HYDRO-GEO ENGINEERS (PTY) LTD
Co. Reg No. 2013/099764/07
P O Box 31785, Braamfontein
2017

21 Sunset Valley, Berger street
Vorna Valley, Midrand
Johannesburg
Tel: +27 78 388 2247

HYDRO-GEO ENGINEERS (PTY) LTD

100-YEAR FLOODLINES FOR THE PROPOSED ESTABLISHMENT OF AN INTEGRATED HUMAN SETTLEMENT IN VENTERSDORP TOWN, NORTH WEST PROVINCE, SOUTH AFRICA

FOR

PREPARED FOR:

LESEKHA CONSULTING

REPORT NO: 01

NOVEMBER 2017

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1 INTRODUCTION

1.1 Background

Hyro Geo Engineer (PTY) LTDhas been appointed by Lesekha Consultingto undertake floodlines assessmentsrelating to the proposed development on for the Proposed Establishment of an Integrated Human Settlement and related infrastructure on Elandskuil Farm No.205 & 206 IP, in Ventersdorp within the jurisdiction of JB Marks Local Municipality, in the North West Province. Ventersdorp is located approximately 62 km South East of Potchefstroom.

The following section details the approach and the methods used in the development of a hydraulic model for the purposes of defining the 1:100 year flood extents for a section of the stream traversing proposed Settlement site.

2 PROJECT SITE

2.1 Hydrology Setting

The Project Area is situated within the Vaal Water Management Area (WMA 5), within the C24E quaternary catchment Figure 2-1

The surface water attributes of the C24E quaternary catchment are summarised in **Error! Reference source not found.**. This includes the Mean Annual Precipitation (MAP), Mean Annual Runoff(MAR), and Mean Annual Evaporation (MAE) as obtained from the Water Resources of South Africa 2012 Study (WR2012).

Table 2-1 : Summary of the Surface Water Attributes of the C21D Quaternary Catchment

Quaternary Catchment	Catchment Area	MAE (mm)	Evaporation Zone	Rainfall Zone	MAP (mm)	MAR (Mm^3)*
C24E	925	1800	10A	C2F	560	20.87

*Mm^3 refers to a Million cubic metres

The project site is within the Skoonspruit catchment, more specifically a to a non-perennial tributary to the river draining through the town of Ventersdorp. The Skoonspruit originates north east ofVentersdorp, in the North West Province,and flowing south west, joined by several tributaries, eventually flowing through theKlerksdorp Dam then finally joining the Vaal River about 91 km from the project site.

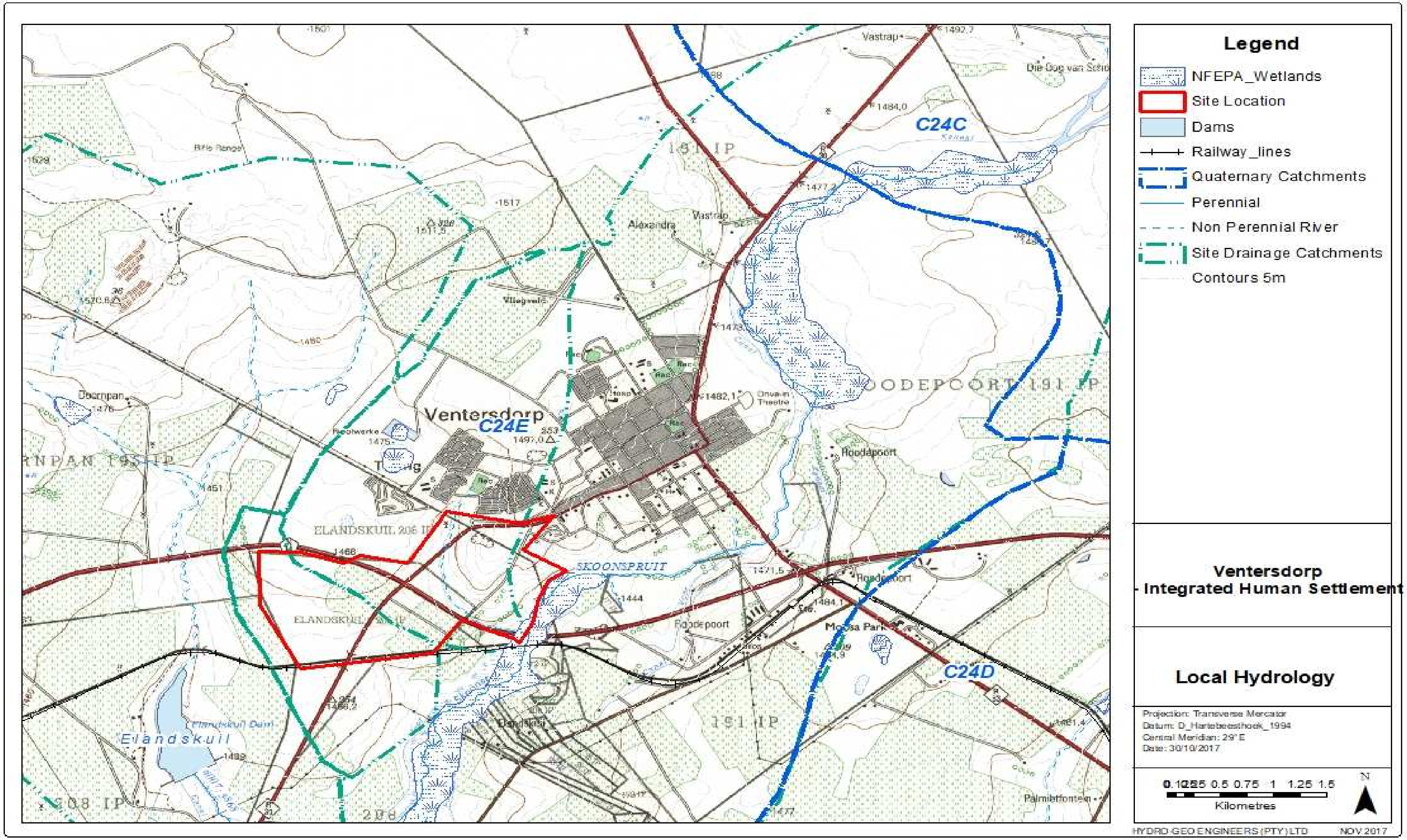


Figure 2-1: Local Hydrology

3 EXPERTISE OF THE SPECIALIST

This surface water study was undertaken by a suitably qualified and experienced Hydrologist registered with the South Africa Council for Natural Scientific Professions (SACNASP) as a Professional Natural Scientist (Pr.Sci.Nat.) in the field of Water Resources Science, the CV is available of request

4 STUDY OBJECTIVES

The objective of this study is to determine the 1:100 year floodlines for the tributary to the Skoonspruit traversing the proposed settlement site.

5 METHODOLOGY

5.1 Introduction

This section provides the methodology and inputs used to determine the 1:100-year floodlines and the model results.

Three sub-catchments were delineated to cover the watercourses within the vicinity of the project site and were utilised to determine the flood peaks for the 1: 100-year extreme event for the purposes of defining the flood risks.

5.2 Input Data Sources

5.2.1 Topography

The topography of the project area and surrounds is undulating with some relatively side floodplains and wetlands. The contour interval of this dataset is 5m, from this data a DEM was modelled and used further in the floodlines modelling.

The common land use in the area residential areas and town within Ventersdorp and cultivated areas and the soil in the project area is of moderate to good infiltration and drainage characteristics.

5.2.2 Subcatchment Delineation

Subcatchments were delineated to cover the streams within the project boundary and were utilised to determine the flood peaks for 1: 100-year extreme events. The delineated subcatchments are highlighted in Figure 5-1.

The following catchments were delineated based on 5m elevation contour lines data from the national database

- Skoonspruit Upper: covering the upstream part of the Skoonspruit before the confluence with the tributary; and
- Skoonspruit Lower: covering the total Skoonspruit catchment up to the catchment boundary located south west of the Settlement Site;
- Project Stream, a tributary to the Skoonspruit flowing through the site.

The sub catchments were characterised for the peak flows calculations as detailed in the Drainage Manual (SANRAL, 2007). The values of each of these model parameter classes were then determined by professional subjective judgement/ discretion, and visual inspection on the terrain and fraction of the catchment.

Catchment characteristics (Table 5-1) were evaluated and used to estimate the flood peaks for the following catchments:

Table 5-1: Catchment Characteristics

Parameter	Skoonspruit (Upper)	(Project stream) Tributary	Skoonspruit Combined Catchment
Catchment area - km2	35.82	7.0661	42.89
Mean annual precipitation - mm	614	614	614
Length of longest stream - km	12.20	4	12.20

Parameter	Skoonspruit (Upper)	(Project stream) Tributary	Skoonspruit Combined Catchment
Height difference along 10-85 slope -m	30.00	24.00	30.00
Average slope along the 10-85 - m/m	0.003	0.014	0.033
SDF Basin	7	7	7

These inputs are applied in the modelling the peak flows.

5.2.3 Methodology

Flood peaks for the three catchments selected for flood modelling were estimatedby the following methods using the Utility Programs for Drainage (UPD) software, 2007 with the methods detailed in SANRAL, 2013:

- Rational Method (RM);
- Alternative Rational Method (ARM);
- Standard Design Flood (SDF);

5.2.3.1 Rational Method

This method is based on the conservation of mass and is applicable for catchment areas below 15 km^2. Aerial and time distributions of rainfall in this method are assumed to be uniform throughout the catchment. Flood peaks and empirical hydrographs can be determined by this method.

Where: The peak flow is obtained from the following relationship:

$$Q = \frac{CIA}{3.6}$$

Where: Q = peak flow (m^3/s)

C = runoff coefficient (dimensionless)

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

A = effective runoff area of the catchment (km^2)

3.6 = conversion factor

5.2.3.2 Alternative Rational Method

This method is based on the rational method with the point precipitation being adjusted using the Design Rainfall Estimation Methodology developed by Smithers and Schulze (2003) to take into account local South African conditions. This method can work for large catchments without any limitation.

Data was extracted from Daily Rainfall Estimate Database File from the following six closest stations considering the site location as Ventersdorp (26°18'S; 26°49'E) are listed in Table 5-2.

Table 5-2 : Closest rainfall stations

Station Name	SAWS Number	Distance (km)	Record (Years)	Latitude (°) (')	Longitude (°) (')	MAP (mm)	Altitude (m)
Ventersdorp (Hosp)	0473559_W	0	76	26.3	26.8	614	1480
Palmietfontein	0473713_W	10.2	55	26.4	26.9	530	1455
Roodekop	0473686_W	15.4	74	26.4	26.9	569	1455
Klipplaatdrift (SKL)	0473416_W	17	62	26.4	26.7	490	1398
Makokskraal "Benroy"	0473200_W	21.9	34	26.3	26.6	576	1460
Buckingham	0474020_W	21.9	48	26.3	27.0	650	1517

The design rainfall input into the Alternative Rational method are detailed below.

Table 5-3: Design Rainfall inputs to the ARM

Design rainfall return period (yrs) / Storm Duration	1:2	1:5	1:10	1:20	1:50	1:100	1:200
1d	49.3	65.7	76.8	87.5	101.5	112.1	122.7
2d	60.6	80.8	94.3	107.5	124.7	137.7	150.8
3d	68.3	91.1	106.4	121.2	140.7	155.4	170.1
7d	86.1	114.8	134.1	152.8	177.3	195.8	214.4

5.2.3.3 Standard Design Flood

The standard design flood method (SDF) was developed to address the uncertainty in flood prediction under South African conditions. It is based on historical data to adequately describe the flood frequency relationships. The runoff or discharge coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 29 regions of WMAs. This method can work for large catchments without any limitation.

The SDF method requires catchment area and slope in addition to the specification of the site as lying within SDF Basin number 7.

5.3 Peak Flow Estimates

The resulting peak flows from the three catchments are presented inTable 5-4. It was decided to use the average of all methods for the flood modelling.

Table 5-4: Modelling results and Peak Flow estimates for 1:100 years (m^3/s)

Catchment Name	Skoonspruit -Upper	Tributary-Project Stream	Total Combined

Catchment Name	Skoonspruit -Upper	Tributary- Project Stream	Total Combined
Average slope	0.003	0.015	0.0026
Time of concentration (h)	4.12	0.64	4.49
Runoff Coefficient (C)	0.327	0.416	0.343
Catchment area - km^2	35.82	7.0661	42.89
RationalMethod (RM)	103.94	108.62	121.12
Alternative Rational (ARM)	110.16	113.92	128.25
Standard Design Method (SDF)	181.57	147.85	201.66
Average m³/s	**131.89**	**123.46**	**150.34**

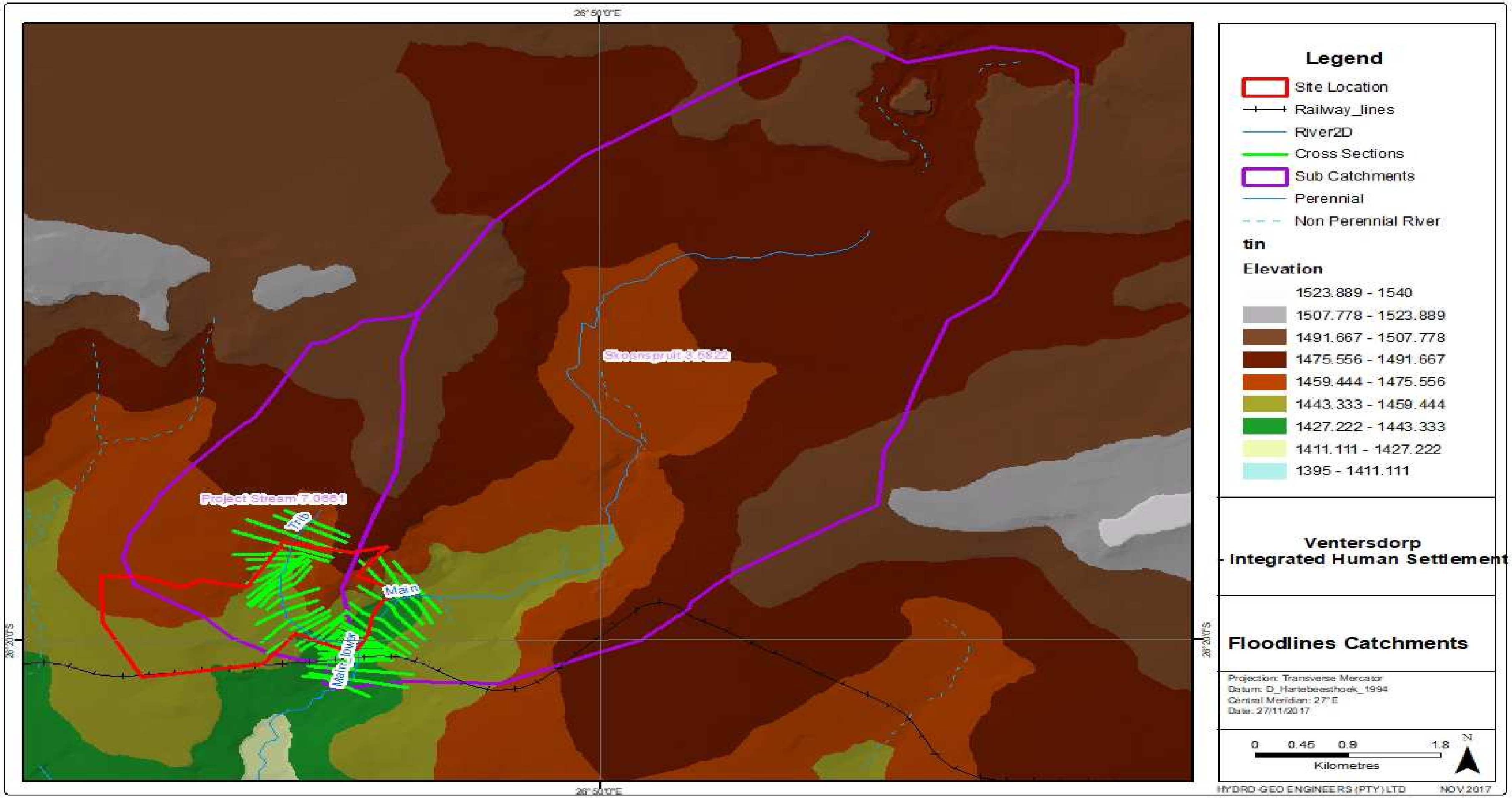


Figure 5-1: Delineated Catchments

6 FLOOD MODELLING

6.1.1 Choice of Software

HEC-RAS4.0 was used for the purpose of modelling the flood elevation profile for the 1: 100 year flood event.HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

6.1.2 Topographic Profile Data

A triangulated irregular network (TIN)from the 5m contour datasets , and forms the foundation for the HEC-RAS model and was used to extract elevation data for the river profile together with the river cross-sections. The TIN was also used to determine placement positions for the cross-sections along the river profile, such that the watercourse can be accurately modelled to the resolution of the provided topographical data.

6.1.3 Manning's Roughness Coefficients

Manning's roughness factor (n) is used to describe the channel and adjacent floodplains resistance to flow. A Manning factor of 0.15 to best represent the frictional characteristics of the channel and 0.1 of the floodplain areas.

	
Location at R30, upstream of culvert (-26° 19.527' S 026° 48.140' E)	Location at R30, facing downstream from Culvert (-26° 19.544' S 026° 48.138' E)

Figure 6-1: Photograph showing the channels characterised by heavy stand of water weeds

6.1.4 Inflows and boundary conditions

The estimated peak flows used in the hydraulic model are described in Section 5.3. A summary of the modelling flow and boundary conditions input data is presented in Table 6-1.

Table 6-1: Modelling Assumptions: Skoonspruit and tributary (1:100 year flood lines)

River-Reach	Reach	Normal depth slope	Peak Flows (m^3/s)	Normal depth Slope
ProjectStream	Trib	2182.789	123.46	0.01
Skoonspruit	Main	1689.738	131.89	0.003
Skoonspruit	Mainlower	652.0865	150.34	0.004

6.1.5 Hydraulic Structures

A survey of the hydraulic structures was undertaken for two culverts, one on the R30 and the other on N14, the dimension of which are detailed below in Table 6-2.

Modelling hydraulic structures was hampered by the lack of good resolution topographical data (better than 5m contours), as such, the structures were therefore ineffective in the hydraulics of the river as well as ineffective areas as a result of the raised roads specifically on the N14 could not me modelled effectively.

However, the floodlines determine in most areas are comparable to the floodplains extents observed during the site assessments undertaken on 11 November 2017 and are therefore adequate for environmental purposes. The observed hydraulic structures are presented below in Table 6-2.

Table 6-2: Hydraulic Structure Measurements

Site ID	Photograph	Opening Width (m)	Opening Height (m)	No of piers/pipes	No of pipe Openings	Pier Width (m)	Pier Spacing	Road Width
R30 Culvert		5.6	3			5.6		16
N14 Culvert		16	3.6	5		3	0.2	16

Railway Crossing		18	6			18		

6.2 Model Development

HEC-RAS version 5.03 (Brunner, 2016) was used for the purpose of modelling the flood elevation profile for the 1:100 year flood event.HEC-RAS is a hydraulic programme used to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels.

Development of the hydraulic model included the following steps:

- Creation of a TIN from the contour data;
- Digitising the stream centre lines and flow paths using HEC-GeoRAS;
- Generating cross-sections approximately 100 m apart through the watercourses using HEC-GeoRAS;
- Importing geometric data into HEC-RAS;
- Entering the Manning's values, peak flows, and upstream and downstream slope boundary conditions in HEC-RAS;
- Performing steady, mixed-flow regime hydraulic modelling within HEC-RAS to generate flood levels at modelled cross-sections; and
- Importing flood levels and projecting levels onto the TIN using HEC-GeoRAS to determine the flood inundation areas.

6.3 Key assumptions in the Hydraulic Model

In-line with the development of the flood-lines the following assumptions were made:

- The topographic data provided was of a sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail;
- The Manning's 'n' values used is considered suitable for use in the 1 1:100 year events modelled, representing all the channels and floodplains;
- No abstractions from the river section or discharges into the river section were taken into account during the modelling;
- Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate; and

- A mixed flow regime which is tailored to both subcritical and supercritical flows was selected for running of the steady state model.

6.4 Results

6.5 Floodlines

The results of the flood elevations in HEC-RAS output table are presented in in **Error! Reference source not found.**and AppendixA

As can be seen, the floodlines extent coarsely determine from the 5m contours will overtop the R30 road, this can be attributed to the resolution, unable to pick raised road surfaces adequately to model no flow areas. This results in a wider floodline, in south west corner of the project site.

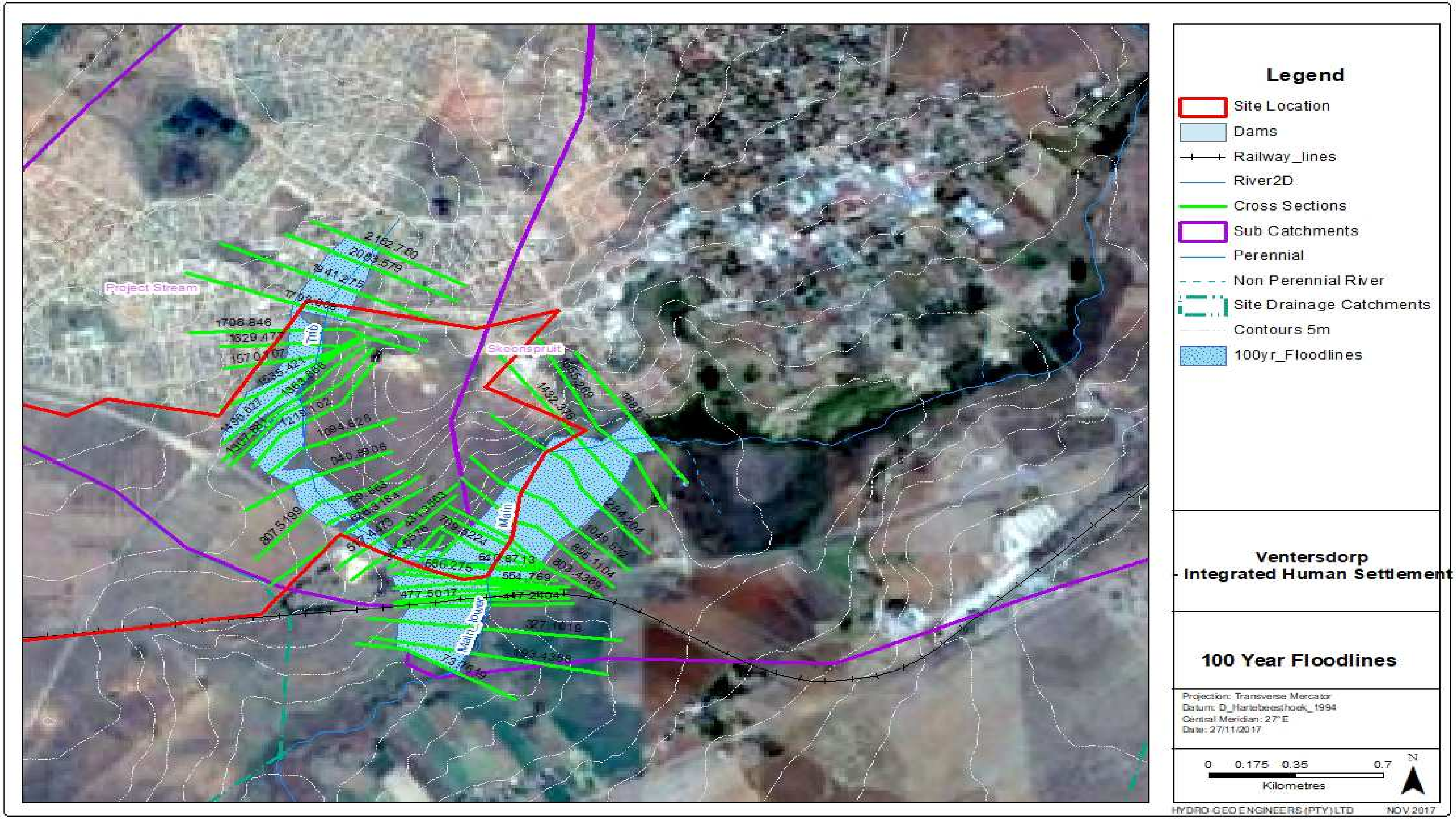
It is important to note that the floodlines determination methodology used is conservative and considered a worst case scenario given up to a 1:100 year flood peak. The 1:100 year floodlines are indicated onFigure 6-2.

6.6 Limitations and Further Work

Steady state flood modelling was undertaken which is a conservative approach as it ignores the effect of storage within the system and therefore produces higher flood levels than would be expected to occur in reality. A steady state modelling will result in worst case (conservative) estimates of flooding, andresultant flood levels and floodplain extents would decrease if unsteady state modelling were undertakenusing an inflow hydrograph as opposed to continuous peak flow.

Despite the above mentioned, the manning coefficient being large due to heavy presence of weeds in the channels, and the low resolution topographic data, the flood risk to the surface infrastructure has been adequately assessed on the Project Stream tributary, therefore; given that the flooding extent will mostly be utilised as green areas/parks in the site plan, and houses should be ensured that they are all outside the conservative estimate offlood-lines and the 100 m buffer, no further flood modelling work is considered necessary. It would only be considered necessary when more detailed topographical data is available and there is need to increase the area available for use for housing as well as development of flood control measures / embankments.

It is recommended that detailed design studies be undertaken in more detail for design purposes of road that any supporting structures locatedwithin the flood-lines are designed to withstand the flow velocities. This will necessitate more detailed elevation data to a good resolution even up to 0.5 / 1m .


Legend
Site Location
Dams
Railway_lines
River2D
Cross Sections
Sub Catchments
Perennial
Non Perennial River
Site Drainage Catchments
Contours 5m
100yr_Floodlines
Ventersdorp
Integrated Human Settlement
100 Year Floodlines
Projection: Transverse Mercator
Datum: D_Hartebeesthoek_1994
Central Meridian: 27°E
Date: 27/11/2017
0 0.175 0.35 0.7
Kilometres
N
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Project Stream
Skoonspruit

Figure 6-2: 1:100 Year Floodlines

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Author: Chenai Makamure (Pr Sci Nat) & Blessing Taenzana (PrSci Nat)	2017/11/27
Reviewer: Tenisia Rugora (PrEng)	
Client Reviewer:	

Appendix A: HECRAS Results

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Skoonspruit	Main	1689.738	100yr	131.89	1443.61	1445.3	1444.55	1445.31	0.00663	0.49	245.98	400.12	0.17
Skoonspruit	Main	1555.269	100yr	131.89	1441.48	1442.36	1442.36	1442.6	0.293005	2.18	60.53	128.98	1.02
Skoonspruit	Main	1432.376	100yr	131.89	1440	1441.3	1440.34	1441.31	0.002329	0.36	337.28	308.42	0.11
Skoonspruit	Main	1284.204	100yr	131.89	1440	1441		1441.01	0.001767	0.28	366.76	386.08	0.09
Skoonspruit	Main	1049.632	100yr	131.89	1438.6	1439.43	1439.43	1439.59	0.23384	1.79	76.66	254.54	0.89
Skoonspruit	Main	896.1104	100yr	131.89	1436.38	1438.81	1437.28	1438.82	0.000722	0.26	481.55	327.74	0.06
Skoonspruit	Main	803.4389	100yr	131.89	1435	1438.8		1438.8	0.000093	0.14	882.62	341.45	0.03
Skoonspruit	Main	766.5526	100yr	131.89	1435	1438.79		1438.8	0.000059	0.12	1027.46	347.4	0.02
Skoonspruit	Main	709.5224	100yr	131.89	1435	1438.79		1438.79	0.000042	0.11	1100.04	319.15	0.02
Skoonspruit	Main_lower	652.0865	100yr	150.34	1435	1438.79		1438.79	0.000028	0.09	1411.22	385.12	0.01
Skoonspruit	Main_lower	640.8713	100yr	150.34	1435	1438.79	1435.25	1438.79	0.000021	0.07	1605.62	445	0.01
Skoonspruit	Main_lower	612.561		Culvert									
Skoonspruit	Main_lower	586.275	100yr	150.34	1435	1438.78		1438.78	0.000028	0.08	1829.77	509.61	0.01
Skoonspruit	Main_lower	569.8837	100yr	150.34	1435	1438.78		1438.78	0.000029	0.08	1843.45	532.09	0.01
Skoonspruit	Main_lower	554.769	100yr	150.34	1435	1438.78		1438.78	0.000034	0.09	1733.87	519.47	0.02
Skoonspruit	Main_lower	529.7176	100yr	150.34	1435	1438.78	1435.28	1438.78	0.000023	0.08	1562.73	457.97	0.01
Skoonspruit	Main_lower	518.0016		Culvert									
Skoonspruit	Main_lower	507.0777	100yr	150.34	1435	1436.07		1436.08	0.002589	0.34	333.44	339.85	0.11
Skoonspruit	Main_lower	477.5017	100yr	150.34	1435	1435.98		1436	0.003364	0.37	303.96	331.08	0.12
Skoonspruit	Main_lower	447.2404	100yr	150.34	1435	1435.85		1435.87	0.005174	0.43	264.75	327.72	0.15
Skoonspruit	Main_lower	327.1019	100yr	150.34	1434.39	1434.61		1434.67	0.026952	0.26	145.42	322.61	0.24
Skoonspruit	Main_lower	193.4358	100yr	150.34	1432.54	1432.99		1433.01	0.007018	0.19	212.48	299.95	0.14
Skoonspruit	Main_lower	73.76192	100yr	150.34	1431.28	1432.37	1431.63	1432.39	0.004008	0.32	268.08	296.73	0.13
ProjectStream	Trib	2182.789	100yr	123.46	1465.59	1467.19	1466.53	1467.23	0.010988	0.64	152.75	176.45	0.22
ProjectStream	Trib	2083.579	100yr	123.46	1463.58	1464.2	1464.2	1464.41	0.180003	1.5	65.49	167.84	0.77
ProjectStream	Trib	1941.275	100yr	123.46	1460	1461.63	1460.51	1461.64	0.002969	0.44	249.85	199.87	0.12
ProjectStream	Trib	1793.008	100yr	123.46	1460	1460.71		1460.75	0.018018	0.69	153.86	234.59	0.27
ProjectStream	Trib	1706.846	100yr	123.46	1457.21	1457.78		1458	0.069717	0.76	63.04	103.75	0.46
ProjectStream	Trib	1629.477	100yr	123.46	1455	1456.68		1456.71	0.006854	0.67	165.13	134.67	0.18
ProjectStream	Trib	1570.107	100yr	123.46	1455	1455.91		1455.97	0.028703	0.99	113.57	146.9	0.35
ProjectStream	Trib	1535.421	100yr	123.46	1455	1455.74		1455.75	0.002475	0.26	301.73	365.01	0.1
ProjectStream	Trib	1496.627	100yr	123.46	1455	1455.74	1452.52	1455.75	0.00003	0.03	1220.52	537.3	0.01
ProjectStream	Trib	1404.831		Culvert									
ProjectStream	Trib	1363.866	100yr	123.46	1450.98	1451.5		1451.52	0.004609	0.18	194.96	221.1	0.12
ProjectStream	Trib	1307.881	100yr	123.46	1450	1451.36		1451.36	0.001712	0.3	302.54	285.68	0.09
ProjectStream	Trib	1219.102	100yr	123.46	1450	1451.2		1451.21	0.001682	0.26	303.95	294.56	0.09
ProjectStream	Trib	1094.628	100yr	123.46	1450	1450.34	1450.34	1450.51	0.149129	1.17	69.47	207.18	0.67
ProjectStream	Trib	940.8906	100yr	123.46	1445	1447.06	1445.97	1447.09	0.006797	0.74	161.57	124.13	0.19
ProjectStream	Trib	807.5199	100yr	123.46	1445	1446.51		1446.53	0.002826	0.45	248.39	188.91	0.12
ProjectStream	Trib	709.663	100yr	123.46	1445	1445.95		1446	0.014162	0.76	141.09	152.89	0.25
ProjectStream	Trib	626.3184	100yr	123.46	1442.82	1443.46		1443.61	0.083869	1.35	75.28	133.4	0.56
ProjectStream	Trib	517.4473	100yr	123.46	1440	1441.47	1440.67	1441.51	0.008159	0.66	150.88	138.02	0.2
ProjectStream	Trib	431.3563	100yr	123.46	1438.71	1439.36	1439.36	1439.61	0.163664	1.74	57.76	115.04	0.77
ProjectStream	Trib	361.5576	100yr	123.46	1435.76	1438.96	1436.83	1438.97	0.000622	0.29	354.84	159.59	0.06
ProjectStream	Trib	308.2995	100yr	123.46	1435	1438.89		1438.91	0.002282	0.58	211.33	81	0.12
ProjectStream	Trib	245.9154	100yr	123.46	1435	1438.78		1438.79	0.001446	0.45	274.41	112.18	0.09