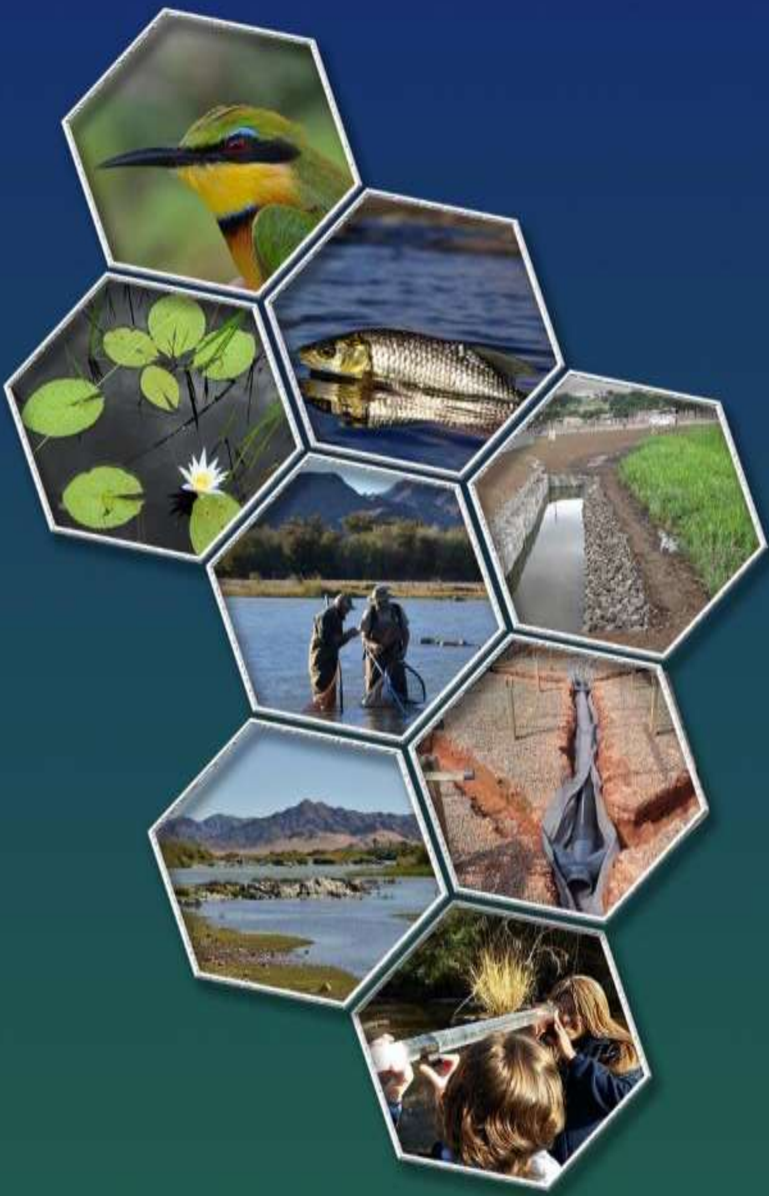
BROOKDALE ASSESSMENT CENTRE

BASELINE SURFACE WATER POLLUTION ASSESSMENT

FINAL



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GroundTruth Water, Wetlands and Environmental Engineering (GroundTruth), established in 2004, hereby acknowledge that it does not have any invested interests in the following project, and is thus independent to the proponent as required in terms of Section 33 of Government Notice Regulation 358 published under Section 24 of the National Environmental Management Act (Act 107 of 1998). Furthermore, in line with Appendix 6 of the 2014 EIA regulations (GN R982), GroundTruth under directorship of Dr Mark Graham, declares that:

- The independent specialists in this application; do not have and will not have any vested interest (either business, financial, personal or other) in the undertaking of the proposed activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014;
- All the work relating to the project will be performed in an objective manner, even if this results in views and findings that are not favourable to the client;
- That there are no circumstances that may compromise the objectivity of GroundTruth in performing such work;
- The expertise required in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity, are possessed by all involved;
- Compliance with the Act, regulations and all other applicable legislation;
- There are no conflicting interests, and none shall be engaged in, during the undertaking of the assigned activity;
- GroundTruth undertakes to disclose to the applicant and the competent authority all material information it may be in possession of that reasonably has or may have the potential of influencing - any decision to be taken with respect to the outcome of the project by the competent authority; and - the objectivity of any report, plan or document to be prepared by GroundTruth for submission to the competent authority;
- All the particulars furnished by team members in this document are true and correct; and
- GroundTruth is aware that any person(s) is guilty of an offence in terms of Regulation 48 (1) of the EIA Regulations, 2014, if that person provides incorrect or misleading information. A person who is convicted of an offence in terms of sub-regulation 48(1) (a) to (e) is liable to the penalties as contemplated in section 49B(1) of the National Environmental Management Act, 1998 (Act 107 of 1998).

Signed: ………………………………………….   Date: ……………………………………..

Mark Graham
Pr. Sci. Nat. (Ecology) Reg. No. 400099/96

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1. INTRODUCTION

Following the court order issued to Woodglaze Trading (Pty) Ltd for case number 662/2020 in the matter of The State and Woodglaze Trading (Pty) Ltd, GroundTruth was appointed to carry out surface water pollution assessments at the Brookdale Assessment Centre development site (Erfs 1086 and 1661), in Phoenix within the eThekwini Municipality. The purpose of the assessments was to establish the current baseline condition in respect to water quality for each of the surface water ecosystems present on the site and to inform the rehabilitation plan monitoring requirements.

Figure 1-1 below shows the location of the Brookdale Assessment Centre development site within Phoenix relative to the Ohlanga River, which is the main water course draining the broader catchment area.

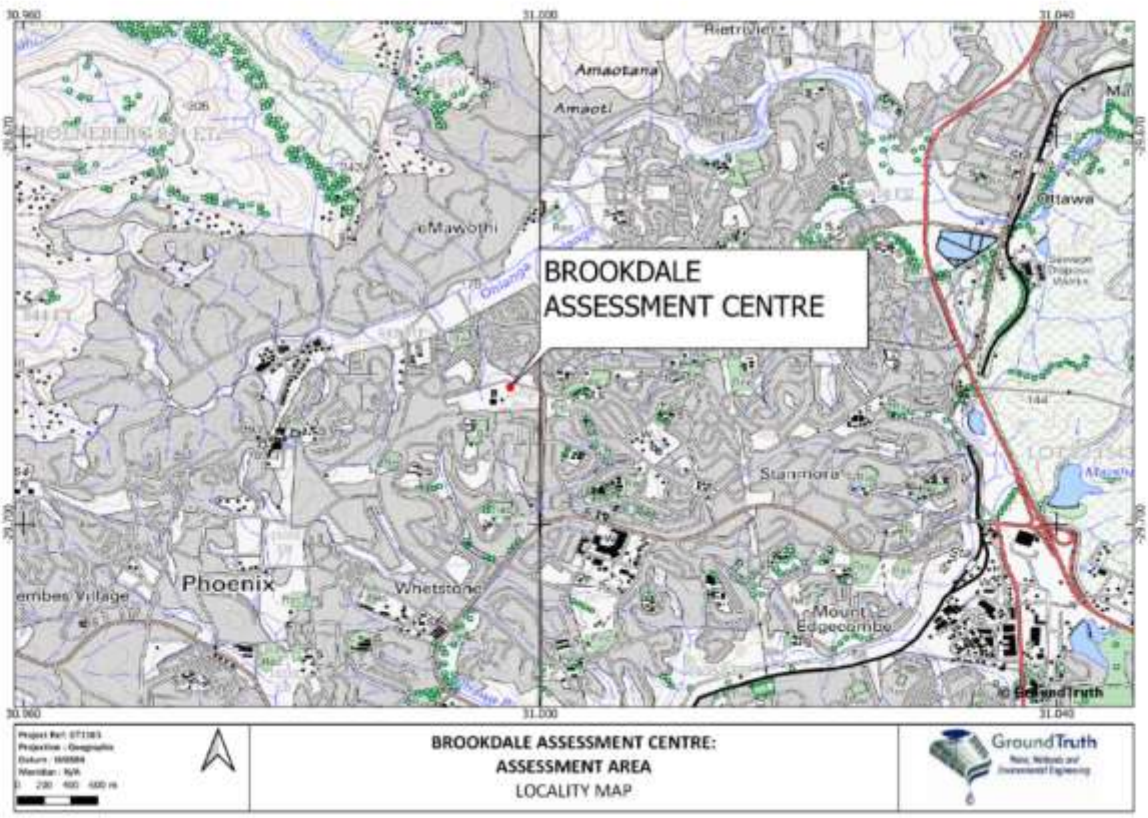

Figure 1-1 Locality map for the Brookdale Assessment Centre development site

2. ASSUMPTION AND LIMITATIONS

The following assumptions and limitations are noted for this project:

- Sampling was undertaken at the three main aquatic systems on-site where surface water was observed. Investigations of additional drainage lines or stormwater channels entering the site, or direct seepage from the landfill/stockpile were not undertaken.
- There were visible external inputs to the site, namely several stormwater outlets from the adjacent urban areas. The water quality results of the stream and wetland are likely to be affected, which will reflect a combination of all inputs.
- The location of the wetland sample site was selected based on the high probability of standing water occurring throughout both wet and dry seasons, thereby allowing for reliable repeat sampling during the rehabilitation monitoring period.
- It must be noted that water quality guidelines are available for a given number of constituents and in some cases the concentrations of other constituents could not be assessed against a prescribed limit. In the absence of stipulated limits, the results of the monitoring sites were compared to the control sites (i.e. unaffected by the impact of concern) located in nearby drainage systems.

3. METHODS OF ASSESSMENT

3.1 Site locations and descriptions

An initial field investigation was carried out by GroundTruth on the 14th and 15th October 2021 (Trip 1) and surface water samples were collected from three aquatic ecosystems on site, namely the small dam (SW1), the stream (SW2) that traverses the western portion of the site, and the wetland area (SW3) in the northern section of the site **(Table 3-1 and Figure 3-1).** These represent the surface water ecosystems potentially impacted by the infilling activities and will serve as monitoring sites during the rehabilitation process.

To verify the signals of high concentrations of several chemical constituents obtained from the initial sampling trip, repeat sampling was undertaken on the 14th of December 2021 (Trip 2). Sampling was undertaken at the three sites previously sampled, as well as an additional four urban surface water ecosystems beyond the boundaries, but near the Brookdale Assessment Centre development site (‘control sites’). This was undertaken to establish background chemical levels of the broader catchment for comparison with the monitoring sites.

Photographs of site conditions at the time of sampling are provided in **Appendix 1**.

Table 3-1 Co-ordinates and brief description of sample sites for the baseline surface water pollution assessment (on-site monitoring sites are highlighted in blue)

Site	Aquatic system	Description	South (decimal degrees)	East (decimal degrees)
SW1	Dam	Artificial feature located somewhat central to the site, behind the Phoenix Assessment and Therapy Centre on a mid-level terrace of fill material. The dam is colonised by hydrophytes (*Typha*) and is utilised by water-associated bird species, e.g. Reed Cormorant. Green filamentous and clump-forming algae were abundant.	-29.689104°	30.997325°
SW2	Stream	Located on the western boundary, downslope of main fill area and adjacent to residential housing. Narrow sandy channel (av. 1m wide), stream banks and adjacent flat areas used for market gardening. Informal dwellings are present. Numerous juvenile fish and solid waste were observed in the stream. Stream receives stormwater run-off from western residential area.	-29.688298°	30.995933°
SW3	Wetland	Runs from east to west along the northern boundary of the site and joins into the western stream. Colonised by typical wetland species, e.g. *Cyperus spp.* Sample point is fed by a stormwater outlet from the adjacent residential area. At this point, the upstream standing pool of water is heavily polluted by solid waste dumping from the neighbouring property.	-29.687785°	30.996195°
CS1	Wetland	Approx. 1 km NE of the site. Channelled urban wetland, draining northwards into the Ohlanga River. Densely vegetated with alien vegetation, polluted with solid waste, visible grey colouration with an odour of raw sewage, surrounded by dense residential settlement.	-29.680453°	31.003944°
CS2	Stream	Approx. 1.5 km NE of the site. Urban stream emanating from upstream wetland area and draining eastwards towards the Ohlanga River, adjacent to JG Champion Drive. Steeply incised and polluted with litter.	-29.682321°	31.014121°
CS3	Stream	Approx. 0.5 km NE of the site. Urban stream, steeply incised and polluted with litter. Surrounded by dense residential settlement with open spaces along the riparian corridor.	-29.686684°	31.005272°

CS4	Stream	Approx. 0.8 km NW of the site. Urban stream draining northwards into the Ohlanga River. Surrounded by dense residential settlement. Polluted with solid waste (illegal dumping), visible grey colouration with an odour of raw sewage.	-29.6860940°	30.988004°

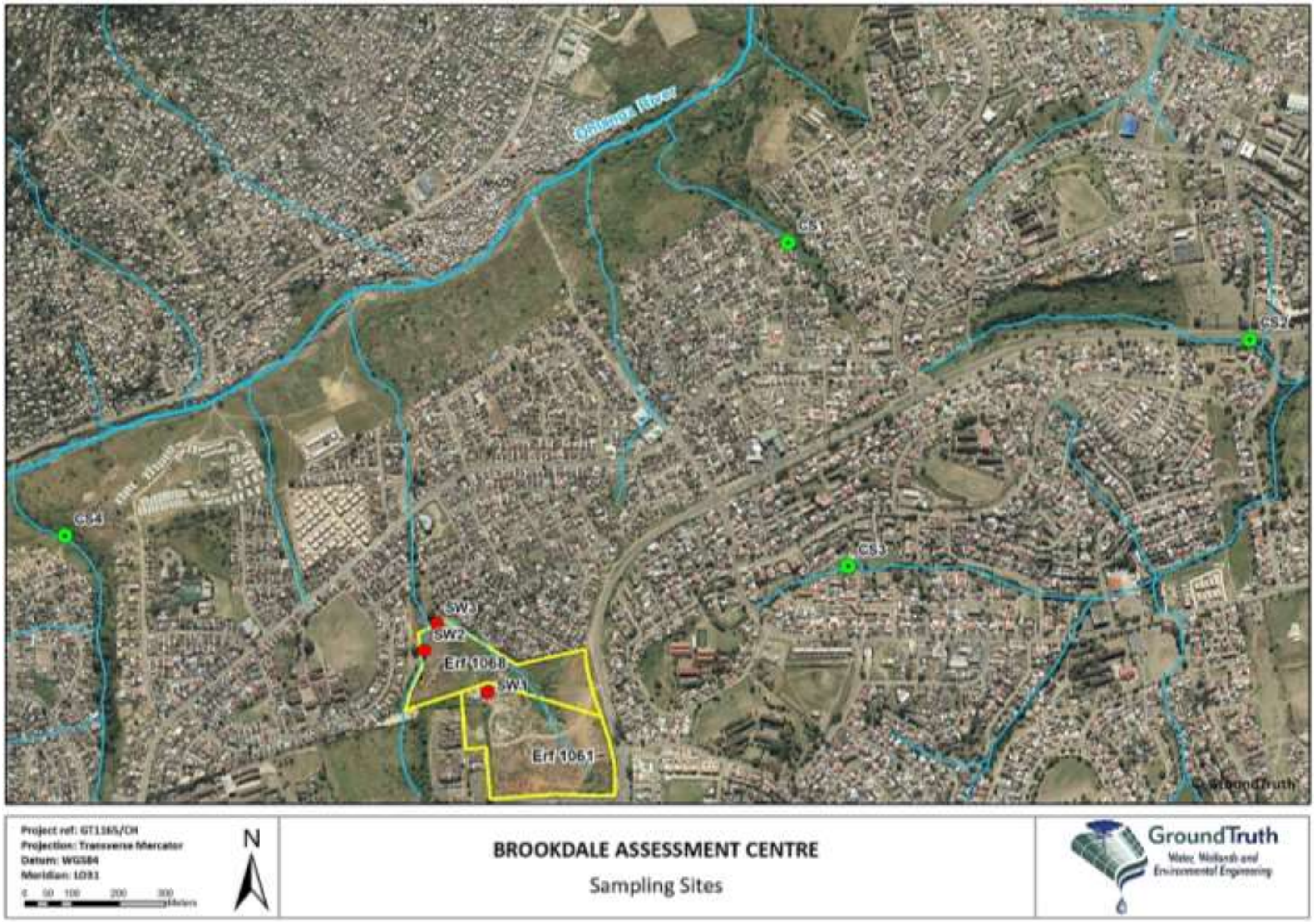

Figure 3-1 Location of the three on-site monitoring sites (red) representing the dam (SW1), stream (SW2) and wetland (SW3) systems present on the Brookdale Assessment Centre development site, and four control sites (CS1-4) (green) within the surrounding urban residential areas.

3.2 Chemical analyses

In accordance with best practice and to inform the biological assessments, *in-situ* measurements of the following physico-chemical water quality parameters were recorded using a hand-held digital water meter:

- Electrical conductivity (EC),
- Total dissolved salts, (TDS)
- pH,
- Dissolved oxygen (DO), and
- Temperature

And using a water clarity tube, measuring water clarity.

In addition, water samples were collected at all sites and submitted to an ISO-accredited laboratory to assess potential pollutants impacts on the surface water. The following chemical constituents were analysed:

- Alkalinity,
- Nutrients (ammonia, nitrate, orthophosphate),
- Metals,
- Volatile and semi-volatile organic compounds (VOC, SVOC),
- Total suspended solids (TSS),
- Chemical oxygen demand (COD),
- Oils, greases and soaps,
- Faecal coliform (*E. coli*), and
- Pesticides (organochlorine and organophosphorous compounds).

The results of the chemical analyses were compared with the Target Water Quality Range (TWQR) of the South African Water Quality Guidelines (SAWQG) for Aquatic Ecosystems (DWAF, 1996), and the results of the control sites where aquatic limits were not available . The wastewater limit values applicable to the discharge of wastewater into a water resource were also referenced were applicable (DWA, 2013).

3.3 Biological sampling

Benthic diatom (algae) samples were collected at all three impact sites, and two control sites in closest proximity to the development site (CS3 and CS4) to provide an indication of the likely water quality impacts on aquatic biota. Data from the diatom samples were interpreted according to the Specific Pollution sensitivity Index (SPI) (Taylor et al., 2007) to assess the "health status" of the surface water ecosystems present on-site (Kleynhans & Louw, 2007) (**Table 3-2**). The Percentage of Pollution Tolerant Valves (%PTV) was also determined for each of the samples. The %PTV is the proportion of diatoms within a sample that can withstand organic pollution, therefore giving further indication of water quality modifications to the systems.

Table 3-2 Diatom SPI score and water quality classes (derived from Harding and Taylor, 2011)

Water Quality Class		SPI
Natural	≥	17.0
Good	≥	13.0
Fair	≥	9.0
Poor	≥	5.0
Seriously Modified	<	5.0

3.4 Aquatic toxicity analyses

The initial surface water sampling event yielded results indicating toxic levels of several chemical constituents. The sampling protocol of the second sampling trip was expanded to include definitive aquatic toxicity analyses to verify the current toxicity of the surface water ecosystems. This entailed the collection of water samples from all three impact sites, and the two control sites in closest proximity to the development site (CS3 and CS4) for comparative purposes. The analyses undertaken represented various key aquatic ecological trophic levels, namely:

- algae (*Selanastrum capriconutum*), representing "primary producers"
- bacteria (*Allivibrio fischeri*), representing the microbial community
- invertebrate (*Daphnia magna*), representing "primary consumers/secondary producers" and
- vertebrate (*Poecilia reticulata*), presenting "secondary consumers".

Generally, there are acute and chronic endpoints in aquatic toxicity. Acute toxicity is usually determined with short-term exposure of the organisms to a series of concentrations of a known chemical or suite of toxicants, with the concentration that is lethal to 50% of the test organisms calculated and expressed as an LC50 value. Chronic toxicity is relates to longer-term exposure and covers the effects on hatching, growth and survival and is used for the determination of NOEC (No Observed Effect Concentration) values, LOEC (Lowest Observed Effect Concentration) or ECx values where x is a % (e.g. 10%) and is concentration of a chemical where 10% of the population show some sort of effect.

This laboratory-based process involves exposing biota to water samples to determine the potential risk of the water to the biota (DWAF, 2003; Pearson et al., 2015). A Risk Category/Hazard Class is determined based on the percentage of mortalities (or inhibition/stimulation) of the exposed biota **(Table 3-3)**. It is important to note that the toxicity hazard is for aquatic biota and does not represent toxicity to humans or mammals. Each of these methods and analyses were undertaken by BioTox Lab, a SANAS accredited laboratory (Accreditation number: T0663), to South African National Standards (SANS) or ISO standards.

Table 3-3 Hazard classfication system for definitive tests (Pearson et al., 2015; BioTox, 2021)

Class I	No acute/short-chronic environmental toxicity hazard – none of the tests show a toxic effect (i.e. an effect value significantly higher than that in the control)
Class II	Slight acute/short-chronic environmental toxicity hazard – the percentage effect observed in at least one toxicity test is significantly higher than in the control, but the effect level is below 50% (TU is <1)
Class III	Acute/short-chronic environmental toxicity hazard – the L(E)C50 is reached or exceeded in at least one test, but in the 10fold dilution of the sample the effect level is less than 50% (1≤TU≤9.99)
Class IV	High acute/short-chronic environmental toxicity hazard – the L(E)C50 is reached in the 10-fold dilution for at least one test, but not in the 100fold dilution (10≤TU≤99.99)
Class V	Very high acute/short-chronic environmental toxicity hazard – the L(E)C50 is reached in the 100-fold dilution for at least one test (TU is ≥100)

4. RESULTS

4.1 Chemical analyses

4.1.1 *In-situ* physico-chemical analysis

The results of the *in-situ* physico-chemical measurements of the first (October 2021) and second trip (December 2021) are summarised in the following sections and provided in **Table 4-1**:

4.1.1.1 Trip 1

- Water temperature was consistent with the ambient air temperatures on the day and at the time of sampling and local site conditions (exposed versus shaded sites).
- The pH level in the dam (SW1) was highest (alkali) and exceeded the target water quality range for aquatic ecosystem health (DWAF, 1996), while the other two sites were within the acceptable limits.
- Electrical conductivity ranged from 59.6mS/m – 124.1mS/m and TDS concentrations from 417mg/L – 868mg/L, being lowest in the dam and highest in the wetland.

- Electrical conductivity in the stream and the wetland exceeded the special limit value (100mS/m), which is a more conservative target for sensitive aquatic ecosystems (DWS, 2013).
- Total dissolved salt concentrations were elevated, particularly in the stream and the wetland, which were well above levels found in rivers polluted by domestic and industrial pollution (e.g. the uMsunduzi River, Pietermaritzburg).
- Dissolved oxygen concentrations, measured under laboratory conditions, were within the acceptable range for all sites.
- Water clarity was overall low. Of the three sites, the wetland exhibited the clearest water (best clarity), facilitated by dense vegetation cover to slow down flow and trap particulate matter. The stream system was poorest in terms of clarity and this can be largely attributed to the denuded river banks and the mobilisation of sediment through wind, market gardening, trampling, surface run-off, and river flow.

Table 4-1 *In-situ* physico-chemical measurements from three monitoring sites on the Brookdale Assessment Centre development site (blue) and four control sites (grey) sampled on the 14th and 15th of October 2021 and 14th of December 2021 (Trip 2) (Values in red text indicate exceedance of the aquatic ecosystem TWQR or waste water standards)

Parameter	Unit	SW1 (dam)		SW2 (stream)		SW3 (wetland)		CS1	CS2	CS3	CS4
		Oct	Dec	Oct	Dec	Oct	Dec	Dec	Dec	Dec	Dec
Temperature	°C	30.9	31.0	32.4	29.4	24.3	24.0	23.8	27.1	26.3	25.5
pH	pH	**9.9**	**9.5**	8.3	**8.3**	7.9	7.3	7.0	7.4	7.3	7.2
Electrical Conductivity	mS/m	59.6	78.2	**108.3**	57.2	**124.1**	84.3	51.6	75.3	59.7	25.8
Total Dissolved Salts	mg/L	417	**500**	748	366	868	**539**	330	482	382	165
Dissolved oxygen	mg/L	7.95†	13.88	8.01†	8.15	7.97†	**2.07**	**0.51**	**1.91**	**2.45**	**3.68**
Dissolved oxygen	% sat.	ns	186.9	ns	106.8	ns	**24.6**	**6.0**	**24.0**	**30.4**	**45.0**
Clarity	cm	22	25	17	13	27	63	11	56	86	27

†Results of laboratory test at 25°C

ns – not sampled

4.1.1.2 Trip 2

- The pH level remained relatively high in the small dam. Using the control sites to calculate a background average value, the pH of the dam (SW1) and stream (SW2) exceeded the TWQR for aquatic ecosystems, while the wetland site (SW3) was within the acceptable limits.
- Total dissolved salt levels were marginally lower in comparison to the first trip. However, based on the average background levels calculated from the control sites (340 mg/L), the dam (SW1) and the wetland (SW3) exceeded the TWQR.
- Electrical conductivity measured at all three of the aquatic systems on site, as well as the controls sites, were below the special limit value for waste water discharge to a water course.
- The average EC and TDS measurements from the impact sites over both trips and that of the control sites were highly comparable.
- Dissolved oxygen concentrations in the wetland (SW3) and all the control sites (CS1-CS4) were well below the TWQR for healthy aquatic ecosystems and could be attributed to slow flow and/or urban pollution (dumping, litter, sewage, etc.). Conversely, the dam (SW1) exhibited supersaturation, which could be attributed to the visible proliferation of algae at this site.
- Water clarity was best at the wetland (SW3) and site CS3, and poorest in the stream (SW2) where the site conditions remained unchanged, and at site CS1. The latter was visibly murky and discoloured, and carrying an odour, suggesting the impacts of raw sewage and/or domestic grey water.

4.1.2 Laboratory chemical analyses

A summary of the water chemistry analyses of the first (October 2021) and second trip (December 2021) are summarised in the following sections and are presented in **Table 4-2**. The full laboratory results are provided in **Appendices 2 and 3**.

4.1.2.1 Trip 1

- The concentrations of pesticides (organochlorine and organophosphorous compounds) and volatile and semi-volatile organic compounds were all below the detectable limit at all the sample sites. If present, the exact concentrations are unknown.

- The hardness of the water present on the site was hard to very hard (120 to >180 mg $CaCO_3$/L) (i.e. having high concentration of salts, particularly of calcium, sodium and magnesium).
- The stream (SW2) exhibited that highest concentration of dissolved metals (314.05mg/L), followed closely by the wetland system (SW3) (306.79mg/L).
- The maximum concentrations of the metals present were most frequently recorded in the dam (n=14, 52%), followed by the wetland (n=8, 30%), then the stream (n=4, 15%).
- Of the metals detected in the dam, four exceeded the AEV (aluminium, copper, lead and zinc), and one (selenium) the CEV, for aquatic ecosystems.
- In the stream, the concentrations of lead (3x) exceeded the AEV, and mercury (10x) and selenium (3x), exceeded the CEV.
- In the wetland, the concentration of mercury was the highest of all three sites and exceeded the CEV by an order of magnitude (12x). Lead was also present and exceeded the AEV (2x). Copper was slightly above the TWQR for aquatic ecosystems.
- In respect to nutrients, ammonia and orthophosphate levels were 2.6 and 2 times higher than the CEV in the wetland, respectively. Orthophosphate levels exceeded the AEV in both the dam and the stream. Nitrate levels marginally exceeded the TWQR in the dam only.
- While there are no aquatic ecosystem guidelines for oils and grease[1], the concentration of these in the dam and wetland exceeded the general limit values for waste water discharge.
- Chemical oxygen demand levels were below the general limit value for waste water discharge, indicating that despite the presence of contaminants, the concentrations were not detrimental to the oxygen availability for aquatic biota.

[1] Vegetable oils, waxes, minerals (non-volatile hydrocarbons), fats, soaps, greases

Table 4-2 Summary of water chemistry results for three aquatic ecosystems on the Brookdale Assessment Centre development site and four control sites sampled on the 14th and 15th of October 2021 (Trip 1) and the 14th of December 2021 (Trip 2)

Values in *italics* represents the maximum value of three aquatic ecosystem monitoring sites per trip
Blue values exceed the average background value of the control sites during trip 2 only, for comparative purposes and in the absence of an applicable limit
Green values exceed the TWQR but are within acceptable limits
Orange values exceed the Chronic Effects Value of the SAWQG, or the *Special Limit Values for the discharge of waste water to a water course
Red values exceed the Acute Effects Value of the SAWQG or the *General Limit Values for the discharge of waste water to a water course

Determinand	Unit	SW1 (dam)		SW2 (stream)		SW3 (wetland)		CS1	CS2	CS3	CS4
		Oct '21	Dec '21	Oct '21	Dec '21	Oct '21	Dec '21	Dec '21	Dec '21	Dec '21	Dec '21
Aluminium	mg Al/L	***0.1310***	*0.0016*	*0.0005*							**0.0182**
Antimony	mg Sb/L			*0.0004*	0.0085		*0.0117*	0.0001	0.0101	0.0130	0.0001
Arsenic	mg As/L		*0.0045*	*0.0073*					0.0052	0.0051	0.0019
Barium	mg Ba/L	0.0013	0.0119	0.0599	0.0721	*0.0713*	***0.1147***	0.0657	0.1554	0.1308	0.0754
Boron	mg B/L		*0.1765*		0.1090		0.1009	0.1105	0.1206	0.1020	0.0711
Calcium	mg Ca/L	4.52	9.79	26.80	22.82	*37.86*	***36.49***	22.88	30.70	27.92	17.00
Chromium	mg Cr/L	*0.0144*		0.0055	*0.0103*	0.0034	0.0004	0.0085	**0.0126**	**0.0135**	
Cobalt	mg Co/L	*0.0004*	*0.0002*					0.0007		0.0004	
Copper	mg Cu/L	***0.0031***	**0.0020**	0.0014	***0.0026***	**0.0015**	**0.0014**	0.0012	**0.0016**	0.0011	**0.0014**
Iron	mg Fe/L	*0.3637*	***0.7230***	0.0052	**0.0137**	0.0615	0.0627	0.1337	0.0676	0.0189	0.0540
Lead	mg Pb/L	***0.0088***	***0.0126***	**0.0067**	**0.0064**	**0.0048**	**0.0071**	**0.0055**	**0.0038**	**0.0085**	
Lithium	mg Li/L		*0.0049*	0.0006		*0.0007*	0.0001				0.0002
Magnesium	mg Mg/L	6.06	14.38	23.33	17.28	*28.900*	***26.24***	15.72	23.60	19.72	11.42
Manganese	mg Mn/L	0.0846	**0.5460**	0.0034	0.0786	*0.1763*	***0.5978***	0.1165	**0.7431**	**0.5059**	0.1429
Mercury	mg Hg/L		***0.0055***	**0.0177**	**0.0033**	***0.0198***		**0.0058**	**0.0030**	**0.0033**	**0.0027**
Molybdenum	mg Mo/L	*0.0051*	0.0173		0.0025		***0.0484***	0.0254	0.0339	0.0317	0.0241
Nickel	mg Ni/L	*0.0022*	***0.0022***	0.0008	**0.0010**	0.0008	**0.0009**	0.0004	0.0024	0.0002	0.0002
Potassium	mg K/L	0.2041	0.741	1.4130	1.860	*5.2740*	***5.644***	4.462	6.419	3.073	3.280

Determinand	Unit	SW1 (dam)		SW2 (stream)		SW3 (wetland)		CS1	CS2	CS3	CS4
Selenium	mg Se/L	0.0553	0.0164	*0.1014*	*0.2386*		0.0433	0.1192	0.0871	0.0776	0.2234
Silver	mg Ag/L	*0.0005*									
Sodium	mg Na/L	167.6	*213.7*	*247.1*	123.1	212.1	187.9	119.6	150.5	121.3	38.16
Strontium	mg Sr/L	0.0238	0.0489	0.1530	0.1394	*0.1863*	*0.2029*	0.1458	0.1660	0.1459	0.0943
Sulphur	mg/L	4.64	2.09	11.09	9.46	*18.31*	*15.57*	14.82	7.16	8.77	6.48
Thallium	mg Tl/L		*0.0024*		0.0014			0.0008	0.0020	0.0045	0.0108
Tin	mg Sn/L	*0.0040*	*0.0075*	0.0003	0.0054	0.0001	0.0067	0.0047	0.0099	0.0042	0.0078
Titanium	mg Ti/L	*0.0040*	*0.0015*		0.0007		0.0001	0.0011	0.0003	0.0001	0.0019
Uranium	mg U/L	0.0044	0.0026	*0.0098*	0.0056	0.0042	*0.0132*	0.0068	0.0090	0.0117	0.0067
Vanadium	mg V/L	*0.0091*	*0.0021*	0.0012	0.0019	0.0009	0.0015	0.0014	0.0009	0.0010	0.0013
Zinc	mg Zn/L	*0.0044*	*0.0024*			0.0002	0.0007	0.0123	0.0008	0.0009	0.0006
Zirconium	mg Zr/L	*0.0011*	*0.0017*	0.0004	0.0009		0.0001	0.0001	0.0003	0.0001	0.0002
Sum metal conc.	mg/L	187.64	245.98	*314.05*	178.83	306.79	*276.64*	181.79	223.33	185.47	80.64
Chemical Oxygen Demand (total)*	mg O_2/L	*47.76*	*109.27*	11.88		39.60	15.61	58.54	23.41	7.80	
Total Alkalinity	mg $CaCO_3$/L	168.41	*300.18*	*274.78*	194.29	225.25	216.82	151.19	203.38	173.56	100.92
Total Ammonia	mg N/L		0.02		0.21	*6.01*	*4.96*	0.93	6.29	1.85	1.59
Nitrate	mg N/L	*0.7*			*2.02*				0.68	0.20	0.54
Orthophosphate	mg P/L	0.03	0.01	0.05	0.05	*0.51*	*0.21*	0.18	0.02	0.17	0.40
Total Oil & Grease*	mg/L	*3.1*	*10.0*	1.7	6.0	2.9	3.2	6.8	0.4	0.4	2.0
Suspended Solids at 105°C	mg/L	11	13	20	*39*	*37*	12	36	12	10	9
Benzo[k+b]fluoranthene	µg/L		*0.3*								
Benzo[g,h,i]perylene	µg/L		*1.0*								
Indeno[123-cd]pyrene	µg/L		*0.6*								
*E. coli**	MPN/100ml	9.8	9.7	648.8	1986.3	*>2419.6*	*>2419.6*	>2419.6	>2419.6	>2419.6	>2419.6

4.1.2.2 Trip 2

- The COD level in the dam (SW1) exceeded the general limit for waste water discharge (1.5x), suggesting that the presence of contaminants was having a detrimental effect the oxygen availability for aquatic biota COD levels at the control sites were generally low, except at CS1.
- The wetland system (SW3) exhibited that highest concentration of dissolved metals (276.64mg/L), followed closely by the dam (SW2) (245.98mg/L). The lowest concentration of dissolved metals was recorded in the stream (178.83mg/L). This is opposite to the findings of previous sampling trip. Total concentration of dissolved metals at all three was slightly lower than previously sampled, but slightly elevated relative to average background concentration of the control sites (167.81mg/L).
- As before, the maximum concentrations of the metals present were most frequently recorded in the dam (n=15, 60%), followed by the wetland (n=8, 32%), then the stream (n=2, 8%).
- Of the elements detected in the dam (SW1), three exceeded the AEV (lead 5.3x, manganese 1.5x, and selenium 3.3x), and two (mercury 3.2x, iron) the CEV, for aquatic ecosystems. The exceedance of iron was 10x higher than average background concentration of the control sites and well beyond the acceptable range. Copper and zinc exceeded the TWQR but were within acceptable limits. The concentrations of a further six elements were higher than the average background concentrations of the control sites.
- In the stream (SW2), the concentration of lead (2.7x) exceeded the AEV, and concentrations of mercury (2x) and selenium (8x), exceeded the CEV. The concentration of mercury was the highest of all three sites (0.0055mg/L). Copper was slightly above the TWQR for aquatic ecosystems. Iron was below the required range based on the control sites.
- Mercury was not detected in the wetland (SW3), whereas previously this was the site with the highest concentration. In the wetland, selenium exceeded the CEV by 1.4 times. Lead and manganese were also present in relatively high amounts and exceeded the AEV by 3 and 1.6 times, respectively. The concentrations of a further eight elements were higher than the average background concentration of the control sites.

- Nutrient levels, specifically ammonia and orthophosphate, were markedly higher in the wetland than in the stream and exceeded CEV at both these sites. Nitrate levels exceeded the TWQR in the stream only.
- The concentration of oils and grease at all three sites exceeded the general limit values for waste water discharge (2.5mg/L).
- The concentrations of pesticides (organochlorine and organophosphorous compounds) and volatile and semi-volatile organic compounds were below the detectable limit in the stream or the wetland. However, three polycyclic aromatic hydrocarbons (PAHs) where detected in the dam, and occurred in concentrations slightly exceeding the detection limit (0.2µg/L), namely, Benzo[k+b]fluoranthene (0.3µg/L), Benzo[g,h,i]perylene (1.0µg/L) and Indeno[123-cd]pyrene (0.6 ug/L). These were not detected in the initial round of sampling.

4.2 Biological sampling

4.2.1 Benthic diatoms

A summary of the benthic diatom community results for the first (October 2021) and second trip (December 2021) are summarised in the section that follow and displayed collectively in **Figure 4-1**.

4.2.1.1 Trip 1

- No cells were present in the diatom sample collected from the small dam (SW1). There are several possible reasons for this. The development of a biofilm (containing diatoms) may have been affected by wetting and drying cycles of the shallow dam (i.e. the rise and fall of water levels) resulting in insufficient time for biofilm to develop, or difficulty in using vegetation to obtain a sample as the biofilm is regularly sloughed off from plants (in comparison to rocks).
- The stream (SW2) and wetland (SW3) systems were found to be in fair and poor health condition, respectively.
- The prevalence of pollution tolerant valves was relatively high at both sites and indicates noteworthy inputs of contaminants, and more so in the wetland. However, a low proportion of deformed cells (<2%) was recorded for both sites, which indicates negligible impact of heavy metals.
- Within the stream, the dominant species was *Fallacia tenera* (27% of the sample), which is tolerant of high salt concentrations/electrolytes, as well as moisture fluctuations (i.e. periods of wetting and drying); followed by *Nitzschia frustulum* (23%), *Gomphonema pumilum* (19%) and *Gomphonema parvulum* (16%). The

latter three species are tolerant of highly polluted water; *N. frustulum* is indicative of high salt concentrations, and *G. parvulum* of high sediment loads (siltation).

- In the wetland, the dominant species was *G. parvulum* (16%), followed by *Nitzschia sp.* (11%), and *Bacillaria paradoxa* and *Navicula erifuga* (both 10%). As for the stream, all these species are tolerant of high salt concentrations; *N. erifuga* is also tolerant of high nutrient loads and *Nitzschia* sp. of siltation.
- These results are in alignment with the *in-situ* and in part, the water chemistry results, which indicate high conductivities, total dissolved salts, hardness and nutrient levels.

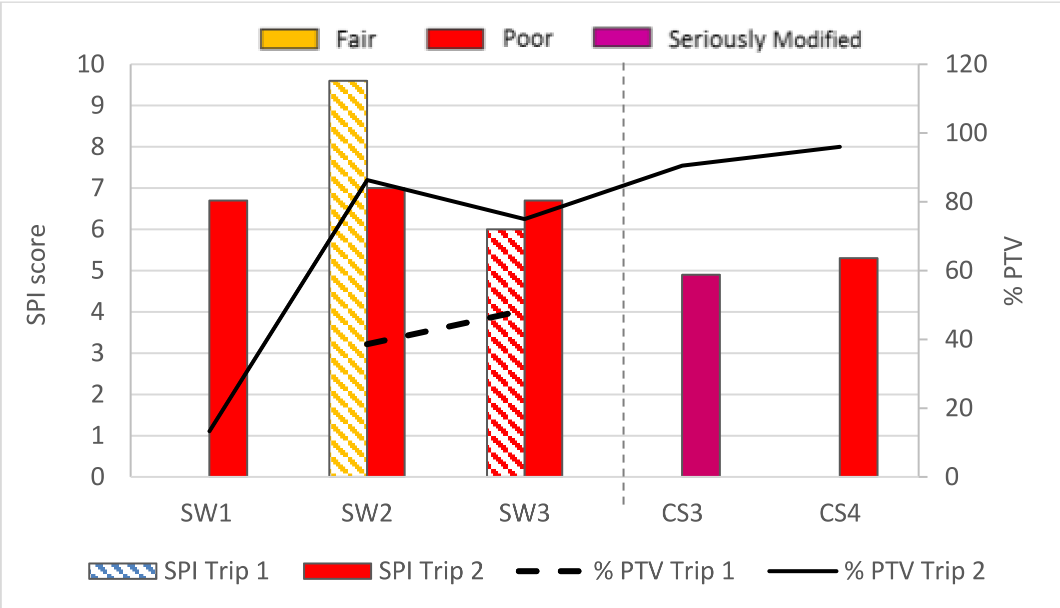

Figure 4-1 Summary results for the benthic diatom community analyses showing SPI scores and % PTV for samples collected on the 14th and 15th of October (Trip 1) and 14th December 2021 (Trip 2) (Note: no results were obtained at SW1 during Trip 1)

4.2.1.2 Trip 2

- As found during the first sampling trip, no diatoms were present in the sample collected from marginal vegetation in the small dam. However, a water sample provided sufficient material to complete the analysis.
- The three aquatic ecosystems on the development site, and the control site CS4 were found to be in poor health condition, based on the diatom communities present. The CS3 was in a seriously modified condition.

- The number of species recorded at the monitoring sites (14-18 spp.) was slightly higher than the previous results (12-17), and the number of species was higher relative to the control sites (5 – 13 spp.). Site SW1 recorded the highest number of species (18 spp.), while site CS4 had the lowest (5 spp.).
- Apart from SW1, the proportion of pollution tolerant valves was high across all sites (≥ 75%), particularly at the control sites.
- CS3 was the only site where the diatom sample exhibited a high degree cell deformation indicating the impact of heavy metal contamination.
- In the dam, the following three species were dominant, and accounted for 56.6% of the sample: *Amphora veneta* (20.5%), *Gyrosigma rautenbachiae* (19.3%) and *Nitzschia* sp. (16.8%). *Amphora veneta* is tolerant of high salt concentrations/electrolytes and severe pollution, whilst *G. rautenbachiae* is indicative of standing, brackish (high salt content) waters impacted by industrial pollutants. *Nitzschia* sp. is an indicator of high silt loads/siltation.
- *Nitzschia frustulum* was the predominant species in the stream, accounting for 85.5% of the sample, and in the wetland, *G. parvulum* was the dominant species comprising 65% of the sample.
- For both control sites, *G. parvulum* was the dominant species accounting for 62% and 90% of the samples respectively, with *Nitzschia frustulum* contributing 33.4% to the CS3 sample.

4.3 Aquatic toxicity

Due to the apparently high concentrations of some potential pollutants, toxicity sampling was added to the follow up survey and and included sampling of the three on-site aquatic ecosystems and two control sites in closest proximity to the development site. The results of the toxicity analyses for the four key aquatic trophic levels are summarised in **Table 4-3.** The full toxicity test report is provided in **Appendix 4.**

- The control sites, CS3 and CS4, were found to possess a Class I toxicity hazard and thus posed little to no toxicity risk to aquatic organisms. Water from these two sites was, in fact, found to stimulate both bacteria and algae.
- Of the impact sites, only SW1 (dam) and SW3 (wetland) were found to pose a toxicity risk to aquatic organisms. This risk was, however, low with both sites possessing a Class II toxicity hazard (slight acute/short-chronic environmental toxicity hazard).

- Similar to the control sites, the water at SW1 and SW3 was found to stimulate bacterial and algal activity, and only posing a risk to higher trophic levels (i.e. invertebrates and vertebrates).
- The water at SW1 resulted in 15% mortality for invertebrate test organisms and 42% mortality for vertebrates, whilst water at SW3 did not result in invertebrate mortalities but resulted in 17% mortality amongst vertebrate test organisms.
- Although possessing the same hazard class, the water at SW1 poses a slightly higher risk to aquatic organisms, particularly invertebrates and vertebrates, than the water at SW3.
- The water at SW2 was found to possess a Class I toxicity hazard and thus posed no acute toxicity risk to aquatic organisms. This water did, however, result in an 11% algal growth inhibition, and a 5% and 8% mortality amongst invertebrate and vertebrate test organisms, respectively.
- Due to increasing inhibition/mortality effects with dilution noted for at least one aquatic trophic level at all sites (i.e., the water became more toxic to at least one aquatic trophic level with increasing dilution), it was not possible to determine a safe dilution factor for the water at any of the sites.
- Overall, the results suggest that where water stands (i.e. in the dam at SW1 and wetland at SW3), there is a slight acute toxicity risk, particularly to vertebrates.
- Based on the findings from the control sites, it is likely that this low toxicity is a result of on-site contamination, and not as a result of greater catchment issues.

Table 4-3 Summary of toxicity results obtained on the 14th of December 2021 from three surface water ecosystems present on the Brookdale Assessment Centre development site and adjacent control sites

Result	SW1	SW2	SW3	CS3	CS4
A. fischeri (bacteria) inhibition	38	14	45	38	26
S. capricornutum (micro-algae) inhibition	2	-11	11	7	14
D. magna (invertebrate) mortality	15	5	0	5	10
P. reticulata (vertebrate) mortality	42	8	17	8	0
Safe dilution factor	<1	<1	<1	<1	<1
Hazard Class	Class II	Class I	Class II	Class I	Class I

5. DISCUSSION

The purpose of this baseline surface water pollution assessment was to assess the three surface water ecosystems at the Brookdale Assessment Centre development site to determine the current condition of these systems and to inform the site rehabilitation monitoring requirements.

The results of the first round of sampling found that concentrations of aluminium, copper, lead, and zinc in the dam exceeded the CEV limits for healthy aquatic ecosystems, that is, present in concentrations that are likely to cause adverse negative effects over the long-term for aquatic organisms. It was more concerning that selenium and mercury were detected in the different surface water ecosystems in high concentrations exceeding the AEV, that is, present in concentrations that are likely to cause acute effects on aquatic biota after short or frequent exposure. The concentrations of mercury in the stream and wetland appeared to be an order of magnitude higher than the AEV.

Both selenium and mercury are considered extremely toxic to aquatic fauna and are used in numerous industrial and manufacturing processes and products (DWAF, 1996). Selenium is a non-metal, similar to sulphur that causes a range of toxic effects in fish, including changes in feeding behaviour, equilibrium, deformities, blood changes and mortality (DWAF, 1996).

Immobilisation, reduced survival and reduced reproduction have been observed in invertebrates exposed to selenium (DWAF, 1996). Mercury causes neurological disturbance and renal dysfunction, and is particularly toxic to mammals. Both selenium and mercury accumulate within animal tissue and thus pose a risk to higher trophic levels (DWAF, 1996).

Based on the diatom communities present, the stream and the wetland system were found to be in fair and poor aquatic ecological condition, respectively. The community assemblages were representative of highly polluted environments, bearing high dissolved salts, which is in agreement with the *in situ* measurements of conductivity, total dissolved salts, and water hardness. The low proportion of deformed cells in the stream and wetland indicated that heavy metal contamination appeared to be of limited consequence for the aquatic communities present.

Given the toxic concentrations measured for several metals and other determinants, and concerns regarding the real toxicity to aquatic communities, a second round of sampling was commissioned to confirm these findings relative to the urban background levels, and to try to understand if the concentrations observed were part of a broader catchment signal, or isolated to the site in question. This was supplemented by definitive aquatic toxicity testing using serial dilutions of the water collected from the surface water ecosystems.

The results from the second round of sampling found that the two areas of standing water, namely the dam and the wetland, possessed higher total metals concentrations in comparison with the stream. Previous sampling indicated the stream as possessing the highest metal concentration. The concentrations of lead and manganese were found mostly exceeding the AEV, while copper and zinc were only slightly above the recommended limits. The main elements of concern were iron (dam only), and again mercury and selenium, which were found in exceedance of the CEV, particularly in the stream. However, high levels of lead, manganese, mercury and selenium were ALSO common across the control sites, providing evidence of a broader geological and urban signature of these pollutants. The inference here is that the high concentrations measured at the monitoring sites are therefore not necessarily driven by the infilled material on-site, but rather part of broader catchment related issues.

Iron was markedly higher in than dam than any other site (including control sites). Iron is a natural weathering product from soils and most geological formations (DWAF, 1996). It is also released to the environment through the burning of coal, sewage, landfill leachates and the corrosion of iron and steel and is used in various industrial processes. It is toxic to aquatic organisms at high concentrations resulting in enzyme inhibition, however overall toxicity and bioavailability is low (DWAF, 1996). This site also exhibited high metal concentrations, COD, total alkalinity, oil and grease, and the presence of PAHs.

Review of available aerial imagery indicates that the dam is a recent (ca. 2020) artificial feature formed from a depression created by the dumping and moving of the fill material. The findings of this pollution assesment indicate that some materials of the landfill are leaching into this ecosystem, and it is also likely receiving contaminated surface run-off from the elevated areas. The condition of the dam is exacerbated in that it is a closed, isolated, standing body of water where no flushing occurs and substances that are transported into the system may accumulate. Evaporation will also contribute to increased concentrations of contaminants. Similarly, the presence of numerous metals, and high concentrations of some of these elements, in the wetland is indicative of the water purification function of wetlands in trapping and assimilating contaminants emanating from the urban environment, entering though the stormwater network immediately upstream, with potential inputs from the landfill.

The benthic diatom analyses indicated that all sites were in poor health, except for the control site CS3, which was in a seriously modified state and exhibited some impact from heavy metals.

The aquatic toxicity results revealed that the surface water ecosystems present on the site were not particularly toxic, despite the exceedances of many substances according to the SAWQG for aquatic ecosystems (DWAF, 1996) and DWA standards for waste water (DWA, 2013). Only the dam and the wetland presented a slight acute environmental toxicity hazard, which appeared to be related to site-based impacts as opposed to broader catchment level impacts, as indicated by the control site results. While invertebrates and vertebrates were most vulnerable, the overall effect was low. This may be attributed in part to the elevated water hardness, as water hardness generally improves the buffering capacity of a water body, and thereby reduces the toxicity of many dissolved metals to aquatic biota (DWAF, 1996).

The findings of this surface water pollution assessment are corroborated by independent assessments of the groundwater quality (Geomeasure, 2021) and soil and waste classification of the landfill (Woolf and Gemmel, 2021). Groundwater sampling detected concentrations of copper, manganese, zinc, fluoride, chloride and sulphate and two sets of total organic hydrocarbons (Geomeasure, 2021). Manganese and fluoride concentrations exceeded the drinking water standards, whilst mercury concentrations were below the limits; selenium was not part of the suite of determinants assessed (Geomeasure, 2021). According to the soil and waste assessment (Woolf and Gemmel, 2021), mercury was only detected at two sites (IP20, IP25) and in negligible amounts (0.2mg/kg). Selenium was detected in low concentrations (≤ 3mg/kg) in soils of the upper terrace and the mid-way terrace where the dam is situated, and slightly higher concentrations (≤ 7mg/kg) were detected at depth at boreholes BH4 and BH5 in close proximity to the stream (Woolf and Gemmel, 2021). The total and leachable concentrations were below any thresholds and both elements were not listed as being of concern (Woolf and Gemmel, 2021).

Manganese and barium were considered problematic in the soil and waste assessment (Woolf and Gemmel, 2021). Within the surface water ecosystems, manganese concentrations exceeding the AEV were detected in the dam and wetland, yet were not severely toxic according to the toxicity results. There are no national guideline limits for barium against which to assess the measured concentrations. Studies on fish after a 30- day exposure period to barium exhibited no effects, while Daphnids exposed to 5.8mg Ba/L over a 21-day period experienced impairment of reproduction and growth reductions (WHO, 1990). The USA Environmental Protection Agency prescribes 2.0mg Ba/L as the maximum contaminant level for drinking water (USEPA, 2013), and the World Health Organisation limit is 0.7mg/L (WHO, 2004). The barium concentrations measured in both surface water assessments were lower than these limits, and were thus not considered to be of concern for the surface water ecosystems on the development site.

Both the stream and the wetland are linked to the surrounding urban landscape through a number of stormwater outlets, as well as general surface run-off into the stream. The stream was visibly impacted by market gardening, informal dwellings and solid waste. The lower portion of the wetland was impacted by solid waste pollution through the stormwater network, illegal dumping from a neighbouring property, as well as human ablutions and notable odour. Elevated levels of ammonia, orthophosphate, oil and grease, suspended solids and *E. coli* in these two ecosystems, point to the prevalence of external urban impacts affecting the surface water ecosystems on-site.

6. CONCLUSION AND RECOMMENDATIONS

The key findings of this baseline surface water pollution assessment are summarised as follows:

- All three of the monitoring sites contained high metal concentrations which may cause acute or chronic effects to aquatic biota.
- The main substances of concern were lead, manganese, iron, selenium and mercury; particularly the latter three elements, which were found in potentially toxic concentrations.
- However, apart from iron, high concentrations of these substances were found to be common in urban drainage systems of the surrounding landscape.

- This suggests that the high concentrations measured at the monitoring sites were not driven by the infilled material but rather by broader geological and urban inputs.
- The diatom communities indicated that the monitoring sites AND control sites were in a poor or seriously modified condition.
- The definitive toxicity testing indicated that only the dam and wetland presented a slight acute environmental toxicity hazard, and this was ascribed to on-site impacts. The overall effect was however low.
- Read in conjunction with the results of the other specialist studies, external sources/broader catchment drivers of contamination appear to be the likely impactors of the surface water ecosystems, via several stormwater outlets discharging to the site and surrounding market gardening and urban activities.

Based on these findings the following recommendations are proposed:

- Routine biomonitoring of benthic diatoms is undertaken quarterly for the duration of the rehabilitation process at the three on-site monitoring sites (dam, stream and wetland) as well as the two control sites in closest proximity to the development site, namely CS3 and CS4.
- The dam is a new artificial feature and the results show that it is receiving and accumulating harmful substances and causing slight toxicity effects. Water contained in the dam must therefore be prevented from entering the adjacent stream and wetland during construction and rehabilitation activities.
- Given that the dam is not part of, or hydrologically linked, to the wetland according to the historical wetland delineation (Eco-Pulse Consulting, 2020), nor is it to be included in the open space system of the development concept, the dam may be infilled for development purposes provided no other listed activities or environmental legislation are triggered.

In adopting a precautionary approach with respect to the re-use of removed fill material, the material may be reused with the following provisions:

- It may not be used close to (<100m) sensitive aquatic features (e.g. streams, wetlands, waterbodies, drainage lines etc.).
- It may not be used to fill/level, or used as top dressing, in areas designed for use as open space areas, e.g. lawns, parks, grassed banks, verges, etc. that will be exposed to rainfall, surface run-off, percolation or subsurface water movement.

- It is recommended that it be used for construction purposes in foundations, etc. where the material will be sealed/isolated from the hydraulic influences mentioned above to prevent leaching of further potential contaminants into the surrounding aquatic environment.

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8. APPENDICES

APPENDIX 1

Site Photographs

Plate 8-1 Aerial view of the dam (SW1) from access road

Plate 8-2 Ground level view of the dam (SW1)

Plate 8-3 Aerial view of the stream (SW2) from lower terrace

Plate 8-4 Ground level upstream view of the stream (SW2)

Plate 8-5 Ground level downstream view of the stream (SW2)

Plate 8-6 Aerial view of lower portion of the wetland (SW3) from lower terrace

Plate 8-7 Ground level up-gradient view of the wetland (SW3)

Plate 8-8 Ground level down-gradient view of the wetland (SW3)

Plate 8-9 Solid waste polluting stormwater outlet at wetland (SW3)

Plate 8-10 Overview of stream channel at site CS1

Plate 8-11 Upstream (left) and instream view (right) at site CS1

Plate 8-12 Downstream view at site CS1

Plate 8-13 Upstream view at site CS2

Plate 8-14 Downstream view at site CS2

Plate 8-15 Overview of river channel at site CS3

	
Plate 8-16 Upstream view at site CS3	**Plate 8-17 Downstream view at site CS3**

Plate 8-18 Overview of river channel at site CS4

Plate 8-19 Upstream view at site CS4

Plate 8-20 Downstream view at site CS4

APPENDIX 2

Water Quality Laboratory Results

Trip 1 (14 and 15 October 2021)

See separate Certificate of Analyses 007417/21 and 007491/21,

APPENDIX 3

Laboratory Results

Trip 2 (14 December 2021)

See separate Certificate of Analyses 000321/22

APPENDIX 4

Toxicity Test Report

Trip 2 (14 December 2021)

See separate report GRT-GT1-A-21_TOX