Response lists to the comments on the manuscript

Groundwater as an emergency source for drought mitigation in the Crocodile River catchment, South Africa

F. Mussá et al.

Dear Editor

We appreciate constructive comments from two anonymous reviewers on the above manuscript. Below please find our point to point response to the comments of the reviewers.

Kind regards,

Fatima Mussa on the behind of the authors

Anonymous Referee #1

Received and published: 21 April 2014

General comments:

This manuscript investigates the use of groundwater as an emergency source for drought mitigation in a specific area (river catchment) in South Africa. Water scarcity & drought are often exacerbated by the lack of understanding of groundwater. Most data are incomplete, fragmented or outdated, and scientists in Africa lack the tools to assess groundwater to rapidly improve water supplies. Hence, actors in this continent lack the policies and skills necessary to manage groundwater that would help build long-term preparedness to drought. The current study is a good case study showing how conjunctive water management of groundwater and surface water resources is necessary to mitigate droughts impacts. The use by the authors of a multi-approach taking into account coupled modelling of surface water and groundwater fluxes with sufficient time series data of groundwater levels were very efficient for a good calibration of the model.

The paper is quite correct and precise regarding its English, structure, methodology and presentation.

On the other hand, the authors give proper credit to related work and clearly indicate their own contribution. I would only suggest mentioning as well some related works such as: Groundwater Resources Investigation for Drought Mitigation in Africa Programme (GRIDMAP), a scientific consortium of regional partners that aims to assess groundwater potential and build drought management capacities across the Horn of Africa and other parts of Africa, and which contributed to provide precise understanding of where safe groundwater resources exist and how much can be used for emergency

and long-term development needs in Africa. Southern African Development Community - SADC - Groundwater and Drought Management Project: which aims at developing cooperatively a strategic regional approach to support and enhance the capacity of its member States in the definition of drought management policies, specifically in relation to the role, availability (magnitude and recharge) and supply potential of groundwater resources.

The current work may be very helpful in future works studying drought and water scarcity in that specific study area and in similar river catchments by means of the use of groundwater resources data and modelling. There are no specific further comments.

Therefore, I would recommend accepting that paper.

Response: We thank the reviewer for highlighting the general picture of drought and importance of using groundwater to mitigate drought impacts in Africa and two interesting projects. We have added these two projects in the introduction section as follows:

Two large regional projects have been conducted in Africa to investigate groundwater potential for water supply during the drought. Groundwater and Drought Management Project (SADC, 2014) has developed strategic regional approach to support and enhance the capacity in Southern African Development Community in the definition of drought management policies, specifically in relation to the role, availability, and supply potential of groundwater resources. Groundwater Resources Investigation for Drought Mitigation in Africa Programme (GRIDMAP, 2014) aimed at assessing the availability of groundwater resources in the Horn of Africa and determining how much groundwater resources can be utilized safely for emergency and long-term development demands.

Anonymous Referee #2

Received and published: 4 November 2014

General comments

The study investigates droughts occurred in the Crocodile River catchment, located in South Africa, during the past 60 years and explores the feasibility of abstracting groundwater for emergency water supply during a drought event. It is a useful study given the fact that groundwater has increasingly been tapped for irrigation and other purposes in many parts of the world and the impact of such practices has not been thoroughly studied. The paper is well organized. The authors have conducted many analyses but not all interesting results are shown. In particular, many statements and conclusions are not supported by appropriate figures. The paper also needs additional editing on word choices and sentence construction.

General response: we appreciate the critical review comments and revised the paper accordingly.

Specific comments are:

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1) Line 17: I believe you meant to say “the meteorological drought severity varies accordingly with mean precipitation”. If this statement is based on Fig.4, it is only true for the 92-95 drought. I don’t see any other results that show the correlation between mean annual precipitation and drought severity. SPIs are anomalies, relative to the temporal mean, and so are generally independent of mean precipitation. Fig. 4 may be an isolated case.

Response: we agree with the comment: SPI should be independent from the mean precipitation. The 92-94 drought is a special case. We revised the text accordingly.

2) Line 25: This is the most important conclusion of the study and it needs more results than what has been presented. Specifically, I would have to see that groundwater can return to its natural state once abstraction stops to believe that it is a feasible strategy. I suggest you extend your groundwater simulation beyond the 4-year period, preferably to 2012, with groundwater abstraction turned off during non-drought years. If groundwater cannot recover to its natural state before the onsite of the next drought, it is not sustainable to use groundwater for emergency water supply.

Response: we accepted the suggestions. We have extended model simulations to 15 years. The model simulation period consists of 4 drought years (taking 1992-1995 drought as reference) followed by 11 normal years. Groundwater is abstracted during the drought years, but switched off during the normal years. The results are presented in the revised figure 12. They show that groundwater levels will recover back to the pre-drought situation after 9 normal years.

Page 2724

1) Line 20: what is “daily infilled precipitation”? Is it daily precipitation?

Response: It is daily precipitation. The word "infilled " is deleted.

2) Line 25: Data gaps do not necessarily suggest lack of reliability. Use percentage of non-missing data instead of data reliability when needed.

Response: accepted and revised.

3) Line 28: high percentage of reliability -> less missing data

Response: accepted and revised.

Page 2725

1) Line 1: time cover -> time period

Response: accepted and revised.

2) Line 9: “and the Lower Crocodile is even scarcer in terms of wells and well data” -> “, especially in Lower Crocodile”.

Response: accepted and revised.

3) Line 19: “are those presented in” -> were provided by

Response: accepted and revised.

4) Line 22: “(Nonner, 2010)” -> Nonner (2010)

Response: accepted and revised.

Page 2726
1) Line 21: what is the time scale of SPI and SRI you calculated in this study?

Response: The time scale for both SPI and SRI is 12 months. We have indicated in the text.

Page 2727

1) section 2.3.2 “Water deficit during drought period”. It would help readers to get a bigger picture of water demand and water availability in the area if you provide a time series plot of annual water deficit/surplus for a relative longer time period, for instance the last 10 to 20 years. I think you have all the data needed.

Response: We have plotted annual water availability and demand since 1960 in a new Figure 9.

3) Line 10 to 12: These two sentences can be combined into one. For instance, “The water deficit per sub-catchment during a drought was computed as the water availability minus the water requirements.” This section describes your methods in general and so there is no need to specify that the calculation is for the most severe drought event.

Response: accepted and revised.

Page 2728

1) Section 2.3.3. Since you calibrated your model, I like to see a comparison of modeled estimates with in situ observations. Provide plots of monthly precipitation, groundwater storage (or levels) from MODFLOW and observation wells, stream flow from the model and gauges for the entire simulation period at selected well sites/gauge stations or as averages over the entire region. These graphs will provide background information on the hydro-meteorological conditions of the region and how difference processes interact with each other.

Response: accepted and revised. The model is calibrated under the steady state. A scatter plot of calculated and observed heads is presented in a new Figure 10. Since there is no systematic groundwater level monitoring in the catchment, transient model is not calibrated.

2) Line 28: “obtained from (DWAF, 2009) study” -> provided by DWAF (2009)

Response: accepted and revised.

Page 2729

1) Line 11: “which drains a large area (>65% of the sub-catchment area) were taken into account”. This sentence does not make sense to me.

Response: accepted and revised. The text is revised as: Only the storage of the major dams (storage capacity > 1.0M m^3) was considered. These are Kwena, Klipkopje, Longmere and Primkop dams with full storage capacities of 158.9Mm^3, 11.9Mm^3, 4.3Mm^3 and 2Mm^3, respectively.

2) equation (1): define what are Tout and Tin.

Response: accepted and defined.

Page 2730

1) Line 20: provides time series plots of SPI and SRI averaged over all stations to accompany this sentence.

Response: accepted and revised. A new Figure 3 is added.

Page 2731

1) Line 3. “most severe” -> “several severe”. Again if you have a time series plot of SPI12, it would be very easy for readers to see these severe droughts.

Response: accepted and revised. The sentence is revised as: Three severe droughts occurred in 1983, in 1992-1995, and in 2003-2004.

2) Line 9. What are “the graphs”?

Response: It referred to Figure 3, revised.

3) Line 20. Was the annual precipitation in Fig. 4 calculated based on precipitation from 1992-1995 or the entire data period? As I indicated earlier, drought severity generally is independent of mean annual precipitation. Do you see similar correlation in other drought events?

Response: The annual precipitation in Fig. 4 was the mean annual precipitation of the entire period. Since the drought severity is generally independent of mean annual precipitation, the contour map of the mean annual precipitation is removed for the revised manuscript. Only the drought severity map is shown in the revised Fig 4. The text is revised accordingly.

Page 2732

1) Line 23: “are not only dependent on precipitation, they are highly affected” -> “are not only affected by precipitation but also”

Response: accepted and revised.

2) Line 25 &28: “the most”-> most

Response: accepted and revised.

Page 2733

1) Line 3: The section title can be changed to “Water deficit and groundwater abstraction”; consequently, the sub-sections of 3.2.1 and 3.2.2 are not needed.

Response: accepted and revised.

Page 2734

1) Line 24: Accompany this sentence with a graph comparing monthly modeled groundwater and in situ groundwater observations either at selected well sites or plotted as averages over all well sites. A graph is worth a thousand words!

Response: accepted and revised. A scatter plot of calculated and observed heads is presented in a new Figure 10.

Page 2735

1) Line 1: again show monthly time series of modeled base flow versus that of observed based flow. In addition, how do you derive base flow from stream flow data which include surface runoff and base flow?

Response: The model was calibrated in the steady state. The long term average values are presented in a new Table 6. Baseflow and direct Runoff was separated using HYSEP, software from USGS for hydrograph separation. A reference is included.

Page 2736

1) Line 15. I don’t understand “monthly stress period considering the longest consecutive drought in the history”?

Response: the sentence is revised as: The monthly stress period is used to consider seasonal variation of groundwater recharge.

2) Section 4.2: As I suggest at the beginning, you should extend your model simulations beyond the 1992-95 period to show if and how quickly groundwater can return to its natural state once abstraction stops. If groundwater cannot recover before the next drought, it is very questionable to implement such abstraction strategy.

Response: accepted and revised as: The model simulation period consists of 4 drought years (taking 1992-1995 drought as reference) followed by 11 normal years. Groundwater is abstracted during the drought years, but switched off during the normal years.

Page 2737

1) Line 15-19: Once again, if this conclusion is based on Fig. 4 only, it is an isolated case and should be clearly indicated. If not, you need to show other results to back it up.

Response: accepted and revised.

2) Line 19-22: Similarly, is this conclusion based on the 1992-95 drought only?

Response: the same conclusion can be drawn from 1983, 2003-2004 drought as shown in Figure 3.

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1) Line 10: revisit this conclusion after you extend your simulation beyond 1995.

Response: The model is extended. The conclusion is re-affirmed.