

Supplementary materials

Table S1. Selected Guideline Values for CCME WQI Calculation

Sample ID	Unit	Upper Limit	Guideline Source
pH		8.5	World Health Organization [25]
Hardness calculation	mg/L as CaCO ₃	200	Office of Legislative Counsel-PNG [24]
Total alkalinity	mg/L as CaCO ₃	200	Bureau of Indian Standards [26]
TDS	mg/L	500	Office of Legislative Counsel-PNG [24]
Turbidity	N.T.U.	5	Bureau of Indian Standards [26]
Conductivity	µS/cm	400	World Health Organization [25]
<i>E. coli</i>	colonies/100 ml	1	Office of Legislative Counsel-PNG [24]
Calcium	mg/L	75	Bureau of Indian Standards [26]
Iron	mg/L	0.1	Office of Legislative Counsel-PNG [24]
Manganese	mg/L	0.05	Office of Legislative Counsel-PNG [24]
Mercury	mg/L	0.001	Bureau of Indian Standards [26]

Table S2. WQ guidelines, raw WQ data and comparison of results from spreadsheet WQI calculator vs CCME WQI calculator. UA series.

Sample ID	Unit	Guideline value	Guideline value flag	UA1	UA2	UA3	UA4	UA5	UA6	UA7	UA8
pH		8.5	1	8.3	8.24	8.31	8.2	8.2	8.1	8.2	8.1
Hardness calculation	mg/L as CaCO ₃	200	1	155	152	158	1489	135	199	303	993
Ca hardness	mg/L		0	140	139	121	1400	94	158	255	916
Mg hardness	mg/L		0	15	13	37	89	41	41	48	77
Total alkalinity	mg/L as CaCO ₃	200	1	388	424	700	140	150	160	180	170
TDS	mg/L	500	1	129	165	151	1300	1000	740	1700	1100
Turbidity	N.T.U.	5	1	14	16	12	18	16	18	17	14
Temperature	°C		0	28.2	28.7	31.1	31.27	31.5	31.6	31.33	31.23
Conductivity	µS/cm	400	1	266	243	315	374	412	410	422	439
<i>E. coli</i>	colonies/100 ml	1	1	40	150	1800	5400	4100	4300	5400	7000
Calcium	mg/L	75	1	53	51	36	580	38	63	102	367
Iron	mg/L	0.1	1	0.2196	0.00245	0.0049	0.14	0.17	0.15	0.14	0.25
Manganese	mg/L	0.05	1	0.0349	0.0335	0.0331	0.019	0.041	0.041	0.024	0.02
Mercury	mg/L	0.001	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Number of guidelines			11								
FAILED				4	3	3	6	5	5	7	7
F1				36.3636	27.2727	27.2727	54.5454	45.4545	45.4545	63.6363	63.6363
F2				36.3636	27.2727	27.2727	54.5454	45.4545	45.4545	63.6363	63.6363
				0	0	0	6.445	0	0	0.515	3.965
				0.94	1.12	2.5	0	0	0	0	0
				0	0	0	1.6	1	0.48	2.4	1.2
				1.8	2.2	1.4	2.6	2.2	2.6	2.4	1.8
				0	0	0	0	0.03	0.025	0.055	0.0975
				39	149	1799	5399	4099	4299	5399	6999
				0	0	0	6.7333	0	0	0.36	3.8933
				1.196	0	0	0.4	0.7	0.5	0.4	1.5
NSE				3.9032	13.8472	163.9	492.4343	372.9936	391.1459	491.3754	637.4050
F3				79.6054	93.2647	99.3935	99.7973	99.7326	99.7449	99.7969	99.8433
CCME				45.2819	41.7290	38.4441	27.1740	31.4929	31.4869	22.4120	22.3921
CCME calculator				45.3	41.7	38.4	27.2	31.5	31.5	22.4	22.4

Ca, calcium; CCME, Canadian Council of Ministers of the Environment; TDS, total dissolved solids; Mg, magnesium; NTU, Nephthelene Turbidity unit; WQ, water quality; WQI, water quality index; NSE, normalized sum of excursions.

Table S3. Survey questionnaire for Bumbu watershed water quality assessment.

Papua New Guinea University of Technology
Department of Civil Engineering
Ph. 473 4371, 473 4624

Dear valued respondent,

Your participation in filling this survey form will provide information necessary for the completion of the research project titled: Bumbu Watershed Water Quality Assessment as a requirement for the Master's Degree in Solid Waste & Resource Management, Department of Civil Engineering at the PNG University of Technology. This survey will assess water use, sources of pollution, hygiene/sanitation, health & community concerns, & other issues in settlement and urban residence around Bumbu Watershed. All the information gathered through this survey will be treated as confidential and used solely for this study; no information will be distributed to third parties. We appreciate your participation.

Bumbu Water Shed Survey		2020		
Date of Interview	Name Initials	Community	Population	LLG/Ward No
Household Demographics				
1. Age	<input type="checkbox"/> 18 – 29	<input type="checkbox"/> 30 – 39	<input type="checkbox"/> 40 – 49	<input type="checkbox"/> 50+
2. Gender	<input type="checkbox"/> Male	<input type="checkbox"/> Female		
3. Property	<input type="checkbox"/> Settlement	<input type="checkbox"/> Village	<input type="checkbox"/> Urban centre	<input type="checkbox"/> Other
4. Education	<input type="checkbox"/> Primary	<input type="checkbox"/> Secondary	<input type="checkbox"/> Vocational Training	<input type="checkbox"/> College <input type="checkbox"/> Other
5. Water Use Practices	<input type="checkbox"/> Drinking	<input type="checkbox"/> Washing	<input type="checkbox"/> Irrigation	<input type="checkbox"/> Laundry
	<input type="checkbox"/> Car wash	<input type="checkbox"/> Waste disposal	<input type="checkbox"/> Other	
6. Drinking water source	<input type="checkbox"/> Piped Water	<input type="checkbox"/> On Spot Water Supply	<input type="checkbox"/> Rainwater	<input type="checkbox"/> River Water <input type="checkbox"/> Other
7. Alternative Drinking Water Source. (Specify)				
8. Water Treatment method used	<input type="checkbox"/> Boil water	<input type="checkbox"/> Chlorine or bleach	<input type="checkbox"/> Both	<input type="checkbox"/> Other (Specify)
9. Do you have a water storage tank?	<input type="checkbox"/> Yes	<input type="checkbox"/> No		
10. Treatment	<input type="checkbox"/> Yes	<input type="checkbox"/> No (If Yes please specify)		
11. Time spent inside river (bath, playing etc)?	Hours / day		hours / week	
12. Time spent in contact with river water (washing clothes, irrigation)?	Hours / day		hours / week	

Hygiene and Sanitation			
11. Do you wash your hands before eating and after using the toilet? <input type="checkbox"/> Yes <input type="checkbox"/> No (If No skip to 13)			
12. When you wash your hands, how often do you use soap? <input type="checkbox"/> Always/almost always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never/rarely			
13. What kind of toilet facility do you use? <input type="checkbox"/> Flush toilet to sewer system <input type="checkbox"/> Flush toilet to septic tank <input type="checkbox"/> Pit latrine <input type="checkbox"/> Using the river <input type="checkbox"/> Other (specify)			
14. If pit latrine, how many people use the latrine on a regular basis?			
15. How do you dispose of your solid waste? <input type="checkbox"/> Collect <input type="checkbox"/> Dump <input type="checkbox"/> Burn <input type="checkbox"/> Compost <input type="checkbox"/> Bury <input type="checkbox"/> Dispose into the river <input type="checkbox"/> Other (please state below)			
Health and Community Concerns			
16. How many children under 5 years old live in this household?			
17. Has this child/have any of these children had diarrhoea in the past 2 weeks? <input type="checkbox"/> Yes <input type="checkbox"/> No (If NO, skip to 19)			
18. Action Taken: <input type="checkbox"/> Taken to the hospital/health centre <input type="checkbox"/> Taken to private clinic <input type="checkbox"/> Purchased medicine <input type="checkbox"/> Home remedy, please specify <input type="checkbox"/> No action/illness went away <input type="checkbox"/> Died <input type="checkbox"/> Other			
19. Has this child/have these children had any other illness in the past 2 weeks <input type="checkbox"/> Yes <input type="checkbox"/> No If yes, please specify <input type="checkbox"/> Skin infection <input type="checkbox"/> Respiratory infection <input type="checkbox"/> Accident/injury <input type="checkbox"/> Other			
Issues in your Community			
20. Water quality or quantity	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
21. Rubbish or pollution	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
22. Crime or violence	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
23. Diarrhoea or stomach ailment	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
24. Mosquitoes or malaria	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
25. Other chronic diseases (diabetes/cancer).	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
26. HIV/AIDS	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
27. Respiratory illnesses	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
28. Skin infection	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem
29. Water borne diseases.	<input type="checkbox"/> A big problem	<input type="checkbox"/> Somewhat a problem	<input type="checkbox"/> Not a problem

Table S4a. Value scores for 6 household health variables based on 50 community responses in proximity of the 22 water quality sampling stations.

Locality	Total participants	ID	Household health variables						Mean VS
			VS_DWS	VS_TF	VS_WT	VS_WS	VS_WD	VS_WBD	
Bumbu Upstream	50	UA1	0.20	0.30	0.00	0.10	0.40	0.80	0.30
Trench	50	UA2	0.22	0.33	0.00	0.14	0.36	0.52	0.26
Bumbu Main	50	UA3	0.23	0.35	0.10	0.46	0.30	0.30	0.29
CIS Bridge	50	UA4	0.40	0.50	0.14	0.20	0.42	0.46	0.35
Kamkumu	50	UA5	0.20	0.45	0.10	0.22	0.44	0.26	0.28
Cassoawary	50	UA6	0.40	0.50	0.12	0.38	0.52	0.34	0.38
Butibam	50	UA7	0.23	0.45	0.08	0.44	0.50	0.24	0.32
Downstream	50	UA8	0.40	0.40	0.06	0.76	0.60	0.16	0.40
Irom	50	UB1	0.10	0.40	0.00	0.14	0.60	0.76	0.33
Wombong	50	UB2	0.11	0.38	0.10	0.20	0.46	0.70	0.33
Wonkos	50	UB3	0.22	0.37	0.06	0.10	0.72	0.64	0.35
Igam Creek	50	UB4	0.42	0.50	0.00	0.80	0.78	0.10	0.43
Butu Stream	50	UB5	0.36	0.40	0.08	0.80	0.80	0.46	0.48
Sukos	50	UB6	0.43	0.43	0.10	0.90	0.64	0.22	0.45
Butibam 1	50	UB7	0.31	0.45	0.14	0.76	0.74	0.48	0.48
Butibam 2	50	UB8	0.39	0.41	0.06	0.70	0.72	0.54	0.47
Ambiun1	50	UC1	0.13	0.28	0.14	0.20	0.44	0.56	0.29
Ambiun 2	50	UC2	0.05	0.28	0.10	0.00	0.66	0.12	0.20
Wara Rice	50	UC3	0.42	0.40	0.06	0.28	0.56	0.30	0.34
Wara Misin	50	UC4	0.55	0.33	0.10	0.06	0.90	0.10	0.34
SopWara	50	UC5	0.66	0.63	0.14	0.10	0.76	0.14	0.41
Sikambu	50	UC6	0.59	0.60	0.18	0.14	0.80	0.24	0.43
TOTAL	1100								
Percentage	1								

VS_DWS, value score household drinking water source; VS_TF, value score household toilet facility; VS_WT, value score household water treatment; VS_WS, value score household water storage; VS_WD, value score household waste disposal; VS_WBD, value score water borne disease; VS, value score.

Table S4b. Green space runoff IV and community overlain on green space.

Locality	Total participants	ID	Community health variables									Mean
			VS_WQ	VS_P	VS_C	VS_SA	VS_MOS	VS_HIV	VS_COPD	VS_SI	VS_WBD	VS
Bumbu Upstream	50	UA1	0.76	0.62	0.60	0.47	0.54	0.68	0.78	0.52	0.53	0.61
Trench	50	UA2	0.49	0.61	0.72	0.38	0.60	0.62	0.71	0.69	0.69	0.61
Bumbu Main	50	UA3	0.79	0.60	0.76	0.41	0.61	0.68	0.50	0.62	0.51	0.61
CIS Bridge	50	UA4	0.52	0.24	0.47	0.64	0.52	0.61	0.74	0.68	0.64	0.56
Kamkumu	50	UA5	0.20	0.33	0.43	0.51	0.62	0.78	0.64	0.68	0.66	0.54
Cassoawary	50	UA6	0.48	0.36	0.34	0.55	0.59	0.85	0.66	0.46	0.66	0.55
Butibam	50	UA7	0.38	0.31	0.44	0.60	0.43	0.52	0.64	0.60	0.70	0.51
Downstream	50	UA8	0.15	0.05	0.15	0.08	0.31	0.64	0.30	0.18	0.17	0.23
Irom	50	UBI	0.16	0.71	0.46	0.64	0.58	0.58	0.52	0.42	0.47	0.50
Wombong	50	UB2	0.28	0.45	0.80	0.64	0.58	0.66	0.67	0.67	0.54	0.59
Wonkos	50	UB3	0.22	0.25	0.67	0.65	0.50	0.73	0.66	0.69	0.54	0.55
Igam Creek	50	UB4	0.11	0.16	0.56	0.26	0.16	0.69	0.49	0.26	0.24	0.33
Butu Stream	50	UB5	0.48	0.52	0.88	0.52	0.60	0.62	0.41	0.64	0.71	0.60
Sukos	50	UB6	0.45	0.45	0.90	0.54	0.57	0.77	0.51	0.46	0.61	0.58
Butibam 1	50	UB7	0.74	0.59	0.52	0.65	0.50	0.78	0.62	0.77	0.50	0.63
Butibam 2	50	UB8	0.68	0.70	0.57	0.70	0.51	0.70	0.62	0.69	0.49	0.63
Ambiun1	50	UC1	0.67	0.65	0.70	0.75	0.56	0.63	0.55	0.60	0.62	0.64
Ambiun 2	50	UC2	0.24	0.16	0.62	0.21	0.22	0.68	0.46	0.18	0.42	0.35
Wara Rice	50	UC3	0.65	0.52	0.51	0.68	0.51	0.66	0.56	0.40	0.51	0.56
Wara Misin	50	UC4	0.35	0.09	0.70	0.33	0.14	0.46	0.48	0.10	0.20	0.32
SopWara	50	UC5	0.30	0.17	0.22	0.09	0.13	0.68	0.52	0.19	0.27	0.29
Sikambu	50	UC6	0.26	0.13	0.27	0.31	0.12	0.52	0.27	0.17	0.31	0.26

VS_WQ, value score water quality; VS_P, value score community pollution; VS_C, value score community crime; VS_SA, value score community stomach ailments; VS_MOS, value score community mosquito/malaria; VS_HIV, value score community HIV/AIDS; VS_COPD, value score community respiratory ailments; VS_SI, value score community skin illness; VS_WBD, value score water borne disease; VS, value score.

Table S5. Results of forward regression of household health scores versus factors of WQ parameters and runoff of land-use types, evaluated at all 22 sampling stations.

Model summary household health						
Model	R	R ²	Adjusted R ²	Std. error of the estimate		
1	0.694	0.482	0.456	0.056		
Predictors: (constant), Factor 3						
Coefficients						
Unstandardized coefficients			Standardized coefficients			
Model		B	Std. Error	Beta	t	Sig.
1	(constant)	0.36	0.012		29.924	0
	Factor 3	0.053	0.012	0.694	4.312	0
Dependent variable: mean vs household health.						
Sig, significant Std, standard; WQ, water quality						

Table S6. Results of forward regression of community health scores versus factors of WQ parameters and runoff of land-use types, evaluated at all 22 sampling stations.

Model summary community health					
Model	R	R ²	Adjusted R ²	Std. error of the estimate	
2	0.833	0.694	0.662	0.079	
Predictors: (constant), Factor 5, Factor2					
Coefficients					
Unstandardized coefficients			Standardized coefficients		
Model		B	Std. error	Beta	t Sig.
2	(constant)	0.502	0.017		29,721 0
	Factor 5	-0.083	0.017	-0.612	-4.823 0
	Factor 2	-0.077	0.017	-0.566	-4.459 0
Dependent variable: mean vs community health					
Sig, significant Std, standard; WQ, water quality.					

Table S7. Results of forward regression of Total Health Scores versus factors of WQ parameters and runoff of land-use types, evaluated at all 22 sampling stations.

Model summary Total Health						
Model	R	R ²	Adjusted R ²	Std. error of the estimate		
3	0.863	0.745	0.703	0.047		
Predictors: (constant), Factor 5, Factor 2, Factor 3						
Coefficients						
Unstandardized coefficients			Standardized coefficients			
Model		B	Std. error	Beta	t	Sig.
3	(constant)	0.445	0.01		44.819	0
	Factor 5	-0.052	0.01	-0.609	-5.115	0
	Factor 2	-0.039	0.01	-0.459	-3.861	0.001
	Factor 3	0.035	0.01	0.404	3.397	0.003
Dependent variable: mean vs Total health						
Sig, significant Std, standard; WQ, water quality.						