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Lot 89 Coconut Grove
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Shakas Head

CK 2018/478639/07

Zimbali Coastal Resort

Eastern

Stormwater Management Plan

June 2020

Prepared by :

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List of Drawings

Drawings are not attached to this report and form part of a separate annexure to the report due to their size.

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1.0 Background :

In September 2018 Mono Block submitted a quotation to undertake a hydrological assessment and issue an associated stormwater management plan for the steam that runs through the Valley of the Pools in Zimbali. The quotation was approved shortly thereafter with the survey of the streams catchment being obtained in March 2019 and May 2020.

The objective of the stormwater management plan is to undertake a review of the stormwater flows for a 1:10 year, 1:20 year, 1:50 year and 1:100 year flood intervals for the stream leading through the North Eastern wetland, past the 14thy and 15th fairways, into the Valley of the Pools entertainment area and exiting through the eastern Zimbali boundary fence onto the beach. Based on these four flood peaks, the engineering assessment of the anticipated flow volumes, peak water surface, water velocities and the outflow through the Zimbali estate adjacent to the stream have been calculated. In addition, the discharge onto the beach for these four storm scenarios has been evaluated.

This stormwater management plan has been guided by the requirements for assessing flood events in terms of the Department of Water Affairs and Forestry's "Guideline for Developments within a Floodline" March 2007.

Furthermore consideration is to also be given to the remedial work required to ensure the structural stability of an existing dam and five cascading weirs directly downstream of the dam where the stream leads to the exit of the estate and discharges into the sea.

2.0 Purpose of the Stormwater Management Plan :

The purpose of this stormwater management plan is to identify the anticipated high water marks and associated flood characteristics for four flood peaks within Zimbali from the stream that traverses the estate near its northern boundary and the associated impact that the floods may have on the existing infrastructure that is adjacent to the stream within Zimbali.

In addition, the plan will verify the flood peak discharges into the ocean's high water mark and table a proposed discharge configuration into the ocean for consideration.

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3.0 Site Description and Environmental Sensitivities:

The stream that is under consideration originates in the adjacent Seaward Estate that is on the north eastern boundary of Zimbali Estate.

The stream traverses the estate near its north eastern boundary, passing through two existing wetlands next to the 14th and 15th fairways of the estates golf course. It then feeds into a man-made dam which has a capacity of approximately 25 000 m3 before flowing through five small manmade cascade or weir structures spread over 300 meters between the base of the dam and the estates boundary fence. The stream then passes through the eastern boundary fence of the estate before being deflected, in a north-eastern direction and parallel to the estates boundary fence, for approximately 150m. Subsequently, under normal flow conditions, the stream discharges into a stilling pond in the beach dunes. In the event of a significant storm the stream may breach the beach dunes and discharge directly into the ocean at the high water mark.

Up to the point where the stream discharges through the estates eastern boundary fence and into the beach dunes, no new interventions within any environmental sensitive areas are anticipated.

Once the stream passes through the boundary fence, the north-eastern path of the stream has continued to facilitate significant erosion of the dunes and vegetation parallel to the estates boundary fence that is directly north of the Valley of the Pools. This erosion has resulted in the security fence on the boundary of ZEMA's property being undermined, thereby compromising the security of the estate. As a result of this erosion, the security fence has had to be re-positioned more than once.

Should suitable interventions not be taken to address possible future erosion by the north-easterly stream migration, the possibilities of further undermining of the Zimbali Estates security and boundary fence is likely.

The total length of the stream is approximately 2 220 m with a catchment area of approximately 221 hectares.

The grid coordinates of the site stream's discharge point out of the estate are:

S29°33'02.84" and E31° 12'25.49".

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Figure One – Google Earth image of the North Eastern side of Zimbali with the existing stream position.

Figure Two – Google Earth image of the streams current discharge route into the ocean.

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4.0 Catchment Area and Existing Drainage :

As the Zimbali Valley of the Pools stream's catchment area, at 2.21 km2, is less than 15 km2, the results of Rational Method of design has been accepted for the calculation of the four different flood peaks. The Standard Design Flood, Unit Hydrograph and Empirical Methods are based on regional parameters and are not as site specific as the Rational Method. They have however provide some confidence level to the results of the Rational Method.

The results of the Rational Method for the 1:10 year, 1:20 year, 1:50 year and 1:100 year recurrence intervals are tabled below. These results are based the following variables :

- Mean Annual Rainfall = 971 mm
- Length of the longest river course = 2.22 km
- Height difference along the 10-85 slope = 36.185 m
- Average slope of the stream = 0.021831 m/m
- Combined catchment "C" value = 0.434
- Time of Concentration = 21.7 minutes;

Table One - Rational Method Peak Flow Results :

Return Period (years)	**Average Intensity (mm/hr)**	**Peak Flow (m3/sec)**
1:10	71.5	19.04
1:20	88.2	23.48
1:50	114.5	30.47
1:100	140.7	37.45

Utilising this hydrological data, survey data of the whole catchment area sourced from the University of Stellenbosch that gives a vertical accuracy within 500mm and the HEC-RAS 5.0.7 free surface flow modelling program, the following key flood lines parameters were calculated for each of the flood peaks for nine different cross sections:

- The Water Surface Elevation;
- The Energy Gradient Elevation;
- The flow volume in the main channel and when overtopped, the flows in the left and right banks of the stream;
- The associated water velocity within the stream as well as in the left and right banks when the streams banks are overtopped;
- The energy gradient; and
- The Froude # which indicates whether the flow is sub critical (Fr # < 1.0) or super critical (Fr # > 1.0) during the four different flood peaks.

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Table Two - Summary table of the 1:100 year, 1:50 year and 1:10 year flood variables for the nine cross sections taken within the Zimbali section of the catchment.

Zimbali Valley of the Pools

Flood Assessments for 1:10, 1:20, 1:50 and 1:100 year flood events.

(Left & Right bank as looking downstream.)

River Sta	Flow Profile	Water Surface Elevation (m)	Energy Gradient Elevation (m)	Flow Volume (Q) Left Bank (m3/s)	Flow Volume (Q) Main Channel (m3/s)	Flow Volume (Q) Right Bank (m3/s)	Water Velocity Left Bank (m/s)	Water Velocity Right Bank (m/s)	Average Water Velocity (m/s)	Energy Gradient Slope (m/m)	Froude #
9	1:10 year	23.82	24		19.04				1.31	0.0041	0.54
9	1:20 year	23.91	24		23.48				1.39	0.0040	0.54
9	1:50 year	24.04	24		30.06				1.5	0.0039	0.54
9	1:100 year	24.17	24		37.45				1.59	0.0038	0.55
8	1:10 year	22.83	23		19.04				2.33	0.0151	1.01
8	1:20 year	22.92	23		23.48				2.46	0.0146	1.01
8	1:50 year	23.04	23		30.06				2.62	0.0140	1.01
8	1:100 year	23.16	24		37.45				2.77	0.0136	1.01
7	1:10 year	20.56	21		19.04				2.09	0.0225	1.14
7	1:20 year	20.6	21		23.48				2.24	0.0244	1.2
7	1:50 year	20.66	21		30.06				2.46	0.0271	1.28
7	1:100 year	20.71	21		37.45				2.68	0.0302	1.36
6	1:10 year	18.93	19		19.04				0.42	0.0004	0.17
6	1:20 year	19.05	19		23.48				0.44	0.0004	0.17
6	1:50 year	19.2	19		30.06				0.46	0.0003	0.16
6	1:100 year	19.35	19		37.45	0		0	0.49	0.0003	0.16
5	1:10 year	18.92	19		19.04	0		0	0.23	0.0001	0.08
5	1:20 year	19.03	19	0	23.48	0	0	0	0.26	0.0001	0.08
5	1:50 year	19.19	19	0	30.05	0.01	0	0	0.28	0.0001	0.08
5	1:100 year	19.33	19	0	37.43	0.02	0	0	0.31	0.0001	0.09

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River Sta	Flow Profile	Water Surface Elevation (m)	Energy Gradent Elevation (m)	Flow Volume (Q) Left Bank (m3/s)	Flow Volume (Q) Main Channel (m3/s)	Flow Volume (Q) Right Bank (m3/s)	Water Velocity Left Bank (m/s)	Water Velocity Right Bank (m/s)	Average Water Velocity (m/s)	Energy Gradent Slope (m/m)	Froude #
4	1:10 year	18.88	19		19.04				0.56	0.0006	0.21
4	1:20 year	18.99	19		23.48				0.6	0.0006	0.21
4	1:50 year	19.14	19		30.06				0.65	0.0006	0.21
4	1:100 year	19.29	19		37.45	0		0	0.7	0.0005	0.21
3.2	1:10 year	18.82	19		19.04				0.83	0.0008	0.26
3.2	1:20 year	18.93	19		23.48				0.93	0.0010	0.28
3.2	1:50 year	19.06	19	0	30.06		0		1.06	0.0011	0.31
3.2	1:100 year	19.2	19	0	37.43		0		1.16	0.0013	0.34
3.1	1:10 year	12.77	13		19.04				2.17	0.0160	1.01
3.1	1:20 year	12.85	13		23.48				2.28	0.0155	1.01
3.1	1:50 year	12.95	13		30.06				2.43	0.0145	1
3.1	1:100 year	13.05	13		37.45				2.6	0.0139	1
3	1:10 year	10.71	11		19.04				3.76	0.0691	2.01
3	1:20 year	10.77	12		23.48				3.96	0.0689	2.04
3	1:50 year	10.84	12		30.06				4.23	0.0700	2.08
3	1:100 year	10.92	12		37.45				4.47	0.0698	2.11
2	1:10 year	9.88	9.9		19.04				0.4	0.0003	0.14
2	1:20 year	9.93	9.9		23.48				0.46	0.0003	0.16
2	1:50 year	10	10		30.06	0		0	0.54	0.0004	0.18
2	1:100 year	10.08	10	0	37.45	0	0	0	0.62	0.0005	0.2
1	1:10 year	5.45	5.7		19.04				2.04	0.0160	1
1	1:20 year	5.53	5.8		23.48				2.14	0.0155	1
1	1:50 year	5.62	5.9		30.06				2.28	0.0151	1
1	1:100 year	5.71	6		37.45				2.4	0.0147	1.01

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The associated plan elevation, stream cross sections, stream long sections and the anticipated flood inundation footprints for the four different flood scenarios of the catchment area drawings should be read in conjunction with this stormwater management report.

The plan drawings show the anticipated extent of the inundation areas for the 1:100 year, 1:50 year and 1:10 year flood peaks. The cross section and long section drawings showing the anticipated flood water surface, energy gradient surface, critical depth line that distinguished between sub and super critical flow as well as the extent of flooding over the streams embankments in the event of a flood.

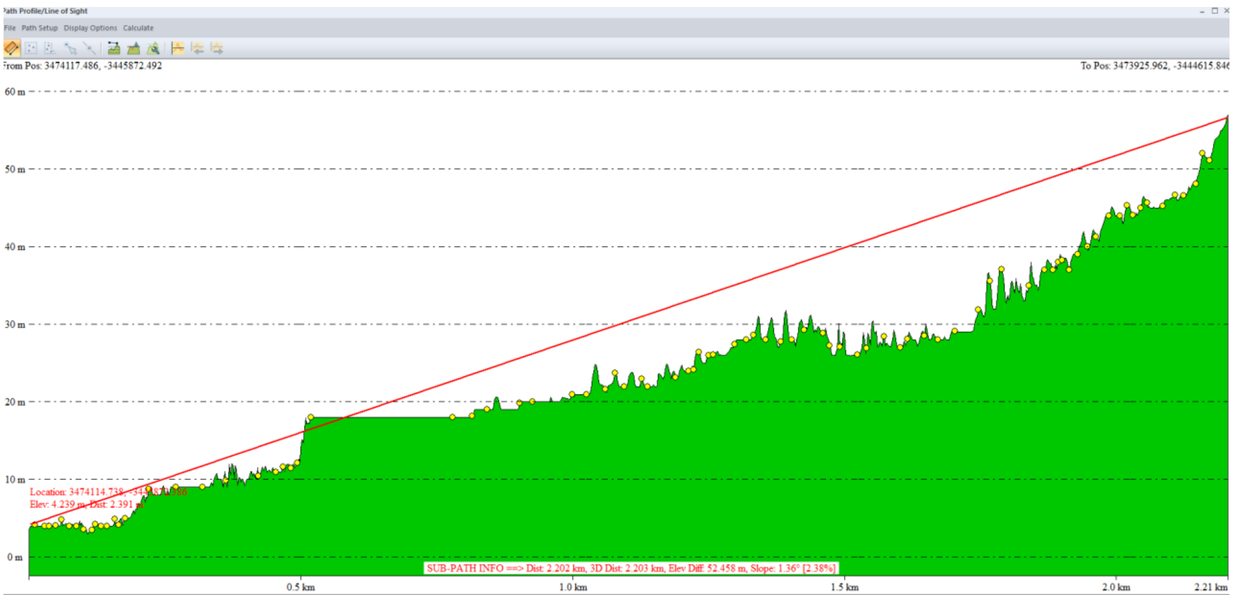

Figure Three – Global Mapper image of the stream long section over 2 220 m, from source in Ballito through to discharge into the sea at the Valley of the Pools.

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5.0 Deductions :

5.1 Potential Flood Areas:

Within the estate and as shown in the “Stream Flood Inundation Areas – Plan Layout” drawing, in the cross sections drawings and the associated Annexure A, flooding outside of the existing streams embankments will, in the event of a 1:50 year or 1:100 year flood event, occur in specific areas.

These areas being in the vicinity of cross sections 6 which is at the top reach of the dam, at the choke point of the dam wall as shown on cross section 3.2, as well as over the vehicle bridge leading to Holy Hill between cross sections 2 and 3.

5.2 Erosion :

Erosion of the streams channel is more likely to occur when the energy of the water is high, as depicted in the energy gradient slope and when the Froude # in Annexure A are greater than one. With a Froude # greater than one, the water being transported within the stream is super critical and will facilitate a high probability of erosion occurring, as super critical flows have higher turbulence, energy and erosion capabilities when compared to sub critical flows.

Super critical flows revert to sub critical flows as the water looses energy, resulting in hydraulic jumps occurring at the transition point from super to sub critical flow. At the point of a hydraulic jump, additional turbulence occurs which increases the potential of erosion occurring in a stream bed.

Areas of the stream in Zimbali where super critical flow is likely to occur are between cross sections 7.0 and 8.0 as well as just downstream of the dam wall, at sections 3.0 and 3.1 and as the stream exits the estate at cross section 1.0.

In the flood events, hydraulic jumps will occur just downstream of cross sections 2, 3 and 7.

5.3 Existing Dam and Cascade Weir Infrastructure :

It has been noted, as part of a series of ZEMA Bulk Infrastructure reports that were compiled for ZEMA in April 2018 that the structural stability of the existing five meter high dam wall should be reviewed. As part of the “ZEMA Dam Infrastructure” report, compiled by Mr. A. Knox of Bosch Projects, it was noted that potential uncontrolled scour on the right hand side of the dam’s spillway be verified. It was also noted that the current spillway capacity possibly does not meet the required design norms. In the event of a dam failure the ZEMA infrastructure downstream of the dam, including the park area, parking lot, road, swimming pool and recently renovated restaurant and club house area would be at risk.

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The five cascades downstream of the dam are minor structures, ranging in height between one and two meters with storage volumes between 200m3 and 3000m3. The common area of concern for these five structures pertains to scour around the sides and toes of the weirs.

5.4 Anticipated Normal Daily and Annual Flow through the Catchment and Discharge into the Ocean:

Due to the streams small catchment area, at 2.21 km2, there is no gauging weir on the stream to measure the average daily and annual flows that discharge into the ocean. However, using the closest South African Weather Station to the site, Frasers (SAWS # 0241302_W) with a suitable duration of recorded weather, 70 years, an estimate of the anticipated daily and annual flows through the stream and discharging into the ocean have been made.

Utilising the following variables :

- Mean Annual Precipitation : (MAP) = 971 mm
- Catchment Area = 2.21 Km2
- Average slope of the catchment = 0.021831 m/m
- Combined C factor = 0.434.

The anticipated average daily discharge into the ocean = 2 551 m3/day (29.5 l/sec)

The anticipated average annual discharge into the ocean = 931 325 m3/year.

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6.0 Stormwater Management Recommendations :

Two construction processes are tabled for consideration.

6.1 Remedial work to the existing dam and 5 cascading weirs :

The first is to consider the current structural stability of the five meter high dam, just upstream of the Valley of the Pools entertainment area and the maintenance required for the five existing cascading structures downstream of the dam.

The remedial work as recommended in the ZEMA Dam Infrastructure report of April 2018 should initially involve the repair of the identified scour areas of the dam and five cascading weirs under the supervision of a suitably qualified engineer and be undertaken by a specialist contractor. In addition, it is highly recommended that consideration be given to ascertain the existing structural stability of the dam.

In addition to the remedial works recommended in the report of April 2018, consideration should also be given to the re-design and construction of the fifth cascading weir as the stream exits the estate. The reconstruction of the weir should be done such that a suitable hydraulic jump is formed just before the stream exists the estate. The proposed hydraulic jump will allow the flood waters that exist the estate to be sub critical, with a Froude # < 1.0, thereby facilitating flows into the beach zone to have less energy and less of a destructive force. Stormwater flows that have had their energy dissipated by the proposed hydraulic jump that would be more inclined to be directed straight towards the high water mark as opposed to diverting in a north easterly direction as is currently the situation.

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6.2 Re-alignment of the stream as it exits the estate :

Currently the stream exits the Zimbali property and meanders in a northerly direction over a distance of approximately 150 m prior to linking in with the sea. The stream varies its position over time as it meanders over the 150 m and, as a result of its change of directions, has often undercut and eroded the base of the dunes that form the boundary line of the Zimbali property. If the erosion of the dunes is significant, as has occurred in the past, the Zimbali boundary fence is undermined and collapses into the stream.

In order to avoid a reoccurrence of the undermining of the Zimbali boundary fence, consideration should be given to directing the stream in a straight line to the high water mark as it leaves the estate.

Due to the need to avoid any hard structures or any artificial embankments such as “Geo-container” bags, consideration is to be given to opening up a natural channel directly from the stream’s exit from the estate directly towards the sea’s high water mark. As this channel is proposed to not contain any man made structures, it is anticipated that a regular maintenance program will be required to sustain the channels cross sectional area as it flows directly towards the sea.

The required cross sectional area of the steam leading to the sea will need to be a minimum 17 m2. This cross sectional area will accommodate the 37.86 m3 / sec flow that is anticipated for a 1:100 year storm. However, with this cross section, the velocities in the stream will be 2.23 m/sec which is excessive. It is therefore recommended that the minimum cross sectional area of the stream, when it does not contain any man made support structures, will need to be closer to 40 m2. The final width and depth of the proposed channel would be verified on-site.

Should the maintenance of the channel be considered to be potentially problematic, consideration could then be given to lining the channel with geo-container bags as has been successfully achieved elsewhere on the North Coast.

Alternatively, consideration can be given to forming a sufficiently large man-made stilling pond for the stream to discharge into as it leaves the estate. Currently the stream soaks a way for normal daily flows within a pool that it has formed in the dunes 150 m north of the streams exit from the estate. Through careful interventions and effective maintenance, it may be feasible to establish a similar stilling pool directly opposite the point where the steam exits the estate.

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Figure Four – Google Earth image of the streams current discharge route into the ocean and the proposed realignment of the stream. (green).

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7.0 Conclusions :

This stormwater management report has clarified two key issues that need to be considered within the catchment of the stream that runs into the north eastern boundary of the Estate. The first area that needs to be considered is the existing stormwater infrastructure near the Valley of the Pools. The second area of consideration is the most environmentally sustainable solution to discharging the stormwater as it leaves the estate.

As noted, the existing stormwater infrastructure near the Valley of the Pools consists of a 5 meter high dam and five small cascading weirs. It was noted in the ZEMA report of April 2018, and verified in this report, that the current dam spillway is probably undersized and that a throttle point will be established at the dam in the event of a flood greater than 1:50 years. Given these conclusions, the danger exists that failure of the dam may occur in the event of a significant storm greater than 1:50 years. Should excessive flood water not be contained within the dam's spillway, the possibility exists that scouring occurs outside the dam's spillway, resulting is a potential risk to people downstream of the dam as well as to the Valley of the Pool's infrastructure that is below the dam.

The stormwater flows out of the estate into the beach dunes is currently being diverted in a northerly direction for approximately 150 m. This stream, in the event of a significant storm is eroding the Zimbali boundary fence and the edge coastal dune forest that is within the estate. Ideally the dune build up that has occurred directly in front of the streams exit from the estate has impeded the possible natural flow direction of the stream to the sea. This natural flow direction possibly being directly to the sea or possibly at an inclined northerly angle feeding into the sea.

Ideally consideration can be given to re-directing the stream to follow a more direct route to the sea in the event of a significant storm. As part of the proposed re-alignment of the stream, consideration can also be given to establishing a sufficiently large man-made stilling pond for the stream to discharge into as it leaves the estate under normal flow conditions.

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