NTUZUMA B – KWAMANCINZA SEWER RETICULATION PIPELINE

HYDROLOGICAL ASSESSMENT STUDY

KWAZULU-NATAL

August 2020
Version 01

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PROJECT TITLE:

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HYDROLOGICAL ASSESSMENT STUDY
KWAZULU-NATAL

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SPECIALIST DECLARATION:

Lwandisa Holdings (Pty) Ltd have undertaken this assessment in an objective manner, even if this results in views and findings that are not favourable to the client. Lwandisa has the expertise required to undertake the specialist hydrological assessment study and the following report presents the results in an objective manner. The main author of the report, Mr. Nhlakanipho Zondi is a senior hydrologist, has a BSc Honours in Hydrology with nine years of experience in various hydrological studies and is professionally registered with the South African Council of Natural Scientific Professions (SACNASP).

Verification	Name	Signature	Date
Author	Nhlakanipho Zondi ***Pr. Sci. Nat***		August 2020

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KWAZULU-NATAL

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1 INTRODUCTION

Lwandisa Holdings (Pty) Ltd were appointed by the eThekwini Metropolitan Municipality Water and Sanitation to undertake a series of hydrological specialist studies for the proposed Ntuzuma B – KwaMancinza Sewer Reticulation Pipelines, near the town of Durban in KwaZulu-Natal. The hydrological specialist studies are required as part of the Water Use Licence Application (WULA) process, in terms of the Section 21 of the National Water Act (NWA) No. 36 of 1998, and includes a baseline hydrological assessment study, floodlines and stormwater management plan.

This report constitutes the Baseline Hydrology and Floodlines Analysis. The floodlines study includes the delineation of the 1:100-year return period floodlines for the four drainage lines (herein referred to as Un-named Streams 1 to 4) intersecting with, or in the vicinity of, the proposed sewage collector pipelines.

1.1 Study Objective

The objectives of this hydrological study are to:

- Describe the hydrology, landuse and topographical conditions of the study area by defining the general catchment and climatic conditions.
- Identify and delineate streams and river channels and their associated catchment areas in the vicinity of the proposed development sites.
- Determine the Mean Annual Runoff (MAR) for the project area and any contributing catchments in the vicinity of the project sites.
- Undertake a hydrological impact assessment of the proposed sewer reticulation pipelines, focusing on the potential risks associated with the development, related specifically to local and regional hydrology and water quality. Using the impact assessment, possible mitigation measures have been provided to reduce the risks associated with the identified potential impacts.
- Calculating the 1:100-year return periods peak discharge values for the four drainage lines.
- Delineating the 1:100-year return period floodlines for the four drainage lines.

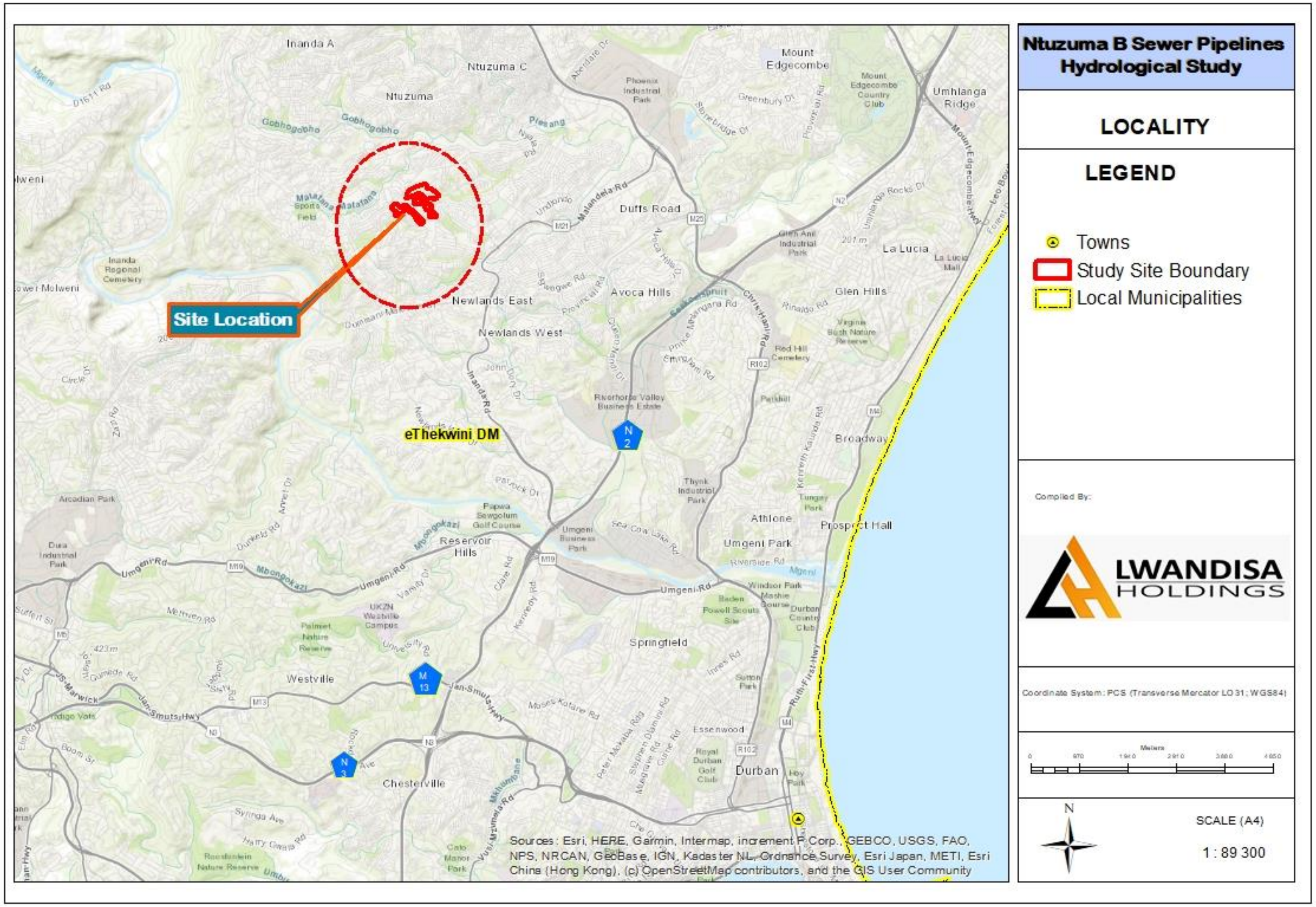
2 SITE DESCRIPTION

2.1 Locality

The greater project to which this study pertain, proposes the construction of the sewer collector pipelines. The location of the project site is presented in **Figure 2-1**. As depicted in this map, the proposed Ntuzuma B sewer pipelines are located approximately 15 km north west of the Durban town, in the eThekwini Metropolitan Municipality of the KwaZulu-Natal Province. A site plan, presenting the proposed Ntuzuma B sewer collector pipelines is provided in **Figure 2-2**. As presented in **Figure 2-2**, the proposed sewer collector pipelines are located in the vicinity of the Un-named Streams 1 to 4.

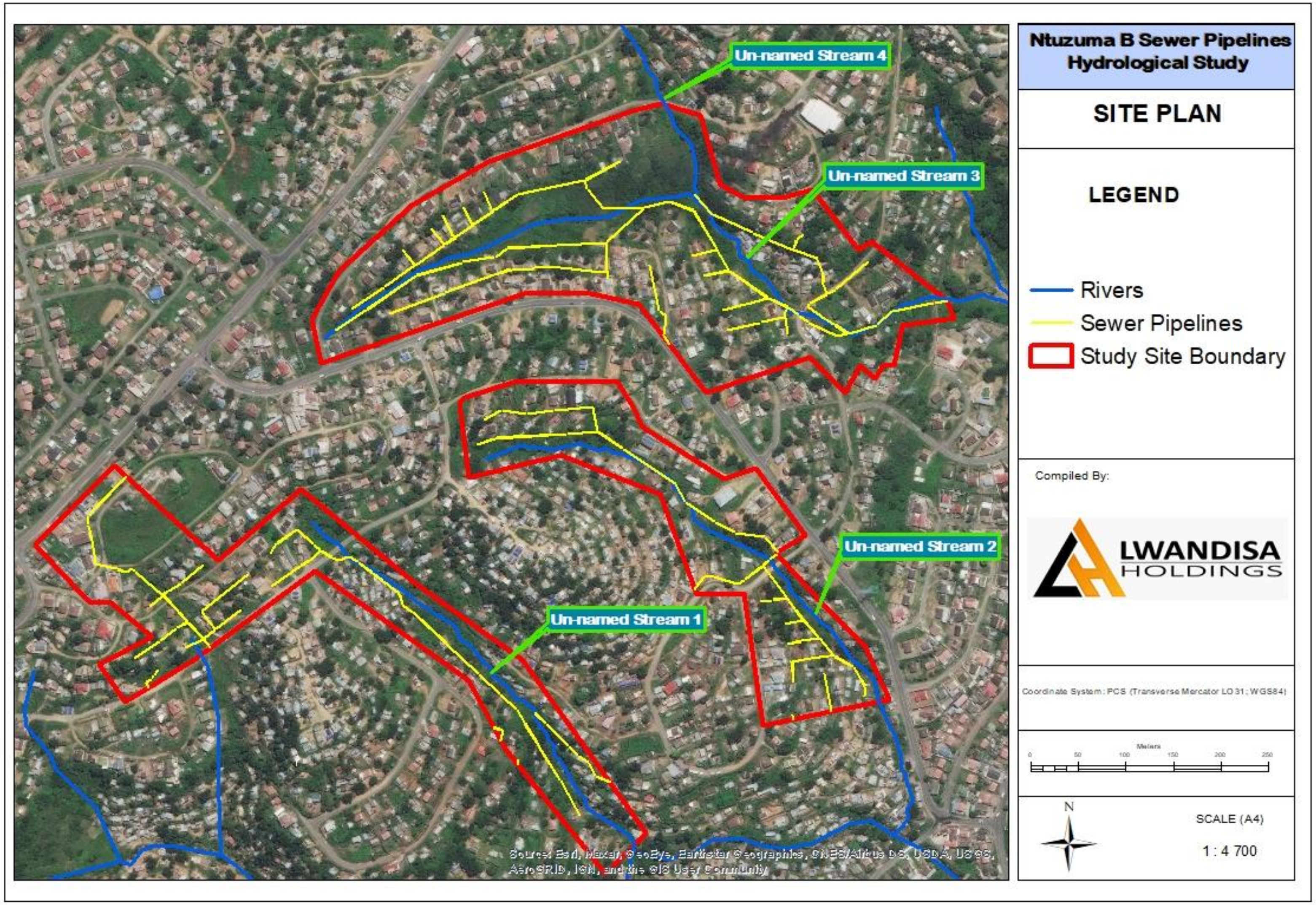
2.2 Pre-Development Site Condition

A site visit of the project area was undertaken in July 2020. The objectives of this site visit were to assess topographical, soil and land cover characteristics of the project area. These site characteristics form the basis of understanding of the hydrology (peak discharge calculations) and hydraulic analysis (floodline delineations) of the study area. The vegetation in the vicinity of the proposed sewer collector pipeline ranges from dense vegetation, particularly on the banks of the respective streams to high dense valley bushveld and grasslands beyond the immediate stream banks. The greater catchment consists of predominately high dense housings. **Photo 2-1** and **2-2**, taken during the site visit, present the general landcover and topographical characteristics of the study area particularly in the vicinity of the proposed sewer collector pipelines.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 2-1: Locality Map for the Proposed Ntuzuma B Sewer Collector Pipelines Hydrological Study



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2-2 Site Plan for the Proposed Ntuzuma B Sewer Pipelines Hydrological Study

Photo 2-1: *General Depiction of the Land Cover within Proposed Sewer Pipelines Catchments*

Photo 2-2: *General Depiction of the Land Cover within Proposed Sewer Pipelines Catchments*

3 BASELINE CLIMATE AND HYDROLOGICAL CHARECTERISTICS OF THE STUDY AREA

The following sections outline the basic study site climatic conditions and hydrological characteristics of the project site catchments.

3.1 Climate Description

Temperature data for the project area was obtained from the South African Weather Services (SAWS) meteorological station **0241042 S**, as presented in **Table 3-1**. The average monthly minimum and maximum temperatures for the project area are depicted in **Table 3-2**. As presented in **Table 3-2**, the monthly distribution of average daily maximum temperatures during summer months shows that the average midday temperatures range from 19.9°C in October to 23.1°C in March. The region is the coldest during July when the mercury drops to 11.1°C on average during the night.

Table 3-1: Climate Station Details

Station Number	Station Name	Longitude(E)	Latitude (S)
0241042 S	Experiment Stn	31º 01’49.039"	29º 42’0.282"

Table 3-2: Temperature Recorded at SAWS Station 0241042 S

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	23.6	23.8	23.1	21.1	19.0	17.0	16.7	17.4	18.8	19.9	21.3	22.8
Min. Temperature (°C)	20.1	20.2	19.3	16.8	13.9	11.3	11.1	12.2	14.5	16.1	17.6	19.2
Max. Temperature (°C)	27.2	27.4	26.9	25.4	24.0	22.6	22.3	22.6	23.1	23.8	25.0	26.4

3.2 Rainfall

Rainfall data for the project area was obtained from the SAWS rainfall station 0240738 W. This rainfall station is located approximately 6 km south of the project site and was selected based on its record length and the reliability of the historical rainfall data. The details of this rainfall station are presented in **Table 3-3**. The mean monthly rainfall amounts are presented in **Table 3-4**. The Mean Annual Precipitation (MAP) for the project site is 888.3 mm. From **Table 3-4**, it is evident that most of the rainfall falls over the summer period (October to March). It is also noted that low rainfall values are recorded over the winter months (April to September).

Table 3-3: Rainfall Station Details

Station Number	Station Name	MAP (mm)	Reliability (%)	Longitude (E)	Latitude (S)
0240738 W	Durban Height (PUR)	888.3	98.8	30º 55’48.589"	29º 48’0.53"

Table 3-4: Average Rainfall Depths Recorded for Years 1950 – 2000 at Rainfall Station 0240738 W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAP
Rainfall Depth (mm)	123.8	116.5	102.0	60.8	37.6	17.3	22.0	37.6	60.7	95.5	96.5	118.1	888.3

As expected, there is a variation in the annual rainfall data obtained from rainfall station **0240738 W**. The lowest recorded annual rainfall value over the assessed period is 319.6 mm, recorded in the year 1992. **Table 3.5** shows the 10 wettest years over the assessed period and indicates that the wettest year within this period was 1954 which had a total annual rainfall of 1 550.4 mm.

Table 3-5: Ten Wettest Years Recorded

Ranking	Year	MAP (mm)
1	1954	1550.4
2	1985	1349.5
3	1953	1299.4
4	1987	1292.0
5	1977	1193.9
6	1984	1176.4
7	1976	1132.2
8	1978	1128.8
9	1988	1120.9
10	1964	1116.3

3.2.1 Design Rainfall

The 24-hour design rainfall depths (point rainfall) for the 1:2, 1:10, 1:20, 1:50, 1:100 and 1:200-year recurrence intervals were extracted using the Design Rainfall Estimation Utility (Smithers and Schulze, 2003) and are shown in **Table 3.6**, below.

Table 3-6: 24-hour Design Rainfall Depths for the Ntuzuma B Sewer Pipelines

Duration (hr)	Rainfall Depth (mm)						
24	1:2	1:5	1:10	1:20	1:50	1:100	1:200
	34.5	51.7	65.2	79.9	101.8	120.8	142.1

3.3 Evaporation

The evaporation data used for the project site was obtained from Evaporation Zone 30B (WR 2012). The Mean Annual Evaporation (MAE) for the area is 1 200 mm (WR2012). From **Table 3-7**, the highest evaporation rates occur during the hotter summer months of October to March. Catchment evapo-transpiration is calculated by applying 12 monthly evapotranspiration conversion factors, as presented in **Table 3-7**. Similarly, evaporation losses from an exposed water body are calculated by applying 12 monthly lake evaporation conversion factors, as presented in **Table 3-7**.

Table 3-7: Ntuzuma B Sewer Pipelines Development Sites Potential Evaporation Rates

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Evaporation Rate (mm)	144.6	124.0	120.1	86.6	70.0	57.5	62.0	74.2	89.8	107.4	124.3	139.6	1 200
Lake Evaporation Factor	0.84	0.88	0.88	0.87	0.85	0.83	0.81	0.81	0.81	0.81	0.82	0.83	
Evapotranspiration Factor	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.80	0.80	0.80	1.00	1.00	

4 HYDROLOGICAL IMPACT ASSESSEMNT

4.1 Risk Assessment Methodology

In order to be compliant with statutory requirements, a hydrological impact assessment was undertaken as per the Department of Water and Sanitation (DWS) Risk Assessment Matrix, 2016.

The risk rating matrix methodology used is based on the following quantitative measures:

- The severity of each impact.
- The spatial extent or geographic sense of each impact occurring.
- Duration of occurrence.
- The frequency of each activity.
- The frequency of each impact.
- Legal issues of the activity.
- Detection of the impact.

In order to determine the significance of each identified potential impact, a numerical value has been linked to the respective factor. **Table 4-1** provides the ranking scales used in this study.

Table 4-1: Risk Rating Matrix

RISK ASSESSMENT KEY (REFERENCED FROM 2016 DWS RISK-BASED WATER USE AUTHORISATION APPROACH AND DELEGATION GUIDELINES) **RATINGS**	
SEVERITY	
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful and/or wetland(s) involved	5
SPATIAL SCALE	
Area specific (at impact site)	1
Whole site (entire surface)	2
Regional / neighbouring areas (downstream within quaternary catchment)	3
National (impacting beyond secondary catchment or provinces)	4
Global (impacting beyond SA boundary)	5
DURATION	

RISK ASSESSMENT KEY (REFERENCED FROM 2016 DWS RISK-BASED WATER USE AUTHORISATION APPROACH AND DELEGATION GUIDELINES) **RATINGS**	
One day to one month, PES, EIS and/or REC not impacted	1
One month to one year, PES, EIS and/or REC impacted but no change in status	2
One year to 10 years, PES, EIS and/or REC impacted to a lower status but can be improved over this period through mitigation	3
Life of the activity, PES, EIS and/or REC permanently lowered	4
More than life of the organisation/facility, PES and EIS scores, an E or F	5
FREQUENCY OF THE ACTIVITY	
Annually or less	1
6 monthly	2
Monthly	3
Weekly	4
Daily	5
FREQUENCY OF THE INCIDENT/IMPACT	
Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5
LEGAL ISSUES	
No legislation	1
Fully covered by legislation (wetlands are legally governed)	5
DETECTION	
Immediately	1
Without much effort	2
Need some effort	3
Remote and difficult to observe	4
Covered	5

Based on the ranking scales presented in **Table 4-1**, the significance of each impact is calculated using the following formula:

Significant Value = (Severity + Spatial Scale + Duration) x (Frequency of Activity + Frequency of Incident +Legal Issues + Detection).

The risk significance rating has been subdivided into three categories, as presented in **Table 4-2**.

This ranking system is based on the DWS risk assessment requirements and has therefore been used to determine risk significances in this study.

Table 4-2: Risk Assessment Significance Value

RATING	CLASS	MANAGEMENT DESCRIPTION
1 – 55	(L) Low Risk	Low potential impact on the receiving environment and downstream water resources. No mitigation measures required.
56 – 169	(M) Moderate Risk	Moderate risk for impact to the receiving environment and downstream water resources. Mitigation measures are required to reduce the risk of the anticipated potential impact.
170 – 300	(H) High Risk	High risk for impact to the receiving environment and downstream water resources with potentially long-term consequences. Mitigation measures are required to reduce the risk of the anticipated potential impact.

4.2 Impact Assessment

The following potential hydrological impacts were identified to be associated with the proposed Ntuzuma B sewer pipelines on the downstream watercourses and are therefore included as part of this impact assessment:

- Changes in catchment water quality due to:
    - Removal and disturbance of vegetation along the banks of the streams, will results to bank erosion which would lead to further deposition of sediments in the streams with an associated drop in water quality;
    - Risk of contamination associated with the hydrocarbons contamination from the earthworks; and
    - Risk of contamination resulting from sewage, if the pipeline leak or burst.
- Changes in catchment water resources due to:
    - Alteration of river flow patterns; and
    - Abstraction from the water resources.
- Changes in catchment flood hydrology due to:
    - Increase impervious areas and
    - Impending of flow.

Table 4-3 presents the results of the significance ratings attributed to each of the identified potential impacts for both the during and post-construction scenarios.

Table 4-3: Significance Ratings of Identified Potential Impacts

No.	Phases	Activity	Aspect	Impact	Severity	Spatial scale	Duration	Consequence		Frequency of activity	Frequency of impact	Legal Issues	Detection	Likelihood	Significance	Risk Rating	Confidence level
	Pre Mitigation																
			Reduction in Catchment Water Quality														
1	**Construction**	**Sewer Pipeline Laying**	Excavation, infilling, use of machinery for opening trenches	Potential for increased sediments to enter the system through surface water dispersion. Increased Sediment input into the streams.	**2**	**2**	**4**	**8**		**4**	**3**	**5**	**2**	**14**	**112**	**M**	**90**
			Clearing of vegetation	Decreased roughness, Increased runoff (volume and velocity), Soil compaction and Loss of Habitat	**2.5**	**2**	**4**	**8.5**		**4**	**4**	**5**	**2**	**15**	**127.5**	**M**	**95**
			Waste and chemical pollutants	Potential hydrocarbon leaks/spills entering via subsurface pathways.	**0.75**	**1**	**2**	**3.75**		**3**	**3**	**5**	**1**	**12**	**45**	**L**	**90**
			Change in Catchment Water Resources														
			Reduction of surface water volumes	Abstraction from the watercourse	**0.25**	**2**	**1**	**3.25**		**1**	**1**	**5**	**4**	**11**	**35.75**	**L**	**90**
			Limiting water inflow into the streams	Impending or diverting the flow of water in a watercourse	**0.75**	**2**	**2**	**4.75**		**3**	**1**	**5**	**1**	**10**	**47.5**	**L**	**90**
			Destabilising and altering the river beds and banks	Altering the bed, banks and characteristics of the streams	**1**	**2**	**3**	**6**		**3**	**4**	**5**	**1**	**13**	**78**	**M**	**90**
			Changes in Flood Hydrology														
			Open pipeline trenches	Impending flow	**0.5**	**1**	**2**	**3.5**		**2**	**2**	**5**	**1**	**10**	**35**	**L**	**90**
Changes in Catchment Water quality																	
2	**Operation**	**Sewer pipelines collecting and discharging effluent**	Damages and faults on the sewer pipelines	Discharge water or water containing waste into a water resources through the sewer pipelines leaks or bursts.	**1.75**	**3**	**3**	**7.75**		**1**	**2**	**5**	**2**	**10**	**77.5**	**M**	**80**
			Change in Catchment Hydrology														
			Infilled trenches and removed vegetation	Increased in impervious areas as the result of soil compactions	**1**	4	1	**6**		2	1	5	1	**9**	**54**	**L**	**80**

No.	Phases	Activity	Aspect	Impact	Severity	Spatial scale	Duration	Consequence		Frequency of activity	Frequency of impact	Legal Issues	Detection	Likelihood	Significance	Risk Rating	Confidence level
Post Mitigation																	
3	**Construction**	**Sewer Pipeline Laying**	**Reduction in Water Quality**														
			Excavation, infilling, use of machinery for opening trench	Potential for increased sediments to enter the system through surface water dispersion. Increased Sediment input into the water source.	**1**	2	1	**4**		1	2	5	1	**9**	**36**	**L**	**95**
			Clearing of vegetation	Decreased roughness, Increased runoff (volume and velocity), Soil compaction and Loss of Habitat	**1.25**	2	1	**4.25**		1	2	5	1	**9**	**38.25**	**L**	**95**
			Waste and chemical pollutants	Potential hydrocarbon leaks/spills entering via subsurface pathways.	**0.5**	1	1	**2.5**		1	2	5	1	**9**	**22.5**	**L**	**90**
			Change in Catchment Water Resources														
			reduction of surface water volumes	Abstraction form the watercourse	**0.25**	2	1	**3.25**		1	1	5	2	**9**	**29.25**	**L**	**80**
			Limiting water inflow into a water course	Impending or diverting the flow of water in a watercourse	**0.25**	2	2	**4.25**		2	1	5	1	**9**	**38.25**	**L**	**80**
			Destabilising and altering the river bed and banks	Altering the bed, banks and characteristics of a water course	**0.5**	2	2	**4.5**		2	2	5	1	**10**	**45**	**L**	**85**
			Change in flood hydrology														
			Open pipeline trenches	Open pipeline trenches	**0.25**	1	1	**2.25**		2	2	5	1	**10**	**22.5**	**L**	90
4	**Change in Water Quality**																
	Operation	**Sewer pipeline collecting and discharging effluent**	damages and faults on the sewer pipeline	Discharge water or water containing waste into a water resource through a sewer pipeline leaks or burst	**1.75**	3	3	**7.75**		1	2	5	1	**9**	**69.75**	**M**	**80**
			Change in Flood Hydrology														
			Infilled trenches and removed vegetation	Increased in impervious areas as the result of soil compaction	**0.625**	2	1	**3.625**		2	1	5	1	**9**	**32.625**	**L**	**80**

4.2.1 Reduction in Catchment Water Quality

Due to the potentially hazardous nature of the raw sewage collected in the proposed pipelines, any spillages from the pipelines will be associated with a high risk of reducing the catchments water quality. Although there are no licenced water users in the vicinity of the proposed sewage collector pipelines, the community in the general area are likely to use water in the streams for various purposes. As a result of this, the significance of reducing catchment water quality is high. In addition to this, during the construction of the pipeline there is a risk of reducing the catchments water quality through:

- erosion from disturbed and/or open ground, and
- hydrocarbon spills from machinery used in construction activities.

In order to mitigate against these identified impacts, the following measures are proposed:

- To limit soil erosion, construction activities (more specifically clearing of land) should be limited to the dry season (May to October) as far as possible.
- During the construction phase, upstream and downstream berms should be implemented for any area where the vegetation has been stripped or there are open ground areas. Upstream diversions will ensure limited surface flows through exposed areas. Downstream berms will ensure that sediments eroded from within the exposed site will be trapped, therefore reducing the impact to the downstream receiving environment. It is recommended that the berms are constructed out of a non-erodible material, such as sand bags with plastic liners.
- Materials excavated during the construction phase should be deposited in areas outside of the drainage lines and stormwater channels. This will ensure minimal contact between concentrated stormwater runoff and the excavated materials.
- Machinery used during the construction phase should be regularly (at least daily) checked for oil leaks. During periods where the machinery is not in use, drip trays should be placed under the machinery to contain any spillages.
- Fuels and hydrocarbon stores used on the site should be lined and bunded such that spills from the store areas will not enter the receiving environment.
- Clearing of vegetation for construction purposes must be undertaken in accordance with a method statement. The method statement must include the method of clearing, recovery of and disposal of vegetation.
- As far as possible the sewage collector pipelines should be located outside of the 1:100- year floodline. If this is not possible, the engineering design of the pipelines

should consider the potential for upliftment (and therefore failure) of the pipelines during a flood event. In order to counteract this potential risk of pipe failure, the sewage collector pipelines engineering design should include the following:

- Appropriate backfilling, particularly within the delineated floodlines, to ensure upliftment will not occur during a flood event, and
- The use of appropriate pipe material to ensure the least likelihood of buoyancy (i.e. cement pipes are less likely to uplift than plastic or Glass Reinforced Pipe (GRP).

It is envisaged that if the above mentioned mitigation measures are implemented, the risk of negatively impacting upon the water resources and ecosystem functionality downstream of the project site will be largely reduced.

4.2.2 Changes in Catchment Water Resources

A hydrological characterisation of the local catchment area (catchment areas of drainage lines in the vicinity of, or intersecting with, the proposed sewage collector pipelines) was undertaken using quaternary catchment based information. This consisted of the MAE, MAP and MAR from the WR2012 hydrological studies (Middleton and Bailey, 2009 and Water Resources of South Africa,20012), as presented in **Table 4-4**. Furthermore, an analysis of the licensed water abstractions within the U20M quaternary catchment downstream of the proposed development sites was undertaken using the 2016 DWS Water Authorisation and Registration Management System (WARMS) database. This database indicated that there are no licenced water users' in the vicinity (within 5 km) of the study area. With regards to the impact on catchment water resources, it is our understanding that the proposed activity (construction of the sewage collector pipelines) will not involve the abstraction of water from the Un-named Streams 1 to 4. It was concluded that the proposed construction of the sewage collection pipelines will not impact upon the water resources (volume of water) of the streams located within the study area.

Table 4-4: Hydrological Characterisation

Quaternary Catchment U20M	
U20M Catchment Area (km^2)	360
U20M MAR (MCM/annum)	61.19
U20M Runoff Depth (mm/annum)	170

During the pipeline construction process, it is likely that the beds and the banks of the respective drainage lines will be impacted upon and the flows in the drainage lines may need to be diverted. This may negatively impact upon the ecosystem functionality at the disturbed sites as well as downstream from the disturbed sites. The proposed mitigation measures to alleviate the identified negative impacts include:

- All soil excavated during the pipelines excavations should be deposited outside of the river banks. This will limit the amount of fine sediments transported downstream (negatively affecting ecosystems).
- Once the pipelines constructions have been completed, rehabilitation of the affected areas should be undertaken. This should include planting indigenous vegetation to ensure that erosion from the construction sites is avoided.

4.2.3 Changes in Flood Hydrology

It is unlikely that there will be any significant changes in the flood hydrology downstream of the proposed sewer pipelines construction. The only potential impact would be a backwater effect (increase in flood levels) upstream of where the sewer pipelines crosses the streams. This impact is, however, associated with a low significance rating. No mitigation measures are therefore required.

5 FLOODLINES DELINEATATION

This section outlines the methodology adopted for the calculation of the 1:100-year return period peak discharge values and hydraulic modelling of floods for the Un-named Streams 1 to 4 within the study site.

5.1 Design Floods Methodology

The peak discharge value with an associated recurrence interval can be calculated using various methodologies that typically fall into three categories, namely:

- Deterministic;
- Empirical; and
- Statistical.

The appropriate methodology to be applied in calculating peak discharge values depends largely on the size of the contributing catchment and the level of hydrological data available (e.g. gauged peak flow values and design rainfall data) for a particular catchment.

The Un-named Streams 1 to 4 at the project site had a catchment areas of approximately 0.13 km^2, 0.17 km^2, 0.22 km^2 and 0.04 km^2, respectively and no gauged streamflow records were available. Based on the sizes of the contributing catchments, the Rational Method, as described in **Section 5.1.1**, was used to calculate the 1:100-year peak discharge values.

5.1.1 Rational Method

The Rational Method is one of the best known and widely used methods for determining peak discharge values of small to medium catchments. The peak flow equation (*cf*. **Equation 5-1**) is based on a runoff coefficient (C), average rainfall intensity (I) and the effective area of the catchment (AC).

$$\boldsymbol{Q_p = \frac{CIA}{3.6}}$$ **Equation 5-1**

Where:

Q_p = peak flow (m³/s)

C = run-off coefficient (dimensionless)

I = average rainfall intensity over catchment (mm/hour)

A = effective area of catchment (km²)

Design rainfall depths are one of the important inputs into the Rational Method. Design rainfall depths for the study site were obtained from the Design Rainfall Estimation Program (Smithers and Schulze, 2003). This information is presented in **Table 5-1**, below.

Table 5-1: 1:100 Year Design Rainfall Values Used in the Rational Method

Duration	Design Rainfall Depth (mm)
	1:100-Year Return Period
5 min	33.3
10 min	51.5
15 min	66.4
30 min	89.6
45 min	106.7
1 hour	120.8
1.5 hour	143.9
2 hour	162.9
4 hour	200.4
6 hour	226.2
8 hour	246.5
10 hour	263.5
12 hour	278.3
16 hour	303.3
20 hour	324.2
24 hour	342.4
2 day	358.5
3 day	410.1
4 day	431.7
5 day	449.3
6 day	464.1
7 day	477.0

The determination of the Un-named Streams 1 to 4 catchments applicable average design rainfall intensity was undertaken by calculating the following variables for the study catchments:

- The time of concentration (T_c) to determine the relevant design rainfall depth of the study site catchments;
- The point rainfall intensity at the catchments centroids (centre of the catchment);
- The areal reduction factor to account for the spatial distribution of the rainfall intensity over the study catchments; and
- The average rainfall intensity over the study catchments.

A summary of the input variables used in the Rational Method to calculate the 1:100-year peak discharge values for the Un-named Streams 1 to 4 are presented in **Table 5-2**.

Table 5-2: Summary of Inputs for Peak Discharge Calculations

Catchment	Catchment Area (km^2)	Longest Water Course (km)	Average Water Course Slope (m/m)	Time of Concentration (hours)
Un-named Stream 1	0.13	0.48	0.1561	0.25
Un-named Stream 2	0.17	0.70	0.1202	0.25
Un-named Stream 3	0.22	0.84	0.1056	0.25
Un-named Stream 4	0.04	0.22	0.2048	0.25

Catchment C-factors required as input for the Rational Method, are determined by accounting for a combination of catchment land use types. These consist of a catchment's:

- Rural (C_1) component;
- Urban (C_2) component; and
- Water body (C_3) component.

The rural component of the Rational Method C-factor (C_1) consists of three sub-components, namely:

- Vegetation (C_v);

- Soil permeability (C_p); and
- Catchment slope (C_s).

The respective areas of grasslands, thicket and bushes, light bushes in the study catchments were calculated in order to determine C_v. With regard to the C_p value, the soils of the contributing catchment were classed as Sandy Loam (SaLm) to Sandy Clay (SaCl) soils, which are classified in Soil Conservation Service–South Africa (SCS-SA) series as Glenrosa Gf15 (Schulze et al., 2004). The surface slopes for the study catchments were estimated using two-meter contour information that was available for the study area. The surface slopes were classed according to the threshold slopes < 3, 3 – 10, 10 – 30 and 30 - 100 %. Based on these inputs, the calculated C-factors (1:100-year) for the study catchments are presented in **Table 5-3**. The resultant peak discharge values are presented in **Table 5-4**.

Table 5-3: Study Site Catchment C-Factor Calculations for the Un-named Streams 1 to 4

Variable	**Un-named Stream 1**	**Un-named Stream 2**	**Un-named Stream 3**	**Un-named Stream 4**
Catchment Land Use Distribution (%)				
Rural Area	8.0	7.0	8.0	4.0
Urban Area	92.0	93.0	92.0	96.0
Water Bodies	0.0	0.0	0.0	0.0
Catchment Slope Distribution (%)				
>3	1.0	0.0	2.0	5.0
0-10	8.0	8.0	8.0	17.0
10-30	49.0	67.0	62.0	44.0
30-100	42.0	25.0	27.0	34.0
Catchment Soil Permeability Distribution (%)				
Permeable	50.0	50.0	50.0	50.0
Semi-permeable	50.0	50.0	50.0	50.0
Rural Component Vegetation Distribution (%)				
Thick bush and forests	60.0	70.0	65.0	72.0
Light bush	15.0	10.0	20.0	20.0
Grasslands	35.0	20.0	15.0	8.0
Final C Factor Values (1:100)	**0.51**	**0.50**	**0.50**	**0.50**

Table 5-4: 1:100-Year Peak Discharge Values

Catchment	1:100-Year Peak Discharge (m^3/s)
Un-named Stream 1	4.9
Un-named Stream 2	6.3
Un-named Stream 3	8.1
Un-named Stream 4	1.5

5.2 Floodlines Delineations

5.2.1 Hydraulic Modelling Methodology

The HEC-RAS Model was used to undertake the one-dimensional hydraulic modelling to determine the extents of the floodlines corresponding to the previously calculated 1:100-year return period flood events. Spatial Information consisting of two-meter interval contour data were input into ArcMAP (*cf*. **Figure 5-1**). The contour data were input into ArcMap and used to create a Digital Elevation Model (DEM) as presented in **Figure 5-1**. This allows for the cross-sectional elevations and other topology to be extracted from the DEM utilising HEC-GeoRAS (an ArcMap 10.5 extension that links directly with the hydraulic model). This data was subsequently exported into the HECRAS model for hydraulic modelling of the previously calculated 1:100-year peak discharge values.

The roughness of the respective channel and floodplain surfaces is an important input into the hydraulic model and thus needed to be accounted for. The roughness of the floodplain is used in hydraulic calculations in order to assess the frictional impact that topography, landcover and soils have on the water flow, thus enabling the assessment of the friction losses on flow velocities, discharge and cross-section flow areas. In this case, Manning's “n” values (Chow, 1959) were used to describe the surface roughness within the HEC-RAS model. Appropriate Manning's “n” values were assigned based on visual observations made during the site visit (**Photos 5-1 to 5-3**). **Table 5-5** presents the general Manning's “n” values for the rivers/streams reaches modelled.

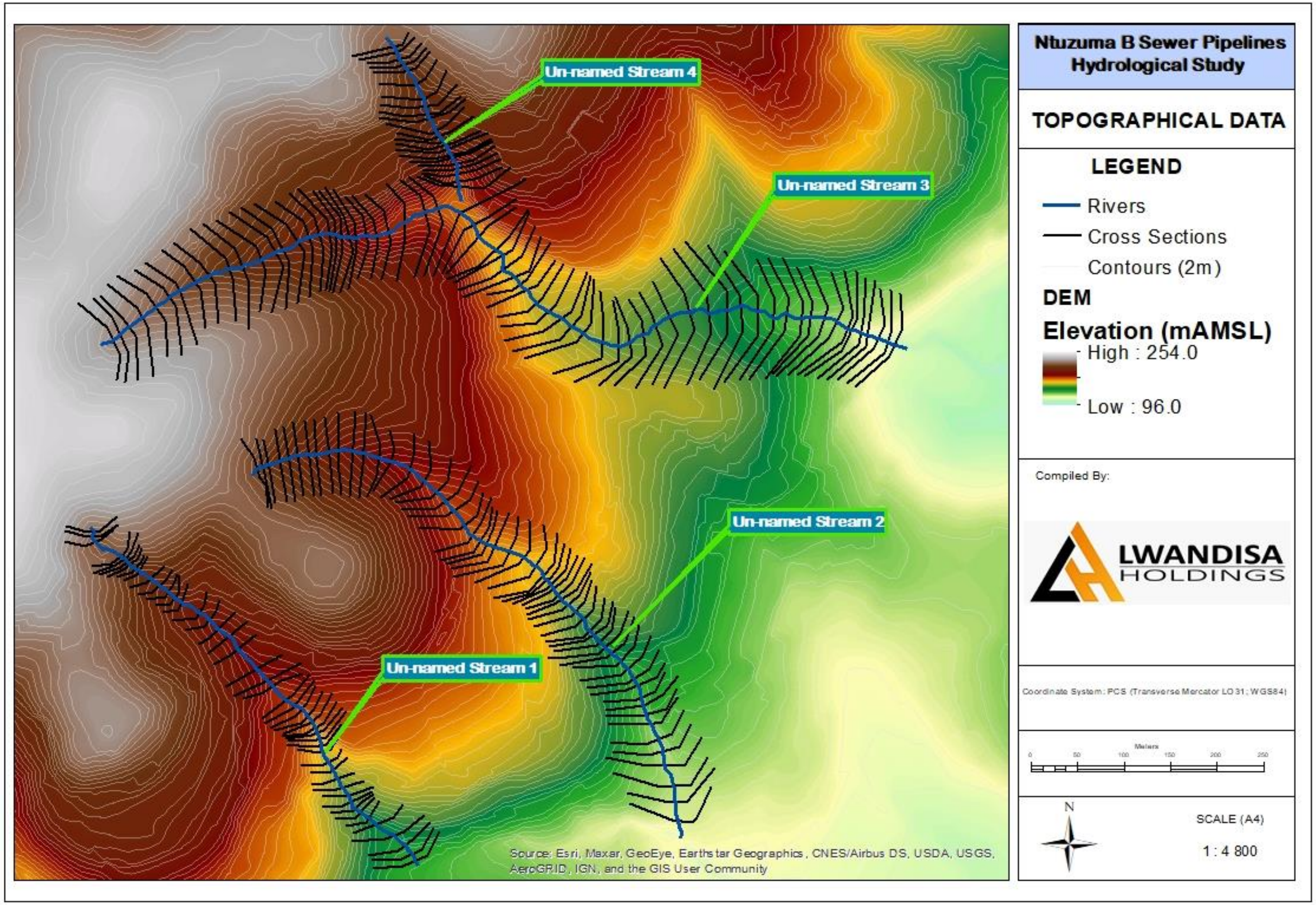


Figure 5-1: Contour Data and DEM Used in the Hydraulic Modelling of the 1:100-Year Floodlines

Photo 5-1: General Channel and Floodplain View of the Un-named Stream 1 at the Project Site

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Photo 5-2: General Channel and Floodplain View of the Un-named Stream 2 at the Project Site

Photo 5-3: General Channel and Floodplain View of the Un-named Stream 3 at the Project Site

Table 5-5: Manning’s n Values (Chow, 1959) Used for the Un-named Streams 1 to 4 in the Project Area

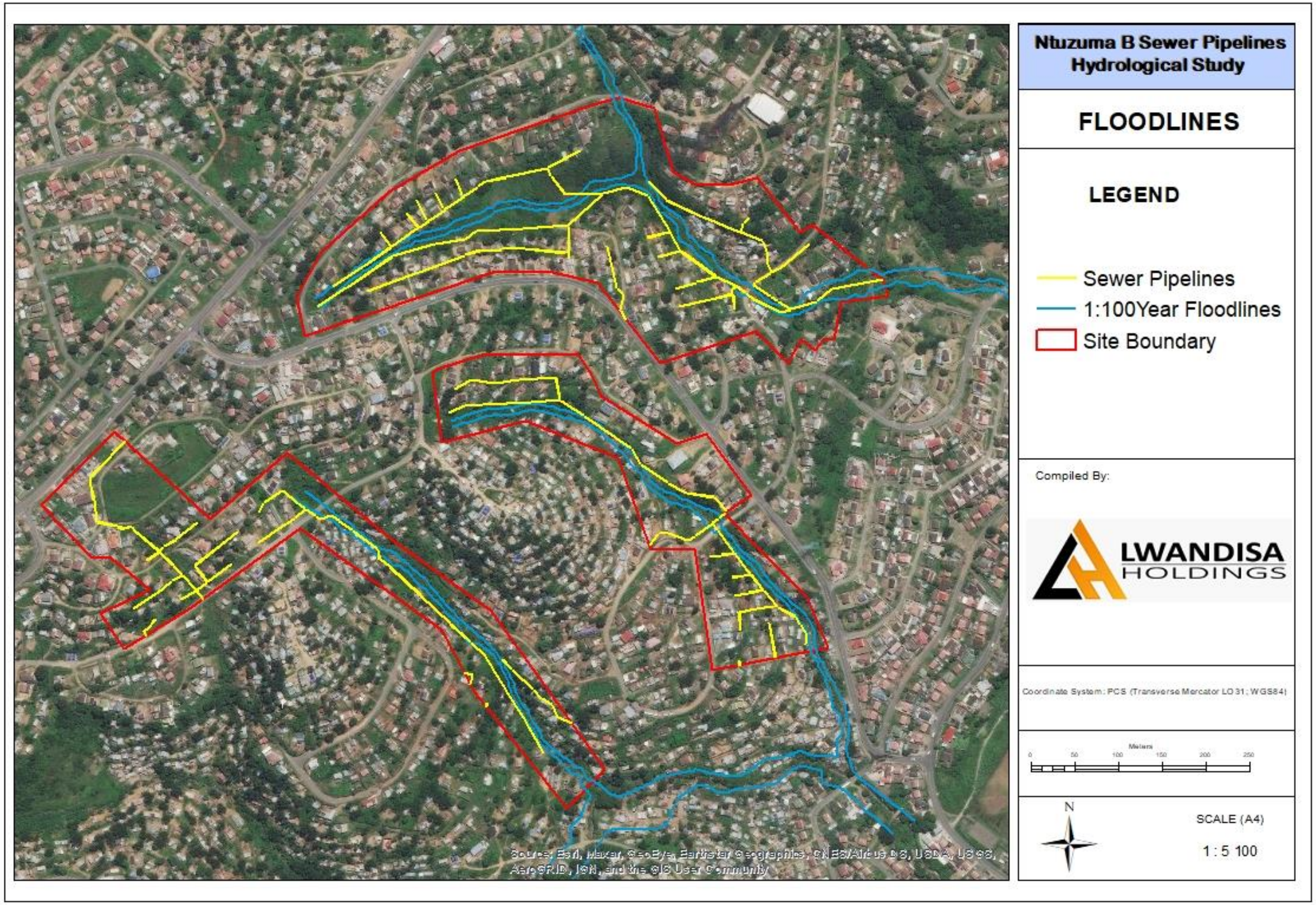
Drainage Line	Location	Manning’s n Value	Description
Un-named Stream	Channel	0.06	Sluggish reaches, weedy and some pools
	Right Floodplain	0.065	Light brush and trees, grassland and heavy weeds
	Left Floodplain	0.065	Light brush and trees, grassland and heavy weeds

One simulation was undertaken during the hydraulic modelling component of this study. The simulation was undertaken under present site conditions to assess the extent of the areas inundated by the 1:100-year return period flood events. Once the hydraulic modelling was completed, the resultant floodlines were imported into ArcMAP for delineation over the project area. The resultant 1:100-year floodlines are presented in **Section 5.2.2**

5.2.2 Floodlines Results

The floodlines delineation produced in this study are based on the two-meter interval contour data. It is important to note that the accuracy of the 1:100-year return period floodlines are dependent on the quality of the spatial data.

The resultant 1:100-year return period floodlines delineations for the Un-named Streams 1 to 4, are presented in **Figure 5- 2 to 5-4.** Based on the results of this floodline study, significant portions of the proposed sewer pipelines are located within the 1:100-year return period floods high water lines. In order to reduce the risk of spillage resulting from breaking of the sewage collector pipelines, recommendations provided in **Section 4.2.1** should be implemented. These recommendations included ensuring appropriate backfilling along the sewage collector pipelines and using appropriate pipeline materials particularly within the delineated floods zones. The aim of these engineering interventions is to reduce the risk of pipes upliftment (and therefore potential pipes breaks) in areas potentially affected by the 1:100-year return period floods events.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 5-2: 1:100 Year Floodlines for the Un-named Streams 1 to 4 Within the Project Site Boundary

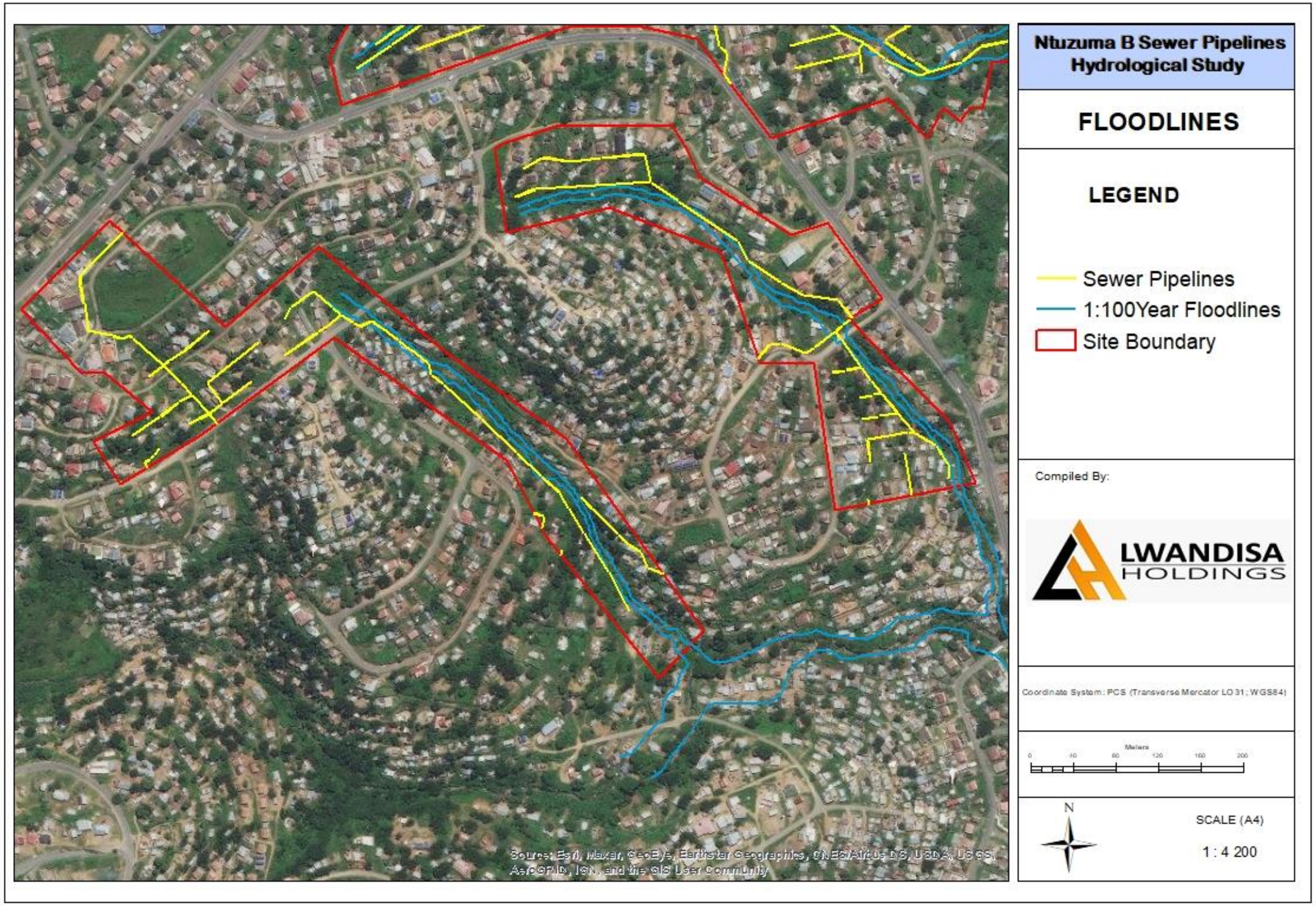


Figure 5-3: 1:100 Year Floodlines for the Un-named Streams 1 and 2 Within the Project Site Boundary

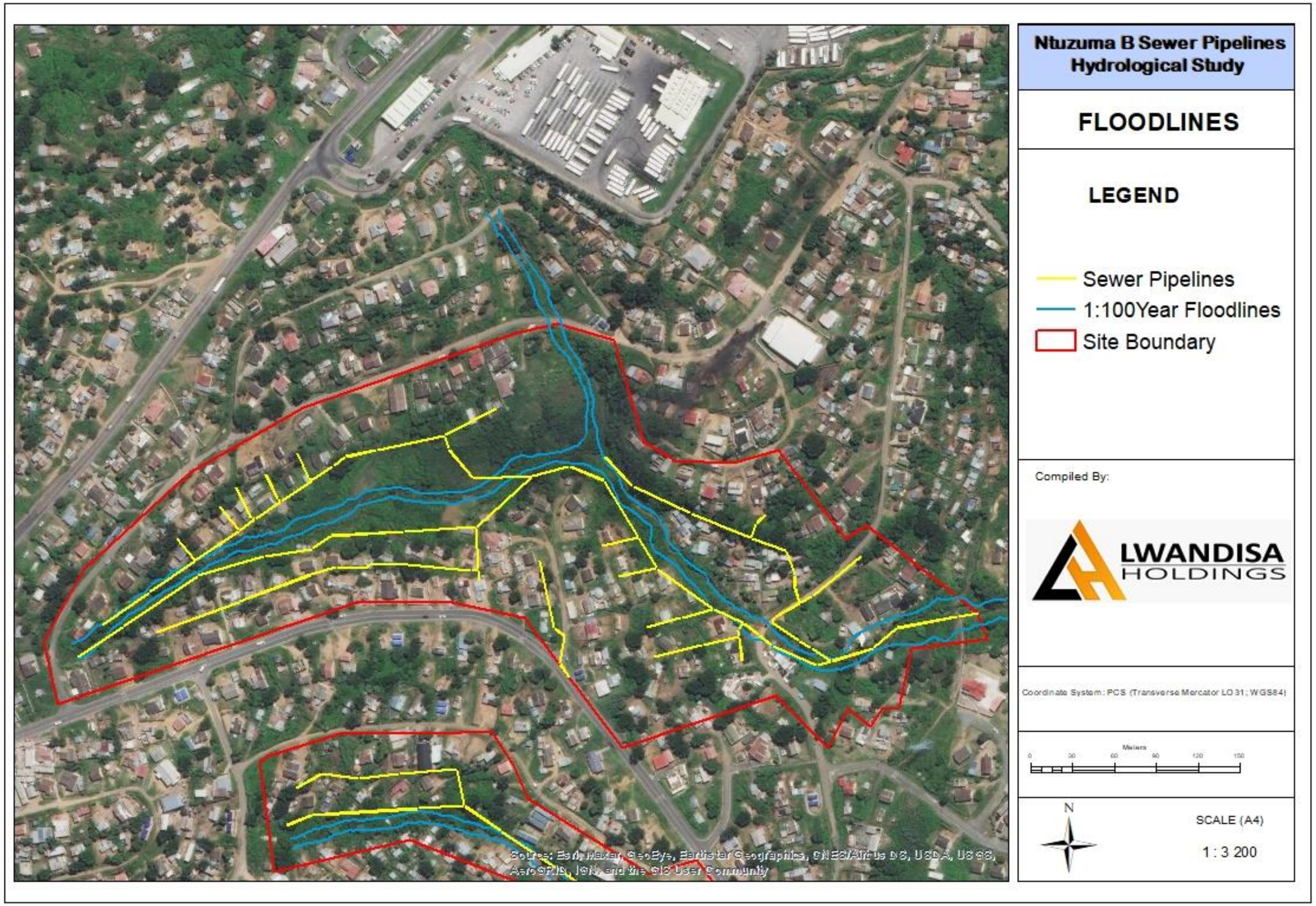


Figure 5-4: 1:100 Year Floodlines for the Un-named Streams 3 and 4 Within the Project Site Boundary

6 CONCLUSIONS

As part of this specialist study, a general hydrological characterisation of the area in which the proposed Ntuzuma B Sewer Pipelines are to be constructed was undertaken. It was noted that the proposed sewer pipelines will largely run parallel with the four drainage lines (i. e. Un-named Streams 1 to 4), within the U20M Quaternary Catchment. The catchment areas associated with the Un-named Streams 1 to 4 are approximately 0.13 km^2, 0.17 km^2, 0.22 km^2 and 0.04 km^2, respectively. No licenced water users were identified in the vicinity (within 5 km) of the proposed project sites.

In addition to the hydrological characterisation of the site, a high level impact assessment was undertaken. Mitigation measures to reduce the significance of the identified potential impacts were provided. The potential impacts identified included:

- Changes in catchment water quality, predominantly due to the risk of spillage of the hazardous sewage water contained within the collector pipelines. Mitigation measures to reduce the risk of spillage from pipelines breaks included ensuring appropriate backfilling along the sewage collector pipelines and using appropriate pipeline materials particularly within the 1:000-year delineated flood prone zones. The aim of these engineering interventions is to reduce the risk of pipes upliftment (and therefore potential pipes breaks) particularly for sections of the pipelines falling within the delineated 1:100 year floodline zones. It should be noted the risk of a reduction of catchment water quality due to erosion from the pipelines construction sites was also identified. Numerous recommendations pertaining to stormwater management at the construction sites were provided.
- Changes in catchment water resources and ecosystem functionality as a result of the construction of the sewer pipelines. It was noted that while the construction of the pipeline would have little to no impact on the volumetric water resources of the catchment, the potential for negative impacts on ecosystem functionality downstream of the construction sites may result. This may be attributed to alterations in the beds and banks of the respective drainage lines during and after construction. Mitigation measures included ensuring that soil and any other overburden is stored outside of the drainage lines during construction. Once construction is complete, it was recommended that the affected sites are rehabilitated with indigenous vegetation to ensure that the risk of erosion from the sites is limited.

In addition to the hydrological impact assessment, an assessment of the 1:100 year return period floodlines for the Un-named Streams 1 to 4 in the vicinity of the proposed sewage collector pipelines was undertaken. The Rational Method was used to calculate the design peak discharge values that were used in hydraulic simulations. The hydraulic modelling was undertaken using the 1-d HEC-RAS hydraulic model and based on two-meter contour interval topographical information. The result of the floodlines analysis indicated that some sections of the proposed pipelines are falling within the 1:100-year return period delineated floodlines. It is recommended that either the pipelines are moved to areas outside of the 1:100-year return period delineated floodlines or appropriate engineering measures are employed to ensure the risk of pipe bursts is reduced as far as possible.

It should be noted, due to the fact that the proposed pipelines will be located within the 1:100 year floodlines, this trigger the requirement of an environmental authorisation process to be undertaken, as per National Environmental Management Act (NEMA) No. 107 of 1998, *Environmental Impact Assessment (EIA) Regulations 2014, as amended on the 7th of April 2017.*

In terms of water use licensing, the sections of sewer pipelines within the 1:100-year floodlines triggers a Section 21 (S21) of the National Water Act No. 36 of 1998 water use license authorisation, as follows:

- S21 (c) - Impeding or diverting flow of a water course; and
- S21 (i) - Altering the beds, banks or characteristics of a watercourse.

7 REFERENCES

Chow, V. T., 1959. Open Channel Hydraulics. McGraw Hill, New York, United States of America.

Hydrological Research Unit (1972). Report No. 1/72, Design flood determination in South Africa. University of the Witwatersrand, Department of Civil Engineering, Johannesburg

Kunz, R (2004). Daily Rainfall Data Extraction Utility, Version 1.4.

National Water Act 36 of 1998. To provide for fundamental reform of the law relating to water resources; to repeal certain laws; and to provide form matters connected therewith.

Middleton, B.J. and Bailey, A.K. (2012) Water Resources of South Africa, 2012 Study. Water Research Commission, Pretoria, Report TT382/08.

SANRAL, 2013. Drainage Manual (Sixth Edition). South African National Roads Agency Ltd, Pretoria, South Africa, pp. 646.

Smithers, J.C. and Schulze, R.E. 2003. Design Rainfall and Flood Estimation in South Africa. Water Research Commission, Pretoria, RSA, WRC Report 1060/1/03. pp 156 plus CD-ROM.

US Army Corps of Engineers. (1995). HEC RAS Hydraulic Modelling Software. Version