**Balderja (Pty) Ltd**

## Concept design of the proposed

# Bernardskloof Dam

Report Nr. JB2091-01
2021-11-15

**Prepared for:**

Balderja (Pty) Ltd
Palmiet Rd, Redford Rd
The Crags, 6602

Balderja

**Prepared by:**


Jan Brink Pr Eng
20 Manor Rd
Kingswood Golf Estate
George

JAN BRINK
CONSULTING ENGINEERING

## Executive Summary

Bernardskloof Dam is a proposed new dam on Portion 17 of the farm Redford in The Crags area near Kurland in the Bitou Local Municipality in the Western Cape.

This report advises the owner on the engineering and technical requirements for the project, in terms of the technical scope of works, regulatory requirements and recommendations on further investigations and design.

The dam is to be a 17 m high earthfill dam with storage capacity of 73 000 $m^3$. Water will be fed from an irrigation canal. The natural catchment is on 0,2 $km^2$.

Based on its size the dam will be registered as a dam with a safety risk in terms of the National Water Act and classified as a Category II dam in terms of the Dam Safety Regulations. An Approved Professional Person will have to be employed to oversee the design and construction of the dam.

The feasibility design concluded that an uncontrolled bywash spillway should be constructed on the left flank. A 150 mm diam. bottom outlet pipe should be installed for emergency draw-down and environmental releases (if required.)

No further studies are required for the feasibility design. A geotechnical survey of the site and material should be conducted as part of the detail design phases.

**Issued**

Compiled by:

2021-11-15

JA Brink Pr Eng

Date

# Contents

Executive Summary....2
Abbreviations and Acronyms....4
1 Introduction....5
1.1 Background....5
1.2 Scope of Report....5
2 Summary of information....5
3 Dam safety legislation....6
3.1 Legislation and Classification....6
3.2 Responsibility for design and construction....6
4 Dam type....7
5 Embankment....8
5.1 General description....8
5.2 Materials on site....9
5.3 Geotechnical investigation....10
6 Hydrology....11
6.1 Flood Hydrology....11
6.2 Catchment Yield and dam sizing....11
7 Spillway Design....12
7.1 Flow cases and Freeboard....12
7.2 Spillway Options....12
7.3 Spillway hydraulics....13
7.4 Return Channel....13
8 Outlet pipe....13
9 Construction arrangements, Control and Monitoring....14
9.1 Site arrangements....14
9.2 Contracting....14
9.3 Specifications and monitoring....14
10 Further studies....15
11 References....16
Appendix A – Hydrology Calculations....17
Appendix B – Spillway Calculations....18
Appendix C – Drawings....19

### Abbreviations and Acronyms

APP ........ APPROVED PROFESSIONAL PERSON
c ........ COHESION
DSE ........ DAM SAFETY EVALUATION
DSO ........ DAM SAFETY OFFICE
DWS ........ DEPARTMENT OF WATER AND SANITATION
EPP ........ EMERGENCY PREPAREDNESS PLAN
FSL ........ FULL SUPPLY LEVEL
FOS ........ FACTOR OF SAFETY
FSC ........ FULL SUPPLY CAPACITY
HRU ........ HYDROLOGICAL RESEARCH UNIT
MAP ........ MEAN ANNUAL PRECIPITATION
NOC ........ NON-OVERSPILL CREST
O&M ........ OPERATION AND MAINTENANCE
RBL ........ RIVER BED LEVEL
RDD ........ RECOMMENDED DESIGN DISCHARGE
RDF ........ RECOMMENDED DESIGN FLOOD
REGULATIONS ........ DAM SAFETY REGULATIONS IN TERMS OF NATIONAL WATER ACT
RL ........ REDUCED LEVEL
RMF ........ REGIONAL MAXIMUM FLOOD
SANCOLD ........ SOUTH AFRICAN NATIONAL COMMITTEE ON LARGE DAMS
SEF ........ SAFETY EVALUATION FLOOD
$t_c$ ........ TIME OF CONCENTRATION
ø ........ PIPE DIAMETER
Φ ........ ANGLE OF FRICTION

# 1 INTRODUCTION

## 1.1 BACKGROUND

A new dam is proposed on Portion 17 of the farm Redford in The Crags area near Kurland in the Bitou Local Municipality in the Western Cape. The owner commenced with site clearance and material stockpiling before being made aware of the legal- and regulatory requirements of establishing a new dam.

The required dam capacity is approximately 73 000 m³. The wall height will be 17 m.

This report advises the owner on the engineering and technical requirements for the project in terms of the technical scope of works, regulatory requirements and recommendations on further investigations and designs.

The report also describes the general scope of the design and construction project for the purposes of Water Use License- and environmental approvals.

## 1.2 SCOPE OF REPORT

The owner appointed Jan Brink Pr. Eng. as engineer to complete the concept design of the dam. The scope of the work was agreed to include the following:

- A site visit
- Basic flood hydrology calculations to determine potential floods from the catchment
- Engagement with other specialists (WULA and Environmental) to confirm specific information required.
- Dam layout options
- Spillway options
- Outlet works requirements
- Basic sketches and/or drawings showing the pertinent aspects of the project.
- Advice on further project phases, including, but not limited to:
  - approval process for eventual License to Construct
  - site survey(s)
  - geotechnical investigation
- Compile a Concept Design Report

# 2 SUMMARY OF INFORMATION

The information below summarises the data that will be recorded in the Dam Safety Office's database. The table should be updated in future reports on the dam design, before final registration with the DSO.

| | |
|---|---|
| **Name of dam** | Bernardskloof Dam |
| **Departmental file reference for dam** | 12/2/K700/…. (Number to be assigned by DSO) |
| **Designer/Approved Professional Person** | Jan Brink Pr. Eng. (APP only at detail design phase) |
| **Name of Owner** | Balderja (Pty) Ltd |
| **Representative of Owner** | Ms Denina Bernard |
| **Address of Owner** | Portion 17 of Farm Redford 232, Palmiet Rd, Redford Rd, The Crags, 6602 |
| **Tel.** | 082 781 3155 |
| **Email** | deninabernard@me.com |

| | | | |
|---|---|---|---|
| **Nearest Town (distance)** | Pletttenberg Bay (20 km) | | |
| **Province** | Western Cape | | |

| | | | |
|---|---|---|---|
| **Latitude** | 33°57'02" S | **Longitude** | 23°26'45" E |
| **Wall type** | Earthfill | **Wall height** | 17 m |
| **Storage capacity** | 73 000 m³ | **Completion date** | t.b.c. |
| **Crest length** | 110 m | **Crest width** | t.b.c. |
| **Contractor** | t.b.c. | | |


**Figure 1: Location of dam site**

# 3 DAM SAFETY LEGISLATION

## 3.1 LEGISLATION AND CLASSIFICATION

Dam Safety is regulated in terms of Chapter 12 of the National Water Act (Act 36 of 1998) and the Dam Safety Regulations (“the Regulations”, Government Notice R.139 of February 2012) published in terms of the Act.

The Act defines a “dam with a safety risk” as a dam with a wall height of more than 5 m (as measured from the downstream toe to the crest) and being able to contain more than 50 000 m³ of water. Bernardskloof will therefore be a dam with a safety risk.

The Regulations provide for classification in three categories. Benardskloof Dam will be categorised as Category I or II depending on the final wall height. With the planned wall height of 17 m the dam will likely be classified as Category II.

## 3.2 RESPONSIBILITY FOR DESIGN AND CONSTRUCTION

Once the project proceeds to detail design, the Regulations require that an Approved Professional Person (APP) be appointed to oversee the design and construction of the Category II dam. An APP is not expressly required for feasibility and preliminary design phases, although continuity through project phases is generally more cost effective. It is recommended that the APP be appointed as soon as the decision to proceed with the project is made.

When the decision is made to proceed with the project the dam must be registered with the Dam Safety Office (DSO) at the Department of Water and Sanitation (DWS). The DSO will then confirm the final dam category based on a risk assessment submitted by the owner.

For a Category II dam the APP must submit an application for a license to construct to the DSO. The application must include a detail design report, drawings and specifications. The DSO assesses the design before issuing the license. A license will not be issued if the Water Use License does not specifically provide for the dam.

During the construction phase the APP remains responsible for compliance with specifications. He/she must report to the DSO on progress with the works. At the completion of construction the APP must apply for a license to impound water in the dam before the dam can be filled. This application must in turn be supported by a completion report, an operation- and maintenance manual and an emergency preparedness plan for the dam.

# 4 DAM TYPE

The dam type selection focusses on the most cost-effective dam option, but must also consider lifetime costs and environmental impact. The options to consider include earth- and rock fill dams and arch- and gravity concrete dams.

In general, concrete dams are more expensive than fill dams as they require expensive cement and aggregates (gravel and sand) for concrete, specialised batching and placing equipment and construction expertise. The aggregates are usually produced on site, requiring large crushers. Concrete dams further require competent rock foundations and varying levels of foundation treatment, such as grouting and drainage. Concrete options only become viable when the scope of the project is large enough to balance the cost of importing materials, equipment and expertise and when the volume of fill materials are insufficient.

Fill- or embankment dams are constructed from soil or rock, or a combination of the two. They are distinguished based on which of the materials forms the bulk of the structure. These dams are generally constructed with the materials available at, or close to the dam site. Water in the dam is retained by an impervious zone or membrane which is supported by general fill. Materials are preferably obtained from the dam basin. This has the advantage of limiting the environmental impacts of quarrying, because the borrow area becomes part of the dam basin.

The disadvantages of fill dams are that they are more susceptible to erosion at the water level in the dam and especially when overtopped. Spillway capacity and freeboard must therefore be sufficient for all foreseeable circumstances. Fill dams also require better planning for temporary diversion during construction, as even minimal overtopping can cause severe damage to a partially built embankment. Bernardskloof Dam will require very little diversion of streamflow from the small natural catchment.

Based on the cost advantage only embankment dams are considered feasible for the site under consideration.

# 5 EMBANKMENT

## 5.1 GENERAL DESCRIPTION

Embankment dams rely on a core zone constructed with clay or sandy clay for water tightness. The impervious zone can be surrounded and protected by more permeable zones or shell material. If the materials available on the site are suitably dense, no formal zoning may be necessary. The denser material is then placed towards the upstream side of the embankment and the permeable materials downstream.

To prevent water from seeping under the embankment, a cut-off core is excavated into the foundation until it reaches impervious rock, or material of higher density and lower permeability than the core itself. The core is constructed from the trench bottom. The shell material can be placed on weaker foundations, as long as long term settlement will be within acceptable limits to prevent deformation and cracking of the embankment.

The up- and downstream slopes' gradients are calculated based on the engineering properties of the soils used, expected ground acceleration from earthquake loads and moisture content of the soils. The upstream slopes may vary between 1:2.5 and 1:3.5 (vertical:horizontal) and the downstream between 1:1.5 and 1:2.5. The required slopes for each dam will be calculated based on results of soil testing during the preliminary design.

Over time the core becomes saturated and seepage paths may develop. To lower the level of saturation, or phreatic surface, fee-draining internal filter zones are built into higher dams. The filters allow seepage to drain from the embankment, but prevent internal erosion by retaining fine materials. Filters are also required where there is a sudden transition between materials of different grading. Filter materials are usually obtained from commercial quarries and are therefore more expensive. They do, however, improve the stability of the embankment and therefore may allow steeper slopes and thus less general fill material.

For lower dams with materials less prone to internal erosion, a rock toe can be utilised. See Figure 3. A rock toe serves as a basic internal filter at the downstream end of the embankment. It lowers the phreatic surface and provides a neat and stable embankment toe. Where rock is used as part of the general fill it is usually placed in the downstream area of the embankment and automatically creates a free-draining toe.

On the upstream slope the embankment must be covered with a gravel or boulder riprap layer to protect the fill material against wave erosion at the water surface. The riprap is designed based on the calculated wave height, which is in turn dependent on wind speeds of the region.

The embankment crest is finished off with a gravel capping that can resist moderate vehicle traffic and surface erosion.

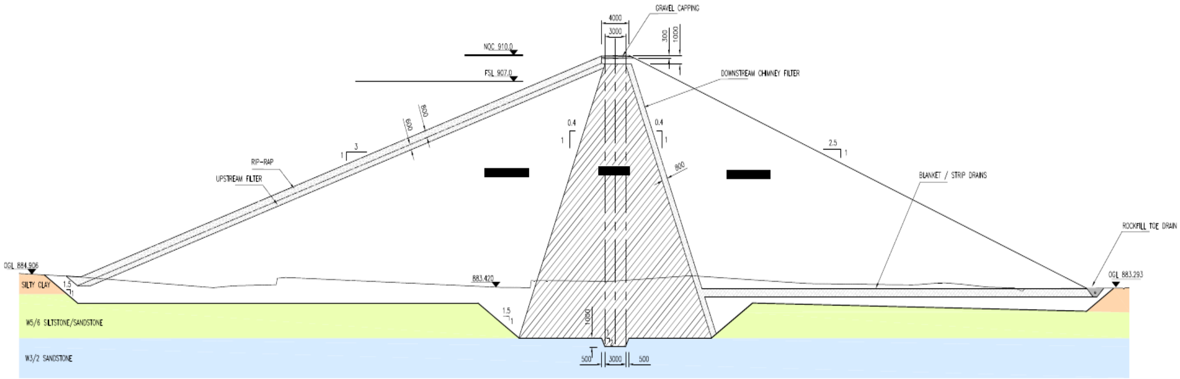



**Figure 2: Typical section through a high embankment dam**

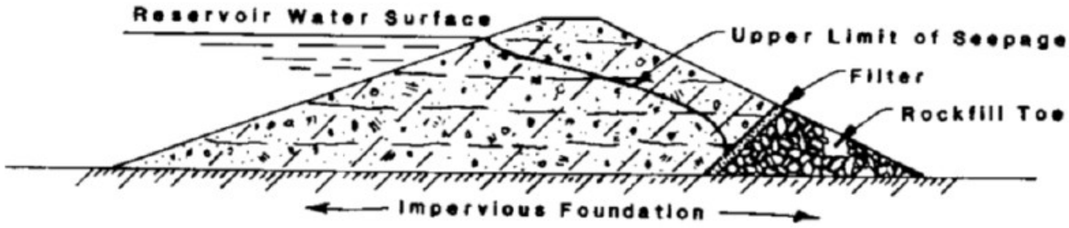



**Figure 3: Embankment rock toe (USBR, 2012)**

### 5.2 MATERIALS ON SITE

Fill dams are constructed with materials from borrow areas in the dam basin as far as possible.

The site for the dam was partly cleared and materials were stockpiled in- and next to the basin. From observation the soft overburden material is thin and contains little fines. Additional clayey material was stockpiled at a nearby borrow pit. According to the owner's appointed contractor he will be able to excavate sufficient material from the basin. The stockpiled clay will not be sufficient to use as a core, but they have additional fine material available at a nearby site. This can potentially be mixed with the stockpiled finer clay to provide sufficient core material.

**Figure 4: Cleared basin**

Figure 5: Stockpiled fill material

Figure 6: Stockpiled clay

### 5.3 GEOTECHNICAL INVESTIGATION

To optimise the design of the embankment and identify as many of the possible underground risks, a geotechnical investigation of the site must be conducted in the detail design phase.

The scope of such an investigation may include the following:

- Review of available geotechnical information on the area.
- Site inspection to assess general site conditions and general geotechnical risks.
- Subsurface investigations from test pits to determine e.g. local rock and soil types, ground water table and borrow area materials.
- Soil sampling for embankment materials.
- In situ and laboratory testing of potential construction materials. Testing of factors such as Atterberg limits, sheer strength parameters and others as advised by specialist.
- Slope stability analyses to confirm optimum embankment slopes.

# 6 HYDROLOGY

## 6.1 FLOOD HYDROLOGY

Two extreme floods are calculated to determine the required capacity of the spillway. The Recommended Design Flood (RDF) is used for the hydraulic design of the spillway. A dam's spillway must be able to discharge the RDF without any damage to the spillway, dam or appurtenant structures. The Safety Evaluation Flood (SEF) is the most extreme flood that may occur in the catchment. During the SEF the dam may be on the brink of failure and significant damage may be experienced as long as the dam does not actually fail.

The SANCOLD guidelines (SANCOLD, 1991) recommends using the regional maximum flood (RMF) calculated with the method explained the TR137 (Kovacs, 1987) as SEF. The catchment area was measured as 0,2 km². This catchment size is too small to use the TR137-method and a simple Alternative Rational-method was used. A probable maximum flood (PMF) of 7,78 m³/s was calculated. The same alt-rational calculation was used to calculate a 1:100-year flood of 911 ℓ/s. Hydraulically the dam is effectively an off-channel dam and the incoming floods are very small.

The calculations are attached as Appendix A. The calculated flows are summarised in the table below.

| Recurrence Interval | Flow Rate (ℓ/s) |
|---|---|
| 1:10 | 307 |
| 1:50 | 656 |
| 1:100 as Recommended Design Flood | 911 |
| 1:200 | 1 031 |
| PMF as Safety Evaluation Flood | 7 778 |

## 6.2 CATCHMENT YIELD AND DAM SIZING

The yield and annual flow pattern from the catchment was studied separately by Dr James Dabrowski [1]. The yield analysis and water requirement for the owner's intended development determined that a dam size up to 100 000 m³ may be required.

A digital terrain model was developed based on a site survey. Two embankment options were modelled on the terrain and optimised to determine the maximum storage basin that can be created. The following maximum dam size was determined:

| | |
|---|---|
| Upstream embankment slope | 1:3 |
| Downstream embankment slope | 1:2,5 |
| Dry freeboard | 1 m |
| Wall height (from downstream toe) | 17 m |
| Earthfill volume | 26 621 m³ |
| Basin volume | 46 611 m³ |
| Combined volume | 73 232 m³ |

The "combined volume" indicate the construction of the embankment with material excavated from the basin. This is therefore the maximum storage volume that can be created. The owner confirmed that 73 000 m³ will be acceptable. This volume is therefore taken as the design storage capacity.

# 7 SPILLWAY DESIGN

## 7.1 FLOW CASES AND FREEBOARD

Dam spillways are designed to discharge extreme floods safely. Statistics (Nortjé, 2010) show that inadequate spillway capacity, at 47%, is by far the biggest cause of failure of dams in South Africa. It is therefore critically important to ensure that extreme flood calculations and spillway designs are done with great care.

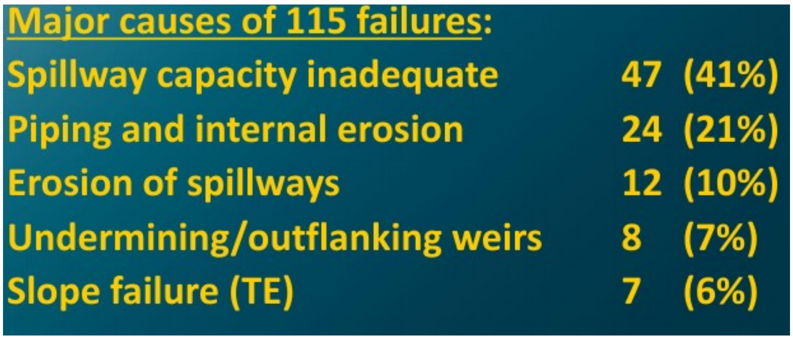



**Figure 7: Causes of dam failures in South Africa (Nortjé, 2010)**

During the SEF, the upstream water level can be allowed to reach the non-overspill crest (NOC) level of the dam. The spillway may even be allowed to suffer extensive damage, as long as the dam remains intact. Dam types such as mass concrete dams can be designed to allow moderate overtopping of the NOC.

For the RDF-case no damage to the spillway and structure should be allowed. Suitable freeboard must be provided to accommodate wave action from e.g. wind over the water surface, flood surges and earthquake- or landslide-induced waves. An allowance of 0.5 m freeboard above the RDF water level is considered adequate for the concept phase.

For the purposes of this report, the SEF and RDF calculated above are used. In the further design phases the attenuation of these floods may be considered to optimise the spillway capacity.

## 7.2 SPILLWAY OPTIONS

The spillway selection is dictated by the required discharge capacity, dam type, site layout, material availability and founding conditions. The peak flow rates are relatively small and no elaborate spillways are required. No mechanical flow control equipment are considered.

As discussed in Chapter 4, the most feasible dam type is an earthfill embankment dam. For fill embankments the most practical spillway options are bywash- and side channel-type spillways. Bywash spillways are the most common solution for farm dams and consist of a channel excavated through the flanks and a return channel to the downstream river. Side channel spillways are employed when the required spillway length is too long for a by wash structure.

The spillway must be founded on competent rock. Where the rock is too deep to form the natural invert of the spillway, a concrete structure must be built up to the required level. A concrete structure has the advantage of providing a fixed flow control position, as opposed to a rough channel where the control point is dependent on the flow rate.

The return channel conveys water back to the river. Its capacity must be similar to the capacity of the spillway crest. Rapid flow rates in the channel have a high erosion potential. Water must therefore be guided away from the dam embankment. The channel alignment must be selected to avoid highly erodible areas, as lining of the channel will be very expensive.

The left flank of the valley appears more suitable for the spillway. It is slightly flatter and will therefore require less excavation for both the spillway and return channel. The valley also becomes slightly wider on the downstream left flank. This will allow a gentler return channel slope. The final position and layout will be determined by the rock conditions.

**Figure 8: Side-channel spillway example**

**Figure 9: Typical bywash spillway with concrete end sill and retaining wall against fill embankment**

### 7.3 Spillway hydraulics

A range of flow depth and spillway widths were calculated for the dam based on broad-crested weir theory. To discharge the SEF with zero freeboard, i.e. a flow depth of 1,0 m, a 5,37 m long weir will be required. Rounding this length to 5,4 m will give a flow depth of 238 mm for the 911 ℓ/s of the RDF.

The broad-crested weir calculations are attached as Appendix B.

### 7.4 Return Channel

The return channel conveys water back to the river. Its capacity must be similar to the capacity of the spillway crest. Rapid flow rates in the channel have a high erosion potential. Water must therefore be guided away from the dam embankment. To avoid expensive concrete lining, the return channel should be excavated to reasonably hard rock.

The channel slope will determine the velocity of the water from the spillway. A gradual slope is preferable to avoid expensive concrete erosion protection lining.

## 8 Outlet pipe

Dams have outlets to abstract water for use and to lower the water level in the dam in case of an emergency. Lowering the water level in the dam when imminent failure is suspected might save the dam and prevent catastrophic flooding downstream. For this reason some form of draw down capacity is usually a dam safety requirement for all but the very smallest dams.

Outlet pipes must be installed on solid foundation and encased in reinforced concrete to prevent settlement and consequent cracking and leaking of the pipes. More than one pipe can be installed in the same encasement. Either steel or high-density poly-ethylene (HDPE) pipes are recommended as outlet pipes, as they are durable, flexible and require little maintenance after installation. For small dams PVC pipes can be considered.

**Pipe intakes** for farm dams can either be submerged, or connected to a float via a flexible coupling. This is dependent on water quality requirements. Submerged intakes must be equipped with trash screens to prevent large objects from entering the pipes. See Figure 10 as an example. Floating inlets allow the abstraction of better quality water near the water surface. The intake level can also be adjusted by changing the length of the ropes suspending the pipe intake from the float. These inlets are more expensive than bottom inlets and require regular maintenance of the float and flexible coupling.

Variable level intake towers are rarely constructed for small to medium farm dams and are not considered at this stage.

**Figure 10: Typical submerged inlet (two pipes)**

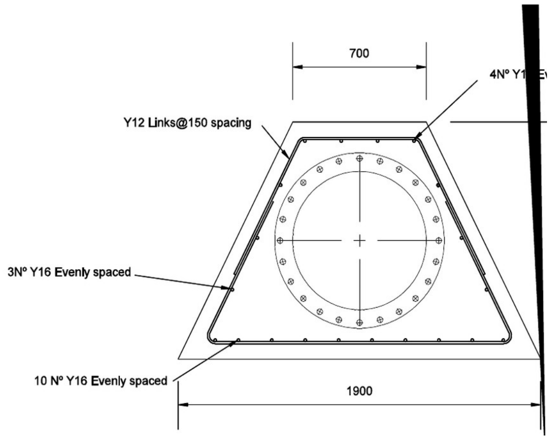



**Figure 11: Example of section through outlet pipe encasement**

Discharge is to be controlled on the downstream end of the outlet pipe. The size of the dam does not warrant the purchase- and maintenance cost of dedicated flow control valves. Gate valves designed for high flow velocities can be utilised. Knife gates or butterfly valves cannot be used for flow control and should not be utilised.

The draw-down and abstraction requirements will be confirmed with the detail design and is dependent on environmental flow requirements and reservoir draw-down rates. For the purpose of this concept design a single 150 mm diameter outlet pipe will be adequate.

# 9 Construction arrangements, Control and Monitoring

## 9.1 Site arrangements

The site is accessible from the north (upstream) and both flanks. There is sufficient clear area for plant, site office and work area. The environmental management requirements may place limitations on the extent and layout of construction activities around the dam.

## 9.2 Contracting

A standard form of contract for civil engineering works is recommended to manage the risk of both the owner and contractor. The latest version of the South African Institution of Civil Engineers' General Conditions of Contract (GCC, 2015) can be recommended.

## 9.3 Specifications and monitoring

A set of construction specifications based on the SANS 1200 range of documents should be used. All contractors with suitable expertise in dam building will be familiar with the documents. This will simplify compliance and control.

The level of independent quality control by an engineer's representative can be negotiated and agreed to between the Employer and Contractor. A project of this scale does not warrant a full time site agent (or "Employer's Agent's Representative" per GCC 2015). Critical aspects of the construction that will require careful monitoring must be identified by the Engineer and then highlighted in the Contractor's programme to allow the Engineer (or "Employer's Agent") to monitor these activities physically. These items may include filter placement, outlet pipe founding and encasement reinforcing, etc. Other monitoring results may be submitted by the Contractor at agreed intervals or at milestones.

# 10 FURTHER STUDIES

A geotechnical investigation must be completed as part of the next phase of the design, as discussed in paragraph 5.3.

## 11 References

[1] Dabrowski, JM (2021) **Hydrological Assessment for a Proposed Dam on Portion 17 of Farm 232 Redford**, Confluent Environmental, George, September 2021

[2] Nortjé J (2010), **Requirements of Dam Safety Legislation in SA**, Presentation at the SANCOLD Short Course, Stellenbosch, 2010

[3] SAICE (2015), **General Conditions of Contract for Construction Works, Third Edition**, South African Institution of Civil Engineering, Midrand, 2015.

[4] SANCOLD (1991) **Safety Evaluation of Dams: Guidelines on Safety in Relation to Floods**. Report No. 4, December 1991. South African National Committee on Large Dams, Pretoria.

[5] SANCOLD (2011) **Guidelines on Freeboard for Dams: Volume II**. South African National Committee on Large Dams, Pretoria.

[6] SANS 1200, **South African Bureau of Standards, Standardized Specifications for Civil Engineering Construction**, SABS, Pretoria

## Appendix A – Hydrology Calculations

# BERNARDSKLOOF DAM

**Catchment detail**

| | | |
|---|---|---|
| Size of catchment (A) | 0,2 | $km^2$ |
| Longest watercourse (L) | 0,44 | km |
| Top Level (m) = | 240 | |
| Bottom Level (m) = | 220 | |
| MAP = | 775 | mm |
| Dam capacity = | 70 000 | $m^3$ |
| Dam surface area = | 3 000 | $m^2$ |

**Defined watercourse**

| | | |
|---|---|---|
| Level at 85% (m) = | 237 | $H_{0.85L}$ |
| Level at 15% (m) = | 222,0 | $H_{0.10L}$ |
| F = $H_{0.85L}$ - $H_{0.10L}$ (m) = | 15 | |
| $S_{AV}$ = F/L (ave over 75%L) (m/m) = | 0,045 | |
| $S_{AV}$ = | 4,55% | |

**Overland flow**

| | | |
|---|---|---|
| Cover (Select) | Sparse grass over fairly rough surface | |
| Permeability r = | 0,30 | |
| Height H = | 20,00 m | |
| Catchment slope S = | 0,045454545 (m/m) | |
| Overland flow $T_c$ = | $0.604 \times (rL/(S_{av})^{0.5})^{0.467}$ | |
| = | 0,48 h | |
| = | 28,97 min | (Should not be shorter than 15 min) |

**Run-off coefficient**

| | | |
|---|---|---|
| Land Use Distribution: | Urban = | 0,00% |
| | Rural Area = | 100,00% |

| Rural ($C_1$) | | | | |
|---|---|---|---|---|
| **Component** | **Classification** | **MAP** | **A** | |
| | | **775** | % | |
| Surface Slope ($C_s$) | Vleis and pans (<3%) | 0,03 | 0 | 0,00 |
| | Flat (3 to 10%) | 0,08 | 75 | 0,06 |
| | Hilly (10 to 30%) | 0,16 | 25 | 0,04 |
| | Steep (>30%) | 0,26 | 0 | 0,00 |
| | Total | | **100** | **0,100** |
| Soil Permeability ($C_p$) | Very permeable | 0,04 | 20 | 0,01 |
| | Permeable | 0,08 | 60 | 0,05 |
| | Semi-permeable | 0,16 | 15 | 0,02 |
| | Impermeable | 0,26 | 5 | 0,01 |
| | Total | | **100** | **0,093** |
| Vegetation Growth ($C_v$) | Thick | 0,04 | 0 | 0,00 |
| | Light | 0,11 | 85 | 0,09 |
| | Grasslands | 0,21 | 10 | 0,02 |
| | No vegetation | 0,28 | 5 | 0,01 |
| | Total | | **100** | **0,129** |

Run-off coefficient, $C_1 = C_s + C_p + C_v$
Adjusted factor for initial saturation, $F_t$ (select) Flat & permeable catchments 3
Adjusted run-off coefficient $C_{1T} = C_1 \times F_t$
Combined run-off coefficient $C_T$ = % Rural x $C_{1T}$ + % Urban x $C_2$

| T | 2 | 5 | 10 | 20 | 50 | 100 | 200 | PMF |
|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0,32 | 0,32 | 0,32 | 0,32 | 0,32 | 0,32 | 0,32 | 0,70 |
| $F_t$ | 0,50 | 0,55 | 0,60 | 0,67 | 0,83 | 1,00 | 1,00 | 1,00 |
| $C_{1T}$ | 0,16 | 0,18 | 0,19 | 0,22 | 0,27 | 0,32 | 0,32 | 0,70 |
| $C_T$ | 0,16 | 0,18 | 0,19 | 0,22 | 0,27 | 0,32 | 0,32 | 0,70 |

**Rainfall**
Point precipitation (1-day design rainfall =, $P_T$)(mm)
Weather Station: Ladismith (TNK) 46479
Point intensity (mm/hr), $P_{iT} = P_T/T_c$
ARF (%) = $(90000 - 12800\ln A + 9830\ln t)^{0.4}$
Average intensity (mm/hr), $I_T = P_{iT} \times ARF_T$
Peak Flow ($m^3$/s) $Q_T = (C_T \times I_T \times A)/3.6$

**Alternative Rational**
M = 35 (2-year return period daily rainfall from TR102)
R = 10 (average number of days per year on which thunder was heard)

| **T** | 2 | 5 | 10 | 20 | 50 | 100 | 200 | PMF (Rat.)* |
|---|---|---|---|---|---|---|---|---|
| **$P_{t,T}$ (Alt Rational) $t_c$ < 6h** | 11 | 19 | 25 | 31 | 38 | 44 | 50 | |
| **$ARF_T$ (%)** | 116 | 116 | 116 | 116 | 116 | 116 | 116 | 0,98 |
| **$I_T$ (mm/h)** | 13 | 22 | 29 | 35 | 44 | 51 | 58 | 200 |
| **$Q_T$ ($m^3$/s)** | 0,1158 | 0,2149 | 0,3066 | 0,4231 | 0,6562 | 0,9109 | 1,0313 | 7,78 |
| **$Q_T$ (ℓ/s)** | 115,8 | 214,9 | 306,6 | 423,1 | 656,2 | 911 | 1031,3 | 7 778 |
| **$Q_T$ ($m^3$/h)** | 416,9 | 773,6 | 1103,9 | 1523,0 | 2362,1 | 3279 | 3712,6 | 28 000 |
| **Flood volume ($m^3$)** | 301,9 | 560,3 | 799,5 | 1103,1 | 1710,8 | 2375 | 2688,8 | 20 279 |
| **Flood/Dam cap.** | 0,43% | 0,80% | 1,14% | 1,58% | 2,44% | 3,39% | 3,84% | 28,97% |
| **Level rise (mm)** | 101 | 187 | 267 | 368 | 570 | 792 | 896 | 6 760 |

* Rational method employed for PMF

## Appendix B – Spillway Calculations

**PROJECT:** Bernardskloof Dam
**PROJECT NUMBER:** JB2091
**DATE:** 2021-11-02
**DESIGN:** JAB

## BROAD-CRESTED WEIR

$$Q = 0.327 * b * \sqrt{2 * g} * H^{3/2}$$

g = 9,810
μ = 0,327

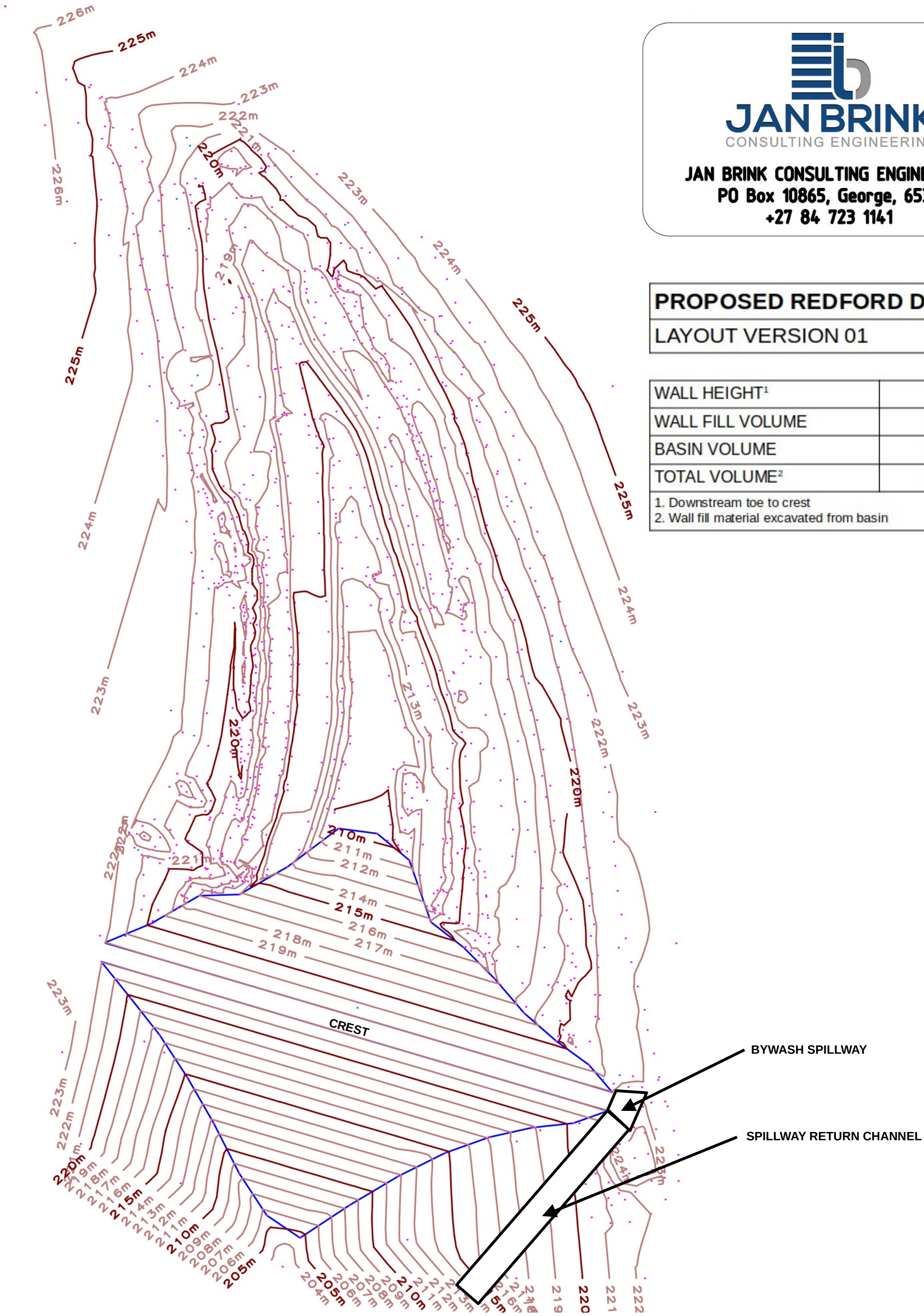
Select spillway length b and then use Goal Seek (Solver) to determine flow depth H to make calculated Q – Target Q = ΔQ = 0
(Same method can be used to select H and then determine required b)

| Target RDD = | | | 0,911 | | | | | |
|---|---|---|---|---|---|---|---|---|
| H = | 0,500 | 0,238 | 0,710 | 0,000 | 0,000 | 0,000 | 0,000 | m |
| b = | 1,779 | 5,400 | 15,000 | 0,000 | 0,000 | 0,000 | 0,000 | m |
| Q = | 0,911 | 0,911 | 13,000 | 0,000 | 0,000 | 0,000 | 0,000 | m³/s |
| ΔQ = | 0,000 | 0,000 | 12,089 | - 0,911 | - 0,911 | - 0,911 | - 0,911 | m³/s |
| | | 262 | -472 | 710 | 0 | 0 | 0 | |

| Target SEF = | | | 7,778 | | | | | |
|---|---|---|---|---|---|---|---|---|
| H = | 0,500 | 1,049 | 1,500 | 1,000 | 0,000 | 0,000 | 0,000 | m |
| b = | 15,189 | 5,000 | 2,923 | 5,370 | 0,000 | 0,000 | 0,000 | m |
| Q = | 7,778 | 7,778 | 7,778 | 7,778 | 0,000 | 0,000 | 0,000 | m³/s |
| ΔQ = | **0,000** | 0,000 | **0,000** | **0,000** | - 7,778 | - 7,778 | - 7,778 | m³/s |
| | | -549 | -451 | 500 | 1000 | 0 | 0 | |

**Result**
Select 5,4 m long spillway.
SEF flow depth will be 1,0 m
RDF flow depth = 0,24 m

## Appendix C – Drawings




JAN BRINK
CONSULTING ENGINEERING

JAN BRINK CONSULTING ENGINEERING
PO Box 10865, George, 6530
+27 84 723 1141

# PROPOSED REDFORD DAM

## LAYOUT VERSION 01

| | |
|---|---|
| WALL HEIGHT[1] | 17 m |
| WALL FILL VOLUME | 26 600 m³ |
| BASIN VOLUME | 46 600 m³ |
| TOTAL VOLUME[2] | 73 200 m³ |

1. Downstream toe to crest
2. Wall fill material excavated from basin