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Application of the Water Evaluation And Planning (WEAP) Model to Assess Future Water Demands and Resources in the Olifants Catchment, South Africa

Roberto Arranz and Matthew McCartney

International Water Management Institute

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Acronyms and Abbreviations

CMAs	-	Catchment Management Areas
DWAF	-	Department of Water Affairs and Forestry
ER	-	Environmental Reserve
HG	-	higher growth
IA	-	International Agreement
IFR	-	instream flow requirements
LG	-	lower growth
lpcd	-	liters per capita per day
MG	-	medium growth
NI	-	new infrastructure
PES	-	present ecological state
PGM	-	platinum group metals
REC	-	recommended ecological class
RESIS	-	Revitalization of Small-Scale Irrigation Systems
SEI	-	Stockholm Environment Institute
WC&DM	-	water conservation and demand management
WEAP	-	Water Evaluation And Planning
WSAM	-	Water Situation Assesment Model

Summary

The Olifants catchment is one of 19 Catchment Management Areas in South Africa. Different water users (i.e., rural, urban, mining, subsistence and commercial irrigated agriculture, commercial forestry, industry and power generation) are present in the catchment. Rising population and increasing water provision in rural areas, in conjunction with the development of the mining industry, the construction of new power generation plants, the implementation of environmental flows and the need to meet international flow requirements are going to greatly exacerbate the complexity of future water resources management in what is already a water-stressed catchment.

Being able to assess the ability of the catchment to satisfy potential water demands is crucial in order to plan for the future and make wise decisions. In this study, a scenario analysis approach was used in conjunction with the Water Evaluation And Planning model, in order to assess the impacts of possible water demands on the water resources of the Olifants catchment in 2025. For each scenario, the water resource implications were compared to a 1995 "baseline." The model enabled analyses of unmet water demands, streamflows and water storage for each scenario.

The model results show that for the different scenarios considered in this study the implementation of the Environmental Reserve (an instream requirement to guarantee the health of the riverine ecosystems) will increase the shortages for other sectors. The construction of the main water storage infrastructure proposed by the Department of Water Affairs and Forestry, in conjunction with the application of Water Conservation and Demand Management practices, can reduce the unmet demands and shortfalls to levels lower than, or similar to, those experienced in the 1995 baseline. However, in all cases these interventions will be insufficient to completely meet the demands of all the sectors. A tight control of the growth in future demands is essential, although this may be difficult in a rapidly developing country like South Africa.

INTRODUCTION AND OBJECTIVES

Problem Description and Justification of the Research

The Olifants catchment is one of 19 catchment management agencies (CMAs) in South Africa. Different water users (i.e., rural, urban, mining, subsistence and commercial irrigated agriculture, commercial forestry, industry, power generation) are present in the catchment. There is an inequity issue in the access to water. In the former homelands (i.e., rural areas where the African population was concentrated during the apartheid era) access to water, even for domestic needs, remains limited. There are several natural reserves that demand special protection, and environmental flows are needed to preserve ecosystems. The Olifants river is a tributary of the Limpopo river, an international river shared by South Africa, Botswana, Zimbabwe and Mozambique. Currently, there is no International Agreement (IA) regarding the sharing of the water of the Olifants river, although it is likely that one will be established in the near future. Following the end of the apartheid regime in 1994, there has been a significant transformation of the water and land legislation in South Africa. This is ongoing and will affect future land distribution and water allocation.

The development of the mining industry, mainly platinum group metals (PGM) and coal, and the construction of new power generation plants, along with the population growth, the consideration of environmental flows, the revitalization of small-scale irrigation schemes and the improvement in accessibility to water in the former homelands are going to increase the water demands in this already water-stressed catchment. On top of this, climatic change may increase hydrological variability making it more difficult to satisfy increasing demands. Further information regarding the hydrology and water resources of the Olifants catchment can be found in McCartney et al. 2004.

There are several socioeconomic, political and legal processes taking place in the Olifants catchment that will affect the water demand and the way this water is allocated. Being able to assess the ability of the catchment to satisfy its future water demands is crucial in order to plan for the future and make wise decisions. The Department of Water Affairs and Forestry (DWAF) has identified the use of modeling tools in conjunction with scenario analysis as an important approach to developing catchment management strategies and achieving integrated management of catchments (DWAF 2004). Computer-based Decision Support Systems (DSS) are very useful tools for this because they allow the user to forecast and evaluate the impacts of different possible future trends and management strategies before implementing them.

Objective of the Research

The objective of this research was to assess the impacts of the likely future water use on the water resources of the Olifants catchment. As it is not possible to predict the exact outcome of future water demands in the Olifants a scenario analysis was chosen as the most appropriate approach to meet this objective. The computer-based modeling tool used was the WEAP System Model developed by the Stockholm Environment Institute (SEI). The WEAP model was configured for the catchment in a previous study (McCartney et al. 2005). The main output of the model was unmet demands for the different sectors in each of the modeled sub-catchments.

THE WEAP MODEL FOR THE OLIFANTS CATCHMENT

The WEAP System Model

The WEAP System model was developed by the SEI to enable evaluation of planning and management issues associated with water resources development. The WEAP model can be applied to both municipal and agricultural systems and can address a wide range of issues including sectoral demand analyses, water conservation, water rights and allocation priorities, streamflow simulation, reservoir operation, ecosystem requirements and project cost-benefit analyses (SEI 2001).

WEAP model has two primary functions (Sieber et al. 2004):

- Simulation of natural hydrological processes (e.g., evapotranspiration, runoff and infiltration) to enable assessment of the availability of water within a catchment.

- Simulation of anthropogenic activities superimposed on the natural system to influence water resources and their allocation (i.e., consumptive and non-consumptive water demands) to enable evaluation of the impact of human water use.

To allow simulation of water allocation, the elements that comprise the water demand-supply system and their spatial relationship are characterized for the catchment under consideration. The system is represented in terms of its various water sources (e.g., surface water, groundwater, desalinization and water reuse elements); withdrawal, transmission, reservoirs, and wastewater treatment facilities, and water demands (i.e., user-defined sectors but typically comprising industry, mines, irrigation, domestic supply, etc.). The data structure and level of detail can be customized (e.g., by combining demand sites) to correspond to the requirements of a particular analysis and constraints imposed by limited data. A graphical interface facilitates visualization of the physical features of the system and their layout within the catchment.

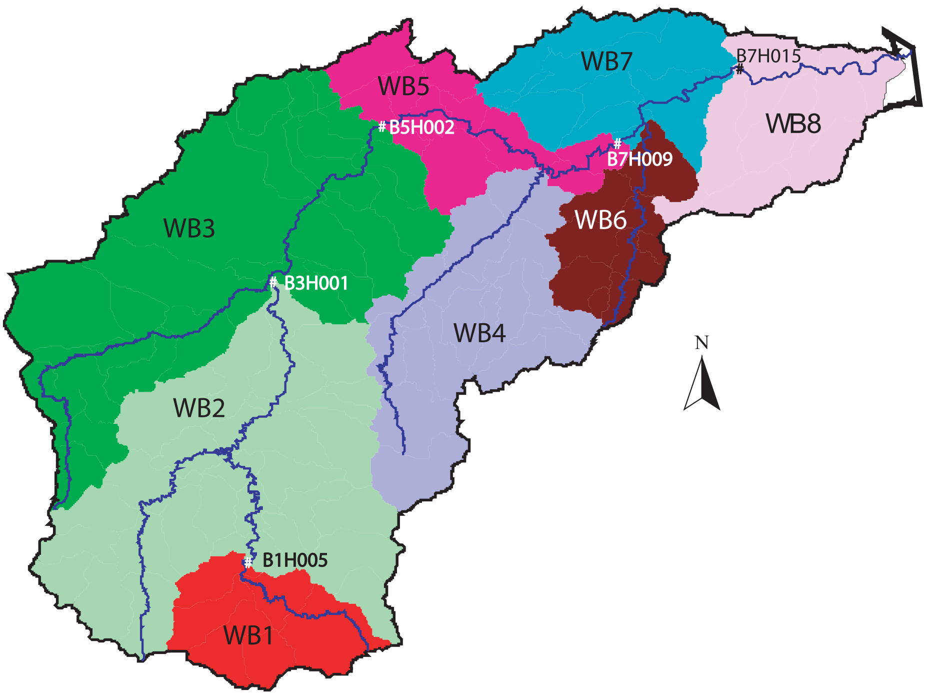
The WEAP model essentially performs a mass balance of flow sequentially down a river system, making allowance for abstractions and inflows. To simulate the system, the river is divided into reaches. The reach boundaries are determined by points in the river where there is a change in flow as a consequence of the confluence with a tributary, or an abstraction or return flow, or where there is a dam or a flow gauging structure. Typically, the WEAP model is applied by configuring the system to simulate a recent “baseline” year, for which the water availability and demands can be confidently determined. The model is then used to simulate alternative scenarios (i.e., plausible futures based on “what if” propositions) to assess the impact of different development and management options. The model optimizes water use in the catchment using an iterative Linear Programming algorithm, whose objective is to maximize the water delivered to demand sites, according to a set of user-defined priorities. All demand sites are assigned a priority between 1 and 99, where 1 is the highest priority and 99 the lowest. When water is limited, the algorithm is formulated to progressively restrict water allocation to those demand sites given the lowest priority. More details of the model are available in Sieber et al. 2004 and SEI 2001.

The WEAP Model for the Olifants Catchment

The WEAP model was configured for the Olifants catchment as part of a previous study of water resources development in the catchment (McCartney et al. 2005). This was used as the starting point for the current study.

Within the Olifants catchment there are 114 quaternary catchments. In South Africa quaternary catchments are the primary water management units. Many of the analyses conducted using the WEAP model were underpinned with data for these catchments. However, although theoretically possible, limited computer power made it impractical for the WEAP model to simulate each quaternary catchment separately. Consequently, for this study, the WEAP model was configured to replicate eight sub-catchments (figure 2.1 and table 2.1). This configuration was adopted, in preference to the five water management regions used by DWAF, partly because it meant the most important tributaries (the Steelpoort and Blyde rivers) were simulated individually and partly because it facilitated model calibration, since five of the sub-catchments had flow gauging stations located at their outlets. For the eight WEAP model sub-catchments, estimates were made of water resources, water abstraction and consumption. The model was tested by comparison of time series of simulated and observed river flow at the five gauging stations (McCartney et al. 2005).

Figure 2.1. Map showing the configuration of the WEAP model to simulate flow within eight sub-catchments (WB1 to WB8) and the five gauging stations (B1H005, etc.) used for the model calibration and validation.



Water Resources

Water resources data were obtained from a variety of sources, mainly from the DWAF. The most important data were obtained from the WR90 study, which was a national 5-year project undertaken in South Africa to provide baseline hydrological data required for water resources planning and development (Midgley et al. 1994). This study provided the naturalized flow and rainfall estimates used in the WEAP model. Naturalized streamflow data were used as the main hydrological input. Rainfall data were used to estimate net evaporation from reservoirs, groundwater recharge and interannual variation in irrigation demand. Details are provided in McCartney et al. 2005.

Table 2.1. The sub-catchments used for WEAP model simulation.

Sub-catchment	Area (km^2)	Quaternary catchments	Flow-gauging station
WB1	3,211	B11A to B11F	B1H005
WB2	13,344	B11G to B11L; B12A to B12E; B20A to B20J; B32A to B32J	B3H001
WB3	14,918	B31A to B31J; B51A to B52G	B5H002
WB4	7,136	B41A to B41K; B42A to B42H	--
WB5	3,918	B52H to B52J; B71A to B71H	B7H009
WB6	2,842	B60A to B60J	--
WB7	4,542	B71J; B72A to B72K	B7H015
WB8	4,397	B73A to B73H	--

Source: McCartney et al. 2005.

There are a large number of reservoirs within the Olifants catchment. It was not possible to simulate the operation of all these reservoirs. However, it was decided that all reservoirs with individual capacity greater than 25 Mm^3 should be explicitly included within the model. Nine reservoirs, with a cumulative capacity of just over 1,000 Mm^3 (i.e., 68% of the total storage within the catchment) were identified (table 2.2). Net evaporation from the reservoirs (the difference between monthly evaporation and precipitation) was computed from rainfall and estimates of potential open water evaporation data (Schulze et al. 1997). No operating rules were available for the dams because DWAF has not yet formalized rule curves for the dams in the Olifants catchment. Consequently, with the exception of the Blyderivierspoort dam, no operating rules were incorporated within WEAP model. This meant that the reservoirs were not drawn down to attenuate wet-season floods and no restrictions were applied on abstractions as the reservoirs emptied. Because the Blyderivierspoort dam, which is located on the highest flowing tributary, is used for flood control, a simple rule that did draw the reservoir down prior to wet season was applied for this dam. However, this was an assumed curve, which was not verified by DWAF.

Table 2.2. Reservoirs explicitly included in the WEAP modeling.

Dam	Long °E	Lat °S	River	WEAP model sub-catchment	Current height (m)	Storage (Mm^3)	Year built
Loskop	29.36	25.42	Olifants	WB2	53	374.3	1939
Rhenosterkop	28.92	25.10	Elands	WB3	35	205.8	1984
Flag Bosheilo	29.43	24.80	Olifants	WB3	36	105.0	1987
Witbank	29.32	25.89	Olifants	WB2	42	104.0	1949
Bronkhorspruit	28.73	25.89	Bronkhorst	WB2	32	57.9	1948
Blyderivierspoort	30.80	24.54	Blyde	WB6	71	54.1	1975
Middelburg	29.55	25.77	Klein Olifants	WB2	36	48.4	1979
Rust de Winter	28.53	25.23	Elands	WB3	31	27.2	1934

Source: McCartney et al., 2005.

It is estimated that there are close to 10,000 operating boreholes in the Olifants catchment. In relation to the WEAP model sub-catchments, groundwater abstraction is greatest in WB3 and WB4. In the former it is believed that it primarily supplements irrigation, whilst in the latter it is primarily used to contribute to mine water requirements. The WEAP model was configured to simulate groundwater resources and use them in these two sub-catchments.

Water Demand

Five water-use sectors were modeled within each one of the eight sub-catchments. These were irrigation, urban, rural, mining and commercial forestry. In the Olifants catchment, there is also a large demand from the power sector for cooling water. This was estimated to be 160.2 Mm^3 in 1995. However, this demand is met largely through interbasin transfers from the Vaal, Inkomati and Usutu catchments (McCartney et al. 2004). Most of the water is transferred directly to reservoirs located at the power stations and leaves the catchment as evaporation. Consequently, it was believed to have a minor impact on the overall hydrology of the system and so was not simulated within the WEAP model. A small amount of water is transferred out of the catchment to supply Polokwane, in the Limpopo management area (i.e., 3 Mm^3y^{-1}) and the Crocodile West management area in the vicinity of Pretoria (i.e., 5 Mm^3 y^{-1}) (DWAF 2003).

Data on water demand for each of the sectors were obtained from the Water Situation Assesment Model (WSAM) database. The WSAM provides water use estimates for the different sectors in all the quaternary catchments of South Africa for the year 1995. The data for 1995 were obtained for each WEAP model sub-catchment by summing the relevant data from all the quaternary catchments located within that sub-catchment. The WSAM contains information that enables calculation of both gross demand and consumption for each sector. In the current study, with the exception of irrigation, all demands were entered into the WEAP model as consumption. For irrigation, the demands were entered as a gross requirement, but with an estimate of the return flow. For both irrigation and commercial forestry, it was necessary to derive estimates of the within-year variation. Until recently, the only environmental flow requirement was for minimum flows within the Kruger National Park. Historically, a minimum flow of 0.57 m^3s^{-1} was required to reach the western edge of the National Park (McCartney et al. 2005).

Model Calibration and Validation

The WEAP model was calibrated using observed flow data obtained from 5 gauging stations located on the main stem of the Olifants river. Calibration was achieved by estimating the historic pattern of water demand and simulating the resultant flows (McCartney et al. 2005). Calibration involved changing assumptions about the pattern of historic demand, altering demand priorities, modifying the operating rules of the Blyderivierspoort dam and including environmental flow requirements, to improve the fit between simulated and observed flows. The WEAP model optimizes water allocation, based on an *a priori* definition of priorities. Since past water resources management within the catchment will not have optimized water use perfectly, even if all the assumptions made in the modeling were completely correct, an exact fit between the simulation and observed flows could not be expected. The only objective function used in the calibration was percentage error in the average annual flow. Otherwise, only subjective criteria were used, specifically, visual comparison of the simulated and observed time series and mean monthly flows.

One way the model was calibrated was by modifying the priority for each demand site to simulate what were assumed to be not only the true priorities within the catchment (i.e., between different sectors) but also the probable realities of upstream-downstream allocation (table 2.3). In all sub-catchments, forestry was given first priority, because it is a flow reduction activity rather than a true demand. All dams were given priority 51 (i.e., lower than all the demand sites), which meant that, at any given time, keeping the reservoirs full was of less importance than meeting demands. This is unlikely to be the case in reality, since limits will have been placed on demands during periods of water shortage. The environmental flow through the National Park was simulated and, in addition, for the purpose of calibration, a second environmental flow was introduced into the model immediately upstream of flow gauging station B5H002. This was incorporated in the model calibration to improve the simulation of low flows at the gauging station. As such, it does not represent a genuine environmental flow requirement, but rather the reality that demand allocation upstream of B5H002 was not completely optimized.

Table 2.3. Demand priorities for the different water sectors.

Sub-catchment	Rural	Urban	Mining	Irrigation	Forestry	Dams	Environmental flows
WB1	2	3	4	5	1	-	-
WB2	6	7	8	9	1	51	-
WB3	10	11	12	13	1	51	1
WB4	2	3	4	5	1	51	-
WB5	14	15	16	17	1	-	-
WB6	2	3	4	5	1	51	-
WB7	18	19	20	21	1	-	-
WB8	22	-	-	-	1	-	1

DESCRIPTION OF THE FUTURE SCENARIOS

Overview

A scenario can be defined as a plausible description of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces. Scenarios are neither predictions nor forecasts. Since it is not possible to predict exactly how the water demands and other factors that affect water resources are going to change in the future it was decided to use scenarios in the current study. A set of scenarios were developed to account for possible changes in the evolution of the water demands, the implementation of the Environmental Reserve (ER), International Agreements (IAs), water conservation programs and infrastructural development.

For each sector included in the WEAP model (rural, urban, irrigated agriculture, mining and commercial forestry) three scenarios were developed (figure 3.1). They were called the higher growth (HG), medium growth (MG) and lower growth (LG) scenarios. All of them were developed based on a mixture of available quantitative and qualitative information and they try to reflect the higher, intermediate and lower ends of the future water demands. There are other factors that can impact future water resources development in the Olifants catchment (e.g., the development of new water infrastructure, application of the ER or IAs, water conservation and demand management [WC&DM] practices, etc.). Scenarios to account for these other factors were developed separately and then combined with the demand scenarios.

Figure 3.1. Sketch of the three different water demand scenarios considered for each sector.

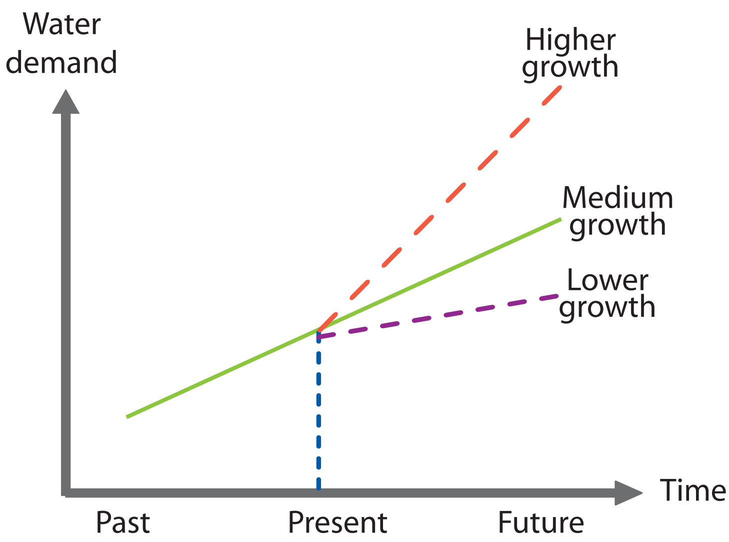
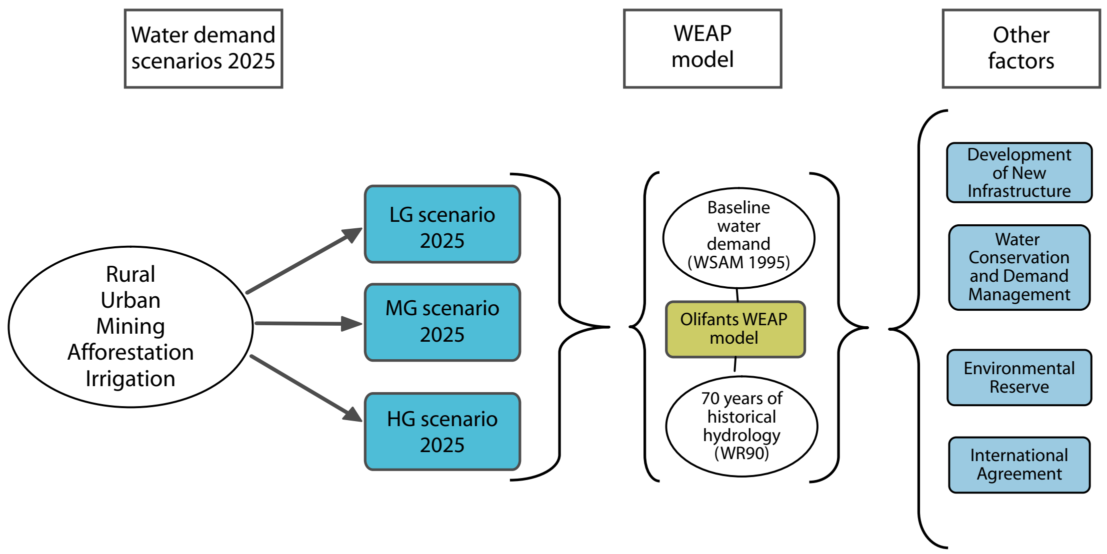


Figure 3.2 is a schematic of the conceptual framework underpinning the study. Each scenario comprised two elements:

- changes in water demand (see section on Water Demand Scenarios for the Different Sectors)
- other factors affecting water resources (see section on Simulation of Additional Factors)

Combinations of changes in water demand and other factors were linked using the WEAP model. 1995 was the baseline against which the other scenarios were assessed. The WSAM and WR90 databases provided the baseline water demand and hydrology, respectively.

Figure 3.2. Layout of the scenarios considered, baseline data and the WEAP model.



Water Demand Scenarios for the Different Sectors

In this section future scenarios for the different sectors (rural, urban, mining, irrigation and commercial afforestation) are presented.

Water Demand Baseline Data

The water demand baseline data were obtained from the WSAM database at a quaternary catchment scale using data for 1995. It was hoped to use an updated version of the database, for the year 2000, but the release of this dataset was postponed and therefore the hoped for version could not be used in the current study. The demands for each sector in each WEAP model sub-catchment (rural, urban, mining, irrigation and commercial forestry) are shown in table 3.1. In the WEAP model the urban and mining values were entered as net water demands. The gross and net demands for the commercial afforestation and rural sectors are equal (i.e., no return flow) according to the WSAM database, and these values were entered in the WEAP model. The irrigation demands vary annually depending on the annual rainfall in the sub-catchment; in wet years the demand is lower and in dry years it is higher. The method for this approach is described in McCartney et al. 2005. The values presented in table 3.1 correspond to the 1995 hydrology. Gross values with the corresponding return flows have been entered into the WEAP model.

Population Growth

Both rural and urban water demand are influenced by changes in population. In order to build the 2025 water demand scenarios, population data from the WSAM database and from the water information services of the DWAF were used. The mean annual population growth rates were computed using population data from the DWAF water information services for 1994 and 2005 (table 3.2). The data did not distinguish between rural and urban populations. The baseline rural and urban population data for 1995 were obtained from the WSAM database.

Table 3.1. 1995 Water demands from the WSAM database.

	WB1	WB2	WB3	WB4	WB5	WB6	WB7	WB8	Total
Commercial forestry									
Area (km^2)	0	45.2	0	74.6	27.2	221.4	26.8	0	395.2
Depletion of flow (Mm^3)	0	1.30	0	5.11	1.72	43.32	2.70	0	54.2
Irrigation									
Irrigated area (km^2)	24.1	473.2	298.9	131.0	35.0	82.9	57.3	0	1102.4
Gross requirement (Mm^3)	8.61	213.53	174.41	74.56	23.04	31.26	28.86	0	554.3
Return flow (Mm^3)	0.58	17.48	12.52	6.38	1.76	2.67	2.13	0	43.5
Net requirement (Mm^3)	8.03	196.05	161.89	68.18	21.28	28.59	26.73	0	510.8
Urban									
Gross requirement (Mm^3)	2.80	54.45	10.83	2.35	0.06	0.06	6.95	0	77.5
Net requirement (Mm^3)	0.90	19.01	4.69	0.89	0.02	0.03	2.23	0	27.8
Rural									
Total requirement (Mm^3)	0.93	19.76	32.41	7.08	6.99	0.70	5.66	0.02	73.5
Mining									
Gross requirement (Mm^3)	7.94	12.36	2.23	16.55	11.02	0.45	43.16	0	93.71
Return flow (Mm^3)	1.44	2.25	0.41	3.01	2.00	0.08	7.85	0	17.00
Net requirement (Mm^3)	6.49	10.11	1.83	13.54	9.01	0.37	35.31	0	76.70
Total									
Gross requirement (Mm^3)	20.28	301.40	219.88	105.65	42.83	75.79	87.33	0.02	853
Net requirement (Mm^3)	16.35	246.23	200.82	94.80	39.02	73.01	72.63	0.02	743

Table 3.2. Total population data (rural and urban) from the DWAF water information services.

	Population 1996	Population 2001	Mean annual growth rate (%) 1996-2001
WB1	196,929	250,052	2.42
WB2	682,150	869,119	2.45
WB3	922,560	1,103,828	1.81
WB4	238,800	283,822	1.74
WB5	240,535	278,793	1.49
WB6	87,819	103,441	1.65
WB7	205,824	237,764	1.45
WB8	62,609	70,621	1.21
Total	2,637,226	3,197,441	1.94

Rural Water Demand

Rural water demand encompasses all domestic-type water requirements outside the urban areas. It also includes distribution losses, stock watering, subsistence irrigation and other economic activities. In the WSAM database the rural demand encompasses two terms (table 3.3). The first term accounts for the domestic water use including subsistence irrigation and other economic activities. It is computed as the product of the population and per capita use. The second term accounts for livestock watering. It is computed as the product of the number of livestock and a per capita use. For the 1995 data, the return flow from the rural sector was considered to be minimal (the use was very low and no return flow was supposed to be produced), so that the gross and net demands were equal.

According to the WSAM database, in 1995 the total rural demand was 73.37 Mm^3. The per capita domestic usage varies from 32 to 113 liters per capita per day with an average of 84 lpcd for the whole Olifants (table 3.3). For the whole Olifants, the livestock watering component accounted for 9 percent of the total rural demand.

There is an ongoing process of revitalization of small-scale irrigation schemes to alleviate the situation of poverty experienced by the rural population of the former homelands. In the Limpopo province the RESIS (Revitalization of Small-Scale Irrigation Systems) program is being implemented. In table 3.4 the area, estimated gross and net water demand (assuming the same unitary demand as the commercial irrigation from WSAM for 1995) and the number of beneficiary farmers for the irrigation schemes to be revitalized in the Olifants catchment are shown. Further studies are being conducted to assess the sustainability of some of these small-scale schemes and it is anticipated that not all of them will be revitalized (Havenga, personal communication). In the WSAM database the subsistence irrigation demand was lumped within the domestic use, so there was no information regarding the subsistence irrigation water demand for the baseline year. In order to be consistent, the water demand of the RESIS program was added to the rural demand that already included the subsistence irrigation term for 1995.

Table 3.3. 1995 Rural water demand for the different WEAP model sub-catchments from the WSAM database.

	Rural population	Domestic usage* (lpcd)	Domestic demand (Mm^3)	Large stock units**	Livestock usage (lpcd)	Livestock demand (Mm^3)	Ratio domestic/total (%)	Net water demand (Mm^3)
WB1	41,127	32	0.48	16,531	42	0.26	65	0.92
WB2	302,214	113	12.47	214,807	42	3.30	79	19.72
WB3	813,328	86	25.55	18,180	42	0.28	99	32.28
WB4	170,833	78	4.87	54,212	42	0.82	86	7.11
WB5	217,161	69	5.47	5,791	42	0.09	98	6.95
WB6	37,359	34	0.46	6,302	41	0.10	83	0.70
WB7	155,167	74	4.19	17,416	42	0.27	94	5.58
WB8	686	96	0.02	3,780	42	0.06	29	0.10
Total	1,737,874	84	53.52	337,019	42	5.17	91	73.37

* Domestic usage includes subsistence irrigation in small garden plots, small-scale irrigation systems and other economic activities.

** Equivalent to one cow.

Table 3.4. Area, approximate water demand and number of beneficiary farmers for the RESIS projects in the Olifants catchment.

WEAP model sub-catchment	Area (ha)	Gross water demand (Mm^3)	Net water demand (Mm^3)	Number of farmers
3	3,272	19.09	17.72	2,288
4	1,788	10.18	9.31	976
5	768	5.06	4.67	591
7	1,529	7.70	7.13	602
Total	7,357	42.03	38.83	4,457

For the LG and MG scenarios increases in the water demand were attributed to the population growth only, not to variation in the per capita use. The mean annual growth rate from table 3.2 was used for the MG scenario and these same values minus 0.5 percent for the LG scenario. The livestock water demand was kept constant in both scenarios. A 25 percent and 50 percent implementation of the RESIS program was assumed for the LG and MG scenarios, respectively. The LG and MG scenario demands were 118.09 Mm^3 and 144.0 Mm^3, respectively, compared with 73.37 Mm^3 for 1995 (tables 3.5 and 3.6).

For the HG scenario the increases in the water demand were attributed to both population growth (using the mean annual growth rates plus 0.5% from table 3.2) and an increase in the per capita demand due to anticipated socioeconomic development. A future gross use of 200 lpcd (net usage of 125 lpcd) was assumed for this scenario. Overall, the demand in the HG scenario was 245.48 Mm^3 (table 3.7).

Table 3.5. 2025 Rural demand LG scenario.

LG scenario WEAP model										
	Rural population 1995	Mean annual growth rate	Rural population 2025	Domestic usage (lpcd)	Large stock units	Live stock usage (lpcd)	Domestic use (Mm^3)	Livestock use (Mm^3)	Net RESIS (Mm^3)	Gross water demand (Mm^3)
WB1	41,127	1.92	72,699	32	16,531	42	1.06	0.32	0.00	1.38
WB2	302,214	1.95	539,724	113	214,807	42	27.85	4.13	0.00	31.97
WB3	813,328	1.31	1,201,829	86	18,180	42	47.19	0.35	4.43	51.97
WB4	170,833	1.24	247,412	78	54,212	42	8.81	1.03	2.33	12.17
WB5	217,161	0.99	291,573	69	5,791	42	9.19	0.11	1.17	10.46
WB6	37,359	1.15	52,657	34	6,302	41	0.82	0.12	0.00	0.94
WB7	155,167	0.95	206,244	74	17,416	42	6.97	0.34	1.78	9.09
WB8	686	0.71	849	96	3,780	42	0.04	0.07	0.00	0.11
Total	1,737,874	1.35	2,612,985	85	337,019	42	101.92	6.47	9.71	118.09

Table 3.6. 2025 Rural demand MG scenario.

MG scenario WEAP model										
	Rural population 1995	Mean annual growth rate	Rural population 2025	Domestic usage (lpcd)	Large stock units	Live stock usage (lpcd)	Domestic use (Mm^3)	Livestock use (Mm^3)	Net RESIS (Mm^3)	Gross or net water demand (Mm^3)
WB1	41,127	2.42	84,196	32	16,531	42	1.23	0.32	0.00	1.55
WB2	302,214	2.45	625,046	113	214,807	42	32.25	4.13	0.00	36.37
WB3	813,328	1.81	1,393,112	86	18,180	42	54.70	0.35	8.86	63.91
WB4	170,833	1.74	286,818	78	54,212	42	10.21	1.03	4.65	15.90
WB5	217,161	1.49	338,139	69	5,791	42	10.65	0.11	2.33	13.10
WB6	37,359	1.65	61,052	34	6,302	41	0.95	0.12	0.00	1.07
WB7	155,167	1.45	239,194	74	17,416	42	8.08	0.34	3.57	11.98
WB8	686	1.21	985	96	3,780	42	0.04	0.07	0.00	0.12
Total	1,737,874	1.85	3,028,542	85	337,019	42	118.12	6.47	19.41	144.00

Table 3.7. 2025 Rural demand HG scenario.

HG scenario WEAP model										
	Rural population 1995	Mean annual growth rate	Rural population 2025	Domestic net usage (lpcd)	Large stock units	Live stock usage (lpcd)	Domestic use (Mm^3)	Livestock use (Mm^3)	Net RESIS (Mm^3)	Gross or net water demand (Mm^3)
WB1	41,127	2.92	97,441	125	16,531	42	5.56	0.32	0.00	5.88
WB2	302,214	2.95	723,340	125	214,807	42	41.28	4.13	0.00	45.41
WB3	813,328	2.31	1,613,673	125	18,180	42	92.09	0.35	17.72	110.16
WB4	170,833	2.24	332,260	125	54,212	42	18.96	1.03	9.31	29.30
WB5	217,161	1.99	391,857	125	5,791	42	22.36	0.11	4.67	27.14
WB6	37,359	2.15	70,735	125	6,302	41	4.04	0.12	0.00	4.16
WB7	155,167	1.95	277,207	125	17,416	42	15.82	0.34	7.13	23.29
WB8	686	1.71	1,141	125	3,780	42	0.07	0.07	0.00	0.14
Total	1,737,874	2.35	3,507,654	125	337,019	42	200.18	6.47	38.83	245.48

Urban Water Demand

Within the WSAM database the urban water demand constitutes two terms (direct and indirect). The direct demand encompasses all domestic uses and was computed as the product of a per capita use and the population. There were five different classifications for households, each one with a different per capita use (from 320 lpcd for big houses with a large garden to 10 lpcd for shanties supplied by communal taps). The indirect demand encompasses all industrial, commercial, institutional and municipal water demands and is expressed as a lumped value. Within the WEAP model, the net water demand (i.e., consumed and not contributing to sewage/effluent) was entered. It was assumed that the return flows reenter the system as a resource (i.e., water-quality issues were not addressed). Consequently, only net demands were used in WEAP model.

The highest population growths (~2.4%) occur in WB1 and WB2, where important economic development is taking place around the urban areas of Witbank and Middelburg (table 3.2). In the other areas, where most of the population is rural, the population growth is lower (~1.6%). For the whole Olifants the mean annual population growth was ~1.9 percent.

In 1995, the average gross domestic per capita demand was 133 lpcd (table 3.8) for the whole catchment, with a minimum of 65 lpcd in WB5 and a maximum of 266 in WB1. The average ratio of direct/total demand was 65 percent and the average ratio of net/gross demand was 37 percent (that is, about two-thirds of the urban water demand returned to the system). The net/gross demand ratio varied within the sub-catchments depending on the relative contribution of the indirect/direct components of the demands and, within the direct component, depending on the household category. The baseline and future population and water demands are presented in the tables 3.8–3.11.

Table 3.8. 1995 Urban water demand data for the WEAP model sub-catchments from the WSAM database.

	Urban population	Direct per capita usage (lpcd)	Direct use (Mm^3)	Indirect use (Mm^3)	Ratio direct/total demand (%)	Gross water demand (Mm^3)	Net water demand (Mm^3)	Ratio net/gross total demand (%)
WB1	15,450	266	1.50	0.60	72	2.80	0.90	32
WB2	562,729	137	28.18	16.78	63	54.45	19.01	35
WB3	181,950	88	5.86	2.25	72	10.83	4.69	43
WB4	25,950	145	1.37	0.53	72	2.35	0.89	38
WB5	1,400	65	0.03	0.01	72	0.06	0.02	37
WB6	750	116	0.03	0.01	72	0.06	0.03	48
WB7	48,030	214	3.75	1.46	72	6.95	2.23	32
WB8	0	0	0.00	0.00	-	0.00	0.00	-
Total	836,259	133	40.73	21.65	65	77.50	27.77	37

Table 3.9. 2025 Urban demand LG scenario.

	2025 LG scenario WEAP model							
	1995 Urban population	Mean annual growth rate	Urban population 2025	Direct per capita usage (lpcd)	Direct use (Mm^3)	Indirect use (Mm^3)	Gross water demand (Mm^3)	Net water demand (Mm^3)
WB1	15,450	1.92	27,310	266	2.66	0.60	4.34	1.39
WB2	562,729	1.95	1,004,978	137	50.32	16.78	81.24	28.36
WB3	181,950	1.31	268,862	88	8.66	2.25	14.56	6.31
WB4	25,950	1.24	37,582	145	1.99	0.53	3.14	1.19
WB5	1,400	0.99	1,880	65	0.04	0.01	0.07	0.03
WB6	750	1.15	1,057	116	0.04	0.01	0.08	0.04
WB7	48,030	0.95	63,840	214	4.98	1.46	8.59	2.75
WB8	0	0.71	0	0	0.00	0.00	0.00	-
Total	836,259	1.73	1,405,510	133	68.70	21.65	112.02	40.07

For the LG and MG scenarios increases in the direct water demand were attributed to population growth, not to increases in the per capita use. The mean annual growth rates from table 3.2 and these same values minus 0.5 percent were used for the MG and the LG scenarios, respectively. In both cases the indirect demand was kept constant. Overall, the LG scenario urban net demand was 40.07 Mm^3 and for the MG demand it was 44.91 Mm^3 (tables 3.9 and 3.10), compared with the 27.77 Mm^3 for 1995.

For the HG scenario the increases in the direct water demand were attributed to both the population growth (using the mean annual growth rates plus 0.5% from table 3.2) and an increase in the per capita use of water due to anticipated socioeconomic development. No variation in the indirect component of the demand was considered in this scenario. In the sub-catchments where the per capita usage was lower than 200 lpcd, a future use of 200 lpcd was assumed. In WB4 (the Steelpoort catchment) a high urban population increase around the city of Burgersfort is expected due to the increasing PGM mining activities (DWAF 2003, 2004). For the period 2005 to 2010 an increase of about 15,000 persons per year is anticipated (Havenga, personal communication) in the Burgersfort area. In 1995, the total urban population for WB4 was 25,950 according to the WSAM database. In this scenario, for WB4 a 2.24 percent mean annual growth (from table 3 plus 0.5%) was used from 1995 to 2005 and from 2010 to 2025. From 2005 to 2010 an annual population increase of 15,000 persons per year for 5 years was assumed (i.e., 200 lpcd and a net demand of 35% of the gross demand). The demand for this HG scenario was 76.05 Mm^3 compared with the 27.77 Mm^3 in 1995 (table 3.11).

Table 3.10. 2025 Urban demand MG scenario.

	2025 MG scenario WEAP model							
	1995 Urban population	Mean annual growth rate	Urban population 2025	Direct per capita usage (lpcd)	Direct use (Mm^3)	Indirect use (Mm^3)	Gross water demand (Mm^3)	Net water demand (Mm^3)
WB1	15,450	2.42	31,629	266	3.08	0.60	4.90	1.57
WB2	562,729	2.45	1,163,851	137	58.28	16.78	90.87	31.72
WB3	181,950	1.81	311,654	88	10.04	2.25	16.40	7.10
WB4	25,950	1.74	43,568	145	2.30	0.53	3.54	1.35
WB5	1,400	1.49	2,180	65	0.05	0.01	0.08	0.03
WB6	750	1.65	1,226	116	0.05	0.01	0.09	0.04
WB7	48,030	1.45	74,040	214	5.78	1.46	9.65	3.09
WB8	0	1.21	0	0	0.00	0.00	0.00	-
Total	836,259	2.23	1,628,148	133	79.58	21.65	125.53	44.91

Table 3.11. 2025 Urban demand HG scenario.

2025 HG scenario WEAP model								
	1995 Urban population	Mean annual growth rate	Urban population 2025	Direct per capita usage (lpcd)	Direct use (Mm^3)	Indirect use (Mm^3)	Gross water demand (Mm^3)	Net water demand (Mm^3)
WB1	15,450	2.92	36,605	266	3.55	0.60	5.53	1.78
WB2	562,729	2.95	1,346,877	200	98.32	16.78	139.35	48.65
WB3	181,950	2.31	360,996	200	26.35	2.25	38.14	16.52
WB4	25,950	2.24	149,770	200	10.93	0.53	14.33	5.44
WB5	1,400	1.99	2,526	200	0.18	0.01	0.25	0.09
WB6	750	2.15	1,420	200	0.10	0.01	0.15	0.07
WB7	48,030	1.95	85,806	214	6.70	1.46	10.89	3.49
WB8	0	1.71	0	0	0.00	0.00	0.00	-
Total	836,259	2.73	1,984,000	202	146.15	21.65	208.64	76.05

Mining Water Demand

The WSAM database provided data for water demand in the mining sector. At the quaternary scale it provided a lumped value for the gross and net water demand, not specifying the number or type of mines existing within the catchments (table 3.12).

In order to build the future water demand scenarios for the mining sector many sources were consulted. Several reports from the Department of Minerals and Energy (DME) of the Republic of South Africa regarding the present and future trends of the mining sector were reviewed. Several reports from the DWAF were also reviewed and DWAF officials were consulted. There are two geographical areas where increases in mining water demand are expected in the future. First, a huge increase in the PMG (platinum mineral group) mining is anticipated in the Middle Olifants and Steelpoort areas (DME 2006). Second, the water demands of the coal mining sector in the

Table 3.12. 1995 Mining water demands for the WEAP model sub-catchments (in Mm^3) from WSAM.

	Number of active mines[1]	1995 Gross water demand (Mm^3)	1995 Net water demand (Mm^3)	Ratio net/gross water demand (%)
WB1	16	7.94	6.49	82
WB2	32	12.36	10.11	82
WB3	8	2.23	1.83	82
WB4	20	16.55	13.54	82
WB5	4	11.02	9.01	82
WB6	1	0.45	0.37	82
WB7	12	43.16	35.31	82
WB8	0	0	0	-
Total	93	93.71	76.66	82

[1] Number of active mines in the Olifants according to the South African Council of Geoscience (from DWAF 2003).

Upper Olifants, which is very important for the generation of electricity in South Africa, may increase in the future.

In the PMG sector important developments are anticipated in the Middle Olifants and Steelpoort areas (WB2, WB3 and WB4). In January 2006, there were more than 32 potential mining sites being investigated in these areas. The DWAF originally estimated an increase of 25 Mm^3 in the gross water demand for this sector, concentrated in the Middle Olifants (DWAF 2003, 2004). However, these estimates are currently being reviewed by the DWAF and a maximum increase of 120 Mm^3 seems more plausible (Havenga, personal communication).

For the LG scenario the previous estimates of DWAF were used, and an increase of 25 Mm^3 in the mining gross demand in the Middle Olifants area (only in WB3, because in WB5 there are no PGM mines) was assumed. For the HG scenario a total increase of 120 Mm^3 (maximum increase in the demand expected by the DWAF) in the mining gross water demand was considered in the sub-catchments where exploration is currently being conducted (i.e., WB2, WB3 and WB4). This increase was made proportional to the number of exploration projects in each sub-catchment (4, 14 and 14, respectively, for WB2, WB3 and WB4). For the MG scenario a total increase of 70 Mm^3 (average of the LG and HG scenarios) in the mining gross water demand was assumed, proportionally divided into the WEAP model sub-catchments in the same way as in the HG scenario.

Coal is the most important mining industry in the WB1 and WB2 sub-catchments (33 out of 48 mines), supplying the coal needed by the power generation plants located in the Witbank area. Some sources state that coal production is unlikely to increase in this area (DWAF 2003, 2004). This hypothesis was used to build the LG scenario. Therefore, no increase in water demand was assumed for WB1 and WB2 in the LG scenario. Other sources state that the Witbank coal field is expected to supply the coal needed to satisfy future electricity demand of South Africa (DME 2005). This hypothesis was used to build the HG scenario. The average annual growth of the coal production for the whole of South Africa in the period 1995-2004 was 1.65 percent (DME 2005). Even though there are other coal fields in the country, a 1.65 percent annual increase in the coal production and, therefore, in the water demand was adopted for the HG scenario. To build the MG scenario an annual increase of 0.80 percent (i.e., the average increase of the LG and HG scenarios) was assumed.

In WB6 and WB8 the mining sector is not an important water user (table 3.12) and no important increases in water demands are expected (DWAF 2003, 2004; Havenga, personal communication). Hence, for all the future scenarios, the 1995 demands were maintained. In WB7 the mining sector consumed about 35.3 Mm^3 in 1995 (table 3.12). In this area the mining industry is very diversified (i.e., copper, emeralds, asbestos, magnetite, phosphate, clay, feldspar, slate, fertilizer, gold, mica, crushed stone, platinum, andalusite, chrome). A significant increase in the water demand is not expected in this area in the future (DWAF 2003, 2004). Therefore, for all the future scenarios, the 1995 demand was maintained.

Table 3.13 shows that the net water demand would increase from 76.66 Mm^3 in 1995 according to WSAM to 97.16 Mm^3, 138.74 Mm^3 and 185.79 Mm^3 for the LG, MG and HG scenarios, respectively.

Table 3.13. 1995 and 2025 Mining water demands for the WEAP model sub-catchments (in Mm^3).

	1995 Gross water demand (Mm^3)	1995 Net water demand (Mm^3)	2025 Lower gross water demand (Mm^3)	2025 Lower net water demand (Mm^3)	2025 Medium gross water demand (Mm^3)	2025 Medium net water demand (Mm^3)	2025 Higher gross water demand (Mm^3)	2025 Higher net water demand (Mm^3)
WB1	7.94	6.49	7.94	6.49	10.08	8.27	12.97	10.64
WB2	12.36	10.11	12.36	10.11	24.45	20.05	35.19	28.86
WB3	2.23	1.83	27.23	22.33	32.86	26.94	54.73	44.88
WB4	16.55	13.54	16.55	13.54	47.18	38.68	69.05	56.62
WB5	11.02	9.01	11.02	9.01	11.02	9.04	11.02	9.04
WB6	0.45	0.37	0.45	0.37	0.45	0.37	0.45	0.37
WB7	43.16	35.31	43.16	35.31	43.16	35.39	43.16	35.39
WB8	0	0	0	0	0	0	0	0
Total	93.71	76.66	118.71	97.16	169.19	138.74	226.58	185.79

Irrigated Agriculture Water Demand

Within the WSAM database, the irrigated agriculture demand comprises irrigation of large plots and formal schemes. Therefore, only commercial irrigation is represented in this sector. The subsistence irrigation was accounted for within the rural demand. Since it was computed along with the domestic demand in a lumped per capita use, it was not possible to obtain values for the present subsistence irrigation demand in the Olifants.

Future development of commercial irrigation within the Olifants catchment is unlikely (DWAF 2004; Havenga, personal communication). Furthermore, the water demand values from WSAM for 1995 (554.3 Mm^3 from table 3.14) are thought to be overestimated; according to the WARMS water registration database the irrigation water use accounted for only ~370 Mm^3 in 2005. For these reasons the 1995 irrigation demand values from WSAM were kept constant for all the 2025 scenarios (table 3.14). Within the WEAP model the irrigation water demand varied interannually based on rainfall; during wet years the irrigation demand was reduced and during dry years it was increased (McCartney et al. 2005).

Table 3.14. Irrigated area (in km²) and water demand (in Mm³) for the baseline year and 2025 scenarios.

	WSAM 1995 and all 2025 scenarios		
	Area (km²)	Gross water demand* (Mm³)	Net water demand* (Mm³)
WB1	24.1	8.61	8.03
WB2	473.2	213.53	196.05
WB3	298.9	174.41	161.89
WB4	131	74.56	68.18
WB5	35	23.04	21.28
WB6	82.9	31.26	28.59
WB7	57.3	28.86	26.73
WB8	0	0	0
Total	1,102.4	554.3	510.8

* The irrigation demand varies interannually with the annual rainfall; these values correspond to the 1995 hydrology.

Commercial Afforestation and Land Use Changes

Commercial afforestation impacts the hydrology of the catchment by increasing evapotranspiration and so reducing runoff, relative to indigenous vegetation. Commercial afforestation is not a real water demand in the same way as the rural, urban, etc., but it has been declared a flow reduction activity by DWAF (DWAF 2003). Within the Olifants catchment, the Blyde river sub-catchment (WB6) is the area where commercial forestry (mainly pines and eucalyptus) is most developed. In the rest of the Olifants catchment this activity does not reduce the runoff significantly. DWAF has prohibited all further development of commercial forestry in the Olifants catchment because of its negative impact on the availability of surface water resources. For 2025, the water demand for this sector was considered equal to the 1995 demand. It is estimated that new forestry practices (e.g., buffer strips alongside the Olifants river could diminish the present streamflow reduction by about 5%).

Three scenarios were developed (table 3.15). For the higher and MG scenarios the 1995 water demand was maintained constant. For the LG scenario the 1995 demand was reduced by 5 percent to simulate the impact of the new forestry practices applied.

The Olifants catchment is a mature catchment. Consequently, no major land use changes are expected in the future (Havenga, personal communication). In addition, only commercial afforestation, alien vegetation and the cultivation of sugarcane were declared flow reduction activities by DWAF (DWAF 2003). Since no major land use changes are anticipated and most of the possible land use changes are not expected to have an important impact on the availability of water resources, further land use changes were not considered in this study.

Table 3.15. 1995 and 2025 Commercial forestry demands for the WEAP model sub-catchments (in Mm^3).

	WSAM 1995 WEAP model	2025 LG scenario	2025 MG scenario	2025 HG scenario
WB1	0	0.00	0	0
WB2	1.3	1.24	1.3	1.3
WB3	0	0.00	0	0
WB4	5.11	4.85	5.11	5.11
WB5	1.72	1.63	1.72	1.72
WB6	43.32	41.15	43.32	43.32
WB7	2.7	2.57	2.7	2.7
WB8	0	0.00	0	0
Total	54.2	51.44	54.2	54.2

Summary and Comparison with the DWAF Scenarios for 2025

Table 3.16 summarizes the 1995 baseline water demand and the three water scenarios for 2025. All demands shown are gross demands. The most important increases were experienced in the:

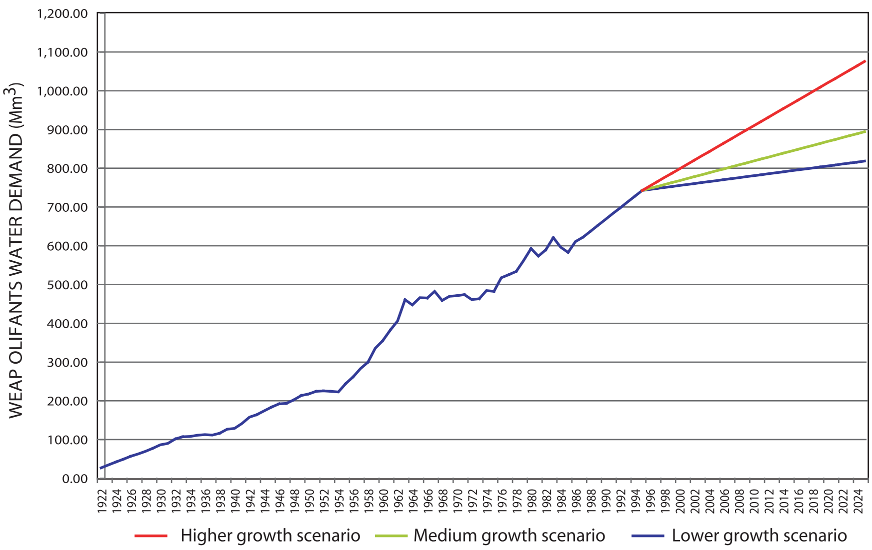
- rural sector - the demand was almost doubled for the LG scenario and more than tripled for the HG scenario
- urban sector - the demand increased by ~50% for the LG scenario and more than 150 percent for the HG scenario
- in the mining sector - the demand increased by ~30 percent for the LG scenario and more than 150 percent for the HG scenario

The historic development of water demands in the Olifants catchment as simulated by WEAP model (McCartney et al. 2005) along with the three future scenarios developed in the current study are presented in figure 3.3.

Table 3.16. Summary table of the 1995 baseline and 2025 scenarios (gross demands shown).

Water demand sector	WSAM 1995 (Mm^3)	2025 LG scenario (Mm^3)	2025 MG scenario (Mm^3)	2025 HG scenario (Mm^3)
Rural	73.37	118.89	145.60	248.68
Urban	77.50	112.02	125.53	208.64
Irrigation	554.27	554.27	554.27	554.27
Mining	93.71	118.71	169.19	226.58
Afforestation	54.15	51.44	54.15	54.15
Total	853.00	955.33	1,048.73	1,292.32

Figure 3.3. Past, present and future water demand in the Olifants catchment (as entered in WEAP model).



The scenarios developed in this study and those developed by the DWAF (DWAF 2003, 2004) are compared in table 3.17.

The rural demands cannot be compared directly because the DWAF scenarios only include domestic and livestock watering (i.e., they exclude water use for subsistence irrigation and other smallholder economic activities). The scenarios developed in this study assumed a relatively large increase in the rural sector demand mainly due to a reduction in poverty in the rural areas in conjunction with an increase in domestic use and revitalization of smallholder irrigation schemes along with the anticipated population growth. With respect to the urban water demand, the DWAF scenarios and the ones presented in this report are quite similar. The irrigated agricultural demand scenarios are identical in both studies. In relation to the mining sector, the LG scenarios for both studies were identical, but the HG scenario developed in this study is a lot higher than the one considered by DWAF. In its study, DWAF did not consider an increase in the coal mining sector water demand and assumed a limited increase in the platinum sector. However, the impact of platinum mining development is currently being revised by DWAF. The DWAF scenarios do not explicitly include the flow reduction impact of commercial forestry.

Table 3.17. Comparison of future scenarios with those of DWAF (gross demands shown).

Water demand sector	WSAM 1995 (Mm^3)	2025 LG scenario (Mm^3)	2025 MG scenario (Mm^3)	2025 HG scenario (Mm^3)	DWAF 1995 (Mm^3)	DWAF 2025 low scenario (R)* (Mm^3)	DWAF 2025 high scenario (H)* (Mm^3)
Rural	73.37	118.89	145.60	248.68	41.20	50.3	50.3
Urban	77.50	112.02	125.53	208.64	77.30	126.10	193.40
Irrigation	554.27	554.27	554.27	554.27	557	557	557
Mining	93.71	118.71	169.19	226.58	93.80	118.80	118.80
Total	798.85	903.89	994.58	1238.17	769.30	852.20	919.50

* Of the two DWAF scenarios developed for 2005, one is more conservative (R), equivalent to LG of this paper and the other supposes a higher growth of the demand (H), equivalent to the HG of this paper.

Simulation of Additional Factors

In this section, the other factors that could impact future water use in the Olifants catchment are considered. The application of an IA with Mozambique, the ER and the construction of new water storage infrastructure, as well as the application of WC&DM practices were all considered.

Development of New Water Infrastructure

The development of new water infrastructure (reservoirs) is an important factor that must be considered in future resource planning. The most important dams that DWAF is considering building in the near future were included in this study (table 3.18). The construction of two new dams, one on the mainstream of the Middle Olifants river (Rooipoort dam in WB5) and the other on the Steelpoort river (De Hoop dam in WB4, whose construction was to have started in 2006) along with the raising of the Flag Boshielo dam (in WB3, completed in 2006) were considered.

Table 3.18. New Infrastructure in the Olifants catchment.

Name	Location	Description	Volume
De Hoop dam	WB4	New dam in the Steelpoort river	347 Mm^3
Rooipoort dam	WB5	New dam in the Middle Olifants river	300 Mm^3
Flag Boshielo dam	WB3	Raising existing dam 5 m	193 Mm^3 (88 Mm^3 extra)

Water Conservation and Demand Management

The National Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997) have provided an enabling environment for WC&DM. DWAF has identified WC&DM strategies as important tools to assist in the reconciliation of water demands and water resources in the Olifants catchment. The maximum water savings expected in the Olifants catchment due to WC&DM practices (table 3.19) were obtained from Mr. Beyers Havenga (Chief Engineer, DWAF).

Table 3.19. Maximum water saving due to WC&DM.

Water sector	Expected saving (%) in WC&DM
Irrigation	25
Rural	20
Urban	15
Mining	5

Even though efficient techniques like drip and sprinkler irrigation are widely used in the Olifants catchment, significant water losses have been detected in the water distribution infrastructure (i.e., canals and ditches) (Havenga, personal communication). A maximum saving of 25 percent of the total demand is anticipated in the agriculture sector. In the rural sector (generally meaning former homelands in the Olifants catchment) important water losses due to the deficiency in the water supply infrastructure and the existence of illegal connections have been found (Havenga, personal communication). A maximum saving of 20 percent of the total demand is expected in the rural sector. In the urban sector the losses and illegal connections are less important than in rural areas (Havenga, personal communication). In the urban sector maximum savings of 15 percent are expected. The mining sector is already quite efficient in water use with most process water being recycled. Consequently, a maximum saving of just 5 percent is anticipated in this sector.

Environmental Reserve

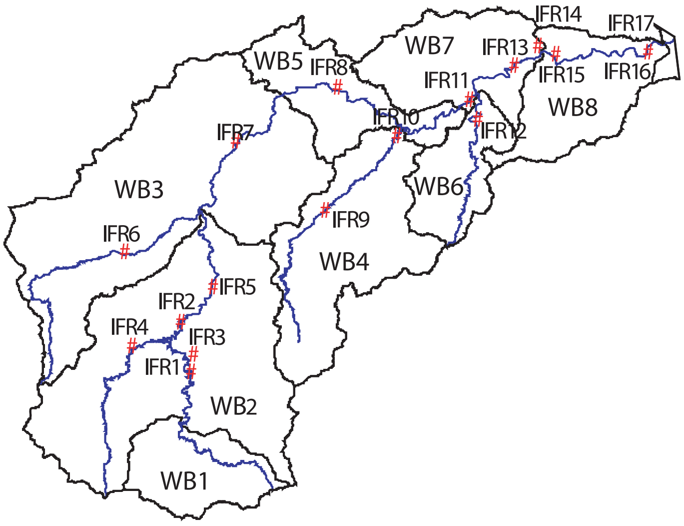
Under the 1995 National Water Act (NWA) the concept of the Reserve (water required to meet basic human needs and ensure environmental sustainability) was developed. The Reserve is considered as a water "right" by the NWA. Consequently, it must be satisfied before water is used for any other purposes (NWA 1998). Different levels of resource use, resource protection and ecosystem health are possible. Therefore, each water body, for which the Reserve is determined, must be classified. The classification system describes levels of desired ecosystem integrity, and on the basis of this, tolerable degrees of risk to ecosystem health, and levels of acceptable use of the resource are identified. The volume and quality of water allocated to the ecological Reserve therefore depends on the level of classification (from A to F, with A being the most natural and E and F degraded and non-sustainable). For future targets, by law, all rivers must be between A and D. In the Olifants catchment, a study conducted to determine environmental flow requirements selected 18 so-called instream flow requirement (IFR) points. For each, the quantity and quality of the water needed to achieve the Recommended Ecological Class were determined. Flow variability is recognized as being a key component of environmental flows and both "drought" and the so-called "maintenance" flow requirements were determined (Palmer 2001a, b, c).

In table 3.20, the Present Ecological State (PES) and the Recommended Ecological Class (REC) for the IFR points used in the WEAP model in the current study are presented. The "Olifants River Ecological Water Requirements Assessment: Comprehensive Ecological Reserve (Water Quantity)" for the Lower, Middle and Upper Olifants (Palmer 2001a, b, c) reports were reviewed. In these reports environmental flow time series for the historic hydrology (1920 to 1990) were determined for the different IFR points (figure 3.4). Only the IFR points located close to the outlets of the WEAP model sub-catchments were used in the current study, because it was only at the outlets of these sub-catchments that the WEAP model streamflow simulation represented reality. This is because it was only at these points that the water resources and demands for the whole sub-catchment are computed.

Table 3.20. Selected instream flow requirement cross-sections for the different WEAP model sub-catchments.

WEAP model sub-catchment	IFR cross section	Present ecological state (PES)	Recommended ecological class (REC)	Naturalized streamflow (%)	Long-term flow requirement (Mm^3)
WB2	IFR 5	C	B	24	120.2
WB3	IFR 8	D	D	19	155.1
WB4	IFR 10	D	D	18	69.9
WB5	IFR 11	E	D	13	174.1
WB6	IFR 12	B	B	34	128.5
WB8	IFR 16	C	B	20	393.6

Figure 3.4. Existing IFR locations and WEAP model sub-catchment subdivisions for the Olifants.



Six IFR locations were identified to represent the ER at the outlets of the WEAP model sub-catchments. The largest ER requirement is in the Blyde river, or WB6 (~29% of the naturalized streamflow to achieve a recommended class B). The lowest ER is at the outlet of WB5 (~11% of the naturalized streamflow to achieve a recommended class D) (table 3.20). At IFR16, the most downstream location, the total Reserve requirement is estimated to be 394 Mm^3 (i.e., about 20% of the annual water resources of the catchment). However, comparison of the naturalized flow and the derived environmental flows indicates that dry season environmental flow requirements require a significantly higher proportion of the naturalized river flow (i.e., up to 78%) than is the case in the wet season.

International Agreement

The Olifants river is a tributary of the Limpopo river, which is shared by South Africa, Botswana, Zimbabwe and Mozambique. Downstream of the Kruger National Park the Olifants flows into Mozambique, prior to its confluence with the Limpopo. Currently, there is no IA regarding the sharing of the water of the Olifants river between South Africa and Mozambique.

According to DWAF, a minimum flow of approximately 5 percent of the monthly naturalized streamflow of the Olifants river across the border with Mozambique is a reasonable estimate of an eventual future agreement with Mozambique (Havenga, personal communication).

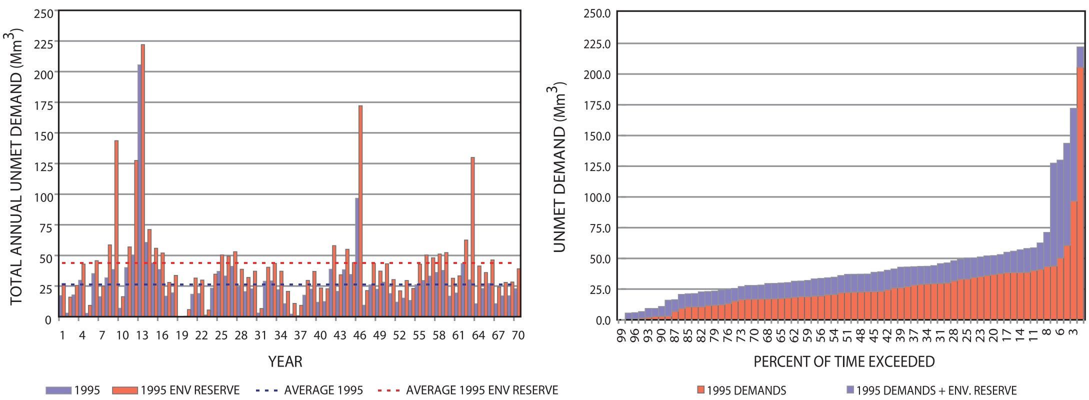
ANALYSIS OF THE WEAP MODEL RESULTS

In this section, the outputs of the WEAP model for the Olifants catchment and the different scenarios considered are analyzed. For each scenario, the main output analyzed was the degree of satisfaction of the water demands in the different sectors and sub-catchments. Consideration was also given to other outputs such as the streamflow at the catchment outlet and changes in reservoir storage. The results from the different scenarios were compared to assess the impact of the increasing water demands, the effectiveness of the development of NI, the impact of the Reserve and WC&DM practices.

1995 Baseline Water Demand

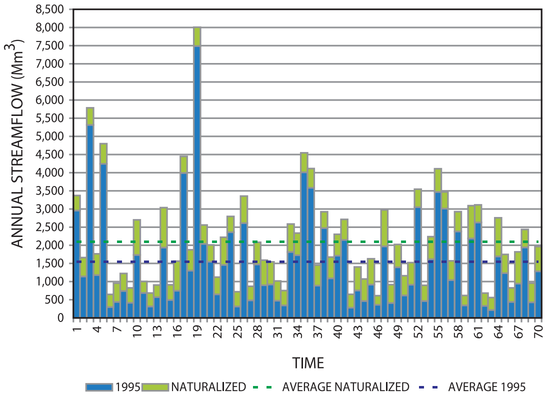
The WEAP model was initially set up for the 1995 baseline water demand and run for the 70 years of historic hydrological data available from the WR 90 study (figures 4.1a and 4.1b, and table A1, and figures A1a, b, c and d in the appendix). The average annual unmet demand over the 70 years of hydrology was 26.4 Mm^3 for the whole Olifants catchment (i.e., 3.4% of the total annual demand). The greatest shortages were experienced during the 13th year (i.e., 205.5 Mm^3, or 22.8 % of the total demand) with the largest shortfalls in sub-catchments WB2, WB3 and WB4, where 85 percent of the irrigation demand is concentrated. The second worst year was the 46th year. The 1st, 2nd and 4th most severe droughts in the Olifants occurred from the 41st to 45th years, from the 5th to 8th years and from the 10th to the 12th years, respectively (McCartney et al. 2004). In all cases, because it was given the lowest priority within each sub-catchment, the irrigation sector was the most affected. Overall shortages in irrigation accounted for 26.3 Mm^3 of the average annual shortfall of 26.4 Mm^3 of the total shortfall. The longest duration with shortages (considering all the demands in the whole Olifants catchment) was 8 months, starting in April of the 6th and 45th years and in March of the 46th year.

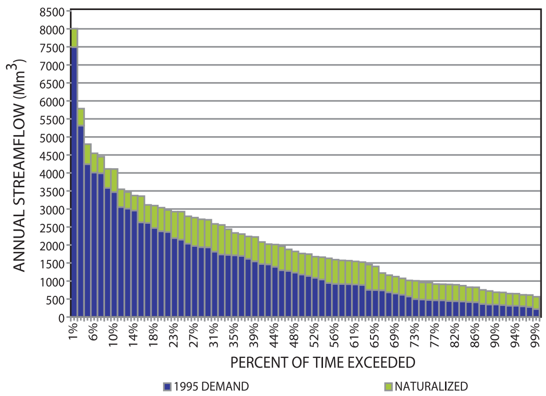
Figures 4.1a and 4.1b. Total unmet demands for the 1995 baseline (with and without ER).



The impact of the 1995 demand on the annual naturalized streamflow for the whole Olifants catchment is presented in figure 4.2a. The flow to Mozambique, if there were no human activities in the catchment, has a mean value of 2,096 Mm^3, with a maximum of 8,006 Mm^3 (year 19) and a minimum of 561 Mm^3 (year 63). Figure 4.2b shows that 75 percent of the time, the naturalized streamflow was greater than 1,000 Mm^3, 45 percent of the time it was greater than 2,000 Mm^3 and 20 percent of the time it was greater than 3,000 Mm^3. The impact of the 1995 baseline demand on the flow to Mozambique was to reduce the average annual flow over the 70 years of hydrology to 1,540 Mm^3, with a maximum of 7,488 Mm^3 (year 19) and a minimum of 218 Mm^3 (year 63, less than half of the naturalized condition). Figure 4.2b shows that 55 percent of the time the flow was greater than 1,000 Mm^3 (instead of 75%), 25 percent of the time it was greater than 2,000 Mm^3 (instead of 45%), and 13 percent of the time it was greater than 3,000 Mm^3 (instead of 20%).

Figures 4.2a and 4.2b. Annual streamflow for the whole Olifants catchment (naturalized and 1995 demand).





The aggregate of the monthly storage at all the modeled reservoirs is presented in figure 4.3. Storage dropped to its minimum values during the 13th, 46th and 63rd years. The maximum storage capacity of the modeled reservoirs (~1,000 Mm^3) was reached many times during the 70 years of historic hydrology. In more than 6 percent of the months all the modeled reservoirs were spilling at the same time. The simulated storage capacity of the catchment was less than half the mean annual naturalized streamflow so there was no important interannual regulation and, as explained above, during wet periods the storage capacity was reached easily. In 2006, a few months of heavy rains were enough to make most of the reservoirs in the Olifants catchment spill after several years of drought. The Massingir reservoir, located on the Olifants river in Mozambique (catchment area to the dam is 67,504 km^2) has a storage capacity of 2,840 Mm^3 (more than twice the total storage of all the reservoirs on the South African side of the Olifants catchment and one and a half times its mean annual naturalized streamflow) (McCartney et al. 1998). This multipurpose reservoir (used for irrigation, energy production, flood control, control of salt water intrusion and urban and rural supply) regulates the streamflows leaving the South African side of the Olifants catchment.

After running the WEAP model for the 1995 baseline, the ER requirement was added (figures 4.1a and 4.1b above and table A2 and figures A2a, b, c and d in the appendix). The ER was given priority 1 as required by the NWA, 1998. Therefore, it was satisfied before satisfying any other demand. In this case, the average annual unmet demand over the 70 years of hydrology was 43.8 Mm^3 (5.6% of the total annual demand) compared with the 26.4 Mm^3 without considering the ER (figure 4.1a). During the 13th year the greatest shortages were experienced (222.0 Mm^3 or 24.6% of the total demand compared with 205.5 Mm^3 without ER). As earlier, the most affected areas were WB2, WB3 and WB4. The second worst year was again the 46th year, with significant shortages during the 10th, 12th and 64th years. In all cases, the irrigation sector was the most affected, because it was given the lowest priority within a sub-catchment, with an average annual shortage of 43.6 Mm^3. The longest periods with shortages (considering all the demands in the whole Olifants catchment) were 8 months, commencing in April of the 3rd, 45th and 62nd years and in March of the 46th year.

The impact of the application of the ER on water storage is presented in figures 4.3a and 4.3b. At a monthly time scale, the average volume of water stored decreased by 40 Mm^3 in order to satisfy the flow requirements of the ER. On average, the flow entering Mozambique increased by 24.4 Mm^3 per year. However, in 18 out of the 70 years there was a reduction in the flow because in wet years the reservoirs were refilled after releasing higher flows to ensure the environmental flows during the drier years (figure 4.4b).

Figures 4.3a and 4.3b. Monthly storage in all the modeled reservoirs for the 1995 demand with and without the ER (time series and storage exceedance curves).

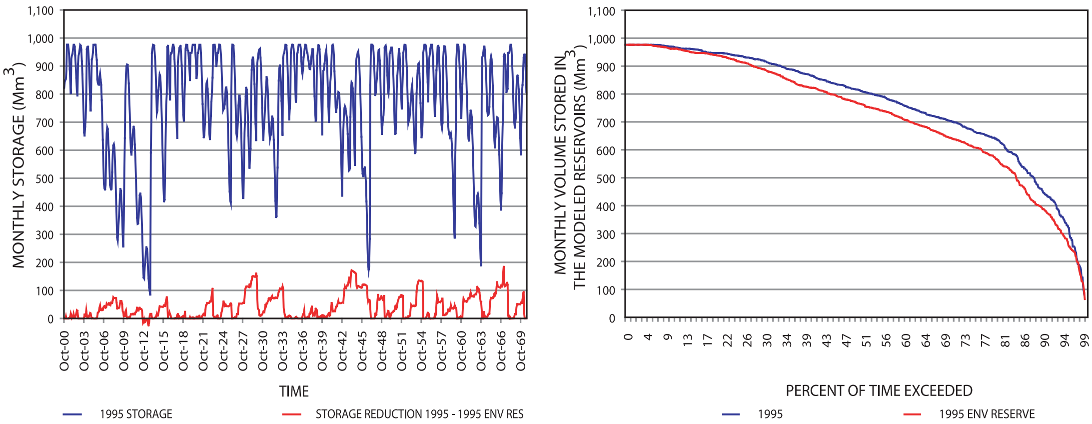


Figure 4.4a shows the monthly streamflows at the border. Under the naturalized conditions the minimum monthly streamflow was 15.7 Mm^3. For the 1995 baseline demand a minimum environmental flow of 1.5 Mm^3 was adopted and given priority 1 at the Kruger National Park. Without this minimum flow requirement, the Olifants river at the border would have been dry in about 2 percent of months. After the application of the ER to the 1995 baseline demand, there was an improvement in the minimum monthly streamflows at the border. Monthly streamflows of less than 10 Mm^3 never occurred under the naturalized conditions. But those that occurred in 15 percent of months for the 1995 baseline demand did so only in 4 percent of the months after the introduction of the ER.

Figures 4.4a and 4.4b. Monthly and annual streamflow released to Mozambique (flow duration curve and impact of the ER for the 1995 demands).

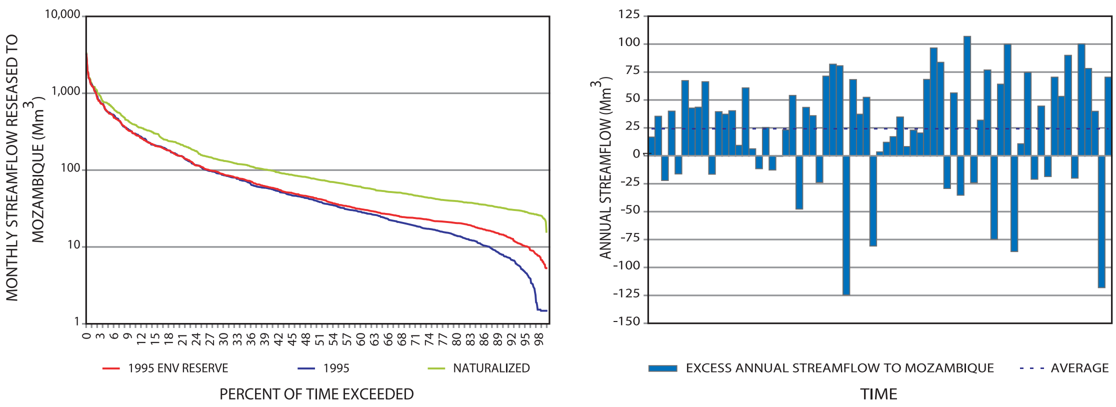
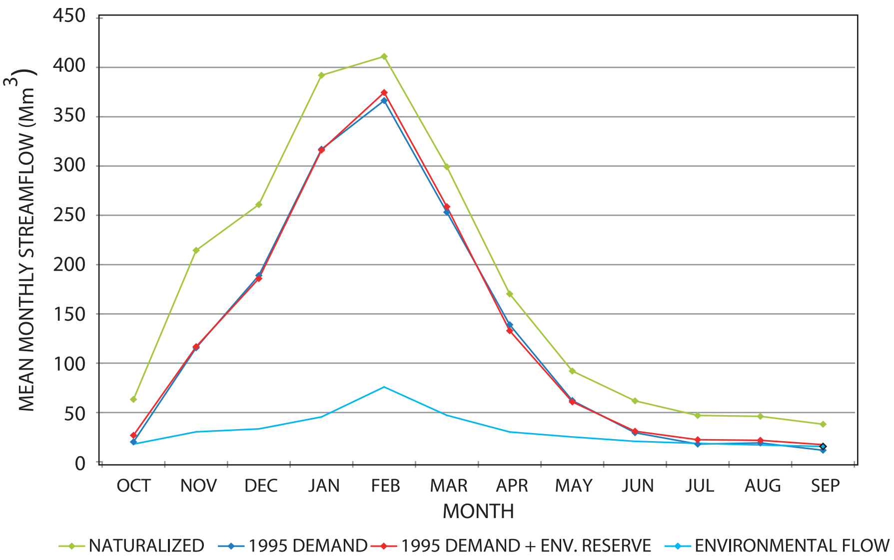


Figure 4.4c shows the mean monthly flows going to Mozambique for the naturalized and 1995 conditions, with and without the ER. The naturalized flows were reduced by ~25% as a result of the 1995 demands. Introduction of the Reserve does not have a significant impact on the high and medium flow conditions but it does in relation to low flows (figure 4.4a).

Figure 4.4c. Mean monthly streamflow released to Mozambique.



2025 Water Demand Scenarios

After analyzing the 1995 baseline and the impact of the ER, the WEAP model was configured for the 2025 LG, MG and HG scenarios. It was again run for the 70 years of historic hydrological data available from the WR 90 study (figure 4.5 and tables A3 to A5 and figures A3a, b, c and d to A5a, b, c and d in the appendix).

The average annual unmet demands over the 70 years of hydrology were 33.0 Mm^3 (3.8% of the total annual demand), 45.5 Mm^3 (4.9% of the total annual demand) and 88.6 Mm^3 (7.9% of the total annual demand) for the LG, MG and HG scenarios, respectively (c.f. for the 1995 baseline it was 26.4 Mm^3). For the LG and MG scenarios the greatest shortfalls were experienced during the 13th year (310 Mm^3 or 36% of the total demand for the LG and 357 Mm^3 or 38.1% of the total demand for the MG). Once again the most affected areas were WB2, WB3 and WB4. The second worst year was the 46th year. Figure 4.5 shows that for the HG scenario there was a shift in the worst year, and the highest unmet demands were experienced during the 46th year (587 Mm^3 or 52.6% of the total demand). During the 8th, 9th, 12th, 13th 33rd and 63rd years there were shortages of more than 200 Mm^3. In all cases, the irrigation sector was the most affected with an annual average shortage of 32.5 Mm^3, 44.5 Mm^3 and 79 Mm^3 but with increasing shortages in the urban, rural and mining sectors for the scenarios with higher demands (table 4.1). The longest periods with any shortage were 8 months for the LG scenario (starting in April of the 3rd, 45th and 62nd years and in March of the 46th year), 9 months for the MG scenario (March of the 45th year) and 10 months for the HG scenario (March of the 45th and 62nd and January of the 59th years).

Figure 4.5. Total annual unmet demand for the 2025 scenarios and the 1995 baseline.

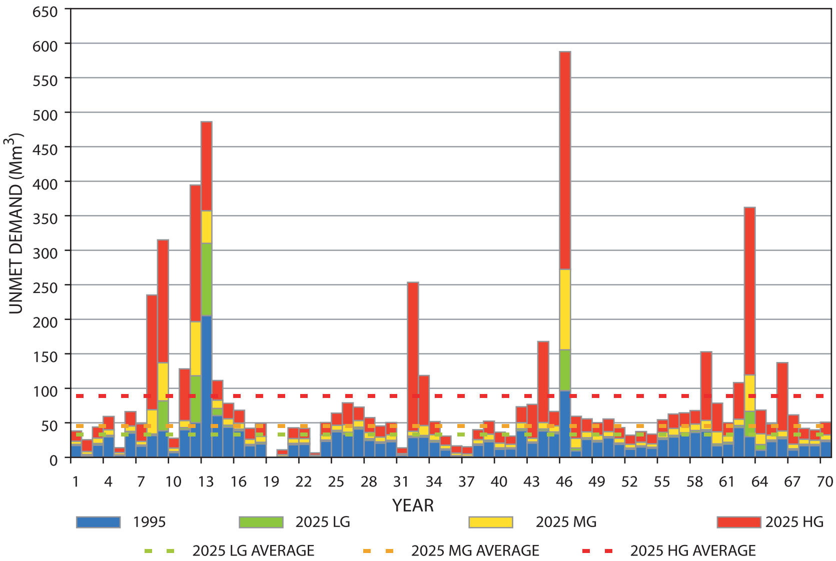


Table 4.1. Average annual unmet demand for the different sectors.

Scenario	1995		2025 LG		2025 MG		2025 HG	
Sector	Demand		Demand		Demand		Demand	
	Mm³	(%)	Mm³	(%)	Mm³	(%)	Mm³	(%)
Irrigation	26.3	4.8	32.5	5.9	44.4	8.0	79.0	14.3
Rural	0.0	0.1	0.2	0.2	0.4	0.3	3.1	1.3
Urban	0.0	0.0	0.0	0.1	0.1	0.2	1.1	1.4
Mining	0.1	0.1	0.2	0.2	0.6	0.4	5.4	2.9

Figure 4.6 presents the annual flow into Mozambique for each scenario. The mean value decreased from 2,096 Mm³ for the naturalized conditions to 1,481 Mm³, 1,434 Mm³ and 1,315 Mm³ for the LG, MG and HG scenarios, respectively. The minimum annual value also decreased from 561 Mm³ for the naturalized conditions to 201 Mm³, 179 Mm³ and 122 Mm³ (i.e., about one-fifth of the naturalized conditions) for the LG, MG and HG scenarios, respectively (year 63). Figure 4.7 shows that 45 percent of the time the flow was greater than 1,000 Mm³ (instead of 55% for the 1995 baseline and 75% for the naturalized conditions), 21 percent of the time it was greater than 2,000 Mm³ (instead of 25% for the 1995 baseline and 45% for the naturalized conditions), and 10 percent of the time it was greater than 3,000 Mm³ (instead of 13% for the 1995 baseline and 20% for the naturalized conditions). Figure 4.8 shows the monthly flow duration curves at the border. Under the naturalized conditions the minimum monthly streamflow was 15.7 Mm³. For the 1995 baseline and the three 2025 scenarios, a minimum environmental flow of 1.5 Mm³ was adopted and given priority 1 at the Kruger National Park. Without this minimum flow requirement the Olifants river would have been dry at the border in about 6 percent of the months for the 2025 HG scenario (c.f. for the 1995 baseline it would have been dry in ~2% of months).

Figure 4.6. Annual streamflow for the Olifants catchment (naturalized, 1995 and 2025 scenarios).

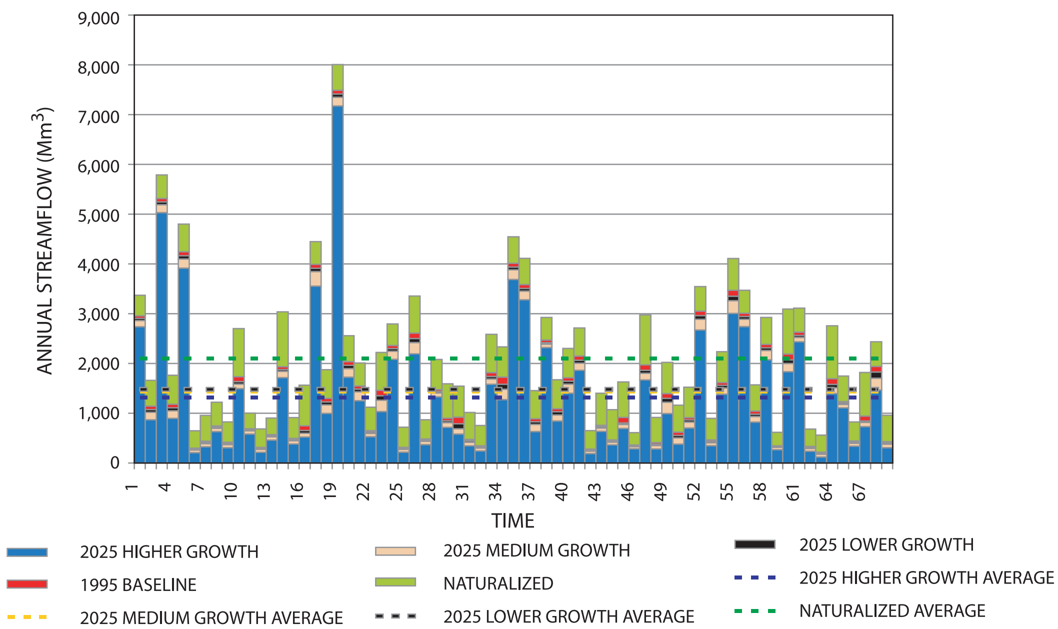


Figure 4.7. Exceedance diagram of the annual streamflow for the Olifants catchment (naturalized, 1995 and 2025 HG scenarios).

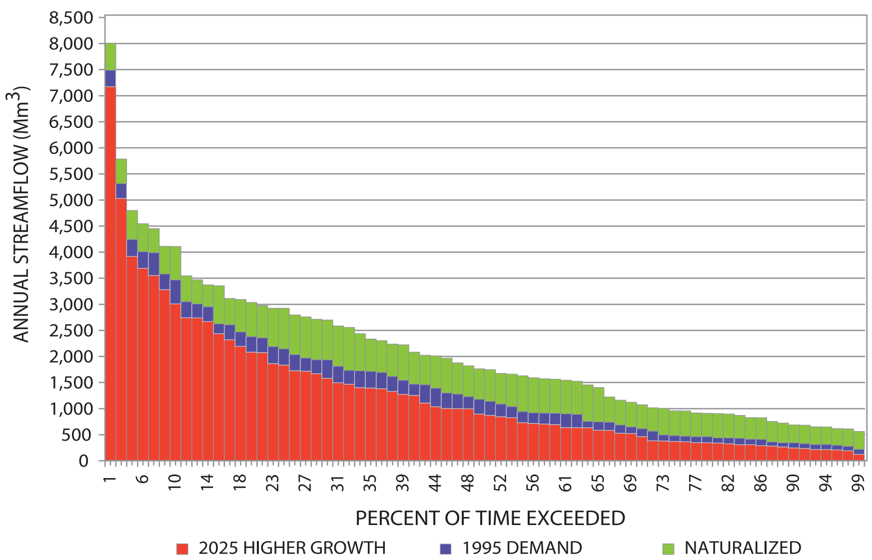
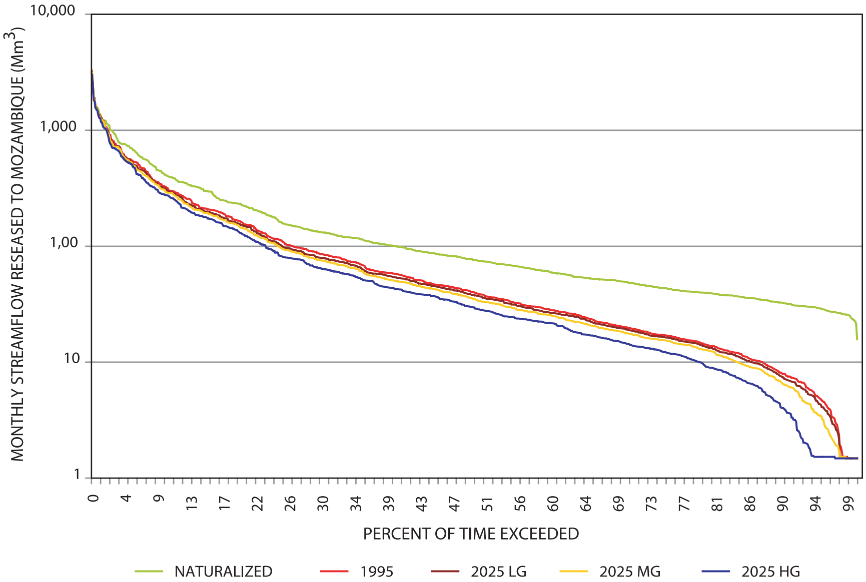


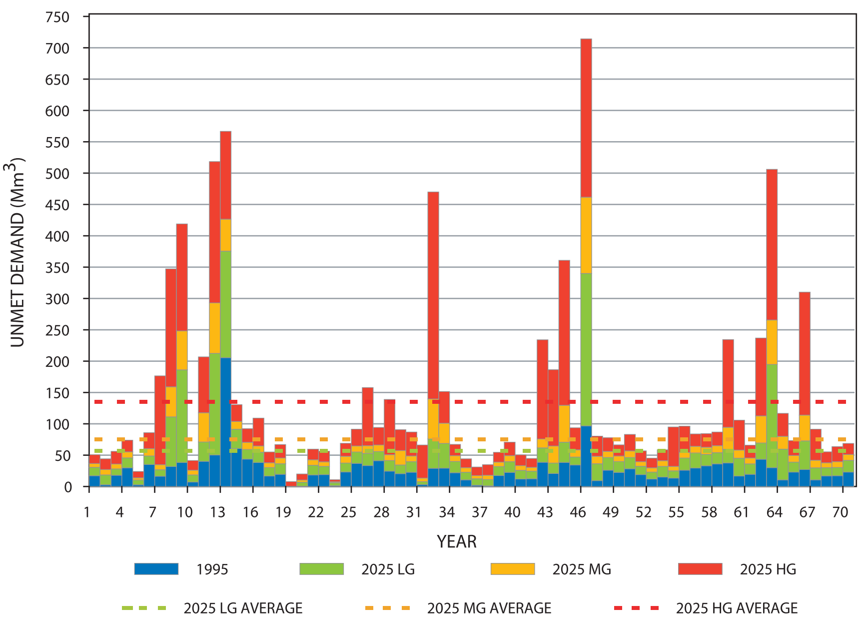
Figure 4.8. Monthly streamflow released to Mozambique (flow duration curve for the naturalized, 1995 and 2025 water demand scenarios).



Impact of the Environmental Reserve

After analyzing the 2025 water demand scenarios, the impact of the ER was assessed. As previously, the ER was given priority 1. The WEAP model was run for the 70 years of historic hydrological data (figure 4.9 and tables A6 to A8 and figures A6a, b, c and d to A8a, b, c and d in the appendix).

Figure 4.9. Total annual unmet demand for the 2025 scenarios with ER and the 1995 baseline.



The average annual unmet demands over the 70 years of hydrology were 56.6 Mm^3 (i.e., 6.6% of the total annual demand, instead of 33 Mm^3 without ER), 75.1 Mm^3 (i.e., 8% of the total annual demand, instead of 45.5 Mm^3 without ER) and 135.2 Mm^3 (i.e., 12.1% of the total annual demand, instead of 88.6 Mm^3 without ER) for the LG, MG and HG scenarios, respectively (c.f. 26.4 Mm^3 for the 1995 baseline without the ER). For the LG scenario the greatest shortages were experienced in the 13th year (375.5 Mm^3 or 43.6% of the total demand instead of 310 Mm^3 without considering the ER). The second worst year was the 46th year.

Figure 4.10 shows that for the MG and HG scenarios there was a shift in the worst year, and the highest unmet demands were experienced during the 46th year (461.6 Mm^3 or 49.3% of the total demand and 714.2 Mm^3 or 64% of the total demand, respectively, instead of the 357 Mm^3 and 587 Mm^3 without the ER). During the 8th, 9th, 12th, 13th, 33rd, 42nd, 44th, 59th, 62nd, 63rd and 66th years there were shortages of more than 200 Mm^3 for the HG scenario. In all cases, the irrigation sector was the most adversely affected, with increasing shortages in the urban, rural and mining sectors for the scenarios with higher demands (table 4.2).

Table 4.2. Average annual unmet demand for the different sectors with the environmental reserve enforced.

Scenario	1995 (No ER)		2025 LG environment		2025 MG environment		2025 HG environment		2025 HG environment different priorities	
Sector	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)
Irrigation	26.3	4.8	71.7	12.9	55.4	10.0	111.5	20.1	113.1	20.4
Rural	0.0	0.1	1.1	0.7	0.5	0.5	6.4	2.6	4.4	1.8
Urban	0.0	0.0	0.4	0.8	0.2	0.6	2.9	3.9	3.6	4.7
Mining	0.1	0.1	1.9	1.4	0.4	0.4	14.3	7.7	14.4	7.7

To assess the impact of the demand priorities set in WEAP model (table 2.3), a fourth scenario was run with the 2025 HG demand. In this case, no differentiation was made between upstream and downstream demands and prioritization was fixed simply by sector. The ER was given priority 1, the rural demands priority 2, the urban demands priority 3, the mining demands priority 4 and the irrigation demands priority 5. In table 4.2 and in table A21 and figures A21a, b, c and d in the appendix it can be observed that the modification of the priorities did affect the pattern of unmet demands. This can be explained by the fact that the sub-catchments experiencing the greatest shortages (also having the greatest demands) are the upstream catchments (WB1 to WB4) and the less-stressed ones are those located downstream. Neglecting the upstream-downstream considerations effectively transfers water from the irrigation and mining sectors upstream to meet the unmet demands of the rural and urban sectors downstream. The overall impact is a very slight increase in the total unmet demand, from 135.1 Mm^3 to 135.5 Mm^3, with a small absolute reduction in the unmet demand of the rural sector, but increased unmet demand in the urban, mining and irrigation sectors (table 4.2). The fact that demand was still not fully met in the rural sector can primarily be attributed to lack of storage in the upper catchment.

The longest periods with any shortage (considering all the demands in the whole Olifants catchment) was 8 months for the LG (starting in April of the 3rd, 45th and 62nd years and in January of the 46th year), 9 months for the MG (March of the 45th and April of the 62nd years) and 11 months for the HG scenario (March of the 45th year).

Figure 4.10 presents the annual flow going to Mozambique. The application of the ER increased its mean value to 1,519 Mm^3 (instead of 1,418 Mm^3 without the ER), 1,479 Mm^3 (instead of 1,434 Mm^3) and 1,377 Mm^3 (instead of 1,315 Mm^3) for the LG, MG and HG scenarios, respectively. The minimum annual value also increased to 313 Mm^3 (instead of 201 Mm^3), 300 Mm^3 (instead of 179 Mm^3) and 268 Mm^3 instead of 122 Mm^3) for the LG, MG and HG scenarios, respectively. Figure 4.11 shows the difference between the annual flows to Mozambique with and without considering the ER. As previously, and for the same reason, it can be observed that in 18 of the 70 modeled years the flow decreased.

Figure 4.10. Annual streamflow for the Olifants catchment (naturalized and 2025 with ER scenarios).

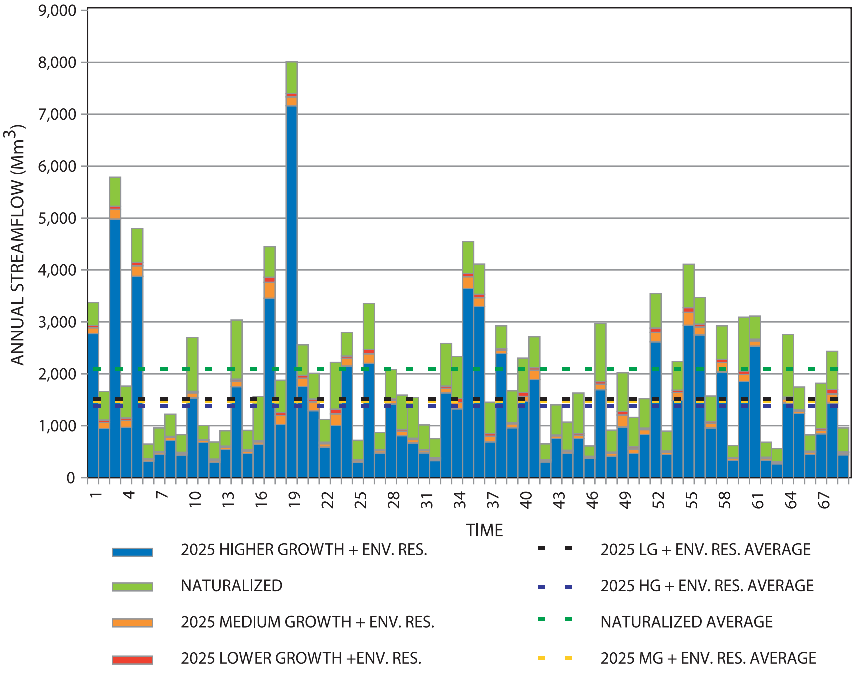
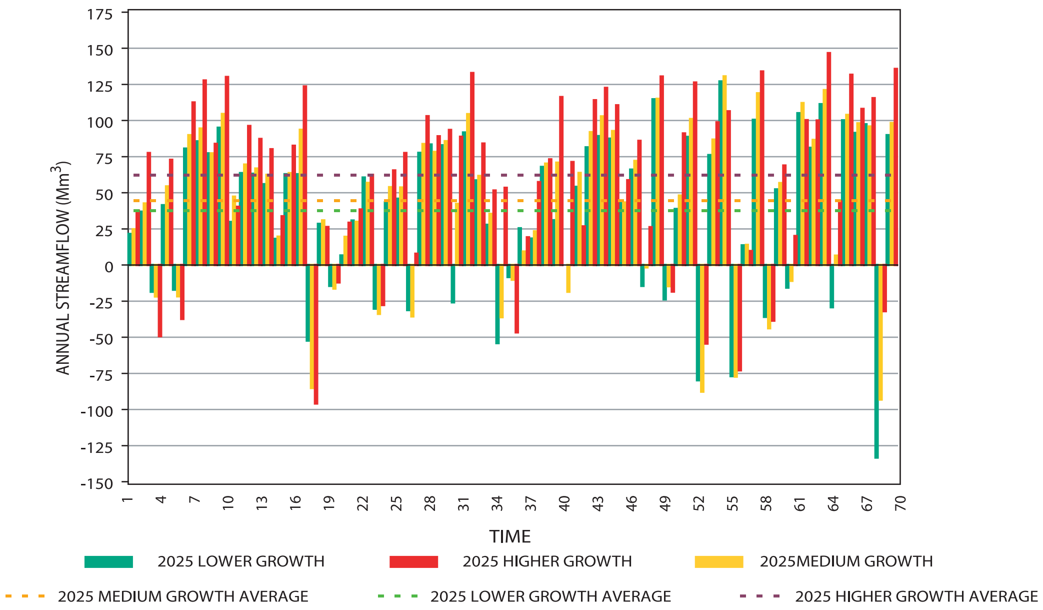


Figure 4.12a shows the flow duration curves at the border. After applying the ER the minimum monthly flow increased from 1.5 Mm^3 to 5.3 Mm^3 for all the scenarios. Monthly streamflows of less than 10 Mm^3 that never occurred under the naturalized conditions and that occurred 14 percent, 16 percent and 21 percent of the months for the 2025 LG, MG and HG scenarios, occurred in less than 6 percent of the months after the application of the ER. Figure 4.12b shows how the mean monthly flows slightly increase after the application of the ER.

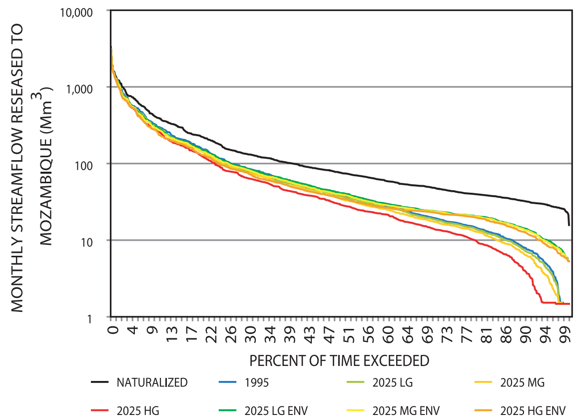
Impact of an International Agreement

The application of an IA to share the water of the Olifants river with Mozambique was added to the model to assess the impact on the 2025 water demand scenarios. It was given priority 1, along with the ER (tables A9 to A11 and figures A9a, b, c and d to A11a, b, c and d in the appendix).

Figure 4.11. Difference between the streamflow released to Mozambique for the 2025 scenarios with and without the ER.



Figures 4.12a and 4.12b. Monthly streamflow released to Mozambique (flow duration curves and mean monthly values for the naturalized, 1995, 2025 and 2025 with ER water demand scenarios).



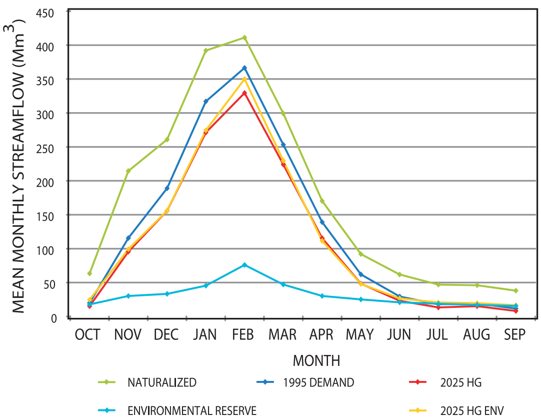


Figure 4.13 shows that at an annual time scale, the IA water requirement (modeled as 5% of the naturalized streamflow for the whole Olifants catchment) is met for even the 2025 HG scenario.

Figure 4.14 shows how at a monthly time scale the requirement of the IA was almost fully satisfied (more than 98% of the months) with exceptions in just the most critical periods (some months during the years 6-7, 12-13, 24-25, 63-64, etc.) of the 2025 HG scenario. This result can be explained in part because an environmental flow requirement of 0.57 m^3s^{-1} (1.47 Mm^3 per month) was added at the Olifants river in the Kruger National Park for all the scenarios. This effectively prevented the red line of the hydrograph in figure 4.14 (2025 HG scenario) falling below the black line of the IA, except during the most critical months when it just dropped below the internationally agreed hydrograph. The positive impact of the ER on the satisfaction of the IA is shown by the blue line in figure 4.14. If the ER was applied the IA was satisfied in all months for all the scenarios.

When comparing the rest of the outputs of the WEAP model for the 2025 scenarios with the ER and with and without the IA it was found that the results were the same. This means that the ER requirement was greater than the IA and therefore the latter did not have any impact once the ER was applied.

Figure 4.13. Comparison of the International Agreement water requirement with the naturalized and 2025 HG growth scenario conditions at annual time scale.

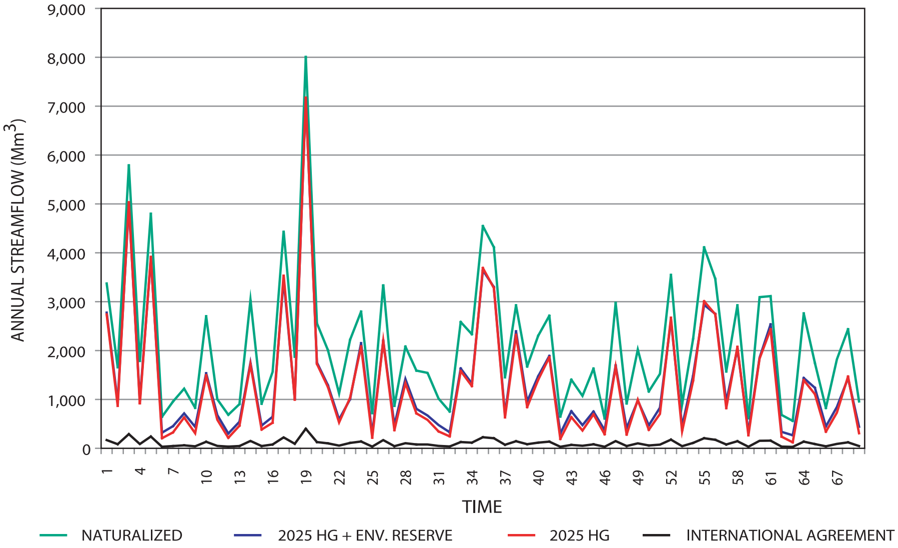
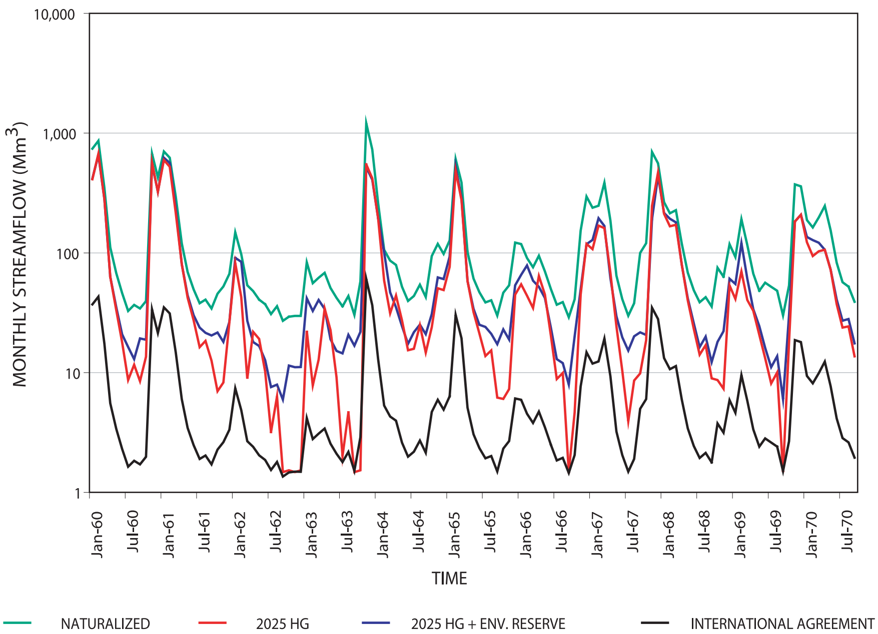


Figure 4.14. Comparison of the International Agreement water requirement with the naturalized and 2025 HG scenario conditions at monthly time scale.

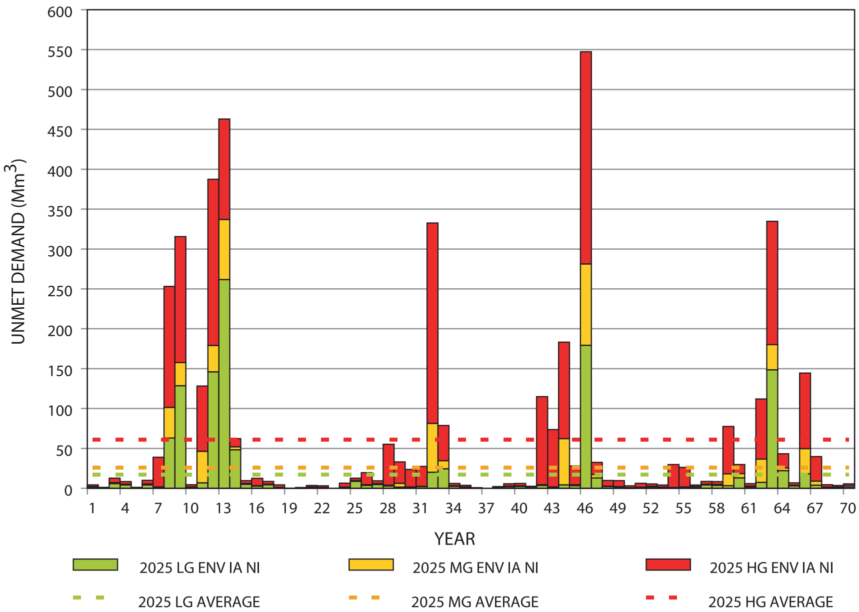


Impact of New Infrastructure

After analyzing the impact of the ER and of the assumed IA with Mozambique on the 2025 water demand scenarios, the impact of the development of new water infrastructure was assessed. The WEAP model was run for the 70 years of historic hydrological data (figure 4.15, p.35 and tables A12 to A14 and figures A12a, b, c and d to A14a, b, c and d in the appendix).

The average annual unmet demands over the 70 years of hydrology were 17.4 Mm^3 (2.0% of the total annual demand, instead of 56.6 Mm^3 without the NI), 26.2 Mm^3 (2.8% of the total annual demand, instead of 75.1 Mm^3) and 60.9 Mm^3 (5.5% of the total annual demand, instead of 135.2 Mm^3) for the LG, MG and HG scenarios, respectively (figure 4.15). For the LG and MG scenarios the average total unmet demand was reduced compared to the 1995 baseline condition, even without the ER. In 65 out of the 70 years the unmet demand was lower and for five it was higher for the LG scenario. For the HG scenario, the total average unmet demand was greater than for the 1995 baseline conditions without ER, with some years when the situation improved and other years when it worsened. For the LG and MG scenarios the greatest shortages were experienced during the 13th year (261.7 Mm^3 or 30.4% of the total demand and 337.1 Mm^3 or 36.0% of the total demand for the LG and MG scenarios, respectively instead of the 375.5 Mm^3 and 461.6 Mm^3 without the NI). WB1, WB2 and WB3 sub-catchments experienced the greatest shortfalls, because they are located upstream of the proposed reservoirs. The situation in WB4 improved significantly with the De Hoop reservoir in the Steelpoort river. The second worst year was the 46th year. Figure 4.15 shows that for the highest growth scenario the highest unmet demands were experienced during the 46th year (547.4 Mm^3 or 49.1% of the total demand instead of the 714.2 Mm^3 without the ER). During the 8th, 9th, 12th, 13th, 32nd, 46th and 63rd years there were shortages of more than 200 Mm^3 for the HG scenario. In all cases, the irrigation sector was the most adversely affected, with increasing shortages in the urban, rural and mining sectors for the scenarios with higher demands (table 4.3). The longest periods with any shortage (considering all the demands in the whole Olifants

Figure 4.15. Total annual unmet demand for the 2025 scenarios with ER, IA, NI and the 1995 baseline.



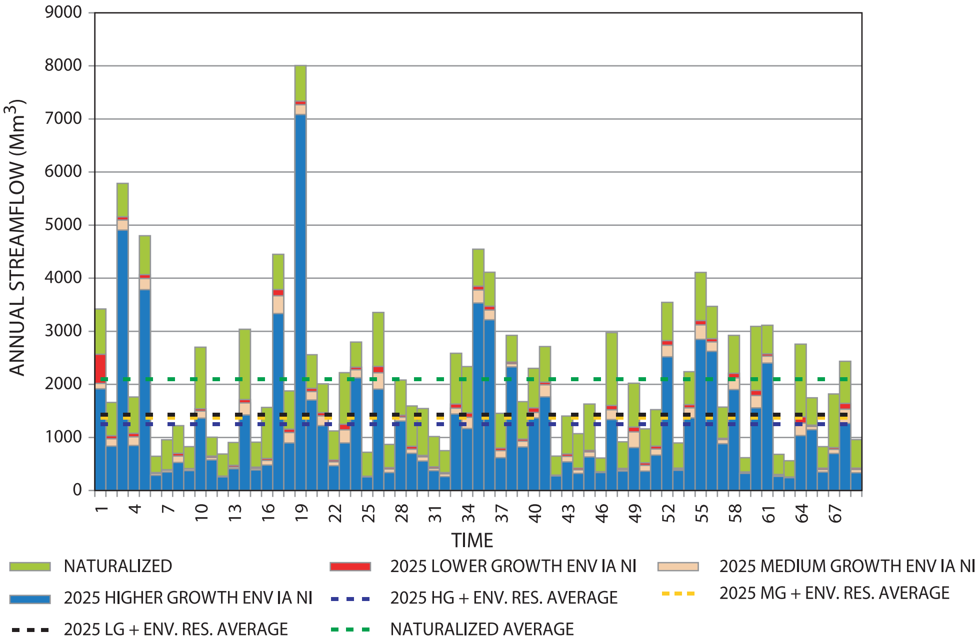
catchment) were 8 months for the LG (starting in April of the 3rd, 45th and 62nd years and in January of the 46th year), 9 months for the MG (March of the 45th and April of the 62nd year) and 11 months for the HG scenario (March of the 45th year).

Figure 4.16 presents the annual flow going to Mozambique. The construction of the NI decreased its mean value to 1,424 Mm^3 (instead of 1,519 Mm^3 without the NI), 1,369 Mm^3 (instead of 1,479 Mm^3) and 1,245 Mm^3 (instead of 1,377 Mm^3) for the LG, MG and HG scenarios, respectively. The minimum annual value also decreased to 254 Mm^3 (instead of 313 Mm^3), 250 Mm^3 (instead of 300 Mm^3) and 241 Mm^3 (instead of 268 Mm^3) for the LG, MG and HG scenarios, respectively. Figure 4.17 shows the monthly flow duration curves at the border. After building the new dams the lower monthly flows were not significantly affected (right-hand side of figure 4.17a), but the higher monthly flows decreased (left-hand side of figure 4.17a). The impact of the operation of the new reservoirs on the mean monthly flow at the outlet of the catchment is shown in figure 4.17b; during wet months the flow is reduced but kept constant during the dry months because of the ER requirements.

Table 4.3. Average annual unmet demand for the different sectors with new infrastructure.

Scenario	1995 (No ER)		2025 LG environment IA NI		2025 MG environment IA NI		2025 HG environment IA NI	
Sector	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)
Irrigation	26.3	4.8	16.8	3.0	24.9	4.5	51.0	9.2
Rural	0.0	0.1	0.3	0.3	0.4	0.3	3.6	1.5
Urban	0.0	0.0	0.1	0.2	0.2	0.5	1.8	2.3
Mining	0.1	0.1	0.2	0.2	0.6	0.4	4.5	2.4

Figure 4.16. Annual streamflow for the Olifants catchment (naturalized and 2025 with ER, IA and NI scenarios).



The Rooipoort reservoir, placed downstream of WB3 and therefore unable to satisfy the demands of WB1, WB2 and WB3, was at a high level most of the months (i.e., it satisfied easily the demands of WB5, WB7 and WB8, but could not satisfy the unmet demands of the upstream sub-catchments) (figure 4.18). The Flag Bohielo reservoir dried up several times (more than 6% of the months) because it was unable to satisfy the demands of WB3 during the most critical periods. The De Hoop reservoir in the Steelpoort sub-catchment (WB4) performed well and was able to reduce the unmet demands significantly.

Figures 4.17a and 4.17b. Monthly streamflow released to Mozambique (flow duration curves and mean monthly flows for the naturalized, 1995 and 2025 with ER, IA and NI water demand scenarios).

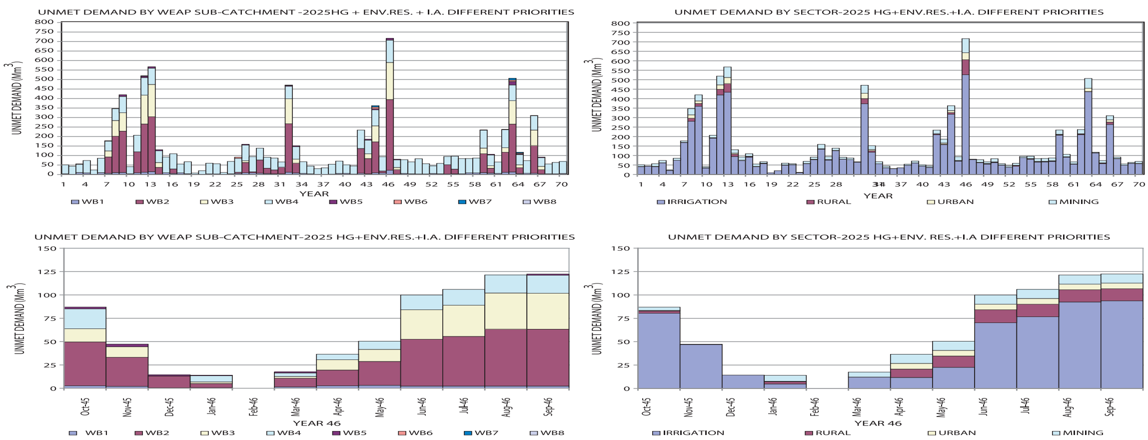
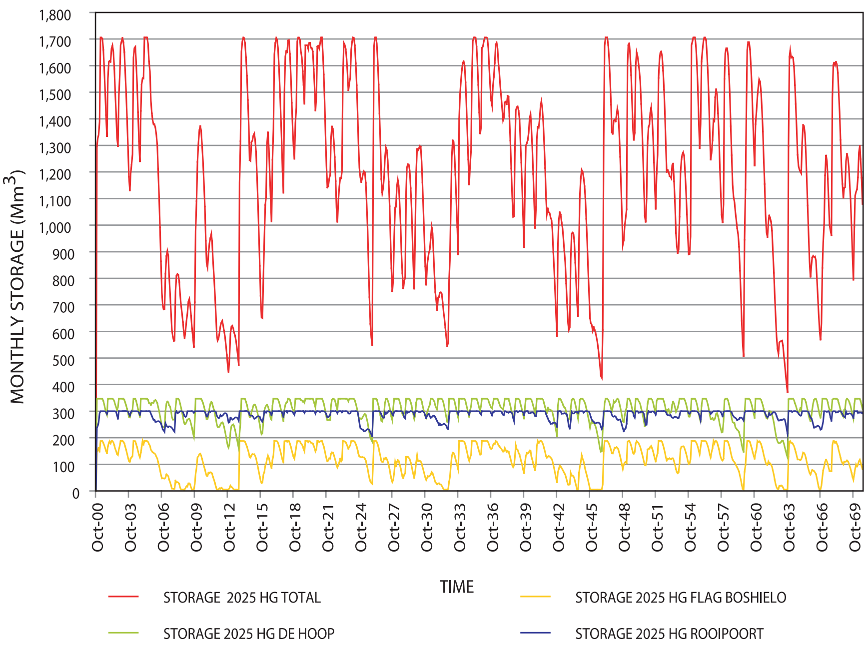


Figure 4.18. Monthly storage in the De Hoop, Flag Boshielo, Rooipoort and all the modeled reservoirs for the 2025 HG scenario with ER, IA and NI.



Impact of Water Conservation and Demand Management

After analyzing the 2025 water demand scenarios with the ER and the proposed IA, the impact of the application of WC&DM practices was assessed. Savings of 5 percent in the mining sector, 15 percent in the urban sector, 20 percent in the rural sector and 25 percent in the irrigation sector were considered (table 3.19). These savings were proportional to the demands; therefore they had the greatest impact in the HG scenario. The WEAP model was run for the 70 years of historic hydrological data (figure 4.19 and tables A15 to A17 and figures A15a, b, c and d to A17a, b, c and d in the appendix).

The average annual unmet demands over the 70 years were 24.9 Mm^3 (3.6% of the total annual demand, instead of 56.6 Mm^3 without WC&DM), 33.8 Mm^3 (4.5% of the total annual demand, instead of 75.1 Mm^3 without WC&DM) and 63 Mm^3 (7% of the total annual demand, instead of 135.2 Mm^3 without WC&DM) for the LG, MG and HG scenarios, respectively. In terms of average annual total unmet demand the situation for the LG scenario was similar to that in the 1995 baseline conditions without the ER (i.e., 26.4 Mm^3). For all the scenarios the highest shortages were experienced during the 13th year (99 Mm^3 or 14.4% of the total demand, 159 Mm^3 or 21% of the total demand and 374 Mm^3 or 41.3% of the total demand, respectively for the LG, MG and HG scenarios instead of the 375.7 Mm^3, 461.6 Mm^3 and 714.2 Mm^3 without considering the WC&DM). The greatest shortages were in the WB2 and WB4 sub-catchments for the LG and MG scenarios and in WB2, WB3 and WB4 for the HG scenario. For the maximum annual total unmet demand, the situation for the LG and MG scenarios improved with respect to that in the 1995 baseline conditions without the ER (205 Mm^3). The second worst year was the 46th year. Only during the 12th, 13th and 46th years do shortages of more than 200 Mm^3 occur in the HG scenario. As usual, in all scenarios the irrigation sector was the most affected, with increasing shortages in the urban, rural and mining sectors for the scenarios with higher demands (table 4.4). The longest periods with any shortage were 8 months for the LG scenario (starting in April of the 3rd, 45th and 62nd years and in January of the 46th year), 9 months for the MG scenario (March of the 45th and April of the 62nd years) and 11 months for the HG scenario (March of the 45th year).

Figure 4.19. Total annual unmet demand for the 2025 scenarios with ER, IA and WC&DM.

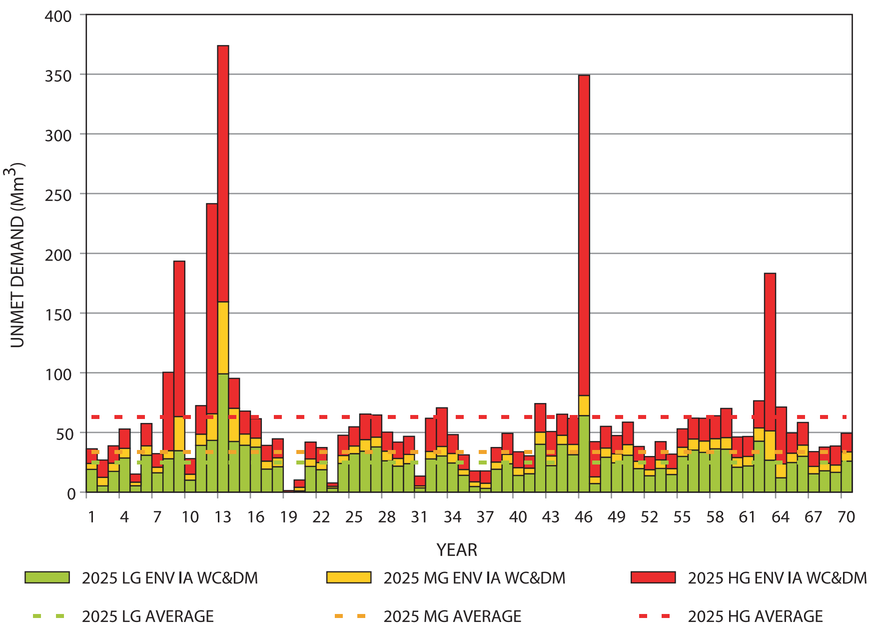
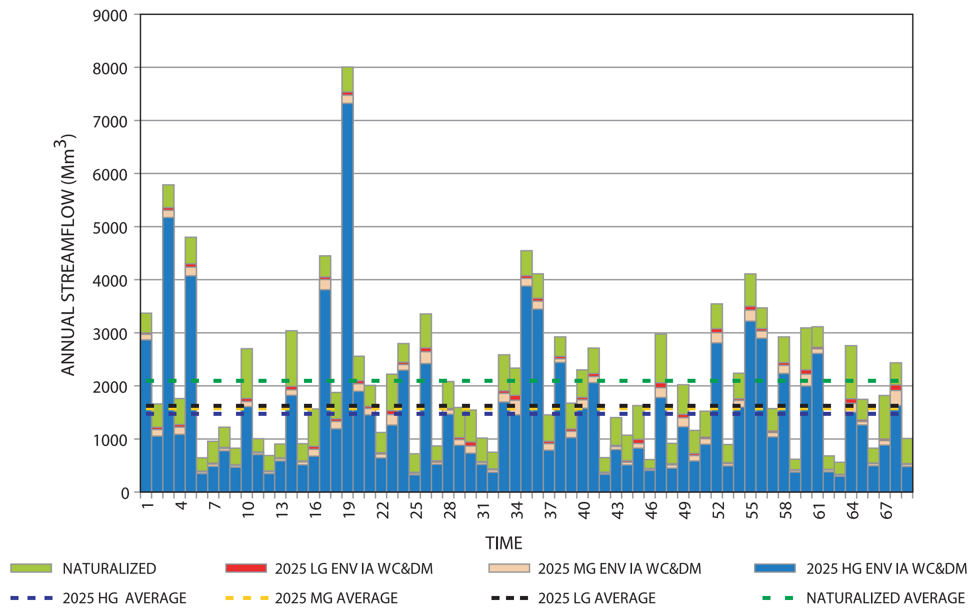


Figure 4.20 presents the annual streamflow at the border with Mozambique. The application of the WC&DM practices increased the mean annual flow to 1,624 Mm^3 (instead of 1,519 Mm^3 without the ER), 1,582 Mm^3 (instead of 1,479 Mm^3) and 1,475 Mm^3 (instead of 1,377 Mm^3) for the LG, MG and HG scenarios, respectively. The minimum annual value also increased to 335 Mm^3 (instead of 313 Mm^3), 322 Mm^3 (instead of 300 Mm^3) and 295 Mm^3 (instead of 268 Mm^3) for the LG, MG and HG scenarios, respectively. Figure 4.21a shows the flow duration curves at the border. After applying the WC&DM practices the flow increased. Figure 4.21b presents the impact of the WC&DM practices on the mean monthly streamflow at the border. The streamflow increased in all the months because the WC&DM practices reduced the demands.

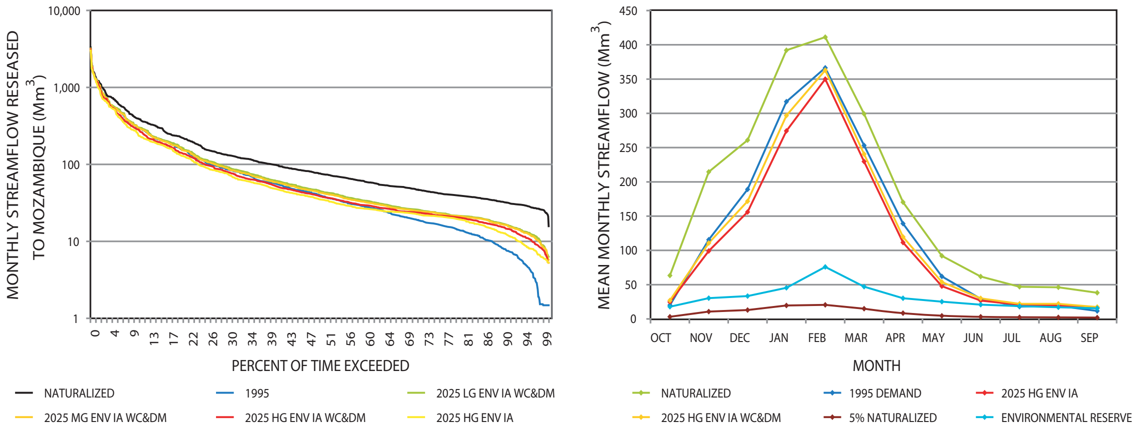
Table 4.4. Average annual unmet demand for the different sectors with WC&DM measures implemented.

Scenario	1995 (No ER)		2025 LG environment IA WC&DM		2025 MG environment IA WC&DM		2025 HG environment IA WC&DM	
Sector	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)
Irrigation	26.3	4.8	24.7	6.0	32.8	7.9	52.0	12.5
Rural	0.0	0.1	0.1	0.1	0.2	0.2	1.7	0.9
Urban	0.0	0.0	0.0	0.0	0.0	0.1	0.9	1.4
Mining	0.1	0.1	0.1	0.1	0.8	0.6	8.4	4.7

Figure 4.20. Annual streamflow for the Olifants catchment (naturalized and 2025 with ER, IA and WC&DM scenarios).



Figures 4.21a and 4.21b. Monthly streamflow released to Mozambique (flow duration curves and mean monthly flows for the naturalized, 1995, and 2025 with ER, IA and WC&DM practices water demand scenarios).



Impact of All Factors on the 2025 Scenarios

The impact of all the factors influencing water resources (i.e. the ER, the IA, the application of WC&DM and the construction of NI in the catchment) was assessed for each of the 2025 water demand scenarios. The WEAP model was run for the 70 years of hydrological data (figure 4.22 and tables A18 to A20 and figures A18a, b, c and d to A20a, b, c and d in the appendix).

The average annual unmet demands over the 70 years of hydrology were 2.4 Mm^3 (0.3% of the total annual demand, instead of 56.6 Mm^3 without WC&DM and NI), 4.2 Mm^3 (0.5% of the total annual demand, instead of 75.1 Mm^3 without WC&DM and NI) and 15.8 Mm^3 (1.7% of the total annual demand, instead of 135.2 Mm^3 without WC&DM and NI) for the LG, MG and HG scenarios, respectively. In terms of average annual total unmet demand the situation for these scenarios improved with respect to the 1995 baseline conditions without ER (26.4 Mm^3). For all the scenarios the highest shortages were experienced during the 13th year (60 Mm^3 or 8.7% of the total demand, 110 Mm^3 or 14.7% of the total demand and 298 Mm^3 or 33% of the total demand, respectively, for the LG, MG and HG scenarios instead of the 375.7 Mm^3, 461.6 Mm^3 and 714.2 Mm^3 without considering the WC&DM and NI). The most affected areas were the WB1, WB2 and WB3 sub-catchments. In terms of the maximum annual total unmet demand the situation for the LG and MG scenarios improved with respect to the 1995 baseline condition without the ER (205 Mm^3). The second worst year was the 46th year. It was only during the 13th year that there were shortages of more than 200 Mm^3 for the HG scenario. In all cases the irrigation sector was the most affected, with increasing shortages in the urban, rural and mining sectors for the scenarios with higher demands (table 4.5). The longest periods with any shortage were 8 months for the LG (starting in April of the 3rd year), 8 months for the MG (April of the 3rd and 45th years) and 9 months for the HG scenario (March of the 45th and 62nd years).

Figure 4.23 presents the annual flow at the border with Mozambique. As discussed above, the application of the WC&DM practices increased the annual streamflows at the outlet, but the impact of the construction of the NI was greater and decreased its mean value to 1,547 Mm^3 (instead of 1,624 Mm^3 with WC&DM and no NI), 1,490 Mm^3 (instead of 1,582 Mm^3) and 1,367 Mm^3 (instead of 1,475 Mm^3) for the LG, MG and HG scenarios, respectively. The minimum annual values also decreased to 266 Mm^3 (instead of 335 Mm^3), 264 Mm^3 (instead of 322 Mm^3) and 257 Mm^3 (instead of 295 Mm^3) for the LG, MG and HG scenarios, respectively. Figure 4.24a shows the flow duration curves at the border. After building the new dams the range of flows decreased. In figure 4.24b the impact of the WC&DM practices on the mean monthly flow at the border can be observed; the streamflow increased in all the months because the WC&DM practices reduced the demands.

Table 4.5. Average annual unmet demand for the different sectors with new infrastructure and WC&DM measures implemented.

Scenario	1995 (No ER)		2025 LG environment IA WC&DM NI		2025 MG environment IA WC&DM NI		2025 HG environment IA WC&DM NI	
Sector	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)	Mm^3	Demand (%)
Irrigation	26.3	4.8	2.3	0.6	4.0	1.0	13.1	3.2
Rural	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.3
Urban	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
Mining	0.1	0.1	0.1	0.1	0.2	0.2	1.7	1.0

Figure 4.22. Total annual unmet demand for the 2025 scenarios with ER, IA, NI and WC&DM scenarios.

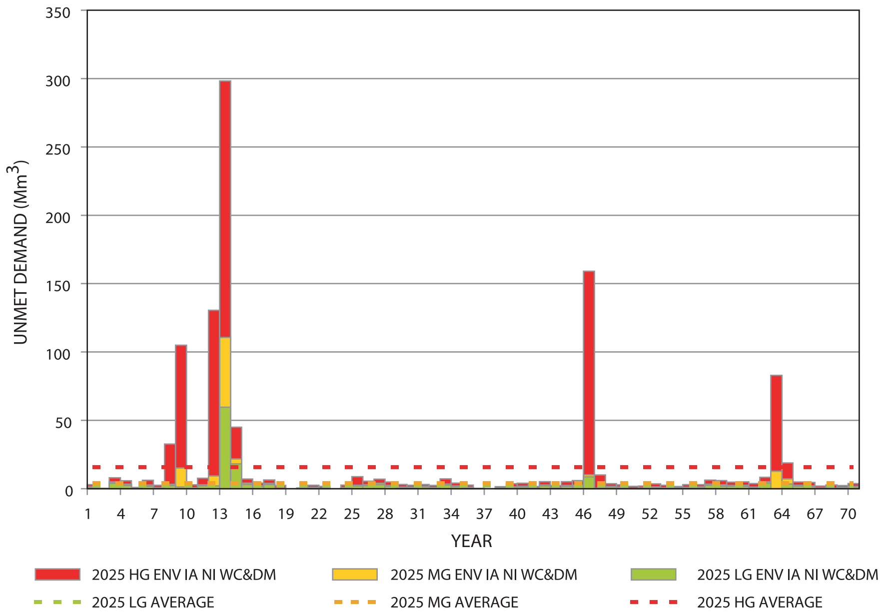
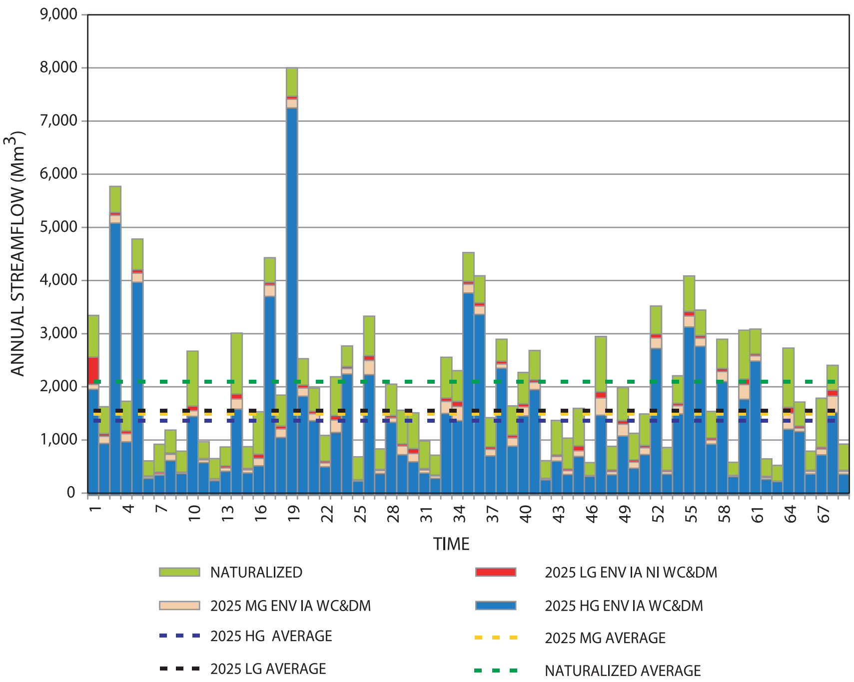
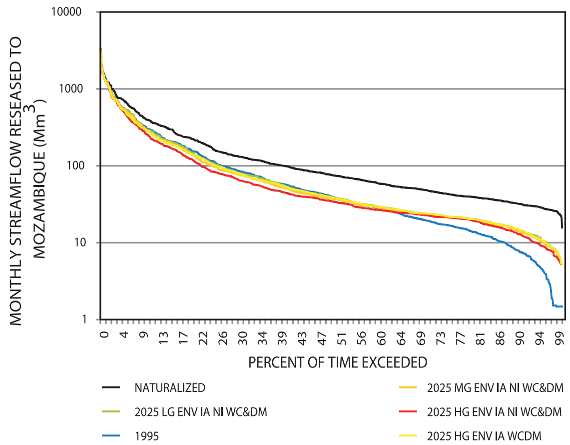
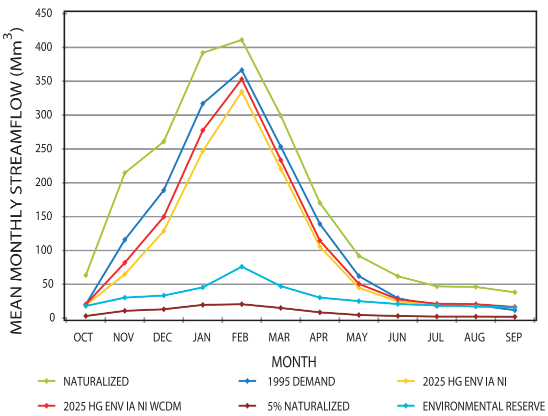


Figure 4.23. Annual streamflow for the Olifants catchment (naturalized and 2025 with ER, IA NI and WC&DM scenarios).



Figures 4.24a and 4.24b. Monthly streamflow released to Mozambique (flow duration curves for the naturalized, 1995, and 2025 with ER, IA, NI and WC&DM practices water demand scenarios).





Summary

For the 1995 baseline condition, there was an average annual shortfall of 26.4 Mm^3 (i.e., 3.4% of the total demand) and a maximum shortage of 206 Mm^3 (22.8% of the total demand). The areas with the greatest shortfalls were WB1, WB2, WB3 (upper and part of the Middle Olifants) and WB4 (Steelpoort) sub-catchments (table 4.6). The most adversely affected sector was the irrigated agriculture. The application of the ER to the 1995 baseline condition increased the average unmet demand by 65 percent, up to 43.8 Mm^3 (i.e., 5.6% of the total demand). The maximum unmet demand increased to 222 Mm^3. In terms of flow at the border with Mozambique, as an average, 1,541 Mm^3 or about 75 percent of the naturalized annual flow went to Mozambique. It is also worth noting that in more than 6 percent of the months, all the modeled reservoirs were spilling simultaneously and that around 2 percent of the months the Olifants river would have been dry in the Kruger National Park if a minimum environmental flow requirement had not been enforced there.

For the LG, MG and HG scenarios, the total demand increased by 12 percent, 23 percent and 50 percent, respectively, with respect to the 1995 baseline conditions. For the HG scenario, shortages increased, on average up to 88.6 Mm^3 or 7.9% of the total demand, (i.e., more than three times greater than for the 1995 baseline) and to a maximum of 587 Mm^3 or 52.6 percent of the total demand (i.e., more than two times greater than for the 1995 baseline).

The application of the ER increased the average annual shortfall to 135 Mm^3 (12.1% of the total demand) for the HG scenario. The irrigated agriculture sector was the most affected, but the mining, rural and urban sectors also suffered increased shortages. The most affected areas were WB1, WB2, WB3 and WB4. Table 4.7 shows that WB1, WB2 and WB3 generate 46.6 percent of the naturalized runoff of the Olifants and account for 68.8 percent of the demands for the 2025 HG scenario. As an average, WB1, WB2 and WB3 together generated an annual runoff of 1,068.2 Mm^3 (compared with the 709.3 Mm^3 of demand) but in the driest year they only produced 214.5 Mm^3 (less than one-third of the demand). Even though there were several reservoirs in the area (92% of the modeled storage) they were not able to completely address the shortages during the critical periods. In WB4 (Steelpoort catchment) the situation was different. The average annual runoff was 393.0 Mm^3 (compared with the 165.9 Mm^3 of demand), and 136.9 Mm^3 during the driest year. Even though the balance was less critical than in the Upper Olifants, the current lack of major regulation infrastructure prevented a better situation during critical periods.

Once the ER is established, the application of an IA with Mozambique (modeled as 5% of the monthly naturalized streamflow at the border) would not have any impact on the unmet demands or the flows going to Mozambique (table 4.6).

The development of more storage infrastructure (Flag Boshielo dam and Rooiport dam in the Olifants and De Hoop dam in the Steelpoort) improved the water resource situation in the catchment, although it was not sufficient to completely meet all the demands, even for the LG scenario. Overall, the average total unmet demand approached that for the 1995 baseline for the LG and MG scenarios, although during the most critical years the unmet demands were still greater than for the 1995 baseline without the ER. The shortages in WB4 (De Hoop reservoir), WB5 (Rooipoort reservoir), WB7 and WB8 decreased significantly, but the situation in WB1, WB2 and WB3 did not improve significantly. The raising of the Flag Boshielo dam alleviated in part the shortages in WB3, but no NI is currently planned for WB1 and WB2. The flows to Mozambique were reduced because of the increased storage.

Table 4.6. Summary table for all the scenarios.

Scenario		Mean annual unmet demand (Mm^3)	Maximum. annual unmet demand (Mm^3)	Mean annual streamflow outlet (Mm^3)	Minimum annual streamflow outlet (Mm^3)
Naturalized		-	-	2,096	561
1995		26.4	206	1,541	219
1995 ER		43.8	222	1,565	309
2025	Low	33	310	1,481	201
	Medium	45.5	357	1,434	179
	High	88.6	587	1,315	122
2025ER	Low	56.6	376	1,519	313
	Medium	75.1	462	1,479	300
	High	135.2	714	1,377	268
2025ER IA	Low	56.6	376	1,519	313
	Medium	75.1	462	1,479	300
	High	135.2	714	1,377	268
2025ER IA NI	Low	17.4	262	1,424	254
	Medium	26.2	337	1,369	250
	High	60.9	547	1,245	241
2025ER IA WC&DM	Low	24.9	99	1,624	335
	Medium	33.8	159	1,582	322
	High	63	374	1,475	295
2025ER IA NI WC&DM	Low	2.4	60	1,547	266
	Medium	4.2	111	1,491	264
	High	15.8	298	1,367	257

Table 4.7. Summary table of hydrology and water demand for the different sub-catchments.

	Mean annual streamflow (Mm^3)	Mean annual streamflow (% total)	Minimum annual streamflow (Mm^3) (1:70 years)	Demand 2005 HG (Mm^3)	Demand 2005 HG (% total)
WB1	111.0	4.8	17.7	26.9	2.5
WB2	474.1	20.7	89.0	336.4	31.7
WB3	483.1	21.1	107.8	346.0	32.6
WB4	393.0	17.1	136.9	165.9	15.6
WB5	180.1	7.9	42.7	59.3	5.6
WB6	432.6	18.9	178.3	35.9	3.4
WB7	143.3	6.2	14.6	90.9	8.6
WB8	75.4	3.3	7.7	0.0	0.0
WB1+WB2+WB3	1,068.2	46.6	214.5	709.3	66.8

The application of WC&DM practices reduced the unmet demands, although the improvement was less than with the NI. Overall, the average and maximum total unmet demands reached values close to those of the 1995 baseline conditions for the LG and MG scenarios, but were still greater for the HG scenario. Since the demands were reduced, the streamflow at the border with Mozambique increased.

The combination of NI and WC&DM practices further improved the situation, reversing it to levels better than, or similar to, the 1995 baseline in terms of average and maximum total unmet demands. However, it should be noted that for these scenarios the most critical areas were again WB1, WB2 and WB3. Although the demands were reduced, thanks to the WC&DM practices, shortages were still experienced during critical years. The average annual streamflows at the outlet of the catchment were also reduced in comparison to 1995 for the MG and HG scenarios.

CONCLUSION

This study has provided an investigation of possible changes in water demand in the Olifants catchment and the impact these changes may have on water resources. Because of the limitations in our ability to predict future water demand, we used three different scenarios of demand and superimposed other factors that affect water resources on to each. Each scenario was run for a period of 70 years to encompass a range of hydrological conditions. The results presented provide a "first estimate" of water demand trends and possible approaches to ensure that water resources are sufficient to meet demands.

The WEAP model for the Olifants catchment along with the input data used to perform this study have many limitations, and a number of assumptions had to be made. The whole Olifants catchment was divided into just eight sub-catchments and the hydrological and water demand data were lumped accordingly. Within a sub-catchment all the individual water demands belonging to the same sector were combined, all the water resources generated in the sub-catchment and upstream were available for them and they were given the same water allocation priority. The hydrological and water demand data came from models and estimates (WR90 study and WSAM database, respectively). Only the most important reservoirs were modeled (~65% of the total storage) and no data about their operating rules were available so no restrictions were placed on drawdowns until they emptied. Groundwater abstraction did not have any impact on the naturalized streamflows. All these assumptions and limitations must be taken into consideration and must be carefully understood when interpreting the outputs and results presented. Nevertheless, the study findings provide useful insights into water resources management in the catchment and the following conclusions can be drawn:

1. For the 1995 baseline condition there are water shortages in the Olifants catchment. For all the 2025 scenarios the water demands increase, producing greater shortfalls. The most affected areas are the Upper and Middle Olifants (WB1, WB2 and WB3) and the Steelpoort catchment (WB4).

2. As a consequence of the application of the ER, which is intended to ensure the sustainability of the resource base, there will be more water flowing in the rivers, but less water available to meet direct human demands. At the most downstream location, the total Reserve requirement is estimated to be 394 Mm^3 (i.e., about 20% of the annual water resources of the catchment). Hence, if fully implemented in the near future, shortages in other sectors will increase.

3. The current storage capacity in the South African side of the Olifants catchment is less than the mean annual naturalized flow. As a consequence of this, during the wet periods the reservoirs are rapidly filled and the excess water is spilled. Conversely, they empty rapidly during droughts. The mean annual volume flowing into Mozambique equates to between 60 percent and 75 percent of the mean annual naturalized flow for the different scenarios analyzed.

4. The IA modeled in this study provides Mozambique with at least 5 percent of the monthly naturalized streamflow at the border. If the ER is applied, such an IA is automatically met at a monthly time step. Even without the ER, and just a minimum flow requirement in the Kruger National Park (i.e., a minimum flow of 0.57 m^3s^{-1}) it will be met in more than 98 percent of the months even in the HG scenario. A key question is how Mozambique would react if South Africa were to develop the infrastructure needed to further regulate the flow and reduce the discharge across the border, particularly given the significant investment the country has made in the Massingir dam.

5. The construction of the dams planned by DWAF will help reconcile the water demands and resources. However, it will not be sufficient to meet all the demands even for the LG scenario. As a consequence of the increased storage, in the future scenarios, average annual flow to Mozambique is reduced by between 95 and 132 Mm^3.

6. The application of WC&DM practices helps reconcile the water resources and demands, but by itself it is not sufficient to satisfy all demands. Shortfalls are greater than those that occur with the construction of new dams, particularly in the Upper Olifants. Since the demands are reduced, there will be an increased flow to Mozambique. Depending on the scenario, the flow to Mozambique increases by between 98 and 105 Mm^3.

7. The combination of NI and WC&DM practices will enable a situation better than, or similar to, that for the 1995 baseline. However, even in this case, there will be still shortages in WB1, WB2 and WB3 and, overall, the flow to Mozambique will be reduced slightly.

8. The planned increase in storage will not be sufficient to meet all the increasing demands. WC&DM practices in conjunction with control of demand growth will be needed, although it is recognized that the latter may be difficult in a rapidly developing country like South Africa, where inequities of the past need to be addressed.

Future research is essential to improve the scenarios developed and weaknesses in the current methodology. This should include: a) better simulation of the dam operating rules and the impact of restrictions during droughts, b) assessment of the social and economic consequences of the different scenarios, c) impacts of further development and the use of groundwater resources (i.e., conventional aquifers and dewatering of abandoned mines), and d) the possible impacts of climate change.

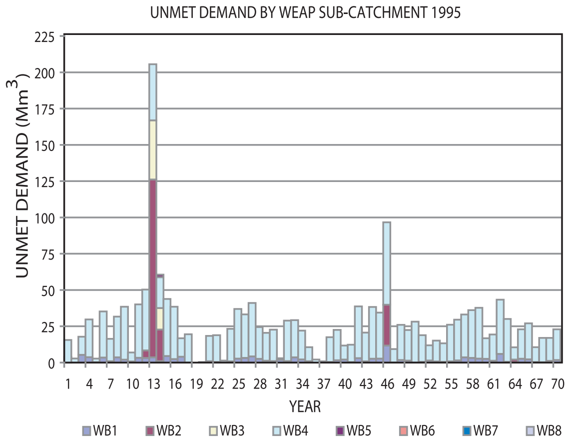
APPENDIX

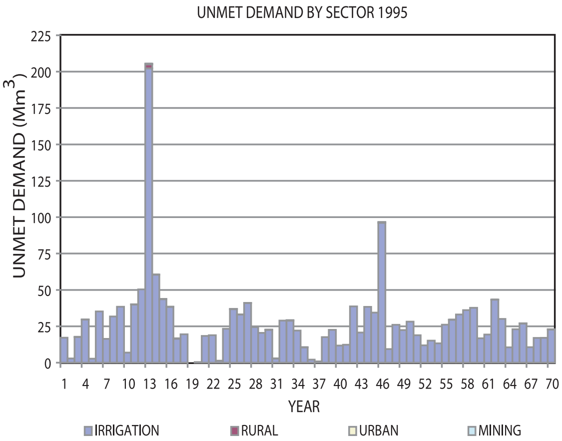
OUTPUTS OF THE WEAP MODEL

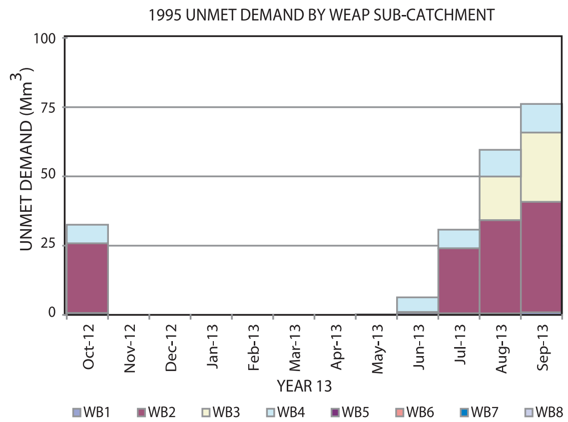
Table A1 and figures A1a, b, c and d. WEAP model outputs for 1995 demand baseline.*

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	8.61	5	27.0	93.0	80.6	46	8	21.9
	Rural	0.93	2	0.0	0.0	0.0			0.0
	Urban	0.9	3	0.0	0.0	0.0			0.0
	Mining	6.49	4	4.0	30.0	7.9	46	5	0.8
WB2	Irrigation	213.53	9	1.0	7.0	38.5	13	5	1.2
	Rural	19.76	6	0.0	0.0	0.0			0.0
	Urban	19.01	7	0.0	0.0	0.0			0.0
	Mining	10.11	8	0.0	0.0	0.0			0.0
	Forestry	1.3	1	0.0	0.0	0.0			0.0
WB3	Irrigation	174.41	13	0.8	3.0	18.3	13	3	0.4
	Rural	32.41	10	0.3	1.0	8.3	13	1	0.1
	Urban	4.69	11	0.3	1.0	8.3	13	1	0.1
	Mining	1.83	12	0.3	1.0	8.3	13	1	0.1
WB4	Irrigation	74.56	5	33.0	99.0	58.1	46	6	28.3
	Rural	7.08	2	0.0	0.0	0.0			0.0
	Urban	0.89	3	0.0	0.0	0.0			0.0
	Mining	13.54	4	0.0	0.0	0.0			0.0
	Forestry	5.11	1	0.0	0.0	0.0			0.0
WB5	Irrigation	23.04	17	0.3	1.0	6.9	14	1	0.1
	Rural	6.99	14	0.0	0.0	0.0			0.0
	Urban	0.02	15	0.0	0.0	0.0			0.0
	Mining	9.01	16	0.0	0.0	0.0			0.0
	Forestry	1.72	1	0.0	0.0	0.0			0.0
WB6	Irrigation	31.26	5	0.0	0.0	0.0			0.0
	Rural	0.7	2	0.0	0.0	0.0			0.0
	Urban	0.03	3	0.0	0.0	0.0			0.0
	Mining	0.37	4	0.0	0.0	0.0			0.0
	Forestry	43.32	1	0.0	0.0	0.0			0.0
WB7	Irrigation	28.86	21	0.0	0.0	0.0			0.0
	Rural	5.66	18	0.0	0.0	0.0			0.0
	Urban	2.23	19	0.0	0.0	0.0			0.0
	Mining	35.31	20	0.0	0.0	0.0			0.0
	Forestry	2.7	1	0.0	0.0	0.0			0.0
WB8	Rural	0.02	22	0.0	0.0	0.0			0.0

* Figures mentioned in the captions of tables from here onward are located on the odd-numbered pages from p.49 to p.89.


UNMET DEMAND BY WEAP SUB-CATCHMENT 1995
UNMET DEMAND (Mm^3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR 1995
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION RURAL URBAN MINING


1995 UNMET DEMAND BY WEAP SUB-CATCHMENT
UNMET DEMAND (Mm^3)
Oct-12 Nov-12 Dec-12 Jan-13 Feb-13 Mar-13 Apr-13 May-13 Jun-13 Jul-13 Aug-13 Sep-13
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

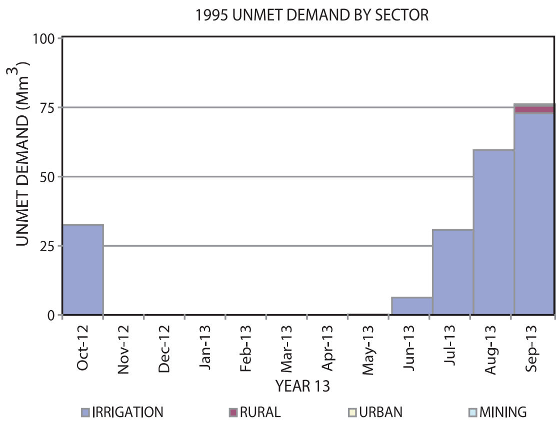
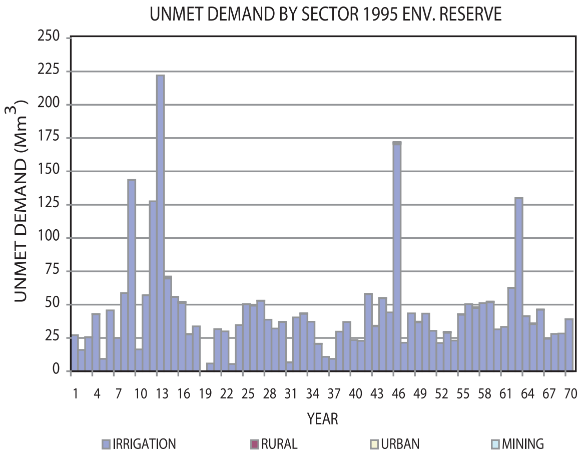

1995 UNMET DEMAND BY SECTOR
UNMET DEMAND (Mm^3)
Oct-12 Nov-12 Dec-12 Jan-13 Feb-13 Mar-13 Apr-13 May-13 Jun-13 Jul-13 Aug-13 Sep-13
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A2 and figures A2a, b, c and d. WEAP model outputs for 1995 demand baseline and application of the ER.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	8.61	5	27.0	93.0	80.6	46	8	21.9
	Rural	0.93	2	0.0	0.0	0.0			0.0
	Urban	0.9	3	0.0	0.0	0.0			0.0
	Mining	6.49	4	4.0	30.0	1.1	46	5	0.8
WB2	Irrigation	213.53	9	3.0	13.0	52.5	13	5	3.7
	Rural	19.76	6	0.0	0.0	0.0			0.0
	Urban	19.01	7	0.0	0.0	0.0			0.0
	Mining	10.11	8	0.0	0.0	0.0			0.0
	Forestry	1.3	1	0.0	0.0	0.0			0.0
WB3	Irrigation	174.41	13	0.3	1.0	1.7	14	1	0.0
	Rural	32.41	10	0.0	0.0	0.0			0.0
	Urban	4.69	11	0.0	0.0	0.0			0.0
	Mining	1.83	12	0.0	0.0	0.0			0.0
WB4	Irrigation	74.56	5	38.0	99.0	74.0	46	7	45.0
	Rural	7.08	2	1.0	16.0	16.7	46	1	1.2
	Urban	0.89	3	1.0	16.0	16.7	46	1	1.4
	Mining	13.54	4	0.0	0.0	0.0			0.0
	Forestry	5.11	1	0.0	0.0	0.0			0.0
WB5	Irrigation	23.04	17	0.3	1.0	13.2	14	1	0.2
	Rural	6.99	14	0.3	1.0	8.3	14	1	0.1
	Urban	0.02	15	0.3	1.0	8.3	14	1	0.1
	Mining	9.01	16	0.3	1.0	8.3	14	1	0.1
	Forestry	1.72	1	0.0	0.0	0.0			0.0
WB6	Irrigation	31.26	5	0.5	3.0	13.7	64	1	0.4
	Rural	0.7	2	0.3	1.0	8.3	64	1	0.1
	Urban	0.03	3	0.3	1.0	7.8	64	1	0.1
	Mining	0.37	4	0.3	1.0	8.2	64	1	0.1
	Forestry	43.32	1	0.0	0.0	0.0			0.0
WB7	Irrigation	28.86	21	0.0	0.0	0.0			0.0
	Rural	5.66	18	0.0	0.0	0.0			0.0
	Urban	2.23	19	0.0	0.0	0.0			0.0
	Mining	35.31	20	0.0	0.0	0.0			0.0
	Forestry	2.7	1	0.0	0.0	0.0			0.0
WB8	Rural	0.02	22	0.0	0.0	0.0			0.0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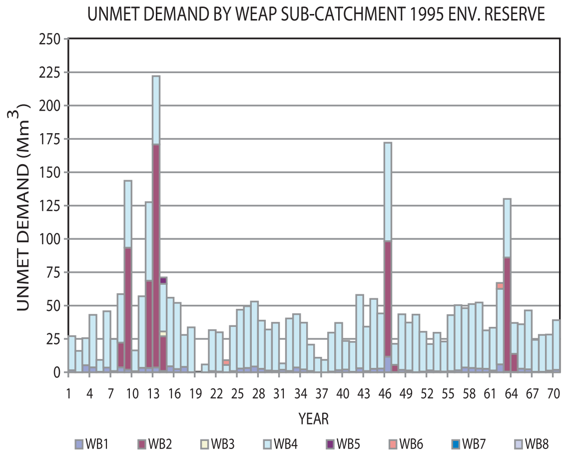
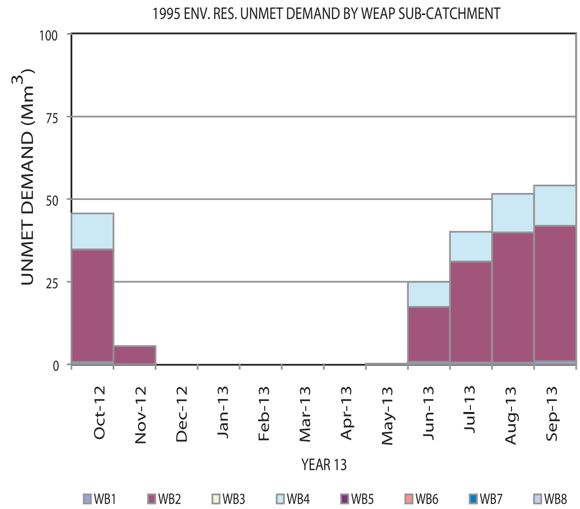
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT 1995 ENV. RESERVE
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


1995 ENV. RES. UNMET DEMAND BY WEAP SUB-CATCHMENT
UNMET DEMAND (Mm3)
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

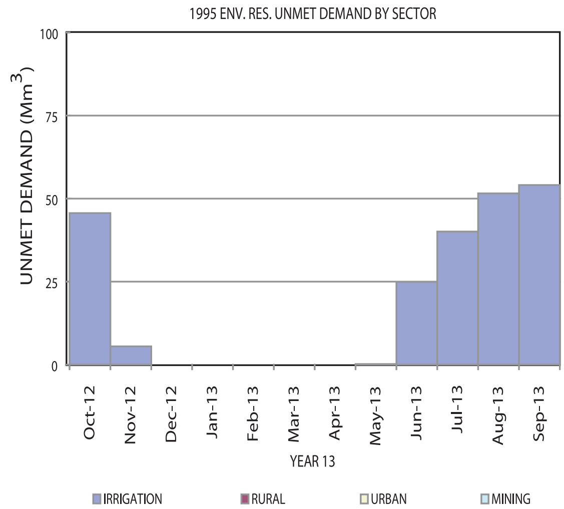
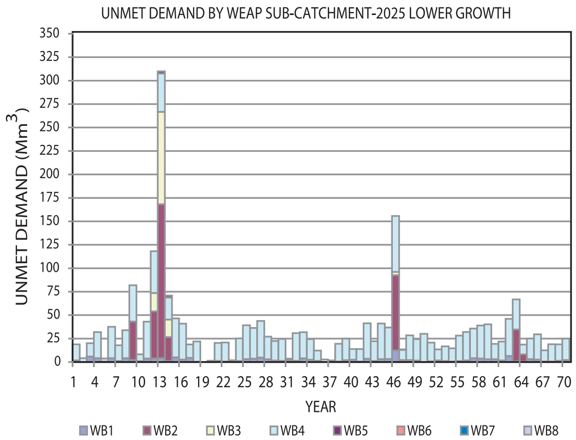

1995 ENV. RES. UNMET DEMAND BY SECTOR
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A3 and figures A3a, b, c and d. WEAP model outputs for 2025 LG scenario.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.6	29.0	93.0	83.4	46	8	24.6
	Rural	2	1.4	0.0	0.0	0.0			0.0
	Urban	3	1.4	0.0	0.0	0.0			0.0
	Mining	4	6.5	6.0	41.0	13.2	46	6	1.5
WB2	Irrigation	9	213.5	2.0	11.0	50.9	13	5	2.7
	Rural	6	32.0	0.0	0.0	0.0			0.0
	Urban	7	28.4	0.3	0.0	1.7	13	1	0.0
	Mining	8	10.1	0.5	0.0	13.4	13	2	0.2
	Forestry	1	1.2	0.0	0.0	0.0			0.0
WB3	Irrigation	13	174.4	1.0	6.0	38.2	13	4	1.0
	Rural	10	52.0	1.0	3.0	24.9	13	4	0.4
	Urban	11	6.3	1.0	3.0	25.0	13	4	0.5
	Mining	12	22.3	1.0	3.0	25.0	13	4	0.5
WB4	Irrigation	5	74.6	34.0	99.0	60.9	46	6	30.7
	Rural	2	12.2	0.0	0.0	0.0			0.0
	Urban	3	1.2	0.0	0.0	0.0			0.0
	Mining	4	13.5	0.0	0.0	0.0			0.0
	Forestry	1	4.9	0.0	0.0	0.0			0.0
WB5	Irrigation	17	23.0	1.0	4.0	8.7	13	1	0.3
	Rural	14	10.5	0.0	0.0	0.0			0.0
	Urban	15	0.0	0.0	0.0	0.0			0.0
	Mining	16	9.0	0.0	0.0	0.0			0.0
	Forestry	1	1.6	0.0	0.0	0.0			0.0
WB6	Irrigation	5	31.3	0.0	0.0	0.0			0.0
	Rural	2	0.9	0.0	0.0	0.0			0.0
	Urban	3	0.0	0.0	0.0	0.0			0.0
	Mining	4	0.4	0.0	0.0	0.0			0.0
	Forestry	1	41.2	0.0	0.0	0.0			0.0
WB7	Irrigation	21	28.9	0.0	0.0	0.0			0.0
	Rural	18	9.1	0.0	0.0	0.0			0.0
	Urban	19	2.7	0.0	0.0	0.0			0.0
	Mining	20	35.3	0.0	0.0	0.0			0.0
	Forestry	1	2.6	0.0	0.0	0.0			0.0
WB8	Rural	22	0.1	0.0	0.0	0.0			0.0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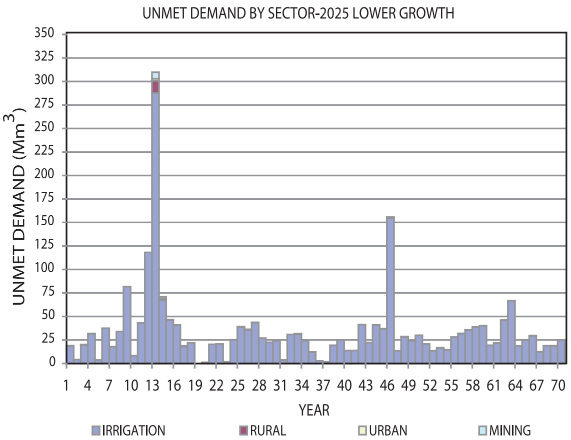
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8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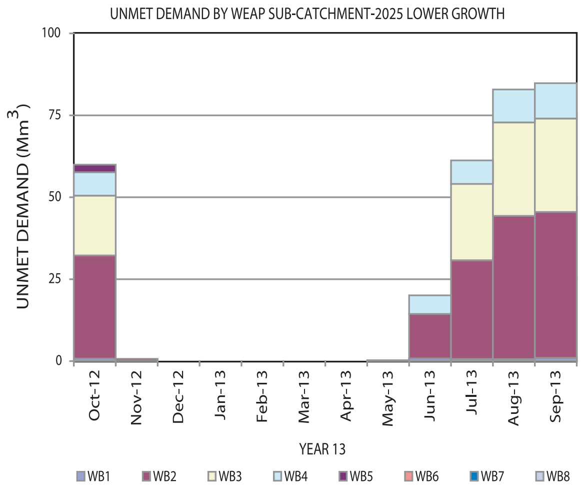
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING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UNMET DEMAND (Mm3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

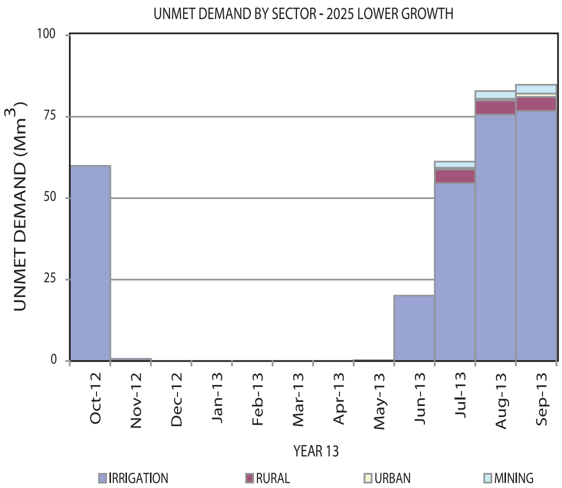
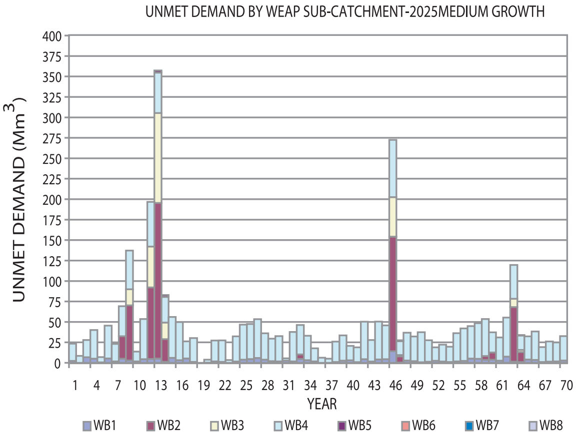
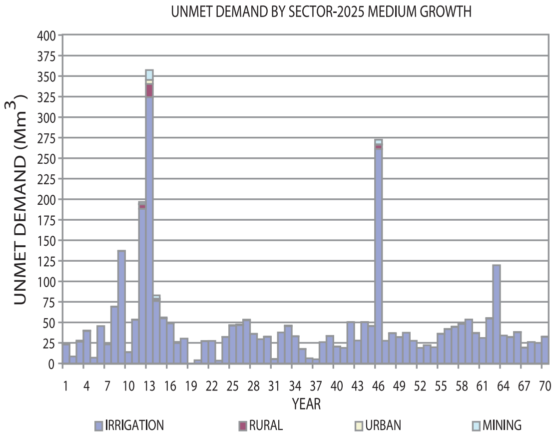
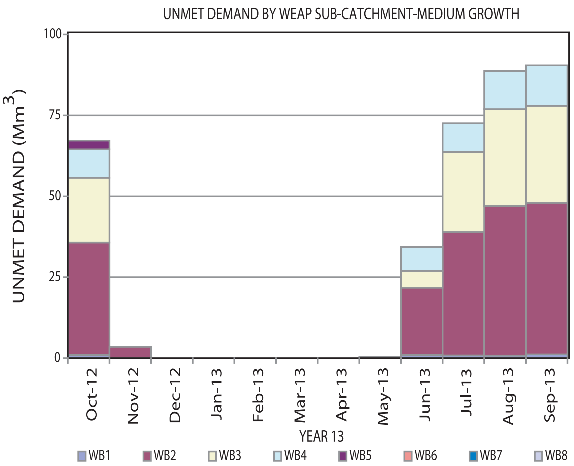

UNMET DEMAND BY SECTOR - 2025 LOWER GROWTH
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A4 and figures A4a, b, c and d. WEAP model outputs for 2025 MG scenario.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	32	94.0	86.5	46	9	30.5
	Rural	2	1.55	0		0.0			0.0
	Urban	3	1.57	0		0.0			0.0
	Mining	4	8.27	12	67.0	24.7	46	7	3.4
WB2	Irrigation	9	213.53	3	17.0	57.1	13	5	4.2
	Rural	6	36.37	0		0.0			0.0
	Urban	7	31.72	0.5	1.0	10.3	13	2	0.1
	Mining	8	20.05	1	4.0	24.8	13	4	0.5
	Forestry	1	1.30	0		0.0			0.0
WB3	Irrigation	13	174.41	2	11.0	41.6	13	5	1.8
	Rural	10	63.91	1.0	6.0	25.0	13	4	0.6
	Urban	11	7.10	1.0	6.0	25.0	13	4	0.7
	Mining	12	26.94	1.0	6.0	25.0	13	4	0.7
WB4	Irrigation	5	74.56	36.0	99.0	71.5	46	7	39.6
	Rural	2	15.89	0.0		0.0			0.0
	Urban	3	1.35	0.0		0.0			0.0
	Mining	4	38.66	0.3	1.0	1.1	16	1	0.0
	Forestry	1	5.11	0.0		0.0			0.0
WB5	Irrigation	17	23.04	1.0	6.0	10.2	13	1	0.4
	Rural	14	13.10	0.0		0.0			0.0
	Urban	15	0.03	0.0		0.0			0.0
	Mining	16	9.04	0.0		0.0			0.0
	Forestry	1	1.72	0.0		0.0			0.0
WB6	Irrigation	5	31.26	0.0		0.0			0.0
	Rural	2	1.07	0.0		0.0			0.0
	Urban	3	0.04	0.0		0.0			0.0
	Mining	4	0.37	0.0		0.0			0.0
	Forestry	1	43.32	0.0		0.0			0.0
WB7	Irrigation	21	28.86	0.0		0.0			0.0
	Rural	18	11.98	0.0		0.0			0.0
	Urban	19	3.09	0.0		0.0			0.0
	Mining	20	35.31	0.0		0.0			0.0
	Forestry	1	2.70	0.0		0.0			0.0
WB8	Rural	22	0.12	0.0		0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MEDIUM GROWTH
UNMET DEMAND (Mm^3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 MEDIUM GROWTH
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-MEDIUM GROWTH
UNMET DEMAND (Mm^3)
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

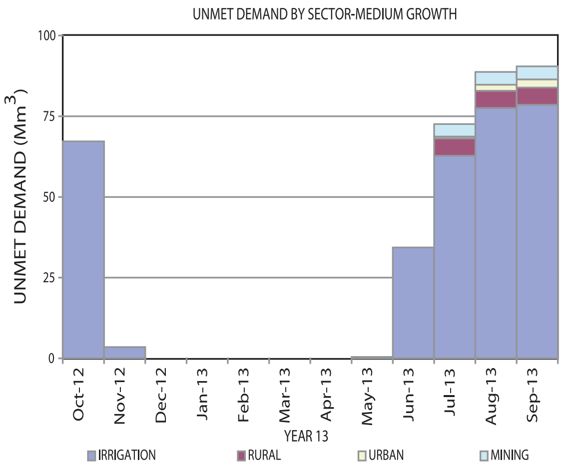
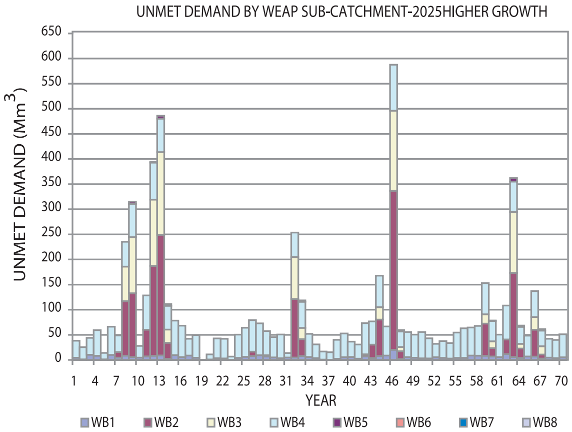
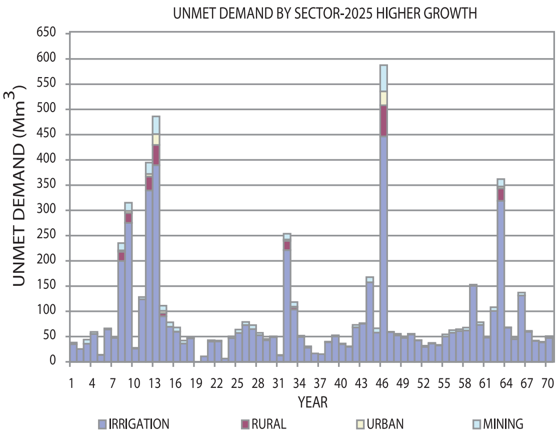
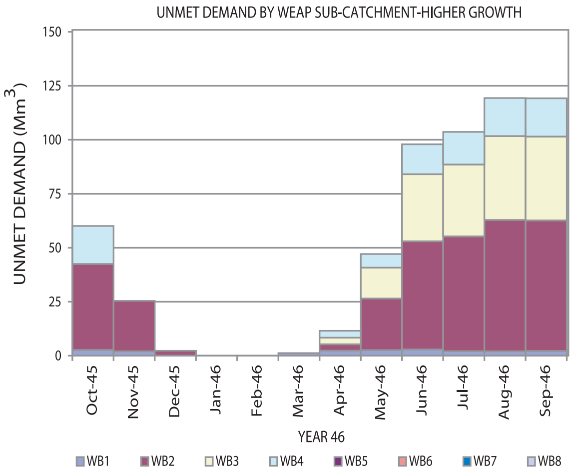

UNMET DEMAND BY SECTOR-MEDIUM GROWTH
UNMET DEMAND (Mm^3)
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A5 and figures A5a, b, c and d. WEAP model outputs for 2025 HG Scenario

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	39.0	97.0	92.0	46	9	44.2
	Rural	2	5.88	1.0	4.0	8.3	46	1	0.1
	Urban	3	1.78	3.0	24.0	24.8	46	3	1.7
	Mining	4	10.64	28.0	94.0	59.7	46	9	15.4
WB2	Irrigation	9	213.53	8.0	33.0	84.5	46	7	10.8
	Rural	6	45.41	1.0	3.0	33.7	46	5	0.6
	Urban	7	48.65	1.0	6.0	41.7	46	5	1.2
	Mining	8	28.86	2.0	10.0	41.7	46	5	1.7
	Forestry	1	1.30	0.0	0.0	0.2			0.0
WB3	Irrigation	13	174.41	5.0	23.0	49.8	13	6	5.5
	Rural	10	110.16	3.0	13.0	41.7	46	5	2.6
	Urban	11	16.52	3.0	13.0	41.7	46	5	2.9
	Mining	12	44.88	4.0	16.0	48.5	46	6	3.4
WB4	Irrigation	5	74.56	41.0	99.0	81.5	46	8	56.6
	Rural	2	29.29	0.3	1.0	0.6	16	1	0.0
	Urban	3	5.44	0.3	1.0	8.3	16	1	0.1
	Mining	4	56.60	15.0	81.0	20.6	16	6	3.1
	Forestry	1	5.11		0.0	0.0			0.0
WB5	Irrigation	17	23.04	2.0	14.0	25.6	63	3	2.1
	Rural	14	27.14		0.0	0.0			0.0
	Urban	15	0.09		0.0	0.0			0.0
	Mining	16	9.01	0.3	1.0	0.9	14	1	0.0
	Forestry	1	1.72		0.0	0.0			0.0
WB6	Irrigation	5	31.26		0.0	0.0			0.0
	Rural	2	4.16		0.0	0.0			0.0
	Urban	3	0.07		0.0	0.0			0.0
	Mining	4	0.37		0.0	0.0			0.0
	Forestry	1	43.32		0.0	0.0			0.0
WB7	Irrigation	21	28.86		0.0	0.0			0.0
	Rural	18	23.29		0.0	0.0			0.0
	Urban	19	3.49		0.0	0.0			0.0
	Mining	20	35.31		0.0	0.0			0.0
	Forestry	1	2.70		0.0	0.0			0.0
WB8	Rural	22	0.02		0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025HIGHER GROWTH
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 HIGHER GROWTH
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-HIGHER GROWTH
UNMET DEMAND (Mm3)
Oct-45
Nov-45
Dec-45
Jan-46
Feb-46
Mar-46
Apr-46
May-46
Jun-46
Jul-46
Aug-46
Sep-46
YEAR 46
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

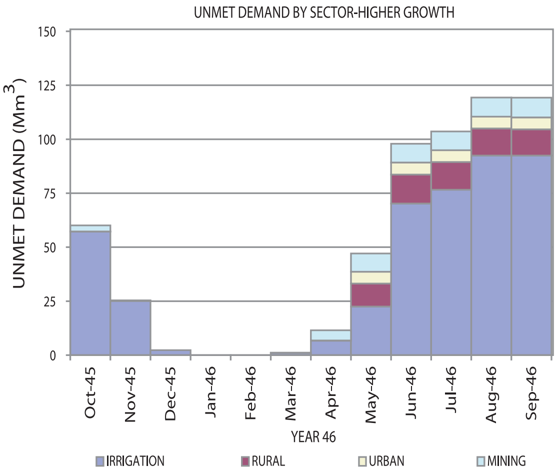
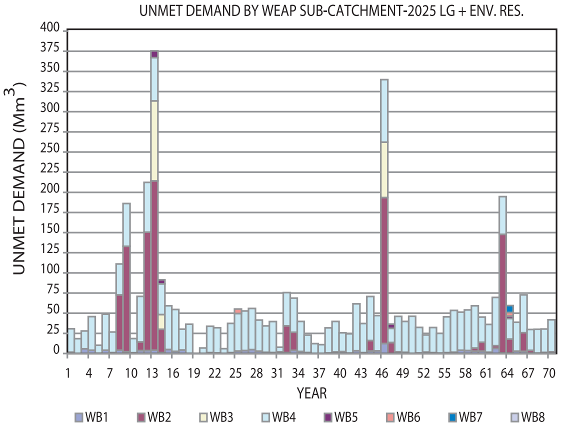
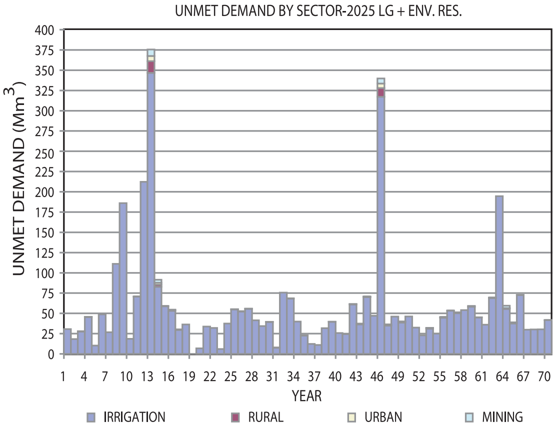
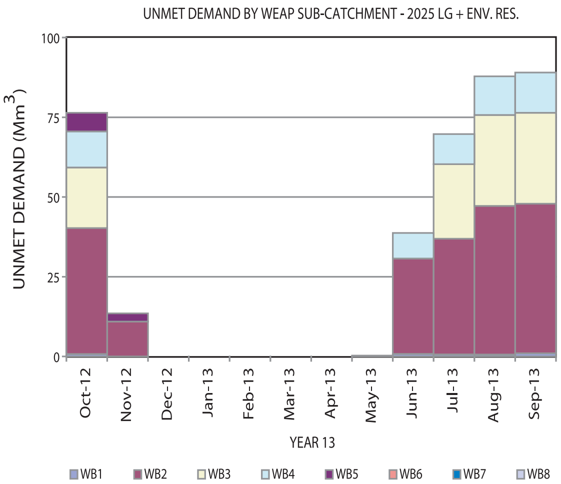

UNMET DEMAND BY SECTOR-HIGHER GROWTH
UNMET DEMAND (Mm3)
Oct-45
Nov-45
Dec-45
Jan-46
Feb-46
Mar-46
Apr-46
May-46
Jun-46
Jul-46
Aug-46
Sep-46
YEAR 46
IRRIGATION
RURAL
URBAN
MINING

Table A6 and figures A6a, b, c and d. WEAP model outputs for 2025 LG scenario and ER.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	29.0	93.0	83.4	46	8	24.6
	Rural	2	1.38	0.0	0.0			0	
	Urban	3	1.39	0.0	0.0			0	
	Mining	4	6.49	6.0	41.0	13.2	46	6	1.5
WB2	Irrigation	9	213.53	5.0	26.0	63.7	13	6	7.0
	Rural	6	31.97	0.5	1.0	2.0	13	2	0.0
	Urban	7	28.36	1.0	4.0	16.7	13	2	0.5
	Mining	8	10.11	1.0	4.0	16.7	13	3	0.6
	Forestry	1	1.24	0.0	0.0			0	
WB3	Irrigation	13	174.41	1.0	6.0	38.5	13	4	1.2
	Rural	10	51.97	1.0	4.0	25.0	13	4	0.6
	Urban	11	6.31	1.0	4.0	25.0	13	4	0.7
	Mining	12	22.33	1.0	4.0	25.0	13	4	0.7
WB4	Irrigation	5	74.56	39.0	99.0	76.9	46	7	47.8
	Rural	2	12.17	2.0	17.0	16.7	46	1	1.3
	Urban	3	1.19	2.0	19.0	16.7	46	1	1.7
	Mining	4	13.53	0.0	0.0	0.0		0	0.0
	Forestry	1	4.87	0.0	0.0			0	
WB5	Irrigation	17	23.04	1.0	6.0	25.9	13	2	1.0
	Rural	14	10.46	0.8	4.0	8.3	13	1	0.4
	Urban	15	0.03	0.8	4.0	8.3	13	1	0.4
	Mining	16	9.01	0.8	4.0	8.3	13	1	0.4
	Forestry	1	1.64	0.0	0.0			0	
WB6	Irrigation	5	31.26	0.5	3.0	17.7	25	1	0.4
	Rural	2	0.94	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0				0	0.0
WB7	Irrigation	21	28.86	0.3	1.0	16.2	64	1	0.2
	Rural	18	9.09	0.3	1.0	8.3	64	1	0.1
	Urban	19	2.75	0.3	1.0	8.3	64	1	0.1
	Mining	20	35.31	0.3	1.0	8.3	64	1	0.1
	Forestry	1	2.57	0.0				0	0.0
WB8	Rural	22	0.11	0.3	1.0	8.3	64	1	0.1


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025 LG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 LG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

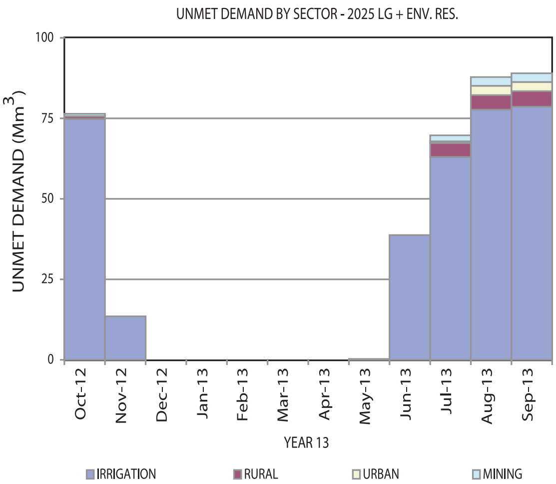
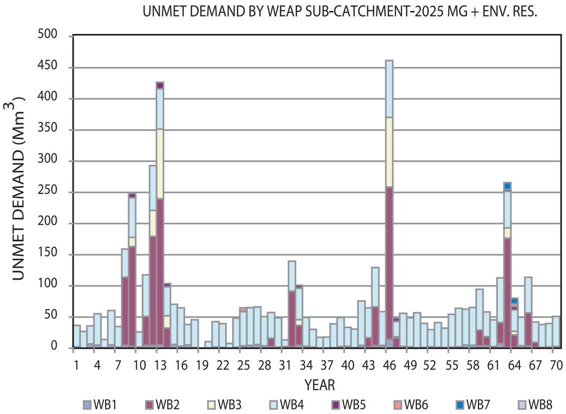
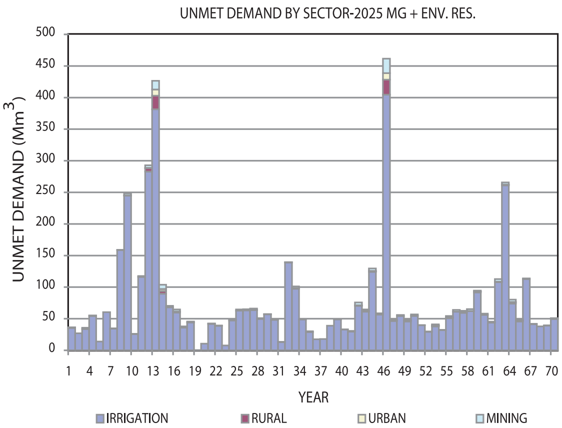
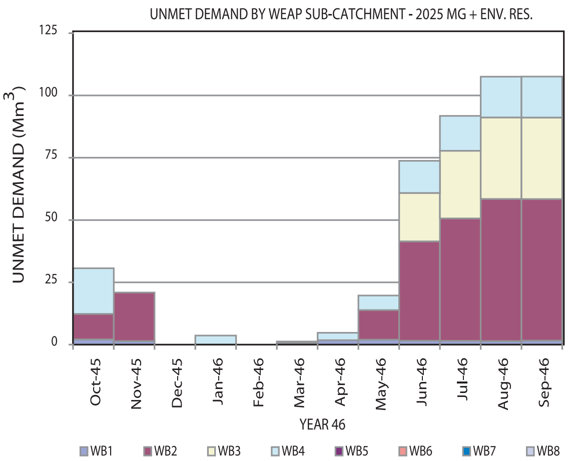

UNMET DEMAND BY SECTOR - 2025 LG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A7 and figures A7a, b, c and d. WEAP model outputs for 2025 MG scenario and ER.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	32.0	94.0	86.5	46	9	30.5
	Rural	2	1.55	0.0	0.0	0.0			0.0
	Urban	3	1.57	0.0	0.0	0.0			0.0
	Mining	4	8.27	12.0	67.0	24.7	46	7	3.4
WB2	Irrigation	9	213.53	7.0	29.0	71.0	46	6	10.2
	Rural	6	36.37	1.0	4.0	13.9	46	4	0.4
	Urban	7	31.72	1.0	4.0	25.0	46	4	0.8
	Mining	8	20.05	1.0	7.0	25.3	46	4	1.0
	Forestry	1	1.30	0.0	0.0	0.0			0.0
WB3	Irrigation	13	174.41	2.0	13.0	42.5	13	5	2.2
	Rural	10	63.91	1.0	6.0	25.0	46	4	0.9
	Urban	11	7.10	1.0	6.0	31.0	46	4	1.0
	Mining	12	26.94	1.0	6.0	33.3	46	4	1.1
WB4	Irrigation	5	74.56	43.0	100.0	83.2	46	8	57.5
	Rural	2	15.89	2.0	21.0	16.7	46	2	1.4
	Urban	3	1.35	2.0	23.0	16.7	46	2	2.2
	Mining	4	38.66	13.0	79.0	17.7	46	6	2.6
	Forestry	1	5.11	0.0	0.0				
WB5	Irrigation	17	23.04	1.0	10.0	26.0	13	2	1.8
	Rural	14	13.10	1.0	9.0	15.1	13	2	0.7
	Urban	15	0.03	1.0	9.0	16.7	13	2	0.8
	Mining	16	9.04	1.0	9.0	16.7	13	2	0.8
	Forestry	1	1.72	0.0	0.0	0.0			
WB6	Irrigation	5	31.26	0.5	3.0	19.0	25	1	0.5
	Rural	2	1.07	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32	0.0	0.0				
WB7	Irrigation	21	28.86	0.5	3.0	23.3	63	2	0.6
	Rural	18	11.98	0.5	3.0	8.3	63	2	0.2
	Urban	19	3.09	0.5	3.0	8.3	63	2	0.2
	Mining	20	35.31	0.5	3.0	8.3	63	2	0.2
	Forestry	1	2.70	0.0	0.0				0.0
WB8	Rural	22	0.12	0.5	3.0	8.3	63	2	0.2


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 MG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 MG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 MG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR 46
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

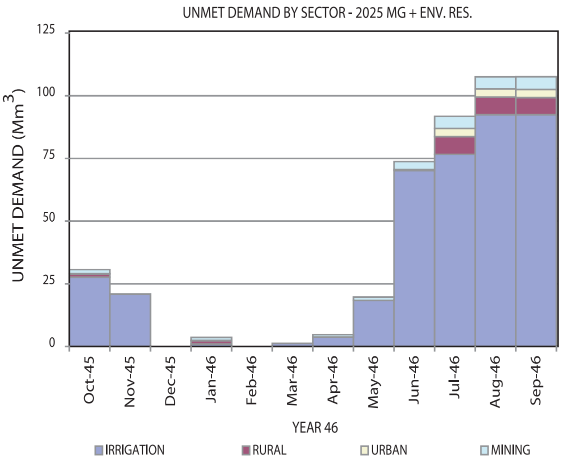
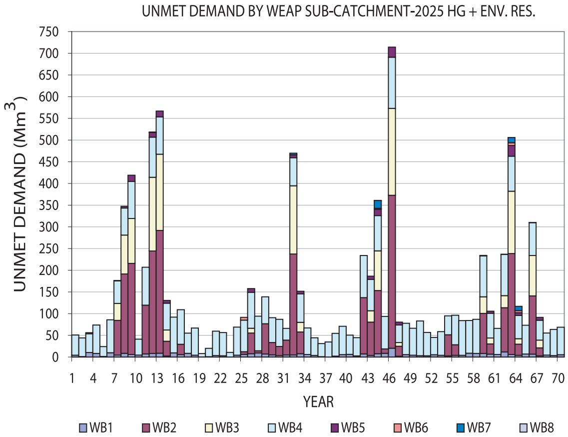
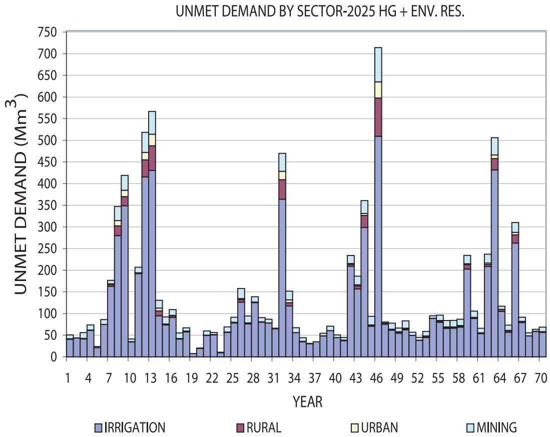
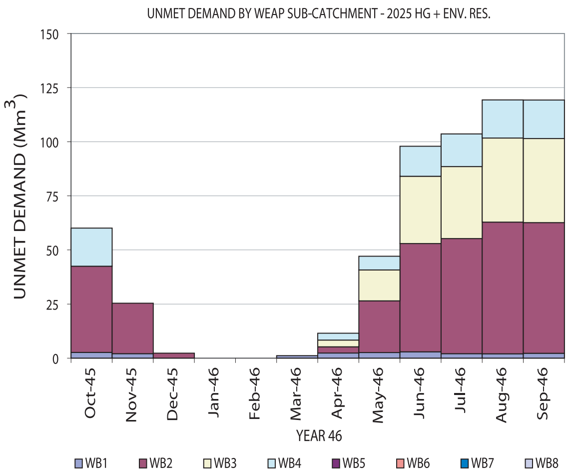

UNMET DEMAND BY SECTOR - 2025 MG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR 46
IRRIGATION
RURAL
URBAN
MINING

Table A8 and figures A8a, b, c and d. WEAP model outputs for 2025 HG scenario and ER.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	39.0	97.0	92.0	46	9	44.2
	Rural	2	5.88	1.0	4.0	8.3	46	1	0.1
	Urban	3	1.78	3.0	24.0	32.9	46	4	1.8
	Mining	4	10.64	28.0	94.0	61.5	46	9	15.5
WB2	Irrigation	9	213.53	14.0	46.0	93.2	46	9	19.3
	Rural	6	45.41	1.0	9.0	37.2	46	4	0.9
	Urban	7	48.65	4.0	16.0	49.5	46	6	2.7
	Mining	8	28.86	5.0	19.0	50.8	13	7	4.5
	Forestry	1	1.30			0.0			0.0
WB3	Irrigation	13	174.41	7.0	29.0	52.0	46	6	7.6
	Rural	10	110.16	5.0	23.0	50.0	46	7	3.9
	Urban	11	16.52	5.0	23.0	54.8	46	6	5.3
	Mining	12	44.88	7.0	26.0	69.6	46	7	5.9
WB4	Irrigation	5	74.56	49.0	100.0	85.0	46	10	68.7
	Rural	2	29.29	11.0	73.0	27.2	46	6	3.3
	Urban	3	5.44	15.0	83.0	66.7	46	6	13.0
	Mining	4	56.60	33.0	94.0	40.7	46	9	14.6
	Forestry	1	5.11			0.0			0.0
WB5	Irrigation	17	23.04	5.0	29.0	58.8	63	4	6.1
	Rural	14	27.14	3.0	21.0	29.9	46	4	2.6
	Urban	15	0.09	3.0	21.0	41.7	46	4	3.2
	Mining	16	9.01	3.0	23.0	41.7	46	4	3.3
	Forestry	1	1.72			0.0			0.0
WB6	Irrigation	5	31.26	1.0	7.0	20.7	25	2	1.0
	Rural	2	4.16	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.07	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32			0.0			0.0
WB7	Irrigation	21	28.86	1.0	7.0	34.2	44	3	1.3
	Rural	18	23.29	1.0	4.0	8.3	44	2	0.4
	Urban	19	3.49	1.0	4.0	8.6	44	2	0.4
	Mining	20	35.31	1.0	4.0	16.7	44	2	0.5
	Forestry	1	2.70			0.0			0.0
WB8	Rural	22	0.02	1.0	7.0	100	44	3	5.8


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 HG + ENV. RES.
UNMET DEMAND (Mm^3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025 HG + ENV. RES.
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 HG + ENV. RES.
UNMET DEMAND (Mm^3)
Oct-45 Nov-45 Dec-45 Jan-46 Feb-46 Mar-46 Apr-46 May-46 Jun-46 Jul-46 Aug-46 Sep-46
YEAR 46
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

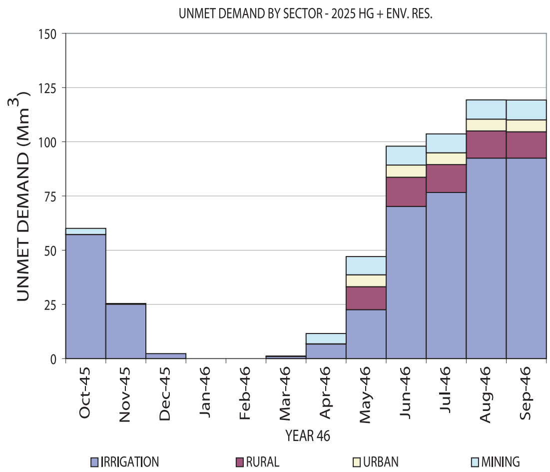
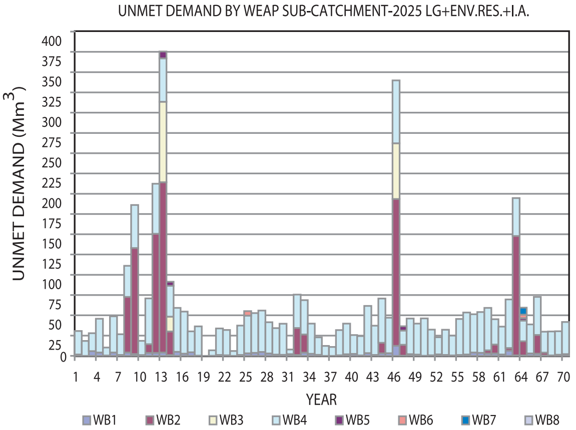
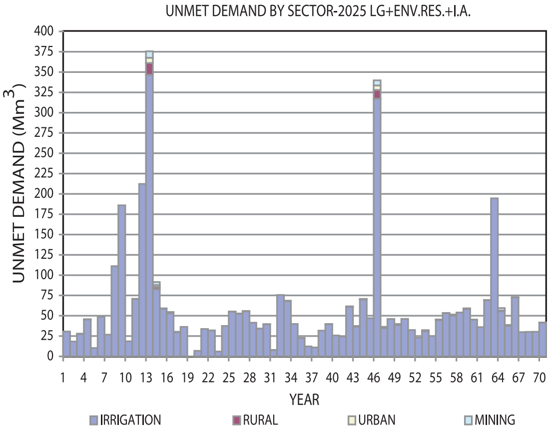
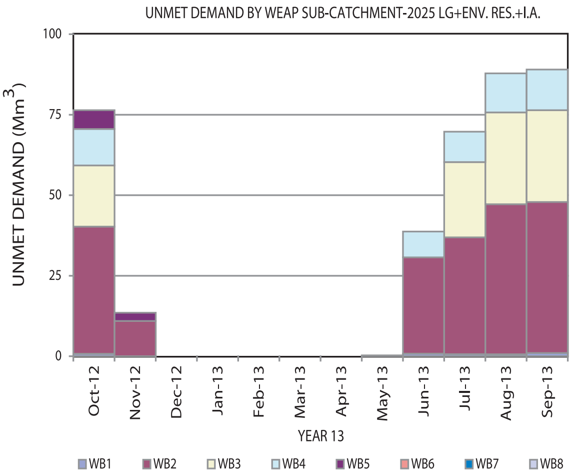

UNMET DEMAND BY SECTOR - 2025 HG + ENV. RES.
UNMET DEMAND (Mm^3)
Oct-45 Nov-45 Dec-45 Jan-46 Feb-46 Mar-46 Apr-46 May-46 Jun-46 Jul-46 Aug-46 Sep-46
YEAR 46
IRRIGATION RURAL URBAN MINING

Table A9 and figures A9a, b, c and d. WEAP model outputs for 2025 LG Scenario, ER and IA.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	29.0	93.0	83.4	46	8	24.6
	Rural	2	1.38	0.0	0.0			0	
	Urban	3	1.39	0.0	0.0			0	
	Mining	4	6.49	6.0	41.0	13.2	46	6	1.5
WB2	Irrigation	9	213.53	5.0	26.0	63.7	13	6	7.0
	Rural	6	31.97	0.5	1.0	2.0	13	2	0.0
	Urban	7	28.36	1.0	4.0	16.7	13	2	0.5
	Mining	8	10.11	1.0	4.0	16.7	13	3	0.6
	Forestry	1	1.24	0.0	0.0			0	
WB3	Irrigation	13	174.41	1.0	6.0	38.5	13	4	1.2
	Rural	10	51.97	1.0	4.0	25.0	13	4	0.6
	Urban	11	6.31	1.0	4.0	25.0	13	4	0.7
	Mining	12	22.33	1.0	4.0	25.0	13	4	0.7
WB4	Irrigation	5	74.56	39.0	99.0	76.9	46	7	47.8
	Rural	2	12.17	2.0	17.0	16.7	46	1	1.3
	Urban	3	1.19	2.0	19.0	16.7	46	1	1.7
	Mining	4	13.53	0.0	0.0	0.0		0	0.0
	Forestry	1	4.87	0.0	0.0			0	
WB5	Irrigation	17	23.04	1.0	6.0	25.9	13	2	1.0
	Rural	14	10.46	0.8	4.0	8.3	13	1	0.4
	Urban	15	0.03	0.8	4.0	8.3	13	1	0.4
	Mining	16	9.01	0.8	4.0	8.3	13	1	0.4
	Forestry	1	1.64	0.0	0.0			0	
WB6	Irrigation	5	31.26	0.5	3.0	17.7	25	1	0.4
	Rural	2	0.94	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0				0	0.0
WB7	Irrigation	21	28.86	0.3	1.0	16.2	64	1	0.2
	Rural	18	9.09	0.3	1.0	8.3	64	1	0.1
	Urban	19	2.75	0.3	1.0	8.3	64	1	0.1
	Mining	20	35.31	0.3	1.0	8.3	64	1	0.1
	Forestry	1	2.57	0.0				0	0.0
WB8	Rural	22	0.11	0.3	1.0	8.3	64	1	0.1


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG+ENV.RES.+I.A.
UNMET DEMAND (Mm^3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025 LG+ENV.RES.+I.A.
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG+ENV. RES.+I.A.
UNMET DEMAND (Mm^3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

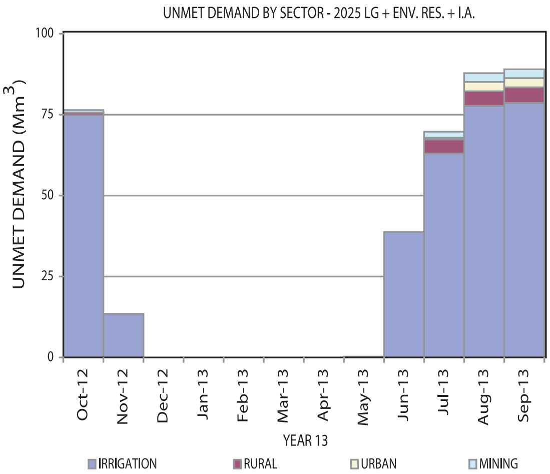
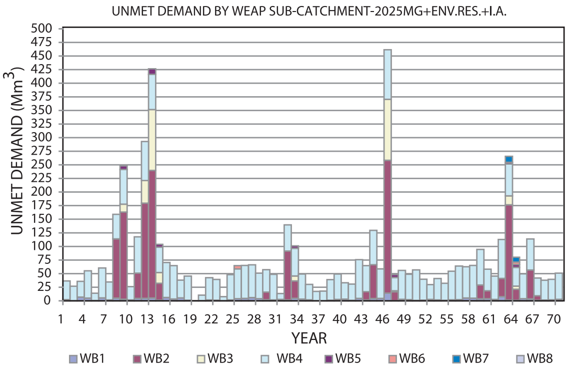
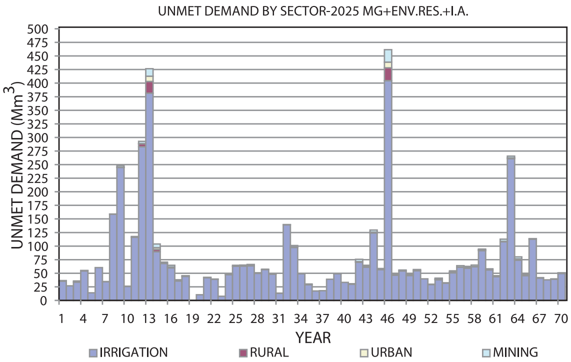

UNMET DEMAND BY SECTOR - 2025 LG + ENV. RES. + I.A.
UNMET DEMAND (Mm^3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A10 and figures A10a, b, c and d. WEAP model outputs for 2025 MG scenario, ER and IA.

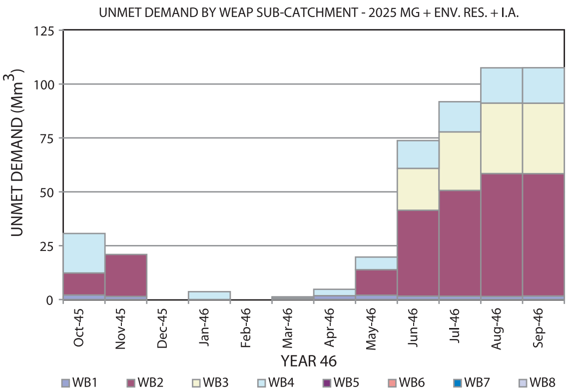
	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	32.0	94.0	86.5	46	9	30.5
	Rural	2	1.55	0.0	0.0	0.0			0.0
	Urban	3	1.57	0.0	0.0	0.0			0.0
	Mining	4	8.27	12.0	67.0	24.7	46	7	3.4
WB2	Irrigation	9	213.53	7.0	29.0	71.0	46	6	10.2
	Rural	6	36.37	1.0	4.0	13.9	46	4	0.4
	Urban	7	31.72	1.0	4.0	25.0	46	4	0.8
	Mining	8	20.05	1.0	7.0	25.3	46	4	1.0
	Forestry	1	1.30	0.0	0.0	0.0			0.0
WB3	Irrigation	13	174.41	2.0	13.0	42.5	13	5	2.2
	Rural	10	63.91	1.0	6.0	25.0	46	4	0.9
	Urban	11	7.10	1.0	6.0	31.0	46	4	1.0
	Mining	12	26.94	1.0	6.0	33.3	46	4	1.1
WB4	Irrigation	5	74.56	43.0	100.0	83.2	46	8	57.5
	Rural	2	15.89	2.0	21.0	16.7	46	2	1.4
	Urban	3	1.35	2.0	23.0	16.7	46	2	2.2
	Mining	4	38.66	13.0	79.0	17.7	46	6	2.6
	Forestry	1	5.11	0.0	0.0				
WB5	Irrigation	17	23.04	1.0	10.0	26.0	13	2	1.8
	Rural	14	13.10	1.0	9.0	15.1	13	2	0.7
	Urban	15	0.03	1.0	9.0	16.7	13	2	0.8
	Mining	16	9.04	1.0	9.0	16.7	13	2	0.8
	Forestry	1	1.72	0.0	0.0	0.0			
WB6	Irrigation	5	31.26	0.5	3.0	19.0	25	1	0.5
	Rural	2	1.07	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32	0.0	0.0				
WB7	Irrigation	21	28.86	0.5	3.0	23.3	63	2	0.6
	Rural	18	11.98	0.5	3.0	8.3	63	2	0.2
	Urban	19	3.09	0.5	3.0	8.3	63	2	0.2
	Mining	20	35.31	0.5	3.0	8.3	63	2	0.2
	Forestry	1	2.70	0.0	0.0				0.0
WB8	Rural	22	0.12	0.5	3.0	8.3	63	2	0.2



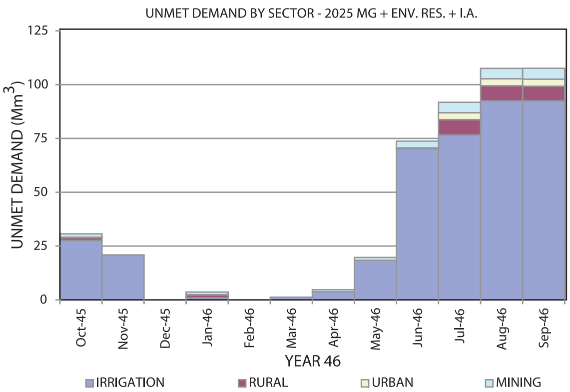
UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8



UNMET DEMAND BY SECTOR-2025 MG+ENV.RES.+I.A.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING



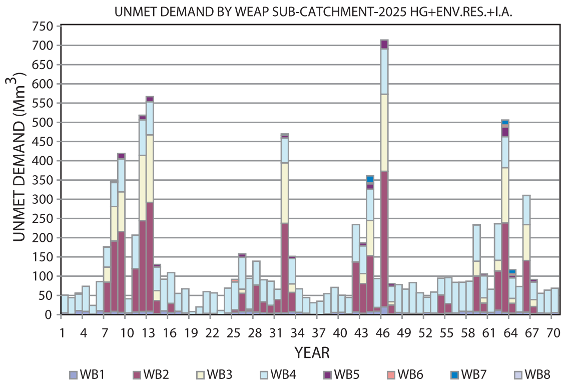
UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 MG + ENV. RES. + I.A.
UNMET DEMAND (Mm3)
YEAR 46
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

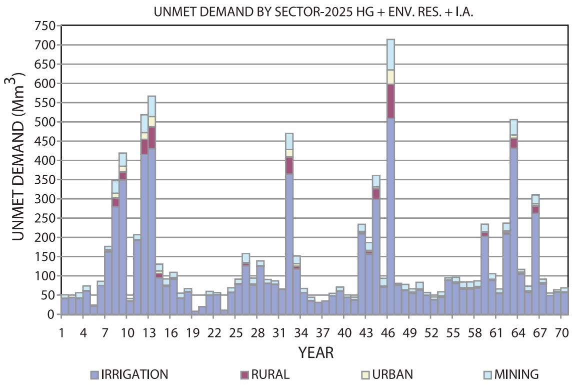


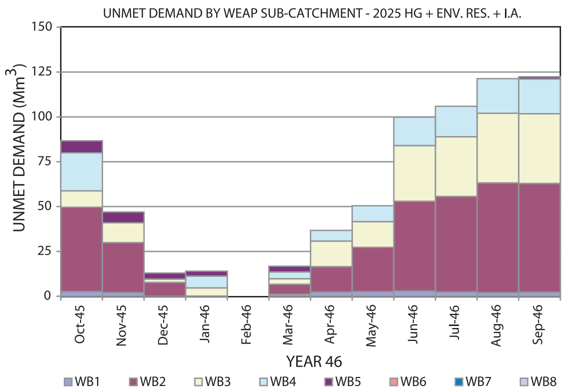
UNMET DEMAND BY SECTOR - 2025 MG + ENV. RES. + I.A.
UNMET DEMAND (Mm3)
YEAR 46
IRRIGATION
RURAL
URBAN
MINING

Table A11 and figures A11a, b, c and d. WEAP model outputs for 2025 HG scenario, ER and IA.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	39.0	97.0	92.0	46	9	44.2
	Rural	2	5.88	1.0	4.0	8.3	46	1	0.1
	Urban	3	1.78	3.0	24.0	32.9	46	4	1.8
	Mining	4	10.64	28.0	94.0	61.5	46	9	15.5
WB2	Irrigation	9	213.53	14.0	46.0	93.2	46	9	19.3
	Rural	6	45.41	1.0	9.0	37.2	46	4	0.9
	Urban	7	48.65	4.0	16.0	49.5	46	6	2.7
	Mining	8	28.86	5.0	19.0	50.8	13	7	4.5
	Forestry	1	1.30			0.0			0.0
WB3	Irrigation	13	174.41	7.0	29.0	52.0	46	6	7.6
	Rural	10	110.16	5.0	23.0	50.0	46	7	3.9
	Urban	11	16.52	5.0	23.0	54.8	46	6	5.3
	Mining	12	44.88	7.0	26.0	69.6	46	7	5.9
WB4	Irrigation	5	74.56	49.0	100.0	85.0	46	10	68.7
	Rural	2	29.29	11.0	73.0	27.2	46	6	3.3
	Urban	3	5.44	15.0	83.0	66.7	46	6	13.0
	Mining	4	56.60	33.0	94.0	40.7	46	9	14.6
	Forestry	1	5.11			0.0			0.0
WB5	Irrigation	17	23.04	5.0	29.0	58.8	63	4	6.1
	Rural	14	27.14	3.0	21.0	29.9	46	4	2.6
	Urban	15	0.09	3.0	21.0	41.7	46	4	3.2
	Mining	16	9.01	3.0	23.0	41.7	46	4	3.3
	Forestry	1	1.72			0.0			0.0
WB6	Irrigation	5	31.26	1.0	7.0	20.7	25	2	1.0
	Rural	2	4.16	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.07	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32			0.0			0.0
WB7	Irrigation	21	28.86	1.0	7.0	34.2	44	3	1.3
	Rural	18	23.29	1.0	4.0	8.3	44	2	0.4
	Urban	19	3.49	1.0	4.0	8.6	44	2	0.4
	Mining	20	35.31	1.0	4.0	16.7	44	2	0.5
	Forestry	1	2.70			0.0			0.0
WB8	Rural	22	0.02	1.0	7.0	100	44	3	5.8


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 HG+ENV.RES.+I.A.
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 HG + ENV. RES. + I.A.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 HG + ENV. RES. + I.A.
UNMET DEMAND (Mm3)
YEAR 46
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

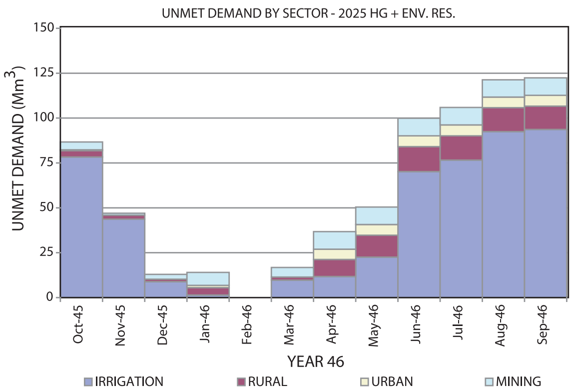
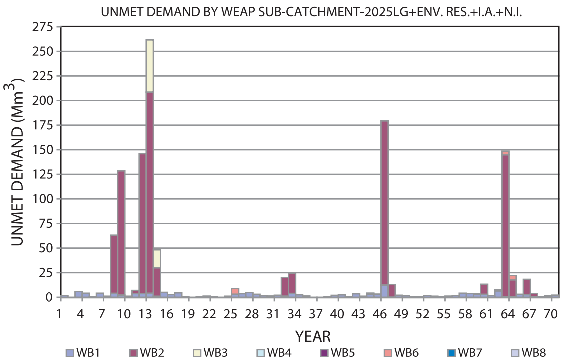
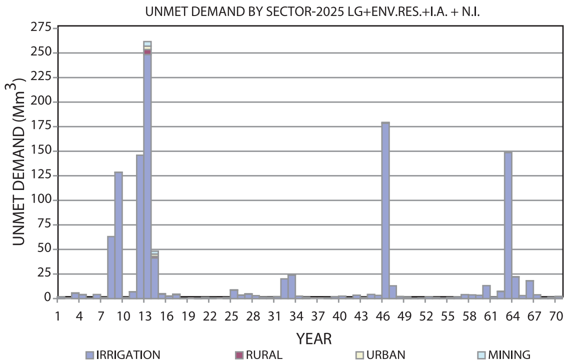
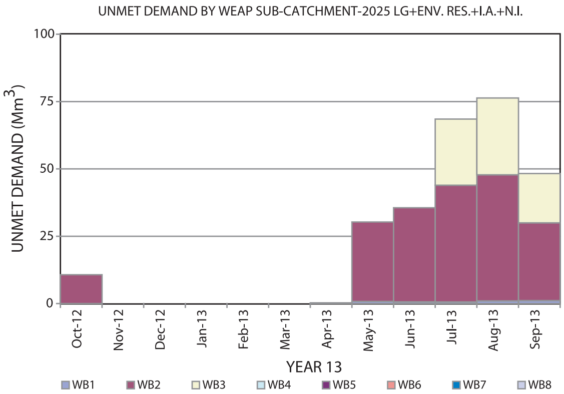

UNMET DEMAND BY SECTOR - 2025 HG + ENV. RES.
UNMET DEMAND (Mm3)
YEAR 46
IRRIGATION
RURAL
URBAN
MINING

Table A12 and figures A12a, b, c and d. WEAP model outputs for 2025 LG scenario, ER, IA and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	29.0	93.0	83.4	46	8	24.6
	Rural	2	1.38	0.0	0.0				
	Urban	3	1.39	0.0	0.0				
	Mining	4	6.49	6.0	41.0	13.2	46	6	1.5
WB2	Irrigation	9	213.53	5.0	26.0	63.0	13	6	6.5
	Rural	6	31.97	0.3	1.0	1.3	13	1	0.0
	Urban	7	28.36	5.0	3.0	8.3	13	2	0.2
	Mining	8	10.11	0.8	3.0	9.6	13	3	0.3
	Forestry	1	1.24	0.0	0.0				
WB3	Irrigation	13	174.41	0.8	3.0	21.2	13	3	0.5
	Rural	10	51.97	0.8	3.0	9.1	13	3	0.2
	Urban	11	6.31	0.8	3.0	16.7	13	3	0.4
	Mining	12	22.33	0.8	3.0	16.7	13	3	0.4
WB4	Irrigation	5	74.56	0.0	0.0	0.0			0.0
	Rural	2	12.17	0.0	0.0	0.0			0.0
	Urban	3	1.19	0.0	0.0	0.0			0.0
	Mining	4	13.53	0.0	0.0	0.0			0.0
	Forestry	1	4.87	0.0	0.0				
WB5	Irrigation	17	23.04	0.0	0.0	0.0			0.0
	Rural	14	10.46	0.0	0.0	0.0			0.0
	Urban	15	0.03	0.0	0.0	0.0			0.0
	Mining	16	9.01	0.0	0.0	0.0			0.0
	Forestry	1	1.64	0.0	0.0				
WB6	Irrigation	5	31.26	0.8	4.0	18.4	25	2	0.6
	Rural	2	0.94	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0	0.0				0.0
WB7	Irrigation	21	28.86	0.0	0.0	0.0			0.0
	Rural	18	9.09	0.0	0.0	0.0			0.0
	Urban	19	2.75	0.0	0.0	0.0			0.0
	Mining	20	35.31	0.0	0.0	0.0			0.0
	Forestry	1	2.57	0.0	0.0				0.0
WB8	Rural	22	0.11	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025LG+ENV. RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 LG+ENV.RES.+I.A. + N.I.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG+ENV. RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

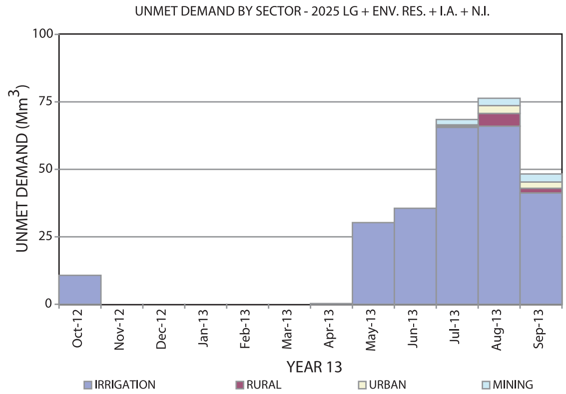
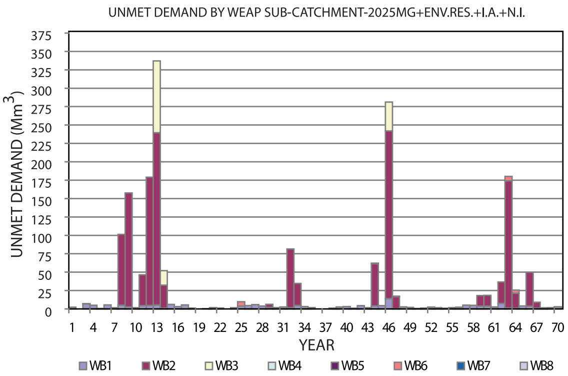
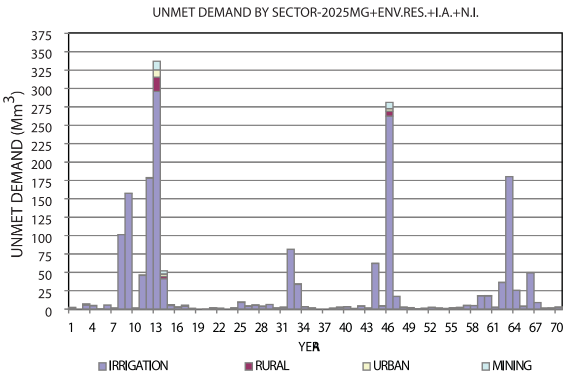
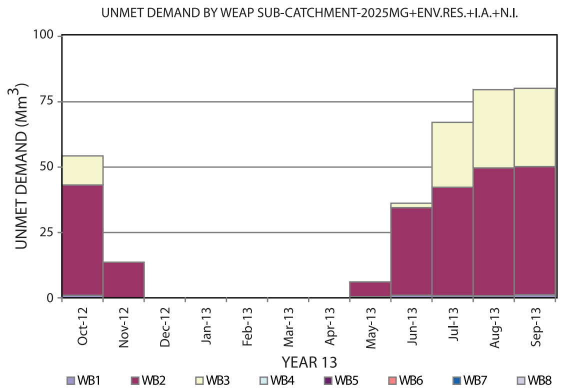

UNMET DEMAND BY SECTOR - 2025 LG + ENV. RES. + I.A. + N.I.
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A13 and figures A13a, b, c and d. WEAP model outputs for 2025 MG scenario, ER, IA and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	32.0	94.0	86.5	46	9	30.5
	Rural	2	1.55	0.0	0.0				0.0
	Urban	3	1.57	0.0	0.0				0.0
	Mining	4	8.27	12.0	67.0	24.7	46	7	3.4
WB2	Irrigation	9	213.53	7.0	27.0	68.8	46	6	9.5
	Rural	6	36.37	1.0	4.0	9.7	13	4	0.2
	Urban	7	31.72	1.0	4.0	25.0	13	4	0.6
	Mining	8	20.05	1.0	7.0	25.0	13	4	0.9
	Forestry	1	1.30	0.0	0.0				0.0
WB3	Irrigation	13	174.41	1.0	6.0	35.5	13	5	1.0
	Rural	10	63.91	1.0	4.0	25.0	13	4	0.5
	Urban	11	7.10	1.0	4.0	25.0	13	4	0.6
	Mining	12	26.94	1.0	4.0	25.0	13	4	0.6
WB4	Irrigation	5	74.56	0.0	0.0	0.0			0.0
	Rural	2	15.89	0.0	0.0	0.0			0.0
	Urban	3	1.35	0.0	0.0	0.0			0.0
	Mining	4	38.66	0.0	0.0	0.0			0.0
	Forestry	1	5.11	0.0	0.0				0.0
WB5	Irrigation	17	23.04	0.0	0.0	0.0			0.0
	Rural	14	13.10	0.0	0.0	0.0			0.0
	Urban	15	0.03	0.0	0.0	0.0			0.0
	Mining	16	9.04	0.0	0.0	0.0			0.0
	Forestry	1	1.72	0.0	0.0				0.0
WB6	Irrigation	5	31.26	1.0	7.0	19.2	63	2	0.8
	Rural	2	1.07	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.04	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32	0.0	0.0				0.0
WB7	Irrigation	21	28.86	0.0	0.0	0.0			0.0
	Rural	18	11.98	0.0	0.0	0.0			0.0
	Urban	19	3.09	0.0	0.0	0.0			0.0
	Mining	20	35.31	0.0	0.0	0.0			0.0
	Forestry	1	2.70	0.0	0.0				0.0
WB8	Rural	22	0.12	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

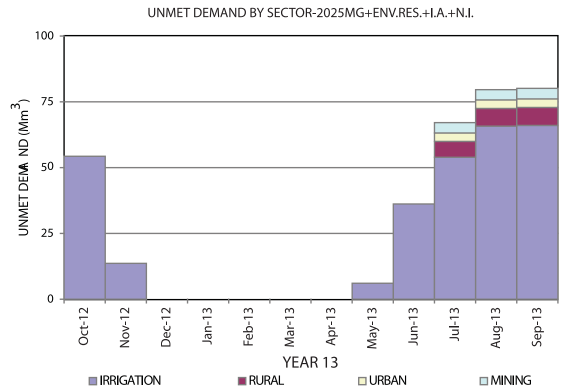
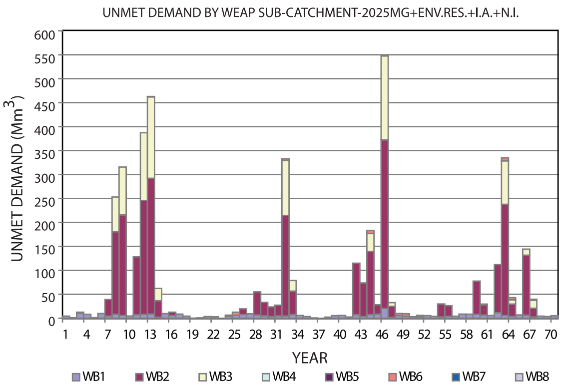
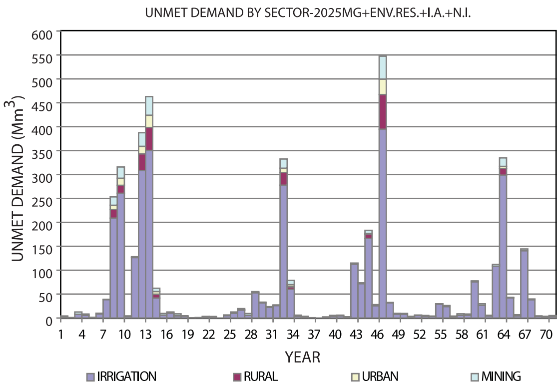
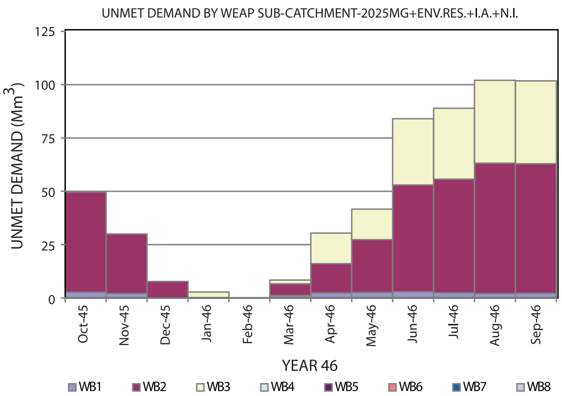

UNMET DEMAND BY SECTOR-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
Oct-12
Nov-12
Dec-12
Jan-13
Feb-13
Mar-13
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A14 and figures A14a, b, c and d. WEAP model outputs for 2025 HG scenario, ER, IA and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	39.0	97.0	92.0	46	9	44.2
	Rural	2	5.88	0.8	4.0	8.4	46	2	0.1
	Urban	3	1.78	3.0	24.0	33.1	46	4	1.8
	Mining	4	10.64	28.0	94.0	61.5	46	9	15.5
WB2	Irrigation	9	213.53	13.0	43.0	93.2	46	9	17.7
	Rural	6	45.41	1.0	7.0	37.2	46	5	0.9
	Urban	7	48.65	3.0	13.0	48.6	46	6	2.4
	Mining	8	28.86	5.0	17.0	51.0	13	7	3.9
	Forestry	1	1.30	0.0	0.0	0.0			0.0
WB3	Irrigation	13	174.41	5.0	21.0	49.6	13	6	5.0
	Rural	10	110.16	3.0	14.0	50.0	46	6	2.9
	Urban	11	16.52	3.0	14.0	50.0	46	6	3.5
	Mining	12	44.88	4.0	14.0	59.8	46	7	3.8
WB4	Irrigation	5	74.56	0.0	0.0	0.0			0.0
	Rural	2	29.29	0.0	0.0	0.0			0.0
	Urban	3	5.44	0.0	0.0	0.0			0.0
	Mining	4	56.60	0.0	0.0	0.0			0.0
	Forestry	1	5.11	0.0	0.0	0.0			0.0
WB5	Irrigation	17	23.04	0.0	0.0	0.0			0.0
	Rural	14	27.14	0.0	0.0	0.0			0.0
	Urban	15	0.09	0.0	0.0	0.0			0.0
	Mining	16	9.01	0.0	0.0	0.0			0.0
	Forestry	1	1.72	0.0	0.0	0.0			0.0
WB6	Irrigation	5	31.26	2.0	17.0	20.7	25	3	2.1
	Rural	2	4.16	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.07	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.3	1.0	8.3	64	1	0.1
	Forestry	1	43.32	0.0	0.0	0.2			0.0
WB7	Irrigation	21	28.86	0.0	0.0	0.0			0.0
	Rural	18	23.29	0.0	0.0	0.0			0.0
	Urban	19	3.49	0.0	0.0	0.0			0.0
	Mining	20	35.31	0.0	0.0	0.0			0.0
	Forestry	1	2.70	0.0	0.0	0.0			0.0
WB8	Rural	22	0.02	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.+N.I.
UNMET DEMAND (Mm3)
YEAR 46
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

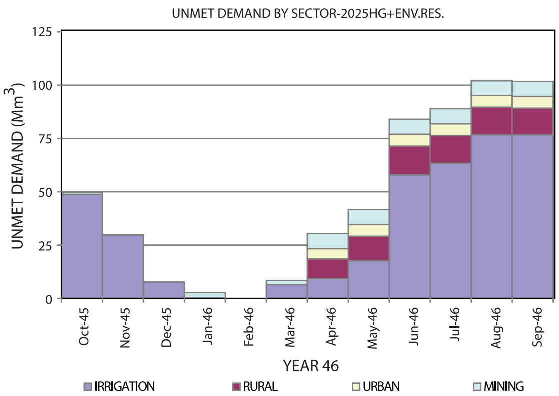
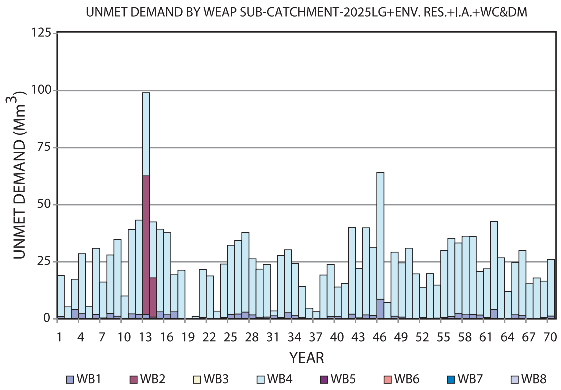
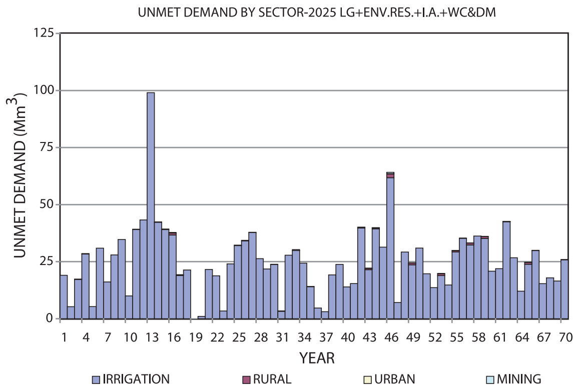
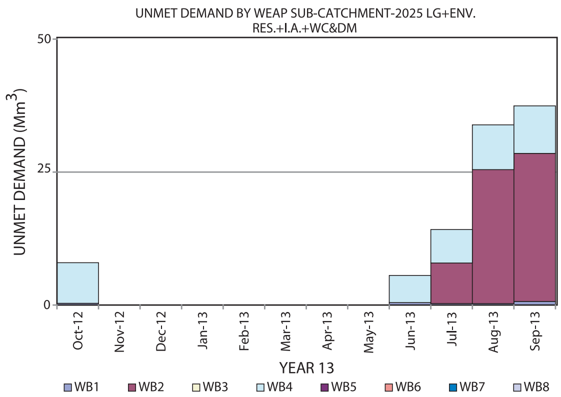

UNMET DEMAND BY SECTOR-2025HG+ENV.RES.
UNMET DEMAND (Mm3)
YEAR 46
IRRIGATION RURAL URBAN MINING

Table A 15 and figures A15a, b, c and d. WEAP model outputs for 2025 LG scenario, ER, IA and WC&DM.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	23.0	87.0	58.0	46	8	18.4
	Rural	2	1.10	0.0	0.0				
	Urban	3	1.18	0.0	0.0				
	Mining	4	6.16	4.0	34.0	9.0	46	5	0.9
WB2	Irrigation	9	160.15	1.0	3.0	19.0	13	4	0.7
	Rural	6	25.58	0.0	0.0	0.0			0.0
	Urban	7	24.11	0.0	0.0	0.0			0.0
	Mining	8	9.60	0.0	0.0	0.0			0.0
	Forestry	1	1.24	0.0	0.0				
WB3	Irrigation	13	130.81	0.0	0.0	0.0			0.0
	Rural	10	41.58	0.0	0.0	0.0			0.0
	Urban	11	5.36	0.0	0.0	0.0			0.0
	Mining	12	21.21	0.0	0.0	0.0			0.0
WB4	Irrigation	5	55.92	46.0	99.0	54.9	46	7	40.1
	Rural	2	9.73	2.0	16.0	16.7	46	1	1.2
	Urban	3	1.01	2.0	17.0	16.7	46	1	1.5
	Mining	4	12.86	0.0	0.0	0.0			0.0
	Forestry	1	4.87	0.0	0.0				
WB5	Irrigation	17	17.28	0.0	0.0	0.0			0.0
	Rural	14	8.37	0.0	0.0	0.0			0.0
	Urban	15	0.03	0.0	0.0	0.0			0.0
	Mining	16	8.56	0.0	0.0	0.0			0.0
	Forestry	1	1.64	0.0	0.0				
WB6	Irrigation	5	23.45	0.0	0.0	0.0			0.0
	Rural	2	0.75	0.0	0.0	0.0			0.0
	Urban	3	0.03	0.0	0.0	0.0			0.0
	Mining	4	0.35	0.0	0.0	0.0			0.0
	Forestry	1	41.24	0.0	0.0				0.0
WB7	Irrigation	21	21.65	0.0	0.0	0.0			0.0
	Rural	18	7.27	0.0	0.0	0.0			0.0
	Urban	19	2.34	0.0	0.0	0.0			0.0
	Mining	20	33.54	0.0	0.0	0.0			0.0
	Forestry	1	2.57	0.0	0.0				0.0
WB8	Rural	22	0.09	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025LG+ENV. RES.+I.A.+WC&DM
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025 LG+ENV.RES.+I.A.+WC&DM
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG+ENV. RES.+I.A.+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

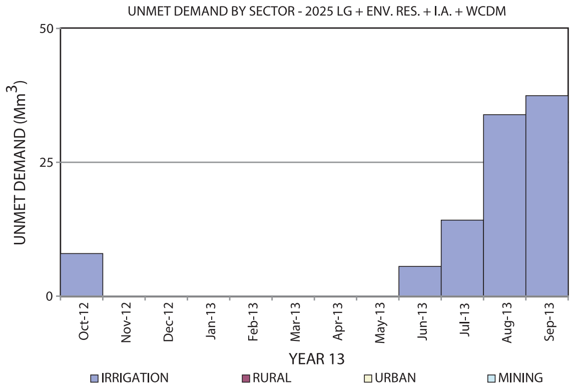
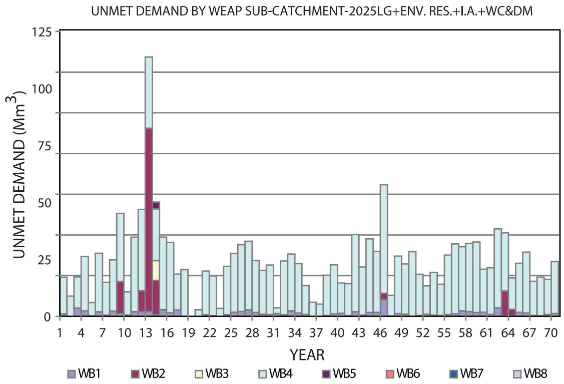
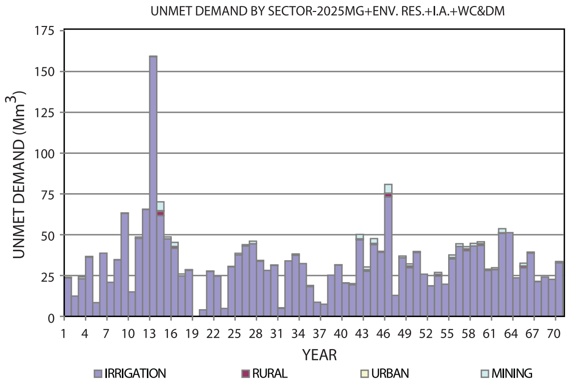

UNMET DEMAND BY SECTOR - 2025 LG + ENV. RES. + I.A. + WCDM
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A16 and figures A16a, b, c and d. WEAP model outputs for 2025 MG scenario, ER, IA and WC&DM.

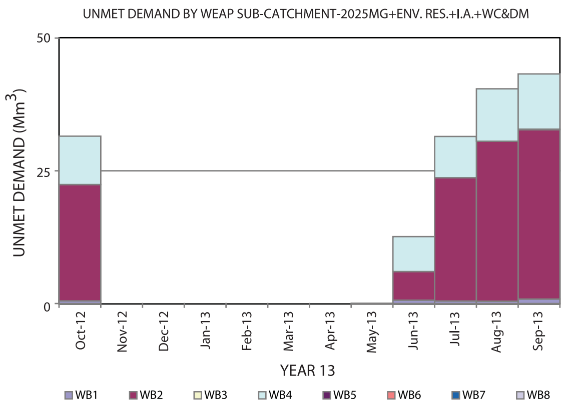
	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	26.0	93.0	62.3	46	8	24.6
	Rural	2	1.24	0.0	0.0				0.0
	Urban	3	1.33	0.0	0.0				0.0
	Mining	4	7.85	9.0	60.0	18.9	46	7	2.3
WB2	Irrigation	9	160.15	2.0	10.0	35.3	13	5	1.7
	Rural	6	29.10	0.0	0.0	0.0			0.0
	Urban	7	26.96	0.0	0.0	0.0			0.0
	Mining	8	19.05	0.3	1.0	7.5	14	1	0.1
	Forestry	1	1.24	0.0	0.0				0.0
WB3	Irrigation	13	130.81	0.5	3.0	3.8	14	2	0.1
	Rural	10	51.13	0.3	1.0	3.3	14	1	0.0
	Urban	11	6.03	0.3	1.0	8.3	14	1	0.1
	Mining	12	25.59	0.3	1.0	8.3	14	1	0.1
WB4	Irrigation	5	55.92	39.0	91.0	61.9	46	8	50.8
	Rural	2	12.71	2.0	19.0	16.7	46	1	1.3
	Urban	3	1.15	2.0	20.0	16.7	46	2	1.7
	Mining	4	36.73	8.0	61.0	10.5	46	6	1.4
	Forestry	1	4.87	0.0	0.0				0.0
WB5	Irrigation	17	17.28	0.3	1.0	9.9	14	1	0.2
	Rural	14	10.48	0.3	1.0	8.0	14	1	0.1
	Urban	15	0.03	0.3	1.0	8.3	14	1	0.1
	Mining	16	8.59	0.3	1.0	8.3	14	1	0.1
	Forestry	1	1.64	0.0	0.0				0.0
WB6	Irrigation	5	23.45	0.0	0.0	0.0			0.0
	Rural	2	0.86	0.0	0.0	0.0			0.0
	Urban	3	0.03	0.0	0.0	0.0			0.0
	Mining	4	0.35	0.0	0.0	0.0			0.0
	Forestry	1	41.24	0.0	0.0				0.0
WB7	Irrigation	21	21.65	0.0	0.0	0.0			0.0
	Rural	18	9.58	0.0	0.0	0.0			0.0
	Urban	19	2.63	0.0	0.0	0.0			0.0
	Mining	20	33.54	0.0	0.0	0.0			0.0
	Forestry	1	2.57	0.0	0.0				0.0
WB8	Rural	22	0.10	0.0	0.0	0.0			0.0



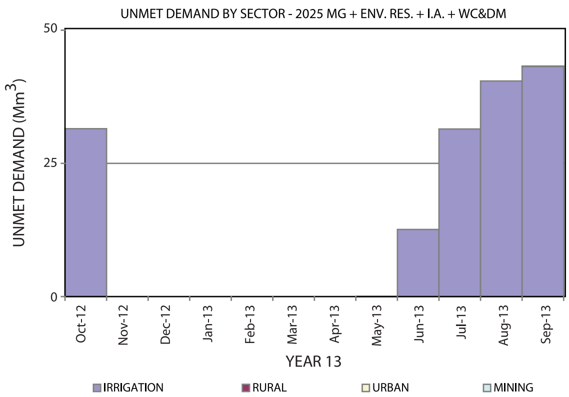
UNMET DEMAND BY WEAP SUB-CATCHMENT-2025LG+ENV. RES.+I.A.+WC&DM
UNMET DEMAND (Mm^3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8



UNMET DEMAND BY SECTOR-2025MG+ENV. RES.+I.A.+WC&DM
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION RURAL URBAN MINING



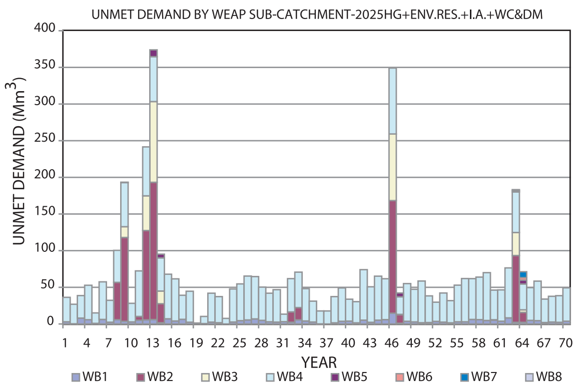
UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV. RES.+I.A.+WC&DM
UNMET DEMAND (Mm^3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8



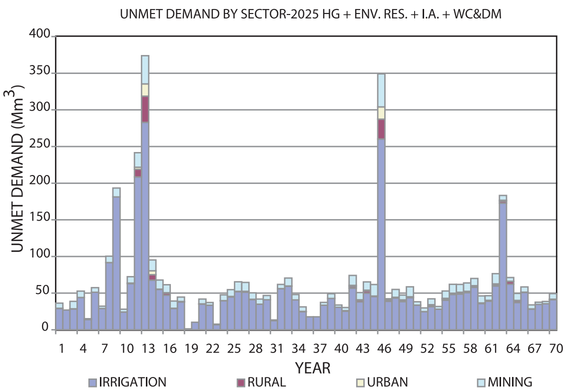
UNMET DEMAND BY SECTOR - 2025 MG + ENV. RES. + I.A. + WC&DM
UNMET DEMAND (Mm^3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A17 and figures A17a, b, c and d. WEAP model outputs for 2025 HG scenario, ER, IA and WC&DM.

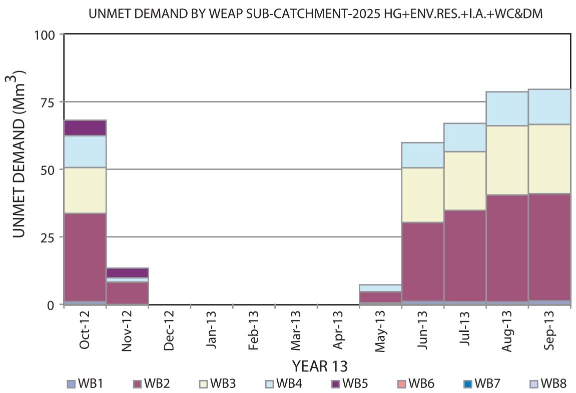
	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	36.0	96.0	68.7	46	9	38.9
	Rural	2	4.70	0.0	0.0	0.0		0	0.0
	Urban	3	1.51	1.0	11.0	5.1	33	1	0.2
	Mining	4	10.10	23.0	90.0	50.1	46	7	11.5
WB2	Irrigation	9	160.15	5.0	19.0	50.9	13	6	6.7
	Rural	6	36.33	1.0	4.0	10.0	13	4	0.2
	Urban	7	41.35	1.0	4.0	28.8	13	5	0.9
	Mining	8	27.42	2.0	7.0	34.3	13	5	1.2
	Forestry	1	1.24	0.0	0.0	0.0		0	0.0
WB3	Irrigation	13	130.81	2.0	11.0	28.5	13	5	2.0
	Rural	10	88.13	1.0	7.0	33.3	13	5	1.1
	Urban	11	14.04	1.0	7.0	33.3	13	5	1.3
	Mining	12	42.64	2.0	9.0	41.3	13	5	1.6
WB4	Irrigation	5	55.92	45.0	100.0	63.8	46	9	63.9
	Rural	2	23.43	5.0	44.0	18.5	46	4	2.1
	Urban	3	4.62	10.0	66.0	61.1	46	6	7.5
	Mining	4	53.77	30.0	91.0	37.9	46	8	11.4
	Forestry	1	4.87	0.0	0.0	0.0		0	0.0
WB5	Irrigation	17	17.28	1.0	9.0	19.5	13	3	1.3
	Rural	14	21.71	1.0	6.0	12.4	13	2	0.5
	Urban	15	0.08	1.0	6.0	16.7	13	2	0.6
	Mining	16	8.56	1.0	6.0	16.7	13	2	0.6
	Forestry	1	1.64	0.0	0.0	0.0		0	0.0
WB6	Irrigation	5	23.45	0.3	1.0	13.7	64	1	0.2
	Rural	2	3.33	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.06	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.35	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0	0.0	0.0		0	0.0
WB7	Irrigation	21	21.65	0.5	3.0	16.2	64	2	0.3
	Rural	18	18.63	0.3	1.0	8.3	64	1	0.1
	Urban	19	2.97	0.3	1.0	8.3	64	1	0.1
	Mining	20	33.54	0.3	1.0	8.3	64	1	0.1
	Forestry	1	2.57	0.0	0.0	0.0		0	0.0
WB8	Rural	22	0.02	0.5	3.0	58.3	64	2	1.7



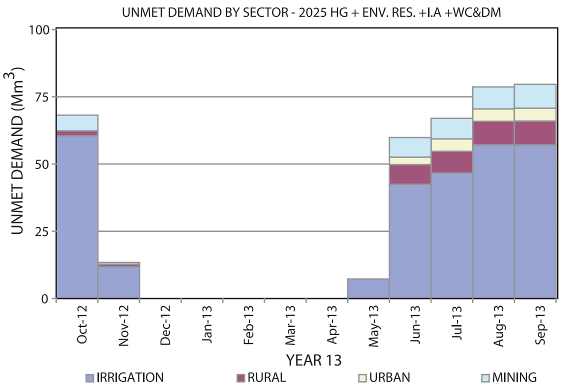
UNMET DEMAND BY WEAP SUB-CATCHMENT-2025HG+ENV.RES.+I.A.+WC&DM
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8



UNMET DEMAND BY SECTOR-2025 HG + ENV. RES. + I.A. + WC&DM
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING



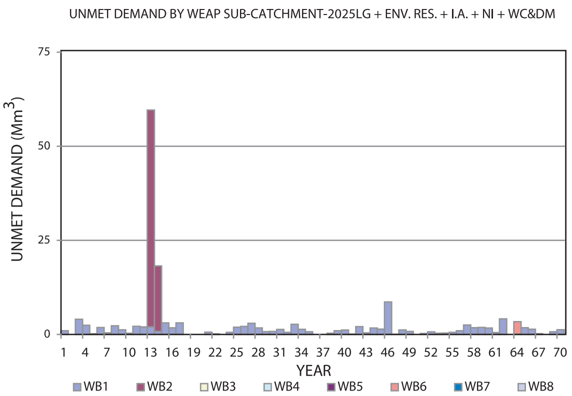
UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 HG+ENV.RES.+I.A.+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

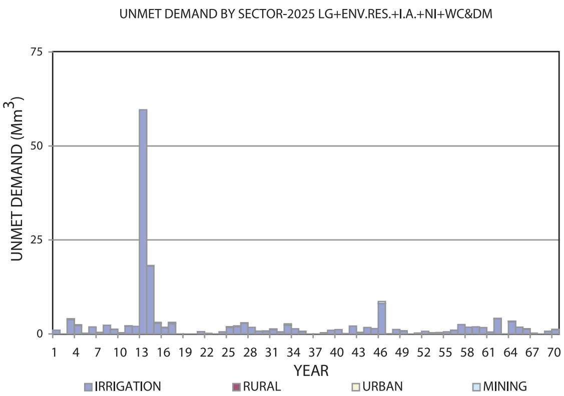


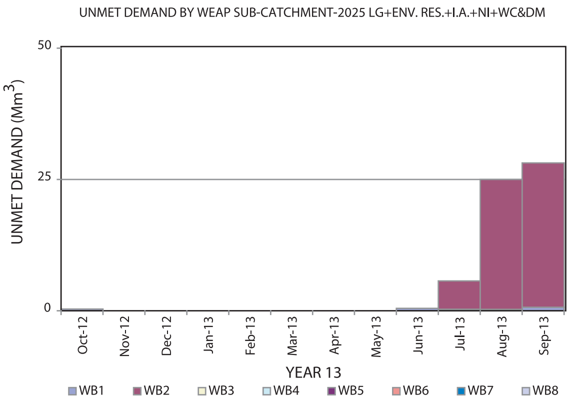
UNMET DEMAND BY SECTOR - 2025 HG + ENV. RES. +I.A +WC&DM
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION RURAL URBAN MINING

Table A18 and figures A18a, b, c and d. WEAP model outputs for 2025 LG scenario, ER, IA, WC&DM and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	23.0	87.0	58.0	46	8	18.4
	Rural	2	1.10	0.0	0.0				
	Urban	3	1.18	0.0	0.0				
	Mining	4	6.16	4.0	34.0	9.0	46	5	0.9
WB2	Irrigation	9	160.15	1.0	3.0	18.1	13	4	0.7
	Rural	6	25.58	0.0	0.0	0.0			0.0
	Urban	7	24.11	0.0	0.0	0.0			0.0
	Mining	8	9.60	0.0	0.0	0.0			0.0
	Forestry	1	1.24	0.0	0.0				
WB3	Irrigation	13	130.81	0.0	0.0	0.0			0.0
	Rural	10	41.58	0.0	0.0	0.0			0.0
	Urban	11	5.36	0.0	0.0	0.0			0.0
	Mining	12	21.21	0.0	0.0	0.0			0.0
WB4	Irrigation	5	55.92	0.0	0.0	0.0			0.0
	Rural	2	9.73	0.0	0.0	0.0			0.0
	Urban	3	1.01	0.0	0.0	0.0			0.0
	Mining	4	12.86	0.0	0.0	0.0			0.0
	Forestry	1	4.87	0.0	0.0				
WB5	Irrigation	17	17.28	0.0	0.0	0.0			0.0
	Rural	14	8.37	0.0	0.0	0.0			0.0
	Urban	15	0.03	0.0	0.0	0.0			0.0
	Mining	16	8.56	0.0	0.0	0.0			0.0
	Forestry	1	1.64	0.0	0.0				
WB6	Irrigation	5	23.45	0.3	1.0	13.7	64	1	0.2
	Rural	2	0.75	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.03	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.35	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0	0.0				0.0
WB7	Irrigation	21	21.65	0.0	0.0	0.0			0.0
	Rural	18	7.27	0.0	0.0	0.0			0.0
	Urban	19	2.34	0.0	0.0	0.0			0.0
	Mining	20	33.54	0.0	0.0	0.0			0.0
	Forestry	1	2.57	0.0	0.0				0.0
WB8	Rural	22	0.09	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025LG + ENV. RES. + I.A. + NI + WC&DM
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 LG+ENV.RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 LG+ENV. RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

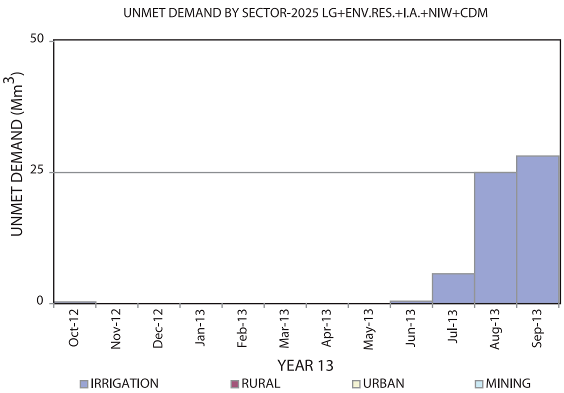
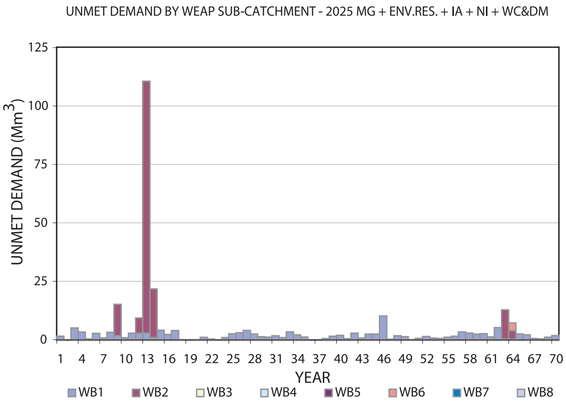
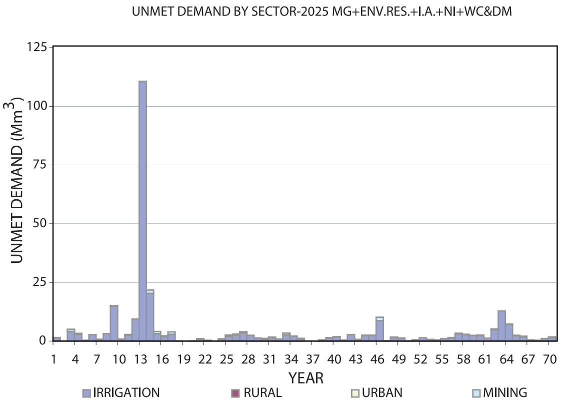
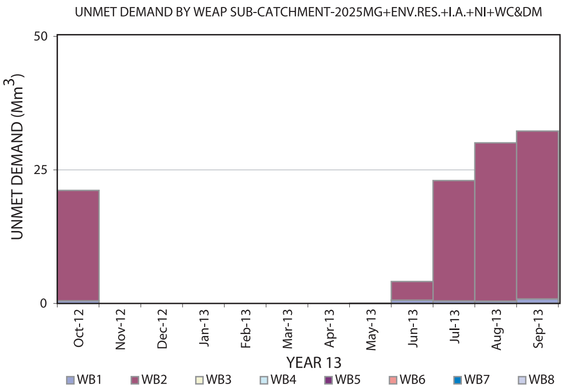

UNMET DEMAND BY SECTOR-2025 LG+ENV.RES.+I.A.+NIW+CDM
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A19 and figures A19a, b, c and d. WEAP model outputs for 2025 MG scenario, ER, IA, WC&DM and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	26.0	93.0	62.3	46	8	24.6
	Rural	2	1.24			0			0.0
	Urban	3	1.33			0			0.0
	Mining	4	7.85	9.0	60.0	18.9	46	7	2.3
WB2	Irrigation	9	160.15	1.0	9.0	33.8	13	5	1.5
	Rural	6	29.10			0.0			0.0
	Urban	7	26.96			0.0			0.0
	Mining	8	19.05	0.3	1.0	5.7	14	1	0.1
	Forestry	1	1.24						
WB3	Irrigation	13	130.81			0.0			0.0
	Rural	10	51.13			0.0			0.0
	Urban	11	6.03			0.0			0.0
	Mining	12	25.59			0.0			0.0
WB4	Irrigation	5	55.92			0.0			0.0
	Rural	2	12.71			0.0			0.0
	Urban	3	1.15			0.0			0.0
	Mining	4	36.73			0.0			0.0
	Forestry	1	4.87						
WB5	Irrigation	17	17.28			0.0			0.0
	Rural	14	10.48			0.0			0.0
	Urban	15	0.03			0.0			0.0
	Mining	16	8.59			0.0			0.0
	Forestry	1	1.64						
WB6	Irrigation	5	23.45	0.3	1.0	13.7	64	1	0.2
	Rural	2	0.86	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.03	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.35	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.3	1.0				
WB7	Irrigation	21	21.65			0.0			0.0
	Rural	18	9.58			0.0			0.0
	Urban	19	2.63			0.0			0.0
	Mining	20	33.54			0.0			0.0
	Forestry	1	2.57						
WB8	Rural	22	0.10			0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT - 2025 MG + ENV.RES. + IA + NI + WC&DM
UNMET DEMAND (Mm3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 MG+ENV.RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025MG+ENV.RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8

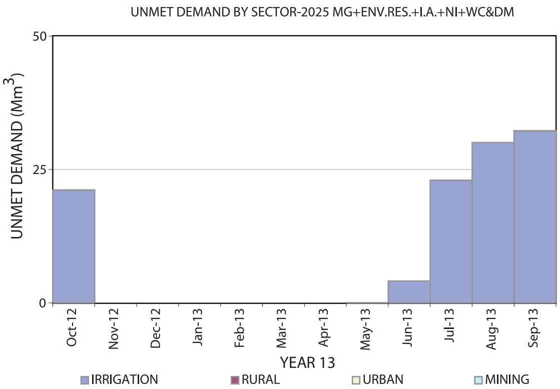
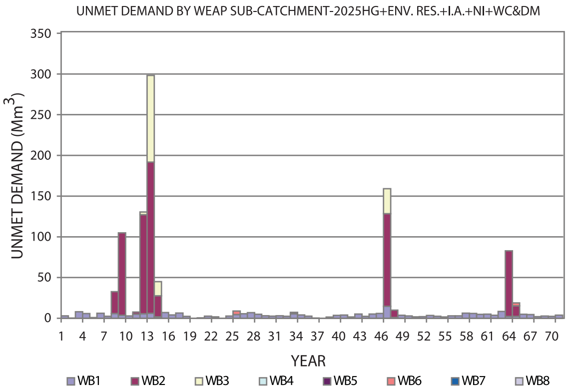
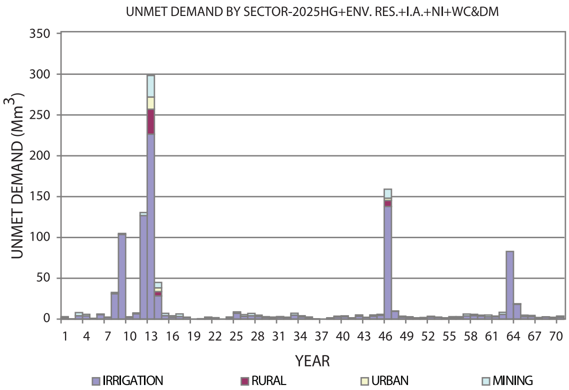
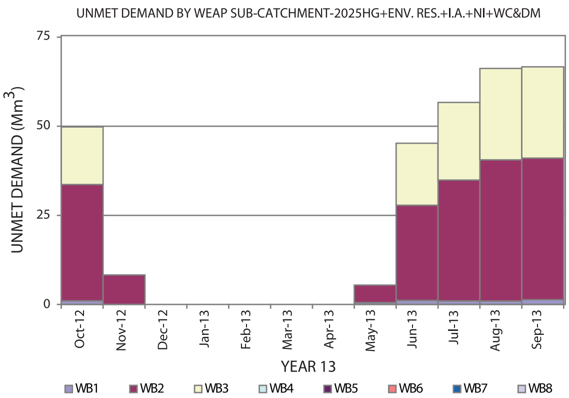

UNMET DEMAND BY SECTOR-2025 MG+ENV.RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION
RURAL
URBAN
MINING

Table A20 and figures A20a, b, c and d. WEAP model outputs for 2025 HG scenario, ER, IA, WC&DM and NI.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	6.46	36.0	96.0	68.7	46	9	38.9
	Rural	2	4.70	0.0	0.0	0.0			0.0
	Urban	3	1.51	1.0	11.0	5.1	33	1	0.2
	Mining	4	10.10	23.0	90.0	50.1	46	7	11.5
WB2	Irrigation	9	160.15	4.0	16.0	51.2	13	6	5.8
	Rural	6	36.33	1.0	3.0	10.8	13	4	0.2
	Urban	7	41.35	1.0	4.0	25.0	13	4	0.5
	Mining	8	27.42	1.0	7.0	30.8	13	5	0.8
	Forestry	1	1.24	0.0	0.0	0.0			0.0
WB3	Irrigation	13	130.81	1.0	6.0	28.5	13	5	1.0
	Rural	10	88.13	1.0	4.0	30.2	13	5	0.6
	Urban	11	14.04	1.0	4.0	33.3	13	5	0.7
	Mining	12	42.64	1.0	4.0	39.4	13	5	0.8
WB4	Irrigation	5	55.92	0.0	0.0	0.0			0.0
	Rural	2	23.43	0.0	0.0	0.0			0.0
	Urban	3	4.62	0.0	0.0	0.0			0.0
	Mining	4	53.77	0.0	0.0	0.0			0.0
	Forestry	1	4.87	0.0	0.0	0.0			0.0
WB5	Irrigation	17	17.28	0.0	0.0	0.0			0.0
	Rural	14	21.71	0.0	0.0	0.0			0.0
	Urban	15	0.08	0.0	0.0	0.0			0.0
	Mining	16	8.56	0.0	0.0	0.0			0.0
	Forestry	1	1.64	0.0	0.0	0.0			0.0
WB6	Irrigation	5	23.45	0.5	3.0	18.3	25	1	0.5
	Rural	2	3.33	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.06	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.35	0.3	1.0	8.3	64	1	0.1
	Forestry	1	41.24	0.0	0.0	0.0			0.0
WB7	Irrigation	21	21.65	0.0	0.0	0.0			0.0
	Rural	18	18.63	0.0	0.0	0.0			0.0
	Urban	19	2.97	0.0	0.0	0.0			0.0
	Mining	20	33.54	0.0	0.0	0.0			0.0
	Forestry	1	2.57	0.0	0.0	0.0			0.0
WB8	Rural	22	0.02	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025HG+ENV. RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8


UNMET DEMAND BY SECTOR-2025HG+ENV. RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR
IRRIGATION RURAL URBAN MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025HG+ENV. RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
WB1 WB2 WB3 WB4 WB5 WB6 WB7 WB8

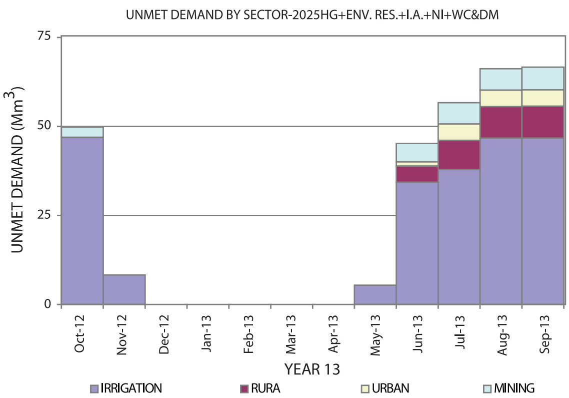
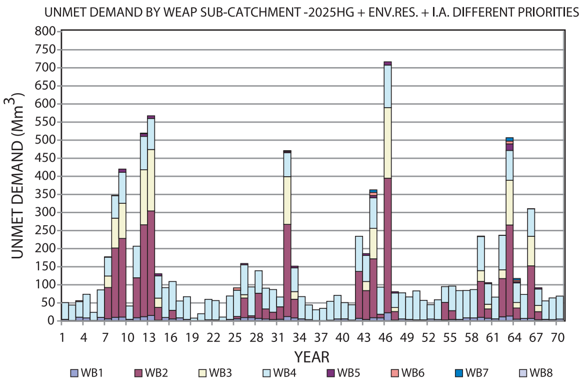
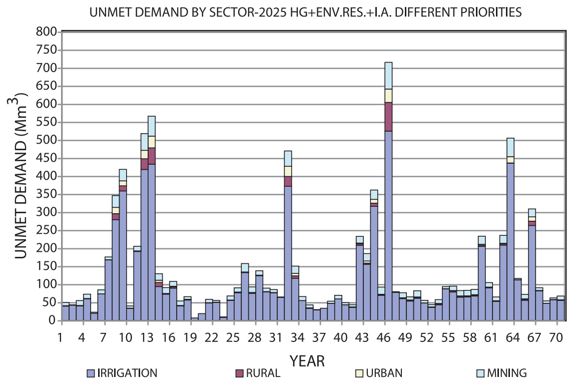
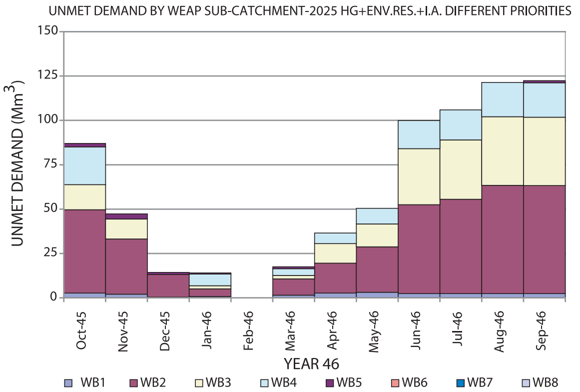

UNMET DEMAND BY SECTOR-2025HG+ENV. RES.+I.A.+NI+WC&DM
UNMET DEMAND (Mm3)
YEAR 13
IRRIGATION RURA URBAN MINING

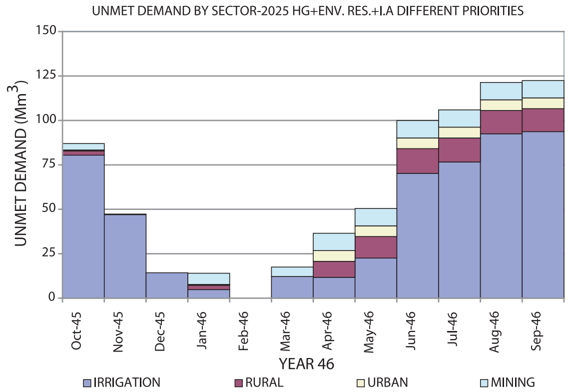
Table A21 and figures A21a, b, c and d. WEAP model outputs for 2025 HG scenario, ER, IA and different priorities.

	Sector	1995 demand	Priority	Months with shortage (%)	Years with shortage (%)	Maximum shortage (demand %)	Maximum shortage (years)	Longest period of shortage (months)	Mean shortage (demand %)
WB1	Irrigation	5	8.61	43.0	97.0	84.8	46	11	46.4
	Rural	2	5.88	4.0	16.0	44.3	46	6	2.1
	Urban	3	1.78	7.0	37.0	52.1	46	6	5.4
	Mining	4	10.64	30.0	94.0	69.4	46	9	18.4
WB2	Irrigation	5	213.53	14.0	46.0	97.5	46	9	19.6
	Rural	2	45.41	3.0	14.0	44.3	46	6	2.1
	Urban	3	48.65	5.0	19.0	50.0	46	6	4.3
	Mining	4	28.86	6.0	24.0	58.1	46	7	5.6
	Forestry	1	1.30	0.0	0.0	0.0			0.0
WB3	Irrigation	5	174.41	7.0	29.0	54.5	46	7	8.0
	Rural	2	110.16	3.0	13.0	44.3	46	6	2.1
	Urban	3	16.52	5.0	19.0	50.0	46	6	4.2
	Mining	4	44.88	6.0	23.0	58.1	46	7	5.2
WB4	Irrigation	5	74.56	49.0	100.0	85.0	46	10	68.8
	Rural	2	29.29	11.0	73.0	27.2	46	6	3.3
	Urban	3	5.44	15.0	83.0	66.7	46	6	13.0
	Mining	4	56.60	33.0	94.0	40.7	46	9	14.7
	Forestry	1	5.11	0.0	0.0	0.0			0.0
WB5	Irrigation	5	23.04	5.0	29.0	58.8	63	4	5.2
	Rural	2	27.14	1.0	4.0	5.4	63	1	0.2
	Urban	3	0.09	1.0	9.0	8.3	14	2	0.7
	Mining	4	9.01	2.0	13.0	28.9	14	3	1.3
	Forestry	1	1.72	0.0	0.0	0.0			0.0
WB6	Irrigation	5	31.26	1.0	10.0	28.0	44	3	1.4
	Rural	2	4.16	0.3	1.0	8.3	64	1	0.1
	Urban	3	0.07	0.3	1.0	8.3	64	1	0.1
	Mining	4	0.37	0.5	3.0	8.3	64	2	0.2
	Forestry	1	43.32	0.0	0.0	0.0			0.0
WB7	Irrigation	5	28.86	1.0	7.0	25.2	44	3	1.0
	Rural	2	23.29	0.0	0.0	0.0			0.0
	Urban	3	3.49	0.0	0.0	0.0			0.0
	Mining	4	35.31	0.3	1.0	6.7	63	1	0.1
	Forestry	1	2.70	0.0	0.0	0.0			0.0
WB8	Rural	2	0.02	0.0	0.0	0.0			0.0


UNMET DEMAND BY WEAP SUB-CATCHMENT -2025HG + ENV.RES. + I.A. DIFFERENT PRIORITIES
UNMET DEMAND (Mm^3)
YEAR
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 HG+ENV.RES.+I.A. DIFFERENT PRIORITIES
UNMET DEMAND (Mm^3)
YEAR
IRRIGATION
RURAL
URBAN
MINING


UNMET DEMAND BY WEAP SUB-CATCHMENT-2025 HG+ENV.RES.+I.A. DIFFERENT PRIORITIES
UNMET DEMAND (Mm^3)
YEAR 46
WB1
WB2
WB3
WB4
WB5
WB6
WB7
WB8


UNMET DEMAND BY SECTOR-2025 HG+ENV. RES.+I.A DIFFERENT PRIORITIES
UNMET DEMAND (Mm^3)
YEAR 46
IRRIGATION
RURAL
URBAN
MINING

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