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Effect on Water Quality due to Residential Development – A Case Study on Kolonnawa Canal

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Abstract: Due to the increasing number of residential buildings in Colombo and its suburbs, the wastewater volume generated and discharged by them is also to be increased. It would affect water bodies and would eventually lead them to be heavily polluted. As the canal network which is a part of the surface drainage system in Colombo acts to drain out the flood water from Colombo to the sea and Kelani river while providing and receiving water from urban wetlands, their water quality should be properly monitored and controlled.

This study attempted to measure surface water quality in Kolonnawa canal, find out the Grey Water Footprint (GWF) and analyse the effect caused by the domestic wastewater discharged into Kolonnawa canal and its marsh. This study is conducted by using water quality parameters including pH, Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Salinity, Resistivity, Chemical Oxygen Demand (COD), NO_3-N and PO_4-P and ultimately finding the GWF by collecting 3 sets of samples from 8 locations at 10-day intervals. Test results indicated DO, BOD and COD as downgrading water quality parameters showcasing major differences from allowable water quality standard values. GWF is calculated as 131.25 m^3/s, a considerably high discharge rate which could only be achieved in flood situations. According to the water quality results and site investigations, it was concluded that the Kolonnawa canal receives a considerable load of pollutants from its sub-catchment and domestic originated greywater is a major contributor

Keywords: Grey Water Footprint, Water Quality, Colombo Canal System, Kolonnawa Canal

Introduction

Over the past few years, the residential development in Sri Lanka is arriving to a peak. Condominium and apartment units are now being built or have been planned to be built in Colombo and its suburbs and may spread into the other major cities as well (Ariyawansa et al. 2018). Although the development of residential settlements is high, an average of 10-15% of the housing stock in suburban cities of Colombo are at substandard quality. With the increasing trend of urban sprawl and population growth in Colombo, its suburbs will have more residential land use in the future (UN Habitat, 2018).

Unlike those modern housing units, most average residential settlements in urban and suburban areas of Colombo does not have access to sewerages which is only covering the Colombo Municipal Council boundary and also in need of rehabilitation. According to the existing practice, domestic wastewater from the areas where sewerage networks are not available, disposes onto the ground with or without onsite treatment or into the surface drainage network, waterways or marshes (Ministry of Housing & Construction of the Government of Democratic Socialist Republic of Sri Lanka, 2018).

Colombo city depends on its 20km^2 of wetlands for fresh and wastewater management, biodiversity protection, flood mitigation, ecosystem services such as recreation, air quality maintenance etc.;

they are also essential parts of the city infrastructure. Despite of their importance, 50% of the Colombo wetland network was in a very bad quality. 15% of the network had a bad water quality. 15% and 20% of the network had medium and good water qualities respectively. The pollution increase was growing faster from 2010 and the overall actual water quality was poor (Ministry of Megapolis and Western Development, 2016b). Colombo canal network is a part of this surface drainage system which drains out flood water from Colombo to sea and Kelani river (Moufar and Perera 2018).

For the purpose of water quality analysis in the study, the selected geographical scope is an area belongs to the sub-catchment to Kolonnawa canal which has an area of 5.43 km^2. Sub-catchment in Figure 1 is the collection of four Metro Colombo Wetland (MCW) zones namely, MCW 06 (Kolonnawa East-Gothatuwa), MCW 07 (Kolonnawa South-Madinnagoda), MCW 11 (Kolonnawa-West Salamulla) and MCW 12 (Kolonnawa-West Yakbedda).

Figure 1- Selected Geographical Scope Sub-catchment to Kolonnawa Canal

Colombo Canal Network

Colombo canal network is a 67km long complex interconnected system of natural and manmade open canals, lakes and marshes. The canal beds have zero slope and lay -1m above Mean Sea Level. The Parliament lake is considered as the head of the Colombo canal system. The main canals in the system are, Kolonnawa Ela, Heen Ela, Kotte Ela, Mahawatte Ela, Wellawatta canal, Dehiwala canal, Torrington canal, St. Sebastian canal, Dematagoda canal, Kirulapona canal, Bolgoda canal and main drain. 400ha of flood retention marshes are attached to the system which consist of Kolonnawa marsh, Heen Ela marsh and Kotte Ela marsh (Anurangi et al, 2011).

For the purpose of developing the software “Water Quality Monitor”, a water quality assessment has been carried out for the Colombo canal system. Monthly measurements of 10 water quality parameters including BOD_5, COD, DO, Nitrate, Phosphates, Ammonia, pH, conductivity, turbidity and temperature has been done in 20 locations. It was concluded that the Colombo north canal system is more polluted than the south canal system and the pollution level of the grid area should be lowered by introducing proper solid waste management, wastewater treatment and sewage treatment facilities (Eriyagama and Ratnayake 2008).

Grey Water Footprint

Water Footprint (WF) is a concept introduced by Hoekstra (2002). It is a comprehensive multidimensional indicator of the direct and indirect use of freshwater. There are three components of WF as Blue, Green and Grey Water Footprints. The WF is a volumetric measure of water consumption and pollution but not a measure of how severe the impact of consumption and pollution are for the local water system. It can be used in a vast range from a single product to a whole nation. GWF was introduced to express pollution as volume polluted to facilitate the comparison between the volume consumed and polluted. It is calculated by the following equation (Aldaya et al., 2012).

$$GWF = L/L_{crit} \times R \qquad \ldots(1)$$

L – Pollutant load entering a water body (mass/time)

Lcrit – Critical load (mass/time)

R – Runoff, flow rate of the water body (volume/time)

GWF – Grey water footprint (volume/time)

$$Lcrit = R \times (Cmax - Cnat) \quad ...(2)$$

Cmax - Maximum acceptable concentration of the pollutant (mass/volume)

Cnat – Natural concentration of the pollutant in receiving water body (mass/volume)

An assessment of water use and total pollution load in Kelani river within the Western province has been conducted by Sri Lanka Land Reclamation and Development Corporation (SLLRDC) as a part of "Every Drop Matters" project aiming to control pollution in Kelani river basin. All the pollution and consumption points in the study area have been identified and GWF has been calculated using the total pollutant load. Policies and technical solutions have been made to reduce the pollution within the study area. GWF had been calculated according to the baseline accounting method. The points where branch rivers/ canals discharge their water flow into Kelani river were considered as the point source pollutions from each sub-catchment area. Any non-point source pollutant in subcatchments were considered to be mixed with branches before reaching the discharge point. A total of 16 sub-catchments were considered (Sri Lanka Land Reclamation and Development Corporation, 2015).

Methodology

Selected canal segment in this study holds a significant importance as it is a part of few major development projects in Sri Lanka. It is also attached to the Kolonnawa marsh which is a part of Ramsar recognised wetlands in Colombo Wetland City. Parts of its sub-catchment area are included in large scale projects such as Commercial City Development Project, Capital City Development Project and Rajagiriya Elevated Highway Project. (Urban Development Authority, 2019a; Urban Development Authority, 2019b; Road Development Authority,2019)

A. *Water Sample Testing*

Selection of sampling locations was done based on several factors. In order to calculate GWF, pollutant loads coming into the canal were to be found. Since there are many waterways which bring water to the canal and marsh, testing water quality and flow rate of each and every one of them for baseline method of GWF calculation was not practical. Therefore, water quality and flow rate of the canal was directly tested and measured from the canal itself form several locations which hold significant importance. As the quality of water which comes through residential areas was needed to be assessed, some peripheral waterways which receive residential wastewater were also selected. Other than these reasons, ease of access also played a significant role on location selection as many discharge points of smaller waterways were not easily accessible. Sampling points shown in Figure 2 were selected across the Kolonnawa canal and its peripheral water canals due to the reasons shown in Table 1. Water quality parameters pH, DO, BOD_5, TDS, EC, COD, salinity, conductivity, temperature, NO_3-N and PO_4-P as defined by Environmental Protection Agency, (2001) were checked at these locations. Three sets of data were collected with 10 days intervals. The collected data were used to analyse the quality of water that gets discharged into Kolonnawa canal and marsh from residential areas against ambient water quality standards and calculate GWF of the Kolonnawa canal.

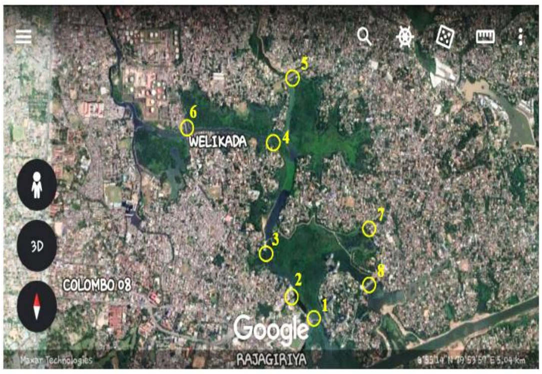

Figure 2 - Locations of Water Quality Measuring Points

Table 1 - Location Justification

Location	Justification
1	Inflow to sub catchment of Kolonnawa canal
2	Small waterway on left canal bank
3	Small waterway on left canal bank
4	Intersection of Kolonnawa canal and waterway to Kittampahuwa canal
5	Harward Bund, Inflow to Kittampahuwa Canal
6	Outflow from sub catchment of Kolonnawa Canal
7	Small waterway on right canal bank
8	Small waterway on right canal bank

Besides BOD_5, COD, NO_3-N and PO_4-P, all the other parameters were measured on site between 10.00am-12.00pm using HACH HQ40d Portable Multimeter and 3 probes. A quantity of 2.5l water from each location was taken for laboratory testing. Laboratory testing for COD, NO_3-N and PO_4-P were done by the SLLRDC laboratory at Attidiya. BOD_5 was tested at the Central Engineering Consultancy Bureau (CECB) laboratory at Colombo 05.

B. Ambient Water Quality Standard

For the calculation of GWF, Central Environment Authority (CEA) provided water quality were used. As the study area is to be developed as a linear park, transportation network etc. and is currently serving as a source of biodiversity preservation zone, the quality of water was checked against "Category C" which is defined for fish and aquatic life water by Central Environmental Authority, (2018) and Department of Government Printing, (2019).

Flow Rates

Centre for Urban Water Sri Lanka (CUrW), which has been set up for Metro Colombo Urban Development Project (MCUDP) has a system for obtaining real time water level data from several water level stations. These data are observed from water level gauges based in IOT and also available to general public. The stations include, Janakala Kendraya, Diyasaru gate upstream, Ingurukade, Wellampitiya, Wellawatta, Diyasaru Uyana, Ranwala Bridge and Yakbedda (Curwsl.org, 2019). Station Yakbedda coincides with the sampling location 6. From that, real time water level of sample location 6 was obtained.

As this is the only available water level measuring station in the study area, canal water flow rates of sampling locations were obtained based on it. In order to do that, data from Ministry of Megapolis and Western Development, (2016a) was used. The report has provided with data of hydraulic functions of several wetlands for different storm events. Data of three cross sections of the Kolonnawa canal and marsh were obtained. From real time water level of location 6, storm event was assumed. Flow rates of the above indicated three locations for that specific storm event were then obtained from the data set available in the hydraulic report.

Reults and Discussion

A. Water Quality

Table 2 - Onsite Water Quality Measurments

Location	Day	Temperature (˚C)	pH	Conductivity (µS/cm)	Salinity (‰)	Resistivity (kΩ/cm)	TDS (mg/l)	DO (mg/l)
1	1	29.8	7.88	229.0	0.11	4.47	109.2	5.31
	2	28.5	8.40	168.0	0.08	5.95	79.7	5.76
	3	28.4	7.49	423.0	0.20	2.36	204.0	3.72
2	1	28.9	8.64	282.0	0.13	3.54	134.8	3.42
	2	28.4	8.29	178.6	0.08	5.60	84.8	5.65
	3	26.9	7.41	488.0	0.23	2.04	236.0	0.88
3	1	30.1	7.95	309.0	0.15	3.24	147.7	4.30
	2	27.8	8.45	176.0	0.08	5.68	83.8	3.99
	3	28.0	7.47	432.0	0.21	2.32	208.4	0.53
4	1	30.4	7.84	366.0	0.17	2.73	176.1	8.87
	2	28.7	8.37	217.0	0.10	4.61	103.2	4.13
	3	28.3	7.30	497.0	0.24	2.01	240.0	0.33

5	1	30.3	7.99	316.0	0.15	3.17	151.4	4.29
	2	28.0	8.76	307.0	0.14	3.27	146.3	2.41
	3	26.1	7.53	371.0	0.17	2.72	177.5	2.38
6	1	30.8	8.01	322.0	0.15	3.10	154.3	6.13
	2	27.7	7.65	264.0	0.12	3.78	126.7	0.85
	3	28.7	8.38	526.0	0.25	1.90	255.0	0.28
7	1	28.0	7.95	373.0	0.18	2.68	179.4	3.02
	2	28.5	8.40	168.0	0.08	5.95	79.7	5.76
	3	27.8	8.06	385.0	0.18	2.60	185.2	1.39
8	1	30.1	7.85	223.0	0.10	4.46	106.8	9.64
	2	29.4	8.07	207.5	0.10	4.82	98.7	9.45
	3	28.9	8.38	287.0	0.14	3.49	137.2	11.23

When considering the measured water quality across the canal and sub catchment, results in Table 2 could be concluded as follows. Temperature of surface water is within the range of 31-26°C. pH value varies within the range 7.3-8.76. Except for 2 occasions among 24 samples, pH value is in the range of required standard 6-8.5. There are no specified standards for conductivity, salinity and resistivity for this category. It could be seen that maximum value of conductivity 526 μS/cm results from a salinity of 0.25‰ which is a far less value than in salty water. It also results the lowest resistivity value of 1.9 kΩ/cm. Minimum value of conductivity measured is 168 μS/cm which has been resulted from a salinity of 0.08‰. The highest resistivity related to those values is measured as 5.95 kΩ/cm.

Total dissolved solid concentration also doesn't have a specified standard value in the ambient water quality standards. Maximum value is measured as 255 mg/l and minimum value is measured as 79.7 mg/l. However, except for location 5 and 8, all other locations showed a gap of more than 100 mg/l in value between their maximum and minimum measured TDS values. From that it could be concluded that the TDS values vary significantly in a single location with time.

According to the water quality standard, DO value of a water sample is required to be equal or above 5 mg/l at 25°C temperature in fish and aquatic life waters. However, only 9 occasions out of 24 gave a satisfactory DO value. From 8 locations, only the location 8 had a constantly high DO value which also provided the highest measured DO value of 11.23 mg/l. Every other location also indicated a deterioration of DO value. In some locations, the DO value drastically change through the 3 sampling days. In location 6, the DO value went from 6.13 to 0.28 mg/l which was the lowest measured value and in location 4, it went from 8.87 to 0.33 mg/l. These values however are measured at the respective water temperatures of each location as they were measured onsite. Low DO values could be resulted due to different reasons. Water being too warm, high amount of bacteria, excess amount of BOD, fertilizer runoff, taking samples in the morning hours and relatively still water as the flow rate was low could be some of the reasons.

Table 3 gives the results of BOD_5, COD, NO_3-N and PO_4-P tests. From the values is clearly visible that both biochemical and chemical oxygen demands are well above the allowable values. The maximum BOD_5 value of 80 mg/l is recorded from the outlet of the Kolonnawa canal. Compared to that, the inlet BOD values are much lower. Therefore, it could be concluded that the catchment adds a pollutant load to the canal. The minimum value of BOD_5 is 4.2 mg/l which is still above the minimum standard. COD values are always higher than that of BOD. The highest value is 140 mg/l while the lowest is 18 mg/l. As Nitrate and Phosphate concentrations are very low and within the allowable standard limits, it can be seen that the oxygen demands are not for oxidation of those nutrients but of other pollutants.

Table 3 - Laboratory Tested Water Quality Measurements

Location	Day	BOD_5 (mg/l)	COD (mg/l)	NO_3-N (mg/l)	PO_4-P (mg/l)
1	1	30.0	48	0.7	0.1
	2	15.0	32	0.9	0.1
	3	20.0	77	0.1	0.3
2	1	4.2	27	0.6	0.1
	2	17.0	33	0.9	0.1
	3	55.0	140	0.1	1.2
3	1	35.0	66	0.6	0.1
	2	18.0	21	0.8	0.1
	3	55.0	85	0.2	0.3
4	1	35.0	42	0.5	0.2
	2	17.0	39	0.7	0.1
	3	45.0	89	0.1	2.1
5	1	30.0	48	0.6	0.1
	2	19.0	38	0.6	0.1
	3	60.0	56	0.1	0.1
6	1	50.0	68	0.5	0.5
	2	17.0	28	0.7	0.4
	3	80.0	130	0.1	2.7
7	1	17.7	43	1.1	0.2
	2	22.0	46	1.1	0.1
	3	28.3	76	1.2	0.7
8	1	15.0	18	1	0.1
	2	18.0	38	0.9	0.1
	3	40.0	63	0.3	0.1

B. *Flow Rates*

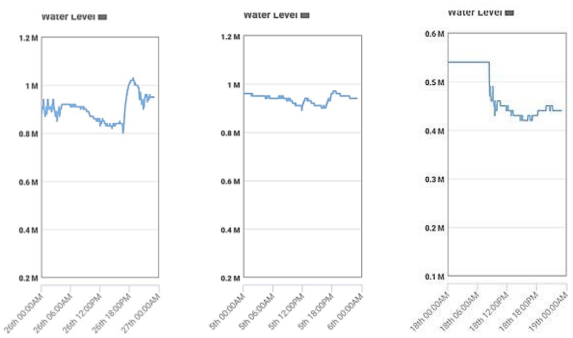

Figure 3 shows the flow water levels at sample location 6 for 3 sampling days taken from CUrW. From that, water levels were taken as 0.9m for first 2 days and the final day had a water level of 0.5m.

These water levels were similar to the 2 year favourable flood condition and dry condition in Kolonnawa canal according to Ministry of Megapolis and Western Development, (2016a). Figure 4 shows the canal cross section and flow data near sample location 6.

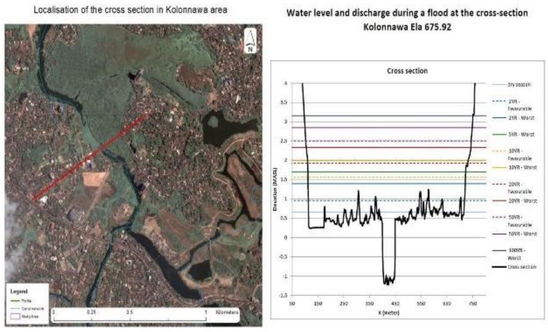

Figure 4 - Canal Cross Section and Water Levels for Different Storm Events of Sapmle Location 6

Data in Table 4 were obtained for the water level variations on the days of sampling collection.

Table 4 - Flow Rates

Location	Flow Rate (m^3/s) Day 1	Flow Rate (m3/s) Day 2	Flow Rate (m3/s) Day 3
1	8.5	8.5	4
4	6	6	3.5
6	10.5	10.5	5

Table 5 - GWF Calculation Day 1

Location	Pollutant	Concentration (mg/l)	Flow Rate (m3/s)	L=Ceff*Deff (mg/s)	Cmax (mg/l)	Cnat (mg/l)	GWF=L/(Cmax-Cnat) (l/s)	GWFmax (m3/s)
1	BOD	30.0	8.5	255000	4	0	63750	63.750
	COD	48		408000	15	0	27200	
	NO3	0.7		5950	10	0	595	
	PO4	0.1		850	0.4	0	2125	
4	BOD	35.0	6	210000	4	0	52500	52.500
	COD	42		252000	15	0	16800	
	NO3	0.5		3000	10	0	300	
	PO4	0.2		1200	0.4	0	3000	
6	BOD	50.0	10.5	525000	4	0	131250	131.250
	COD	68		714000	15	0	47600	
	NO3	0.5		5250	10	0	525	
	PO4	0.5		5250	0.4	0	13125	

Table 6 - GWF Calculation Day 2

Location	Pollutant	Concentration (mg/l)	Flow Rate (m3/s)	L=Ceff*Deff (mg/s)	Cmax (mg/l)	Cnat (mg/l)	GWF=L/(Cmax-Cnat) (l/s)	GWFmax (m3/s)
1	BOD	15.0	8.5	127500	4	0	31875	31.875
	COD	32		272000	15	0	18133	
	NO3	0.9		7650	10	0	765	
	PO4	0.1		850	0.4	0	2125	
4	BOD	17.0	6	102000	4	0	25500	25.500
	COD	39		234000	15	0	15600	
	NO3	0.7		4200	10	0	420	
	PO4	0.1		600	0.4	0	1500	
6	BOD	17.0	10.5	178500	4	0	44625	44.625
	COD	28		294000	15	0	19600	
	NO3	0.7		7350	10	0	735	
	PO4	0.4		4200	0.4	0	10500	

Table 7 - GWF Calculation Day 3

Location	Pollutant	Concentration (mg/l)	Flow Rate (m3/s)	L=Ceff*Deff (mg/s)	Cmax (mg/l)	Cnat (mg/l)	GWF=L/(Cmax-Cnat) (l/s)	GWFmax (m3/s)
1	BOD	20.0	4	80000	4	0	20000	20.533
	COD	77		308000	15	0	20533	
	NO3	0.1		400	10	0	40	
	PO4	0.3		1200	0.4	0	3000	
4	BOD	45.0	3.5	157500	4	0	39375	39.375
	COD	89		311500	15	0	20766	
	NO3	0.1		350	10	0	35	
	PO4	2.1		7350	0.4	0	18375	
6	BOD	80.0	5	400000	4	0	100000	100.000
	COD	130		650000	15	0	43333	
	NO3	0.1		500	10	0	50	
	PO4	2.7		13500	0.4	0	33750	

According to the above tabulated calculations in Table 5, Table 6 and Table 7, the GWF of Kolonnawa Canal could be taken as 131.25m^3/s which means that the water flow rate of Kolonnawa canal should reach the value 131.25m^3/s for the pollutant load to be assimilated and diluted down to the acceptable pollutant concentration. It is the highest GWF value in the sample. It can be also recognized that the GWF is depending on the BOD_5 value of samples. Therefore, even when the COD value is higher, it has not been represented in the maximum GWF values.

The other important finding is that the GWF of catchment outflow location is always higher than the other 2 locations. It can be concluded that the catchment itself adds a load of pollutants to the canal. These pollutant concentrations may get reduced due to the ecological functions of the surrounding wetland. At the Location-4 which is in the middle of the canal path and connecting to another comparatively large water body (canal), the GWF had a lower value in first 2 sampling days. Although the pollutant concentration seems to be reduced at that location, it again goes into a higher value at the next location which is the catchment outlet.

Rest of the five locations were analysed to recognise characteristics of water that flow into the Kolonnawa canal and marsh, also of the water flowing into Kittampahuwa canal.

Conclusion and Recommendations

According to the above analysed results it could be seen that the water quality of the outflow from the catchment through Kolonnawa canal is worse than the water quality of the inflow into the catchment. It could be concluded that the catchment gathers a certain pollutant load to the canal through its way down. Some peripheral canals through residential zones are polluted and they discharge their pollutant loads into the Kolonnawa canal directly or through the marsh. Even though the marsh generally acts as a method of reducing pollutant concentrations from water, the canal still receives a pollutant load from residential wastewater. To dilute the pollutant concentrations to an acceptable value, flow of the canal must be higher than 131.25 m^3/s. As it means, in flood situations, the water quality of the canal could get better.

For a better water quality in the Kolonnawa canal and its marsh, pollutant load coming to them must be reduced. In many locations it could be seen that the residential wastewater discharge points are connected to peripheral canals rather than the Kolonnawa main canal. These connections must be regularised with certain quality measures if not connecting them to a central sewerage collecting system and then discharging after necessary treatments. Also solid waste dumping to the marsh and canals should be stopped.

During the flushing of north canal system, if it would take a longer time than ideal, Kolonnawa canal should also be pumped with water in order to maintain a better water quality as it cut downs both inflow and outflow of the catchment. Cleaning of the canal should be conducted regularly to control plant growth on the canal water surface.

NWSDB of Sri Lanka already have some projects to build more sewerage connections to the areas where they are required. Even though the entire study area in still not included in those projects, Kolonnawa UC is being considered as an area which requires sewerage pipeline connection. SLLRDC is maintaining the wetland marsh and canal network and have been able to reduce the amount of solid waste dumping into the wetland in some areas significantly.

As a part of this canal segment acts as a boundary to the Commercial City Development Project and Capital City Development Project, it is important to know the behaviour of water quality in the canal due to different land use patterns of its catchment. Also the quality of water will affect the Rajagiriya Elevated Highway Project form the start of construction and to the end of its design life.

The water quality of Kolonnawa canal could be measured throughout a year for different storm event conditions to figure out how the pollutant concentrations in canal changes with the different water levels and discharges. Also peripheral canals could be regularly checked with land use pattern and population changes. A study could also be conducted to recognise the effect on the catchment caused by blocking of flows during flushing of Colombo north canal system.

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