Motueka Forest sediment study:

data report July 2006-June 2008 and analysis of sediment yield

prepared for

Landcare Research Ltd and Tasman District Council

by

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Providing Service and Solutions in Hydrology and the Environment

Contents

Executive Summary

Turbidity sensors and auto-samplers were installed at three sites in the Motueka Catchment on the west bank for the Integrated Catchment Management Programme. These sites are at Little Pokororo at Recorder, Big Pokororo at Recorder and Herring at Recorder. Continuous turbidity and auto sediment samplers commenced in 2006/2007. The collection of auto-samples has enabled calibration relationships to be established that relate turbidity to suspended sediment concentration (SSC) for all three sites. Subsequently a SSC time series has been derived, allowing the calculation of sediment yields. The sediment yields have then been compared to previous years (1997 to 2001).

1. Introduction

Envirolink Ltd were contracted in September 1994 by Rayonier NZ Limited to carry out hydrological monitoring of the streams draining forest catchments in the Motueka Forest, to determine any impacts of forest harvest operations on these streams. At this stage Rayonier owned and managed the Motueka Forest in the northern and western foothills of the Motueka district. The Motueka Forest encompasses, the Kaiteriteri, Marahau and the West Bank Forests, but at this point in time, monitoring was confined to the Kaiteriteri Forest.

In October 1996, a similar monitoring programme was established in the Little Pokororo and Big Pokororo catchments within the West Bank Forest, using an adjacent catchment (Herring Creek) as a reference site. Shortly after the West Bank monitoring network was set up, it was decided to combine the two networks into one for reporting purposes, and to entitle the programme 'The Motueka Forest Hydrological Study'.

The Motueka Forest contains large areas of erosion prone Separation Point Granites, coupled with significant areas of steep topography. The focus of this study was on the risk of accelerated erosion resulting from the removal of groundcover and the stability of soils during and after forest harvesting activities. Rainfall events on such exposed soils can lead to runoff, earth slippage and stream bank slumping; factors that have been proven to impair the clarity and the sediment concentrations in streams. Table 1.1 summarises catchment characteristics.

In April 2000 Rayonier NZ Ltd relinquished its forest harvesting rights to Renewable Resources Ltd at which point, the monitoring programme ceased. The continuation of flow records is particularly important to establish trends over time and to record the characteristics of each stream during extreme events, i.e., floods and droughts. For this reason, Envirolink Ltd approached the Tasman District Council and Landcare Research to seek financial assistance to maintain and service the water level recorders. A token grant was donated by TDC to maintain the water level recorders and Landcare Research supplied an automatic sediment sampler for the site located on the Kaiteriteri stream. As a result, little water quality information is available from these sites for the period April 2000 to April 2002, as all resources were dedicated solely to the maintenance of flow records.

In October 2002, Carter Holt Harvey was contracted to manage the forest harvesting rights within the Motueka Forest and Envirolink Ltd resumed the water quality monitoring along with the flow records as specified in the original programme set-up for Rayonier NZ Ltd.

In the 2006/2007 year, suspended sediment monitoring commenced at Little Pokororo at Recorder, Big Pokororo at Recorder and Herring at Recorder as part of the West bank monitoring. The aim of the data collection now to compile continuous records of suspended sediment concentration (SSC) for all three sites. The SSC records will be used to compute sediment loads during runoff events and long-term yields.

The measurement strategy has two main components:

- to continuously record back-scatter-type turbidity as a surrogate for SSC
- to collect samples using automatic samplers in order to compile calibration relationships between turbidity and SSC beside the sensors

This report describes the installations, the data that has been collected from July 2006 to June 2008 and compares to the results obtained prior to July 2006, and the turbidity/suspended sediment concentration relationships developed.

1.1 Geology

The Pokororo Block drainage system is made up of five major catchments, namely Shaggery River, Rocky River, Herring Stream, Big Pokororo, and Little Pokororo River, all draining from the Mount Arthur Range in the west into the Motueka River. The catchments range in size from 8 to 23 km^2, with the total drainage area amounting to approximately 50km^2.

The Pokororo Block consists predominantly of Separation Point Batholith (Separation Point Granites). These granites are situated in the lower half of the catchments and tend to weather readily to a white sandy soil (Grindley, 1980). Rocks in this region are very unstable and prone to severe erosion (Hall, 1996), even moderate rainfall events cause the stability of the soil to decrease markedly.

The upper reaches of the catchments consist of Arthur Marble, Brooklyn Diorite, Pokororo Pyroxenite, Campbell Gabbro and a small amount of Onekaka Schist. Grindley (1986) noted that the marbles in this area were low grade, mostly fine-grained, with inter bedded micaceous and muddy layers. The Diorites, Gabbros and Pyroxenites belong to the Riwaka group is relatively stable, in comparison to the other rocks present in the catchments.

There are three types of soils present on separation point granites, those being Kaiteriteri Sandy Loam, Kaiteriteri Hill Soils, and Pokororo Steepland Soils. These soils give way to Pikikiruna, Haupiri and Brooklyn Steepland Soils at higher altitudes. The lower altitude soils are normally more erosion prone and less fertile than their upland counterparts (Fahey and Coker, 1989).

1.2 Forest Management

Big Pokororo

Development work was well under way in the Big Pokororo catchment when the monitoring programme commenced in December 1996. This was mainly roading development, with some harvesting in the lower reaches of the catchment. Harvesting stepped up in 1998 with 62 ha clearfelled in this year and a further 100 ha in 1999.

Since October 2002, Carter Holt Harvey has managed the Motueka Forests and re-commenced harvesting in the Big Pokororo Catchment in November 2003. Approximately 13 hectares of forest was salvaged and 40 hectares clearfelled in the period November 2002 to August 2003. Several kilometres of road maintenance and upgrade was also carried out. The majority of the catchment was replanted from 1999 to 2004. A windthrow event in October 2005 caused major damage across the Nelson region with damage in the three catchments to differing degrees. Most damage in Big Pokororo catchment was in the eastern compartments, where salvage took place in 2006.

Little Pokororo

Harvesting operations began in Little Pokororo catchment in 1997, and continued progressively until the cessation of ownership by Rayonier Forests in 2000. The majority of the catchment was replanted from 1997 to 2001. Several hectares were uprooted in 2005 due to the windthrow event, but were inaccessible to harvest. Subsequently, natives and pine seedlings are regenerating in these damaged areas.

Herring

Herring had no forest activity post the initial study of 1997. As this catchment was planned to be the reference catchment, no harvesting was planned to this date. However, the 2005 windthrow event meant the majority of the catchment was harvested in late 2005 and 2008. The majority of the catchment was replanted from 2005 to 2007.

Table 1.1: Site characteristics

Site	Catchment area (km^2)	Map Ref 260 series 1:50000	Altitude Range (m)	Channel Slope	Landuse and activities prior to this study*
Big Pokororo at Recorder	23.6	N27: 989016	70 – 1473	15	21% pines, 74% native, 5% pasture
Little Pokororo at Recorder	8.6	N27: 984011	60 – 930	14	19% pines, 60% native, 21% pasture
Herring at recorder	6.1	N27: 014048	80 – 1042	18	75% pines, 25% native and scrub
Big Pokororo Rainfall	NA	N27: 974055	276	NA	NA

* as of 2002

2. Instrumentation

In December 1996 a network of monitoring sites were established within the Pokororo Forest, on the Big Pokororo and Little Pokororo streams, with a primary control site in the nearby catchment of Herring Stream. These sites were established to monitor the changes in stream water clarity, temperature, dissolved oxygen and suspended sediment downstream of forest harvesting. Water level recorders were also established in these streams to provide a flow-based medium with which to compare events within and between catchments. Monitoring was carried out weekly over the period late November 1996 to mid February 1997, after which, sampling became monthly and rainfall event based.

Water clarity was measured using the black disk method (Davies-Colley 1988, Davies-Colley and Smith 1992) during low flows and at higher flows, water clarity observations gave way to suspended sediment sampling. Dissolved oxygen and temperature were recorded using a YSI 55 Dissolved Oxygen meter with ± 0.01 precision.

Suspended sediments in the Pokororo Forest were taken initially as grab samples during a number of rainfall events as well as during normal flows and then by auto samplers, which were installed over a period from October 2006 to August 2007 at the three sites. The samplers were programmed to take a sample of the river water via a hose attached to a motorised pump, which is triggered by a predetermined water level. As the water level rises, the datalogger activates the pump to begin sampling, and river water is pumped into a carousal of 24, one litre bottles housed beneath the pump at a 15 minute interval until the bottles are filled or the water level falls below the trigger level. Sediment samples were forwarded to Cawthron Laboratories in Nelson for analysis and the results have been used to construct suspended sediment rating curves.

Along with the installation of the auto samplers, turbidity sensors were installed, logging at 15 minute intervals along with water level. The turbidity sensors were of the nephelometric/back-scattering type. They are equipped with a small water pump, which regularly squirts a jet of water over the lens to inhibit bio-fouling. To check the calibration of the turbidity sensors, the suspended sediment samples that were tested by Cawthron Laboratories were also tested for their turbidity levels.

Rainfall was recorded at Greens Quarry in the Pokororo Forest (see Table 1.1). The raingauge has a 200 mm diameter receiver that directs rainfall through a siphon to a 0.2 mm tipping bucket. Data is stored on a Hobo event logger that is downloaded approximately every three months.

The installations are shown on Figures 1.1 to 1.3. Site-specific instrumentation is detailed in Appendix 1.

Figure 1.1a and b: Little Pokororo at Recorder. The auto-sampler is located on the catwalk of the logger housing. The auto-sampler hosing and turbidity sensor are strapped to the water level static pipe.

Figure 1.2: Big Pokororo at Recorder. The auto-sampler hose and turbidity are tied off to a waratah 1.5 meters upstream of the water level static tube.

Figure 1.3a and b: Herring at Recorder. The auto-sampler is located on the catwalk of the logger housing (the tower and housing were painted green 2007). The auto-sampler hosing and turbidity sensor are strapped to waratah slightly upstream of the static tube. It can be seen from the lower photo that the hose, sensor and static tube were prone to silting up.

3. Field procedures, laboratory analyses, and data archiving

Field procedures are detailed in Appendix 2.

A ‘triage’ procedure has been developed for selecting which auto-samples to analyse for SSC in the laboratory. While it would be ideal to analyse every auto-sample collected, the budget prevents this, and so only a selection of samples are processed. Initially, composite samples were analysed to keep the cost of each sampling round down. When the turbidity sensors were installed, the selection process for each batch of auto-samples involved inspecting the flow levels of the event that triggered the sampler and checking to see if any similar events that occurred recently had already been sampled. If so, the samples were discarded.

The time series data are archived into raw, working, and final TIDEDA files. The raw turbidity records are archived onto Rivers.mtd along with records of stage. The master stage and discharge record is the processed data with gaugings and their stage-discharge ratings. Raw data are archived under the site numbers given in Table 3.1.

Data editing, calibration, and gap-filling is then done within a working file Working_WBM.mtd. As detailed in section 5, calibration is done using the relationships between SSC and turbidity. Gaps in the turbidity record are filled preferentially with auto-sample data if it exists, otherwise using a SSC vs. discharge rating relationship. The final SSC time series are then copied into the file Final_WBM.mtd. Each SSC value is tagged according to whether it was derived from a calibrated turbidity record, an auto-sample, or an SSC rating. The parameters and site numbers for Working_WBM.mtd and Final_WBM.mtd are summarised in Tables 3.2 and 3.3, respectively. The derivations of the turbidity/SSC and river discharge/SSC relationships, using the auto-sampler data, are in an Excel table (WBM turb and flow vs ssc.xls).

The site numbers for the SSC time series (derived from turbidity time series), where auto-sample data and river discharge/SSC relationships have been used to fill gaps and ‘tie down’ flood peaks, are 5707111, 5707411, and 5707711 for Little Pokororo, at Recorder, Big Pokororo at Recorder and Herring at Recorder, respectively.

Table 3.1: Archive details for raw West Bank monitoring turbidity sites (Rivers.mtd)

Site	Parameter	Site No.	Item
Little Pokororo at Recorder	Stage	57071	1
	Turbidity	“	2
Big Pokororo at Recorder	Stage	57074	1
	Turbidity	“	2
Herring at Recorder	Stage	57077	1
	Turbidity	“	2

Table 3.2: Archive details for the West Bank monitoring turbidity sites (Working_WBM.mtd)

Site	Site No.	Item	Parameter	Processing
Little Pokororo at Recorder	57071	1	Stage	Data ramped to allow for sediment build up. Bad data removed.
		2	Discharge	Ratings developed based on stage record and gaugings.
	87071	1	SSC	None (laboratory results).
	5707101	1	Turbidity	Spike, bio-fouling & bad data removed. Data ramped (bio-fouling).
Big Pokororo at Recorder	57074	1	Stage	Data ramped to allow for sediment build up. Bad data removed.
		2	Discharge	Ratings developed based on stage record and gaugings.
	87074	1	SSC	None (laboratory results).
	5707401	1	Turbidity	Spike, bio-fouling & bad data removed. Data ramped (bio-fouling).
Herring at Recorder	57077	1	Stage	Data ramped to allow for sediment build up. Bad data removed.
		2	Discharge	Ratings developed based on stage record and gaugings.
	87077	1	SSC	None (laboratory results).
	5707701	1	Turbidity	Spike, bio-fouling & bad data removed. Data ramped (bio-fouling).

Table 3.3: Archive details for the West Bank monitoring turbidity sites (Final_WBM.mtd)

Site	Site No.	Item	Parameter	Processing
Little Pokororo at Recorder	71	1	SSC	Auto-sample lab results to fill gaps in the turbidity time series
		2	Tag(=1)	[subset of site 87071 in Working_WBM.mtd]
	81	1	SSC	SSC = f(Q)
		2	Tag(=0)	Derived SSC from 57071 flow
	57071	1	Stage	Data to derive SSC=f(Q) for gaps in turbidity time series.
		2	Discharge	[same as Site 57071 in Working_WBM.mtd]
	5707101	1	Turbidity	same as Site 5707101 in working_WBM.mtd
	5707111	1	SSC	Site 5707101 converted to SSC using a turbidity/SSC relationship. Gaps filled, where possible, with auto-samples (Site 71 and SSC=f(Q) (derived from Site 57071)).
		2	Tag	Tag = 0 [for SSC=f(NTU)], 1 [for auto-sample data] or 10 [for SSC=f(Q)]
Big Pokororo at Recorder	74	1	SSC	Auto-sample lab results to fill gaps in the turbidity time series
		2	Tag(=1)	[subset of site 87074 in Working_WBM.mtd]
	84	1	SSC	SSC = f(Q)
		2	Tag(=0)	Derived SSC from 57074 flow
	57074	1	Stage	Data to derive SSC=f(Q) for gaps in turbidity time series.
		2	Discharge	[same of Site 57074 in Working_WBM.mtd]
	5707401	1	Turbidity	same as Site 5707401 in working_WBM.mtd
	5707411	1	SSC	Site 5707401 converted to SSC using a turbidity/SSC relationship. Gaps filled, where possible, with auto-samples (Site 74 and SSC=f(Q) (derived from Site 57074)).

		2	Tag	Tag = 0 [for SSC=f(NTU)], 1 [for auto-sample data] or 10 [for SSC=f(Q)]
Herring at Recorder	77	1	SSC	Auto-sample lab results to fill gaps in the turbidity time series
		2	Tag(=1)	[subset of site 87077 in Working_WBM.mtd]
	87	1	SSC	SSC = f(Q)
		2	Tag(=0)	Derived SSC from 57077 flow
	57077	1	Stage	Data to derive SSC=f(Q) for gaps in turbidity time
		2	Discharge	[same as Site 57077 in Working_WBM.mtd]
	5707701	1	Turbidity	same as Site 5707701 in working_WBM.mtd
	5707711	1	SSC	Site 5707701 converted to SSC using a turbidity/SSC relationship. Gaps filled, where possible, with auto-samples (Site 77 and SSC=f(Q) (derived from Site 57077)).
		2	Tag	Tag = 0 [for SSC=f(NTU)], 1 [for auto-sample data] or 10 [for SSC=f(Q)]

4. Summary of data collected from July 2006 to June 2008

The flow and turbidity records, and auto-sediment samples available for the report period of July 2006 to June2008 are summarised in Table 4.1.

Table 4.1: Dates summary for West Bank monitoring sites

Site	Flow (and rainfall) time series	Turbidity time series	Auto sediment samples*
Little Pokororo at Recorder	6-Dec-1996 to 21-Jul-2008	22-Aug-2007 to 2-Jun-2008	130 over 8 events 59 over 3 events
Big Pokororo at Recorder	7-Aug-1998 to 5-Jun-2008	16-May-2007 to 25-Jun-2008	50 over 4 events 48 over 2 events
Herring at Recorder	2-Sep-1999 to 21-Jul-2008	19-Oct-2006 to 28-Mar-2008	111 over 8 events 87 over 5 events
Big Pokororo Rainfall	12-Aug-1999 to 15-Aug-2008		

*Unfortunately, not all samples had turbidity time series available. The number of samples and events in italics has associated turbidity time series data available.

5. Derivation of suspended sediment concentration

The water discharge and raw turbidity time series records from July 2006 to June 2008 (inclusive) are shown in Appendix 3 for the three turbidity sites. The raw turbidity records contain single-value spikes generated mostly during low flows (usually due to leaf litter around the sensor) and sometimes show drift relating to bio-fouling of the sensor. The sensor lenses were cleaned at least every 6 weeks, which meant a stable turbidity record for approximately a week. Then spikes and drift would become more prominent sensitivity fluctuations would increase. The spikes were removed if they did not correlate to a flood event. Some sites also seem to have problems with siltation, especially during the flood recession and have resulted in non-conforming corresponding turbidity versus SSC values. This has resulted in some auto-samples with high SSC not being able to be used in the derivation of calibration relationships, as the turbidity data relating to the same time period is unreliable. Gaps have been inserted in the turbidity time series when this occurs (these gaps are subsequently patched with the auto-sample data).

Where possible, the data spikes and drift were removed from the turbidity data before conversion to SSC records using TIDEDA editing processes. For the SSC time series derived from the turbidity time series, gaps in the record occurring during flood events (as a result of instrument malfunction, siltation, etc) were filled, where possible, to provide a continuous time series. The steps for filling gaps in the record were:

1. If a gap occurred during a period of low flow, where SSC levels are likely to remain low and constant, the gap in the record is removed by replacing it with a straight line.

2. If reliable auto-sampler data exist for the gap, auto-sample lab results for SSC are inserted into the SSC time series.

3. If there are no auto-samples to adequately fill the gap, a SSC time series based on a flow/SSC relationship is inserted in the gap.

4. If there are still gaps (i.e. no auto-samples or flow record) then the gaps in the record must remain.

Sections 5.1 to 5.3 below detail the conversion of the turbidity data into a SSC time series, for each site.

5.1 Little Pokororo at Recorder

5.1.1 Editing turbidity record

The water discharge and raw turbidity time series from August 2006 to June 2008 are shown in Appendix 3 (Figure A3.1). These raw turbidity data were edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor. There appears to be an increase in the sensitivity over time of the recorder to fluctuations in turbidity at the baseflows. Where possible, the fluctuations were smoothed, otherwise they were left in if fluctuating within the range of 6 NTU.

5.1.2 Generating turbidity/SSC relationship

Auto-sampler data were used to generate the turbidity/SSC relationships. The auto-sampler collects water samples every 15 minutes once a water level trigger reached. As described in section 3, a selection of the auto-samples is forwarded for laboratory analysis of SSC. Overall, a total of 144 auto-samples from 8 events between 4 June 2006 and 22 June 2008 have been analysed. Of these 144 auto-samples, only 59 samples had data from the turbidity time series to match.

Once laboratory analyses determined the SSC (g/m3) of each auto-sample, the data are compared against lab analysed turbidity, the recorded turbidity, and river discharge at the time that each auto-sample was collected. Any points that did not follow the trend of the turbidity and/or river discharge data were excluded from further analyses. The lab analysed turbidity was also used to check for drift in the site sensor, and also provide further insight as to whether the turbidity time series, flow time series or auto-sampled SSC are reliable. Figure 5.1 shows the plot of time series turbidity versus lab analysed turbidity. There appears to be no systematic drift, just scatter and an increase in diversion from the expected 1:1 relationship the higher turbidity gets.

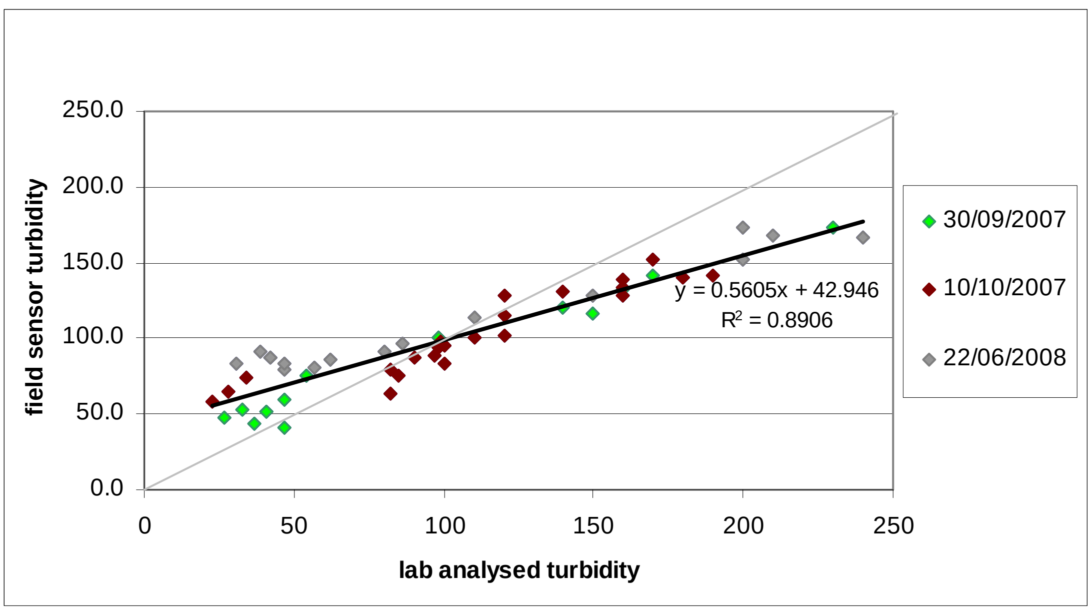


Figure 5.1: Lab analysed turbidity versus field sensor turbidity. The light grey line represents the expected 1:1

relationship.

NIWA have also found a difference between lab analysed turbidity and field sensor turbidity. They have found that the pumps on the turbidity sensor not working to full capacity, thus allowing bio-fouling of the sensor (L. Basher, (2009, personal communication))

After eliminating erroneous data (e.g., typically due to there not being a reliable concurrent match between the auto-sample SSC and sensor turbidity, due perhaps to sensor fouling or siltation), 50 samples were considered reliable to calculate the turbidity/SSC relationship. There were no significant shifts in turbidity over time, but the turbidity plotted against SSC showed a possible shift between the turbidity/SSC relationship with the 22/06/08 event. To confirm if the shift was systematic or not, the 4 events (61 samples) without field sensor turbidity were plotted with adjusted lab analysed turbidity (based on the relationship between lab analysed turbidity and the time series turbidity) against SSC. Of the 61 extra samples, 58 of the samples were considered reliable, therefore doubling the overall sample size and also provided more confidence at the higher end of the SSC/turbidity relationship, where there lacked samples. The 108 auto-sample data are plotted in Figure 5.2.

The SSC versus turbidity data (Figure 5.2) were first inspected for signs of drift – i.e., a systematic shift in the relationship with time that might result from instrument drift. Despite the scatter among the data from various events (assumed to be associated with variations in suspended sediment particle size), it was noted that:

- Looking at only the three events that had recorded turbidity, there appears to be a shift between October 2007 and June 2008. That is, the later event generally gave lower SSC values for the same recorded turbidity reading compared to the two events of September and October 2007.
- The 4 events (November 2006, May 2007, June 2007 and July 2008) whose turbidity values are derived from the lab analysed versus field sensor turbidity fit well together and also with the three events mentioned above.

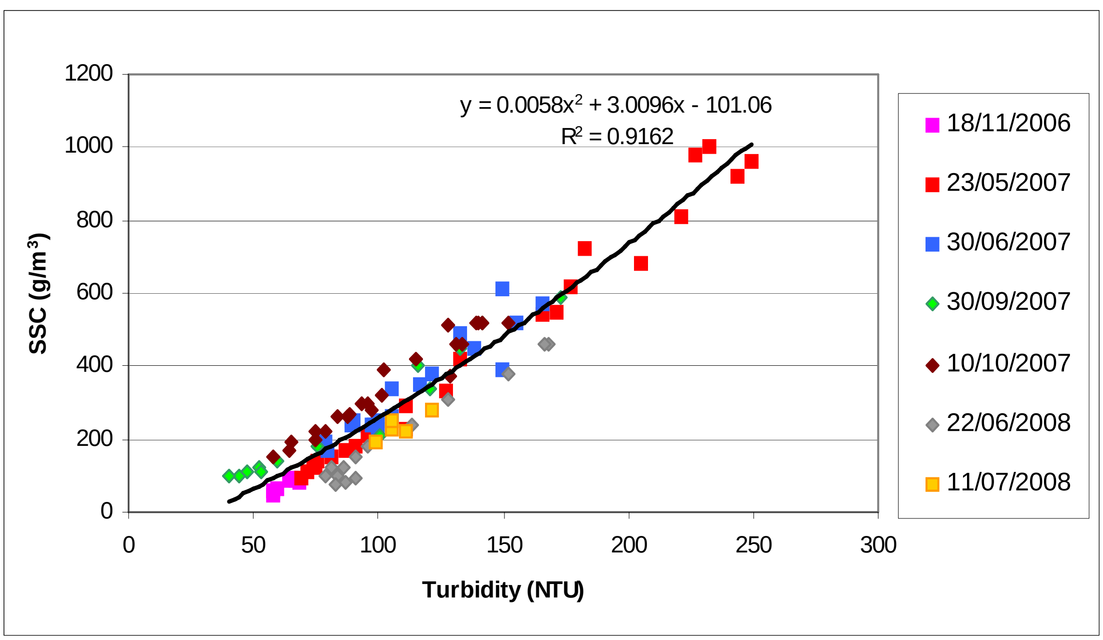


Figure 5.2: Measured auto-sample SSC versus recorded turbidity for Little Pokororo at Recorder. Diamond shaped symbols represent auto-samples with turbidity record. Square symbols represent auto samples with calculated

field sensor turbidity.

Thus, one best-fit line was applied to cover the full period of the data to July 2008 (Figure 5.2). The resulting relationship, which was used to convert the turbidity time series (NTU) into a suspended sediment concentration (SSC) time series, is summarised in Table 5.1. Where turbidity was low and the relationship returned negative SSC values (the low end of the turbidity/SSC relationship could not be calibrated due to no auto-samples taken with turbidity values lower than 40), the derived SSC values were filed as zero.

Table 5.1: Turbidity/SSC relationship for Little Pokororo at Recorder

Date Range	Equation
November 2006 to July 2008	$SSC = 0.0058NTU^2 + 3.0096NTU - 101.05$

The edited turbidity time series (and therefore the generated SSC time series) has approximately 60 days of gaps (excluding gaps occurring during low flows/low NTU time periods which have already been removed).

Also seen with Wild et al. (2006) report, the turbidity/SSC relationships have some curvature, despite the expected linear response of the Greenspan turbidity sensor. This may reflect the effect of a slight overall coarsening of sediment particle size as sediment concentration increases at the site (for a given SSC, the sensors indicate a lower NTU value for coarser sediment).

5.1.3 Generating discharge/SSC relationship

None of the gaps in the turbidity record could be filled using auto-sample data, only one sample in August 2006 was of value, therefore the gaps need to be filled using a river discharge/SSC relationship. This was developed using auto-sample data for events occurring between September 2006 and July 2008. This relationship excluded any SSC results that did not follow the general trend of the river discharge data. In total, 117 of the 129 auto-samples collected between September 2006 and July 2008 were used to derive a relationship for SSC from discharge. Of the 8 events sampled, 5 events sampled both the rising and falling limbs of the flood event. The rising limb of these 5 events all had a higher SSC than the falling limb. The lower SSC after the flood peak suggests that the main sediment source is in the immediate vicinity of the site. Figure 5.2 shows this complex relationship between SSC and flow. With the distinct differences between the SSC values for the rising and falling limbs of the hydrograph, a relationship was given for both limbs. The data range was also split into two periods; pre June 2007 and post June 2007. For the first period, both rising and falling relationships are good. However for the later period, the relationships are not so great, but are the best we can do for the amount of data we have. The auto-sample data is plotted in Figure 5.3 and the relationships given in Table 5.2.

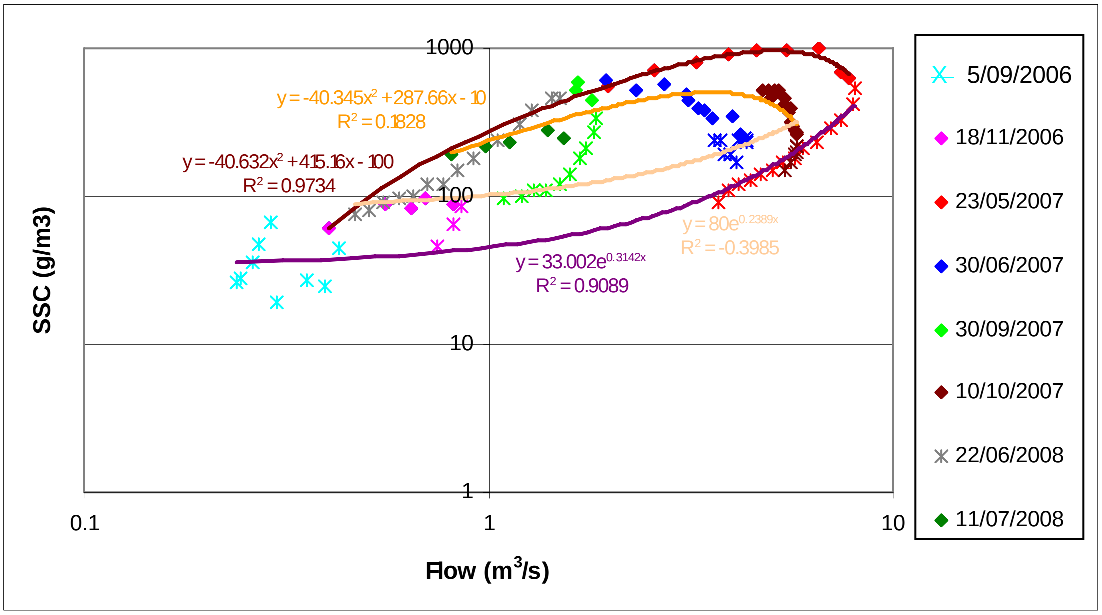


Figure 5.3: Measured auto-sample SSC versus recorded river flow at Little Pokororo at Recorder for September 2006 to July 2008. Diamond shaped symbols represent auto-sampled SSC values on the rising limb of the hydrograph and cross symbols represent auto-sampled SSC values on the falling limb of the hydrograph.

Table 5.2: River discharge/SSC relationships for Little Pokororo at Recorder

Date Range	Hydrograph limb	Equation
November 2006 – June 2007	Rising	SSC = $-40.632Q^2 + 415.16Q - 100$
September 2006 – June 2007	Falling	SSC = $33.002e^{0.3142Q}$
June 2007 – July 2008	Rising	SSC = $-40.345Q^2 + 287.66Q - 10$
June 2007 – June 2008	Falling	SSC = $802e^{0.2389Q}$

5.1.4 Final SSC time series

Some of the gaps in the SSC time series generated from the turbidity time series can be filled with auto-sample data and SSC derived from the river discharge record (from July 2006 to June 2008). Approximately 42 days of gaps could not be filled. The main flood/sediment events, along with periods in the SSC time series where gaps in the turbidity record occurred, are shown in Appendix 4 in Figures A4.1 to A4.5.

There is a smooth transition between the different methods of generating SSC. There are however jumps between the rising and falling limbs of river discharge derived SSC, and also at the end of the falling limb of the river discharge derived SSC. The jump between the rising and falling limb was due to the change in equation used to calculate SSC. While it is not a smooth transition, the generated SSC still displays higher SSC values on the rising limb compared to the falling limb as Figure 5.3 indicates. Jumps in the river discharge derived SSC that occur on the lower part of the falling limb are due to the lack of auto-sample data at the lower flows, thus the discharge/SSC relationship is poor at the lower ends. Where possible, commonsense has been used to smooth the transition from rising to falling limb and the lower part of the falling limb. However, these jumps are expected to have minimal effect on the overall SSC analysis.

5.2 Big Pokororo at Recorder

5.2.1 Editing turbidity record

The water discharge and raw turbidity time series from May 2007 to June 2008 are shown in Appendix 3 (Figure A3.2). These raw turbidity data were edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor. There appears to be an increase in the sensitivity over time of the recorder to fluctuations in turbidity at the baseflows. Where possible, the fluctuations were smoothed, otherwise they were left in if fluctuating within the range of 6 NTU.

5.2.2 Generating turbidity/SSC relationship

Auto-sampler data were used to generate the turbidity/SSC relationships. The auto-sampler collects water samples every 15 minutes once a water level trigger reached. As described in section 3, a selection of the auto-samples is forwarded for laboratory analysis of SSC. Overall, a total of 50 auto-samples from 4 events between 30 June 2006 and 18 December 2007 have been analysed. Of these 50 auto-samples, only 48 samples had data from the turbidity time series to match.

Once laboratory analyses determined the SSC (g/m^3) of each auto-sample, the data are compared against lab analysed turbidity, the recorded turbidity, and river discharge at the time that each auto-sample was collected. Any points that did not follow the trend of the turbidity and/or river discharge data were excluded from further analyses. The lab analysed turbidity was also used to check for drift in the site sensor, and also provide further insight as to whether the turbidity time series, flow time series or auto-sampled SSC are reliable. Figure 5.3 shows the plot of time series turbidity versus lab analysed turbidity. Plotting only these two events with such a small and low turbidity range gives the impression of a shift in turbidity. However, there is only an approximate 15NTU difference between the events. In the big picture, the maximum recorded turbidity from the continuous turbidity record is over 500NTU. Therefore, the shift in NTU at the low end is insignificant.

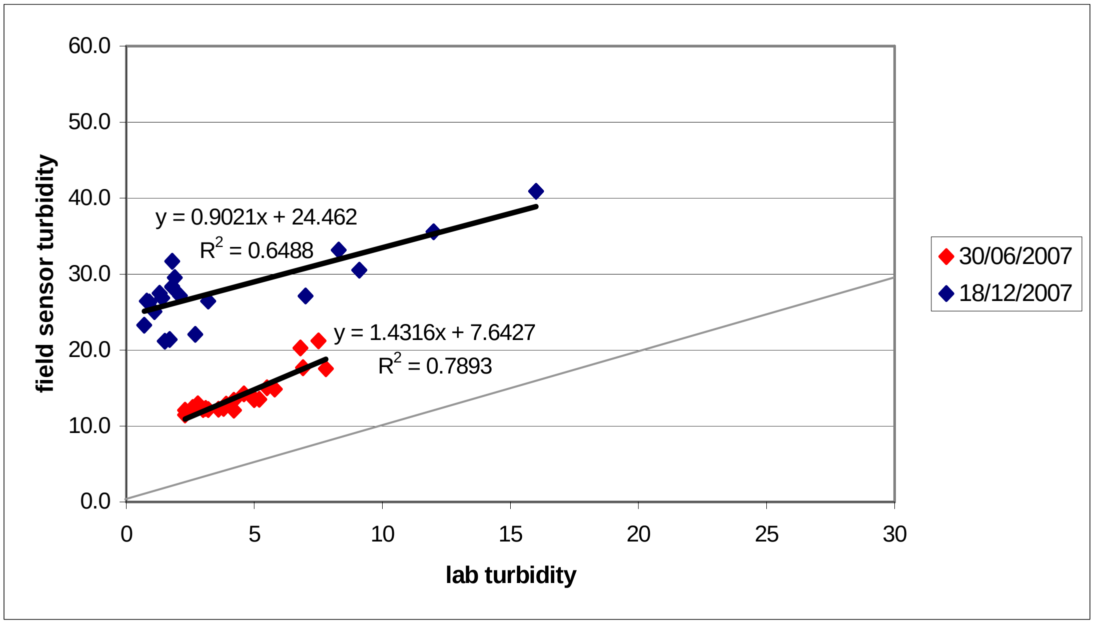


Figure 5.3: Lab analysed turbidity versus field sensor turbidity. The light grey line represents the expected 1:1 relationship. Note the small range of turbidity.

After eliminating erroneous data (e.g., typically due to there not being a reliable concurrent match between the auto-sample SSC and sensor turbidity, due perhaps to sensor fouling or siltation), 43 samples were considered reliable to calculate the turbidity/SSC relationship. With only two events, which are quite small, it did not seem feasible to apply a SSC/turbidity relationship only based on these two small events. It is considered that Big Pokororo and Little Pokororo are similar in catchment characteristics (with the exception of size), therefore it was considered to combine the data from both these sites to gain a SSC/turbidity relationship for Big Pokororo. The combined data are plotted in Figure 5.4.

The inclusion of Little Pokororo SSC versus turbidity data with Big Pokororo provided a data set that covered a much bigger turbidity range. Big Pokororo data fitted the low end of the Little Pokororo SSC/turbidity relationship well. Thus, one best-fit line was applied to cover the full period of the data (Figure 5.4). The resulting relationship, which was used to convert the turbidity time series (NTU) into a suspended sediment concentration (SSC) time series is summarised in Table 5.3.

The derived turbidity/SSC relationship is based on turbidity values up to 248NTU. There are two events, 22 January and 18 April 2008 that exceed 248NTU. Especially with the January event (peak turbidity of 532NTU), the derived SSC appears to be too high. The turbidity time series data looks feasible during these two events, but with a derived equation based on much lower NTU values, the calculated SSC values should be treated with caution.

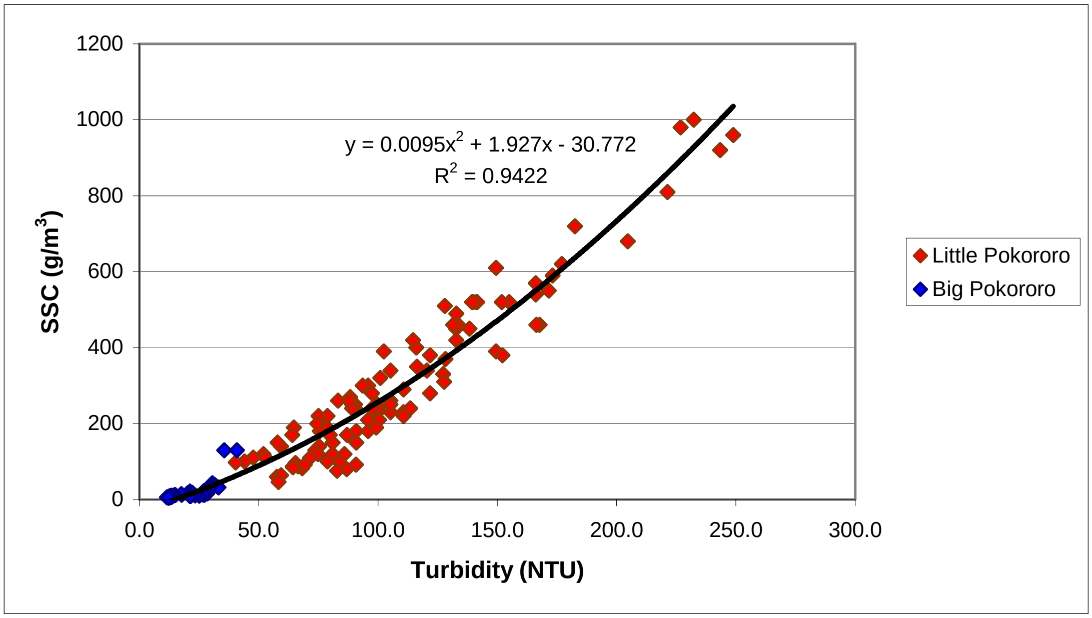


Figure 5.4: Measured auto-sample SSC versus recorded turbidity for Little Pokororo and Big Pokororo at Recorders.

Table 5.3: Turbidity/SSC relationship for Big Pokororo at Recorder

Date Range	Equation
May 2006 to June 2008	SSC = $0.0095NTU^2 + 1.927NTU - 30.772$

The edited turbidity time series (and therefore the generated SSC time series) has approximately 73 days of gaps (excluding gaps occurring during low flows/low NTU time periods which have already been removed). Some of these gaps are from logger and battery problems, while some gaps are from deleting rouge turbidity data.

5.2.3 Generating discharge/SSC relationship

None of the gaps in the turbidity record could be filled using auto-sample data. Only two extra values could be added to the start of the record in August and September 2006, therefore the gaps need to be filled using a river discharge/SSC relationship. This was developed using auto-sample data for events occurring between July 2007 and December 2007. This relationship excluded any SSC results that did not follow the general trend of the river discharge data. In total, 46 of the 50 auto-samples collected between August 2006 and December 2007 were used to derive a relationship for SSC from discharge. Only one relationship was developed to cover all of the gaps occurring over this time. The auto-sample data is plotted in Figure 5.5 and the relationship is given in Table 5.4.

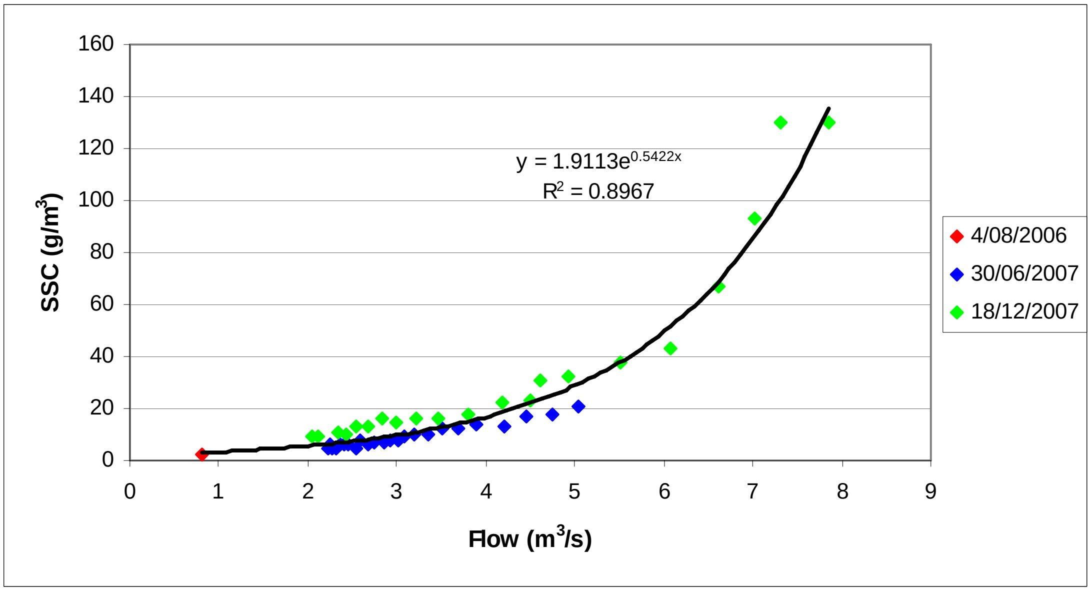


Figure 5.5: Measured auto-sample SSC versus recorded river flow at Big Pokororo at Recorder for August 2006 to December 2007.

Table 5.4: River discharge/SSC relationship for Big Pokororo at Recorder

Date Range	Equation
August 2006 to June 2008	$SSC = 1.9113e^{0.5422Q}$

With only two events sampled, plus two single samples in 2006, the range of SSC and flow measured were low. The highest SSC sample corresponded to a flow of 7.856m^3/s. The maximum flow recorded during a gap in the turbidity record was 9.464 m^3/s.

5.2.4 Final SSC time series

Apart from three gaps totalling 10 days, all other gaps in the SSC time series generated from the turbidity time series can be filled with auto-sample data and SSC derived from the river discharge record (from July 2006 to June 2008). The main flood/sediment events, along with periods in the SSC time series where gaps in the turbidity record occurred, are shown in Appendix 4 in Figures A4.6 to A4.8.

At full scale, there is a smooth transition between the different methods of generating SSC. When zooming onto the low ranges of SSC, a jump between the different methods can be seen of =/-2NTU. Straight lines are needed to join the gaps between SSC generated from the turbidity/SSC relationship and the inserted auto-sample points.

5.3 Herring at Recorder

5.3.1 Editing turbidity record

The water discharge and raw turbidity time series from October 2006 to May 2008 are shown in Appendix 3 (Figure A3.3-4). These raw turbidity data were edited to remove spikes and drift, likely to have been caused by bio-fouling or silting up of the turbidity sensor.

5.3.2 Generating turbidity/SSC relationship

Auto-sampler data were used to generate the turbidity/SSC relationships. The auto-sampler collects water samples every 15 minutes once a water level trigger reached. As described in section 3, a selection of the auto-samples is forwarded for laboratory analysis of SSC. Overall, a total of 117 auto-samples from 9 events between 25 April 2006 and 26 June 2008 have been analysed. Of these 117auto-samples, only 87 samples had data from the turbidity time series to match.

Once laboratory analyses determined the SSC (g/m^3) of each auto-sample, the data are compared against lab analysed turbidity, the recorded turbidity, and river discharge at the time that each auto-sample was collected. Any points that did not follow the trend of the turbidity and/or river discharge data were excluded from further analyses. The lab analysed turbidity was also used to check for drift in the site sensor, and also provide further insight as to whether the turbidity time series, flow time series or auto-sampled SSC are reliable. The event on the 29 June 2007 was excluded from analyse as the SSC data contained several large spikes, with both lab and field sensor turbidity data not corresponding to SSC, flow or each other. Figure 5.5 shows the plot of time series turbidity versus lab analysed turbidity. The first 3 events plot relatively close to the expected 1:1 relationship (light grey line in Figure 5.5). However the event on 18 December 2007 plots well away from the other events.

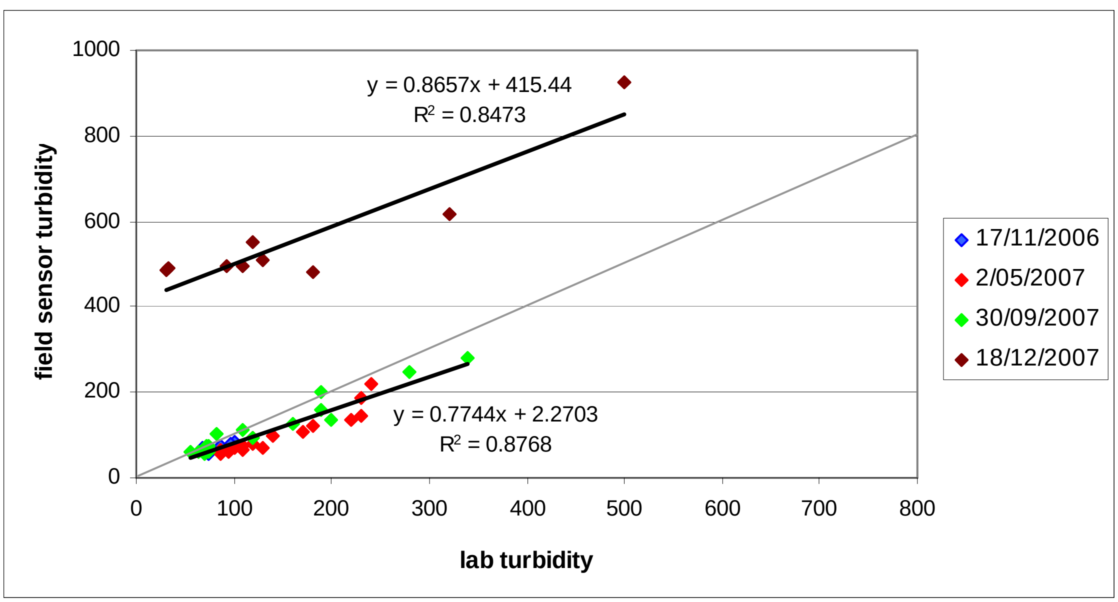


Figure 5.5: Lab analysed turbidity versus field sensor turbidity. The light grey line represents the expected 1:1 relationship.

While the event on 18 December 2007 plots well above the previous events, there are no events analysed after December to confirm this shift. Also, when looking at the turbidity time series data, it would be expected to see a shift of that magnitude, but the data shows no such shift.

After eliminating erroneous data (e.g., typically due to there not being a reliable concurrent match between the auto-sample SSC and sensor turbidity, due perhaps to sensor fouling or siltation), 44 samples were considered reliable to calculate the turbidity/SSC relationship. The event on the 29 June 2007 was once again excluded from analysis due to the inconsistency between all the parameters measured. To confirm that the shift in turbidity of the 18 December 2007 event is actually just an anomaly, the event on the 22 June 2008 that was captured by the auto-sampler, but did not have any corresponding field sensor turbidity data available, was used with the adjusted lab turbidity data (based on the relationship between lab analysed turbidity and the time series turbidity). Not only did this fit the SSC/turbidity relationship but also extended the relationship. The sample size now increased to 59. The 59 auto-sample data are plotted in Figure 5.6.

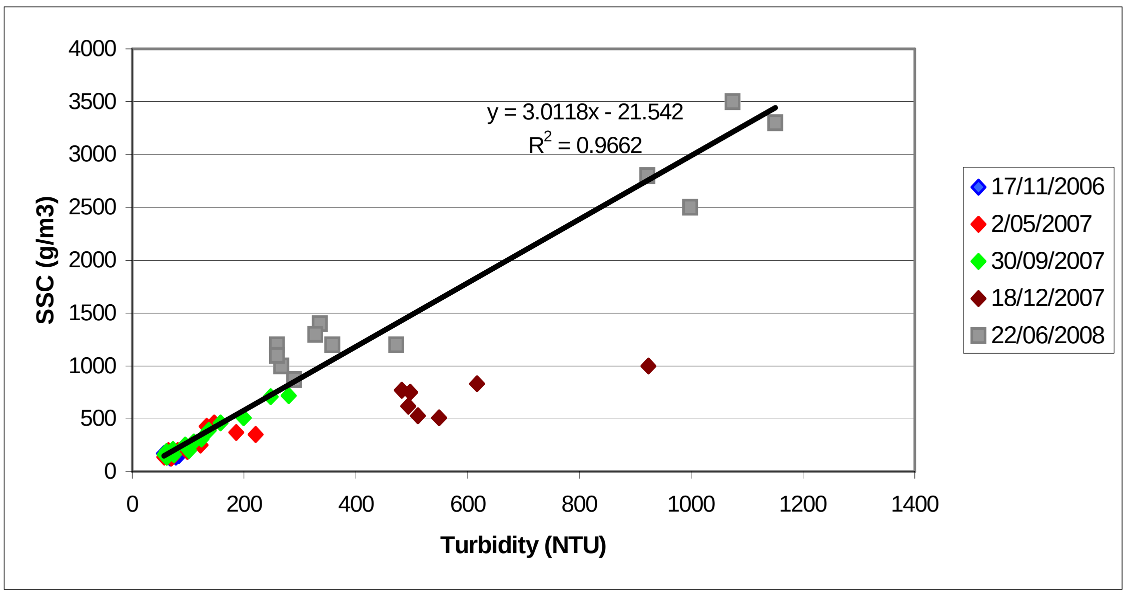


Figure 5.6: Measured auto-sample SSC versus recorded turbidity for Herring at Recorder. The 18 December 2007 event has been left in the plot but not included in the relationship.

The SSC versus turbidity data (Figure 5.6) were first inspected for signs of drift – i.e., a systematic shift in the relationship with time that might result from instrument drift. Despite the scatter among the data from various events (assumed to be associated with variations in suspended sediment particle size), it was noted that:

- Samples under 200 NTU have a strong relationship.
- The 22 June 2008 event whose turbidity values were derived from the lab analysed versus field sensor turbidity fit well with the previous events and extended the relationship for higher turbidity

readings.

One best-fit line was applied to cover the full period of the data (Figure 5.6). The resulting relationship, which was used to convert the turbidity time series (NTU) into a suspended sediment concentration (SSC) time series is summarised in Table 5.4.

Table 5.4: Turbidity/SSC relationship for Herring at Recorder

Date Range	Equation
November 2006 to June 2008	SSC = 3.0118NTU – 21.452

5.3.3 Generating discharge/SSC relationship

None of the gaps in the turbidity record could be filled using auto-sample data, only either side of the series data could be added to, therefore the gaps need to be filled using a river discharge/SSC relationship. This was developed using auto-sample data for events occurring between April 2006 and June 2008. This relationship excluded any SSC results that did not follow the general trend of the river discharge data. In total, 78 of the 117 auto-samples collected between April 2006 and June 2008 were used to derive a relationship for SSC from discharge. While there was no clear cut relationship between river discharge and SSC, the April 2006 event was a definite out layer. There is no known reason for this difference, and therefore this event was not used in the discharge/SSC relationship. Also the December 2007 event was ignored due to non-conformal discharge/SSC relationship. Therefore, only one relationship was developed to cover all of the gaps occurring over this time. The auto-sample data is plotted in Figure 5.7 and the relationship is given in Table 5.5.

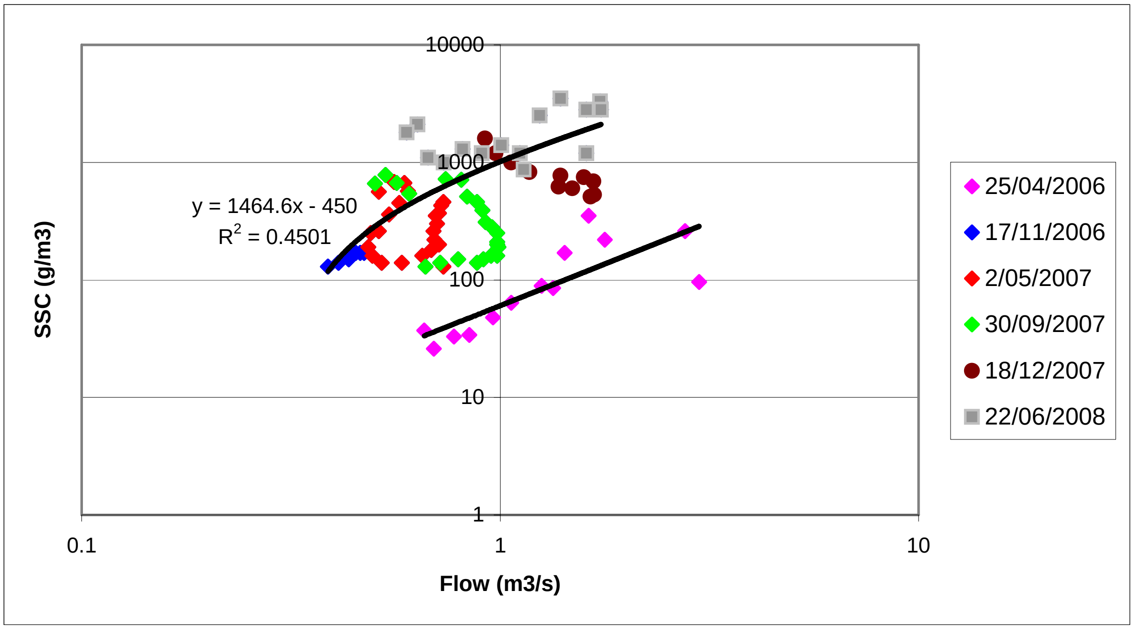


Figure 5.7: Measured auto-sample SSC versus recorded river flow at Herring at Recorder for April 2006 to June 2008. While both the April 2006 and December 2007 events are shown in the plot, they have not been used to calculate the river discharge/SSC relationship.

Table 5.5: River discharge/SSC relationship for Herring at Recorder

Date Range	Equation
November 2006 to June 2008	SSC = 1464.6Q – 450

5.3.4 Final SSC time series

Most of the gaps in the SSC time series generated from the turbidity time series (from July 2006 to June 2008) can be filled with auto-sample data and SSC derived from the river discharge record. There are now approximately 88 days of gaps. The main flood/sediment events, along with periods in the SSC time series where gaps in the turbidity record occurred, are shown in Appendix 4 in Figures A4.9 to A4.14.

There is a smooth transition between the different methods of generating SSC in all cases, except for three small gaps in October 2007, where the river discharge derived SSC appears to be higher than the adjoining turbidity derived SSC. This is the only period that the difference occurs between the two methods and therefore has been left in, as it is not possible to check the river discharge/SSC relationship for this small period.

6. Sensor calibrations

The sensor turbidity and auto-sampled SSC relationships used in the analyses are shown in Figure 6.1. Figure 6.2 shows the fit between the measured and predicted SSC values using the calibration relationships derived in Sections 5.1 to 5.3. From Sections 5.1 to 5.3 and Figure 6.2 it appears that the calibrations are quite reasonable, although there was a need for more data in the higher NTU ranges (i.e. >250 NTU) for Big Pokororo to further calibrate the sensor and also at Herring to confirm the turbidity /auto-sampled SSC relationship, subsequently giving more confidence through the high end scatter.

The lowest specific turbidity (steepest relationship) occurs at both Little Pokororo and Big Pokororo, which apart from catchment size are similar in site characteristics and lack of harvesting activity (which is discussed below in section 7.1). Specific turbidity ($NTU/gm^{3\ -1}$) tends to be lower for coarser particles relating to coarser suspended load (Wild et al. 2006).

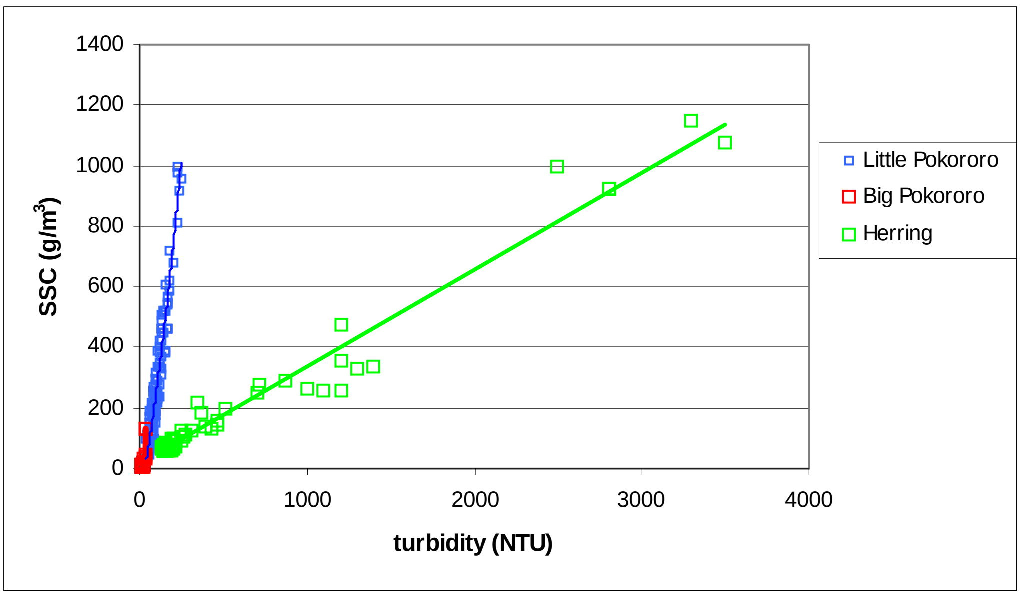
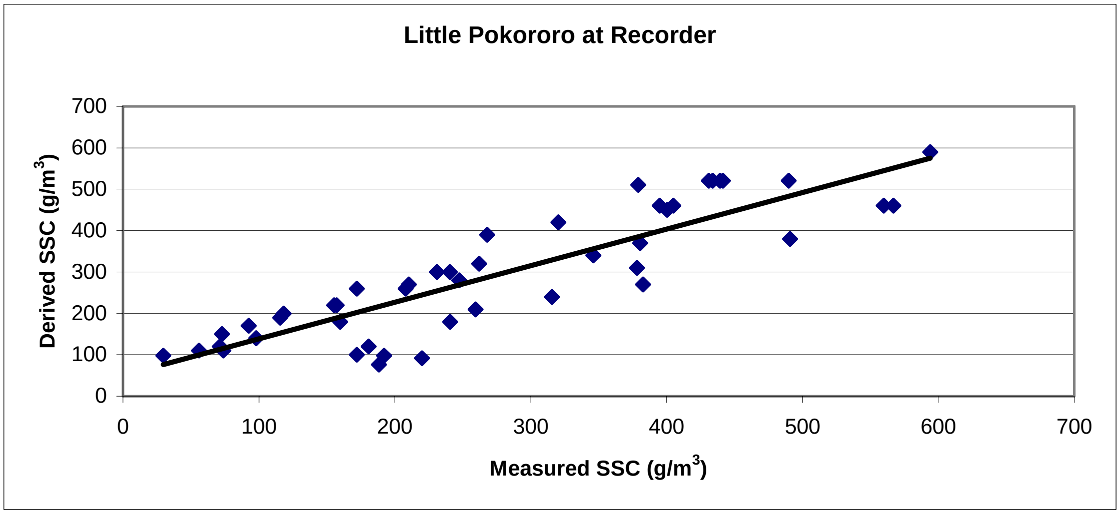
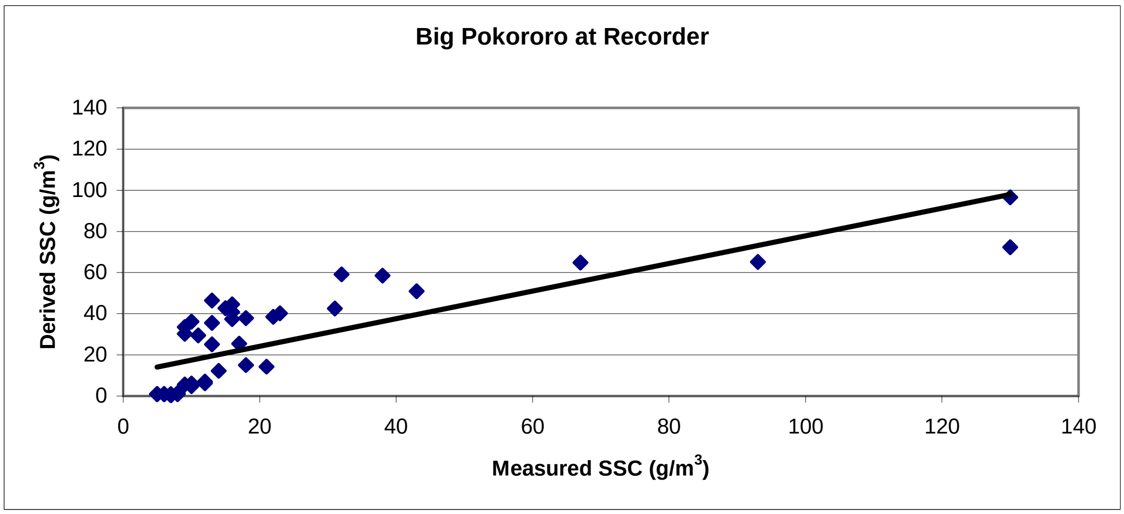


Figure 6.1: Relationships between auto-sampled SSC and turbidity for the three sites.





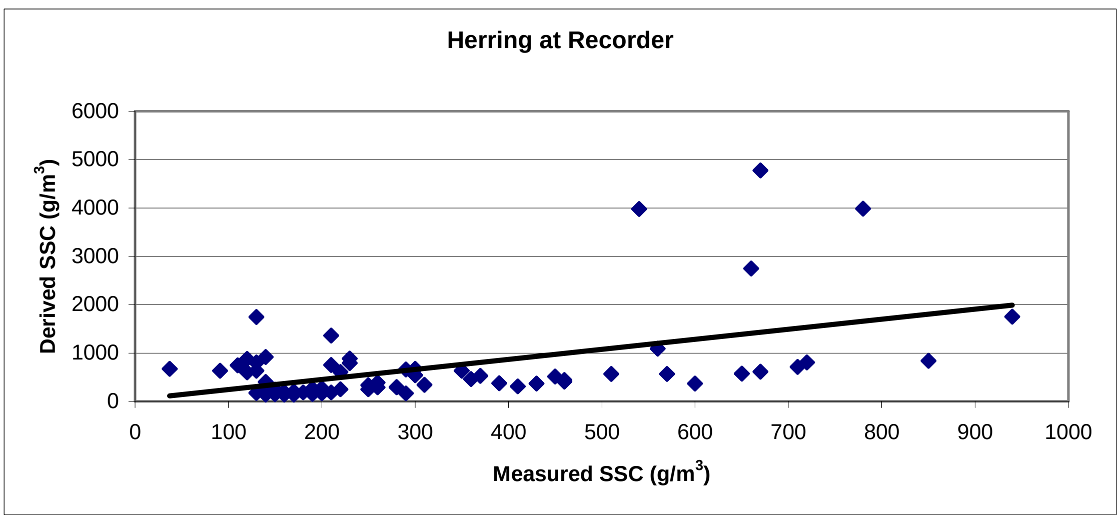


Figure 6.2: Relations between measured (from auto-samples) and derived (from turbidity) SSC values for the

three sites.

Table 6.1 summarises the minimum and maximum turbidity, flows and SSC measured.

Table 6.1: Summary of parameters for each site (June 2006 to July 2008)

	Little Pokororo at Recorder	Big Pokororo at Recorder	Herring at Recorder
Minimum flow (m^3/s)	0.104	0.366	0.040
	(20/01/2008)	(19/04/2007)	(15/04/2007)
Maximum flow (m^3/s)	8.016	28.888	4.501
	(23/05/2007)	(23/05/2007)	(19/07/2006)
Mean flow	0.191	0.744	0.151
Maximum turbidity (NTU)	379	537	1793
	(10/10/2007)	(22/01/2008)	(30/06/2007)
Sensor range (NTU)	0-2000	0-2000	0-2000
Maximum SSC (mg/l)	1872[a]	3691[a]	6142[b]
	(10/10/2007)	(22/01/2008)	(19/07/2006)
No. gaps in derived SSC record	4	2	3
Total length of gaps (days)	42	5	88

[a] SSC *f*(NTU)

[b] SSC *f*(Q)

7. Suspended sediment

7.1 Storm suspended sediment yields

Suspended sediment storm yields (SSSY) were calculated for events that at least two or more of the catchments responded to and had data available. There are several occasions where there is no data available due to instrument failure of some kind. The events that did not have data available were from: 19/07/2006 at Little Pokororo; 12/07/2006 and 22/06/2008 at Big Pokororo; and 5/09/2006, 2/10/2006 and 23/05/2007at Herring. The SSSY were calculated in tonnes and are plotted in Figure 7.1 along with rainfall totals from Big Pokororo rainfall site for each event. Where there appears to be no data on the graph for a site that does not coincide with the above dates for missing record is because of no or little suspended sediment response.

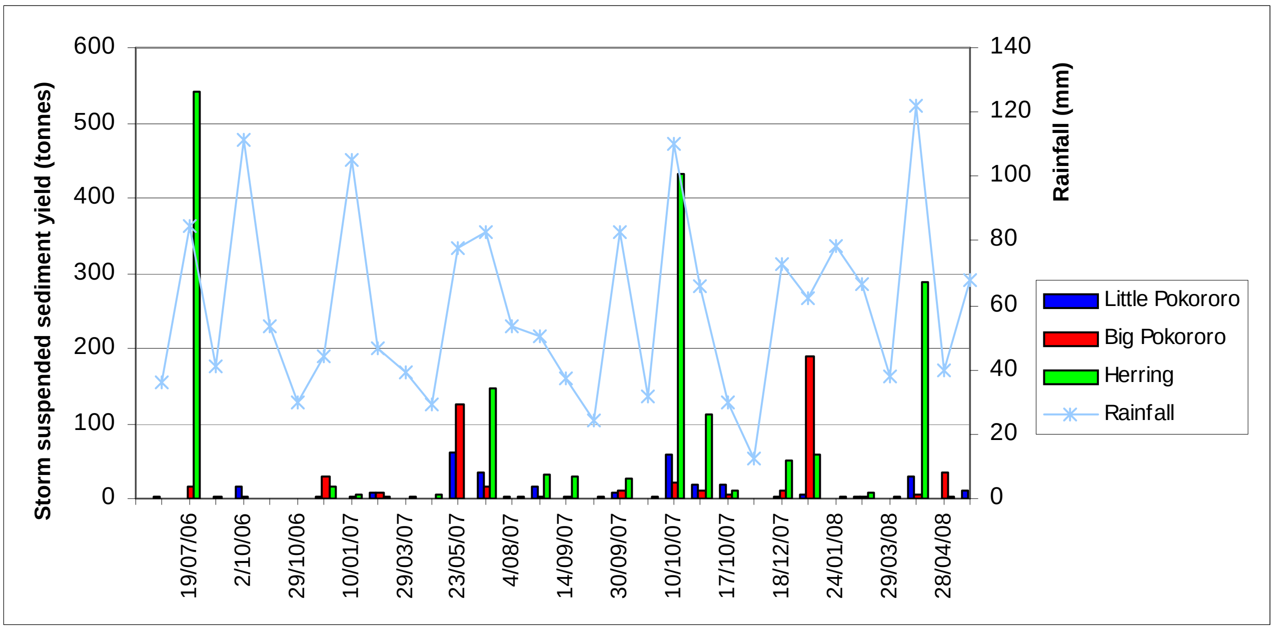


Figure 7.1: Suspended sediment storm yields in tonnes for Little Pokororo, Big Pokororo and Herring against event rainfall totals.

The above graph does not show a strong relationship between rainfall and SSSY. On several occasions there has been little suspended sediment response for a high rainfall total. In most events, Herring volumes were much larger, with several events at least three times greater than the other two sites. While Figure 7.1 is at full scale, Figure 7.2 has been rescaled to show Little Pokororo and Big Pokororo volumes clearer and smaller suspended sediment responses.

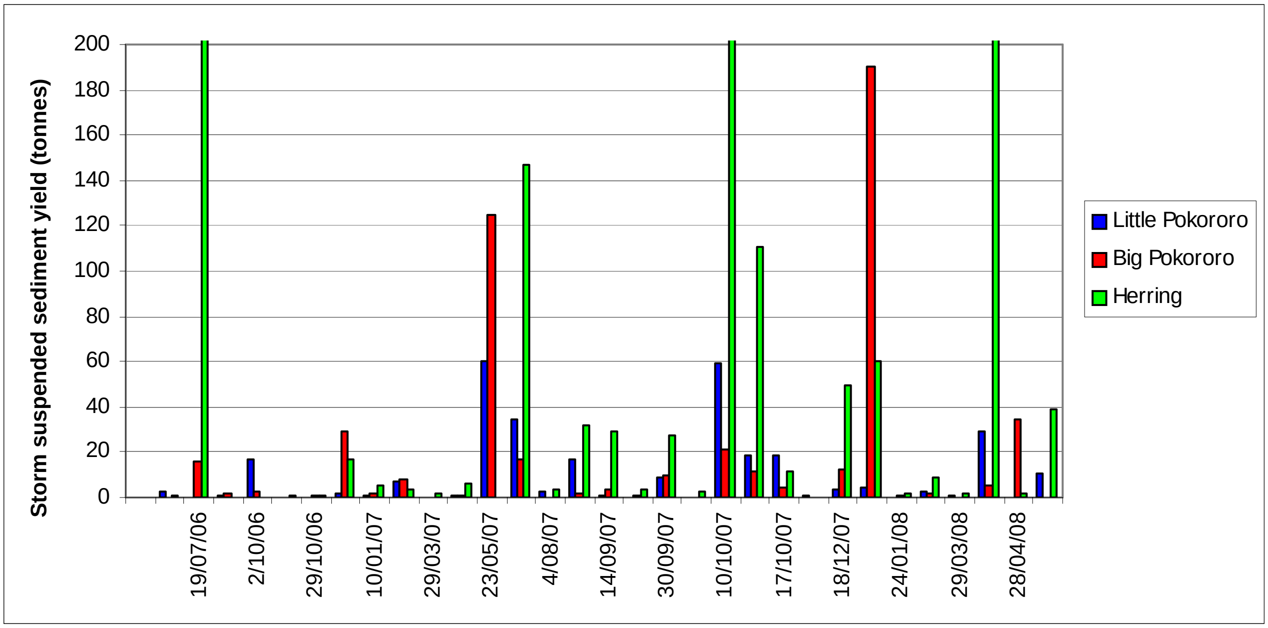


Figure 7.2: Suspended sediment storm yields in tonnes for Little Pokororo, Big Pokororo and Herring (zoomed in).

Looking at the smaller scale in Figure 7.2, Big Pokororo volumes has two events that also stand out on the 23/05/2007 and 18/12/2007 (unfortunately there is no data available for Herring for the May event). Both these events had rainfall totals close to 75mm, but still totals are nowhere near the bigger rainfall events.

While annual sediment yield relates mainly to the longer-term general activities and natural characteristics within the catchment as a whole, individual one-off events can provide the shorter-term spectacular results, as shown above with the storm event on 19/07/2006, which produced 76% of the total annual sediment yield from Herring catchment.

Hicks et al. (1990) have noted in smaller streams with catchment areas less than a few square kilometres, the sediment concentration for a given discharge can vary greatly, as shown by Herring at Recorder discharge/SSC relationship in graph 5.7 that shows a high scatter. The variance may also be equated to the smaller catchments sediment concentrations responding more to random injections from specific erosion sites than from overall catchment changes (Hicks et al. 1990). In such streams, good relationships can often be found between storm sediment yield and some index of storm magnitude such as the peak discharge or rainfall. Figure 7.3 shows SSSY plotted against discharge.

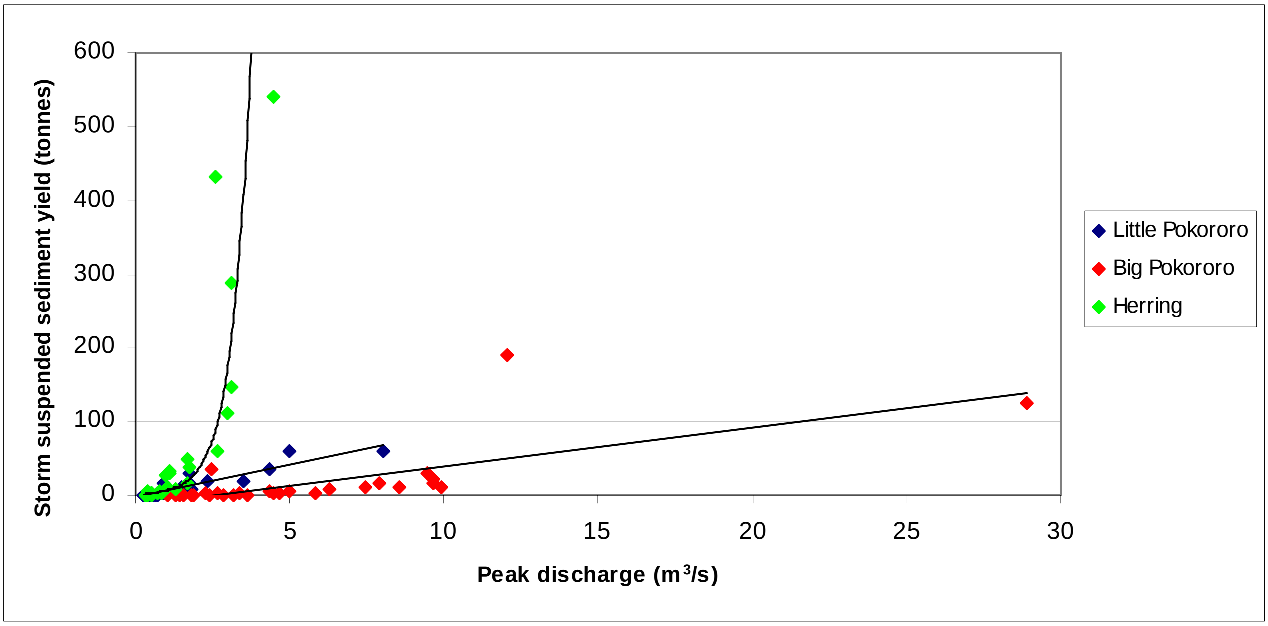


Figure 7.3: Peak discharge in m3/s of the event versus suspended sediment storm yields in tonnes for Little Pokororo, Big Pokororo and Herring.

Apart from the outliers for Big Pokororo on 22/01/08 and Herring on 10/10/2007, there is a good relationship between peak discharge and SSSY. Both Little Pokororo and Big Pokororo appear to have a linear relationship of a higher peak discharge equates to a higher SSSY. Herring has more of a curvature relationship with SSSY increasing greater as the peak discharge increases. The curvature relationship shown at Herring probably reflects the increase in forestry activity over the past two years. A wind throw event in October 2005 saw the Herring catchment sustain a lot of damage with trees blown down and many stands damaged. Harvesting to minimise financial loss in the Herring took place in 2005 and then in 2008 (B. Hughes, (2009, personal communication)). While Little Pokororo received several hectares of damage from the windthrow event, the damaged areas were inaccessible to harvest, thus natives and pine seedlings established themselves amongst the damage. And in the Big Pokororo catchment, only some of the eastern compartments were recovered and replanted from the windthrow event.

7.2 Annual sediment yields

With the period of data collection and analysis for this study being from July 2006 to June 2008, the 12 month period for calculating annual sediment yields has been based on the hydrological year rather than the calendar year (i.e., July to June inclusive). Table 7.1 shows the annual sediment yields for the above periods and also the annual sediment yields from 1997 to 2001 from Hewitt, 2002. Annual rainfall and mean flow are also given for comparison, along with the forestry activity details. Figure 7.4 plots the specific annual sediment yields along with rainfall. Annual rainfall is primly calculated from Big Pokororo rainfall station where possible, otherwise calculated from Riwaka at Moss Bush station.

Table 7.1: Annual sediment yields, flows, forestry activity and rainfall for Little Pokororo, Big Pokororo and Herring.

	Little Pokororo at Recorder			Big Pokororo at Recorder			Herring at Recorder			Big Pokororo Rainfall
Year	Annual mean flow (m^3/s)	Sediment yield (t/km^2)	Forest activity	Annual mean flow (m^3/s)	Sediment yield (t/km^2)	Forest activity	Annual mean flow (m^3/s)	Sediment yield (t/km^2)	Forest activity	Rainfall total (mm)
2007/2008	0.200	21		0.770	13		0.155	181	Final harvesting and replanting	1570 [1]
2006/2007	0.178	15		0.710	8	Last harvesting & planting in eastern cpmt due to windthrow event	0.143	116	Replanting	1312 [1]
2005 (Oct windthrow event)			Some damage from event, but no harvesting						Harvesting of damaged pines	
2001	0.231	45	Last planting	1.322	21		0.143	18		1780 [1]
2000	0.393	142	Last harvesting	1.606	76		0.239	43		2559 [1]
1999	0.273	67		1.265	111	100 ha clearfelled	0.229	20		1664 [2]
1998	0.307	151		1.080	54	62 ha clearfelled	0.219	44		2081 [2]
1997	0.155	44		0.628	21		0.134	26		1160 [2]

[1] Rainfall values from Big Pokororo Rainfall station.

[2] Rainfall values from Riwaka at Moss Bush rainfall station.

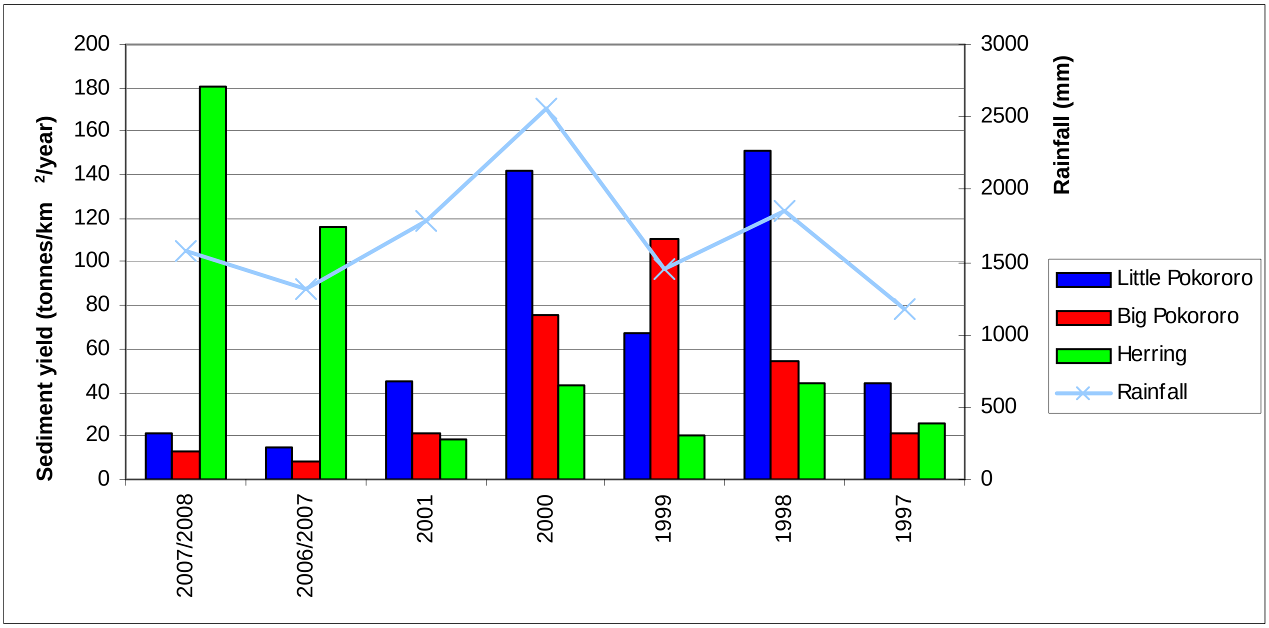


Figure 7.4: Annual specific sediment yields in tonnes/km^2 and annual rainfall (mm) for Little Pokororo, Big Pokororo and Herring.

Again the relationship between sediment yield and rainfall is not fantastic, more so for Big Pokororo and especially Herring. The poor relationship is dominated by Herrings high sediment yields in the later years that corresponds to low average rainfall and Big Pokororo's sediment yield in 1999 and again corresponding to low rainfall. Little Pokororo has the closest relationship to annual rainfall. Plotting sediment yield against the annual mean flow as shown in Figure 7.5, is not too dissimilar to the relationship with rainfall, as expected.

The higher sediment yields from 1999 and 2000 can be attributed to the 25 and 16ha, respectively, harvested in Little Pokororo; and 100 and 74ha, respectively, harvested in Big Pokororo. The very high sediment yields of Herring from 2006 to 2008 as mentioned earlier are related to the wind throw event and subsequent harvesting.

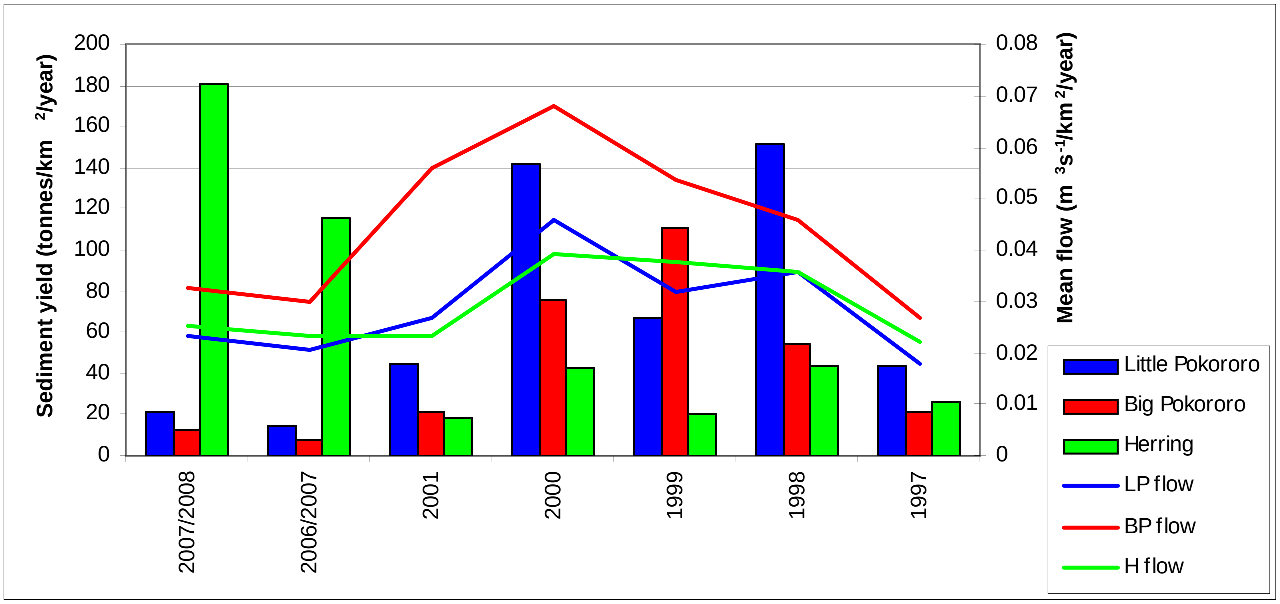


Figure 7.5: Annual specific sediment yields in tonnes/km^2 and mean annual flow (m^{3}s^{-1}/km^2) for Little Pokororo, Big Pokororo and Herring.

8. Conclusions

Two years of turbidity and auto-sampler data from July 2006 to June 2008 have now been collected for Little Pokororo at Recorder, Big Pokororo at Recorder and Herring at Recorder sites. The collection of the auto-samples has enabled calibration relationships to be established that relate turbidity to suspended sediment concentration for all three sites. Where the turbidity /suspended sediment relationship could not be used due to missing data, a river discharge /suspended sediment relationship was developed to fill in the gaps. The turbidity /suspended sediment relationships were hindered by a lack of auto-sample data, especially at Big Pokororo. This was overcome by combining Big Pokororo and Little Pokororo data. Little Pokororo showed a classic loop rating for turbidity /suspended sediment, where SSC values were generally higher on the rising limb of the flood hydrograph than on the falling limb. The final values calculated are extremely sensitive to these relationship rating interpretations, however, the results appear realistic in terms of relativity between sites, catchments and forestry activity.

From the derived SSC time series, sediment storm yields have been calculated. SSSY in the Herring catchment have been up to 12 times higher than the other two catchments despite its smaller catchment size. Rainfall totals for individual events do not seem to be the driver behind the high SSSY values, but there is a stronger relationship between peak discharge and SSSY. While Little Pokororo and Big Pokororo have a linear relationship, Herring illustrates an exponential increase in SSSY to peak discharge. The Herring relationship is attributed to the wind throw event on October 2005 and subsequent harvesting in the Herring catchment, which Little Pokororo and Big Pokororo sustained a lot less damage and subsequent harvesting.

In comparison to previous years of 1997 to 2001, annual rainfall and flow has been lower than average for 2006 to 2008. Annual sediment yields for Little Pokororo and Big Pokororo sediment yield have decreased significantly from an average of 90 and 57 tonnes/km^2/year for 1997 to 2001 respectively, to 18 and 11 tonnes/km^2/year for 2006 to 2008. The decease in sediment yield reflects the lack of forestry activity in these catchments and the below average rainfall and flows. Whereas, Herring's sediment yield has increased dramatically from an average of 30 tonnes/km^2/year, to 149 tonnes/km^2/year, which coincides with the 2005 wind throw event and subsequent harvesting.

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Acknowledgement

The author would like to thank Tasman District Council and Landcare Research (in particular Les Basher) for their financial and logistical support.

Appendix 1: Instrumentation inventory for West Bank monitoring sediment sampling stations

Each of the three sites had the identical equipment as shown in Table A1.1.

Table A1.1: Instrumentation Inventory for the three monitoring sites

Equipment/Parameter	Make	Model	Range	Signal
Logger	Campbell	CR10X		
Stage	ISD Instruments	ISD	0-5m	0-5V
Turbidity	Greenspan	TS1200	0-2000NTU	SDI12
AWS	Isco	3700		

Appendix 2: Monitoring strategy and instructions for West Bank monitoring suspended sediment sites

Little Pokororo at Recorder

Big Pokororo at Recorder

Herring at Recorder

General aims and monitoring strategy

Provide information on impacts of forest harvesting, and recovery from harvesting on flow and suspended sediment transport, by:

Analyse flow, suspended sediment and turbidity data from the Herring, Little Pokororo and Big Pokororo catchments to produce a time series of flow and sediment concentration.

Extract storm event data, calculate event sediment loads and relate to event indices such as peak flow.

Relate measured sediment yields to forest harvesting activities within each catchment and compare with results obtained prior to July 2006 (in relation to land use activities and climate).

Maintaining turbidity sensors and records

The Greenspan sensors should be inspected and downloaded at least 6-weekly, more often and ideally monthly. The turbidity and stage series data should be extracted from the data-logger archived on TIDEDA files. Plot and inspect the series data as soon as it is downloaded, checking for problems such as fouling, drift, or missing record. At every visit check the turbidity sensor reading against the calibrated sonde.

Auto-sampler operation, maintenance, sample and data processing

The auto-samplers are there to collect calibration samples and to provide a back-up in case the turbidity record croaks. They are scheduled to sample when the water level reaches a certain level, which initially has been predetermined by analyses of historic flow. The trigger levels were increased regularly to try and sample the range of flows.

All auto-samples should be analysed for SSC by the filtration method. Report results are imported into an Excel table as …

Date Time Stage SSC(auto) Turbidity (lab results) Turbidity (off the logger at the matching time)

Dates, times, and stage can be extracted from the logger files by matching-up bottle numbers and add to this table with every batch of samples.

Manual sampling during events

On several occasions, the auto-sampler was manually triggered when heavy rain warnings were coming to tuition and the sampler trigger level was set much higher.

Appendix 3: Raw turbidity and discharge series

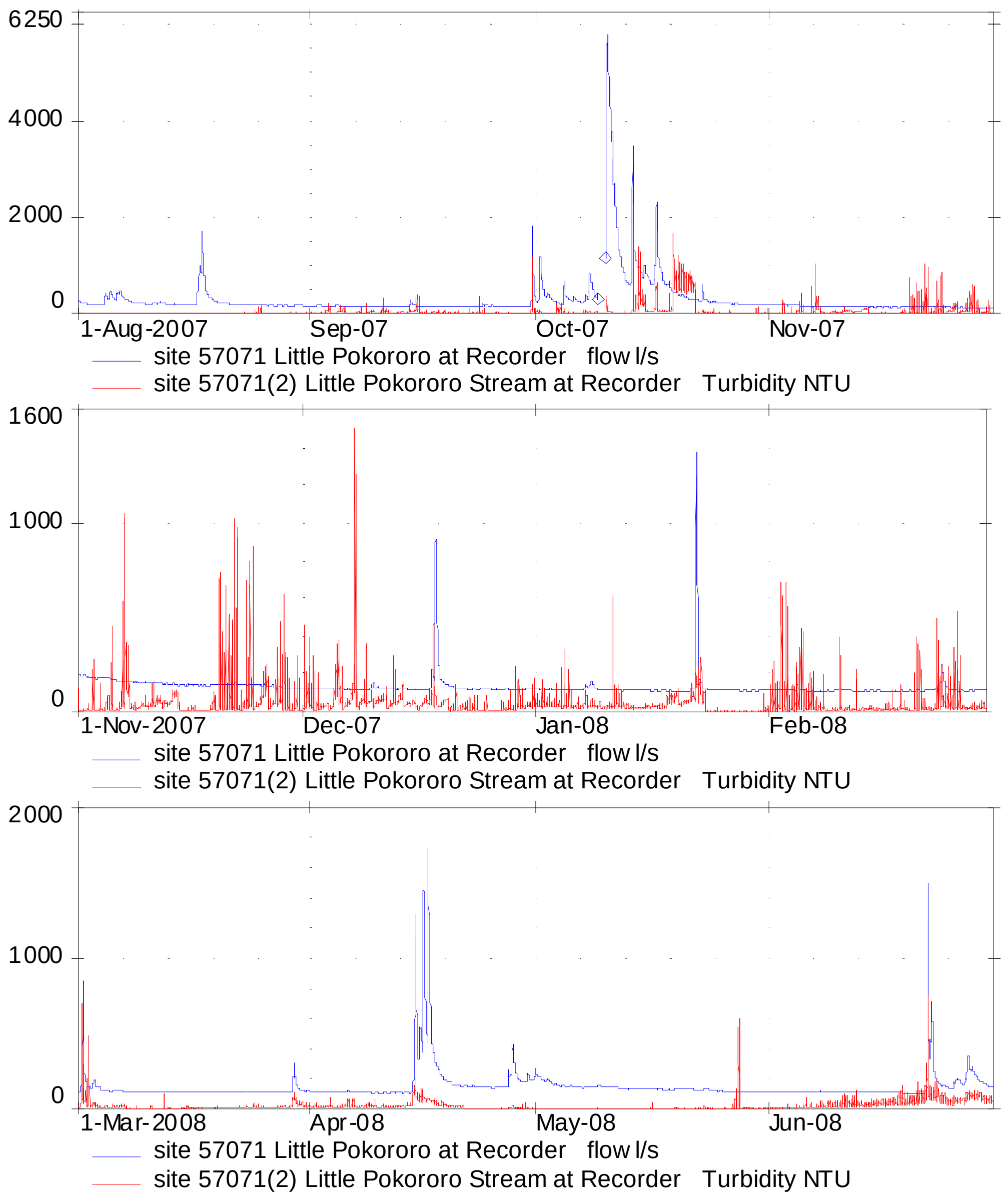


Figure A3.1: Flow (blue, in l/s) and raw turbidity (red, in NTU) records 1 August 2007 to 1 July 2008 at Little Pokororo at Recorder.

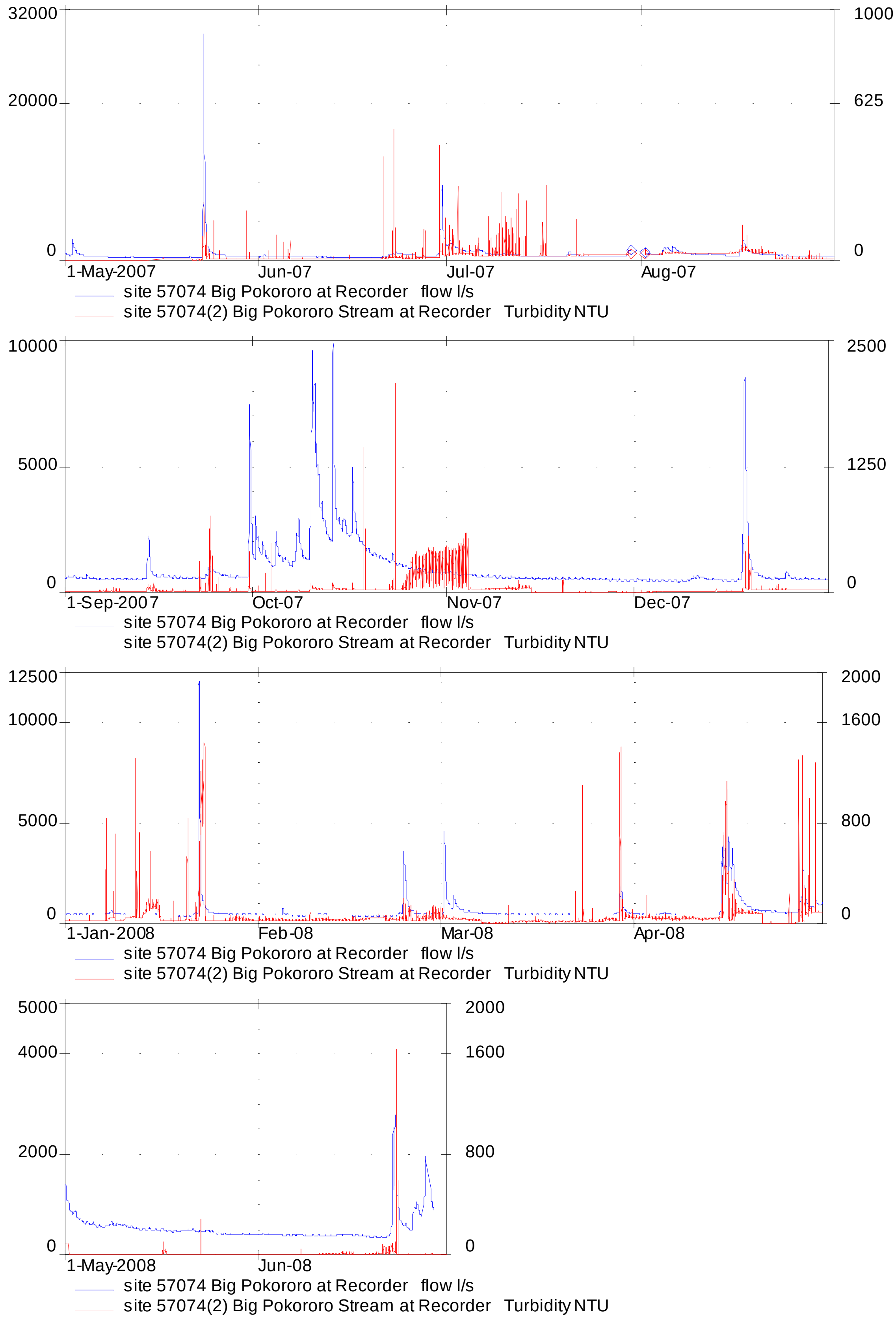


Figure A3.2: Flow (blue, in l/s) and raw turbidity (red, in NTU) records 1 May 2007 to 1 July 2008 at Big Pokororo at Recorder.

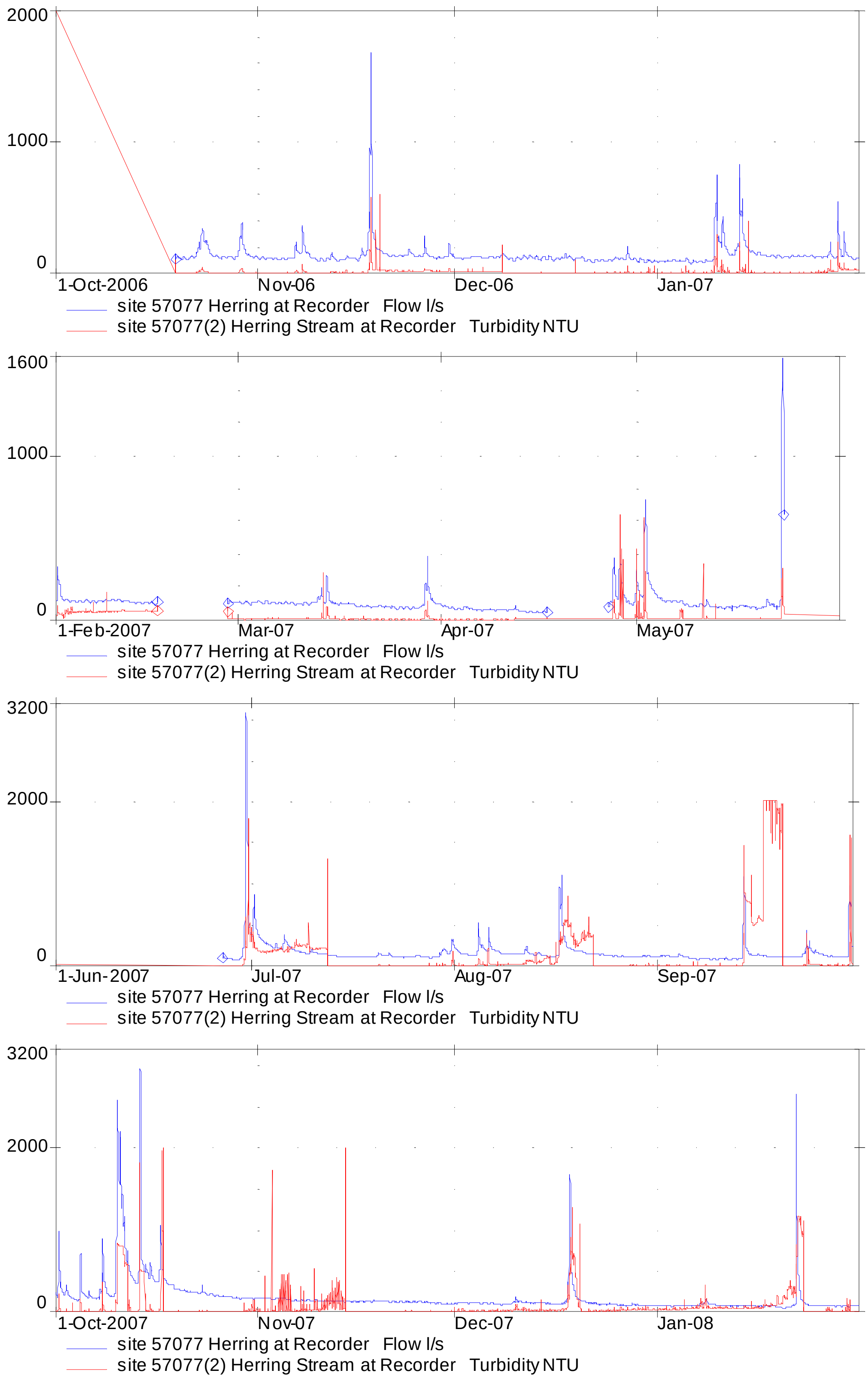
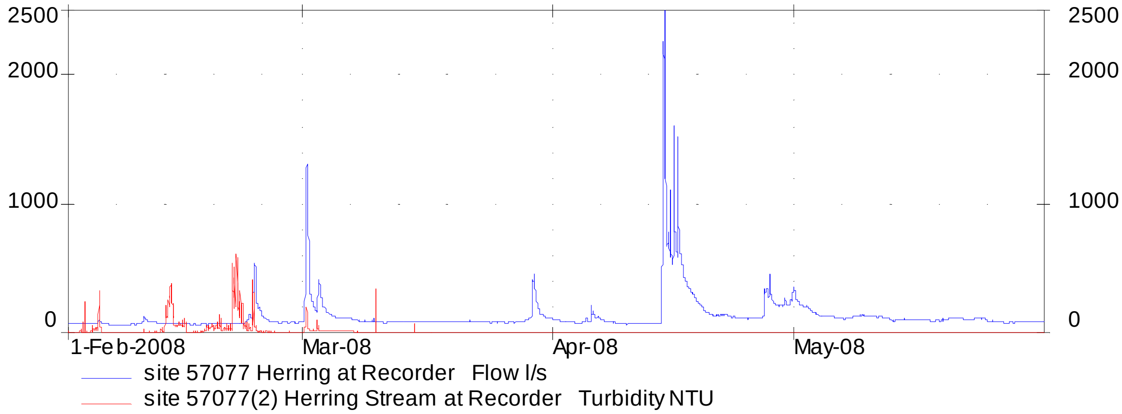


Figure A3.3: Flow (blue, in l/s) and raw turbidity (red, in NTU) records 1 October 2006 to 1 February 2008 at Herring at Recorder.



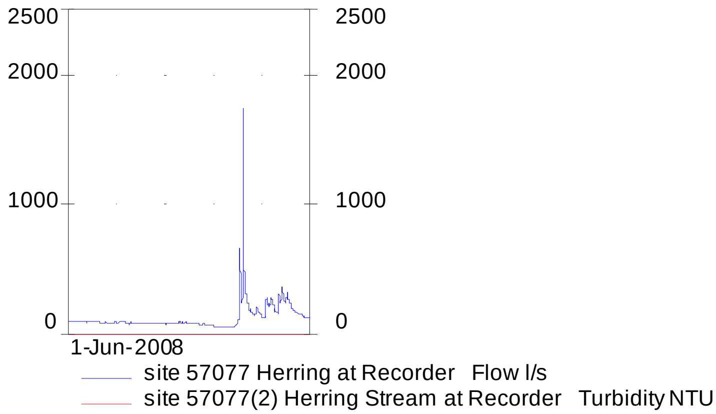


Figure A3.4: Flow (blue, in l/s) and raw turbidity (red, in NTU) records 1 February 2008 to 1 July 2008 at Herring at Recorder.

Appendix 4: Derived SSC and discharge plots

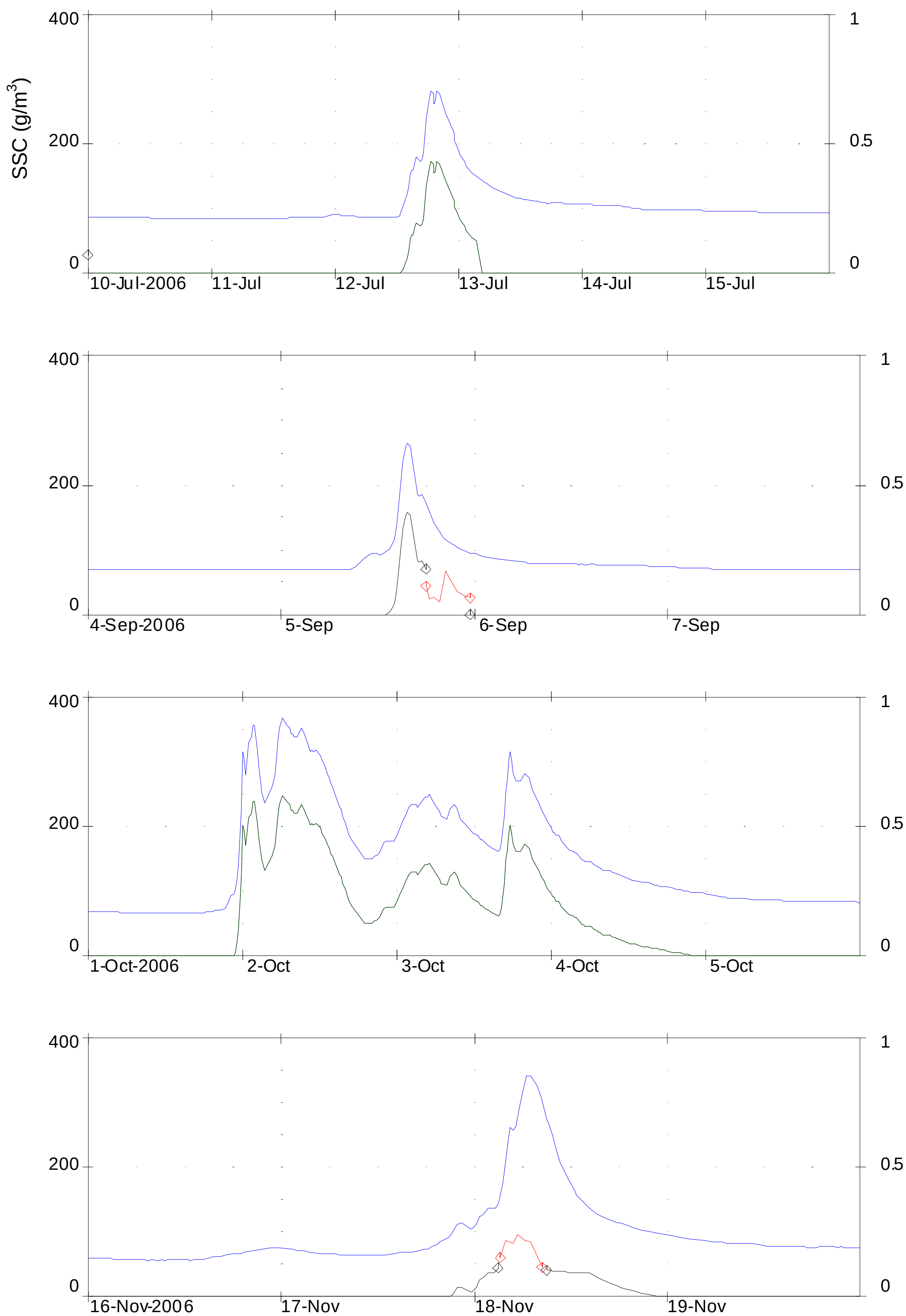


Figure A4.1: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Little Pokororo at Recorder.

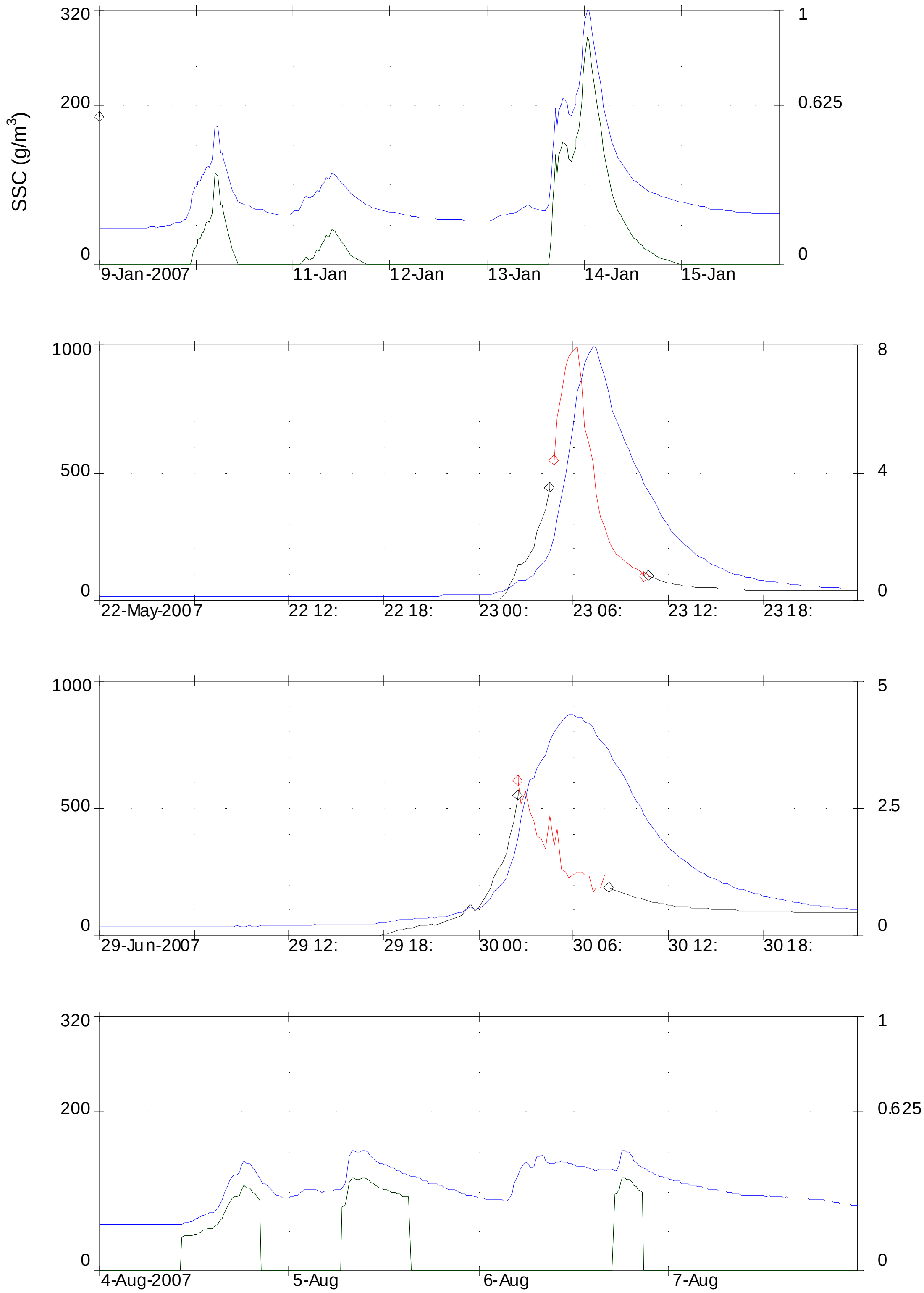


Figure A4.2: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Little Pokororo at Recorder.

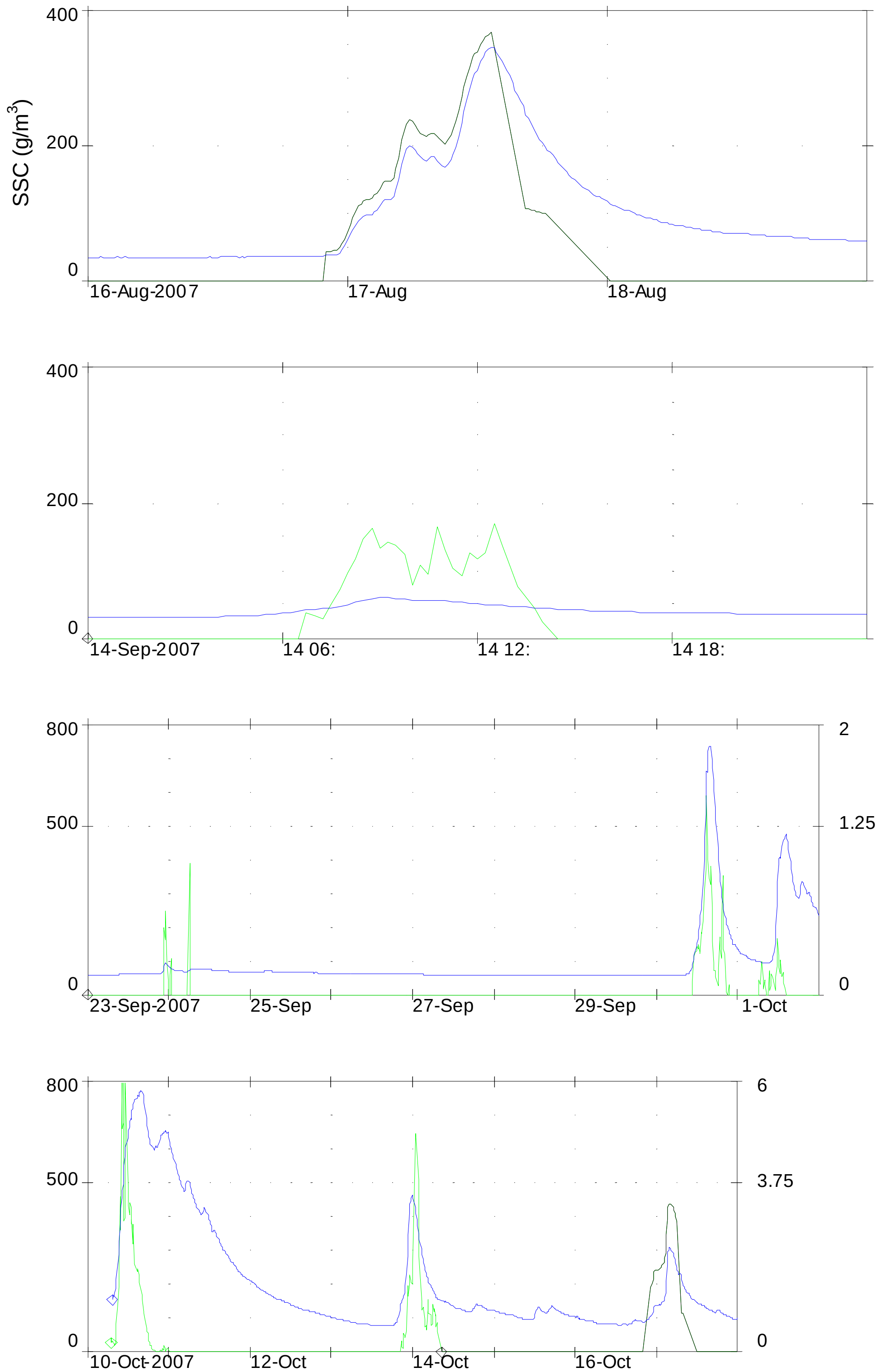


Figure A4.3: River discharge (blue, m3/s) and SSC derived time series ‘components’ – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Little Pokororo at Recorder.

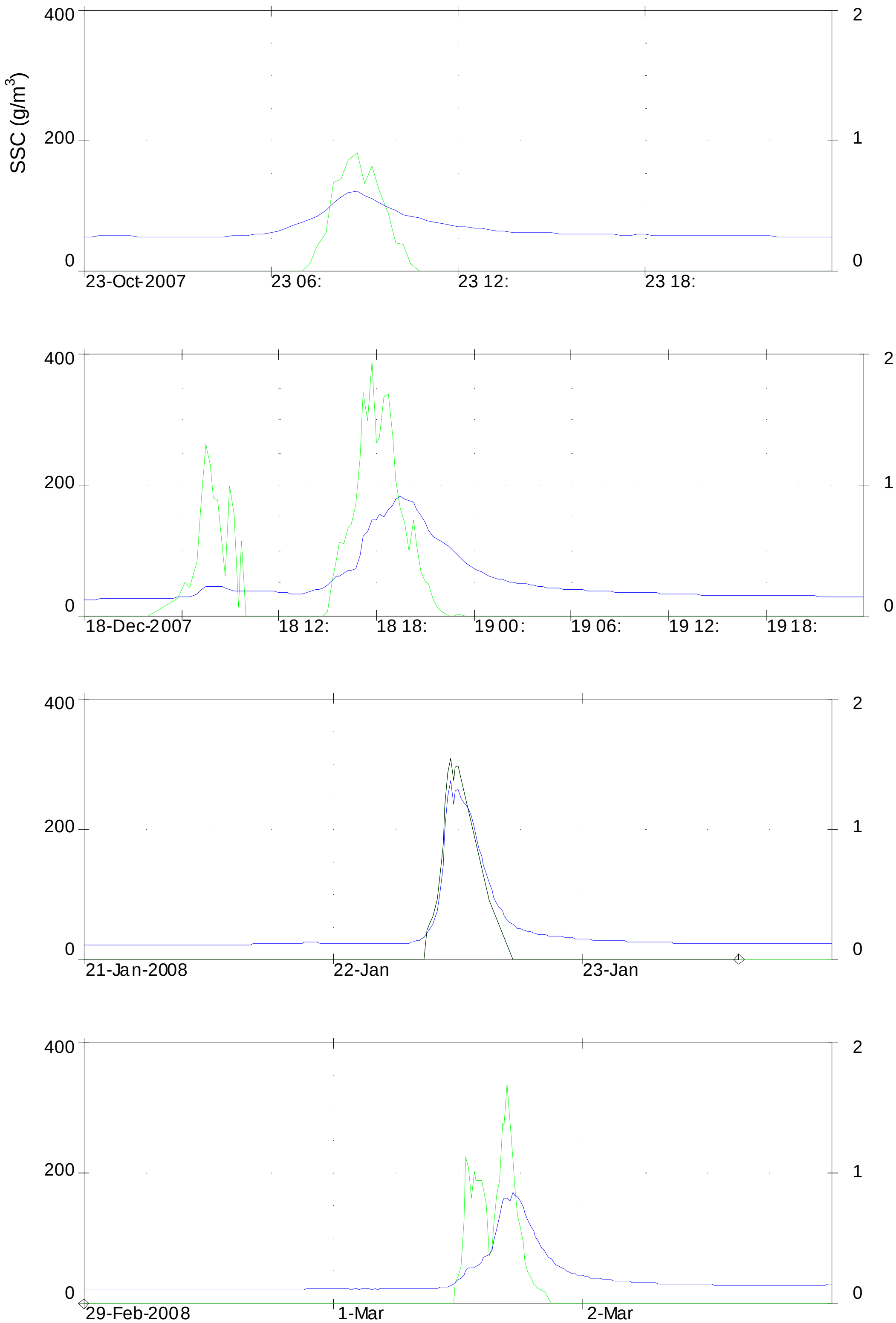


Figure A4.4: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Little Pokororo at Recorder.

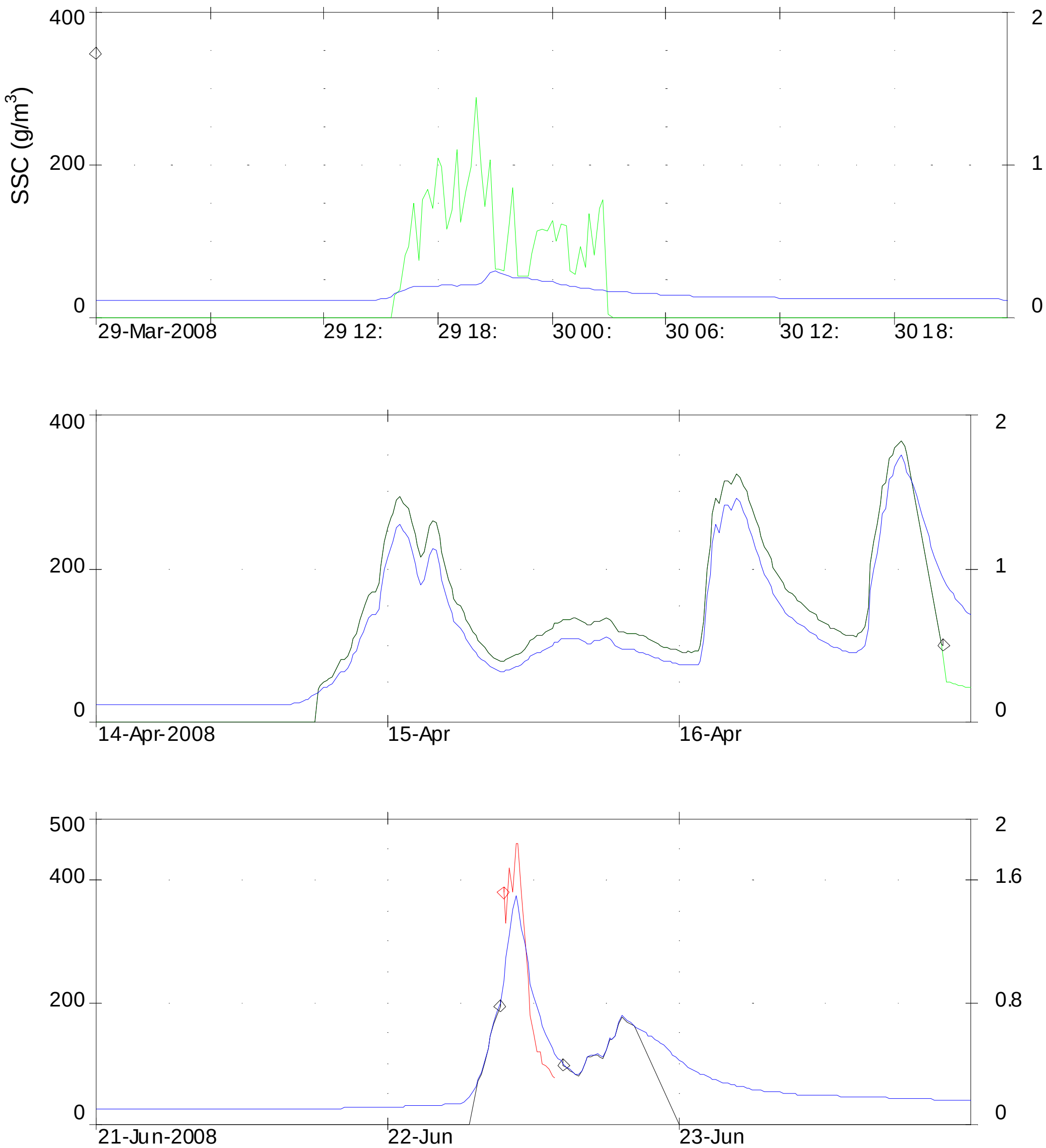


Figure A4.5: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Little Pokororo at Recorder.

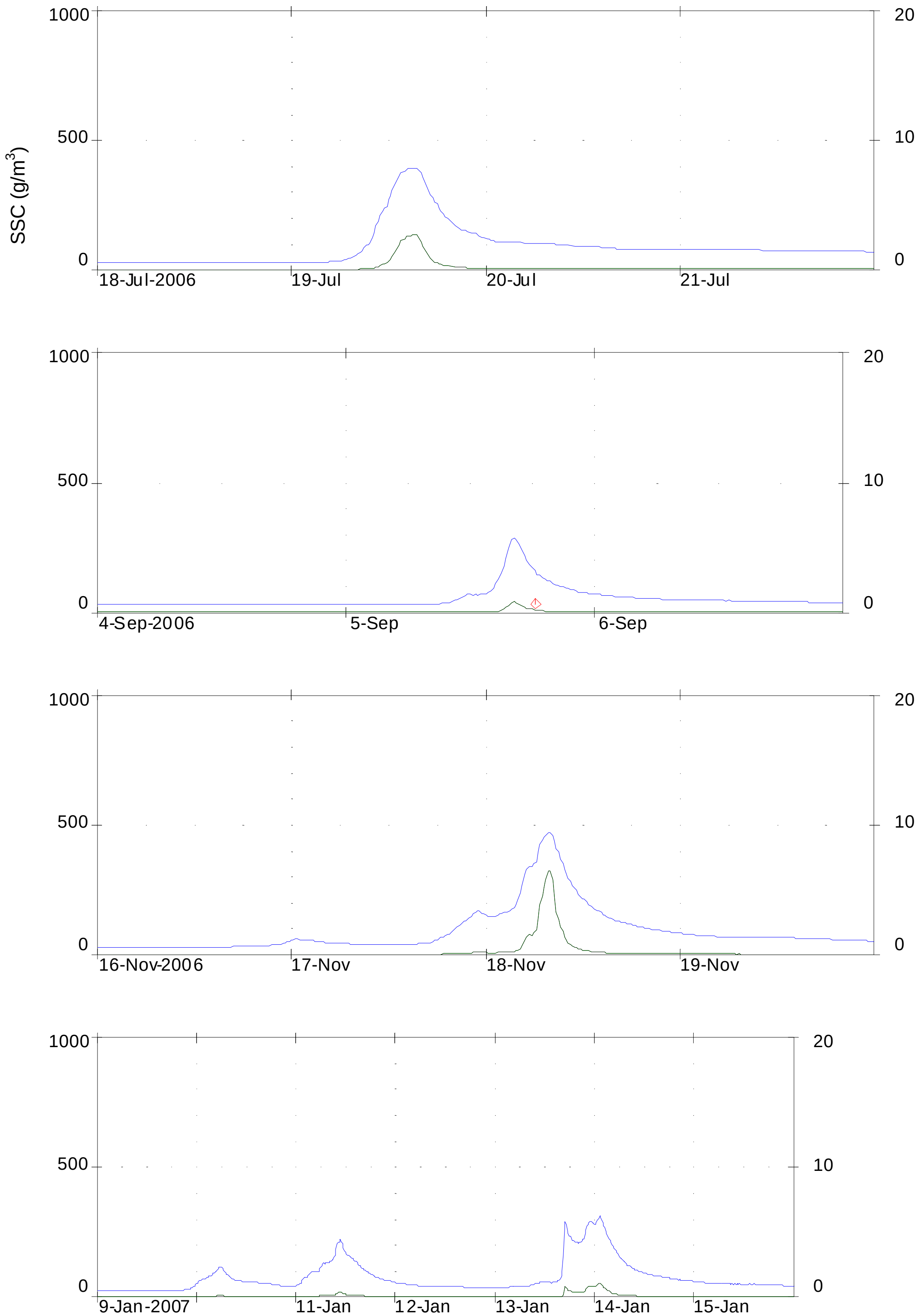


Figure A4.6: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Big Pokororo at Recorder.

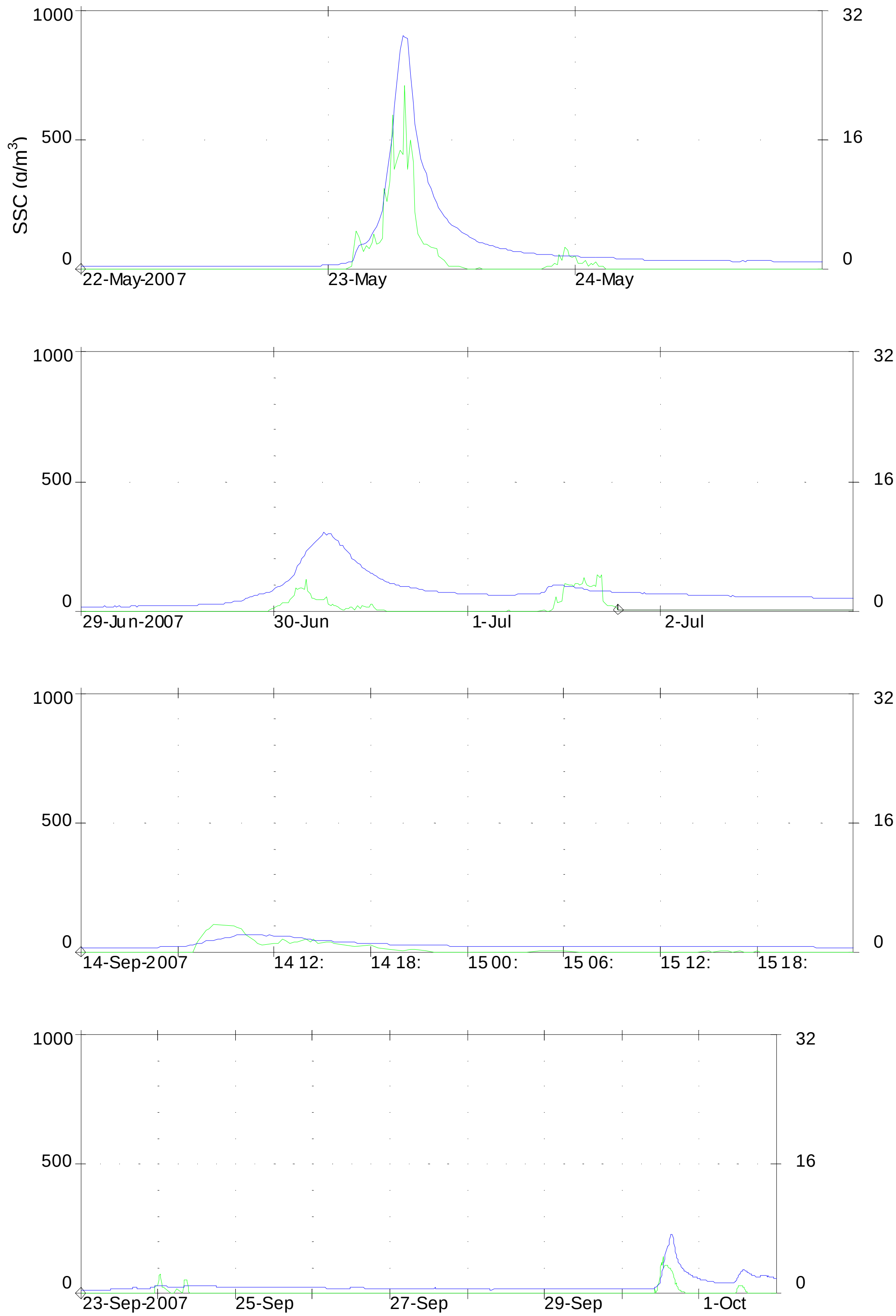


Figure A4.7: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (gray) for events at Big Pokororo at Recorder.

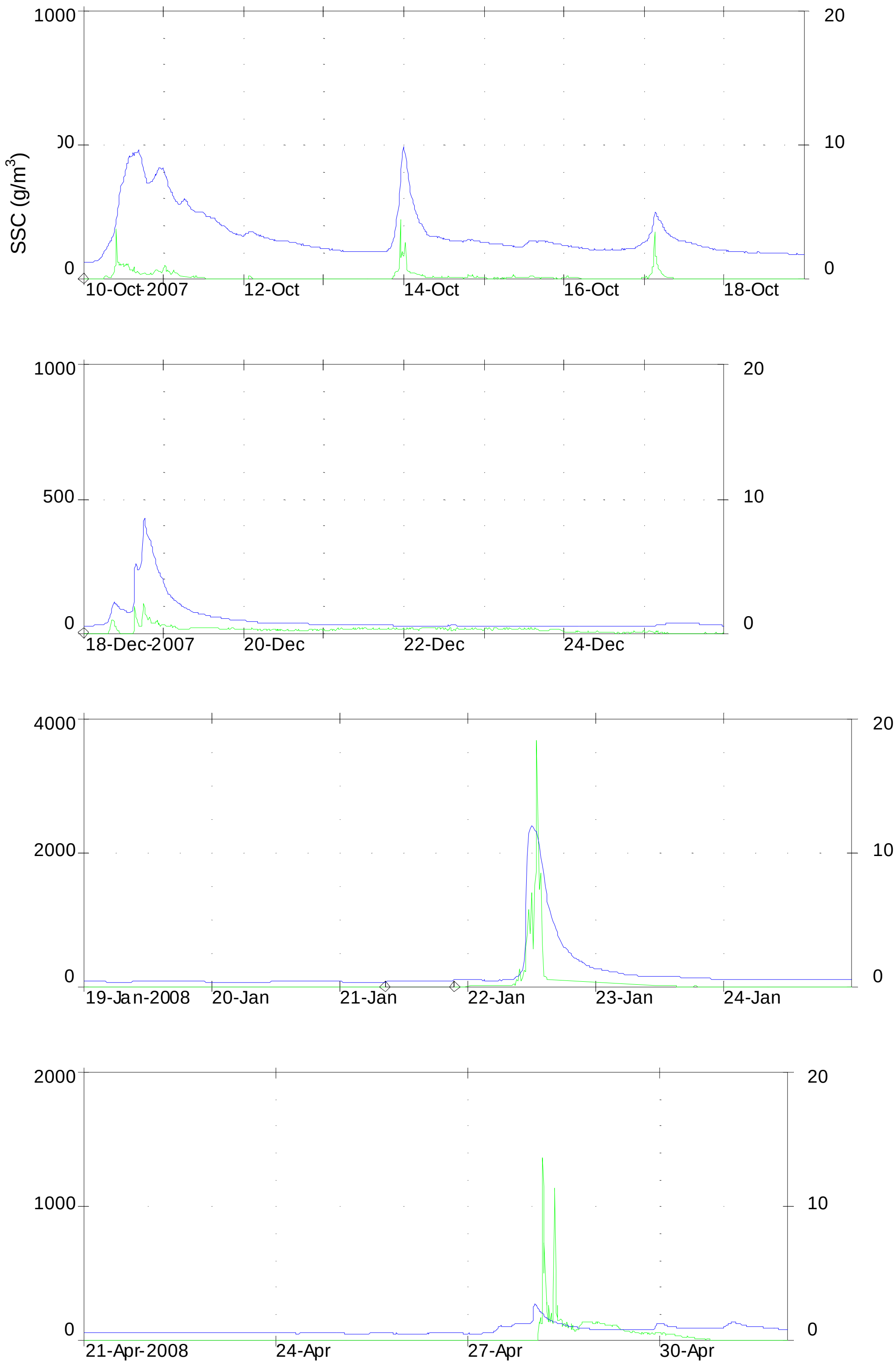


Figure A4.8: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Big Pokororo at Recorder.

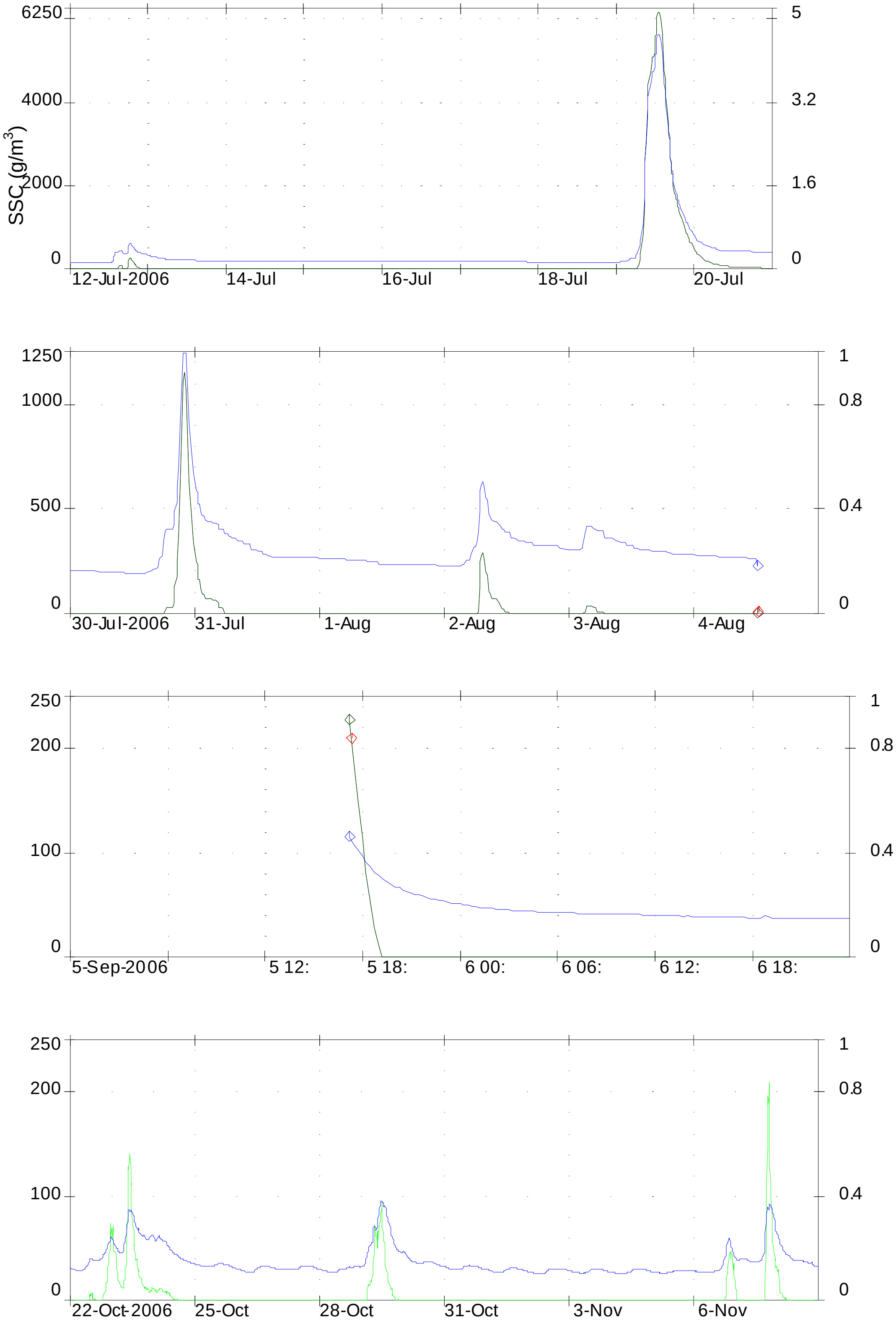


Figure A4.9: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

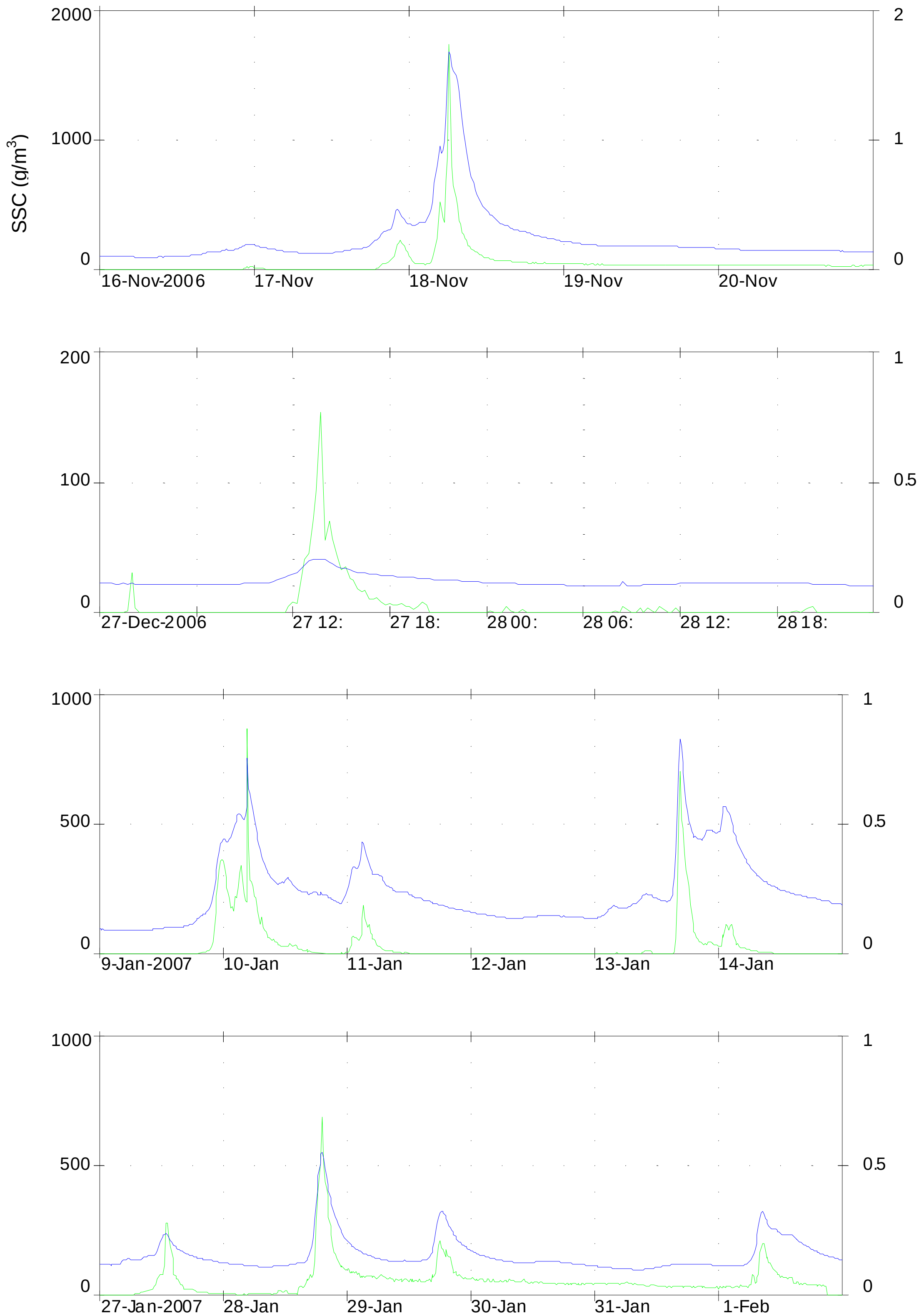


Figure A4.10: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

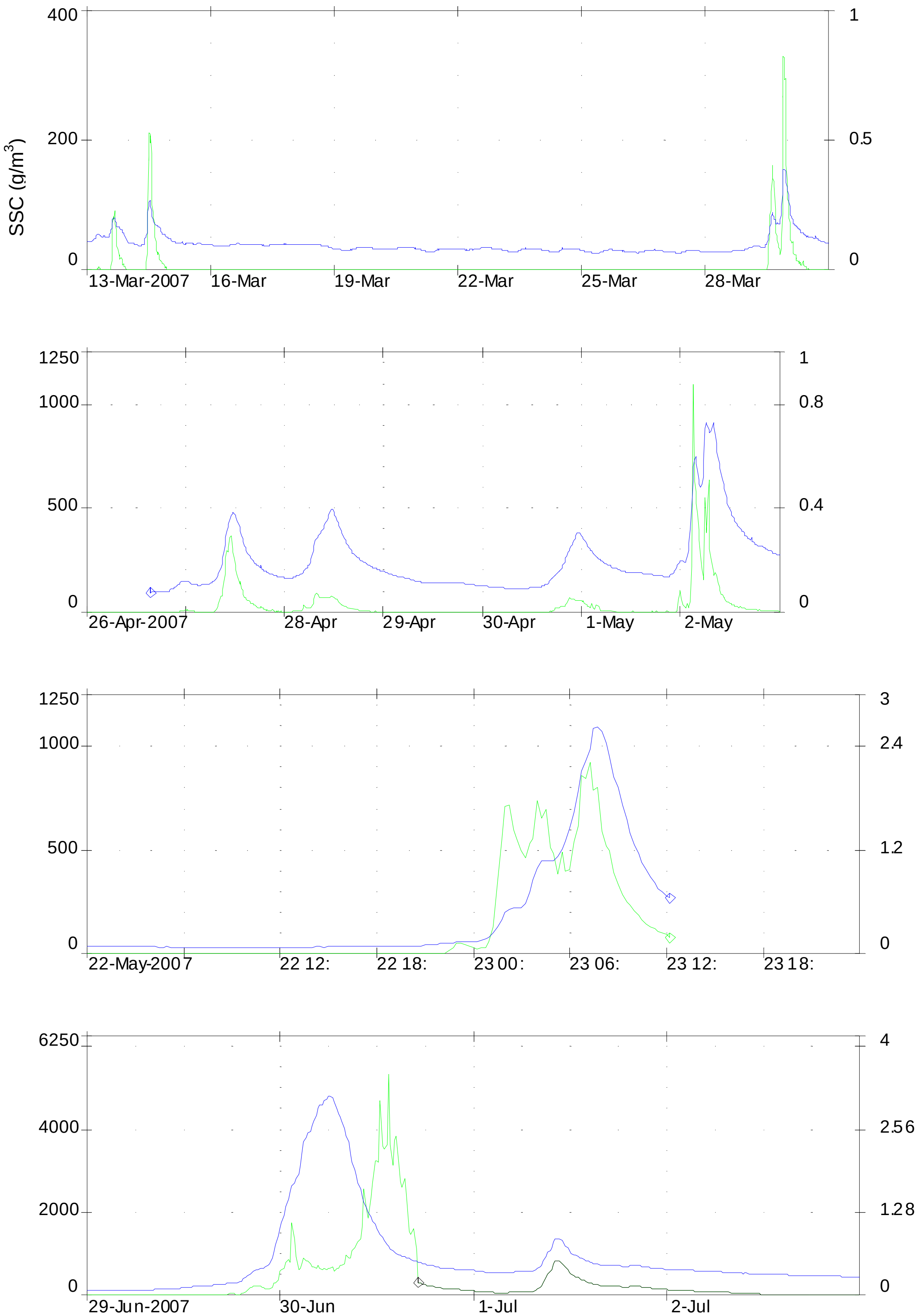


Figure A4.11: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

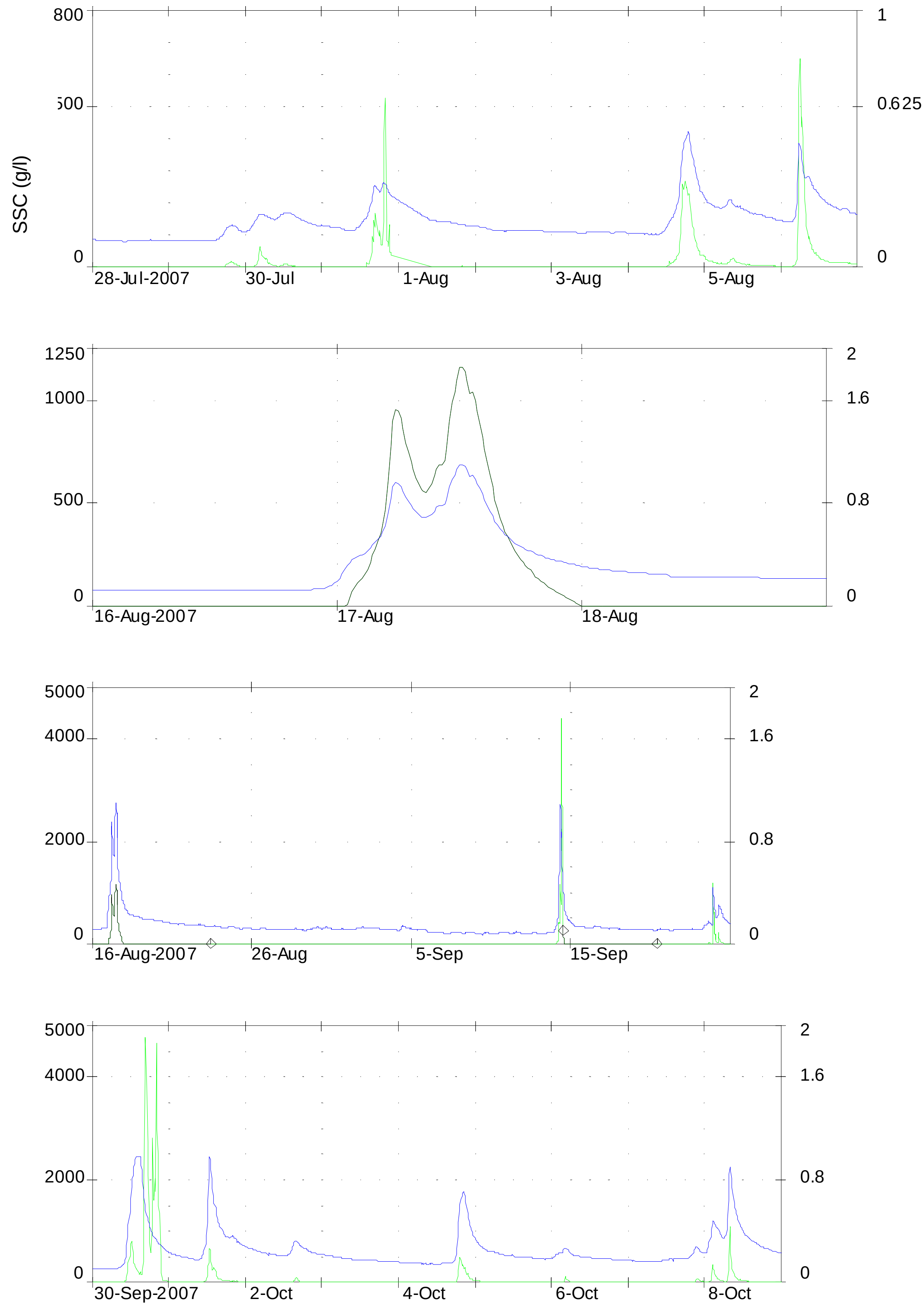


Figure A4.12: River discharge (blue, m3/s) and SSC derived time series ‘components’ – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

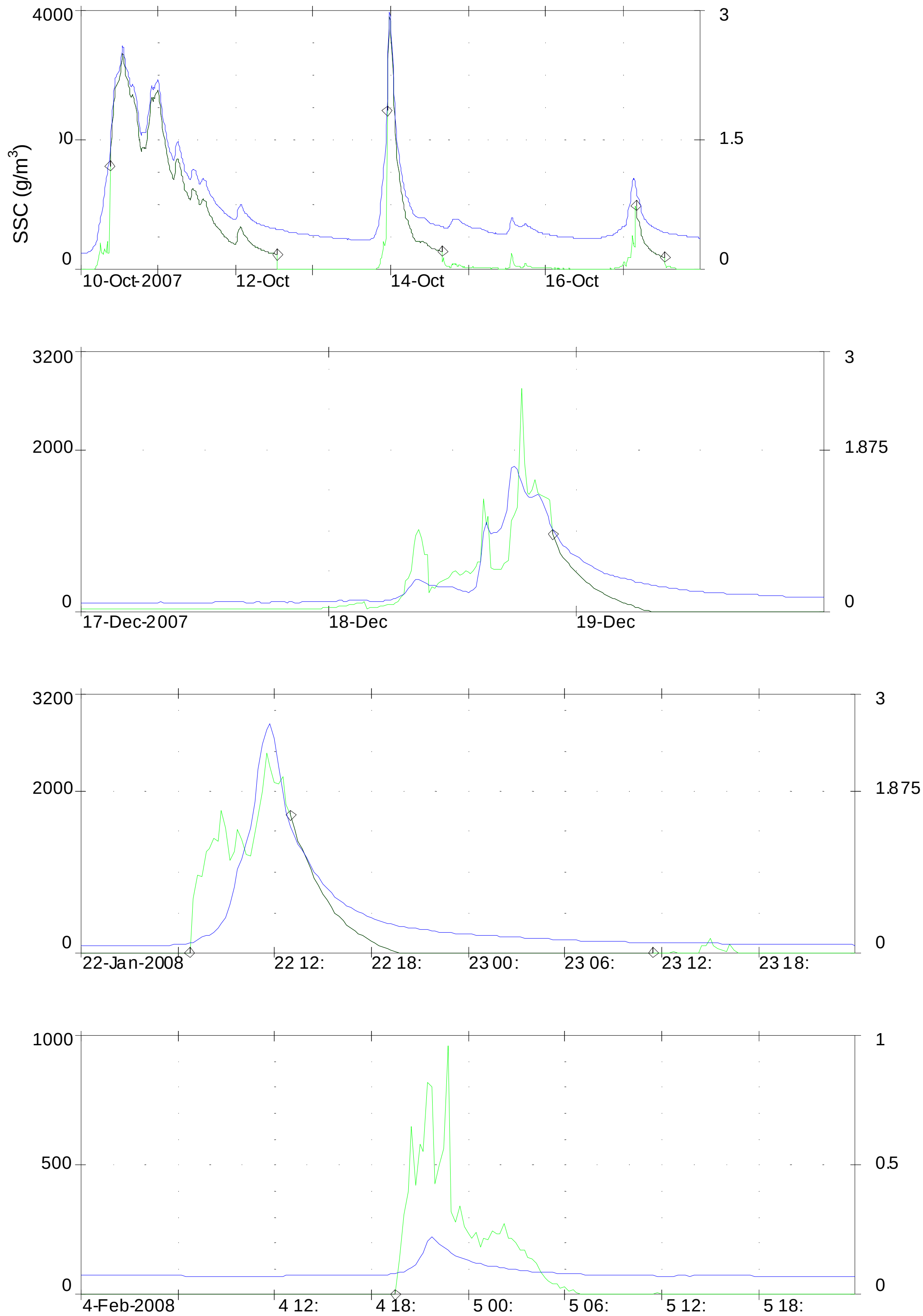


Figure A4.13: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

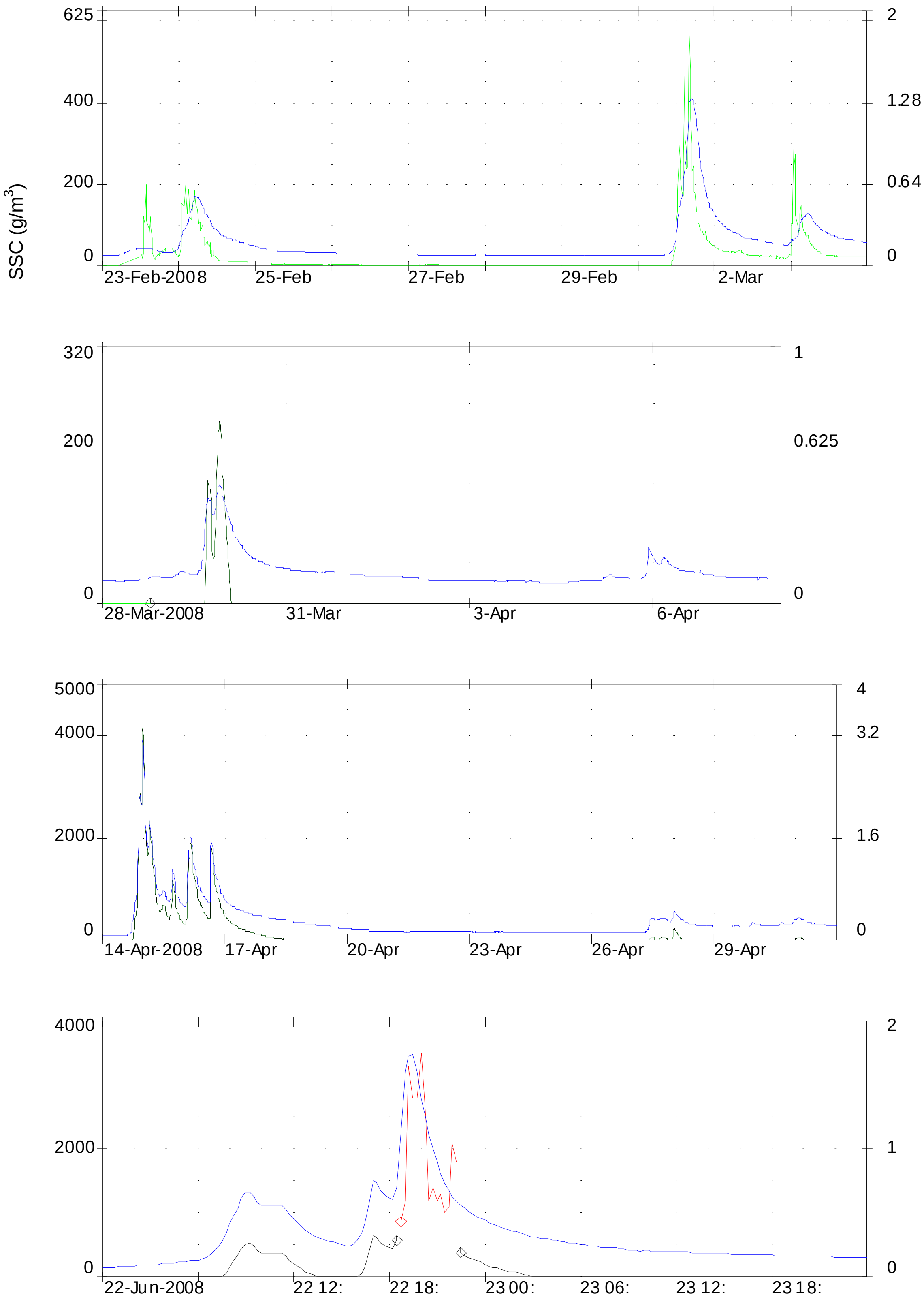


Figure A4.14: River discharge (blue, m3/s) and SSC derived time series 'components' – autosamples (red), NTU/SSC relationship (green), discharge/SSC relationship (grey) for events at Herring at Recorder.

Appendix 5: Final SSC time series

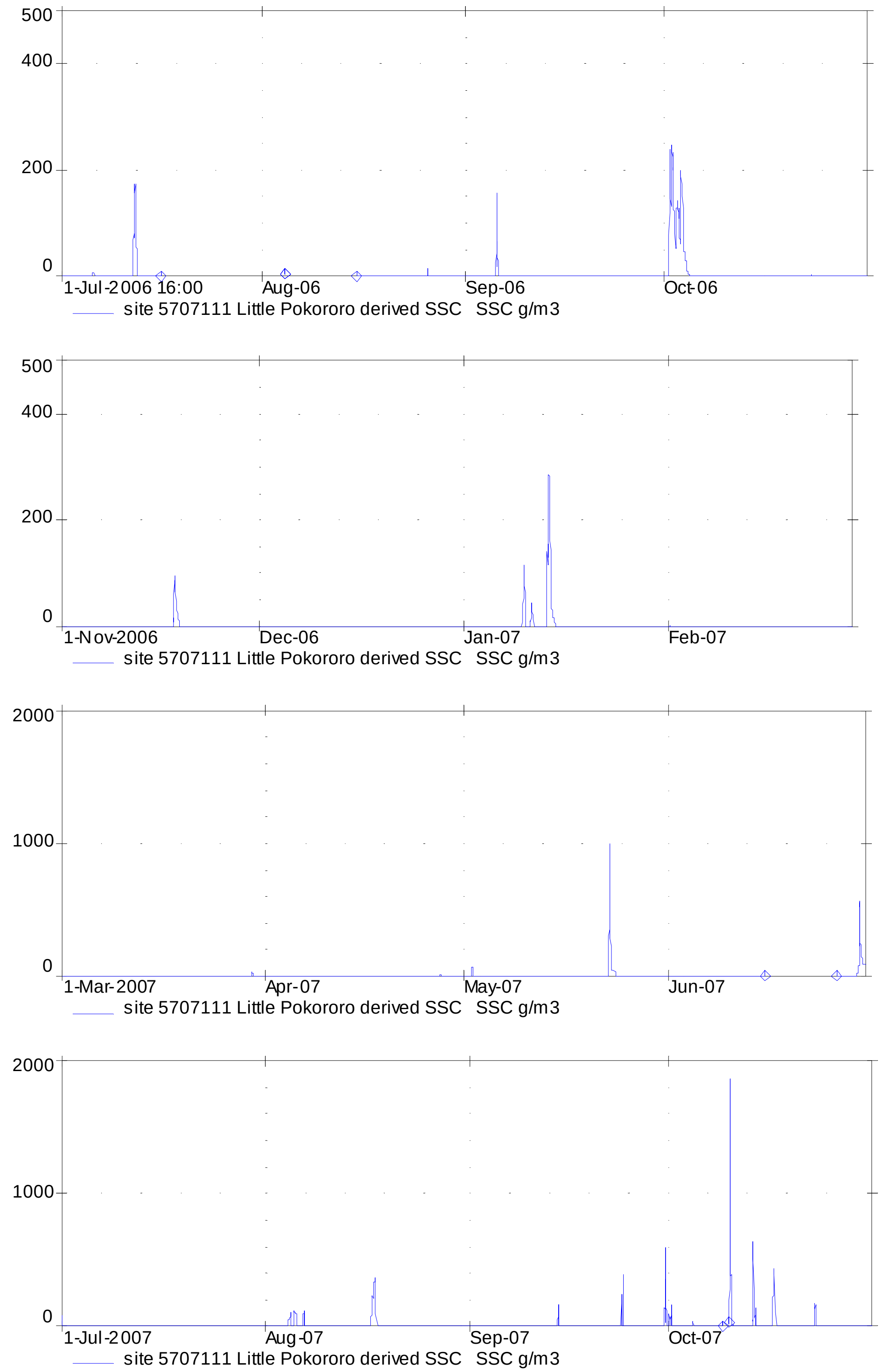


Figure A5.1: Derived suspended concentration (SSC, g/m3) record, July 2006 to October 2007 at Little Pokororo at Recorder.

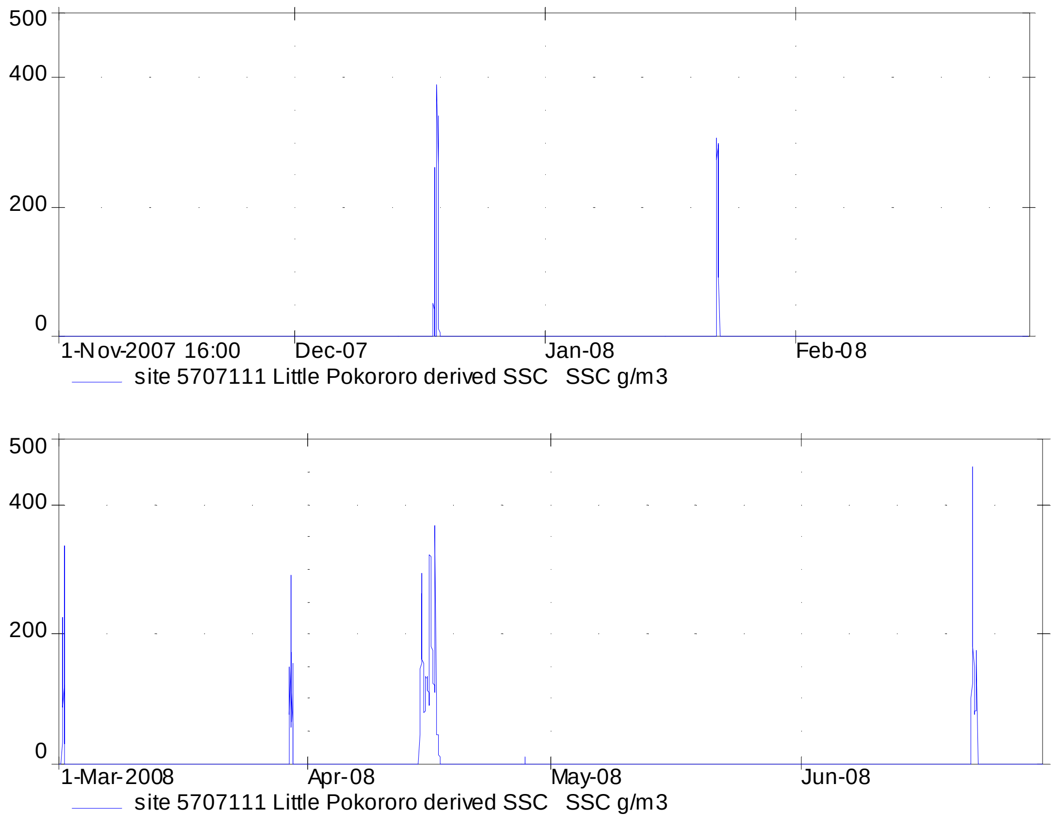


Figure A5.2: Derived suspended concentration (SSC, g/m3) record, November 2007 to June 2008 at Little Pokororo at Recorder.

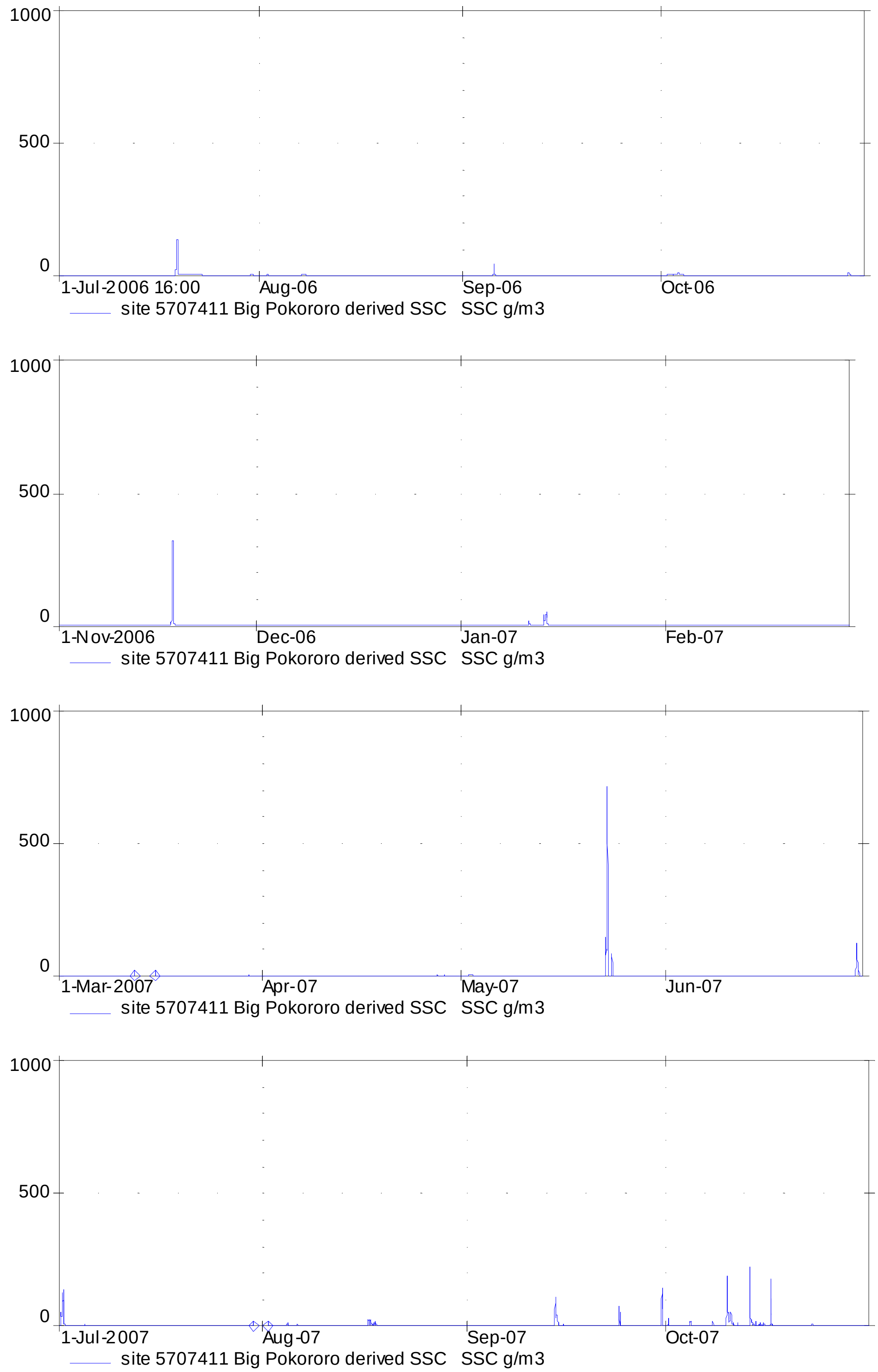


Figure A5.3: Derived suspended concentration (SSC, g/m3) record, July 2006 to October 2007 at Big Pokororo at Recorder.

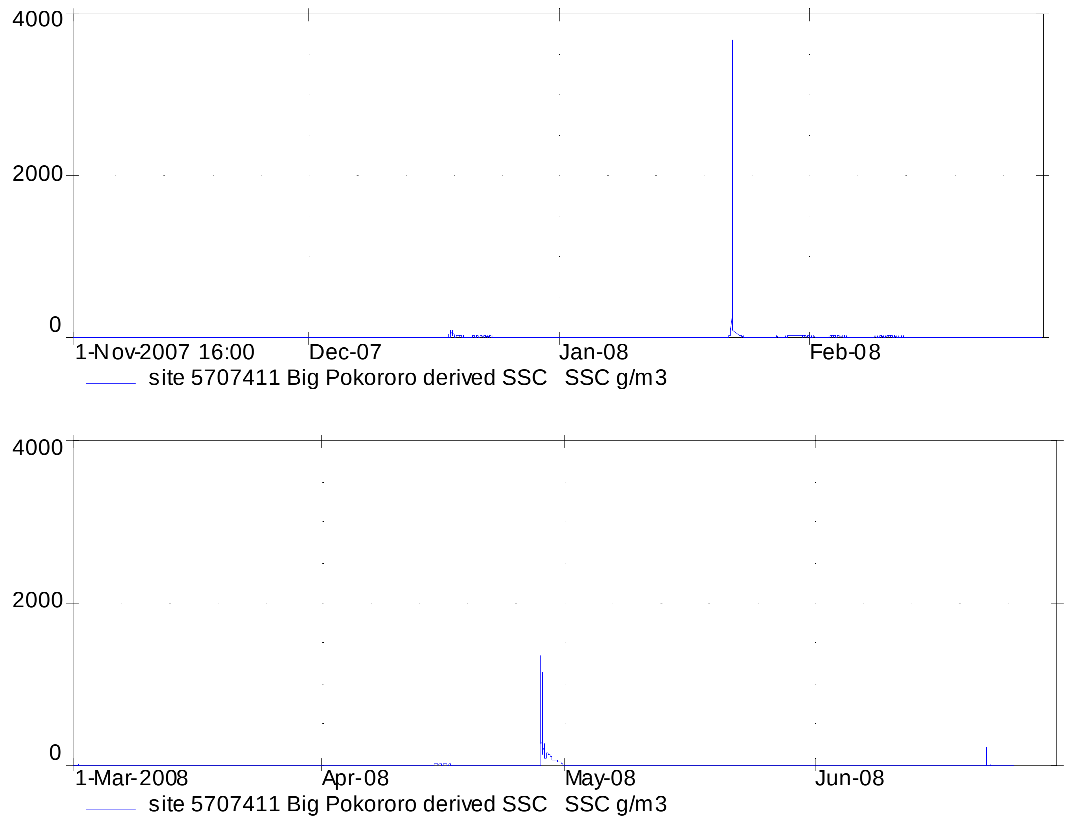


Figure A5.4: Derived suspended concentration (SSC, g/m3) record, November 2007 to June 2008 at Big Pokororo at Recorder.

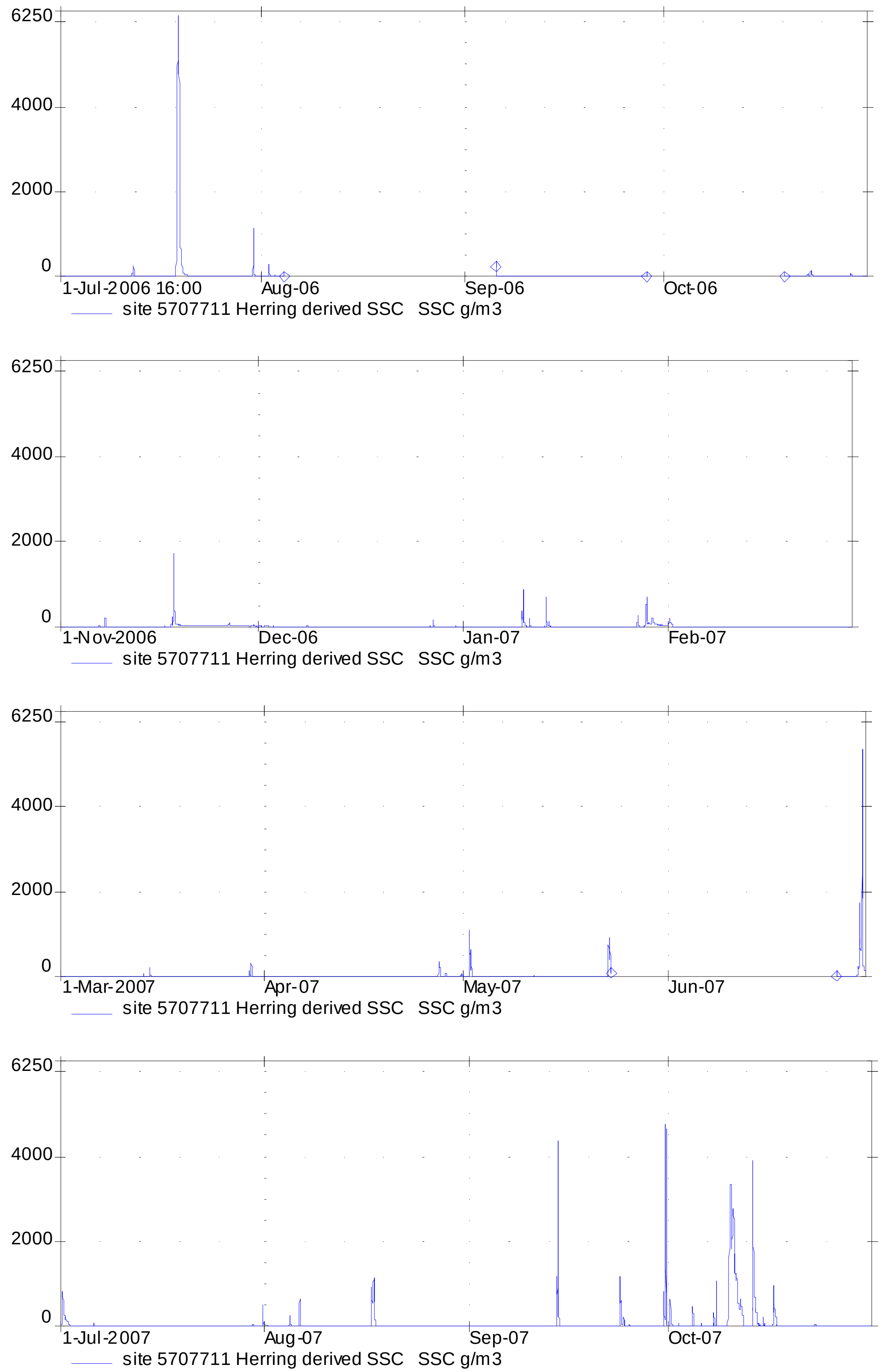
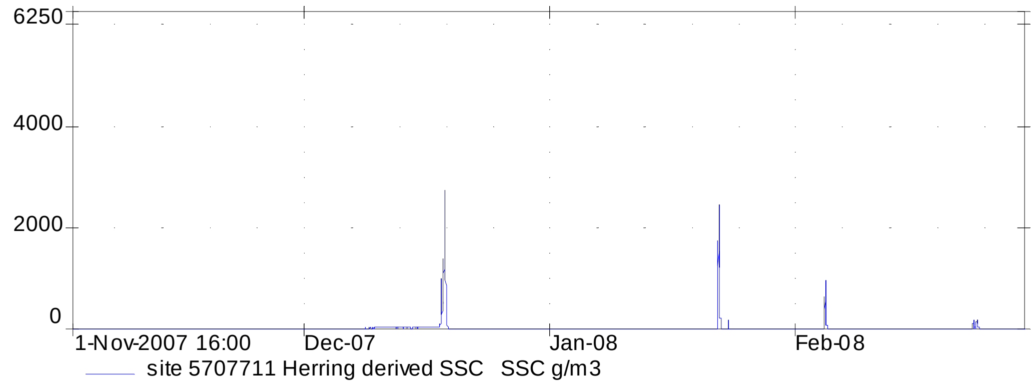


Figure A5.5: Derived suspended concentration (SSC, g/m3) record, July 2006 to October 2007 at Herring at Recorder.



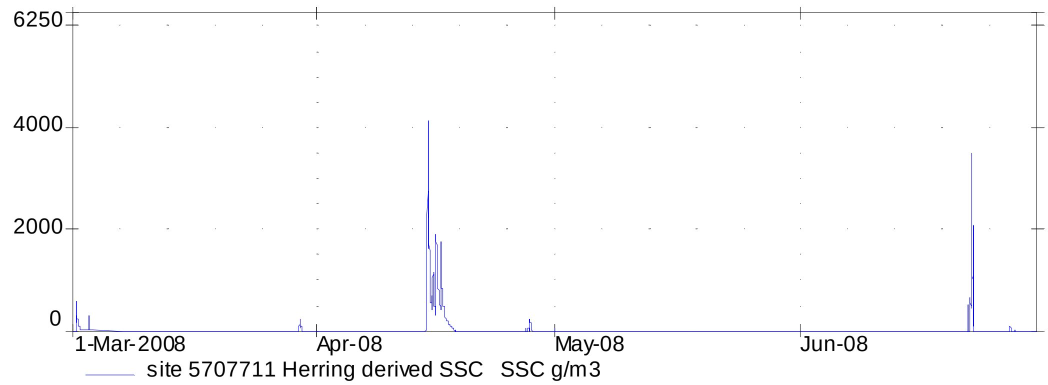


Figure A5.6: Derived suspended concentration (SSC, g/m3) record, November 2007 to June 2008 at Herring at Recorder.