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AN INVESTIGATION INTO WATER USE AT THE ARABIE-OLIFANTS IRRIGATION SCHEME

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An Investigation into Water Use at the Arabie-Olifants Irrigation Scheme

1. BACKGROUND

This case study was commissioned by the International Water Management Institute (IWMI) as part of an investigation into the Olifants River basin in the Northern Province of South Africa. It is a water-accounting study and is, as far as we know, the first of its kind done on this scheme since its inception. Because of the lack of records abstraction values had to be obtained indirectly. This was done with satellite imagery to obtain actual irrigated area, pump capacity calculations, and canal and storage capacity determinations.

Although the study was done with a fair amount of detail, the exact field situation could not be determined in the time available for this study.

2. OBJECTIVE AND METHODOLOGY

The objective of the study was to establish the abstraction of water for agriculture from the Olifants River downstream of the Arabie Dam to Apèl. The methodology for the study can be summarized as follows:

The area was visited on four occasions. The first and second visits were to obtain an overview of the scheme in relation to infrastructure and general farming activities. The objective of the last two visits was to establish the technical details of the pumps and canals and to have discussions with various individuals of the parties involved.

Throughout the study, existing reports on the scheme were obtained and studied, relevant organizations contacted, and discussions held.

The areas actually irrigated in 1990, 1991, 1992, and 1998 were calculated from satellite imagery and are reflected in tables A and B in the appendix.

Technical detail verification would not have been possible without the field visits.

3. THE STUDY AREA

3.1 Location

The location of the sub-catchment is shown in figure 1. More specific details of farms bordering the Olifants River in the study area are given in figure 2. The sub-catchment covers an area of 4,213 km^2, or about 8 percent of the total Olifants River catchment of approximately 54,000 km^2. It is also identified as the sub-catchments B51A, B51B, B51C, B51E, B51F, B51G, and B51H in the Water Research Commission's *Surface Water Resources of South Africa* and is indicated by a thick dark line in figure 1. For the purpose of this report the combined catchment area will be called the study catchment and the focus will be only on the irrigation activities along the Olifants River on the farms indicated in figure 2. The study area is defined as the irrigable area along the river between the Arabie Dam and Apèl.

3.2 History of the Scheme

This stretch of the Olifants River has been regulated by the 1926 Water Court normal flow apportionment. The river abstraction weir, abstraction pump house, and earth canals were constructed in 1933. The existing concrete canals were constructed from 1948 to early 1960. The scheme formed part of the Olifants and Sekhukhuneland irrigation districts, which were formed during 1967 and 1968, respectively. Sprinkler irrigation and electricity were installed during 1982/83. Between 1983 and 1988, the greater part of the scheme was managed by the Agricultural Management Services (AMS) on behalf of the Government of Lebowa and the rest by the Lebowa Department of Agriculture and Environmental Conservation (LDA) itself. From 1989 to 1992, the parastatal Lebowa Agricultural Corporation (LAC) took over from AMS and, since the consolidation of the provinces in 1992, the LAC's successor, Agricultural and Rural Development Corporation (ARDC) has managed the greater part of the scheme. The Northern Province Department of Agriculture, Land and Environment (NPDALE) is currently (1999) managing the remaining part of the scheme.

3.3 Climate

The study area falls in the summer rainfall region of South Africa and the average annual rainfall varies from 500 mm at Hindostan to 442 mm at Mooiplaats. The average evaporation values (Symons pan adapted) at the Arabie and the Piet Gouws Dams are 1,180 mm and 1,270 mm per annum, respectively. The area falls in the Lowveld climatic zone with warm to hot summers and rare frost occurrences during winter. It can be classified as arid to semiarid.

Figure 1. Arabie-Olifants study catchment marked with thick line.

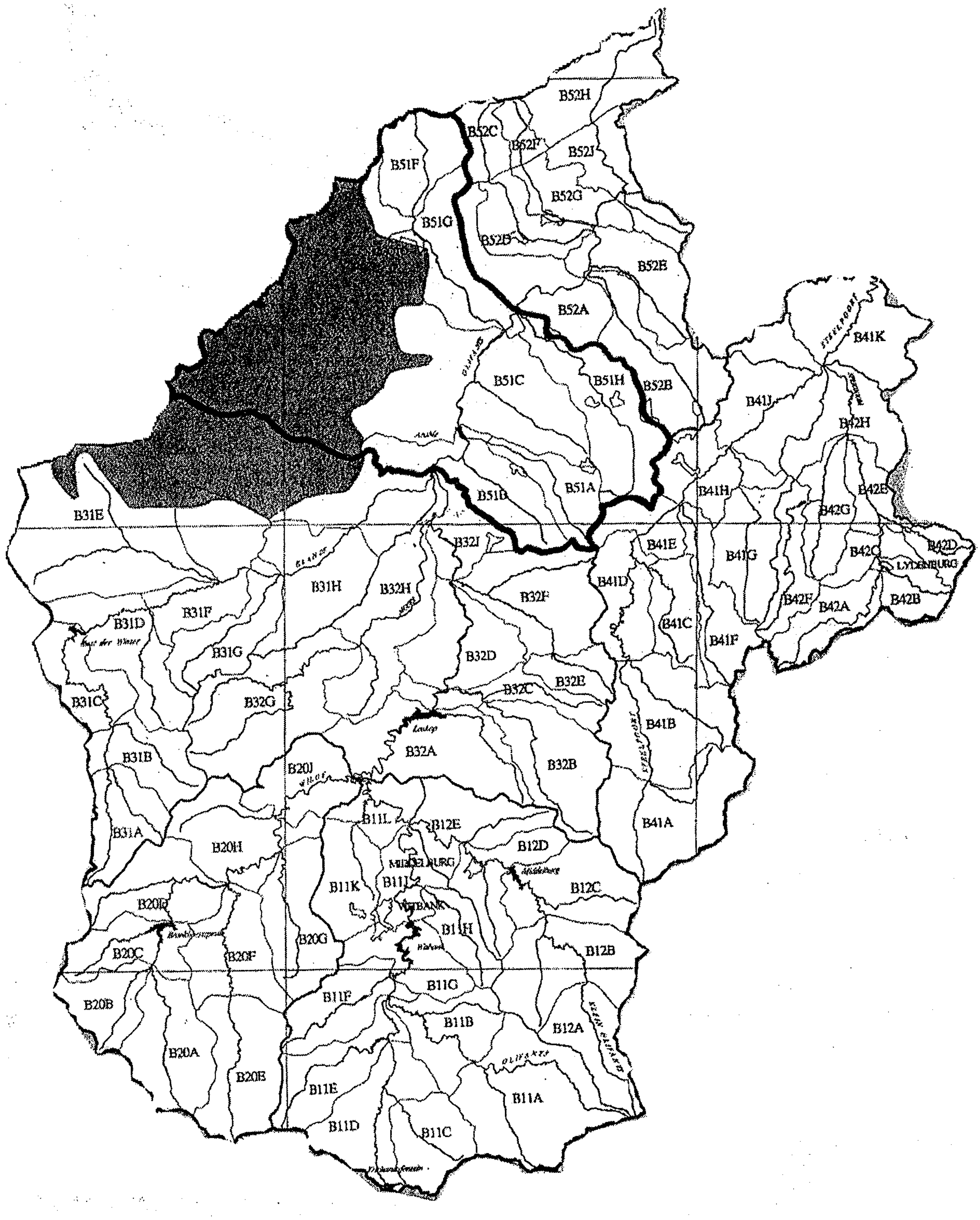
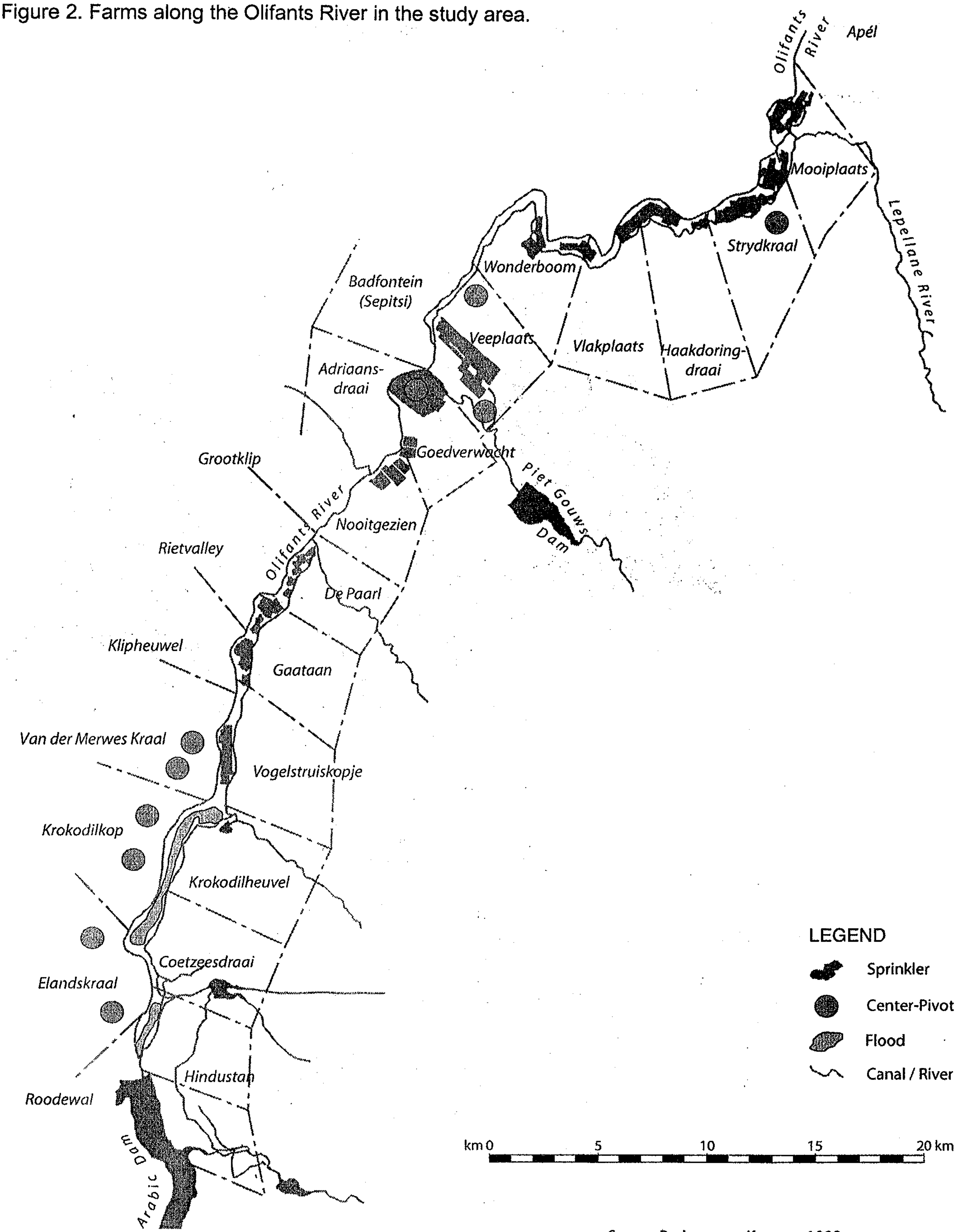


Figure 2. Farms along the Olifants River in the study area.



Source: Barbara van Koppen 1999.

The main climatic data for the sub-catchments B51C and B51H, which form part of the study catchment, are listed in table 1.

Table 1. Climatic data for the sub-catchments B51C and B51H.

Climatic data	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Rainfall % of MAP*	8.7	16.6	16.9	17.5	13.6	11.1	6.8	2.5	1.1	0.8	1.0	3.4
Evap. % of MAE**	11.1	10.5	10.7	10.3	8.8	8.7	7.0	6.0	4.8	5.4	7.3	9.4
Average temp. (°C)	23.1	24	24.6	25.9	24.9	22.6	19.4	16.1	12.9	13.0	16.4	21
Ave. max. temp. (°C)	30.2	29.9	30.8	31.8	30.5	28.7	26.8	24.2	23.3	22.4	25.9	29.4
Ave. min. temp. (°C)	20.0	19.1	16.5	11.9	8.0	2.6	3.4	6.8	12.5	15.8	18.0	18.4

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*MAP = Mean annual precipitation or rainfall; Evap. = Evaporation; **MAE = Mean annual evaporation; Ave. = Average; Max. = Maximum;
Min. = Minimum; Temp. = Temperature.
The average temperatures are based on data for 1995 to 1997 at the Veeplaats weather station.

The rainfall as a percentage of the MAP gives an indication of the annual rainfall distribution. From the table it is seen that the monthly rainfall increases from August/September, peaks during December/January, and decreases in July, after which it starts to increase again.

The evaporation percentage of the MAE gives an indication of the annual distribution of evaporation. From this table it is seen that the evaporation is minimal during June/July and maximal during December/January.

3.4 Topography

The study area along the river is characterized by savanna biome type having a few hillocks with a maximum height of 350 meters on both riverbanks.

3.5 Hydrology

The catchment forms part of the Olifants River catchment as stated in previous paragraphs. The mean annual virgin runoff at the Arabie Dam is estimated at 698 million m^3/annum. Under the 1990 development conditions, the MAR was 248 million m^3/annum at Apèl and 300 million m^3/annum downstream of Apèl. The virgin condition is defined as the natural state or condition in which no human activities such as agriculture and urbanization, etc., have taken place. The 1990 values accounted for activities such as cultivation, forestation, urbanization, etc., in the calculation of the MAR at that specific time. The Loskop Dam and irrigation scheme have reduced runoff significantly.

According to the Department of Water Affairs and Forestry, the estimated firm yield from the Arabie Dam is 52.8 million m^3/annum.

The inflow from tributaries in the current development condition in the study area was not taken into account in this investigation. The nature of development of storage infrastructure and irrigation on these tributaries is such that only spills from dams in years of high rainfall will have an influence on the Olifants River in the area under investigation. The main tributaries with their dams are: Motsphiri with the Lola Montes Dam, Makotswane tributary with the Makotswane Dam (Buffelsdoorn Dam), Nwaritsi with the Piet Gouws Dam, Nkumpi with the Upper- and Lower-Gompies Dams, and the Mogoto Dam (figures 2, 3, and 4).

3.6 Infrastructure

A network of gravel roads links the cultivated areas with the main roads to the closest towns: Marble Hall, Lebowakgomo, and Pietersburg. The general condition of the roads on the scheme is poor with severe corrugations and inadequate surface drainage in places. The electricity distribution in the area appears to be sufficient, although regular power failures do occur and have been a problem, especially in the 1998/99 irrigation season. The other infrastructural aspects are not addressed in this report.

3.7 Primary Water Use

A new bulk water distribution network for supplying potable water from the Arabie Dam to the villages has been installed recently on a pay-before-you-drink basis. It is designed for a treatment flow rate of 8,000 m^3/day or 2.9 million m^3/annum. According to officials, the current utilization is less than 12 percent or 1,000 m^3/day. A possible reason for this was stated as the users' unwillingness to pay for the water while it is readily available from the irrigation canals. Another reason can be the inability of the town or local community to pay for the in-town distribution networks needed to link up with the main supply network. The capacity of the purification works at the Piet Gouws Dam is reportedly 3,000 m^3/day or 1.1 million m^3/annum.

The return flow of water from the primary users is negligible.

An unknown volume of water is abstracted directly from the canals for primary use by means of buckets and pipes. For an estimated population of 10,000 with easy access to the canals, this volume is estimated at 100,000 m^3 per annum (approximately 10.l/capita/day).

Figure 3. Diagrammatic illustration of water-related infrastructure, Coetzeesdraai canal (May, 1999).

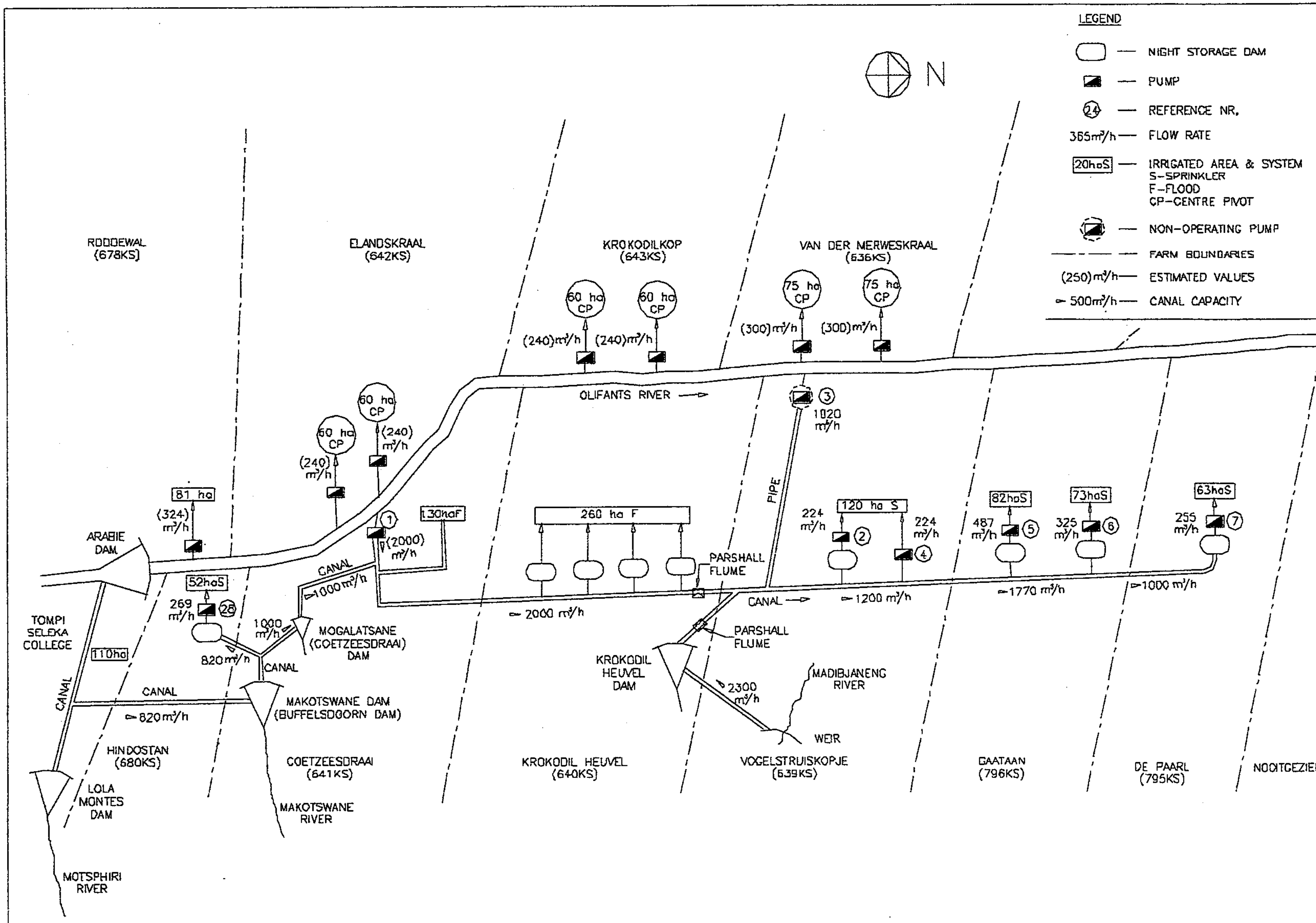
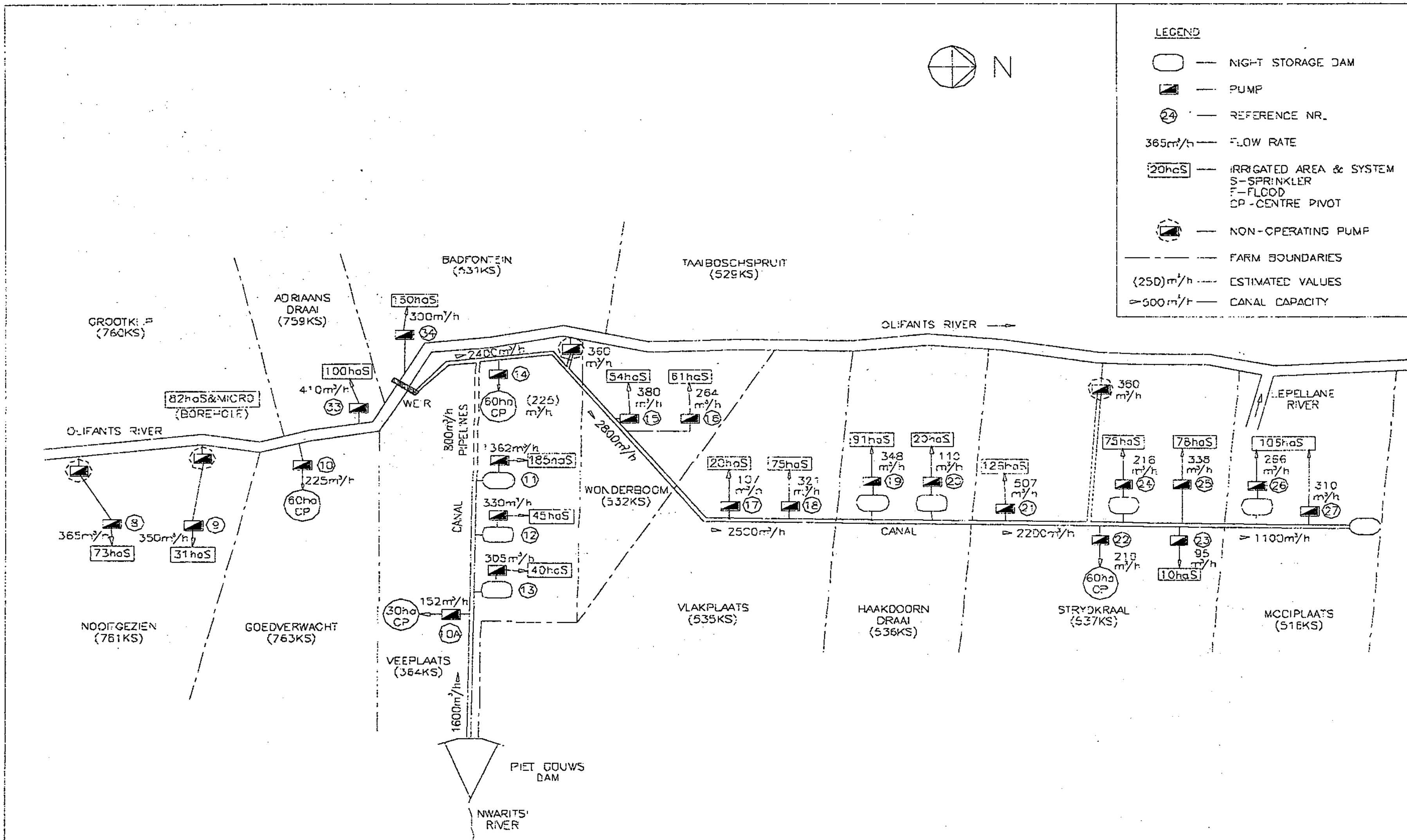


Figure 4. Diagrammatic illustration of ater-related infrastructure, Veeplaats and Piet Gouws canals (May, 1999).



3.8 Cropping

The traditional farming practices are limited dryland cropping and livestock farming including cattle, goats, and sheep. The main irrigated summer crops are cotton and maize with marginal yields. Vegetables are grown on a limited scale on food plots alongside the canal scheme. Citrus and grapes are grown on one farm (Grootklip) with a total area of 82 hectares. Citrus was grown at Mooiplaats in the 1970s and 1980s, but was abandoned due to theft of crops. The winter crop is usually wheat with limited small-scale vegetable cultivation. While the scheme was centrally managed, maize was planted during September and wheat during May–June. Currently, maize is planted during December–January and wheat is often not planted because of the late maize planting.

need cropping map

3.9 Irrigation

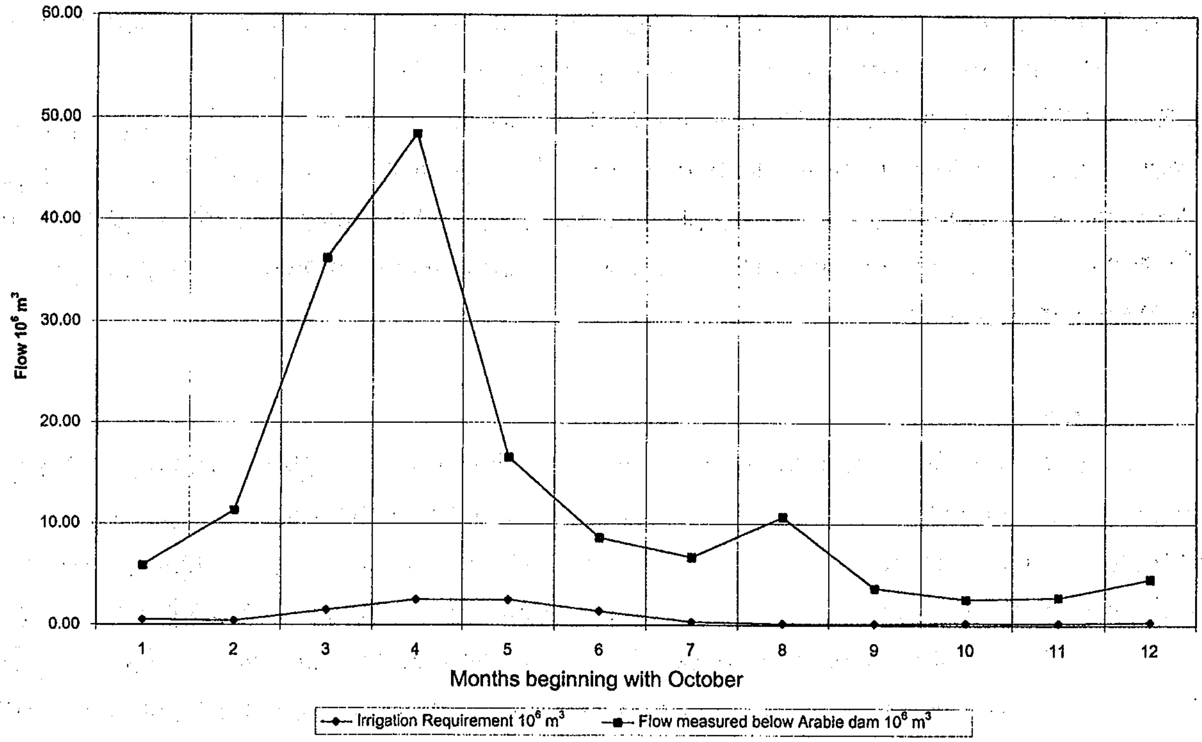
The irrigation potential in terms of available surface water from the Arabie Dam and other dams on the scheme are estimated at 5,500 hectares, according to an investigation done in 1991. The currently developed irrigable area is calculated at 2,768 hectares. This represents a volume of 16.6 million m^3/annum at an estimated demand of 6,000 m^3/ha/annum. This value is based on the SAPWAT model that takes account of effective rain and an irrigation system efficiency of 67 percent. The crop water requirement of 6,000 m^3/ha/annum is a general value that varies according to the crop, the planting date, and the planting density of the crop. In commercial farming operations at the Loskop scheme, typical irrigation requirement values of 400 to 500 mm/ha/annum (4,000–5,000 m^3/ha/annum) for maize and wheat were measured in the 1980s. A scenario for the abstraction of water during the irrigation season is illustrated in table 11 and figure 5.

Altogether 2,768 hectares have been developed for irrigation. A calculated area of 1,873 hectares (ARDC, LDA) has been developed for irrigation from canals on the Eastern riverbank, from Hindostan to Mooiplaats. The systems are conventional sprinkler (71%), center pivot (10%), and flood (19%).

In addition, an estimated 895 hectares have been developed for irrigation by direct abstraction from the river. The systems using direct abstraction are estimated as center pivot (50%) and sprinkler (29%), and the balance micro-irrigation and other systems. The irrigated area served by boreholes is estimated at 82 hectares.

Additional information on the operation of the scheme is given in section 4.4.

Figure 5. Measured flow and irrigation requirements: Arabie Dam releases versus irrigation requirement (scenario 1).



4. WATER SUPPLY AND DISTRIBUTION

Water is supplied to the scheme primarily from the Olifants River and its tributaries below the Arabie Dam, with some additional pumping of groundwater. Water is supplied to farms in two main areas, namely:

- farms on the Western or left-hand riverbank, which are supplied by a series of direct abstraction pumps from the Olifants River and boreholes

- farms on the Eastern or right-hand riverbank, which are supplied through a system of dams, weirs and canals, with supplementary pumping into the canals (figures 3 and 4)

The combined storage of the three dams in the Eastern bank system, the Lola Montes Dam on the Motshiri, the Makotswane Dam (Buffelsdoorn Dam), and the Piet Gouws Dam, is 11.29 million m^3. Smaller tributaries were not taken into account in this investigation.

The two canals starting at Coetzeesdraai and Veeplaats, respectively, are the main distribution structures on the Eastern bank. The Coetzeesdraai-De Paarl canal serves 728 hectares and the Veeplaats-Mooiplaats canal serves an estimated 836 hectares. The Piet Gouws canal serves 300 hectares and its overflow is directed into the Veeplaats-Mooiplaats canal.

Water is supplied to the fourteen farms on the Eastern bank via six main infrastructural units namely:

- Hindostan, by canal from the Lola Montes and Makotswane Dams
- Coetzeesdraai, Krokodilheuvel, Vogelstruiskopje, Gaataan, and De Paarl, from the Coetzeesdraai-De Paarl canal
- Nooitgezien, by direct pumping from the Olifants River
- A portion of Veeplaats, by direct pumping from the Olifants River
- A portion of Veeplaats and the farm Goedverwacht, by canal from the Piet Gouws Dam
- A portion of Veeplaats and the farms Wonderboom, Vlakplaats, Haakdoorndraai, Strydkraal, and Mooiplaats, from the Veeplaats-Mooiplaats canal

The realistic total abstraction capacity of the Olifants River in the study area is 10,074 m^3/h, serving 2,811 hectares of irrigation. The abstraction capacities of the various infrastructural units are listed below in table 2.

Table 2. Abstraction capacity of the Olifants River.

Description of infrastructural unit	Area developed for irrigation (ha)	Abstraction from dams and weirs into canals* (m^3/h)	Pumping from river to augment canal flow (m^3/h)	Pumping from river directly into irrigation systems (m^3/h)
Hindostan	52	820		
Coetzeesdraai-De Paarl canal	728	2,000	3,020	
Nooitgezien direct pumping	104			715
Goedverwact direct pumping	60			225
Piet Gouws canal	300	1,600		
Veeplaats-Mooiplaats canal	836	2,400	720**	
Direct pumping on Western bank – Roodewal to Badfontein	731***			2,594
Total	2,811	5,820	720	3,534

* Based on canal capacities.
** Two pumps of an estimated capacity of 360 m^3/h each (Veeplaats and Strydkraal).
*** Additionally, 82 hectares are irrigated from groundwater at Grootklip.

The pumping capacity into pressurised irrigation systems in the fields (sprinkler and center pivot) in the study area totals 11,164 m^3/h, serving 2,421 hectares of irrigation. This often implies double pumping and high energy costs, since canal flow is being augmented by river pumps as shown above in table 2. Thus the realistic total potential abstraction from the river is 10,074 (m^3/h).

Table 3. Pumping capacity into sprinkler and center pivot irrigation systems (m^3/h).

Description of Infrastructural unit	Area developed for pressurised irrigation (ha)	Pumping from canals into irrigation systems (m^3/h)	Pumping from balancing dams into irrigation systems (m^3/h)	Pumping from river directly into irrigation systems (m^3/h)
Hindostan	52		269	
Coetzeesdraai-De Paarl canal	338 *	1,515		
Nooitgezien direct pumping	104			715***
Goedverwacht direct pumping	60			225
Piet Gouws canal	300	2,149		
Veeplaats-Mooiplaats canal	836	3,697		
Direct pumping on Western bank—Roodewal to Badfontein	731 **			2,594
Total	2,421	7,361	269	3,534

* The difference between this value and the value for the Coetzeesdraai-De Paarl irrigation in table 2 is flood irrigated.

** Additionally, 82 hectares are irrigated from groundwater at Grootklip.

*** Water at Nooitgezien is pumped twice: the river pumps supply water to a set of booster pumps that supply the irrigation systems.

Table 4. Current abstraction from the Olifants River according to 1998 satellite data.

Description of Infrastructural unit	Area developed for pressurised irrigation (ha)	Pumping from canals into irrigation systems (m^3/h)	Pumping from balancing dams into irrigation systems (m^3/h)	Pumping from river directly into irrigation systems (m^3/h)
Hindostan	0	0		
Coetzeesdraai-De Paarl canal	185.6	1,000	2,000*	
Nooitgezien direct pumping	6.2			715*
Goedverwacht direct pumping				225
Piet Gouws canal	227.9	1,600		
Veeplaats-Mooiplaats canal	234	2,400**		
Direct pumping on Western bank—Roodewal to Badfontein	115			690
Total	768.7			

* Values based on pump capacities. It can be assumed that the pumping time was adjusted according to the irrigation requirements.

** Value based on canal capacity although it can be assumed that less water was abstracted due to partially blocked canals.

4.1 Supply on the Eastern or Right-Hand Riverbank

The total length of the main canals from Arabie to Mooiplaats is estimated at 90 kilometers. The length of the Piet Gouws canal is 8 kilometers (see figures 3 and 4 for details).

Previously, quite a number of farmers were abstracting water directly from the river through no-fines abstraction wells, which are double-walled circular concrete tanks with an outside diameter of 4 meters and an inner diameter of about 2.5 meters. Both the outer and inner walls are constructed of no-fines concrete, which is a mixture of cement and crusher stone, allowing water to seep through the concrete. The cavity between the inner and outer walls is filled with a filter of graded crusher stone and sand to prevent sediment intrusion. The tanks are normally 2.5 to 3 meters deep and are constructed in the riverbed and provided with a concrete roof that protrudes less than 0.5 meter above the riverbed. The well houses either a submersible pump or the suction pipe of a centrifugal pump.

During the floods of 1995/96, a number of these wells were damaged, which resulted in water abstraction directly from the river, without the use of the no-fines wells. The damaged delivery lines of the floating submersible pumps at Nooitgezien have not been repaired since the floods.

A supply pump from the river to the canal at Vogelstruiskopje has been out of action since the end of 1998, when the power supply cable of the motor was stolen.

The condition of the canal was not investigated due to the flow of water in the canal. In general it appeared to be fair.

4.1.1 Supply from Lola Montes Dam

Lola Montes Dam Specifications

Catchment area	323 km^2
Storage capacity	1.48 million m^3
MAR	5.6 million m^3/annum
Estimated firm yield	0.8 million m^3/annum

Water from the Lola Montes Dam is fed into a weir from which a canal with a capacity of 820 m^3/h supplies water to the Makotswane Dam and another canal supplies water to 110 hectares of irrigation development at the Tompi Seleka Agricultural College. Overflow from the Lola Montes Dam and the Tompi Seleka canal spills into the Arabie Dam, and has therefore not been taken into account in the calculation of the water balance downstream of Arabie. Although the Lola Montes Dam can play a potentially significant part in the water supply to the scheme with improved management, the survey showed that the current contribution of the Lola

Montes canal is negligible and this was thus not taken into account in the current water balance (see figure 3).

The survey team did not investigate the condition of the Lola Montes canal.

4.1.2 Supply from the Makotswane Dam

Makotswane Dam Specifications

Catchment area	113 km^2
Storage capacity	3.4 million m^3
MAR	2.2 million m^3/annum
Estimated firm yield	1.0 million m^3/annum

From the Makotswane Dam, a canal with a capacity of 820 m^3/h supplies 52 hectares of sprinkler irrigation at Hindostan, while another canal with a capacity of 1,000 m^3/h carries the bulk of the water to the Mogalatsane Dam and onwards to join the main Coetzeesdraai-De Paarl canal, which is supplied from the Coetzeesdraai pump station and which carries water to the farms on the right-hand riverbank up to and including De Paarl. During times of low irrigation requirements, water is diverted from the Makotswane Dam and is used for primary purposes directly from the canal (see figure 3).

The condition of this canal can be described as fair, but the sides are not smooth and the concrete is pitted. Minor maintenance on this canal is being undertaken currently.

4.1.3 Supply from the Coetzeesdraai-De Paarl Canal

The Coetzeesdraai-De Paarl canal serves a total irrigated area of 728 hectares on the Coetzeesdraai, Krokodilheuvel, Vogelstruiskopje, Gaataan, and De Paarl farms. The estimated capacity of this canal is 2,000 m^3/h. A Parshall flume for flow measurement has been installed at Krokodilheuvel, just downstream of the outlets to the last two night storage dams on this farm (see figure 3 and table A in the appendix).

The Coetzeesdraai Dam, with a capacity of 0.1 million m^3 and the Krokodilheuvel Dam, with a capacity of 0.21 million m^3, are on tributaries of the Olifants River and form part of the supply to the Coetzeesdraai-De Paarl canal. A second Parshall flume can be found at the outlet of the Krokodilheuvel Dam before it links up with the Coetzeesdraai-De Paarl canal. Water from these dams can be used for direct supply to the scheme, but since the Coetzeesdraai-De Paarl canal is at a lower level, the dams cannot be gravity-fed from the canal and are, therefore, used as balancing dams.

There are seven pump houses in this system, two pumping directly from the Olifants River into the water supply system and the other five pumping from the canal into the sprinkler irrigation system. Table A in the appendix lists the number of pump stations and areas served by each station.

The night storage dams found at four of the five canal pump houses were originally constructed as part of the flood irrigation scheme and are still being used for storage, although sprinkler irrigation systems were installed on all the farms, except Coetzeesdraai and Krokodilheuvel, during 1982/83. The night storage dams have not been maintained, are overgrown, and their capacity has been reduced by sediment.

Table 5 shows a canal flow balance and illustrates the current water supply problem downstream of Krokodilheuvel. Without augmentation from the river pump at Vogelstruiskopje there is a deficit at all the farms from Gaataan downstream, and with full augmentation from the Vogelstruiskopje River pump, the deficit is experienced only from De Paarl downstream.

Table 5. Canal flow balance for maximum canal capacity (Coetzeesdraai-De Paarl canal).

Farm	Canal flow[1] (m^3/h)	Canal flow[2] (m^3/h)	Abstraction[3] (m^3/h)	Canal capacity[4] (m^3/h)	Irrigable area[5] (ha)
Coetzeesdraai (641 KS)	2,000		650	2,000	130
Krokodilheuvel (640 KS)	1,350		1,300	2,000	260
Vogelstruiskopje (639 KS)	50	1,020	448	1,200	120
Gaataan (796 KS)	-398	622	812	1,770	155
De Paarl (795 KS)	-1,210	-190	255	1,000	63
End of canal	-1,465	-445			

1. Balance of flow in canal after full upstream abstraction. Negative values denote shortages.
2. Balance of flow in canal after full upstream abstraction with full use of pumping capacity (1,020 m3/h) at Vogelstruiskopje River pump station (e.g., flow of 622=1,020+50-448).
3. Abstraction capacity per farm.
4. Canal capacity estimated at each farm.
5. Area currently developed for irrigation on each farm.

Table 6 shows the canal flow balance for the actual maximum irrigation water use in any of the four years (1990, 1991, 1992, and 1998), as derived from satellite imagery for those four years.

Table 6. Canal flow balance for actual areas irrigated from the Coetzeesdraai-De Paarl canal in recent years.

Farm	Canal flow[1] (m^3/h)	Canal flow[2] (m^3/h)	Abstraction[3] (m^3/h)	Canal capacity[4] (m^3/h)	Actual Irrigated area[5] (ha)
Coetzeesdraai (641 KS)	2,000		454	2,000	90.8
Krokodilheuvel (640 KS)	1,546		1,054	2,000	210.9
Vogelstruiskopje (639 KS)	491	1,200[6]	148	1,200	39.7
Gaataan (796 KS)	343	1,052	330	1,770	63.1
De Paarl (795 KS)	13	722	80	1,000	19.8
End of canal	-67	642			

1. Balance of flow in canal after full upstream abstraction. Negative values denote shortages.
2. Balance of flow in canal after full upstream abstraction with full use of pumping capacity (1,020 m3/h) at Vogelstruiskopje River pump station (e.g., flow of 1,052=1,200-148).
3. Actual irrigated area.
4. Canal capacity estimated at each farm.
5. Actual area irrigated in 1998.
6. Canal capacity limits flow to 1,200 m^3/h.

The condition of the canal is fair to good in the first section, but the section downstream of Krokodilheuvel is very rough, which implies a high Manning Roughness Coefficient and a decreased flow rate. The concrete shows signs of damage by the sun, since it has been in disuse and totally dry for a number of years. The canal will have to be made smooth to reduce flow capacity problems when the utilization of irrigation fields increases towards full capacity.

4.1.4 Supply from the Veeplaats Weir and the Veeplaats-Mooiplaats Canal

The capacity of this canal at the weir is estimated at 2,400 m^3/h and the canal supplies a portion of Veeplaats and the five farms Wonderboom, Vlakplaats, Haakdoorndraai, Strydkraal, and Mooiplaats. Currently (1999), the capacity is estimated at only about 550 m^3/h, due to the high sediment level (500 mm) in the canal. The capacity of the canal varies along the route as indicated in figure 4. A floating pump station was installed in the Olifants River at Strydkraal to augment the flow in the canal and to supply water to the center pivot at Strydkraal. This river pump installation was also damaged during the flood and is currently not operating, which aggravates the existing deficit in water supply to Strydkraal and Mooiplaats, especially during times of peak requirement. The water distribution and the canal are poorly managed.

The area developed for irrigation from the Veeplaats-Mooiplaats canal was estimated at 790 hectares. While there are night storage dams at only 5 of the 14 pump stations there are no measuring structures on the canal. Table B in the appendix lists the relevant information in terms of location, capacities, systems, etc.

The canal flow balance in table 7 illustrates the water supply problem downstream of Haakdoorndraai, even without considering the current reduced canal capacity due to sedimentation.

Table 7. Canal flow balance for maximum canal capacity (Veeplaats-Mooiplaats canal).

Farm	Canal flow[1] (m^3/h)	Canal flow[2] (m^3/h)	Abstraction[3] (m^3/h)	Canal capacity[4] (m^3/h)	Irrigable area[5] (ha)
Veeplaats (764 KS)	2,400		250	2,400	60
Wonderboom (532 KS)	2,150		644	2,800	215
Vlakplaats (535 KS)	1,506*		428	2,500	95
Haakdoorndraai (536 KS)	1,078		458	2,200	111
Strydkraal (537 KS)	620	980	1,550	2,200	296
Mooiplaats (516 KS)	-930	-570	576	1,100	106
End of canal	-1,506	-1,146			

1. Balance of flow in canal after full upstream abstraction. Negative values denote shortages.
2. Balance of flow in canal after full upstream abstraction with full use of pumping capacity (360 m^3/h) at Strydkraal pump station.
3. Abstraction capacity per farm.
4. Canal capacity estimated at each farm.
5. Area currently developed for irrigation on each farm.

Table 8 presents the canal flow balance for the actual maximum irrigation water use in any of the four years (1990, 1991, 1992, and 1998), as derived from satellite imagery for those four years.

Table 8. Canal flow balance for actual areas irrigated from the Veeplaats-Mooiplaats canal in recent years.

Farm	Canal flow[1] (m^3/h)	Canal flow[2] (m^3/h)	Abstraction[3] (m^3/h)	Canal capacity[4] (m^3/h)	Actual Irrigated area[5] (ha)
Veeplaats (764 KS)	2,400		250	2,400	60
Wonderboom (532 KS)	2,150		687	2,800	123
Vlakplaats (535 KS)	1,463		426	2,500	94
Haakdoorndraai (536 KS)	1,037		503	2,200	127
Strydkraal (537 KS)	534	894	1,446	2,200	276
Mooiplaats (516 KS)	-912	-552	708	1,100	130
End of canal	-1,620	-1,260			

1. Balance of flow in canal after full upstream abstraction. Negative values denote shortages.
2. Balance of flow in canal after full upstream abstraction with full use of pumping capacity (360 m^3/h) at Strydkraal pump station.
3. Actual abstraction capacity per farm.
4. Canal capacity estimated at each farm.
5. Area currently developed for irrigation on each farm.

The project team did not have the opportunity to investigate the canal while it was empty, but its condition seemed generally good in terms of construction. The physical damage to the canal is evident in a few places where joints have not been sealed properly and where soil has been washed away from behind the canal sides, leading to the collapse of the canal. Also, the canal sides have been broken in several places for abstraction of water for increasing food gardening beside the canal.

However, the apparent lack of maintenance is probably more significant than physical damage in this canal. Cleaning of the first 1–2 kilometers downstream of the weir could be difficult due to the high protection berms on both sides of the canal and in some places the canal is filled to more than 50 percent of its depth with coarse sand and sediment. The first section of the canal, between the weir and the first abstraction point at Wonderboom, is overgrown with grass and some shrubs. Some stretches of the canal further downstream have also not been cleaned for some time, as was evident from strands of algae and sand accumulation.

Blockages have serious consequences for the canal capacity and water availability at the lower end of the canal. This could explain the serious water shortages experienced at Strydkraal and Mooiplaats in the past irrigation season (1998/99), despite minimal water use by the upstream farmers.

4.1.5 Supply from the Piet Gouws Dam

Piet Gouws Dam Specifications

Catchment area	694 km^2
Storage capacity	6.51 million m^3
MAR	12.1 million m^3/annum
Estimated firm yield	3.2 million m^3/annum

The loss of storage volume due to sedimentation in the Piet Gouws Dam is unknown.

The major part of Veeplaats, namely 300 hectares out of 489, is supplied from the Piet Gouws Dam, via a canal with a capacity of 1,600 m^3/h. A weir downstream of the dam diverts water into the Piet Gouws canal. The spill from this canal is piped to the Veeplaats-Mooiplaats canal and the capacity of this pipeline is estimated at 800 m^3/h.

A water purification plant has been erected at this dam for primary water supply to a number of villages. This plant is in the process of being upgraded (May, 1999). The design yield of this plant is a maximum of 3,000 m^3/day or 1.1 million m^3/annum.

Although the canal was flowing at full capacity during the investigation, its condition seemed good and a few spot checks did not show serious sedimentation.

4.1.6 Supply from the Olifants River

Nooitgezien is supplied by two float-mounted submersible pumps that feed into centrifugal pumps, which supply the irrigation system. These pumps are currently not connected to the centrifugal pumps. Apparently, this is due to the 1995/96 flood damage. One of the center pivots on Veeplaats is supplied by a floating inlet on the river. The no-fines abstraction well was also damaged during the floods of 1995/96. The high sediment load in the Olifants River, especially downstream of Veeplaats necessitates the use of some pump-impeller protection equipment or structures.

The supply from the Vogelstruiskopje River abstraction point to the main canal is currently not functioning due to the theft of the power supply cable at the end of 1998. The pump has not been utilized for the past two to three seasons.

Table 9 shows the storage capacities of the existing dams and illustrates their impact on the infrastructural units in the scheme. The dams with a direct impact are those that will have sufficient water available for the specific infrastructural unit.

Table 9. Storage capacity of dams and impact on canal sections and direct abstraction points.

Name of dam	Storage capacity (x million m^3)	Hindostan	Coetzeedraai-De Paarl canal	Direct abstraction: Nooitgezien
Arabie	103.4		•	*
Lola Montes	1.48	•	•	*
Makotswane	3.4	•	•	*
Coetzeesdraai	0.1		•	*
Krokodilheuvel	0.21		•	*
Piet Gouws	12.1			*

Name of dam	Storage capacity (x million m^3)	Direct abstraction: Veeplaats	Piet Gouws canal	Veeplaats-Mooiplaats canal	Direct abstraction: Left riverbank Roodewal to Badfontein
Arabie	103.4	•		•	•
Lola Montes	1.48	*		*	•
Makotswane	3.4	*		*	•
Coetzeesdraai	0.1	*		*	•
Krokodilheuvel	0.21	*		*	•
Piet Gouws	12.1	*	•	•	•

A "•" denotes a direct or definite impact and an "*" denotes an indirect or limited impact. A blank cell denotes no impact.

4.2 Supply on the Western or Left-Hand Riverbank

All the major irrigation systems on the western riverbank, an estimated 730 hectares of irrigation, are supplied directly by pumping from the Olifants River. The farms on the western bank in the study area from Roodewal to Badfontein are listed in table B in the appendix.

The farm Roodewal is in the Mpumalanga Province and all the others are in the Northern Province. The farms Grootklip, Adriaansdraai, and Badfontein are currently managed by the ARDC. The others are owned by the government and leased to private farmers.

4.3 Farm-Level Irrigation Development and Activities in the Study Area

The activities and current development on the farms on both the western and eastern riverbanks are summarized in tables A and B, respectively, in the appendix. They are grouped according to the source or supply. Currently (1999), approximately 30 percent of the total irrigable area is being irrigated.

Currently, there is apparently a problem with the management of the canals and the abstraction of water from the river to supply the canals. Due to the lack of an effective organizational body in this area, communication between the Department of Water Affairs and Forestry and the water users is limited and ineffective. Information on water management, abstraction, availability, and use is, therefore, haphazard. This situation could deteriorate with the withdrawal of the ARDC.

It was also mentioned that the water users would be liable for the payment of water in the near future. This will be in accordance with the new National Water Act. An organized water user body or association will be necessary in the near future for efficient water management in the study area. The payment of electricity bills will be direct from the account of the farmers and new electricity consumption meters have been installed at most of the pump stations.

The shortages experienced by the farmers on Mooiplaats during the latter part of the past season may have been the result of reduced flow in the canal, due to blockages in the canal, illegal water abstraction with associated physical damage to the canal, and poor management. According to the farmers, critical water shortages have resulted in lower crop yields in the past season.

The level of on-farm irrigation management was not investigated. In general, overirrigation tends to occur in the absence of training and management assistance. One may assume that overirrigation occurs also on this scheme. The crop factors used for calculating water use should be adapted for planting densities lower than those in customary commercial practices. For the sprinkler systems an 18 m x18 m spacing was assumed, although some farmers are using a 12 m x18 m spacing. Typically, sprinklers with a single 11/64" (4.4 mm) size nozzle and line lengths of 240 m are used on the ARDC-managed systems. Table 10 shows the various irrigation systems supplied by the infrastructural bulk water supply units.

Table 10. Area covered by the various irrigation systems (ha).

Description of infrastructural unit for bulk water supply	Flood	Sprinkler	Center pivot	Micro-irrigation	Total
Hindostan		52			52
Coetzeesdraai-De Paarl canal	390	338			728
Nooitgezien direct pumping		104			104
Goedverwacht direct pumping			60		60
Piet Gouws canal		270	30		300
Veeplaats-Mooiplaats canal		716	120		836
Direct pumping on Western river-bank—Roodewal to Badfontein		403	390	20*	813
Total	390	1,883	600	20	2,893

* Supplied by boreholes.

4.4 Scheme Operation

4.4.1 Overview

Figures 3 and 4 can be used to obtain a general overview of the scheme layout, while tables A and B in the appendix list data on water supply and irrigation infrastructure in the study area.

As described above, water for agriculture is supplied to the study area from the Olifants River through a system of canals and pump stations. The Arabie Dam can be viewed as the main source. According to officials of the Department of Water Affairs and Forestry, water releases from the dam are on the basis of water demands by the users downstream, but it is unclear how these requests are relayed to the department. Apparently, no water is being released currently specifically for ecological purposes. The volume of water supplied to Pietersburg from the Arabie Dam is estimated at 5.5 million m^3/annum.

The second most important source is the Piet Gouws Dam, which supplies water to Veeplaats and the potable water purification plant. This dam falls under the jurisdiction of DWAF but is operated by Veeplaats, which can lead to problems during dry periods, since water is a priority of the DWAF, while Veeplaats has an agricultural focus.

According to the pump attendants, the farmers are responsible for cleaning the canals. The stretches of canals that are far away from any farming activity and that are difficult for the farmers to reach due to lack of transport seem to have inadequate maintenance. Cleaning of these "dead canal" stretches, or "no-mans land" seems to depend on cooperation between the respective tribal authorities to mobilize their people for this task. These long "dead" stretches and the absence of balancing dams complicate the proper management of the scheme.

4.4.2 *Water Accounting*

Accounting for water availability and use in the study area require several assumptions:

- There are no flow measurements downstream of the study area, since readings at the measuring station at Olifantspoort have been discontinued since 1980.

- Similarly, there are no data on the actual water use from the canals by food gardeners and household users.

- Losses from the canals due to physical damage (seepage, leakage, and breakage) are particularly difficult to quantify.

- Crop factors have had to be adapted for the low planting density in the study area. The irrigation requirement for each crop was based on the SAPWAT (Crosby) model, which takes into account planting density, effective rainfall, and expected irrigation system efficiency. In this scenario, cotton has the highest monthly water requirement and the longest growing season. The low and erratic summer rainfall has little impact on the irrigation requirement.

- Riverine vegetation is estimated to cover an area of 1,925 hectares according to satellite imagery, and is assumed to use as much water as the irrigated area.

- The impact of the smaller dams such as the Lola Montes, the Makotswane, and the Piet Gouws has not been taken into account in this water accounting study. To estimate the impact accurately, a hydrological model will have to be designed and linked to potential cropping patterns. This would be an important preliminary step for feasibility studies on the study area.

- The flow rate was based on a 12-hour irrigation time per day and a 30-day month.

Table 11 presents a monthly water balance for a realistic 12-month scenario (scenario 1) under current circumstances, with 1,700 hectares (57% of the irrigable area) of summer crops (70% maize and 30% cotton) and 300 hectares (10%) of winter crops (50% wheat, 50% cabbage). This represents a total annual irrigated area of only 2,000 hectares, because the current late planting of maize precludes a winter crop on large portions of the scheme. Figure 5 compares the resultant irrigation requirement with actual releases from the Arabie Dam including spills, averaged over the past 12 years.

The total irrigation requirement and the total volume that each crop needs is shown in the "Total" column on the right hand side of table 11. The rows in the "month" columns of the table show the total pump rate for that specific month. The graph showing the "Flow measured below Arabie" in figure 5 denotes the average flow over the weir just downstream of the Arabie Dam.

From the graph and the table it is clear that the historic releases from the Arabie Dam exceed the irrigation requirement for the current "realistic" scenario (table 11) by at least six times during the period of the lowest river flow. The major constraint has not been the water availability from the river, but the capacity, condition, and management of the water supply infrastructure. With this in mind, the possible cultivation of permanent crops should be investigated.

Where does the surplus go?

Two more scenarios are included in the appendix. Scenario 2 illustrates the impact of the currently irrigated area of 500 hectares (see table G and figures G1 and F1). In scenario 2, a total area of 500 hectares was planted to summer crops (350 ha cotton, 35 ha maize) and winter crops (5 ha cabbage and 100 ha wheat). This scenario can be a good indication of what happened this past season. From what we could gather from the pump attendants at the Coetzeesdraai to De Paarl canal and Nooitgezien farm, no irrigation had taken place for the past 3 to 4 years. It can thus be assumed that it was not only this year that a well-below-average abstraction took place. Detailed information on the historical water use patterns is available only from the satellite images. Based on discussions with people on the scheme, it became clear that maize and cotton were the main summer crops and wheat the major winter crop. Vegetables were grown on a limited scale only. Scenario 3 illustrates the impact of a potential irrigated area of 2,750 hectares (see table H and figures H1 and F2). The maximum irrigation requirement is based on this area. The cropping pattern used was:

A. Summer : 1,800 hectares cotton and 400 hectares maize

B. Winter : 50 hectares cabbage and 500 hectares wheat

Table 11. Water accounting (scenario 1).

Water accounting	Scenario 1	Season
Areas:		
Crop 1 Cabbage	150	Winter
Crop 2 Cotton	500	Summer
Crop 3 Maize	1200	Summer
Crop 4 Wheat	150	Winter
Total Summer	1,700	
Total Winter	300	
Total year	2,000	

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
Crop 1 Cabbage													
Area (ha)	0	0	0	0	0	0	150	150	150	150	150	0	
Irrigation requirement (mm)							35	67	78	95	70		345
Volume (m^3)	0	0	0	0	0	0	52,500	100,500	117,000	142,500	105,000	0	517,500
Pump rate (m^3/h)	0	0	0	0	0	0	146	279	325	396	292	0	
Crop2 Cotton													
Area (ha)	500	500	500	500	500	500	500	0	0	0	0	0	
Irrigation requirement (mm)	36	42	135	138	132	78	21						582
Volume (m^3)	180,000	210,000	675,000	690,000	660,000	390,000	105,000	0	0	0	0	0	2,910,000
Pump rate (m^3/h)	500	583	1,875	1,917	1,833	1 083	292	0	0	0	0	0	
Crop 3 Maize													
Area (ha)	0	0	1,200	1,200	1,200	1,200	1,200	0	0	0	0	0	
Irrigation requirement (mm)			63	152	150	85	12						462
Volume (m^3)	0	0	756,000	1 824 0	1,800,000	1,020,000	144,000	0	0	0	0	0	5,544,000
Pump rate (m^3/h)	0	0	2,100	5 067	5,000	2,833	400	0	0	0	0	0	
Crop 4 Wheat													
Area (ha)	150	150	0	0	0	0	0	0	0	150	150	150	
Irrigation requirement (mm)	182	106								39	65	154	546
Volume (m^3)	273,000	159,000	0	0	0	0	0	0	0	58,500	97,500	231,000	819,000
Pump rate (m^3/h)	758	442	0	0	0	0	0	0	0	163	271	642	
Month total													
Total pump rate m^3/h	1,258	1,025	3,975	6,983	6,833	3,917	838	279	325	558	563	642	
Calculated irrigation abstraction m^3/h	0.45	0.37	1,43	2.51	2.46	1.41	0.30	0.10	0.12	0.20	0.20	0.23	9.79
Flow measured below Arabie m^3/h	5.84	11.31	36.21	48.40	16.56	8.62	6.68	10.62	3.67	2.57	2.74	4.55	180,82
Pump rate is that which is needed if water was readily available, with no storage and with no lag time in the canals												Year total	
As well as irrigation for a 12-h irrigation day, according to current practice.												Volume	9,790,500

4.4.3 Return Flow

There are only small earthen canals from the dams at the lower end of both the Coetzeesdraai-De Paarl and the Veeplaats-Mooiplaats canals, which do not provide for effective return or measurement of overflows to the Olifants River.

Using the available data, the return flow from the study area is estimated as follows:

Assuming 2,000 hectares of crops with an irrigation requirement of 9.79 million m^3/annum and a system efficiency of 80 percent, with effective rain already subtracted, the diversion from the Olifants River can be calculated as follows:

- The Coetzeesdraai-De Paarl canal capacity is 2,000 m^3/h, or 17.5 million m^3/annum. This canal is supplied by a pump and it can be assumed, therefore, that it will be operating only 25 percent of the time, resulting in a diversion of 4.4 million m^3/annum.

- The river abstraction pumps have a capacity of 3,534 m^3/h. If they are operating at 25 percent of the time, the diversion is 7.7 million m^3/annum.

- The Veeplaats-Mooiplaats canal capacity is 2,400 m^3/h, or 21 million m^3/annum. At 50 percent capacity, the diversion is 10.5 million m^3/annum.

- The probable total diversion by the above infrastructures and equipment for an irrigated area of 2,000 hectares are therefore 22.6 m^3/annum (the sum of the above diversions).

The irrigation requirement for the current "realistic" scenario as depicted in table 10 is 9.8 million m^3/annum. This leaves a theoretical balance of 12.8 million m^3/annum.

According to current thinking, this could be reduced by 50 percent to make provision for deep percolation of water in case of overirrigation, canal losses, evaporation, and illegal abstraction.

From the above, the return flow is estimated as 6.4 million m^3/annum for the Arabie-Olifants scheme, which is about 30 percent of this scenario's diversion.

If the area should be developed to the estimated potential of 5,500 hectares, the potential diversion should be 62 million m^3/ha for a 27 million m^3/annum irrigation requirement. This exceeds the total yield of the Arabie and the other scheme dams estimated at 57 million m^3.

Using the available information and according to SWIM Paper 1, four accounts were done at subbasin level for the study area. Table C in the appendix illustrates an "average year" inflow and table D, the year 1992. Table E illustrates an "average year" inflow and 500 hectares of irrigation, which are the estimated current season's developments. Table F illustrates an "average year" inflow and 2,750 hectares of irrigation.

4.5 Agricultural Output from This Area

Using the available information it is impossible to supply accurate values for the financial output of the Arabie-Olifants scheme. Based on the few financial results that we obtained from the ARDC, the assumption can be made that the net profits for maize and wheat were R500/ha each. For an area of 2,000 hectares this amounts to R1 million. This is based on direct costs only and excludes management salaries and electricity costs, etc.

The value of crops grown for personal consumption can be considerable but is difficult to establish.

5. CONCLUSIONS

It is clear from this study that the capacity and condition of the infrastructure at the Arabie-Olifants Irrigation Scheme limit the water supply to irrigation farms more significantly than the available flow in the river. From the values it can be seen that the abstraction for the current irrigation is a maximum of 15 percent of the river flow during the low-flow period in the winter months. The river flows used in this study were based on releases from the Arabie Dam and should there be a higher demand, the supply can be increased if water is available at that time.

The lack of coordinated management of the scheme has resulted in the current situation in which the infrastructure is not utilized close to its potential.

A similar procedure could be followed to establish how much irrigation development is possible. This could be useful for catchment level discussions.

Direct demand for the Pietersburg Municipality downstream of the investigated scheme, from the Arabie Dam, is currently an estimated 5.5 million m^3/annum. The abstraction point is at the now-abandoned Olifantspoort measuring weir, which is between 15 and 20 kilometers downstream of Apèl.

According to DWAF officials, the volume and flow rate of water required for downstream environmental purposes have not been determined yet.

For upgrading this scheme or increasing the irrigated area, a more detailed investigation and analysis are needed as the situation at system and community levels would determine the success or failure of the scheme.

APPENDIX

Table A. Summary of irrigation infrastructure and irrigated areas (Eastern River Bank).

Farm	Map ref. No.	Source	Irrigable area (ha)	Area irrigated (ha)				System currently used	Pump capacity (m^3/h)	Canal capacity (m^3/h)	General
				90	91	92	98				
HINDOSTAN (680KS)			52					Sprinkler	269.5		
Pump house no.1	28	Makotswane dam		0	0	0	0				1 Night storage dam. LDA-managed.
COETZEESDRAAI (641KS)		Makotswane dam and	130					Flood			1 Storage dam. LDA-managed
Pump house no.1	1	Olifants river abstraction -		90.8	87.1	81	37.3				
		Supply to canal	2,000**								
KROKODILHEUWEL (640KS)		Coetzeesdraai canal	245	205.1	200.2	210.9	148.1	Flood			LDA-managed
VOGELSTRUISKOPJE (639KS)			119	27.8	39.7	3.1	0	Sprinkler	1,508		ARDC-managed
Pump house no.1	2	Coetzeesdraai canal							244		Main canal blocked by Vogelstruiskopje
Pump house no.2	3	Olifants river abstraction							1,020		farmers, before Gataan.
Pump house no.3	4	Coetzeesdraai canal							244		Pump house 2 - cable stolen, not operational.
											1 Storage dam
GATAAN (796KS)			155	0	62.3	63.1	0.1	Sprinkler	812		ARDC-managed
Pump house no.1	5	Coetzeesdraai canal							487		2 Night storage dams
Pump house no.2	6	Coetzeesdraai canal							325		
DE PAARL (795KS)			63	0	0	19.8	0.1	Sprinkler	255		ARDC-managed
Pump house no.1	7	Coetzeesdraai canal									Coetzeesdraai canal ends in night storage dam
NOOITGEZIEN (761KS)			104	0	90.6	92.4	6.2	Sprinkler	715		ARDC-managed
Pump house no.1	8	Olifants river abstraction	73						365		2 Float mounted pumps on river
Pump house no.2	9	Olifants river abstraction	31						350		
VEEPLAATS (764KS)			420	462.7	447.8	489.9	287.9		2,342		ARDC-managed
Pump house no.1 (CP)	10	Olifants river abstraction	60					Center pivot	225		
Pump house no.2 (CP)	10A	Canal from Piet Gouws dam	30					Center pivot	152		
Pump house no.3 (CP)	14	Veeplaats canal	60					Center pivot	250		
Pump house no.4	13	Canal from Piet Gouws dam	40					Sprinkler	305		
Pump house no.5	12	Canal from Piet Gouws dam	45					Sprinkler	330		
Pump house no.6	11	Canal from Piet Gouws dam	185					Sprinkler	1,362		
WONDERBOOM (532KS)			115	120.1	122.7	119.5	0	Sprinkler	644		ARDC-managed
Pump house no.1	15	Veeplaats canal	54						380		
Pump house no.2	16	Veeplaats canal	61						264		
VLAKPLAATS (535KS)			75	94.4	93.5	88.2	0	Sprinkler	428		ARDC-managed
Pump house no.1	17	Veeplaats canal	20						107		
Pump house no.2	18	Veeplaats canal	55						321		
HAAKDOORNDRAAI (536KS)			111	122	126.6	52.1	0	Sprinkler	358		ARDC-managed
Pump house no.1	19	Veeplaats canal	91						348		1 Night storage dam
Pump house no.2	20	Veeplaats canal	20						110		
STRYDKRAAL (537KS)			356	276.2	133.3	187.8	164.9		1,404		ARDC-managed
Pump house no.1	21	Veeplaats canal	126					Sprinkler	507		1 Night storage dam
Pump house no.2 (CP)	22	Veeplaats canal	60					Center pivot	210		Many weeds in canal
Pump house no.3	23	Veeplaats canal	10					Sprinkler	95		
Pump house no.4	24	Veeplaats canal	57					Sprinkler	190		
Pump house no.5	25	Veeplaats canal	78					Sprinkler	338		
MOOIPLAATS (516KS)			106	130.3	21.3	40.1	9.1	Sprinkler	576		ARDC-managed
Pump house no. 1	26	Veeplaats canal	50						266		1 Night storage dam
Pump house no. 2	27	Veeplaats canal	56						310		
Total			1997*	1,529	1,425	1,448	653.7				

** Reports of the former Lebowa Government give this area as 2,160 ha. ** Estimated pump delivery.*

Table B. Summary of irrigation infrastructure and irrigated areas (Western River Bank).

Farm	Map ref. no.	Source	Irrigable area (ha)	Area irrigated (ha)				System currently used	Current pump capacity (m^3/h)	Pump capacity (m^3/h) '97 DWAF	General
				90	91	92	98				
Roodewal(678KS)			81	0	0	0	0			340	
Pump station no.1	29	Olifants river abstraction	41								
		Olifants river abstraction	40								
Elandskraal (642KS)			120	0	45.7	109	0		480*	1240	
Pump station no.1	30	Olifants river abstraction	60					Center Pivot	240*		Privately rented
Pump station no.2		Olifants river abstraction	60					Center Pivot	240*		
Krokodilkop (643 KS)			120	81.6	115	211	0		480*	320	
Pump station no.1	31	Olifants river abstraction	60					Center Pivot	240*	160	Privately rented
Pump station no.2		Olifants river abstraction	60					Center Pivot	240*	160	
V/D Merweskraal (636 KS)			150	0	0	0.3	77.9		600*	540	
Pump station no.1	32	Olifants river abstraction	75					Center Pivot	300*		Privately rented
Pump station no.2		Olifants river abstraction	75					Center Pivot	300*		
Grootklip (760KS)			82	0	0	0	0				ARDC-managed
Borehole		Borehole						Micro irrigation and Sprinkler		Unknown	2 Night storage dams ARDC-managed
Adriaansdraai (759KS)			100	69.2	82.6	40.1	15.2			270	ARDC-managed
Pump station no.1	33	Olifants river abstraction						Sprinkler	410		
Badfontein (531KS)			160	36.8	81.2	97.2	21.9			360	ARDC-managed
Pump station no.1	34	Olifants river abstraction						Sprinkler	300		
Total			1,284	188	325	458	115				

Table C. Water accounting for average conditions and 2,000-ha irrigated area.

Time - Average year. Inflow based on the yield of Arabie Dam (2,000 ha irrigation).
Space - Arabie-Olifants study area.

		Total (million m^3/annum)	Component (million m^3/annum)
Inflow			
Gross inflow		54.7	
	Precipitation		1.9
	Subsurface sources from outside subbasin		0
	Surface sources from outside subbasin		52.8
	Trans-basin diversion		0
Storage change		0	
	Surface		0
	Subsurface		0
Net inflow		54.7	
Outflow		0	
Total outflow		24.4	
	Surface outflow from rivers		24.4
	Surface outflow from drains		0
	Subsurface outflow		0
	Other		0
Committed water		5.5	
	Primary use downstream		5.5
	Environment maintenance (assumed)		0
Nonutilizable		0	
Available water		49.2	
	Total (gross inflow, less committed water, less nonutilizable)	0	
Depletive use			
Process depletion		14.2	
	Evapotranspiration from irrigated crops		9.8
	M & I uses		4
	Navigation		0
	Mining		0
	Power generation		0
	Stock watering		0.4
	Exotic plantations		0
	ET from rain-fed crops		0
Non-process depletion		16.1	
	Flows to internal sinks		0
	Evaporation from free water surface		4.6
	Evaporation from other vegetation (*riverine vegetation)*		11.5
	Other evaporation		0
Total Depletion		30.3	

Table D. Water accounting, based on 1992 data.

Time: Oct. 91-Sept.92. Inflow based on the Arabie Dam releases and the January 1992 satellite survey (1,906 ha irrigation).
Space: Arabie-Olifants study area.

		Total (million m^3/annum)	Component (million m^3/annum)
Inflow			
Gross inflow		66	
	Precipitation		1.9
	Subsurface sources from outside subbasin		0
	Surface sources from outside subbasin		64.1
	Trans-basin diversion		0
Storage change		0	
	Surface		0
	Subsurface		0
Net inflow		66	
Outflow		34.5	
Total outflow		34.5	
	Surface outflow from rivers		0
	Surface outflow from drains		0
	Subsurface outflow		0
	Other		0
Committed water		5.5	
	Primary use downstream		5.5
	Environment maintenance (assumed)		0
Nonutilizable		0	
Available water		61.5	
	Total (gross inflow, less committed water, less nonutilizable)	0	
Depletive use			
Process depletion		15.4	
	Evapotranspiration from irrigated crops		11
	M & I uses		4
	Navigation		0
	Mining		0
	Power generation		0
	Stock watering		0.4
	Exotic plantations		
	ET from rain-fed crops		0
Non-process depletion		16.1	
	Flows to internal sinks		0
	Evaporation from free water surface		4.6
	Evaporation from other vegetation (*riverine vegetation)*		11.5
	Other evaporation		0
Total Depletion		31.5	

Table E. Water accounting, based on 500-ha irrigated area (scenario 2).

Time: Average year. Inflow based on the yield of Arabie Dam (500 ha irrigation/yr.).
Space: Arabie-Olifants study area.

		Total (million m^3/annum)	Component (million m^3/ annum)
Inflow			
Gross inflow		54.7	
	Precipitation		1.9
	Subsurface sources from outside subbasin		0
	Surface sources from outside subbasin		52.8
	Trans-basin diversion		0
Storage change		0	
	Surface		0
	Subsurface		0
Net inflow		54.7	
Outflow		0	
Total outflow		30.9	
	Surface outflow from rivers		30.9
	Surface outflow from drains		0
	Subsurface outflow		0
	Other		0
Committed water		5.5	
	Primary use downstream		5.5
	Environment maintenance (assumed)		0
Nonutilizable		0	
Available water		49.2	
	Total (gross inflow, less committed water, less nonutilizable)	0	
Depletive use			
Process depletion		7.7	
	Evapotranspiration from irrigated crops		3.3
	M & I uses		4
	Navigation		0
	Mining		0
	Power generation		0
	Stock watering		0.4
	Exotic plantations		0
	ET from rain-fed crops		0
Non-process depletion		16.1	
	Flows to internal sinks		0
	Evaporation from free water surface		4.6
	Evaporation from other vegetation (*riverine vegetation)*		11.5
	Other evaporation		0
Total Depletion		23.8	

Table F. Water accounting, based on 2,750-ha irrigated area (scenario 3).

Time: Average year. Inflow based on the yield of Arabie Dam (2,750 ha irrigation/yr.).
Space: Arabie-Olifants study area.

		Total (million m^3/ annum)	Component (million m^3/ annum)
Inflow			
Gross inflow		54.7	
	Precipitation		1.9
	Subsurface sources from outside subbasin		0
	Surface sources from outside subbasin		52.8
	Trans-basin diversion		0
Storage change		0	
	Surface		0
	Subsurface		0
Net inflow		54.7	
Outflow		0	
Total outflow		19.0	
	Surface outflow from rivers		19.0
	Surface outflow from drains		0
	Subsurface outflow		0
	Other		0
Committed water		5.5	
	Primary use downstream		5.5
	Environment maintenance (assumed)		0
Nonutilizable		0	
Available water		49.2	
	Total (gross inflow, less committed water, less nonutilizable)	0	
Depletive use			
Process depletion		19.6	
	Evapotranspiration from irrigated crops		15.2
	M & I uses		4
	Navigation		0
	Mining		0
	Power generation		0
	Stock watering		0.4
	Exotic plantations		0
	ET from rain-fed crops		0
Non-process depletion		16.1	
	Flows to internal sinks		0
	Evaporation from free water surface		4.6
	Evaporation from other vegetation (*riverine vegetation)*		11.5
	Other evaporation		0
Total Depletion		35.7	

Figure F1 (scenario 2). Irrigated area 500 hectares, average year climate (approximates present situation).

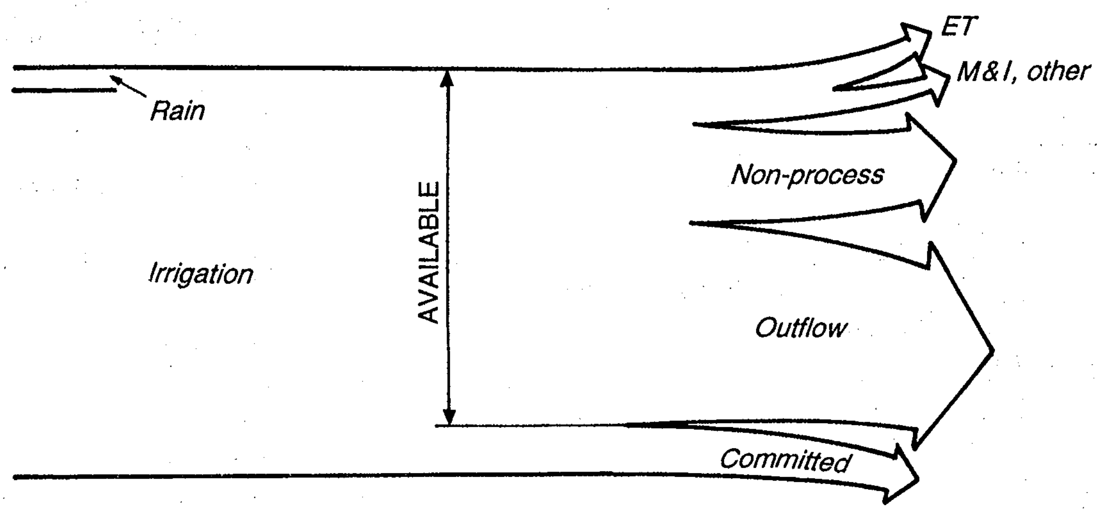


Figure F2 (scenario 3). Irrigated area 2,750 hectares, average year climate (approximates estimated potential of scheme).

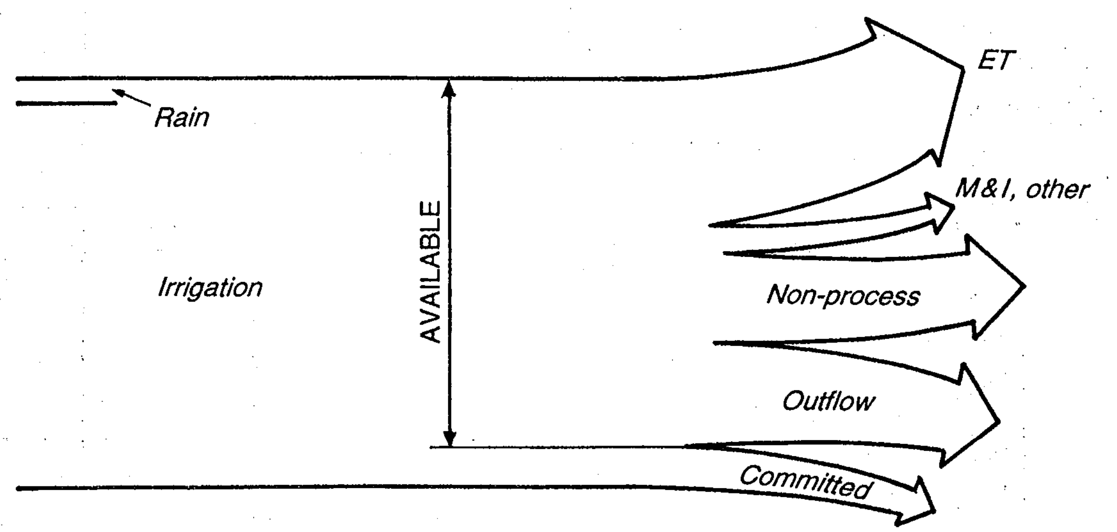


Table G. Water accounting (scenario 2).

Areas	Area (ha)	Season										
Crop 1 Cabbage	5	Winter										
Crop 2 Cotton	345	Summer										
Crop 3 Maize	150	Summer										
Crop 4 Wheat	100	Winter										
Total Summer	495											
Total Winter	105											
Total year	600											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
Crop 1 Cabbage													
Area (ha)	0	0	0	0	0	0	5	5	5	5	5	0	
Irrigation requirement (mm)							35	67	78	95	70		345.00
Volume (m^3)	0	0	0	0	0	0	1,750	3,350	3,900	4,750	3,500	0	17 250.00
Pump rate (m^3/h)	0	0	0	0	0	0	5	9	11	13	10	0	
Crop 2 Cotton													
Area (ha)	345	345	345	345	345	345	345	0	0	0	0	0	
Irrigation requirement (mm)	36	42	135	138	132	78	21						582.00
Volume (m^3)	124,200	144,900	465,750	476,100	455,400	269,100	72,450	0	0	0	0	0	2 007 900.00
Pump rate (m^3/h)	345	403	1,294	1,323	1,265	748	201	0	0	0	0	0	
Crop 3 Maize													
Area (ha)	0	0	150	150	150	150	150	0	0	0	0	0	
Irrigation requirement (mm)			63	152	150	85	12						462.00
Volume (m^3)	0	0	94,500	228,000	225,000	127,500	18,000	0	0	0	0	0	693 000.00
Pump rate (m^3/h)	0	0	263	633	625	354	50	0	0	0	0	0	
Crop 4 Wheat													
Area (ha)	100	100	0	0	0	0	0	0	0	100	100	100	
Irrigation requirement (mm)	182	106								39	65	154	546.00
Volume (m^3)	182,000	106,000	0	0	0	0	0	0	0	39,000	65,000	154,000	546 000.00
Pump rate (m^3/h)	506	294	0	0	0	0	0	0	0	108	181	428	
Month totals													
Max pump rate m^3/h	851	697	1,556	1,956	1,890	1 102	256	9	11	122	190	428	
Irrigation requirement 10^6 m^3	0.31	0.25	0.56	0.70	0.68	0.40	0.09	0.00	0.00	0.04	0.07	0.15	3.26
Flow measured below Arabie Dam 10^6 m^3	5.84	11.31	36.21	48.40	16.56	8.62	6.68	10.62	3.67	2.57	2.74	4.55	180.82
Theoretical return flow 10^6 m^3	2.77	5.53	17.82	23.85	7.94	4.11	3.29	5.31	1.83	1.26	1.34	2.20	88.78
Pump rate is that which is needed if water was readily available, with no storage and with no lag time in the canals as well as irrigation for a 12-h irrigation day, according to current practice.											Year total		
											Volume		3,264,150.00

Figure G1. Measured flow and scenario 2 irrigation requirement.

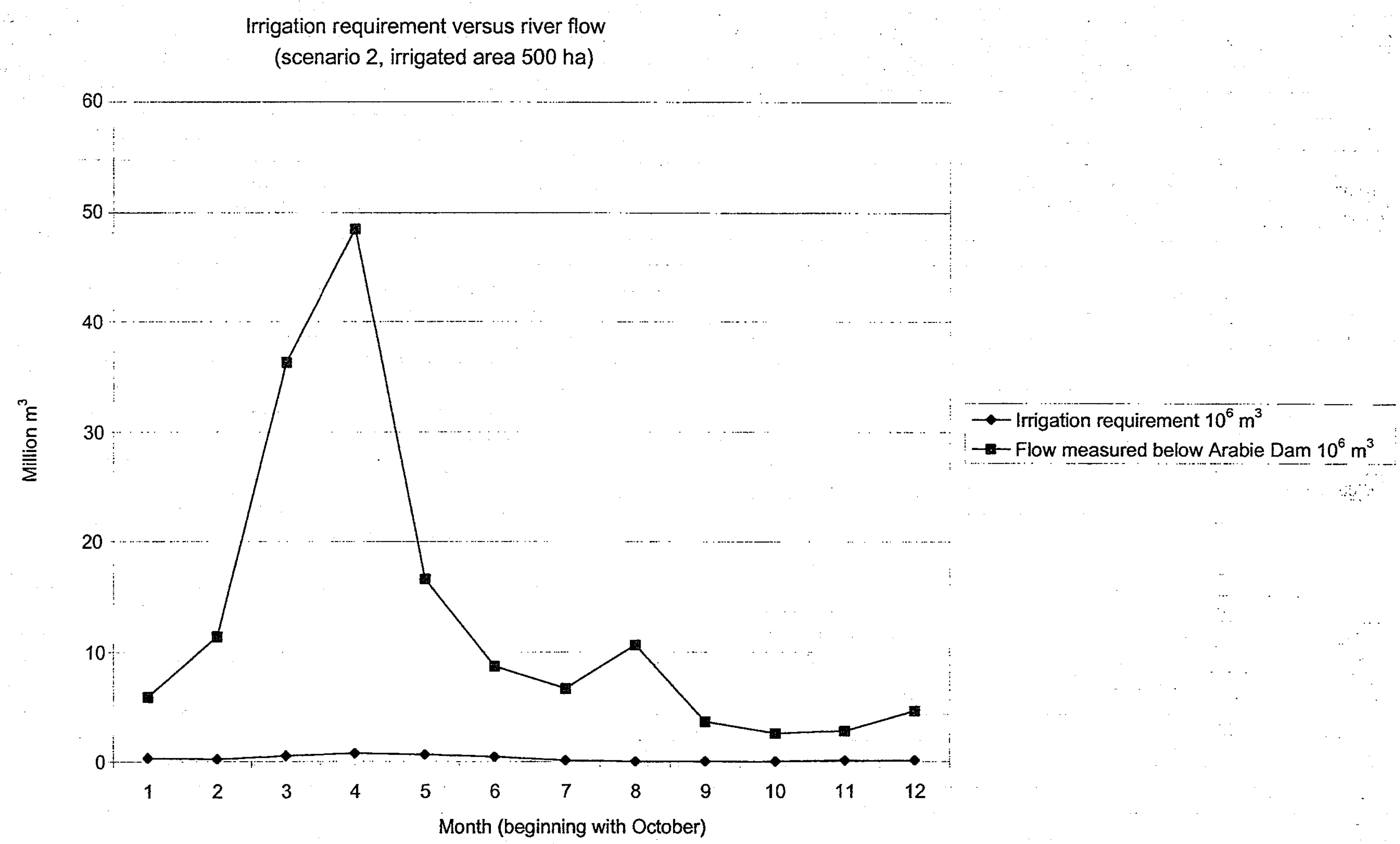
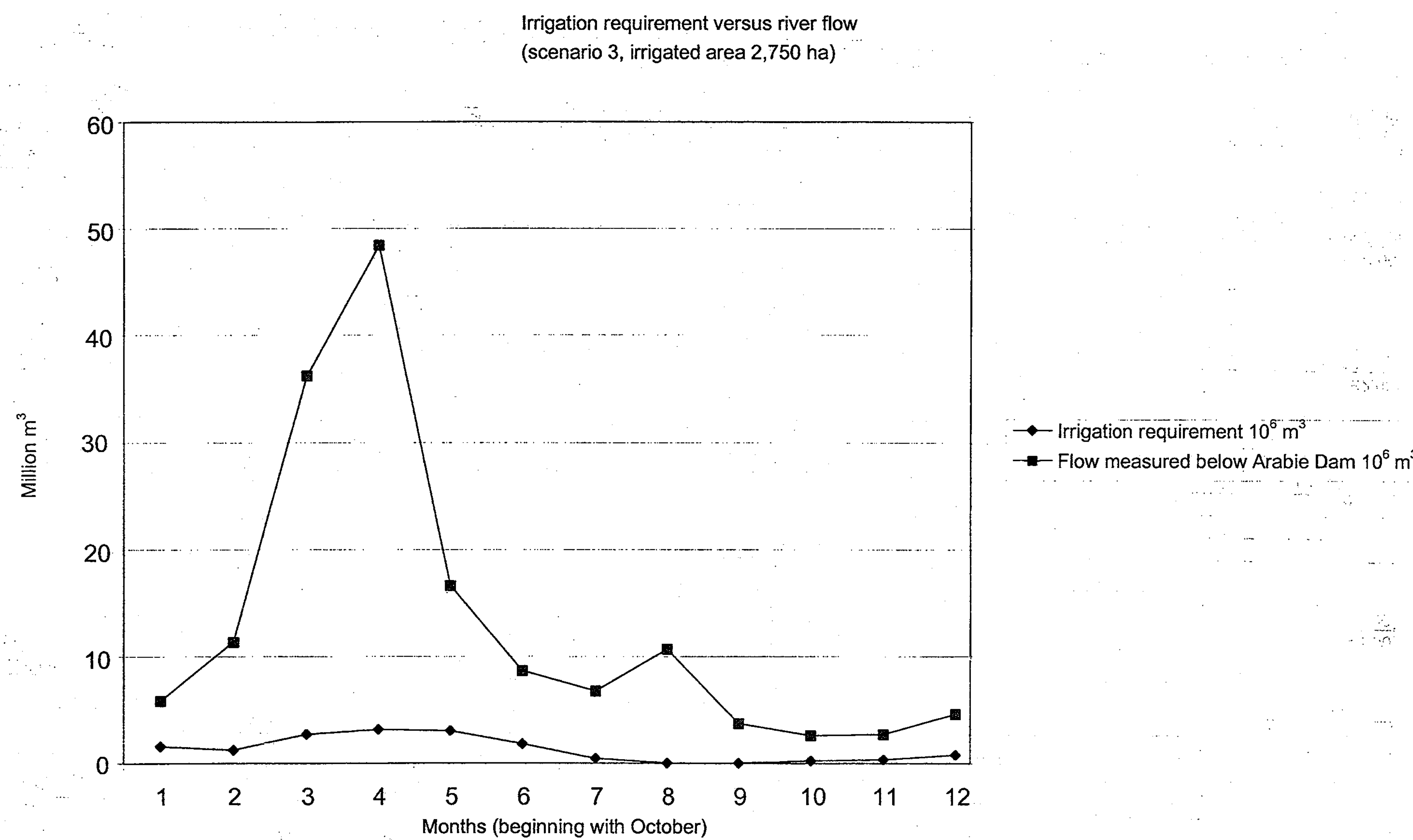


Table H. Water accounting (scenario 3).

Water accounting	Area (ha)	Season										
Areas:												
Crop 1 Cabbage	50	Winter										
Crop 2 Cotton	1,800	Summer										
Crop 3 Maize	400	Summer										
Crop 4 Wheat	500	Winter										
Total Summer	2,200											
Total Winter	550											
Total year	2,750											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
Crop 1 Cabbage													
Area (ha)	0	0	0	0	0	0	50	50	50	50	50	0	
Irrigation requirement (mm)							35	67	78	95	70		345.00
Volume (m^3)	0	0	0	0	0	0	17,500	33,500	39,000	47,500	35,000	0	172,500.00
Pump rate (m^3/h)	0	0	0	0	0	0	49	93	108	132	97	0	
Crop 2 Cotton													
Area (ha)	1,800	1,800	1,800	1,800	1,800	1,800	1,800	0	0	0	0	0	
Irrigation requirement (mm)	36	42	135	138	132	78	21						582.00
Volume (m^3)	648,000	756,000	243,0000	2,484,000	2,376,000	1,404,000	378,000	0	0	0	0	0	10,476,000.00
Pump rate (m^3/h)	1,800	2,100	6,750	6,900	6,600	3,900	1,050	0	0	0	0	0	
Crop 3 Maize													
Area (ha)	0	0	400	400	400	400	400	0	0	0	0	0	
Irrigation requirement (mm)			63	152	150	85	12						462.00
Volume (m^3)	0	0	252,000	608,000	600,000	340,000	48,000	0	0	0	0	0	1,848,000.00
Pump rate (m^3/h)	0	0	700	1,689	1,667	944	133	0	0	0	0	0	
Crop 4 Wheat													
Area (ha)	500	500	0	0	0	0	0	0	0	500	500	500	
Irrigation requirement (mm)	182	106								39	65	154	546.00
Volume (m^3)	910,000	530,000	0	0	0	0	0	0	0	195,000	325,000	770,000	2,730,000.00
Pump rate (m^3/h)	2,528	1,472	0	0	0	0	0	0	0	542	903	2,139	
Month totals													
Max pump rate m^3/h	4,328	3,572	7,450	8,589	8,267	4,844	1,232	93	108	674	1,000	2,139	
Irrigation requirement 10^6 m^3	1.56	1.29	2.68	3.09	2.98	1.74	0.44	0.03	0.04	0.24	0.36	0.77	15.23
Flow measured below Arabie Dam 10^6 m^3	5.84	11.31	36.21	48.40	16.56	8.62	6.68	10.62	3.67	2.57	2.74	4.55	180.82
Theoretical return flow 10^6 m^3	2.14	5.01	16.76	22.65	6.79	3.44	3.12	5.29	1.82	1.16	1.19	1.89	82.80
Pump rate is that which is needed if water was readily available, with no storage and with no lag time in the canals as well as irrigation for a 12-h irrigation day, according to current practice.											Year total	
											Volume	15,226,500.00

Figure H1. Measured flow and scenario 3 irrigation requirement.



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