APPENDIX IV-E

LONG-TERM SUSPENDED SEDIMENT YIELD FROM THE MAIN FISH BAY GUT WATERSHED

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Purpose

The main objective of this component of the study was to quantify long-term sediment yield rates into Fish Bay from the Main Fish Bay Gut watershed. These yield rates were compared to estimated sediment yield rates resulting from the application of the GIS-based STJ-EROS sediment budget model to the same basin as a way to test the model results (Chapter 5).

Methods

Rainfall was measured at on the western area of Fish Bay Estate. Watershed-scale runoff response was monitored at the main Fish Bay Gut between October 1998 and October 2001. The gaging station consisted of a pressure transducer connected to a datalogger. The pressure transducer and datalogger were calibrated prior to installation in 1998. Instrument readings were checked against actual stage measurements at a frequency ranging from once a week to once every three months. The datalogger recorded instantaneous stream stage at 15-minute intervals. The drainage area at this location was determined with the digital elevation model for St. John, and it was 3.46 km^2.

A rating curve was developed to convert stage measurements into flow rates. The rating curve was developed based on a combination of field measurements and Manning's flow velocity equation (Dunne and Leopold, 1978). Field measurements were taken in November 1998 and they consisted in a detailed cross-section survey, a longitudinal profile of the stream reach, and three discharge measurements. Discharge measurements were taken with a current meter by wading the channel during discharge events (Buchanan and Somers, 1980). The maximum stream stage represented by these measurements was 1.13 m, which converts to a discharge rate of 0.67 $m^3 s^{-1}$ or 0.07 cm hr^{-1}. Measurements were not taken at higher flow rates due to the impossibility of wading the stream at higher flows.

Manning's equation (Dunne and Leopold, 1978) was used to estimate flow velocities for stream stages higher than 1.13 m. A longitudinal survey of the stream reach determined that the channel had a slope of 0.002 m m^{-1}. Manning's roughness coefficient for the stream reach was estimated as 0.06. The resulting rating curve is shown in Figure 1.

The runoff record from the main Fish Bay Gut lasted for a period of only 3.3 years. In order to estimate long-term runoff and sediment yield rates a longer record is preferred. A fifteen year record exists for the 0.95 km^2 Guinea Gut basin. This gaging station is run by the US Geological Survey and is approximately two kilometers west of the main Fish Bay Gut station.

The first step was to determine if the main Fish Bay Gut and Guinea Gut basins had similar runoff response in terms of peak discharges and total runoff. Peak discharge and overall runoff response measured at both stations was compared for the period extending from October 1998 to November 2001 by plotting individual storm hydrographs. Total runoff for both stations was also compared by constructing flow duration curves for the 15-minute discharge data. A flow duration curve indicates the percentage of time a given river discharge is exceeded (Julien, 1995). The following discrete flow rate intervals were used in developing the flow duration curves: 0.00, 0.01, 0.05, 0.10, 0.25, 0.50, and continuing on to 4.5 cm hr^{-1} at every 0.25 cm hr^{-1} increments (Table 1- Column A). The annual average flow rate for each discrete flow rate interval is calculated as the product of the total percent time of each flow category (Column C) times the average flow rate for the interval (Column D) and a conversion factor. The sum of the products for all flow rate intervals (Column E) equals the long-term runoff total. A close match of the flow duration curves for both stations permitted the estimation of long-term annual runoff and sediment yields for the Main Fish Bay Gut by use of the Guinea Gut flow duration curve.

Thirty-five suspended sediment samples were collected from the main Fish Bay Gut over ten different runoff events between October 1998 and February 2000 with a DH-48 sampler. The samples were analyzed for suspended sediment concentration following standard methods (ASTM, 1977). A sediment-rating curve was determined by plotting suspended sediment concentration against discharge.

An annual average suspended sediment yield estimate for the main Fish Bay Gut was based on the 35 samples and the flow duration curve from Guinea Gut. Average annual suspended sediment yield for each flow rate interval in the Guinea Gut flow duration curve was calculated as the product of the total runoff for each flow rate class (Table 1-Column E) times the average suspended sediment concentration for the entire 35 sample data set. The sum of the total sediment yield for all flow rate categories (Column G) equals the long-term suspended sediment yield for the main Fish Bay Gut.

Results

Semi-annual hydrographs show runoff measured at the main Fish Bay Gut station between October 1998 and October 2001 (Figures 2a-2d). These figures show the ephemeral nature of streams that is typical of St. John. Long periods with no flow are occasionally interrupted by short-lived runoff events. These runoff events are generally associated with hurricanes or intense thunderstorms with high antecedent moisture levels.

The relationship between direct runoff in the main Fish Bay Gut and rainfall was examined for all 59 events between October 1998 and December 1999 that showed a runoff response on the stream (Table 2). These events produced a total rainfall of 90.8 cm, and had an average rainfall of 1.54 cm per event with values ranging from 0.08 to 12.9 cm. Runoff response for individual events had a mean of 0.22 cm. The total runoff was 12.9 cm for an overall runoff coefficient of 0.14 cm cm^{-1}. Direct runoff showed a non-linear relationship with total rainfall (Figure 3).

Main Fish Bay Gut hydrographs show that 4.3 cm hr^{-1} was the highest runoff rate between 1998 and 2001 and this occurred during Hurricane Lenny on 17 November 1999

(Figures 2a-2d). The total runoff during this period was 51.2 cm. The total rainfall laws 167 cm for an overall runoff coefficient of 0.31 cm cm^{-1}.

By combining field observations with the hydrographs shown in Figures 2a-2d it was possible to determine that discharge rates of less than 0.01 cm hr^{-1} were not delivering runoff or sediment into the bay. Flow rates less than or equal to 0.01 cm hr^{-1} were not sufficient to overtop and break a sandy-berm that separates a narrow wetland area from Fish Bay. This berm prevented runoff and sediment being carried by the gut to be delivered into the marine environment. By discarding all flows equal to or less than 0.01 cm hr^{-1} it was estimated that only 4.4 cm, or 8% of the total 51.2 cm of runoff were delivered into Fish Bay.

Fourteen storm hydrographs from October 1998 to November 2001 show that runoff responses from Fish Bay Gut and Guinea Gut tend to be similar, particularly for events with peak flows exceeding 0.1 cm hr^{-1} (Figures 4a-4n). A flow duration curve for the 15-year Guinea Gut flow record shows only slight discrepancies with the main Fish Bay gut curve (Figure 5). The flow duration curves for both basins show that flows of 0.01 cm hr^{-1} are exceeded only 0.8 % of the time. Flows between 0.10 and 1.5 cm hr^{-1} are slightly more common on Guinea Gut than on the main Fish Bay Gut, but flows exceeding 2.0 cm hr^{-1} were more common on the main Fish Bay Gut than on Guinea Gut. Despite these differences it was concluded that the long-term Guinea Gut flow duration curve could be used to estimate runoff yields from the main Fish Bay Gut. Application of the flow duration curve from Guinea Gut estimated that on average only 3.3 cm of runoff are delivered into Fish Bay every year (Table 1).

Suspended sediment concentrations from flows ranging between 0.0004 and 0.61 cm hr^{-1} (0.04 to 5.8 m^3 s^{-1}) showed concentrations from 0.007 to 4.6 g L^{-1} with a geometric average of 0.57 g L^{-1} (Table 3). A plot of sediment concentration versus runoff rates showed no correlation (Figure 6), which precluded the use of a rating curve to estimate sediment yields. Use of the flow duration curve with the mean value of 0.57 g L^{-1} resulted in an average suspended sediment yield of 65 tons yr^{-1} or 19 tons per km^2 yr^{-1} for the 3.46 km^2 main Fish Bay Gut watershed (Table 1).

References

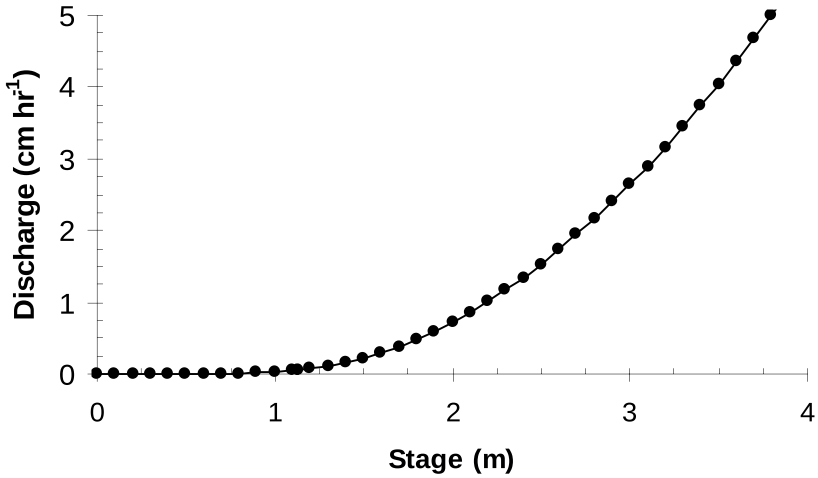
ASTM-D 3977-97. 1997. Standard test methods for determining sediment concentration in water samples. Annual Book of ASTM Standards. 11.01.

Buchanan TJ, Somers WP. 1980. Discharge measurements at gaging stations, Chapter A8, Book 3, Applications of hydraulics, US Geological Survey, 64 p.

Dunne T, Leopold LB. 1978 Water in environmental planning. WH Freeman and Company, New York, NY, 818 p.

Julien PY. 1995. Erosion and Sedimentation. Cambridge University Press, 280 p.

Figure 1. Stage-discharge rating curve for the Main Fish Bay Gut.



Figures 2a-2d. Runoff data collected at main Fish Bay Gut from 1998 to 2001.

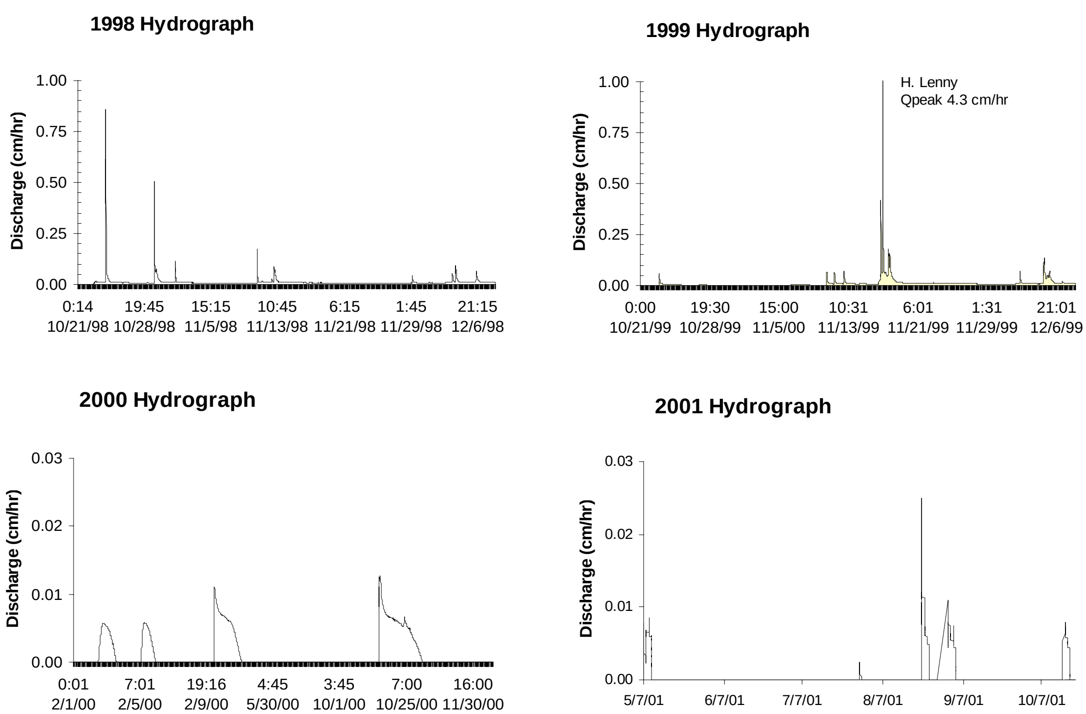
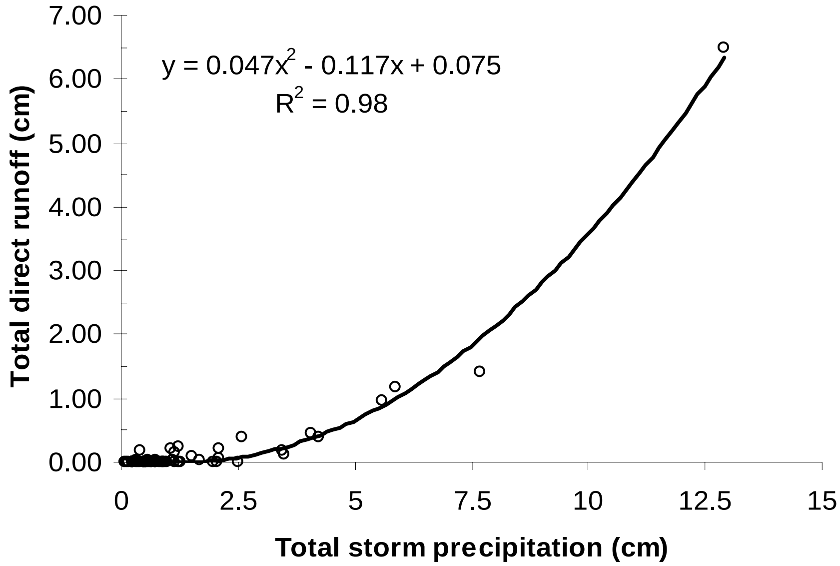
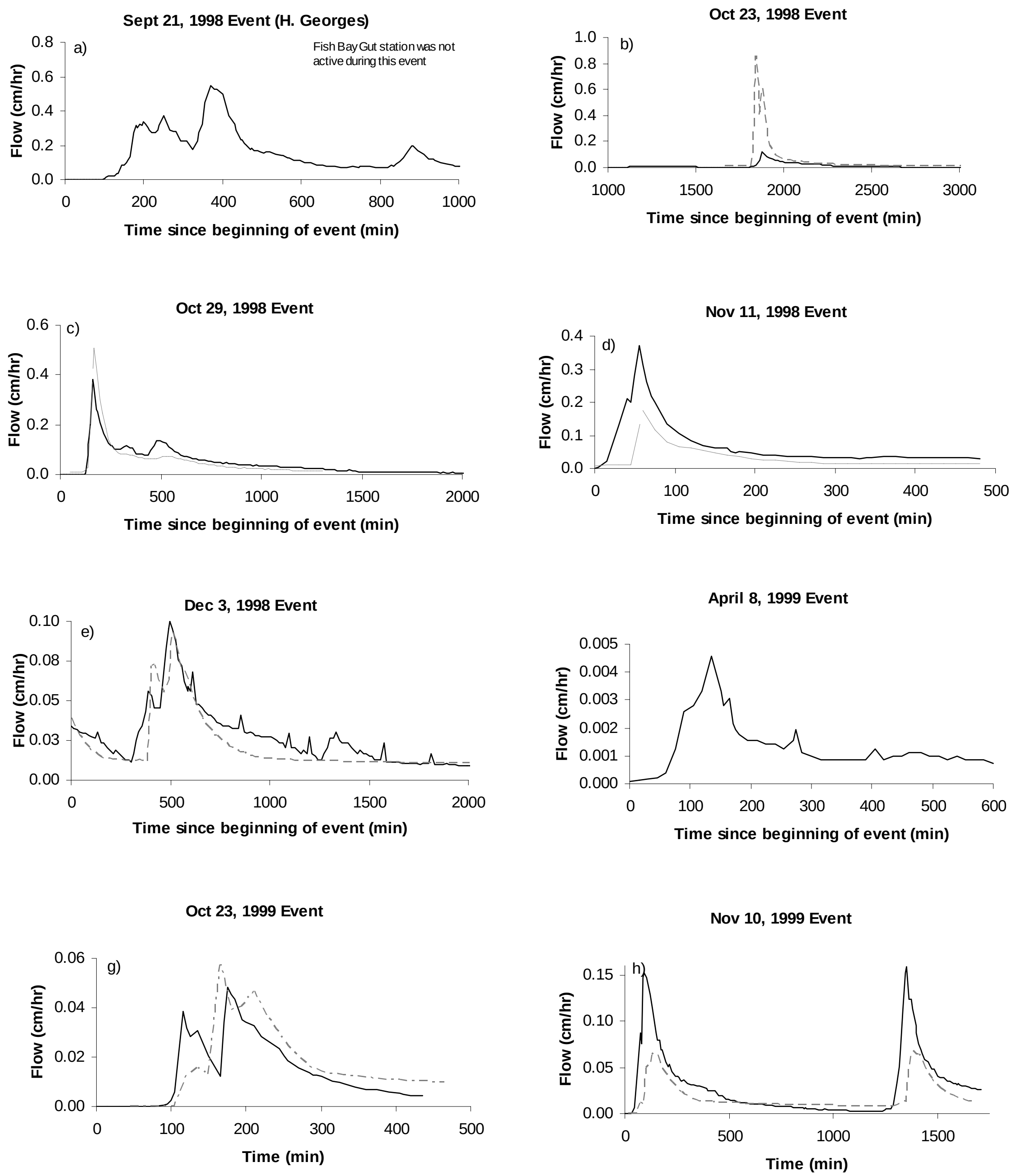


Figure 3. Relationship between storm precipitation and storm runoff at the main Fish Bay Gut.



Figures 4a-4n. Hydrographs for the fourteen events between October 1998 and November 2001 for Guinea Gut (solid black line) and the main Fish Bay Gut (dashed gray line).



Figures 4a-4n (cont.).

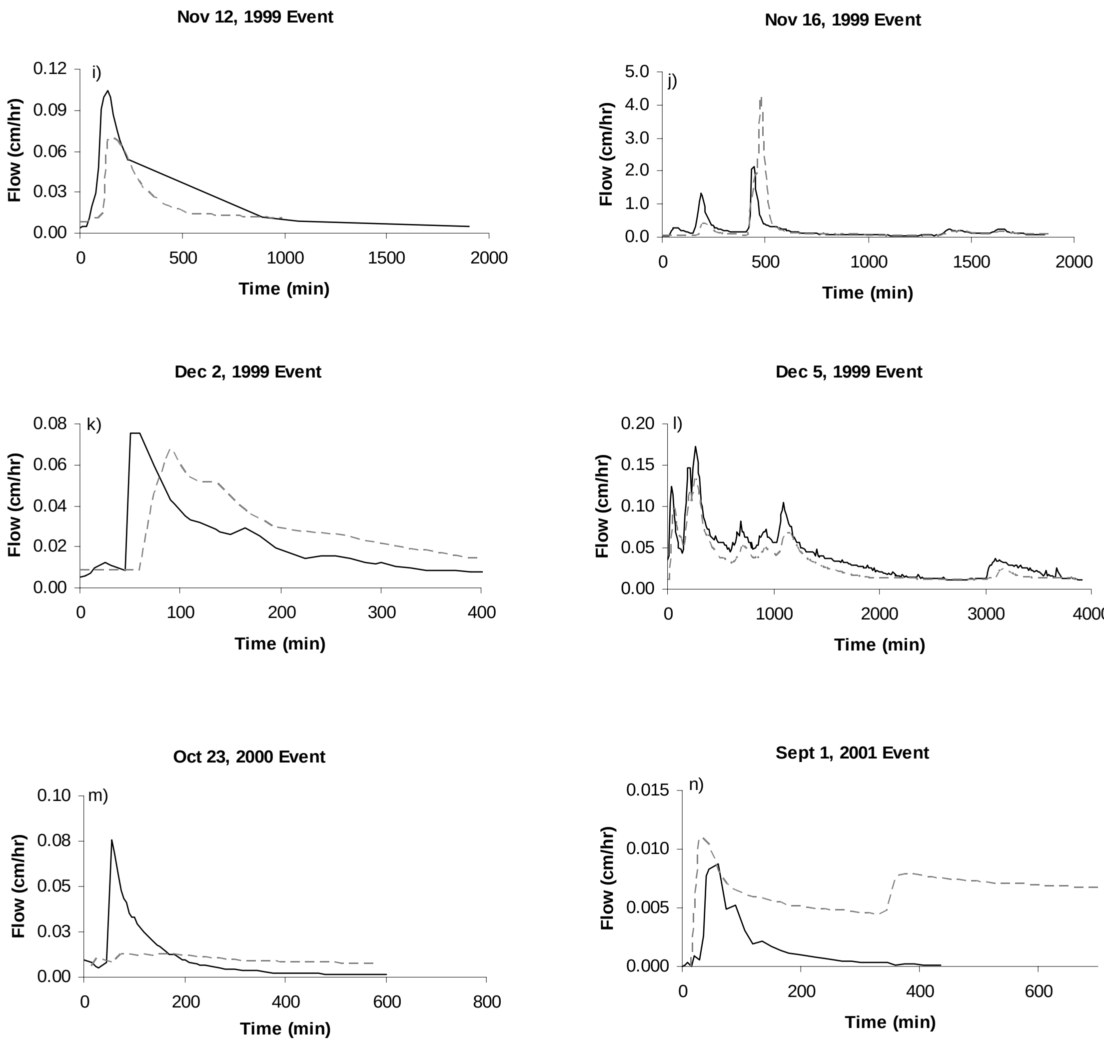


Figure 5. Flow duration curves for Guinea Gut and main Fish Bay Gut.

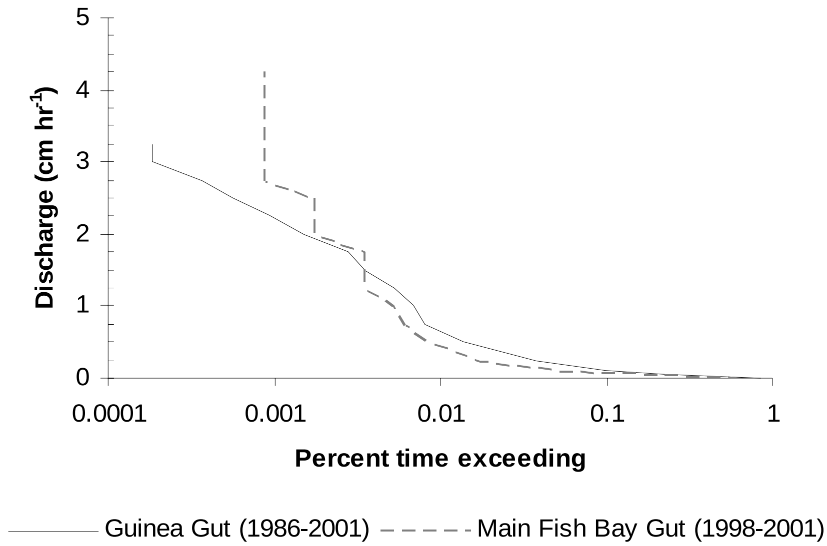


Figure 6. Sediment rating curve for 35 samples collected from the main Fish Bay Gut.

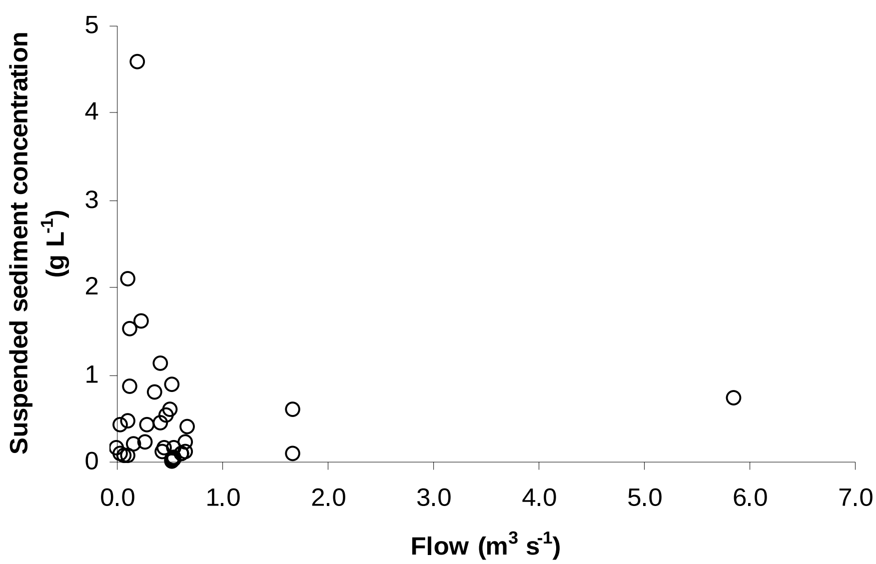


Table 1. Flow duration curve method for estimating long-term runoff and sediment yield rates from the main Fish Bay Gut.

(A) Flow rate (cm hr^{-1})	(B) Percent time exceeded	(C) Percent time for flow category	(D) Equivalent discharge for main Fish Bay Gut (m^3 s^{-1})	(E) Total runoff for flow rate class (cm yr^{-1})	(F) Sediment yield rate (kg min^{-1})	(G) Total sediment yield for flow rate category (tons)
0.0001	57		0.0010		0.033	
0.01	0.84	56	0.096		3.3	
0.05	0.23	0.62	0.48	1.4	16	27
0.1	0.099	0.13	0.96	0.84	33	17
0.25	0.038	0.061	2.4	0.67	82	13
0.5	0.014	0.024	4.8	0.27	164	5.3
0.75	0.0080	0.0058	7.2	0.063	247	1.2
1	0.0069	0.0011	9.6	0.012	329	0.24
1.25	0.0052	0.0017	12.0	0.018	411	0.36
1.5	0.0035	0.0017	14.4	0.018	493	0.36
1.75	0.0028	0.0007	16.8	0.008	575	0.16
2	0.0015	0.0013	19.2	0.014	657	0.28
2.25	0.00093	0.00056	21.6	0.0061	740	0.12
2.5	0.00056	0.00037	24.0	0.0041	822	0.081
2.75	0.00037	0.00019	26.4	0.0020	904	0.040
3	0.00019	0.00019	28.8	0.0020	986	0.040
3.25	0.00019	0.00000	31.2	0.0000	1068	0.000
3.5	0	0.00019	33.6	0.0020	1151	0.56
3.75	0	0				
4	0	0				
4.25	0	0				
4.5	0	0				
			Sum	***3.3***		***65***

Columns A, B, and C refer to Guinea Gut long-term data.

Table 2. Relationship between storm precipitation and storm runoff at the main Fish Bay Gut.

Date	Total storm precipitation (cm)	Direct runoff (cm)
21-Oct-98	1.98	0.00
23-Oct-98	3.45	0.17
23-Oct-98	0.97	0.010
24-Oct-98	5.59	0.97
26-Oct-98	1.68	0.018
30-Oct-98	5.89	1.2
1-Nov-98	0.43	0.18
9-Nov-98	0.89	0.003
11-Nov-98	1.07	0.22
12-Nov-98	2.59	0.40
27-Oct-98	0.48	0.00
18-Nov-98	0.58	0.003
22-Nov-98	0.15	0.00
28-Nov-98	0.43	0.00
29-Nov-98	2.08	0.07
3-Dec-98	1.09	0.04
4-Dec-98	4.06	0.45
7-Dec-98	1.24	0.23
10-Dec-98	0.64	0.00
13-Dec-98	0.23	0.003
15-Dec-98	0.76	0.008
21-Dec-98	0.66	0.00
22-Dec-98	0.61	0.015
24-Dec-98	0.74	0.017
27-Dec-98	0.48	0.003
1-Jan-99	0.08	0.00
5-Jan-99	0.13	0.00
6-Jan-99	0.25	0.00
10-Jan-99	0.23	0.00
11-Jan-99	0.23	0.00
14-Jan-99	0.25	0.00
15-Jan-99	0.84	0.00
15-Jan-99	0.89	0.013
19-Jan-99	0.36	0.00
23-Jan-99	0.53	0.00
24-Jan-99	0.76	0.00
26-Jan-99	0.53	0.00
3-Feb-99	0.48	0.003
6-Feb-99	1.29	0.00
8-Apr-99	3.5	0.11
12-Jun-99	1.52	0.095
1-Sep-99	0.94	0.00
12-Sep-99	0.76	0.00
13-Sep-99	2.06	0.00
19-Sep-99	0.33	0.00
27-Sep-99	1.24	0.00
28-Sep-99	2.51	0.00
14-Oct-99	1.17	0.00
10-Nov-99	2.11	0.20
11-Nov-99	4.24	0.38
15-Nov-99	0.56	0.03
17-Nov-99	12.9	6.5
20-Nov-99	0.23	0.003
23-Nov-99	0.33	0.023
3-Dec-99	1.17	0.15
4-Dec-99	7.7	1.4
20-Dec-99	0.48	0.008
25-Dec-99	0.53	0.005
27-Dec-99	0.86	0.005

Table 3. Suspended sediment data collected at the main Fish Bay Gut.

Date	Time	Stage (m)	Flow ($cm\ hr^{-1}$)	Flow ($m^3\ s^{-1}$)	Co ($g\ L^{-1}$)
24-Oct-98	734	1.91	0.61	5.9	0.73
11-Nov-98	1300	0.80	0.01	0.11	2.10
11-Nov-98	1330	0.79	0.01	0.11	0.47
29-Nov-98	545	1.02	0.04	0.41	0.43
29-Nov-98	615	0.96	0.03	0.29	0.43
29-Nov-98	715	0.91	0.02	0.21	4.59
29-Nov-98	745	0.88	0.02	0.16	0.20
29-Nov-98	815	0.85	0.01	0.13	0.86
10-Nov-99	2252	0.51	0.00	0.0037	0.16
10-Nov-99	2329	1.05	0.05	0.48	0.52
10-Nov-99	2340	1.07	0.05	0.53	0.89
11-Nov-99	7	1.12	0.07	0.65	0.23
11-Nov-99	27	1.08	0.06	0.55	0.02
11-Nov-99	101	1.02	0.04	0.41	1.13
11-Nov-99	1512	0.71	0.01	0.078	0.06
11-Nov-99	2020	1.04	0.05	0.46	0.16
11-Nov-99	2052	1.11	0.07	0.62	0.08
11-Nov-99	2115	1.08	0.06	0.55	0.05
11-Nov-99	2200	1.00	0.04	0.37	0.80
12-Nov-99	2059	0.86	0.01	0.14	1.53
12-Nov-99	2145	1.16	0.07	0.67	0.39
12-Nov-99	2215	1.13	0.06	0.61	0.09
12-Nov-99	2245	1.08	0.06	0.55	0.15
16-Nov-99	2111	0.93	0.03	0.24	1.62
17-Nov-99	840	1.42	0.17	1.7	0.59
17-Nov-99	840	1.42	0.17	1.7	0.09
17-Nov-99	1646	1.07	0.05	0.53	0.01
2-Dec-99	1710	1.12	0.07	0.65	0.12
2-Dec-99	1740	1.06	0.05	0.50	0.60
2-Dec-99	1910	0.95	0.03	0.27	0.22
5-Dec-99	1348	1.07	0.05	0.53	0.02
5-Dec-99	1825	1.03	0.05	0.43	0.10
23-Feb-00	1420	0.60	0.004	0.037	0.42
23-Feb-00	1448	0.62	0.00	0.044	0.08
23-Feb-00	1515	0.79	0.01	0.11	0.06
	mean		***0.06***	***0.59***	***0.57***