Skywalk at God's Window - Surface Water Management Report

Report Prepared for

Strategic Environmental Focus

Report Prepared by

srk consulting

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Skywalk Project at God's Window Surface Water Management Report

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Strategic Environmental Focus (SEF). The opinions in this Report are provided in response to a specific request from SEF to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

List of Abbreviations

BMP	Best Management Practice
BOD	Biological Oxygen Demand
DEA	Department of Environmental Affairs
DO	Dissolved Oxygen
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
IDC	Industrial Development Corporation
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWM	Integrated Water Management
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MTPA	Mpumalanga Tourism and Parks Agency
NEMA	National Environmental Management Act (Act 107 of 1998)
NEMWA	National Environmental Management Waste Act
NWA	National Water Act (Act 36 of 1998)
SEF	Strategic Environmental Focus
SRK	SRK Consulting
SWMP	Storm Water Management Plan
SWMPr	Surfaced Water Monitoring Program
TCM	Thaba Chweu Local Municipality
WMA	Waste Management Act

1 Introduction and Scope of Report

The Industrial Development Corporation of South Africa (IDC) is funding the Mpumalanga Tourism and Parks Agency (MTPA) to establish the proposed skywalk project at God's Window located on the ridge of the Blyde River Canyon, within the Thaba Chweu Local Municipality (TCM), in the Ehlazeni District Municipality, Mpumalanga Province. The locality of the existing God's window viewpoint is shown on Figure 1-1 below. The aim of the project is to boost regional tourism, thereby having a positive effect on South Africa's economic growth.

Strategic Environmental Focus (Pty) Ltd (SEF), as independent environmental practitioners has been appointed by the IDC on behalf of the MTPA to undertake to S&EIR process for the proposed Skywalk project. SRK Consulting (Pty) Ltd has been appointed by SEF to perform the surface water assessment for the planned project.

The scope of this report is to give a summary of the methodology used, as well as the main findings and recommendations as an outcome from the surface water study performed by SRK. This document should serve as a decision making tool by identifying the anticipated impacts that the planned project will have on the surrounding surface water, and proposing mitigation measures that will minimize the impact. Furthermore, a surface water monitoring plan is presented, that will ensure that the Development is sustainable from a water resource management perspective.

srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Existing Development Footprint at God's Window	Project No. 484734

Figure 1-1: Existing Development footprint at God's Window.

1.1 Background of the Project

The Blyde River Canyon is the world's largest green canyon and the third largest overall. The Canyon is a unique natural environment, with dramatic views across the world's deepest green canyon and dramatic rock formations. Views from God's Window extend down to the lowveld, across to the distant Kruger National Park. The viewpoint is already a popular part of the Panorama Route which comprises a small number of relatively undeveloped, but highly impressive beauty spots.

The skywalk project represents the core component of the Development at God's Window. However, in the future there could be potential to supplement this attraction with the addition of a 'Skylift' and/or an observation tower. The Skylift concept would involve a vertical drop by a hoisting system into a series of suspended walkways in the forest below.

The proposed site for skywalk is situated at God's Window, on the ridge of the Blyde River Canyon. The site falls within Farm De Houtbosch 503 KT and Portion 2 of Farm Lisbon 531 KT. The project site lies 5km north of Graskop, which together with Sabie and Hazyview, forms a triangle of key towns along the tourist route.

The site has the following SG farm Codes:

- T0KT00000000050300000; and
- T0KT00000000053100002.

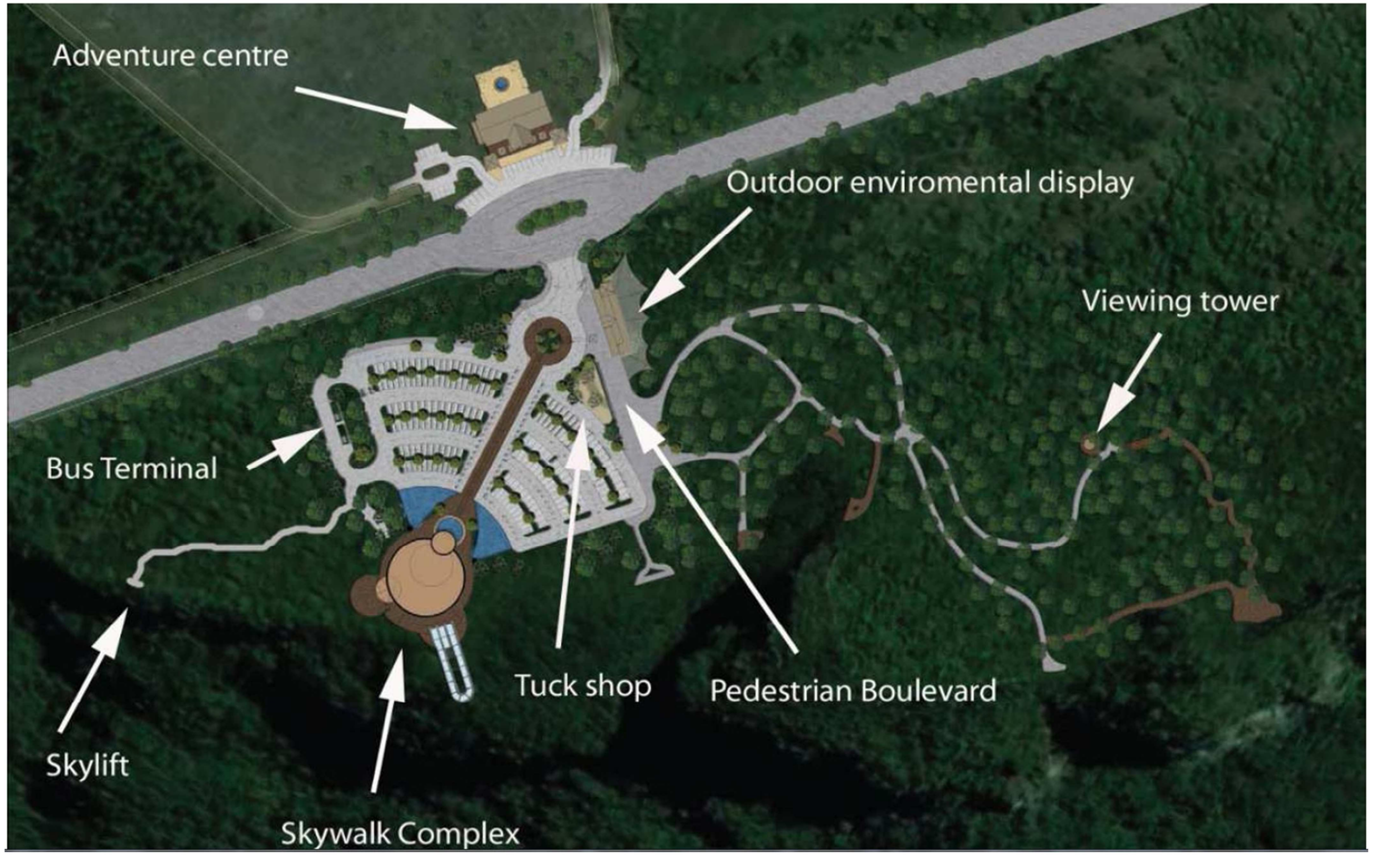
The geographic locality of the site is shown on Figure 1-2 below.

1.1.1 Project Description and planned Development

The skywalk at God's Window is envisaged to be a cantilevered glass walkway, extending some 12 metres from the Canyon's edge, giving a 360° panoramic view creating the feeling of being suspended or hovering in the air, with a 700 metre vertical drop below, as well as a main building which will house a cafeteria and gift shop. This will be achieved by large glass panels on the floor and sides of the walkway, which will be is suspended off the edge of the cliff. The structure will be made of both metal (for strength and rigidity) and glass (for transparency). The skywalk will be designed with a single access and exit route channelling visitors in one direction. In the centre of the walkway, there will be provision for a Skylift platform which will be positioned under the main structure and will be largely out of site. The whole structure will be anchored on top of the cliff using rock anchors and concrete blocks for counter weight. The skywalk will form part of a larger redevelopment of God's Window, including an enhancement of the existing walkways, viewpoints and car park. The conceptual planned Development is shown in Figure 1-3 below.

srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Location of the Skywalk Project	Project No. 484734

Figure 1-2: Location of the Skywalk Project



srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Site map showing the conceptual planned development	Project No. 484734

Figure 1-3: Site map showing the conceptual planned Development

1.2 Nature of the Brief

Strategic Environmental Focus (Pty) Ltd (SEF), as independent environmental practitioners has been appointed by the IDC on behalf of the MTPA to undertake to S&EIR process for the proposed Skywalk project, with the objective of obtaining the following authorisations:

- Environmental Authorisation;
- Waste Management License; and
- Water use License.

SRK Consulting (Pty) Ltd has been appointed by SEF to perform the surface water assessment for the planned project.

1.3 Project Team

The project team responsible for the characterisation of the surface water consists of:

• Manda Hinsch	Project Manager
• Matt Braune	Stormwater Management and Reviewer
• Edward Dupper	Hydrology
• Brigette Nagel	Environmental Scientist
• Joyce Mathole	Baseline Hydrology

1.4 Purpose of the Report

This report contains a surface water assessment that covers the following aspects:

- Describe all the surface water impacts and then propose mitigation measures as normally required for an EIA/EMP. This will be done for the construction and operational phases;
- Compile a Storm Water Management Plan (SWMP) as prescribed by the Best Practice Guideline G1: Storm Water Management by DWAF, 2006. (Department: Water Affairs and Forestry, 2006) All recommendations to be in line with Regulation 704 of the NWA, 1998 and to include the following:
  - Determine catchment characteristics i.e. catchment boundaries, water bodies (pans, dams, etc.), natural flow paths and watercourses;
  - Determine the impact of all water retention infrastructure on the Mean Annual Runoff (MAR) by simulating the life of the Development over the affected catchments and streams;
  - Carry out hydrological modelling to determine the storm water runoff peaks and volumes from the Development site prior to and after construction for various recurrence intervals ;
  - Analyse existing drainage systems at the Development site to establish the current hydraulic capacity; and
  - Determine 50/100 year floodlines along watercourses which are affected by the Development site.
- Develop a surface water monitoring programme as prescribed by the Best Practice Guideline G3. (Department of Water Affairs and Forestry, 2007). No actual sampling will be undertaken for this study.

1.5 Legal Requirements

In accordance with the requirements of the National Environmental Management Act (Act 107 of 1998) (NEMA) and the National Environmental Management Waste Act (Act 59 of 2008) (NEMWA), the IDC, on behalf of the MTPA requires prior approval i.e. Environmental Authorisation (EA) from the Competent Authority, in this case the Department of Environmental Affairs (DEA) to undertake the proposed project. Furthermore, a water use license will be required in terms of the National Water Management Act (Act 36 of 1998) (NWA). Water Use License

Due to water resources identified on site (i.e. non perennial rivers), and the close proximity of the Blyde River and wetlands as seen on Figure 1-4, the proposed development may trigger the following water uses as listed in Section 21 of the National Water Act, 1998 (Act No.36 of 1998) (NWA):

c) Impending or diverting the flow of water in a watercourse; and

i) Altering the bed, banks, course or characteristics of a watercourse.

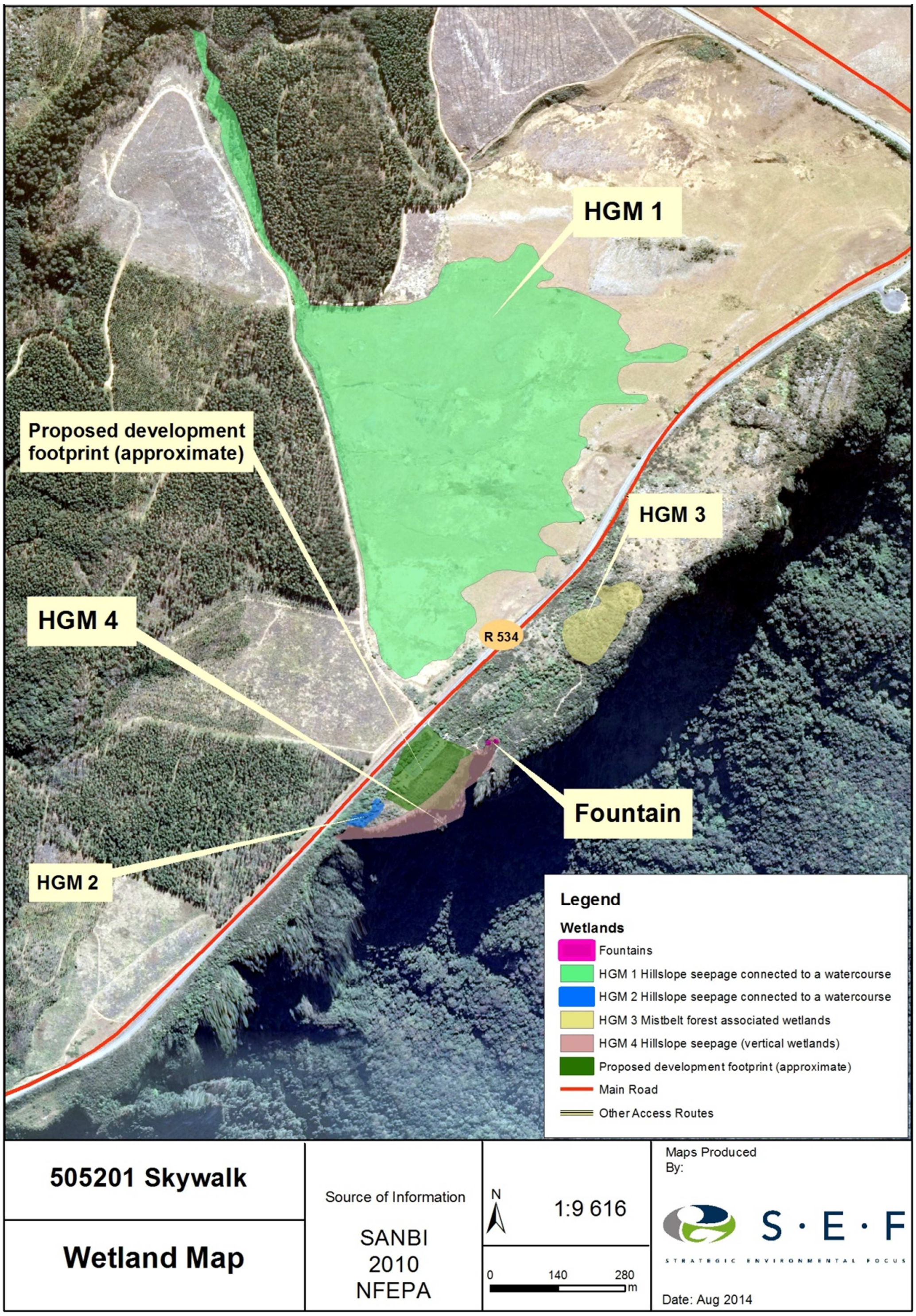
In terms of the National Water Act (Act 36 of 1998), floodlines need to be determined before establishment of townships as highlighted from an extract of the National Water Act below.

National Water Act, Chapter 14, Part 3: Information on Floodlines

Floodlines on plans for establishment of townships

144. *For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by flood waters on average once in every 100 years.*

As is observed from the topography of the site and surrounding area the closest watercourse to the Development site is the Blyde River along the eastern side of the planned Development. It is furthermore determined that the Blyde River invert is about 700m below the surface of the Development site and hence no flooding from the river is expected. In view of above, no floodline study is therefore required.



srk consulting	**Skywalk Project at God's Window** **Surface Water Management Report** Wetlands in close proximity of the planned Development	Project No. 484734

Figure 1-4: Wetlands in close proximity of the planned Development

1.6 Program Objectives

The program objective is to ensure that the impacts the Development may have on the environment is mitigated and to ensure that sufficient mitigatory measures are included in the design of the facility for all water related impacts on the facility

It is therefore important to have storm water management plan and surface monitoring program in place in order to:

- Comply with the legal obligation to fulfil regulatory requirements i.e. NEMA, NEMWA and WMA;
- Identify and therefore proactively manage impacts on the water resources;
- Assess the portability of the water supplied to employees and tourists; and
- Determine the risk for flooding of the project site.

2 Integrated Water Management

As integrated water management underpins all aspects of water management at developments, the following **key principle** are reiterated and explained as the fundamental cornerstones of integrated water management:

2.1 Risk-Based Approach

The risk based approach implies that the development's whole environmental management system and the integrated water management system in particular, are based on an assessment, understanding and management of the true risks. Whereas water management systems are very often based on minimum compliance with current legislation and standards, this approach has a large inherent risk associated with the fact that environmental and water management legislation is firmly grounded on the principles of continuous improvement. The water management report that is based on minimum compliance will therefore continuously be subjected to the need to change and update to accommodate shifting legal and regulatory goalposts. On the other hand, a water management plan that is based on addressing the real scientifically-validated environmental and water resource risks, regardless of the legal need to do so, is based on a firm scientific foundation with a much lower risk of continuous change.

3 Water and Waste Water Requirements for the Project

Water will be extracted from groundwater adjacent to the site. The volume that will be extracted is estimated to be 20m^3/ month. The developer needs to ensure that the source be protected and that the necessary treatment is done to render this water fit for use.

The possibility of two onsite waste management systems is also being investigated. These will include:

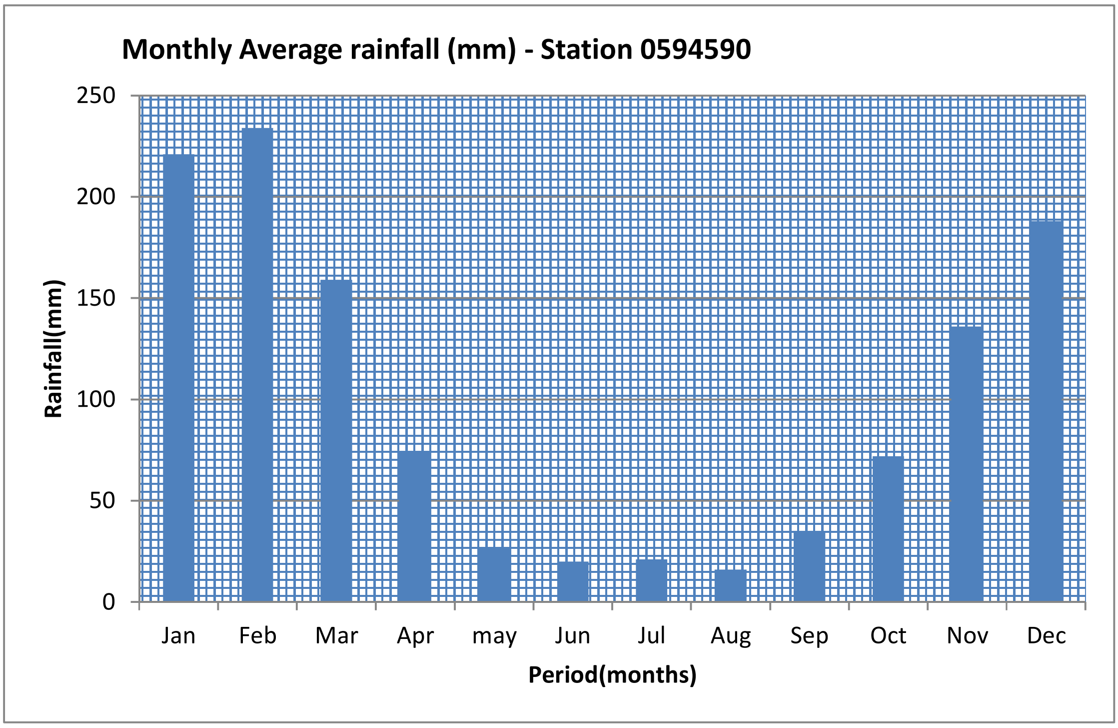
- A flushing toilet with conservancy tank; and
- A Lilliput Sewerage Treatment System.

4 Surface Water Baseline Assessment

4.1 Rainfall

The long term rainfall record was abstracted from the rainfall station 0594590W located 7.9 km from the proposed site at 30^{0}49'48.05'' E 24^{0}49'47.858'' S. The highest monthly rainfall at the station 0594590W was recorded in February 1999 when a total of 785 mm of rainfall was recorded; The Mean Annual Precipitation (MAP) for the area based on station 0594590W is calculated to be 1203 mm. It can be seen that during the wet period (October to March), average rainfall recorded amounts to 1010 mm which is 84 per cent of the total average rainfall for the year. The location of the rainfall station in relation to the project area is shown in Figure 4-1 below.

The Monthly Average (MA) rainfall distribution for rainfall station 0594590_W is shown in



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Monthly Average Rainfall for rainfall station 0594590_W

Figure 4-2 below. The actual Monthly Precipitation Data (MPD) for rainfall station 0594590_W is shown in Table 4-1 below.

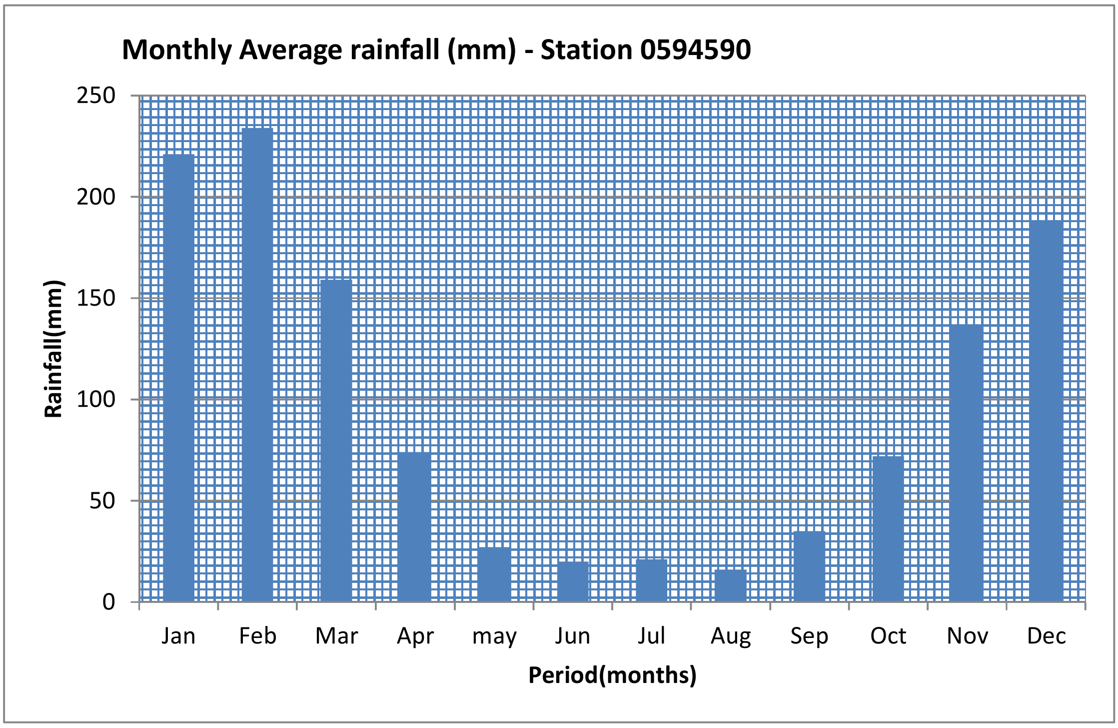
4.2 Mean Annual Runoff Estimation

Based on the Water Recourses of South Africa (WR2005 Study_WRC), the Development falls within quaternary catchment B60B. For this catchment measuring about 382 km^2 the MAP is 1026mm. The MAR for the entire catchment is expected to be 96,64 million cubic metres per annum (mcm/a). Due to the small catchment commanded by the Development of 0.0226 km^2. The expected MAR is very low at 0.00723 mcm/a. The results are summarised in

Table 4-2 below.

srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Site Map showing the closest rainfall station location 0594590_W	Project No. 484734

Figure 4-1: Site Map showing the closest rainfall station 0594590_W



srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Monthly Average Rainfall for rainfall station 0594590_W	Project No. 484734

Figure 4-2: Monthly Average Rainfall for rainfall station 0594590_W

Table 4-1: Monthly Precipitation Data for rainfall station 0594590_W

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
1926	8	94	118	194	162	167	46	12	6	178	28	11	1024
1927	116	113	80	238	109	138	88	12	3	28	18	5	948
1928	24	49	169	176	217	285	13	5	28	17	15	52	1050
1929	158	260	159	239	183	271	156	28	9	13	14	22	1512
1930	9	91	215	168	92	201	81	0	46	90	0	52	1043
1931	47	242	99	156	17	64	40	23	0	0	5	11	704
1932	72	227	282	243	136	86	145	0	4	14	0	56	1265
1933	56	250	243	439	300	240	106	43	83	0	16	61	1836
1934	86	259	337	330	199	62	45	11	7	31	14	19	1401
1935	50	104	142	159	301	366	109	47	22	85	4	133	1522
1936	104	170	242	320	529	155	66	0	0	8	26	38	1658
1937	27	64	312	261	227	104	147	6	21	19	25	122	1336
1938	116	218	682	202	562	240	71	166	37	87	20	59	2461
1939	22	237	234	109	88	182	63	39	86	0	13	109	1181
1940	38	229	240	128	118	96	134	0	1	3	24	6	1017
1941	52	109	203	246	140	174	38	32	162	9	20	80	1265
1942	70	125	216	173	298	123	119	40	2	53	71	88	1377
1943	45	187	71	132	354	62	22	0	31	0	6	18	929
1944	124	83	63	210	200	118	63	3	0	5	5	16	890
1945	95	55	88	352	177	140	38	23	5	0	0	3	975
1946	23	112	145	82	273	127	92	59	59	36	0	35	1043
1947	43	118	232	143	139	417	79	13	0	5	6	35	1230
1948	89	54	120	114	108	209	18	31	44	0	0	30	817
1949	39	191	102	182	309	123	61	25	28	0	38	26	1125
1950	26	49	274	67	88	110	67	63	0	0	77	21	840
1951	91	81	183	60	39	62	10	10	12	12	3	0	563
1952	9	48	50	93	163	152	67	5	0	23	8	26	642
1953	24	134	138	193	154	106	60	15	18	0	33	15	888
1954	71	172	109	441	309	80	100	66	25	3	0	3	1379
1955	136	204	171	153	515	215	79	64	14	17	0	86	1651
1956	51	46	126	118	244	309	57	16	29	37	40	49	1119
1957	91	139	143	674	153	65	85	0	15	7	0	43	1413
1958	66	147	129	323	212	86	27	18	0	39	0	27	1073
1959	33	163	211	85	424	90	88	14	0	0	0	31	1138
1960	24	248	252	243	225	321	93	40	51	18	15	43	1569
1961	63	107	104	178	147	135	76	8	11	5	13	26	870
1962	48	293	316	119	112	125	40	46	75	35	0	18	1226
1963	67	166	157	300	111	18	48	39	11	0	10	7	933
1964	114	138	244	233	124	99	81	3	0	0	20	57	1112
1965	53	200	73	239	263	25	32	19	26	0	15	31	973
1966	97	63	156	204	280	142	252	12	9	34	13	8	1266
1967	72	182	182	106	102	135	61	42	42	5	19	6	951
1968	92	164	137	198	283	194	62	35	0	10	1	23	1197
1969	167	170	111	10	212	33	37	25	45	21	8	7	846
1970	51	79	177	402	224	86	52	29	17	4	0	38	1157
1971	141	130	132	516	553	275	126	97	3	8	2	30	2012
1972	128	119	74	212	168	118	132	11	9	24	5	148	1147
1973	144	165	307	538	400	100	55	27	1	64	0	31	1831
1974	81	170	96	282	275	149	56	23	26	0	9	17	1184
1975	24	48	302	544	326	304	77	64	0	2	0	12	1702
1976	62	95	210	363	542	187	66	18	0	2	33	77	1654
1977	27	157	386	379	210	230	26	6	0	35	7	15	1477
1978	48	141	170	157	80	202	43	16	6	37	44	18	960
1979	42	111	140	122	251	121	46	16	0	2	66	66	981
1980	42	240	172	374	298	121	65	100	0	5	31	79	1526
1981	84	73	133	146	119	105	182	33	0	41	4	14	931
1982	49	116	72	79	88	151	103	35	5	8	43	3	750
1983	83	234	224	114	83	152	82	6	14	209	0	44	1244

1984	76	146	133	203	454	73	9	60	14	0	8	32	1208
1985	113	86	263	223	130	70	191	4	11	1	15	21	1126
1986	111	89	157	60	77	188	15	13	14	3	48	99	872
1987	52	55	177	92	461	186	97	15	71	10	48	48	1312
1988	106	47	93	77	409	82	52	31	51	1	9	5	960
1989	92	186	243	145	148	71	68	3	0	11	17	8	992
1990	55	76	271	450	102	272	0	43	32	0	0	17	1318
1991	44	83	103	100	23	59	105	0	10	5	19	9	559
1992	58	94	220	145	257	351	20	27	8	11	27	2	1219
1993	44	99	200	124	82	218	29	0	0	0	6	22	823
1994	114	45	214	195	264	97	116	20	0	0	27	9	1100
1995	73	204	218	378	698	72	152	107	19	54	54	18	2046
1996	65	113	149	268	212	477	76	63	0	7	3	78	1510
1997	108	86	61	290	149	95	76	0	0	29	12	35	939
1998	181	148	337	287	235	172	102	53	0	0	13	14	1540
1999	76	145	239	427	785	329	88	32	110	7	0	51	2287
2000	56	103	518	86	184	86	112	20	11	41	8	8	1230
2001	164	248	183	155	199	108	15	0	45	25	14	14	1169
2002	89	42	121	107	90	111	73	19	29	0	20	44	744
2003	54	101	110	173	307	316	41	5	5	28	11	9	1158

Table 4-2: Table Showing the Mean Annual precipitation and runoff per Quaternary Catchment (WR2005 Study_WRC).

Quaternary Catchment				Planned Development Catchment	
Quaternary Catchment	**Catchment Surface Area km^2**	**Mean Annual Rainfall (MAP) in mm**	**Mean Annual Runoff (MAR) in million cubic meters (mcm)**	**Catchment Surface Area km^2**	**Mean Annual Runoff (MAR) in million cubic meters (mcm)**
B60B	302	1026	96.64	0.0226	0.00723

5 Storm Water Management

5.1 Objective of the SWMP

Storm Water Management Plan (SWMP) is a critical component of Integrated Water Management (IWM). The core principles for the stormwater management plan is listed below

The SWMP should address the impact of:

- Project operations on the water flow and water quality processes of the hydrological cycle, and the associated upstream and downstream environmental impacts; and
- The hydrological cycle on project operations, including effects such as loss of income, costs, and impacts of both floods and droughts on the tourist activities.

The objectives of the proposed SWMP for the Skywalk project include:

- Protection of life (prevent loss of life) and property (reduce damage to infrastructure) from flood hazards;
- Planning in order to remain operational during drought periods;
- Prevention of land and watercourse erosion (especially during storm events);
- Protection of water resources from pollution;
- Ensuring continuous operation through different hydrological cycles;

- Maintaining the effect on downstream water quantity and quality to an absolute minimum;
- Minimising the impact on downstream water users during construction and operational phase; and
- Preservation of the natural environment (water courses and their ecosystems).

Potential adverse effects of inadequate storm water management include:

- Flooding, with the resultant damage to property, land and potentially loss of life;
- Loss of catchment yield when optimal runoff of clean storm water is not achieved; and
- Erosion of beds and banks of waterways.

5.2 Technical Situation Analysis and Evaluation

The following two cases needed to be modelled in order to perform the technical situation analysis and evaluation.

- Simulate the existing site and catchment conditions to obtain runoff hydrographs; and
- Simulate when the planned Development is established to obtain the impact of the planned Development on the runoff hydrographs.

These results were then analysed and evaluated to determine the increase in runoff as a result of the additional infrastructure.

5.2.1 Catchment Characteristics

5.2.1.1 Existing Development

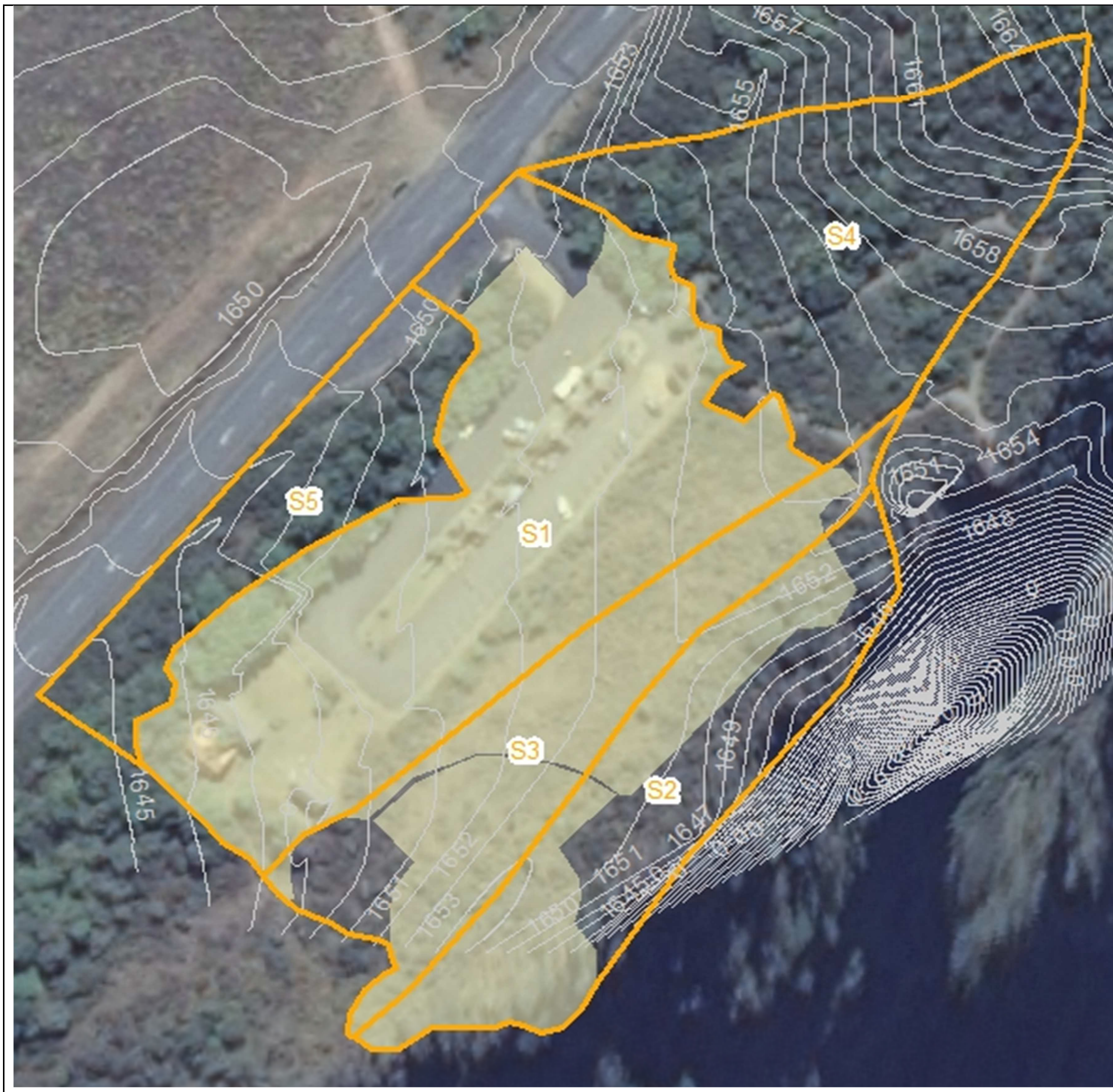
The catchment affecting the site has been subdivided into sub-catchments based on the land-use and topography is shown in Figure 5-1 below. Water will naturally flow in a south-westerly direction over sub-catchments S1, S3, S4, S5, S6, S7 and S8 and over S2 in a south-eastern direction into the canyon.

srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Catchment and sub-catchments affecting the site (existing Development)	Project No. 484734

Figure 5-1: Catchment and sub-catchments affecting the site with existing Development

5.2.1.2 Planned Development

The catchment affecting the site has again been subdivided according to the planned Development and is shown in Figure 5-2 below. The yellow shaded area is the footprint of the planned parking and Skywalk facility as shown in Figure 1-3 above. It can be assumed that water will still naturally flow in a south-westerly direction over sub-catchments S1, S3, S4, S5, S6, S7 and S8 and in a south-eastern direction into the canyon over S2.



srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Catchment and sub-catchments affecting the site (planned Development)	Project No. 484734

Figure 5-2: Catchments and sub-catchments affecting the site (planned Development)

5.3 Effect of Planned Development on Surface Hydrology

The planned Development will cause an increase in runoff because of the impermeable surfaces constructed in the form of the additional parking and the Skywalk facility. It is important to determine the increase in runoff so that a comprehensive SWMP can be put in place to mitigate the increase in runoff. An increase in runoff is of particular concern in this case, due to the sensitive nature of the wetlands surrounding the study area as shown in Figure 1-4 above.

5.3.1 Hydrological Modelling

For this study, the PCSWMM Model, version 5.2.1318 [1] (PCSWMM) has been used to determine the peak flow rates and volumes for both the current and planned Development based on various input parameters described below.

5.3.1.1 Rainfall Data

Design storm rainfall was determined based on a minute by minute rainfall grid developed by Smithers[2] for the Southern African region. The 24 hour design rainfall depths and the SCS-SA storm type 3 were used during this study.

Section 4.1 in this report covers the determination of the rainfall pertaining to the study area. The 24-hr design rainfall depths used in this study, for various return periods are presented in Table 5-1 below.

Table 5-1: Design Rainfall (24-hr)

Return Period	1:2 Year	1:5 Year	1:10 Year	1:20 Year	1:50 Year	1:100 Year
Rainfall depth (mm)	95	133	161	192	236	274

5.3.1.2 Catchment Slope

The catchment slope was determined based on the survey done by Pherekgong Geodesy Consulting of the site area in December 2014. The process involved the creation of a Digital Elevation Model (DEM) using ArcGIS (Build 3035).

5.3.1.3 Catchment Land Use

An important factor, which is considered during the modelling process, is the catchment land use as this is a defining parameter in the estimation of the percentage impervious area and hence contributed to the runoff potential of an area.

In the case of the existing Development, most of the catchment can be classified as undeveloped land accept for catchments S6 and S7 that can be classified as public facilities. S5 and S8 are roads as shown in Figure 5-1 above.

In the case of the existing Development, S4 and S5 can be classified as undeveloped land. S2 and S3 are mixed use and S1 can be classified as a road and is therefore 100% impervious as shown in Figure 5-2 above.

5.3.1.4 Impervious Areas

The impervious areas were determined using a combination of land use and stand size (erf) size. The relationship between erf size and land use is shown in Table 5-2 below. It should be noted that the parking area was considered to be 100% impervious.

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[1] *PCSWMM 5.2.1318 is a spatial decision support system for EPA SWMM5 stormwater management, wastewater and watershed modelling. The EPA Stormwater Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas.*

[2] Smithers, The study estimated design rainfall depths for durations ranging from 5 minutes to 7 days and for return periods ranging from 2 to 200 years. The output indicates the spatial variation in design rainfall depths for a given return period and duration.

The land use and erf size were determined from the future land-use types and the respective size of land-use parcels. A weighted average percentage (%) Imperviousness for each of the determined sub-catchments was hence determined.

Table 5-2: Determination of Impervious Areas

	STAND SIZE (m^2)				
	0	500	1000	2000	4000
	500	1000	2000	4000	MAX
LAND USE	% IMPERVIOUS AREA				
Undeveloped Land	0	0	0	0	0
Conservation and Nature Areas	0	0	0	0	0
Rural and Agriculture	20	10	5	2	1
Urban Open Space	25	20	5	5	5
Mineral Extraction	50	40	30	10	10
Education	60	50	40	30	30
Residential	65	38	30	20	15
Health Services	60	40	30	20	10
Institutional	60	40	30	20	10
Public Facilities	60	40	30	20	10
Military	60	40	30	20	10
Airport	60	40	30	20	10
Rail Facilities	80	80	80	80	80
Commercial	100	80	60	60	50
Industrial	100	80	75	70	60
Informal Housing	80	80	60	60	50

5.3.1.5 Depression Storage

The depression storage depth was calculated using the land-use and topographical slope. i.e. different land use at different slopes provides slightly different depression storage. Depression storage is defined as the ability of a particular area of land, of a certain land use, to retain water within its depressions and is expressed as an equivalent millimetre (mm) depth of water. The depression storage as a function of land use is shown in Table 5-3 and Table 5-4 below.

It was required that the depression storage for both the pervious and impervious areas be determined, as these inherently will have differing values. The values were determined in the same way as the percent impermeable area was determined.

Table 5-3: Estimated Depression Storage for Impervious Areas

	SLOPE (%)					
%	1	3	10	50	80	100
1 in	100	33	10	2	1	1
LAND USE	DEPRESSION STORAGE - IMPERVIOUS (mm)					
Undeveloped Land	0.00	0.00	0.00	0.00	0.00	0.00
Conservation and Nature Areas	0.00	0.00	0.00	0.00	0.00	0.00
Rural and Agriculture	0.00	0.00	0.00	0.00	0.00	0.00
Urban Open Space	0.00	0.00	0.00	0.00	0.00	0.00
Mineral Extraction	3.85	2.25	1.25	0.57	0.45	0.40
Education	4.62	2.70	1.49	0.68	0.54	0.48
Residential	5.39	3.14	1.74	0.79	0.63	0.56
Health Services	1.54	0.90	0.50	0.23	0.18	0.16
Institutional	0.77	0.45	0.25	0.11	0.09	0.08
Public Facilities	0.00	0.00	0.00	0.00	0.00	0.00
Military	3.08	1.80	1.00	0.45	0.36	0.32
Airport	3.08	1.80	1.00	0.45	0.36	0.32
Rail Facilities	3.08	1.80	1.00	0.45	0.36	0.32
Commercial	3.08	1.80	1.00	0.45	0.36	0.32
Industrial	3.08	1.80	1.00	0.45	0.36	0.32
Informal Housing	3.85	2.25	1.25	0.57	0.45	0.40

Table 5-4: Estimated Depression Storage for Pervious Areas

	SLOPE (%)					
%	1	3	10	50	80	100
1 in	100	33	10	2	1	1
LAND USE	DEPRESSION STORAGE - PERVIOUS (mm)					
Undeveloped Land	5.77	3.37	1.87	0.85	0.67	0.60
Conservation and Nature Areas	7.70	4.49	2.49	1.13	0.90	0.81
Rural and Agriculture	9.62	5.62	3.11	1.41	1.12	1.01
Urban Open Space	7.70	4.49	2.49	1.13	0.90	0.81
Mineral Extraction	3.85	2.25	1.25	0.57	0.45	0.40
Education	3.08	1.80	1.00	0.45	0.36	0.32
Residential	2.31	1.35	0.75	0.34	0.27	0.24
Health Services	1.54	0.90	0.50	0.23	0.18	0.16
Institutional	0.77	0.45	0.25	0.11	0.09	0.08
Public Facilities	0.00	0.00	0.00	0.00	0.00	0.00
Military	3.08	1.80	1.00	0.45	0.36	0.32
Airport	3.08	1.80	1.00	0.45	0.36	0.32
Rail Facilities	3.08	1.80	1.00	0.45	0.36	0.32
Commercial	3.08	1.80	1.00	0.45	0.36	0.32
Industrial	3.08	1.80	1.00	0.45	0.36	0.32
Informal Housing	3.85	2.25	1.25	0.57	0.45	0.40

5.3.1.6 Soil Type Determination

An important parameter of the pervious areas is the soil type, which can consist of either clayey (high runoff potential) soils or sandy soils (lower runoff potential). The runoff potential is described simplistically, using hydrological soil groupings, which vary from type A (low runoff potential) to type D (high runoff potential).

The types of soils within the study area fluctuated between a small presence of type A and a stronger presence of type C. A mean of type B/C soil was considered for this study.

5.3.1.7 SCS Curve Number (CN)

There is a frequent need for hydrological information in the planning, design and management of water resources systems on small catchments (< 30 km^2) Storm flow volume and peak discharge rates are required for selected design return periods. These values often need to be estimated with the use of simulation models. One such deterministic model which has become established for use on small catchments is the SCS Method.

Storm flow is defined as the direct runoff response to a given rainfall event, and consists of both surface runoff and subsurface flows, but excludes base flow (i.e. the delayed subsurface response). Storm flow depth is calculated in the SCS model using the following equation.

$$Q_T = [(P-I_a)^2]/(P- I_a+S) \text{ for } P> I_a$$

Where:

Q = storm flow depth (mm)

P = daily rainfall depth (mm), usually as a one-day design rainfall for a given return period.

S =potential maximum soil water retention (mm), index of the wetness of the catchment's soil prior to a rainfall event,

I_a = initial losses (abstractions) prior to the commencement of storm flow, comprising of depression storage, interception and initial infiltration (mm) 0.1 S

Storm flow depth represents a uniform depth over the catchment and may be converted to volume by introducing catchment area.

The potential maximum soil water retention, S, is related to hydrological soil properties, land cover and land management conditions and to the soil moisture status of the catchment prior to a rainfall event.

A dimensionless response index termed the catchment's Curve Number (CN) has been developed.

The CN and S are related as shown in the following Equation:

$$S= (25400/CN) -254$$

Typical CN values used for different soil and land use types are given in Table 5-5 below.

Table 5-5: Recommended Curve Numbers

Land Use Category	Code	Erf Size Range (m2)	Imperviousness (% directly connected)		Curve Number Soil Type						
			Range	Average	A	A/B	B	B/C	C	C/D	D
Open Space	OS	N/A	3-6	4	40	51	61	68	74	78	80
Agriculture	AG	N/A	6-8	7	65	70	75	79	82	84	86
Small Holdings	SH	>4000	10-15	12	46	56	65	72	76	80	82
Residential Low	RL	2000-4000	15-20	16	51	61	68	75	78	82	84
Residential Medium	RM	1000-2000	30-35	33	35	64	71	77	80	84	86
Residential High	RH	<1000	35-45	40	59	75	80	84	86	88	90
Town House	TH	N/A	45-50	48	79	83	86	89	90	92	93
Commercial/Industrial	IND	N/A	70-98	85	89	91	92	93	94	95	95

Descriptions of the four SCS soil types are as follows:

- Type A: Deep sand; and aggregated soils;
- Type B: Shallow sandy loam;
- Type C: Clay loams; shallow sandy loam; soils with low inorganic content; soils usually high in clay; and
- Type D: Soils that swell significantly when wet; heavy plastic clays; certain saline soils.

5.3.1.8 Flood peak determination

Having determined all modelling input parameters, the PCSWMM Model, which uses the SCS method, was used to determine peak flow rates and volumes for each catchment area.

For this study it can be assumed that for the **existing Development**:

- Sub-catchments S1, S4, S5, S6, S7 and S8 are combined to operate as one catchment and has its outflow at the lowest point in S1 named OF1;
- Sub-catchments S2 has its outflow to the south east into the canyon named OF3; and
- Sub-catchment S3 has its outflow to the south west named OF2

The outflow points and catchments are shown in Figure 5-3 below.

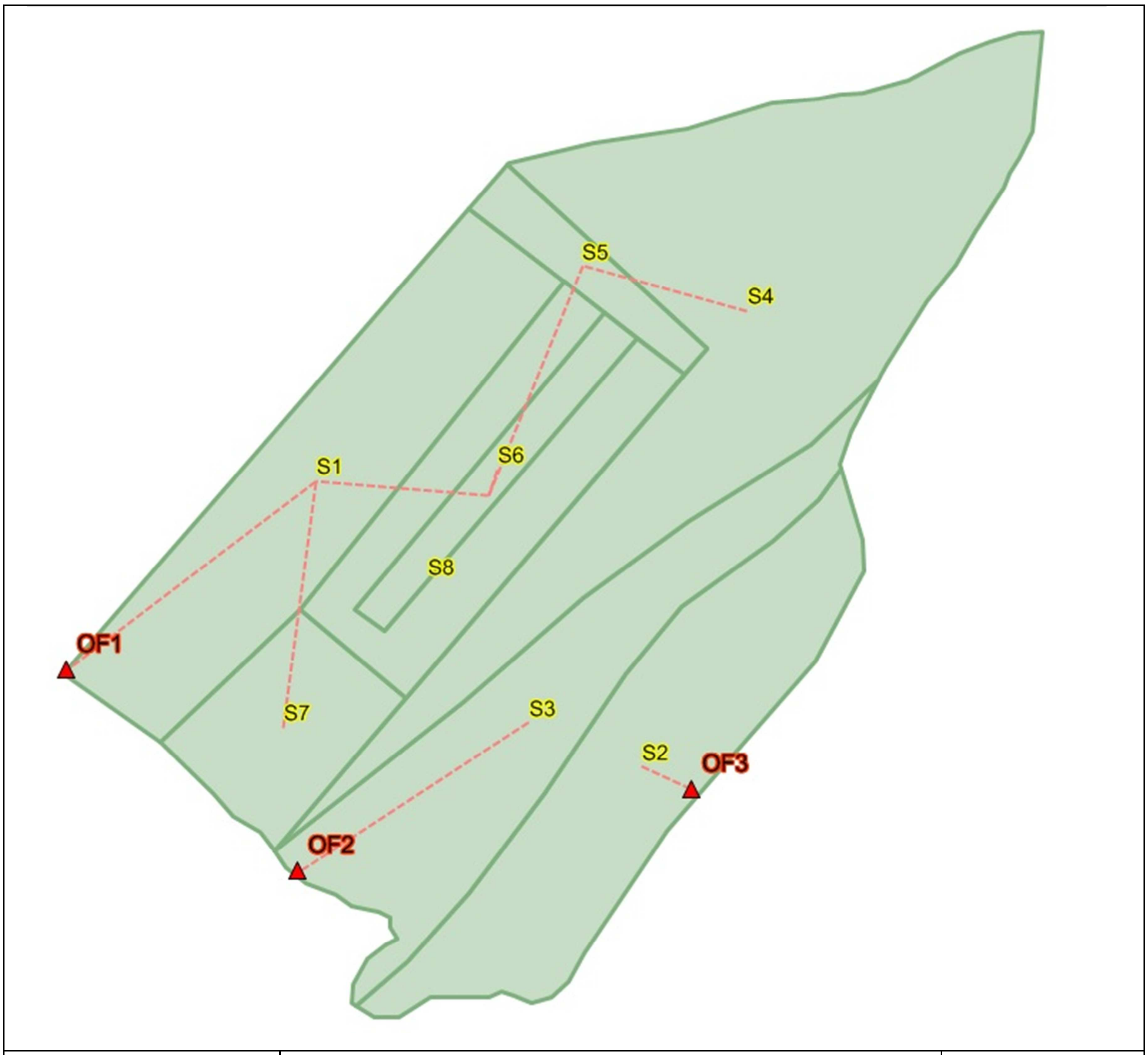
For the **planned future Development** the following scenarios have been analysed and results given below:

i. **Scenario 1**: This assumes that all the additional development consists of impervious materials such as tarmac and concrete lined/paved areas. The following is assumed for each of the sub-catchments:

- Sub-catchments S1, S4 and S5 are combined to operate as one catchment and has its outflow at the lowest point in S5 named OF1;
- Sub-catchments S2 has its outflow to the south east into the canyon named OF3; and
- Sub-catchments S3 has its outflow to the south west named OF2.

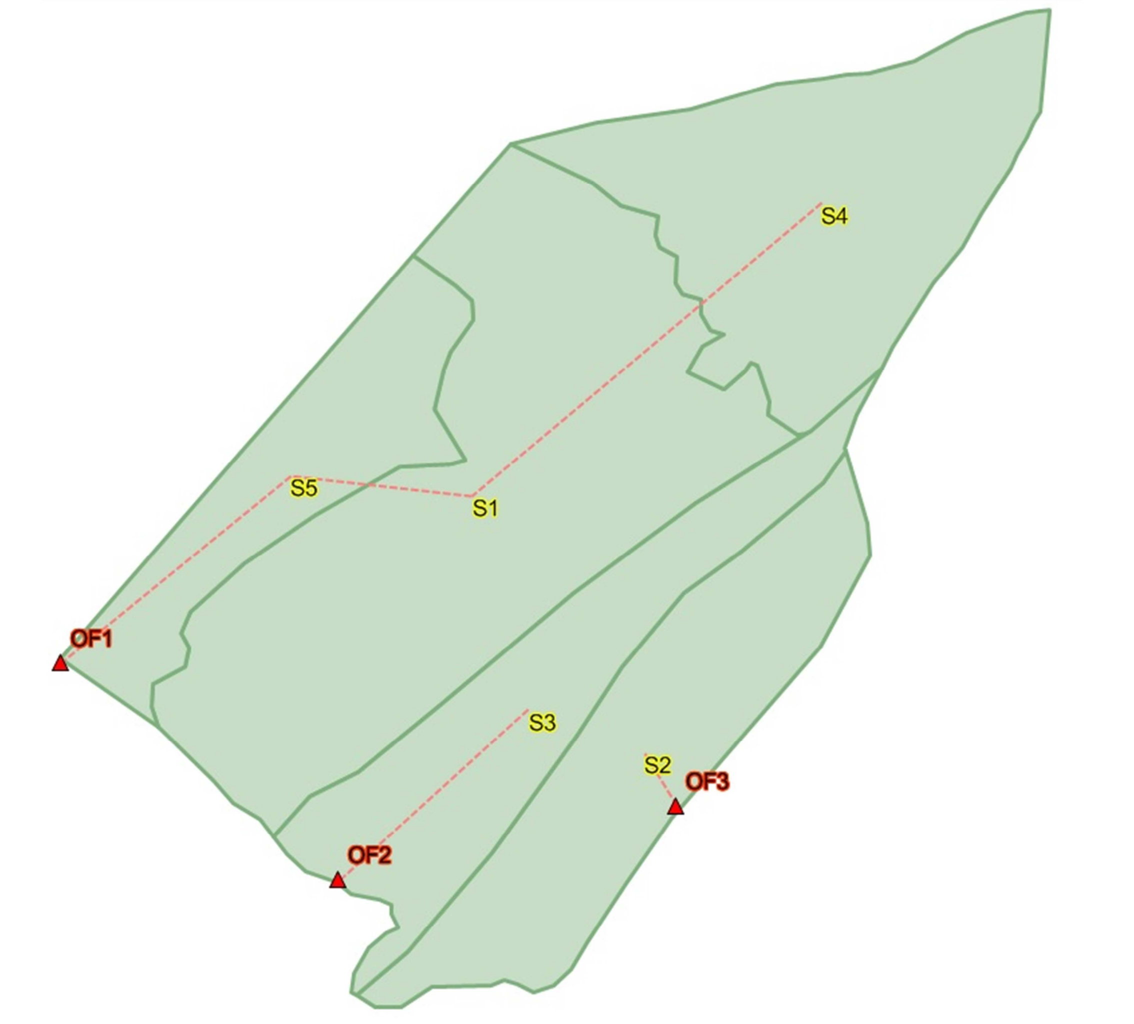
ii. **Scenario 2:** This assumes that all the additional development is based on the SUDS approach consisting of more pervious materials such as permeable pavers, natural rocks and grassed areas. The assumptions for each of the sub-catchments are the same as for Scenario 1 above.

The outflow points and catchments are shown in Figure 5-4 below.



srk consulting	**Skywalk Project at God's Window Surface Water Management Report** Existing Development outflow positions	Project No. 484734

Figure 5-3: Existing Development outflow positions



Skywalk Project at God's Window Surface Water Management Report
Planned Development outflow positions (scenario 1 & 2)

Project No. 484734

Figure 5-4: Planned Development outflow positions (scenario 1 & 2)

Peak flows were determined for the 1:2 year, 1:5 year, 1:10 year, 1:20 year and 1:50 year design storm events.

The difference increase in flood peaks between the existing Development and the planned future Development for scenario 1 and scenario 2 are given below in Table 5-6 and Table 5-7 respectively below.

Table 5-6: Flood peak comparison for existing condition and planned Development (scenario 1)

Flood Peak Changes For Varying Return Periods (m^3/s)						
Existing Development						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1 (existing)	1.563	0.07	0.13	0.18	0.24	0.34
OF2 (existing)	0.330	0.01	0.01	0.02	0.03	0.05
OF3 (existing)	0.368	0.01	0.02	0.04	0.05	0.09
Planned Development						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1 (planned)	1.563	0.21	0.34	0.44	0.57	0.75
OF2 (planned)	0.330	0.14	0.21	0.26	0.32	0.4
OF3 (planned)	0.368	0.14	0.21	0.26	0.33	0.41
Difference in Flood Peaks Between Existing Development and Paved Area (m^3/s)						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1	1.563	0.14	0.21	0.26	0.33	0.41
OF2	0.330	0.14	0.2	0.24	0.29	0.35
OF3	0.368	0.13	0.19	0.22	0.28	0.32

Table 5-7: Flood peak comparison for existing condition and planned Development (scenario 2)

Flood Peak Changes For Different Return Periods (m3/s)						
Existing Development						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1	1.563548071	0.07	0.13	0.18	0.24	0.34
OF2	0.330560836	0	0.01	0.02	0.03	0.05
OF3	0.368098612	0.01	0.02	0.04	0.05	0.09
Planned Development						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1	1.560178826	0.19	0.32	0.43	0.55	0.73
OF2	0.332414406	0.13	0.19	0.24	0.3	0.38
OF3	0.369611901	0.12	0.19	0.24	0.3	0.38
Difference in Flood Peak Between Existing Development and Permeable Paved Area (m3/s)						
Name	Area (ha)	2yr	5yr	10yr	20yr	50yr
OF1	1.560178826	0.12	0.19	0.25	0.31	0.39
OF2	0.332414406	0.13	0.18	0.22	0.27	0.33
OF3	0.369611901	0.11	0.17	0.2	0.25	0.29

The following observations are made from the tables:

- Scenario 1 has a greater increase in peak flow rates than scenario 2 because of the difference in pavement permeability.

- The increase in peak flow rates in scenario 2 is still too high when compared to the existing Development and additional mitigation is required to reduce the flow to acceptable levels.

5.3.2 Existing Drainage Systems & Hydraulic Capacity

At the moment there are no formal storm water drainage systems in place on site. The existing curbed (0.15m curb height) parking lot would function as a channel and will cause water to flow downstream and spill over at the bottom of the parking lot. Water will therefore mainly flow as sheet flow according to the topography.

6 Storm Water Management Plan

In order to have an integrated approach to the study as well as propose sustainable and environmentally friendly flood control measures, a Storm Water Management Plan (SWMP) has been compiled. The aspects that have been considered in compiling the SWMP are summarised below:

i. Current development and topography;
ii. Future planned development layout;
iii. Drainage system requirements and standards;
iv. BMP’s (Best Management Practices) in defining alternative flood remediation measures; and
v. Environmental considerations.

Details of the SMP are now given below

6.1 Identification of surface water impacts

Based on the above Hydrological and hydraulic study it can be concluded that there are several impacts of the planned Development on the surrounding area regarding increased peak flow rates .This is mainly due to the increase in impervious areas due to the planned parking area as well as runoff from the panned infrastructure .

6.2 Drainage system requirements

As there are currently no formal drainage systems at the development site. Additional drainage systems would need to be implemented as part of the SWMP .This would then ensure that there are no negative impacts on the surrounding environment as well as no flooding of the new development due to storm rainfall and runoff. Relevant legal requirements and minimum design standards based on International Best Practice have been summarised in Table 6-1 below.

Table 6-1 : Summary of legislation and required design standards

Drainage system member	Applicable Legislation	Design standard
Minor drainage systems for local small pipes and channels	NTC Regulations	1:5 - 1:10 year flood event
Major drainage systems draining the Minor systems	NTC Regulations	1:25 – 1:100 year flood event
Natural watercourse	National Water Act (Act 36 of 1998)	No significant development flooded up to a 1:100 year flood event
Natural watercourse	National Environmental Management Act (Act 102 of 1998),NEMA	Environmental buffer (32m from river center line)

6.3 Alternative flood control measures

The approach taken in defining possible alternative flood control measures is to make use of the BMP's and SUDS (Sensitive Urban Design Standards) principles.

6.3.1 BMP's

The BMP's can be defined as a multidisciplinary approach in defining appropriate control measures taking into account both Structural and Non-structural BMP's so as to minimise the impact on the environment and have a sustainable solution .

The structural BMP's that have been considered are:

i. Implement a drainage system such that the planned development is not flooded up to a 1:50 year storm event;
ii. Consider the implementation of attenuation facilities to reduce the increased peak flows to that of the current condition for the frequent and high intensity 1:2 to 1:10 year storm events; and
iii. Consider the implementation of energy dissipation measures at the drainage system outlets to handle a 1:2 year to a 1:50 year storm event thereby preventing concentrated flows with a high flow velocity.

The non-structural BMP's that have been considered are:

i. Management plans for the upkeep and maintenance of the stormwater control measures.

6.3.2 SUDS

The SUDS principles have also been considered and consist of the following:

i. Designing of all control measures of materials that are environmentally friendly and cause the least increase in impervious areas ie .Porous pavers;
ii. Planning the construction of the measures such that the environmental impact is minimised both during construction as well as at an operation level; and
iii. Minimising erosion and sedimentation.

6.3.3 Alternative stormwater control measures

Based on the above approach and principles several stormwater control measures and alternatives have been considered and briefly discussed below.

Alternative 1: Impermeable surfaces (Conventional Engineering)

This alternative assumes that all the additional new parking areas and infrastructure will be tarred and concreted forming an impervious surface which would significantly increase the runoff potential.

Alternative 2: Permeable surfaces (Bio-engineering)

This alternative assumes that most of the new developments areas will be constructed using the SUDS approach with permeable pavers and/or materials that enhance the infiltration and hence minimise the runoff potential.

Alternative 3: Permeable surfaces and Attenuation facilities

For this alternative both the SUDS approach as well as attenuation facilities will be used to control all the surface runoff as well as ensure that no increase in flood peaks occurs at the main outflow points.

6.3.4 Selection of preferred Alternative

Based on the modelling results it is proposed that Alternative 3 be considered for implementation .This Alternative has been preferred based on the following aspects :

i. The on-site increase in runoff is minimised by using pervious pavers or similar materials to cover the parking and surrounding area ;

ii. Flow velocities are reduced due the lower peak flow rates; and

iii. Additional required attenuation facilities are in place to ensure that the peak flow rates are not increased and that the energy is dissipated before leaving the site.

6.4 Master Drainage Plan components

Based on the above requirements and the selected Alternative 3 a summary of the selected Stormwater Management Plan Components is given in Table 6-2 below.

The selected components consist mainly of local attenuation ponds which would be constructed as part of the site landscaping .The ponds would be dry most of the time and only contain water during storm conditions. The water in the ponds would then be discharged via small outlet pipes and energy dissipaters that spread out the water before entering the downstream area. The ponds have been positioned such that the natural flow paths are still being utilised.

The locality of the required stormwater control measures are shown in Figure 6-1 below. Typical conceptual details are shown on Figure 6-2 below.

Table 6-2: Summary of Stormwater Management Plan components

Drainage system member	Design standard	Preliminary design details
Attenuation Pond 1	NTC Regulations	• Maximum embankment height: 1.3 m • Storage volume : 650 m^3 • Surface area at FSL: 500m^2 • Inflow peaks : ➢ 2 year : 0.328 m^3/s ➢ 5 year: 0.494 m^3/s ➢ 10 year : 0.662 m^3/s

		• Outflow peaks : ➢ 2 year : 0.07 m^3/s ➢ 5 year: 0.077 m^3/s ➢ 10 year: 0.082 m^3/s • Max temporary water depth in pond : ➢ 2 year : 0.56m ➢ 5 year: 0.94m ➢ 10 year: 1.25m
Attenuation Pond 2	NTC Regulations	• Maximum embankment : 1.2 m • Storage volume : 600 m^3 • Surface area at FSL: 500m^2 • Inflow peaks : ➢ 2 year : 0.186 m^3/s ➢ 5 year:0.275 m^3/s ➢ 10 year :0.343 m^3/s • Outflow peaks : ➢ 2 year : 0.003 m^3/s ➢ 5 year: 0.004 m^3/s ➢ 10 year: 0.004 m^3/s • Max temporary water depth in pond : ➢ 2 year : 0.58m ➢ 5 year: 0.85m ➢ 10 year: 1.05m
Attenuation Pond 3	NTC Regulations	• Maximum embankment height: 0.5 m • Storage volume : 175 m^3 • Surface area at FSL: 350m^2 • Inflow peaks : ➢ 2 year : 0.063 m^3/s ➢ 5 year: 0.101 m^3/s ➢ 10 year : 0.131 m^3/s • Outflow peaks : ➢ 2 year : 0.01 m^3/s ➢ 5 year: 0.011 m^3/s ➢ 10 year: 0.011 m^3/s • Max temporary water depth in pond : ➢ 2 year : 0.23m ➢ 5 year: 0.42m ➢ 10 year: 0.49m
Outlet pipe 1 (Attenuation Pond 1)	NTC Regulations	• Pipe Diameter : ➢ 0.15m • Number of barrels : ➢ 1
Outlet pipe 2 (Attenuation Pond 2)	NTC Regulations	• Pipe Diameter : ➢ 0.05m • Number of barrels : ➢ 1

Outlet pipe 3 (Attenuation Pond 3)	NTC Regulations	• Pipe Diameter : ➢ 0.075m • Number of barrels : ➢ 1
Energy dissipaters	BMPs	• Provide sufficient energy dissipaters at all outlets to comply with environmental legislation. Sizing to be done in detailed design.
On-site drainage system members	NTC Regulations	• In addition to the above attenuation ponds on-site drainage system members such as low flow channels, swales and flow paths would need to be designed and provided.. These systems will ensure that the stormwater will be directed into the required attenuation ponds so as to ensure no flooding and erosion occurs . Due the currently unknown final layout of the planned infrastructure these systems cannot yet be designed. Once more details are available this can be designed as part of the detailed design stage

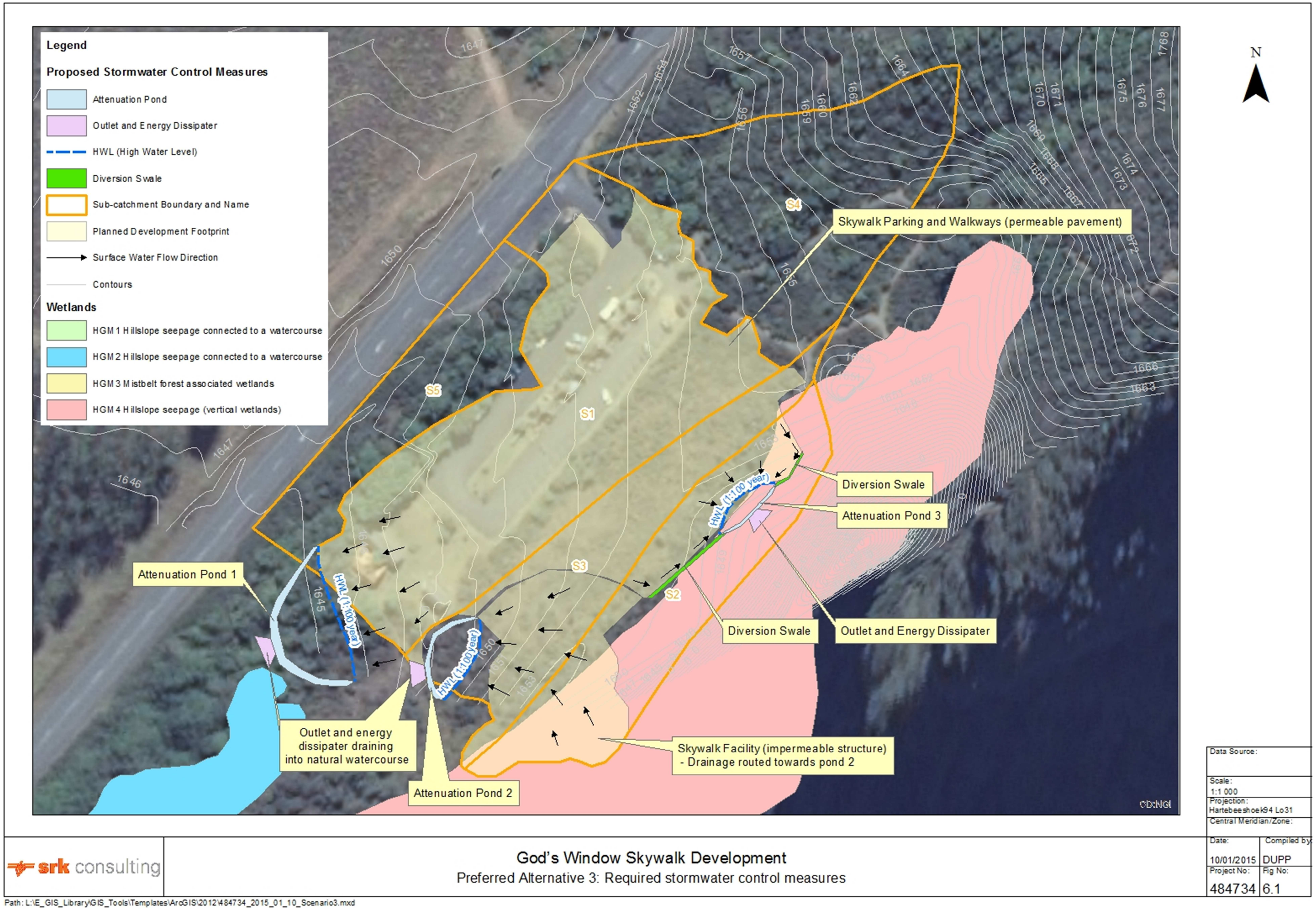


Figure 6-1: Layout of Stormwater Management Plan components

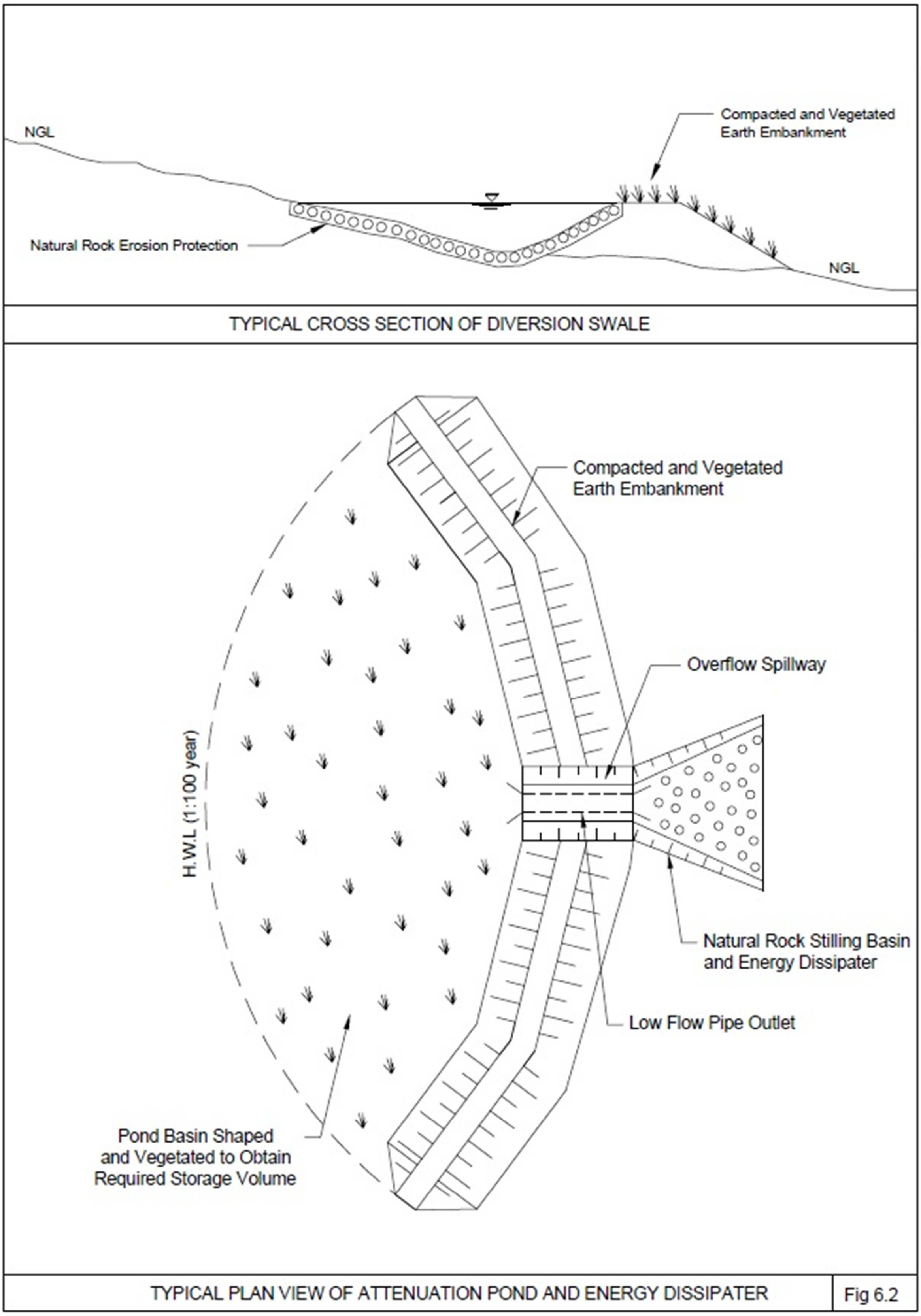


Figure 6-2: Conceptual details

7 Surface Water Impacts and Mitigation

7.1 Water Quantity

Development tends to increase runoff from previously undeveloped areas. Surface area for infiltration is reduced by removing vegetation and increasing the extent of impervious areas. Reduced vegetation also reduces evapotranspiration. Natural surface depressions which previously provided storm water storage are cleared and graded smooth. As a result, runoff volumes, flow rates and flow velocities may increase significantly. Flow direction will remain the same but peak flow rates tend to increase due to the increase of impervious areas.

7.2 Water Quality

Development generates short-term land disturbance and long-term land use intensification. These factors can contribute to reduced water quality. Storm Water pollutants can be generated during construction and after construction from the operation and activities of urban land use. This land use activities may generate wastes and residuals that, if handled improperly, can pollute storm water runoff.

Increased runoff volumes and velocities from impervious areas also can increase offsite pollutant transport, further impacting receiving waters.

7.2.1 Types of Storm Water Pollutants

Pollutants generated by urban land uses can be classified as floatables, sediment, nutrients, oxygen demand, oil and grease, heavy metals, toxic chemicals and bacteria. The causes and effects of these pollutants are summarized below.

7.2.1.1 Floatables:

Floatable debris includes plastic and paper products, yard refuse, metal and glass containers, tires, etc. These pollutants are relatively large, decompose slowly and degrade the visual aesthetics of the receiving waters and shorelines. They present a physical danger to vegetation and wildlife, through habitat congestion, entangling or ingestion. These pollutants originate from litter and improperly disposed refuse.

7.2.1.2 Sediment:

Suspended sediment in high concentrations can cause multiple impacts. Impacts in receiving streams may include increased turbidity, reduced light penetration, reduced prey capture for sight feeding predators, clogging of gills/filters of fish and aquatic invertebrates, and reduced angling success. Impacts in slower receiving waters such as lakes and estuaries include siltation, with subsequent smothering of benthic communities, changes in bottom substrate composition, and decreased depth (creating a need for dredging). Sediment with high clay or organic content efficiently carries trace metals and toxicants, posing a risk to benthic life upon resuspension.

Sedimentation impacts are affected by a number of interrelated site factors, including soil types, topography, surface cover and climate. Generally, the climate of the area promotes the establishment of vegetative cover which can shield the soil and promote infiltration.

7.2.1.3 Nutrients:

Increased phosphorus and nitrogen levels can accelerate eutrophication in downstream fresh waters. Eutrophication can lead to surface algal scums, water discoloration, odours, depressed oxygen levels, and release of toxins. Nutrients tend to build-up on impervious surfaces. Runoff from these areas can lead to high nutrient loads. Intensively landscaped areas and wash water from outdoor cleaning activities are also potential sources of nutrients.

7.2.1.4 Oxygen Demand:

Dissolved oxygen (DO) is an indicator of water quality impact. To support aquatic life, sufficient DO must be available. Decomposition of organic matter by microorganisms depletes DO levels, especially in slower moving streams. Rising temperature from changing weather can also deplete DO by decreasing the solubility of oxygen in water.

The degree of potential DO depletion from organic matter and microorganisms is measured by either the biochemical oxygen demand (BOD) test or the chemical oxygen demand (COD) test. Urban runoff can depress DO levels after large storms. BOD solids can accumulate in bottom sediment during storms causing anoxic (zero oxygen) Development in shallow, slow-moving or poorly flushed receiving waters.

Generally, the greatest export of BOD is from leaking sanitary sewer systems (i.e., sewage overflow) even low density suburban development can export moderate levels of BOD.

7.2.1.5 Oil and Grease:

Oil and grease contain a wide variety of hydrocarbons, some of which are toxic to aquatic life at low concentrations. Surface sheen is usually an indication of the presence of hydrocarbons. However, some hydrocarbons, especially weathered crankcase oil, appear in solution or emulsion and have no sheen. Hydrocarbons have a strong affinity for sediment, and much of the hydrocarbon load adsorbs onto particles and settles out. If not captured, hydrocarbons tend to accumulate in bottom sediments of lakes and estuaries. The major source of hydrocarbons is leakage from crankcase oil and other lubricating agents from the automobile. Hydrocarbon levels generally are highest in runoff from parking lots, roads and service stations.

7.2.1.6 Heavy Metals:

Trace heavy metals are a concern because of their toxicity to aquatic life and the possibility of water supply contamination. The heavy metals with the highest concentrations in urban runoff are copper, lead, zinc, and cadmium. Other heavy metals may be found when inappropriate connections between sanitary and storm sewers are present. Most heavy metals adsorb to particulates, which settle out and reduce the metals immediately available for biological uptake. Substantial sources of lead in the past have been leaded gasoline and lead-based paints. As alternative fuels and paints have been developed, lead has become less common.

7.2.1.7 Toxic Chemicals:

Other toxic chemicals present in runoff include pesticides, herbicides and synthetic organic compounds. Concentrations of these substances in runoff from residential and commercial areas rarely exceed current safety criteria.

7.2.1.8 Bacteria:

Bacteria levels in undiluted urban runoff usually exceed public health standards for water contact recreation. Bacteria multiply faster during warm weather, and substantial differences in bacteria populations are to be expected between summer and winter. The bacteria test, however, is a count of coliform bacteria, which are an indirect and often imprecise indicator of pathogens and viruses which may be present. Thus, the health implications may be unclear. Nonetheless, most urban land uses export enough bacteria to exceed health standards, the problem is especially significant when sanitary sewer overflows that export bacteria derived from human wastes. Improperly maintained or failed septic tank systems are also potentially significant.

7.2.2 Water Quality Impact Mitigation

Pollution prevention principles to consider when developing the physical site plan for the project include the following:

- Use vegetation and ground cover as a method of natural filtration of runoff;
- Minimize the amount of land disturbance (i.e., clearing, grading and excavation);
- Avoid disturbing sensitive areas such as wetlands, steep or unstable slopes, and areas with erodible soils;
- Reduce or alter activities to those that minimize the potential of storm water pollution; and
- Enclose or cover pollution-causing activities to minimize the potential of storm water pollution.

At the heart of the SWMPr is the selection and implementation of a Best Management Practices (BMP) or set of BMPs for water quality management. BMPs are generally grouped into two categories:

- Non-structural Controls; and
- Structural Controls.

Non-structural controls are primarily management-based activities that are general designed to prevent or reduce the potential of storm water runoff contact with pollution causing activities. Selection of non-structural controls is then based on land use activity.

Structural controls are constructed facilities or vegetative practices that are generally designed to reduce pollutant levels in storm water runoff. Targeted pollutants include: particulates, pollutants that bond to particulates (heavy metals), nutrients (phosphorus, nitrogen), oil and grease, oxygen demand, and to a limited extent, bacteria. Initial consideration of structural controls is based on site area. If the site drainage area(s) is less than 5 hectares, vegetative practices may be used. If the drainage area(s) is 5 or more hectares, vegetative practices may be used with other needed structural controls. The water quality detention basin is the primary structural control method for areas of 5 or more hectares. For any site of 3 or more hectares, a program of non-structural controls may be used on a case-by-case basis as an alternative to structural controls.

Detailed mitigation measures are included in the Environmental Management plan in Section 10.

8 Impact Assessment

The methodology used to assess the impacts is attached as **Error! Reference source not found.**

8.1 The effect of runoff on water quality in surrounding wetlands

The surface alterations will have an impact on the permeability of the soil on the project site, which can cause water, polluted by the activities, to run into surrounding wetlands. This will have a negative effect on the wetland ecosystems. The risk assessment after mitigation, is also shown in Table 8-1.

Table 8-1: Impact Assessment: Water quality of Wetlands

Effect of Run-off on water quality in Wetlands			
Rating Definition	**During Construction**	**During Operation**	**After Mitigation**
Magnitude	Moderate	Moderate	Minor
Spatial Scale	Site or Local	Site or Local	Site or Local
Duration	Short Term	Long Term	Long Term
Consequence Rating:	Low	Medium	Medium
Probability	Possible	Possible	Unlikely
Significance Factor:	**Low**	**Medium**	**Low**

8.2 The effect of run-off on water quantity in surrounding wetlands

The surface alterations will have an impact on the permeability of the soil as well as the flow path of surface water, which can cause an increase in water run-off into surrounding wetlands. This can greatly increase the amount of water in the wetlands, which will have a negative effect on the wetland ecosystems. The risk assessment is shown in Table 8-2.

Table 8-2: Impact Assessment: Water quantity of Wetlands

Effect of Run-off on water quantity in Wetlands			
Rating Definition	**During Construction**	**During Operation**	**After Mitigation**
Magnitude	Major	Major	Moderate
Spatial Scale	Site or Local	Site or Local	Site or Local
Duration	Short Term	Long Term	Long Term
Consequence Rating:	High	High	Low
Probability	Possible	Possible	Unlikely
Significance Factor:	**Medium**	**High**	**Low**

8.3 The effect of increased run-off on the planned development

The surface alterations will have an impact on the permeability of the soil as well as the flow path of surface water, which can cause an increase in water run-off into the planned storm water system. This can result in inadequate capacity and a flooding of the Development. The impact assessment is shown in Table 8-3.

Table 8-3: Impact Assessment: runoff flooding planned Development

Effect of Run-off on planned Development			
Rating Definition	**During Construction**	**During Operation**	**After Mitigation**
Magnitude	Minor	Major	Minor
Spatial Scale	Site or Local	Site or Local	Site or Local
Duration	Short Term	Long Term	Long Term
Consequence Rating:	Low	High	Medium
Probability	Definite	Possible	Unlikely
Confidence Level	Medium	High	Low

The proposed mitigation measure is to take the increased flow into account when designing the system. This will result in a greater capacity and will render flooding highly unlikely.

8.4 The effect of surface water flow path alteration on the receiving environment

If the flow path of the surface water will be altered, it can result in the flooding of sensitive areas such as caves in the surrounding environment. The impact assessment is shown in Table 8-4

Table 8-4: Impact Assessment: Surface water flooding receiving environment

Effect of Surface Water Flow Path Alteration on Environment			
Rating Definition	**During Construction**	**During Operation**	**After Mitigation**
Magnitude	Major	Major	Minor
Spatial Scale	Site or Local	Site or Local	Site or Local
Duration	Short Term	Long Term	Long Term
Consequence Rating:	Medium	High	Medium
Probability	Possible	Possible	Unlikely
Confidence Level	Medium	High	Low

From Section 6 above it can be seen that the flow paths have been kept as natural as possible thereby limiting the effect of flow path alterations.

9 Surface Water Monitoring Program

The Surface Water Monitoring Program (SWMPr) specifies management and monitoring systems which need to be defined to ensure that even at the design phase, the infrastructure of the storm water management system functions properly and optimally. This management system includes operational, inspection and maintenance procedures that will ensure that the SWMPr is fully operational and that it functions effectively. This also includes a maintenance program for the stormwater facilities in order to control blockages, overflows, erosion and pollution. The SWMPr is an important tool in risk management and should be used to measure the success of the implemented system in meeting design performance objectives of the infrastructure. The SWMPr includes:

- Regular inspections of the facilities and the monitoring of the condition of each facility. Visual inspections may be sufficient and these include:
    - Pipelines and pipe connections;

  - o Bank and bed erosion inspection in open channels; and
  - o Silt build up in sediment basins.
- Maintenance i.e., clearance of vegetation in canals; and
- Specific personnel need to be allocated the responsibility of monitoring the SWMP associated infrastructure.

9.1 Water quality monitoring

In order to ensure that the stormwater collection and treatment system is achieving its objectives, a short term monitoring program will be implemented. The program will involve the collection of stormwater samples entering and leaving the site. This will determine whether there has been any impact from the Development on stormwater quality.

9.1.1 Stormwater sampling plan

The monitoring locations will need to be chosen once the detailed system has been designed. The sites will be chosen in consultation with the design engineer.

It is proposed that samples be collected on two occasions during the year, at the first flush events in May and in August when flows are steady.

All monitoring is to be performed by a suitably qualified environmental consulting firm.

9.1.2 Stormwater analytical program

Heavy metals could potentially be found in the stormwater. It is proposed that initially only copper, lead and iron are analysed for with oils and grease. However, the analytical suite will be expanded to include a full suite of heavy metals and other parameters after the Development of the project.

10 Environmental Management Plan

An important aspect of the Surface Water control is the compilation of a EMP. This is required to ensure that all construction activities as well as operation activities once the controls have been constructed are in accordance with the SWMP requirements .The EMP for both during construction and Operational stage is given in Table 10-1 below .

Table 10-1: Storm Water Environmental Management Plan during construction phase

Aspect	Impact	Management Objective	Mitigation Measures	Responsible person
Activity: Construction Phase				
Biophysical				
Water Quality	Liquids Storage in Aboveground Tanks Practices	To reduce, contain, and clean-up spills from aboveground tanks, thereby reducing or preventing storm water run-off contact with spilled liquids	Temporary fuel tanks used to fuel vehicles in the field should be placed in a bermed, impervious (using heavy mil plastic or cement) area	Contractor
	Outdoor storage practices for solid materials	To prevent leaching of chemicals, suspended solids, erosion, and	• Where practicable, store materials (Raw materials such as gravel, sand, topsoil, compost, sawdust, wood chips, which are subject to	Contractor

Aspect	Impact	Management Objective	Mitigation Measures	Responsible person
		sedimentation.	leaching and transport by erosion and sedimentation under a covered area on a paved surface • Where covering outdoor storage areas is not practicable, install a drainage system that directs storm water runoff from the area	
	Hazardous Material Storage/Disposal	Prevent storm water runoff contact with toxic or hazardous substances through proper storage and disposal	• Keep products in their original containers with original labels • Store in a cool, dry place • Regularly check containers; place a leaky container inside another container and label accordingly • Store incompatible chemical products separately • Secure lids tightly	Contractor ECO
	Fertilizer and Pesticide Use	• Fertilizer Practice: Reduce the loadings of phosphorus and nitrogen into receiving waters. • Pesticide Practice: Reduce the loadings of toxics into receiving waters	• Native or low maintenance landscaping is strongly encouraged to minimize the need for fertilizers and pesticides and to reduce water usage. • When possible, use the minimal amount of fertilizer needed and apply small, frequent applications. • Avoid using pesticides on a "prevention" schedule basis • Pesticides that degrade rapidly are less apt than others to become storm water pollutants • Pesticides with low solubility in water are less apt than others to cause water pollution through drainage and runoff • Apply pesticides only on affected areas and under windless conditions. • Store pesticides safely and properly dispose of empty containers.	
Surface Water Quantity	This low Impact development utilizes site design techniques that store, infiltrate, evaporate, and detain runoff on the site to replicate pre-development runoff characteristics and mimic the natural hydrology of the site	The purpose is to maintain the pre-development peak storm water runoff and to mimic the pre-development hydrology. Storm water is managed in small, cost effective landscape attenuation ponds and diversion swales routing the runoff into attenuation ponds. The ponds	1. Minimize land clearing that requires removal of the native vegetation. 2. Minimize or avoid mass grading and utilize selective clearing. 3. Reduce impervious surface area and minimize connected impervious surfaces. 4. Increase opportunity for on-site retention, detention, and treatment. 5. Maintain predevelopment hydrologic pattern. 6. Utilize native vegetation. 7. Utilize undisturbed existing	Contractor Design Engineer

Aspect	Impact	Management Objective	Mitigation Measures	Responsible person
		will be constructed prior to the development being implemented therefore acting as a buffer during the construction period	vegetation buffer strips and areas. 8. Preserve soils and areas with high infiltration rate. 9. Provide multi-purpose and multi-benefit storm water detention basin onsite. 10. Grade the site to maximize the overland sheet flow distance. 11. Increase flow-paths or travel distances for surface runoff. 12. Provide adequate buffers between development and natural resources, critical areas and drainage ways.	

Table 10-2: Storm Water Environmental Management Plan during operational phase

Aspect	Impact	Management Objective	Mitigation Measures	Responsible person
Activity: Operational Phase				
Biophysical				
Water Quality	Hazardous Material Storage/Disposal	Prevent storm water runoff contact with toxic or hazardous substances through proper storage and disposal	• Keep products in their original containers with original labels • Store in a cool, dry place • Regularly check containers; place a leaky container inside another container and label accordingly • Store incompatible chemical products separately • Secure lids tightly	Operational Manager
	Litter Control	To prevent litter from becoming storm water pollution primarily as floatables in receiving waters as well as improving the aesthetics of the development and receiving waters.	• Wastes should be securely contained. Frequent inspection is recommended for day-to-day cleanliness of the immediate area around storage areas. Clean up material that may be spilled during pickups. • Litter containers should be conveniently placed and dumped frequently to prevent overflow.	Environmental Manager

	Fertilizer and Pesticide Use	• Fertilizer Practice: Reduce the loadings of phosphorus and nitrogen into receiving waters. • Pesticide Practice: Reduce the loadings of toxics into receiving waters	• Native or low maintenance landscaping is strongly encouraged to minimize the need for fertilizers and pesticides and to reduce water usage. • When possible, use the minimal amount of fertilizer needed and apply small, frequent applications. • Avoid using pesticides on a "prevention" schedule basis • Pesticides that degrade rapidly are less apt than others to become storm water pollutants • Pesticides with low solubility in water are less apt than others to cause water pollution through drainage and runoff • Apply pesticides only on affected areas and under windless conditions. • Store pesticides safely and properly dispose of empty containers.	Environmental Manager
	Vehicle/Equipment Washing and Steam Cleaning Practices	Reduce pollutants (oil and grease, suspended solids, heavy metals, organics and nutrients) in wash water and to restrict wash water entry into the storm water system.	• Wash water from washing facilities should be contained and discharged to a treatment facility or be discharged into and treated by a closed-loop recycling system • Uncovered wash areas must be paved, protected from storm water run-on from adjacent areas, and drain into a process treatment or a waste tank	Environmental Manager
	Liquid Materials Loading and Unloading Practices	To prevent spills and contact between liquid materials and storm water runoff	• To the extent possible, unloading or loading of liquid materials should occur on a hard surface so that any spills not completely retained can be collected to be appropriately disposed of. • The owner should retain onsite the necessary materials for rapid clean-up of spills • An employee trained in spill control and clean-up should be present during loading/unloading	Environmental Manager
	Liquids Storage in Aboveground Tanks Practices	• To reduce, contain, and clean-up spills from aboveground tanks, thereby reducing or preventing storm water run-off contact with spilled liquids	• To minimize the spread of spilled material and to prevent contact with storm water, dry clean-up methods should be used for response to oil spills. • Material Safety Data Sheets (MSDS) should be maintained at a readily accessible location as a suitable information source for appropriate clean-up of specific chemicals.	Environmental Manager
Water Quantity	On-site stormwater control measures at parking areas, walkways and the main centre	• Maintenance and upkeep of the control measures	• Compilation of a operational maintenance plan stipulation required regular maintenance activities	Environmental Manager

	Stormwater attenuation ponds & diversion swales	• Reduce the increased runoff peaks to the pre-development condition • Dissipate additional energy	• Compile a operations manual for the upkeep and maintenance of the attenuation ponds .This would include visual inspection of the outlet works and overflow spillway after a significant rainfall event • Regular maintenance of the vegetation within the ponds to ensure that sufficient storage capacity is available • Maintenance of the vegetation and visual inspection of the diversion swales	Environmental Manager

11 Assumptions and limitations

- The final footprint of the development within the identified area is not known and therefore the entire area which is earmarked for development has been assumed to be impervious ;
- The final layout of the infrastructure and paved/ walking areas is not yet known;
- It is assumed that the development will occur to the east of the R534 road only.

11.1 Digital data

A CD with all the digital data of the project is included in Appendix A.

12 Conclusions

The following is concluded:

- The planned development would have an impact on the surrounding environment due to an increase in peak flow rates if no mitigation measures are implemented;
- The surrounding area consists of wetlands which need to be protected;
- The impact can be managed by mitigation measures both during the construction as well as the operational stage;
- There will be no impact on the MAR due to the very small area being developed when compared to the quaternary catchment size

13 Recommendations

The following is recommended:

- The Alternative 3 (Bio-engineering) control measures to be implemented using the SUDS approach;
- Provisions to be made at the planning stage for the construction of the attenuation ponds and diversion swales which are part of Alternative 3;
- A more detailed layout of the planned development and infrastructure to be obtained to enable the finalisation of the control measures;

- The final position and sizing of the attenuation ponds and diversion swales to be determined once a detailed layout plan is obtained;
- The planned attenuation ponds and diversion swales be constructed prior to implementing the development so as to act as buffers and protect the surrounding environment during the construction period;
- Maintenance and operations guidelines to be compiled to ensure the functionality of the control measures;
- The EMP to be implemented and adhered to both during construction and at the operational stage ;
- The water quality monitoring program be implemented before, during and after construction
- A preliminary and detailed design of the control measures giving construction drawings and a Bill of Quantities be carried out once the conceptual design has been finalised and the final layout plans are obtained.

14 References

Department of Water Affairs and Forestry. (2007). *Best Practice Guideline G3: Water Monitoring Systems.* Pretoria: DWAF.

Department: Water Affairs and Forestry. (2006). *Best Practice Guideline G1: Storm Water Management.* Pretoria: DWAF.

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Appendices

Appendix A: Digital Data

Report Distribution Record

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