Groundwater Complete

SCHOONBERG 108: REPORT ON HYDROLOGICAL INVESTIGATION INTO THE ENLARGEMENT OF A STORAGE DAM

MARCH 2021

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LIST OF ABBREVIATIONS

ABBREVIATION		MEANING
mamsl	-	**Meters above mean sea level**
m^2/s	-	**Meter squared per second**
m^3	-	**Cubic meters**
l/s	-	**Litres per second**
km	-	**Kilometres**
ha	-	**Hectare**
DWS	-	**Department of water & sanitation**
I&APs	-	**Interested & affected persons**
MAP	-	**Mean annual precipitation**
WULA	-	**Water Use License Application**
mm/a	-	**millimetres per year**
SDF	-	**Standard Design Flood**
SCS	-	**Soil classification system**
WR90,12	-	**Water Resources 1990, 2012(update)**
GRA ii	-	**Groundwater Resource Assessment (mark ii)**
DWA	-	**Department of Water Affairs**
Cr	-	**Runoff Coefficient**

SCHOONBERG: REPORT ON HYDROLOGICAL INVESTIGATION INTO THE ENLARGEMENT OF A STORAGE DAM: MARCH 2021

EXECUTIVE SUMMARY:

Groundwater Complete was contracted to conduct a hydrological study and report on findings as specialist input to the water use license application (WULA) on the farm Lower Schoonberg 108, Western Cape (hereinafter referred to only as Schoonberg).

The storage capacity at full supply of Bosse Dam increased from approximately 59 450 m^3 to 163 000 m^3 while the existing lawful use is still only 59 450 m^3. In their letter dated 19 October 2020 the BGCMA indicates that the CSIR proposes that the Existing Lawful Use (ELU) for storage is 1 684 00 m^3 (for all three dams) and for taking water (abstracting) to the volume 200 000 m^3 per year.

The focus of this report is to determine the availability of water to the Bosse Dam, the ecological requirement down-stream from the dam and the effectivity of the enlargement of the dam.

The findings/conclusions of the hydrological study can be summarised as follows:

- The project area is located in the Outeniqua fynbos vegetation and Langkloof Renosterveld region in South Africa, however some of the catchment has been converted to agricultural land over the years.
- The catchment receives an average rainfall of about 370 mm/a estimated from measurements taken on the farm and correlating the data with longer term records.
- A dataset from WR2012 indicated that the MAR is about 5.7% of the rainfall. A range of between 5% and 15% was considered with 10% runoff applied as the most probable for the sub-catchment.
- The natural catchment size is approximately 2.95 km^2 in size, while the channelled catchment is about 1.71 km^2, bringing the total catchment feeding Bosse Dam to 4.66 km^2.
- The 50-year and 100-year flood peak predictions for the Bosse Dam are 37 m^3/s and 46 m^3/s, respectively.
- The mean annual runoff from the total Bosse Dam catchment was estimated to be between 67 800 m^3 (5%) and 203 300 m^3 (15%), while the natural and channelled catchments yielded an average of 85 800 m^3 and 49 700 m^3 (at 10%) respectively for a total of 135 500 m^3/a.
- The runoff values are subject to changes if measurements of actual runoff volumes indicate that a higher volume occurs in the catchment.
- The ecological reserve determination yielded the following results:
  - For most of the year, the reserve would constitute flow 0.02 l/s and 0.4 l/s, which no more water than what would already be naturally released from the dam seepage as a result of seepage through the wall.
  - A release was only recommended for August at a rate of 1,63 l/s and 1,36 l/s in September when it would be most beneficial and meaningful.

- The August and September releases would constitute around 11% of the flow from the catchment during that time.

- In spite of the seepage through the wall that would be similar to the ecological reserve for most of the year, installation of a bypass pipeline is recommended to divert 0.4 l/s from the inflow to the dam to the downstream catchment whenever runoff occurs. This water will constitute a liberal volume of release to sustain the downstream ecology if compared to the situation before the dam size was increased.
- Flow calculations show that despite the enlargement of the Bosse Dam, sufficient runoff is generated in the catchment to spill over the dam and ‘flood’ the stream below the dam.
- Dam size modelling indicated that due to enlargement of the dam, water security for the proposed horticulture development improved significantly and there is much less chance of the dam going dry.
- The Bosse Dam catchment produces less than 1% of the Kamanassie catchment’s total yield.
- The salinity increased due to evaporation of the water flowing out of the Bosse Dam after the increase of the dam size will be approximately 28.3% more than the corresponding increase due to the original dam size.

1 INTRODUCTION AND BACKGROUND

Groundwater Complete was contracted to conduct a hydrological study and report on findings as specialist input to the water use license application (WULA) on the farm Lower Schoonberg 108, Western Cape (hereinafter referred to only as Schoonberg).

A storage dam, mainly used for irrigation of pasture, has been in existence on the farm for more than a century. The dam – referred to as Bosse Dam – was recently cleaned out and rehabilitated while the overflow/spillway was also changed from the east side of the wall to the west side. During the cleaning operation, the dam size (storage capacity) was also increased without the necessary authorisations. The irrigation is also planned to be used in the irrigation of 25 hectares of fruit trees.

The focus of this hydrological investigation is on assessing the impact of increased dam size and availability of water from the catchment of the Bosse Dam.

The study area is located on the farm Schoonberg 1/108, which is situated approximately 16 kilometres due north of the small town of Hoekwil in the Western Cape Province. The water use at Schoonberg is primarily for irrigation. A map showing the location of Schoonberg is provided in **Figure 1**. Apart from Bosse Dam there are also two other dams in use at Schoonberg 1/108 but this study focused on the hydrology of Bosse Dam.

The storage capacity at full supply of Bosse Dam increased from approximately 59 450 m^3 to 163 000 m^3 while the existing lawful use is still only 59 450 m^3. In their letter dated 19 October 2020 the BGCMA indicates that the CSIR proposes that the Existing Lawful Use (ELU) for storage is 1 684 00 m^3 (for all three dams) and for taking water (abstracting) to the volume 2 191 500 m^3 per year.

The main aims with the study were to:

- Conduct a detailed analysis of temporal rainfall characteristics (distribution, intensity, flood peaks etc.) in the area.
- Estimate the mean annual run-off to the Bosse Dam from the sub-catchment as well as the annual run-off of the larger catchment into which the dam feeds.
- Do a run-off analysis and motivate an ecological reserve for scenarios as if the dam did not exist and compare the result with (1) the original dam size and (2) the current size after increasing the volume;
- Estimate the relative effect of the increased dam size of Bosse Dam on the downstream ecological reserve and water availability in the larger catchment.

After the study a sustainable average available volume will be recommended along with an ecological reserve.

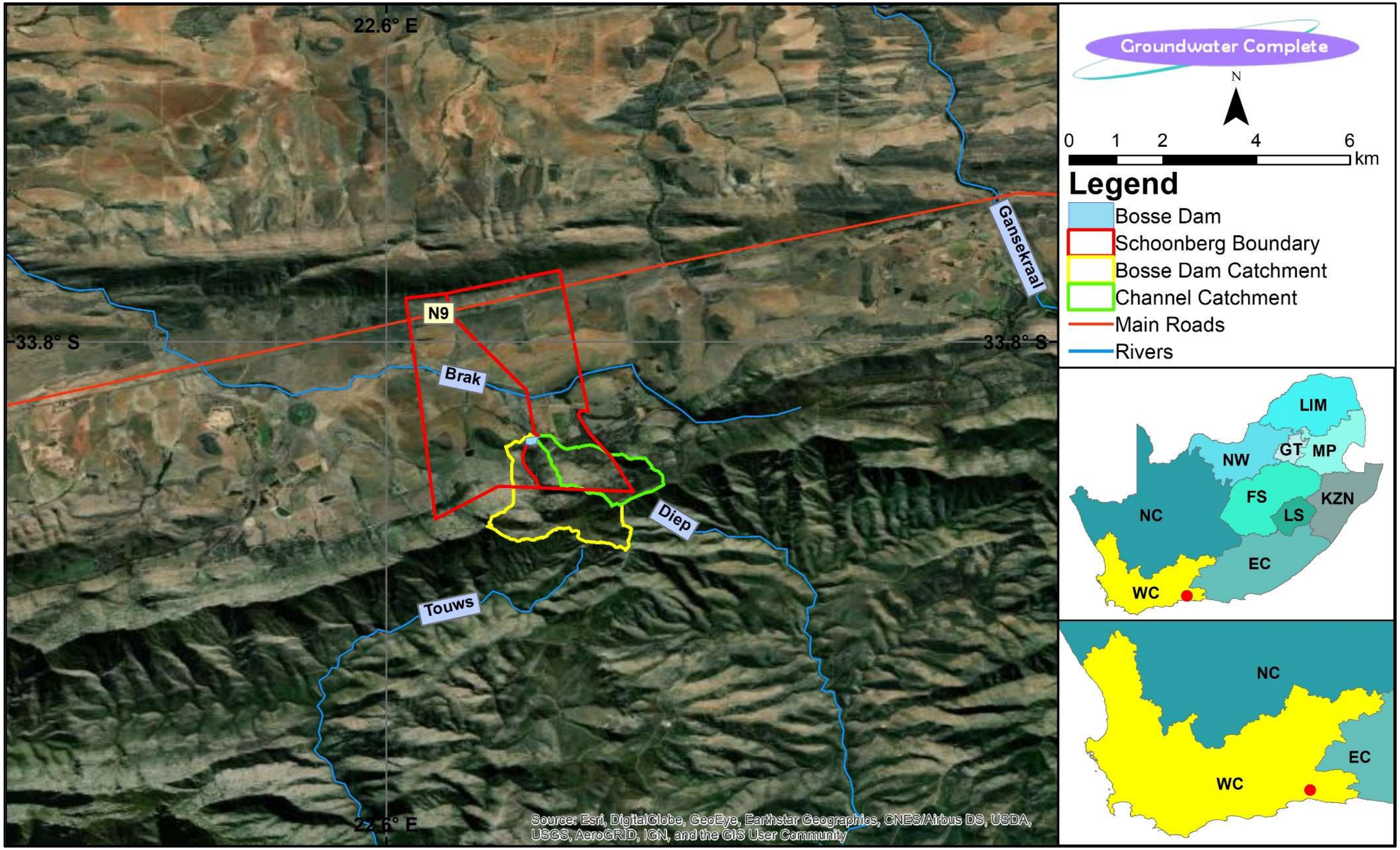

Figure 1: Locality map of the project area

2 GEOGRAPHICAL SETTING

2.1 SURFACE TOPOGRAPHY AND WATER COURSES

The study area is situated in the Klein Karoo region of the Western Cape, South Africa. Schoonberg is situated on the northern slopes of the Outeniqua Mountains, elevated about 600 meters above mean sea level (mamsl). Approximately 1.7 km south of the farm, the elevation increases to ±1110 mamsl. The topography slopes gradually downwards towards the north to ±500 mamsl in the Brak River valley.

The water courses in the area all flow primarily northwards, almost parallel to each other, away from the mountain. The streams in the Schoonberg area are all tributaries of the Brak River.

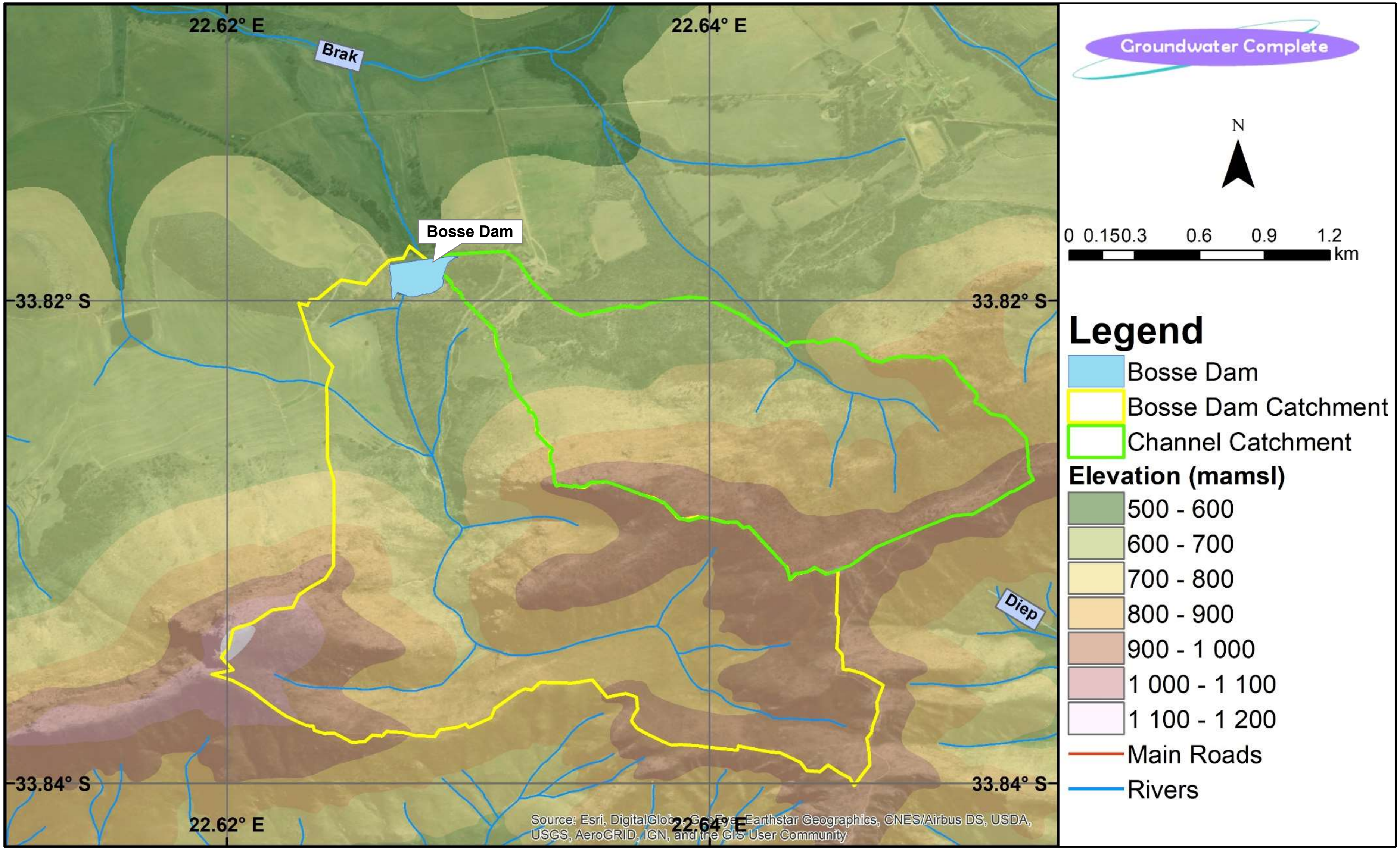

Figure 2: Surface elevations and water courses

2.2 CLIMATIC CONDITIONS

Schoonberg is located within a rainfall region that receives its annual rainfall almost evenly distributed throughout the year, with only a small increase towards the spring and early summer **(Figure 3)**. Daily rainfall records were kept on the farm for a 6-year period from 2014 to present. The monthly averages ranged from 11 mm to 67 mm. The average annual rainfall for the measured period is approximately 300 mm/a. The past five years have been a drier-than-normal rainfall cycle and the long-term average rainfall is probably higher.

It should be noted that the farm is situated in an area where the climate transitions significantly within a very small distance. If the climate is considered from south to north over the region, it changes from a very moderate climate and nearly 700 mm rain per year (at Hoekwil/Wilderness) at the coast to a cool, wet climate (900 mm per year rain) in die Outeniqua mountains just 15 km northwards. The northern slopes of the Outeniqua form a rain 'shadow' and over Schoonberg the climate becomes significantly warmer while the rainfall decreases to less than 350 mm/a. A further 10km northwards in the heart of the Klein Karoo the climate is hot and dry in summer with MAP of around 200 mm/a. Without accurate long-term on-site climate data, this sharp variation in climate leaves accurate hydrological modelling at a definite lower level of confidence.

Average daily temperatures vary from approximately 29 ºC in the summer to ± 19 ºC in the winter. Average nightly temperatures vary from approximately 16 ºC in the summer to ± 5 ºC in the winter **(Figure 4)**

Evapotranspiration is moderate (between 1 400 and 1 500 mm/a), but still resulting in an environmental moisture deficit throughout the year **(Figure 5)**.

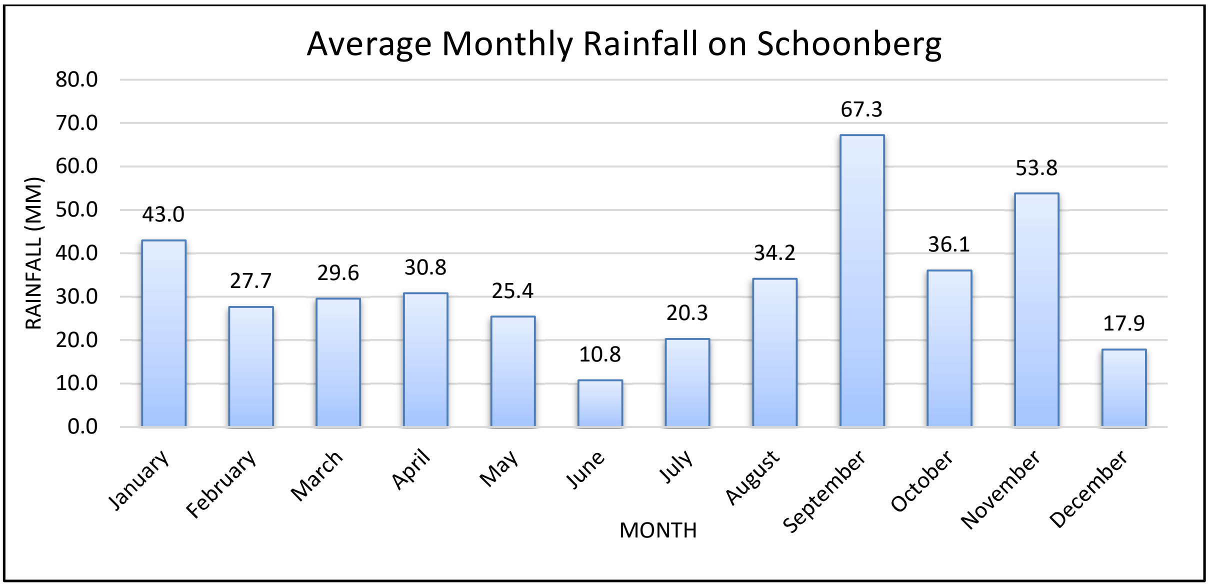

Figure 3: Average monthly rainfall measured on the farm.

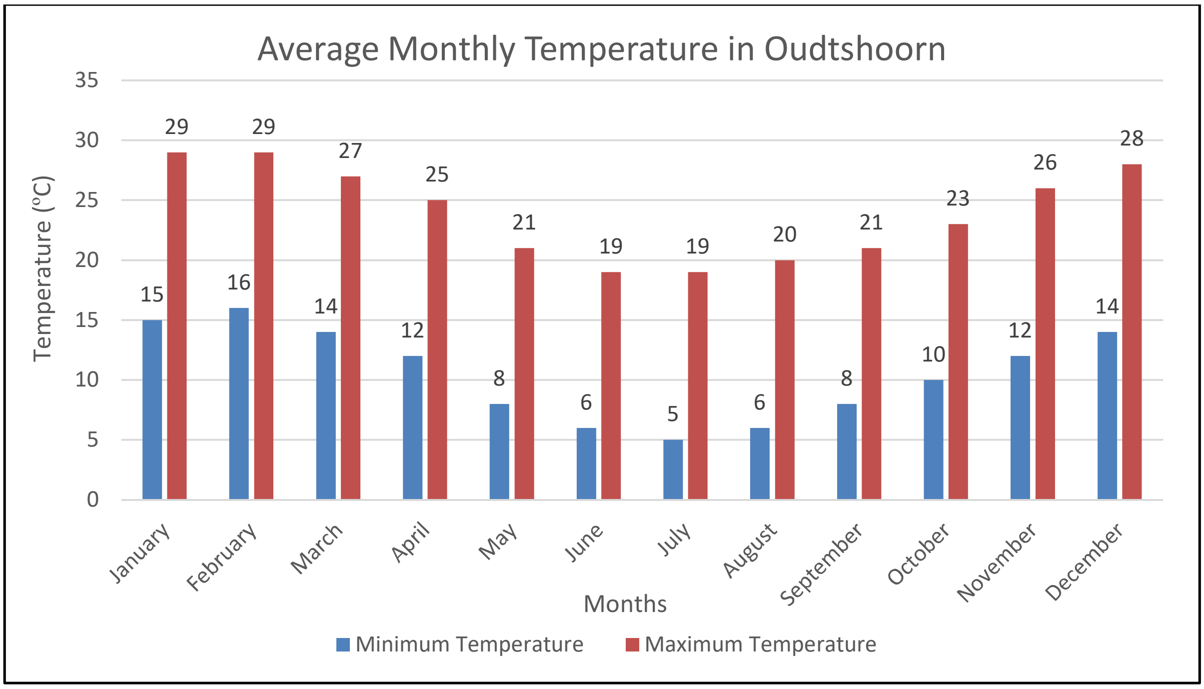

Figure 4: Average monthly temperatures for the Oudtshoorn area *(en.climate-data.org, 2020)*

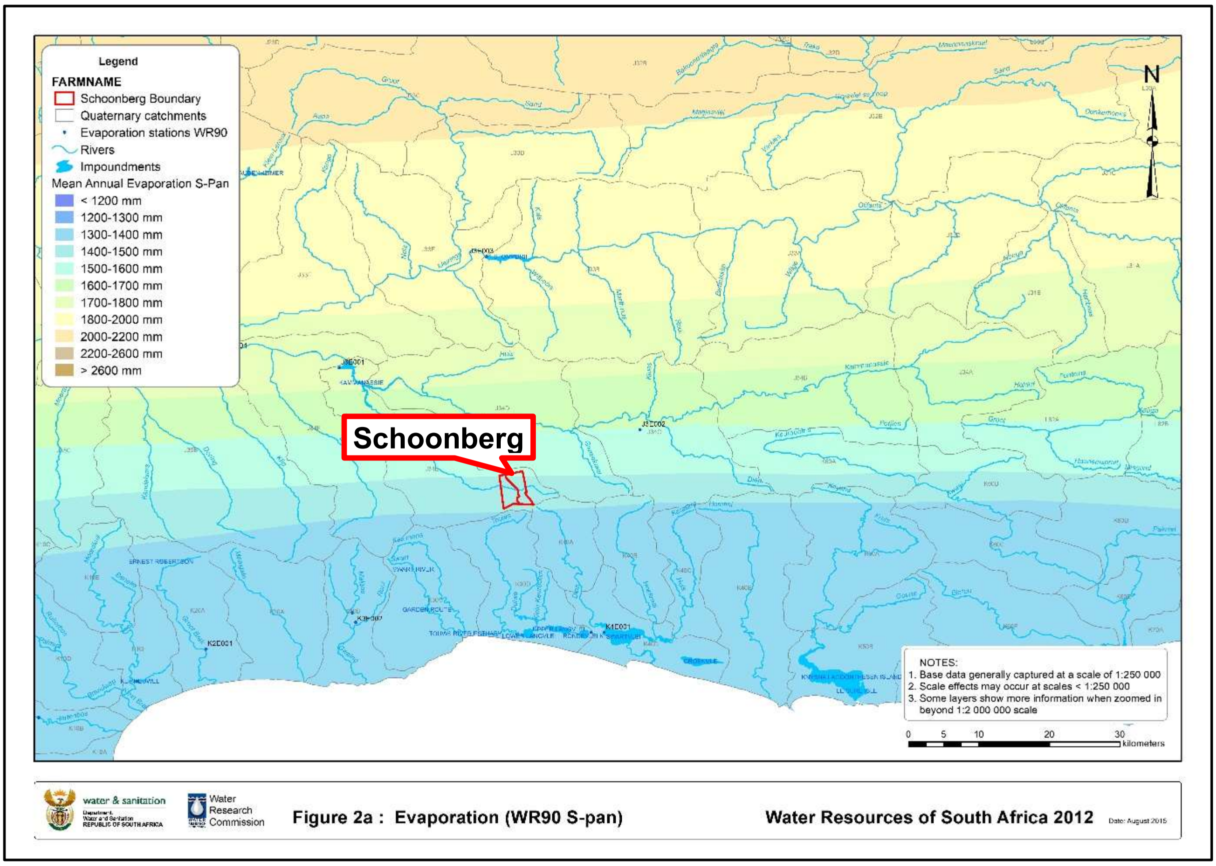

Figure 5: Mean annual evaporation for the project area *(WR90, 2012)*

3 METHODOLOGY

3.1 DESK STUDY

A Section 24G Rectification study according to the National Environmental Management Act (NEMA) was conducted on the Bosse Dam at the end of 2019. This study also prompted the current Water Use License application (WULA) process. **Aquatic assessment in terms of Section 24G of NEMA application for Bosse Dam, Lower Schoonberg Farm, Western Cape by Dabrowski (2019)** was used in the course of this study.

Existing 1:250 000 scale geological maps were also used during the assessment **(Figure 6)**.

3.2 HYDROCENSUS/USER SURVEY

No hydrocensus was conducted during this study.

From assessment of aerial photos and satellite images alone it is evident that no water flows from the Bosse Dam and there is currently no existing available water down-stream. Thus, there are no other users down-stream relying on the water from the Bosse Dam catchment. The main ‘user’ being considered in this report is the ecological aquatic ecosystem down-stream. The ecological reserve will be calculated as part of the study in tandem with aquatic and freshwater specialists.

4 PREVAILING CATCHMENT CONDITIONS

4.1 GEOLOGY

All geological information provided in this report was interpreted from the 1:250 000 scale geological map of the project area provided in **Figure 6**.

4.1.1 REGIONAL GEOLOGY

The project area is underlain by rocks from the Cape Supergroup and quaternary sediments. The lithology in the area is made up mostly of sedimentary rocks deformed by massive tectonic movement. The farm is located on a regional syncline with a roughly east-west fold axis.

The two younger formations – Gydo and Grahamstown – form part of the Bokkeveld shales and younger quaternary sediments, respectively.

4.1.2 LOCAL GEOLOGY

Schoonberg farm is located on Skurweberg, Baviaanskloof and Gydo. These are all geological groups and formations, part of the Cape Supergroup, except for Gydo which is a younger sediment. They are made up of sedimentary rocks like shale, mudstone, siltstone and sandstone.

The catchment areas straddle the Peninsula, Goudini, Skurweberg and Baviaanskloof formations. They are also part of the Cape Supergroup and consist mainly of shale and sandstone.

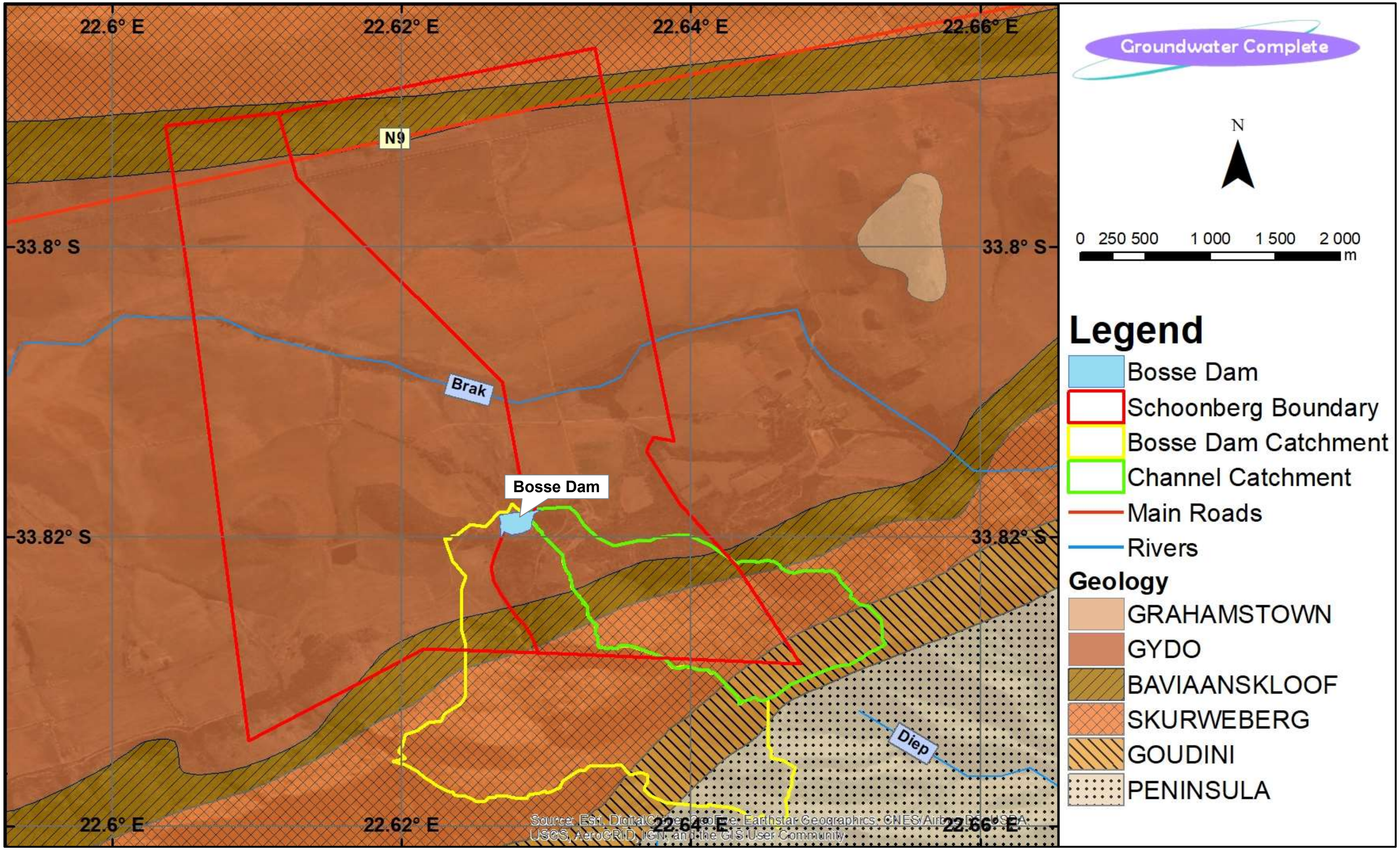

Figure 6: 1:250 000 scale geological map of the project area

4.2 CATCHMENT DELINEATION

The catchment of Bosse Dam consists of two separate hydrological systems. The first system is the natural watercourse conveying water from the mountain catchment to the Bosse Dam. The second system occurs to the east of the natural catchment: the water is conveyed from the northern face of the mountain and the neighbouring catchment via man-made channel, constructed many years (as long as a century) ago.

The catchment was delineated by using a digital elevation model to determine all the areas from which the water flows to a certain point. Topographical highs are identified as watersheds and make up the boundaries of the catchment. Topographical lows and shallows are identified as watercourses or riverbeds.

In this study the focus was on determination of the catchment area that feeds the Bosse Dam. The size, shape and slope of the catchment greatly influences the volume of runoff that reaches the Bosse Dam. In **Figure 7,** the dam and channel were selected as pour points (point where water runs from catchment) and the indicated areas are the areas that feed into the Bosse Dam.

The landcover for the catchment consists of a small section of farmland (about 3% of the natural Bosse Dam catchment) and mainly natural vegetation (Outeniqua fynbos vegetation and Langkloof Renosterveld this case). The river valley is mostly overgrown with the alien species of tree known locally as 'Black Wattle', which covers roughly 5% of the total Bosse Dam catchment area. The ecology and vegetation are further detailed in the freshwater specialist report: *Aquatic assessment in terms of Section 24G of NEMA application for Bosse Dam, Lower Schoonberg Farm, Western Cape* (Dabrowski, J., 2019).

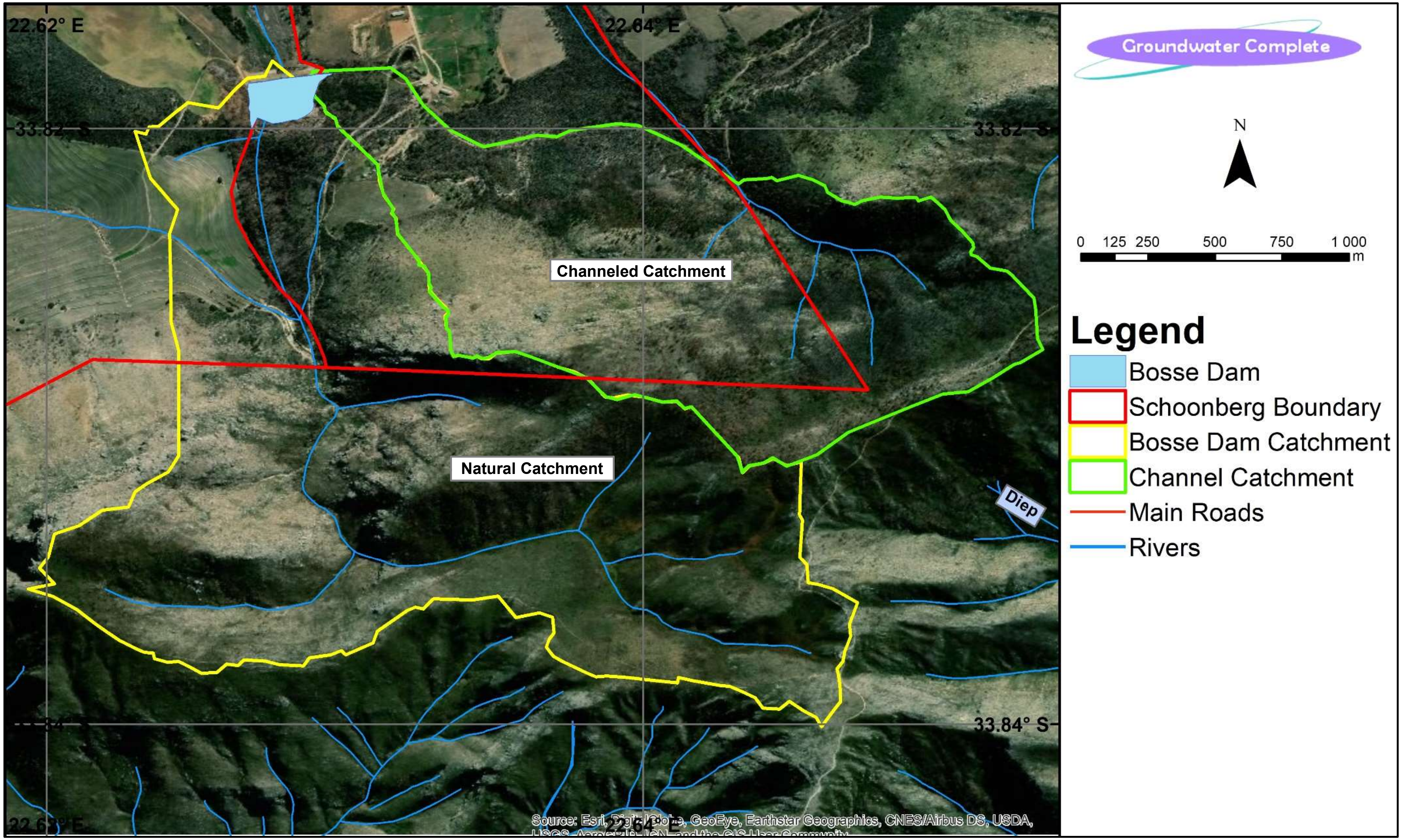

Figure 7: Catchment delineation for the Bosse Dam

5 HYDROLOGY

5.1 CATCHMENT PARAMETERS

The catchments are roughly elliptic-shaped areas to the south of the Bosse Dam **(Figure 7).** The catchments are located in the primary catchment of the Gouritz river (J) and in quaternary catchment J34E. The Bosse Dam catchment is situated in the hills mainly covered by Outeniqua fynbos vegetation and Langkloof Renosterveld but alien invasive species (e.g. Black Wattle *(Acacia mearnsii)*, Blue Gum *(Eucalyptus globulus)* and Australian Blackwood *(Acacia melanoxylon)* are also present, especially in the valleys. The most important hydrological catchment parameters are summarised in **Table 1**.

Calculations from the Rational, SDF and SCS-soils methods **(Table 1)** were used to determine the catchment hydrological parameters and run-off. These calculations are all available in the SANRAL drainage manual application guide (2013). Data was used from the WR12, WR90 and GRAii databases.

Table 1: Catchment Hydrological Parameters used in the Runoff Model

Parameter	Natural Catchment	Channelled Catchment	Total Catchment
Size	2.95 km^2	1.71 km^2	4.66 km^2
Average Slope	0.104	0.077	N/A
Longest water course	3.57 km	2.57 km	3.57 km
SCS soil type	C	C	C
Curve number	78	78	78
Time of concentration	25 min	22 min	25 min

5.2 CALIBRATION DATA

Daily rainfall data for Schoonberg farm is only available for the past 7-year period. It was used to determine the yearly average rainfall in the Schoonberg area. DWA rainfall station J3E001 is the nearest existing rainfall station with reliable long-term data. A ratio was determined of the rainfall measured at Schoonberg and the rainfall measured at J3E001 in the corresponding time period. The ratio was used to adjust the rainfall measured at J3E001 to assimilate the long-term rainfall at Schoonberg.

Please refer to the discussion of high variability of rainfall in **Section 2.2**. The limited period rainfall record on the farm was correlated with the longer period at J3E001 in order to make the most of the available information.

Daily rainfall data for station J3E001 is only available for a 20-year period but it was considered to be sufficient time for simulation of a representative average flood estimation as well as to determine the storage yield of the dam.

No weir or flow gauge data is available in either of the catchments that feed into the Bosse dam. Verification of calculated flows from the catchments in the Bosse dam comes from the WR2012 data base Mean Annual Runoff (MAR). According to the WR2012 the average runoff in the Bosse Dam region is approximately 16.7 mm/year. With an average annual rainfall of ±300 mm/year the runoff to rainfall ratio is thus around 5.7 %.

The WR2012 database, however, used an average runoff value for the whole catchment. The Bosse Dam catchments are located on the northern slops of the Outeniqua mountains and due to the steep slopes and slightly higher rainfall than the catchment in general, the runoff is expected to be higher than 5.7%.

5.3 50-YEAR & 100-YEAR FLOOD PREDICTIONS

Three different methods were used to determine the size of the 50-year and 100-year flood events, namely:

- The Standard Design Flood;
- The Rational; and
- Soil Conservation Service (SCS) method.

Table 2 indicates the different properties and applications for each of the flood prediction methods.

Table 2: Applications and limitations of flood prediction methods

Method	Input Data	Recommended max area (km^2)	Recommended return period
Rational Method (RM)	Catchment area, Watercourse length, Average slope, Catchment characteristics, Design rainfall estimation.	Usually < 15 km^2 but depends on the method of calculating rainfall intensity.	2-200 years
Standard Design flood Method (SDF)	Catchment area, Watercourse length, Average slope, SDF basin number.	No limit on catchment area.	2-200 years
SCS-SA Method	Design rainfall depth, Catchment area, Curve number, Catchment lag.	< 30 km^2	2-100 years

Each of the different methods used predicted flood peaks of different sizes:

- The RM and SDF methods predicted flood peaks of the same order of magnitude, which speaks to the reliability of the two methods.
- The RM method reported the highest flow rates, while the SCS method reported the lowest.
- These values were also applied as a further indicator to calibrate the runoff from normal rainfall events.

The flood peaks estimated with the various methods at different return periods (50 and 100 years) are summarised in **Table 3**. The rational method is commonly used and can be considered as a good representative value for the catchments. While the values calculated by the SDF method ca be considered as extreme maximum values.

Table 3: Results of estimated peak volumes

Method	Dam		Channel		Total	
Period	T50	T100	T50	T100	T50	T100
Unit	*m^3/s*	*m^3/s*	*m^3/s*	*m^3/s*	*m^3/s*	*m^3/s*
Rational	22.9	28.9	13.7	17.2	36.6	46.1
SDF	44.9	60.5	47.2	63.4	92.1	123.9
SCS	4.6	6.0	2.8	3.6	7.3	9.6

5.4 AVERAGE ANNUAL RUN-OFF ESTIMATION

The runoff is expected to be higher than the 5.7% of rainfall as reported by WR2012 **(Section 5.2)**. Based on experience in similar catchment slopes with calibrated flow values, three runoff coefficients were used to calculate a range of catchment runoffs for Bosse Dam, namely a minimum runoff (5%), a most probable runoff (10%) and a maximum runoff (15%). The mean annual runoff values are displayed in **Table 4**.

Please note that the runoff volumes calculated in **Table 4** are derived from data available at the time of the study. These numbers are subject to changes if measurements of actual runoff (which were not available or able to be measured during the study) volumes indicate that a higher volume occurs in the catchment. At present, available data and anecdotal reports support the calculated runoff values.

Table 4: Summary of run-off and catchment values for the Bosse Dam catchments

Catchment	Surface area (km^2)	Annual rainfall on catchment (m^3)	Conservative Annual run-off at Cr = 0.05	Most probable Annual run-off at Cr = 0.1	Liberal Annual run-off at Cr = 0.15
Natural Catchment	2.95	866 956.9	42 900	**85 800**	128 700
Channelled Catchment	1.71	502 541.1	24 900	**49 700**	74 600
Total Bosse Dam	4.66	1 369 500	67 800	**135 500**	203 300

5.5 IRRIGATION PLANNING

The proposed irrigation layout for the Schonberg farm was planned by Greenworld Irrigation. Schoonberg farm intends to develop 25 hectares of apple- and pear trees. A memo from Greenworld is attached as **Annexure A**.

According to the estimation by Greenworld, the irrigation of apple- and pear trees requires about 5000 m^3/ha/year. That adds up to about 125 000 m^3 of water per year. This water will be used more-or-less evenly throughout the year and will also depend on seasonal rainfall.

The planned method of irrigation is micro-drippers as it has the potential to save up to 30% of water compared to other irrigation methods.

6 IMPACT ASSESSMENT RELATED TO THE INCREASED SIZE OF BOSSE DAM

6.1 SETTING THE SCENE

Before discussing the impacts based on the modelled flow results it is first necessary to state what exactly the activities are that will be rated.

As stated earlier, the study is conducted as part of a Water Use License Application. The increased size of the Bosse Dam was not covered by a water use license amendment.

Impacts need to be determined (in concert with the freshwater ecology specialist) of the effect of the increased volume of the Bosse Dam in terms of:

- **The ecological reserve**
- **Effectiveness of the dam sizing**

Pre-existing lawful uses for Schoonberg and Bosse Dam:

- **Storage of water** (old order right) of approximately 59 450 m^3/a;
- **Taking of water** from the catchments of 200 000m^3, annually.

The capacity of the Bosse Dam was increased from 59 450 m^3 to 163 500 m^3 after 2016 without the necessary authorisation. When a Section 24G rectification study was prompted, the increased size without WUL amendment was included as a study requirement.

6.2 IMPACTS ON WATER QUANTITY

The main aspects considered in the impact assessment are the effects of the increased dam size on the reserve (when little or no flow occurs) and its effect on flood events.

The reserve is important since there must be water to sustain aquatic biodiversity in times when flow through the watercourse is limited, i.e. all available water cannot be removed from the watercourse.

Flood peaks are also important downstream from the study area to ensure that the periodic flooding occurs to scour and clean the downstream catchment as required in the natural physical and biological functioning of the watercourse.

The effect of the increased dam size in terms of storage efficiency will also be considered during natural rainfall periods.

The results of modelling and calculations to determine the impacts on the abovementioned aspects are discussed below in **Section 6.2.1, 6.2.2 and 6.2.3**.

6.2.1 MINIMUM WATER REQUIREMENT: DETERMINATION OF THE ECOLOGICAL RESERVE

The National Water Act (No.36 of 1998) (NWA) has been developed to fundamentally reform the law relating to water resources. A major innovation of the Act is the incorporation of the concept of the reserve. The Reserve consisted of two parts: "*Basic Human Needs Reserve*" and "*Ecological Reserve*". Implementation of the NWA requires that an ecological reserve be determined for all significant resources, with those for which development is planned receiving priority attention.

Ecological reserve determination is an estimation of the flow requirements of different components of a river. It focuses on the amount of water required to maintain the system in a particular ecological condition. As habitats for different life history stages of aquatic animals are related to hydraulic parameters such as flow velocity and flow depth, it is required that the amount of water should be converted into such parameters. Hydraulic analyses are the key link in the ecological flow determination.

Determination of the ecological flow is a multidisciplinary procedure that requires development of methodologies suitable for this estimation. As a result of work of many specialists, a generic seven-step RDM methodology has been developed, as described in Water Resources Protection Policy Implementation: Resource Directed Measures for Protection of Water Resources, was developed (DWAF, 1999a). The level of detail or intensity of RDM determination is closely related to the ecological importance and sensitivity of the water resource, the scale and degree of the impact of proposed water use, and the urgency of the Reserve determination. There are four levels of RDM determination:

- Desktop
- Rapid
- Intermediate
- Comprehensive

The principles required to provide hydraulic information for different Reserve determinations are the same, regardless of the level. The difference between rapid, intermediate and comprehensive assessment lies in the amount of measured hydraulic data, and therefore in the accuracy of and confidence in the results produced. As a relatively small catchment with a non-perennial watercourse, the rapid reserve determination level was used for the Bosse Dam catchment. It was determined using the revised desktop reserve model as a module in the SPATSIM software package.

The watercourse(s) feeding the Bosse Dam is strongly non-perennial. This means that the stream only flows for finite periods after rain has fallen in the catchment. For a more detailed discussion on the watercourse classification, ecological status and other characteristics, please refer to the report by the freshwater specialist: *Aquatic assessment in terms of Section 24G of NEMA application for Bosse Dam, Lower Schoonberg Farm, Western Cape* (Dabrowski, J., 2019).

The reserve determination was conducted by mr. Stephen Mallory of IWR Water Resources. The following results and conclusions followed from the assessment:

- For most of the year, the reserve would constitute flow 0.02 l/s and 0.4 l/s, which no more water than what would already be naturally released from the dam seepage as a result of seepage through the wall.

- A release was only recommended for August at a rate of 1,63 l/s and 1,36 l/s in September when it would be most beneficial and meaningful.

- The August and September releases would constitute around 11% of the flow from the catchment during that time.

6.2.2 OPTIONS FOR RELEASING THE ECOLOGICAL RESERVE:

The in-stream position of the Bosse Dam means that all water from the two catchments will report to the dam and only when it is full will water pass through (via the spillway) the dam to the downstream catchment. If the downstream aquatic ecology is to be maintained (or rehabilitated or the status be improved), water will need to be purposefully released to the stream below the Bosse Dam in times of low or median flow.

One way to accomplish this will be to implement a pipeline with intake just before the inlet of the dam which conveys water past the dam and discharges to the stream below the dam. Such a pipeline will allow some water to bypass the dam at intervals when natural run-off occurs from the non-perennial catchment. The run-off will thus feed the aquatic ecosystem below the dam at ‘natural’ intervals.

An offtake pipeline with capacity of 0.4 l/s is recommended for this purpose. This rate is in line with the high-end flows calculated during the reserve determination and constitute a liberal volume of release to sustain the downstream ecology if compared to the situation before the dam size was increased.

When the dam is full and excess water still occurs, the overflow over the spillway will provide water at higher volumes to simulate flood events from the catchment, albeit at lower frequencies than natural runoff.

6.2.3 FLOOD RELEASE REQUIREMENTS

The number of times per year that rainfall was sufficient to cause a spill over the Bosse Dam in the last seven years of complete and available data were estimated as in **Table 5**.

Please note that the use of the word ‘flood’ in this section does not indicate an exceptional or extreme flow event, but nearly all events when rainfall of sufficient depth and intensity occurs to cause significant volumes of run-off and flow into the Bosse Dam. The word ‘flow event’ could have been used to indicate the same phenomenon.

The number of spill events that would take place if the dam were still its original size (59 500 m3) are displayed in **Figure 8**.

Table 5: Floods estimated for the Bosse Dam

Year	No. of Spills	Summer	Winter
2014	1	1	0
2015	8	3	5
2016	0	0	0
2017	0	0	0
2018	6	4	2
2019	0	0	0
2020	0	0	0

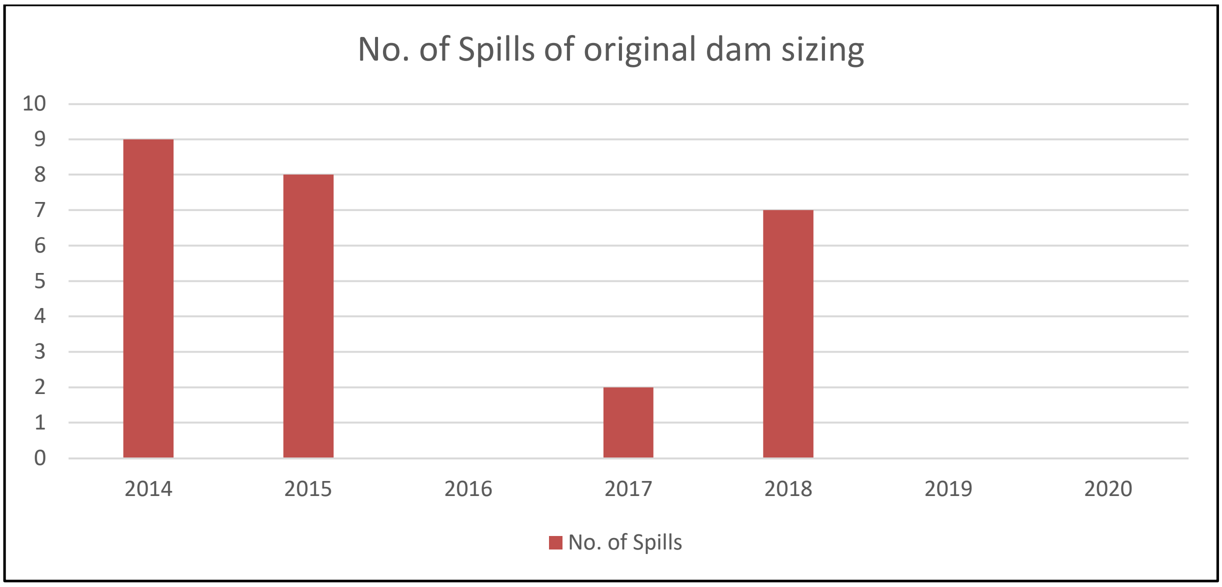

Figure 8: Number of spill-over floods in the past 7 years for original dam size

The flood events displayed in **Table 5** were obtained by calculating the number of times sufficient runoff was produced in the catchment to spill over the dam and 'flood' the stream below the dam.

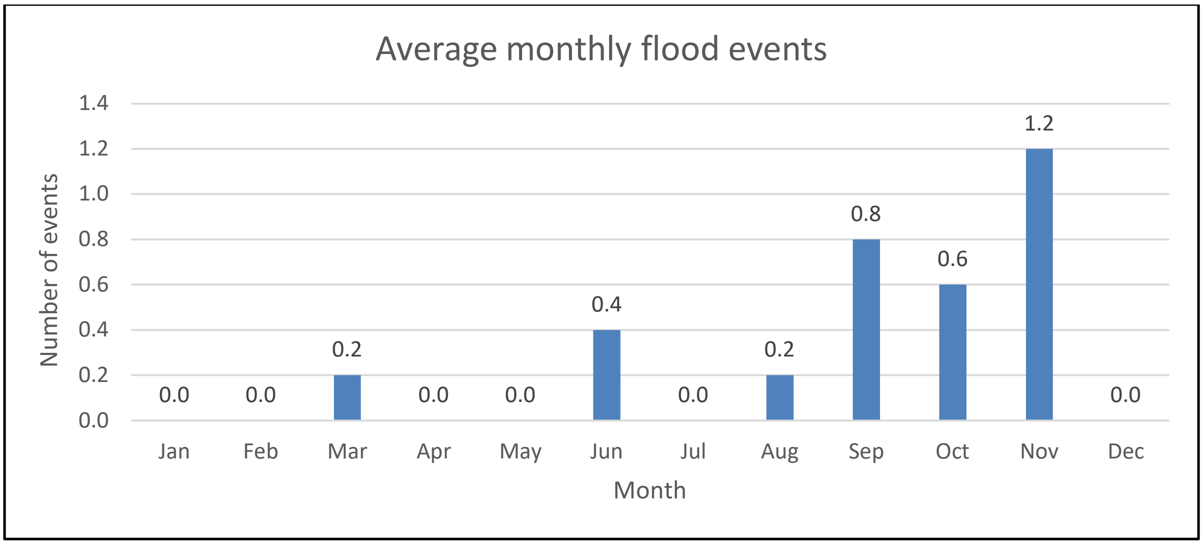

Figure 9: Average monthly spill events

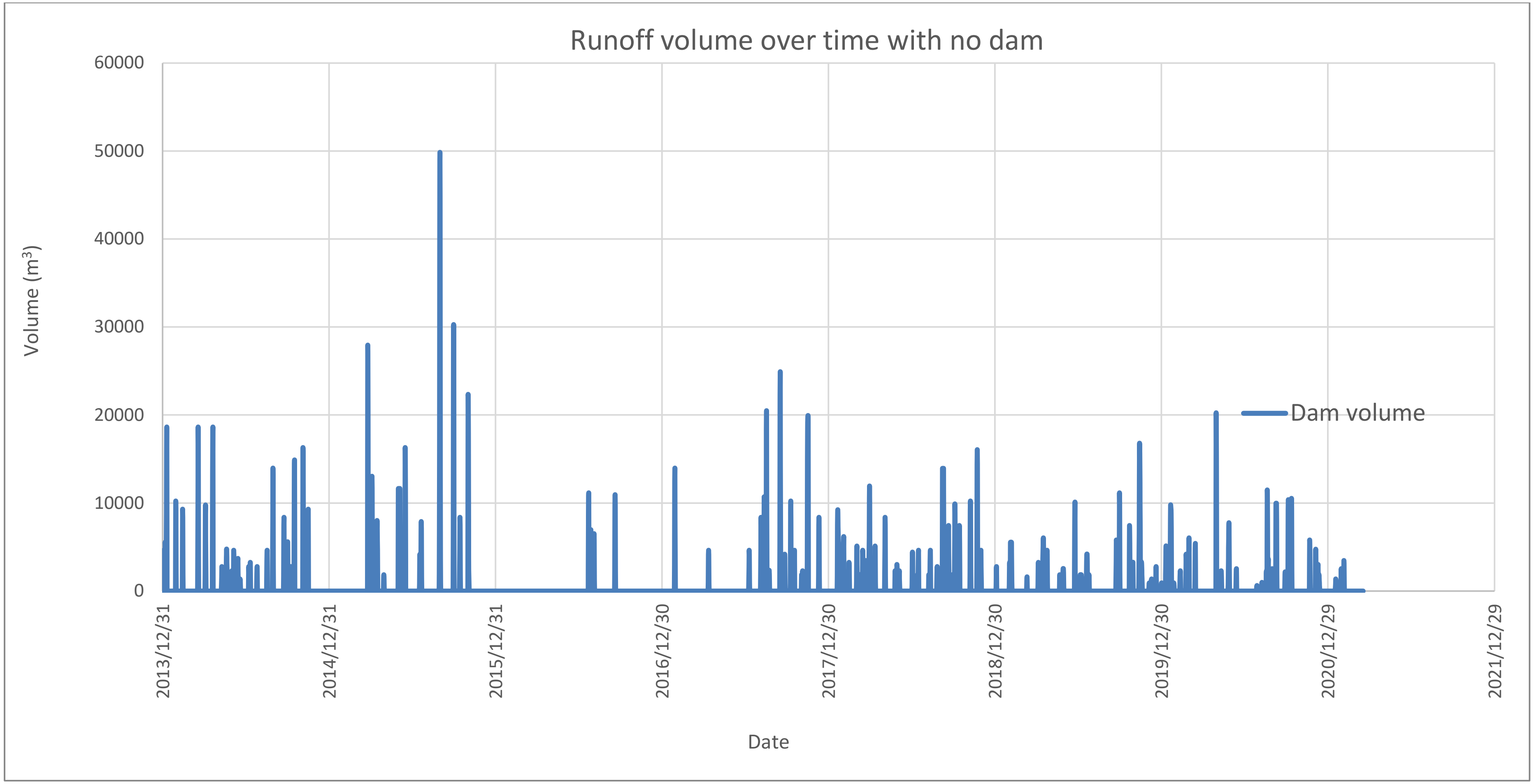

Figure 10: Runoff volumes over time modelled over 7 years from the catchments as if Bosse Dam was not present.

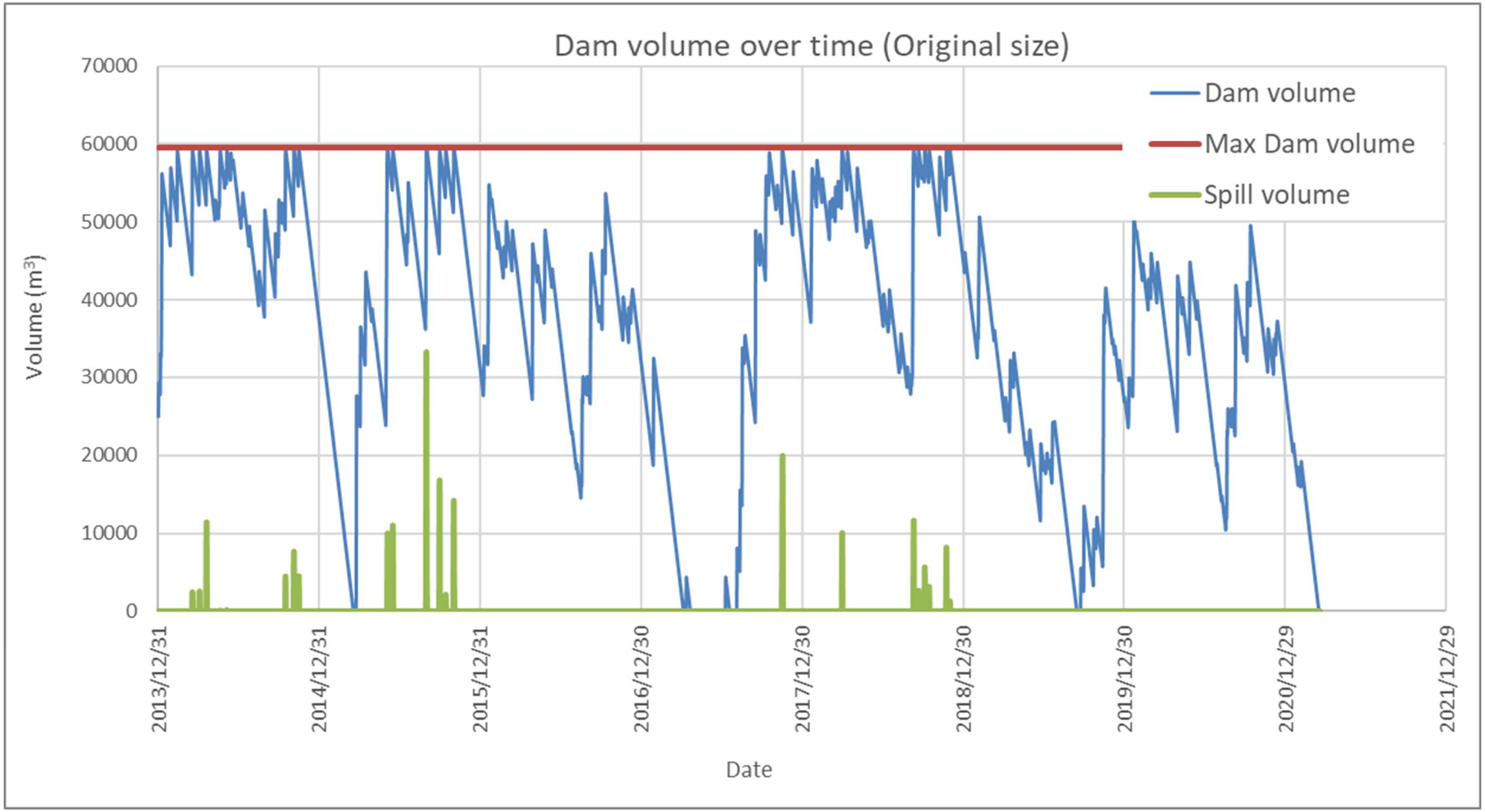

Figure 11: Volumes over time modelled over 7 years to the Bosse Dam with Spill-overs indicated with capacity before enlargement.

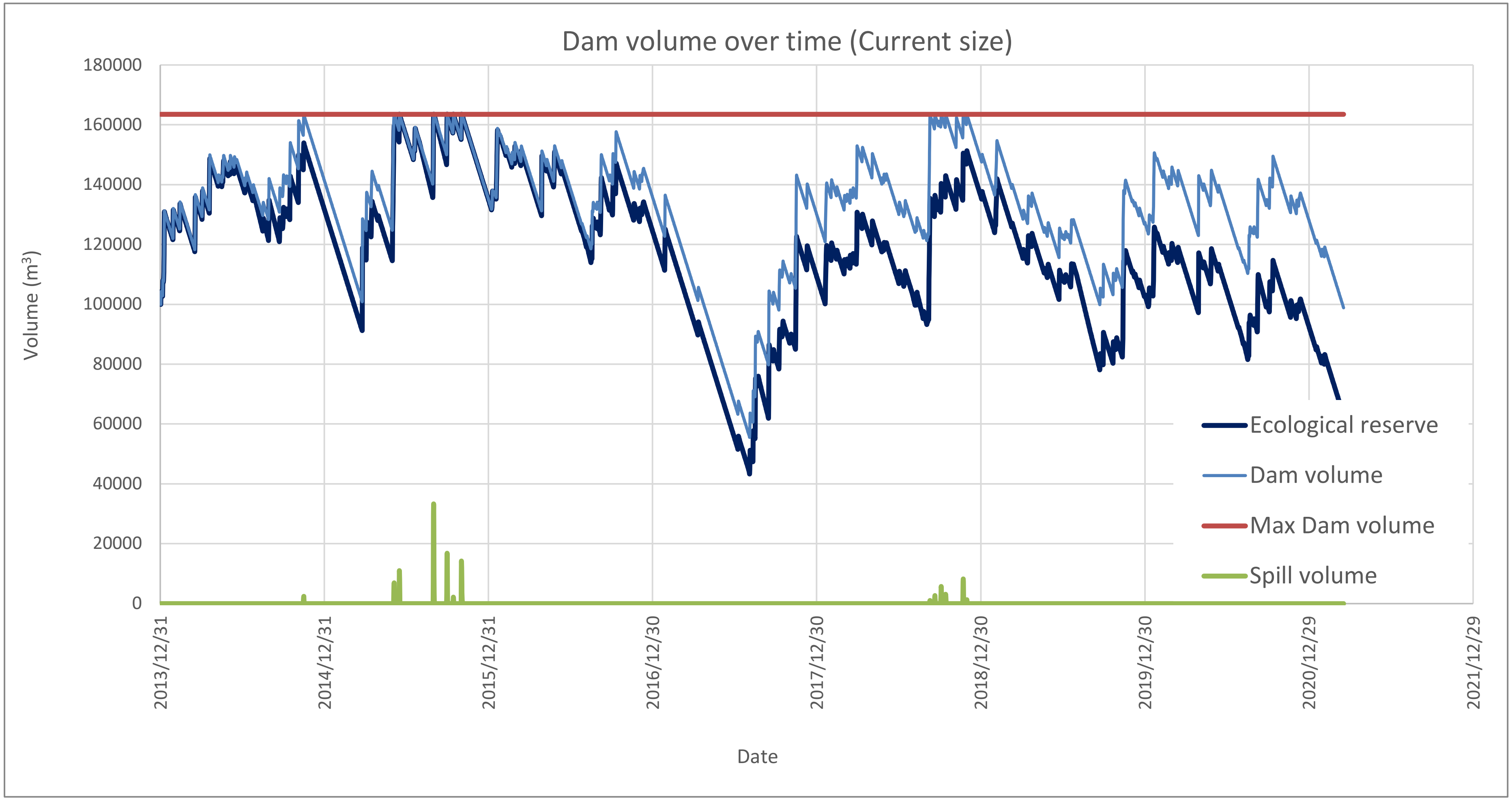

Figure 12: Volumes over time modelled over 7 years to the Bosse Dam with Spill-overs indicated with current Bosse Dam capacity.

6.2.4 DAM SIZING

The volume of the Bosse Dam was modelled for a period of 7-years to indicate the relative effect of the volume/size increase of the dam. **Figure 10, 11 and 12** succeed in showing the following:

- The original size of the dam was emptied completely four times during the modelling period.
- Because the enlargement, the current size dam will be sufficient not empty as easily during times of drought – the model showed that it would not have run empty once during the simulation period.
- In **Figure 12**, two different fluctuating dam volumes are displayed. For the **light blue** line in the graph, water off-take for the **ecological reserve** has **not been factored into the model** and the only factors removing water from the dam are **evaporation losses and irrigation** use.
- The **dark blue** line in the **Figure 12** graph (named: ecological reserve) shows the modelled dam volumes with irrigation, evaporation and the ecological reserve releases taken into account. The ecological reserve releases consist of the two components proposed in Section 6.2.1 and 6.2.2 above, namely (1) an offtake and release of 0.4 l/s whenever there is inflow throughout the year AND a continuous release of 1,63 l/s throughout August and 1,36 l/s throughout September.

Please note that evaporation from the dam surface **(Section 2.2)** was included in the calculations.

Through the enlargement of the dam, water security has increased greatly and the increase in dam size can therefore considered to be justified to ensure the sustainability of the proposed horticulture operation.

The simulated rainfall upon which the modelling was based, was measured during an exceptional dry cycle period and is likely to be representative of a worst-case scenario.

When included **(Figure 12)**, the ecological reserve has influence the modelled dam volumes and frequency and volumes of spill. However, the influence was only of minor consequence to the overall dam volume due to the enlarged size of the dam.

6.2.5 EVALUATION OF DOWNSTREAM IMPACTS

The catchment of the Kamanassie River into which the Bosse Dam drains, encompasses about 1 135km^2 and produces approximately 19 Mm^3 of runoff annually. At most, the Bosse Dam contributes 1% of the Kamanassie River's total water make.

For the past few decades, the watercourse below Bosse Dam has been overgrown with alien vegetation such as Blue Gum, Black Wattle and Blackwood trees. There has also been no controlled release from the Bosse Dam or catchment, except for whatever spills over from the dam in times of extreme flooding events. The original watercourse downstream of Bosse Dam has, for all practical intents, ceased to exist in the ecological sense of the word.

With interventions to divert a small portion of the inflow to the dam to the receiving downstream catchment whenever flow occurs as well as specific volumes during September and August, the watercourse downstream will receive a regular amount of flow from the catchment and, without the constraint of alien vegetation, be allowed to return to a significantly improved ecological state.

6.3 IMPACTS ON WATER QUALITY

The impact on water quality as a result of the enlargement of Basse Dam is expected to be minimal. The dam will mainly be used as storage for freshwater runoff for irrigation of crop on Schoonberg farm. A higher storage volume means longer static time for water in the dam during severe dry spells. This means longer time for evaporation and consequent increase of the salinity of the water in the dam.

The salinity increase as a result of storage in the dam was estimated for two scenarios, namely:

1. Before the dam size and volume was increased; and
2. For the increased surface area of the dam.

Equation 1 describes the expected increase in salinity as a result of the storage in the dam and removal of water through (very low salinity) evaporation from the dam surface.

Equation 1: Salinity increase through evaporation due to storage in the dam

$Q_{out} \times C_{out} = (Q_{in} \times C_{in}) - (Q_{evap} \times C_{evap})$

Where:

Q_{in} – Approximate annual inflow (135 500m^3)
C_{in} – Inflow concentration (assumed to be around 100 mg/l TDS**)
Q_{out} – Output flow (90 500 m^3)
C_{out} – Output Concentration (? Mg/l)
Q_{evap} – Approximate annual evaporation (45 000m^3)
C_{evap} – Evaporation concentration (5 mg/l**)

** *The salinity values/concentrations for the inflow to the dam and the evaporating water are estimations only based on water quality of similar waters in the region, used solely to obtain an expected percentage value.*

The original dam size would have led to a salinity increase to the order of 18.9% of the inflowing water salinity. The increased dam size would cause a further increase to 47.2% due to the increased evaporation surface area.

The estimations are based on the (worst case) assumption that the dams are operated at maximum capacity: if abstraction occurs and the dam is operated at lower levels, the surface area would decrease and the rate of evaporation would decrease concurrently. Similarly, the effect of salinity increase would lessen.

6.4 IMPACT MANAGEMENT AND MITIGATION OF THE PROPOSED ABSTRACTION

According to the runoff calculations and estimations the catchments of the Bosse Dam are currently capable of yielding approximately 135 500 m^3/year. The ecological requirement will be around 11% of the flow into the dam during the months of August and September.

If the proper amount of water is dedicated for release to support the downstream ecological requirement, the ecological status of the watercourse or wetland below Bosse Dam should show definite improvement in ecological status.

7 CONCLUSIONS AND RECOMMENDATIONS

The focus of this report is to determine the availability of water to the Bosse Dam, the ecological requirement down-stream from the dam and the effectivity of the enlargement of the dam.

The findings/conclusions of the hydrological study can be summarised as follows:

- The project area is located in the Outeniqua fynbos vegetation and Langkloof Renosterveld region in South Africa, however some of the catchment has been converted to agricultural land over the years.
- The catchment receives an average rainfall of about 370 mm/a estimated from measurements taken on the farm and correlating the data with longer term records.
- A dataset from WR2012 indicated that the MAR is about 5.7% of the rainfall. A range of between 5% and 15% was considered with 10% runoff applied as the most probable for the sub-catchment.
- The natural catchment size is approximately 2.95 km^2 in size, while the channelled catchment is about 1.71 km^2, bringing the total catchment feeding Bosse Dam to 4.66 km^2.
- The 50-year and 100-year flood peak predictions for the Bosse Dam are 37 m^3/s and 46 m^3/s, respectively.
- The mean annual runoff from the total Bosse Dam catchment was estimated to be between 67 800 m^3 (5%) and 203 300 m^3 (15%), while the natural and channelled catchments yielded an average of 85 800 m^3 and 49 700 m^3 (at 10%) respectively for a total of 135 500 m^3/a.
- The runoff values are subject to changes if measurements of actual runoff volumes indicate that a higher volume occurs in the catchment.
- The ecological reserve determination yielded the following results:
  - For most of the year, the reserve would constitute flow 0.02 and 0.4, which no more water than what would already be naturally released from the dam seepage as a result of seepage through the wall.
  - A release was only recommended for August at a rate of 1,63 l/s and 1,36 l/s in September when it would be most beneficial and meaningful.
  - The August and September releases would constitute around 11% of the flow from the catchment during that time.
- In spite of the seepage through the wall that would be similar to the ecological reserve for most of the year, installation of a bypass pipeline is recommended to divert 0.4 l/s from the inflow to the dam to the downstream catchment whenever runoff occurs. This water will constitute a liberal volume of release to sustain the downstream ecology if compared to the situation before the dam size was increased.
- Flow calculations show that despite the enlargement of the Bosse Dam, sufficient runoff is generated in the catchment to spill over the dam and ‘flood’ the stream below the dam.
- Dam size modelling indicated that due to enlargement of the dam, water security for the proposed horticulture development improved significantly and there is much less chance of the dam going dry.

- The Bosse Dam catchment produces less than 1% of the Kamanassie catchment's total yield.
- The salinity increased due to evaporation of the water flowing out of the Bosse Dam after the increase of the dam size will be approximately 28.3% more than the corresponding increase due to the original dam size.

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