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Verw: 1619DOV-S2

Datum: 26/02/2018

Harmony Trust
PO Box 415
6835 Ceres

Attention: Messrs Denzil van der Merwe & Hein Juries

PRELIMINARY DESIGN REPORT FOR THE PROPOSED NEW TOEKA DAM ON THE FARM HOUDENBEK 415, DISTRICT CERES, HARMONY TRUST

Our previous investigation, *ref 1619DOV-S1, dated 13 May 2016*, as well as your subsequent instruction to proceed with the preliminary design of the above mentioned dam, refers.

Note, this report should be read in conjunction with ***Prelim Design 1618DOV-S2: Harmony 266 Dam***.

1. BACKGROUND

The preliminary design of a dam normally follows after the scoping or feasibility stage during which the position, basic layout as well as the intended storage volume range along with the initial costing had been determined. This will then serve as the basis for the final dam design and contract specifications in line with dam safety regulations in terms of sections 117 to 123, chapter 12 of the National Water Act, 1998 (Act 36 of 1998).

In addition to the aforementioned, before a “License to Construct” can be issued, an environmental impact assessment, namely an *"Environmental Authorisation (EA)"* (previously referred to as the ROD) as well as a *“Water Use License”* have to be obtained from the respective authorities. In order to address these two aspects, a preliminary dam design is required containing specific technical information, which also then serve as a supplement to the specific applications.

The larger ***Harmony project*** entails the design and construction of two proposed instream dams, namely Harmony & Toeka Dams, with a combined provisional storage capacity in the order of **2 250 000m³**. Although both dams would be constructed on farm Houdenbek 415, the accompanying agricultural development would be for the neighbouring BBEEE farming entity, namely ***Harmony Trust***. The new development however, would entail about 75ha fruit orchards stretching over two properties, Houdenbek 415 and the neighbouring Winkelhaak 244, the property of ***Harmony Trust,*** refer to ***Appendix C*** regarding ownership. The two concerned owners are in agreement and will arrange the necessary legal agreements.

The proposed **Toeka Dam** will have a storage capacity of about **2 000 000m³** which will primarily be filled with water being pumped from the Houdenbeks River from the existing Houdenbek-Bo dam with a very small portion of runoff coming from its own catchment. In order to ensure that only winter surplus water would be abstracted, the existing Houdenbek-Bo dam will be utilised as a buffer dam within the river during flood periods while water will be pumped at a lower rate over a longer period.

The overall project focuses on expanding the existing BBEEE agricultural project, namely the ***Harmony Trust*** on the farm Winkelhaak 224. It is a combined project in conjunction with the proposed smaller Harmony 266 dam on the same property, *(refer 1618-DOV-S2, dated Feb 2018)*, whereby an additional 75ha of fruit orchards will be planted in addition to the existing 40ha of vegetables and pastures. This would benefit the existing BBBEE entity and more importantly also the broader economy by creating work opportunities for the previously disadvantaged groups.

Although fully based on new “takings” according to the Water Use Licence Application (WULA), none of the existing downstream uses will be affected negatively since regulatory mechanisms would ensure that only surplus winter water would be abstracted from the Houdenbek catchment.

The proposed site is located within the Koue Bokkeveld area about 15km east from the town, Op-die-Berg as the crow flies as shown in ***Appendix A.***

2. ASSIGNMENT

Sarel Bester Engineers has been appointed as the project engineer coordinating and overseeing the various actions and components regarding the design of the dam along with handling the Water Use Licensing Application (WULA).

Instruction and appointment was received to continue with the preliminary dam design stage for licensing purposes. Both the Environmental Impact Assessment (EIA) according to NEMA guidelines and the Water Use License Application (WULA) are currently in progress under the care of ***Messrs EnviroAfrica*** and ***Sarel Bester Engineers*** respectively.

The preliminary design normally follows after, and is partially based on the outcome from the scoping & feasibility study done by ourselves. The preferred envisaged storage capacity is however based on the site-survey done by *Messrs Boland Opmeting,* dated 9 Feb 2016. This assignment now takes it further by focussing on certain design aspects as well as certain legal implications including a first round of concept design drawings.

Surveyed data was converted to the WGS84 universal grid system in order to relate and overlay it onto the world map for referencing purposes.

The preliminary design process has checked, verified and updated information obtained from previous reports as and where required or applicable with regard to storage capacity, expected earthworks quantities as well as the costing of the project for this purpose.

The intention and purpose of the Preliminary Dam Design Report is and therefore will be used to:

- inform you as client of the concerned investigation regarding storage options along with provisional cost estimations,
- serve as supporting technical appendix to DWS for the water license application,
- serve as technical appendix to DEADP for the environmental impact assessment, and
- serve as a basis to Dam Safety Office for proper classification and APP matters.

3. APPLICATION & MOTIVATION

The Water Use Licence Application (WULA) as such including the relevant motivations is dealt with in full in a separate report compiled by ***Sarel Bester Engineers.***

The 100% black-owned applicant, *Harmony Trust* is planning to expand their current enterprise with fruit orchards for which **Toeka Dam** will store and supply water for **±66ha out of the total of 75ha**. The proposed new dam will ensure long term economic viability as well as sustainability of the present project by creating permanent jobs within the agricultural industry.

The dam site is located along a small tributary within the larger Houdenbek River catchment area upstream of the confluence of the Winkelhaak River into the Riet River which forms part of the larger Doring River, a tributary to the Olifants River system. Building a dam of this capacity should not have any noticeable impact on any of the downstream existing lawful water uses since the abstraction is purely based on surplus winter water.

Other relevant motivational information as required in terms of Section 27 of the National Water Act, forms part of and is included in the WULA to be compiled and submitted separately.

4. ALTERNATIVES

During 2016 *Messrs Van Breda & Associates* conducted a brief investigation on two sites respectively referred to as the "Droë" and "Toeka" dam sites located on the farm Houdenbek 415, being the property of the applicant's partners. The "Droë" dam site entailed raising an existing dam while "Toeka" dam site was a new instream site. A land survey of Toeka dam was done at a later stage by *Messrs Boland Opmeting*. Refer to ***Appendix B*** for detail.

The decisive factors are normally the basin characteristics with reference to available capacity versus demand, optimal costing of the works, risk factors, etc. In this case "Toeka" dam site is favoured as the preferred alternative of the two based on its cost effectiveness and storage capacity in relation to the sacrifice of potential production land over the foreseen sealing problems of the basin of "Droë" dam site. Refer to ***Appendix G*** for more information.

The *Table* below shows the key characteristics of the preferred site.

Table 1: Characteristic of Dam Site

Option:	Toeka Dam
Max wall height (m)	14.1
Crest length (m)	650
Total earthworks (m^3)	192 700
Nett storage capacity (m^3)	±2 000 000
Flooded area (ha)	36.9
Storage : Earthworks	10.6
Estimated Cost (R)	±R13.34mil

The above dam site does have a larger footprint compared to its respective alternative which does sacrifice some of the potential irrigation land to some extend. However, it does have other advantages such as lower wall heights requiring less earthmoving and disturbance resulting in more efficient storage ratios and hence better overall economics.

5. WATER AVAILABILITY

Although the newly proposed dam will be situated on the neighbouring property, namely Houdenbek 415, the water use will be executed on Harmony Trust's property, namely Winkelhaak 224. The idea is that although the dam site and part of the proposed orchard development will be on the neighbouring property, the farm will be subdivided and the concerned land will be consolidated with that of Winkelhaak 224, refer ***Appendix C*** for more information.

We have thus investigated and evaluated Winkelhaak 224 with regard to ownership as well as existing water uses (ELU's).

A) Existing Water Use Refer WUL (Licence no: B191/2/520/68):

- Taking: 400 000m^3
- Storage: 400 000m^3
- Existing Irrigation: 40 ha vegetables

B) Water Use Licence Application:

- New Irrigated Area — 66ha / 75ha fruit @ 9500m^3/ha/a
- New Irrigated Area **(#)** — 9ha / 75ha fruit @ 9500m3/ha/a
- New Taking — 627 000m^3 *(66 @ 9 500m^3/ha/a)*
- New Taking **(#)** — 85 500m^3 *(9 @ 9 500m^3/ha/a)*
- **New Storage** — **2 000 000m^3 *(This Report)***
- New Storage **(#)** — 250 000m^3 *(Report 1618DOV-S2)*
- **Total New Storage** — **2 250 000m^3 *(Toeka + Harmony 266)***

(#) Refer WULA in Prelim Design Report 1618DOV-S2: Harmony 266 Dam

Note, since the characteristics of this area is such that new water takings rely entirely on rapid flushes of surplus winter water available over a very short periods of time during which most of the available water runs past the point of abstraction, all water needs to be collected and abstracted within a 2-3 month window with a 3-4 year carry-over factor. This means that the yield of the dam is extremely low due to runoff patterns and implies that in order to execute such taking in the order of 627 000m^3, the storage should be about factor 3.2 larger.

6. DAM SAFETY & CLASSIFICATION

The project entails the proposed Toeka Dam and one of the first steps is to have the dam classified in terms of dam safety regulations. The application was submitted to the Dam Safety Office and Toeka Dam was classified on 30 Jan 2018 as a Medium size Category II dam with a Low hazard potential rating, refer ***Appendix D***.

Application for APP (Approved Professional Person) for the design and construction supervision of the dam will follow once the WUL has been issued.

7. ENVIRONMENTAL IMPACT

Government Notices R385, R386 & R387 of 21 April 2006, issued under Chapter 5 of the National Environmental Management Act, 1998 (Act 107 of 1998), also known as the "NEMA" procedures determine that Toeka Dam does in fact trigger certain environmental aspects and therefore qualifies for a full EIA study. The impact assessment and application is currently under way under the auspices of ***Messrs EnviroAfrica.*** The final application will be submitted during the second quarter of 2018 with the Environmental Authorisation (EA) expected end 2018.

8. EMPOWERMENT

The proposed project entails the further development of an existing 100% black-owned BBEEE farming entity, namely Harmony Trust, reference T2213/2003. They have been in the agricultural sector and trading successfully for the past 12 years with their neighbouring partner and mentor, ***Morester Boerdery***. The planning is to grow and irrigate an additional 75ha of fruit with this newly applied-for water use. For more detail please refer to the WULA, reference 1733.

9. STATUTORY REQUIREMENTS

Various other statutory requirements might be applicable or of importance depending on site specific conditions apart from the regulations already dealt with above.

In this case the proposed dam site is located in a sensitive area which might concern archaeological and/or heritage aspects. A site visit and proposed research studies are planned at this stage and we await the outcome thereof.

10. HYDROLOGY

The location of the dam site lies within the E21D quaternary catchment under the auspices and care of the Olifants/Doorn WMA. This is an in-stream dam situated within the tributary of Houdenbeksrivier being part of the upper reaches of the larger Olifants River draining into the ocean north from Strandfontein, as shown on ***Appendix E***.

The relevant catchment properties according to the WRC Report TT382/08 (WR2005), also available on GIS-website of Dept Agriculture in cooperation with Elsenburg, are shown in the table below.

Table 2 shows the local catchment information in relation to the quaternary drainage area:

Catchment (ELSENBURG Catchment Delineation Tool)	Quaternary	Local Catchment
Name / Description	**E21D**	**Toeka Dam**
Area [km²]	242.5	2.2
Mean Annual Rainfall (MAP) [mm]	627	482
Mean Annual Runoff (MAR) [mm]	190	97
Gross Average Runoff (MAR) [x 10^6 m³]	46	0.21

Table 3 reflects the water availability from the local runoff of the proposed dam:

WATER AVAILABILITY (ELSENBURG Catchment Delineation Tool)				
	QUATERNARY CATCHMENT	LOCAL CATCHMENT	HOUDENBEK CATCHMENT	
	E21D	Toeka	Houdenbek	
VIRGIN MAR	**46**	**0.21**	Refer Howard	**$x10^6m^3$**
- IFR (25%)		0.05	Refer Howard	$x10^6m^3$
- Existing Dams		0.00	Refer Howard	$x10^6m^3$
NETT MAR		**0.16**	**24.00**	**$x10^6m^3$**
- Available for Storage		0.16	24.00	$x10^6m^3$
- Proposed Storage		0.16	1.840	$x10^6m^3$
BALANCE		**0.00**	**22.16**	**$x10^6m^3$**

From the above figures it is concluded that after the IFR of about 25% has been released from the local stream, the available water (Nett MAR) from the local source is only about 160 000m^3 and since the target storage is in the order of 2 000 000m^3 the dam needs to be filled by pumping directly from the Houdenbeks River during flooding periods.

Note, we refer to a study done by ***Mr G Howard (Appendix I),*** dated February 2010, on the evaluation of the hydrology of certain rivers within the Koue Bokkeveld requested by the *Olifants/ Doorn Catchment Management.* In this report it is stated that the available MAR of the Houdenbeks River is approximately 24 Mm^3/a after the irrigation demand as well as the requested reserve has been protected. Most of this water volume comes down during winter flooding periods or short bursts of rain. The new water use application is thus based upon the abstraction of water during these peak surplus periods. However, the large storage volume is based upon the mentioned 30% statistical failure rate as well as the limiting factor of the pumping capacity. It is thus suggested that in general over a 2-3 year period a volume of about 2mill.m^3 should be potted up in order to ensure availability of irrigation water over 2-4 year wet/dry cycles in order to meet the annual demand of 712 500m^3 for the planned expansion of 75ha.

11. GEOLOGY

According to the Geological Survey of South Africa, the proposed site falls within the Bokkeveld and Witteberg Series all part of the larger Cape System. We refer to ***Appendix F***. These formations are described as follows:

- ***C2S2*** *– Shale, siltstone and thin fine-grained sandstone bands (fossiliferous)*
- ***C2S3*** *– Shale, siltstone and arenaceous shale and thin sandstone bands*
- ***C2Q2*** *– Quartzitic sandstone and graywacke*
- ***C2Q3*** *– Sandstone & argillaceous sandstone*
- ***G2S4*** *– Shale & siltstone (fossiliferous)*

From the geological investigation it was identified that a dip of formation is present north-west from the dam site, in the order of about 25 degrees in a south-eastern orientation. A geological fault or shift also exists east from the proposed site, in a northwest-southeast orientation. The dam basin sits on shale while the banks will have sandstone underneath and the relevant contact areas between the zones are unfortunately parallel to the flow direction. Contact plains and geological break lines tend to consist of severe disintegrated material which pose the potential for water to be redirected and as a result cause the dam to leak. In other words, it means that care must be taken when it comes to placement and sealing off the dam as such.

12. WR2005 SITE PROFILE

The Water Research Commission have recently published their updated study of the Water Resources of South Africa since the previous version thereof dated 1990. The updated report, *TT382/08 dated March 2009*, is well recommended by the Department and widely used throughout South Africa as basis when it comes to water management and development issues.

The *Table* below shows a summary of such characteristics or profile regarding the proposed dam site.

Figure	Property Description	Zone / Index / Value	Unit / Scale
Figure 0	Water Management Area	17 ~ Olifants-Doring	
Figure 1	Rainfall: MAR	400-500	[mm]
Figure 2a	Evaporation (WR90 S-pan)	1600-1700	[mm]
Figure 2b	Evaporation (A-pan)	2000 -2200	[mm]
Figure 3	Runoff: MAR	100-200	[mm]
Figure 4a	Landcover	Irrigated areas and sugarcane	
Figure 6	Simplified Geology (WR90)	Intercalated arenaceous and argillaceous strata	
Figure 7	Soils (WR90) [Depth / Texture / Relief]	Moderate to deep / Sandy loam / Steep	
Figure 8	Sediment (WR90) [Erodibility Index]	15 ~ Medium	**H**igh 1-8 **M**edium 9-15 **L**ow 16-20
Figure 9	Vegetation (Acocks Veld Types)	Sclerophyllous bush types	
Figure 10	EWR Management Class	Class E-F Not an acceptable class	[A-F]
Figure 11	Surface Water Quality - TDS	>2000	[mg/l]
Figure 12	Population Density	0-100	[People / km²]
DWAF GRA2 (2005)	Utilisable Groundwater Exploitation Potential	25 001 – 50 000	[m³/km²/a]

All of the above properties and/or characteristics are well within an acceptable range for when it comes to building a dam and the overall observation and interpretation thereof does not show any alarms as such regarding the design and construction of a dam of this nature.

13. CONCEPTUAL DESIGN

The project entails the design and construction of the proposed in-stream Toeka dam with a straight aligned zoned earthfill embankment across the valley including an open channel side spillway and outlet works under the embankment. Refer to ***Appendices G&H*** for more information.

A) Design Characteristics:
The proposed dam is considered an in-stream with the following characteristics:

Location:	32°59' 30.2"S 19°26' 27.8"E
TOEKA DAM	
Wall crest level (masl)	954.5
Full supply level (masl)	953.0
Lowest ground level (masl)	940.4
Max wall height (m)	14.1
Crest length (m)	650
Crest width (m)	4
Upstream slope	1 : 3
Downstream slope	1 : 2
Free board (m)	1.5
Embankment volume (m^3)	180 500
Total earthworks (m^3)	192 700
Nett storage capacity (m^3)	2 000 000
Flooded area (ha)	36.9
Total footprint (ha)	40.0

B) Foundation: Preliminary test pits and visual inspections show a topsoil layer up to ±0,3m thick on a sandy to silty unweathered sandstone material in the order of 1,5m to 4,0m deep on unweathered shale or sandstone bedrock formation. The formation in general is considered adequate and suitable for this type of structure.

C) Material investigation: No formal in-depth soil analyses had been done as yet. Other dams in the vicinity is constructed of similar material and their behaviour over time is considered adequate and stable. The more gravelly sandy material will be used as unselected mass fill within the up- and downstream embankment zones while the more clayey material will be incorporated into the central core and cut-off zones. Provisional estimates based on visual inspections of the proposed dam site suggests that the availability of material from the dam basin seems to be sufficient. Light dispersiveness is expected on these types of material based on general erosion marks elsewhere in the valley. However, this characteristic will be addressed formally in the final design by way of either chemical stabilisation, increased compaction or built-in sand filters or a combination thereof.

D) Embankment design: The overall layout is that of a straight aligned in-stream dam with a wall crest length of ±650m. The proposed internal embankment profile will be zoned with a selected clayey core and cut-off zones plus unselected up- and downstream mass earthfill zones protected by rip-rap against the upstream slope. Awaiting the outcome of the formal soil testing to be carried out for final design purposes, consideration will be given to the necessity and introduction of built-in sand drains. Due to the possibility of dispersiveness, the core and cut-off zones will be compacted to a higher density in the order of 98% Proctor. The planned maximum wall height is in the order of ±14m with the upstream slope provisionally set at 1v : 3h, the downstream slope at 1v : 2h and the crest width at 4m.

E) Drainage: Due to the height and the possibility of dispersiveness of materials based on experience from within the surrounding area and pending the outcome of the soil tests, the internal embankment profile might require an optional built-in drainage system in the form of a curtain drain on the downstream side of the core plus a blanket drain or strip drains evenly spaced over the downstream solumn area. Apart from this, drainage will also rely on the normal phreatic movement of moisture through the earthfill structure itself.

F) Stability: This aspect is considered part of the final design exercise when a complete slope and internal stability analysis will be conducted based on the results forthcoming from the soil testing. Pending the outcome of these results, including the stability calculations, the proposed profile has been evaluated against and based upon applicable statistics obtained from a database of dams without any obvious risks being identified at this stage. However, the final design will include a formal stability design based on finite element design models.

G) Outlet works: The outlet works is planned as a single ø700mm or alternatively a double ø500mm class 9 outlet pipe configuration in reinforced concrete with a flanged sluice-gate control valve and manifold system on the downstream side. On the upstream side one of the following alternatives will be considered and provided ranging between a stainless steel sieve, a type of sieve pipe on pedestals or custom built float units. The capacity is of importance which has to be sufficient for irrigation purposes as well as for emptying the dam or lowering the water level in case of an emergency condition, say within 10 to 30 days.

H) Spillway & Flood management: Toeka dam is an in-stream dam with uncontrolled inflow from a natural river catchment. The proposed spillway design entails an open channel or by-wash spillway with return channel provisionally planned on the right bank leading the flood water safely around the embankment end and away from the toe-line back into the stream bed at a more gentle slope. The erodibility index is 15 on a scale of 1 to 20 with 1 being high and 20 being low, in other words the index is classified as medium and we foresee an unlined return channel. The total freeboard is provisionally set at ±1,5m based on uncontrolled or natural inflow pattern.

I) Special Requirements: Releasing water for in-stream flow requirements (IFR) will most probably be a condition of the water use license with reference to compulsory auditing. In order to comply, the outlet of the dam will be equipped with a scour system including a calibrated measuring weir or device. This aspect is considered a specialised item and the design thereof will form part of the detail design once the WUL is obtained.

J) Maintenance and Operation: The dam is situated in a winter rainfall area and will primarily be filled during the winter season with water pumped from the Houdenbek River as well as a small amount coming from its own catchment area. The operation and supervision of the dam will take place under the direct control of the owners or delegated person on a seasonal cycle.

K) Specifications: The dam has been classified as a Medium size Category II dam with a Low hazard potential rating. Relevant and applicable specifications are envisaged for this purpose. It is recommended that the following standardized specifications be considered as basis and part of the construction contract:

- General Conditions of Contract for Construction Works (2010)
- SANS/SABS 1200AD: General (Small Dams)
- SANS/SABS 1200DE: Small Earth Dams
- SANS/SABS 1200GA: Concrete (Small Works)
- SANS/SABS 1200L: Medium Pressure Pipeline

14. QUALITY CONTROL

The site surveying, planning, design and construction supervision will be handled by personnel of *Sarel Bester Engineers*. Regular inspections and in-situ compaction tests will be conducted during the construction phase in order to ensure quality of workmanship in accordance with SABS/SANS standards.

15. DOWNSTREAM DEVELOPMENT

The proposed in-stream dam is located in a tributary nearly 1,5km upstream from the confluence with the Houdenbeks River. The potential flood area consists mainly of grazing fields before it joins the Houdenbeks River in which a larg dam is situated. About 5,5km downstream it confluence with Winkelhaak River to form the larger Riet River along which single isolated dwellings and minor roads do exist within the potential flood zone. The potential loss of life and expected economic damage is considered reasonable in accordance to the classification of the dam by Dam Safety Office (DSO).

16. COSTING

The estimated costing of the project is based on recent tender prices of similar type projects within the Western Cape region. The basic costing of the project was done by using related data from other projects and dividing the sum total of all the earthmoving and related costs by the sum total of all the bulk earthmoving volumes in order to obtain an all inclusive unit price for earthmoving. Additional allowance was then made for other costs such as overhead costs, concrete & outlet related costs as well as diverse & unforeseen cost items. These were all added up as the estimated project cost on the attached preliminary design evaluation sheets ***Appendix G*** as summarized below.

Description	Toeka Dam
Max Wall Height (m)	14.1
Total Earthmoving (m^3)	192 700
Nett Storage Capacity (m^3)	±2 000 000
Storage : Earthworks	10.6
Estimated Project Cost (R)	±R14.4mil

The figures above show storage ratios in the order of 10 which is considered very good when it comes to the economics of building a dam. Normally, dam sites are considered more viable or economical when the storage ratio is about 5 and higher.

In this case the earthworks costing was calculated at a basic rate of **±R45/m³** accounting for ±65% of the total cost which translates to an estimated project cost in the order of **R13,34mil**, excluding fees etc.

17. SUMMARY

Toeka dam is planned as an in-stream dam situated in a small tributary of the Houdenbeks River catchment within the larger Olifants River system. Although partly being filled by its local runoff, the main water source is winter surplus from the Houdenbeks River being pumped directly into Toeka dam. Thus, the water use license application is entirely based on new takings. Irrigation from the dam will mainly be by gravitation or by means of a pump system from the outlet of the dam onto surrounding fields.

The layout of the dam is planned as a straight aligned earthfill embankment across the valley. It will be equipped with an open side channel or by-wash spillway around the right flank as well as an outlet pipe under the embankment encased in concrete.

The proposed site is technically challenging with specific reference to the expected geotechnical conditions and consequential design requirements including the spillway cutting through the southern bank. The optimal positioning of various structural components is also influenced by the topographical characteristics of the site between the abutments on either side.

The application is based on new 'takings' thus meaning that the total irrigated area will expand by approximately 66ha out of a total of 75ha over a period of time.

The water use license application (WULA) for the 'taking' and 'storing' of water as well as the environmental impact assessment (EIA) have been initiated under the auspices of our offices and *EnviroAfrica* respectively. The purpose of this document is therefore also to provide certain technical information as part of the above applications to the various departments regarding the proposed works.

All taken into account given the technical challenges, with sound engineering the site is considered suitable for a dam of this nature.

18. APPENDIXES

A) Locality Map
B) Alternatives (Toeka & Droë)
C) Title Deed information (2x)
D) Classification Application, dated Jan 2018
E) HydrologyMap
F) Geology Map
G) Preliminary Design Evaluation: Quantities & Costing
H) Drawing 1619-S2-01: Contour Layout Plan & Sections
I) Hydrology Report ~ G Howard, Feb 2010

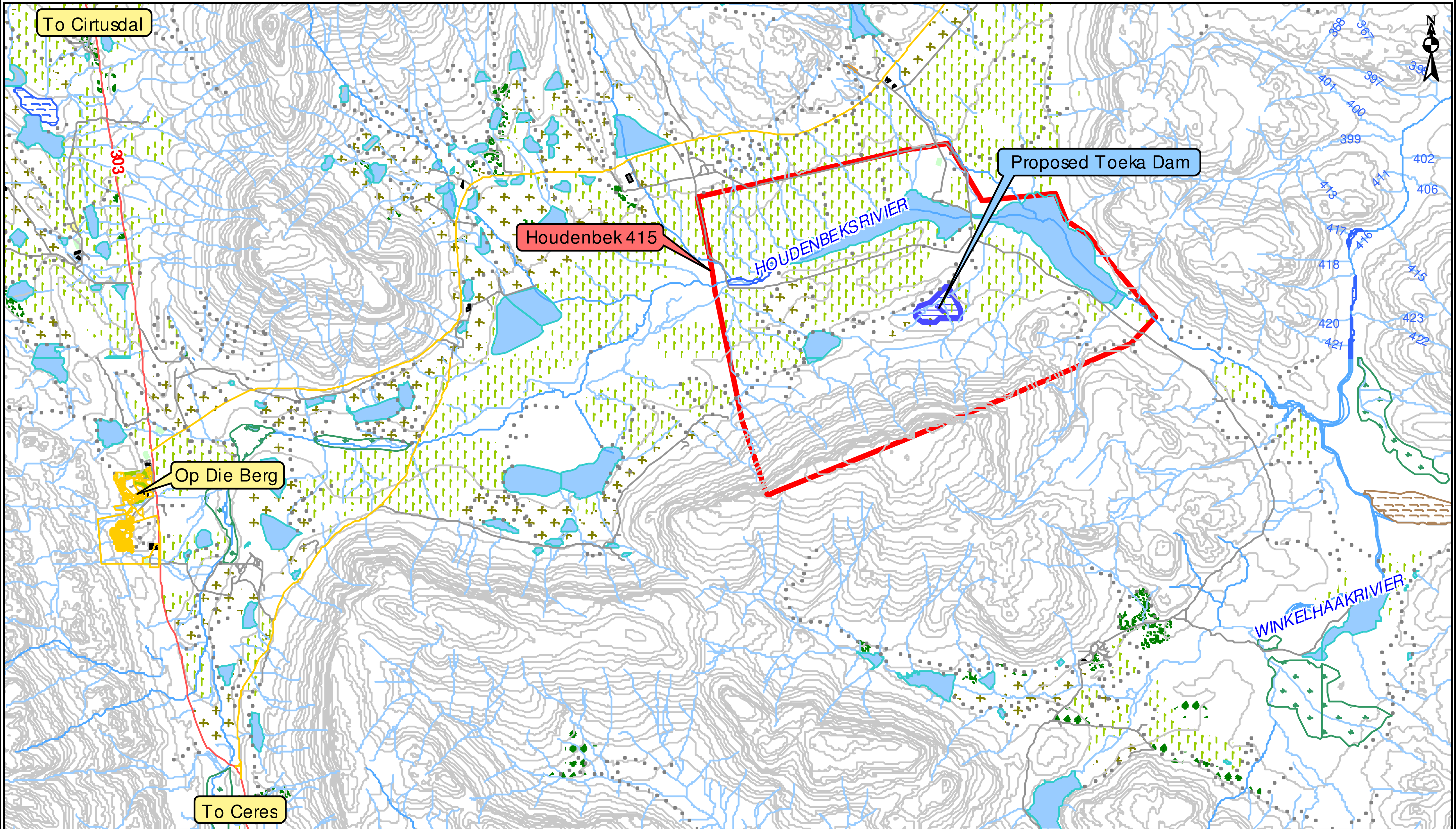
You are welcome to contact us in case of uncertainty about the contents or if more information is required about any aspect or component herein.

We trust that you will find the above in order.

Yours faithfully

M Charl Bester (Pr Ing)

Copies to:	Me Inge Erasmus, EnviroAfrica, Somerset-West Mr Dirk van Driel, Fresh Water Specialist



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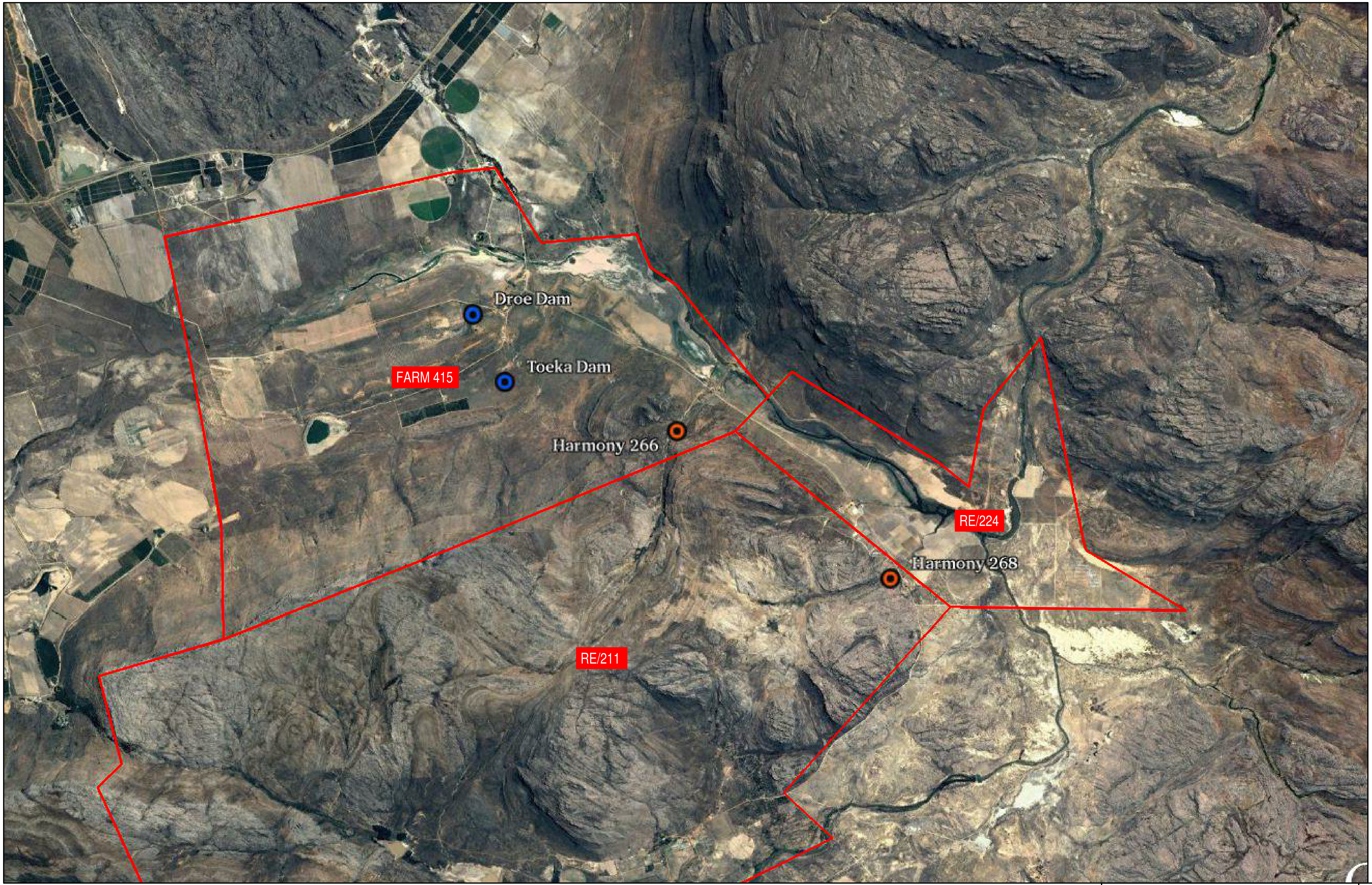
Client: MHB Trust PO Box 20 Kouebokkeveld 6836	Scale: 1: 75 000	Locality Map Toeka Dam
	Map Ref: 3219CD Ceres	Project Ref: 1619



A3

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CLIENT: Harmony Trust
PO Box 20
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6836

PROJECT: PROPOSED DAM SITES FOR TOEKA & HARMONY

DETAIL: Dam Options

DRAWN	DATE	SCALE	SHEET
R van der Merwe	FEB. 2018	1: 40 000	1 of 1
SURVEYED	**DESIGNED**	**DWG. NR.**	**REV.**
N/A	N/A	1733-01	

WinDeed Database Property Report

windeed
A LexisNexis® Product

WINKEL HAAK, 224, 0 (REMAINING EXTENT) (CAPE TOWN)

GENERAL INFORMATION

Date Requested	2017/05/11 17:02
Deeds Office	CAPE TOWN
Information Source	WINDEED DATABASE
Reference	1618

SearchInsure Activated

PROPERTY INFORMATION

Property Type	FARM
Farm Name	WINKEL HAAK
Farm Number	224
Portion Number	0 (REMAINING EXTENT)
Local Authority	WITZENBERG DC
Registration Division	CERES RD
Province	WESTERN CAPE
Diagram Deed	WOQ4PTI-27/1831
Extent	1084.3725H
Previous Description	-
LPI Code	C01900000000022400000

OWNER INFORMATION

Owner 1 of 1

Type	TRUST
Name	HARMONY TRUST
ID / Reg. Number	2213/2003
Title Deed	T22507/2006
Registration Date	2006/03/31
Purchase Price (R)	1,300,000
Purchase Date	2006/02/13
Share	0.00
Microfilm	2009 0131 4839
Multiple Properties	NO
Multiple Owners	NO

ENDORSEMENTS (2)

#	Document	Institution	Amount (R)	Microfilm
1	B50054/2008	NEDBANK LTD	1,000,000	2009 0130 3291
2	FARM CE 224	-	UNKNOWN	1985 0022 0205

HISTORIC DOCUMENTS (11)

#	Document	Owner	Amount (R)	Microfilm
1	T66085/1998	HARMONIE TRUST	1,100,000	2006 0950 2248
2	B1271/2003	LAND & LANDBOUBANK VAN SUID-AFRIKA	15,000,000	2008 0730 3288
3	B1272/2003	LAND & LANDBOUBANK VAN SUID-AFRIKA	10,000,000	2008 0730 3289
4	B6808/1999	-	UNKNOWN	2003 0064 4308
5	T2471/1963	KERSHOFF JOHANNES EDUARD	UNKNOWN	-
6	T27618/1982	KERSHOFF DANIEL JACOBUS	UNKNOWN	1998 0569 1961
7	T3336/1978	KERSHOFF JOHANNES EDUARD	UNKNOWN	1998 0569 1955
8	T66083/1998	KERSHOFF DANIEL JACOBUS	PARTITION	1998 0569 1973
9	T66083/1998	KERSHOFF MARIA ELIZABETH B-E	PARTITION	1998 0569 1973

10	B58050/2005	LAND & LANDBOU ONTWIKKELINGSBANK VAN SUID AFRIKA	3,944,000	2008 0730 3296
11	B31002/2006	LAND & LANDBOU ONTWIKKELINGSBAN	1,100,000	2008 0120 0048

WinDeed Database Property Report

windeed
A LexisNexis® Product

HOUDENBEK, 415, 0 (REMAINING EXTENT) (CAPE TOWN)

GENERAL INFORMATION

Date Requested	2017/05/11 13:00
Deeds Office	CAPE TOWN
Information Source	WINDEED DATABASE
Reference	1618

Activated SearchInsure Activated

PROPERTY INFORMATION

Property Type	FARM
Farm Name	HOUDENBEK
Farm Number	415
Portion Number	0 (REMAINING EXTENT)
Local Authority	WITZENBERG DC
Registration Division	CERES RD
Province	WESTERN CAPE
Diagram Deed	T19586/1975
Extent	2069.5132H
Previous Description	-
LPI Code	C01900000000041500000

OWNER INFORMATION

Owner 1 of 1

Type	TRUST
Name	M H B TRUST
ID / Reg. Number	239/87
Title Deed	T86941/1995
Registration Date	1995/11/22
Purchase Price (R)	1,226,000
Purchase Date	1995/09/26
Share	0.00
Microfilm	2008 0739 3257
Multiple Properties	NO
Multiple Owners	NO

ENDORSEMENTS (6)

#	Document	Institution	Amount (R)	Microfilm
1	I-6241/2004LG	-	UNKNOWN	-
2	B51458/2008	NEDBANK LTD	50,000,000	2009 0170 1934
3	FARM CE 415	-	UNKNOWN	1985 0022 1505
4	FROM CE RD 182,220,1	82/2	UNKNOWN	-
5	B16970/2013	NEDBANK LTD	10,000,000	-
6	B3769/2015	NEDBANK LTD	25,000,000	-

HISTORIC DOCUMENTS (9)

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1	B1271/2003	LAND & LANDBOUBANK VAN SUID-AFRIKA	15,000,000	2008 0730 3288
2	B1272/2003	LAND & LANDBOUBANK VAN SUID-AFRIKA	10,000,000	2008 0730 3289
3	B6808/1999	-	UNKNOWN	2003 0064 4308
4	B78006/1995	ABSA BANK	UNKNOWN	2003 0064 4302
5	B79329/1997	LANDBANK	UNKNOWN	2003 0064 4305

6	T19586/1975	MERWE ALWYN IGNATIUS VAN DER	UNKNOWN	1995 1013 2019
7	B58050/2005	LAND & LANDBOU ONTWIKKELINGSBANK VAN SUID AFRIKA	3,944,000	2008 0730 3296
8	B118864/2006	LAND & LANDBOU ONTWIKKELINGSBANK VAN SUID AFRIKA	6,000,000	2008 0730 3298
9	B118863/2006	LAND & LANDBOU ONTWIKKELINGSBANK VAN SUID AFRIKA	2,000,000	2008 0730 3297

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Private Bag X313, PRETORIA, 0001. Sedibeng Building 185, Francis Baard Street, PRETORIA, 0001.
Tel: +27 12 336 7500 www.dws.gov.za

Ms L A Modise
(012) 336-7758
12/2/E201/FG

modisel@dws.gov.za

Trustee
MHB Trust
P O Box 415
CERES
6835

ATTENTION: MR D VAN DER MERWE (Email: denzil@morester.co.za)

Sir

CLASSIFICATION OF DAM WITH A SAFETY RISK IN TERMS OF CHAPTER 12 OF THE NATIONAL WATER ACT, 1998 (ACT 36 OF 1998) READ WITH REGULATIONS 2 AND 3 OF THE REGULATIONS PUBLISHED IN GOVERNMENT NOTICE R. 139 OF 24 FEBRUARY 2012: PROPOSED TOEKA DAM ON THE REMAINING EXTENT OF PORTION 0 OF THE FARM HOUDENBEK 415, DIVISION OF CERES

A. APPLICATION

The application received from Mr Charl Bester of firm Sarel Bester Ingenieurs Bk, dated 31 July 2017, refers.

B. CLASSIFICATION

1. The classification of the **Proposed Toeka Dam** is as follows:

Vertical wall height Storage capacity	13,5 meters 2 000 000 cubic meters
Size classification Hazard potential rating Category	Medium Low II

2. The classification is based on available information. If you have any information on the basis of which you feel the classification is incorrect, you should submit a substantiated application in writing for its revision.

C. REQUIREMENTS FOR CONSTRUCTING DAMS WITH A SAFETY RISK

1. No construction work as stipulated in regulation 4, 10 to 22 of the said regulations may commence before the following appropriate steps have been followed:

1.1 In terms of Regulation 4(1), no person who intends to construct dams with a safety risk, may begin any construction work, before he is in possession of a **licence to construct**, issued by the Director-General (Dam Safety Regulation (Office)).

12/2/E201/FG

1.2 In terms of Regulation 10, any person who intends to construct a Category II dam, so that the completed dam can be classified as a Category II dam, must-

1.2.1 Acquire the services of an approved professional person to design the proposed projects and to draw up plans and specifications for it.

1.2.2 Apply on an official application form (DW695E available on the website: www.dws.gov.za/DSO) for a licence to **construct**, by submitting to the Director-General (Dam Safety Regulation (Office)) a proposed design complying with acceptable dam engineering practices and criteria as set out in Regulation 10 to 14.

2. In terms of Regulation 4(2) you have to obtain a water use licence before the dam safety licence to construct/alter/enlarge could be issued.

3. In terms of Regulation 25 an application for a licence to impound after completion of the dam on the form (DW696E) must be submitted. Impoundment of water in the dams may not commence until you are in possession of a licence to impound issued by this Department.

4. In terms of section 120 of the National Water Act, 1998, the dams must be registered at the Dam Safety Regulation (Office)) of this Department within 120 days of the date on which the dam become capable of containing, storing or impounding water. The form (DW693E) must be completed and submitted to the Dam Safety Regulation (Office)) for this purpose.

D. THIS LETTER SHALL NOT BE CONSTRUED AS CONFERRING EXEMPTION FROM COMPLIANCE WITH THE FOLLOWING:

1. The provisions of Chapter 4 of the National Water Act, 1998 pertaining to the lawful water use. Address enquiries and applications in this regard to the following address:

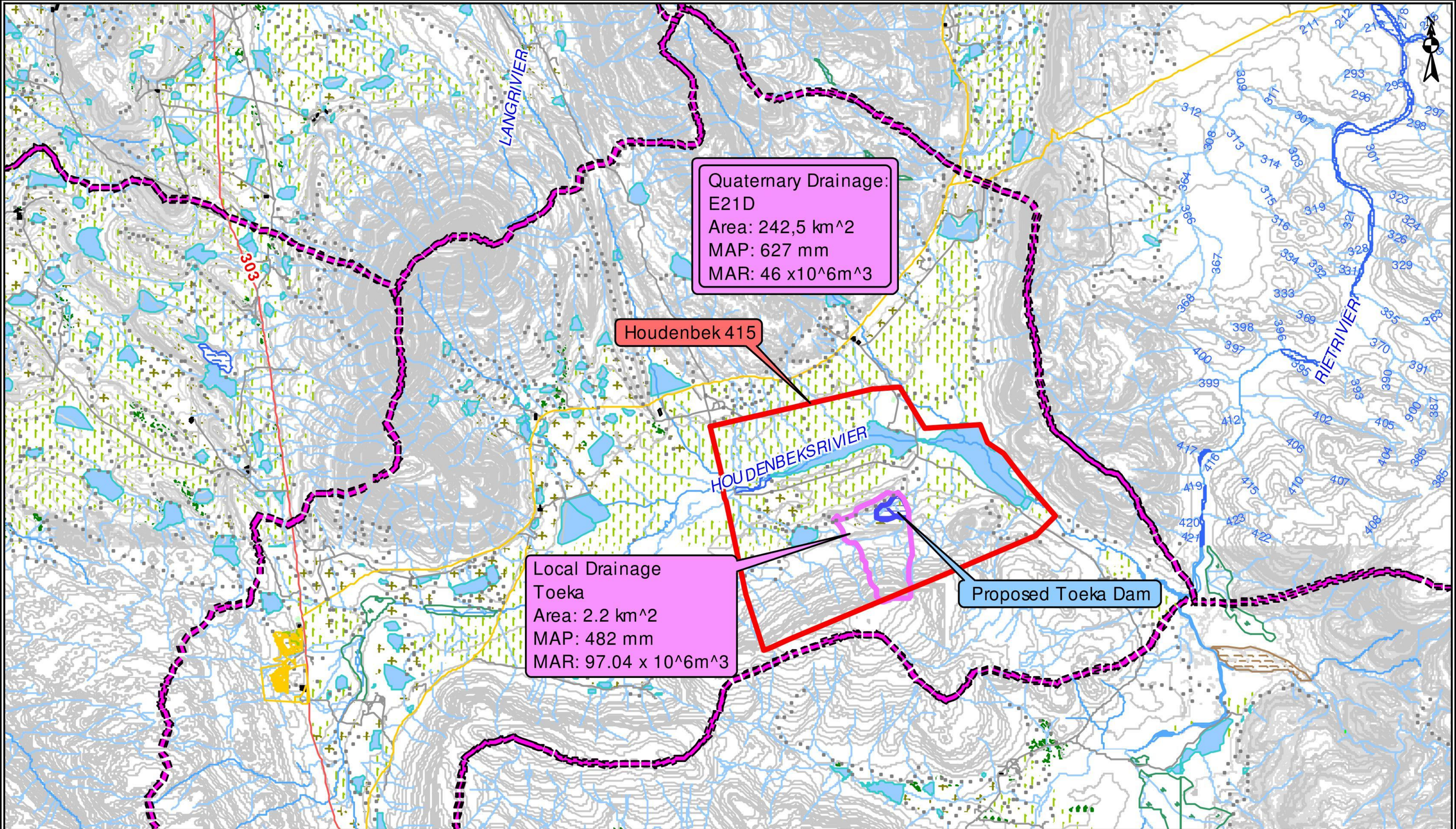
Chief Director: Western Cape
Department of Water and Sanitation
Private Bag X16
SANLAMHOF Tel: (021) 941 6000
7532 Fax: (021) 941 6100

2. The provisions and regulations of the National Environmental Management Act, 1998 (Act No. 107 of 1998) regarding control over activities which may have a detrimental effect on the environment.

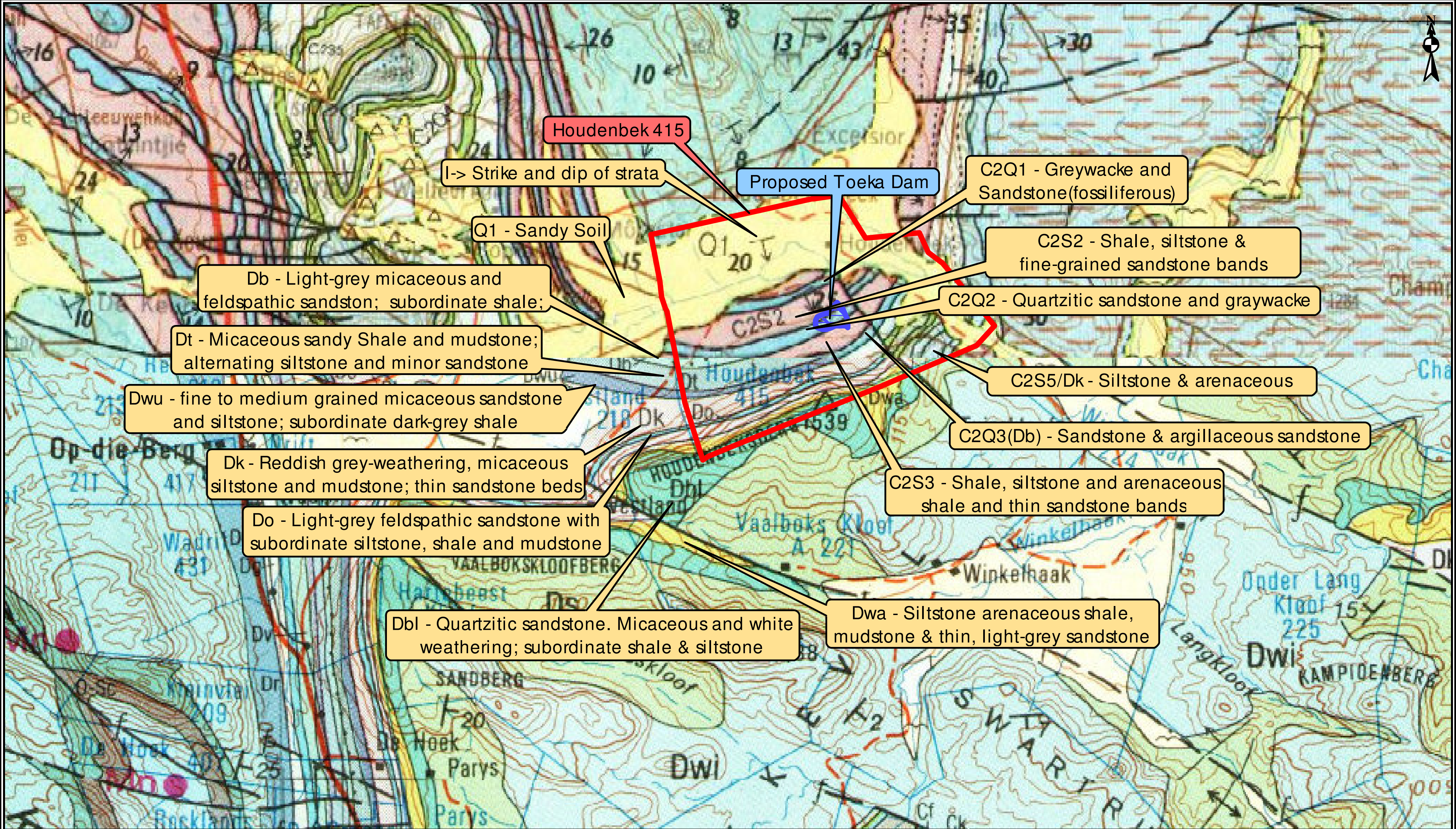
Yours faithfully

Ms L A Modise
Designation: Senior Administration Clerk: Dam Safety Regulation
Date: 30/01/2018

Copy to: Mr Charl Bester(Email: sbri@telkomsa.net)



SAREL BESTER INGENIEURS BK Raadgewende Siviele Ingenieurs / Consulting Civil Engineers Argitektuursdienste / Architectural Services CK1999/69837/23 Bus/Box 21, CERES, 6835 T: 023-312 2017 F: 023-312 3802 E: sbri@telkomsa.net MC BESTER Pr. Ing., LSAISI:970598, LSACAP:T1218	Client: MHB Trust PO Box 20 Kouebokkeveld 6836	Scale: 1: 100 000 Map Ref: 3319AB Gydopas	Catchment Area Map Toeka Dam Project Ref: 1619



SAREL BESTER INGENIEURS BK Raadgewende Siviele Ingenieurs Argitektuurdienste MC BESTER Pr. Ing., LSAISI: 970598, LSACAP: T1218 Posbus 21, CERES, 68.35 Tel 023-3122017	Client: MHB Trust PO Box 20 Kouebokkeveld 6836	Scale: 1: 100 000	Geology Map Toeka Dam
		Map Ref: 3219 Worcester	Project Ref: 1619

PRELIMINARY EVALUATION OF THE PROPOSED EARTH DAM: QUANTITIES AND COSTING

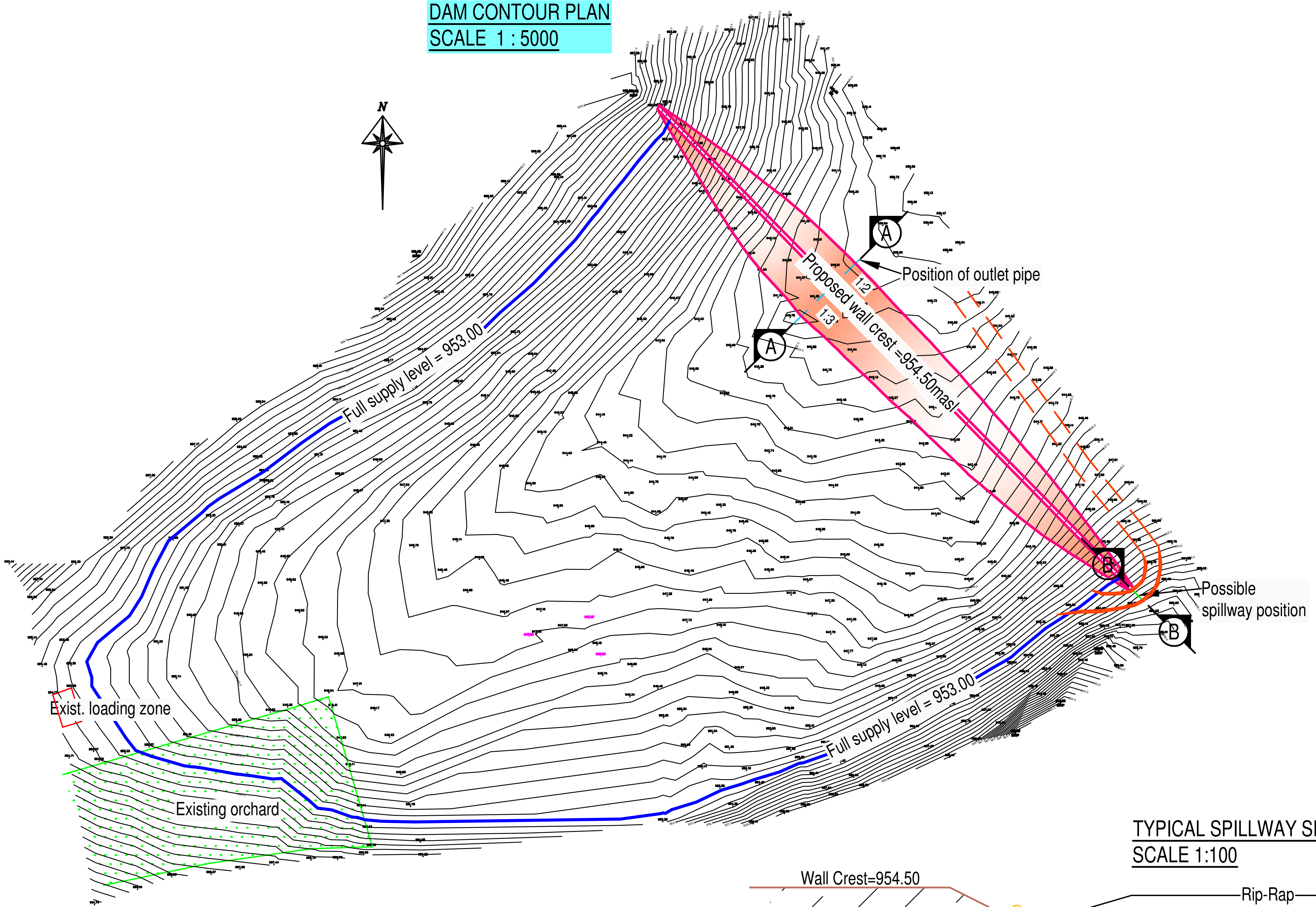
Client:	**Morester Landgoed**	***Project Nr.:***	**1619**	*Version:*	*Okt 2017*
Address:	Posbus 415	***Annexure:***	**A**		
	Ceres, 6835	***Prepared:***	SH	***Report by:***	Charl Bester
Dam:	**TOEKA DAM**	***Date:***	11-Dec-15		SAREL BESTER ENGINEERS
Notes:	1. VAT EXCL.				P.O. Box 21, Ceres 6835
	2. Kapasiteit 2milj. Kubieke meter				Ph: 023-312 2017
	3. Gebasseer op Douw Willemse opmetings				Fax: 086-514 3350

Design Parameters & Assumptions: / **Financial Assumptions:**

Crest width (m):	4.0	*Cut-off depth (m):*	3.00	*Earthmoving Cost (R/m³):*	45.00
Upstream slope 1:	3.0	*Cut-off base (m):*	4.00	*Nominal Engineering Fees (%):*	8.0%
Downstream Slope 1:	2.0	*Cut-off slope 1:*	0.75	*Fees Base Value (R):*	R 11,500,000
Percentage of fill from dam basin:	50%	*Application (m³/ha):*	7,000		

Item	Description		Unit	Stadium 1	Stadium 2	Stadium 3	Stadium 4	Stadium 5
				Stadium / Wall position / Terrain				
	1 EMBANKMENT			*SBRI*				
1.1	Wall crest level		masl	954.50				
1.2	Lowest ground level below wall		masl	940.40				
1.3	Maximum wall height		m	14.10	#N/A	#N/A	#N/A	#N/A
1.4	Wall crest length		m	650.0				
1.5	Wall volume - excluding cut-off		m³	180,500				
1.6	Cut-off trench excavation		m³	12,188	#N/A	#N/A	#N/A	#N/A
1.7	**Total earthmoving**		**m³**	**192,688**	**#N/A**	**#N/A**	**#N/A**	**#N/A**
	2 STORAGE CAPACITY							
2.1	Full supply level		masl	953.00				
2.2	Draw-off level		masl	941.50				
2.3	Total free-board		m	1.50	0.00	0.00	0.00	0.00
2.4	Maximum depth above draw-off level		m	11.50	0.00	0.00	0.00	0.00
2.5	Nett capacity from contours		m³	1,952,100				
2.6	Capacity gain from excavations		m³	90,250	0	0	0	0
2.7	**Potential gross capacity**		**m³**	**2,042,350**	**0**	**0**	**0**	**0**
2.8	Water surface		ha	36.90				
2.9	Potential irrigation		ha	291.76	0.00	0.00	0.00	0.00
2.10	Average water depth		m	5.53	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2.11	Ratio Storage : Earthworks			10.60	#N/A	#N/A	#N/A	#N/A
2.12	Recommended pipe diameter		mm	700	150	150	150	150
	3 COSTING (Excl VAT)							
3.1	Overhead & Preparation	10%	Rand	1,333,990	#N/A	#N/A	#N/A	#N/A
3.2	Earthworks (excavate & construct)	65%	Rand	8,670,938	#N/A	#N/A	#N/A	#N/A
3.3	Concrete & Outlet works	15%	Rand	2,000,986	#N/A	#N/A	#N/A	#N/A
3.4	Diverse & Unforeseen	10%	Rand	1,333,990	#N/A	#N/A	#N/A	#N/A
3.5			Rand					
3.6	**Estimated Construction Cost**		**Rand**	**13,339,904**	**#N/A**	**#N/A**	**#N/A**	**#N/A**
3.7	Adjusted Fees percentage		%	7.9%	#N/A	#N/A	#N/A	#N/A
3.8	Engineers costs (ECSA Fees)		Rand	1,055,473	#N/A	#N/A	#N/A	#N/A
3.9	Engineers costs (Disbursements)		Rand					
3.10	**Estimated Engineers Costs**		**Rand**	**1,055,473**	**#N/A**	**#N/A**	**#N/A**	**#N/A**
3.11			Rand					
3.12			Rand					
3.13	**Total estimated capital cost**		**Rand**	**14,395,377**	**#N/A**	**#N/A**	**#N/A**	**#N/A**
3.14	Capital costs per m³ gross capacity		Rand	7.05	#N/A	#N/A	#N/A	#N/A
3.15	Capital costs per irrigated hectare		Rand	49,339	#N/A	#N/A	#N/A	#N/A

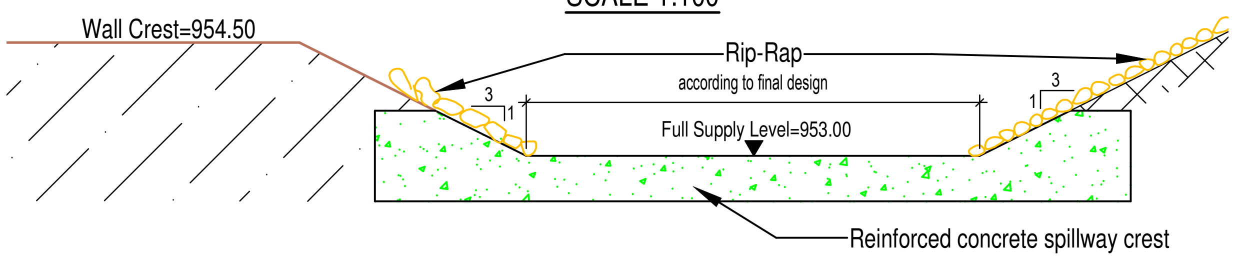
DAM CONTOUR PLAN
SCALE 1 : 5000



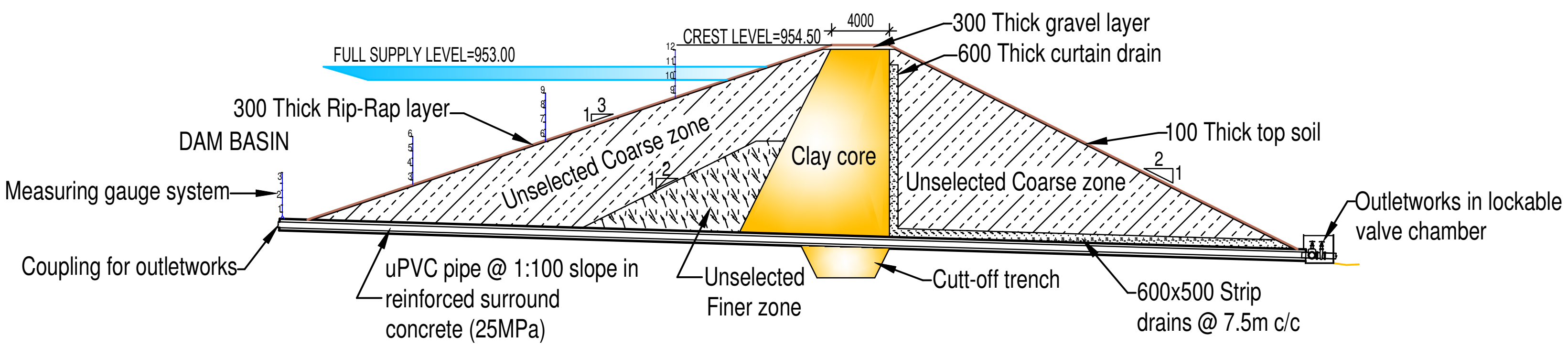
TECHNICAL INFORMATION: TOEKA DAM

Wall crest level		: 954.50 masl
Wall crest width		: 4.00 m
Wall crest length		: 652.00 m
Lowest ground level at embankment toe		: 940.40 masl
Maximum wall height		: 14.10 m
Upstream slope	1V	: 3.00 H
Downstream slope	1V	: 2.00 H
Embankment earthfill: cut-off trench excl.		: ±180 500 m³
Total estimated earthfill		: ±192 730 m³
Full supply level		: 953.00 masl
Total freeboard		: 1.50 m
Netto storage capacity		: 2 000 000 m³
Flooded area		: 36.90 ha
Dam footprint area		: ±40.00 ha

TYPICAL SPILLWAY SECTION (B-B)
SCALE 1:100



TYPICAL SECTION THROUGH EMBANKMENT (A-A)
SCALE 1:500



REVISION

SAREL BESTER ENGINEERS
Consulting Civil Engineers
Architectural Service

Date: 23/2/2018
MC BESTER
Pr. Eng., B.Eng., MSAICE:970598, SACAP:T1218

P.O. Box 21
62 Lyell Street
CERES, 6835

Ph: 023-312 2017
Fax: 023-312 3802
e-mail: admin@sbri.co.za

Harmony Trust
P.O. Box 415
CERES
6835

PROJECT:

PROPOSED NEW TOEKA DAM ON THE FARM HOUDENBEK, KOUEBOKKEVELD, CERES

DETAIL:

Contour Plan, Embankment Cross Section & Spillway Section

DRAWN	DATE	SCALE	SHEET
SC Hartzenberg	FEB. 2018	as shown	1 of 1
SURVEYED	DESIGNED	DWG. NUMBER	REV.
D. Willemse	Sarel Bester Engineers	1619-S2-01	

 A3

water & forestry

Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

Olifants / Doorn Catchment Management:
Western Cape

Project No. 2008-154

Evaluation of the Hydrology of the Leeu River in the Kouebokkeveld

Date : February 2010
Final Report

Author : Gerald Howard

EMZANTSI SYSTEMS

EVALUATION OF THE HYDROLOGY OF THE LEEU RIVER IN THE KOUE BOKKEVELD

EXECUTIVE SUMMARY

The Department of Water Affairs and Forestry (DWAF) is investigating the possibility of developing an empowerment irrigation scheme in the Koue Bokkeveld. Emzantsi Systems was contracted by DWAF to render professional support services for the hydrological component of this project. This report evaluates the hydrology of the Leeu River,Twee River and Houdenbecks River and presents yield curves at several sites of interest.

The ACRU daily hydrological model was used to generate daily flows at all sub-catchments in the study area. Yield curves were then generated at sites of interest to determine the optimum yield from a range of options that include variable diversion capacity from on-channel dams with variable storage to off-channel dams with variable storage. A summary of the most viable options is presented in Table E1 (analysis uses firm yield) and Table E2 (analysis uses 30% failure yield).

Table E1 Most likely development options and corresponding firm yield (Mm3/annum)

RIVER	ON-CHANNEL CAPACITY (Mm3)	DIVERSION (m3/s)	OFF-CHANNEL CAPACITY (Mm3)	YIELD (Mm3/annum)
Heks	2.0	0.25	2.2	2.0
Middeldeur	Same	0.15	1.0	0.83
Skoongesig	2.0	0.3	3.0	2.55
Meul	1.0	0.2	2.5	0.28
Leeu (E2H007)	0	0.5	7.0	3.21
Leeu (Downstrm)	0	0.5	7.0	3.92
Catchment 13	0	0.2	1.0	0.47

Table E2 Most likely development options and corresponding 30% failure yield (Mm3/annum)

RIVER	ON-CHANNEL CAPACITY (Mm3)	DIVERSION (m3/s)	OFF-CHANNEL CAPACITY (Mm3)	YIELD (Mm3/annum)
Heks	2.0	0.25	4.0	4.49
Middeldeur	Same	0.15	1.5	1.40
Skoongesig	2.0	0.3	4.0	4.08
Meul	1.0	0.2	2.5	1.63
Leeu (E2H007)	0	1.0	8.0	7.89
Leeu (Downstrm)	0	1.0	9.0	8.22
Catchment 13	0	0.2	1.2	1.0

REPORT ON THE EVALUATION OF THE HYDROLOGY OF THE LEEU RIVER IN THE KOUE BOKKEVELD

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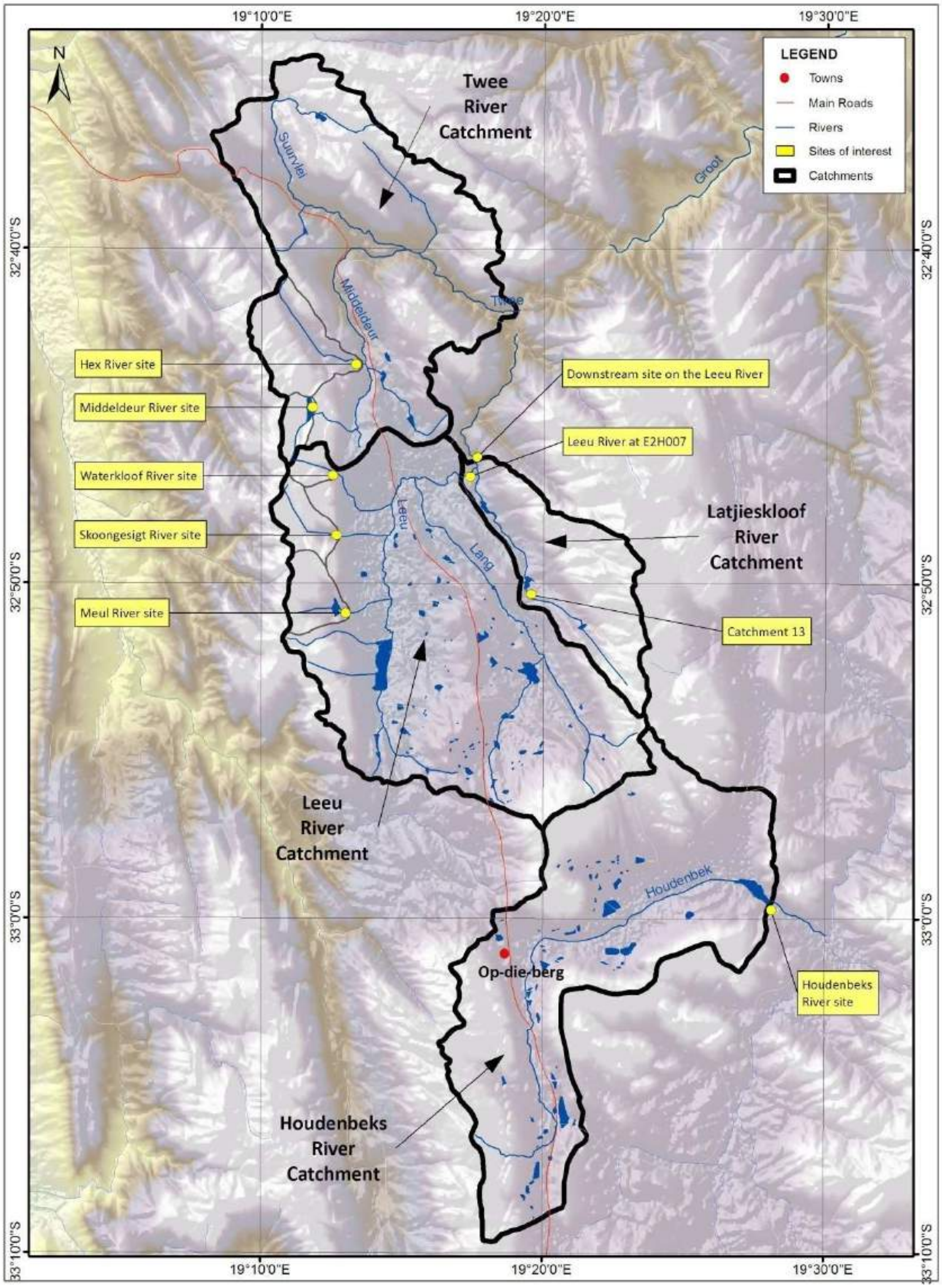
1. INTRODUCTION

The Department of Water Affairs and Forestry (DWAF) is investigating the possibility of developing an empowerment irrigation scheme in the Koue Bokkeveld. Emzantsi Systems was contracted by DWAF to render professional support services for the hydrological component of this project. This report evaluates the hydrology of the Leeu River,Twee River and Houdenbecks River and presents yield curves at several sites of interest.

The location of the study area is presented in Figure 1.1. The most important sources of water for the proposed development is located in the mountain tributaries to the west of the Leeu River and Twee River catchments. Those sub-catchments for which yield curves were produced are identified. In addition to the western mountain sub-catchments, the yield at the Leeu River flow gauge (E2H007) and at a site downstream of the flow gauge (the confluence of the Leeu River and Latjieskloof River) were analysed. The available yield in the Houdenbecks River at Morester was also determined.

This project required the generation of daily flows at numerous locations in the study area. Daily flows are necessary if diversions from tributaries to off-channel storage and subsequent yield assessment are to be made. For this reason it was decided to use the ACRU daily hydrological model to generate daily flows at all sub-catchments. The input data requirements for the ACRU Model are described in the Chapter 2 and the model verification process is presented in Chapter 3.

A suite of in-house software was used to simulate a number of options that include diverting flow from rivers (with and without on-channel storage) to off-channel storage and determining the safe yield and 30% failure yield at all sites of interest. Chapter 4 contains the presentation and discussion of these yield curves and Chapter 5 summarises the best options.



Hydrology of the Koue Bokkeveld

Locality Map

Figure 1.1

2. DATA COLLECTION

Data required for hydrological modelling include climatic data, irrigated crop water requirements as well as physical data such as soil depth, texture and porosity which are related to the hydrological characteristics of the catchment.

2.1 CLIMATIC DATA

The most important climatic data required by the ACRU Model includes daily rainfall data and mean monthly A-pan evaporation data. Daily rainfall data was obtained from the ACRU Daily Rainfall Utility. This database contains patched daily rainfall from the most reliable rainfall stations in South Africa. The database also contains a minute by minute grid of median monthly rainfall for the entire country. The software enables the user to generate daily rainfall at catchments where there is no rainfall data by factoring the median monthly station rainfall to match the catchment median monthly rainfall. Long term daily rainfall (1930 to 1999) was generated for each sub-catchment.

A minute by minute grid of mean monthly A-pan evaporation is available from the Department of Agricultural Engineering (AgEng) at the University of Natal (PMB). This evaporation data is available as an ARCVIEW coverage and was intersected with the sub-catchment coverage to determine the catchment mean monthly A-pan evaporation.

2.2 LAND USE DATA

The main water use in this catchment is irrigation of orchards and vegetables. Domestic abstractions are negligible and were ignored in this study. Agricultural land was identified on a field by field basis using the LANDSAT 2002 images available on GOOGLE , and each field was classified visually as either an orchard or under vegetables. This data was digitised using ARC INFO and is presented in Figure 2.1, Figure2.2 and Figure 2.3. The full supply area of all farm dams was also captured.

This data was then “truthed” with local farmers in the Koue Bokkeveld. Farmers were able to supply additional information such as:

1. The capacity of numerous farm dams. This information was used to establish a relationship between full supply capacity and full supply area which could be applied to determine the capacity of all the digitised farm dams.

2. Identify agricultural land that is dry-land (never irrigated) and land that is used for vegetables. In addition, a rotation period of 4 years was suggested so that 25% of the total area of vegetables

per sub-catchment was modelled as irrigated. Vegetables were assumed to consist of 70% onions, 20% potatoes and 10% butternut.

3. Identifying "irrigation zones" where areas irrigated from the same water source (a dam or river) were identified.

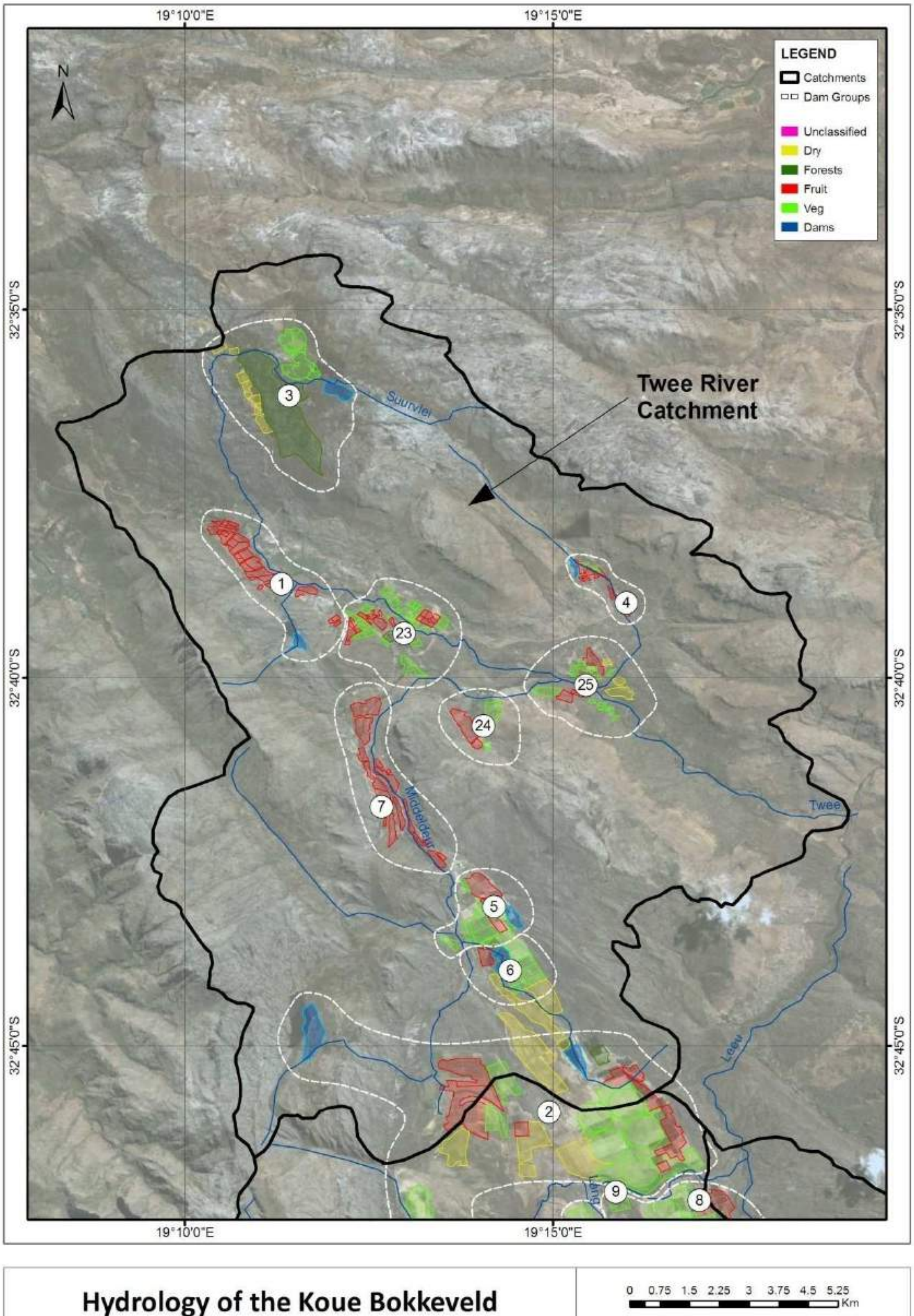
The total irrigated crop area for each irrigated zone was used in conjunction with crop factors for stone fruit, onions, potatoes and butternut as well as irrigation method and A-pan evaporation to generate monthly crop water requirements for each irrigation zone.

Figures 2.1 , 2.2 and 2.3 show the demarcation of irrigation zones and Table 2.1 summarises the irrigated crop area and annual crop water requirement for each irrigation zone.

Table 2.1 Irrigated crop area (ha) and water requirement (Mm3/annum) for each irrigation zone**.**

IRRIGATION ZONE	IRRIGATED FRUIT AREA (Ha)	IRRIGATED VEGETABLE AREA (Ha)	TOTAL IRRIGATED CROP WATER DEMAND (Mm3/annum)
1	85	0	0.672
2	248	112	3.653
3	0	15	0.234
4	26	0	0.207
5	43	20	0.648
6	10	14	0.257
7	115	0	0.909
8	50	92	1.817
9	14	20	0.419
10	22	87	1.518
11	11	82	1.354
12	0	43	0.667
13	118	303	5.595
14	41	50	1.087
15	184	40	2.049
16	466	397	9.575
17	79	0	0.610
18	60	34	0.980
19	107	0	0.827
20	221	188	4.553
21	1130	636	18.084
22	422	172	5.677

23	35	17	0.539
24	27	4	0.273
25	29	8	0.352

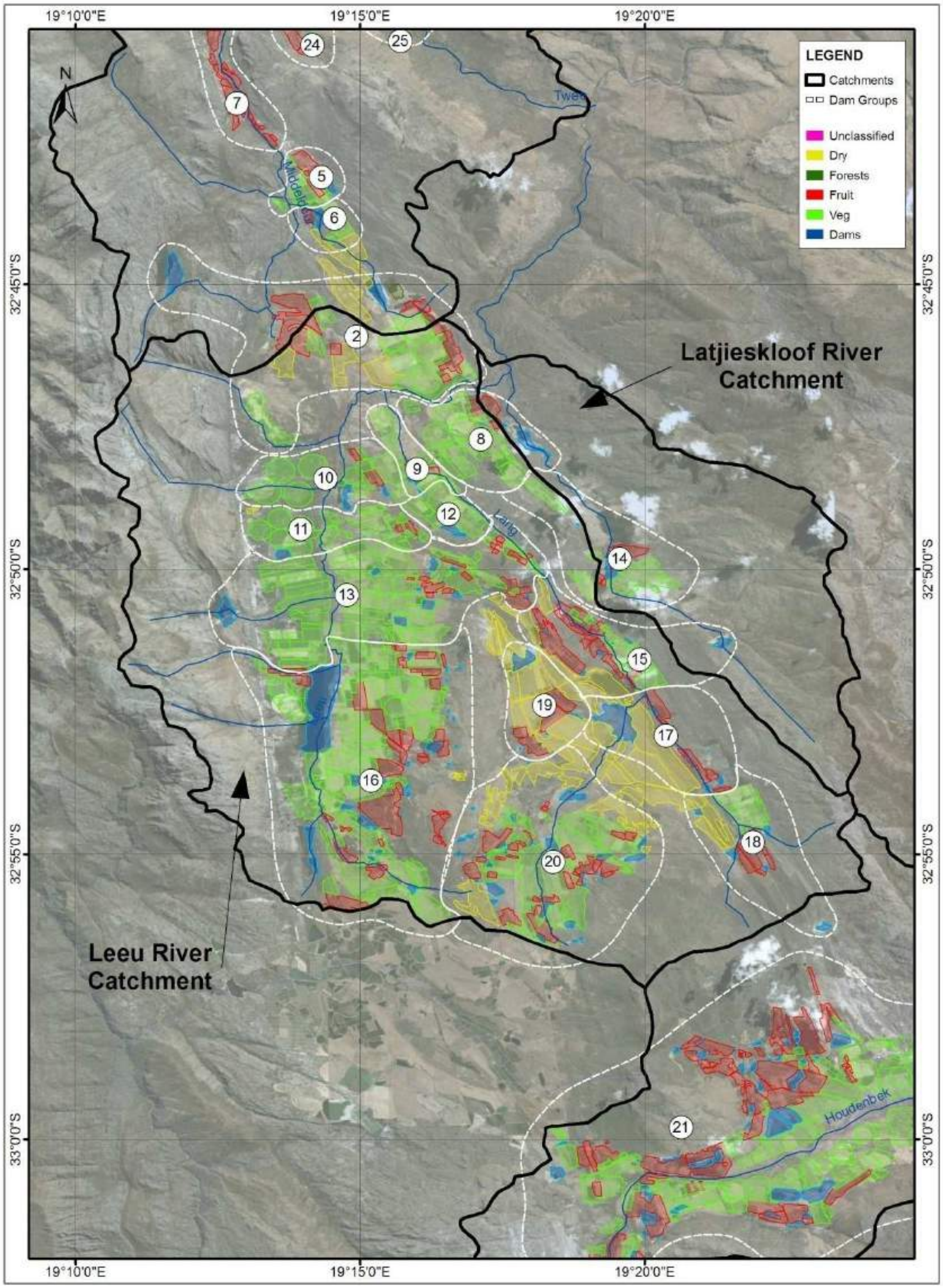


Hydrology of the Koue Bokkeveld

Twee River Catchment : Land-use

0 0.75 1.5 2.25 3 3.75 4.5 5.25 Km

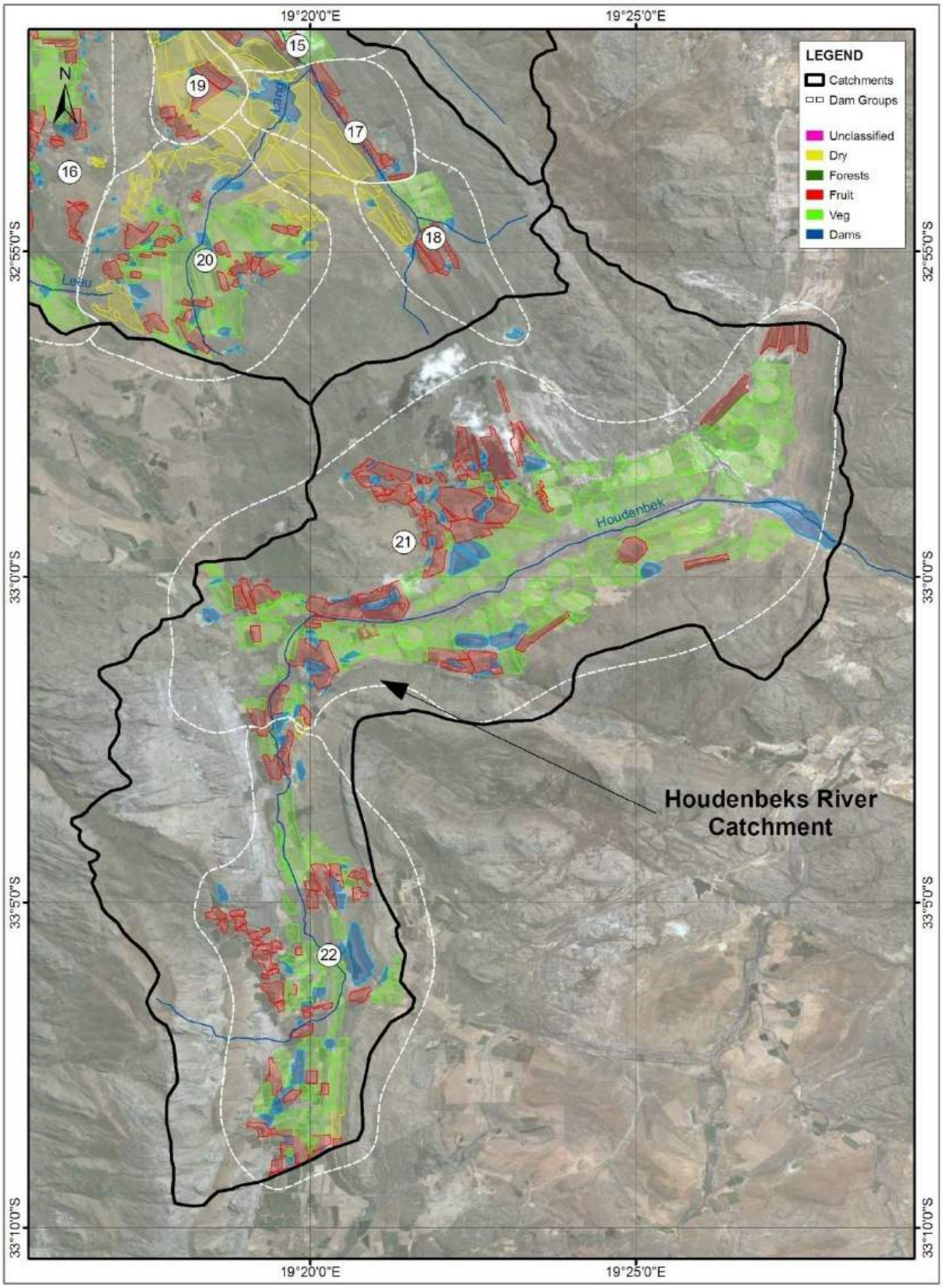
Figure 2.1



Hydrology of the Koue Bokkeveld

Leeu and Latjieskloof River Catchments : Land-use

Figure 2.2



Hydrology of the Koue Bokkeveld

Houdenbeks River Catchment : Land-use

0 0.9 1.8 2.7 3.6 4.5 5.4 6.3 Km

Figure 2.3

2.3 SOIL HYDROLOGICAL CHARACTERISTICS

The ACRU Model requires information regarding the hydrological characteristics of the soil. This data is available from AgEng in the form of GIS coverages . The average depth, texture and porosity of the A and B horizon and other relevant data such as field capacity and wilting point were determined for each sub-catchment shown in Figure 3.1.

2.4 HYDROLOGICAL DATA

Flow data from the DWAF flow gauging structure (E2H007) was required for verification of ACRU Model simulated flows. The recorded flow data was improved by DWAF by extending the rating curve so that more accurate flood information was available. This process has resulted in an increase of the mean annual runoff (MAR) at the flow gauge from 42.6 Mm3 (as presented in the Hydrology Report in 1998) to a more realistic 51.19 Mm3 for the calibration period 1979 to 1999.

3. HYDROLOGICAL MODELLING

3.1 GENERAL DESCRIPTION OF THE ACRU MODEL

The ACRU Model is based on the SCS model (developed in the USA) but is adapted for South African conditions. It is a daily rainfall- runoff model and converts daily rainfall in a catchment to daily runoff or stream-flow. The model simulates the hydrological cycle (rainfall, interception, evaporation from vegetation and soil, direct runoff and infiltration to the soil, interflow from the soil and groundwater interactions). The model also simulates the water use from dams (irrigation of crops or domestic supply) as well as transpiration from vegetation.

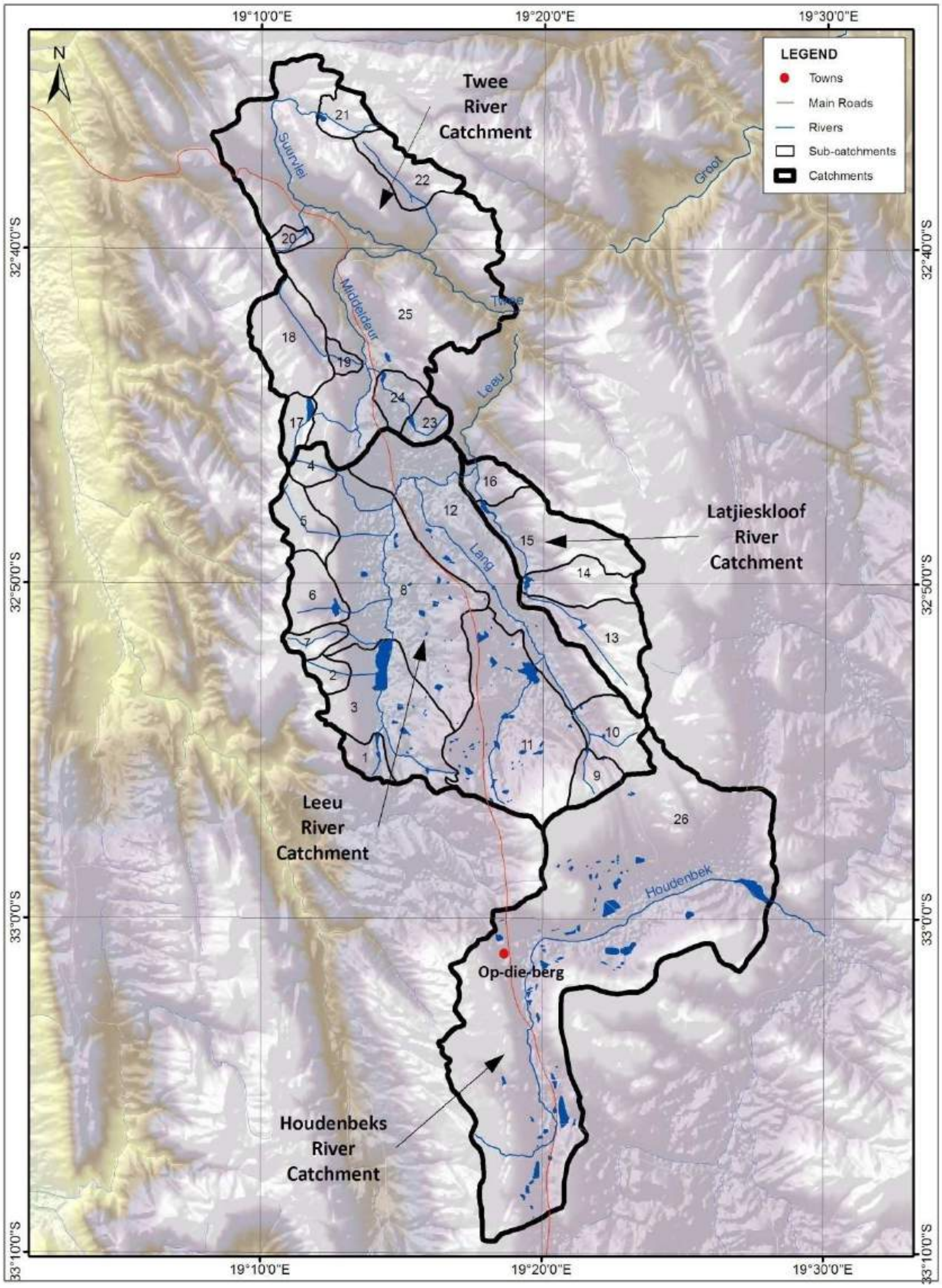
3.2 SUB-CATCHMENT DIVISION

The first step in configuring the model is to sub-divide the catchment into smaller sub-catchments so that the model can generate flows at different locations within the catchment. Figure 3.1 shows the sub-catchment division and Table 3.1 lists the relevant climatic and hydrological information for each sub-catchment. Demarcation of sub-catchment boundaries coincided with the location of possible developmental options as well as clearly defined hydrological features such as tributaries and large dams. Table 3.1 also lists the total farm dam capacity in each sub-catchment , as well as the annual irrigation demand from the applicable irrigation zone.

3.3 MODEL CONFIGURATION

The configuration of the ACRU Model was done using data sources described in Chapter 2. All the data was summarised or averaged for each of the sub-catchments presented in Figure 3.1 .

In addition to this “measured” information (such as daily rainfall, evaporation, irrigated crop area, soil depth, texture etc) the ACRU Model also enables the user to “calibrate” the model by changing variables that affect the flow regime. These variables are briefly discussed in Section 3.4.



Hydrology of the Koue Bokkeveld

Sub-catchments

Figure 3.1

Table 3.1 Climatic and hydrological data for each sub-catchment in the study area

Sub-catchment	Catchment Area (km2)	MAP (mm)	Farm Dam Capacity (Mm3)	Applicable Irrigation Zone	Irrigation Demand (Mm3/ann)	Current Day MAR (Mm3/ann)
1	4.99	1000	With cat 3	-	-	2.83
2	3.67	1250	-	-	-	2.94
3	34.07	900	8.9	16	9.58	17.49 (spill)
4	4.44	1250	-	-	-	3.6
5	9.43	1250	-	-	-	7.43
6	11.12	1250	4.5	Part of13	4.5	3.94 (spill)
7	4.19	1250	0.006	-	Divert 2.4 Mm3 to catchment no 3	3.46
8	65.21	700	2.3	10,11 and part of 13	2.9 and 1.0	40.11
9	6.13	900	-	-	-	2.71
10	12.55	700	0.15	Part of 18	0.22	6.01 (spill)
11	56.31	600	5.7	17,19 and 20	6.0	5.30 (spill)
12	55.86	500	1.0	9 and 12	1.1	56.17
13	20.26	700	1.6	15	2.0	4.62
14	11.70	700	0.5	14	1.1	7.81 (spill)
15	23.01	700	0.9	8	1.8	14.25 (spill)
16	6.68	700	-	-	-	72.51
17	5.23	1250	2.1	Part of 2	2.6	2.03 (spill)
18	20.31	1250	With cat 19	-	-	16.15
19	2.35	1000	-	7	0.91	16.96
20	2.42	1100	0.35	1	0.67	1.09 (spill)
21	6.60	700	0.5	3	0.23	2.11 (spill)
22	11.91	700	0.2	4	0.21	4.15 (spill)
23	5.00	500	1.0	Part of 2	1.1	0.27 (spill)
24	6.39	500	1.0	5 and 6	0.91	0.37 (spill)
25	158.43	500	-	23,24 and 25	1.15	49.93
26	223.33	600	26.8	21,22 and part of 18	23.7 and 0.76	24.68 (spill)

3.4 MODEL VERIFICATION

The verification process involves comparing simulated flow from the model with the observed record at the flow gauge (E2H007) and changing the variables mentioned below until a statistically acceptable "fit" is obtained. Initial output from the model indicated

1. The simulated flow was too low and

2. The hydrological response to rainfall was too gradual.

3.4.1 INCREASING MEAN ANNUAL PRECIPITATION (MAP)

The simulated flow was too low due to rainfall being under-predicted, especially in the mountainous catchments. The DWAF isohyetal map was used to determine the MAP for each sub-catchment and indicated that the daily rainfall needed to be factored upward to reflect realistic catchment MAP.

Note. The ACRU daily rainfall utility is based on the old CCWR rainfall database and is known to under-predict rainfall in mountain catchments. In these situations, the DWAF isohyetal map has been extensively used. Furthermore, a comparison of DWAF MAP with monthly rainfall data supplied from farms in the Leeu River catchment (Tuinskloof, Rietfontein, Kunje, De Straadt and "Dam op die Berg) indicated that the catchment MAP calculated from the DWAF isohyetal map was correct. Sub-catchment MAP is presented in Table 3.1.

3.4.2 INCREASING HYDROLOGICAL RESPONSE

The gradual hydrological response to rainfall was evident in flood peaks being delayed by several days and low flow between floods being too high. This indicates the catchment is absorbing too much rainfall (lowering flood peak) and therefore releasing too much from soil storage (elevating low flow). Variables that affect the hydrological flow regime were used to lower catchment absorbtion and are discussed below.

Impervious Area. This variable was assumed to be 20% in the mountain and zero in the valley catchments.

Stormflow Response. This variable defines what percentage of rainfall becomes streamflow on the same day and was assumed to range from 70% in the mountain catchments to 30% in the valley catchments.

Soil Depth Contributing to Runoff. This variable ranged from 0.1m in the mountains to 0.2m in the valley ie. shallow soil for more runoff.

All these variables were used in a manner that increases the immediate response of the catchment to rainfall.

3.4.3 RESULTS

A comparison of model simulated flow to the recorded flow data at E2H007 is presented in Figure 3.2. Data has been summarised on a monthly basis. Results show the simulated flow is conservative with respect to MAR (the simulated flow is 6% lower than the observed flow) and yield.

Figure 3.2. Comparison of simulated and observed flow statistics (Mm3/ month).

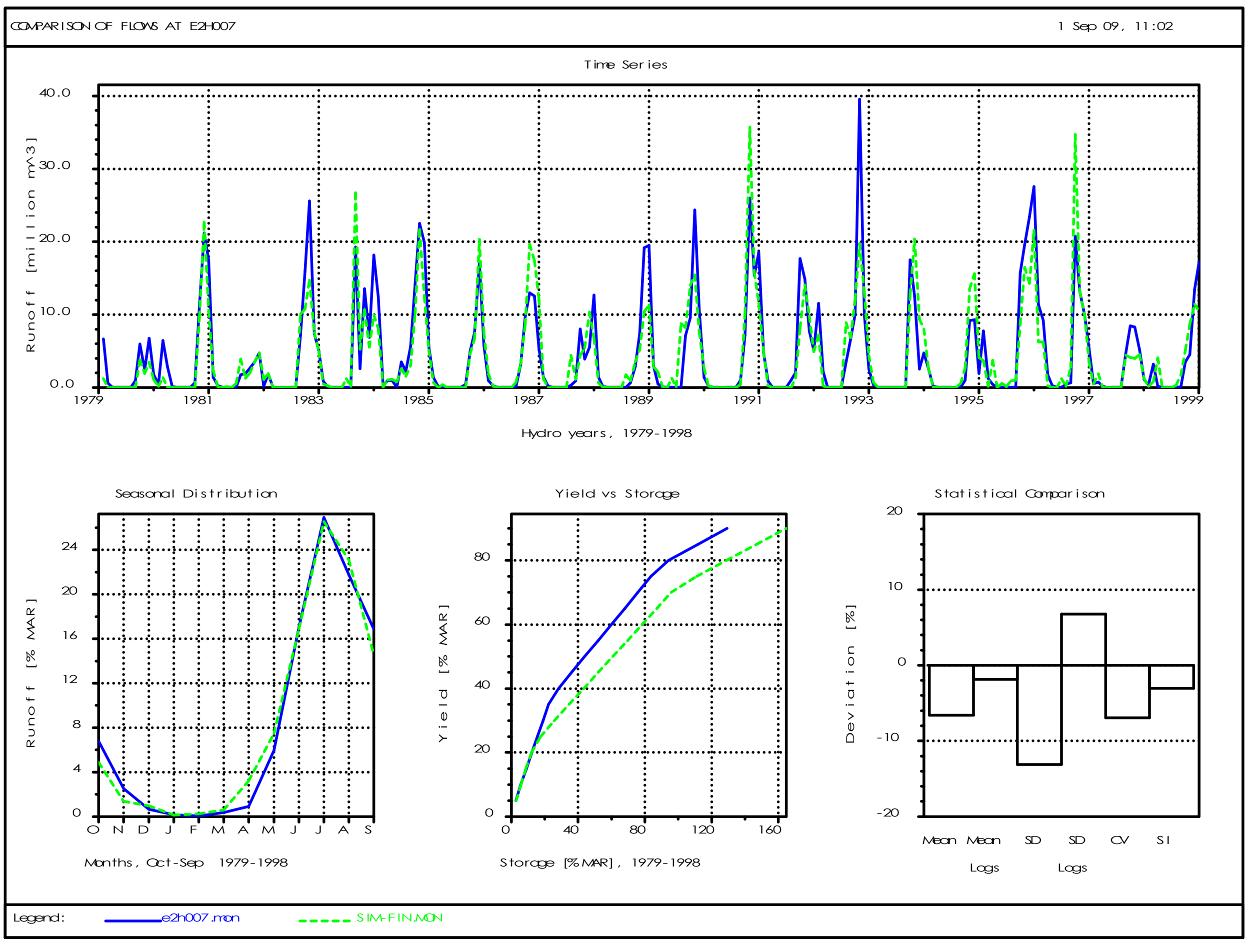
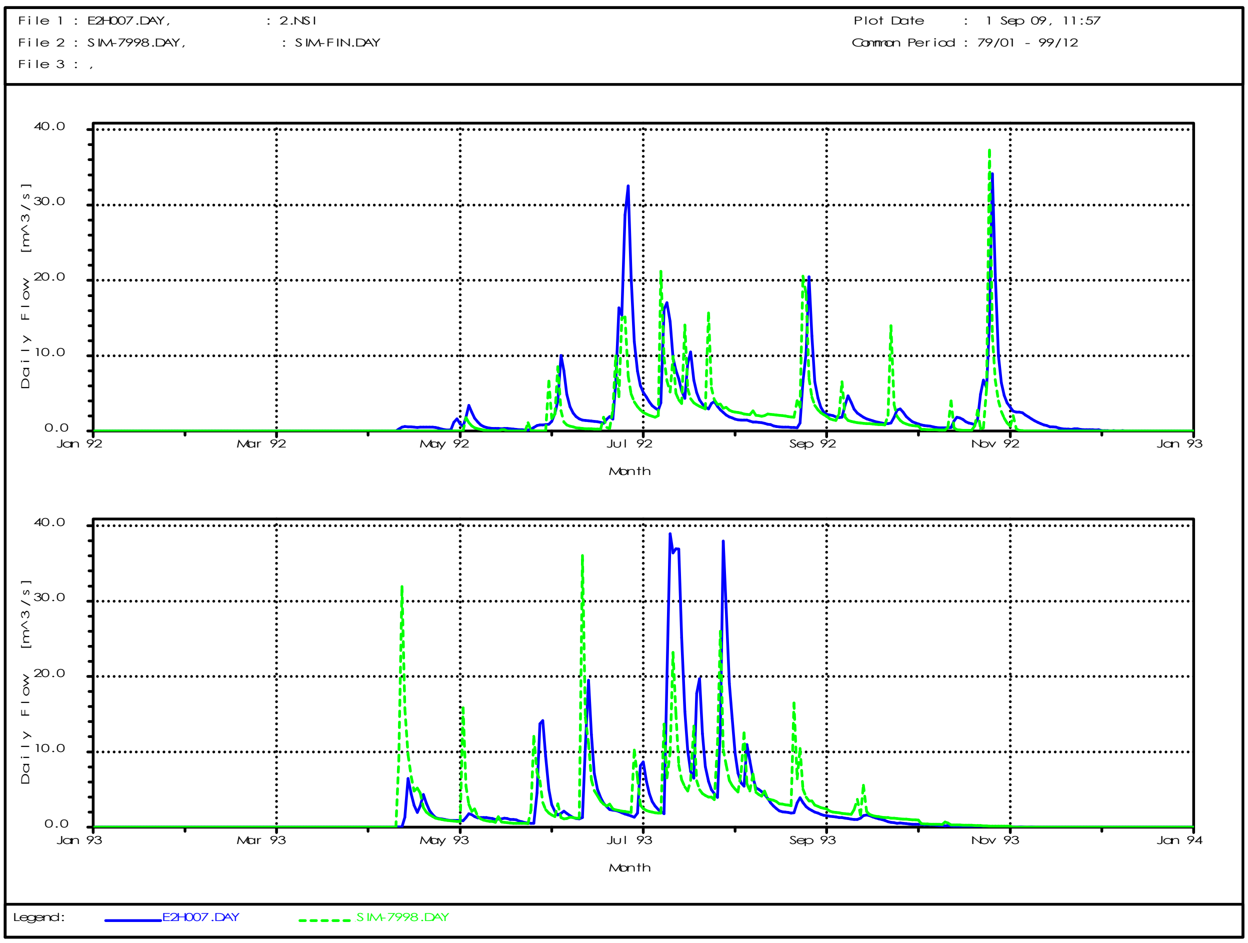


Figure 3.3 shows an example of the daily flow (m3/s) comparison between model simulated flow and the observed daily flow at E2H007. Results show that although the simulated flow is sometimes higher and lower than the observed record, the hydrological signal for peak flow and the low flow recession curve are representative.

Figure 3.3. Comparison of simulated and observed flows (m3/s).



3.4.4 GENERATION OF LONG TERM CURRENT DAY FLOW

Once the model calibration/verification process was complete the model was then used to generate long term flow (for as long as there was rainfall data available) at sites of interest in the catchment. Since the rainfall data is available from 1930 to 1999, flow was generated for this period. These flow sequences represent what the flow would have been from 1930 to 1999 if the current day water use was imposed over this full period. This enables an analysis to be performed where the "critical period" can be identified and the yield from this period can be determined.

4. YIELD

4.1 CONCEPT FIRM YIELD AND FAILURE YIELD

Current day flow time series are analysed to determine the amount of water that can be abstracted annually. Firm yield refers to the amount of water that can be abstracted annually during the driest period on record. In all other years the yield would be higher. A failure yield refers to the amount of water that can be abstracted annually if a certain failure is accepted. For the purpose of this project a failure yield of 30% was used. So this is the amount of water that can be abstracted 70% of the time.

The demand distribution is crucial in the determination of yield. For this study the demand distribution reflects the irrigation demand which peaks in mid-summer.

4.2 DISCUSSION AND RESULTS OF YIELD ANALYSIS AT EACH SITE

In-house software was used to determine yield curves for a number of options at the 9 sites of interest. These options include:

- A theoretical yield using the total flow at the site. This yield ignores downstream irrigation and reserve requirements and provides an estimate of the total potential yield.
- The same yield as above, but using the actual flow at the site. This yield takes account of downstream irrigation and reserve requirements and provides an estimate of the maximum actual yield of an on-channel dam at the site of interest.
- The yield at the site of interest if flow is diverted directly from the river (no on-channel storage) to an off-channel dam with variable capacity. A range of diversion capacities are simulated.
- The yield at the site of interest if flow is diverted from an on-channel dam (with variable capacity) to off-channel storage (with variable capacity). A range of diversion capacities are simulated.

4.2.1 HEKS RIVER

The yield curve results for the Heks River are presented in Appendix 1.
The first yield curve in Appendix 1.1 shows the firm yield and 30% failure yield for a theoretical dam on the Heks River assuming no water-use. The curve indicates an optimum firm yield of 7.0 Mm3/annum for a 7.0 Mm3 dam capacity.

The second yield curve in Appendix 1.2 shows the firm yield and 30% failure yield for a theoretical dam on the Heks River but accounting for the current-day irrigation demand and the reserve. Results indicate that the optimum dam capacity is about 2.0 Mm3 for firm yield of 1.8 Mm3/annum and 5.0 Mm3 for a 30% failure yield of 5.0 Mm3/annum.

The next 3 yield curves in Appendix 1.3 show the yield for an off channel dam with variable capacity that is supplied by a variable diversion directly from the Heks River.
Note. Both current irrigation demand and the reserve releases are accounted for.
Results show that increasing diversion capacity does not increase yield substantially. Increasing diversion capacity from 0.5 m3/s to 1.0 m3/s only results in 30% failure yields of 1.5 Mm3/annum to 2.0 Mm3/annum for a 2.0 Mm3 capacity off-channel dam. Clearly storage on the Heks River is required to obtain a significant diversion and subsequent yield.

Several likely development scenario's were then tested. Storages of 2.0 Mm3, 3.0 Mm3, 4.0 Mm3 and 5.0 Mm3 on the Heks River, with diversions ranging from 0.25 m3/s and 0.50 m3/s to an off-channel dam of variable capacity were modelled. Results are presented in Appendix 1.4 to Appendix 1.7 Results show that increasing on-channel storage does not substantially increase yield. In Appendix 1.4, a 2.0 Mm3 on-channel dam diverts 4.75 Mm3/annum with a 30% failure yield of 4.49 Mm3/annum (with a 0.25 m3/s diversion to a 4.0 Mm3 capacity off-channel dam). This compares well to the 5.0 Mm3 on-channel dam that diverts 6.9 Mm3 with a 30% failure yield of 6.03 Mm3/annum (with a 5.0 m3/s diversion to a 7.0 Mm3 capacity off-channel dam).
Note: Using a smaller capacity on-channel dam will also assist in releasing the high flow component of the reserve as a spill rather than the cost of constructing a large release valve.

4.2.2 MIDDELDEUR RIVER

The yield curve results for the Middeldeur River are presented in Appendix 2.
The first curve in Appendix 2.1 shows the firm yield and 30% failure yield for a theoretical dam on the Middeldeur River assuming no water-use. The curve indicates an optimum firm yield of 2.3 Mm3/annum for a 2.5 Mm3 capacity and a maximum 30% failure yield of 3.9 Mm3/annum for a larger capacity of 4.0 Mm3.

The second curve in Appendix 2.2 shows the firm yield and 30% failure yield for a theoretical dam on the Middeldeur River but accounting for the current-day irrigation demand and the reserve. Results indicate that there is only 2.05 Mm3/annum spill available to be utilised which translates to 0.5 Mm3/annum firm yield and around 1.5 Mm3/annum for a 30% failure yield.

A number of development scenario's were then modelled. Appendix 2.3 shows the yield when winter storage id diverted from the existing dam (with it's current capacity of 2.1 Mm3) to an off-channel dam of variable capacity. A diversion of 0.10 m3/s results in a 30% failure yield of 0.91 Mm3/annum for an off-channel dam capacity of 1.0 Mm3. Increasing the diversion from 0.10 m3/s to 0.15 m3/s has the effect of lowering the irrigation supply from 1.503 Mm3/annum to 1.452 Mm3/annum so although the diverted flow increases from 1.05 Mm3/annum to 1.52 Mm3/annum it does so at the expense of the current irrigation supply.

Appendix 2.4 and Appendix 2.5 show the effect of increasing the diversion and on-channel storage. If the existing dam capacity is increased by 0.4 Mm3 (to 2.5 Mm3) a 30% failure yield of 1.4 Mm3/annum is achieved with a diversion of 0.15 m3/s to an off-channel dam capacity of 1.5 Mm3. Increasing the capacity by 0.9 Mm3 (to 3.0 Mm3) results in a 30% failure yield of 1.87 Mm3/annum with a 2.0 m3/s diversion to a 2 Mm3 off-channel dam. However, increasing the capacity of the existing dam has implications when it comes to releasing the high flow component of the reserve.

4.2.3 WATERKLOOF RIVER

The yield curve results for the Waterkloof River are presented in Appendix 3.
The first curve in Appendix 3.1 shows the firm yield and 30% failure yield for a theoretical dam on the Waterkloof River assuming no water-use. The curve indicates an optimum firm yield of 1.8 Mm3/annum for a 2.0 Mm3 on-channel dam capacity and an optimum 30% failure yield of 3.07 Mm3/annum for a larger capacity of 3.0 Mm3.

The second yield curve in Appendix 3.2 shows the firm yield and 30% failure yield for a theoretical dam on the Waterkloof River but accounting for downstream irrigation demands and the reserve. It is important to note that this catchment has a large reserve due to its ecological importance in sustaining the wetland above the flow gauge. Results show that there is little spare yield left in the Waterkloof catchment. A 30% failure yield of 1.03 Mm3/annum from a 2.0 Mm3 capacity on-channel dam can be achieved using the available flow (1.286 Mm3/annum).

The next 3 yield curves in Appendix 3.3 show the yield of an off-channel dam with variable capacity that is supplied by a variable diversion from the Waterkloof River. The maximum firm yield is around 0.2 Mm3/annum and the 30%failure yield is about 0.4 Mm3/annum.

Results in Appendix 3.4 and Appendix 3.5 show that on-channel storage does not increase yield substantially. Although storage on the Waterkloof River can increase the 30% failure yield to about 0.8 Mm3/annum , the large reserve requirement effectively makes the Waterkloof River a poor option as a future water source.

4.2.4 SKOONGESIG RIVER

The yield curve results for the Skoongesig River are presented in Appendix 4.
The first curve in Appendix 4.1 shows the firm yield and 30% failure yield for a theoretical dam on the Skoongesig River assuming no water-use. The curve indicates an optimum firm yield of 4.33

Mm3/annum for a 4.0 Mm3 capacity on-channel dam and an optimum 30% failure yield of 6.38 Mm3/annum for a larger capacity of 6.0 Mm3.

The second curve in Appendix 4.2 shows the firm yield and 30% failure yield for a theoretical dam on the Skoongesig River but accounting for the reserve and irrigation supply. Note that the irrigation demand consisted of two components namely a winter demand to fill a downstream storage of 0.5 Mm3 and an early summer irrigation requirement directly from flow in the Skoongesig River. Total irrigation demand is 1.354 Mm3/annum of which 1.005 Mm3/annum is, on average currently met, leaving 5.03 Mm3/annum for future use. Results show that the optimum firm yield is approximately 2.3 Mm3/annum for a 2.5 Mm3 capacity on-channel dam and the optimum 30% failure yield is 3.81 Mm3/annum for an on-channel dam with a capacity of 4.0 Mm3.

The next 3 curves in Appendix 4.3 show the yield from an off-channel dam with variable capacity that is supplied by a variable diversion directly from the Skoongesig River. Results show that diverting without on-channel capacity results in a maximum 30% failure yield of 1.5 Mm3/annum for a 2.0 Mm3 capacity off-channel dam.

Storage on the Skoongesig River is necessary to obtain significant yield , and Appendix 4.4 to Appendix 4.7 indicate the yield that can be obtained from variable on-channel storage (capacities from 2.0 Mm3 to 5.0 Mm3 are modelled) with variable diversion to variable off-channel storage. Results indicate that two optimum scenarios are available:
1) An on-channel capacity dam of 2.0 Mm3 with a 0.3 m3/s diversion to off-channel storage with a capacity of 2.0 Mm3. The firm yield for this scenario is 1.97 Mm3/annum. Increasing the off-channel storage to 4.0 Mm3 results in an optimum 30% failure yield of 4.08 Mm3/annum.
2) An on-channel capacity dam of 3.0 Mm3 with a 0.3 m3/s diversion to off-channel storage with a capacity of 3.0 Mm3. The firm yield for this scenario is 2.55 Mm3/annum. Increasing the off-channel storage to 4.0 Mm3 results in an optimum 30% failure yield of 4.17 Mm3/annum.

Combinations of larger storages and diversions only increase diverted runoff from about 4.4 Mm3/annum to a maximum of 5.0 Mm3/annum. This results in a maximum firm yield of 3.37 Mm3/annum and a 30% failure yield of 4.9 Mm3/annum.

4.2.5 MEUL RIVER

The yield curve results for the Meul River are presented in Appendix 5.
The first curve in Appendix 5.1 shows the firm yield and 30% failure yield for a theoretical dam on the Meul River assuming no water-use. The curve indicates an optimum firm yield of 4.18 Mm3/annum for a 4.0 Mm3 capacity and an optimum 30% failure yield of 7.76 Mm3/annum for a capacity of 7.0 Mm3.

The second curve in Appendix 5.2 shows the firm yield and 30% failure yield for a theoretical dam on the Meul River but accounting for the current-day irrigation demand and the reserve. Results indicate that there is little spare yield left in the Meul River catchment. Only 3.09 Mm3/annum is available for use from which a 0.59 Mm3/annum firm yield and a 2.15 Mm3/annum 30% failure yield can be achieved with a 5.0 Mm3 capacity on-channel dam.

Appendix 5.3 shows that simply diverting the available water without extra on-channel storage results in very little yield (up to a maximum of 0.8 Mm3/annum for a 0.2 m3/s diversion to an off-channel dam with a capacity slightly more than 2.0 Mm3).

Appendix 5.4 and Appendix 5.5 show the yield that could be achieved if the capacity in the existing Meul River Dam was increased by 1.0 Mm3 and 2.0 Mm3 (to a total of 5.5 Mm3 and 6.5 Mm3 respectively). The optimum yield is the scenario of increasing the on-channel capacity by 1.0 Mm3, diverting at 0.2 m3/s to an off-channel dam of 2.5 Mm3 which provides a 30% failure yield of 1.63 Mm3/annum. Another option to consider is increasing the on-channel capacity by 2.0 Mm3 which can deliver a maximum 30% failure yield of about 2.14 Mm3/annum.

4.2.6 LEEU RIVER AT E2H007

The yield curve results for the Leeu River are presented in Appendix 6.
The first yield curve in Appendix 6.1 shows the firm yield and 30% failure yield for a theoretical dam on the Leeu River and uses the current-day flow at the site (but with no reserve). The curve indicates an optimum firm yield of 17.0 Mm3/annum for a 30.0 Mm3 capacity and an optimum 30 % failure yield of 40 Mm3/annum for a capacity of 40 Mm3.

The second yield curve presented in Appendix 6.2 shows the firm yield and 30% failure yield for a theoretical dam on the Leeu River but accounting for the reserve. Results indicate that the optimum capacity is about 15.0 Mm3 for a firm yield of 8.36 Mm3/annum and 35.0 Mm3 for a 30% failure yield of 29.86 Mm3/annum.

The last 4 curves in Appendix 6.4 and Appendix 6.5 show the yield from an off- channel dam with variable capacity that is supplied by a variable diversion directly from the Leeu River. Results show that the diverted volume increases substantially from 3.06 Mm3/annum for a 0.25 m3/s diversion to 9.88 Mm3/annum for a 1.0 m3/s diversion. The optimum firm yields for the 4 diversions are presented in Table 4.1. The optimum 30% failure yields for the 4 diversions are presented in Table 4.2. Results show that large off-channel storage greater than 5.0 Mm3 with high diversion capability (greater than 0.5 m3/s) can produce significant yield.

Table 4.1 Optimum firm yield (Mm3/annum) for different diversion and off-channel dam capacity in the Leeu River at E2H007.

Diversion capacity (m3/s)	Diverted flow (Mm3/annum)	Off-channel capacity (Mm3)	Firm Yield (Mm3/annum)
0.25	3.06	3.0	1.81
0.50	5.67	5.5	3.21
0.75	7.95	7.0	4.03
1.00	9.88	7.0	4.19

Table 4.2 Optimum 30% failure yield (Mm3/annum) for different diversion and off-channel dam capacity in the Leeu River at E2H007.

Diversion capacity (m3/s)	Diverted flow (Mm3/annum)	Off-channel capacity (Mm3)	30% Failure Yield (Mm3/annum)
0.25	3.06	3.0	2.77
0.50	5.67	5.0	4.76
0.75	7.95	6.0	6.02
1.00	9.88	8.0	7.89

Clearly storage on the Leeu River will significantly improve yield. For smaller storages on the Leeu River (less than 10.0 Mm3) any scenario involving diversions form this on-channel storage to off-channel storage will result in similar yields to those presented in Appendix 6.2. A large dam on the Leeu River is not an option for this project.

4.2.7 LEEU RIVER DOWNSTREAM OF E2H007

The yield curve results for the Leeu River downstream of E2H007 are presented in Appendix 7. This site includes the runoff from the Latjieskloof River. Results are very similar to those discussed in section 3.6 except the yields are slightly higher. Appendix 7.1 and 7.2 show the yields are approximately 10% higher.

A comparison of the diversion scenarios presented in Appendix 7.3 and Appendix 7.4 indicates that the optimum off-channel storage and optimum yield differs from those at the site upstream. Optimum yields are listed in Table 4.3 and Table 4.4. Results indicate that diversions from the downstream site are advantageous in terms of yield (10% higher) and in terms of optimum structures that are slightly larger.

Table 4.3 Optimum firm yield (Mm3/annum) for different diversion and off-channel dam capacity in the Leeu River (downstream).

Diversion capacity (m3/s)	Diverted flow (Mm3/annum)	Off-channel capacity (Mm3)	Firm Yield (Mm3/annum)
0.25	3.06	3.5	2.81
0.50	5.67	7.0	3.92
0.75	7.95	8.0	4.70
1.00	9.88	9.0	5.21

Table 4.4 Optimum 30% failure yield (Mm3/annum) for different diversion and off-channel dam capacity in the Leeu River (downstream).

Diversion capacity (m3/s)	Diverted flow (Mm3/annum)	Off-channel capacity (Mm3)	30% Failure Yield (Mm3/annum)
0.25	3.22	3.0	2.88
0.50	5.93	6.0	5.52
0.75	8.31	7.0	6.89
1.00	10.37	9.0	8.72

4.2.8 HOUDENBECKS RIVER

The ACRU Model was also configured to generate current day flows in the Houdenbecks catchment. Yield curves were generated at the lower end of the study area (below the large dam on the farm Morester). The current-day flow used in this yield analysis have both upstream irrigation demands and downstream reserve requirements accounted for. Results are presented in Appendix 8.

Significant on-channel storage is required to obtain yield from the Houdenbecks catchment. Appendix 8.1 shows that the optimum 30% failure yield is approximately 10 Mm3/annum for a storage of 15 Mm3. Similar storage in the Leeu River yield about 15 Mm3/annum.

Diverting available water from the Houdenbecks River to off-channel storage is not really an option. Appendix 8.2 shows that a 0.25 m3/s diversion will not deliver a firm yield above 0.5 Mm3/annum and that a 0.5 m3/s diversion to a 4.0 Mm3 off-channel dam results in a 30% failure yield of 1.88 Mm3/annum. The same scenario at the lower Leeu River site has a 30% failure yield of 4.18 Mm3/annum.

4.2.9 EASTERN MOUNTAIN CATCHMENTS

Table 3.1 lists the current day MAR of the sub-catchments identified in Figure 3.1. Results indicate that surplus water could be utilised from the catchments that drain the mountains to the east of the study area, especially since the planned site for off-channel storage and possible future development in "De Meul" are located in this vicinity.

Appendix 9.1 shows the surplus yield that is available from sub-catchment 13 (shown in Figure 3.1) with the current irrigation requirements accounted for. Reserve releases were calculated at 19% of the natural flow and are also accounted for. On-channel storage of 2.5 Mm3 will result in an optimum 30% failure yield of 1.93 Mm3/annum. Appendix 9.2 shows that diverting the available runoff from catchment 13 can yield an optimum 30% failure yield of 1.0 Mm3/annum for a 0.2 m3/s diversion to a 1.2 Mm3 capacity off-channel dam.

5. SUMMARY

Table 5.1 and Table 5.2 summarises the best options for development in the study area. The option to pump directly from the Leeu River is clearly the best option with regards to yield. However, this option has annual costs associated with pumping so transferring water from mountain catchments under gravity may be preferred. Table 5.1 shows that the Heks River and Middeldeur River can be combined to produce a 30% failure yield of 5.89 Mm3/annum for an off-channel dam capacity of 5.5 Mm3. Similarly, the Skoongesig River and Meul River can produce a 30% failure yield of 5.71 Mm3/annum.

Transfers from the western mountain catchments can be augmented with available winter runoff from the catchments in the Latjieskloof River. There is also the possibility of increasing yield if the proposed increase in off-channel storage is able to utilise the available flow from sub-catchment 11 (Table 3.1 shows a surplus MAR of 5.3 Mm3/annum).

In conclusion, yield results show that apart from pumping winter flow from the Leeu River, there is no single source that can achieve the desired yield for the proposed development. Rather, the required yield can be achieved by combining the sources together.

Table 5.1 Most likely development options and corresponding firm yield (Mm3/annum) in the study area.

RIVER	ON-CHANNEL CAPACITY (Mm3)	DIVERSION (m3/s)	OFF-CHANNEL CAPACITY (Mm3)	YIELD (Mm3/annum)
Heks	2.0	0.25	2.2	2.0
Middeldeur	Same	0.15	1.0	0.83
Waterkloof	Not an option	-	-	-
Skoongesig	2.0	0.3	3.0	2.55
Meul	1.0	0.2	2.5	0.28
Leeu (E2H007)	0	0.5	7.0	3.21
Leeu (Downstrm)	0	0.5	7.0	3.92
Houdebecks	Not an option	-	-	-
Catchment 13	0	0.2	1.0	0.47

Table 5.2 Most likely development options and corresponding 30% failure yield (Mm3/annum) in the study area.

RIVER	ON-CHANNEL CAPACITY (Mm3)	DIVERSION (m3/s)	OFF-CHANNEL CAPACITY (Mm3)	YIELD (Mm3/annum)
Heks	2.0	0.25	4.0	4.49
Middeldeur	Same	0.15	1.5	1.40
Waterkloof	Not an option	-	-	-
Skoongesig	2.0	0.3	4.0	4.08
Meul	1.0	0.2	2.5	1.63
Leeu (E2H007)	0	1.0	8.0	7.89
Leeu (Downstrm)	0	1.0	9.0	8.22
Houdebecks	Not an option	-	-	-
Catchment 13	0	0.2	1.2	1.0

APPENDIX 1

HEKS RIVER YIELD CURVES

APPENDIX 2

MIDDELDEUR RIVER YIELD CURVES

APPENDIX 3

WATERKLOOF RIVER YIELD CURVES

APPENDIX 4

SKOONGESIG RIVER YIELD CURVES

APPENDIX 5

MEUL RIVER YIELD CURVES

APPENDIX 6

LEEU RIVER AT E2H007 YIELD CURVES

APPENDIX 7

LEEU RIVER (DOWNSTREAM) YIELD CURVES

APPENDIX 8

HOUDENBECKS RIVER YIELD CURVES

APPENDIX 9

LATJIESKLOOF RIVER YIELD CURVES

APPENDIX 8.1

A mass balance of the existing operation is summarised below.

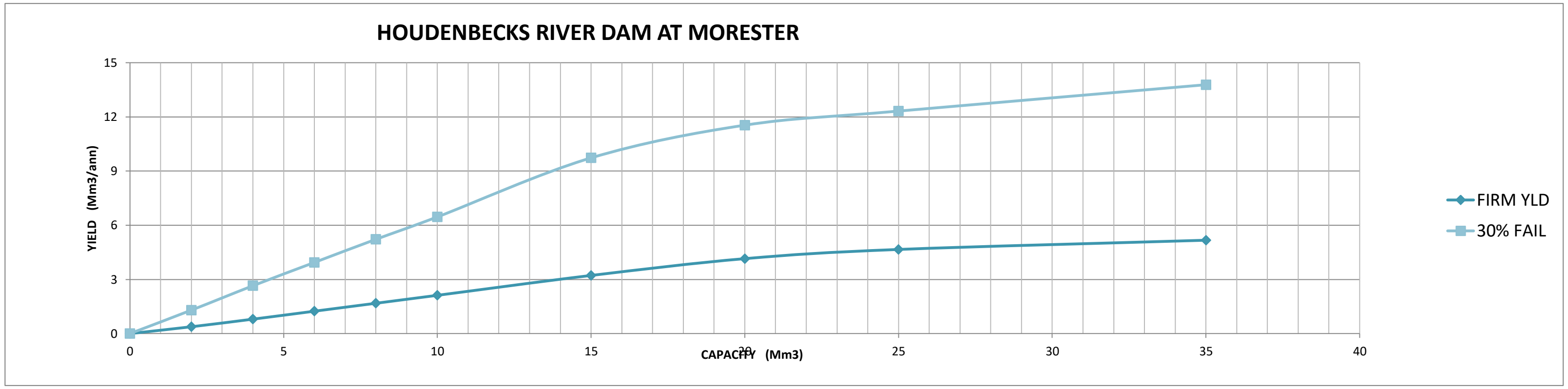
Inflow	Release	Divert	Irrig	Spill	Evap	DwnStrm
52.676	10.531	0.000	16.810	24.68	0.538	35.215

Theoretical dam yield (accounting for irrigation and reserve releases) and based on the summer demand ditribution below :

Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep
0.08	0.17	0.22	0.28	0.14	0.08	0.00	0.00	0.00	0.00	0.00	0.03

MAR = 24.68 Mm3

CAP	FIRM YLD	30% FAIL
0	0	0
2	0.38	1.3
4	0.8	2.65
6	1.24	3.94
8	1.68	5.22
10	2.12	6.46
15	3.22	9.73
20	4.15	11.54
25	4.66	12.32
35	5.17	13.78

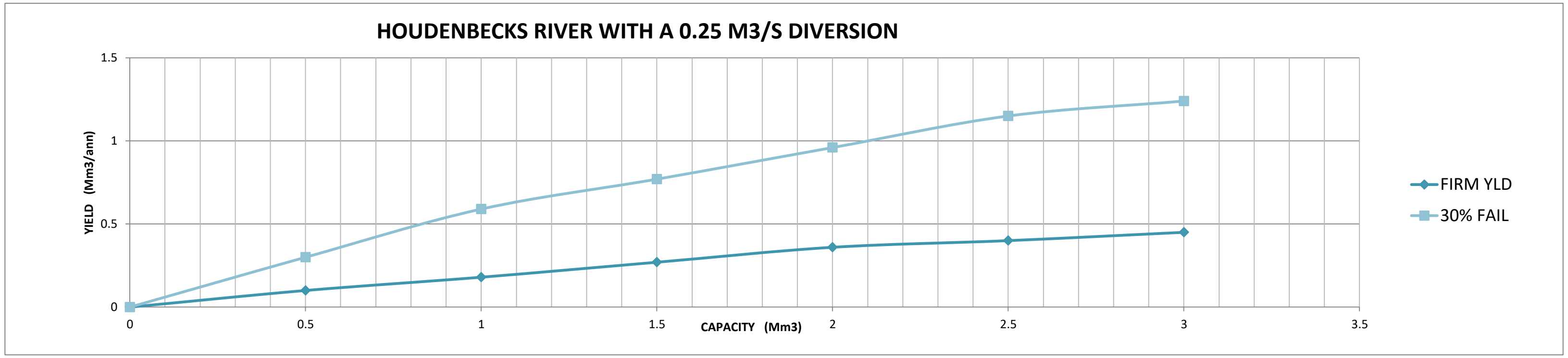


APPENDIX 8.2

Actual yield of surplus water with variable diversion capacity suppling variable storage
Note: No on channel storage

MAR = 1.614 Mm3

CAP	FIRM YLD	30% FAIL
0	0	0
0.5	0.1	0.3
1	0.18	0.59
1.5	0.27	0.77
2	0.36	0.96
2.5	0.4	1.15
3	0.45	1.24



MAR = 3.118 Mm3

CAP	FIRM YLD	30% FAIL
0	0	0
0.5	0.1	0.3
1	0.18	0.62
1.5	0.27	0.94
2	0.38	1.13
2.5	0.48	1.32
3	0.59	1.5
3.5	0.69	1.69
4	0.76	1.88