neurum Creek	0.0	0.0	53.3	70.3	1.5	1.8	2.3	0.0	0.0	0.0	0.8	130.2
Pumicestone Creeks	0.0	2.9	43.9	139.4	1.1	13.0	10.7	0.2	7.0	0.0	13.6	231.8
Redcliffe	0.0	1.9	0.3	2.2	0.0	0.1	14.6	0.0	1.6	0.0	4.0	24.7
Sideling Creek	0.0	3.1	7.8	17.9	0.2	18.9	2.7	0.0	0.0	0.0	1.1	51.6
Stanley River	0.0	0.9	177.9	251.5	3.2	17.6	12.4	0.0	0.6	0.0	3.2	467.2
Upper Pine River	0.0	1.9	48.2	192.9	7.6	77.7	10.0	0.0	0.0	0.0	17.7	355.9
Total	**0.0**	**47.9**	**520.4**	**1096.4**	**22.1**	**342.2**	**213.2**	**6.1**	**37.3**	**29.6**	**73.7**	**2388.9**

Table 4-2 Changes in Land Use from Existing (km^2)

Catchment	Broadacre Agriculture	Dense Urban	Grazing	Green Space	Intensive Agriculture	Rural Residential	Urban	Future with DA	Future with no DA	Future CIGA	Water	Total
Bribie Island	0.00	-0.02	0.00	-1.24	0.00	0.00	-0.04	0.49	0.81	0.00	0.00	0.00
Brisbane Coastal Creeks	0.00	0.00	0.00	-0.18	0.00	0.00	-0.01	0.00	0.19	0.00	0.00	0.00
Burpengary Creek	0.00	0.00	-1.36	-2.96	0.00	-0.14	-0.11	0.04	4.57	0.00	-0.04	0.00
Byron Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caboolture River	0.00	-0.14	-6.29	-9.73	-0.01	-0.21	-0.16	3.74	12.77	0.00	-0.01	0.00
CIGA	0.00	-0.05	-19.62	-6.38	0.00	-2.37	-1.22	0.00	0.00	29.65	0.00	0.00
Hays Inlet	0.00	-0.04	-0.80	-9.88	-0.10	-0.23	-0.25	1.63	9.69	0.00	-0.02	0.00
Lower Pine River	0.00	-0.02	-0.72	-5.28	0.02	-0.05	-0.07	0.88	5.24	0.00	-0.02	0.00
Mary River	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Neurum Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumicestone Creeks	0.00	0.00	-6.18	-0.81	0.00	-0.03	-0.12	0.15	7.01	0.00	-0.02	0.00
Redcliffe	0.00	0.00	0.00	-0.66	0.00	0.00	-0.03	0.00	1.60	0.00	-0.91	0.00
Sideling Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stanley River	0.00	0.00	-0.19	-0.38	0.00	0.00	-0.02	0.00	0.59	0.00	0.00	0.00
Upper Pine River	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Total	**0.00**	**-0.26**	**-35.15**	**-37.53**	**-0.08**	**-3.03**	**-2.02**	**6.93**	**42.51**	**29.65**	**-1.01**	**0.00**



Title:

Selected Subcatchments for Rainfall Analysis

Figure: 4-2

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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4.2.2 Long-Term Average

Long term monthly average rainfall totals were computed for each catchment for the entire rainfall dataset, i.e. from 1950 to 2010 and are reported graphically in Figure 4-3. This figure shows that rainfall totals are highly variable on a temporal and spatial basis. As a result, it was decided to derive a 'typical' rainfall year based on both annual rainfall totals and monthly statistics and this assessment was undertaken across several locations within South East Queensland as described in the following section.

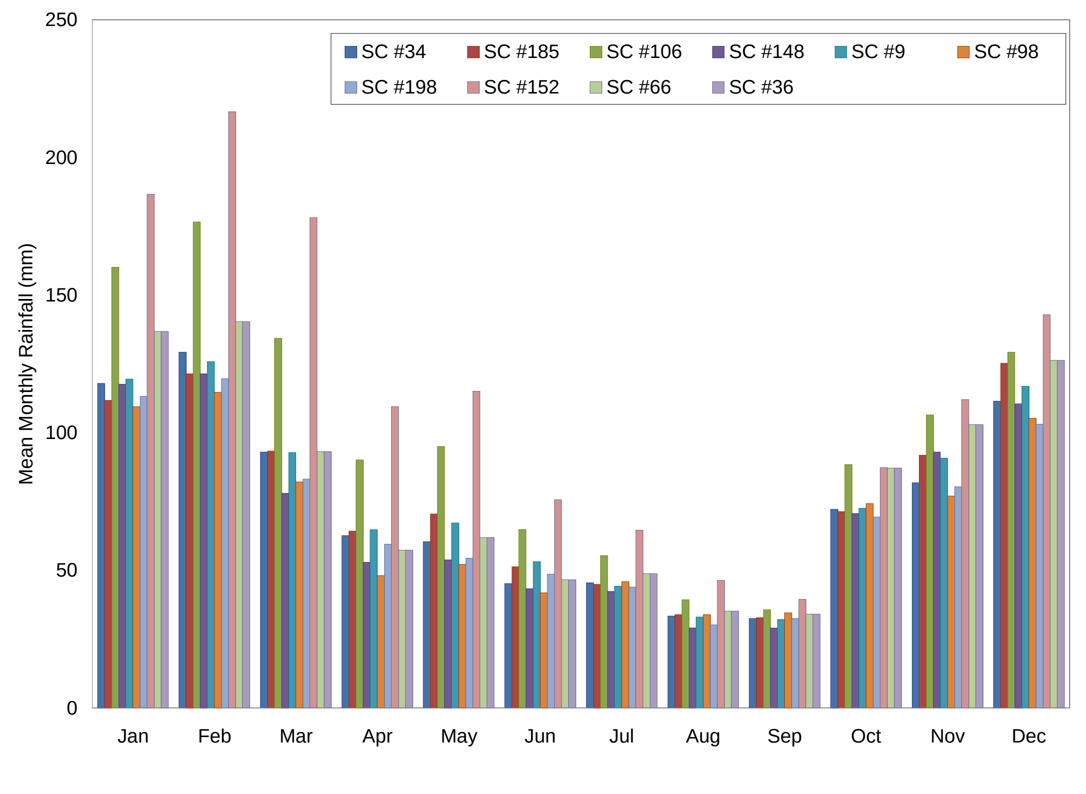

Figure 4-3 Long Term Monthly Average Rainfall

4.2.3 Monthly Average and Annual Totals

For the purposes of the 'typical year' analyses the hydrologic year commenced from July 1 and ended on June 30. The monthly rainfall analysis consisted of the following steps:

- Examination all monthly data from 2002 to 2009;
- Compute a time-series of absolute (i.e. positive) differences by comparing individual monthly rainfall totals to the long term monthly mean for each catchment (as presented in Figure 4-3); and
- Compute the mean and standard deviation of the absolute difference time-series for each catchment.

The monthly data assessed is depicted graphically in Figure 4-4 below.

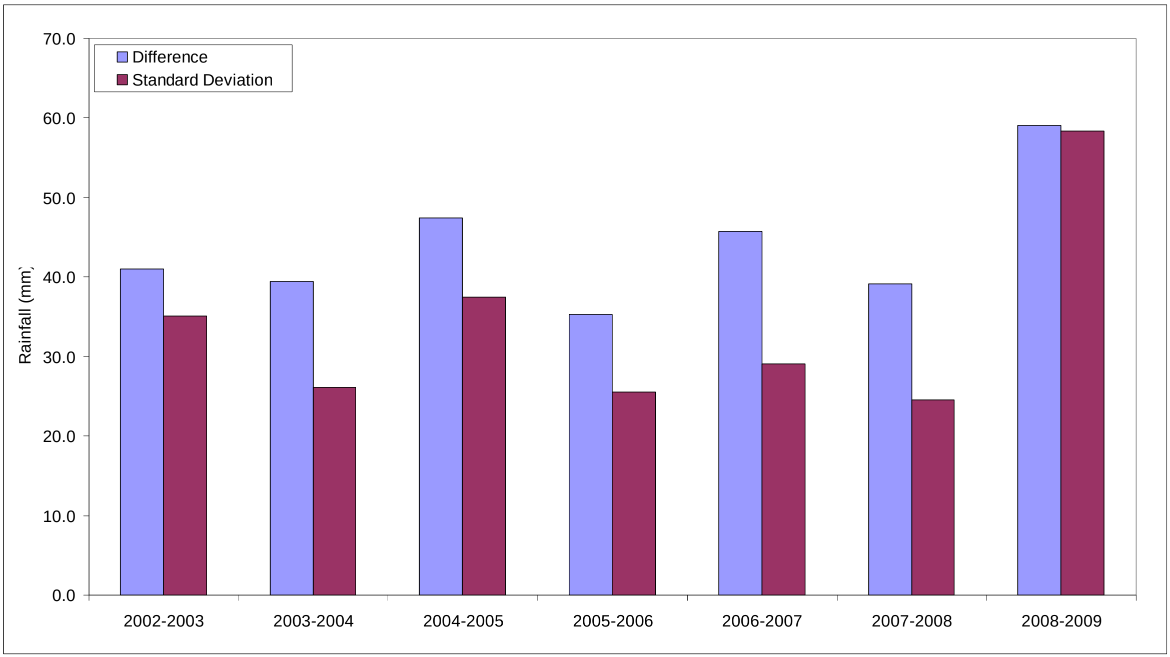

Figure 4-4 Averaged Differences and Standard Deviations

Annual rainfall totals were also computed for each year and compared to the 1950-2009 long-term mean annual rainfall for each water year, similar to the comparisons of the mean monthly rainfall differences. Finally, the mean monthly absolute differences, standard deviations and absolute differences in mean annual rainfall differences were ranked for each year and the sum of ranks for the three categories were compared. These results are shown in Table 4-3.

Ultimately, a 'typical' year was selected where the year had the smallest average absolute difference, standard deviation, and mean annual rainfall difference. Two water years present themselves as candidates for a typical year, these were:

- July 2005 to June 2006; and
- July 2007 to June 2008.

Table 4-3 Summary of Typical Year Statistics

Year (July to June)	Monthly Absolute Diff.	Rank	Standard Deviation	Rank	Mean Annual Diff.	Rank	Overall Rank Sum
2002-2003	41.0	4	35.1	5	220.8	4	13
2003-2004	39.4	3	26.2	3	129.1	2	8
2004-2005	47.5	6	37.5	6	223.4	5	17
2005-2006	35.3	1	25.5	2	205.9	3	6
2006-2007	45.7	5	29.1	4	391.4	7	16
2007-2008	39.1	2	24.6	1	78.4	1	4
2008-2009	59.1	7	58.4	7	325.4	6	20

4.2.4 Results

The analysis presented above highlights two water years which could be considered 'typical' annual periods for a sustainable loads assessment of Moreton Bay. While 2007-2008 is the most favourable year for the analysis, a rainfall event in the beginning of January 2008 caused model instabilities similar to the technical difficulties described in the draft report submitted 4/07/2011. While there were time-consuming workarounds for this, the water year of 2005-2006 was selected for the scenario assessment as it was deemed suitable without technical difficulties.

4.3 Water Quality Objectives

Water quality objectives (WQO) have been established for many of the physico-chemical parameters within the waters of Queensland and are detailed in the Queensland Water Quality Guidelines (DERM 2009b) and more specifically, the Environmental Protection (Water) Policy 2009 (DERM 2009a). The Environmental Protection (Water) Policy (EPP Water) establishes environmental values for Queensland waters along with water quality objectives that commensurate with those values.

Each waterway may have more than one environmental value (and corresponding WQOs) along its reach to coincide with changing conditions along the waterway. For example, the Pine River is listed as upper estuarine through its northern reach from the tidal extent near Youngs Crossing to the Gypmie Road bridge. The Pine River is then listed as middle estuarine throughout the remaining reaches, including the South Pine Reach to its tidal limit up to the Deep Water Bend Reserve. Downstream from that location the Pine River is listed as enclosed coastal. Each of the listings for the Pine River carries different WQOs. Health of a particular waterway is assessed by comparing median water quality concentrations of independent samples against the WQOs.

Figure 4-5 through Figure 4-22 present the WQOs of each waterway as the WQOs change within the waterway. For the Pine and Caboolture River and Pumicestone Passage, the WQOs begin at the upstream boundaries and proceed downstream to the mouth of the waterway. For Bramble and Deception Bays, these WQOs are simply presented as discreet locations with those waterways.

4.3.1 Turbidity

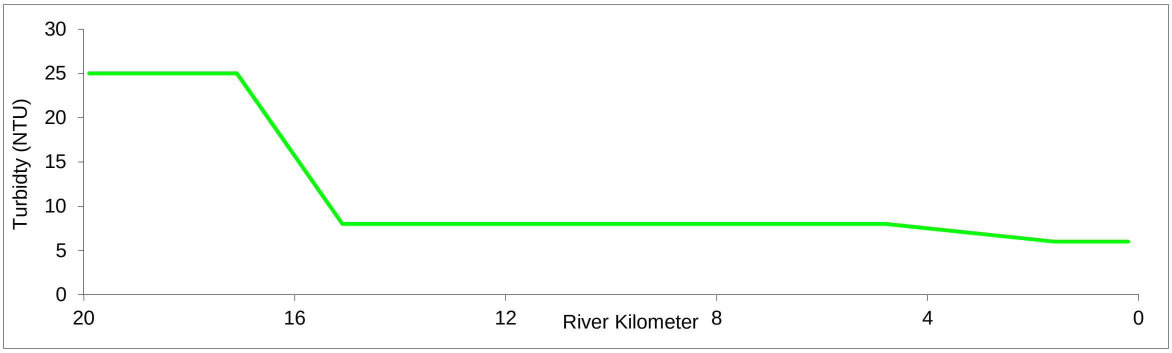

Figure 4-5 Turbidity Water Quality Objectives – Caboolture River

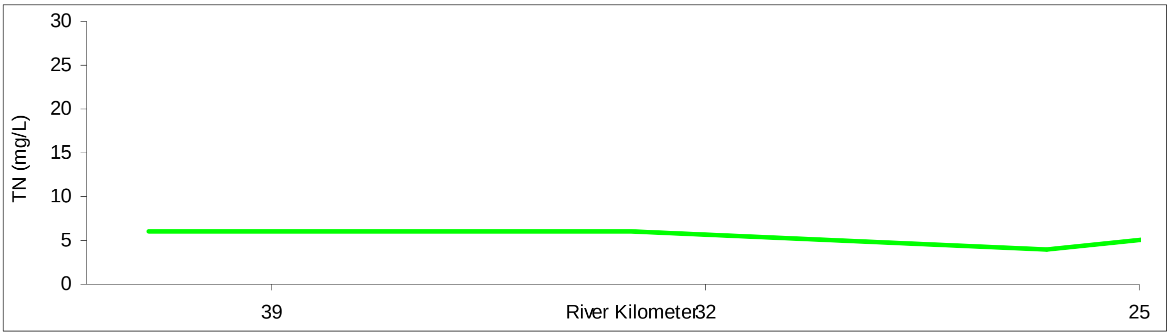

Figure 4-6 Turbidity Water Quality Objectives – Pumicestone Passage

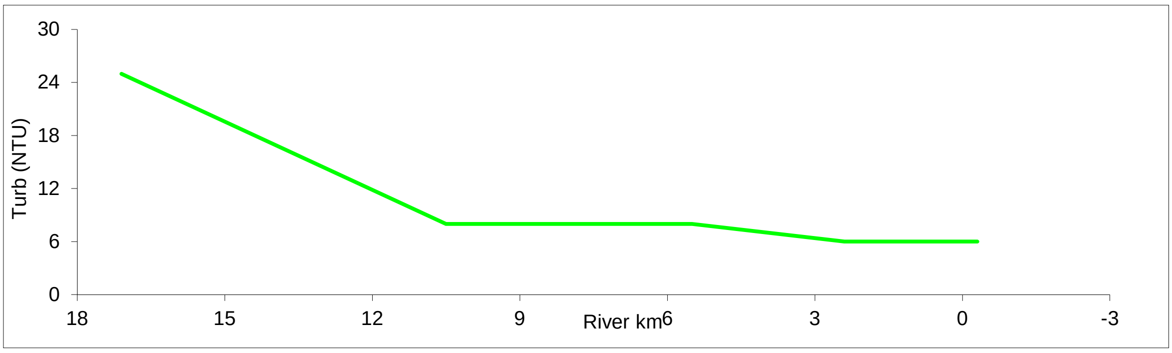

Figure 4-7 Turbidity Water Quality Objectives – North Pine River

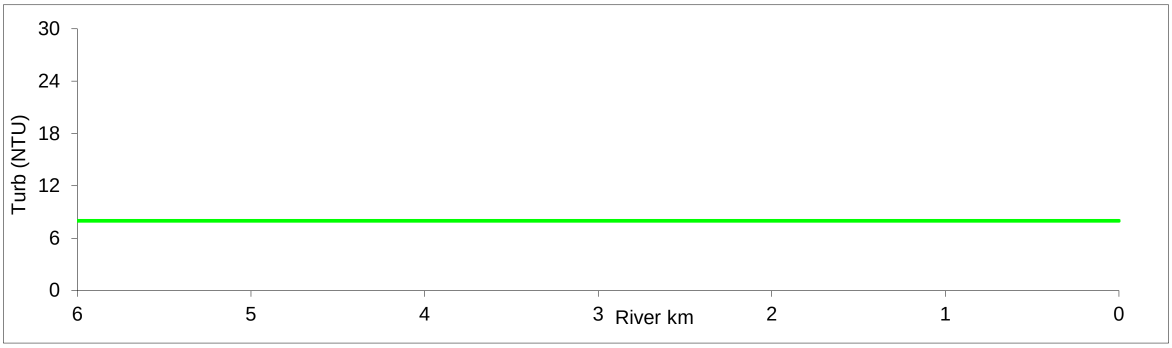

Figure 4-8 Turbidity Water Quality Objectives – South Pine River

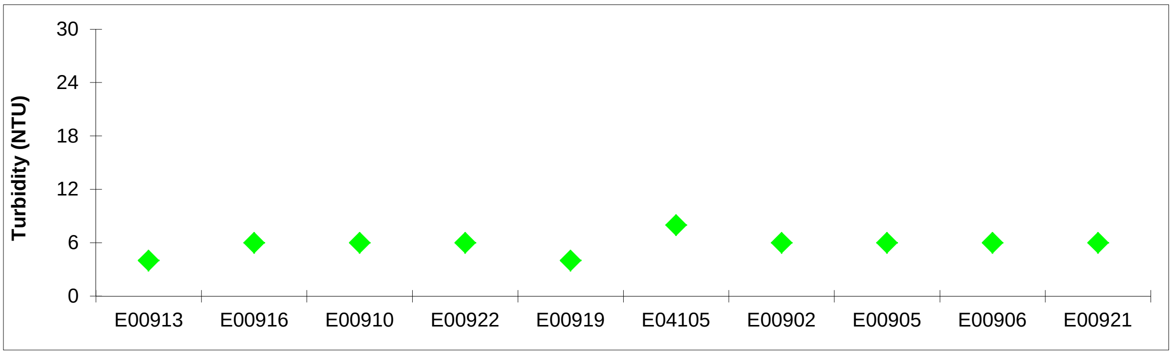

Figure 4-9 Turbidity Water Quality Objectives – Bramble Bay

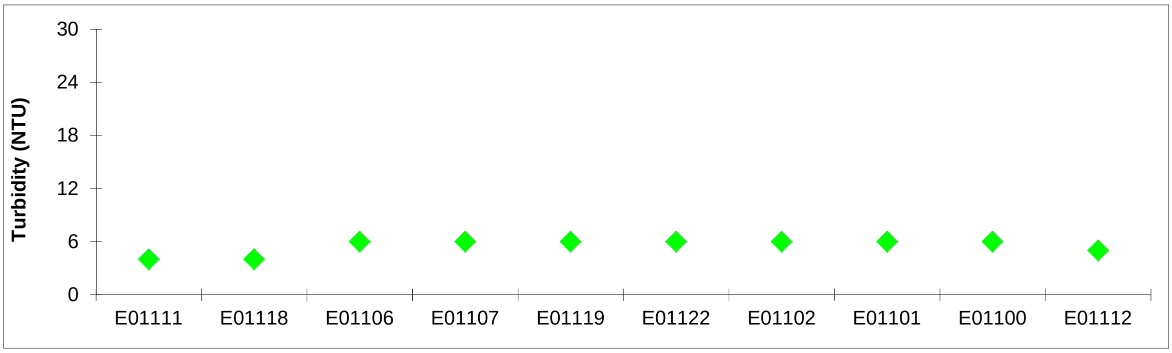

Figure 4-10 Turbidity Water Quality Objectives – Deception Bay

4.3.2 Total Nitrogen

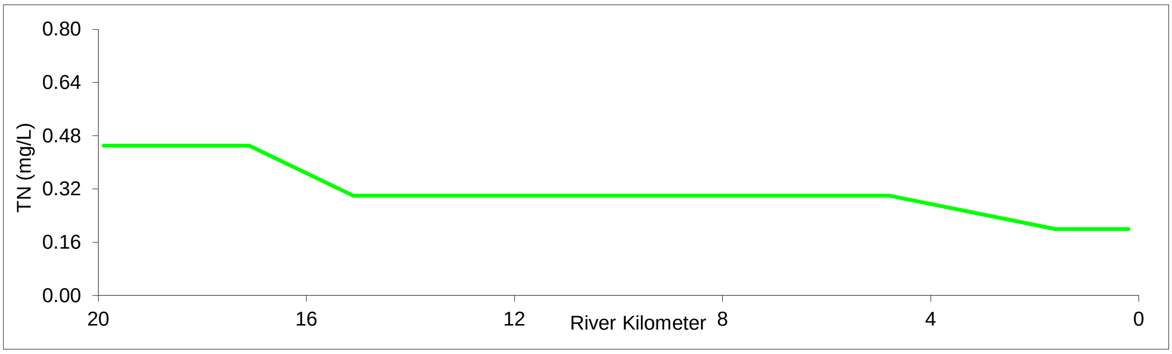

Figure 4-11 Total Nitrogen Water Quality Objectives – Caboolture River

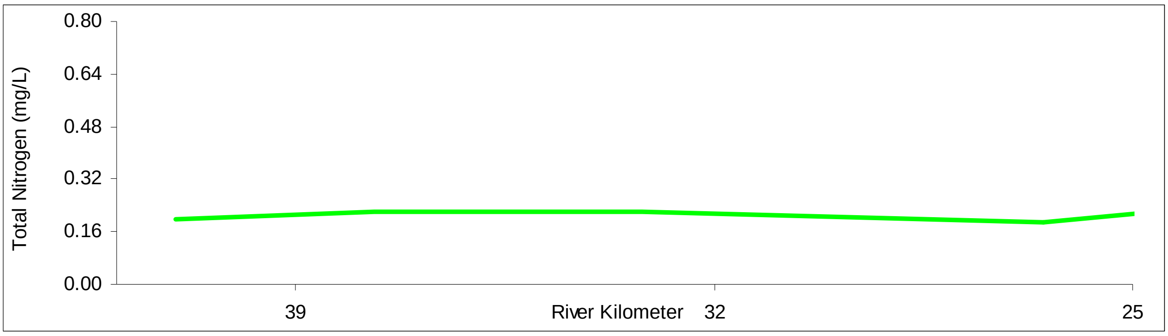

Figure 4-12 Total Nitrogen Water Quality Objectives – Pumicestone Passage

Figure 4-13 Total Nitrogen Water Quality Objectives – North Pine River

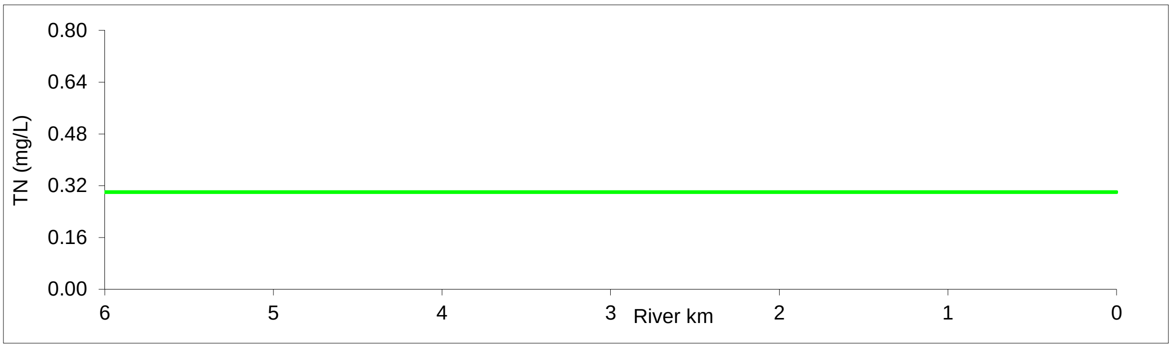

Figure 4-14 Total Nitrogen Water Quality Objectives – South Pine River

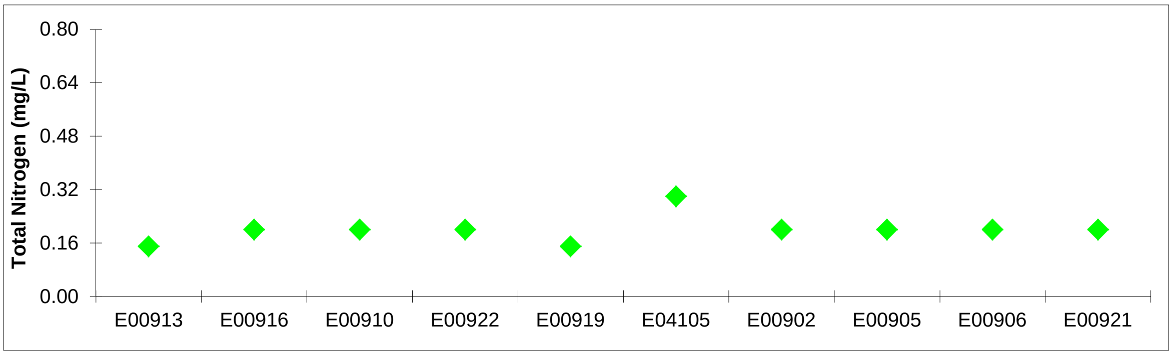

Figure 4-15 Total Nitrogen Water Quality Objectives – Bramble Bay

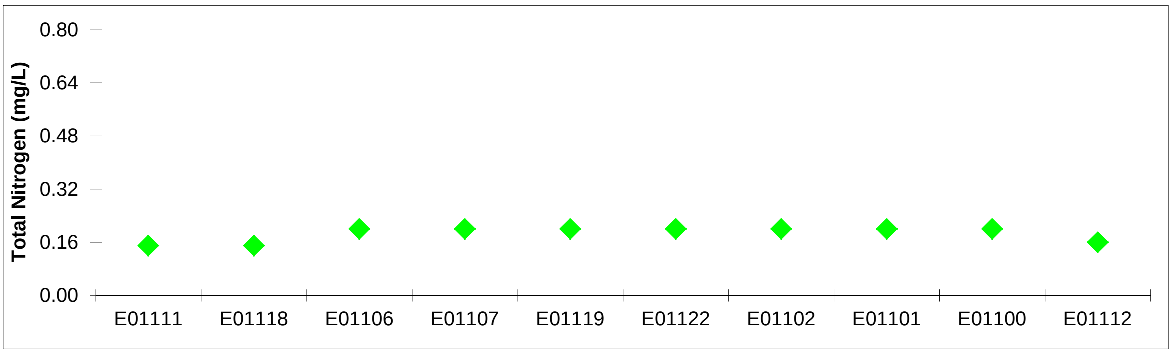

Figure 4-16 Total Nitrogen Water Quality Objectives – Deception Bay

4.3.3 Total Phosphorus

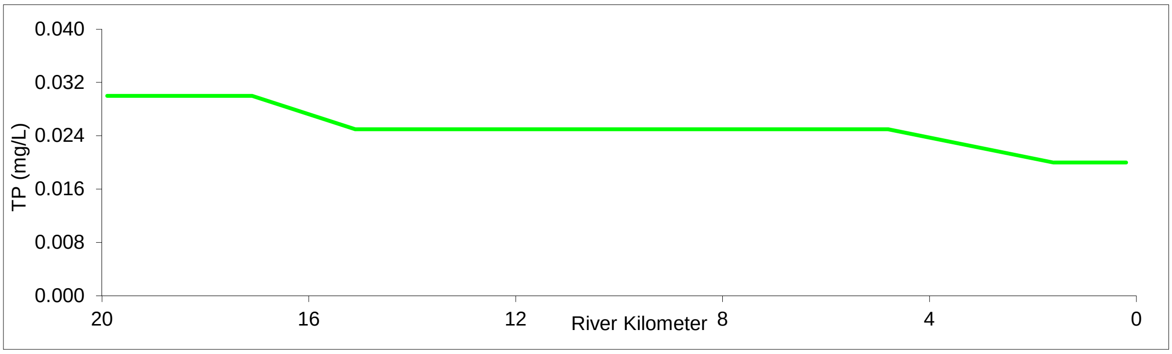

Figure 4-17 Total Phosphorus Water Quality Objectives – Caboolture River

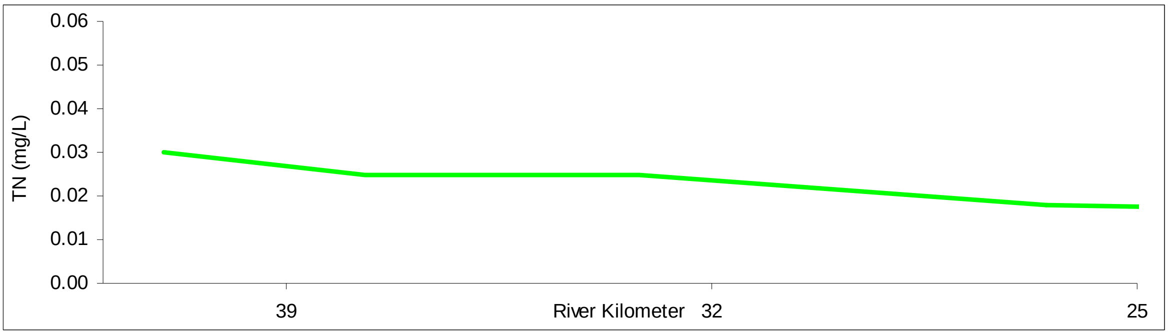

Figure 4-18 Total Phosphorus Water Quality Objectives – Pumicestone Passage

Figure 4-19 Total Phosphorus Water Quality Objectives – North Pine River

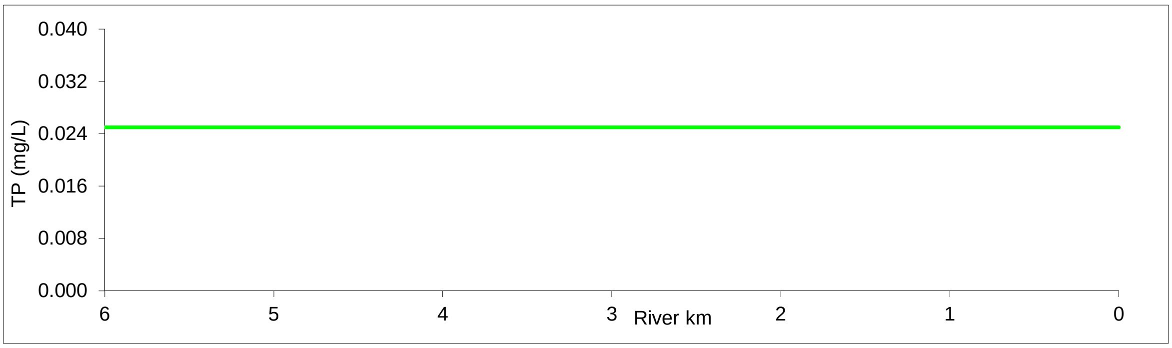

Figure 4-20 Total Phosphorus Water Quality Objectives – South Pine River

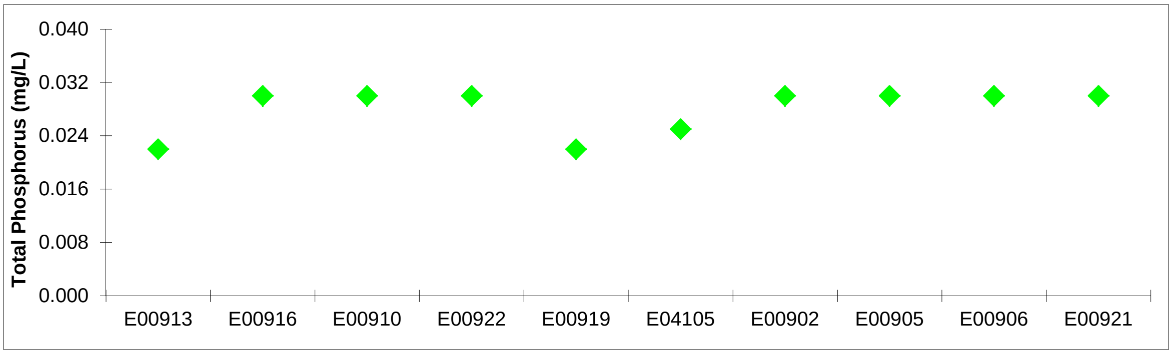

Figure 4-21 Total Phosphorus Water Quality Objectives – Bramble Bay

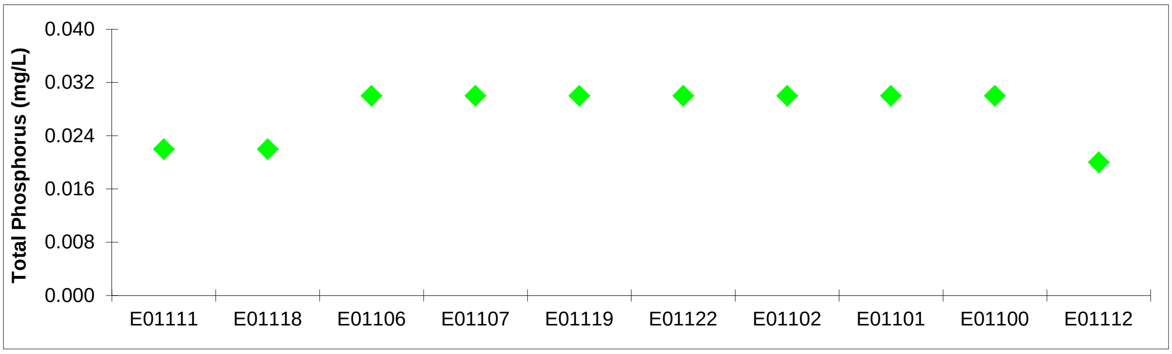

Figure 4-22 Total Phosphorus Water Quality Objectives – Deception Bay

4.4 Sustainable Loads Determination

Upon selection of the typical year, the calibrated Source Catchment and *RWQM V2* model was used to quantify sustainable pollutant loads targets. The sustainable pollutant loads targets enabled a measure of the quantum of pollutant load reduction required from each of the contributing catchments to enable achievement of the water quality objectives (if possible) in the upper, mid and lower portions of the Caboolture and Pine River Estuaries as well as Deception and Bramble Bays. The sustainable pollutant loads was determined by:

1 Representing 'Green Space' conditions with 100% green space revegetation including elimination of STPs and storages; and

2 Iteratively applying increasing load reductions from catchment inflows and STPs and modelling these reductions in the *RWQM V2*. The maximum reduction applied was 90% for catchment and STP loads.

The results of each load reduction scenario were interrogated until a scenario that met receiving water quality objectives was identified. A catchment was deemed to have met a sustainable load only if the waterway to which it drained met water quality objectives at all of the EHMP sites for that waterway for TSS, TN and TP. If the water quality objectives were not met at 90% reduction for a particular water way for which a given catchment drained to then 'Green Space' catchment loads were adopted as the sustainable load for that water way.

A waterway could also meet a "No Worsening" condition if potential load reductions applied to future development returned the receiving water quality to existing (present-day) conditions.

4.4.1 EHMP Calibration to Model Results

To evaluate scenario performance with regard to compliance with WQOs, each catchment was assigned a general area and a representative EHMP site. In some instances more than one catchment drained to the same water way (e.g., CIGA and Caboolture River).

Table 4-4 MBRC Catchment and EHMP Evaluation Sites*

MBRC Catchment	General Area	Applicable EHMP Sites
Bribie Island	Pumicestone Passage	E01304, E01302, E01301, and E01313
Brisbane Coastal	Bramble Bay	E00922 and E00902
Burpengary	Deception Bay	E01122 and E01102
Caboolture	Caboolture River	E01000 - E01011
CIGA	Caboolture River	E01000 - E01011
Hayes Inlet	Bramble Bay	E00900, E00916, and E00913
Lower Pine River	Pine River	E00812, E00814, E00811, and E00806 - E00800
Pumicestone Passage	Pumicestone Passage	E01304, E01302, E01301, and E01313
Redcliffe	Deception/Bramble Bay	E00900, E00916, and E00913
Sideling Creek	Pine River	E00806, E00804, E00803, E00802, E00801, E00800

* Byron Creek, Mary River, Neurum Creek, Stanley River and Upper Pine Catchments were not assessed within the RWQM V2 because they are freshwater catchments.

In order to measure compliance with WQOs or to assess achievement of sustainable loads, adjustment of the modelled results to EHMP data was necessary. While a good calibration of the *RWQM V2* was achieved in most locations (refer to Section 3.3), adjustment of future modelled annual median concentrations to existing EHMP was necessary since there was not a perfect match between existing modelled conditions and EHMP data. Figure 4-23 provides an example that shows the longitudinal profile of modelled existing annual median concentrations along the Caboolture River for total nitrogen compared with EHMP data and WQOs. While the modelled data correlates reasonably well with the EHMP data, a perfect match is unfeasible.

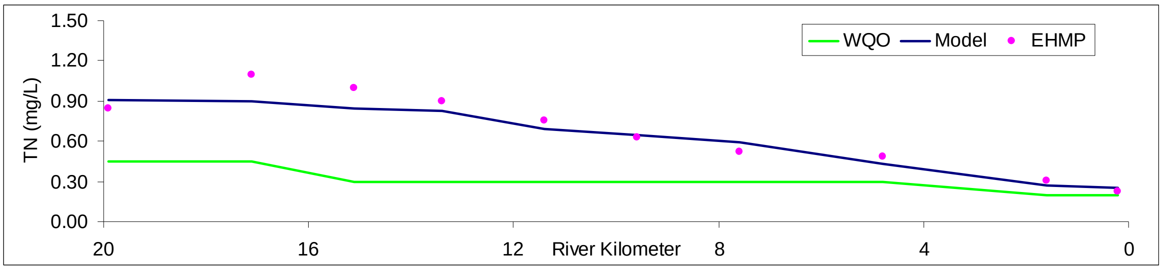

Figure 4-23 Caboolture River Total Nitrogen Evaluation

Modelled results were therefore used to calibrate (i.e. adjust) the EHMP data based upon relative difference between modelled scenarios. This was also necessary as the future developed case with no mitigation, also known as "Future, Business as Usual (Future BAU)," had to be used for baseline conditions (i.e., future development scenarios had to be compared to future baseline conditions).

The EHMP data adjustment process and the process to assess if a particular load reduction achieved a sustainable load was as follows:

- Model results used to determine the percent increase at each EHMP location and the change in annual median concentrations from existing conditions to Future BAU;
- Resulting changes were applied to the EHMP data to represent future water quality conditions at each EHMP site;
- Load reductions were applied to the future BAU scenario and run in *RWQM V2*;
- The percent by which the reduced loads changed the modelled annual median concentrations over the Future BAU conditions was applied to the Future BAU EHMP data; and
- These changes were compared to the WQOs for respective waterways to determine if the sustainable load was met.

For example, if the future development case with no mitigation was predicted by the model to increase annual median concentrations of TN by 5%, then the EHMP annual median TN concentrations for the representative EHMP sites were increased by 5%. Then, if a load reduction scenario reduced annual median TN concentrations over the Future BAU at a site by 40%, the adjusted future EHMP data were reduced by 40%. The resulting adjusted EHMP data was then compared to the WQO to determine if the sustainable loads scenario resulted in compliance with WQOs.

4.4.2 Sustainable Loads

Table 4-5 through Table 4-7 present the sustainable loads for TSS, TN, and TP for each of the catchments draining directly to an estuary. These loads reflect the 2005-2006 typical water year, not the mean annual loads presented earlier in this report.

Table 4-5 Total Suspended Solids Sustainable Loads (t/yr)

MBRC Catchment	Existing	Future BAU	Sustainable Load	Sus. Load Scenario
Bribie Island	228	**246**	**246**	Future BAU
Brisbane Coastal	149	150	11	**'Green Space' conditions**
Burpengary	869	827	140	Susload (90/90)
Caboolture	3,648	3,641	786	**'Green Space' conditions**
CIGA	360	519	94	**'Green Space' conditions**
Hayes Inlet	840	966	53	**'Green Space' conditions**
Lower Pine River	1,466	1,531	123	**'Green Space' conditions**
Pumicestone Passage	1,280	**1,261**	**1,261**	Future BAU
Redcliffe	366	398	16	**'Green Space' conditions**
Sideling Creek	518	518	32	**'Green Space' conditions**

* Caboolture catchment future BAU includes CIGA STP loads

From the results presented, only Pumicestone Passage meets the WQOs for all constituents in the future developed scenario without mitigation. Only the Burpengary catchment meets the sustainable load with a sustainable load reduction for suspended sediment at a 90% reduction in catchment and STP loads. All other catchments did not meet WQOs under any of the scenarios including 'Green

Space' catchment conditions. Therefore, the 'Green Space' catchment loads were adopted as the sustainable load.

Table 4-6 Total Nitrogen Sustainable Loads (t/yr)

MBRC Catchment	Existing	Future BAU	Sustainable Load	Sus. Load Scenario
Bribie Island	10.9	**13.3**	**13.3**	Future BAU
Brisbane Coastal	4.39	4.43	0.75	**'Green Space' conditions**
Burpengary	18.8	19.0	11.1	**'Green Space' conditions**
Caboolture	95.0	123.0	55.3	**'Green Space' conditions**
CIGA	5.7	12.8	6.6	**'Green Space' conditions**
Hayes Inlet	39.5	49.1	3.7	**'Green Space' conditions**
Lower Pine River	57.5	79.8	8.6	**'Green Space' conditions**
Pumicestone Passage	37.0	**38.2**	**38.2**	Future BAU
Redcliffe	9.4	10.2	1.1	**'Green Space' conditions**
Sideling Creek	8.4	8.4	2.3	**'Green Space' conditions**

* Caboolture catchment future BAU includes CIGA STP loads

Table 4-7 Total Phosphorus Sustainable Loads (t/yr)

MBRC Catchment	Existing	Future BAU	Sustainable Load	Sus. Load Scenario
Bribie Island	1.01	**1.27**	**1.27**	Future BAU
Brisbane Coastal	0.44	0.45	0.04	**'Green Space' conditions**
Burpengary	2.27	2.24	0.52	**'Green Space' conditions**
Caboolture	9.18	9.88	2.61	**'Green Space' conditions**
CIGA	0.63	1.47	0.31	**'Green Space' conditions**
Hayes Inlet	3.12	3.87	0.18	**'Green Space' conditions**
Lower Pine River	8.41	13.34	0.41	**'Green Space' conditions**
Pumicestone Passage	3.02	**3.12**	**3.12**	Future BAU
Redcliffe	1.09	1.19	0.06	**'Green Space' conditions**
Sideling Creek	1.03	1.03	0.11	**'Green Space' conditions**

* Caboolture catchment future BAU includes CIGA STP loads

4.4.3 Discussion

Most of the waterways within Moreton Bay do not meet the water quality objectives consistently. The Healthy Waterways Partnership has consistently given lower than average grades to each of the waterways considered in this study. The sustainable loads determinations in this section indicate that reaching water quality objectives within Moreton Bay is unlikely based upon the predictive modelling. Therefore for all catchments, with the exception of Bribie Island, Pumicestone Passage and Burpengary for TSS, the 'Green Space' catchment conditions were adopted as targets for load reductions instead of the water quality objectives.

It should be noted that some catchments might experience difficulties in meeting sustainable loads, as the water ways to which they drain are influenced by sources of sediment and nutrients other than theirs alone. For example, the Brisbane Coastal catchment drains to Bramble Bay via Kedron Brook, Nudgee and Nundah Creeks, however the catchment comprises only 20% of the total catchment area that drains through these creeks, and much of the additional drainage occurs downstream of the Brisbane Coastal catchment.

4.5 Land Use Management Scenarios

Management scenarios developed from the ‘Solution Feasibility Assessment’ in the Moreton Bay TWCMP were represented within the re-calibrated *RWQM V2*. Representation of the management scenarios enabled the efficacies of various options in improving ambient water quality across key waterways to be appropriately assessed and compared to baseline and sustainable load conditions. Water quality objectives were not considered subsequently because they largely could not be met via any sustainable load or pre-settlement conditions.

4.5.1 Scenarios

Summarised in this section are the modelled catchment land use management scenarios as applied to the Source Catchments modelling to estimate flows and loads resulting from the various management strategies discussed in the Total Water Cycle Management Plan for Moreton Bay Regional Council. This section describes how the management was technically applied within the model framework. Please refer to the main body of the report for more detailed descriptions of the management scenarios.

The application of the management strategies were applied as percentages, typically, as correspondence between loads generated by Source Catchments often differ to those generated by MUSIC and the other methods described in the main document. Also summarised are the sewage treatment plant (STP) flows, concentrations and corresponding loads. The combination of the catchment flows and loads and STP flows and loads were used to inform the *RWQM V2* described in the following section (Section 4.5.2).

4.5.1.1 Basecase

The basecase scenario incorporates the existing land use to capture present-day flows and pollutant loads. For STPs, the most up-to-date data was used to reflect the existing treatment levels. Annual median concentrations were adopted to eliminate temporal conditions. Analyses demonstrated that using annual medians concentrations for STPs produced similar and acceptable results to those of the actual data. Table 4-8 summarises the 2009-2010 STP concentrations used to model basecase conditions, and Table 4-9 provides the corresponding flows and pollutant loads for those constituents of concern.

Table 4-8 Basecase (2009-2010) STP Flows and Constituent Concentrations

STP	Flow (MLD)	BOD (mg/L)	DO (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
Redcliffe	14.5	3.00	7.53	2.57	3.61	0.17
Murrumba	17.3	3.00	4.40	2.57	1.50	0.59
Burpengary East	9.8	3.43	7.03	2.07	4.11	0.12
South Caboolture	8.1	3.00	0.02	2.00	1.61	0.02
Bribie	4.7	3.00	6.58	2.00	1.60	0.17
Brendale	8.0	4.00	3.51	2.86	3.60	0.20

Table 4-9 Basecase STP Flows and Loads

STP	Flow (GL/yr)	TSS (t/yr)	TN (t/yr)	TP (t/yr)
Redcliffe	5.3	13.6	19.2	0.89
Murrumba	6.3	16.3	9.5	3.74
Burpengary East	3.6	7.4	14.7	0.42
South Caboolture	3.0	5.9	4.8	0.06
Bribie	1.7	3.4	2.8	0.29
Brendale	2.9	8.4	10.5	0.59

4.5.1.2 Future Development – No Mitigation

The FBAU scenario represents future conditions based on the land use information described in Section 4.1. All converted future urban lands were assumed to have the same hydrologic and pollutant export rates as existing urban lands.

The 2009-2010 annual median STP concentrations were used but with future build-out flows to reflect the demands of development on STPs.

4.5.1.3 Scenario 1 – Low Intensity

The Low Intensity development scenario included:

- Future development compliance utilising Water Sensitive Urban Design (WSUD) to mitigate pollutant loads from development to meet best practice load reductions. These load reductions were applied in Source Catchments as a filter, removing a percentage of the loads from event based flows and do not apply to groundwater baseflows. The percentage reductions are summarised in Table 4-10 for TSS, TP, and TN. Flow reductions were applied in post processing of Source Catchments data for integration with the RWQM V2;
- The Queensland Development Code (QDC) water saving requirements is achieved through rainwater tanks and community stormwater harvesting. The reduction in flow is summarised in Table 4-11. The flow reductions were also applied to future developments with no existing development agreement; and
- Recycled water usage reduced STP discharge to surface waters (compared to the Future BAU scenario) for the Murrumba and South Caboolture STPs. These reductions in flows have a corresponding reduction in pollutant loads.

Table 4-10 WSUD BMP Flow and Load Reductions (%)

Catchment	Flow	TSS	TN	TP
Bribie Island	4.7%	80.0%	47.5%	64.6%
Brisbane Coastal	4.3%	80.3%	46.2%	64.3%
Burpengary Creek	4.4%	80.3%	46.9%	63.9%
Caboolture River	4.3%	79.8%	46.3%	64.8%
CIGA	4.8%	79.9%	44.3%	65.8%
Hays Inlet	4.4%	80.5%	48.4%	66.5%
Lower Pine River	4.5%	80.4%	47.8%	66.4%
Pumicestone Passage	4.3%	80.6%	47.0%	63.8%
Redcliffe	4.6%	80.0%	47.1%	64.1%
Stanley River	4.7%	79.9%	46.7%	64.1%
Upper Pine River	4.8%	80.2%	49.9%	69.3%

Table 4-11 QDC Flow Reductions for Future Development (%)

Catchment	QDC Flow Reduction
Bribie	82%
Brisbane Coastal	100%
Burpengary	100%
Caboolture	72%
CIGA	49%
Hays Inlet	56%
Lower Pine	93%
Pumicestone	3%
Redcliffe	100%
Stanley	100%
Upper Pine	100%

4.5.1.4 Scenario 2 – Medium Intensity

The medium development intensity scenario (Scenario 2) built upon Scenario 1 while incorporating stream rehabilitation BMPs designed to primarily reduce TSS, with some modifications to the QDC reductions for the Hays and Lower Pine catchments. In particular, the following management schemes were applied in Source Catchments:

- Grazing BMPs for 1st and 2nd order streams were applied to TSS export within the grazing functional unit as filters in Source Catchments;
- Riparian revegetation BMPs for 3rd and 4th order stream was applied to TSS export for all functional units within each catchment at a percent reduction. Both grazing and riparian revegetation BMPs are presented in Table 4-12;
- Buffer strips were applied to the intensive agricultural (horticulture) functional units within the Stanley River, Pumicestone Creeks, Caboolture, Upper and Lower Pine, and Sideling catchments. The reductions were applied as a filter in Source Catchments with the following percentage removal:
  - Total Suspended Solids – 84%;

  - Total Nitrogen – 70%; and
  - Total Phosphorus – 75%;
- QDC modifications which are presented in Table 4-13;
- A rainwater tank retrofit for existing urban areas was applied to the Redcliffe catchment with a reduction in flows of 16%; and
- Recycled water usage reduced STP discharge to surface waters (compared to Scenario 1) for the Redcliffe, Murrumba, Brendale, and South Caboolture STPs. The reductions in flows have a corresponding reduction in pollutant loads.

Table 4-12 Grazing and Riparian Revegetation TSS Reductions (%) – Scenario 2

Catchment	Grazing BMP 1st/2nd Order	Riparian Reveg 3rd/4th Order
Burpengary Creek	92%	22%
Caboolture River	91%	16%
CIGA		29%
Hays		21%
Lower Pine River	91%	12%
Pumicestone Passage	91%	13%
Sideling Creek	90%	3%
Stanley River	92%	11%
Upper Pine River	91%	9%

Table 4-13 QDC Flow Reductions for Future Development – Scenario 2

Catchment	QDC Flow Reduction
Bribie	82%
Brisbane Coastal	100%
Burpengary	100%
Caboolture	72%
CIGA	49%
Hayes Inlet	32%
Lower Pine	44%
Pumicestone	3%
Redcliffe	100%
Stanley	100%
Upper Pine	100%

4.5.1.5 Scenario 3 – High Intensity

The high intensity scenario (Scenario 3) incorporated a combination of the previous scenarios with of the following modifications and additions:

- Retrofitting existing urban functional units with WSUD BMPs and rainwater tanks (Table 4-14) in selected catchments. The WSUD load reductions are 80/60/45 percent for TSS, TP, and TN respectively;
- Stormwater harvesting in selected catchments, presented in Table 4-14;
- Modified QDC targets for selected catchments, presented in Table 4-14;

- WSUD BMPs applied to the urban future development, which were modified to achieve a “No Worsening” in pollutant loads slightly different to Scenario 1. Those reductions are summarised in Table 4-15; and
- Recycled water usage reduced STP flow and loads to surface waters (compared to Scenario 2) for the Burpengary, Murrumba, Brendale, and South Caboolture STPs. Scenario 3 included purified recycled water (PRW) from the Brendale, Murrumba, and South Caboolture STPs for indirect potable reuse. As such, PRW will have an associated reverse osmosis brine backwash to be included in the discharge for those STPs currently discharging. The brine discharge volume is approximately 20% of the total flows with water characteristics summarised in Table 4-16.

Table 4-14 QDC, Stormwater Harvesting, Rainwater Tank Retrofit Reductions (%) – Scenario 3

Catchment	QDC Reduction	Stormwater Harvesting	Rainwater Tank Retrofit
Bribie	82%		27%
Brisbane Coastal	100%		28%
Burpengary	99%	58%	
Caboolture	36%	69%	
CIGA	49%	69%	
Hays Inlet	25%	10%	
Lower Pine	35%	19%	
Pumicestone	2%	59%	13%
Redcliffe	100%		
Stanley	100%		
Upper Pine	100%		

Table 4-15 “No Worsening” Flow and Load Reductions (%) – Scenario 3

Catchment	Flow	SS	TN	TP
Burpengary Creek	4.4%	80.3%	46.9%	63.9%
Caboolture River	5.0%	82.5%	49.8%	67.6%
Hays Inlet	7.1%	87.8%	58.9%	74.4%
Lower Pine River	4.5%	80.4%	47.8%	66.4%
Pumicestone Passage	5.4%	84.0%	51.6%	67.5%
Upper Pine River	7.5%	87.2%	59.6%	76.2%
Stanley River	4.7%	79.9%	46.7%	64.1%
CIGA	4.8%	79.9%	44.3%	65.8%

Table 4-16 Purified Recycled Water Characteristics

Parameter	Concentration (mg/L)
BOD	12
DO	6.6
Ammonia	0.46
Nitrate+Nitrite	2.41
TN	7.17
TP	0.47
TSS	1.45

4.5.1.6 Results and Discussion

Figure 4-24 through to Figure 4-27 presents the mean annual flows and loads per catchment for each of the scenarios including existing conditions and Future BAU. The Byron Creek, Mary River, and Neurum Creek catchments were not included in these figures as no development is anticipated nor are there any management scenarios planned for those catchments. Figure 4-28 through Figure 4-31 present the annual STP flows and loads for each of the scenarios including existing conditions and Future BAU. Future South Caboolture STP flows and loads include those from the future CIGA development, including subsequent scenario management factors for the CIGA area.

The general findings from the catchment management scenarios indicate the following:

- Existing Conditions compared to Future BAU:
  - All catchments in which development occurs results in an increase in flows, nitrogen, and phosphorus from existing to future development conditions with no mitigation;
  - Suspended sediment load reductions as a result of development (0.5% overall and 26% in CIGA) are likely due to lower pollutant export rates for the urban functional unit than the grazing functional unit (See Table 2-6 above); and
  - Total nitrogen and phosphorus increased from the basecase by approximately 2% and 3% respectively. The largest increases were observed in CIGA, Hays Inlet and Redcliffe catchments and are likely due to larger percent areas developed.
- Future BAU compared to Scenario 1:
  - Scenario 1 flows were reduced compared to the Future BAU scenario by 3% while catchment loads from Scenario 1 were reduced by 4-6%. The largest change occurred in CIGA, where flows decreased 43% compared to the Future BAU where loads decreased by 54-69%; and
  - Aside from CIGA, Hays Inlet and Redcliffe catchments showed the largest decreases, likely as a result of the larger percentage of areas of future development area within those catchments.
- Future BAU compared to Scenario 2:
  - Scenario 2 showed the most significant decreases in suspended sediment loads (46%), with incremental decreases in TN and TP (6-7%) over Future BAU;
  - The largest percentage decreases in TSS for catchments other than CIGA occurred in the Burpengary, Caboolture, Pumicestone and Upper Pine River catchments (~60% decrease). This was likely due to a combination of factors including the amount of rural and grazing lands to which the rural BMPs were applied, the amount of sediment reduction applied per catchment for the rural BMPs and the hydrologic characteristics of the catchments; and
  - There were slightly greater flows, particularly from Hays Inlet and Lower Pine River Catchments, as a result of lower QDC reductions. Redcliffe, however, produced lower flows as a result of urban retrofitting of rainwater tanks. Both the increases and decreases in flows have associated increases and decreases, respectively, in total pollutant loads.
- Future BAU compared to Scenario 3:

- Overall, Scenario 3 shows only incremental decreases for all pollutants (5-9%) over scenario 2, for a total load reduction of 10-15% over the Future BAU scenario. Most of these reductions are associated with changes in flow rates from future and retrofitted urban areas; and
- Increases in nitrogen and phosphorus loads at the South Caboolture and Brendale STPs were due to PRW schemes for those plants blended with normal discharge flows and lows. While the Murrumba also created PRW, the resulting flow rate was very small compared to the Future BAU.

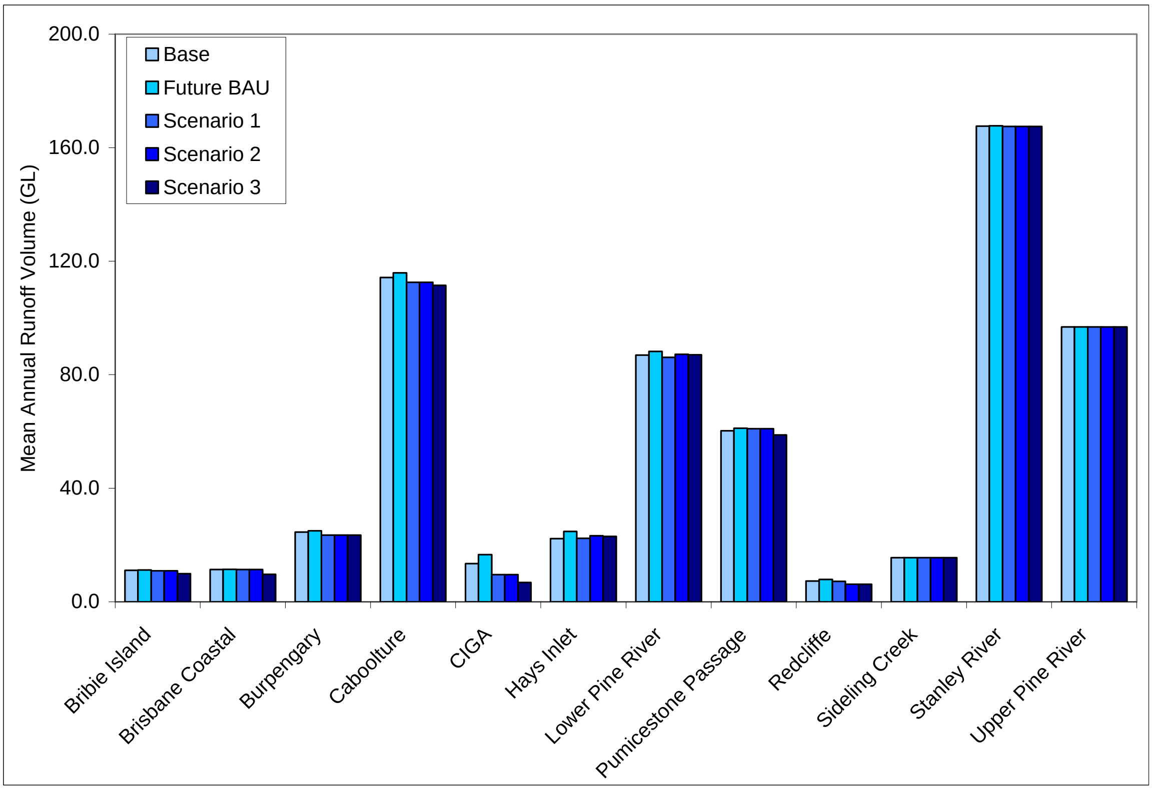

Figure 4-24 Mean Annual Runoff Volumes per Catchments (GL)

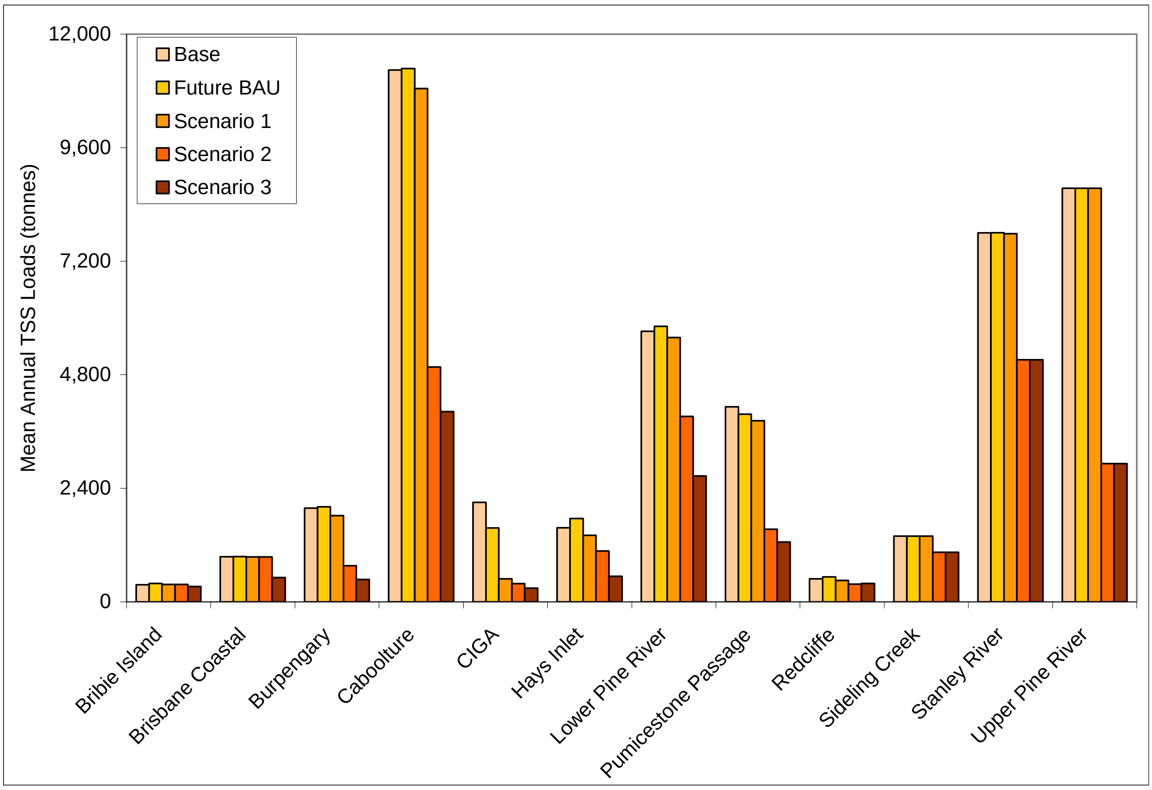

Figure 4-25 Mean Annual Suspended Sediment Loads (tonnes)

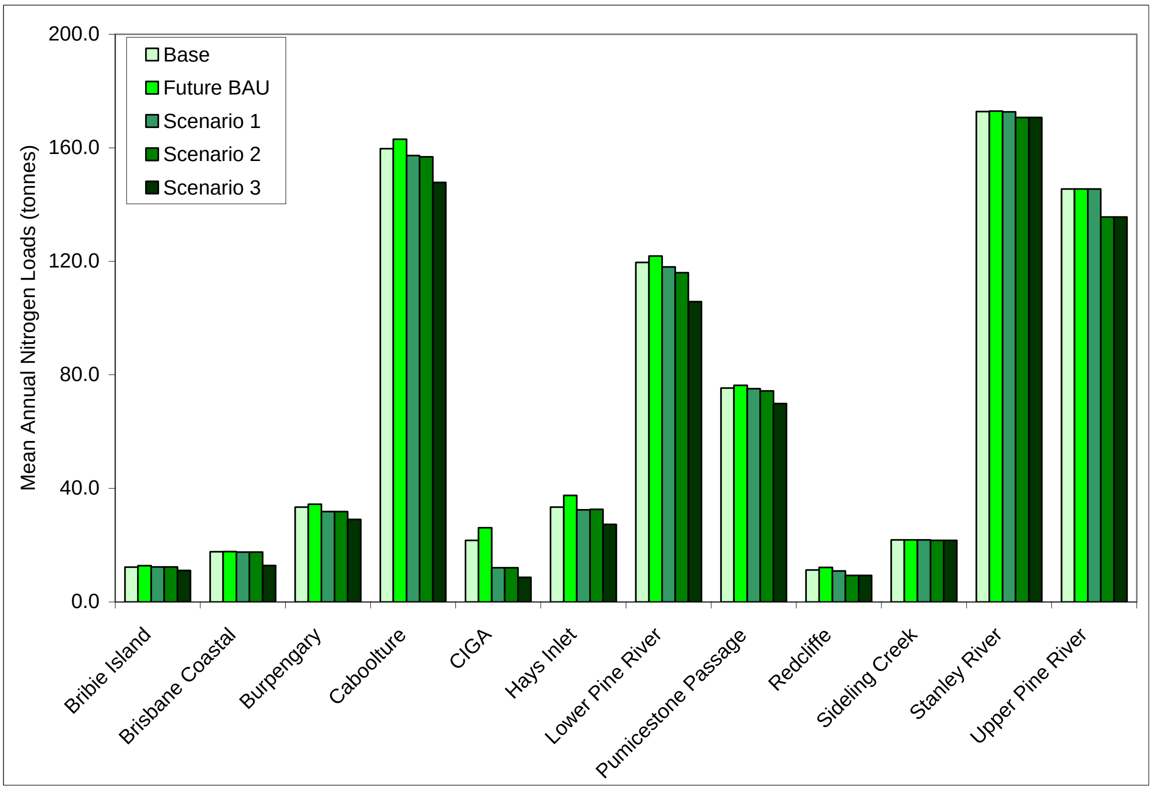

Figure 4-26 Mean Annual Total Nitrogen Loads (tonnes)

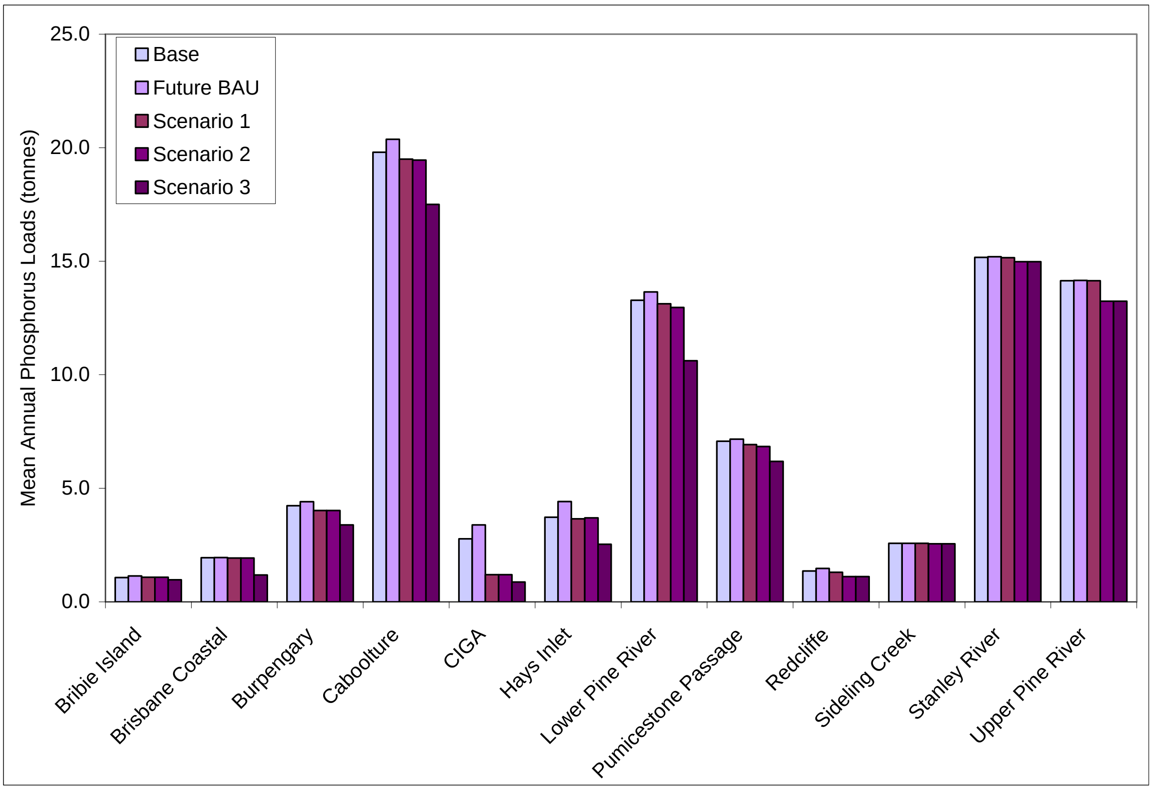

Figure 4-27 Mean Annual Total Phosphorus Loads (tonnes)

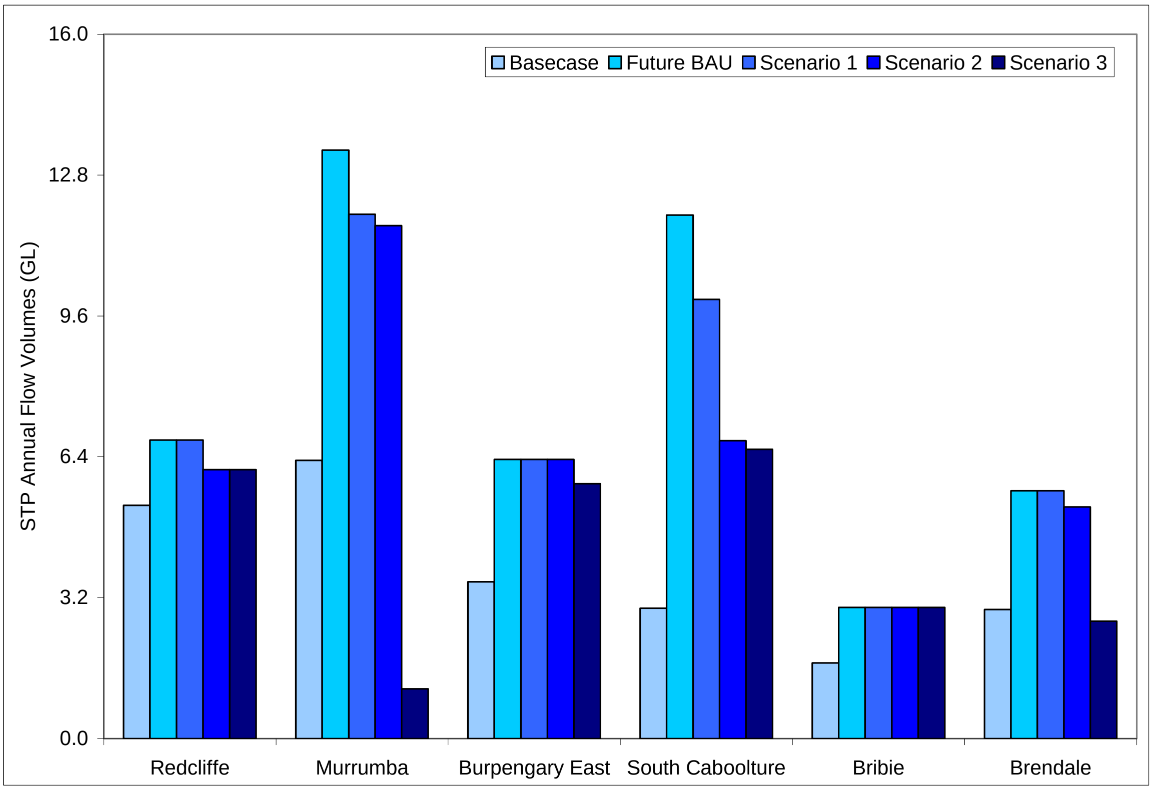

Figure 4-28 Annual STP Discharge Volumes (GL)

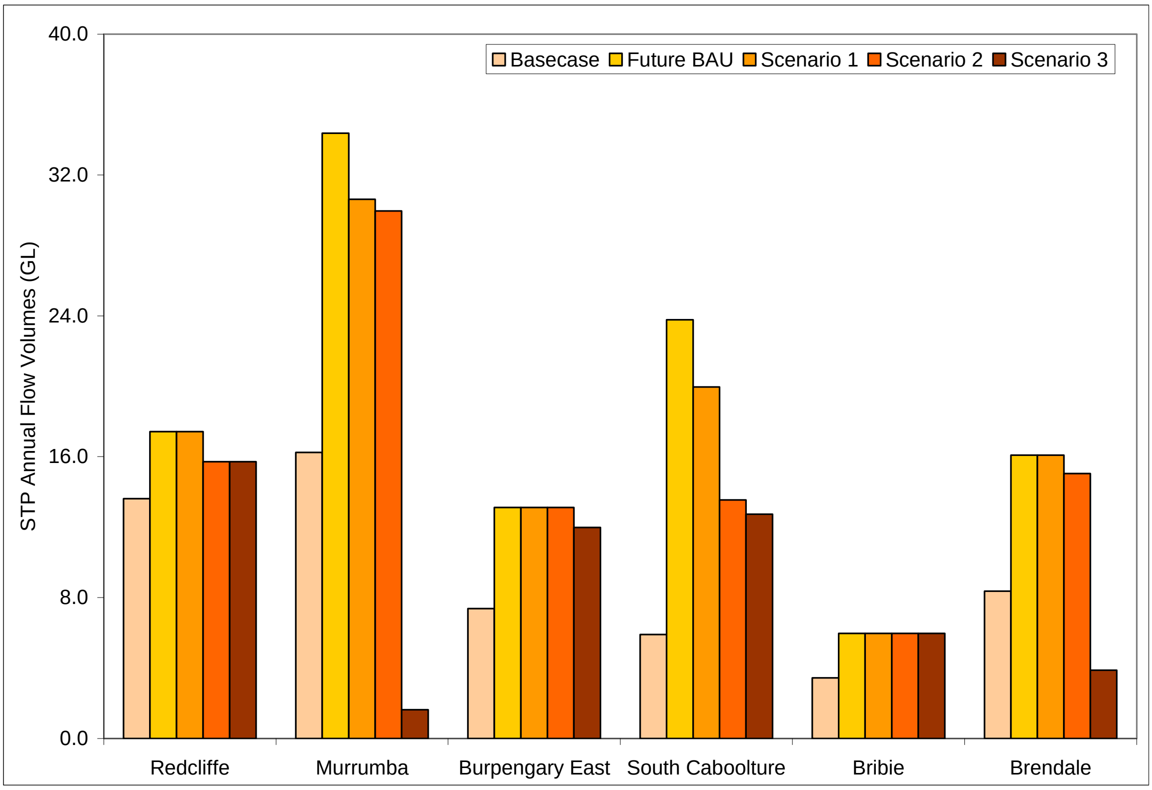

Figure 4-29 Annual STP Suspended Sediment Loads (tonnes)

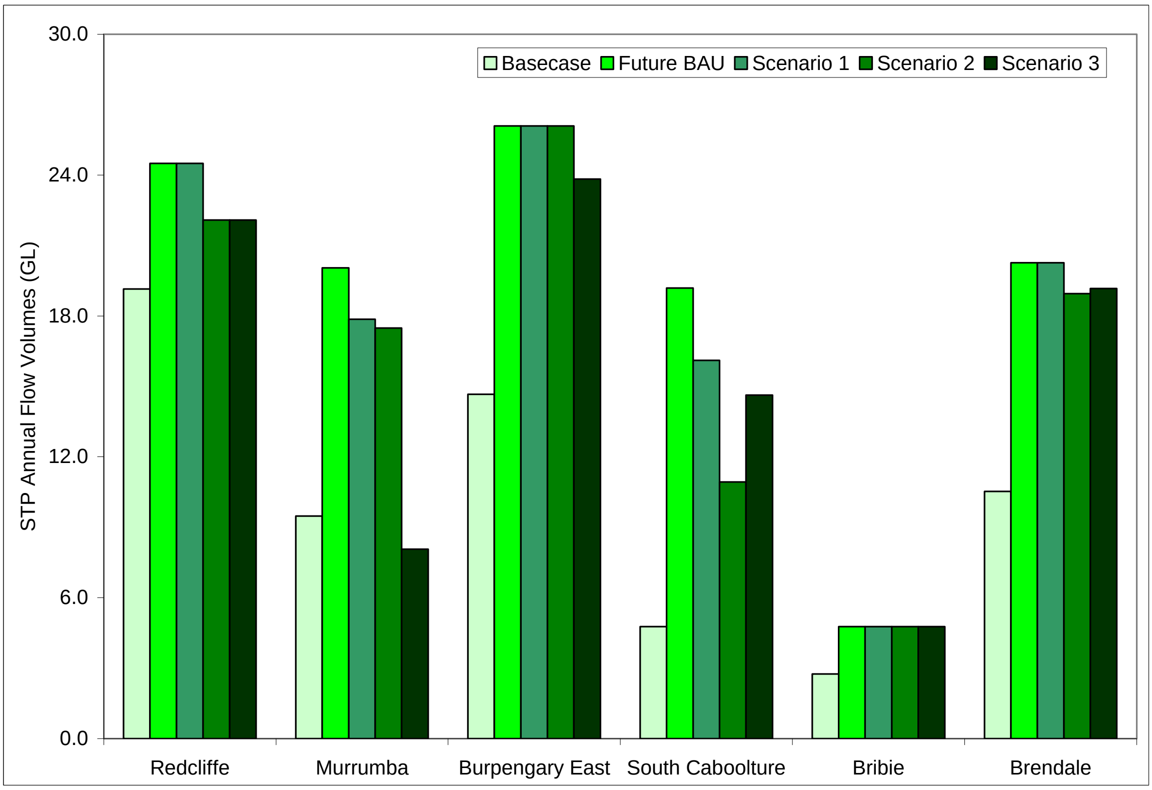

Figure 4-30 Annual STP Total Nitrogen Loads (tonnes)

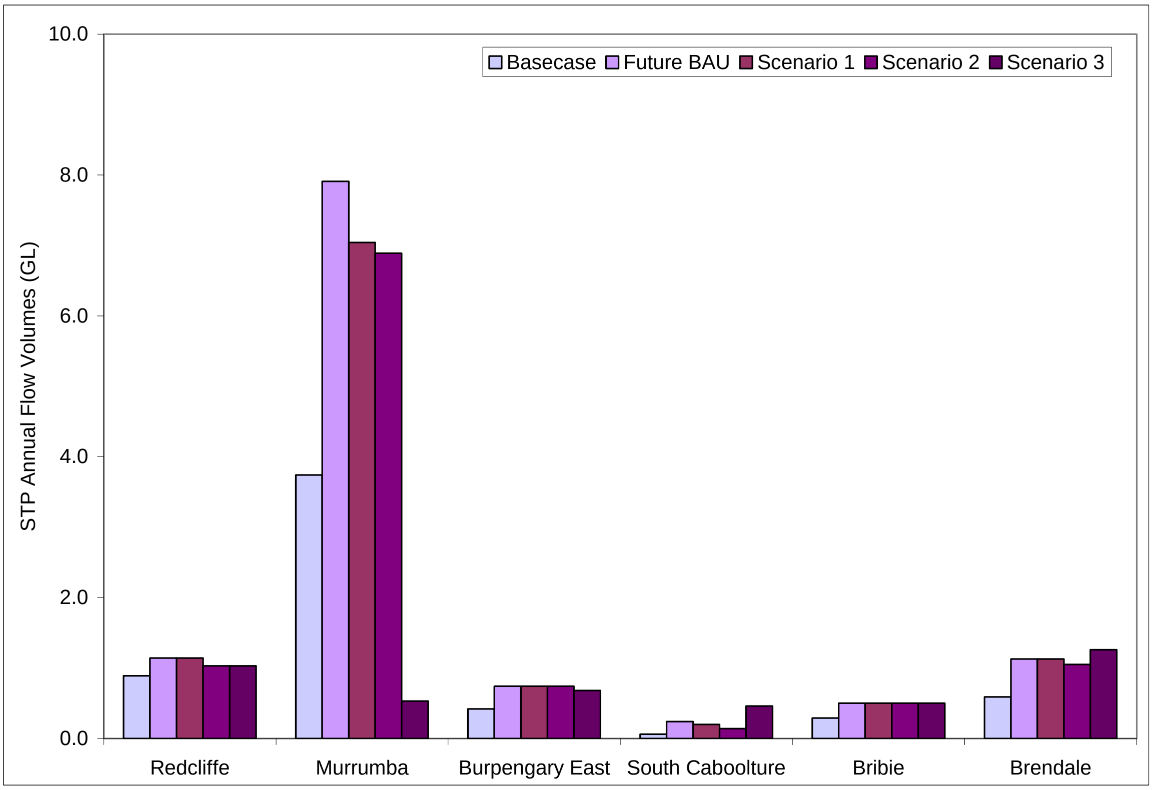

Figure 4-31 Annual STP Total Phosphorus Loads (tonnes)

4.5.2 Receiving Water Quality Impacts

This section summarises the impacts of the modelled catchment and STP management scenarios to individual water ways. Primarily, impacts were assessed in the Caboolture and Pine Rivers, however, Bramble and Deception Bays were also affected by these rivers and direct catchment flows and pollutant loads. Pumicestone Passage was assessed for the southern EHMP locations, the Future BAU meets sustainable loads, and is therefore not discussed subsequently in terms of scenario compliance.

Similar to the methods of assessing sustainable loads and applying scenario management schemes, the receiving water quality impacts were assessed by:

1. Determining the percentage of reduction in annual median concentrations necessary to meet a no worsening condition and a sustainable load condition;
2. Determining the percentage reduction in annual median concentrations resulting from each management scenario; and
3. Comparing reductions achieved in (2) against the needed reductions in (1) to determine if a given scenario meets either the no worsening or sustainable load condition.

The figures in subsections 4.5.2.1 through to 4.5.2.3 show these analyses by plotting the required and achieved reductions as a function of the distance along the river. For Bramble Bay and Deception Bay, the performances of the scenario reductions are represented discretely per location due to the discontinuity of the water ways. It should be noted that a negative percentage reduction achieved by any given scenario at any location represents an increase in the annual median concentration over the Future BAU scenario. Additionally, it should be noted scenarios can result in an increase in the annual median compared to the Future BAU scenario for various reasons. The graphs show the *percent reduction* in annual median concentrations and an increase in annual medians would show as a negative value in the graphs.

Table 4-17 provides a summary of each scenario for each waterway in this study and the compliance with a sustainable load or no worsening condition for each constituent.

Table 4-17 Summary of Management Scenario and Achieved Compliance

Waterway	Future BAU	Scenario 1	Scenario 2	Scenario 3
Caboolture River				
No Worsening		Turb	Turb	Turb
Sustainable Load				
North Pine River				
No Worsening				
Sustainable Load		Turb		Turb
South Pine River				
No Worsening				
Sustainable Load				
Burpengary/Deception Bay				
No Worsening		Turb	Turb	Turb
Sustainable Load				
Brisbane Coast/Bramble Bay				
No Worsening		Turb	Turb	Turb and TP
Sustainable Load				
Hays Inlet/Bramble Bay				
No Worsening		Turb	Turb	Turb and TP
Sustainable Load				
Pumicestone Passage				
No Worsening				
Sustainable Load	Turb, TN and TP			

4.5.2.1 Caboolture River

Figure 4-32 through Figure 4-34 depicts the necessary and achieved percent reductions in annual median concentrations in the Caboolture River for turbidity (Figure 4-32), TN (Figure 4-33), and TP (Figure 4-34).

- All management scenarios demonstrated compliance with turbidity for a no worsening condition, but not for achieving a sustainable load;
- Management scenarios impact on TN and TP and did not result in either no worsening or a sustainable load;
- For TP, a no worsening condition was achieved for all three scenarios for 60-70% of the EHMP sites, depending on the scenario; and
- Scenario 3 resulted in worse conditions near the STP because of the higher concentrations discharged associated with the PRW.

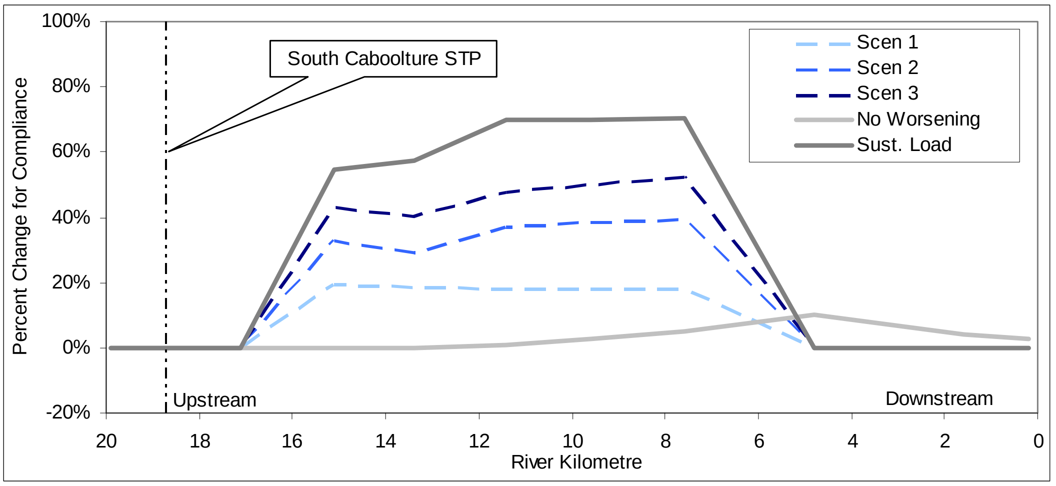

Figure 4-32 Caboolture River Scenario Compliance – Turbidity

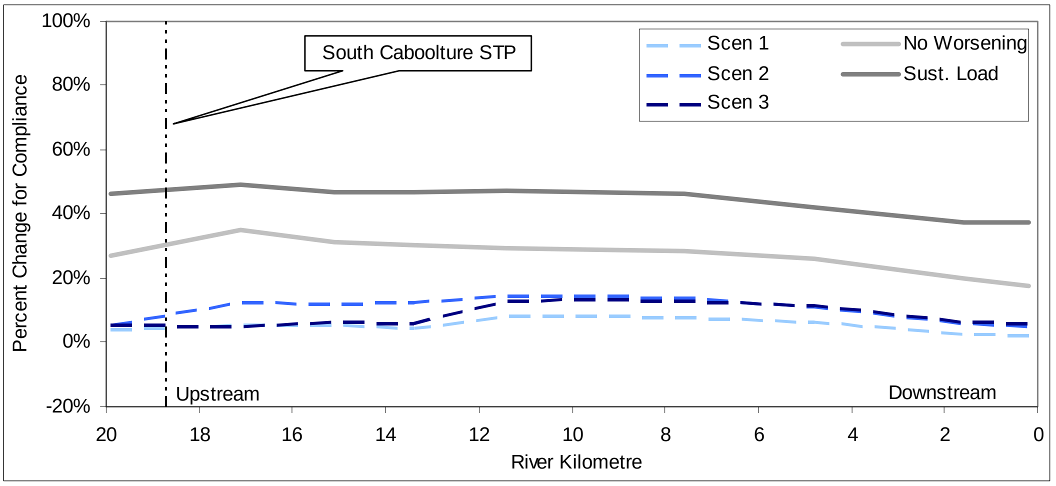

Figure 4-33 Caboolture River Scenario Compliance – Total Nitrogen

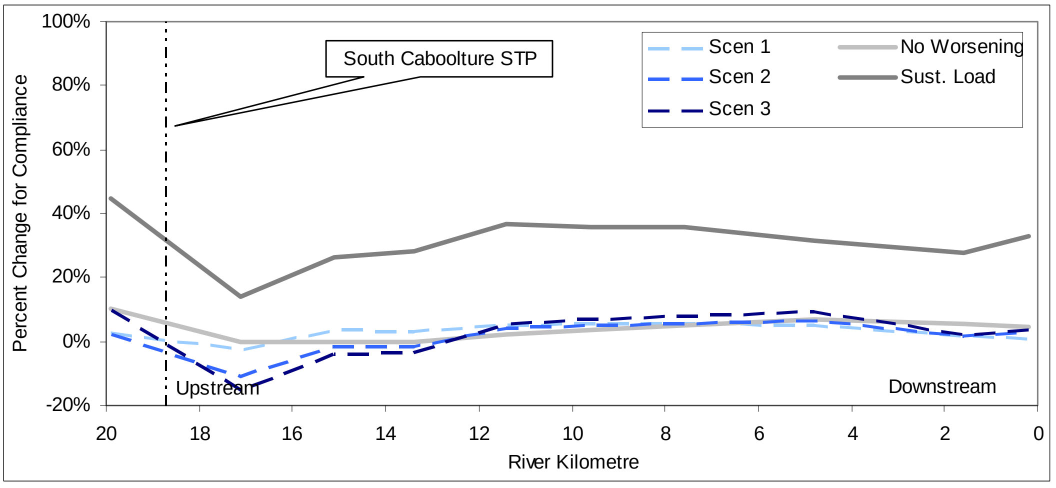

Figure 4-34 Caboolture River Scenario Compliance – Total Phosphorus

4.5.2.2 *Pine River*

Figure 4-35 through Figure 4-37 depicts the necessary and achieved percent reductions in annual median concentrations in the Pine River for turbidity (Figure 4-35), TN (Figure 4-36), and TP (Figure 4-37). Figure 4-38 through to Figure 4-40 show the necessary and achieved percent reductions in annual median concentrations in the Pine River for turbidity (Figure 4-38), TN (Figure 4-39), and TP (Figure 4-40).

- Neither the no worsening nor sustainable load condition was achieved in the South Pine reach for any of the constituents for any of the scenarios;
- In the North Pine reach, a no worsening condition was entirely achieved for turbidity for Scenarios 2, but only partially for Scenarios 1 and 3. The inclusion of PRW brine discharge in Scenario 3 was likely the reason no worsening was not achieved. It should be noted, however, that the no worsening condition in North Pine reach could be achieved by reducing annual median concentrations by at most 1% at any of the EHMP locations; and
- None of the scenarios achieved either condition for TN or TP, however, Scenario 3 achieved no worsening for 4 of the 6 EHMP sites for TP.

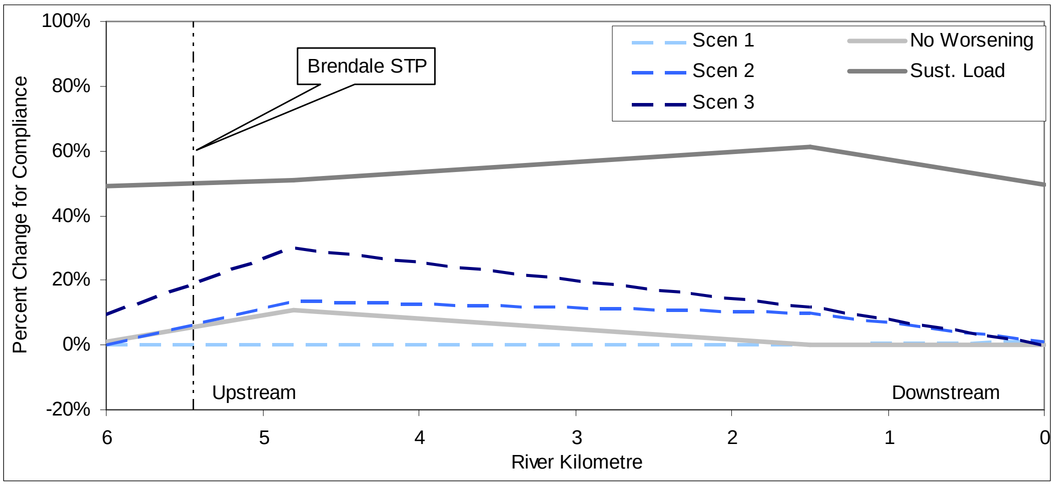

Figure 4-35 South Pine River Scenario Compliance – Turbidity

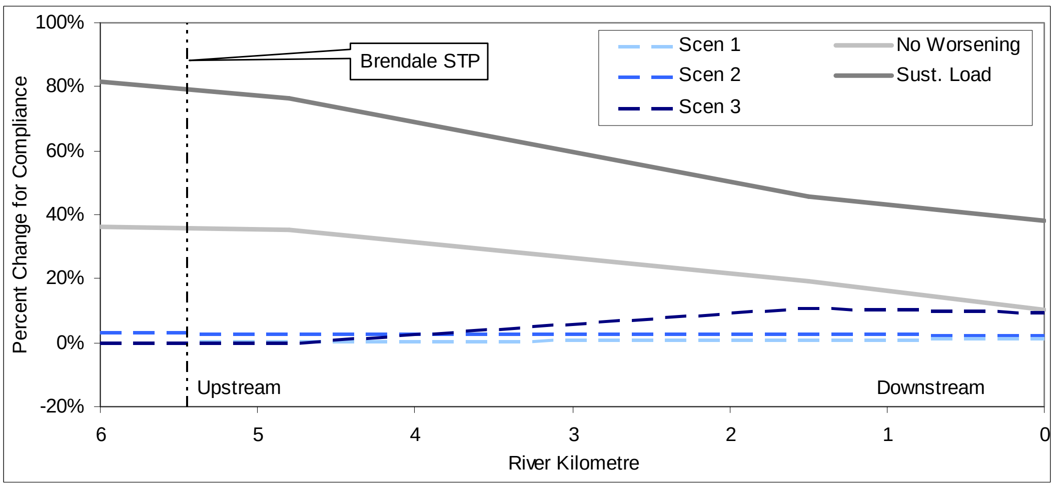

Figure 4-36 South Pine River Scenario Compliance – Total Nitrogen

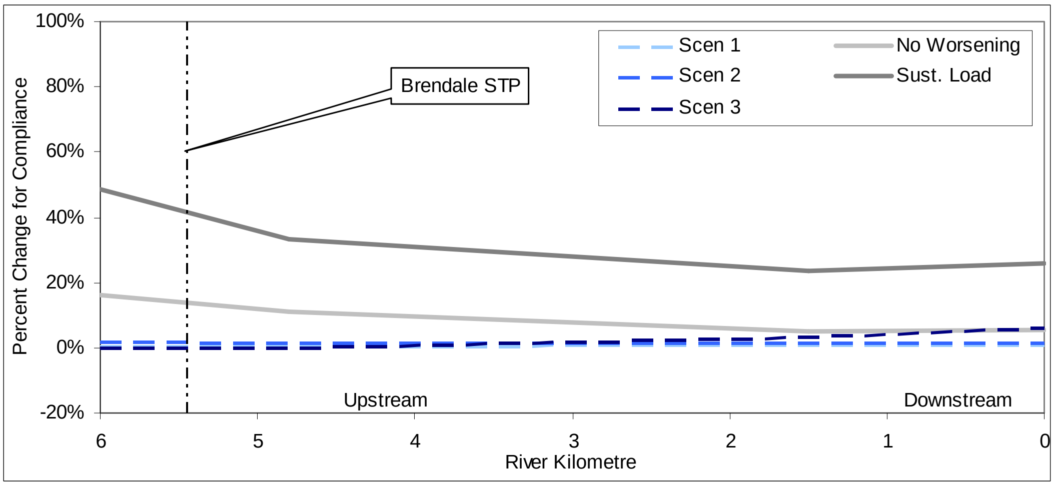

Figure 4-37 South Pine River Scenario Compliance – Total Phosphorus

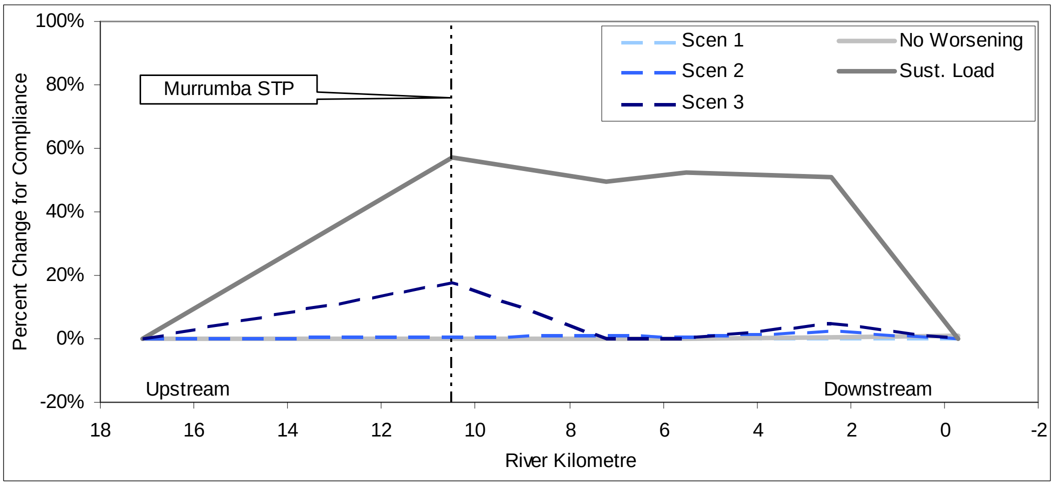

Figure 4-38 North Pine River Scenario Compliance – Turbidity

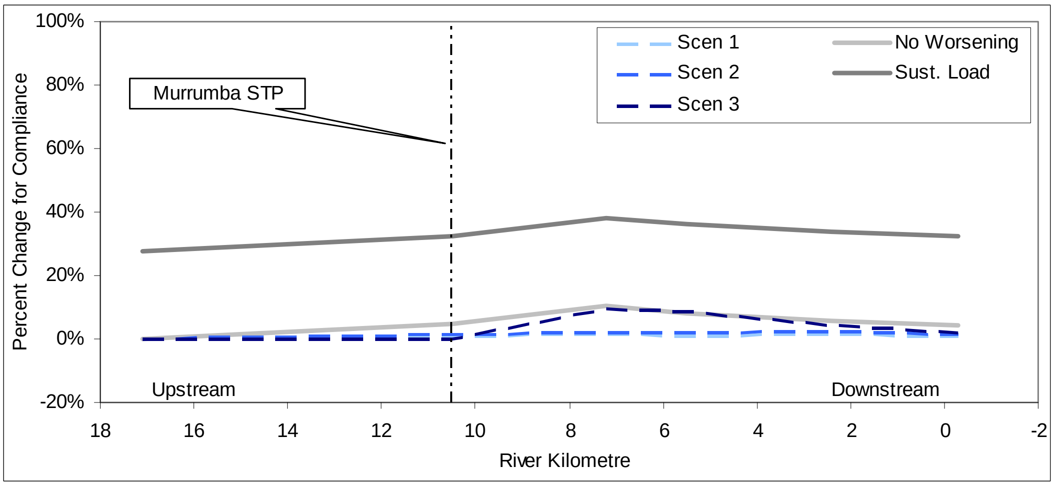

Figure 4-39 North Pine River Scenario Compliance – Total Nitrogen

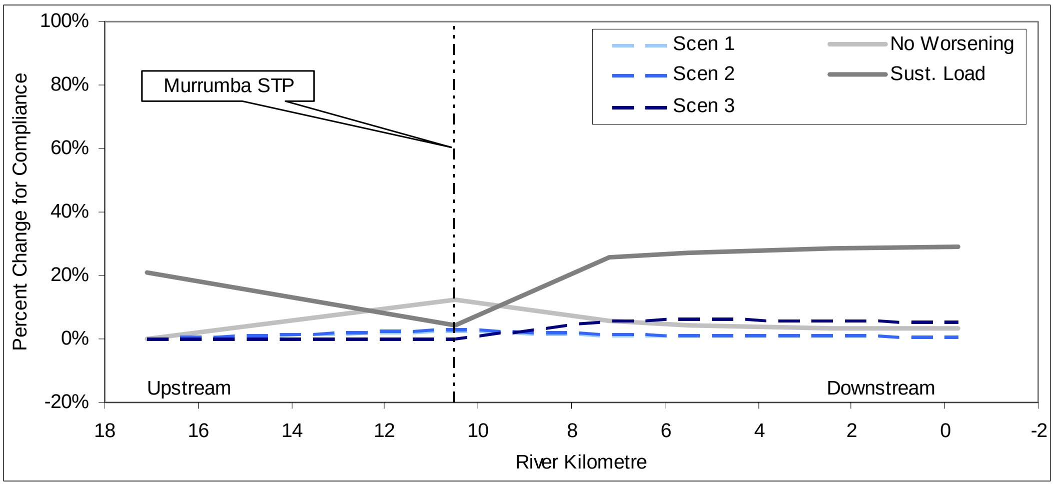

Figure 4-40 North Pine River Scenario Compliance – Total Phosphorus

4.5.2.3 Bramble Bay and Deception Bay

Figure 4-41 through to Figure 4-43 depicts the necessary and achieved percent reductions in annual median concentrations for Deception and Bramble Bays for turbidity (Figure 4-41), TN (Figure 4-42), and TP (Figure 4-43). Table 4-4 and Figure 3-12 presents the locations used to assess compliance for these waterways and the EHMP sites.

- No worsening conditions were achieved for all three scenarios for turbidity in all of the locations with the exception of Scenario 1 at E00916 which was lower than the no worsening condition by 0.3%;
- No worsening was achieved by Scenario 3 in one (E00900) of the 3 EHMP sites representative of the Hays Inlet in Bramble Bay for TN, and Scenario 3 achieved a no worsening condition for the Brisbane Coastal catchment for TN; and
- No worsening was achieved by Scenario 3 for all EHMP sites in Hays Inlet and Brisbane Coastal catchments for TP. The Burpengary catchment achieved a no worsening condition for one of the two locations, but did not achieve it for the other site by less than 0.1%.

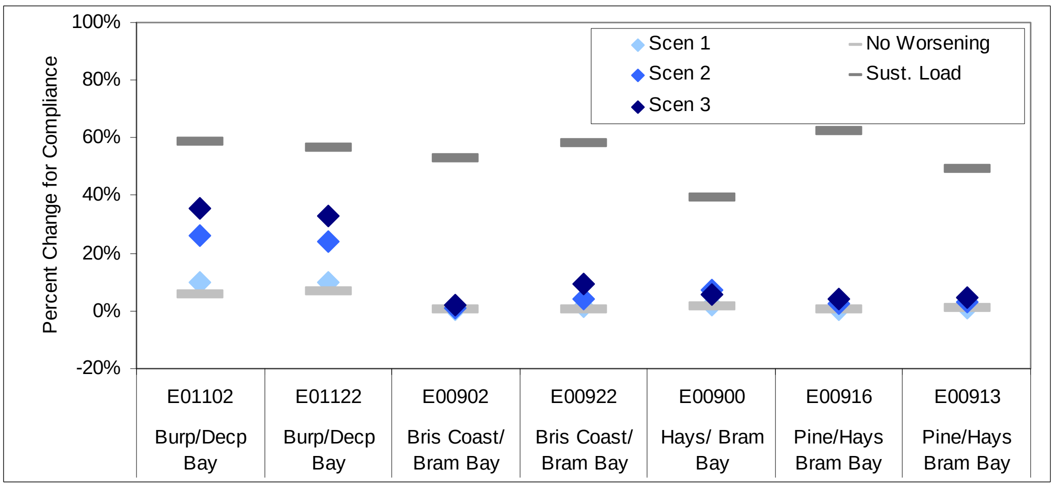

Figure 4-41 Bramble and Deception Bay Scenario Complaince – Turbidity

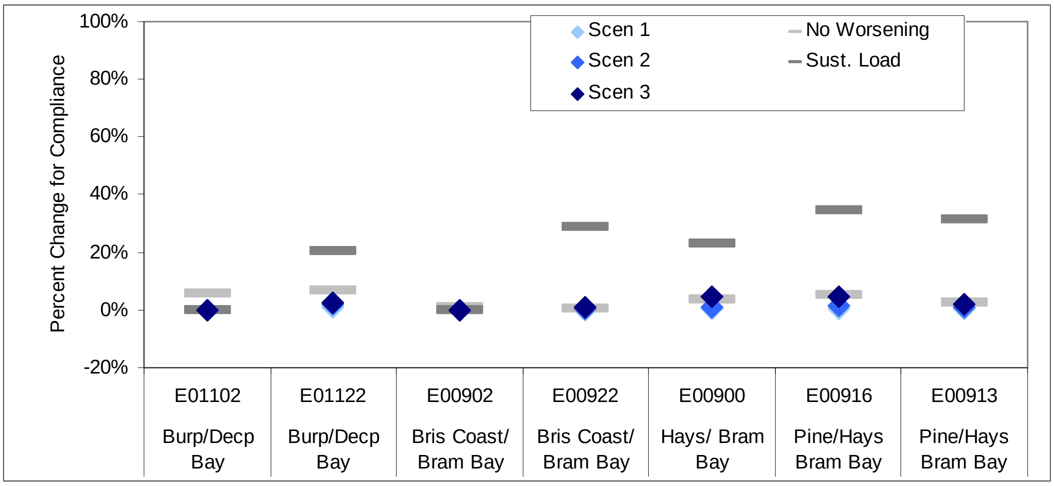

Figure 4-42 Bramble and Deception Bay Scenario Compliance – Total Nitrogen

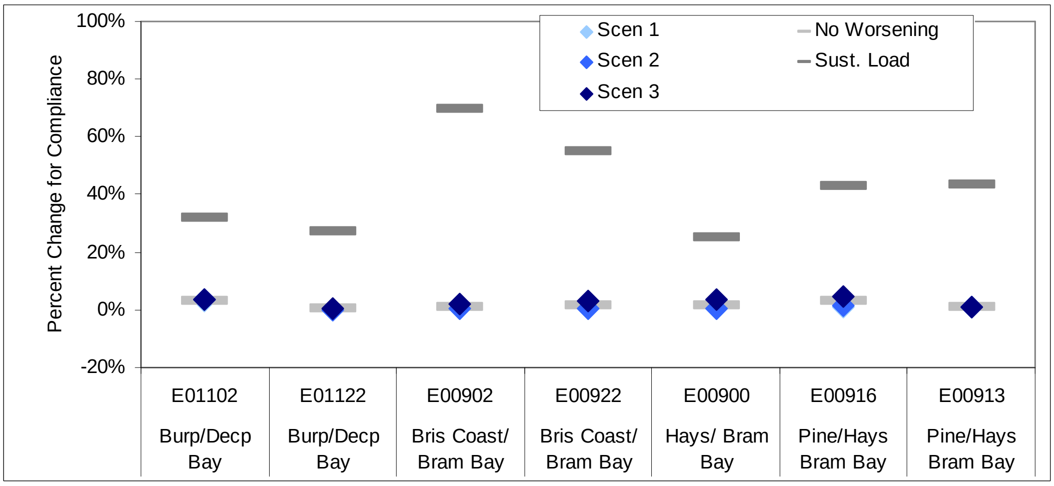

Figure 4-43 Bramble and Deception Bay Scenario Compliance – Total Phosphorus

4.5.2.4 Discussion

The general findings of the receiving water quality impacts of the management scenarios are as follows:

- For many of the waterways, a no worsening condition for turbidity was achieved by Scenarios 2 and 3 for the entire water ways, and in parts, if not all, of each water way for Scenario 1. One reason for this might be that the average required percent reduction of annual median concentrations to achieve no worsening for turbidity across all water ways was 2.0%;
- In contrast, the average required reductions in annual median concentrations for TN and TP across all water ways was 16.1% and 4.3% respectively. In the North Pine and Caboolture reaches, the averaged required reductions to achieve a no worsening condition were 25% and 27%, respectively. Nevertheless, no worsening was achieved for TN in the Brisbane Coastal and Hays Inlet Catchment, and for TP in the Brisbane Coastal catchment;
- None of the scenarios for any of the waterways achieve a sustainable load condition. The only EHMP location that does achieve a sustainable load condition is the North Pine River for TP at

the location of the Murrumba STP. The required average reductions in annual median concentrations for turbidity, TN, and TP across all water ways was 57%, 39%, and 33% respectively;

- Sewage treatment plant operations demonstrated a large influence in the performance of a given management scenario. In particular, Scenario 3, which incorporated the use of purified recycled water and associated RO brine discharge, showed lower reductions in annual median concentrations in a few locations, particularly for TN and TP. For example, Scenario 3 increased TN and TP concentrations near the location of the Brendale STP. This is because the concentrations of the RO brine discharge are greater for Scenario 3 than for Scenarios 1 and 2. These results should be regarded as conservative, however, as the STP sources were represented without conducting near field (initial dilution) modelling first. Near field modelling would estimate the amount of initial dispersion achieved by a diffuser or outfall, and would likely result in more realistic predictions of the fate and transport of pollutants from STPs. It is recommended that any further investigations into water quality in Moreton bay or any of the individual estuaries within Moreton Bay incorporate near field modelling prior to receiving water quality modelling;
- It should be noted that the streams that drain the Brisbane Coastal catchments (Kedron Brook, Nundah and Nudgee Creeks) pass through subsequent catchments prior to discharging to Bramble Bay. It is expected that these downstream catchments will exert a greater influence on the water quality at the representative EHMP sites that the Brisbane Coastal catchments because they're larger than the Brisbane Coastal catchments and the water quality discharging from these creeks will reflect the more downstream catchment conditions.

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APPENDIX A: 2006 DERM LAND USE DATA AND SOURCE CATCHMENT FUNCTIONAL UNITS

FUNCTIONAL UNIT	DERM 2006 PRIMARY LAND USE	SECONDARY LAND USE	TERTIARY LAND USE
Broadacre Agriculture	Production from dryland agriculture and plantations	Cropping	Beverage and spice crops
			Cereals
			Cropping
			Hay and silage
			Sugar
	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated cropping
		Irrigated land in transition	Irrigated land in transition
		Irrigated modified pastures	Irrigated modified pastures
Dense Urban	Intensive uses	Manufacturing and industrial	Manufacturing and industrial
		Services	Commercial services
		Transport and communication	Airports/aerodromes
			Navigation and communication
			Ports and water transport
			Railways
			Roads
			Transport and communication
		Utilities	Electricity generation/transmission
			Utilities
		Waste treatment and disposal	Landfill
			Sewage
			Waste treatment and disposal
Grazing	Production from dryland agriculture and plantations	Land in transition	Abandoned land
			Land in transition
			No defined use
	Production from relatively natural environments	Grazing natural vegetation	Livestock grazing
Green Space	Conservation and natural environments	Managed resource protection	Managed resource protection
		Nature conservation	National park
			Natural feature protection
			Other conserved area
			Protected landscape
		Other minimal use	Defence
			Other minimal use

FUNCTIONAL UNIT	DERM 2006 PRIMARY LAND USE	SECONDARY LAND USE	TERTIARY LAND USE
			Remnant native cover
			Residual native cover
	Production from dryland agriculture and plantations	Plantation forestry	Hardwood production
			Other forest production
			Plantation forestry
	Production from relatively natural environments	Production forestry	Production forestry
Intensive Agriculture	Intensive uses	Intensive animal production	Aquaculture
			Cattle
			Dairy
			Intensive animal production
			Pigs
			Poultry
		Intensive horticulture	Glasshouses (hydroponic)
			Intensive horticulture
	Production from dryland agriculture and plantations	Perennial horticulture	Perennial horticulture
			Shrub nuts fruits and berries
			Shrub nuts, fruits & berries
			Shurb nuts fruits and berries
			Tree fruits
			Tree nuts
		Seasonal horticulture	Seasonal Horticulture
			Vegetable and herbs
	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated perennial horticulture
			Irrigated shrub nuts fruits and berries
			Irrigated tree fruits
			Irrigated tree nuts
			Irrigated vine fruits
		Irrigated seasonal horticulture	Irrigated flowers and bulbs
			Irrigated fruits
			Irrigated seasonal horticulture
			Irrigated vegetables & herbs
			Irrigated vegetables and herbs
Rural Residential	Intensive uses	Residential	Rural living
			Rural residential

FUNCTIONAL UNIT	DERM 2006 PRIMARY LAND USE	SECONDARY LAND USE	TERTIARY LAND USE
Urban	Intensive uses	Mining	Mines
			Mining
			Quarries
		Residential	Residential
			Urban residential
		Services	Defence facilities
			Public services
			Recreation and culture
			Research facilities
			Services
Water	Water	Channel/aqueduct	Drainage channel/aqueduct
		Lake	Lake
			Lake - conservation
			Lake - intensive use
		Marsh/wetland	Marsh/wetland
			Marsh/wetland - conservation
			Effluent pond
		Reservoir/dam	Reservoir/dam
			Water storage - intensive use/farm
			Water storage - intensive use/farm dams
			Water storage and treatment
		River	River
			River - conservation
			River - intensive use

APPENDIX B: CALIBRATION GRAPHS

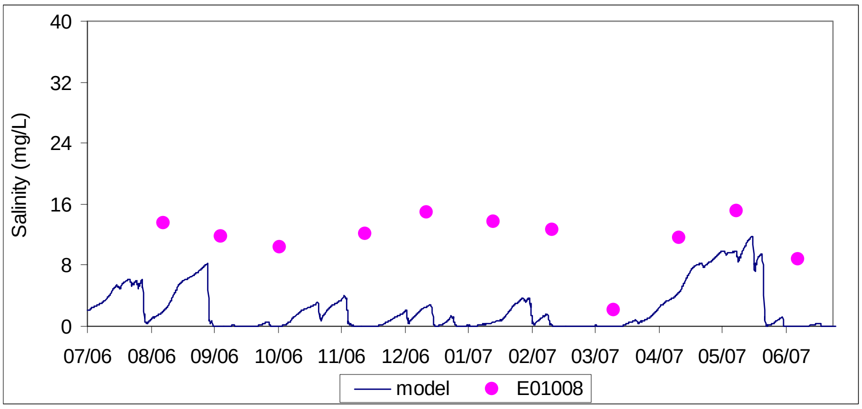
Please refer to Figure 3-12 for EHMP locations. For riverine estuaries the plots begin on the left side of the graph as the uppermost site in the estuary and progress toward the mouth moving to the right of the graph. For the open Bays the locations are generally clustered together.

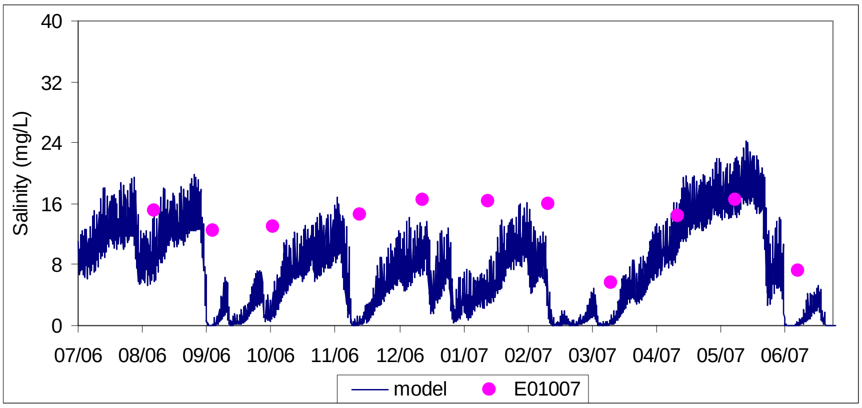
The representative plots of the waterways for which only some of the EHMP sites are presented as follows:

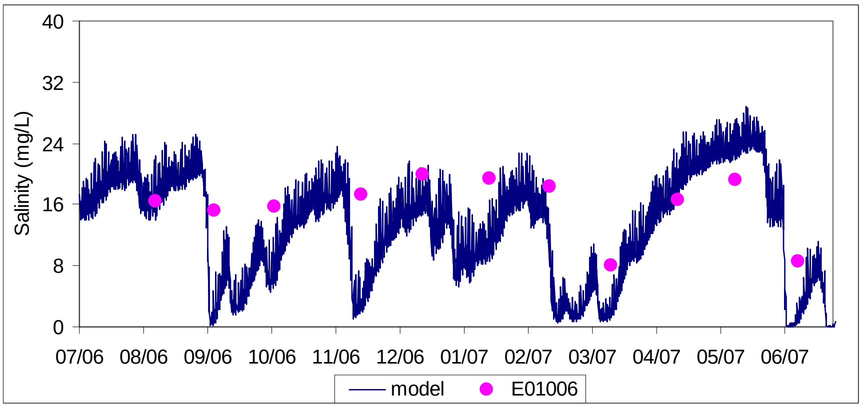
- Moreton Bay:
  - E00525 - Central Moreton Bay;
  - E00510 - Central Moreton Bay;
  - E00310 - Southern Moreton Bay; and
  - E00319 - North Braodwater.
- Brisbane and Bremer Rivers:
  - E00605 - Bremer;
  - E00706 - Upper Brisbane;
  - E00712 - Middle Brisbane; and
  - E00703 - Brisbane CBD;
- Logan and Albert Rivers:
  - E01702 - Albert River;
  - E00211 - Upper Logan;
  - E00204 - Middle Logan; and
  - E00201 - Lower Logan.

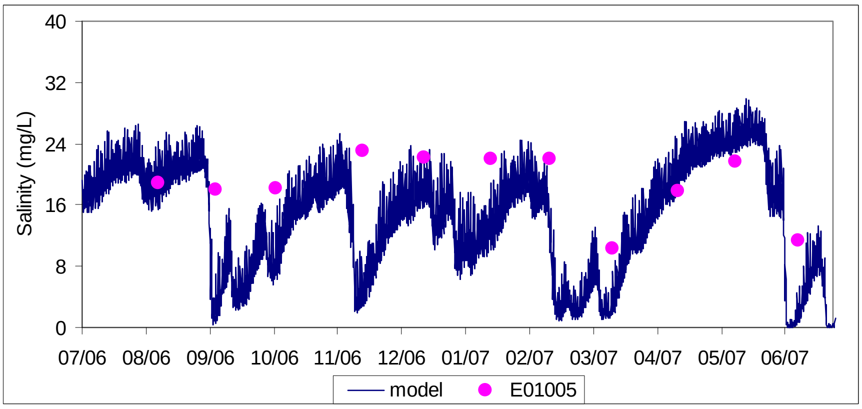
CABOOLTURE RIVER CALIBRATION RESULTS

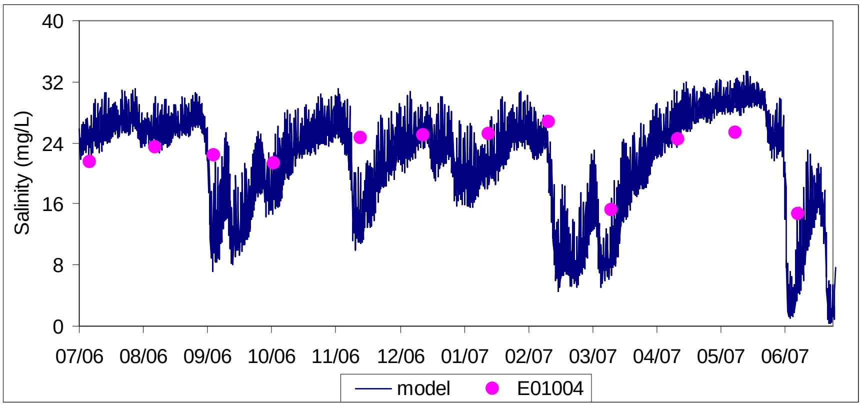
Salinity







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24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
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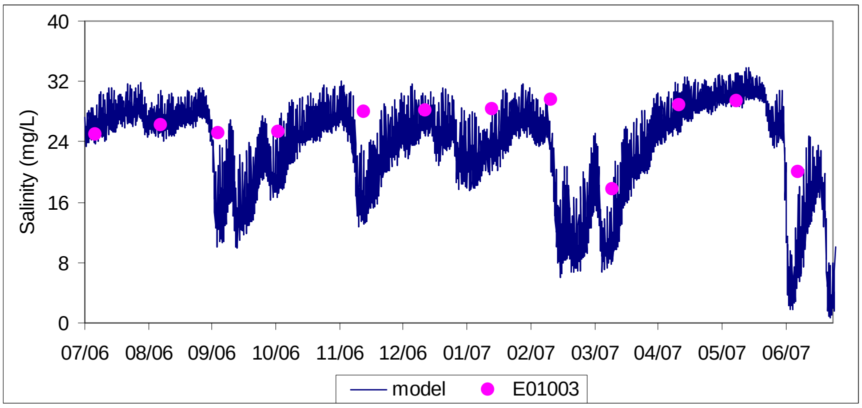
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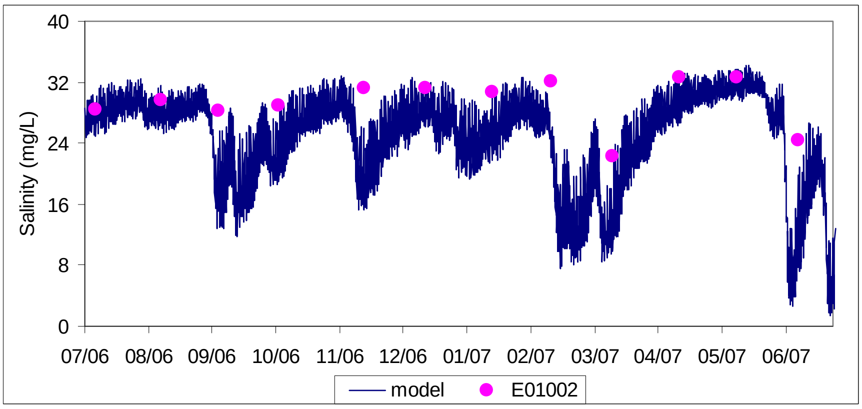
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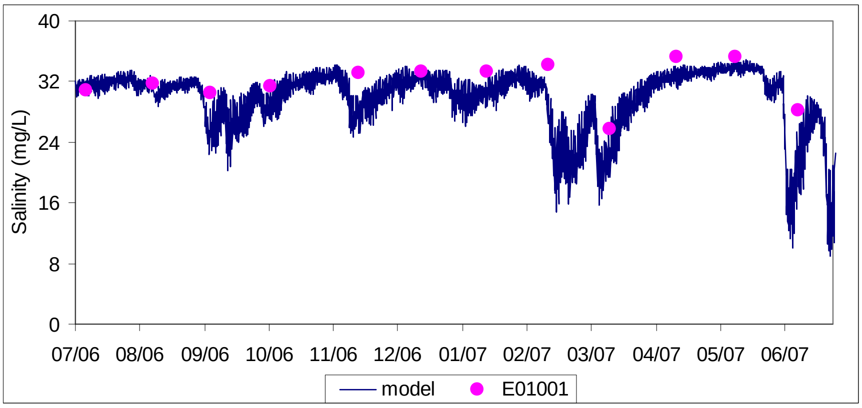
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24
16
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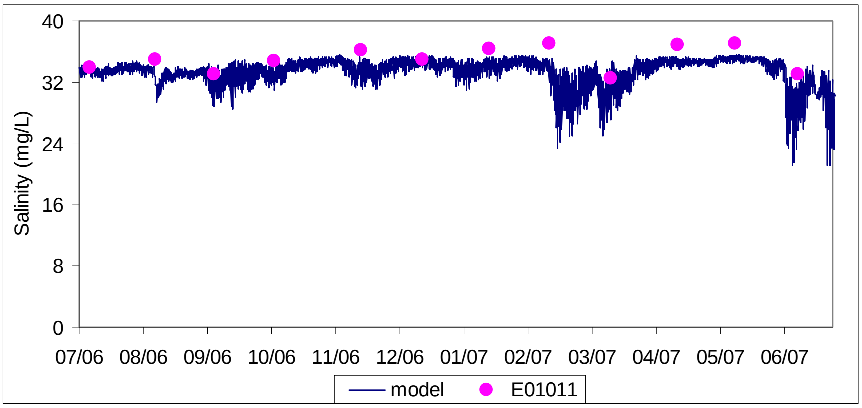
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24
16
8
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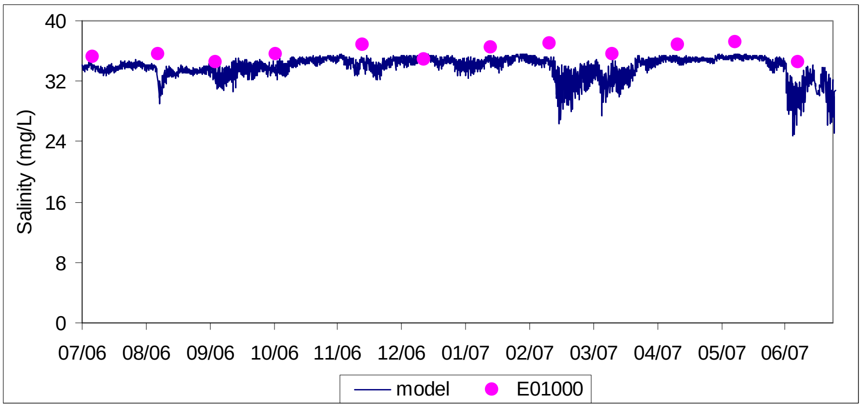
Salinity (mg/L)
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32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
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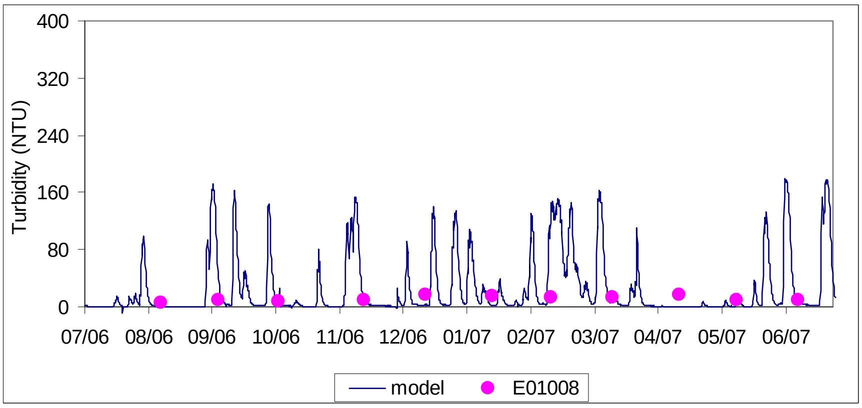
Turbidity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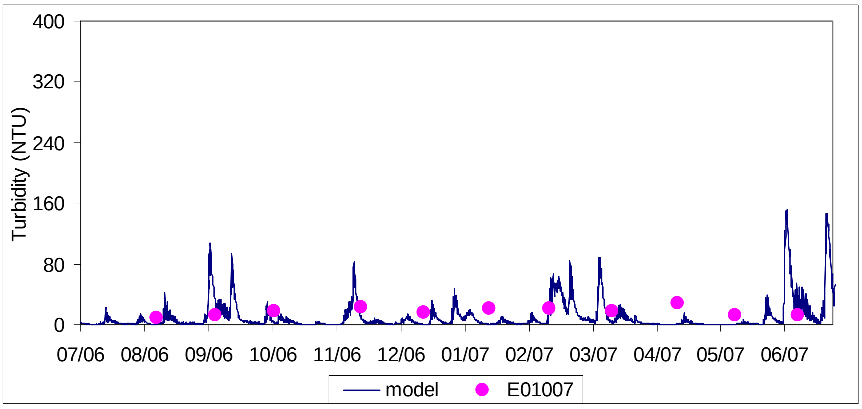
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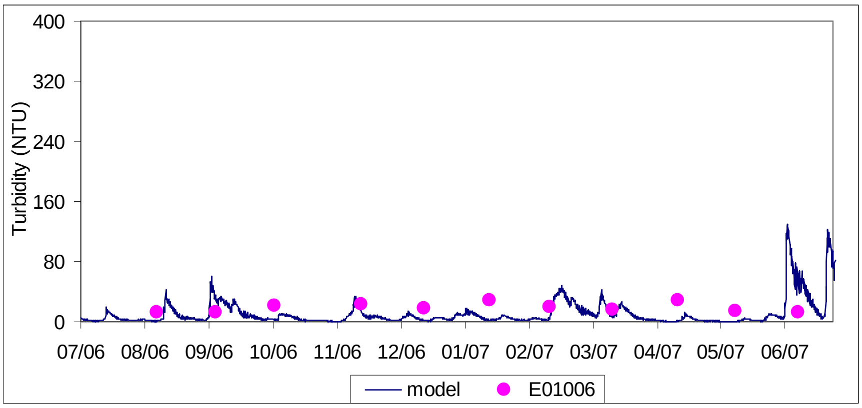
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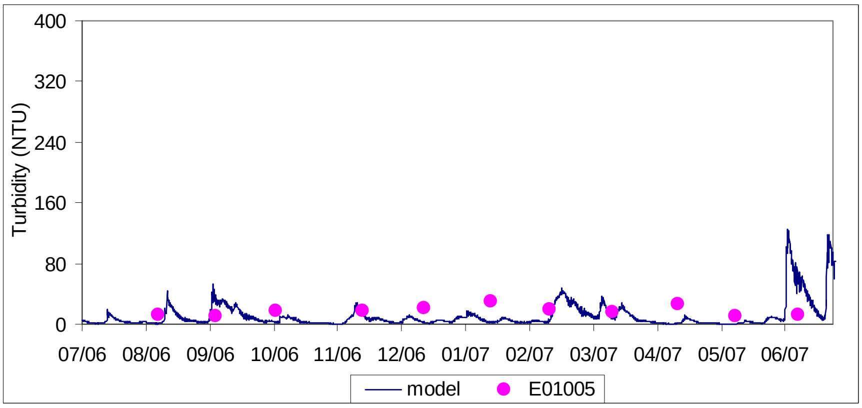
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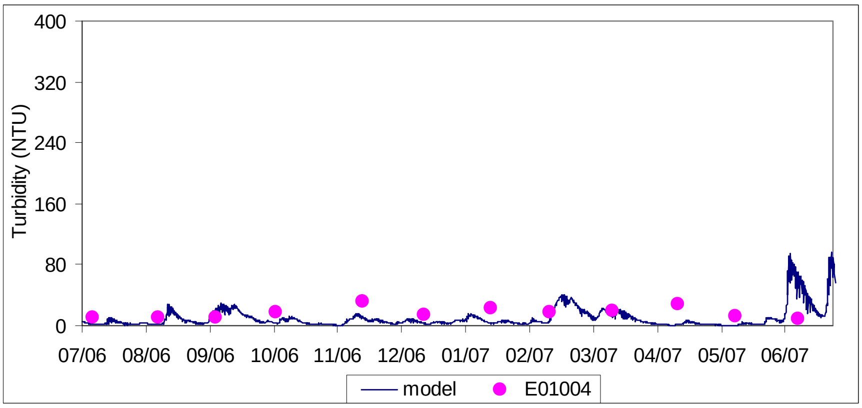
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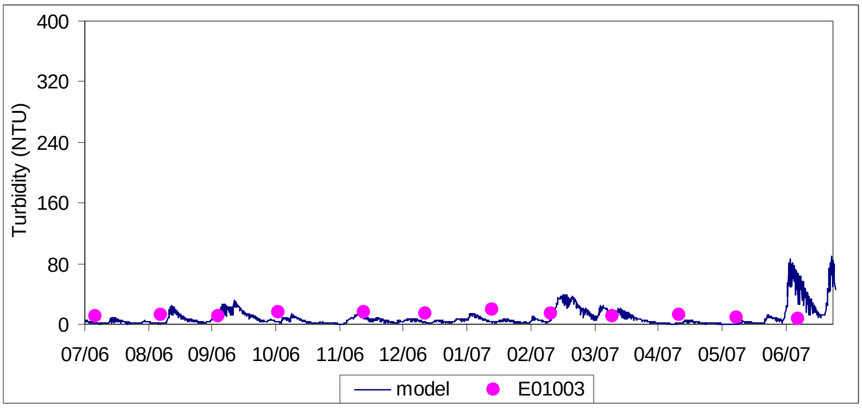
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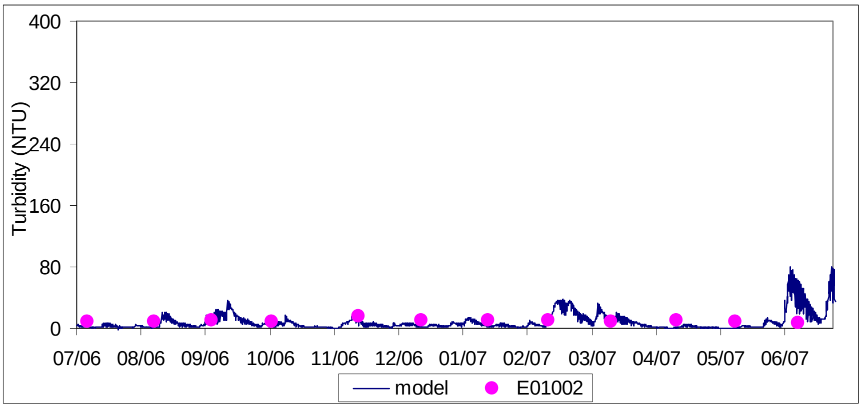
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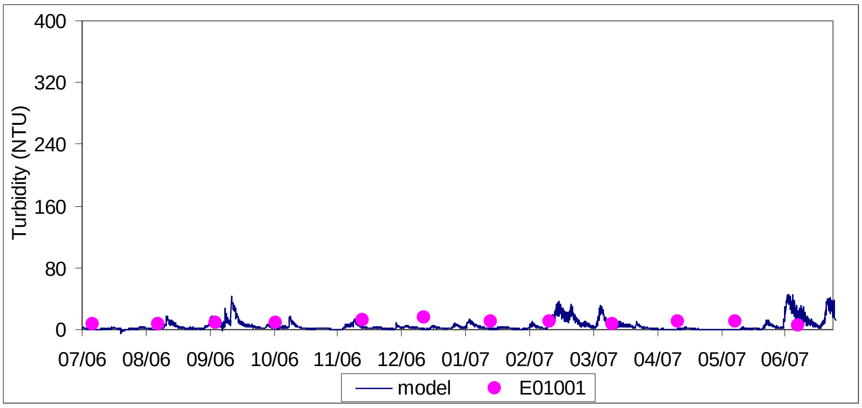
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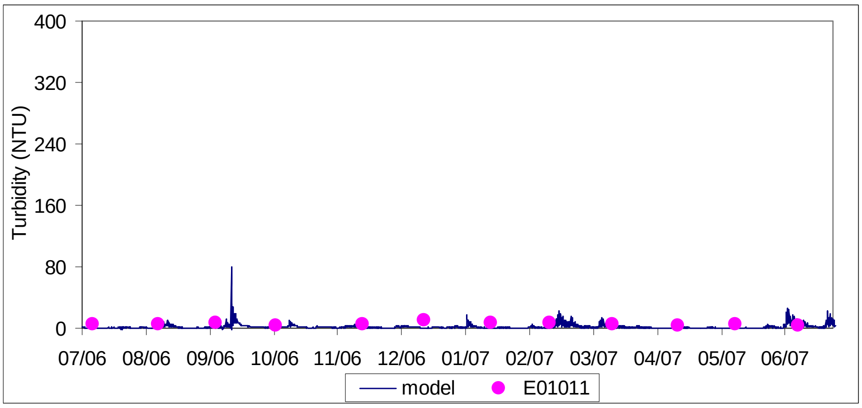
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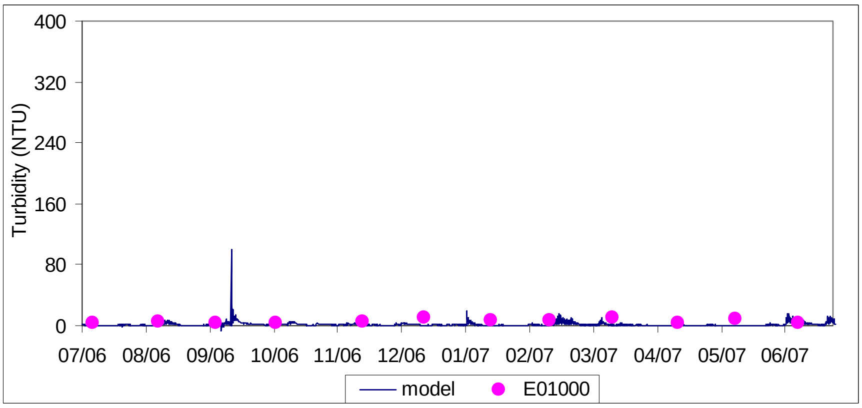
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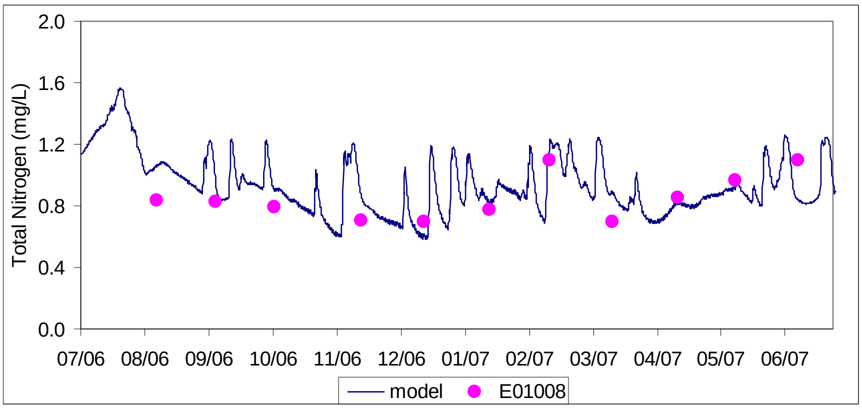

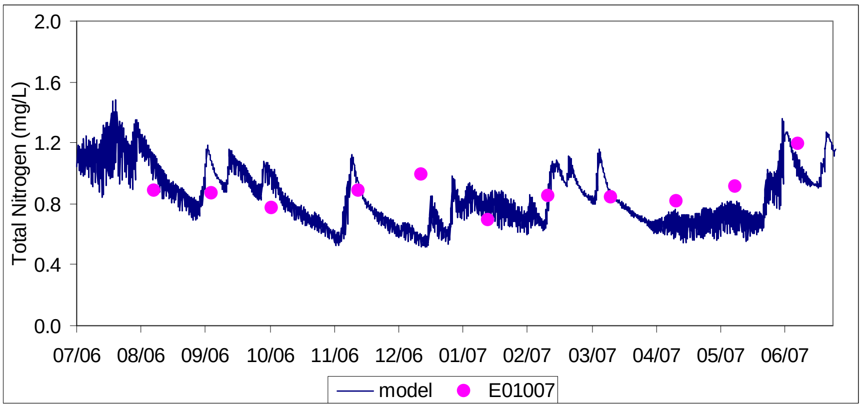

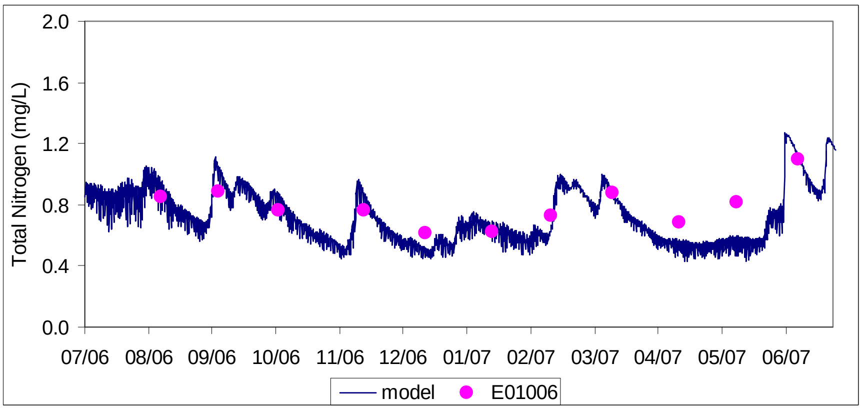

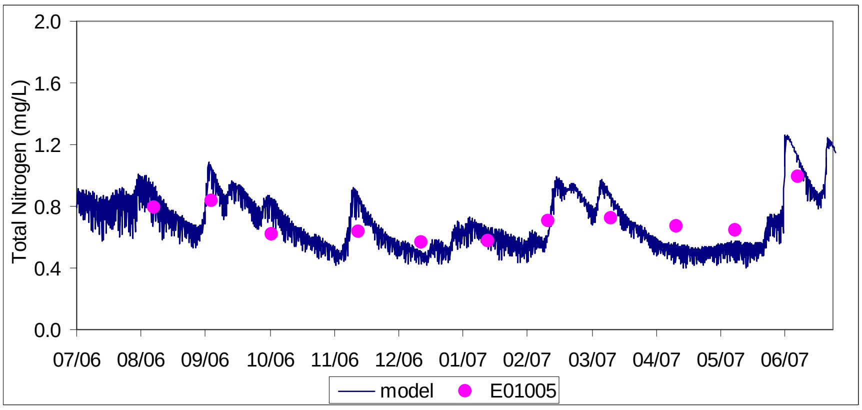

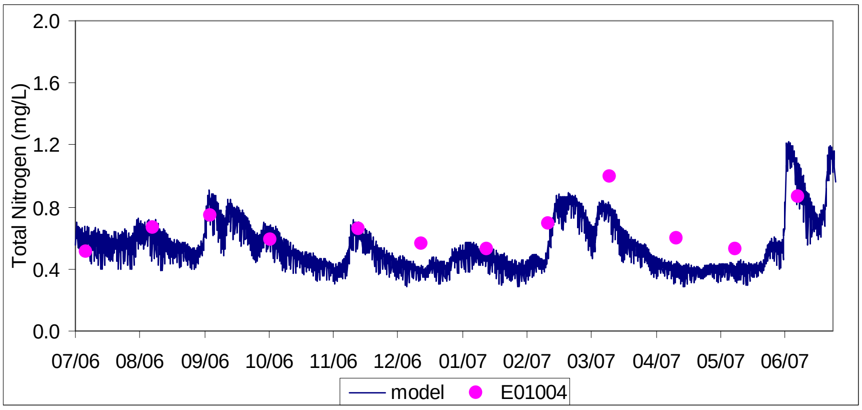
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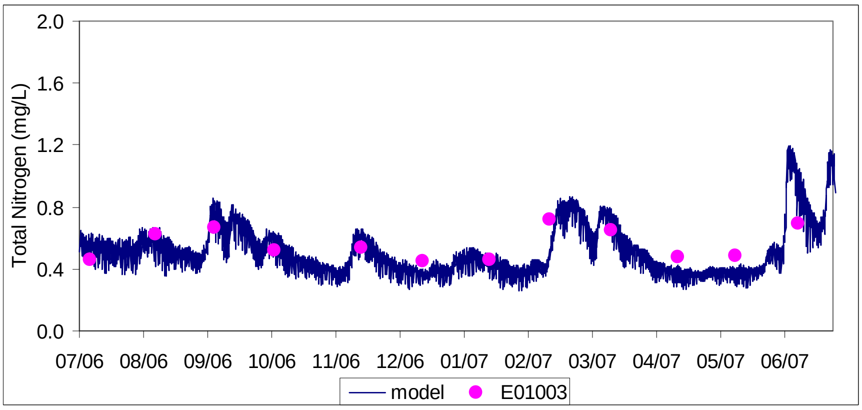
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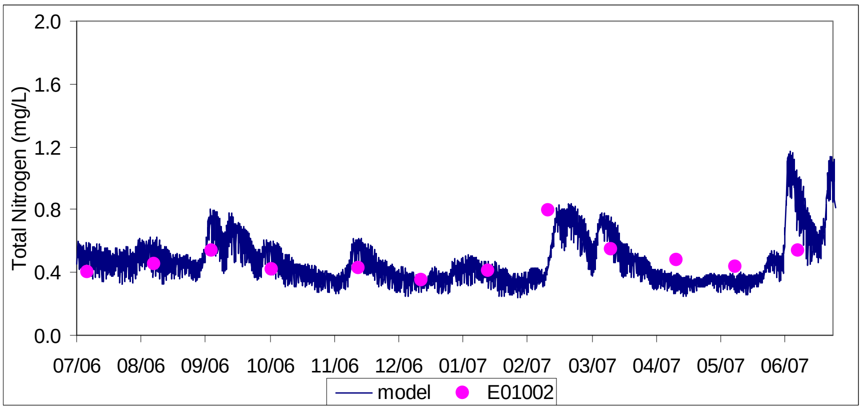
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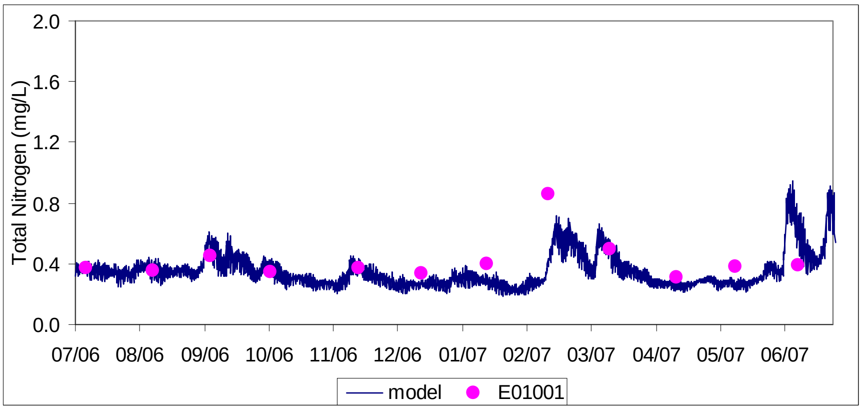
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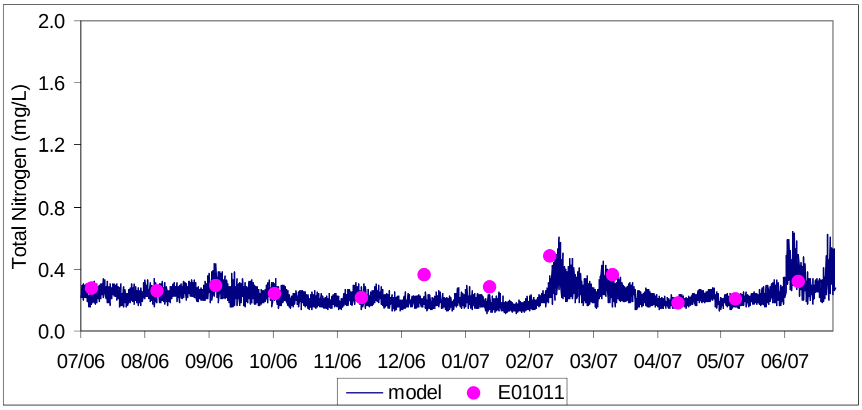
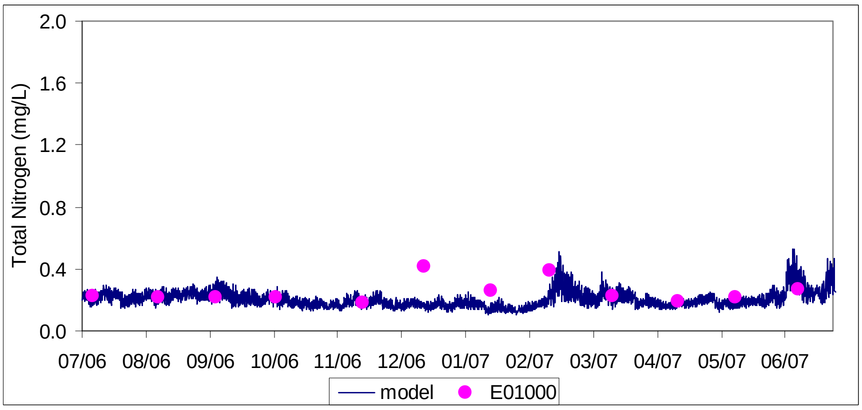
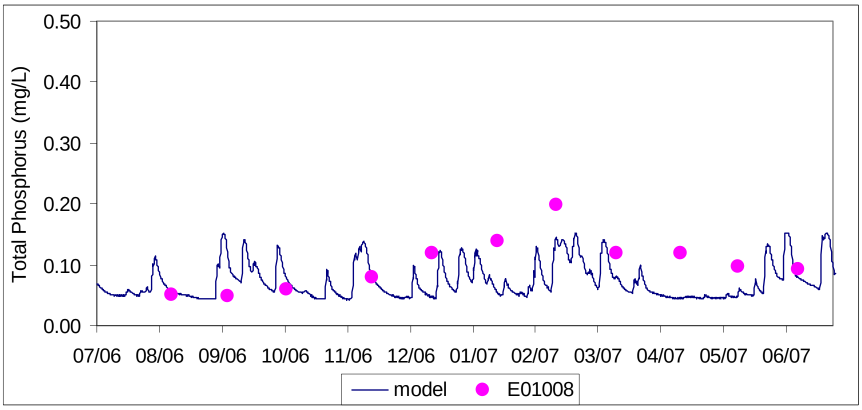
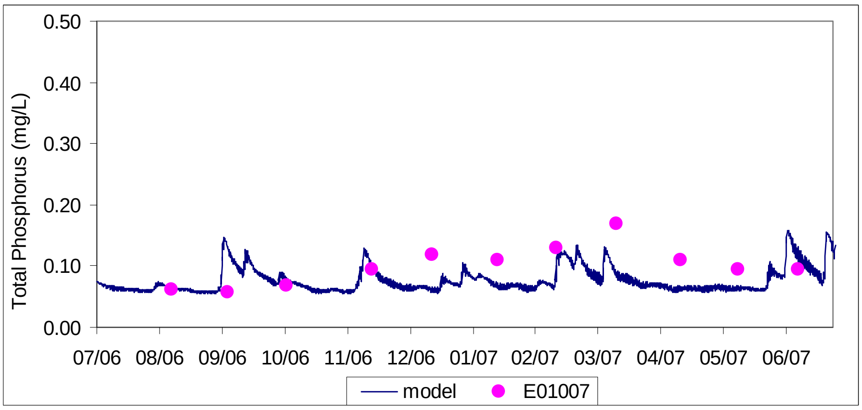
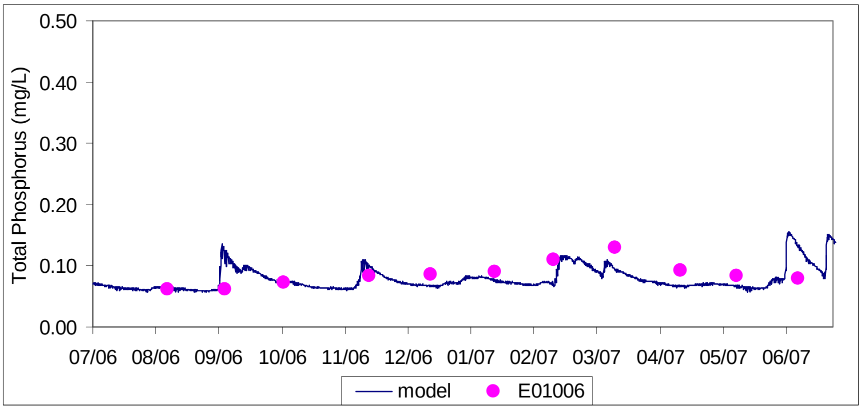


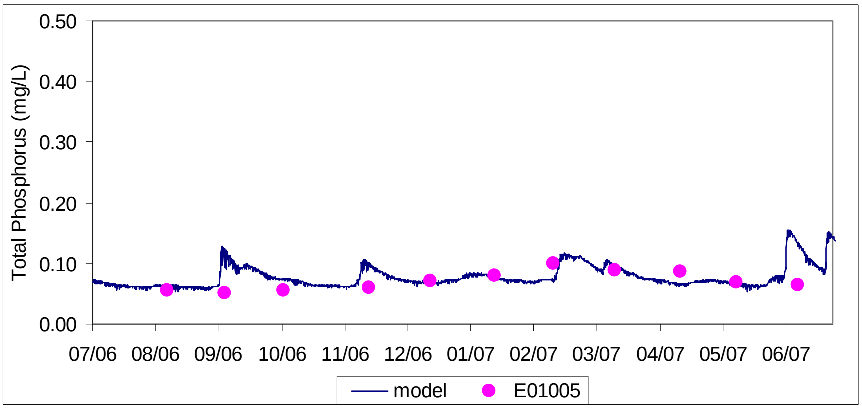


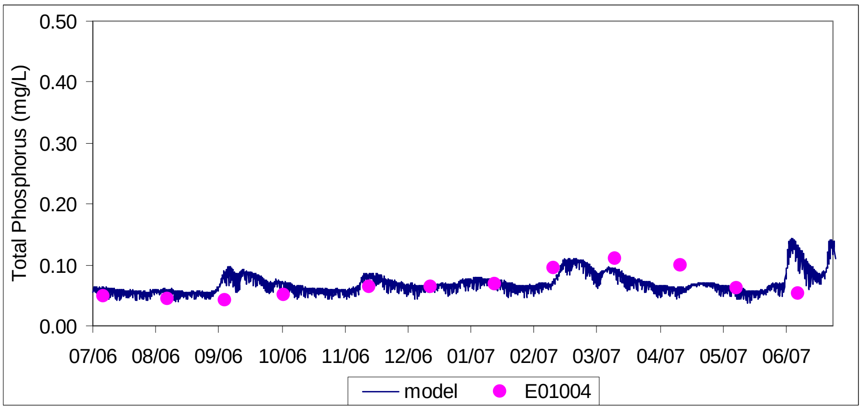
Total Phosphorus

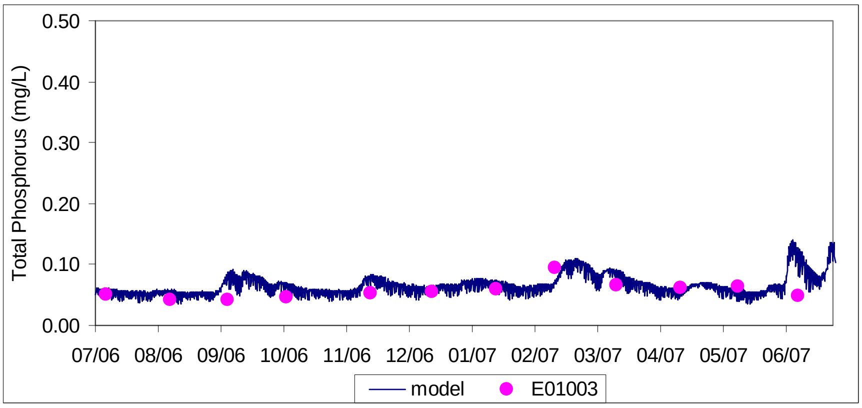


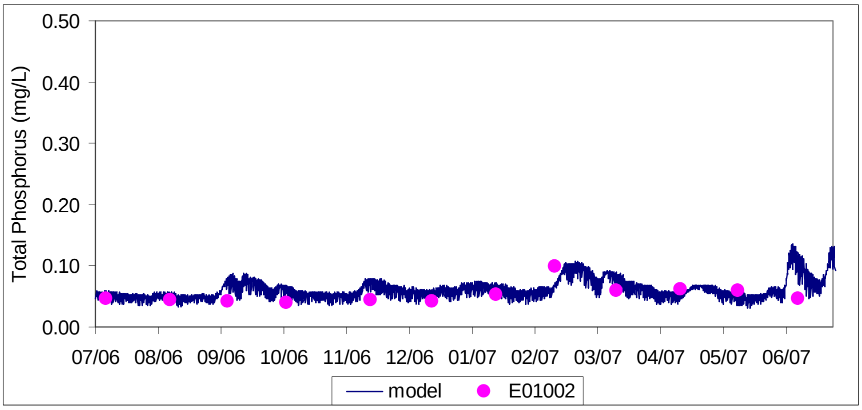


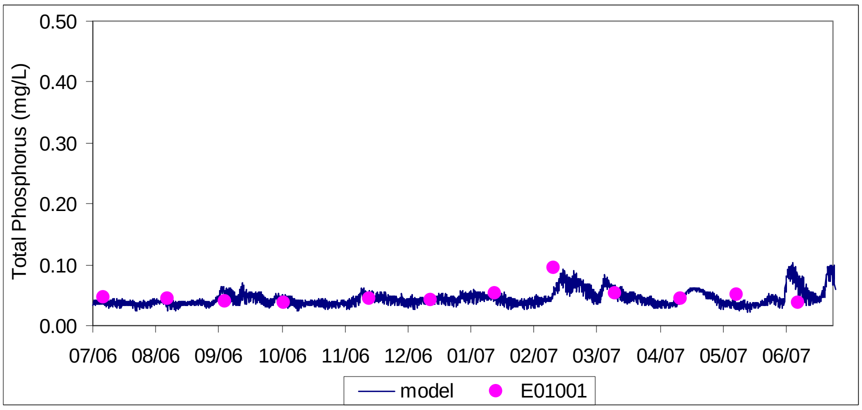

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01006

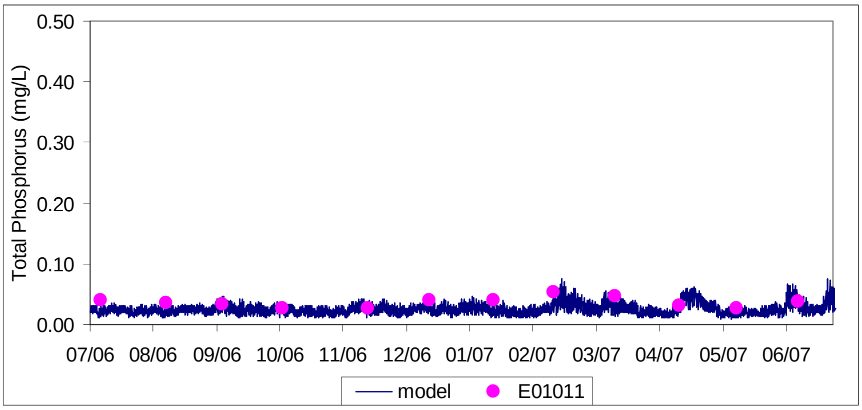

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01005

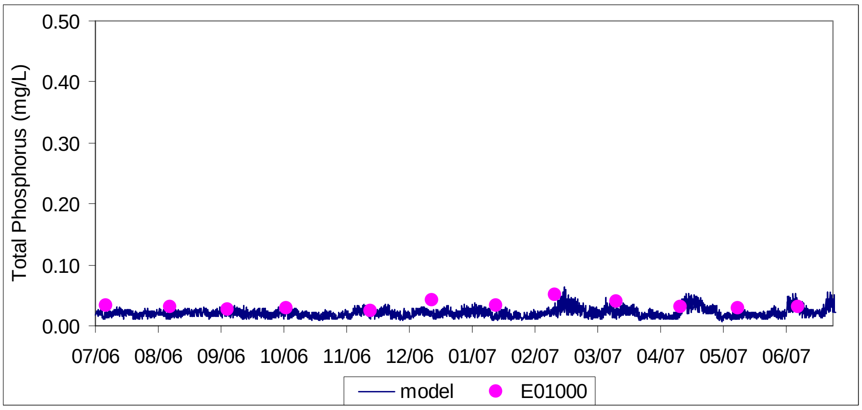

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01004


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01003


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01002

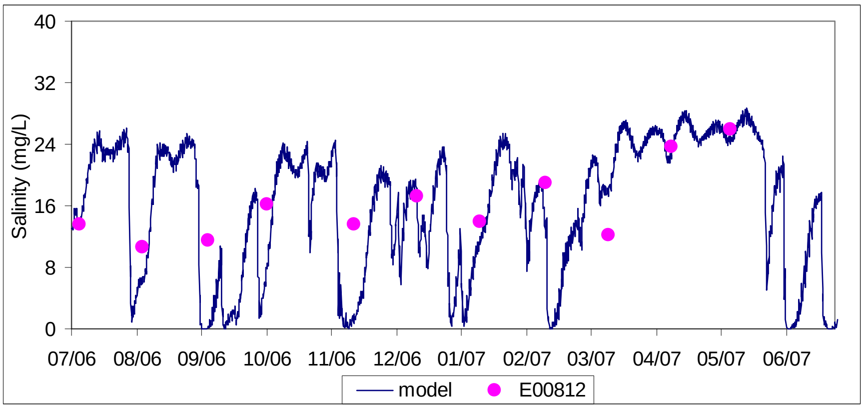

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01001

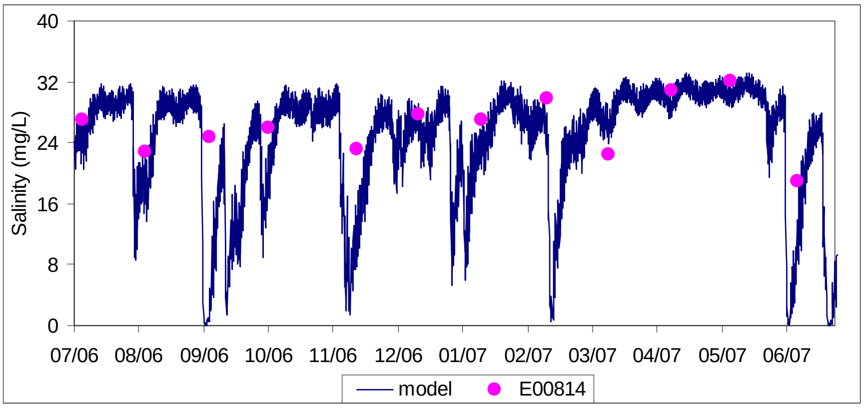

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01011

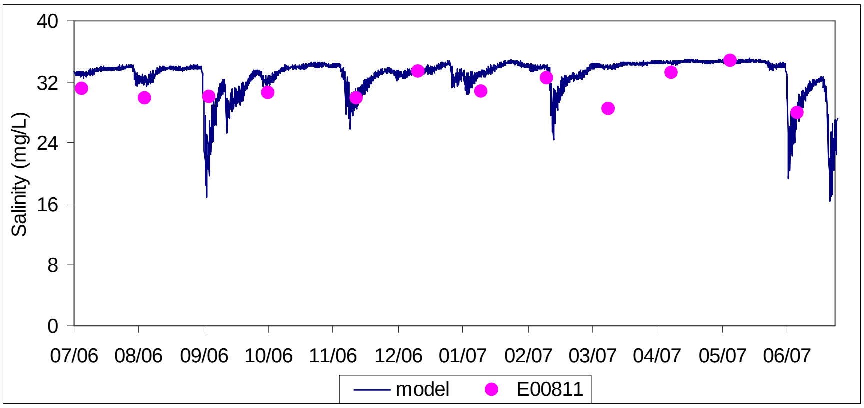

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01000

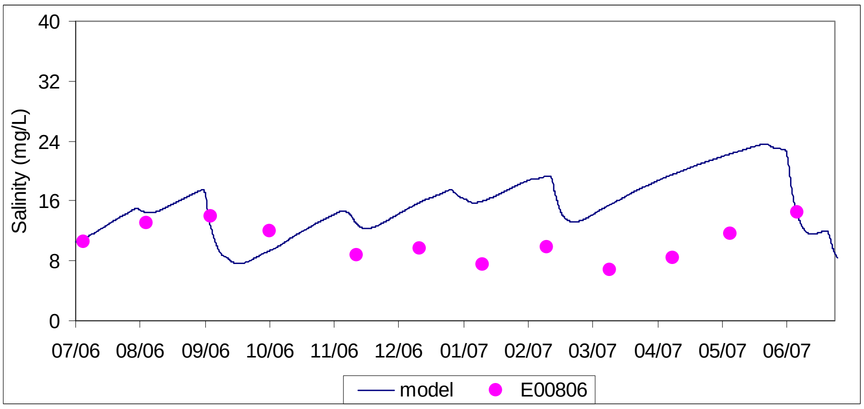
PINE RIVER CALIBRATION RESULTS

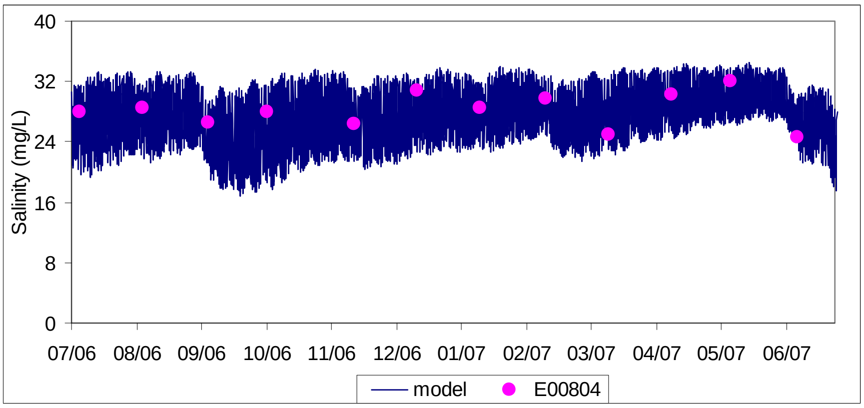
Salinity

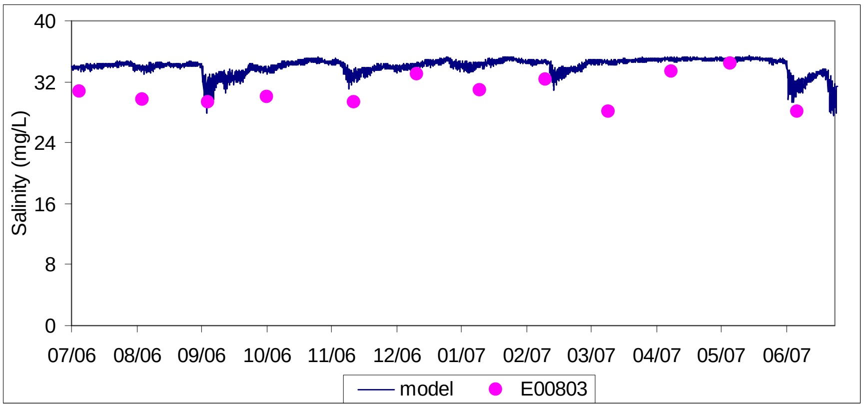


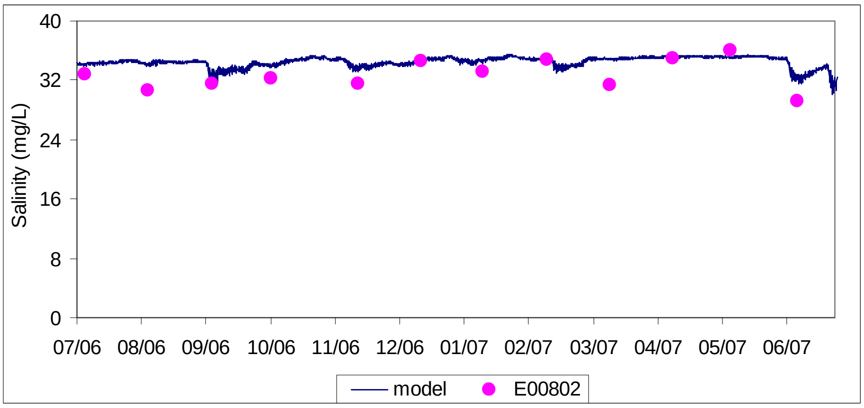


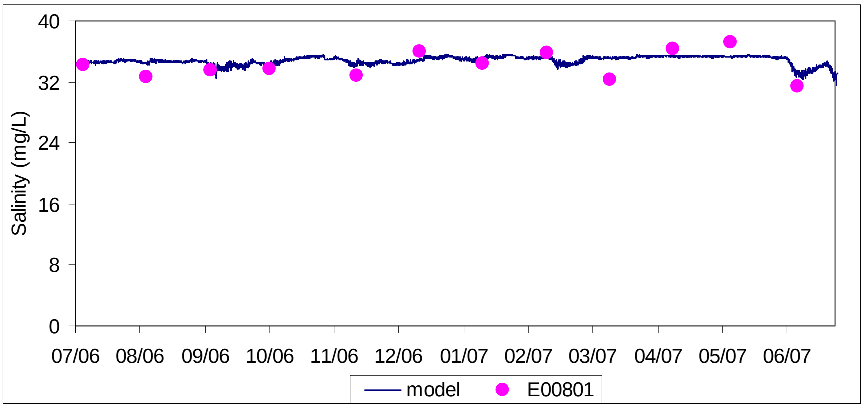




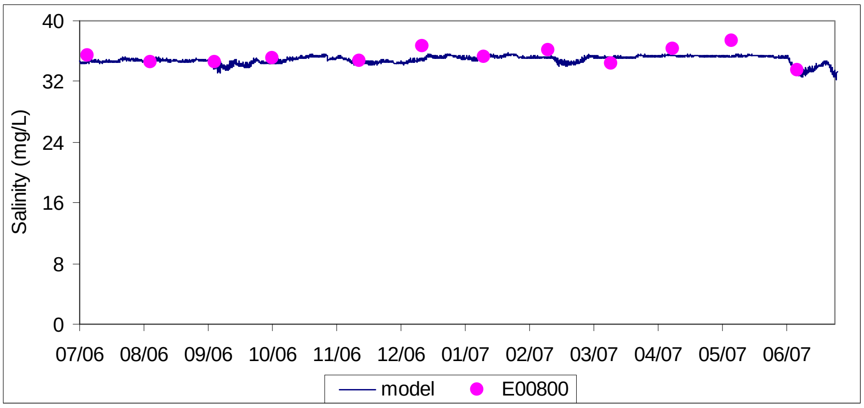

Salinity (mg/L)
40
32
24
16
8
0
07/06
08/06
09/06
10/06
11/06
12/06
01/07
02/07
03/07
04/07
05/07
06/07
model
E00804


Salinity (mg/L)
40
32
24
16
8
0
07/06
08/06
09/06
10/06
11/06
12/06
01/07
02/07
03/07
04/07
05/07
06/07
model
E00803


Salinity (mg/L)
40
32
24
16
8
0
07/06
08/06
09/06
10/06
11/06
12/06
01/07
02/07
03/07
04/07
05/07
06/07
model
E00802

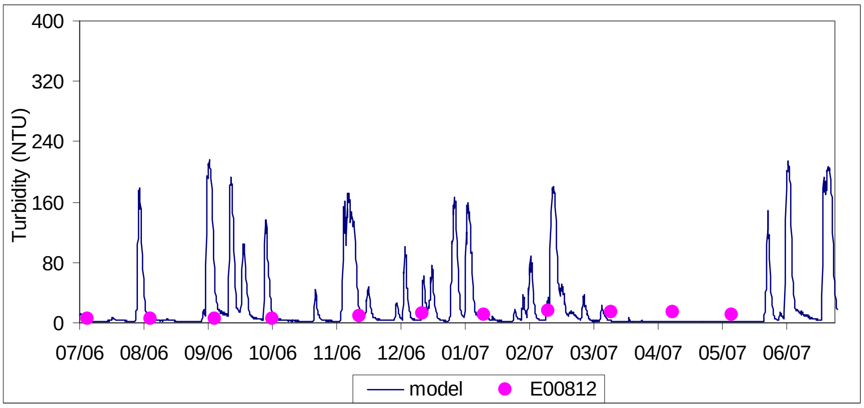


40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00801

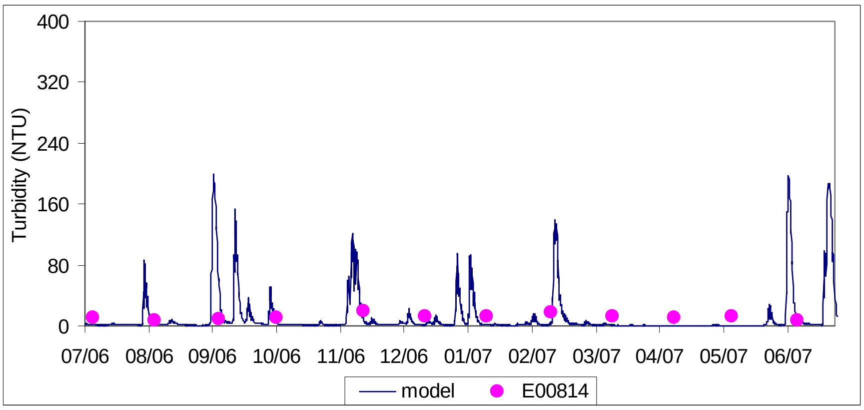


40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00800

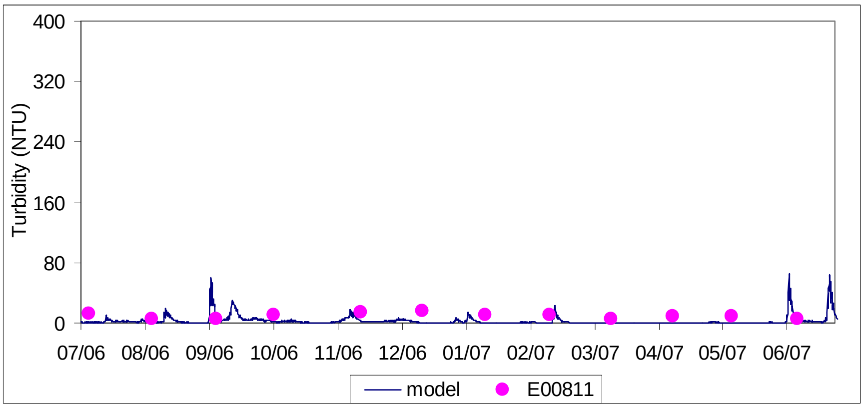
Turbidity

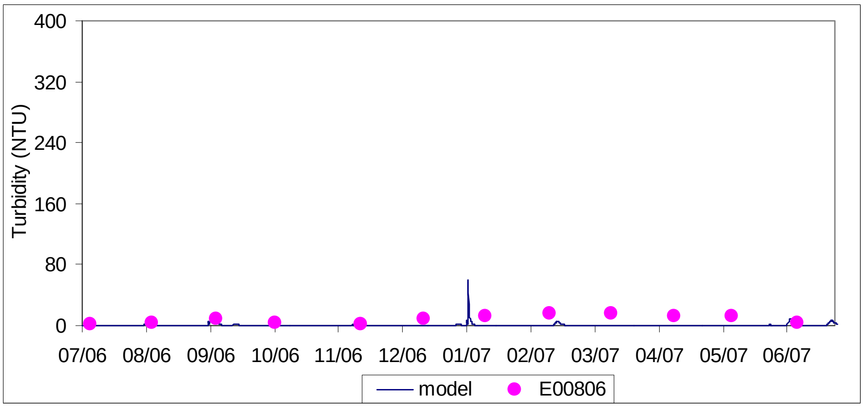


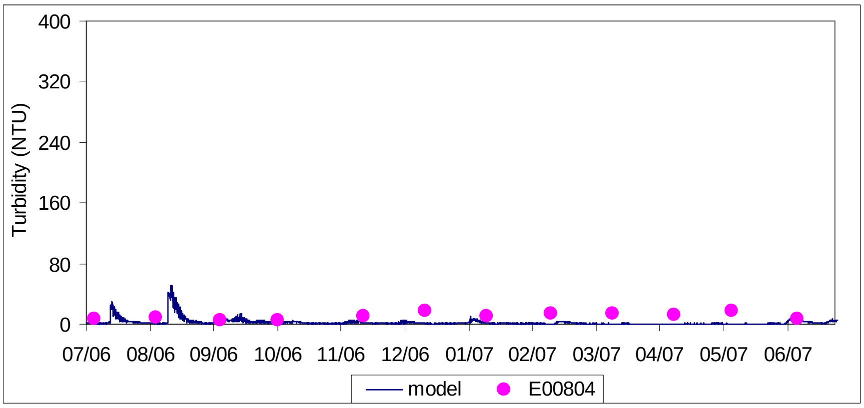
400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00812

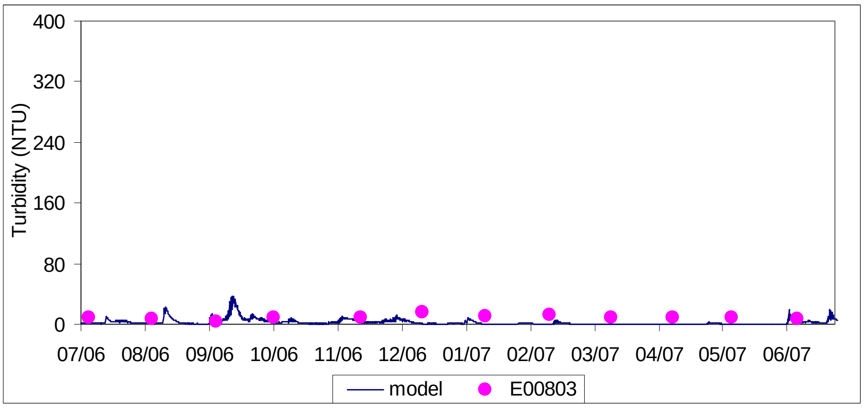


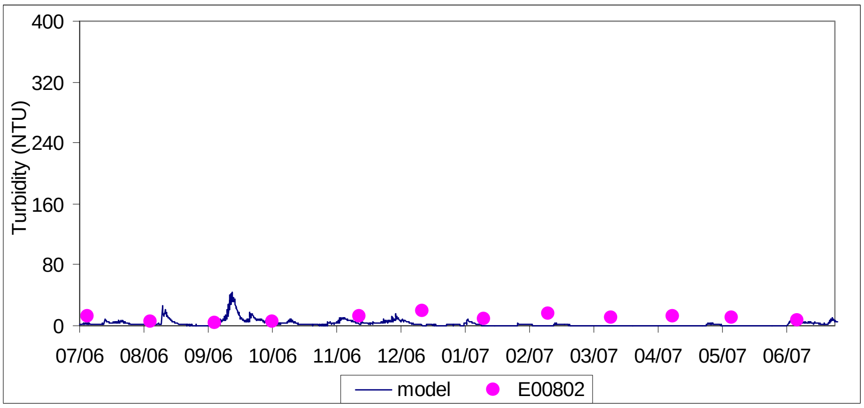
400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00814

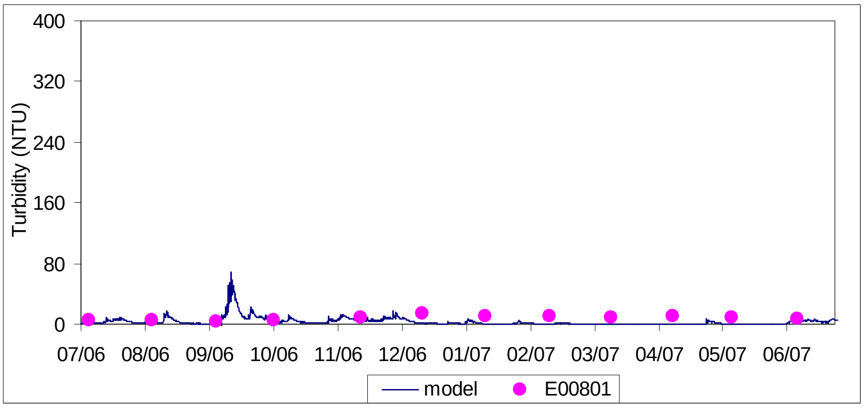

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00811

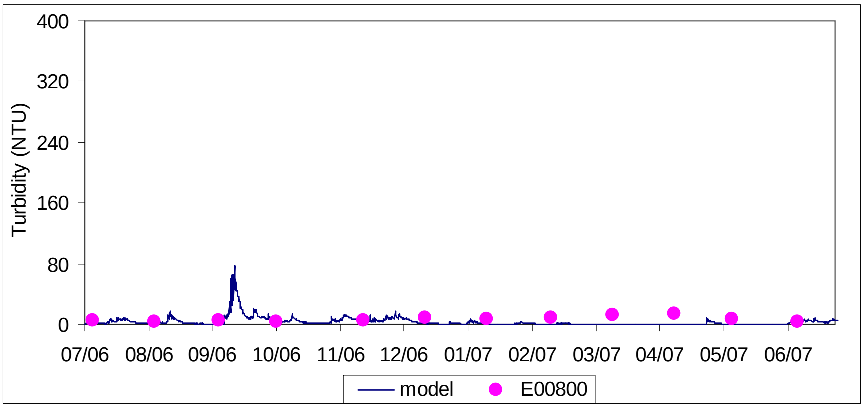

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00806


Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00804

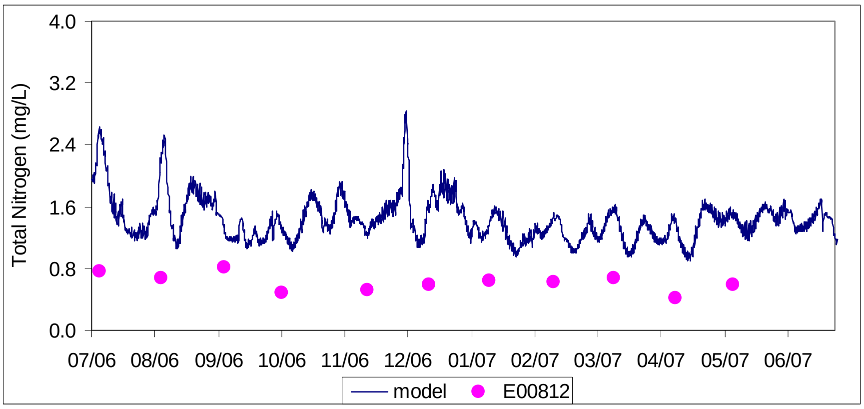

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00803

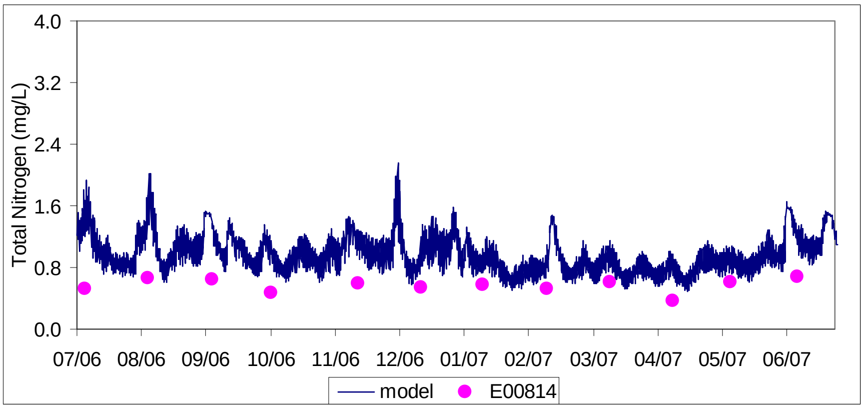

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00802

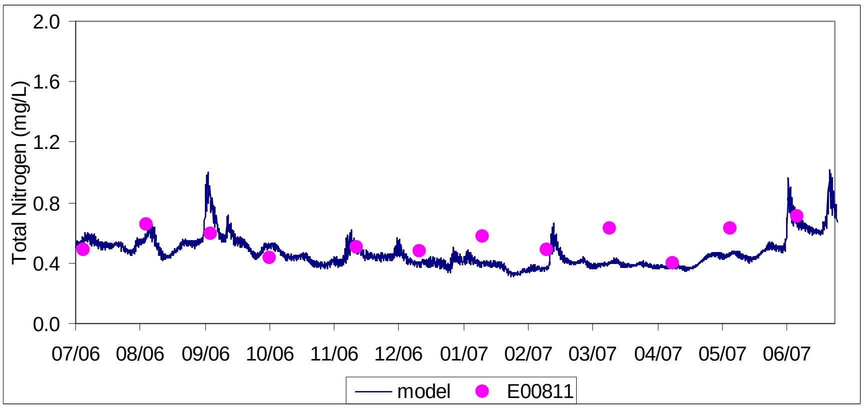

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00801

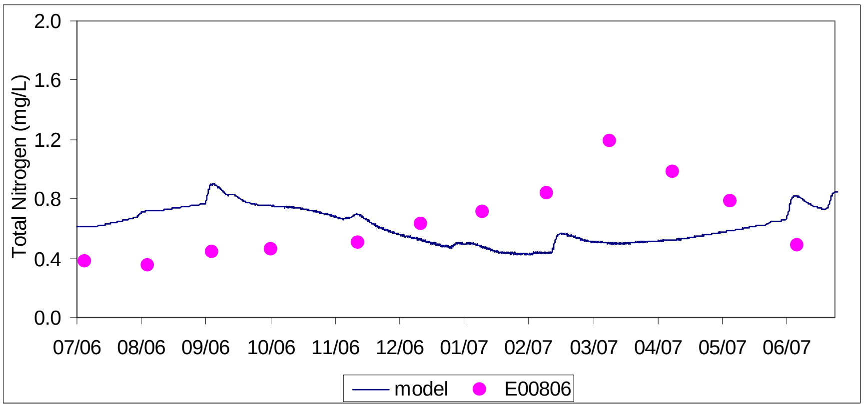

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00800

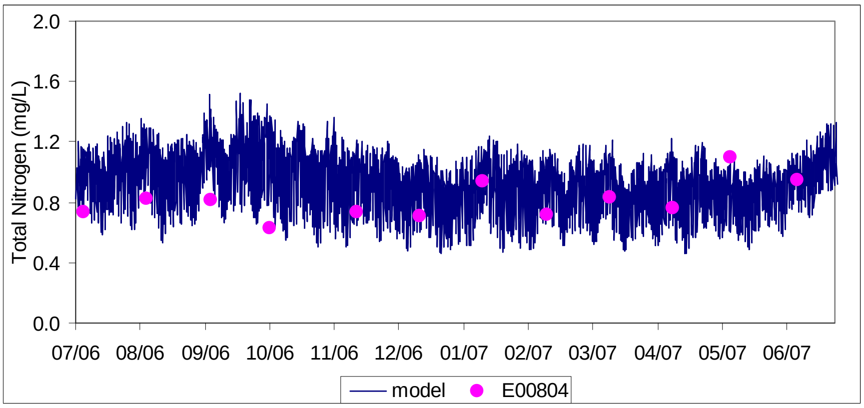
Total Nitrogen

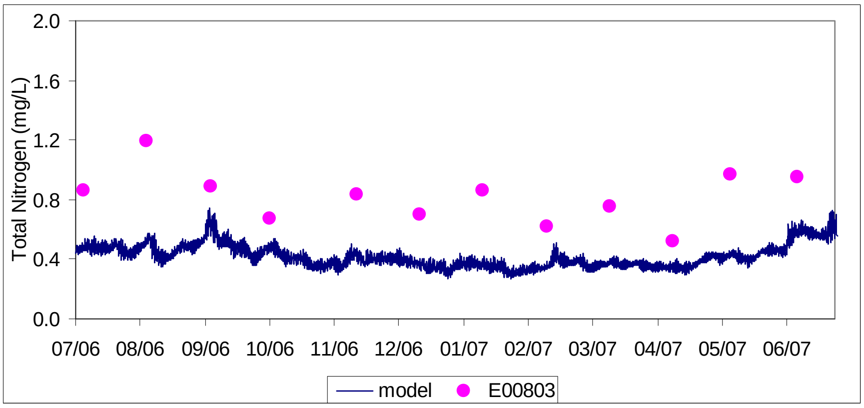


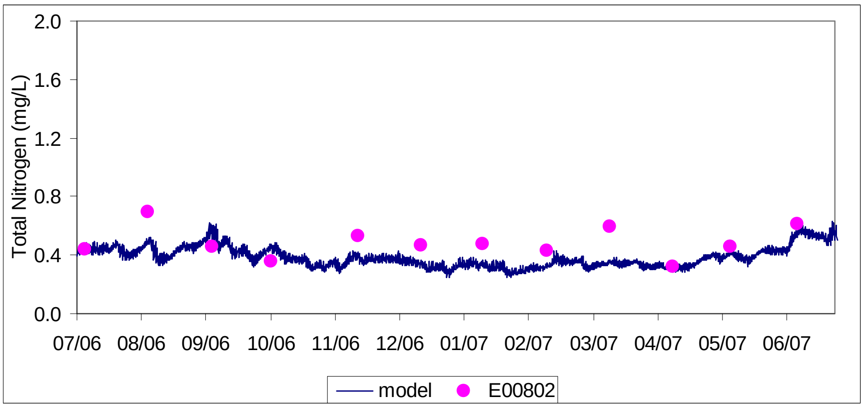


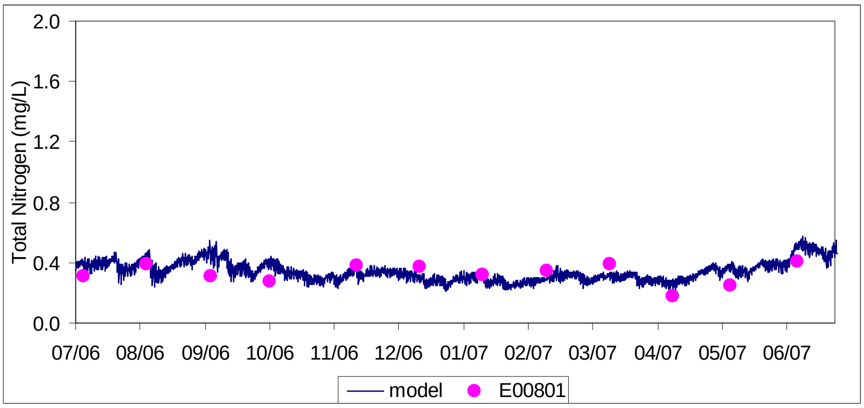


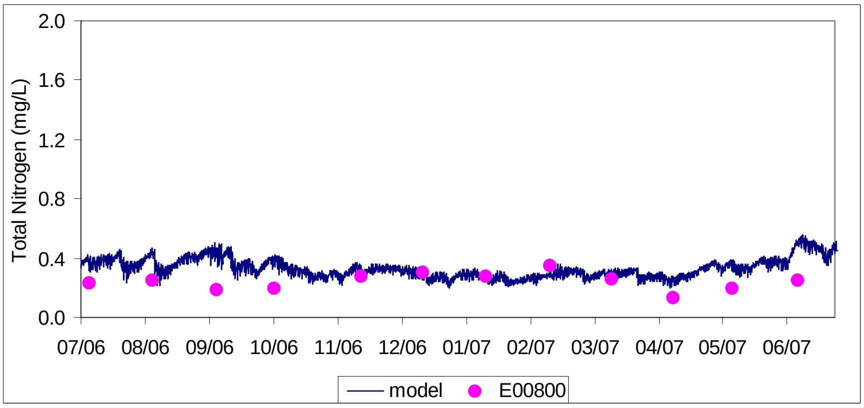



2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00804

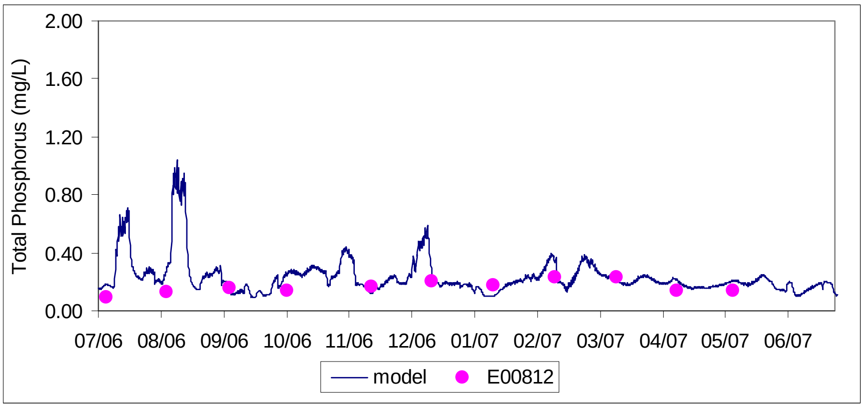

2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00803

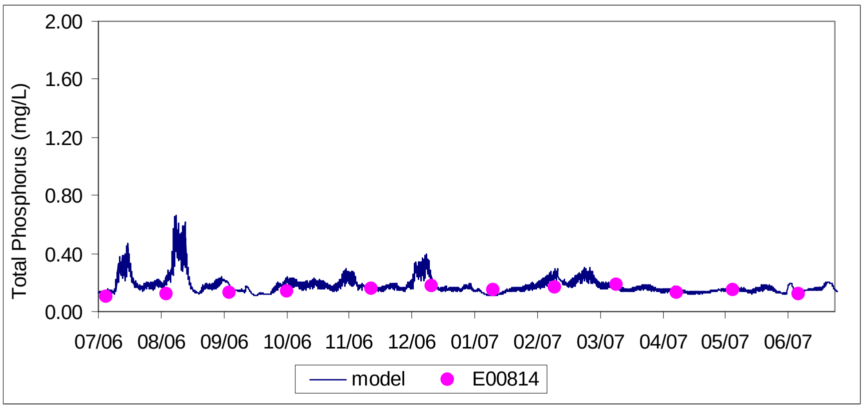

2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00802

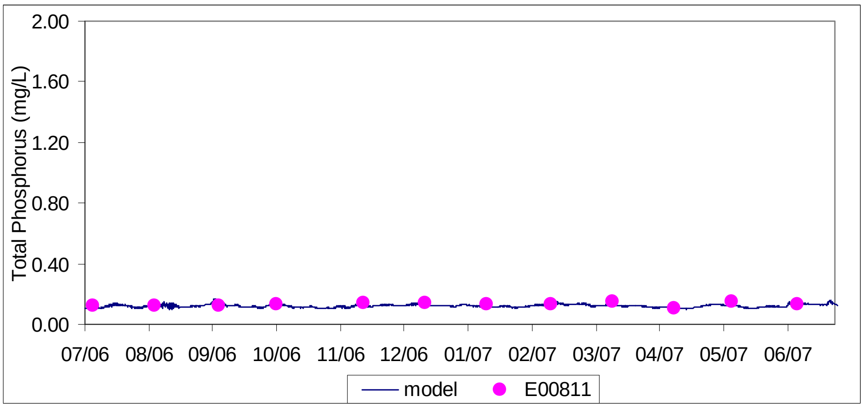


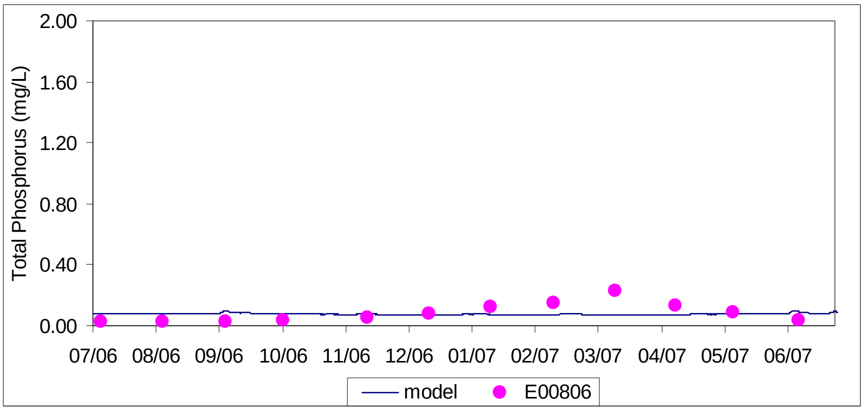


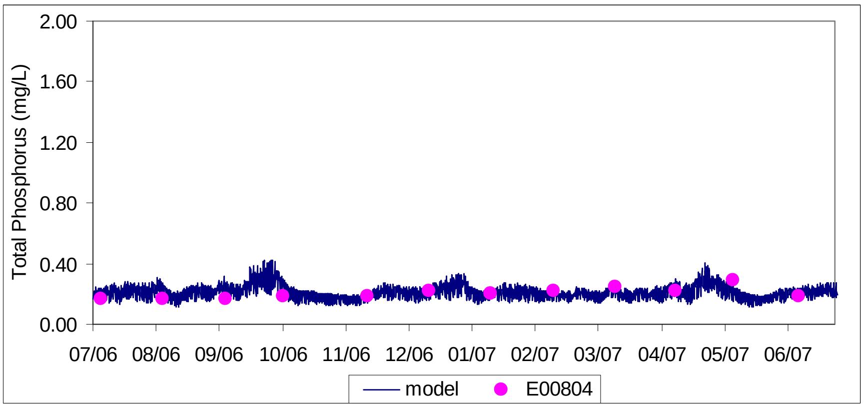
Total Phosphorus

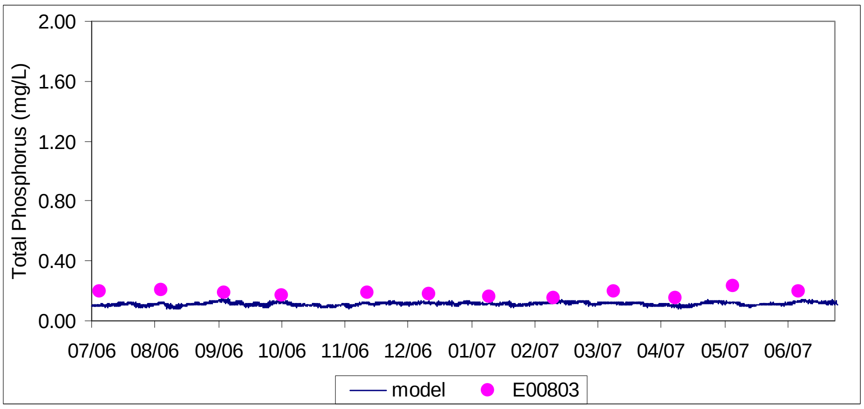


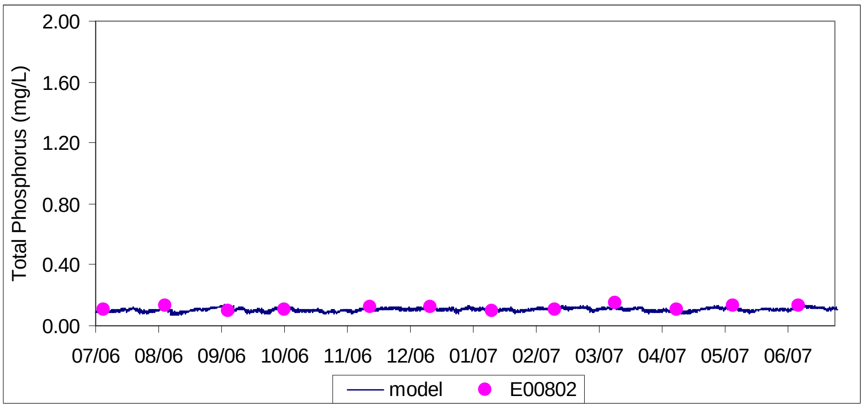



Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00811

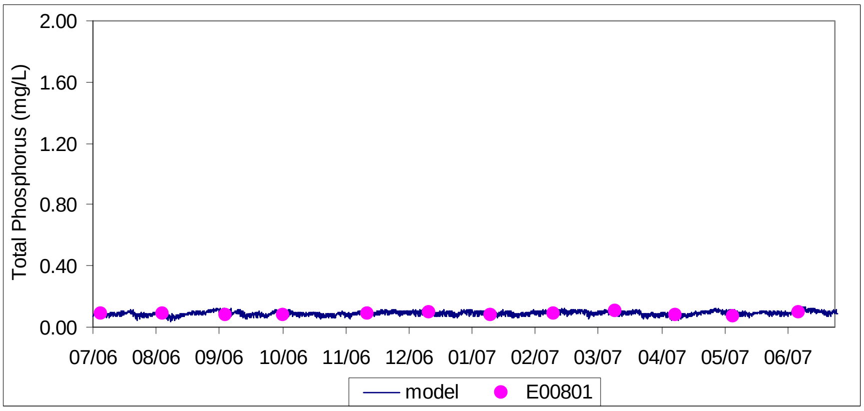

Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00806


Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00804

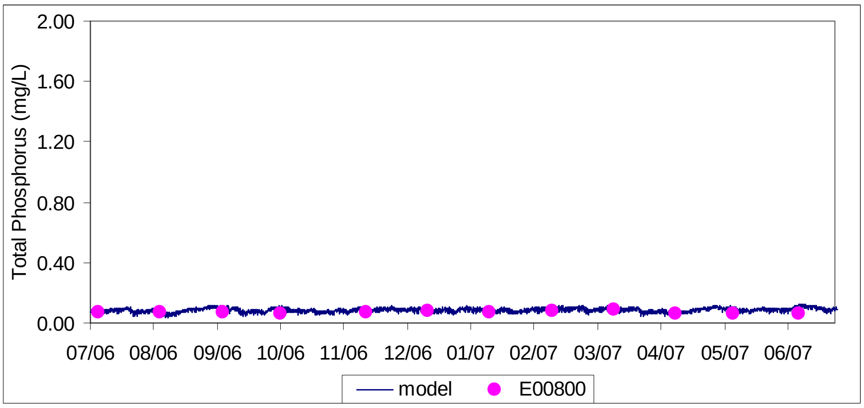

Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00803



Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00802



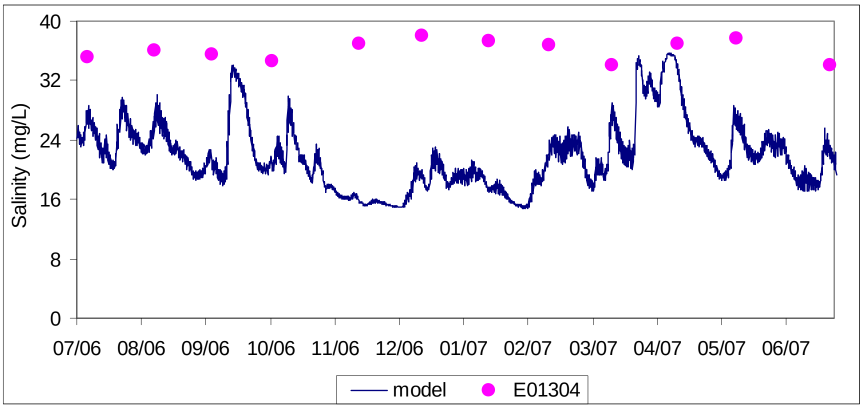
Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00801

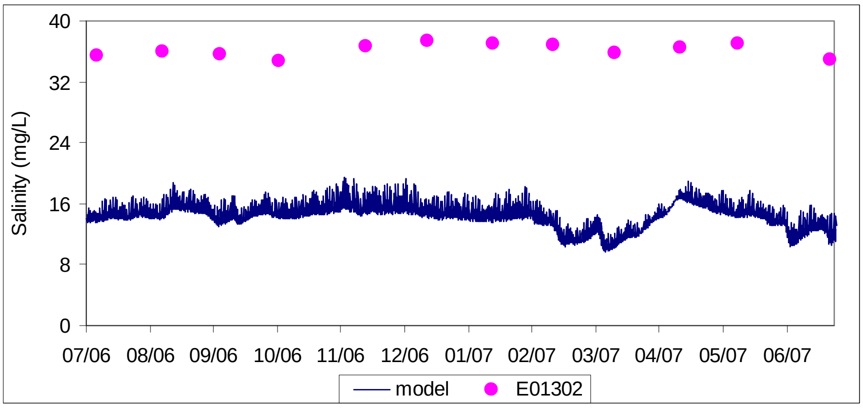


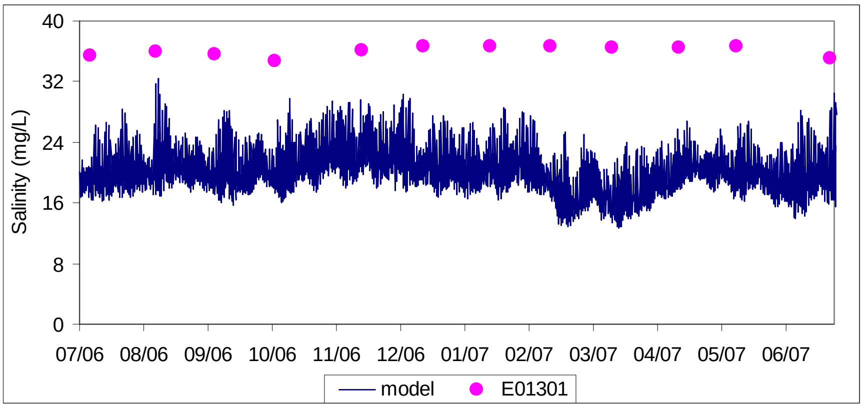
Total Phosphorus (mg/L)
2.00
1.60
1.20
0.80
0.40
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00800

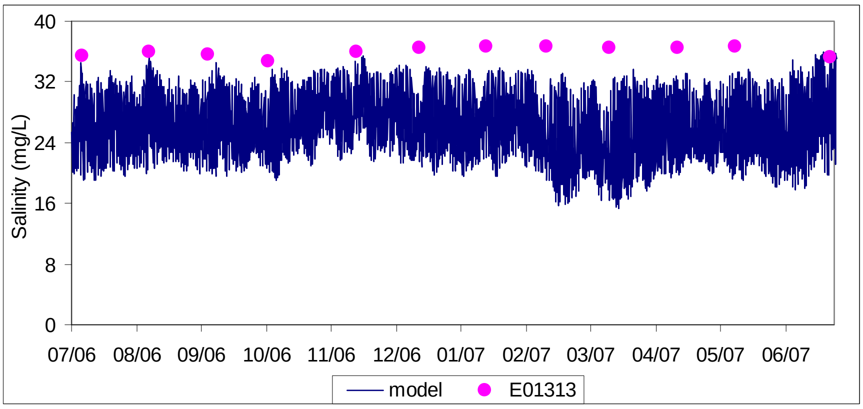
PUMICESTONE PASSAGE CALIBRATION RESULTS

Salinity

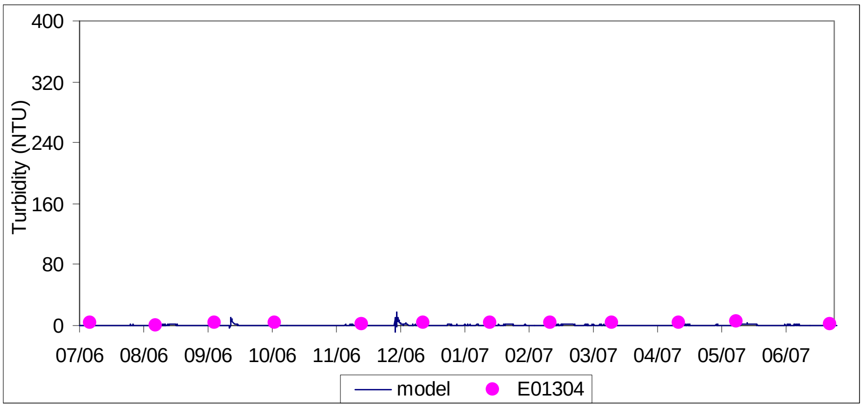


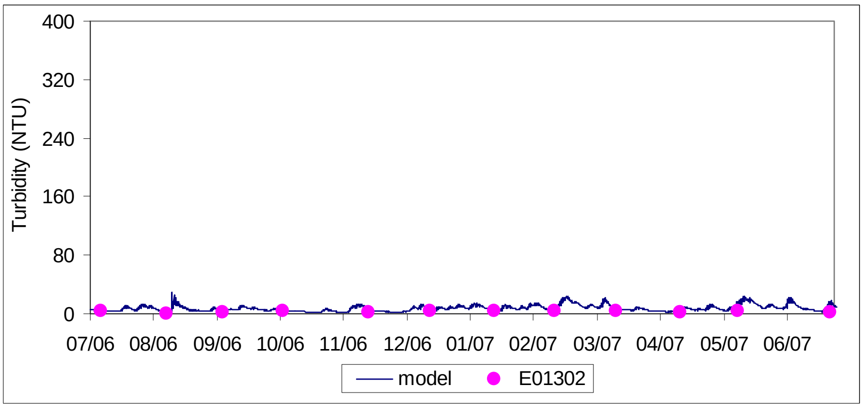


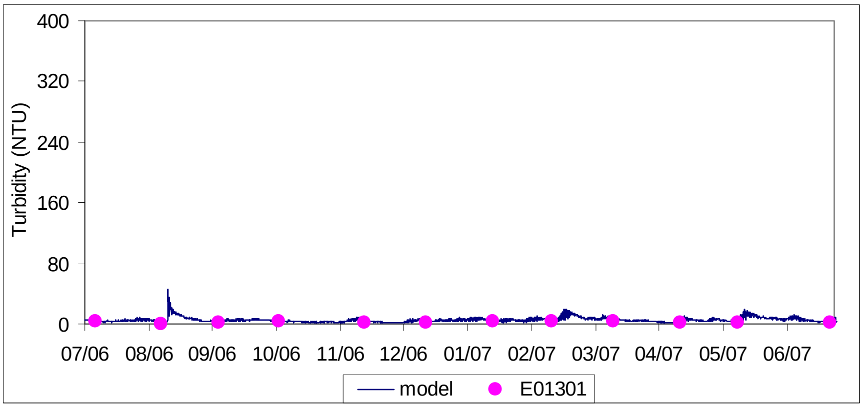


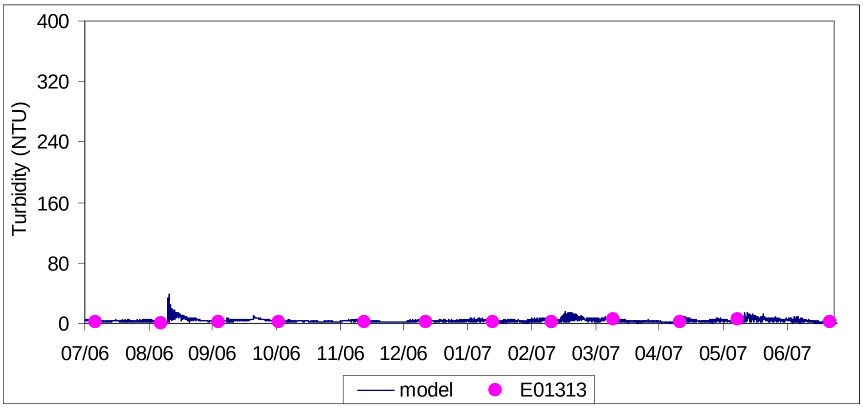


Turbidity

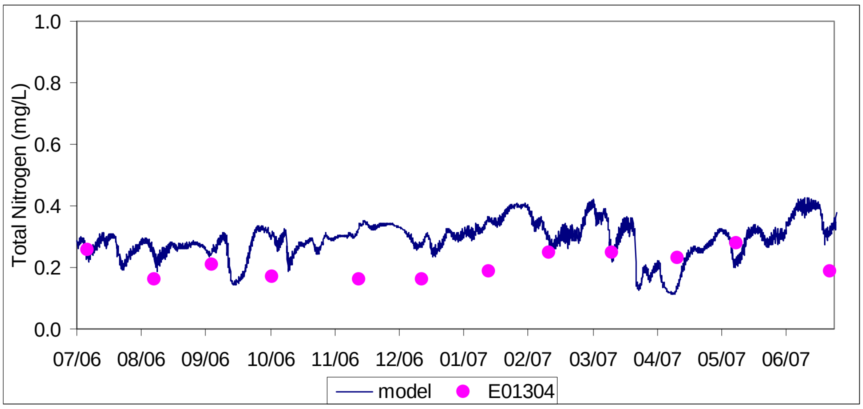

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01304

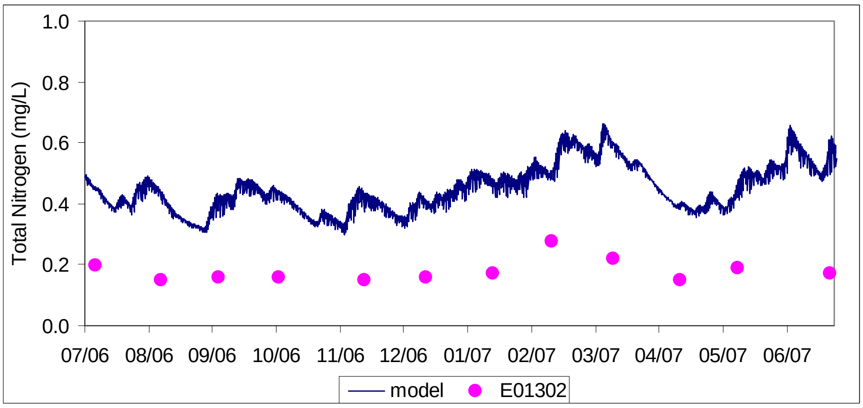

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01302

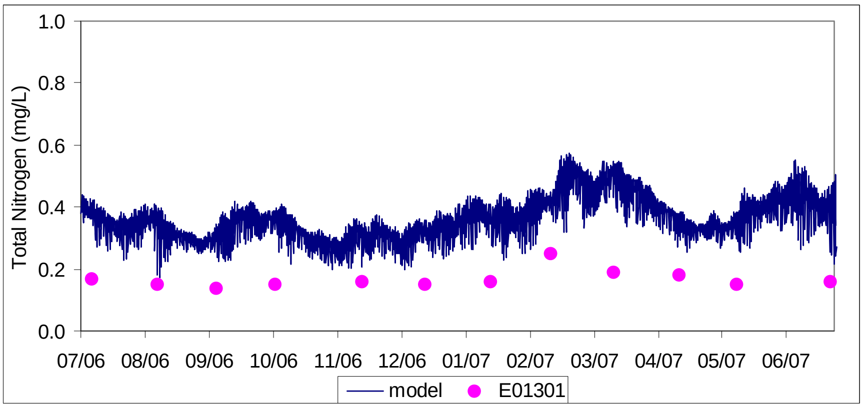

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01301

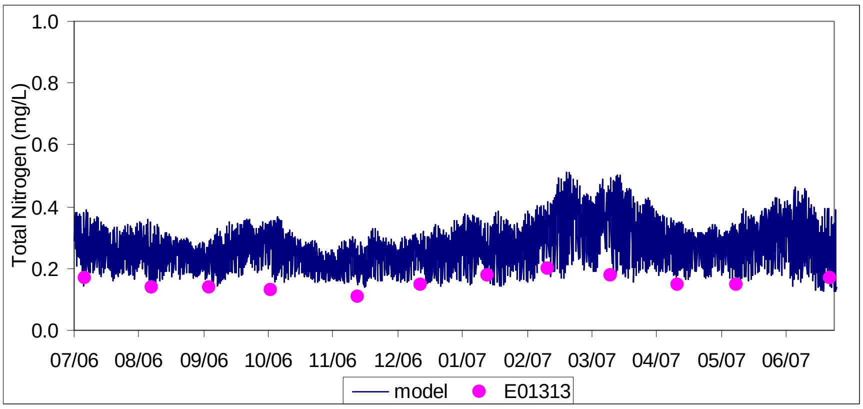

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01313

Total Nitrogen

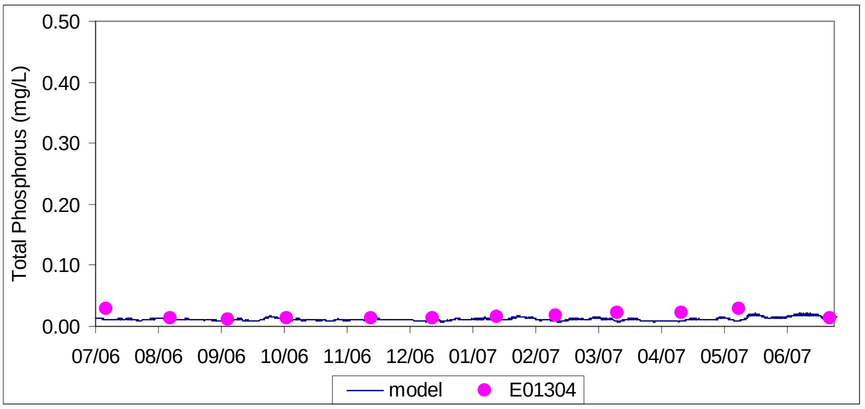


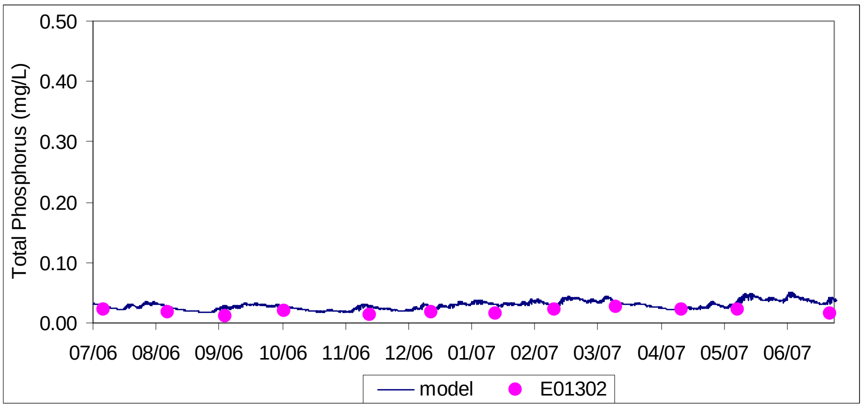


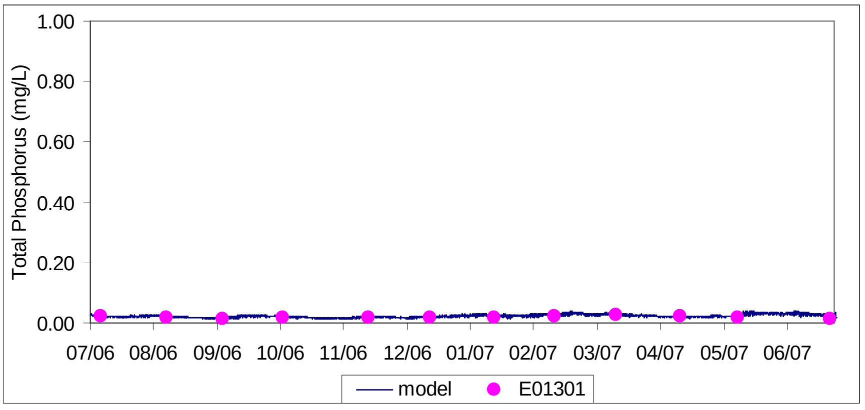


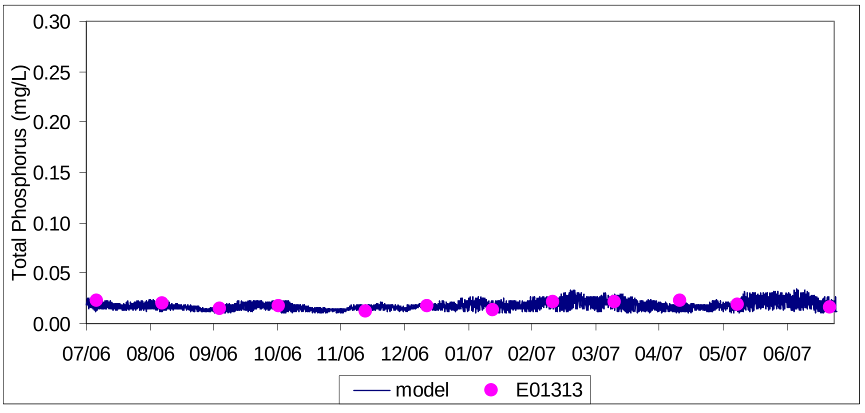


Total Phosphorus



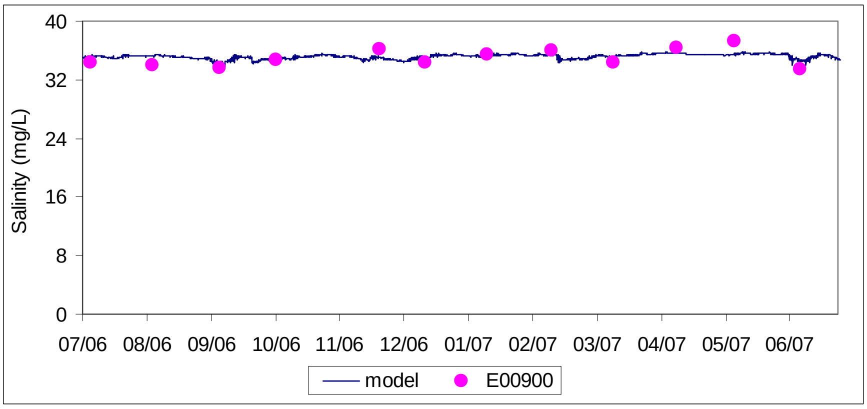


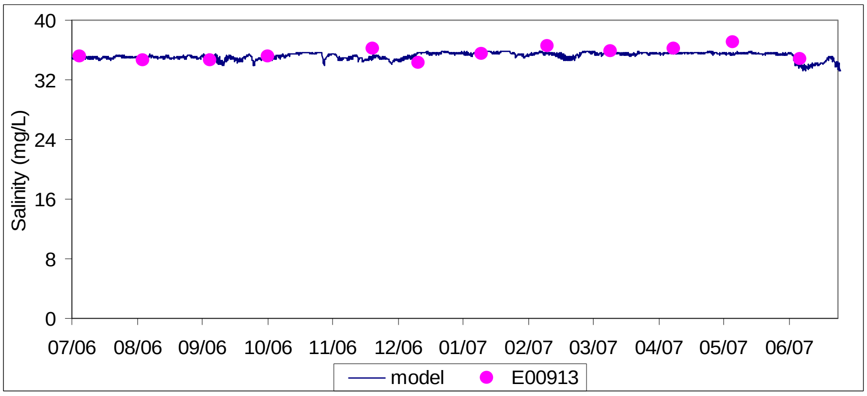


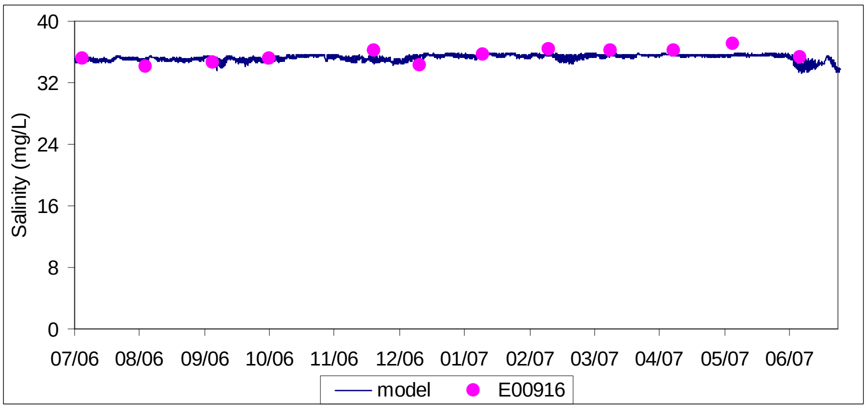


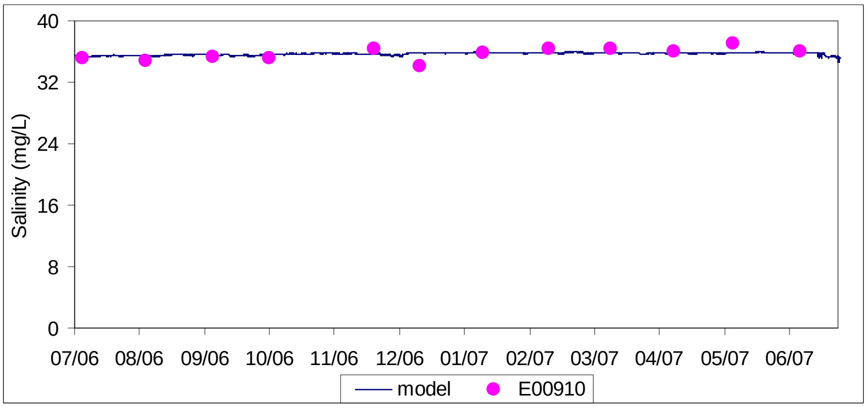
BRAMBLE BAY CALIBRATION RESULTS

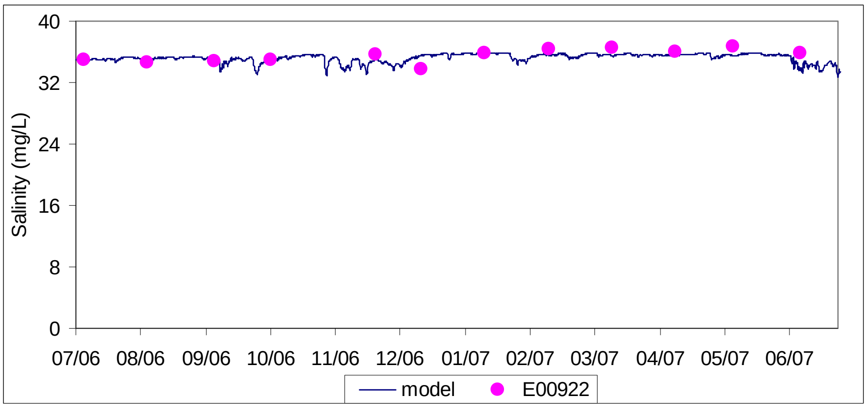
Salinity

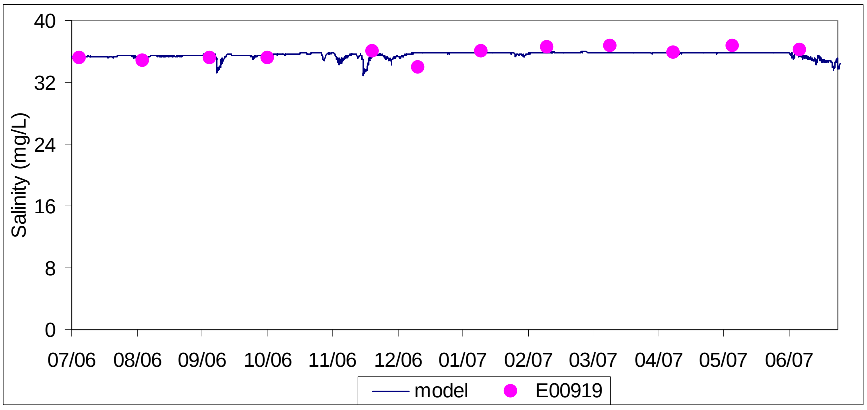


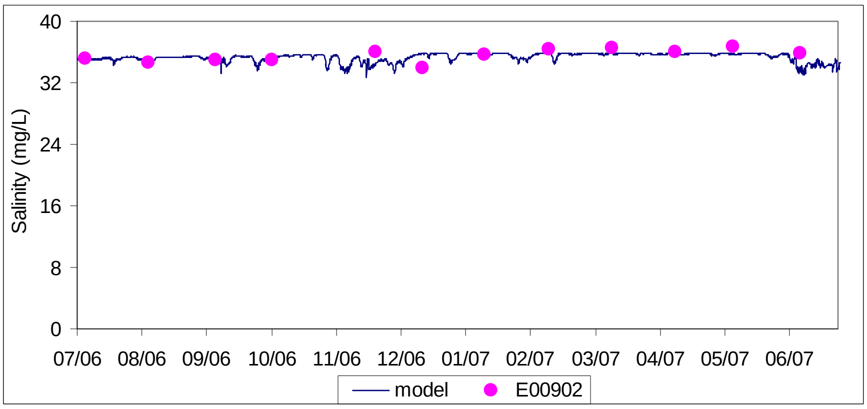


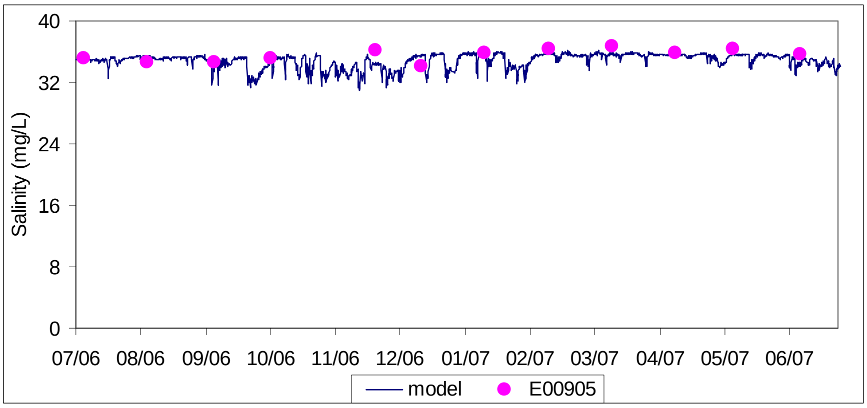


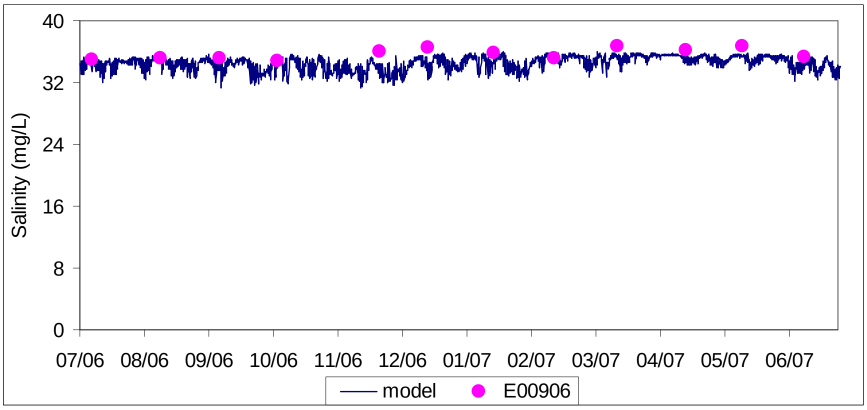


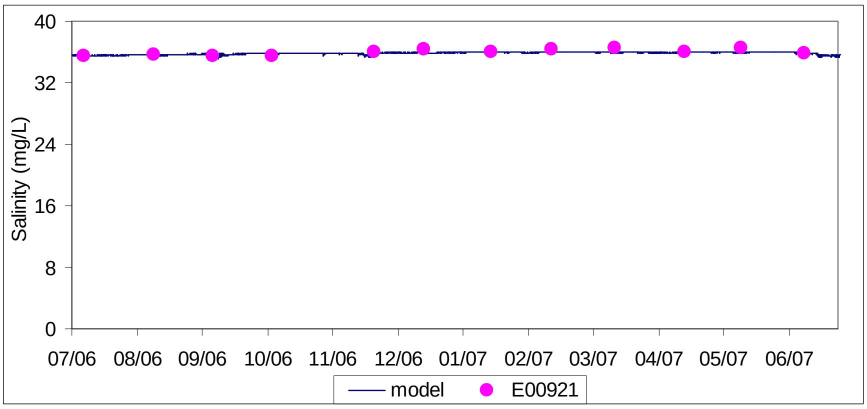

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00922


Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00919

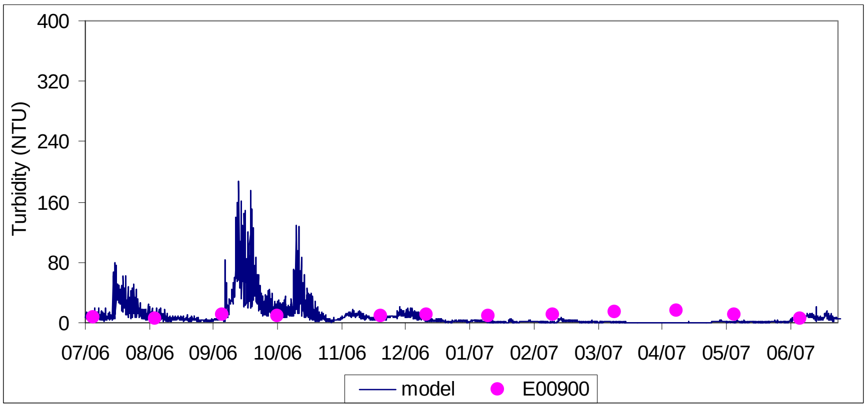

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00902

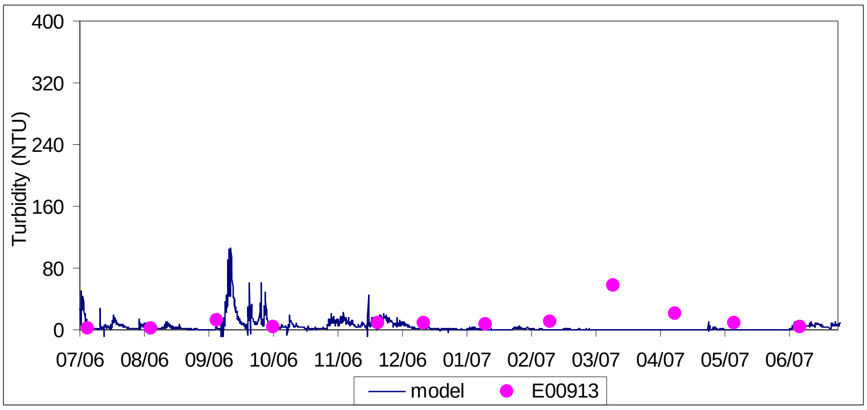

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00905

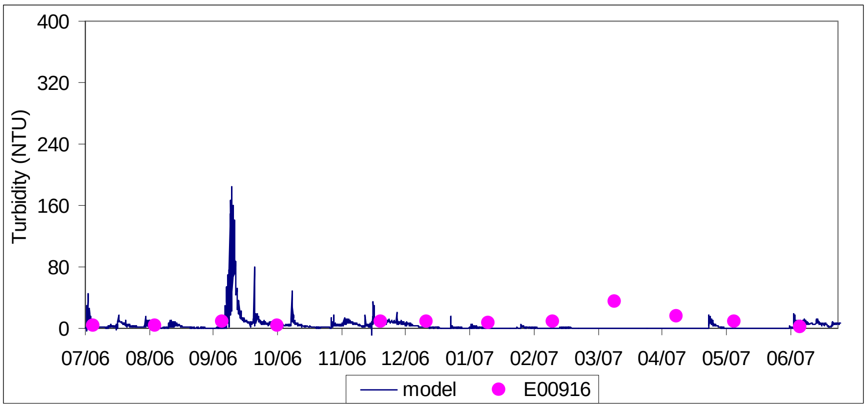

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00906

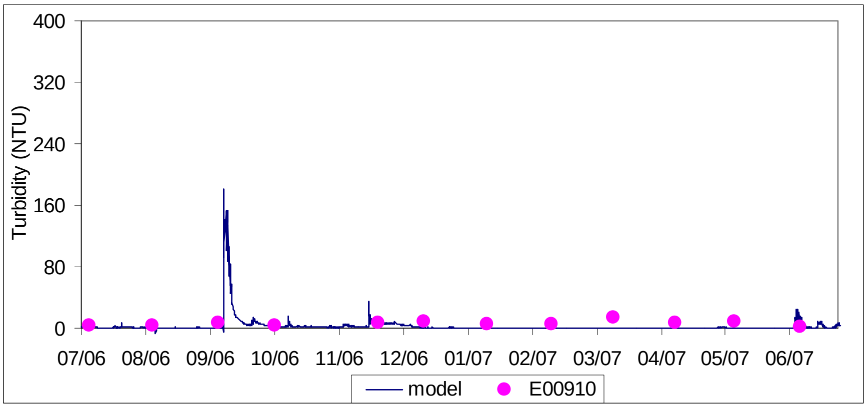

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00921

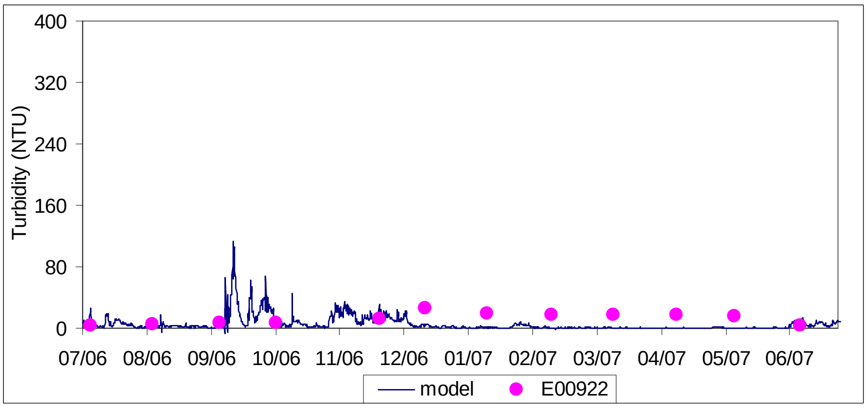
Turbidity

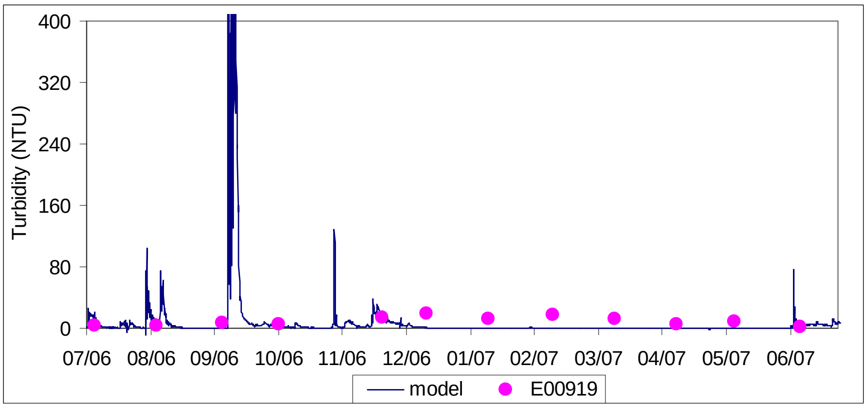

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00900

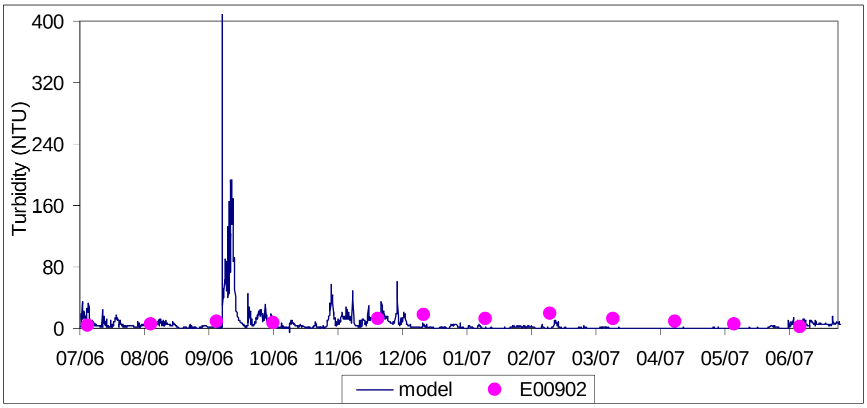

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00913


Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00916

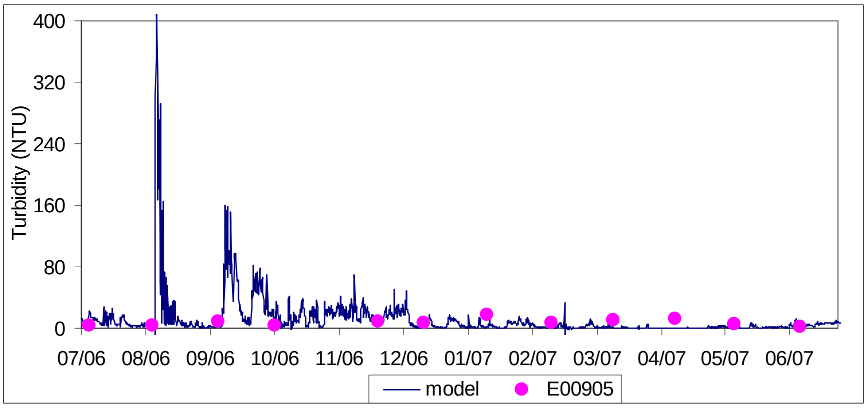

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00910


Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00922

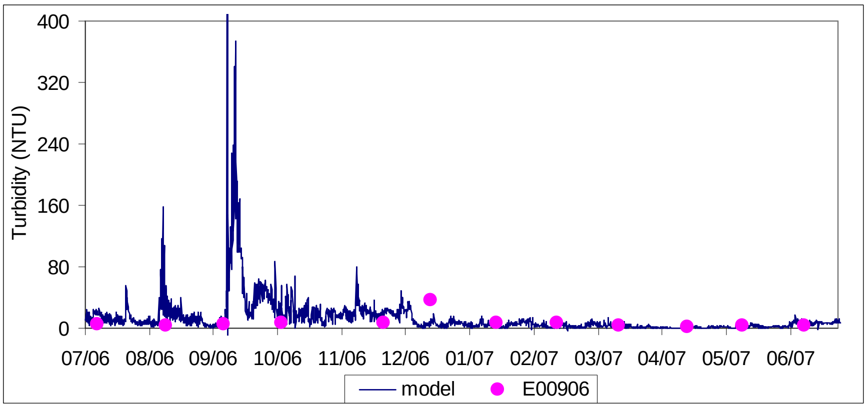

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00919



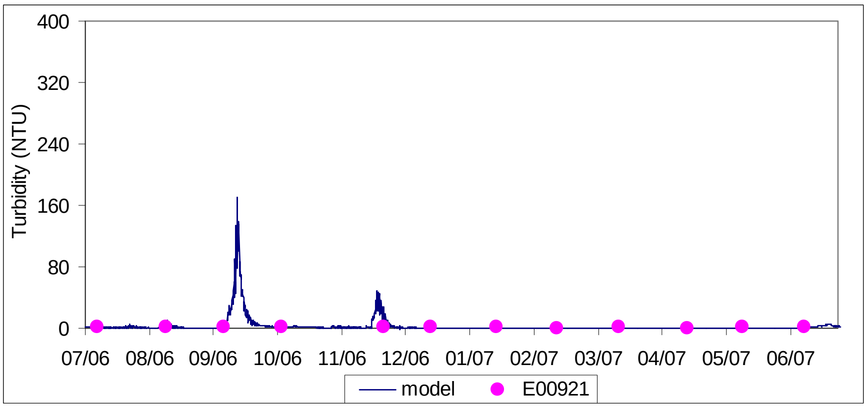
Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00902



Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00905

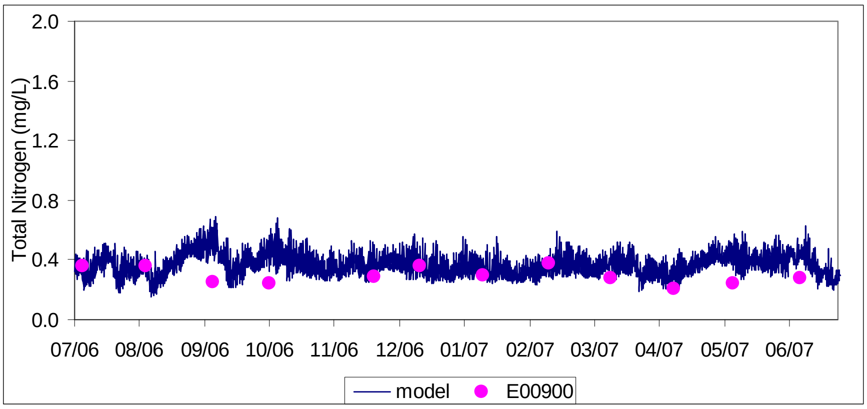


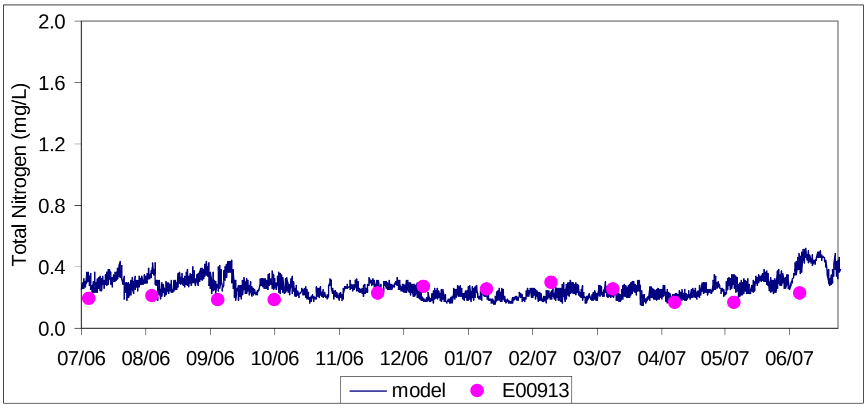
Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00906

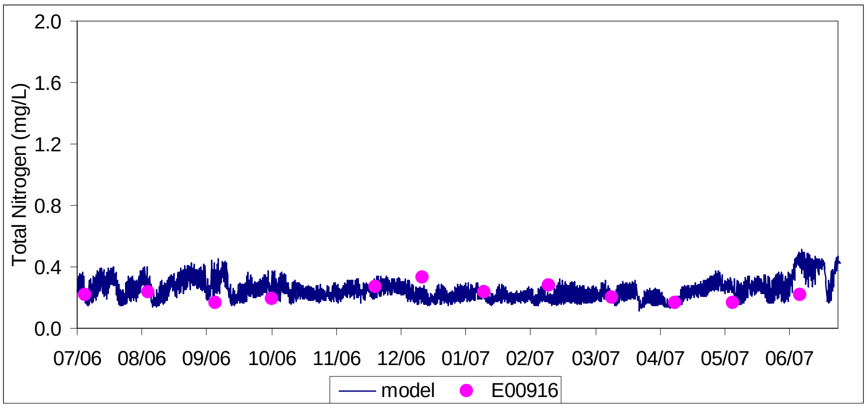


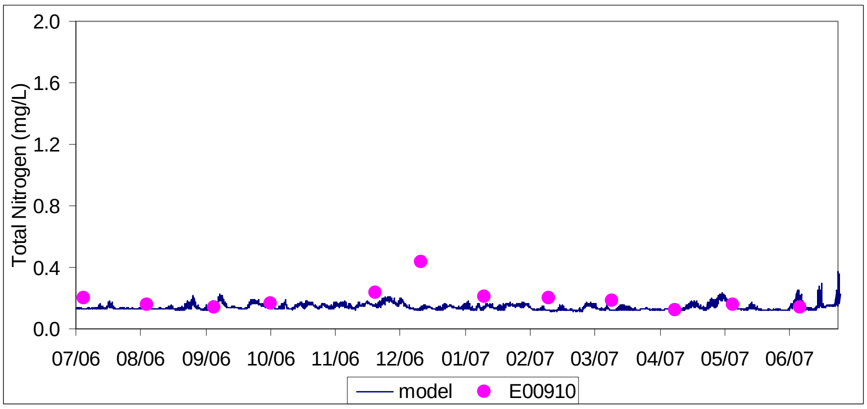
Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00921

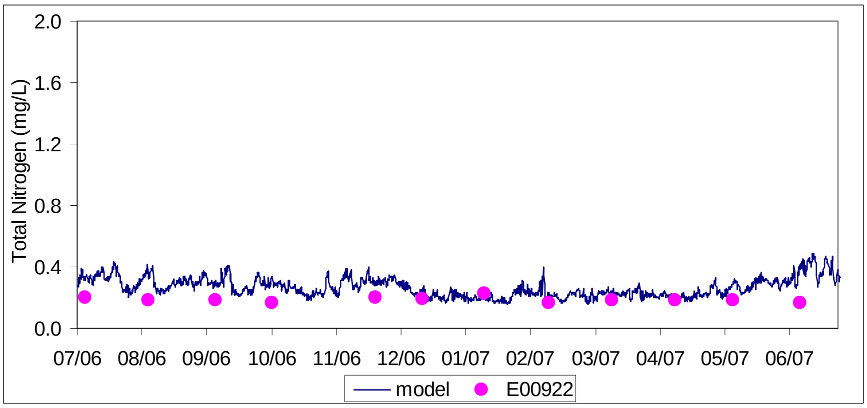
Total Nitrogen



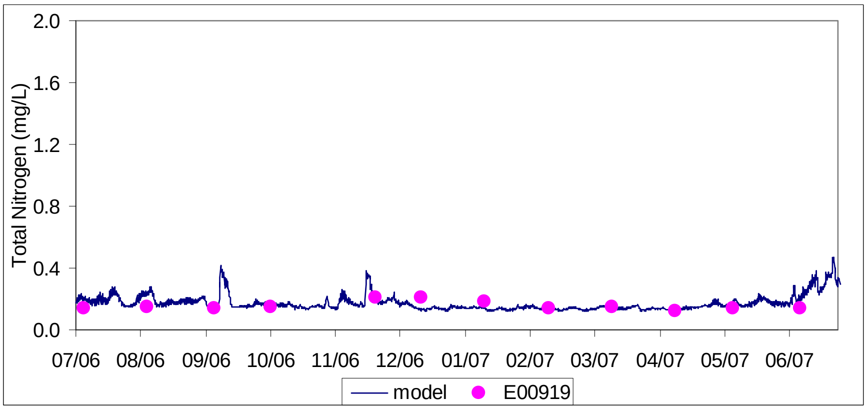




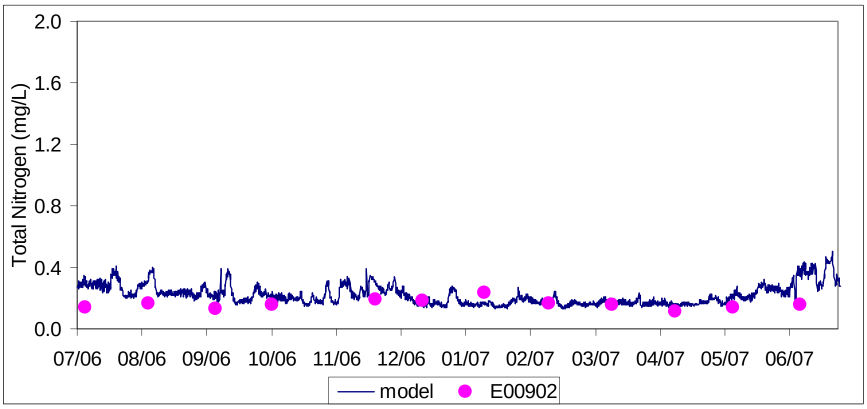




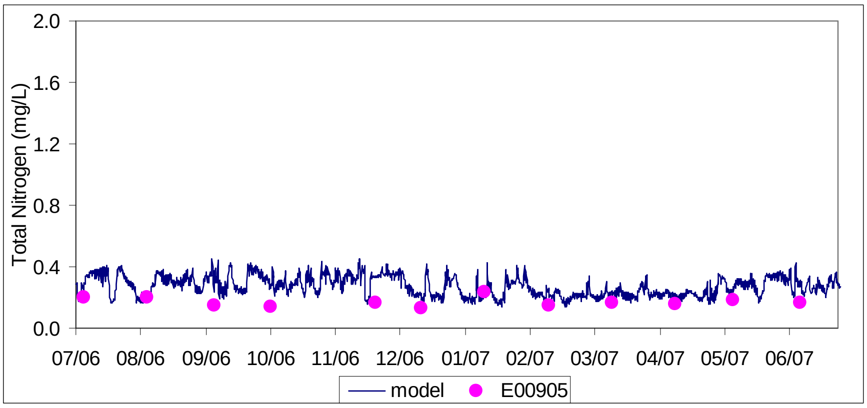
Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00922



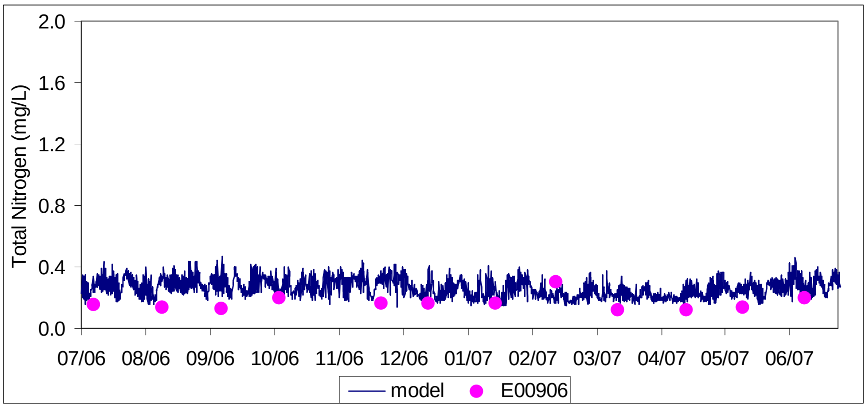
Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00919

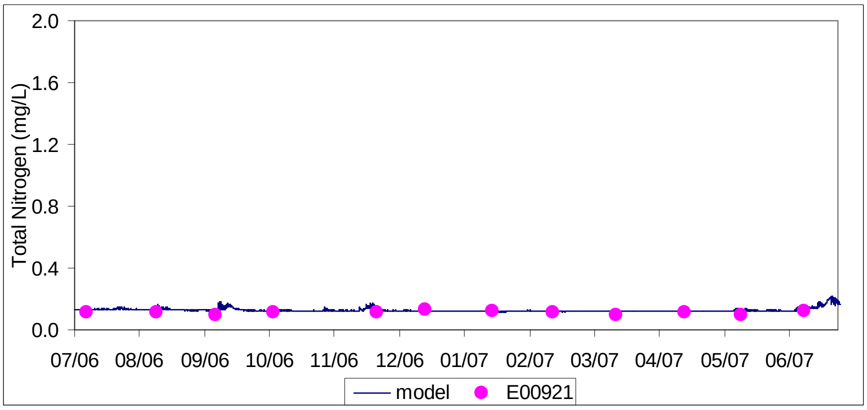


Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00902

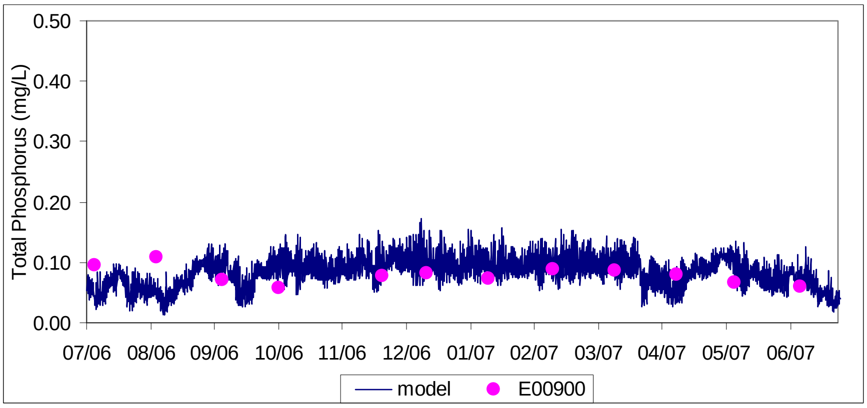


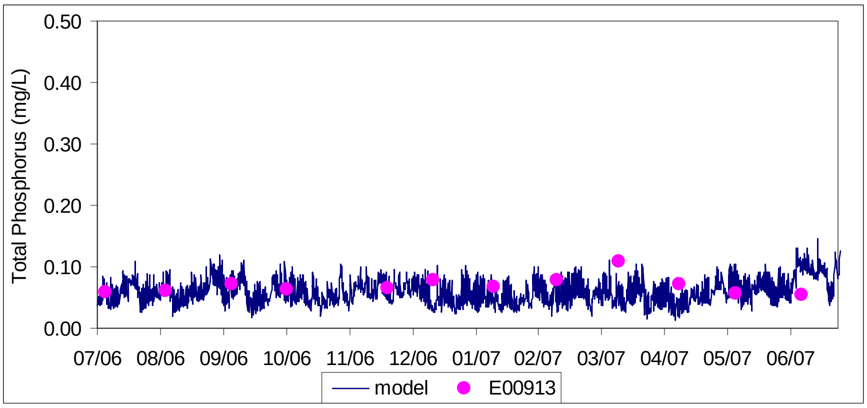
Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00905

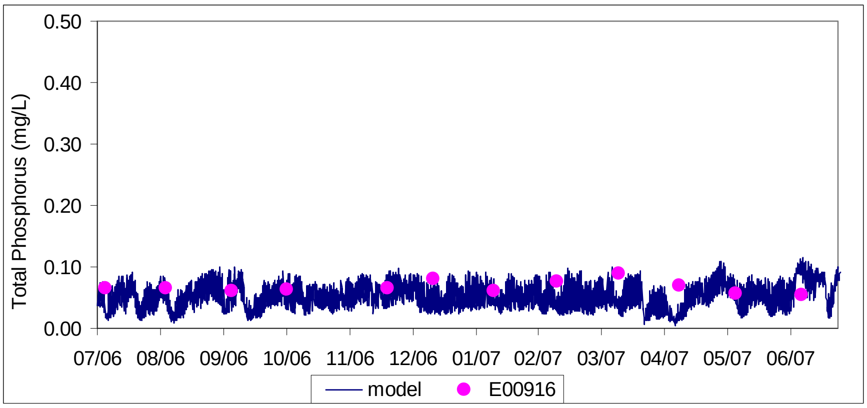


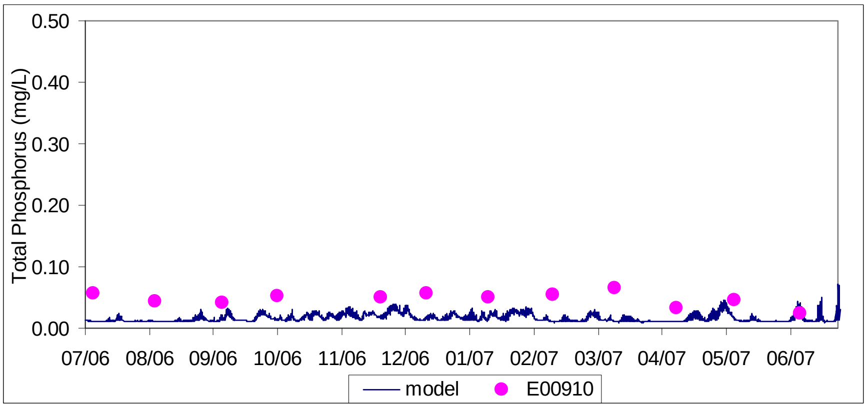


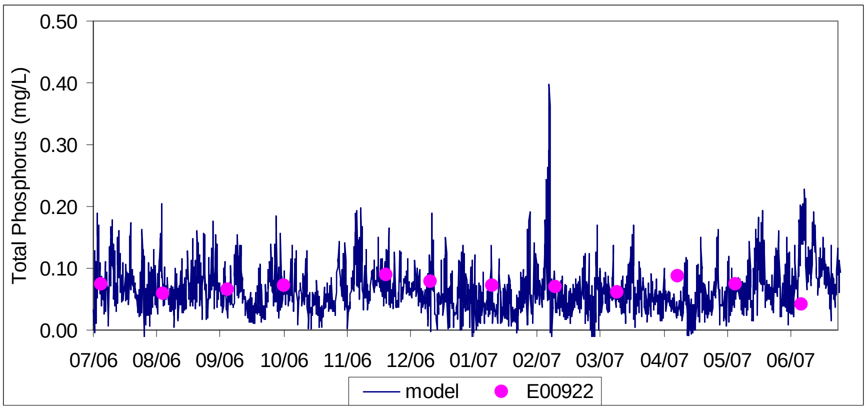
Total Phosphorus

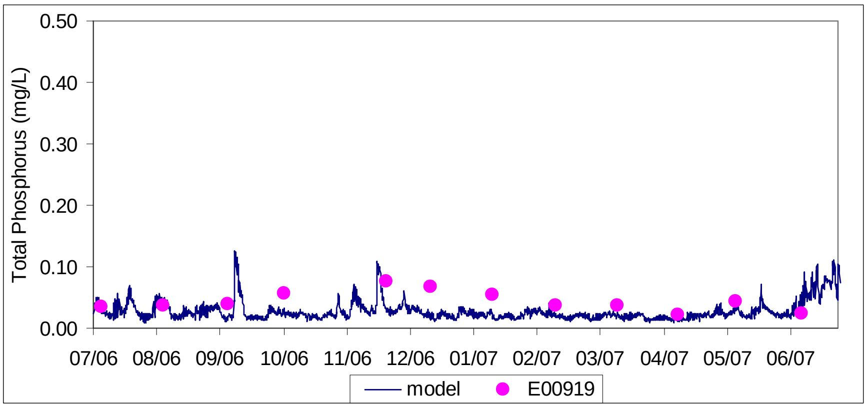


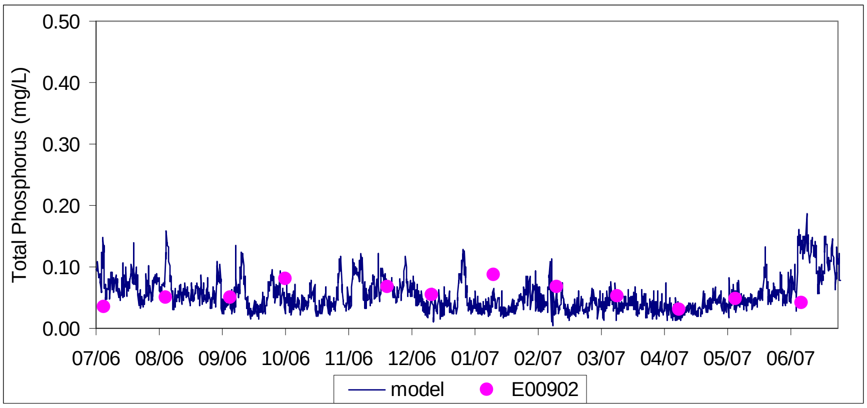


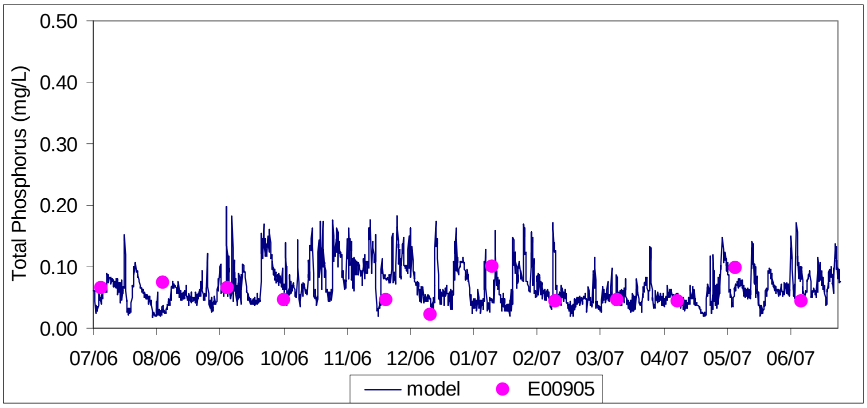

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00916

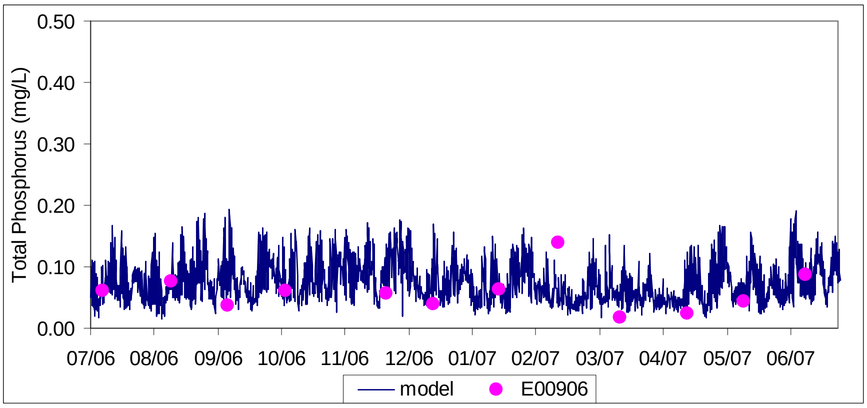

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00910

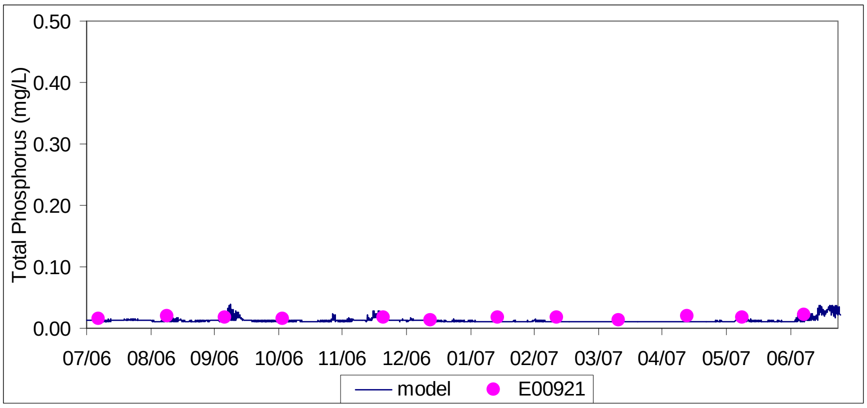

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00922


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00919


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00902

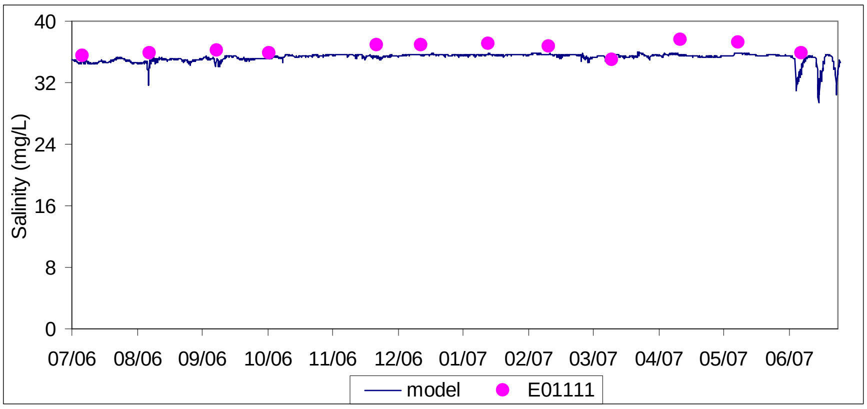

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00905

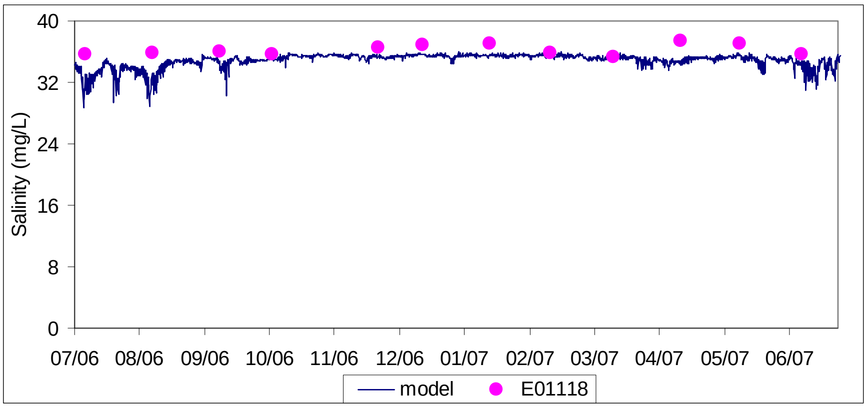

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00906

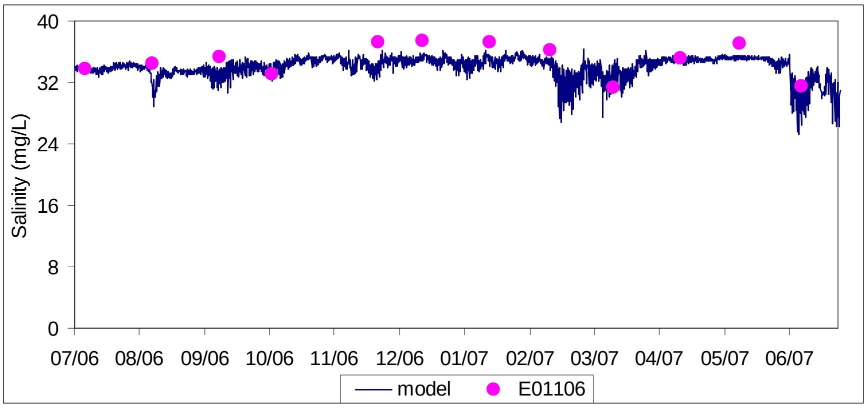

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00921

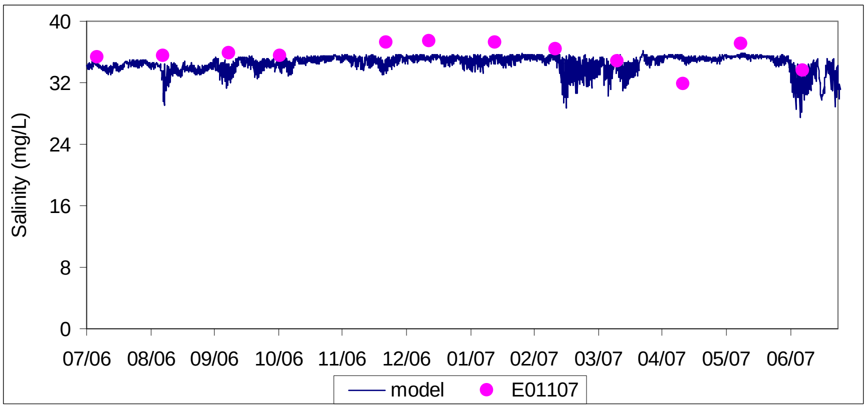
DECEPTION BAY CALIBRATION RESULTS

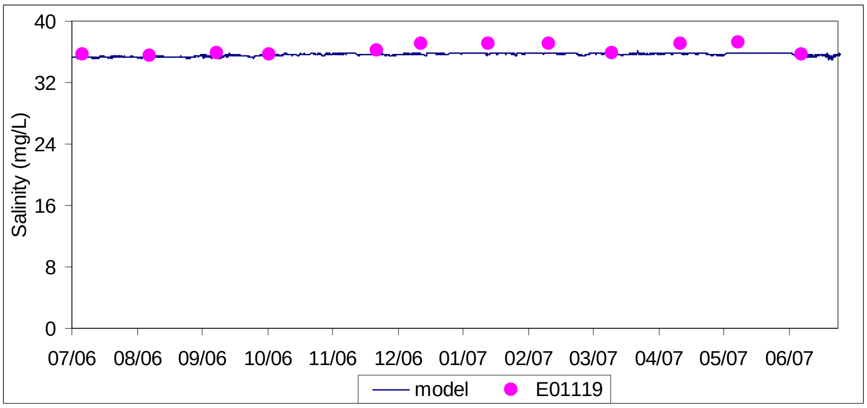
Salinity

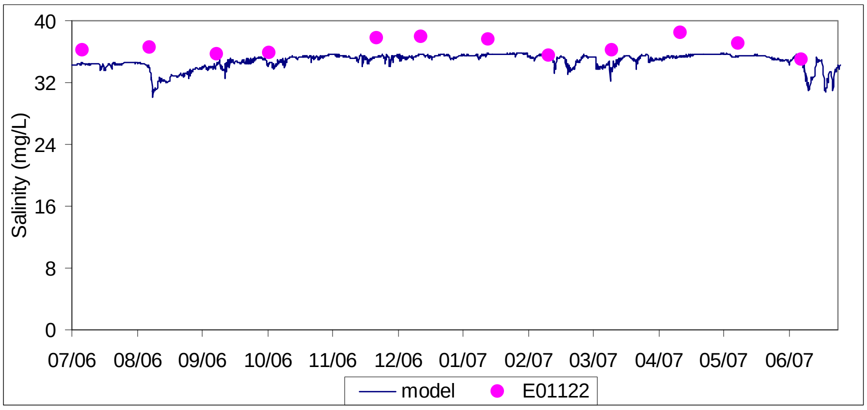


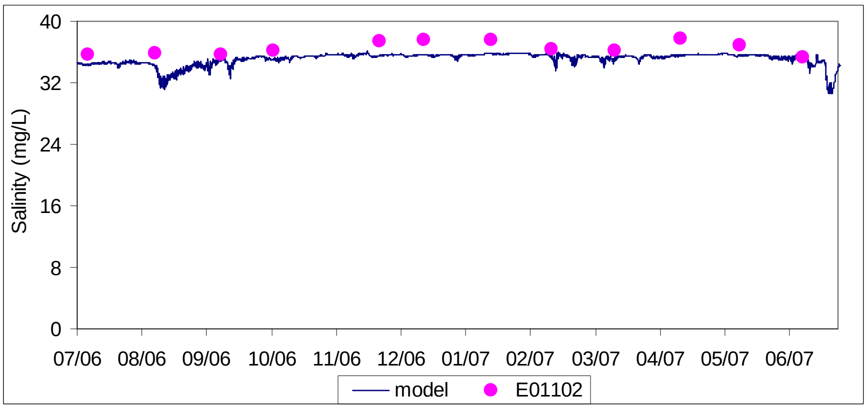


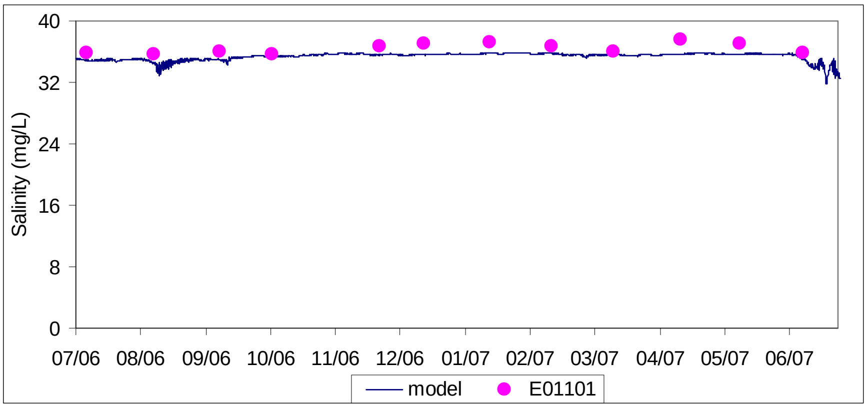


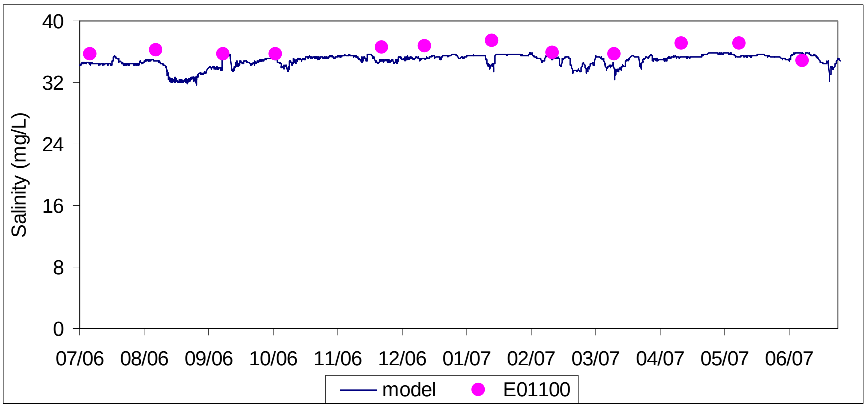


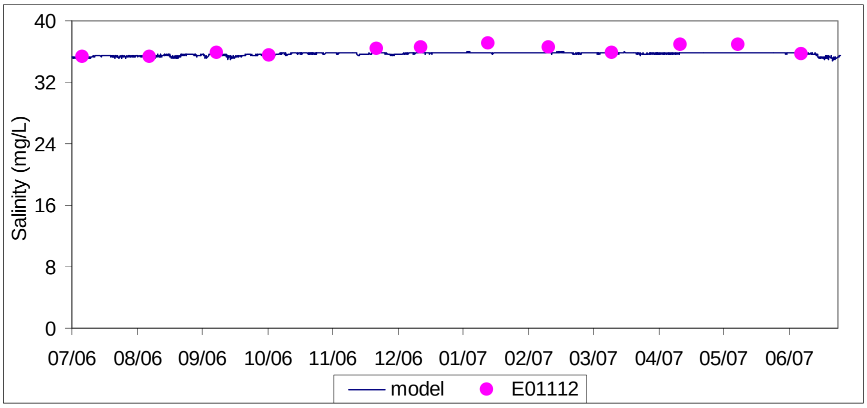

40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01119


40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01122

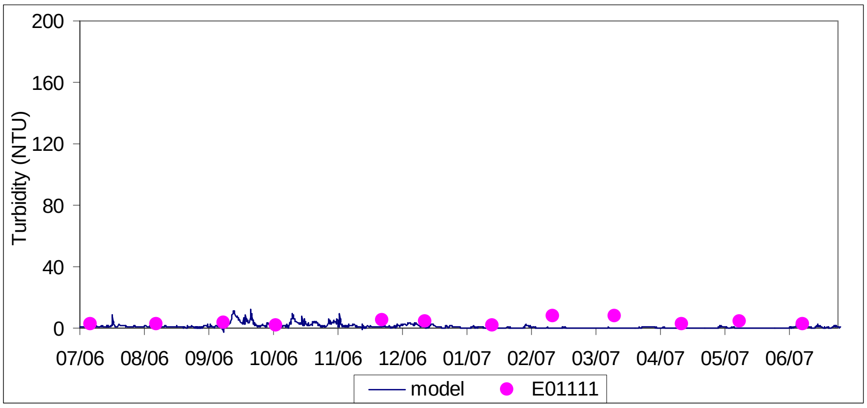

40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01102

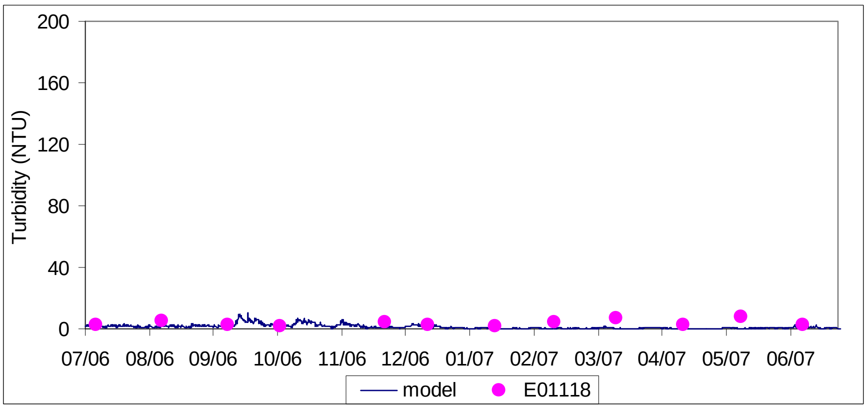

40
32
24
16
8
0
Salinity (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01101

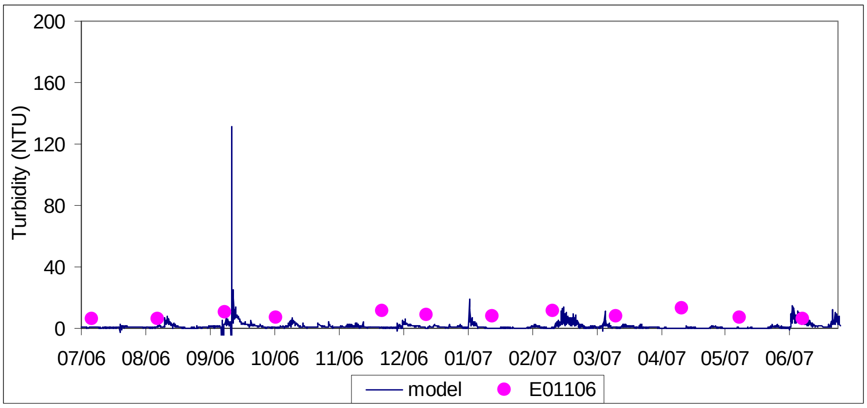

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01100

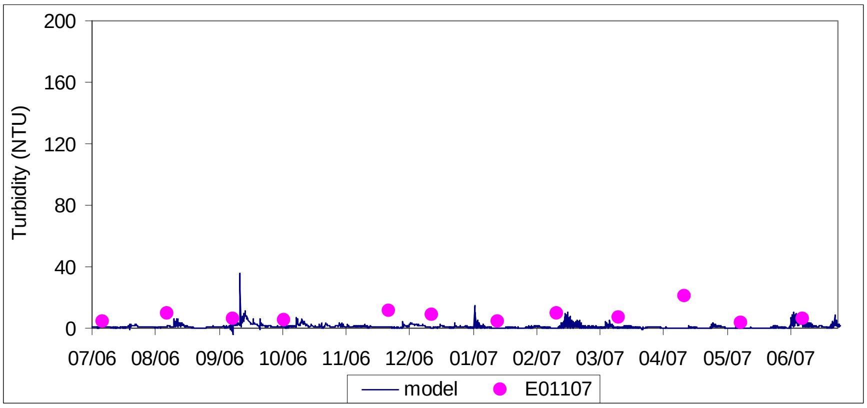

Salinity (mg/L)
40
32
24
16
8
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01112

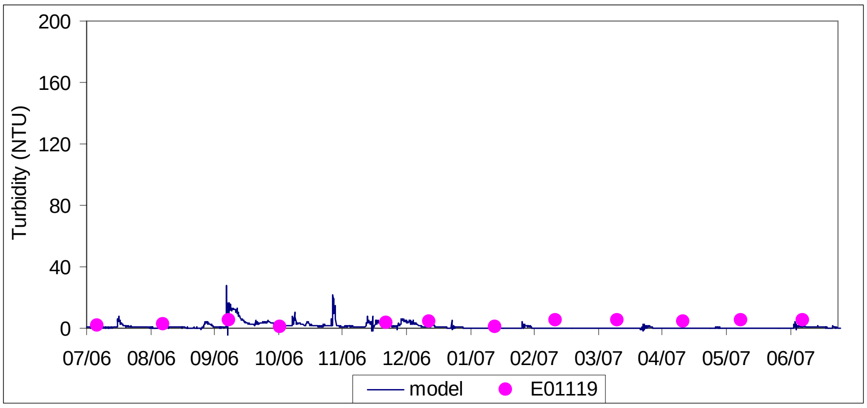
Turbidity

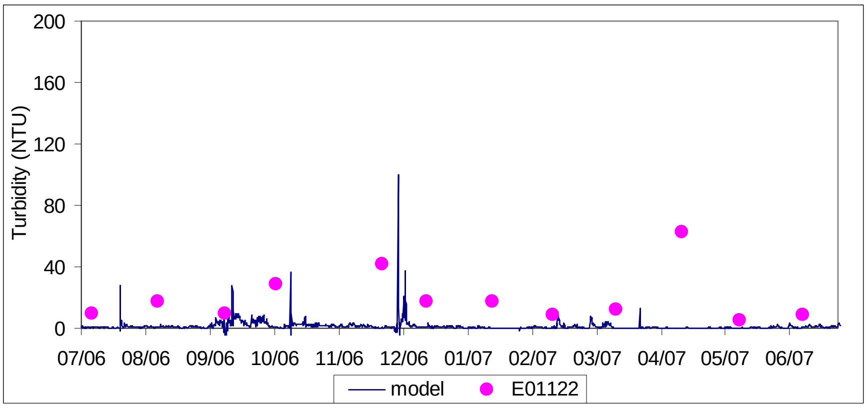

Turbidity (NTU)
200
160
120
80
40
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01111

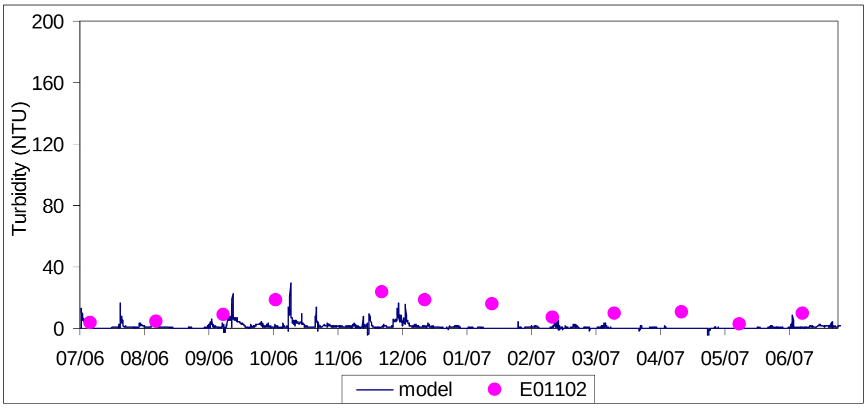

Turbidity (NTU)
200
160
120
80
40
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01118

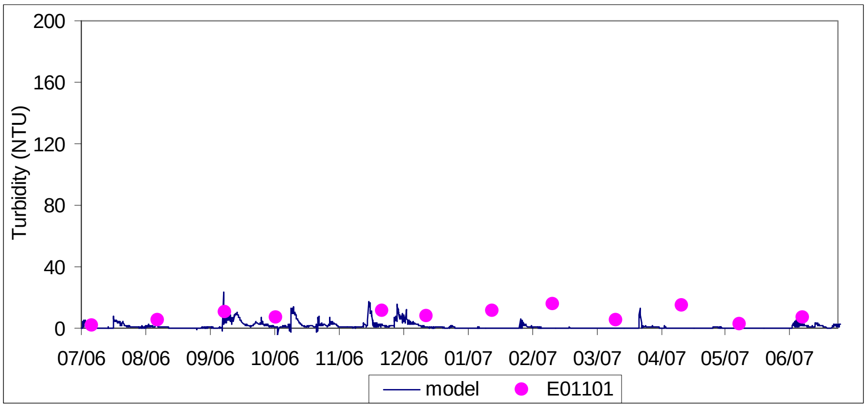

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01106

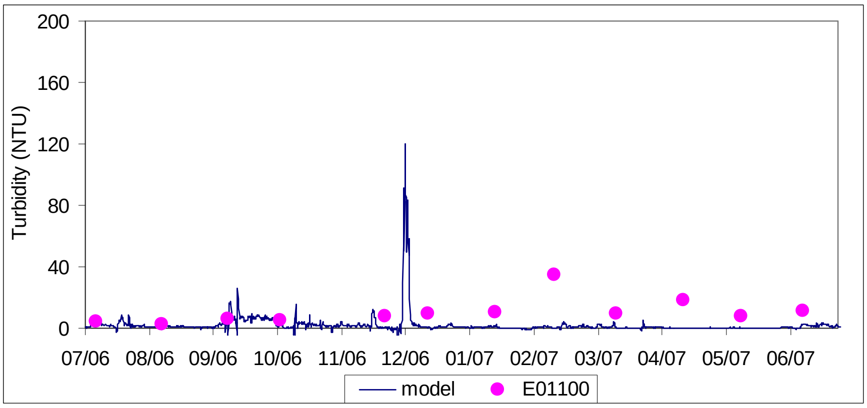

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01107

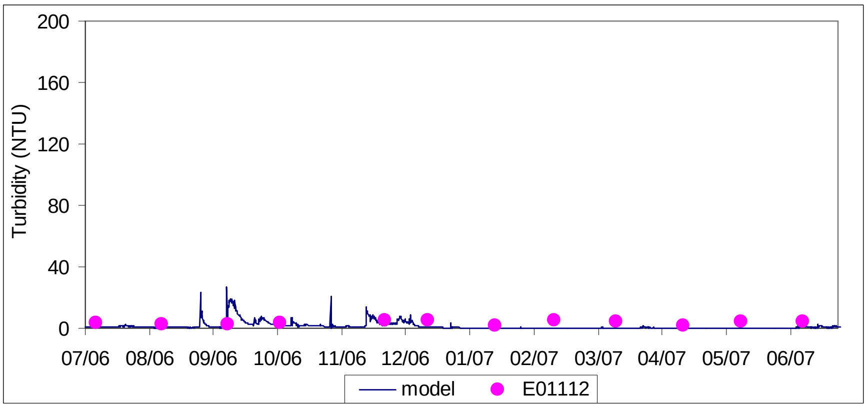

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01119


200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01122

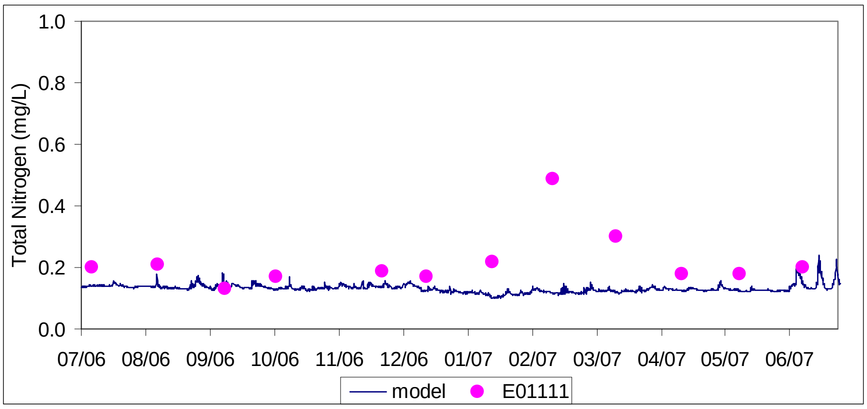

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01102

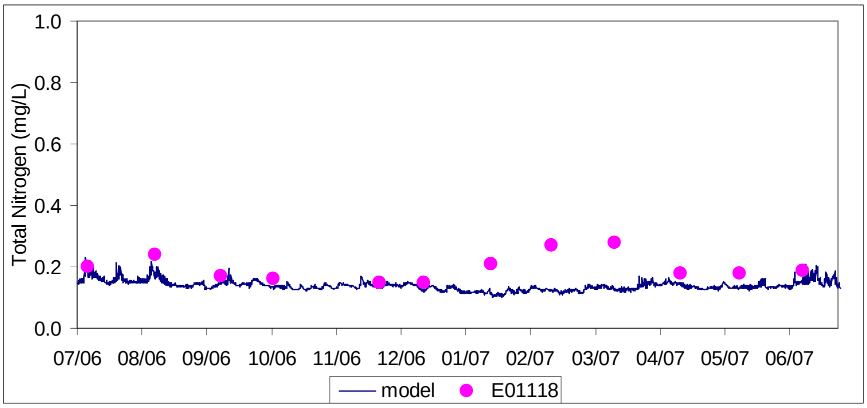

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01101

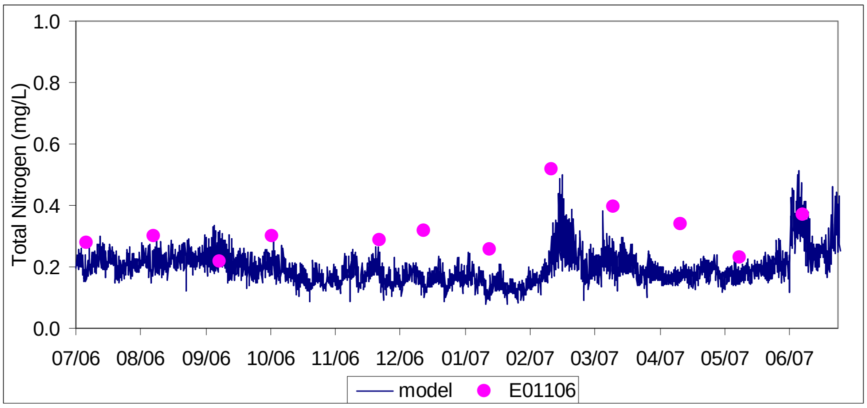

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01100

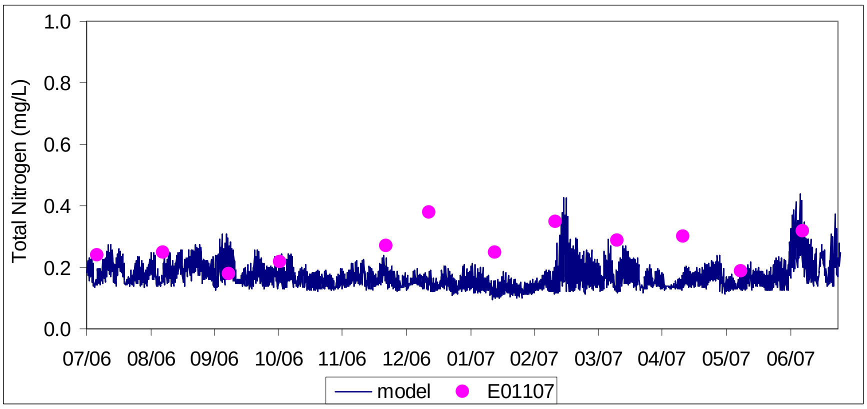

200
160
120
80
40
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01112

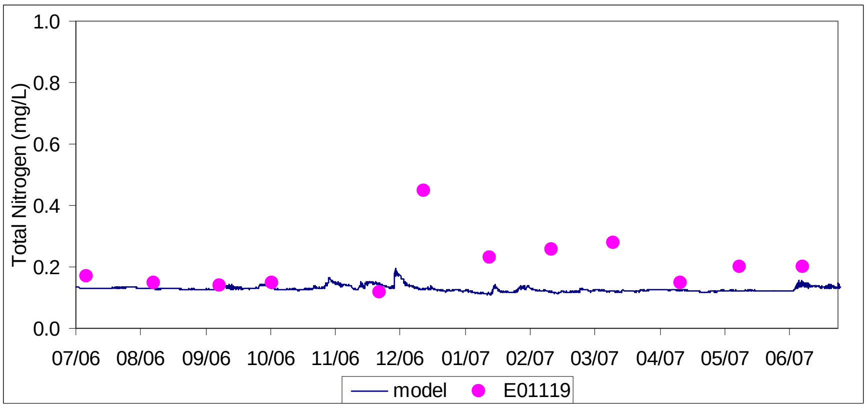
Total Nitrogen

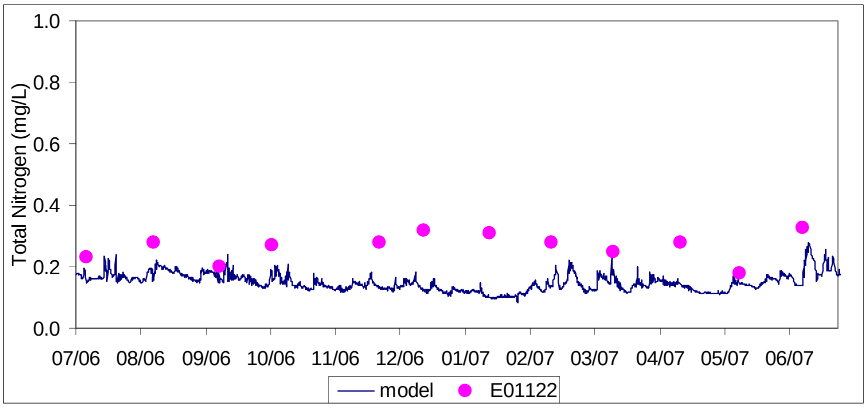


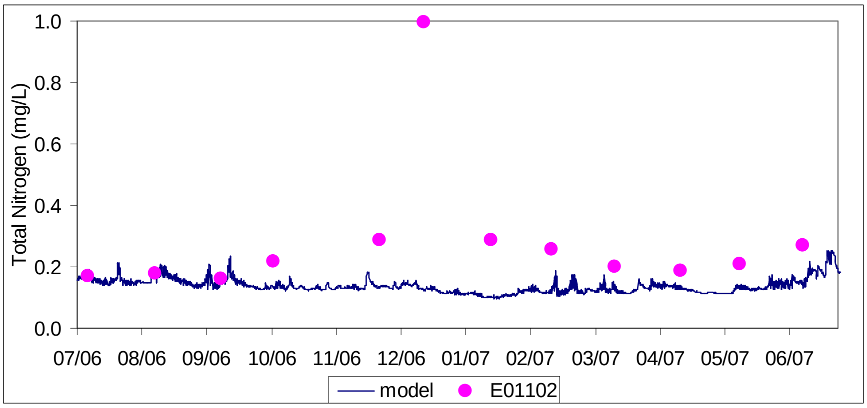


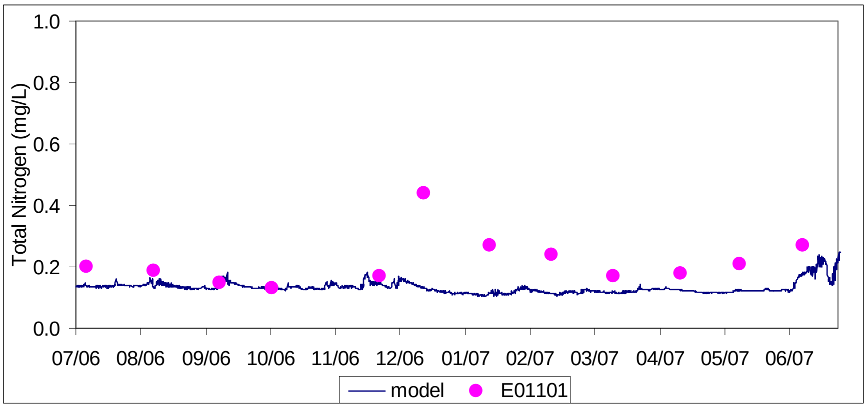


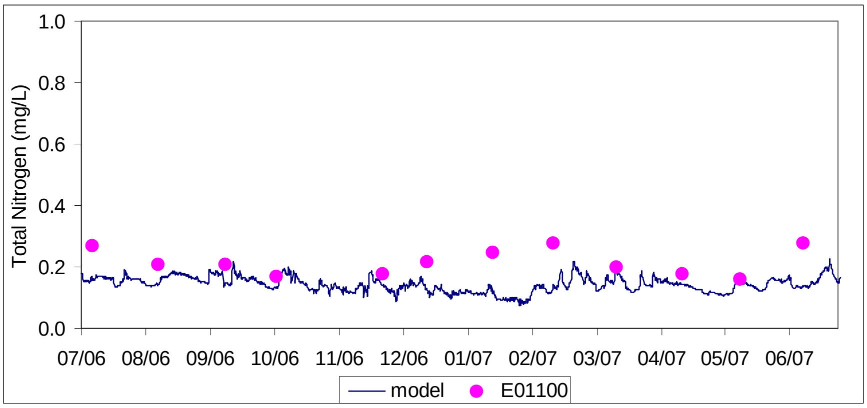


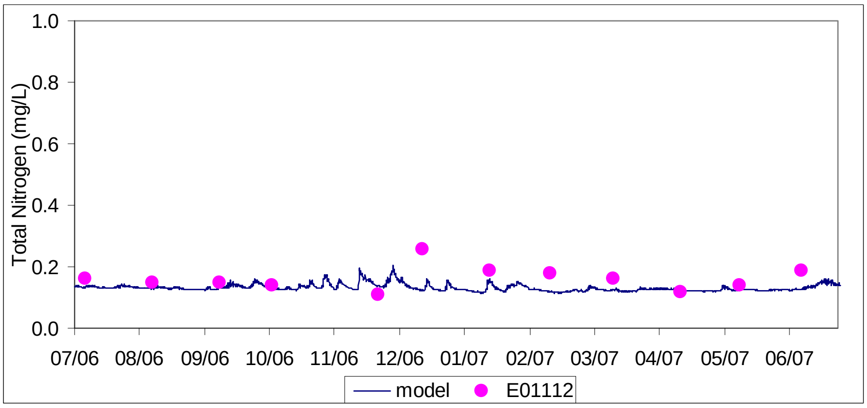

1.0
0.8
0.6
0.4
0.2
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01119


1.0
0.8
0.6
0.4
0.2
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01122

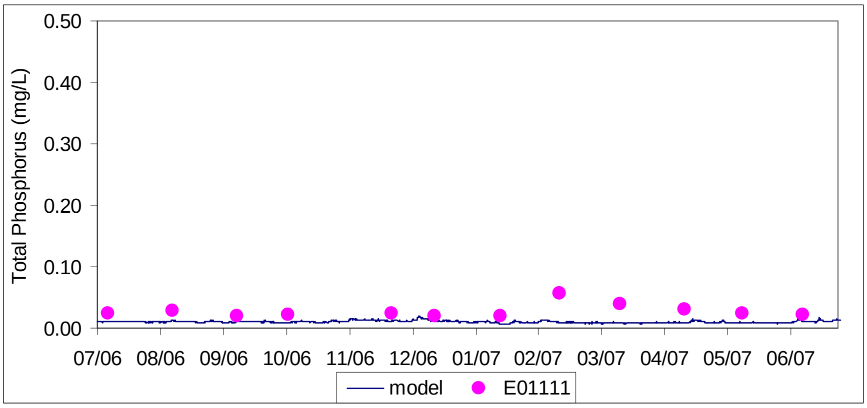

1.0
0.8
0.6
0.4
0.2
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01102

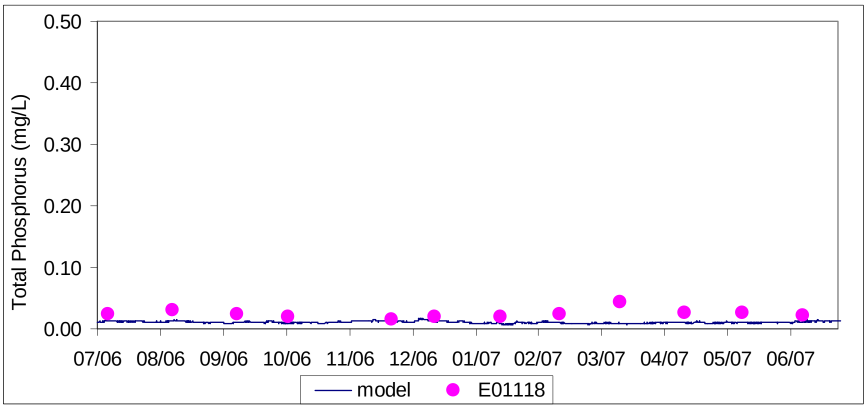

1.0
0.8
0.6
0.4
0.2
0.0
Total Nitrogen (mg/L)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01101

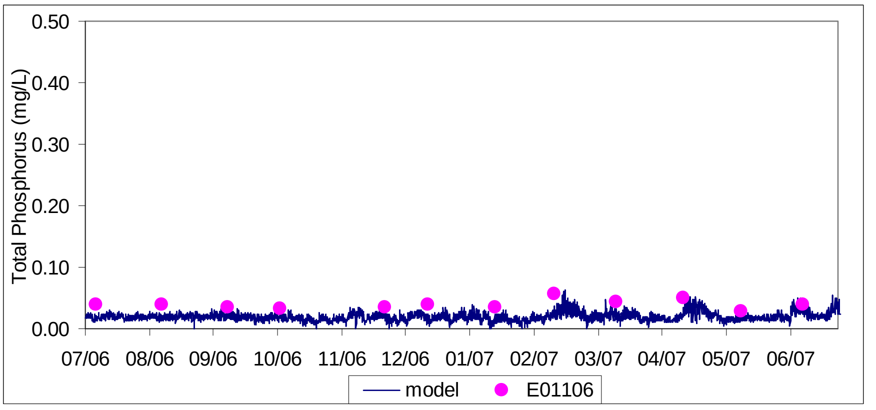


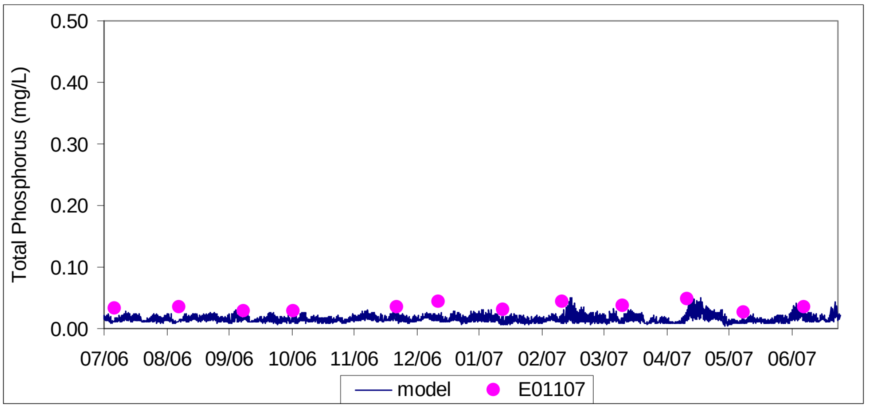


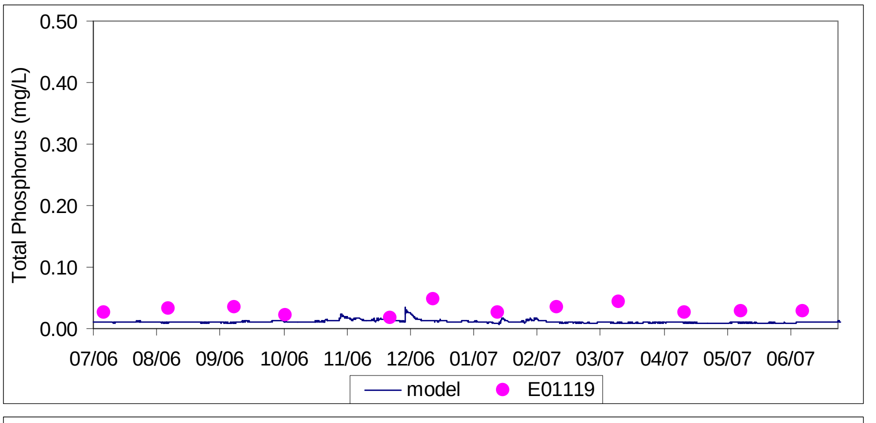
Total Phosphorus

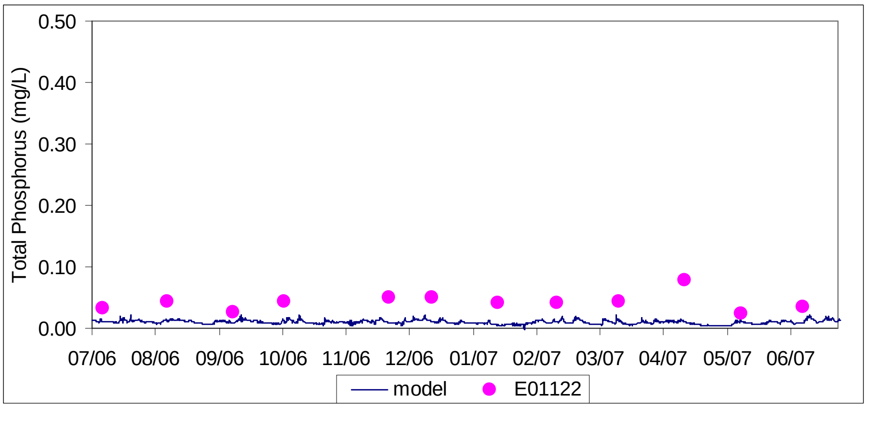


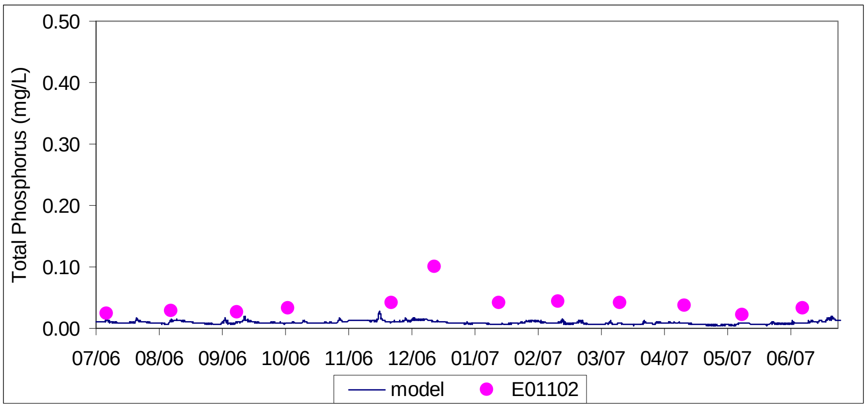


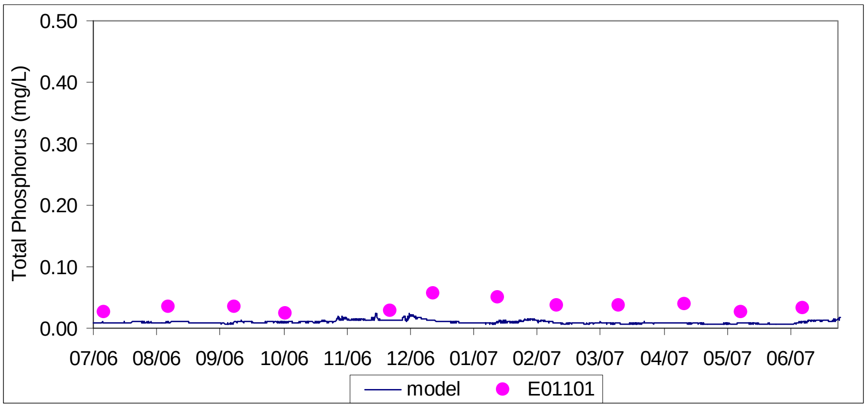

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01106

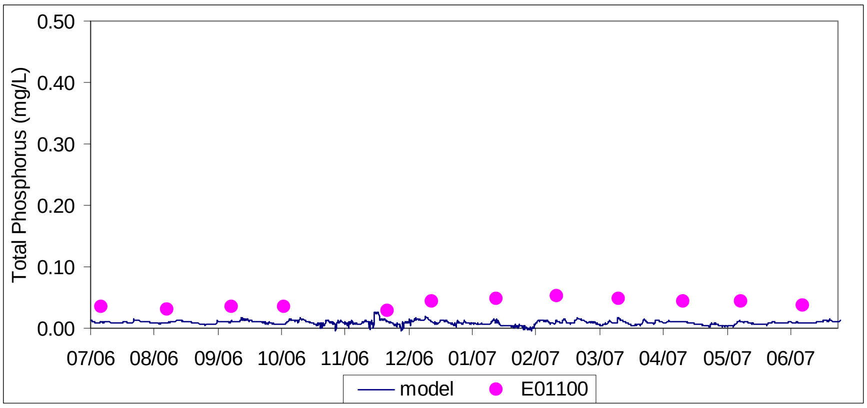

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01107

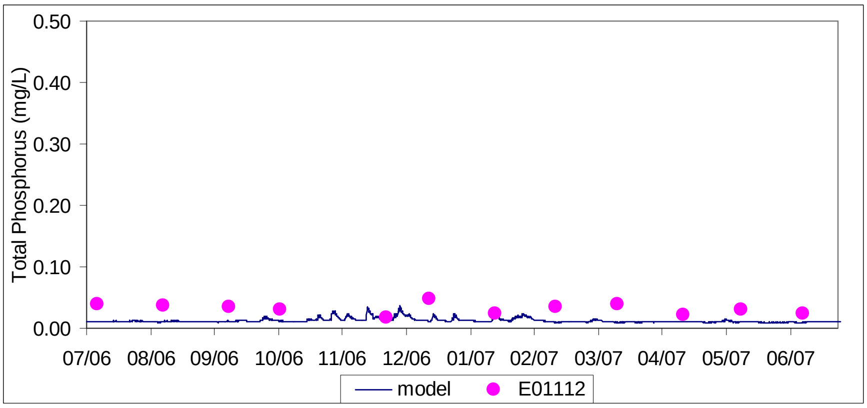

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01119


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01122


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01102

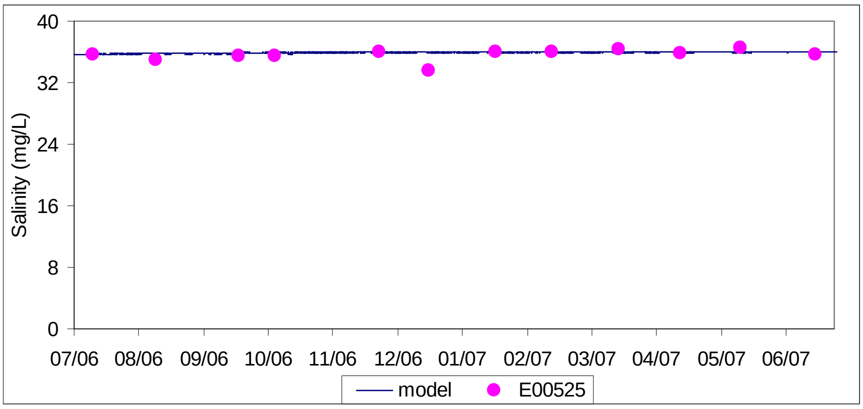

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01101

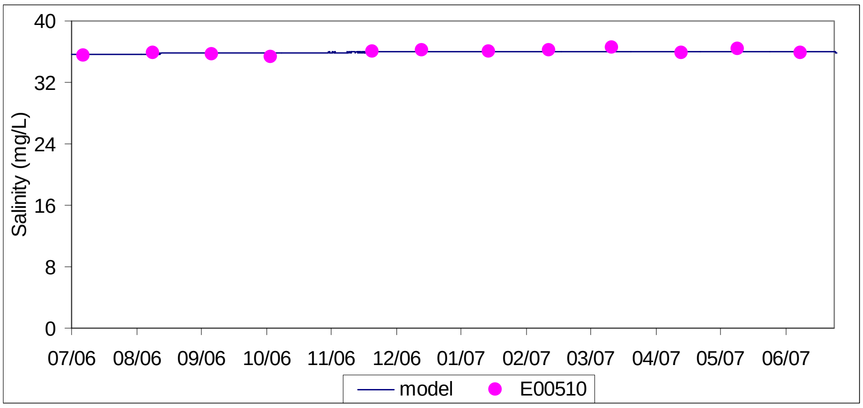

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01100

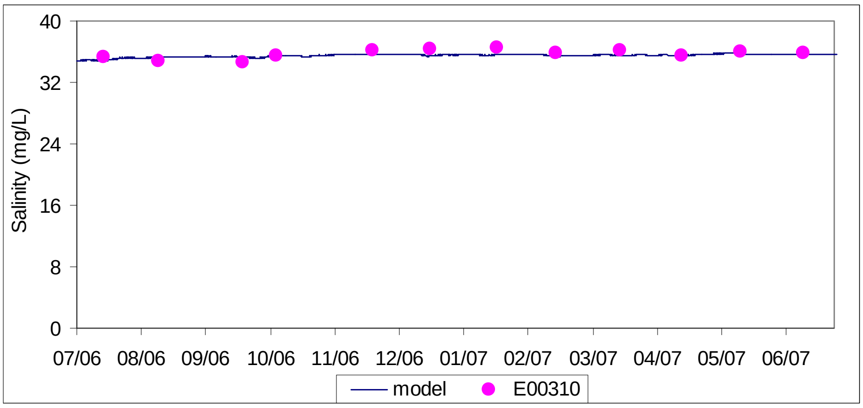

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01112

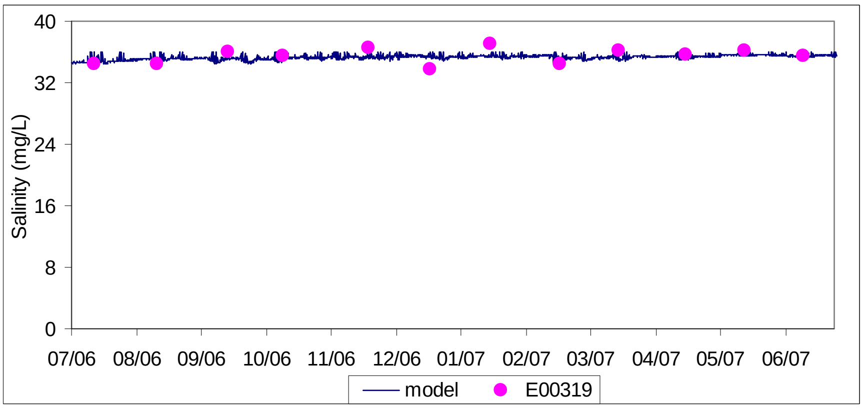
MORETON BAY CALIBRATION RESULTS

Salinity

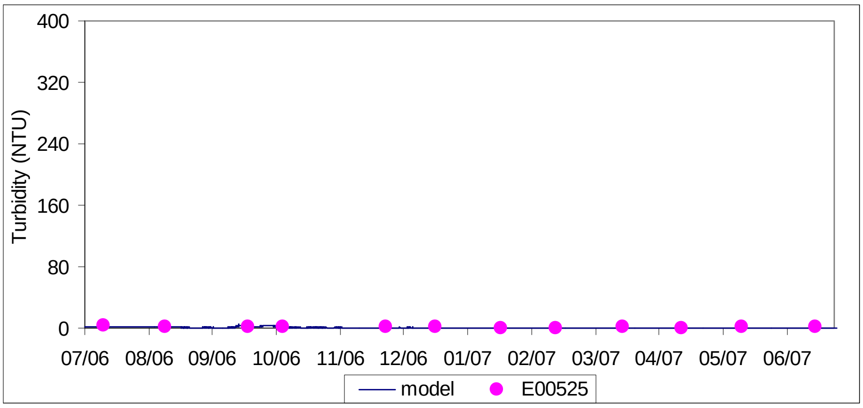




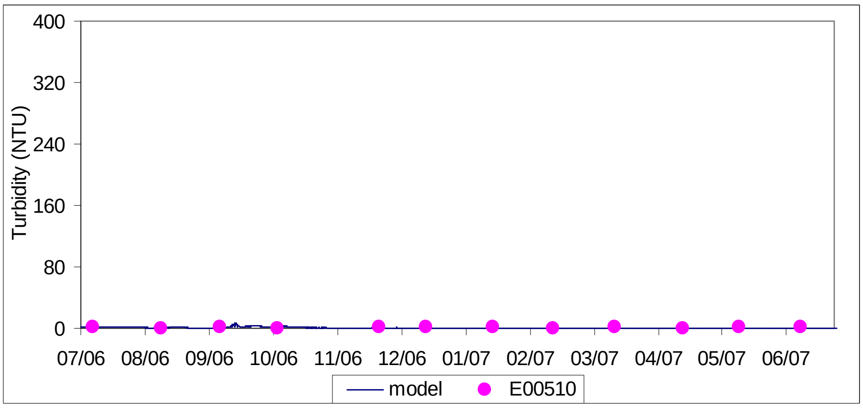




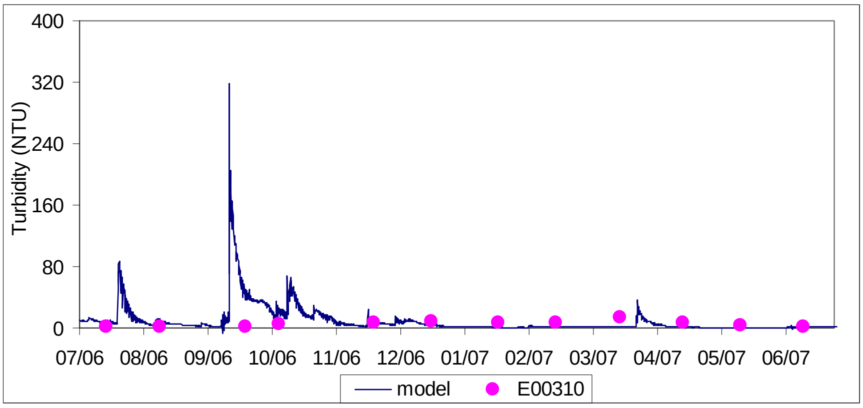
Turbidity



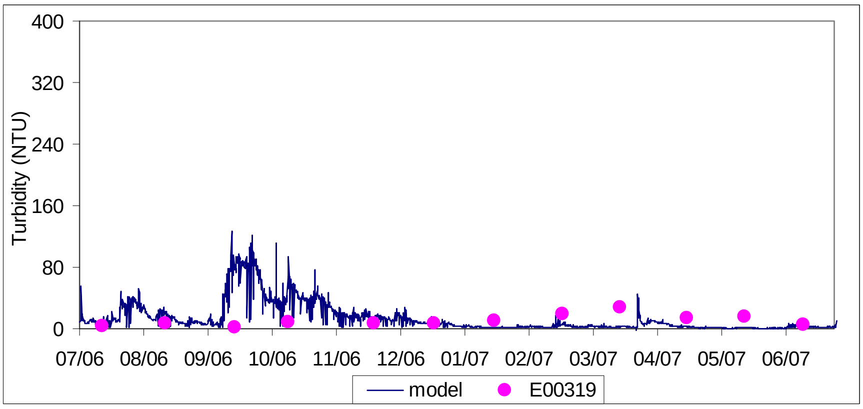
400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00525



400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00510

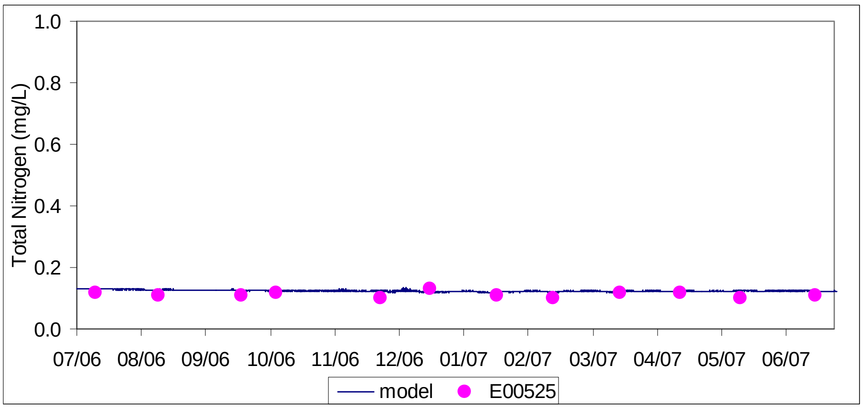


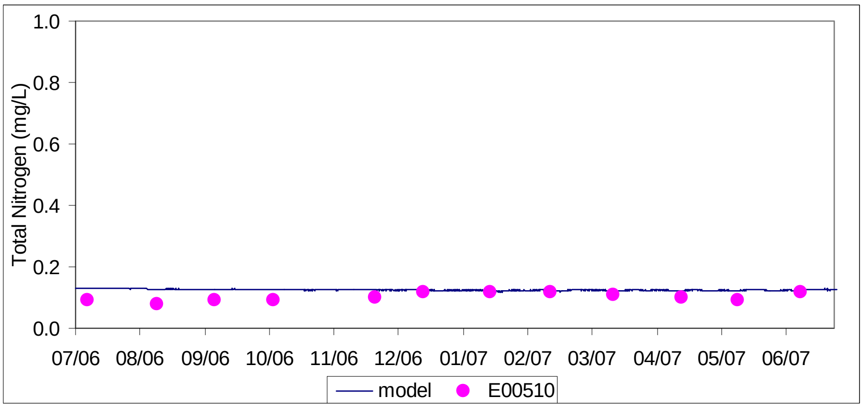
400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00310

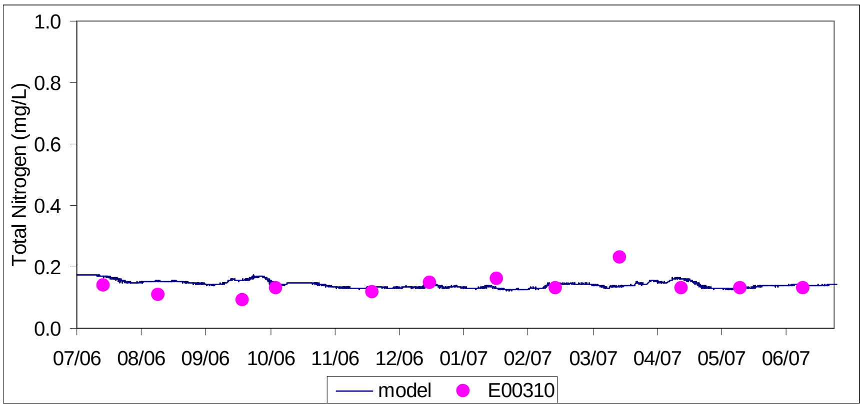


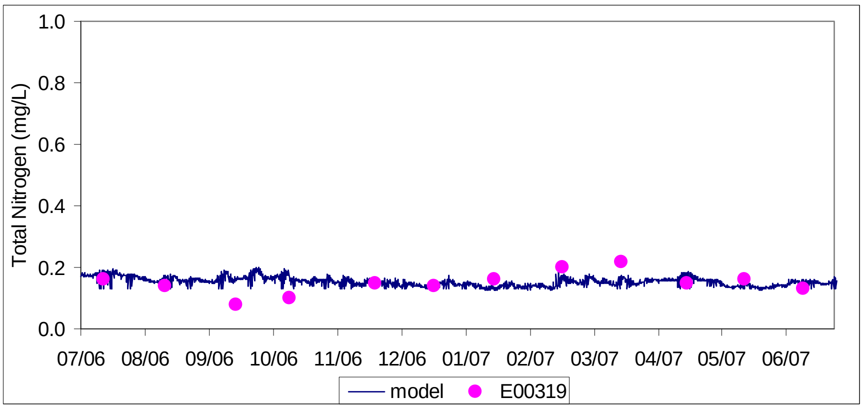
400
320
240
160
80
0
Turbidity (NTU)
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00319

Total Nitrogen

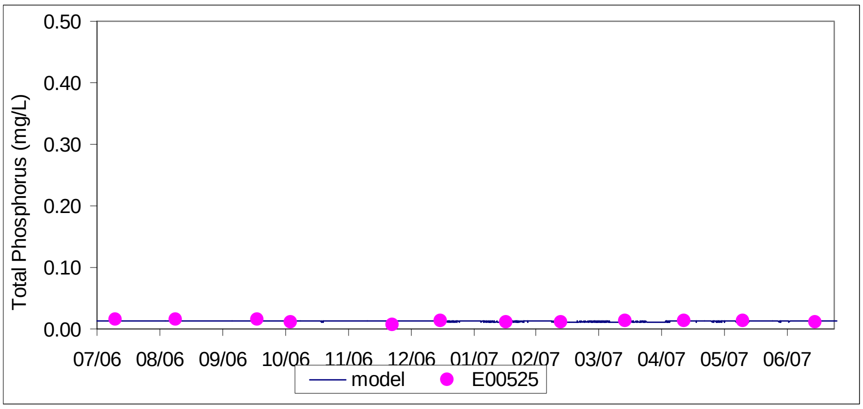


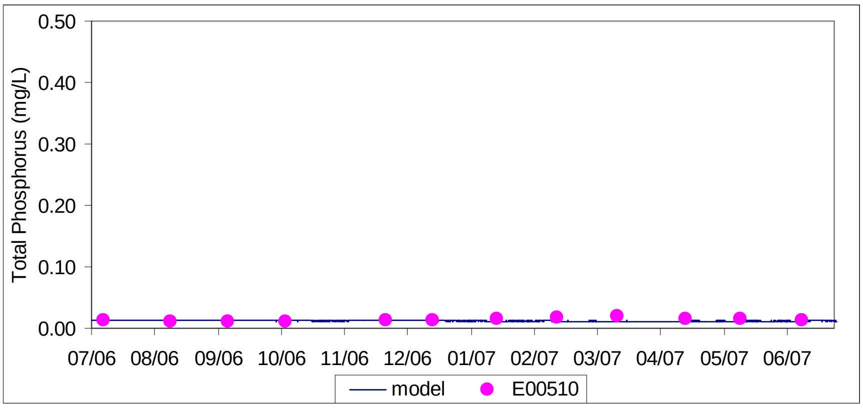


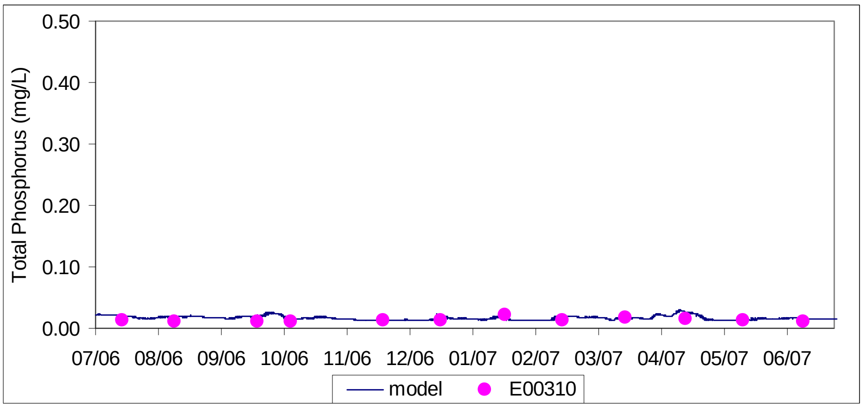


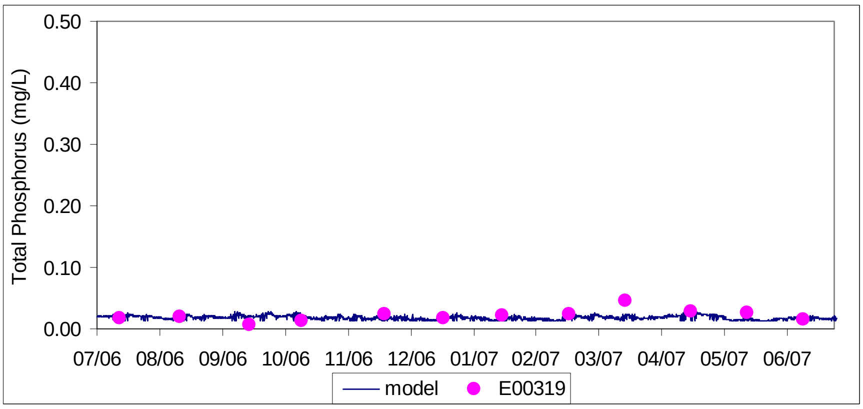


Total Phosphorus



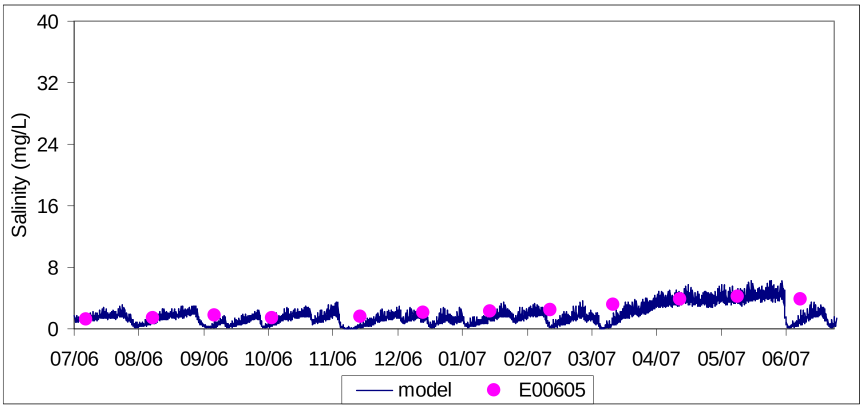


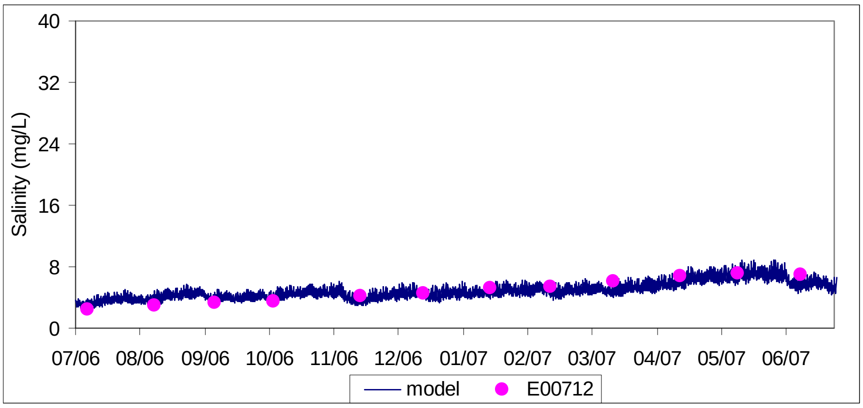


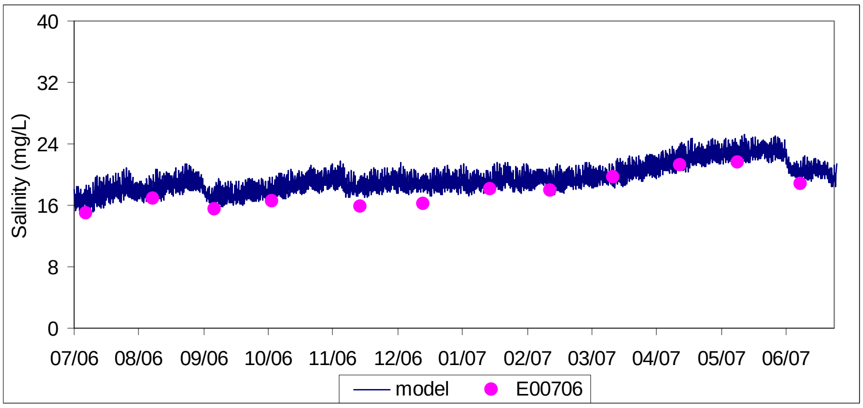


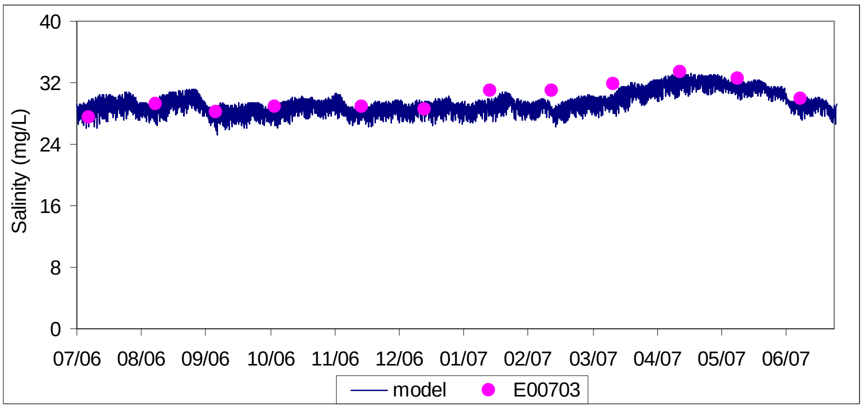
BRISBANE / BREMER CALIBRATION RESULTS

Salinity

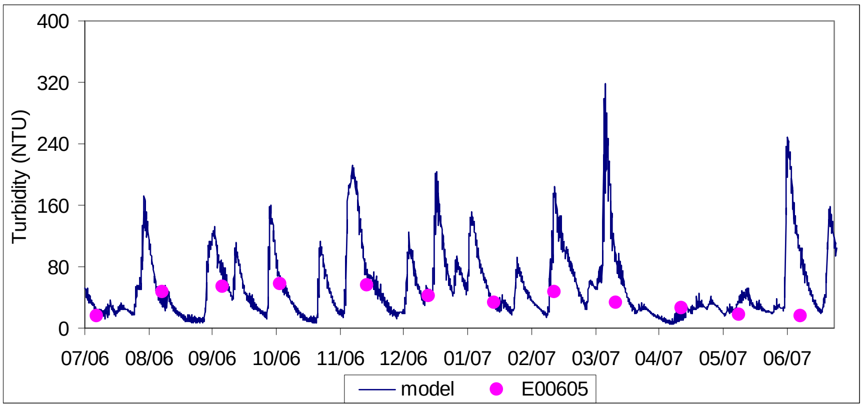


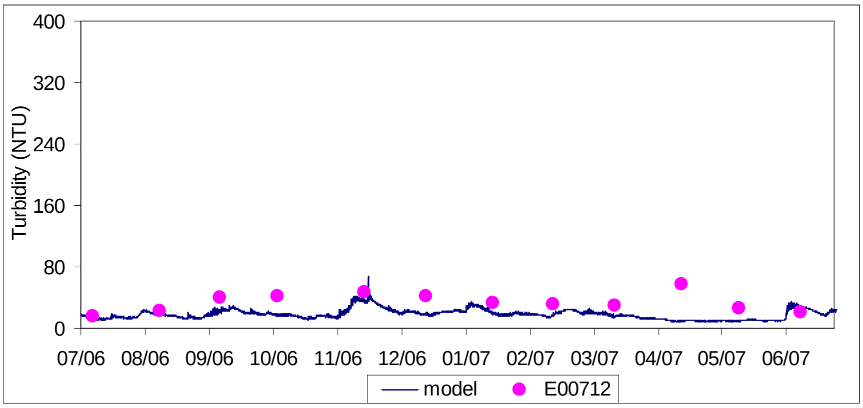


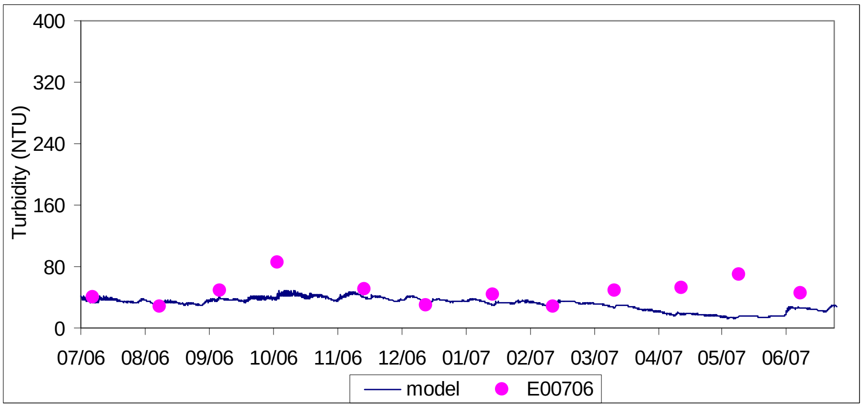


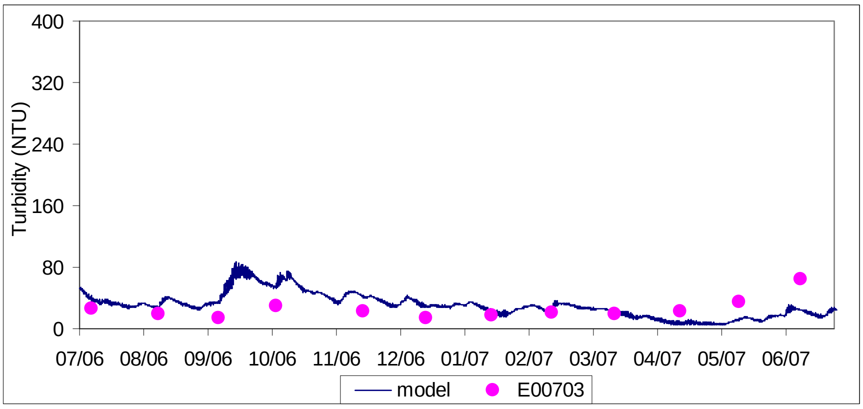


Turbidity

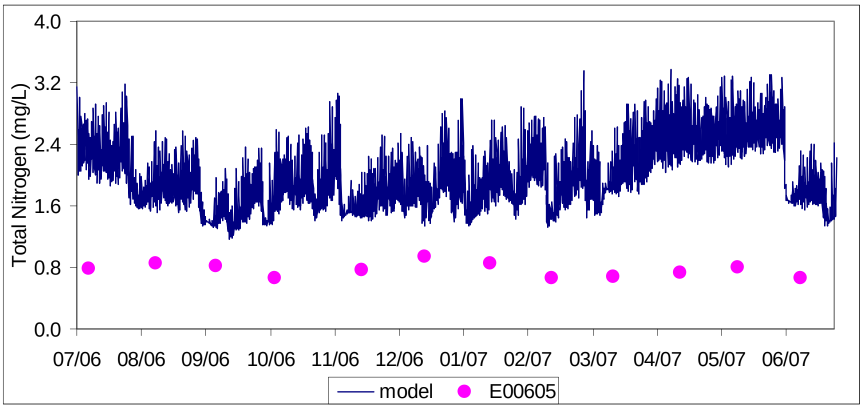

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00605

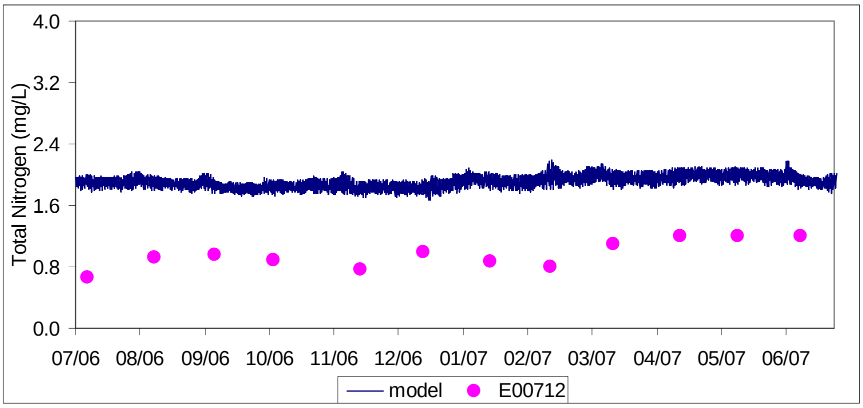

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00712

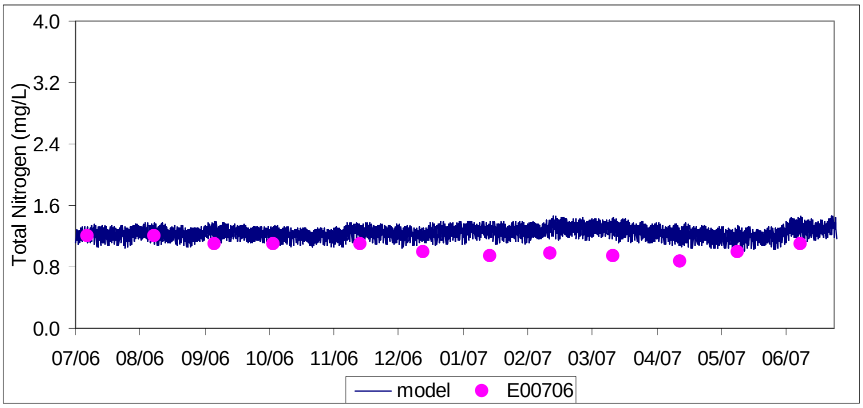

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00706

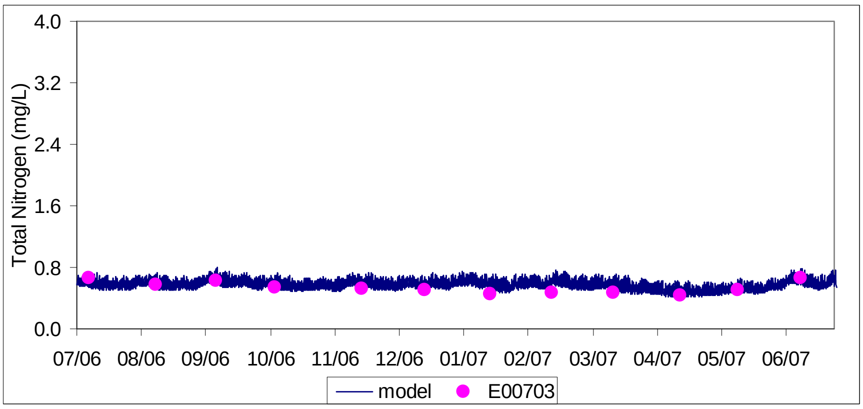

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00703

Total Nitrogen

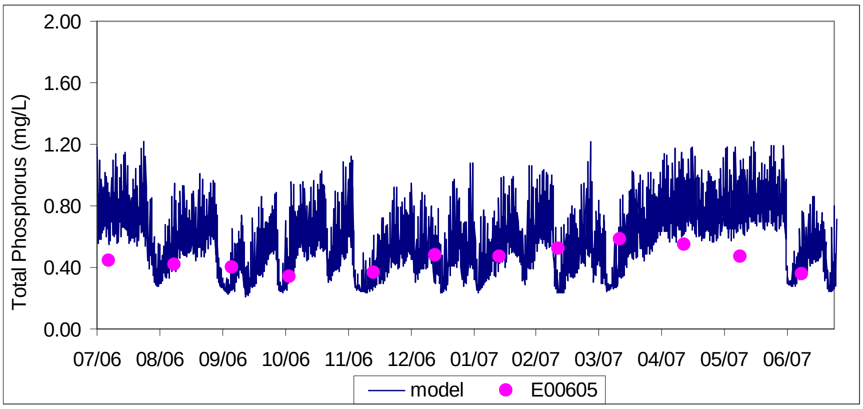


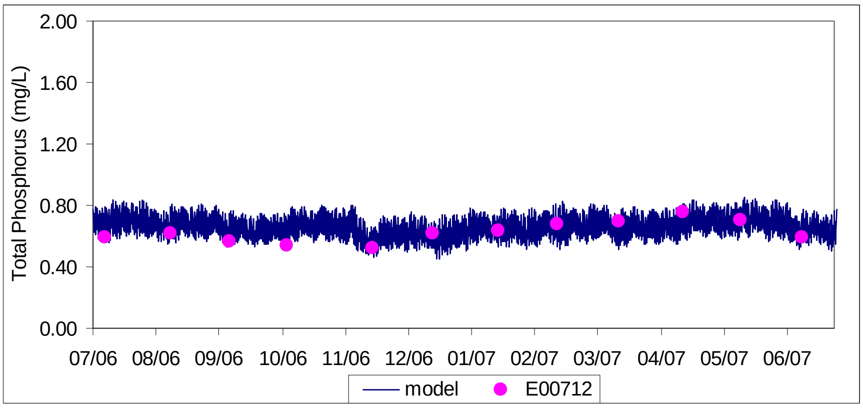


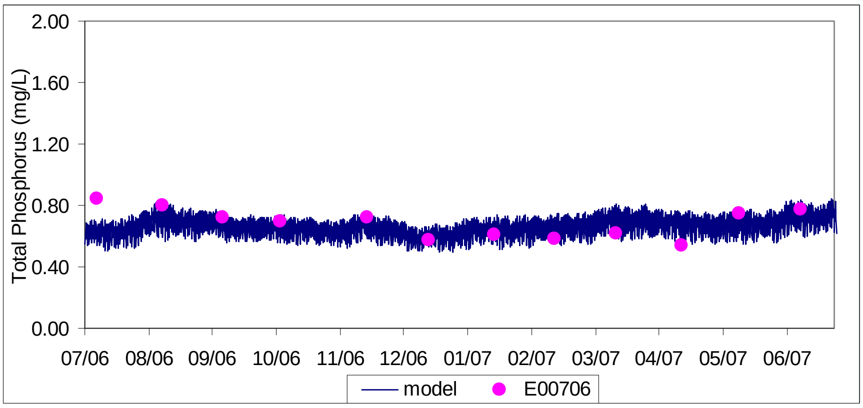


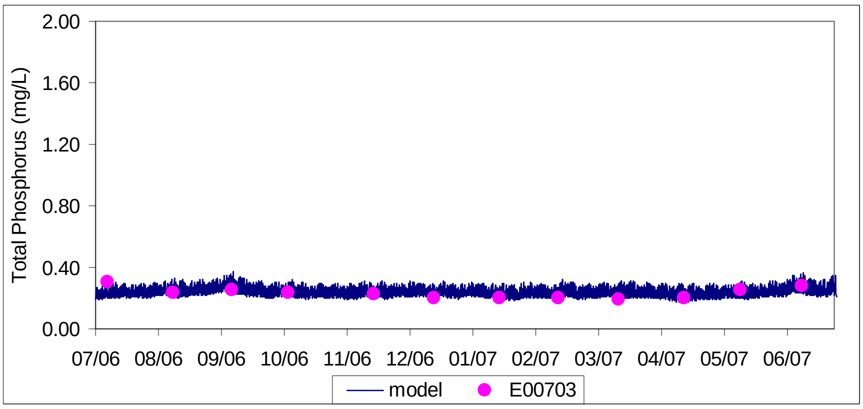


Total Phosphorus



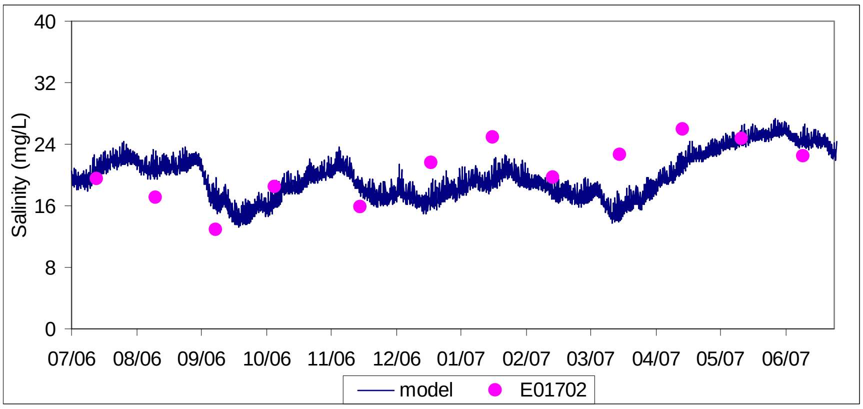


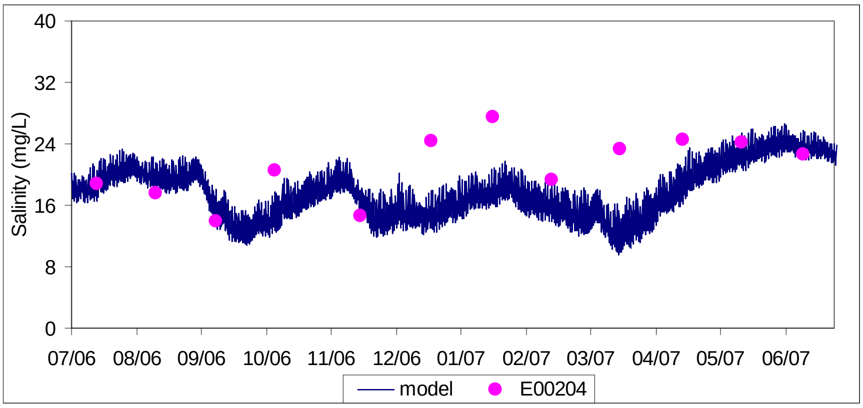


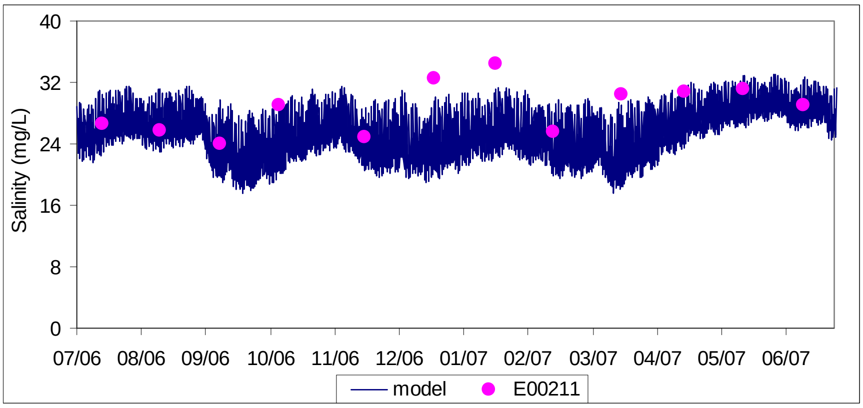


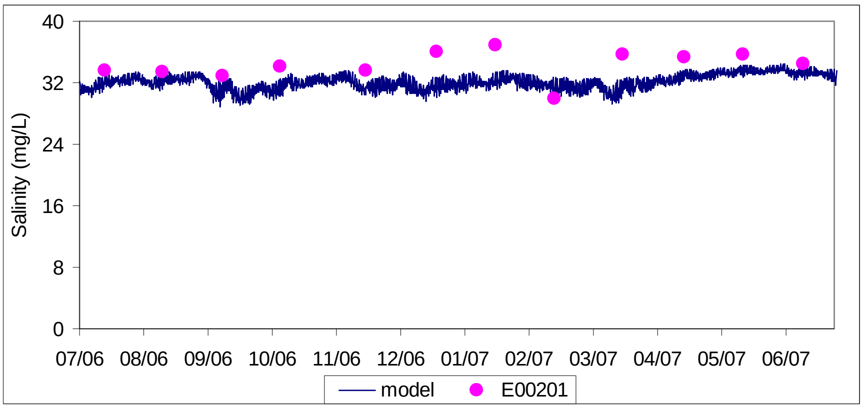
LOGAN / ALBERT CALIBRATION RESULTS

Salinity

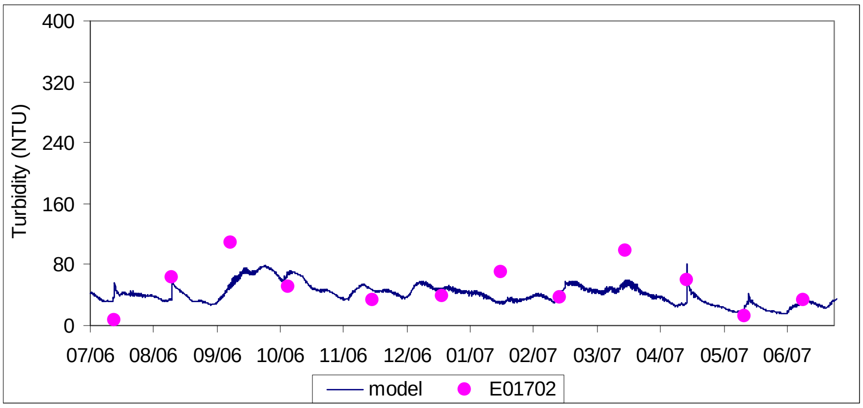


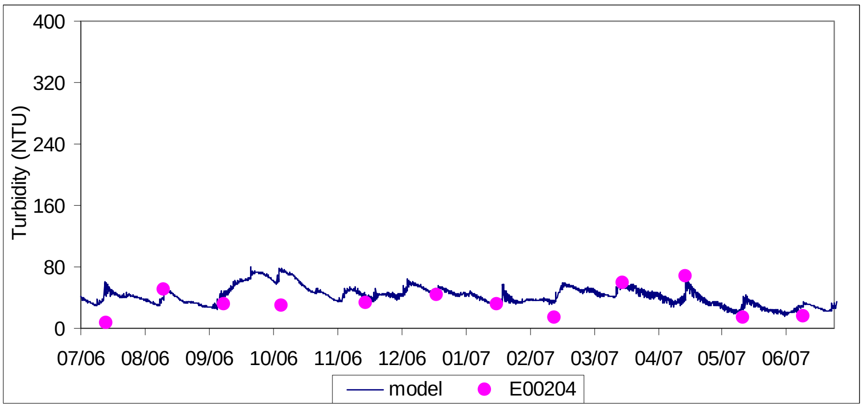


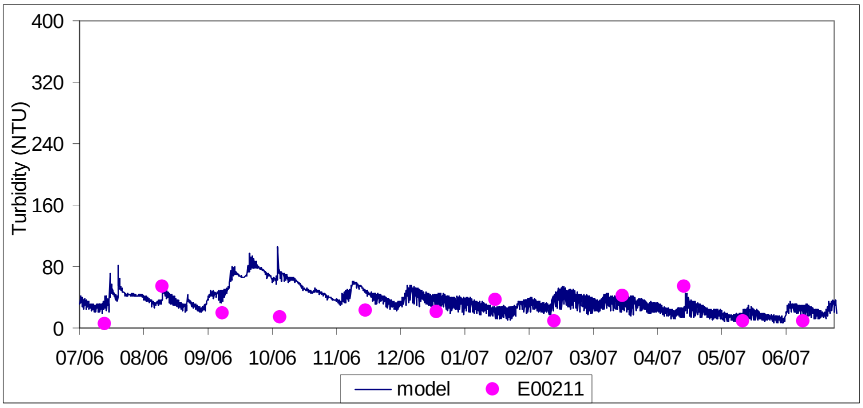


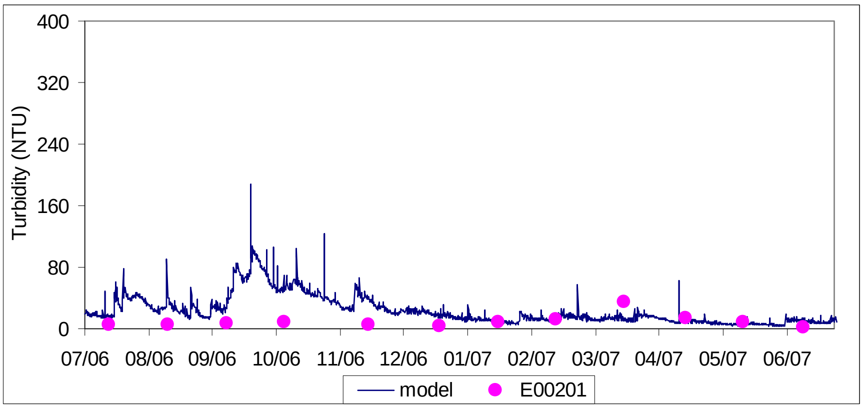


Turbidity

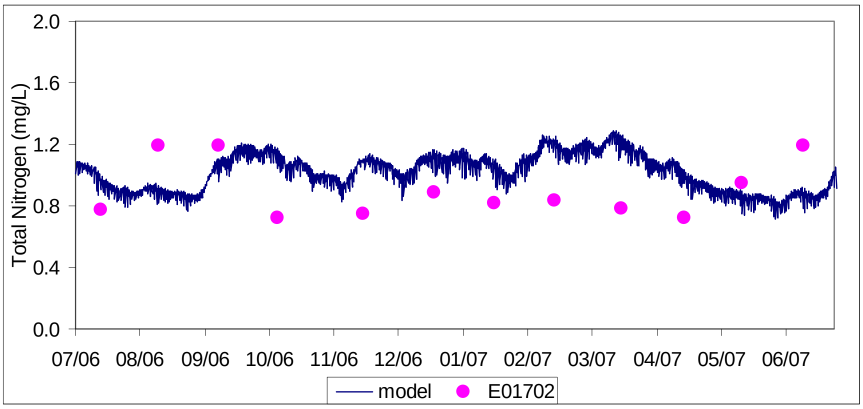

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E01702

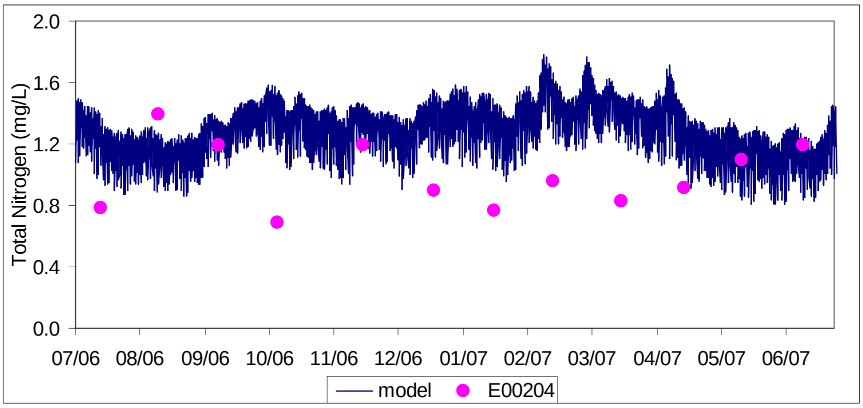

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00204

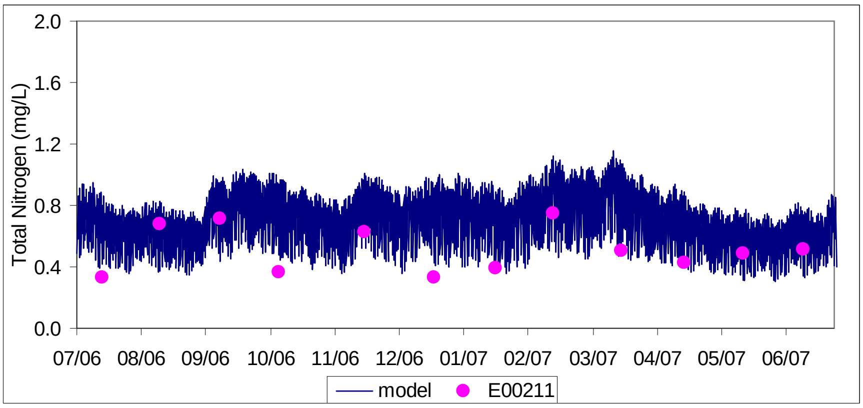

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00211

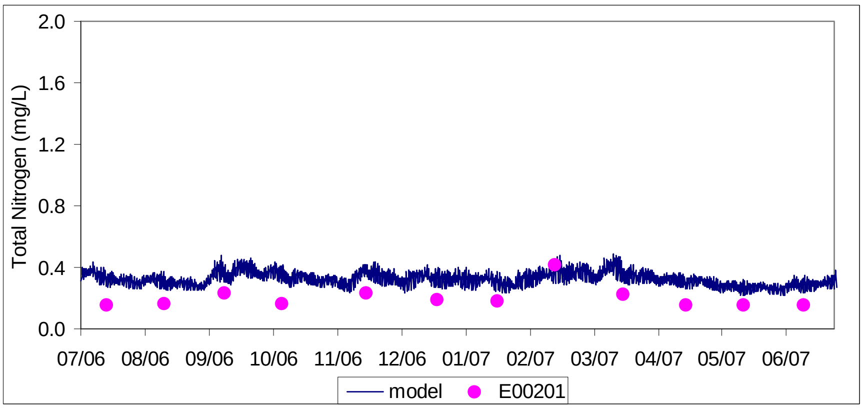

Turbidity (NTU)
400
320
240
160
80
0
07/06 08/06 09/06 10/06 11/06 12/06 01/07 02/07 03/07 04/07 05/07 06/07
model
E00201

Total Nitrogen

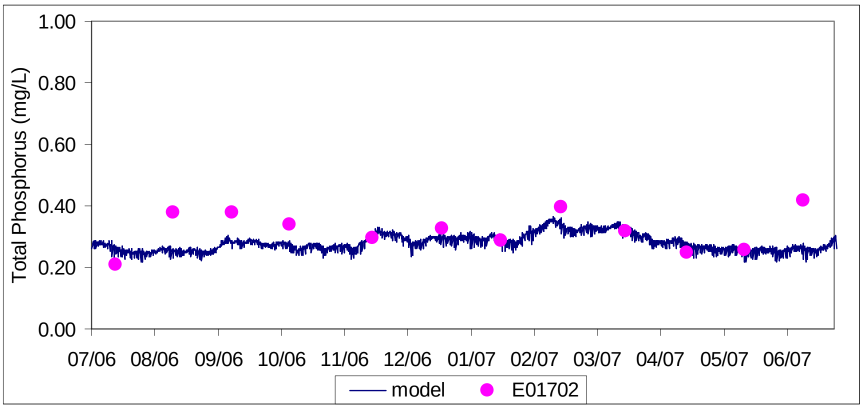


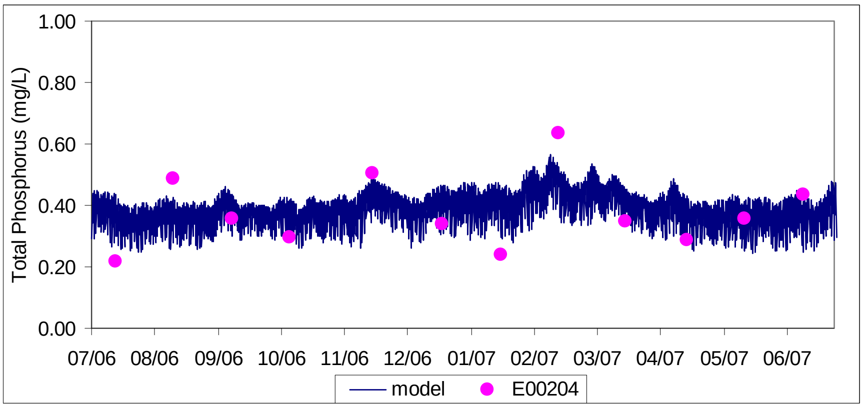


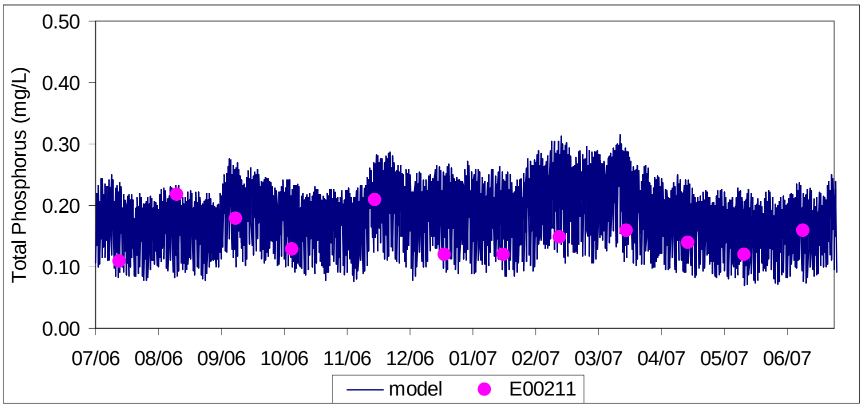


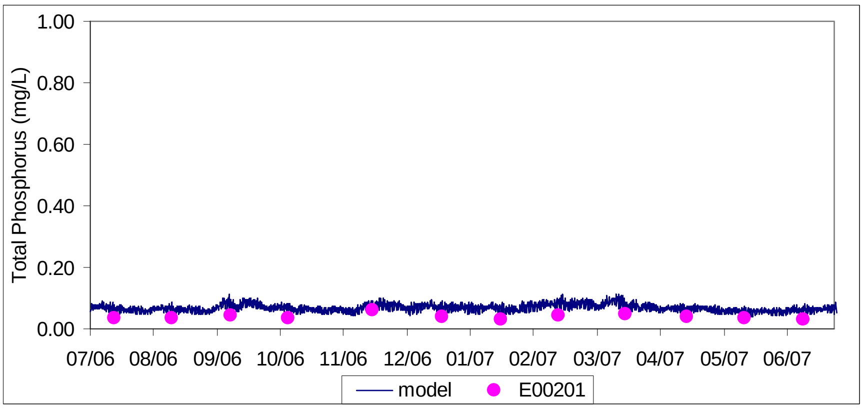


Total Phosphorus





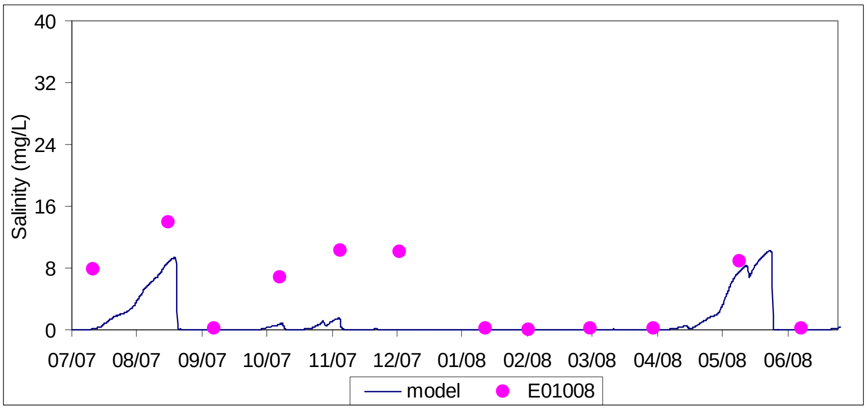


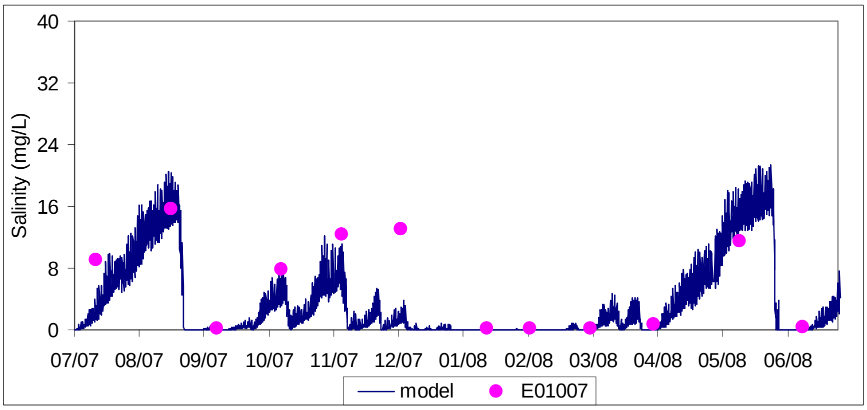


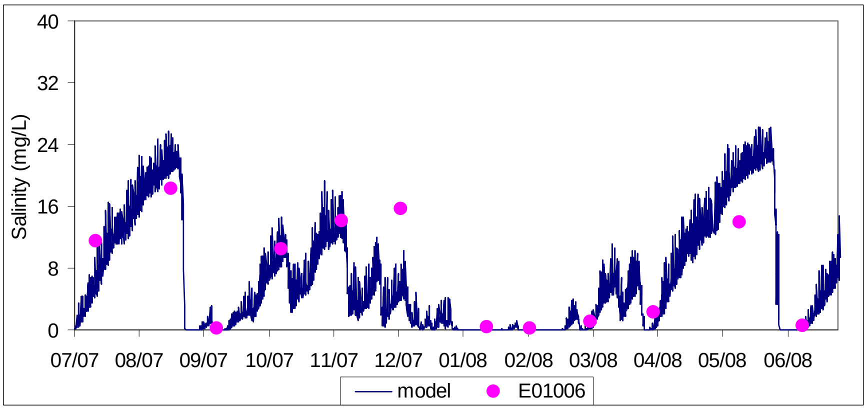
APPENDIX C: VALIDATION GRAPH

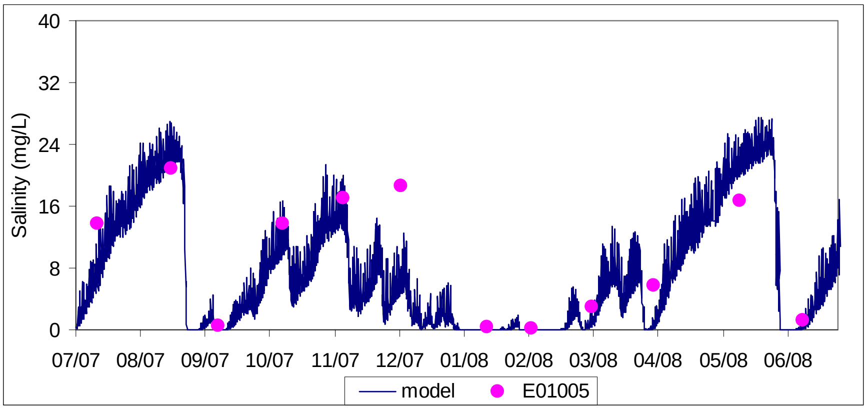
CABOOLTURE RIVER VALIDATION RESULTS

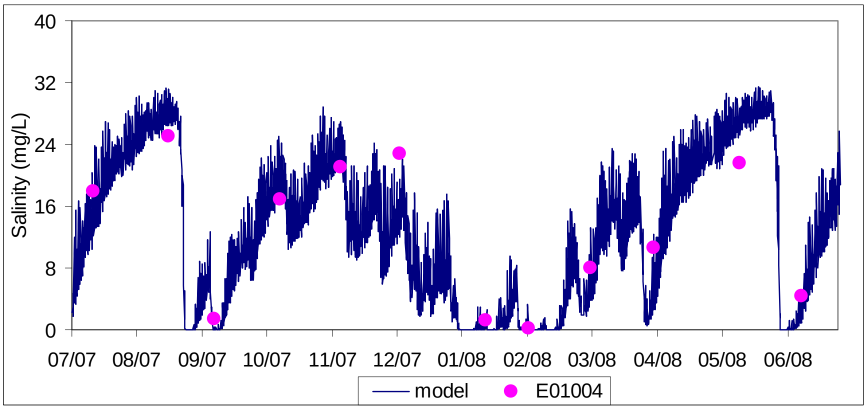
Salinity

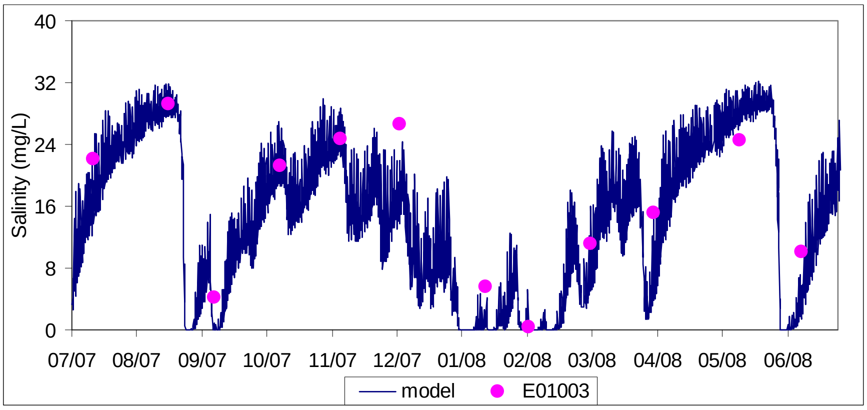


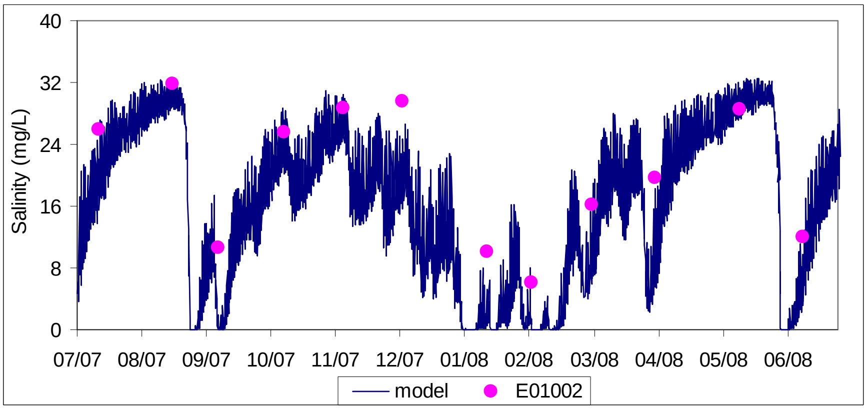


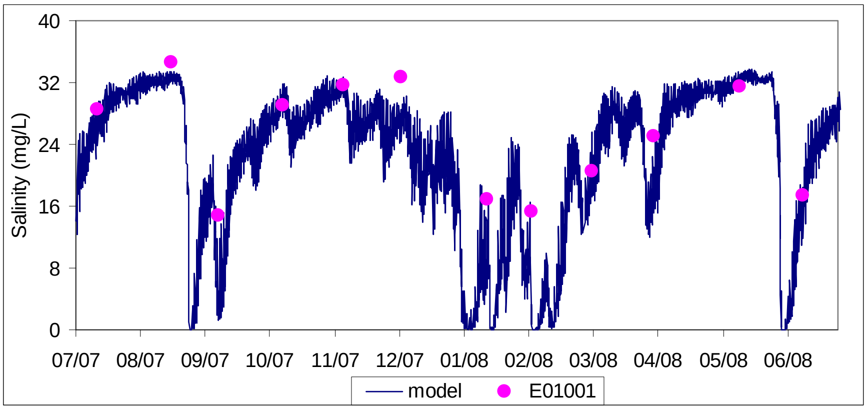


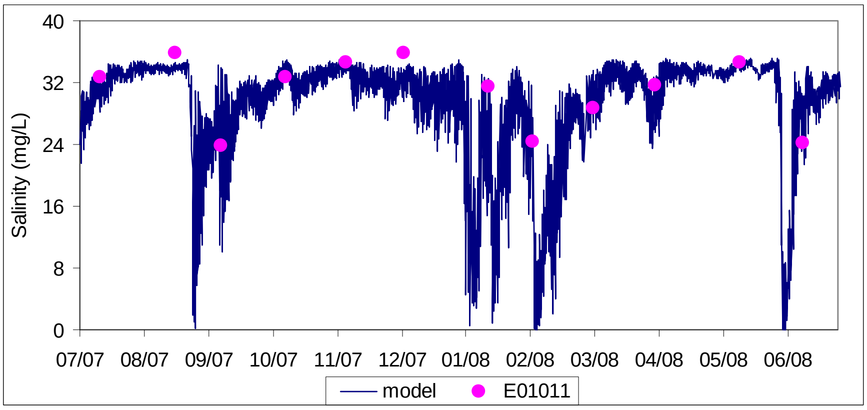

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01005

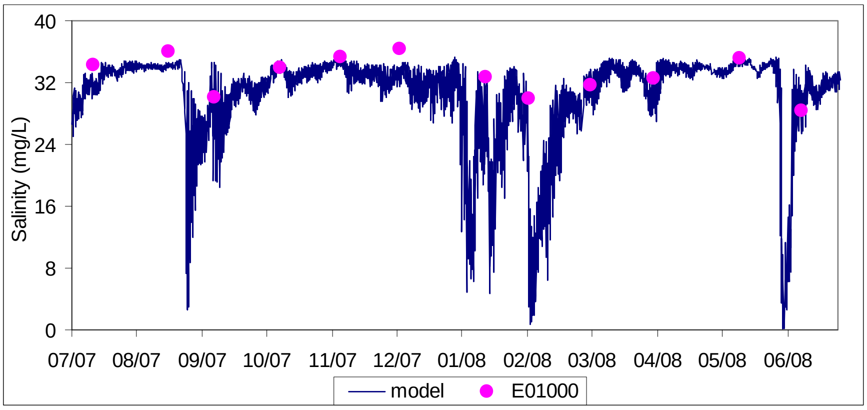

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01004


Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01003

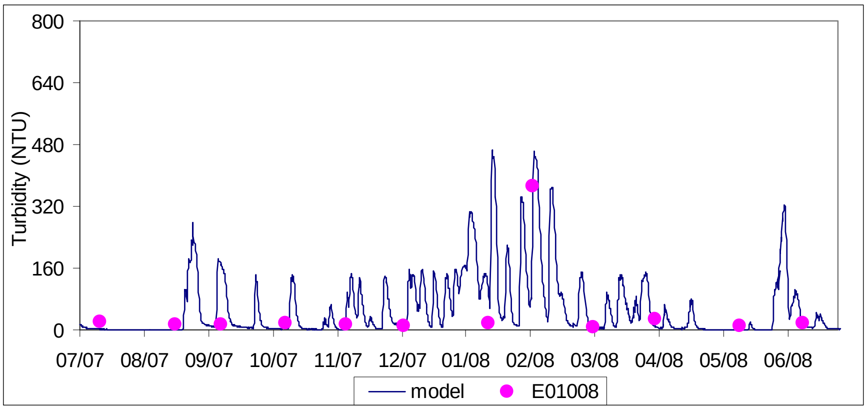

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01002

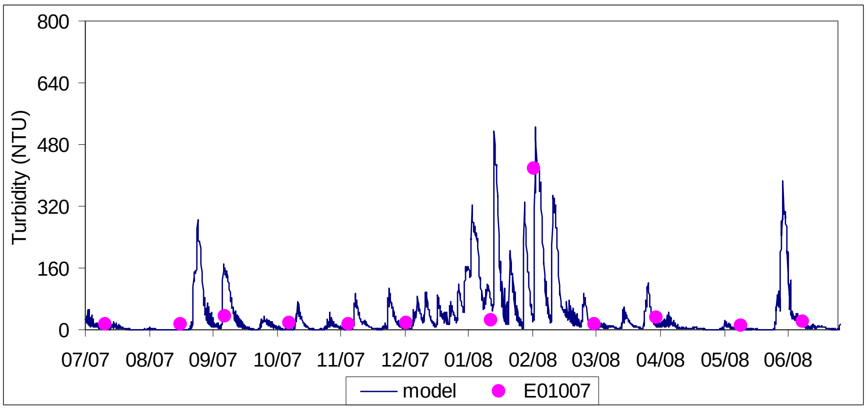

Salinity (mg/L)
0
8
16
24
32
40
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01001

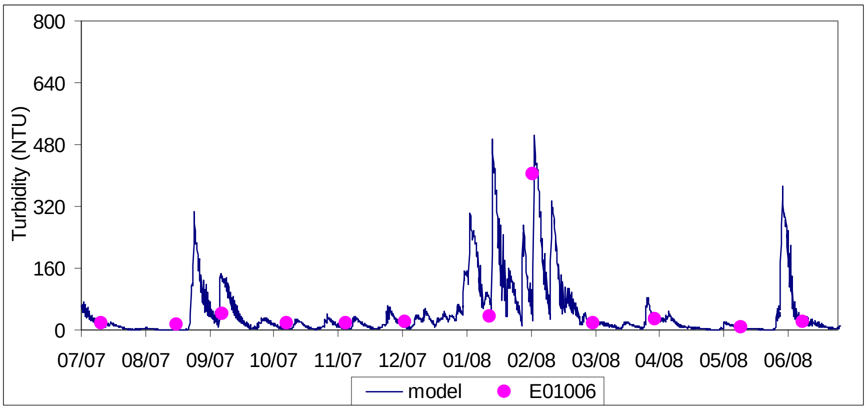

Salinity (mg/L)
0
8
16
24
32
40
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01011

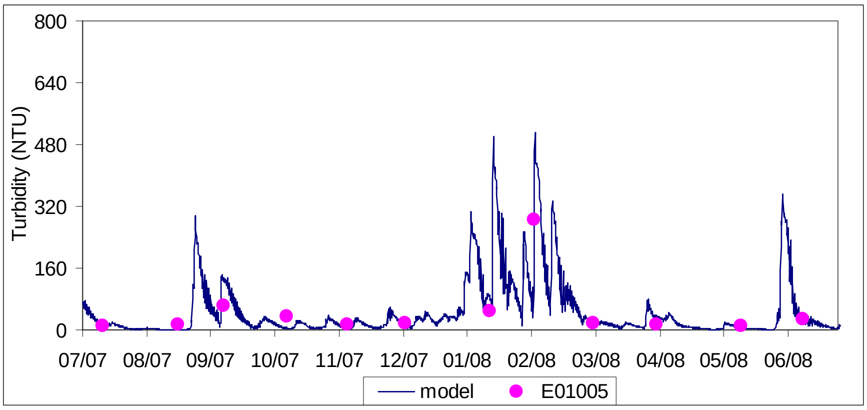

Salinity (mg/L)
0
8
16
24
32
40
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01000

Turbidity

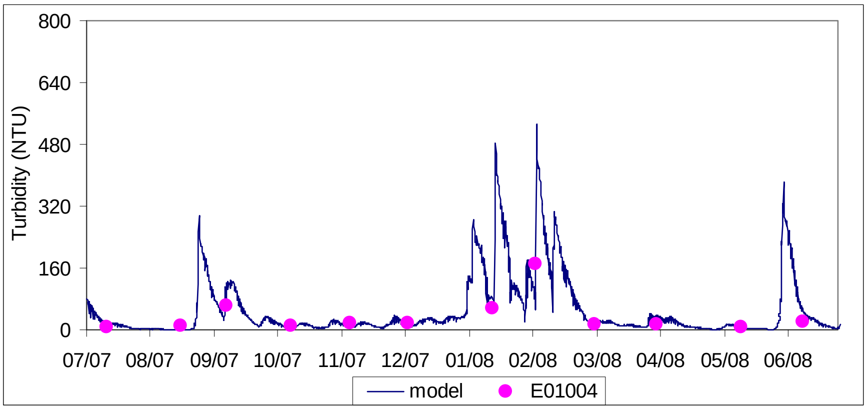


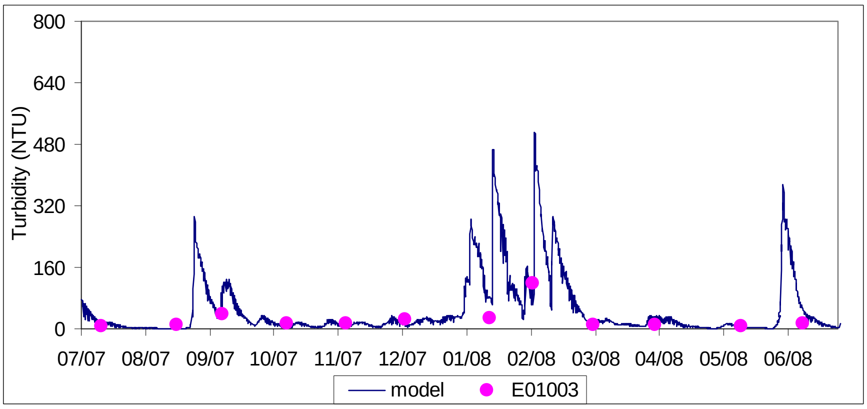


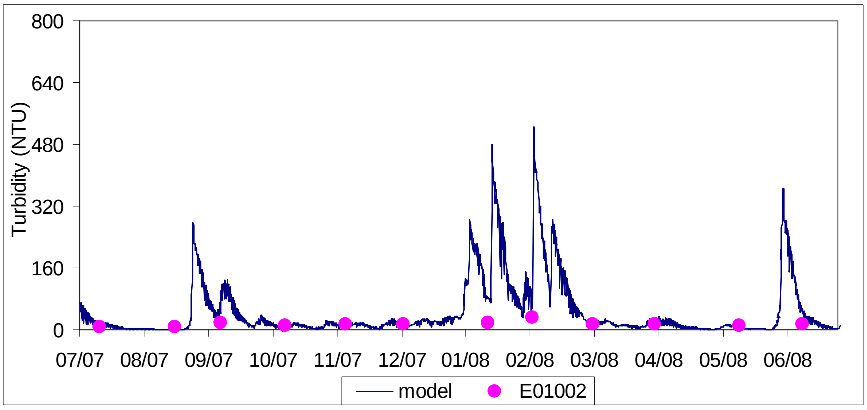


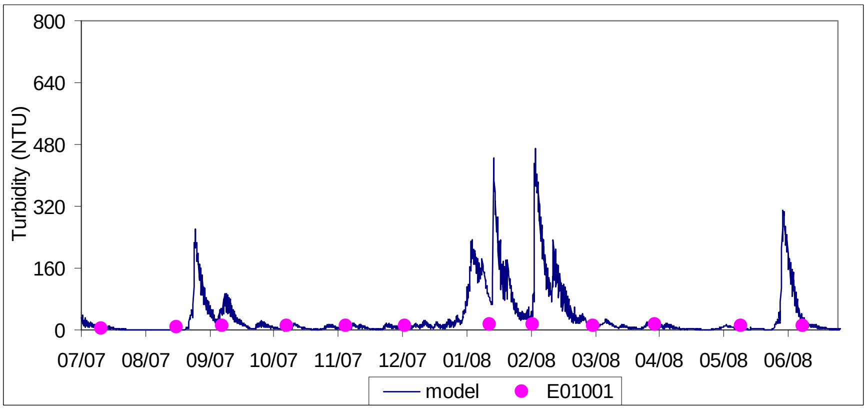


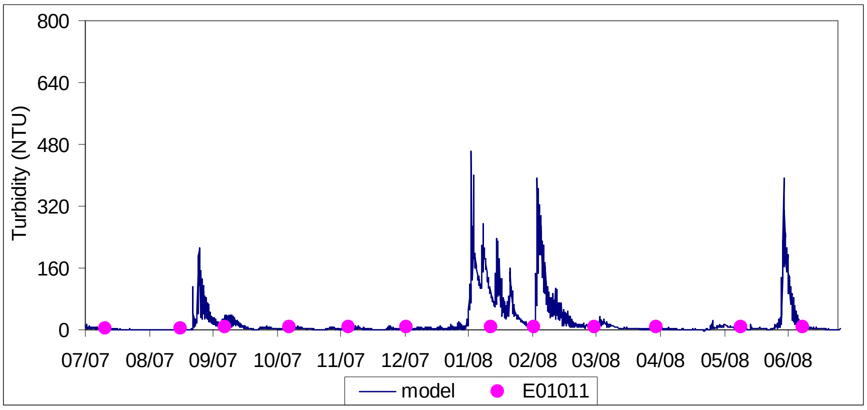
BMT WBM

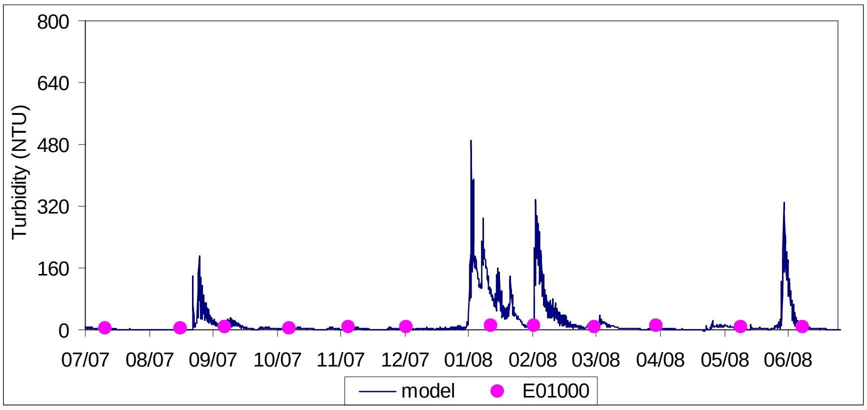

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01004


800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01003

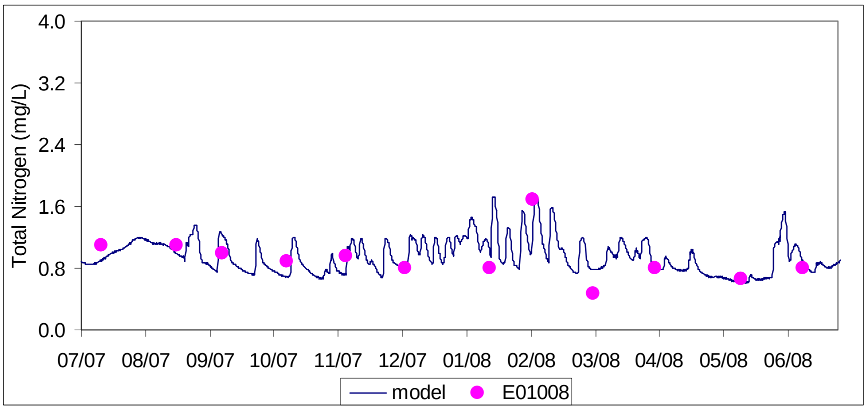

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01002

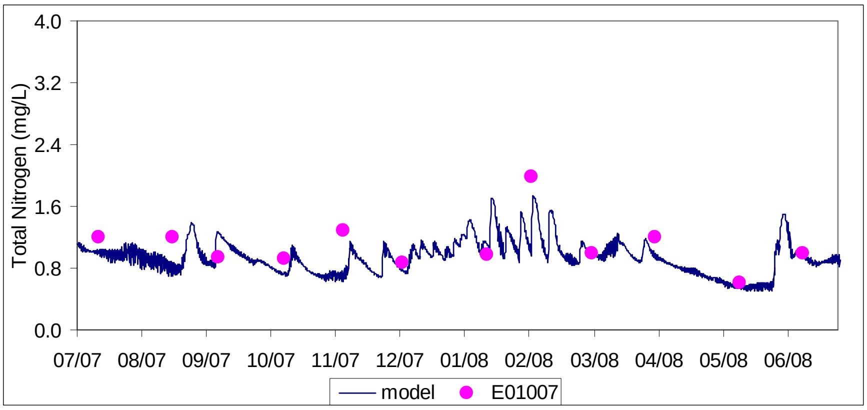

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01001

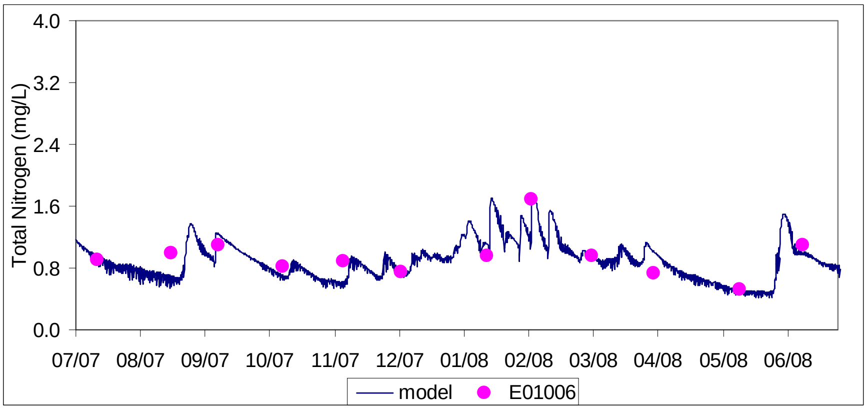


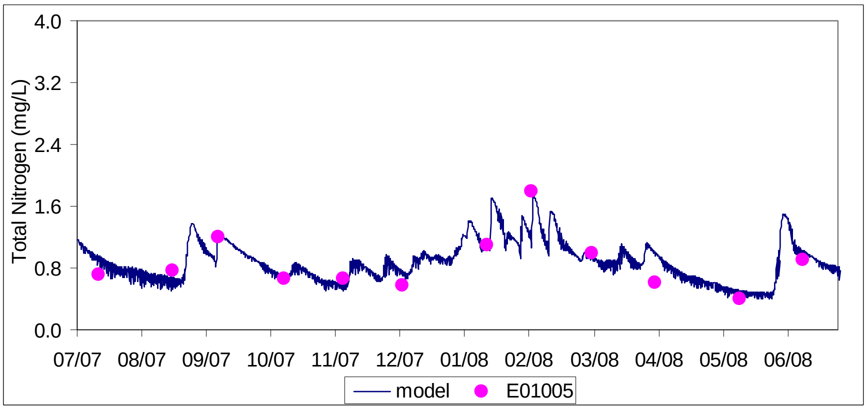


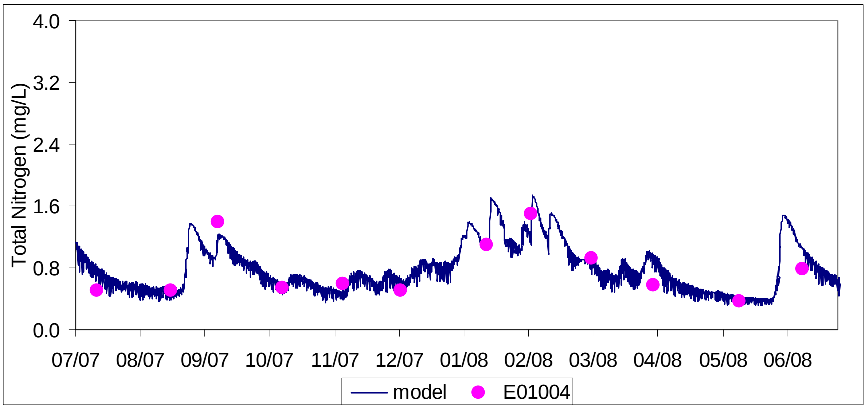
Total Nitrogen

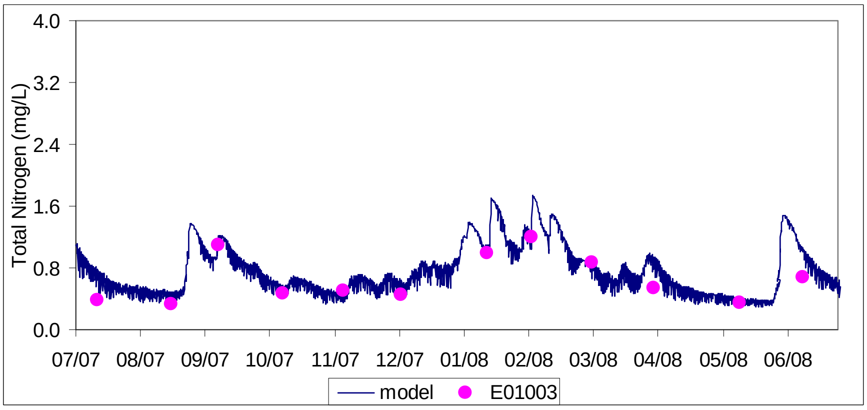


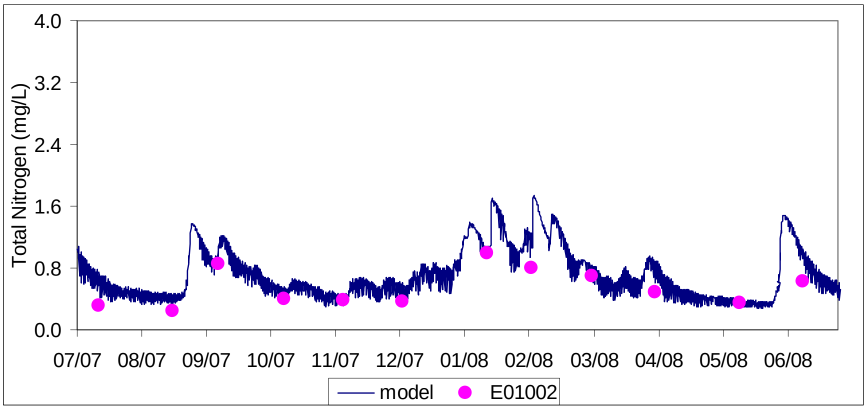


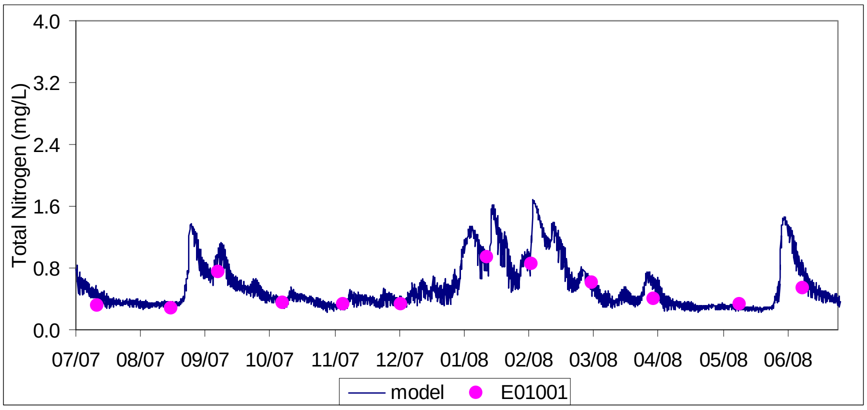

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01006

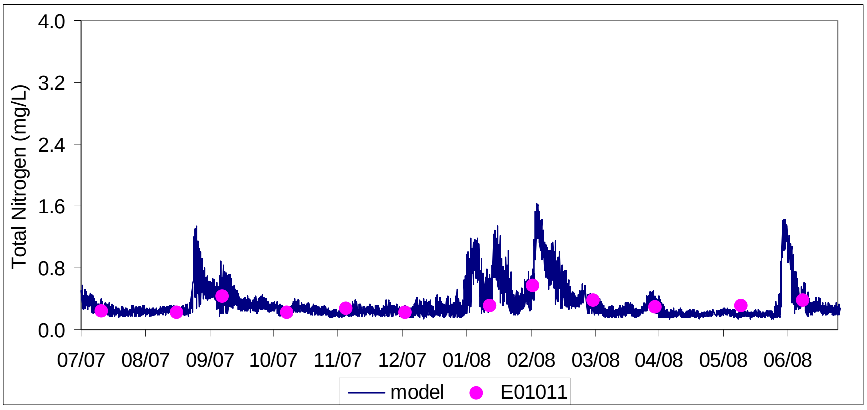

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01005

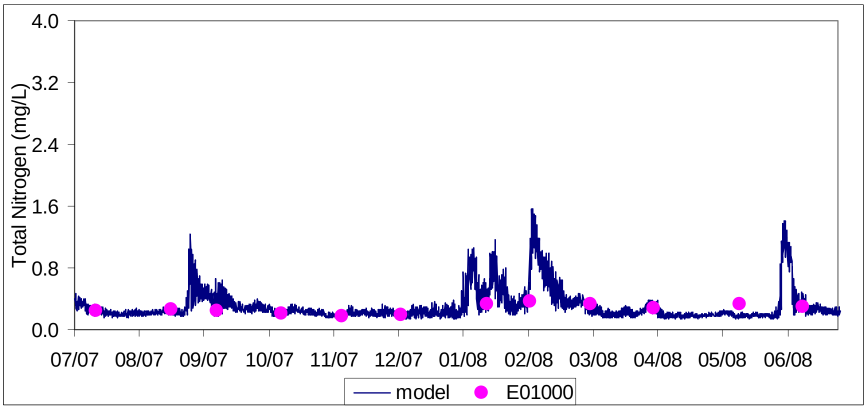

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01004


4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01003

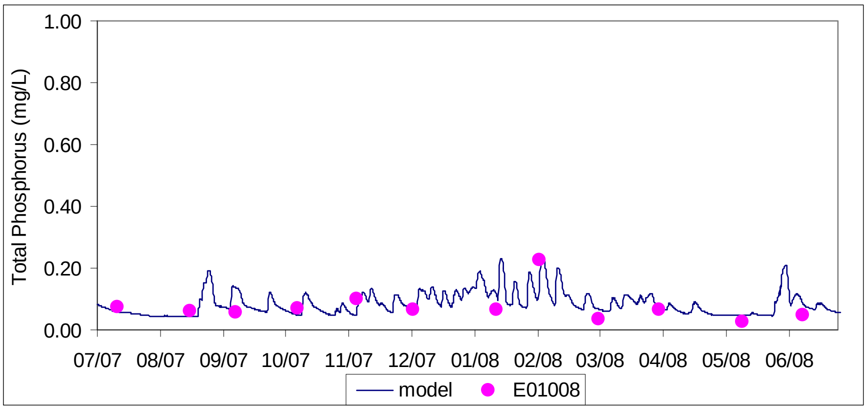

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01002

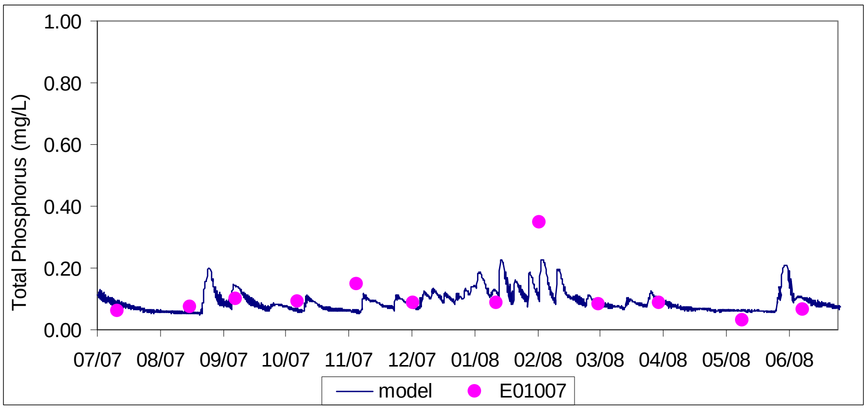

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01001

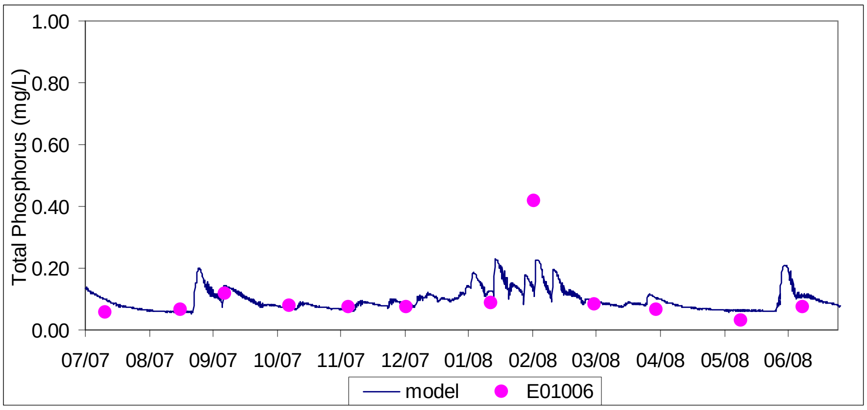

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01011

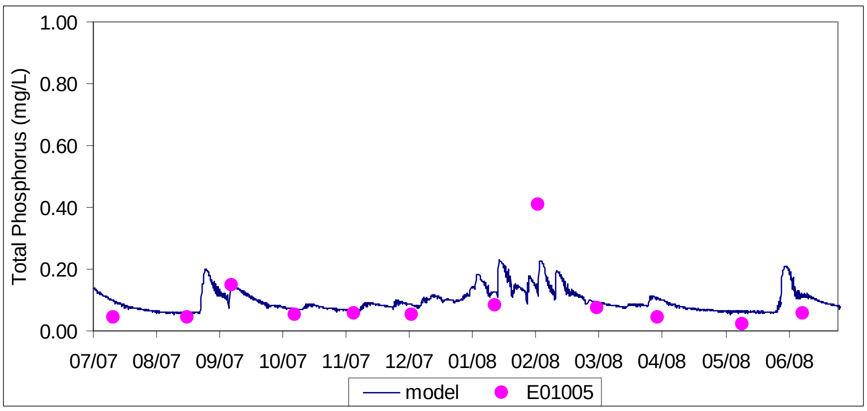

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01000

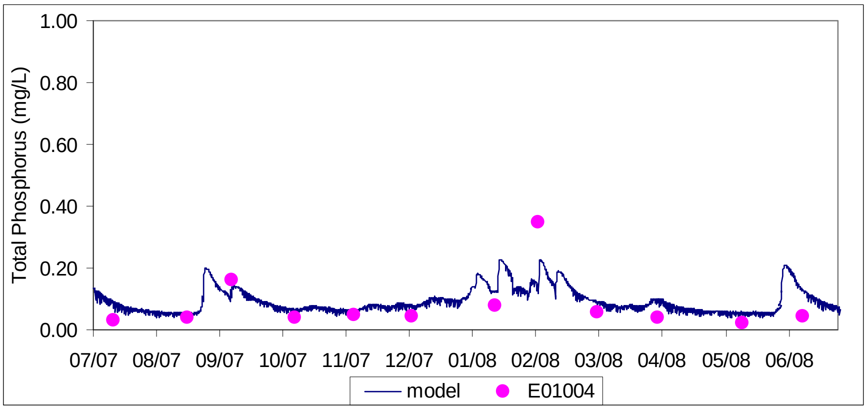
Total Phosphorus

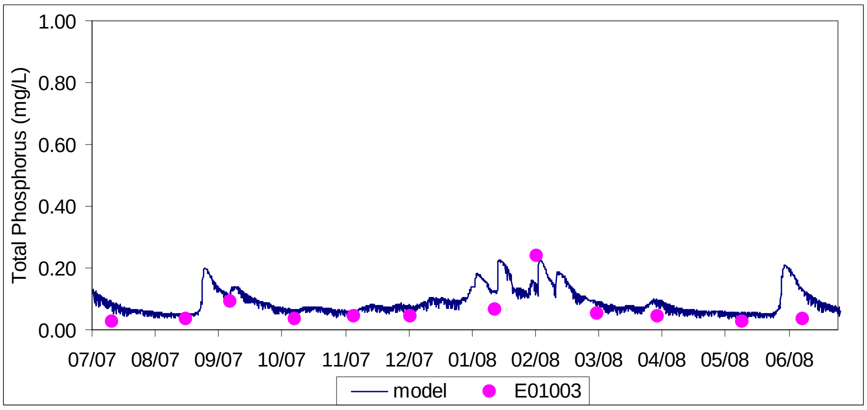


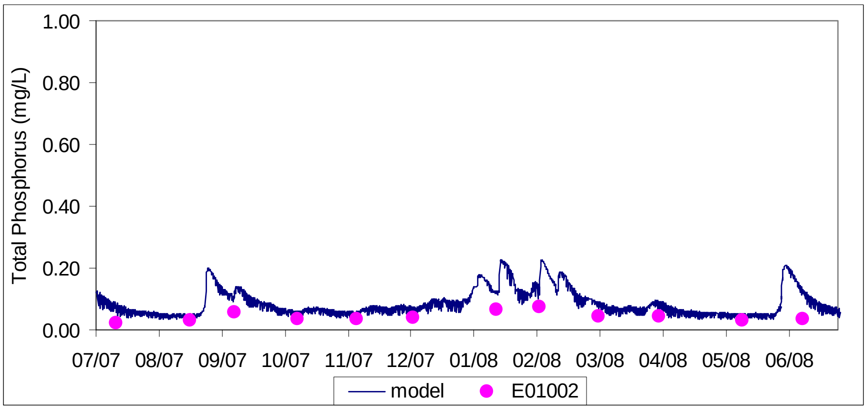


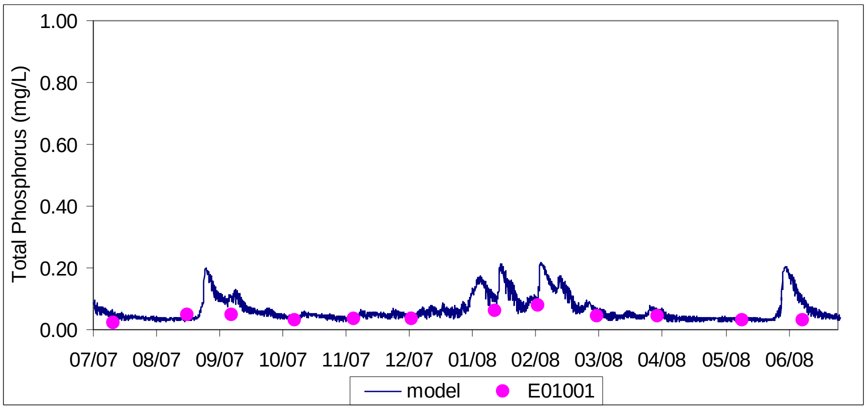


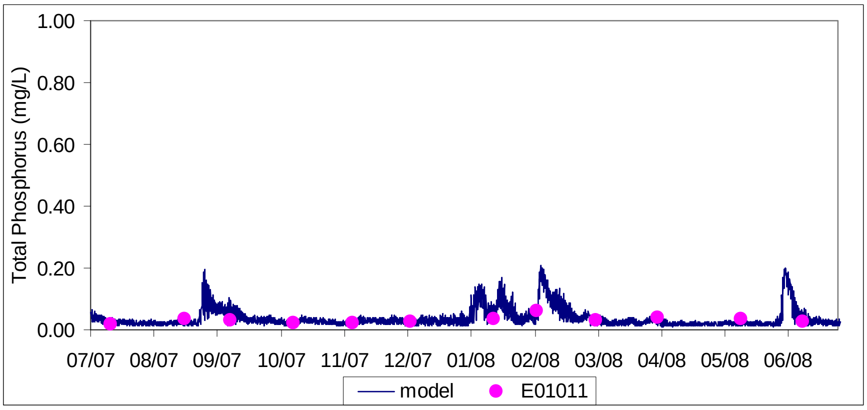


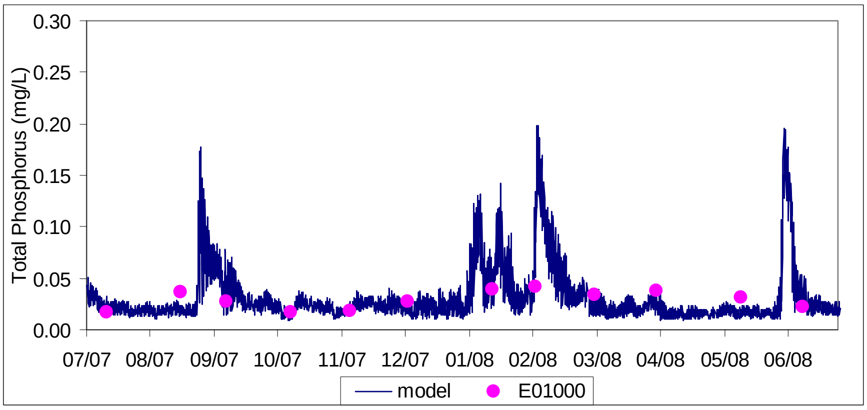

Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01004


Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01003


Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01002

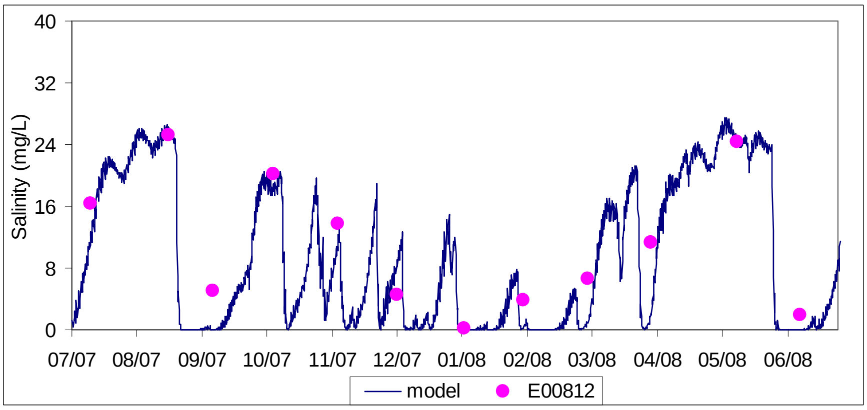

Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01001

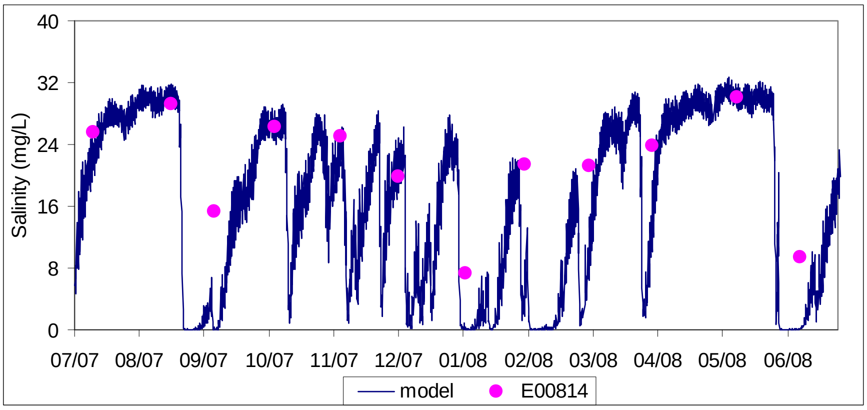


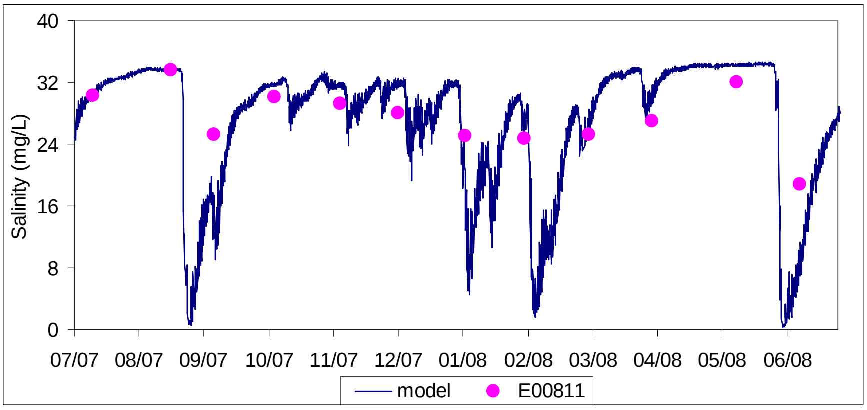


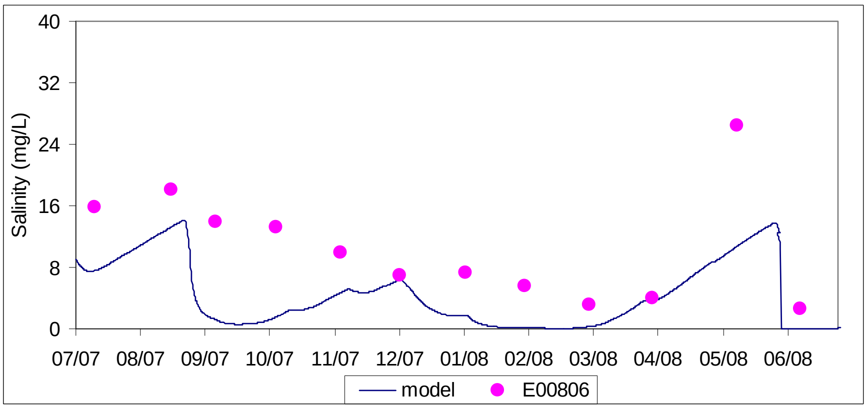
PINE RIVER VALIDATION RESULTS

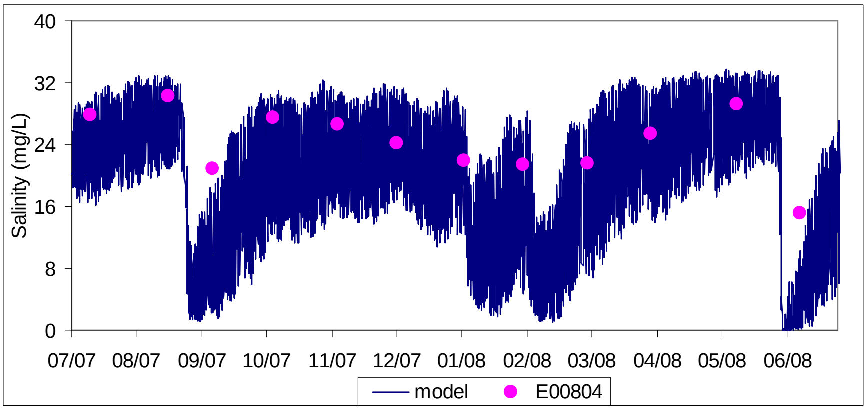
Salinity

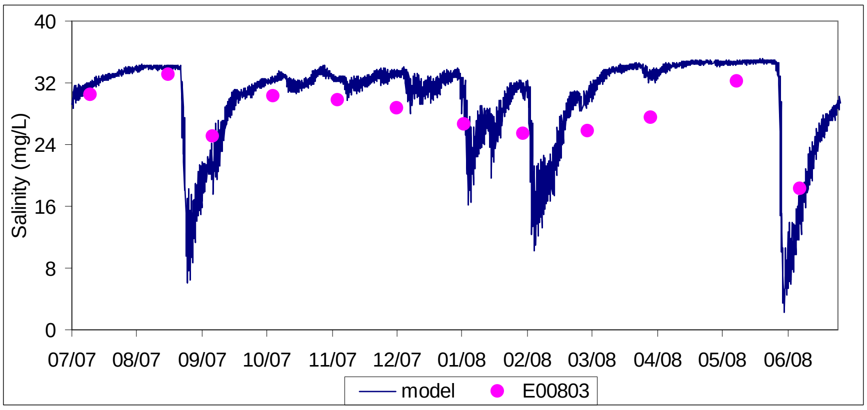


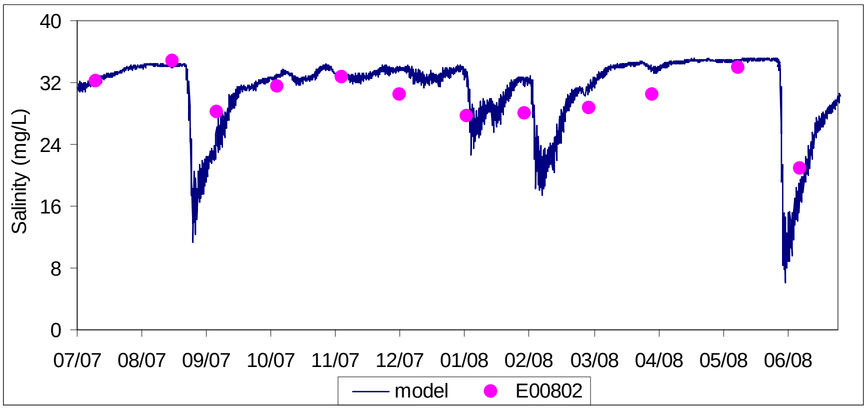


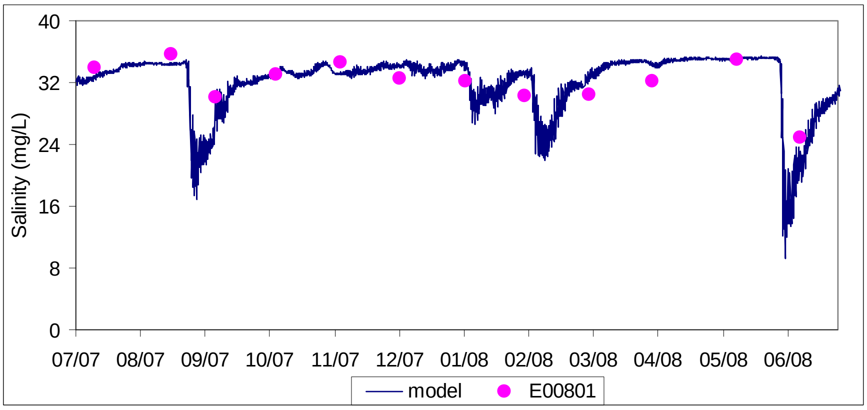

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00811

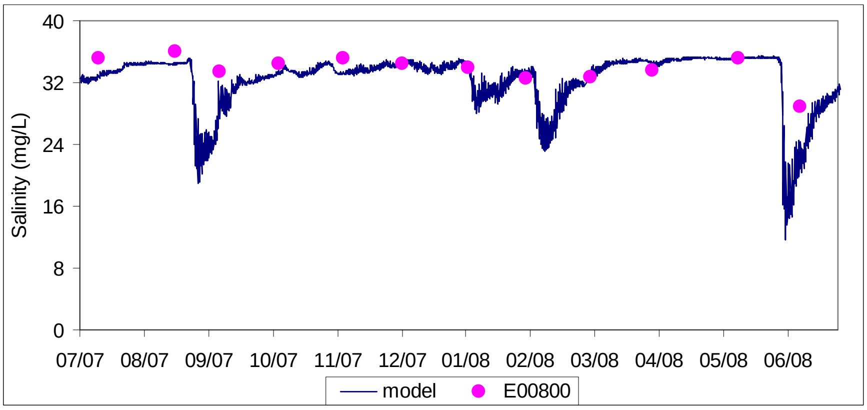

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00806


Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00804

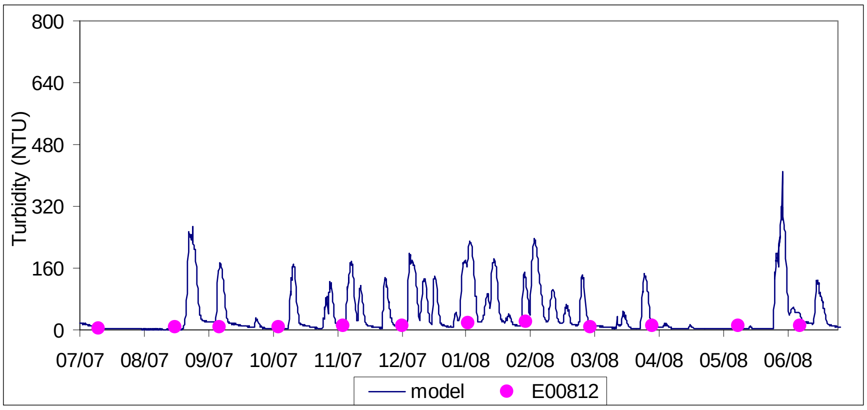

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00803

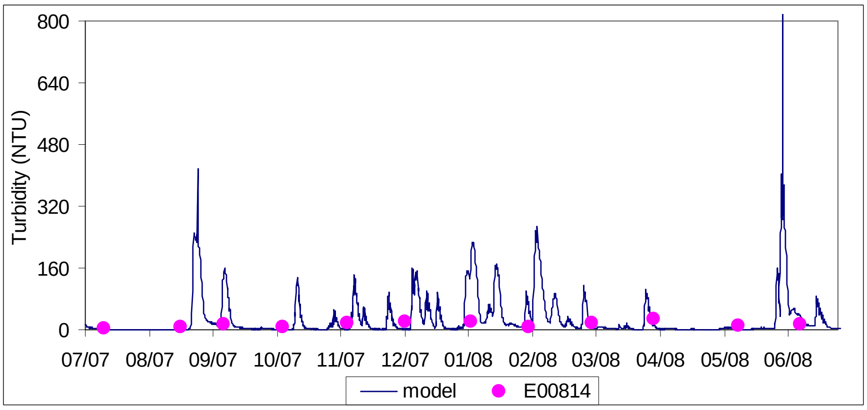

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00802

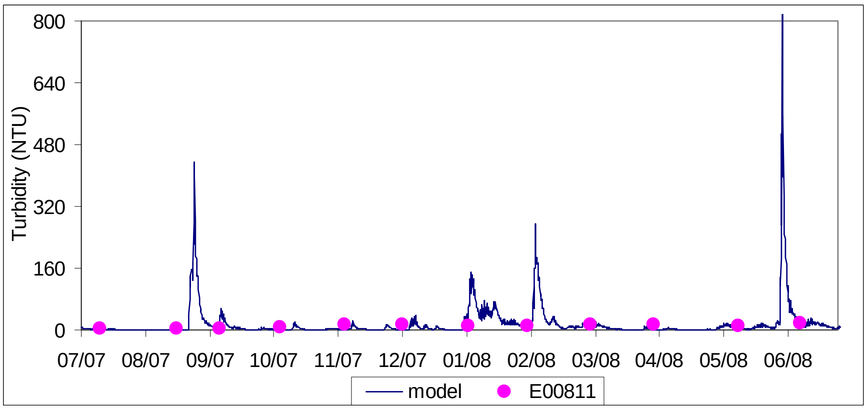

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00801

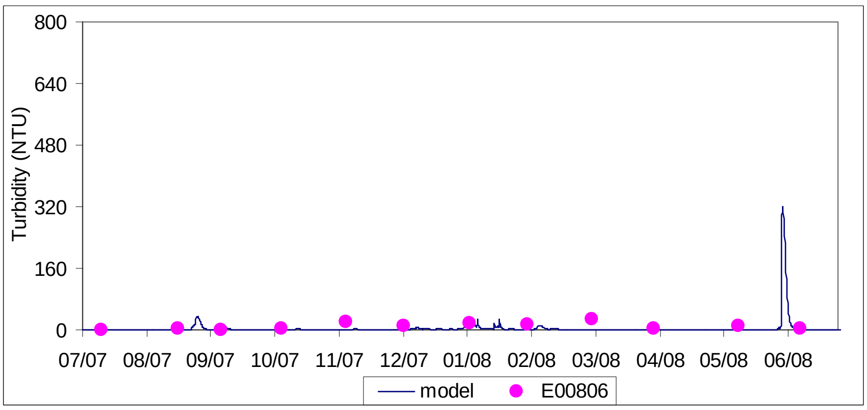

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00800

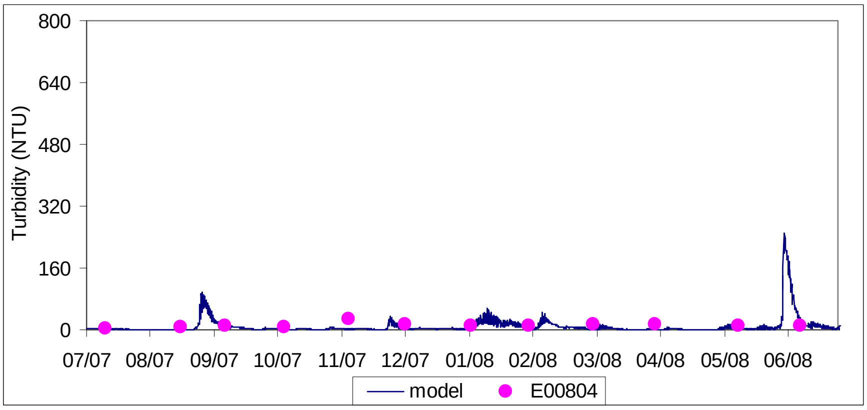
Turbidity

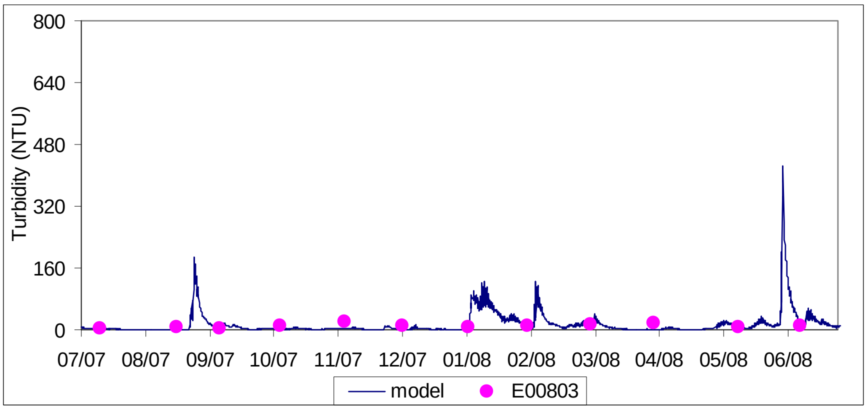

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00812

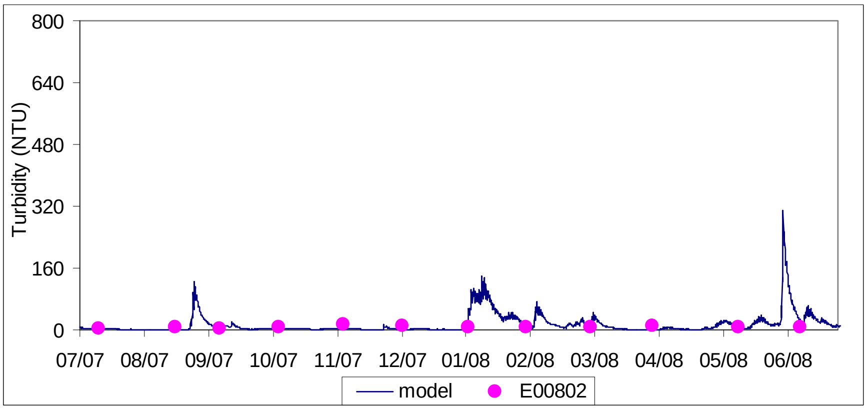

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00814

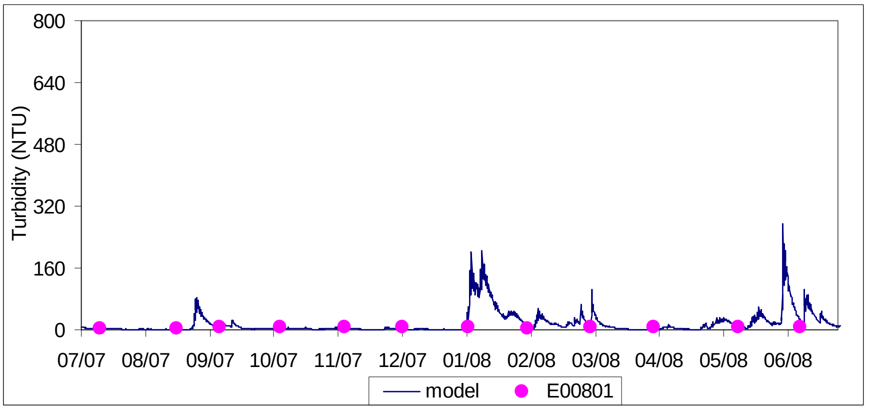

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00811

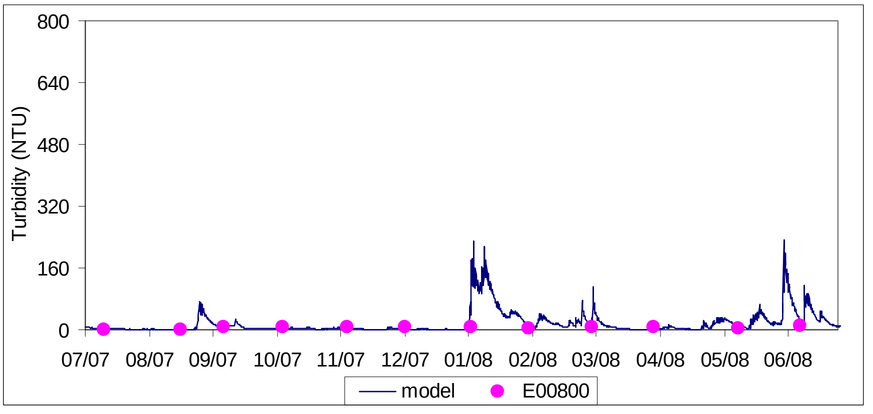

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00806


800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00804

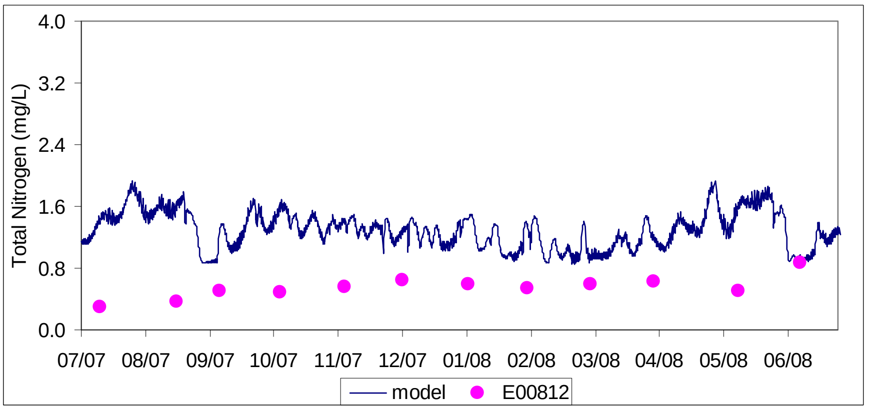

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00803

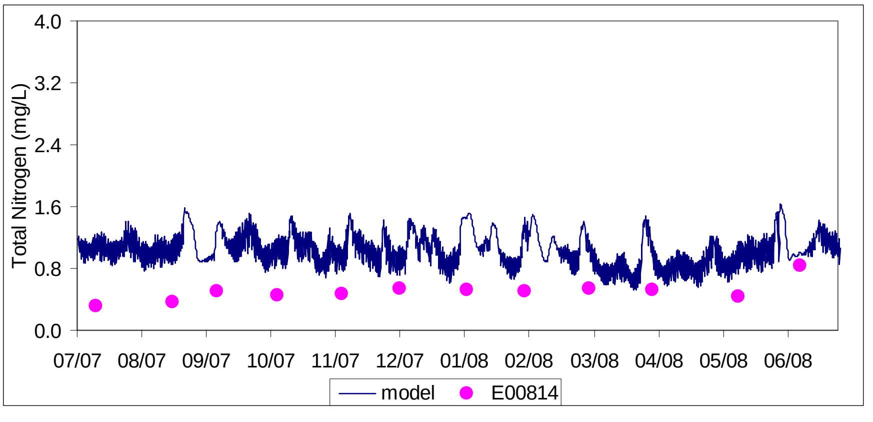

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00802

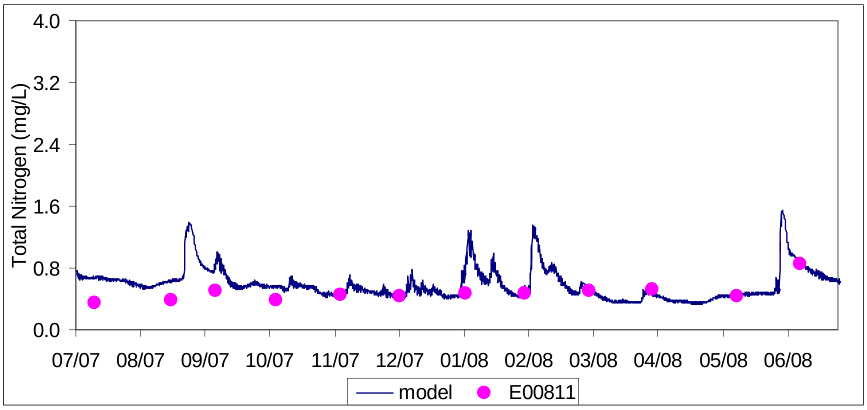


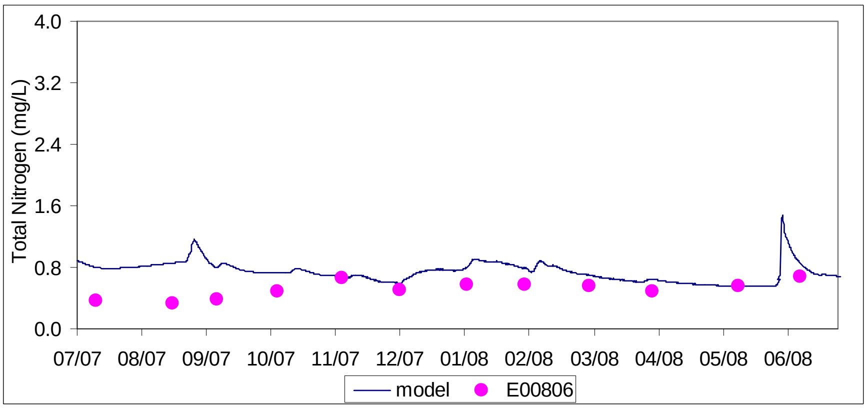


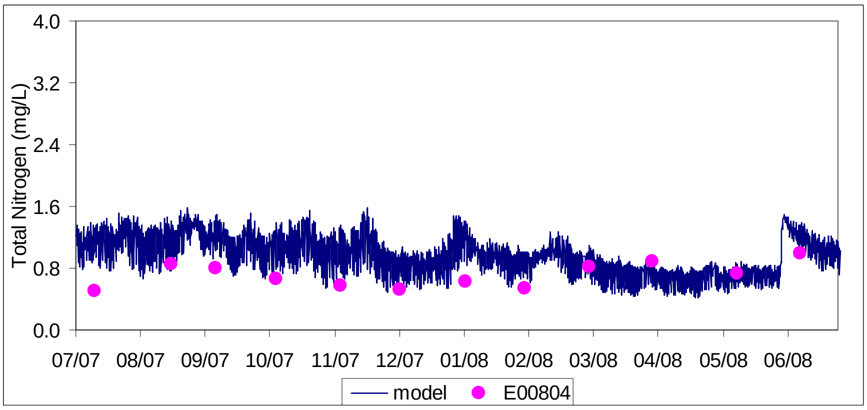
Total Nitrogen

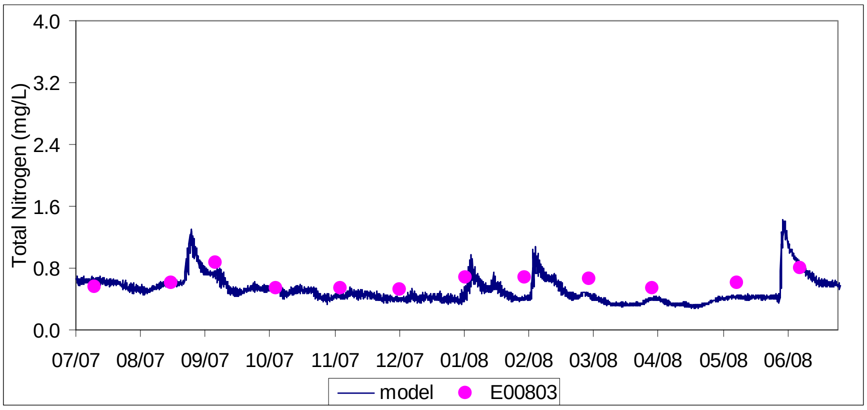


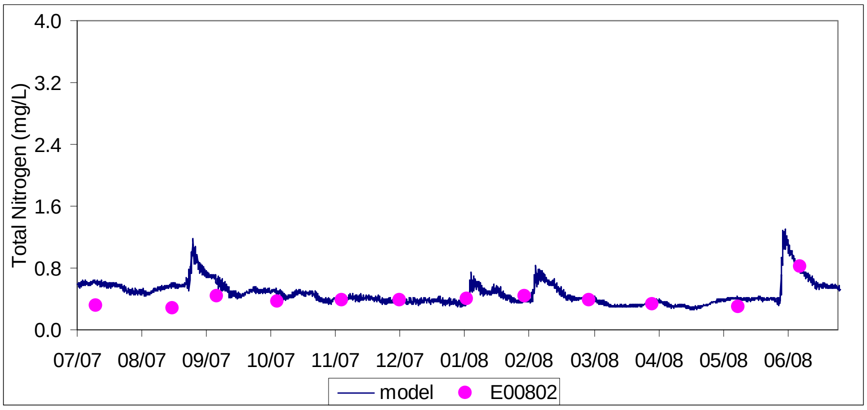


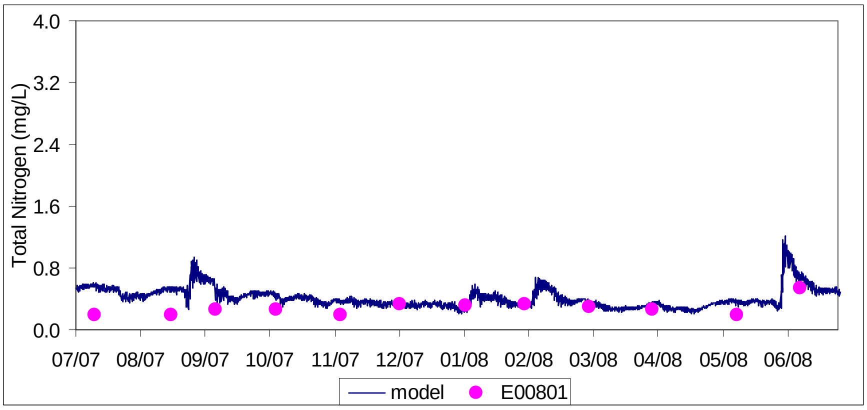

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00811

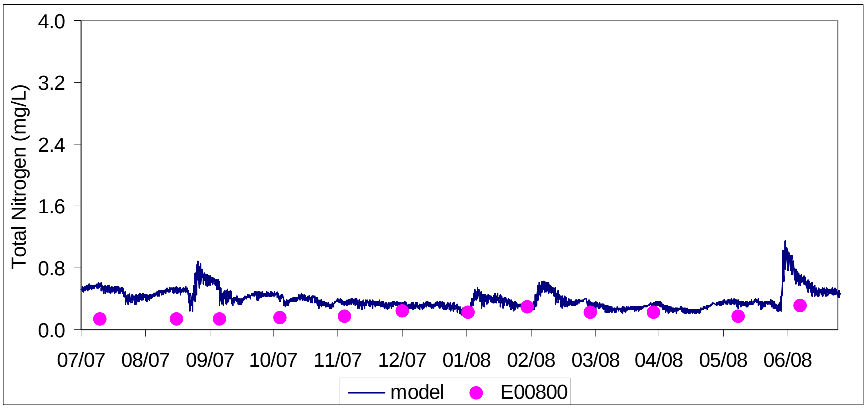

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00806


4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00804

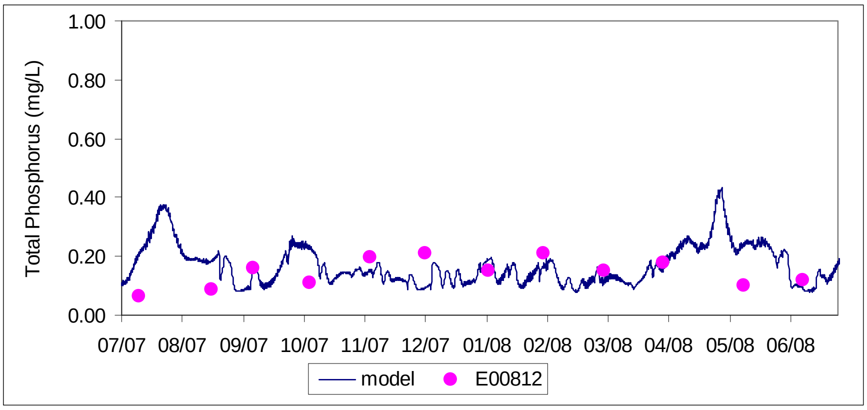

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00803

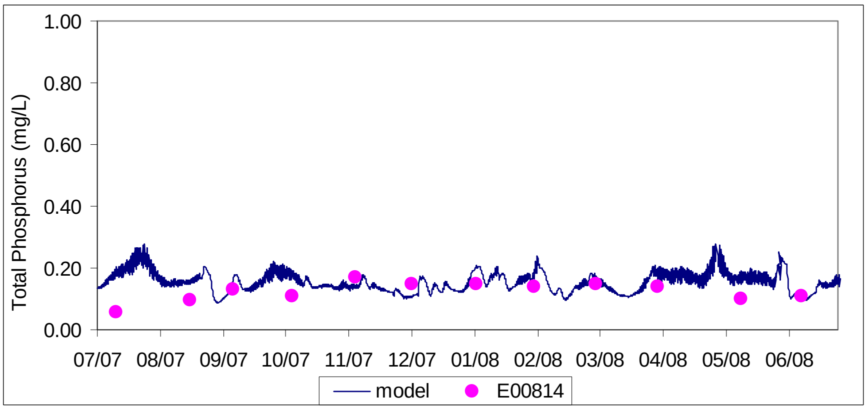

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00802

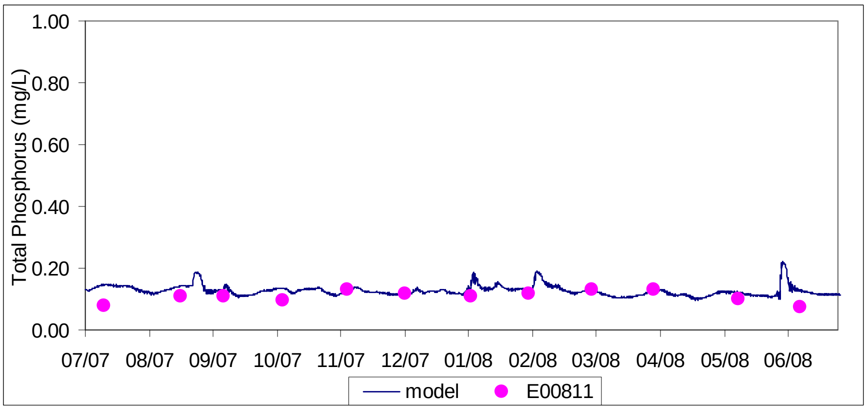

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00801

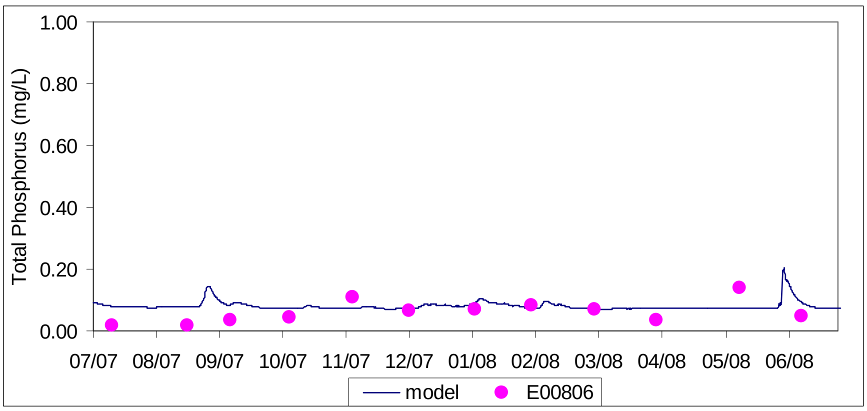

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00800

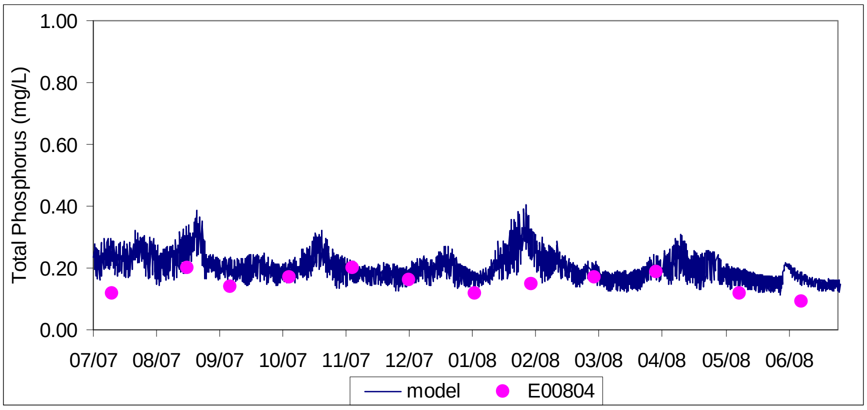
Total Phosphorus

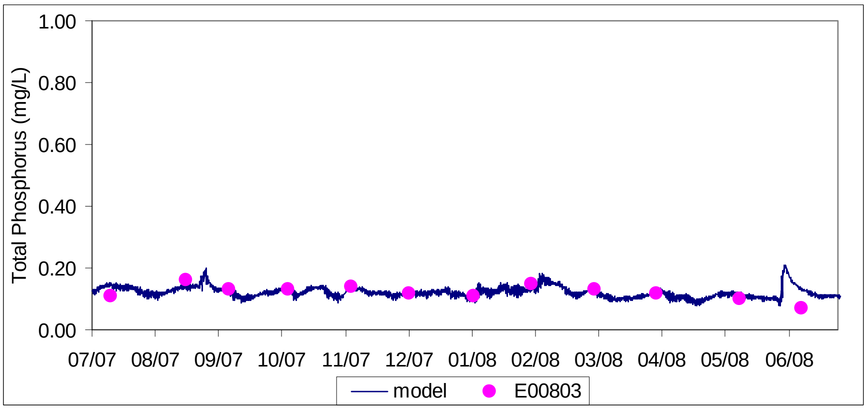


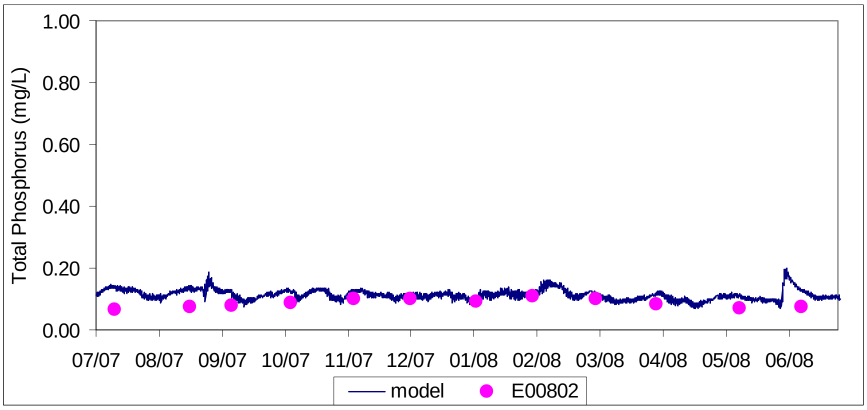


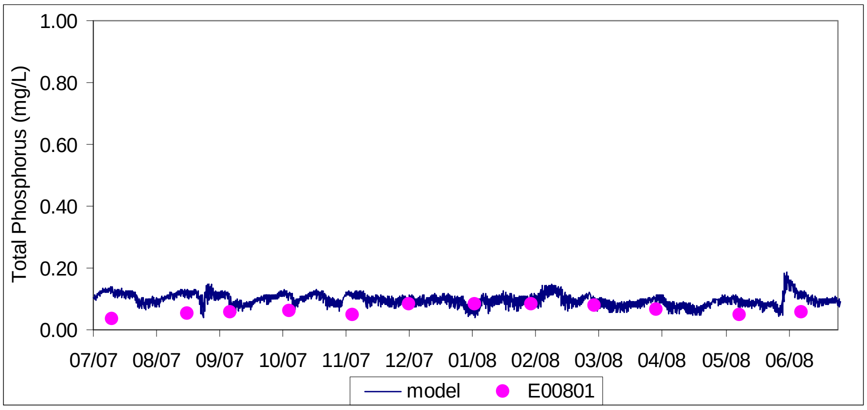


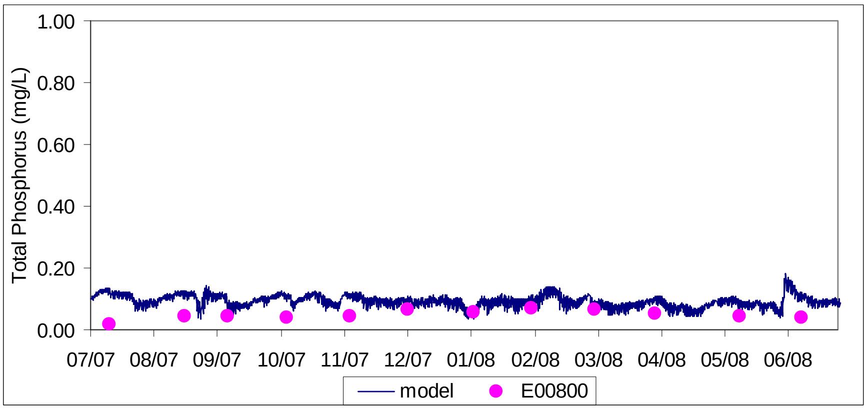



Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00804


Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00803

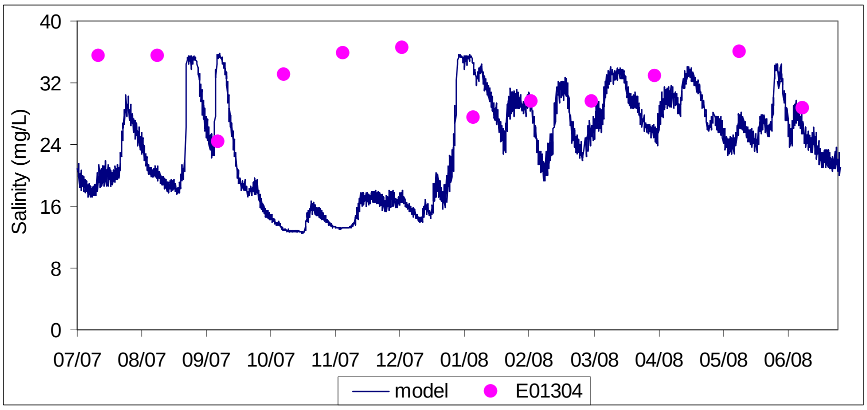

Total Phosphorus (mg/L)
1.00
0.80
0.60
0.40
0.20
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00802

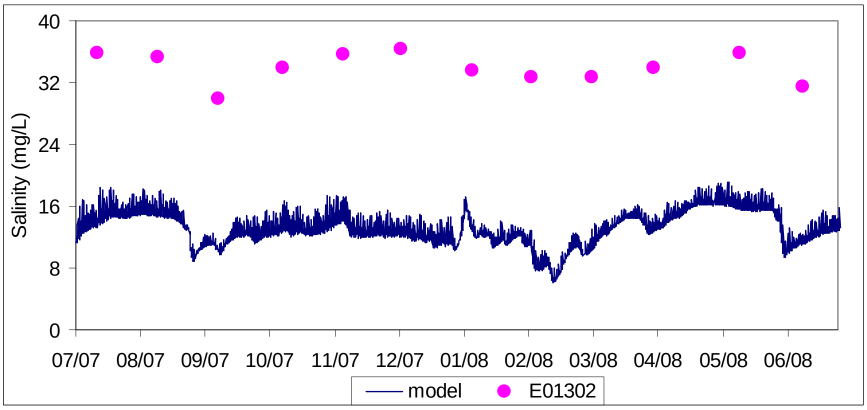


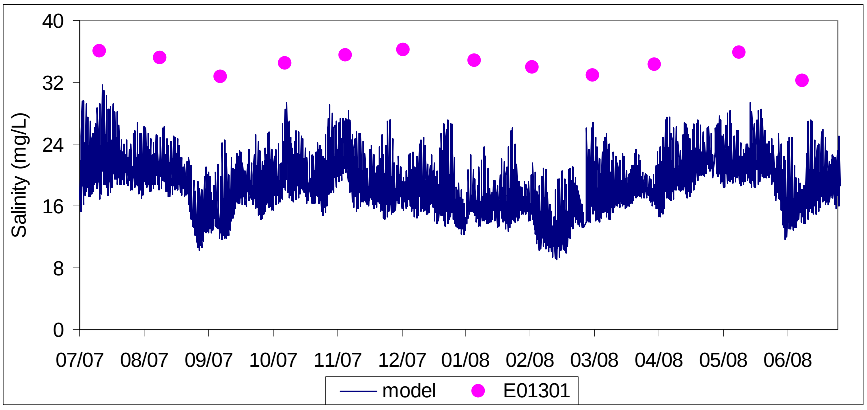


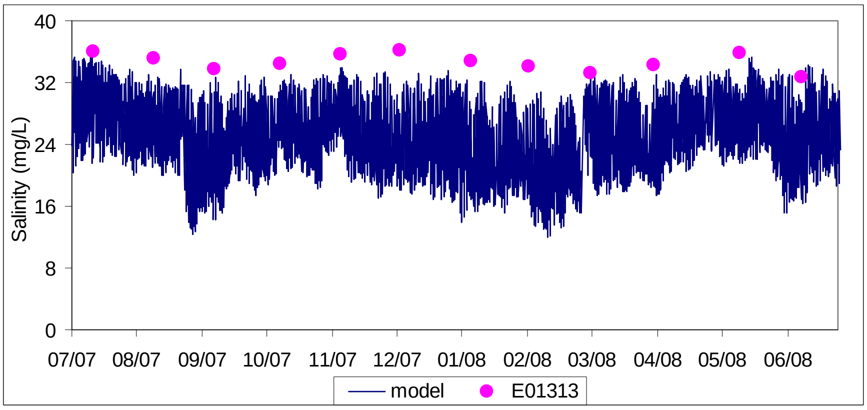
PUMICESTONE PASSAGE VALIDATION RESULTS

Salinity

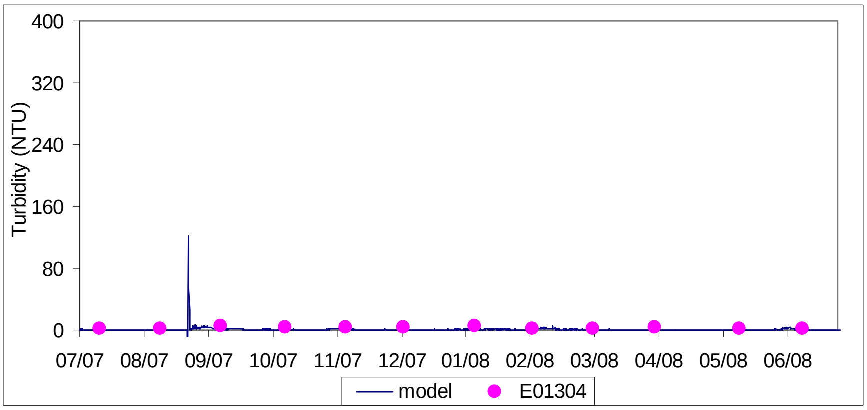


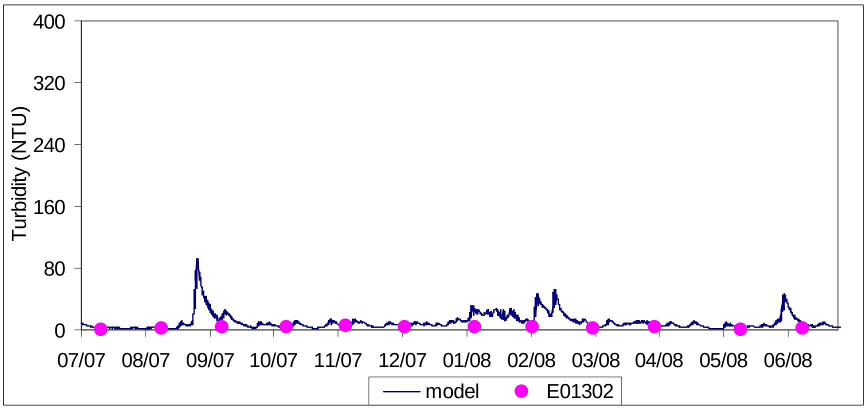


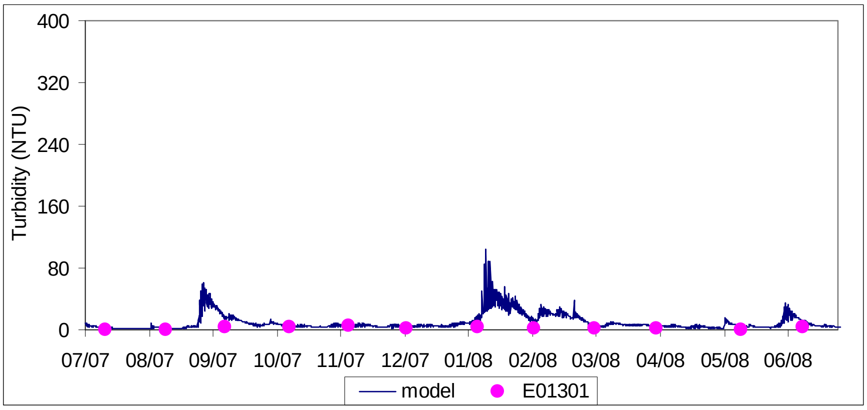

Salinity (mg/L)
0
8
16
24
32
40
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01301

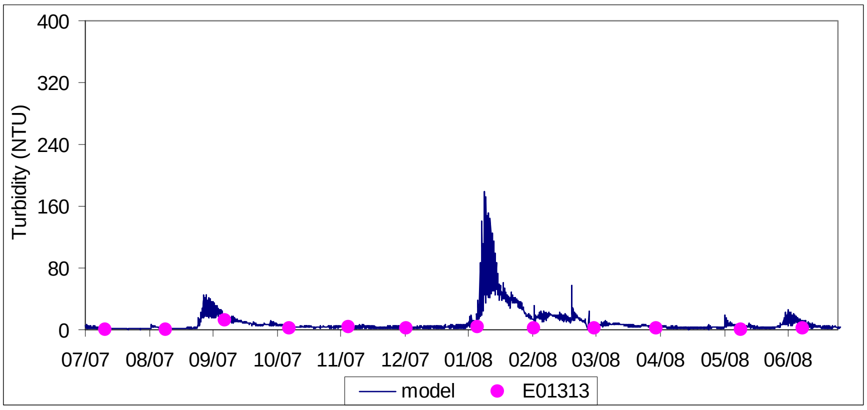

Salinity (mg/L)
0
8
16
24
32
40
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01313

Turbidity

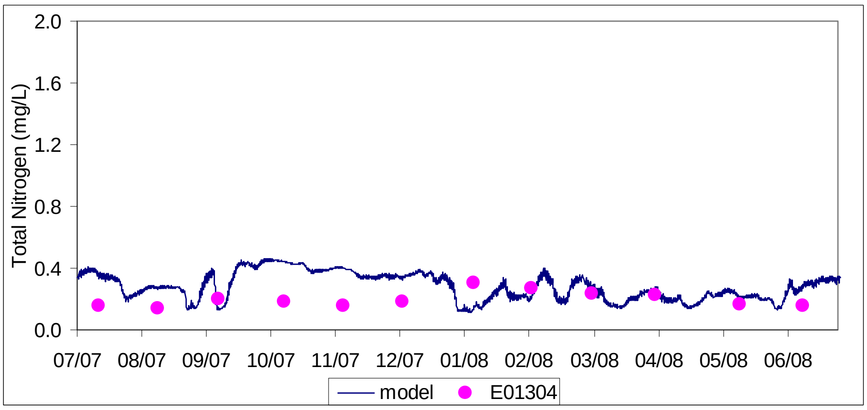

Turbidity (NTU)
0
80
160
240
320
400
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01304

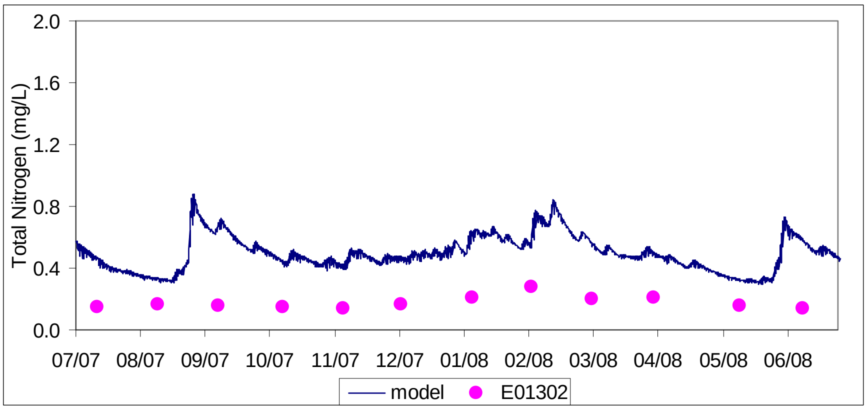

Turbidity (NTU)
0
80
160
240
320
400
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01302

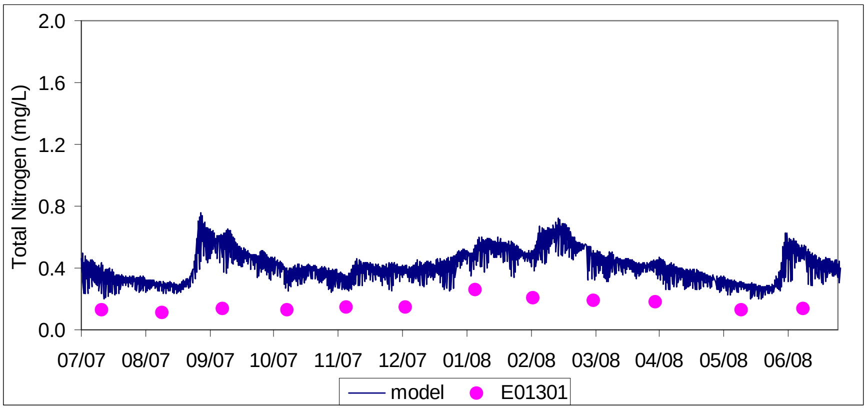


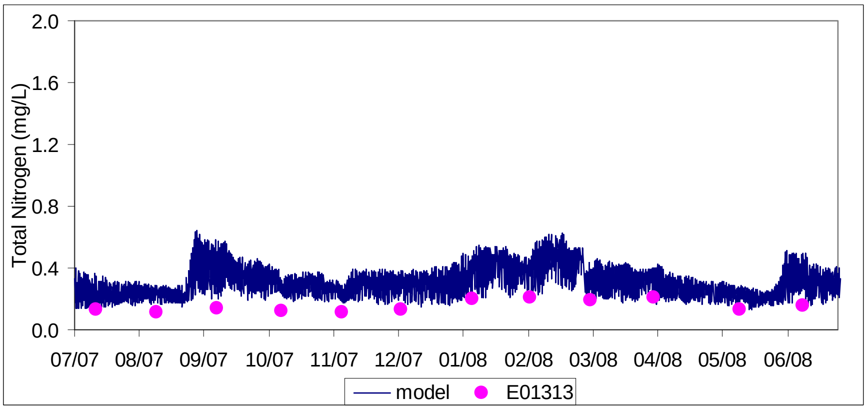


Total Nitrogen

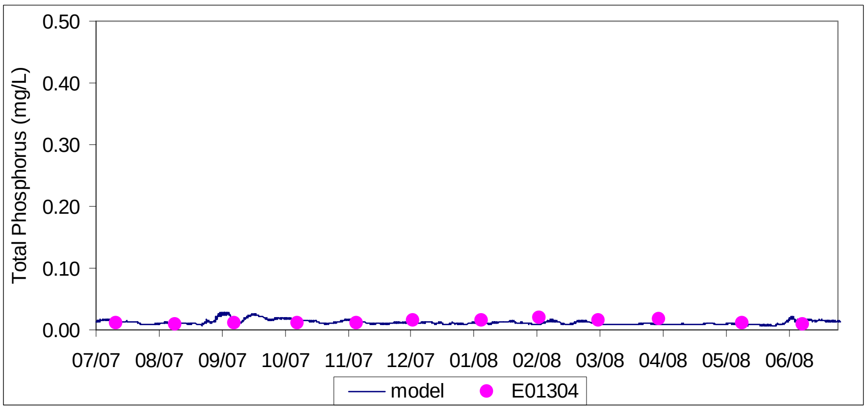


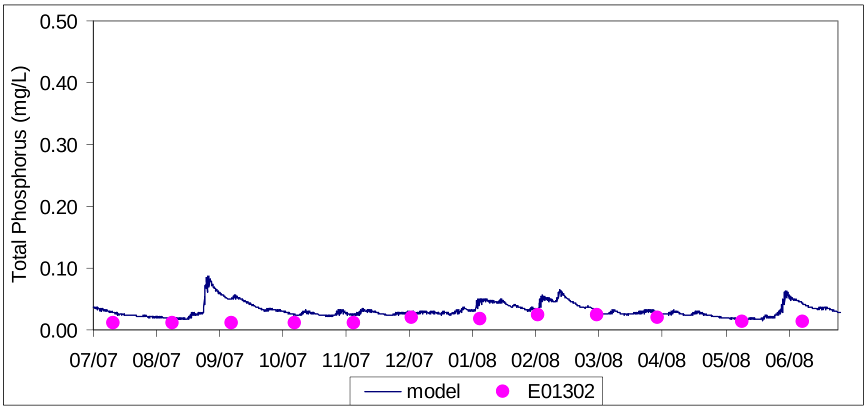


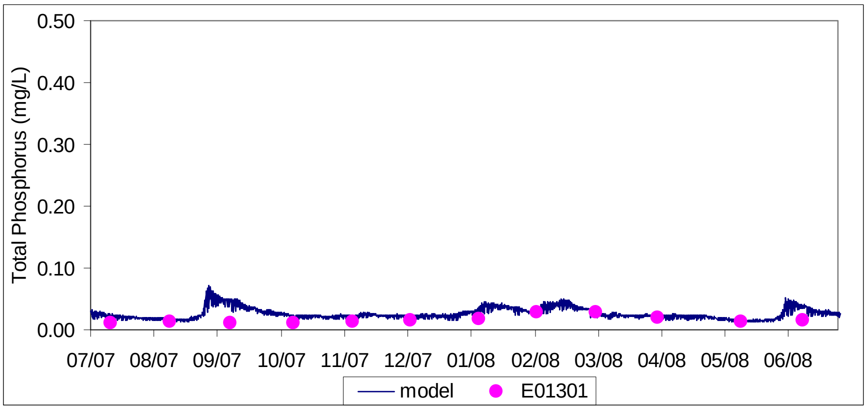


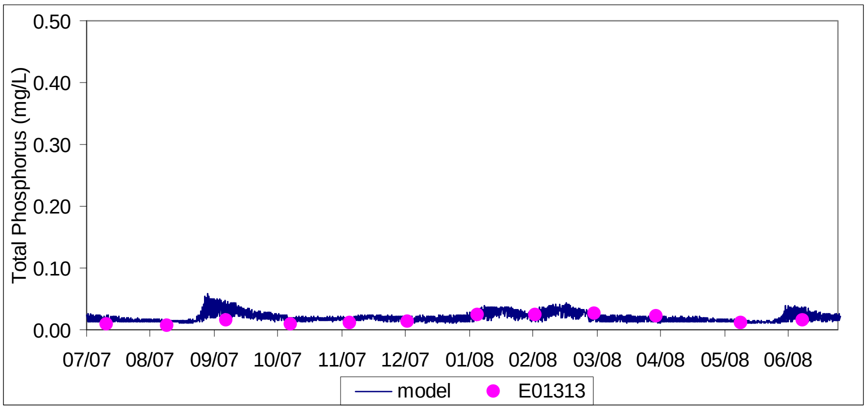


Total Phosphorus



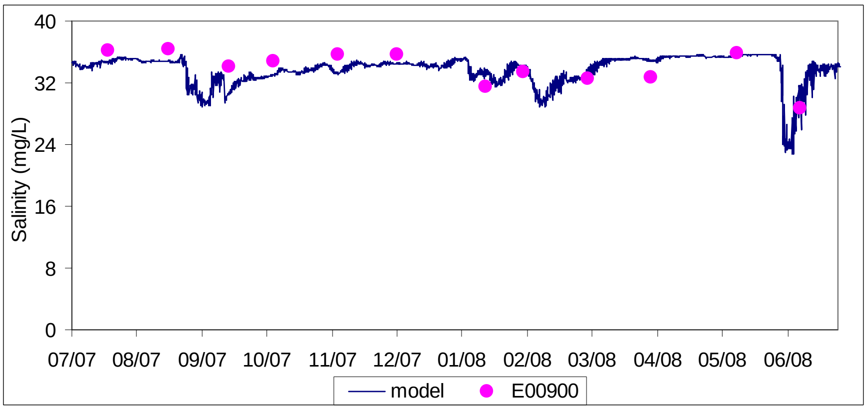


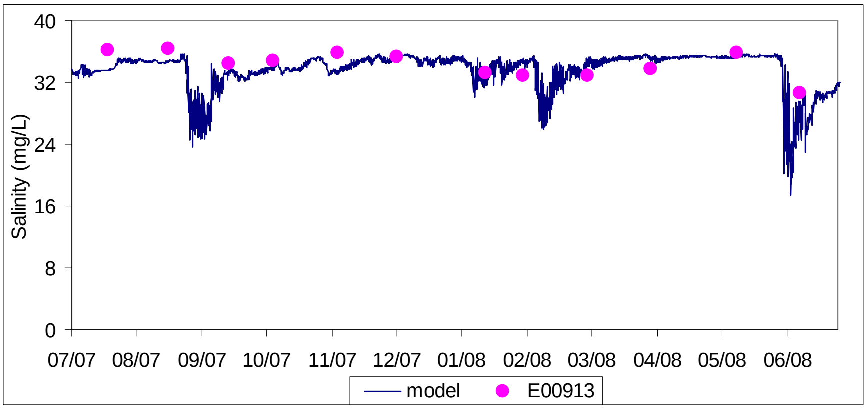


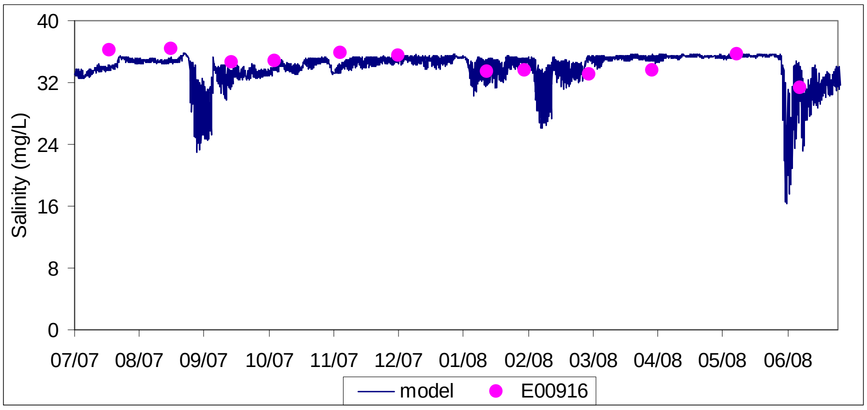


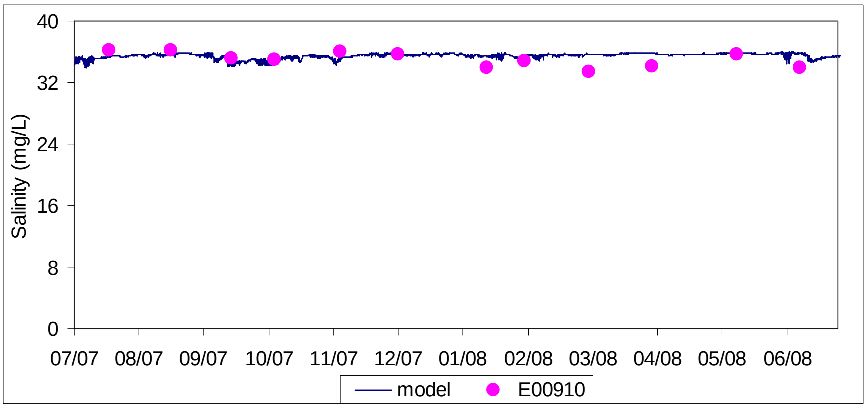
BRAMBLE BAY VALIDATION RESULTS

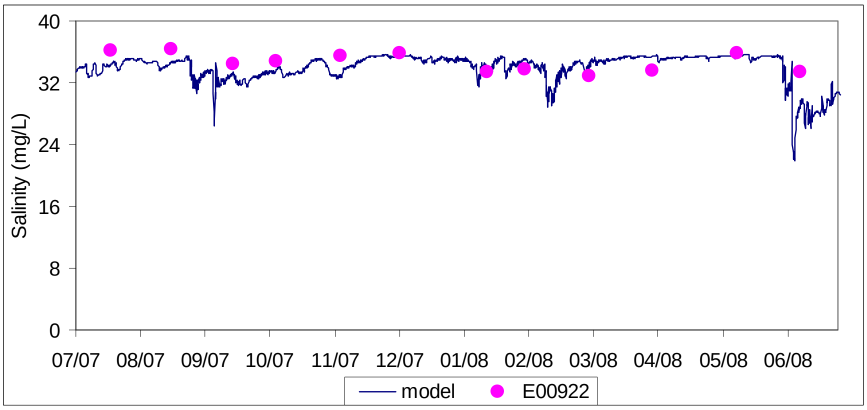
Salinity

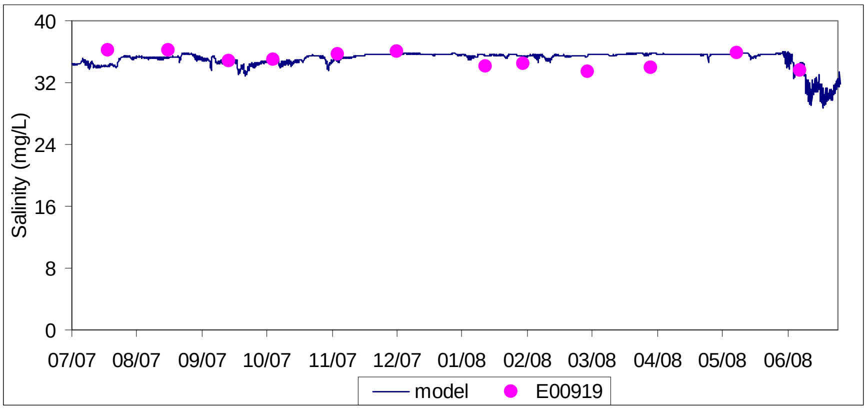


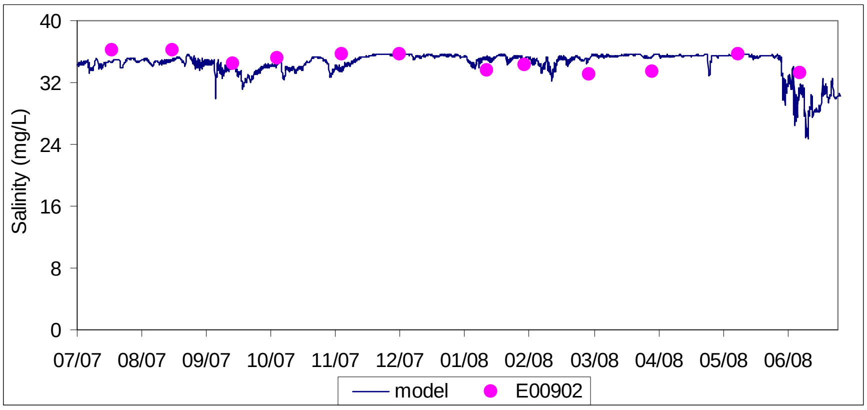


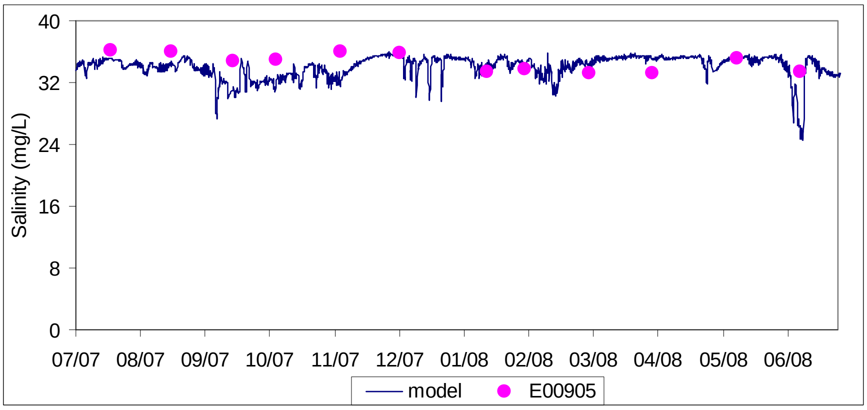

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00916

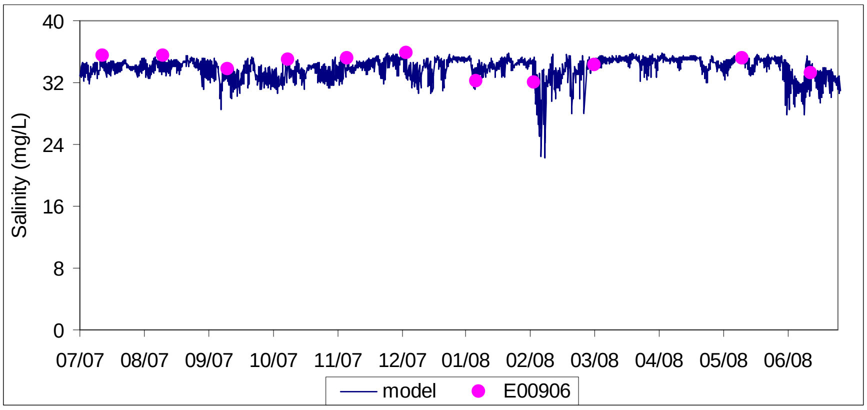

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00910

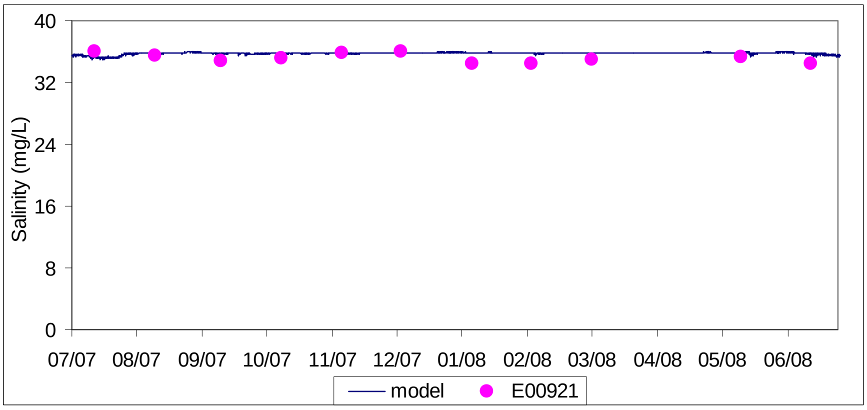

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00922


Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00919

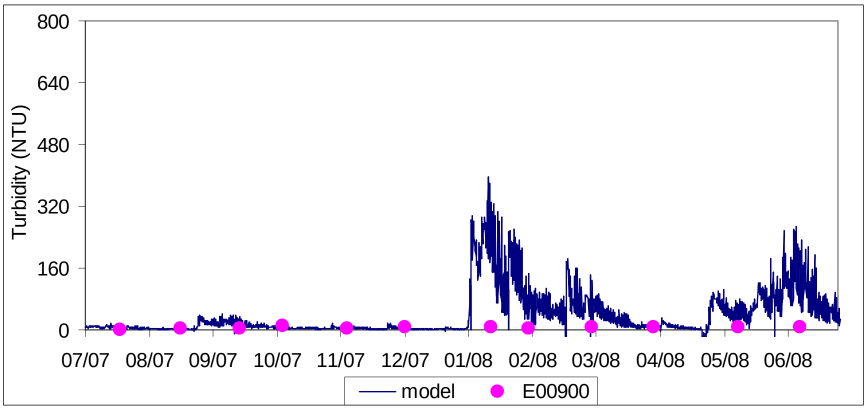

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00902

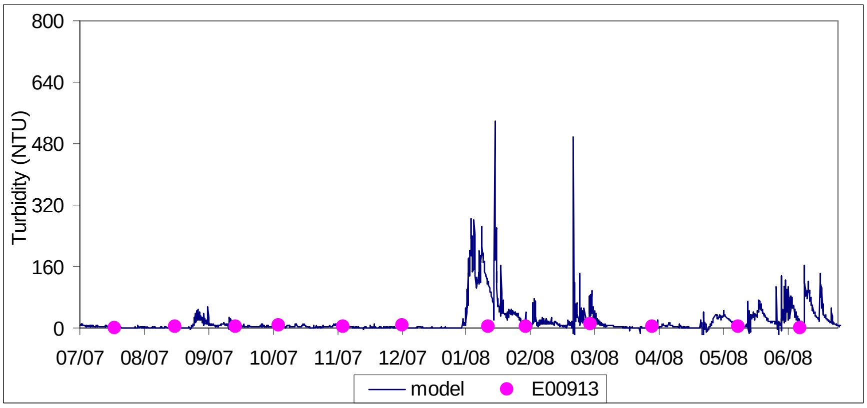

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00905

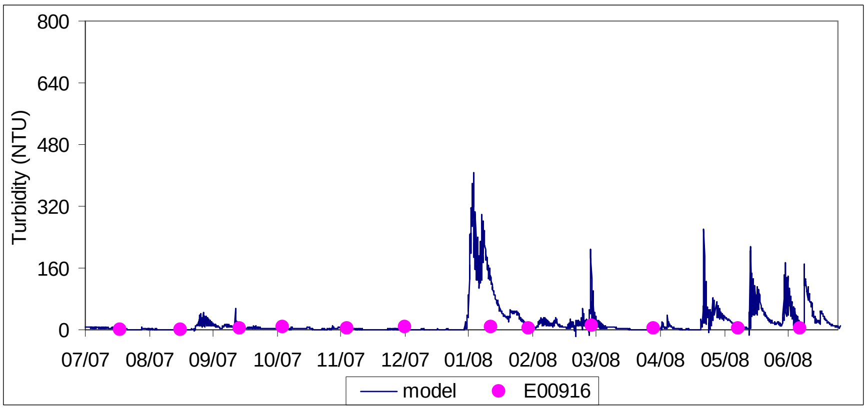

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00906

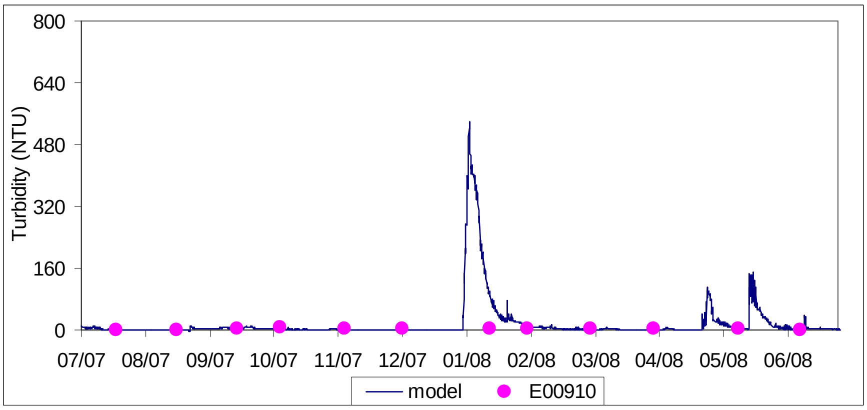

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00921

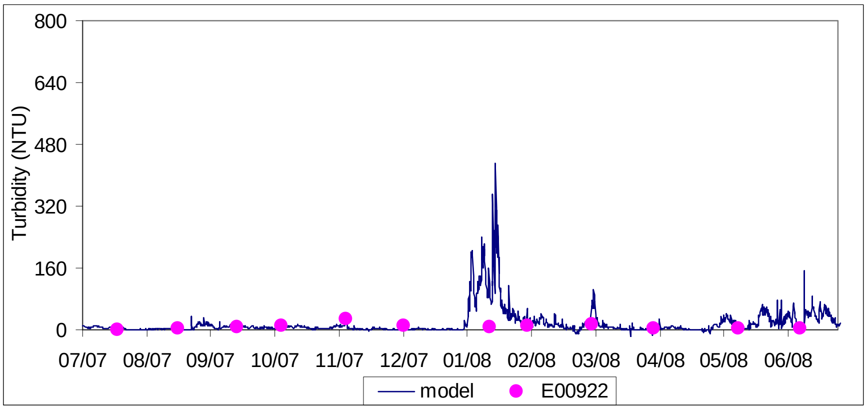
Turbidity

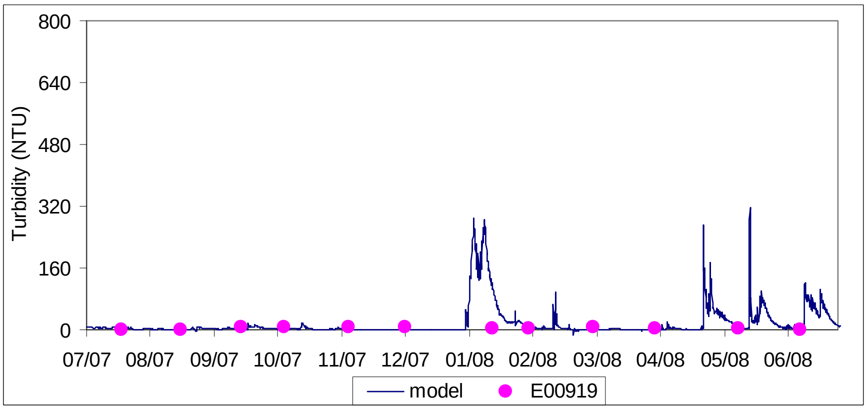

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00900

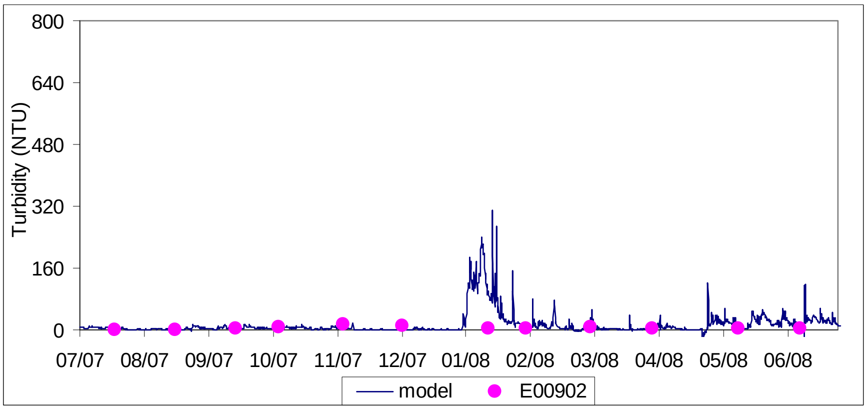

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00913

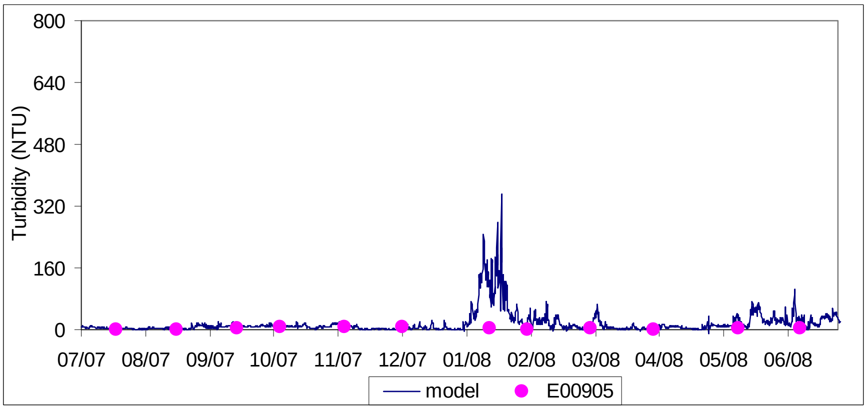

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00916

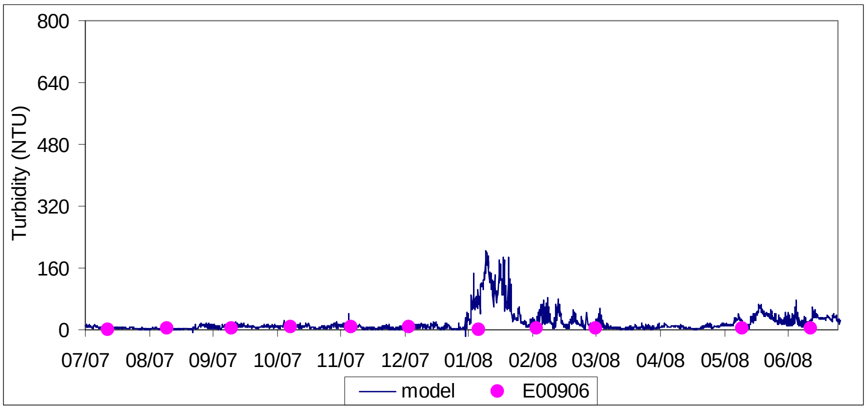

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00910

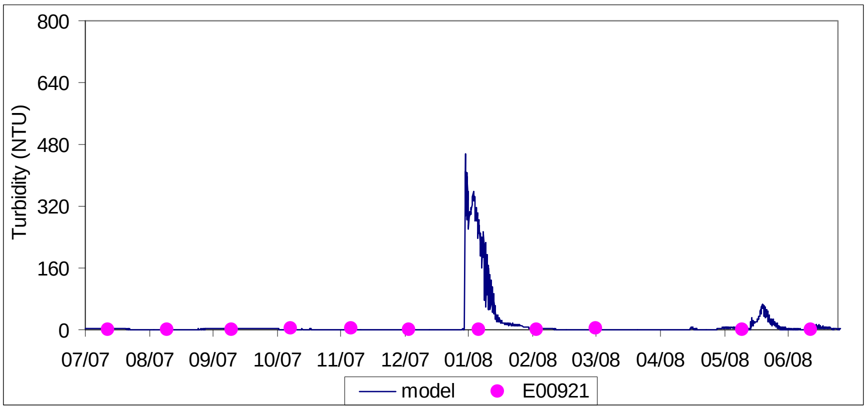

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00922


800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00919

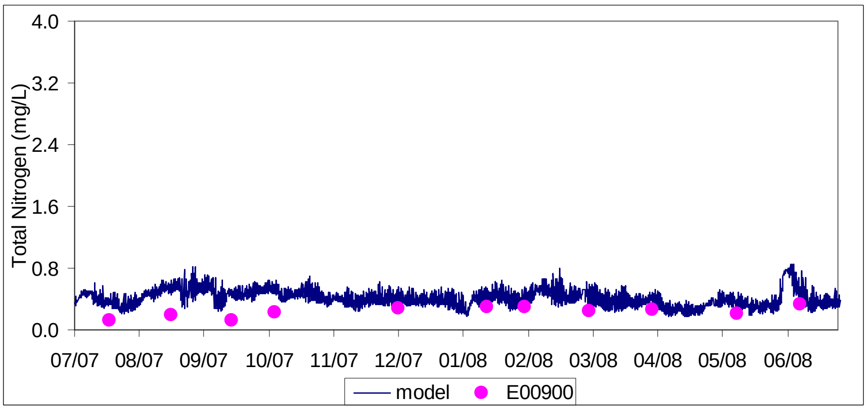

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00902

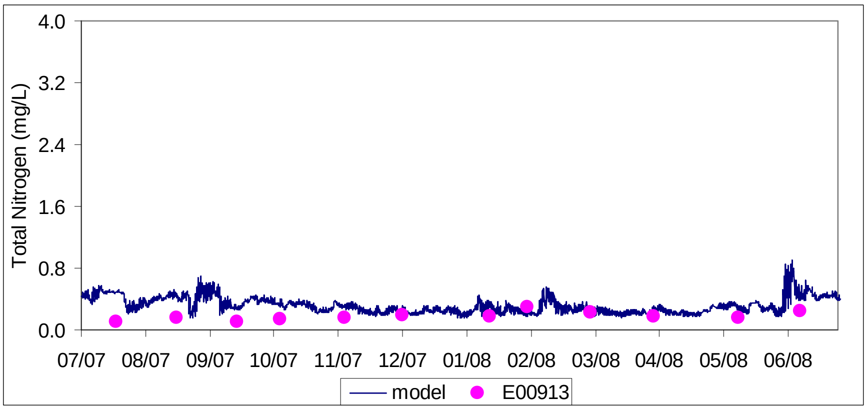

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00905

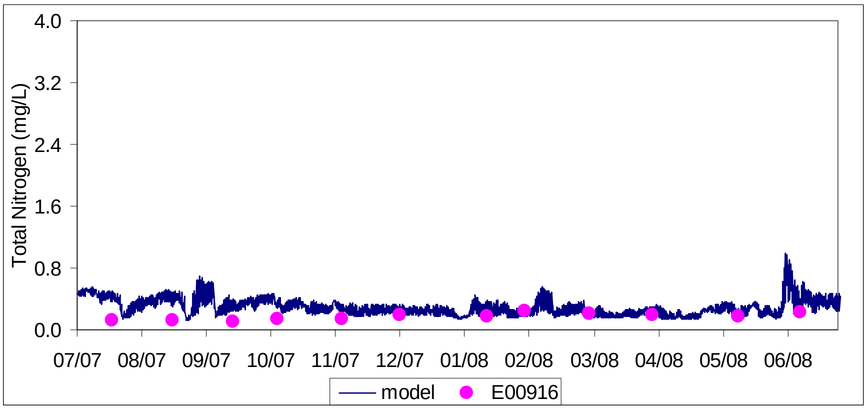


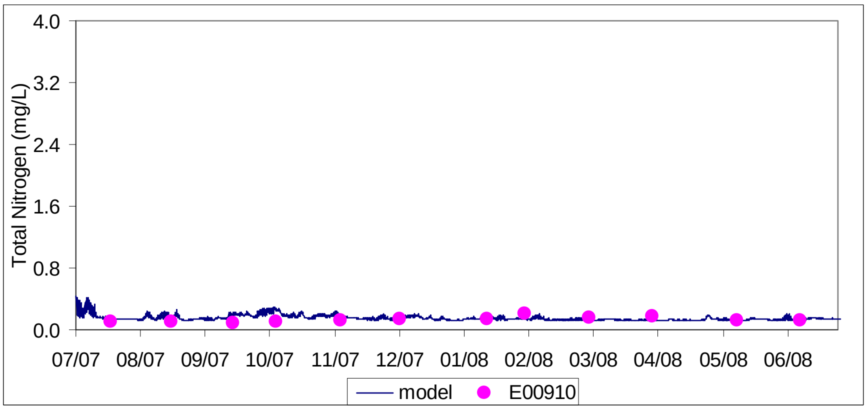


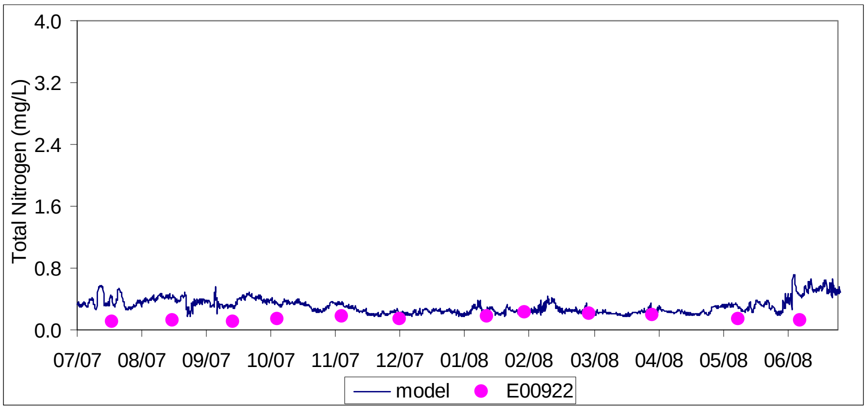
Total Nitrogen

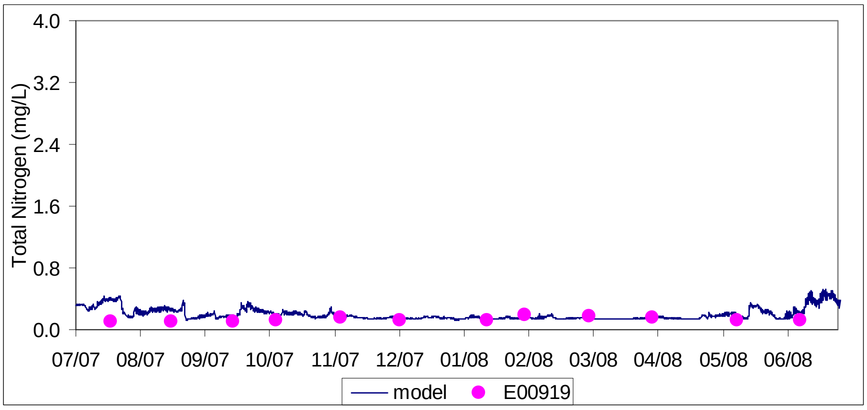


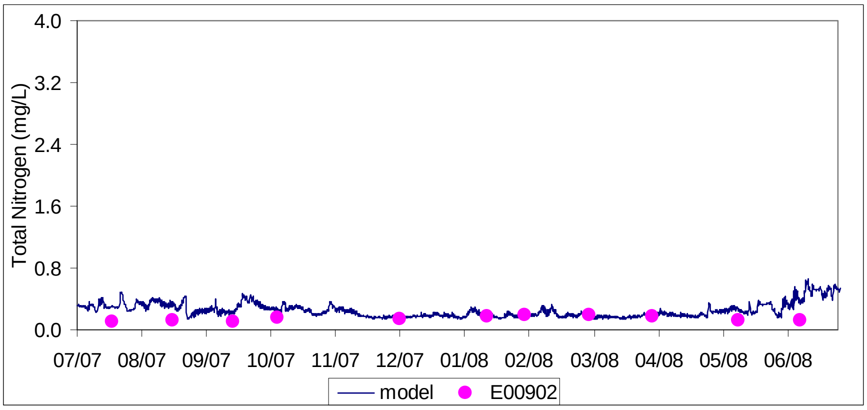


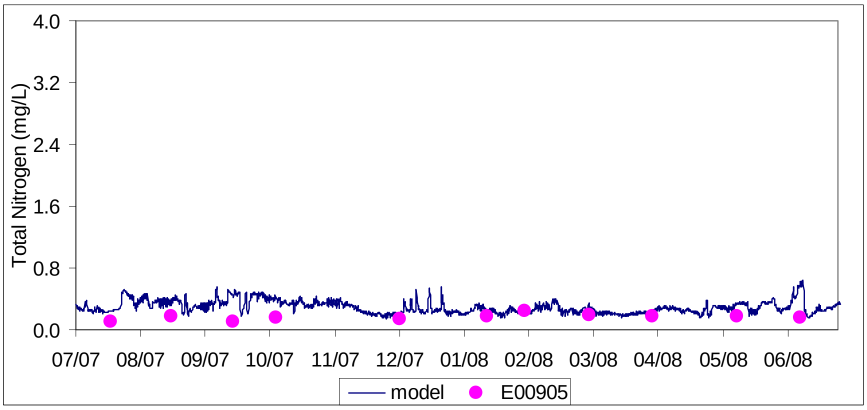

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00916

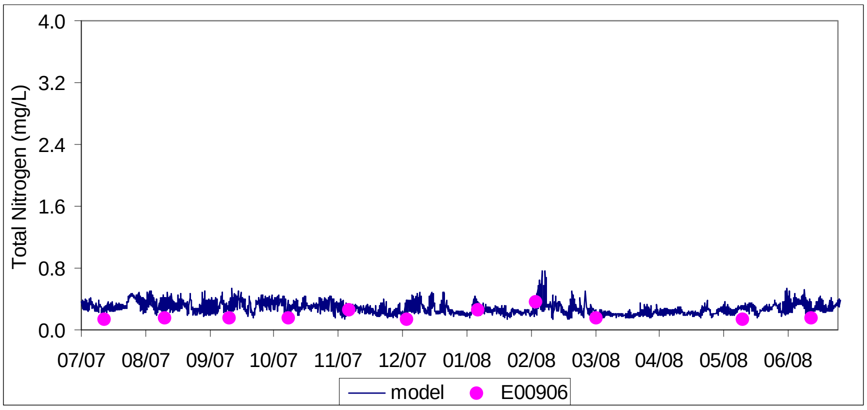

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00910

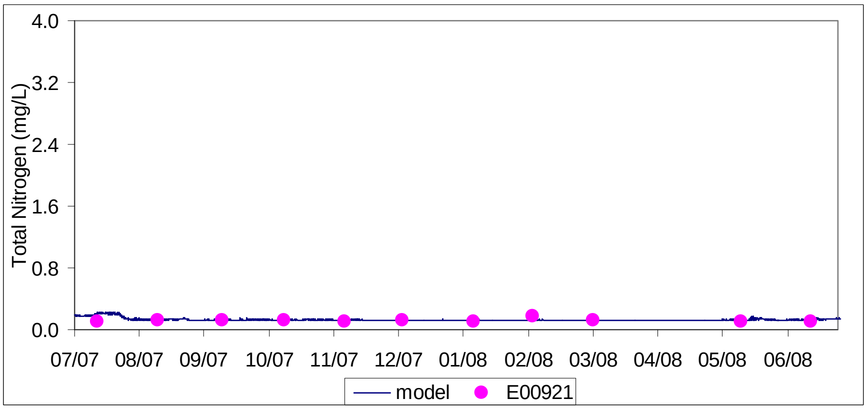

4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00922


4.0
3.2
2.4
1.6
0.8
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00919

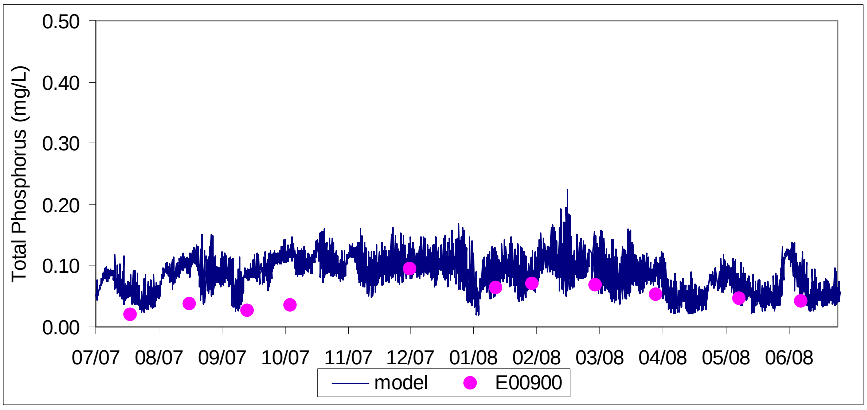

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00902

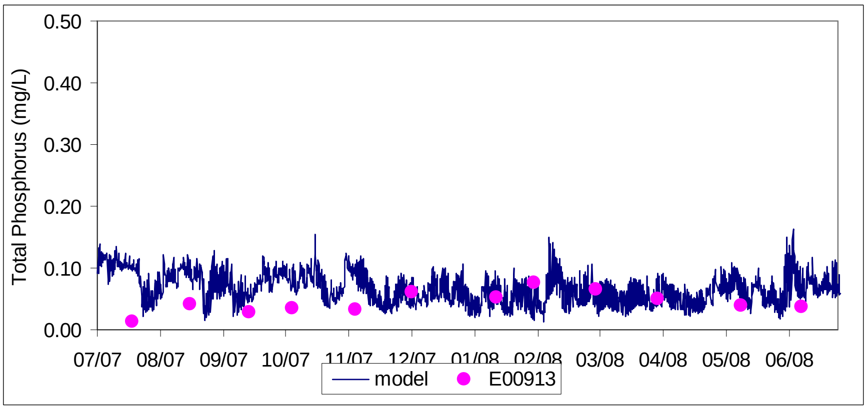

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00905

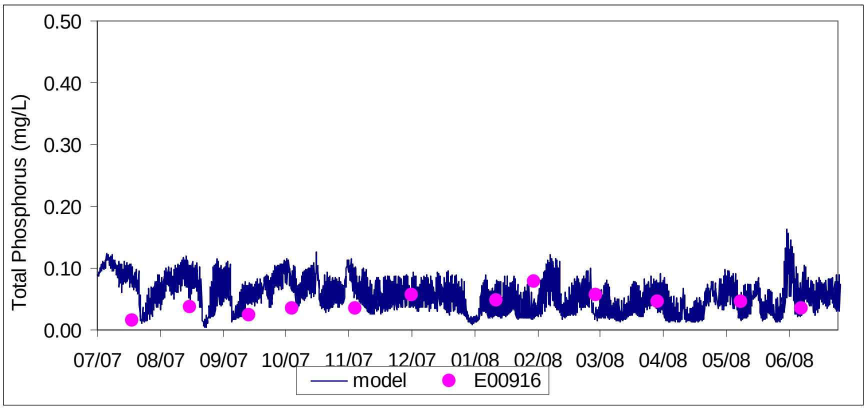

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00906

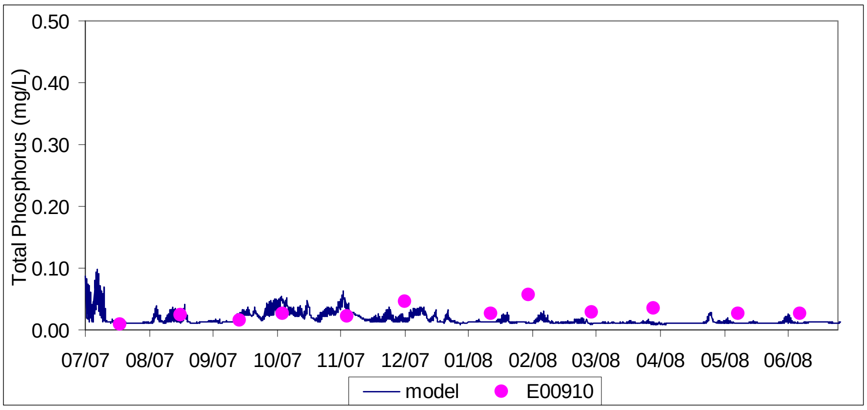

Total Nitrogen (mg/L)
4.0
3.2
2.4
1.6
0.8
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00921

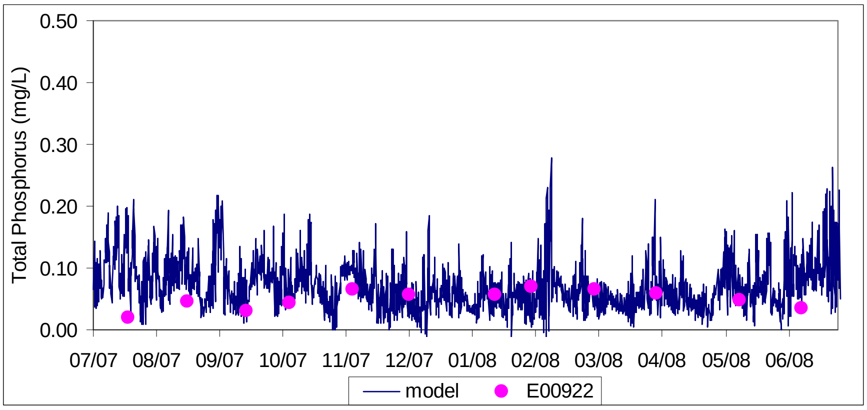
Total Phosphorus



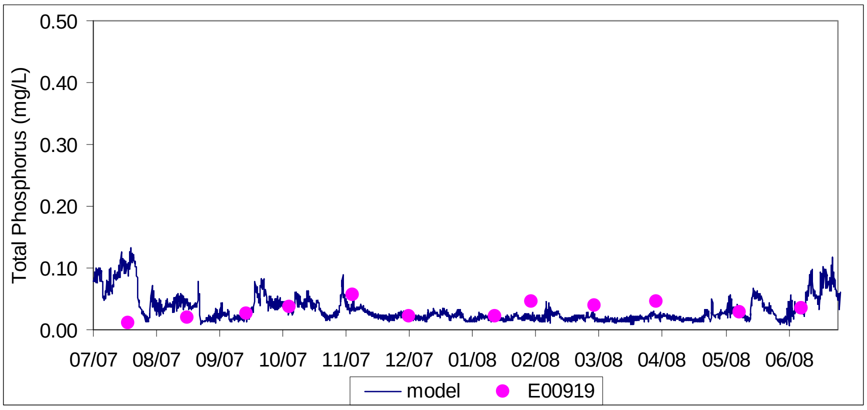




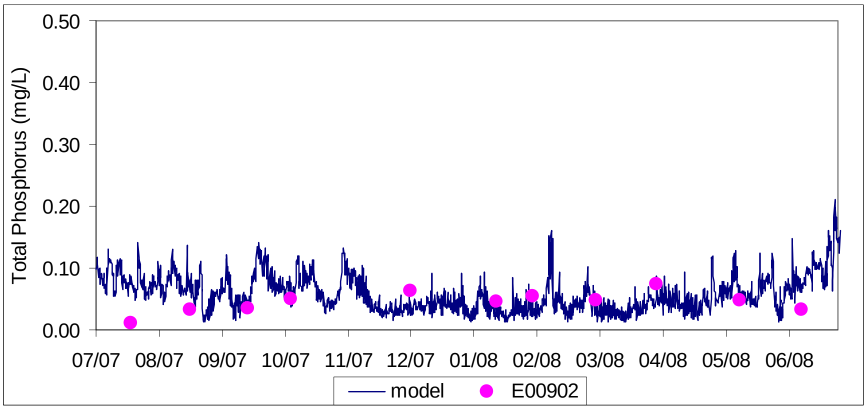




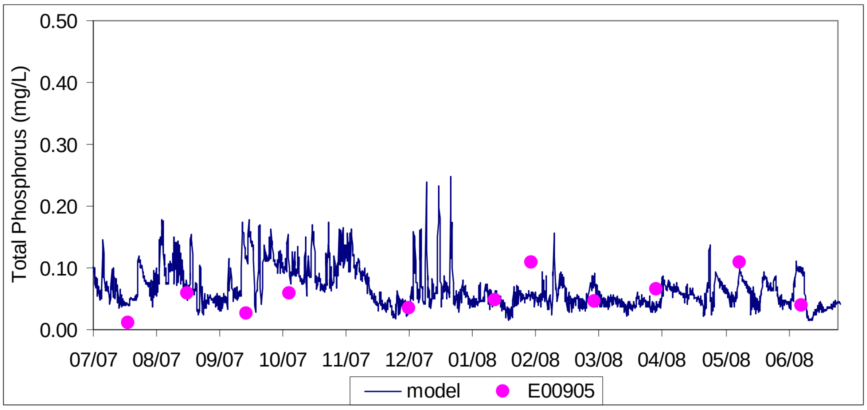
Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00922



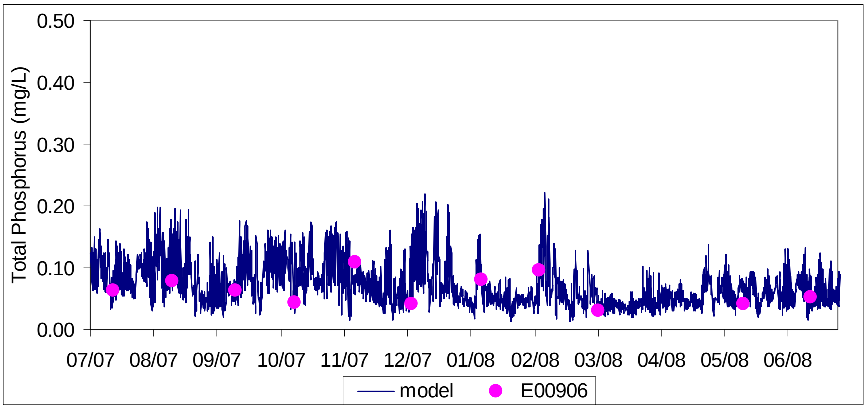
Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00919

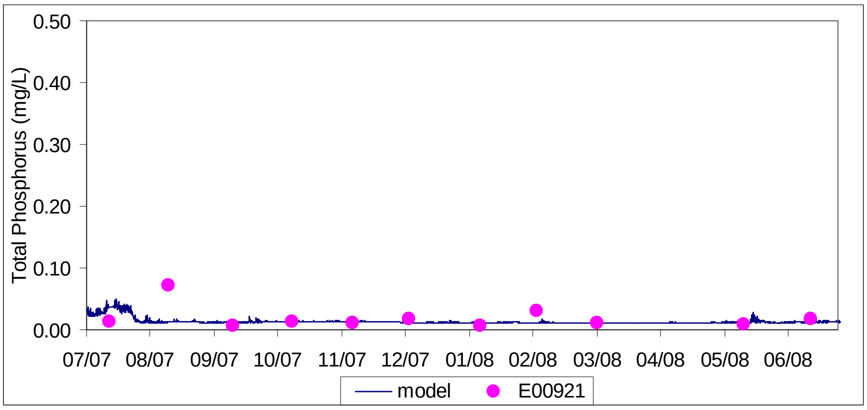


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00902



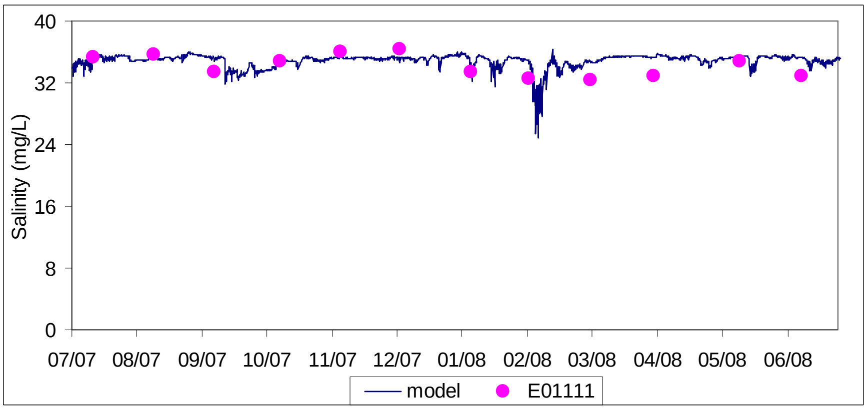
Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00905

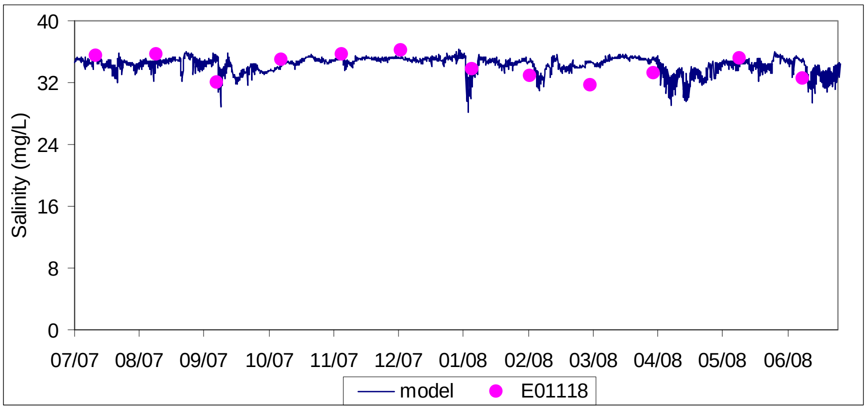


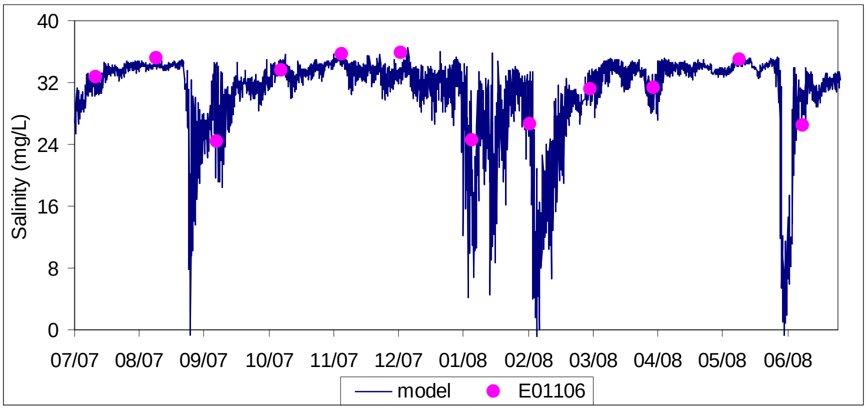


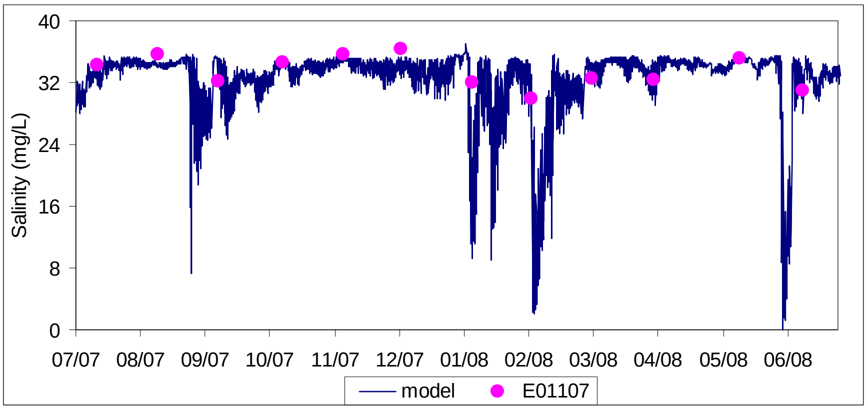
DECEPTION BAY VALIDATION RESULTS

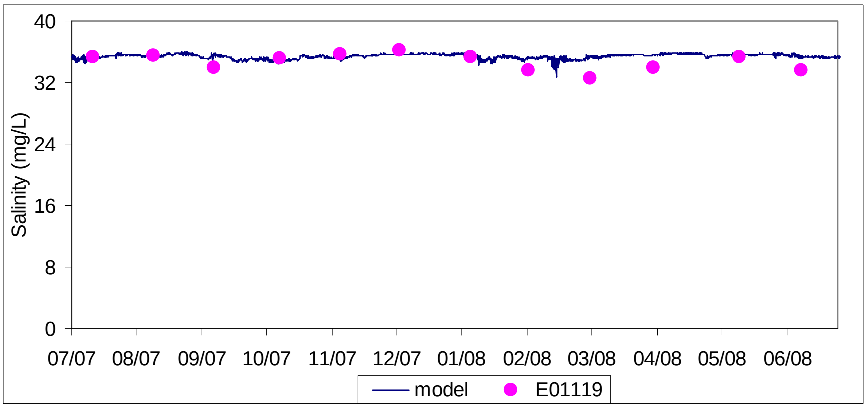
Salinity

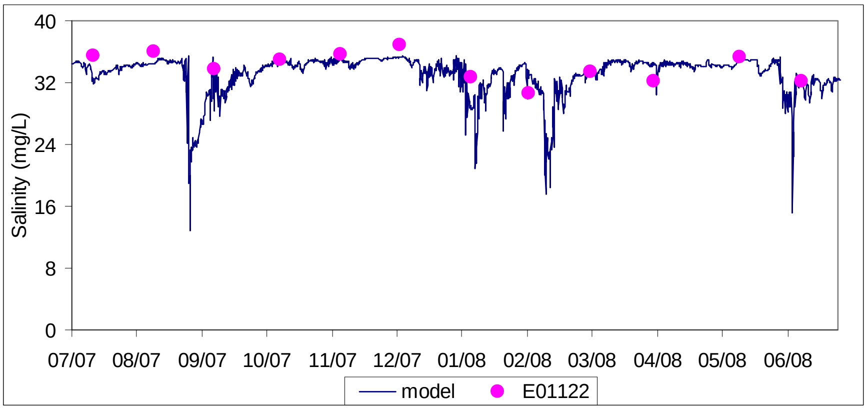


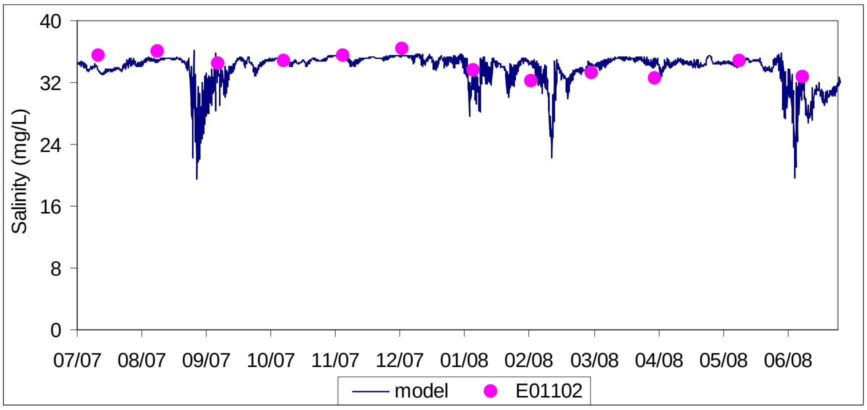


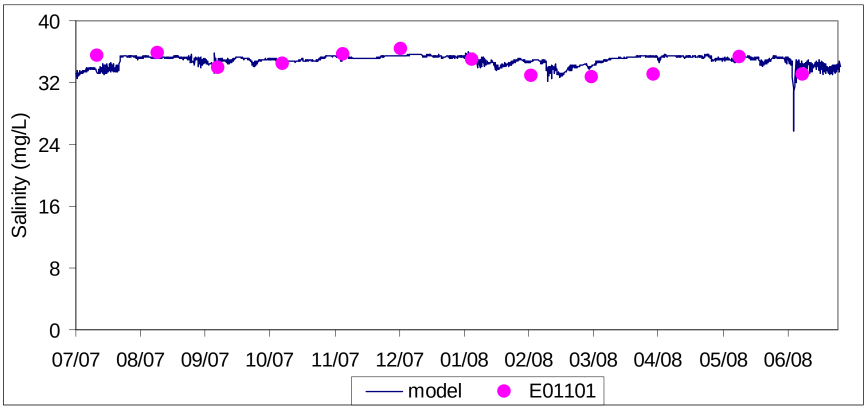

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01106

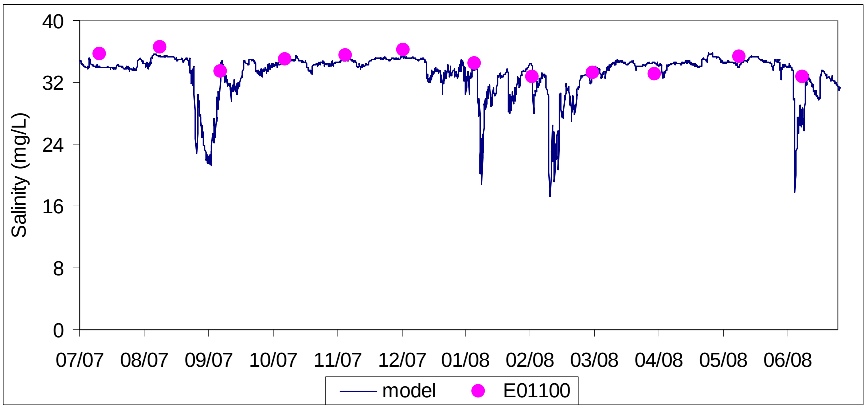

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01107

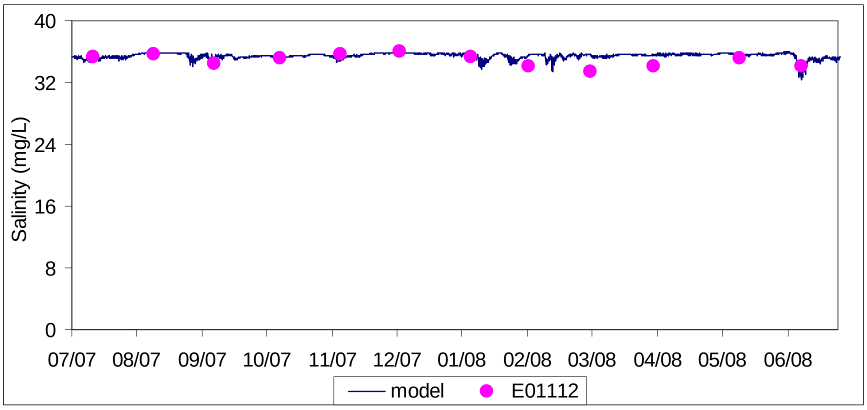

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01119


Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01122

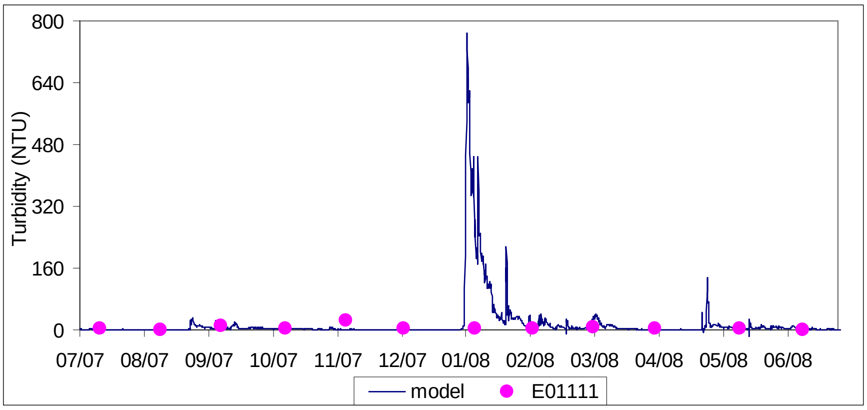

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01102

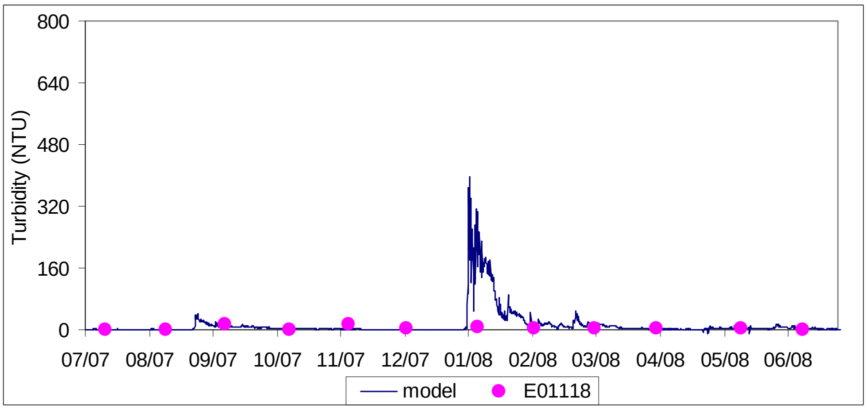

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01101

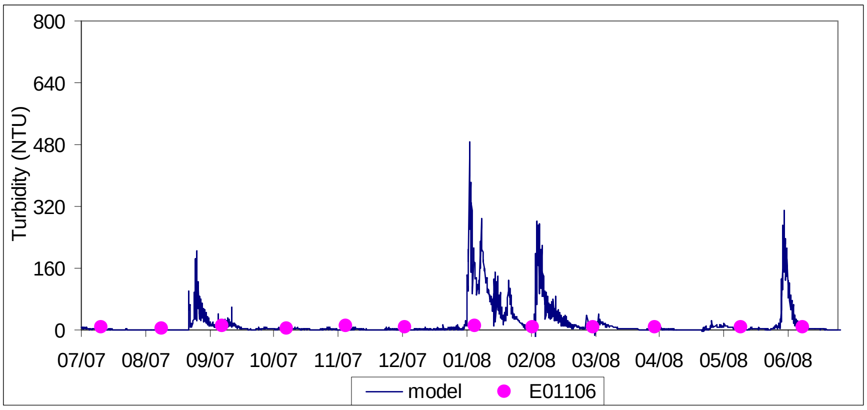

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01100

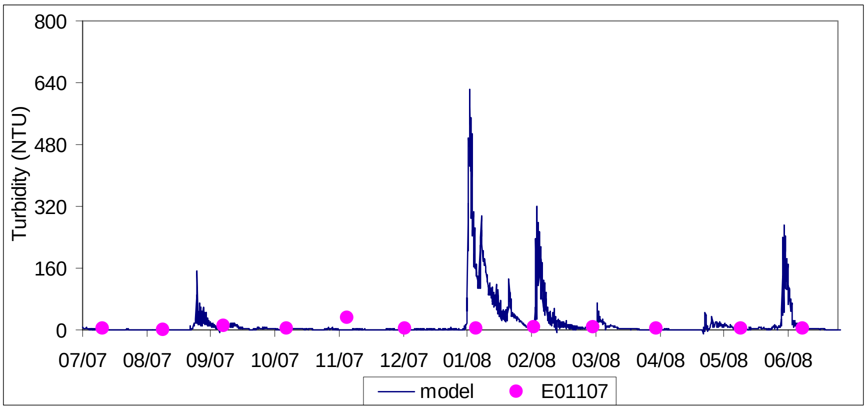

40
32
24
16
8
0
Salinity (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01112

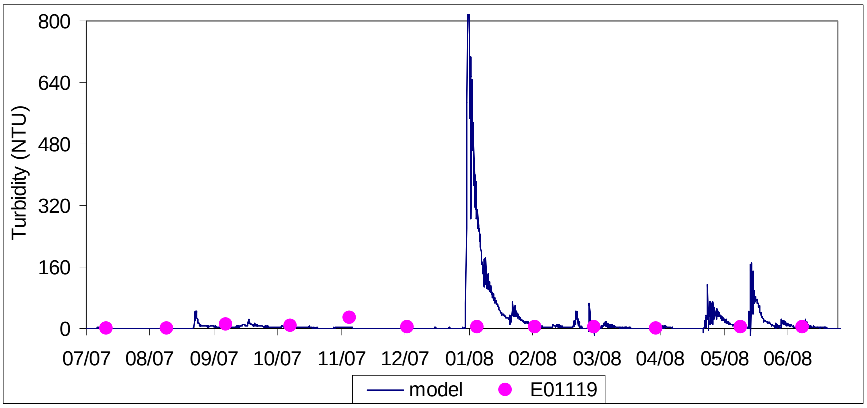
Turbidity

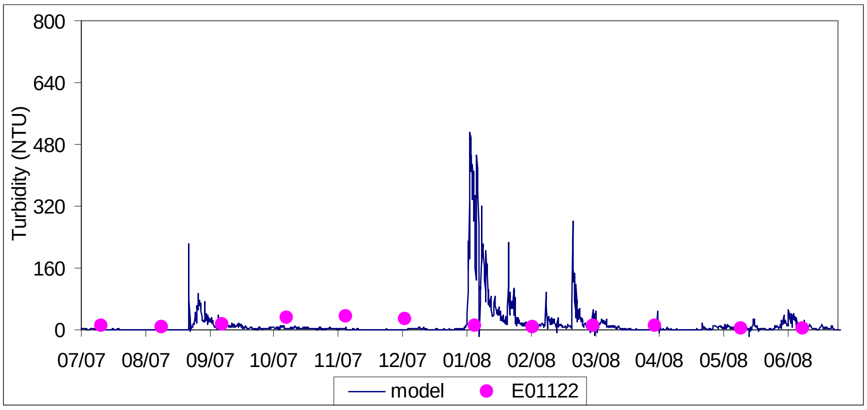

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01111

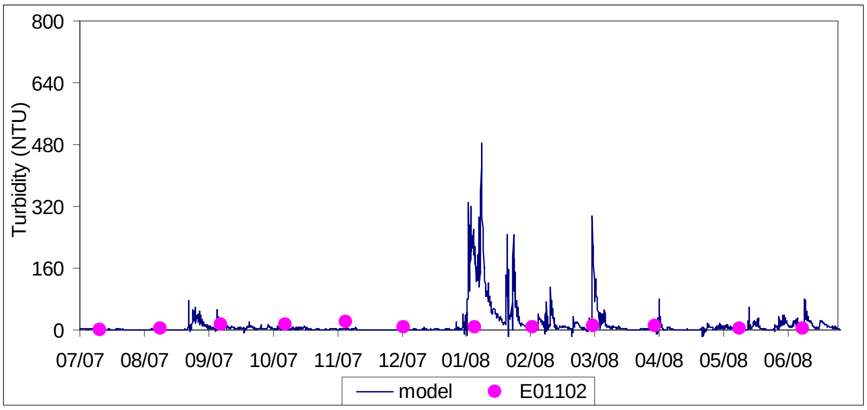

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01118

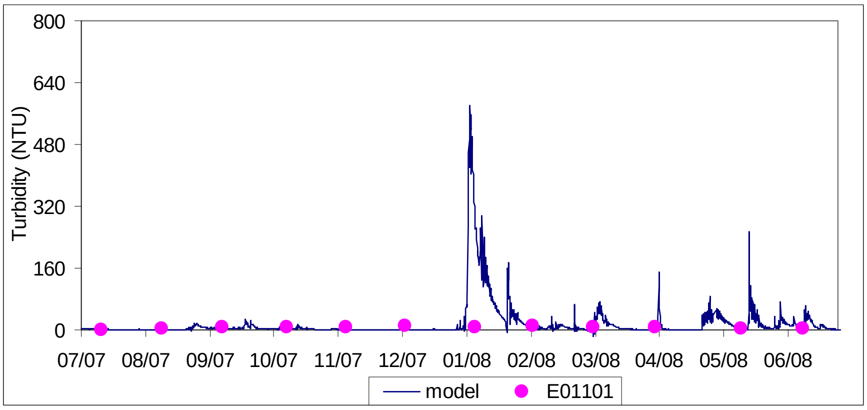

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01106

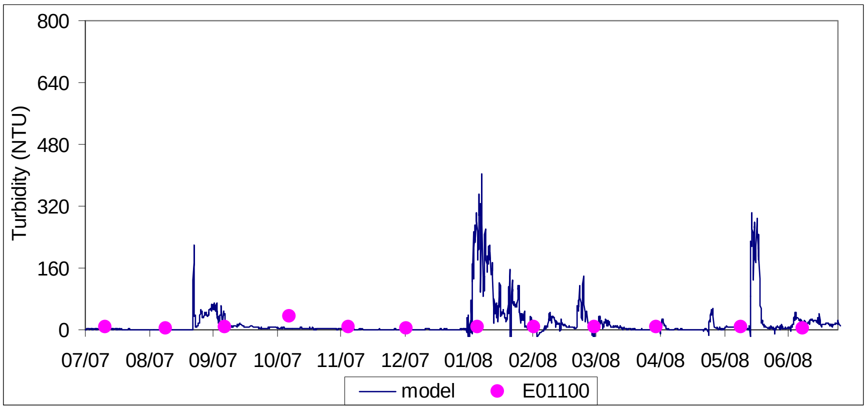

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01107

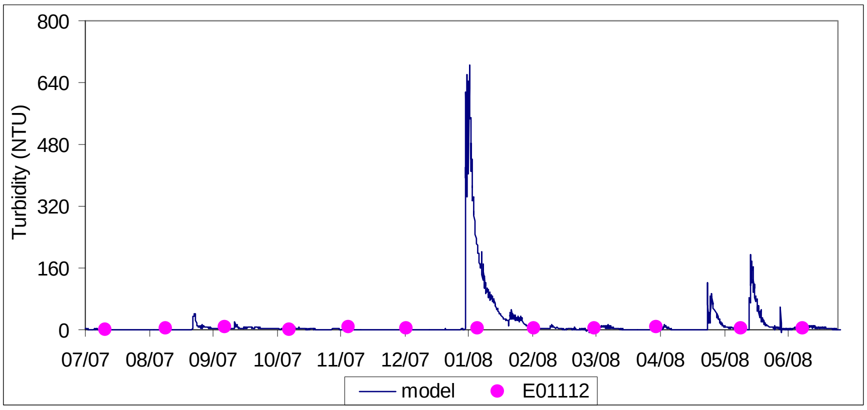

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01119


800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01122

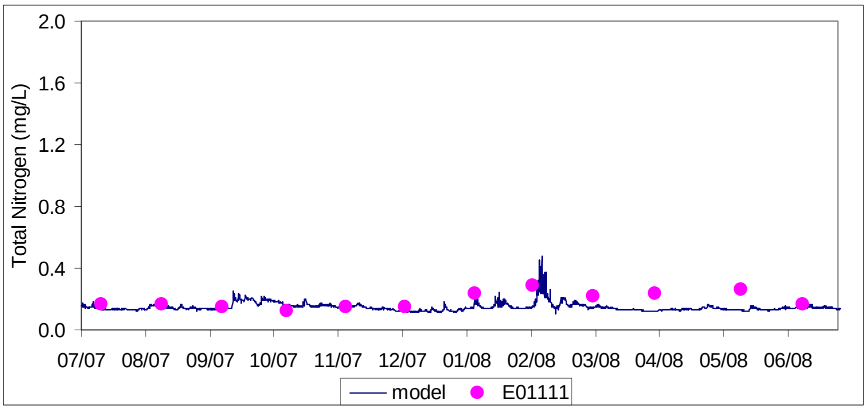

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01102

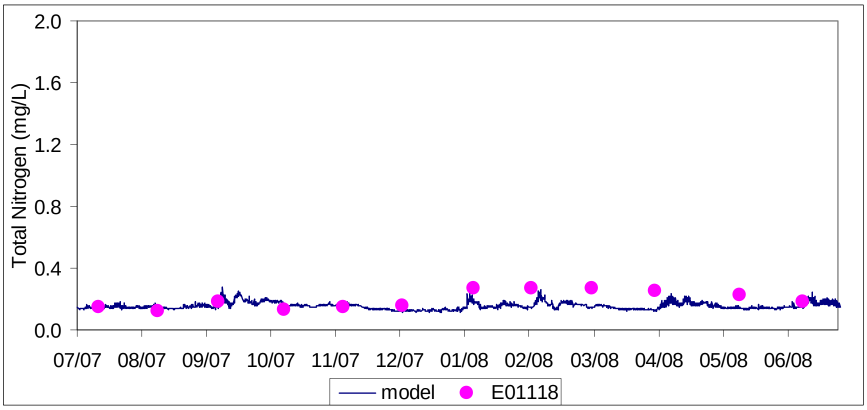

800
640
480
320
160
0
Turbidity (NTU)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01101

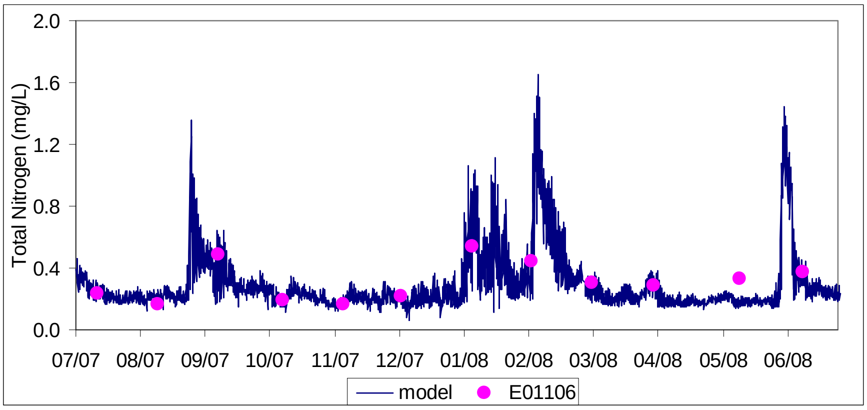


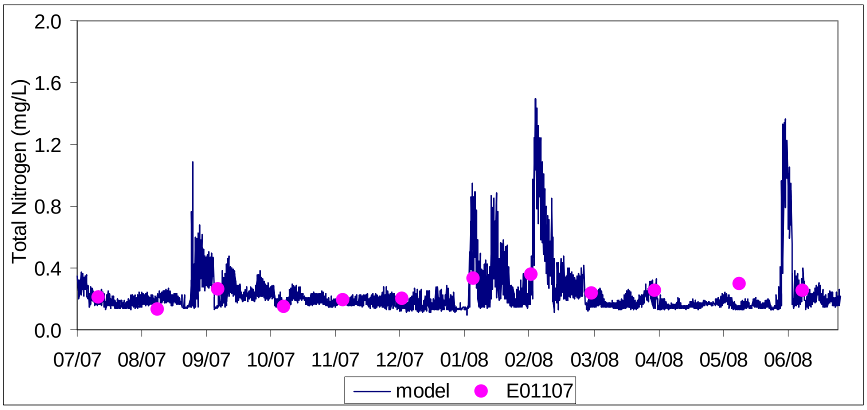


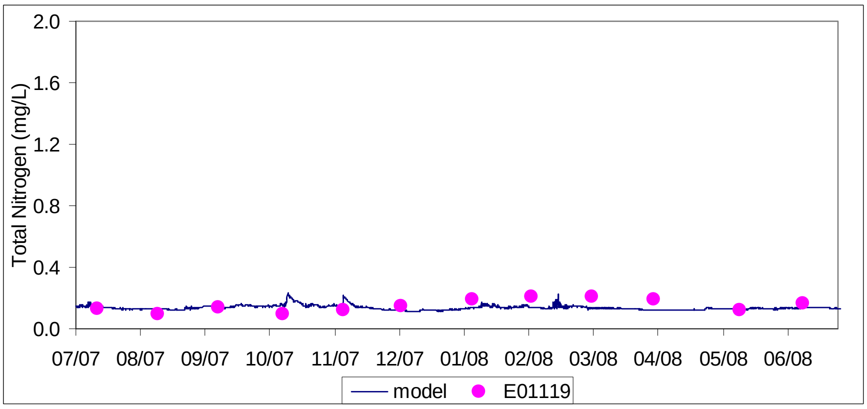
Total Nitrogen

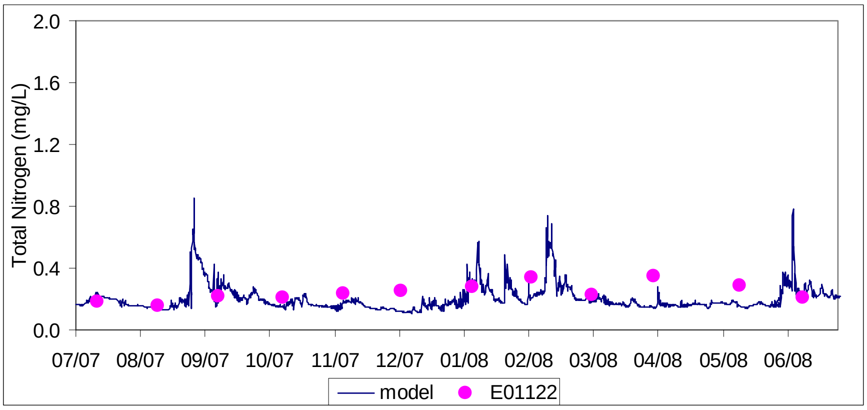


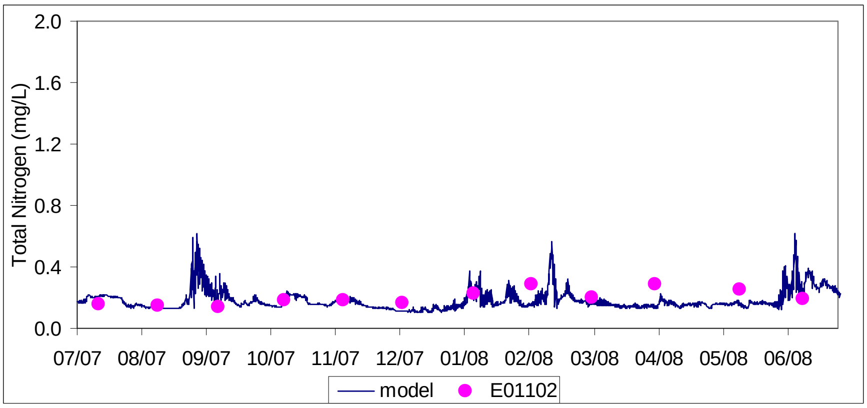


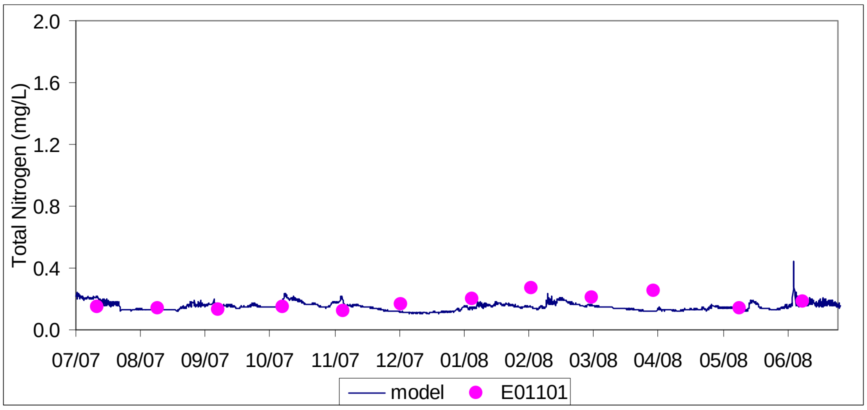

2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01106

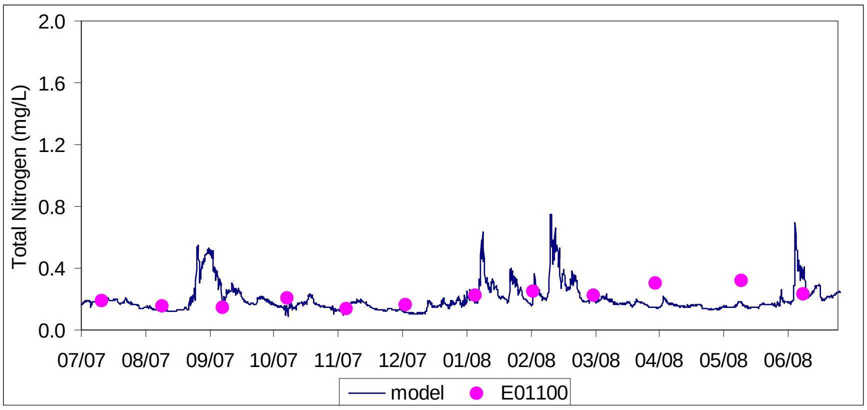

2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01107

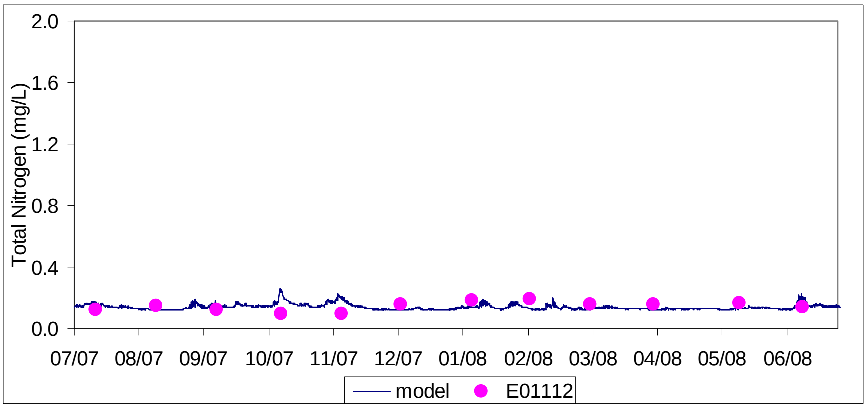

2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01119


2.0
1.6
1.2
0.8
0.4
0.0
Total Nitrogen (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01122

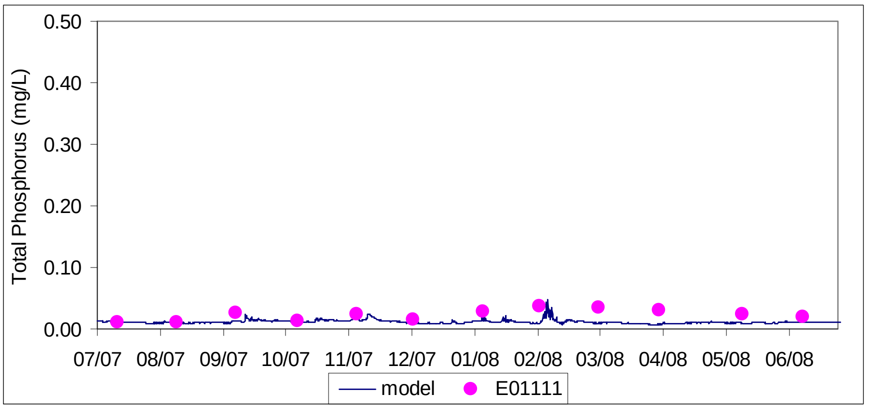

Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01102

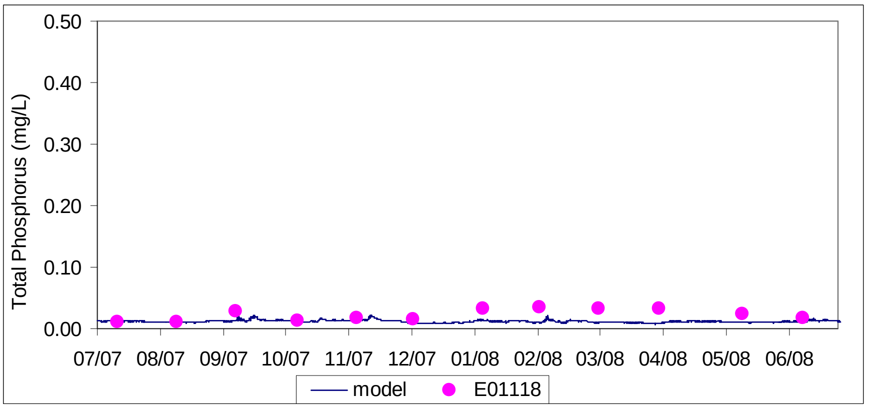

Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01101

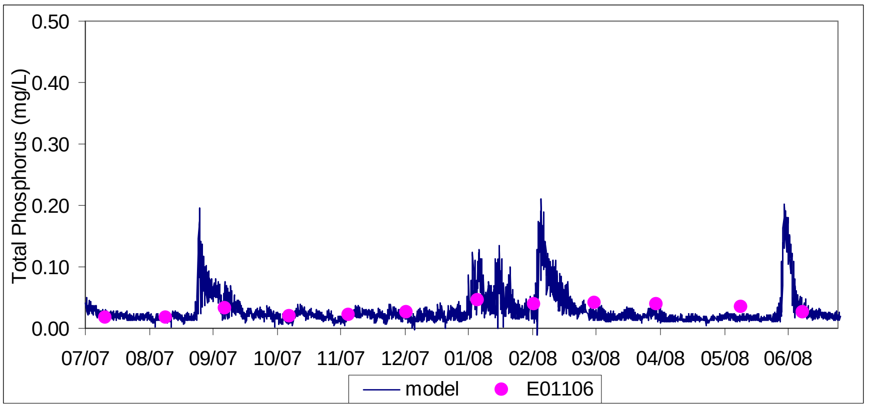

Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01100

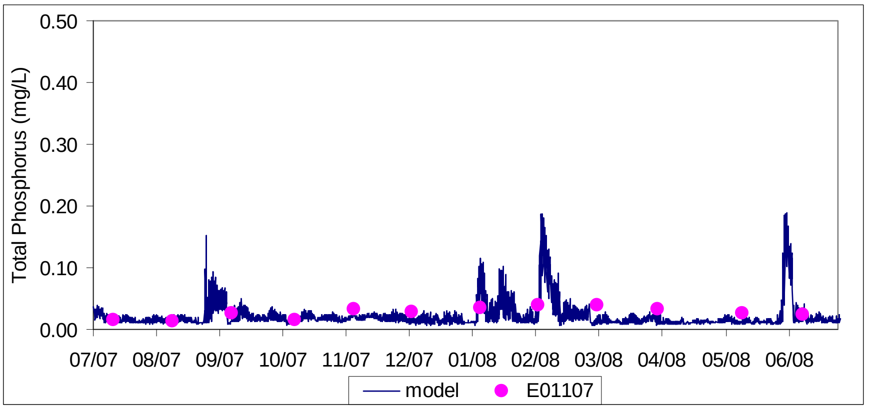

Total Nitrogen (mg/L)
2.0
1.6
1.2
0.8
0.4
0.0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01112

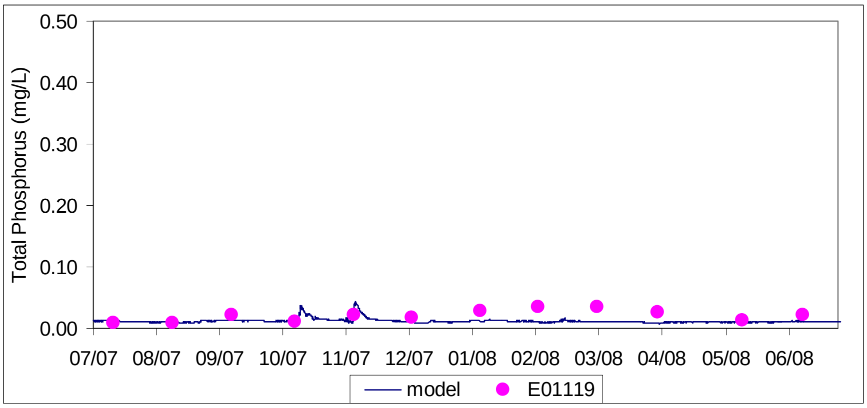
Total Phosphorus

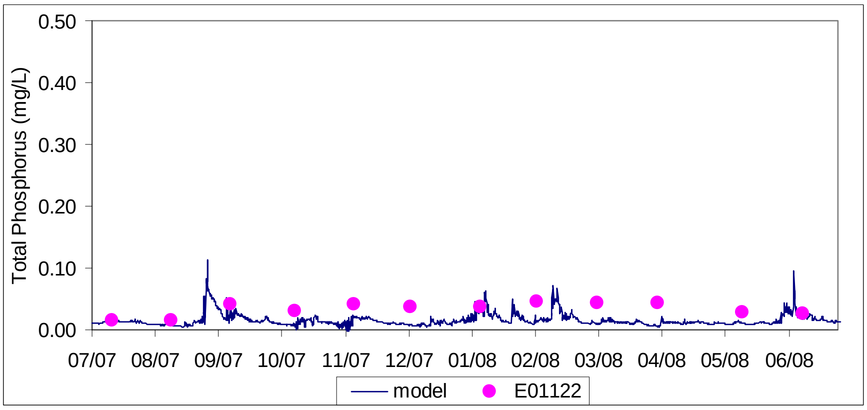


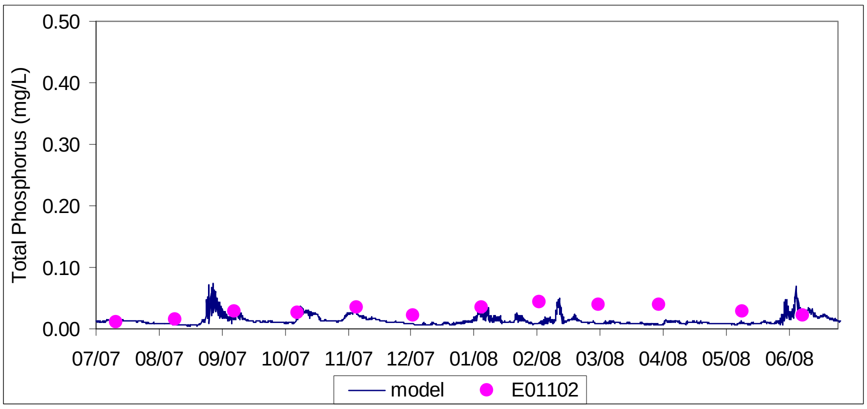


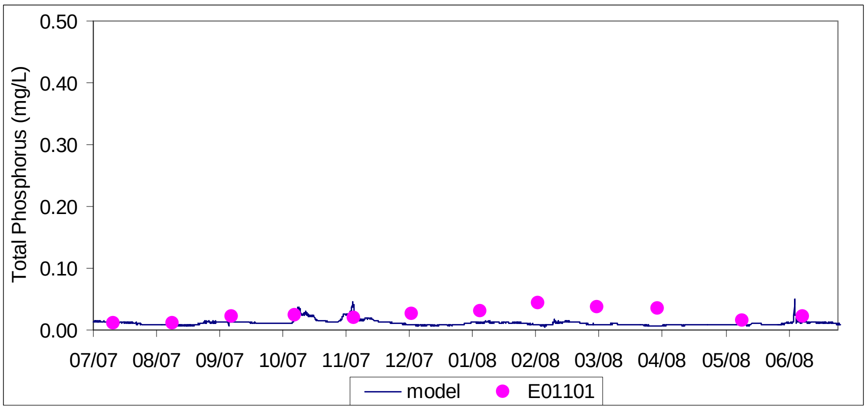


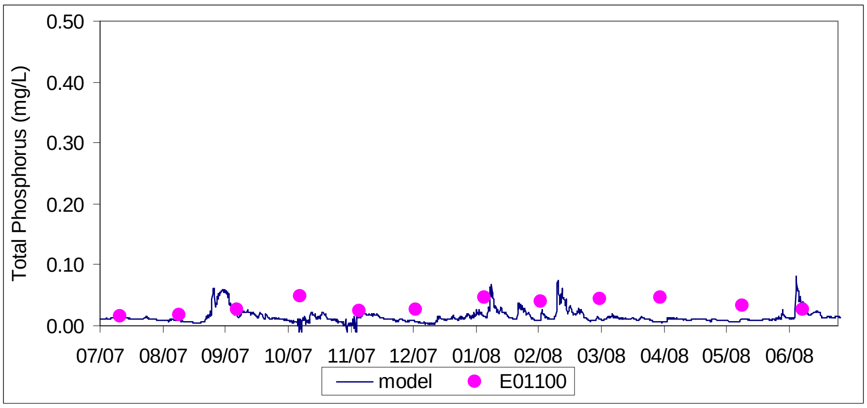


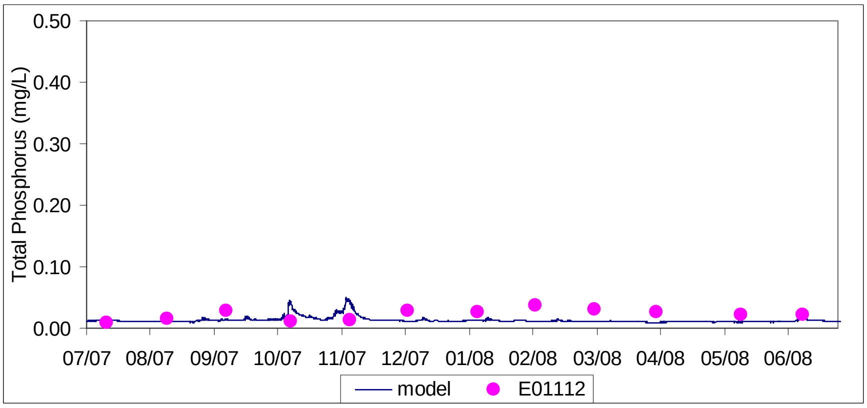

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01119


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01122


Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01102

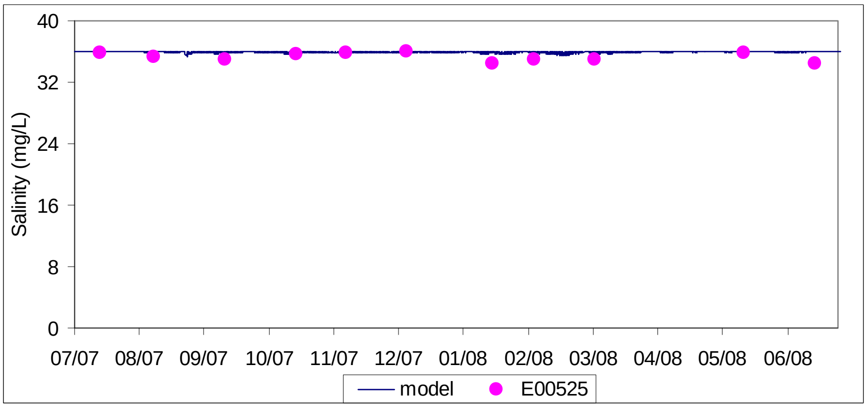

Total Phosphorus (mg/L)
0.50
0.40
0.30
0.20
0.10
0.00
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E01101

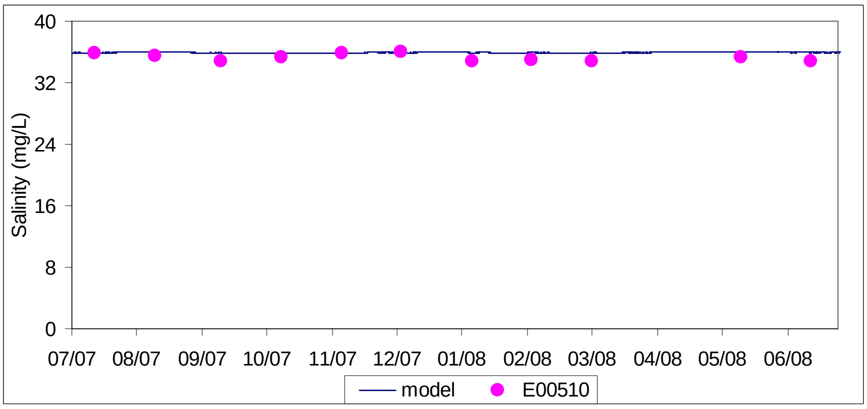


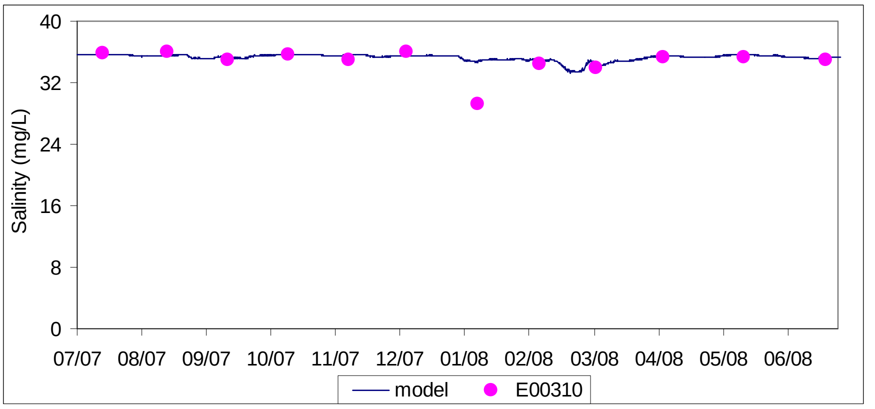


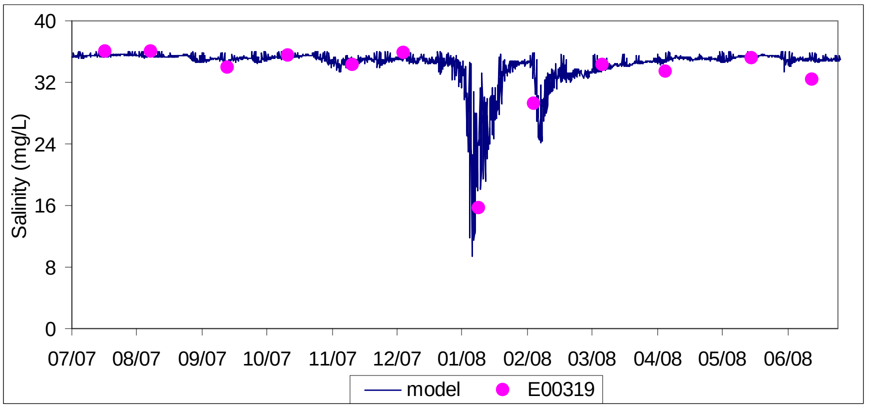
MORETON BAY VALIDATION RESULTS

Salinity

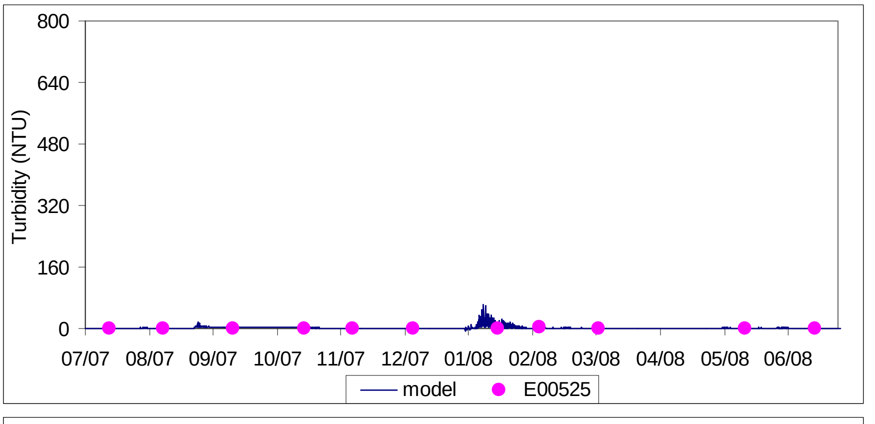


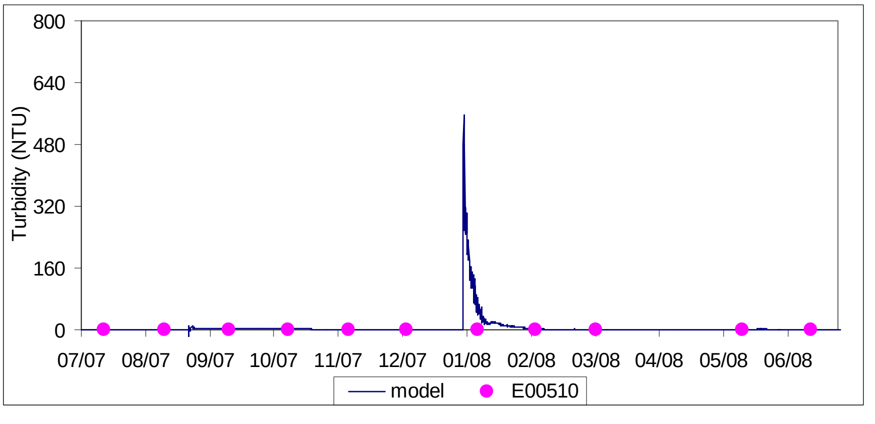


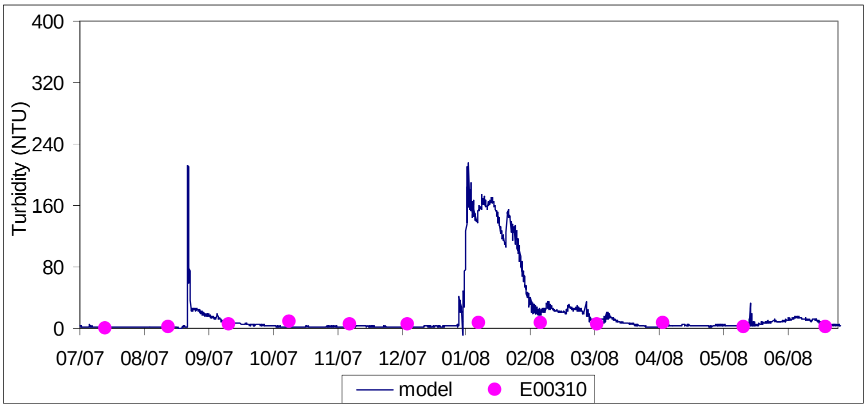

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00310

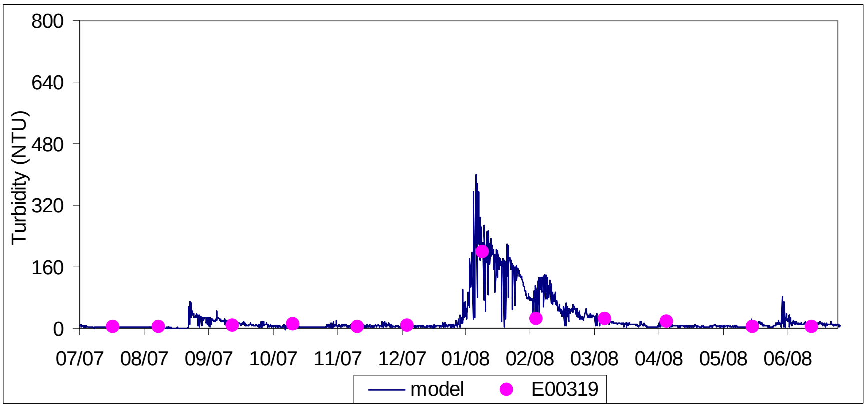

Salinity (mg/L)
40
32
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00319

Turbidity

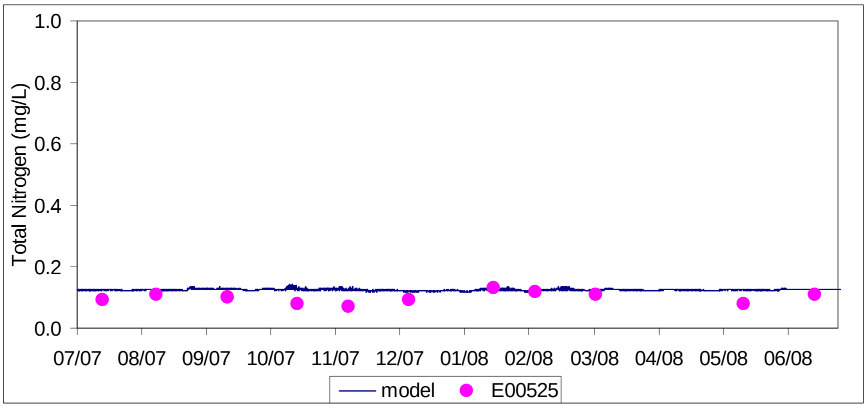

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00525

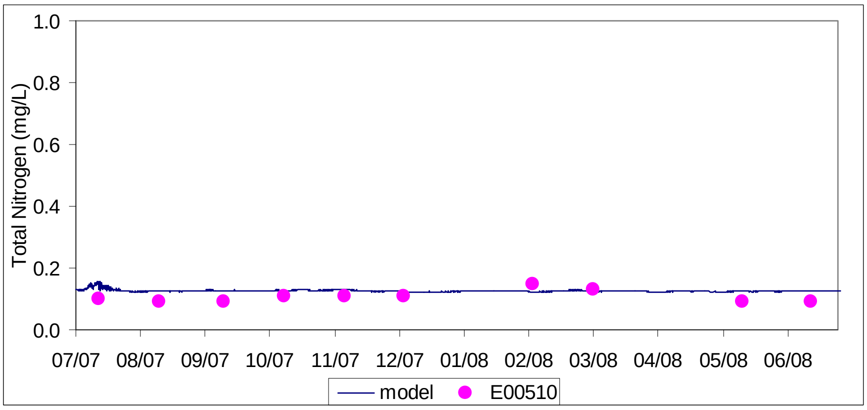

Turbidity (NTU)
800
640
480
320
160
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00510

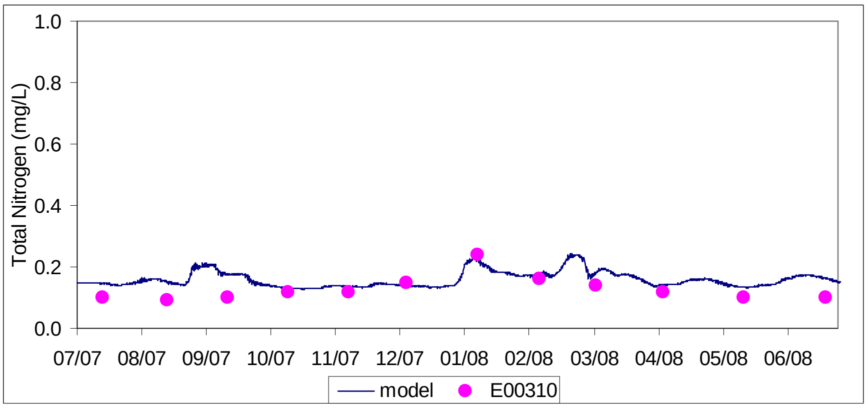


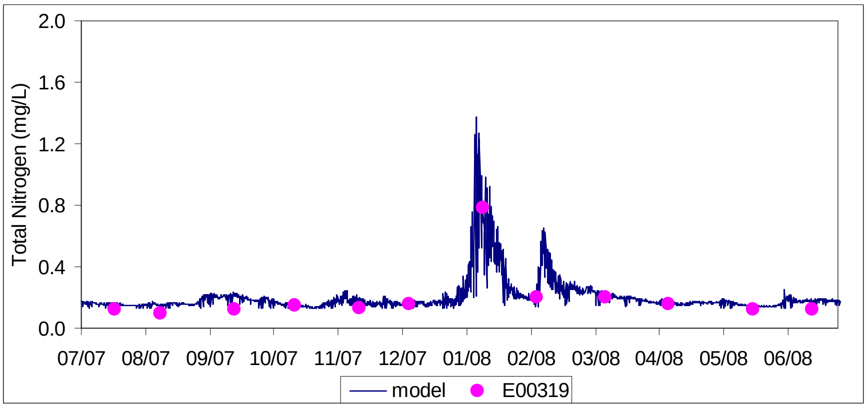


Total Nitrogen

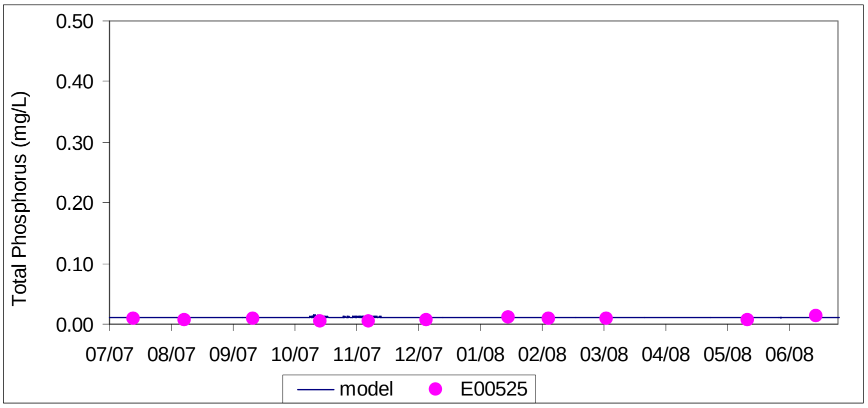


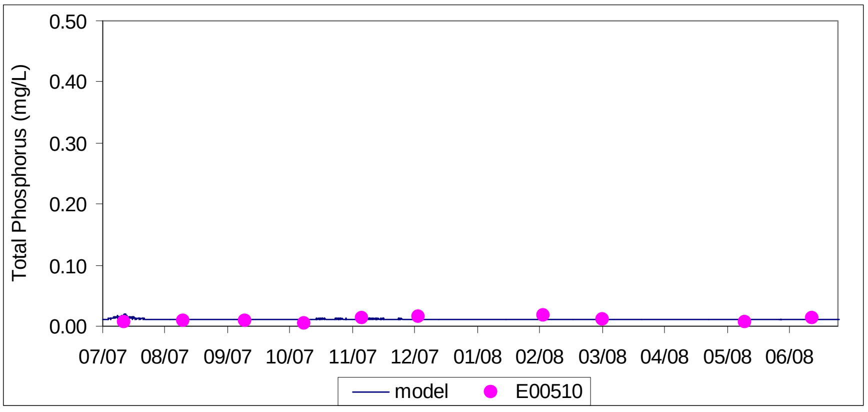


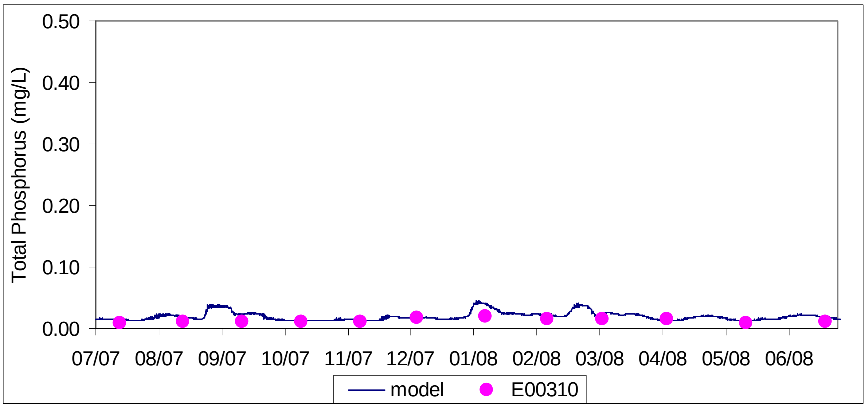


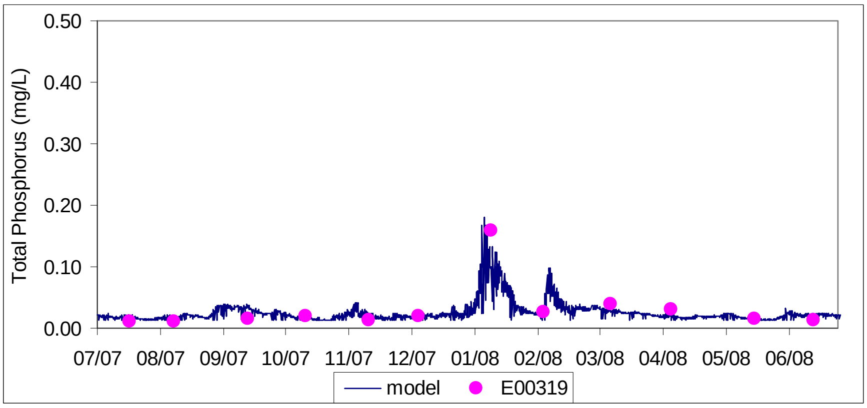


Total Phosphorus



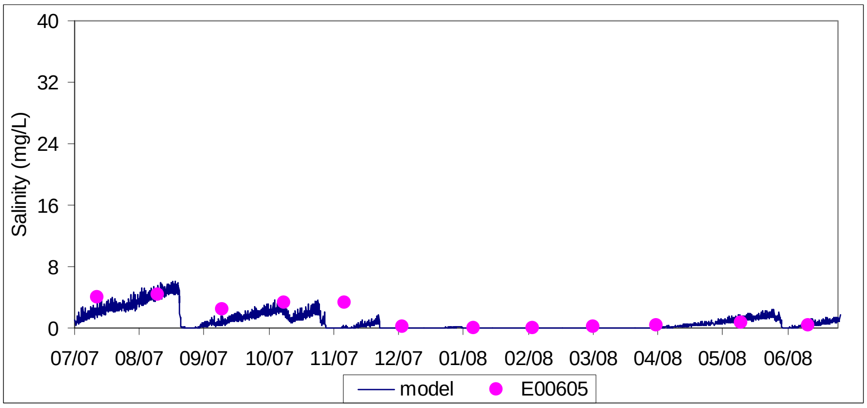


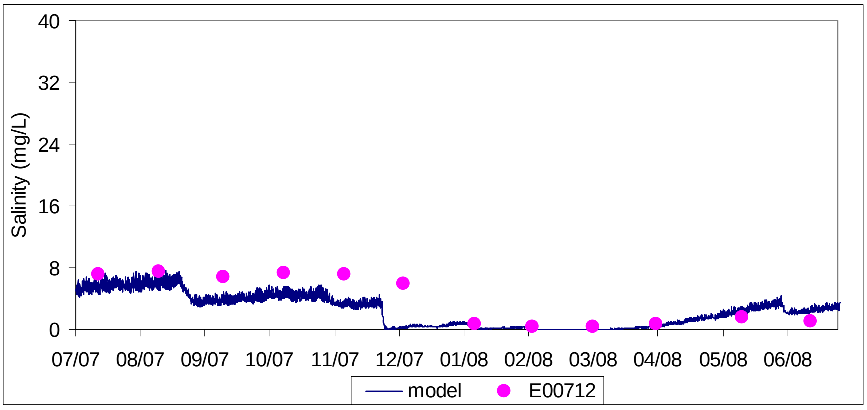


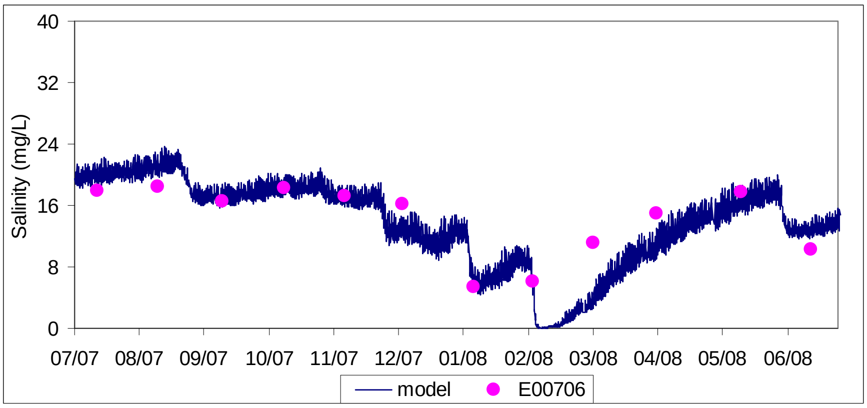


BRISBANE / BREMER VALIDATION RESULTS

Salinity






Salinity (mg/L)
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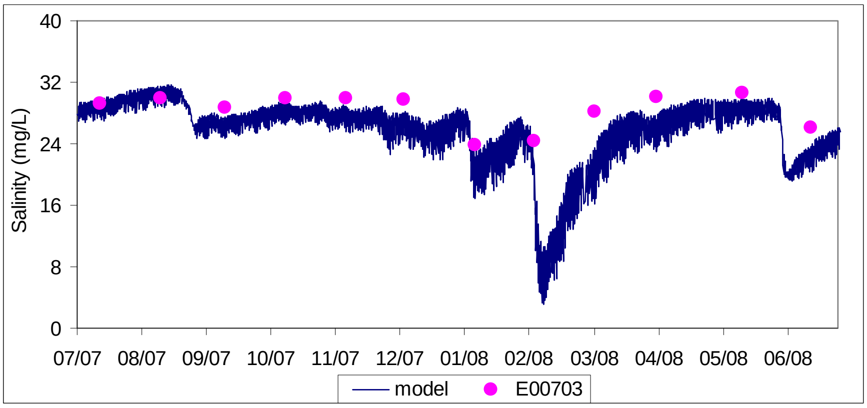
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00706


Salinity (mg/L)
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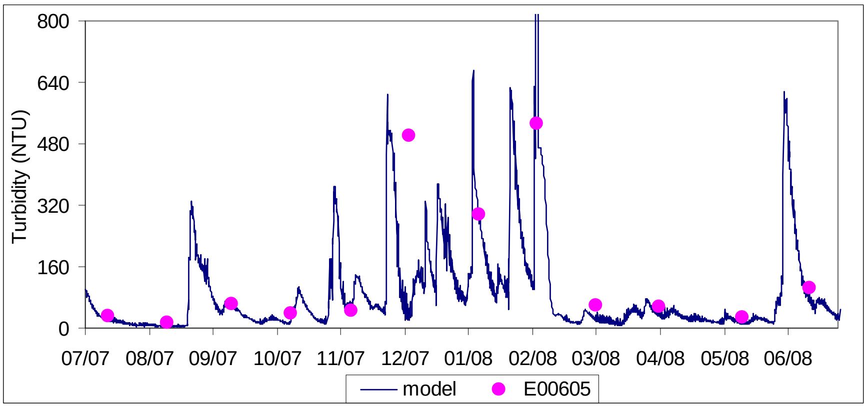
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model
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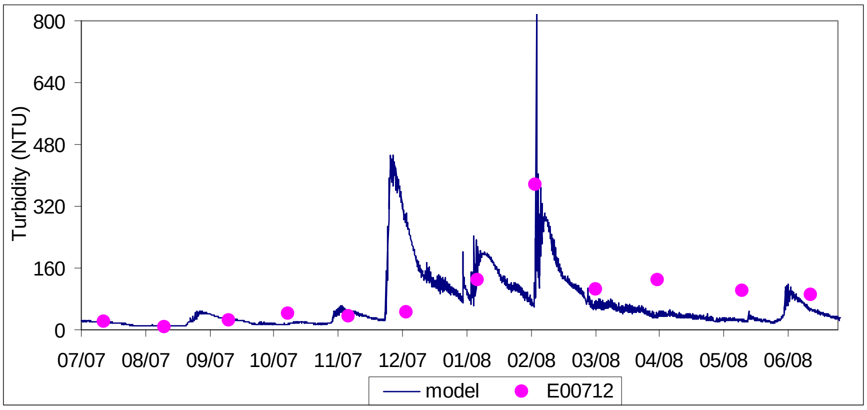
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model
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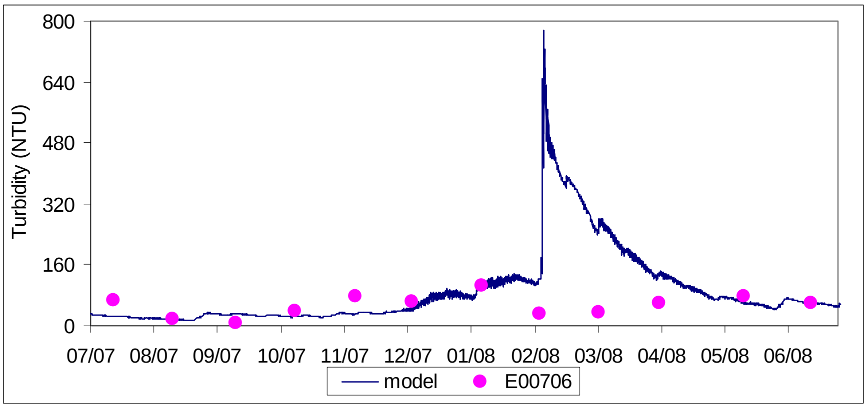

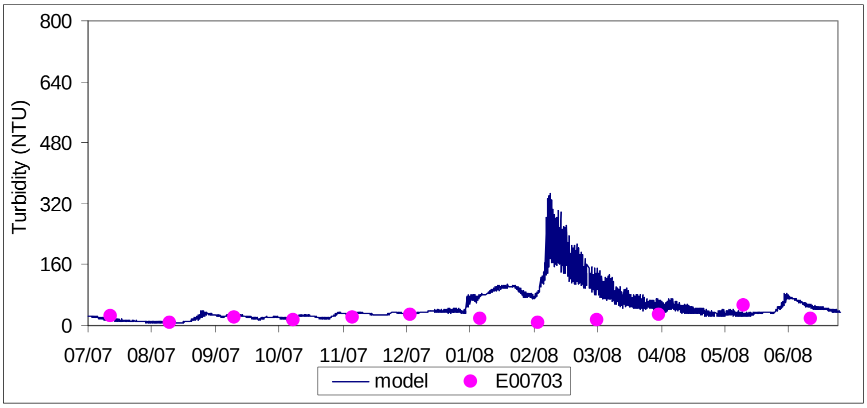

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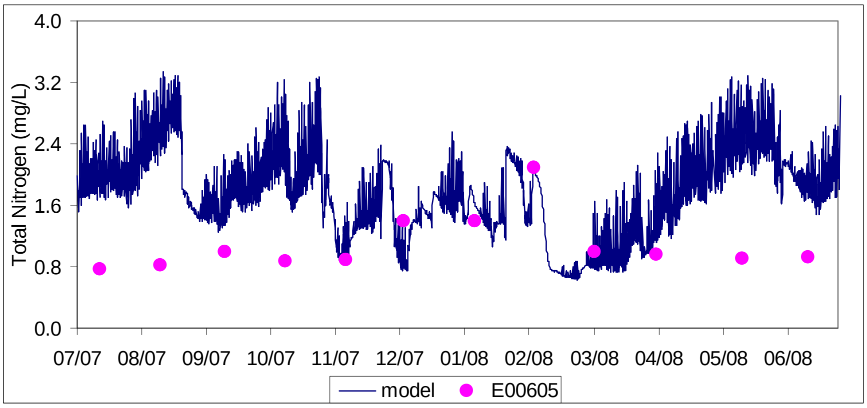

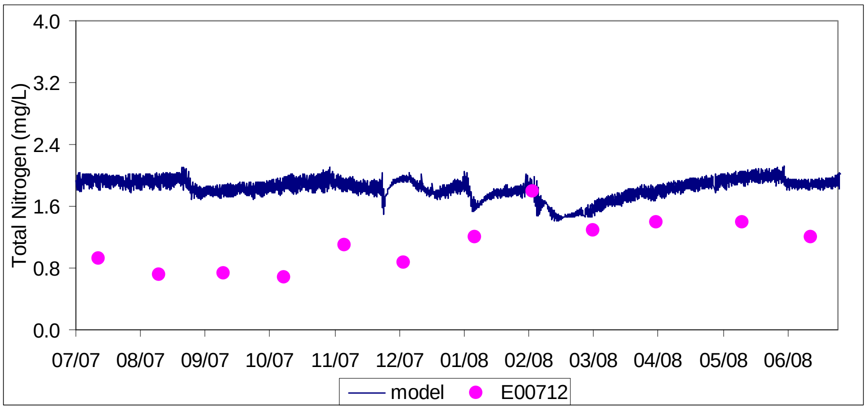

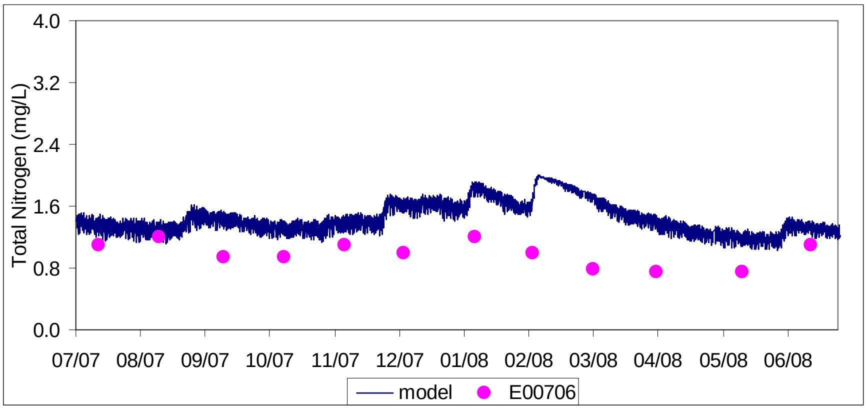

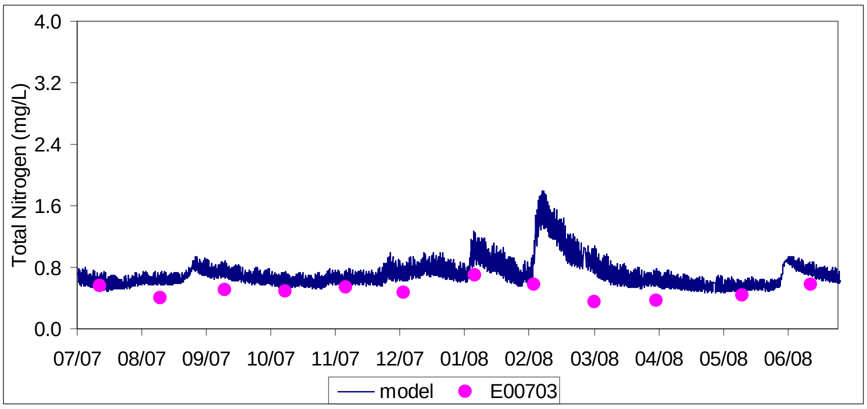

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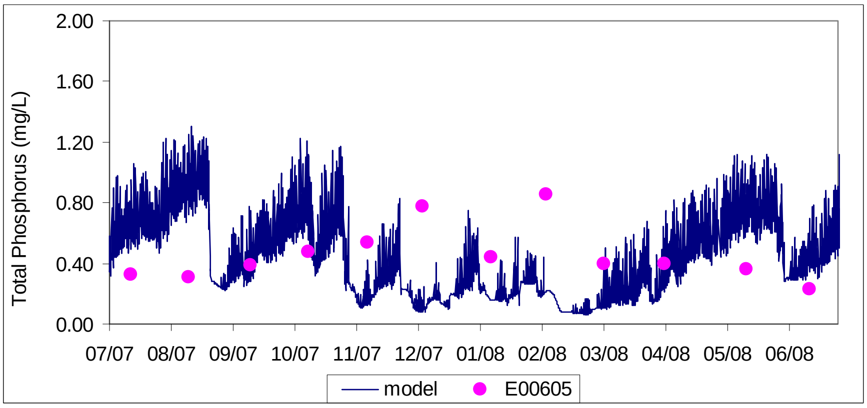
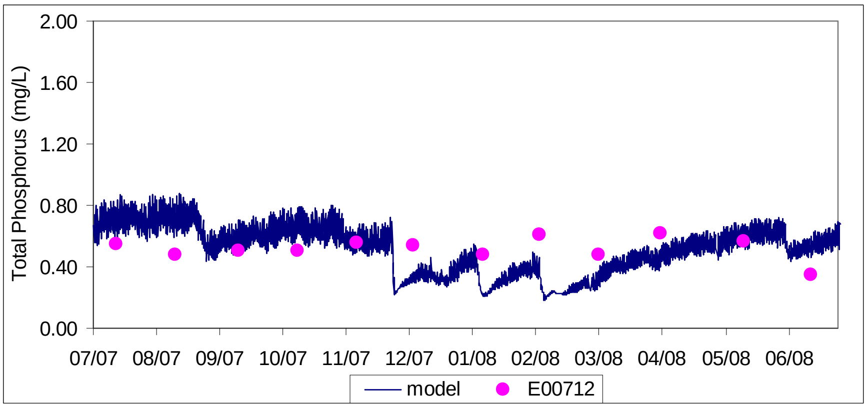
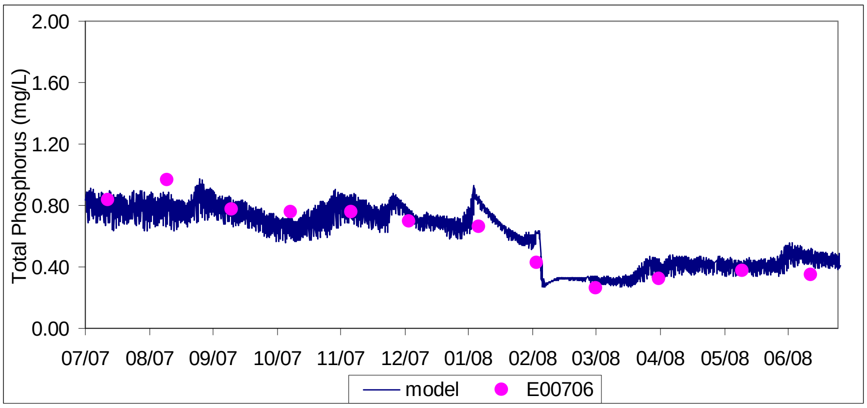
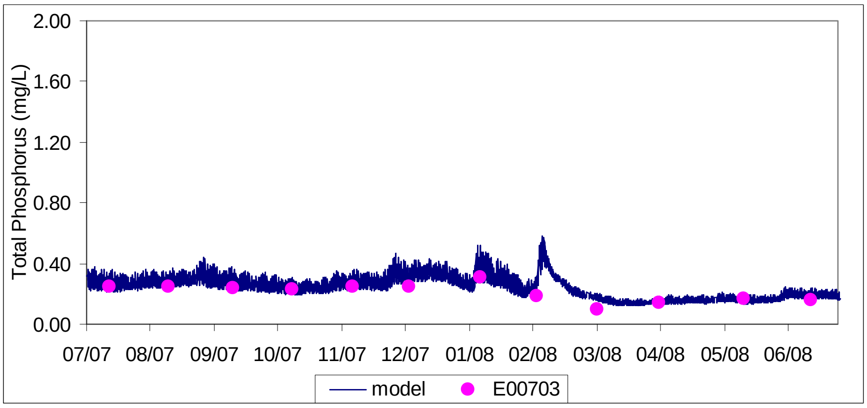


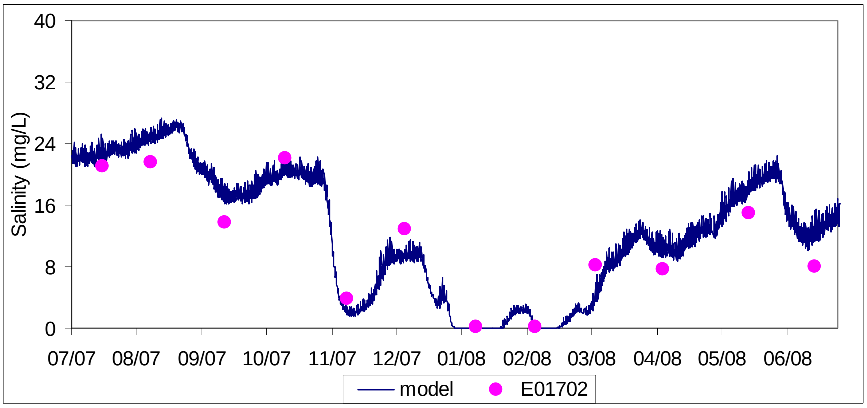


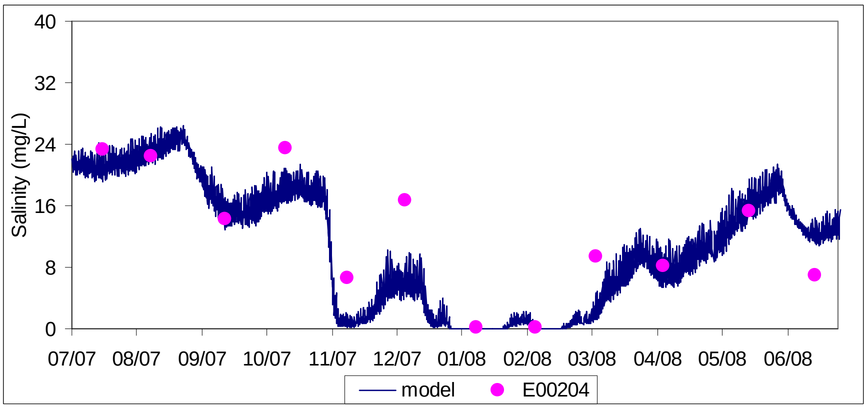


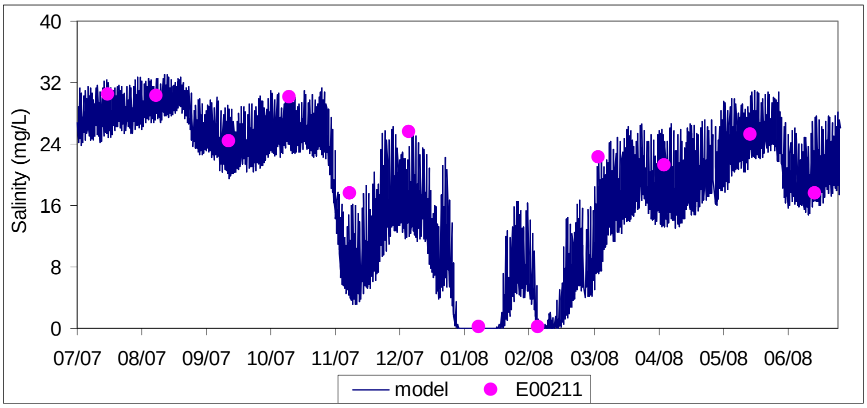


LOGAN / ALBERT VALIDATION RESULTS

Salinity






Salinity (mg/L)
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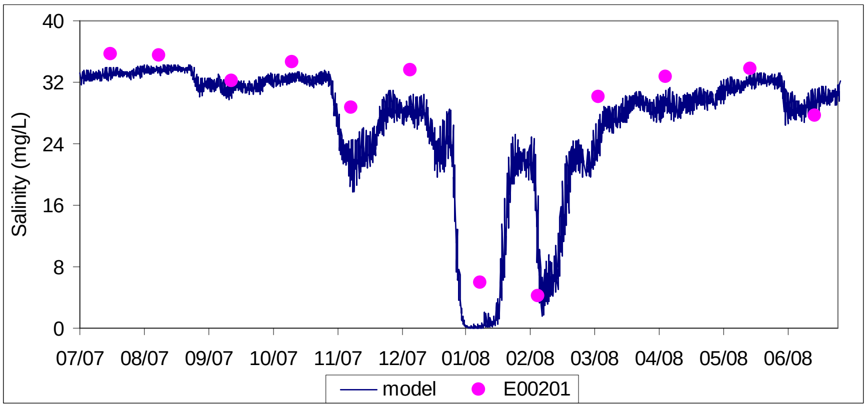
24
16
8
0
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00211


Salinity (mg/L)
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24
16
8
0
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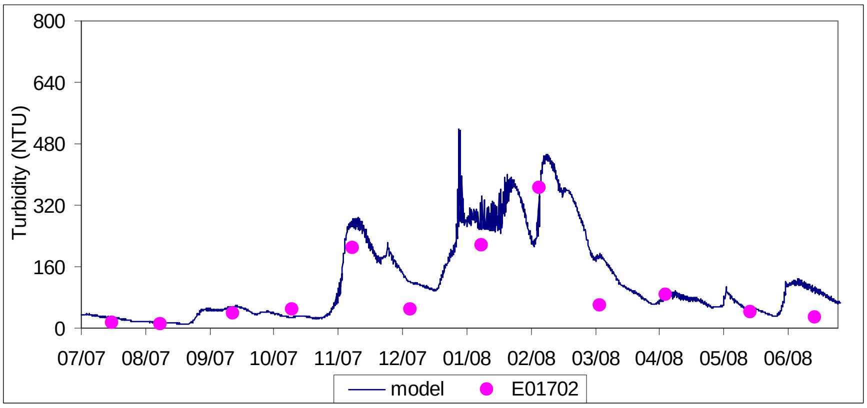
model
E00201

Turbidity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model
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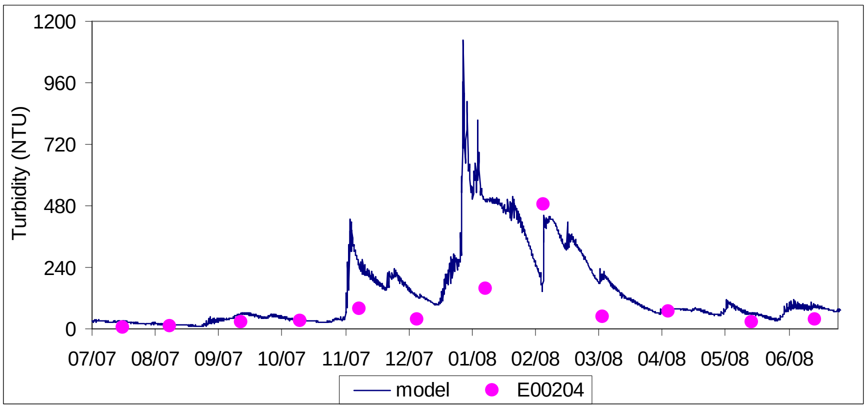
Turbidity (NTU)
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model
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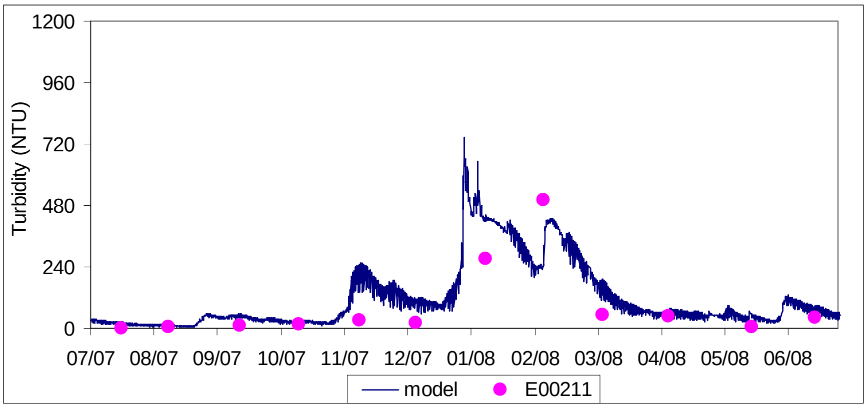

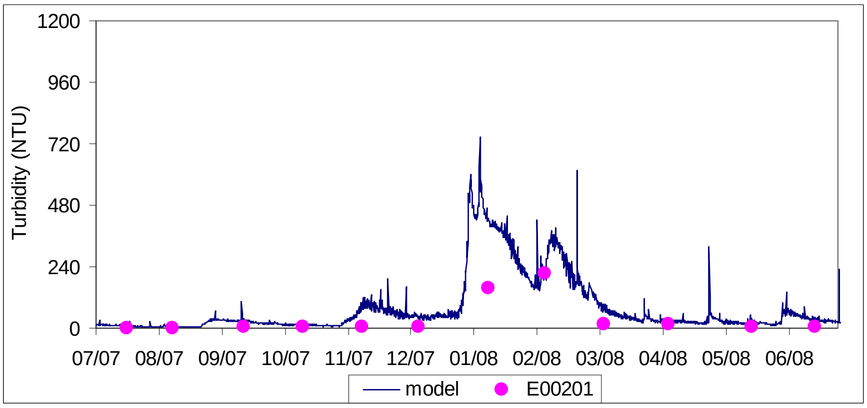

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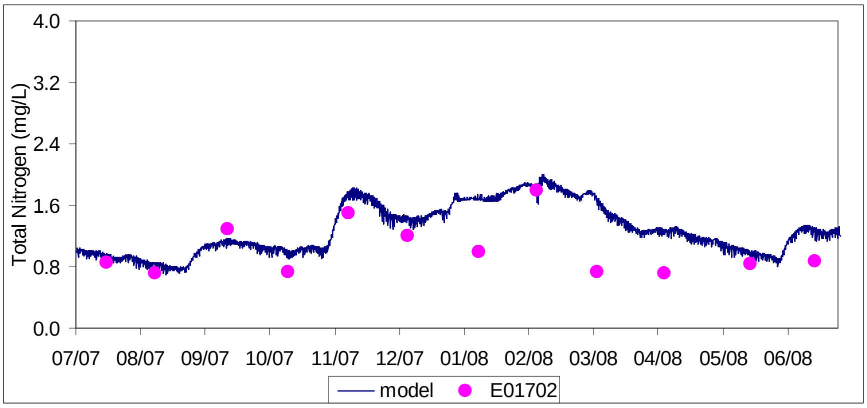
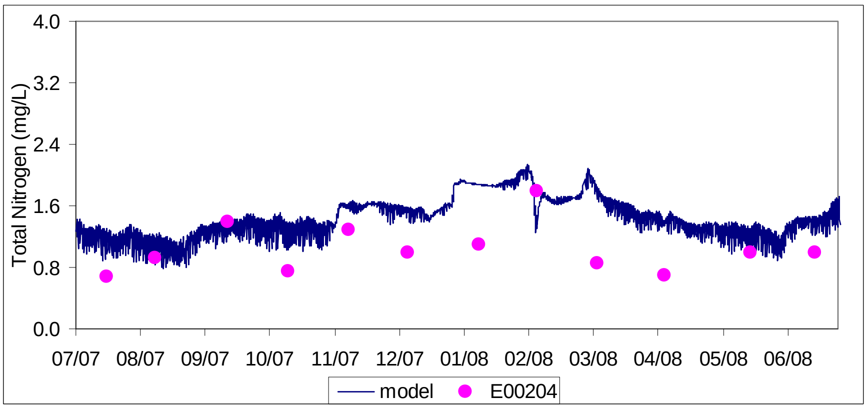
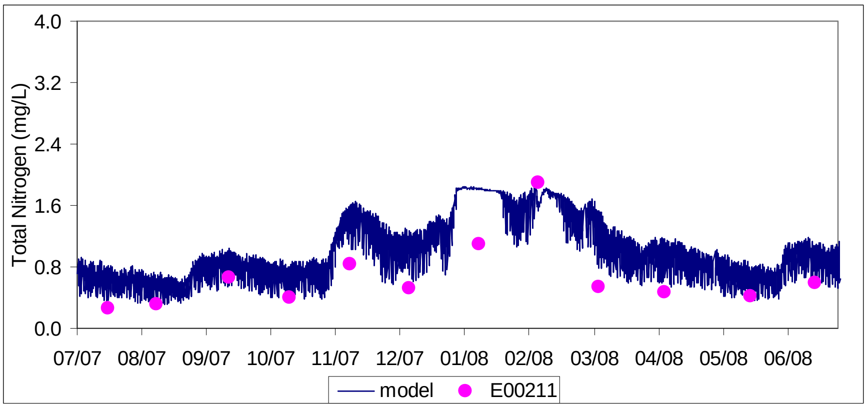
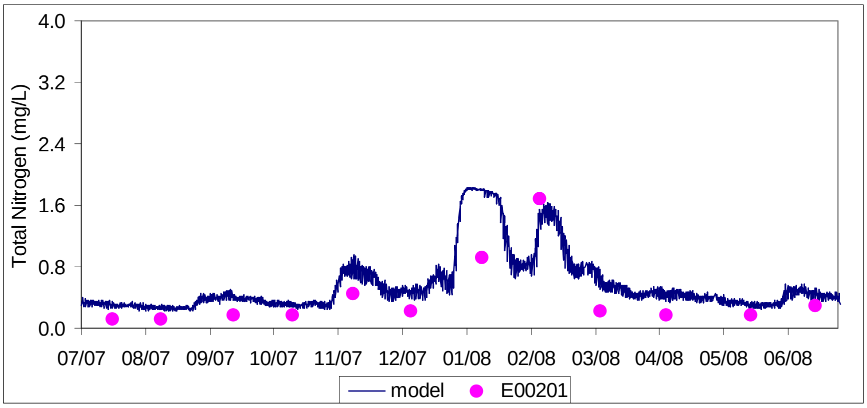
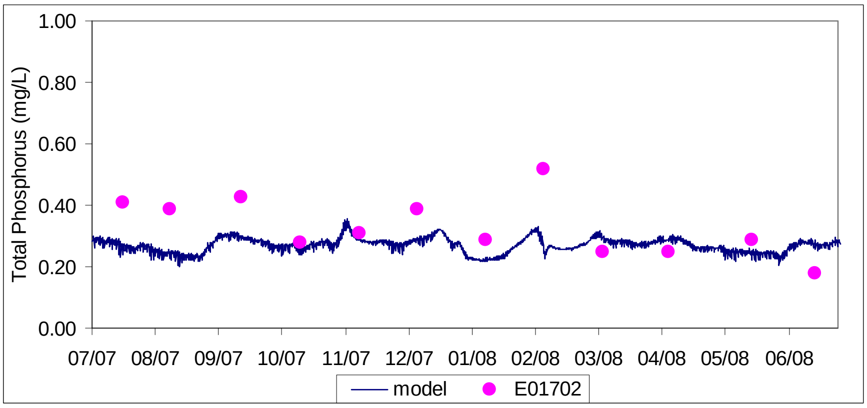


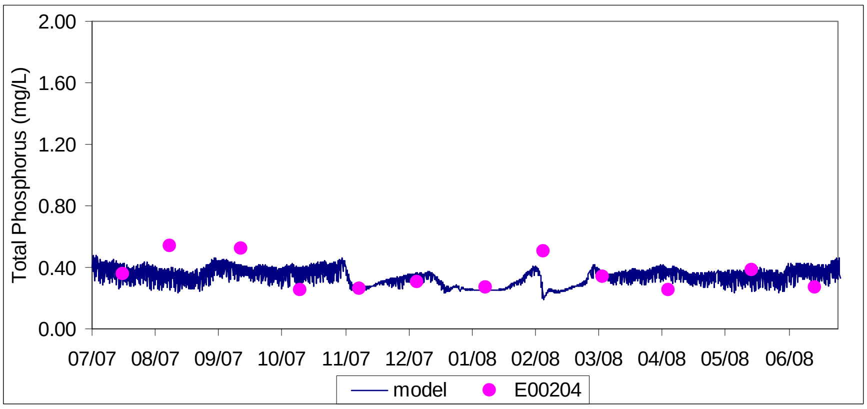


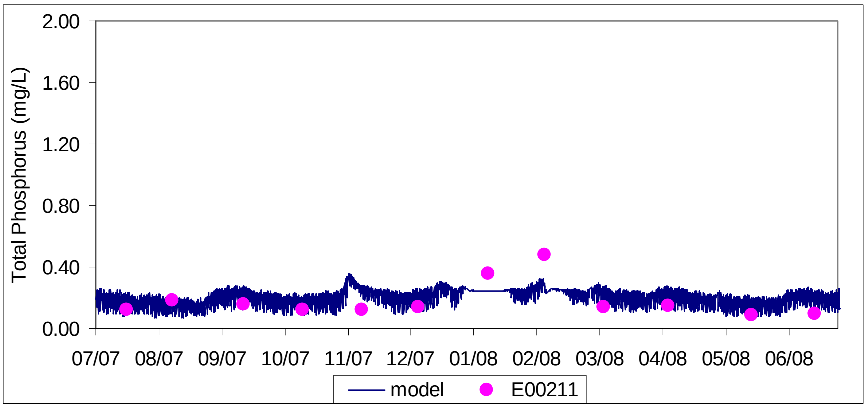


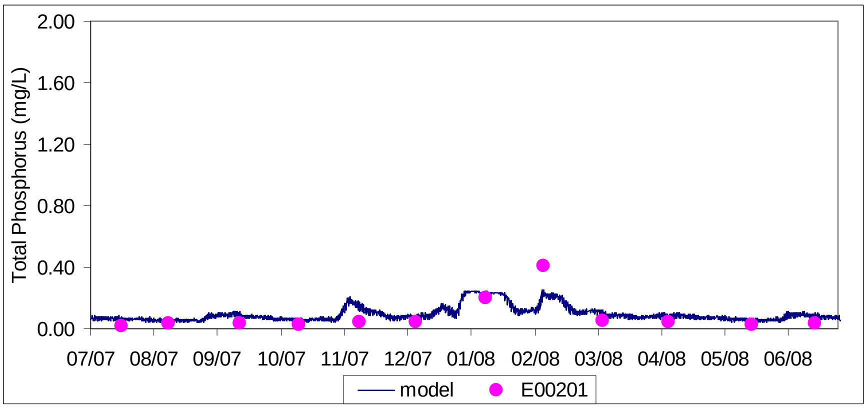


Total Phosphorus






2.00
1.60
1.20
0.80
0.40
0.00
Total Phosphorus (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00211


2.00
1.60
1.20
0.80
0.40
0.00
Total Phosphorus (mg/L)
07/07 08/07 09/07 10/07 11/07 12/07 01/08 02/08 03/08 04/08 05/08 06/08
model
E00201

APPENDIX D: CATCHMENT AND RECEIVING WATER QUALITY MODELLING – UNCERTAINTY ANALYSIS

INTRODUCTION

Uncertainty in mathematical modelling can be described as the degree to which the model and its outputs could differ from the actual system. Model uncertainty is typically introduced through model features such as (Refsgaard et al 2007):

- The theoretical system conceptualisation, e.g., Source Catchments is a lumped hydrological model with a daily time step;
- The technical implementation of the model, e.g., finite difference approximation equations;
- The parameters used to characterise the system, e.g., sediment settling rates or algae growth rates;
- The forcing data used to drive the model, e.g., land use and tidal regimes; and
- The observation data used in calibration and validation, e.g., gauge or water quality monitoring data.

This summary seeks to clarify and quantify the amount of uncertainty contained within the gross elements of the integrated catchment and receiving water quality modelling performed for the Total Water Cycle Management Plan (TWCMP) for Moreton Bay Regional Council. This is largely done through expansion of the discussion regarding the calibration and validation processes, in addition to some additional supplementary background information regarding some of the data.

The interpretations of the uncertainty presented herein provide some measure of the degree of confidence in the possible outcomes or ranges in which those results could reasonably be expected to exist. The first two items of the list above—the theoretical and technical aspects of the models themselves—have been discussed in documentation pertaining to those modelling packages (Bell 1998; Bell and Amghar 2002; eWater CRC 2011), so the uncertainty analysis discussed here focusses primarily on the last three items where practical.

Model calibration and validation are typically used to minimise and characterise the model uncertainties (Hammonds et al 1994), however, due to several circumstances, often relating to the randomness of system variables and input data (stochasticity), or to the temporal variability of the same phenomena, validation cannot explain, reduce or identify all sources and amounts of uncertainty.

CATCHMENT MODELLING (SOURCE CATCHMENTS – SIMHYD)

Hydrologic Calibration and SIMHYD Parameterisation

The calibration of the catchment model was performed and reported on in the Catchment and Receiving Water Quality Modelling report (modelling report) included as an appendix to the TWCMP (See section 2.3). The performance metrics used for the modelling explain as much as possible the variability and uncertainty in the catchment modelling. This includes the input data, such as the climate and storage data and the forcing data, such as the land use data.

Three metrics were used to ensure a robust characterisation of the system. The model was calibrated to:

- Total runoff volume for the entire period of record;
- Monthly runoff volume – to ensure that the longer-term periods are captured correctly; and
- Daily runoff volume – to ensure that the catchment model accurately represented fine-scale model outputs.

For the Caboolture and Pine River catchments, the two catchments in the Moreton Bay region for which flow gauges are used to monitor runoff, the model demonstrated a “good” to “very good” fit of the observed daily and monthly flow rates according to the performance ratings reported in Table 2-4 of the modelling report for gauges 142001A and 142202A. If the NSE coefficient is conceptualised as the coefficient of determination, the model can be considered to account for approximately 70% of the daily variance in the observed data and more than 90% of the monthly volumes for the two Moreton Bay gauges.

While the model was calibrated with high performance metrics for the Moreton Bay gauges, there is uncertainty in the measured flow observations to which the model was calibrated, which will introduce uncertainty into the overall results. This is especially true for large flows because of the increased uncertainty in the rating curves used to assess runoff versus river stage. It is unknown how much this uncertainty affects the overall results of the modelling.

Pollutant Export Rates

The pollutant export rates are perhaps the largest source of uncertainty in the modelling, as the values were used as standard across the model and were not accounted for in the calibration metrics due to a lack of available high temporal resolution data sets that allow for numerical optimisation.

These would likely experience spatial variability indicative of changes in vegetation, soils and land use management practices. Varying export rates according to functional unit accounted for this, however, for example, grazing land export rates may be different between or even within catchments. To account for this, median values based on wide-scale studies of the SEQ region were used. This serves to balance out large differences across the entire model, however, it cannot capture regional variations in export rates.

The median values used in the TWCMP modelling represent EMC/DWCs reviewed and selected as part of the Moreton Bay Water Quality Improvement Plan (WQIP). Included in the reporting of that study, low and high concentrations in addition to median values (WBM 2005), however, the low and high values were not used in the modelling. These values are provided in Table D-1 below. The high values are associated with the 90th percentile median value of all of the sites included, and the low values with the 10th percentile median value.

Table D- 1 EMC and DWC values for South East Queensland (in mg/L)

Functional Use		TSS		TN		TP	
		EMC	DWC	EMC	DWC	EMC	DWC
Green Space	Low	8	3	0.75	0.3	0.015	0.02
	Med	20	7	1.5	0.4	0.06	0.03
	High	90	14	3.75	0.5	0.12	0.06
Grazing	Low	110	5	1.17	0.5	0.128	0.03
	Med	260	10	2.08	0.7	0.3	0.07
	High	600	23	6	0.9	0.77	0.14
Broadacre Agriculture	Low	80	5	0.91	0.5	0.107	0.03
	Med	300	10	1.95	0.7	0.321	0.07
	High	700	23	5.2	0.9	0.803	0.14
Irrigated Agriculture	Low	300	5	2.08	0.5	0.16	0.03
	Med	550	10	5.2	0.7	0.449	0.07
	High	800	23	12.35	0.9	1.177	0.14
Rural residential	Low	40	5	0.9	0.5	0.12	0.03
	Med	130	10	1.6	0.7	0.28	0.07
	High	380	23	4.6	0.9	0.72	0.14
Urban	Low	40	5	0.9	0.9	0.12	0.05
	Med	130	7	1.6	1.5	0.28	0.11
	High	380	27	4.6	2.8	0.72	0.28

To better understand the factors by which each constituent could vary according to Table 1, the percent differences for the low-median and the high-median rates were calculated for each functional unit. These percent differences were then weight-averaged according to the percentage of area for each functional unit in the Moreton Bay catchments (See TABLE 2-1 of the modelling report). These weight-averaged differences are given in Table D-2 below.

Table D- 2 Percent differences for low-median and high-median ranges

	TSS		TN		TP	
	EMC	DWC	EMC	DWC	EMC	DWC
High	252%	134%	169%	34%	130%	106%
Low	-62%	-51%	-47%	-28%	-66%	-45%

Table D-2 indicates that according to the SEQ monitoring data from which the EMC and DWCs were derived local and regional differences in pollutant export values could be 2.5 times greater (in the case of the TSS EMC) or more than two-thirds lower (in the case of the TP EMC) than the value used in the modelling.

RECEIVING WATER QUALITY MODELLING (RWQMV2)

Model Calibration and Validation

The model calibration/validation process was performed on a largely qualitative basis due to the periodic nature in which EHMP data are collected. A qualitative or 'visual' calibration and validation, was deemed appropriate for this study and is similar to the process adopted for the WQIP (WBM 2005). This approach is well within the requirements of the study brief and was considered the most efficient and effective means by which to complete model calibration across all estuaries. It is also the accepted practice within the industry.

The key driver of adopting this approach was the difference in the temporal resolution of the modelled data (2190 points/year/site) and the EHMP data (12 points/year/site). Indeed, regular monthly samples collected at a given location over the course of two years (the calibration or validation period) are more than likely to miss key water quality fluctuations associated with processes such as floods or storms, as the associated monitoring programs are structured to avoid these disturbances to provide a long term data trend rather than indicating extremes associated with these types of events.

As such, statistical comparisons were not deemed necessary for the receiving water quality modelling. In estimating the magnitude of error in the model, however, the 2005-2006 annual medians for both EHMP and modelled data were compared within the 4 of the main waterways in Moreton Bay. These comparisons, presented in consisted of average percent differences between the EHMP and model data. The model under-predicted results in the instance of a negative difference, and over-predicted in the case of a positive difference.

Table D- 3 Percent difference in EHMP and model 2005/06 annual medians

	Waterway	Minimum	Average	Maximum
TN	Caboolture	-18%	-4%	13%
	Pine River	-41%	21%	137%
	Bramble Bay	39%	50%	65%
	Deception Bay	-22%	-17%	-12%
TP	Caboolture	-41%	-8%	37%
	Pine River	-63%	-43%	14%
	Bramble Bay	-4%	6%	27%
	Deception Bay	-69%	-66%	-64%
Turb	Caboolture	-74%	-37%	20%
	Pine River	-79%	-38%	11%
	Bramble Bay	-59%	0%	95%
	Deception Bay	-69%	-64%	-59%

Based on the values in Table D-3, it appears that the model is generally under-predicting constituent concentrations in the key waterways. More detailed examination of the calibration and validation plots suggest that the model is generally capturing the behaviour of the estuary's responses to catchment inflows and loads.

It should be noted that the EHMP data to which the model was calibrated have some measurement uncertainties. Harmel et al (2006) estimate the cumulative probable uncertainty for nutrients to be between 10 to 30% for sampling and/or laboratory analysis errors under typical conditions.

Scenarios and Results

Because of the differences between the modelled and EHMP values, it was decided that analysis of the scenarios would be performed on the percent by which a scenario changed the existing conditions. This was also necessitated by the fact that scenarios were compared to the future development case, for which no EHMP data existed. Further rationale and description of this process is summarised in Section 4.5.2 of the modelling report.

The intent of the adjustment process was to remove the bias by which the model over- or under-predicted in-stream concentrations , and normalise the modelling results with regard to location within and between estuaries. This process undoubtedly introduces conceptualisation uncertainty into the analysis, however, it is unknown the degree to which this is the case.

Finally, it should be noted that In the case of turbidity, model results were converted from the input-outputs form of suspended sediments to turbidity by multiplying the suspended solids by a factor of 2.55. While this value was selected based on a thorough review of available regionally specific reports and data to ascertain a relationship between suspended solids and turbidity, data collected in varying locations and times were highly divergent (WBM 2005). This scalar relationship, similar to the pollutant export rates is an example of a single value representing what is likely a complex and varied relationship.

DISCUSSION

This summary attempts to define and characterise the uncertainty within the modelling for the TWCMP as quantitatively as is practical. While this summary attempts to quantify the uncertainties of certain components, it would be very time intensive to determine the manner in which these uncertainties propagate through the modelling process.

It is unlikely that most if any uncertainties would follow simple additive or multiplicative rules given the various model system conceptualisations. For example, while the SIMHYD rainfall-runoff model in Source Catchments is comprised of many linear relationships, there are also exponential and power relationships, such as the infiltration capacity of soils. Similarly, the nitrogen cycle is made up of numerous subroutines that characterise nitrification/denitrification that are not linear. While determining how each uncertainty contributes to the overall uncertainty of the model and scenario results is possible, it is an immense task.

Therefore, determining the overall quantitative model uncertainty is not practical at this time without significant additional investment. It is possible that in some locations, the uncertainty regarding the pollutant exports propagates though the model in a mostly linear fashion contributing to a wide range of possible outcomes for each of the modelled constituents at each of the locations, however in comparative terms, the different scenario outputs would maintain their validity. Models themselves should only be considered as tools for supporting decision making processes. As such, the catchment and receiving water quality models for MBRC have proven extremely useful to refine the scenario assessments and allow reasonable numeric comparisons to be made.

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