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Flood impact assessment and proposals for improved flood management in Keimoes, South Africa

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Summary

This study assesses the impacts of the floods in early 2011 in the Northern Cape Province in South Africa and focuses especially on the small town Keimoes located on the major Orange River. During this period 33 municipalities in 7 out of the country's 8 provinces were declared as disaster areas due to widespread flooding. In Keimoes and the Northern Cape Province the flood impacts were widespread with severe effects on agriculture, infrastructure and local livelihoods. As agriculture is widespread along the Orange River in the region this sector was especially affected. The fact that the floods hit during harvesting time meant that the agricultural sector besides damages to land and infrastructure also suffered large crop losses. This study shows that the flood emergency walls in this area were in a very poor condition at the time of the flood and many of them broke and failed to hold up for the high flows of the flood. Information about the upcoming floods was insufficient in some areas which resulted in several communities being poorly prepared. Management of dams upstream in the catchment area came up as a main aspect and data presented here points to the conclusion that flood reduction is prioritized unjustifiably low in dam management. However, given the complexity of this issue and the limitations of this study, more analysis would have to be done on the matter before a new dam management framework can be recommended. The facts and argumentations in this study however justify that such analysis with all its cost and resource implications are initiated.

Keywords: Floods, vulnerability assessment, South Africa, Kai!garib Municipality, flood emergency walls, dam management

Preface

This report is written as a master's thesis for a 5-year Master of Science Degree in Civil Engineering focusing on Water Resources Engineering at Lund University. Furthermore it is the result of a collaboration between the division of Water Resources Engineering within the Department of Building and Environmental Technology, Faculty of Engineering at Lund University in Sweden and the African Centre for Disaster Studies at North-West University in South Africa.

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1. Introduction

In January 2011 large areas in 8 out of South Africa's 9 provinces were declared as disaster areas due to widespread flooding. Large parts of the country had under several weeks up until this period received above normal rainfall. In the Northern Cape Province, located in the downstream end of the Orange River catchment area, the impacts of these floods were especially severe. Floods as severe as this one can affect large parts of society and can be a deeply subversive event. On the other hand the effects will likely be different on different parts of society and on different communities. To be able to improve flood management and reduce future negative flood impacts a deeper understanding must be acquired about how a flood of this magnitude affects different areas and parts of society. Together with knowledge about available resources locally and nationally for flood management such impact analysis can provide insights into how flood management can be improved. And as there are several large dams within this catchment area, dam management issues also become relevant to analyze for flood management issues.

This study focuses specifically on the impacts of the floods in 2011 in the town of Keimoes, a small town with a large agricultural sector along the Orange River in the Northern Cape Province. General data is also provided on the impacts for the whole Northern Cape Province which together with the local data on Keimoes provides an overarching and qualitative picture of the flood impacts in this region. The purpose of the study is thus to make an assessment of the impacts of the floods and based on this assessment propose measures on how to improve flood management and reduce future negative flood impacts in the area. The research question is thus two folded:

1. What were the impacts of the flood in 2011 in Keimoes and the Northern Cape Province?
2. What can be done to improve flood management and reduce future negative flood impacts in this region?

The initial sections of this paper present a theoretical background on climate change and vulnerabilities to floods. This is followed by the results section where the different impacts of the floods are outlined. The next section focuses on dam management prior to and during the floods. And finally the presented results are discussed and recommendations are given for how to improve flood management in the concerned areas.

2. Methodology

For this study data was collected both through reports available online and through field studies in South Africa for two months in April and May 2012. The two months of field studies in South Africa were spent both at the African Centre for Disaster Studies at North West University in Potchefstroom and in the flood affected areas in Kai!garib Municipality. The availability of relevant information specific for the area online was generally poor, and the major part of information in this study was thus collected during the field studies. The information collected during the field studies in its turn mainly consisted of two categories: qualitative interviews with stakeholders and collection of reports from local government bodies and private firms working in the area. The three main such locally collected reports were:

- “Consolidated report – Floods in the Northern Cape January 2011”, done by the Department of Cooperative Government Human Settlements and Traditional Affairs, The purpose of this report was to use it to apply for funding from the National Disaster Relief Grant for expenses and damages caused by the floods (COGHSTA 2011:2)
- “Assessment and verification of flooding disaster and storm damaged infrastructure and costing of recovery and rehabilitation”. Prepared by SRK Consulting for the National Disaster Management Centre (SRK 2011)
- Assessment report done by the provincial farmers union, ORLU, on damages and losses to the agricultural sector (ORLU 2011).

These reports present damage cost estimates of the impacts in the whole Northern Cape Province. These estimates, which are presented later on in this study, are all given in South African Rands (ZAR), where 1 ZAR ≈ 0.1 € at the time of writing. The purpose of these reports is to be used for different funding applications in the aftermath of the floods. Although this study also assesses flood impacts, its scope and purpose is sufficiently different to merit its existence. Mainly, as this study is not based on compensation purposes, new investigations and perspectives of both academic and flood management policy values are presented that are not in the compensation reports.

As there were several reports prepared by departments and private consultants on the matter with a clear quantitative approach, it made sense for this study to complement this data by collecting qualitative data from stakeholders in the area. The qualitative data was collected through both individual interviews and community focus groups. Stakeholders that were interviewed in the flood affected areas were:

- Inhabitants and local farmers
- Consulting firms working in the area
- National and provincial agricultural organizations
- Government officials from the following departments:
    - Department of Water Affairs
    - Department of Agriculture
    - Municipal Disaster Management Offices
    - Department of Social Development.

Two community focus groups with 30-40 attendees each were organized for subsistence and emerging farmers (between subsistence and commercial) in two of the poorer and more sparsely populated flood affected areas to get their opinion and input on flood impacts, and possible flood management improvements. When information from interviews and focus groups with local inhabitants and farmers are used in the paper no individual reference is provided. This is both to respect the anonymity of the interviewees and due to the fact that for most interviews names were not taken. Most of the interviews and both focus groups were held in Afrikaans which is the working language in the area. As the author does not speak Afrikaans an interpreter from the North West University in Potchefstroom was used during the field studies. By using an interpreter from another region the risk of bias for certain stakeholders and perspectives was minimized. At the same time, having to use an interpreter meant that another communication link was added to the interviews and focus groups which complicates them and increases the risk that relevant information gets lost.

Based on this methodological approach the impact assessment in this study has two scopes: one focusing on quantitative cost estimates for the whole province and another focusing more qualitatively on the impacts in Keimoes. This dual scope was supported by the fact that there already was solid quantitative cost estimate data available for the provincial level from other reports, and that incorporating these reports together with new qualitative information brings more depth to this study than it would not have been able to achieve without it. This dual scope also provides readers with an overall idea of the total impacts in the province while at the same time shedding light on the local dynamics of the flood impacts for one of the most severely hit areas, namely Keimoes. And although this study only provides qualitative data for Keimoes and thus leaving out many other areas that were similarly affected, having the qualitative local data from one area together with the general estimates for the province provides a fuller view of the impacts of this flood than each of them would have been able to provide on their own.

For the dam management analysis daily hydrological data prior to and during the floods was acquired from the Department of Water Affairs in South Africa. Based on this data a hydrological and dam management analysis could be performed.

2.1. Limitations

The main limitation for this study was that some data on dam management in the country that would be beneficial could not be acquired. Information on hydropower production from some of the larger dams was not acquired despite several requests to the company in charge of this. Detailed information on the dam management models, framework and decision support system was also not acquired. Dam management is a central theme to this study and therefore had to be assessed by using other data. However, with hydrological data for the main rivers in the country available a strong case could still be built up, but it would undeniably be even stronger if direct access was acquired to the dam management models that are used.

Another limitation is that no focus was given to biodiversity or sustainability issues under the flood impact and flood management assessment section of this study. This was because of necessary scope limitations of the study due to time and resource limitations. The scope of the study is thus anthropocentric and in this sense narrow. However, this somewhat narrow scope enables the study to despite its time and resource limitations provide valuable inputs and insights into the field of flood management in the area.

3. Theoretical framework

3.1. Climate change and water availability in South Africa

Return periods for different flows is a fundamental part of flood management analysis and policies. As return period assessments are based on historic flow data for a specific area recent or unprecedented changes to hydrological patterns can have major implications on the accuracy of these assessments. Knowledge of local climate change patterns thus becomes essential to incorporate into flood management policies to be able to accurately use return period assessments and to prepare for changed hydrological patterns.

Although there is a widespread consensus that southern Africa will face higher temperatures due the climate change under the coming century, the magnitude of changes in temperature and rainfall are highly complex matters and only rough predictions can be given at this point (IPCC 2007 in Cooper et al. 2008:24). Table 1 shows regional temperature and rainfall predictions for sub-Saharan Africa for the end of this century.

Table 1 – Regional predictions for climate change in sub-Saharan Africa by the end of the 21st century (ibid.:25)

Region	Season	Temp. Response (°C)					Precipitation Response (%)				
		Min	25	50	75	Max	Min	25	50	75	Max.
West Africa	DJF	2.3	2.7	3.0	3.5	4.6	-16	-2	6	13	23
	MAM	1.7	2.8	3.5	3.6	4.8	-11	-7	-3	5	11
	JJA	1.5	2.7	3.3	3.7	4.7	-18	-2	2	7	16
	SON	1.9	2.5	3.3	3.7	4.7	-12	0	1	10	15
	Annual	1.8	2.7	3.3	3.6	4.7	-9	-2	2	7	13
East Africa	DJF	2.0	2.6	3.1	3.4	4.2	-3	6	13	16	33
	MAM	1.7	2.7	3.2	3.5	4.5	-9	2	6	9	20
	JJA	1.6	2.7	3.4	3.6	4.7	-18	-2	4	7	16
	SON	1.9	2.6	3.1	3.6	4.3	-10	3	7	13	38
	Annual	1.8	2.5	3.2	3.4	4.3	-3	2	7	11	25
Southern Africa	DJF	1.8	2.7	3.1	3.4	4.7	-6	-3	0	5	10
	MAM	1.7	2.9	3.1	3.8	4.7	-25	-8	0	4	12
	JJA	1.9	3.0	3.4	3.6	4.8	-43	-27	-23	-7	-3
	SON	2.1	3.0	3.7	4.0	5.0	-43	-20	-13	-8	3
	Annual.	1.9	2.9	3.4	3.7	4.8	-12	-9	-4	2	6

In the table 25, 50 and 75 quartiles and minimum and maximum predictions of the spread of change are given. Areas where the 25, 50 and 75 quartile predictions are of the same sign are shaded. Although some trends can be outlined from the table, for instance wetter summers in Eastern Africa and dryer winters in Southern Africa, these predictions show that there are even uncertainties to whether rainfall in the regions will increase or decrease (Cooper et al. 2008:25). Besides general monthly and annual rainfall trends there are climate models that predict that extreme events such as flood and cyclones will occur more frequently (Chagutah 2009:113). What is more certain amidst these uncertainties in climate predictions is that there will be changes in rainfall patterns, although it is at this point not very well known in what direction, or to what degree. And with general increased climate variability there is likely to be more hydrological events that societies are neither accustomed to nor planned for.

Increased rainfall variability is thus likely to increase the stress that for instance poor rural communities are already under, be it more drought or more floods. This is especially true for communities that depend on rain-fed agriculture or pastoralism (Cooper et al. 2008:25). In sub-Saharan Africa almost 90% of total staple food comes from rain-fed agriculture (Rosegrant et al. 2002b in Cooper et al. 2008:25). These farm systems are often very poor and vulnerable, in turn making the majority of the whole regional food production system vulnerable as well.

All of South Africa's water resources are scarce and under stress (DWAF 2009:1). With widespread poverty, continued population growth and the challenges of climate change, even more pressure will be put on the already scarce resources. Decreased water availability will for instance hamper agricultural production and thereby worsen the food security situation. As such, it becomes vital to develop strategies to cope with and adapt to these future water management scenarios, which is part of the purpose of this study. Increased population growth and urbanization mean that land use and runoff aspects must be seriously taken into account in flood management planning. As there is so little known about the future climate in the region, and since the only thing that can be expected with certainty at this point is increased variability, the task for planners and stakeholders is to prepare societies for this. Adaptation strategies and resilience thus become vital elements for the development and planning in South Africa, and especially for rural communities.

3.2. Theoretical disaster vulnerability and resilience

The concepts of vulnerability and resilience to climate stresses are necessarily related to each other. The more vulnerable a community or individual are to a certain stress, the less resilient they are, and vice versa. As such, these two concepts are necessarily linked to each other and must be studied and analyzed together.

Vulnerability of a community can broadly be defined as: "a set of conditions and processes resulting from physical, social, economical and environmental factors, which increase the susceptibility of a community to the impact of hazards" (ISDR 2002 in Adelakan 2011:216). Another definition of vulnerability which adds the element of coping and adaptability is: "the characteristics of a person or a group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner et al.

2004 in Adelakan 2011:216). As a function, vulnerability can be conceptualized as (Smit & Pilifosova 2003 in Ford & Smit 2004:393):

$$V_{ist} = f(E_{ist}, A_{ist})$$

where V_{ist}= vulnerability of community i to stimulus s in time t, E_{ist}, = exposure of i to stimulus s in time t and A_{ist} = adaptive capacity of i to deal with stimulus s in time t. Vulnerability is further defined as a having a positive relationship to exposure and a negative relationship to adaptive capacity (ibid.). Another concept which is also widely used in theories on vulnerability is susceptibility, which is the opposite of adaptive capacity and as such has a positive relationship to vulnerability.

Different aspects that can be placed on the vulnerability/resilience spectrum are: capacity to anticipate and cope with and resist stress, ability to recover from stress, access to resources, social patterns, degradation of environment, access to information, initial well-being, livelihood resilience, self-protection, societal protection, social capital (Reid & Vogel 2006:197). Other studies have identified additional main factors such as: geographical location, exposure of population and infrastructure, socio-economic and cultural conditions, and political and institutional structures (Wisner et al. 2004 & Barroca et al. 2006 in Adelakan 2007:216). Although many of these factors are remarkably general and undefined they together give an idea of what can determine the vulnerability of a community. However, different factors will have different magnitude for different local conditions, and no general vulnerability framework is likely to be applicable for any locality, although some factors are probably prevalent in many cases. Fundamentally, the concept of vulnerability in disaster management for human societies becomes a matter of how climate hazards affect the individual experience. As such, everything that the concerned individual depends on and relates to and which is touched upon by the climate event becomes relevant to take into account when doing vulnerability assessments and when working with vulnerability reduction for human societies.

3.2.1. Vulnerability and floods

Concerning flood events, exposure can be seen as constituted by two categories (Messner & Meyer 2006 in Adelakan 2011:216). The first one is the direct exposure of the element at risk, including aspects such as proximity to a river, topography, elevation of area and frequency of floods. The second category on the other hand focuses on flood characteristics such as duration, velocity, inundation depth, and sediment load. Others have included factors such as water depth rise rate, wave characteristics, and water temperature (Jonkman & Kelman 2005 in Adelakan 2011:216). Depending on water use dynamics in the area water quality could also be a relevant aspect. Susceptibility aspects to floods could for instance be: types of buildings and how they are affected by the floods, anticipation of the flood among the affected individuals (Adelakan 2011:217), transportation and communication needs, agricultural practices and spreading of diseases.

3.2.2. Coping and Adaptation strategies

Where coping is a measure that is undertaken as a direct response to an event, adaptation is rather a matter of enduring systemic changes as a means to increase resilience to future stress events. Examples of coping strategies for environmental stresses in rural households and communities are (UNFCC 2002 in Reid & Vogel 2006:198):

- Intensified labor inputs
- Sale of assets
- Reduced consumption
- Migration
- Usage of mutual support networks

And especially for floods (Adelakan 2011:227*f*):

- Sand filling of erosion prone areas
- Clearance of drainage channels
- Digging of holes and channels
- Construction of barriers
- Draining out water from buildings

The concept of adaptation to climate stresses can further be understood as increased capacity or resilience through changes to livelihoods or surrounding structures. It is thus necessarily linked to the vulnerability/capacity spectrum, but with the added element of change. Adaptive strategies will as such always be related to what makes a community vulnerable or resilient to climate stresses. And any change that increases resilience will be an adaptation. Common adaptive strategies for rural communities to water related climate stresses can be (UNFCC 2002 in Reid & Vogel 2006:198, Adelakan 2011:228):

- Crop and income diversification, i.e. more secure income sources
- Increased social capital, such as:
    - Networks and connectedness
    - Memberships of formalized groups
    - Relationships of trust, reciprocity and exchange
- Investments in physical capital, i.e. improved physical structures, buildings, storm water management, flood reduction/diversion etc.
- Migration or relocation within the community
- Improved health and for southern Africa especially reduced HIV/AIDS prevalence
- Relocating during wet season
- Improved information systems

Perception and awareness of flood risk in the inhabited area has been identified as a significant aspect to explain disaster preparedness (Etkin 1999 & Miceli et al. 2008 in Adelakan 2011:224). It can be assumed that communities perceiving a flood risk are accustomed to floods which will increase the probability that they have undertaken preparedness or adaptation measures to this. As such the frequency of floods in an area is expected to be closely related to both the perception of risk and to adaptation strategies and reduced vulnerability. In the same sense an area with few flood occurrences is expected to have a higher level of vulnerability.

Identified coping and adaption strategies can provide input on how authorities and disaster risk management can assist a community, for instance by supporting them in precisely the identified strategies or spreading them to other areas. The coping and adaptation strategies that individuals and communities undertake will to some extent also bear witness of the extent and severity of the experienced floods. When analyzed thoroughly, some strategies might also be deemed more feasible than others, which could also be an important input for the local disaster risk management authorities.

4. Area and flood description

4.1. Local area description

This study focuses on flood impacts in the Kai!garib Municipality (exclamation mark signifies a click-sound) which is located in the Lower Orange area in Siyanda District in the

Northern Cape Province around 400 km downstream of the confluence of the Vaal and Orange rivers. Special focus is given to the town of Keimoes, which is one of three towns in the municipality.

4.1.1. Siyanda District

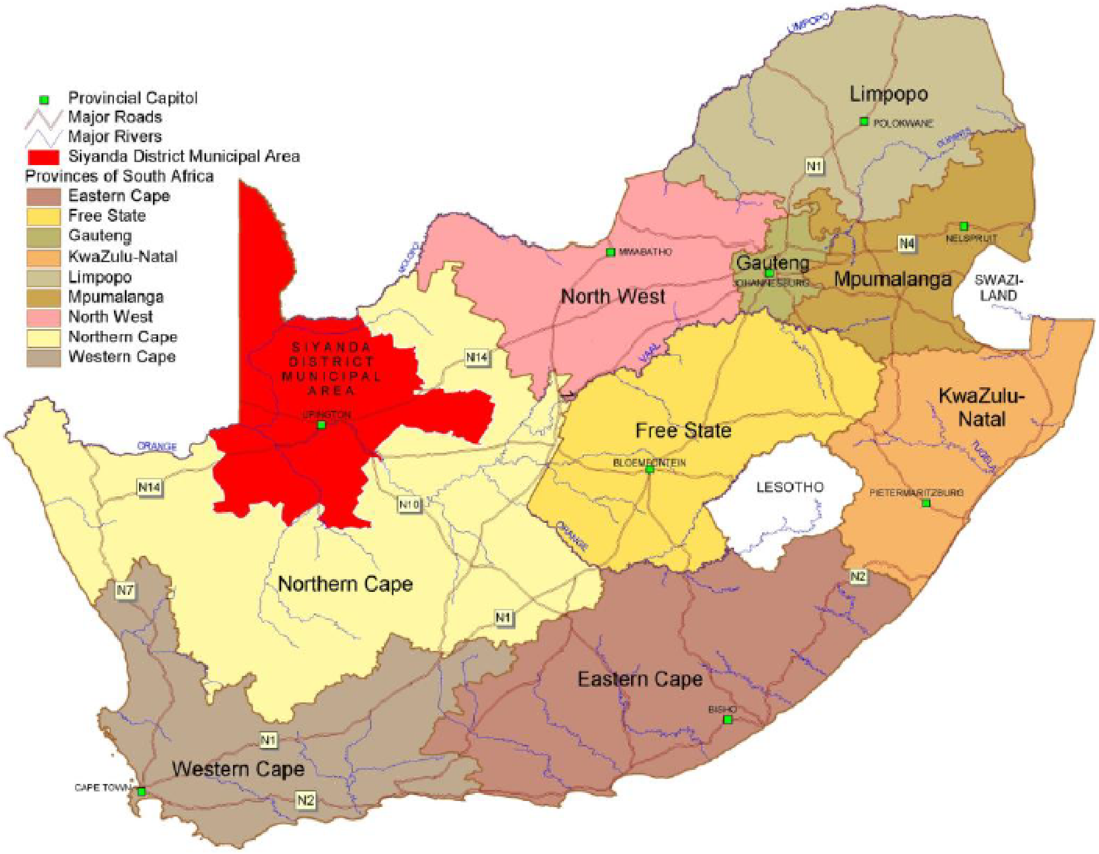

Figure 1 – Siyanda District in Northern Cape Province in South Africa (Siyanda EMF 2008:2)

Figure 1 shows the Siyanda District in the northwestern corner of the country bordering both Namibia to the west and Botswana to the north. The Vaal and Orange Rivers are also marked on the map as major rivers. The confluence between the two is visible just south of the eastern edge of Siyanda District. Keimoes town and Kai!garib municipality is located just south west of the district capital Upington, which is marked in the middle of Siyanda District.

In Siyanda District a network of 121 islands can be found along the Orange River (COGHSTA 2011:15). The district consists of 7 local municipalities, with Khara Hais Municipality with the district capital Upington being the most populated one (74 000) followed by Kai!garib Municipality (56 000) (Atkinson 2007:73, Kai!garib Municipality 2009:10). It is a semi-arid sparsely vegetated district with intense irrigation farming on these islands and along the Orange River (COGHSTA 2011:15). The location of the islands provides fertile soil and easy access to water, but on the other hand makes them very vulnerable to raised water levels and flooding. The landscape is furthermore predominantly flat with occasional and distant hill formations. The average annual rainfall is 189 mm (Kai!garib Municipality 2011b:18). Although a semi-arid area, the low population makes the water availability per capita high (ibid.:22). The vegetation along the river in the area is classified as Lower Gariep Alluvial Vegetation and is considered endangered with 50% transformed by agriculture and only 6% conserved (in the Augrabies National Park) (ibid.:18). There is a notable infestation of alien vegetation on the banks of the Orange River in the area (ibid.:21).

4.1.2. Kai!garib Municipality and Keimoes town

Figure 2 – Satellite image of Keimoes and the Orange River (Google 2012)

Figure 2 gives an idea of the landscape around Kai!garib Municipality with a green and lush stretch of vegetation along the Orange River surrounded by a vast desert landscape. In figure 2 the branching pattern of the Orange River in the area is also visible, as are the extensive agricultural lands. The town centre of Keimoes is located in the t-junction of the N14 and the R27, located in the centre of the figure. The dominant language in the municipality is Afrikaans and it covers an area of 7 449 km^2 and has three towns: Keimoes, Kakamas and Kenhardt (Kai!garib Municipality 2009:9). 57% of the inhabitants are youth and 46.5% are dependent on government pensions, meaning that they have a monthly income of ZAR1800 or less (Kai!garib Municipality 2009:10;2011b:10). Furthermore, 34% have no income and 22% are dependent on social grants, of which 52% are child support grants (Kai!garib Municipality 2011b:10). Identified major social issues are: HIV/AIDS, high rate of teenage pregnancies, high levels of unemployment, increase in drug and alcohol abuse and increase in crime (ibid.:11). Lack of proper water and sanitation services and storm water systems are identified as other priority issues for the area (ibid.:7).

In Kai!garib Municipality the agricultural sector is the main economic sector and the largest employer in the area. One source estimates that the agricultural sector has 6 531 workers in the municipality (ibid.:11), while another source gives this number to be 15 214 (Atkinson 2007:74). Even though these numbers differ greatly, probably due to different definitions used for what a job related to agriculture is, high unemployment numbers mean that both estimates would make agriculture the biggest employer in the area. Commercial farmers mainly grow grapes but other plants are lucerne, cotton, corn and nuts (Kai!garib Municipality 2011b:11). Some constraints for further agricultural development that are identified are poor quality of access roads, lack of finances for emerging farmers and limited cultivation and activities outside of harvest seasons (ibid.). Expansion and diversification of the irrigated agricultural sector are also identified as a potential future economical driver for the area (ibid.). Heavy floods and their impact on the agricultural sector are pointed out as a main threat to development in the area (ibid.:9).

The town of Keimoes and its surroundings consist of several islands with varying size on the Orange River. In general, the island groups are divided into the Northern, Middle, and Southern Islands. Some of the names used for the islands within each group have more official recognition than others, and apparently new names are coming up without the knowledge of the municipality’s office. It should also be noted that some areas are referred to as islands without being surrounded by water and the island prefix has as such become a common feature in local area denomination. Official classification is further obstructed by the fact that the Kai!garib Municipality’s office currently lacks maps of the area.

There are no demographic studies available that distinguish between different areas and islands. Based on the author’s field studies in the area the following general demographic trends however came up:

- The Northern Islands - mainly subsistence and emerging farmers.
- The Middle Islands - mainly emerging farmers
- The Southern Islands - mainly commercial farmers of different scale, some of them large scale

And as farming is widespread in the area it is generally sparsely populated. The Eksteenskuil Farmers Cooperative is an organization supporting subsistence and emerging farmers in Keimoes. Of its 84 members, 34 reside on the Northern Islands, 32 on the Middle, and remaining 18 on the Southern Islands (Eksteenskuil 2012).

4.2. The 2011 floods in South Africa

In January 2011 several regions in South Africa were heavily flooded (SRK 2011:9). 33 municipalities in the provinces of Eastern Cape, Gauteng, Kwazulu-Natal, North-West, Free State, Mpumalanga, Western Cape and Northern Cape were declared as disaster areas (ibid.). Only the Limpopo province in the north eastern part of the country was left without disaster declaration. The Orange River catchment area, which covers 49% of South Africa’s surface (DWA 2011) had under several weeks up until this period received above normal rainfall. In the downstream end of the catchment area floods were especially severe.

4.2.1. The Orange River Basin

The Orange River basin (sometimes referred to as the Orange-Senqu River basin) is an international river basin, shared by Botswana, Lesotho, Namibia and South Africa. It originates in the highlands of Lesotho and flows westwards to its mouth in Namibia and the Atlantic Ocean.

Figure 3 – Orange River Basin (ORASECOM 2007:6)

The total catchment area is 896 368 km^2 (Earle et al. 2005:1). The Orange River has several main tributaries, for instance: the Vaal River in central South Africa, the Caledon River in North West Lesotho, and the Ongers and Sak rivers draining from the western parts of South Africa (ORASECOM 2007:15). For a more thorough presentation on the tributaries in the basin see ORASECOM 2007. Figure 3 also has the main dams marked, which in South Africa are: Vaal Dam and Bloemhof Dam on the Vaal River, and Gariep Dam and Vanderkloof Dam on the Orange River. Commonly used sub water catchment areas are the:

- Vaal river catchment area
- Upper Orange river catchment area - consisting of the catchment area for the Orange river upstream of the confluence with the Vaal river,
- Lower Orange river catchment area - located downstream of this confluence to the mouth in the Atlantic Ocean

These sub catchment areas together with natural runoff are presented in figure 4.

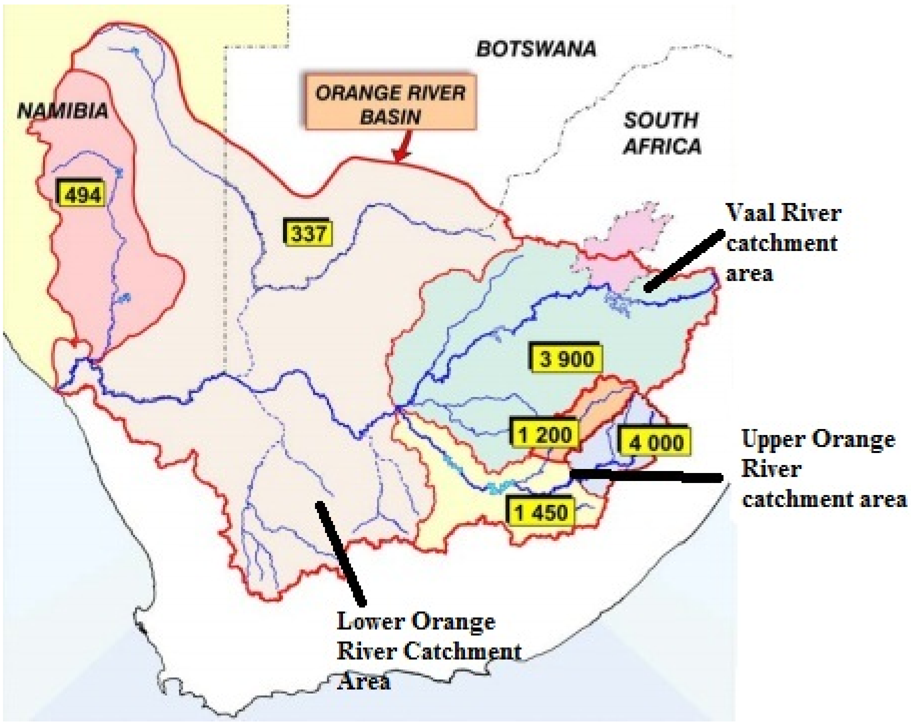

Figure 4 – Sub catchment areas and estimated theoretical natural average annual runoff volumes for the Orange River Basin (ibid.:7)

In figure 4 the Upper Orange river catchment area is divided into three smaller sub areas. The numbers given in the figure are estimates of the natural runoff in million m^3/year had there been no developments in the area (ibid.). Actual annual average runoff at the river mouth is around 175 m^3/s which is considerable less than the 350 m^3/s (=11 000 million m^3/year) which the estimates in figure 4 gives. This is mainly due to major water extractions in the Vaal River basin for domestic and industrial purposes as wells as for extensive irrigation schemes and mining in the Lower Orange river catchment (ibid.:8). Furthermore, evaporation losses account for around 500 to 1 000 million m^3/year depending on the flow and thus surface area of the water (ibid.).

4.2.2. Flood specifics

Kai!garib Municipality and Siyanda District have experienced floods in the past. The biggest one was in 1988 with a peak flow in Upington, located 40 km upstream, of 7 400 m^3/s, equivalent to a stage level of 9.4m (DWA 2012d). Figure 5 shows all the peak flows above 3500 m^3/s that have been measured in Upington since 1944.

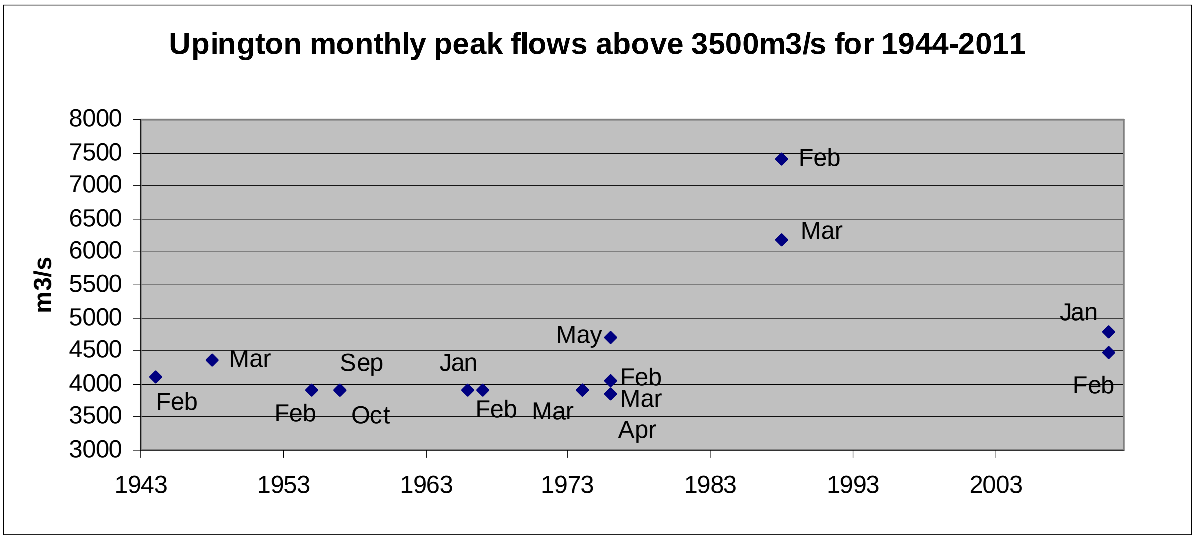

Figure 5 – Peak flows in Upington 1944-2011 (data from DWA 2012d)

Figure 5 shows that the area has had flood events 15 times during the past 68 years. As these are monthly peaks, some peaks are part of the same continuous flood. 12 of the peaks occurred in January-March, 1 in April, and 1 in September and October (same year). Furthermore, it can be seen that the peak flow of the 1988 flood, which peaked both in February and March as indicated in the figure, is significantly higher than any other peaks in the area. Of notice is also the considerable gap between the 1988 and 2011 floods.

During El Nino cycles there is a higher probability for dryer summers in the area, while La Nina cycles imply higher probability for wetter summer periods (DWA 2011a). During the months before the floods in January/February 2011, large parts of the country had above normal rainfall, as indicated in figure 6.

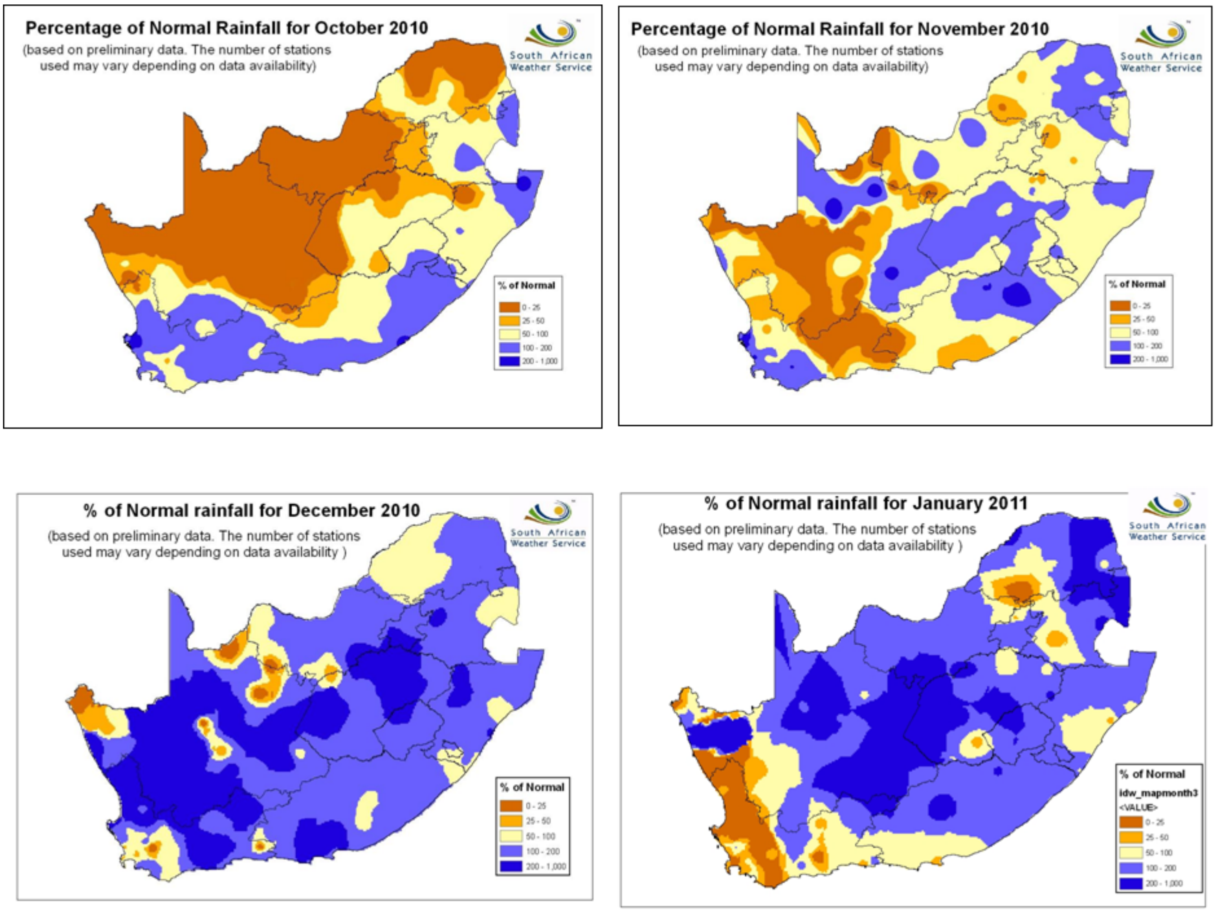

Figure 6 – Percentage of normal rainfall in South Africa for Oct 2010-Jan 2011 (ibid.)

As given in figure 6, light and dark blue colors indicate above normal rainfall. As figure 3 shows, the catchment area for the Orange River system covers large parts of the country, and especially the inland parts. So although these catchment areas had low rainfall in October, they received large amounts of above average rainfall from November 2010 until January 2011.

There is no flow measuring station in Keimoes and its flow will therefore be approximated by the average of the flows at measuring stations in Upington, 40 km upstream of Keimoes, and Neusberg, 20 km downstream of Keimoes. As Keimoes is situated between these two measuring stations and since there are no significant tributaries in this section, the flow in Keimoes can safely be assumed to be in between the two presented hydrographs.

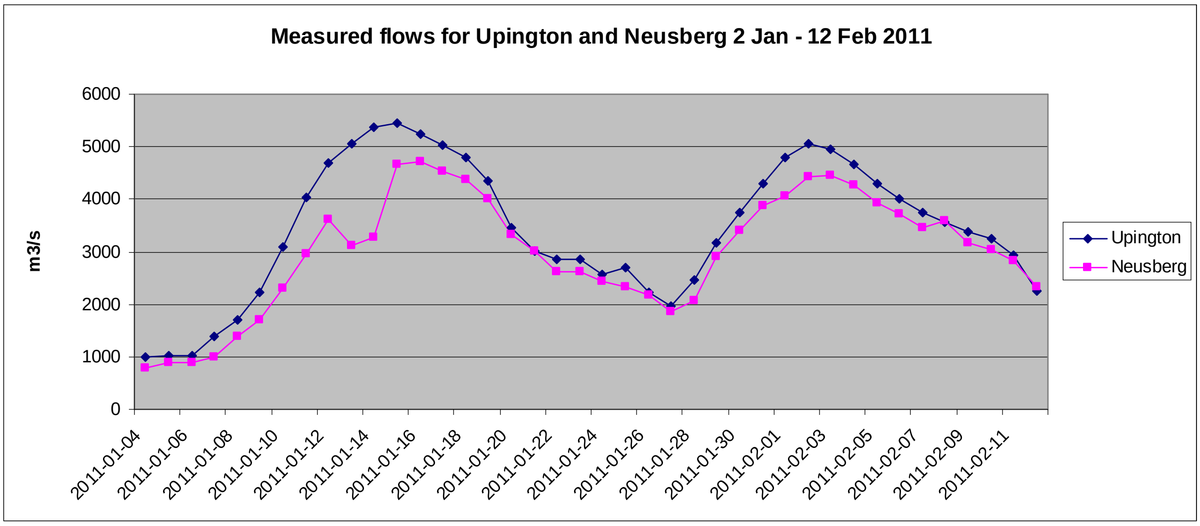

Figure 7 – Flows for Upington and Neusberg during the 2011 floods (flow data from DWA 2012a)

The hydrographs in figure 7 show that the area experienced two peaks during this period, one approximately on the 15-16 January with a peak flow of around 5000 m^3/s, and another one with a somewhat reduced peak flow around the 2-3 February. For Upington, a flow of 5 100 m^3/s is equivalent to a stage level of 7.7m (DWA 2011c). The sudden drop in flow for Neusberg on 13-14 January is probably explained by measurement errors, possibly due to high flows. As these peaks came with such a short interval and given the amount of water in the area this meant that several parts experienced continuous flooding over this period. The flows and return period of these flows are given for different points in the river system in table 2.

Table 2 – Flows and return periods for the 2011 floods (data from DWA 2011a)

		First flood		Second flood	
River	**Measurement point**	**Flow (m^3/s)**	**Return Period (y)**	**Flow (m^3/s)**	**Return Period (y)**
Vaal River	Vaal Dam inflow	2 900	15	1 650	<5
	Bloemhof Dam inflow	3 600	20	1 700	<5
Orange River	Gariep Dam inflow	2 700	5	5 3000	10
	Vanderkloof Dam inflow	2 700	15	3 400	<25
Orange River after confluence with Vaal River	Upington	5 100	20	5 100	20

Upington and Keimoes thus received two 20 year floods within 2-3 weeks during this period. Of notice is also that the Vaal River dams had significantly longer return periods for the flows during the first flood (15 and 20 compared to <5 and <5), while the Orange River dams had longer return periods for the second flood. As described in the catchment area section previously the Orange River catchment area is very large, covers different landscapes with different hydrological patterns and has several major water infrastructures in it. These are all factors that can explain why the flows differ so widely between different points in the system and at different times.

5. Results

5.1. Flood impacts

The impact section is divided into the following impact categories: transportation, emergency relief and health issues, education, agriculture, infrastructure and finally a cost summary of the damages in the province. For the provincial scope only quantitative cost assessments will be presented, while more qualitative data will be given for the case of Keimoes. Data from the three reports on cost implications due to the floods that were mentioned in the methodology section will be presented here as well. As such, data that is not referred to any of these reports (COGHSTA 2011, SRK 2011, ORLU 2011) is data from interviews and meetings that were conducted during the field studies.

5.1.1. Transportation

The geography of Keimoes with its many islands on the river branches means that there are many bridges across the river, points that were all severely affected by the floods. Just as the islands, these bridges are generally low lying. At a certain time during the floods all of the islands in Keimoes were cut off for transportation as large areas and all bridges were submerged (DMU Siyanda 2011). According to another assessment, which was used to coordinate the emergency relief programs, 30 of Keimoes 44 islands, housing 321 households, were totally cut off due to the floods (Kai!garib Municipality 2011a). Farmers of the Northern Islands and officials working in the area stated that this area was cut off for 3 months due to the floods. Farmers from the Middle Island reported that they were completely cut off during 1 month, but that their lands were flooded for 2 months. The Southern Islands still had some roads available further south towards Kakamas, which could be used for both supplies and sales of yields, and was as such only partly cut off. One main aspect concerning transportation issues is the type of roads in the different areas. In the Northern Islands there are only gravel roads and no paved roads. For the other two island groups this varies a bit, some parts are paved, especially main roads, while others are gravel. Gravel roads quickly get muddy and useless when under water, while paved roads resist a high water level better.

To what extent people report to be cut off depends on their livelihoods and the areas they frequently visit. For instance, a commercial farmer on Kanoneiland, a smaller town just upstream of Keimoes, said that their exports were barely affected by transportation issues as they could still reach and export their grapes to Upington, located further upstream. However, the same farmer had to use alternative routes to reach the farming land for harvesting as the main access bridge was cut off, which added almost 80km in each direction, significantly raising the operational costs for the farm. Figure 8-10 below shows a sequence of photos before and during the floods for the largest bridge in Keimoes.

Figure 8 – Main bridge before floods (Eggers 2011)

Figure 9 – Main bridge with raised water levels (Eggers 2011)

Figure 10 – Main bridge submerged, picture taken just before the bridge was shut off in January (Eggers 2011)

This sequence of photos shows the significant rise of water level of the Orange River during the floods.

Roads and transportation being cut off obviously has widespread effects on people's livelihoods in the area, especially as large parts of the area are rural and sparsely populated with daily transportation needs for employment, farming, education and food. When the flow was at its highest not even boats could be used in the water as the currents were too strong. When the currents calmed down some farmers were able to use boats to get access to their fields. This enabled inspection of the field and to some extent harvesting, although profoundly hampered without full access to normal transportation means.

5.1.2. Emergency relief and health issues

As the area was declared a disaster area a large emergency relief operation was undertaken. Beside government bodies several private and non-governmental organization were involved in the relief programs, such as the South African Red Cross Societies and Gift of the Givers. The South African National Defense Forces also assisted by providing helicopters for evacuations, food delivery and recon missions. Overall in the Northern Cape Province a total of 2 983 households were reported to have been affected by the floods (COGHSTA 2011:6).

Communities on 28 islands in Keimoes compromising a total of 995 households were deemed to be in need of emergency relief due to the floods (DMU Siyanda 2011). On January 17th it was reported that 77 people over the past days had been relocated from their islands to a hostel in the city centre of Keimoes (DSD 2011a:2). On January 31st, a further 120 children and 220 adults were relocated to different hostels in town (ibid.). One mother complained about how she was separated from her children as they were being taken to stay at a different hostel for several weeks to be able to attend school. In the district there were a total of 144 evacuations and 264 medical evacuations during the floods, with a majority of them taken place in Keimoes (DMU Siyanda 2011). Several individuals however stayed on the islands, both as there were limits to how many the city hostels could accommodate, but also out of individual willingness to stay on the islands to try to manage the farms and to protect the household against thefts. Some community members also expressed strong relationships to their island where they "had always lived and would never leave". At one of the community meetings on the Northern Islands there were several complaints about people not receiving enough food during the flood from the relief programs. Another farmer from the same meeting said that they did receive food but they had to wait for it. One female said that she had to follow her sick father for a helicopter evacuation and then could not get back to her family on the island and was separated from her children for two weeks. One interviewed farmer of the Northern Islands who had experienced floods before stressed how, with growing age, it was more difficult to handle the floods, as health was no longer as good and due to having lost the ability to swim.

Different reports give different accounts on the number of deaths caused by the flood. One report counted 5 cases of drowning in Kai!garib Municipality (NJOC 2011a), another one gave 9 fatalities for the whole province (COGSHTA 2011:6) and a third assessment counted 40 flood related deaths for the whole country (IFRC 2011).

During the floods around 400 cases of diarrhea were reported in the district (NJOC 2011a). Large amounts of standing water and already poor water and sanitation infrastructure in the area are all factors behind this. Approximately 15 tons of food and 5 tons of animal food were delivered by the South African National Defense Forces (ibid.). Estimated costs of their operations were ZAR 1 014 000 (ibid.). Due to the islands being cut off and transportation being obstructed each case requiring medical attention or medical supplies became an issue. People in need of such assistance are thus especially vulnerable during a flood of this extent.

Throughout the floods, the Department of Health reported expenses of ZAR 1 225 459, which however includes salaries for calling in off-duty staff and staff working extra hours (COGHSTA 2011:10). On top of this, the Department of Social Development had expenditures of ZAR 51 664 000 to be able to provide food parcels, blankets, mattresses, school uniforms, soup kitchens, clothing, essential furniture and utensils (ibid.:11).

5.1.3. Education

To be able to have continued education for the flood stricken areas around 100 students in Keimoes areas were relocated to a hostel of the Keimoes High School during the floods (Department of Education 2011a). An amount of ZAR 287 000 was spent by the Department of Education on beds and mattresses to accommodate them (NJOC 2011). Furthermore, around 300 students from Kanoneiland just north of Keimoes were provided with transportation through Upington to their primary school in Blaauwskop, which is located between Kanoneiland and Keimoes, as all other bridges and access roads were closed (Department of Education 2011a). The costs for these extra transportation measures came at a monthly cost of ZAR 280 000 (Department of Education 2011a). In addition to this, some schools were left without teachers as they could not reach their institutions. For instance, the Neilersdrift Primary School, housing 470 students, was reported to be without teachers for an unknown amount of time (ibid.). By 7 February, 169 students were still stranded on some of the islands in Keimoes, waiting for the water level to drop to regain access to roads (ibid.). Within the whole Siyanda District approximately 2 000 students were provided with extra transportation during the floods (NJOC 2011a). Besides this, no schools were reported to have been physically damaged by the floods (NJOC 2011a).

The total cost of these measures in the province for the Department of Education is reported to be ZAR 978 400 (COGHSTA 2011:8). Of these costs, transportation of students and teachers constitute the main expense with an estimated cost of ZAR669 000 (ibid.).

5.1.4. Agriculture

Due to easy access to water for irrigation purposes and the prevalence of fertile soils agriculture is widespread along the Lower Orange River. Being in low lying areas adjacent to the river makes these areas prone to floods. As such, the floods that hit the area had devastating effects on agriculture. The following general effects were described in a government report on the flood impacts (ibid.:6).

- Most cash crops whose roots submerged suffocated
- Moveable irrigation infrastructure on river banks, such as pumps and dragline systems, had to be removed by land owners to avoid further damages, resulting in irrigation systems being disabled during this time
- Irrigation was further disrupted as electricity supply had to be cut off to protect transformers from damages and due to the threat it could otherwise pose to human lives
- As roads in general were flooded access to crops was severely obstructed. Many crucial agricultural activities, such as orchard maintenance, disease control and harvesting could therefore not take place
- Several farm workers with families had to be evacuated from low lying areas.

Another major concern is soil issues. Firstly as the floods washed away fertile soil and secondly as large amounts of sediment were deposited on the farm lands after the water withdrew. There have been discussions on whether this sediment is good or bad for future farming. Some farmers claimed that this sediment is nutritious but officials at the Department of Agriculture (DoA) stated that due to upstream mining activities and their acid effluents the pH levels of the river are too high, generally around 8 compared to the desired soil pH of around 6.8-6.9 (DoA 2012a). Although the pH in the sediment is generally lower and could in that way balance out the high pH of the river, sediments from the river are not believed to be good for farming purposes by DoA officials (ibid.). The raised water levels also increased the salinity in the soil and lowered the nutrition levels by washing nutrients out. A senior viticulturist at a wine cellar in the area estimated that if river levels can stay low for the coming two seasons the salinity levels would go back to normal (Jordaan 2012). Afterwards soils had to be treated with nutrients like calcium and sodium to raise the nutrient levels. Depending on soil characteristics it will take different amount of time to completely restore the soil quality; one large scale commercial farmer expected that with soil treatments there would be 50-60% of the normal yield for the coming 4-5 years. Another farmer reported to have had 40% of the normal yield in 2012, 1 year after the flood, due to soil issues. Other small scale farmers from the Northern Islands community meetings said that 1 year later much of the land on their island still was not back to normal and that they had had poor harvests this year.

On 7 February 2011, approximately three weeks after the first flood hit, DoA published a report that stated the following impacts in the Northern Cape province (NJOC 2011a):

- 5 800 ha of vineyards damaged
- 17.6 km of flood diversion walls damaged
- 3 978 permanent job losses and 53 105 temporary job losses
- Around 1 000 people evacuated from the agricultural areas

Furthermore the farmers union in the region (ORLU) compiled a report with the following impact assessments for the Northern Cape (ORLU 2011):

- 7 070 ha of farm land under water
- 2 255 ha cut off but can still be harvested
- 8 606 ha can not be irrigated and may wither

One aggravating aspect is that it was harvesting time in the area when the flood hit. Due to this there was a large amount of seasonal workers expecting to find work in the region. A majority of these seasonal workers travel from Kuruman, a city 300 km north east of Keimoes (DoA 2012b). The floods effectively cancelled the absolute majority of these seasonal job opportunities as only a very small amount of the total yield was harvested. It is estimated that 55 605 seasonal job opportunities in the province were lost that year due to the flood (COGHSTA 2011:15). The impact is further aggravated by the fact that these seasonal agricultural workers generally are very poor and seasonal employment might be their only source of income with which they have to support a whole household (ibid.).

Crop losses

The main aspect of the agricultural impact is the crop losses. Harvesting time for grapes, which is one of the largest crops in the area, occurs annually in the end of January. As the flood in 2011 struck during harvesting time the agricultural sector was especially vulnerable. Inaccessibility to farm lands due to obstructed transportation and submerged crops effectively led to substantial crop losses that year. Officials at DoA also observed that the main issue for commercial farmers was flooded lands, while a bigger issue for emerging farmers was access to their lands (DoA 2012b). During the flood in 1988, which was the latest flood of this magnitude, farmers could still harvest their yields in both that and the coming year as the flood hit in March-April which was outside of the harvesting time (Koms Consulting 2012). Impacts on agriculture were therefore significantly less in 1988 than in 2011.

The location of the plants was of high significance for the impacts. One large scale commercial farmer stated having lost 200 out of the annual 350 ton raisin yield, depending on where the water broke in and where the water pools formed. Another commercial farmer on especially high grounds in the area on the contrary stated that the floods did not even affect the yield that year as the water did not reach the lands. Younger vineyards suffered more damages than older ones as they are shorter and were more easily submerged. Depending on the height of the plant and the water table, some plants died while others survived. As such, older and taller plants had higher chances of surviving.

The DoA estimated that 7 359 ha of crop lands were flooded in the province, causing crops to suffocate and grapes to rot (COGHSTA 2011:14). 80% of the grape harvest in the province could not be reached and was lost (ibid.:15). One farmer at the community meeting on the Northern Islands in Keimoes said that everyone in their community was affected by the floods, and that nothing could be harvested. By having each farmer in the province filling out forms after the flood on expected yield and actual yield that year, the regional farmers union ORLU, based on market prices at that time, estimated the total value of crop losses in the province to ZAR 2 488 000 000 (ibid.:14, ORLU 2011).

Agricultural infrastructure

The majority of irrigation areas in the Lower Orange River area bordering the river are protected by flood diversion walls (COGHSTA 2011:14). Many of these walls were severely damaged and failed to keep water from the areas they were supposed to protect (ibid.). Especially walls in low lying areas were damaged by the flood (Koms Consulting 2012). One reason given for their failure was lack of maintenance (COGHSTA 2011:14).
Farmers from both community meetings held on the Northern Islands stated that the communal flood emergency walls for their islands had neither been inspected nor maintained for a very long time. After the flood in 1988 there were substantial repairs to damaged walls in the area, however these walls have in general received no maintenance since then (ORLU 2012). Some large scale commercial farmers however reported that they have conducted regular maintenance on their private emergency walls.

Officials at the DoA stress that there are institutional difficulties to the flood wall issue. There is namely an ongoing governmental land reform program where the government buys land from private owners to give it to disadvantaged citizens. Because of this it is on some parts of the islands unclear who has the responsibility for the walls (DoA 2012a). For some areas in Keimoes, farmers claim that it is the government's responsibility, while the government claims that it is not (ibid.). Something that is further aggravating the situation is that the state of the flood walls is something that affects everyone in the area, not just the farmer closest to the wall (ibid.).

A farmer on Kanoneiland, located just upstream of Keimoes said that as the emergency walls held for their island they did not suffer any damages. And due to water compaction it was even believed that the flood made their emergency walls stronger. The same farmer however added that a further 1 meter raised water level of the flood would have implied big problems for their part of the island.

One of the impact assessment reports for compensation and funding assessed the number of damaged farms in the province to 923, while a later assessment only estimated it to 663, a reduction which was explained by some farms having been counted as flood damaged when their damages turned out to have other causes (SRK 2011:19). The cost implications for the later assessment, conducted by SRK consulting firm for the National Disaster Risk Management Centre, are presented in Table 3.

Table 3 – Agricultural infrastructure impact assessment according to the SRK assessment (ibid.).

	Farms	Cost estimate (ZAR)
Siyanda District	618	1 009 691 271
Northern Cape Province	663	1 021 161 103

These estimates, with Siyanda District having 93% of the damaged farms and 99% of the provincial agricultural infrastructure damages, clearly show that the agricultural sector in Siyanda District was the worst hit in the province.

Another impact assessment report, conducted by Department of Cooperative Government Human Settlements and Traditional Affairs (COGHSTA), on its turn estimates total agricultural infrastructure damages in the province to ZAR 935 000 000, which is based on data collected by the provincial farmers union ORLU (COGHSTA 2011:14). Of this estimate, around ZAR 500 000 is on land and soil, and the remaining ZAR 435 000 on walls and waterworks (ORLU 2011).This assessment reports 854 affected farmers, out of which 293 were classified as emerging farmers (ibid.). This estimate of ZAR 935 000 000 is somewhat lower than the provincial SRK assessment in table 3 of ZAR 1 021 161 103. As the COGHSTA report together with the ORLU assessment presents more detailed information, the estimates presented in their reports (ZAR 935 000 000) will be the ones used for the final cost summary.

5.1.5. Impacts on non-agricultural infrastructure

An early assessment on infrastructure impact, excluding damages on houses and agriculture, in the Northern Cape Province was finished in February 2011 and estimated the damages to ZAR 275 833 627 (SRK 2011:9).

Housing

Table 4 presents damages to housing from two of the impact assessment reports.

Table 4 - Housing impact assessment according to the SRK and COGHSTA assessments (SRK 2011:18, COGHSTA 2011:7)

	SRK Assessment		COGHSTA Assessment	
	Damaged houses	Cost estimate (ZAR)	Damaged houses	Cost estimate (ZAR)
Keimoes/Kakamas area	-	-	1 095	71 175 000
Siyanda District	1 417	18 934 175	-	-
Northern Cape Province	3 742	44 650 359	2 983	175 435 000

The COGHSTA report gives a lower count for total damaged houses, 2 983 compared to 3 742, out of which 1 095 were in Keimoes and 1 000 in Barkly West which is a small city located next to Kimberley just upstream of the confluence of the Vaal and Orange River (COGHSTA 2011:7). These figures further confirm that Keimoes was one of the most severely hit areas, and especially so for the area downstream of the Vaal and Orange River confluence. However, the COGHSTA report, although using a smaller amount of damaged houses presents much higher cost implications. Explanations for the varying cost estimates could be that houses have been deemed to be in need of different repair measures, different cost rates for the repairs have been used, or both. As the SRK report contains more detailed methodology on this section the estimates from this report are assumed to be more accurate and will be the ones used in the final cost summary.

Roads and bridges

As stated before, several roads and bridges were inaccessible and under water. The flood impacts on roads and bridges were thus widespread. The COGHSTA report estimates road costs as follows:

Table 5 – Roads impact cost assessment in COGHSTA report (COGHSTA 2011:13)

	Paved roads (ZAR)	Gravel roads (ZAR)
Siyanda District	7 800 000	12 599 826
Northern Cape Province	35 300 000	134 055 398

The SRK assessment reports that 1 bridge and 125 roads (2,526km) were damaged in the province, with the following cost estimates (SRK 2011:20).

Table 6 – Roads and bridges impact assessment according to the SRK assessment (SRK 2011:20).

	Number of bridges	Cost estimate (ZAR)	Number of roads	Cost Estimate (ZAR)
Siyanda District	-	-	17	79 156 27
Northern Cape Province	1	150 000	125	373 320 096

Total road cost according to the COGHSTA report (ZAR 169 000 000) is significantly lower than the estimate from the SRK report (ZAR 373 000 000). Reasons for why the cost estimates from these reports once again differ so much can be due to two main reasons: either due to differences in covered area and thoroughness, or through usage of different cost rates. None of the two reports state the used cost rates, and any comparison of the accuracy of them is thus impossible. With no further information on the cost rates, it will be assumed that the higher estimates of the SRK report (Table 6) is due to it being based on more reported damages, and as such holds more accurate information about the impacts. And as argued previously the SRK report contains a more detailed methodology. This is thus the data that will be used for the final cost summary.

5.1.6. Summary of cost estimates for Northern Cape Province

Table 7 summarizes the cost estimates from the different impact categories outlined previously.

Table 7 – Cost summary of flood impacts in Northern Cape Province

Section	Costs (ZAR)
Education	978 400
Health	52 889 459
Agriculture (infrastructure)	935 000 000
Agriculture (crops)	2 488 000 000
Roads and Bridges	373 320 096
Houses	44 650 359
TOTAL	3 894 838 314

It should be noted for this summary that the Education and Health categories are solely expenditures during the emergency relief program, while the other categories are assessments of repair costs (infrastructure) and loss of sales and value for crops. Together they however provide an insight into the overall monetizable damages of the 2011 flood of for the Northern Cape Province. This estimate also provides insight into what measures that might be worth taken to reduce and avoid future floods of similar magnitude. But what is also important to remember when assessing impacts of this kind is that only part of the impacts are quantifiable and monetizable as the categories presented in table 7 are. Other dimensions that were brought up in the impact section such as time spent away from family, hunger, health issues, being stranded and general hardship are not as easily quantifiable and are thus not incorporated in these cost estimates. Even though they are not quantifiable within cost impact frameworks they still constitute an important part of the impacts that should not be neglected when flood impacts are assessed and discussed.

5.2. Flood preparedness in Keimoes

The following section covers the preparedness among the inhabitants in Keimoes. As indicated in the theoretical sections in the beginning preparedness and awareness among inhabitants are identified as major aspects in vulnerability and resilience towards floods.

5.2.1. Information about the floods

The local Department of Water Affairs office in Kakamas, next to Keimoes, which is responsible for dissemination of flow info in the area, receives flow data and flood warnings approximately 7-9 days in advance and also verifies this predicted flow with the actual flow in the area. This data is also made publicly available on the department's web page. According to local officials at this office, local flow predictions are generally accurate.

Large scale commercial farmers in Keimoes generally had a good idea of what levels of water they were expecting, and when this would happen. Main information sources for this were dam and river flow levels from the Department of Water Affairs homepage, together with contact with fellow farmers in the area. However from the two community meetings held with small scale farmers on the Northern Islands several individuals expressed the need for more accurate information. Some did receive warnings of a coming flood, but not to what extent, and others had no idea that there was an incoming flood. The information that was received came from either phone calls or visits from staff at the municipality's office. One individual told of how the roof of the house broke before realizing that there was a flood coming. As such there were requests of having more specific flood warning information for their area, indicating what areas that would be flooded and to what extent. An issue for this is that there for the moment are no flood line studies or inundation maps for this area.

This information shows that there is a wide spread in the means and level of access to information between different individuals and groups in Keimoes. Some were very well informed about the coming of a flood and its magnitude, while others apparently did not even know that there was a flood coming.

5.2.2. Preparations and adaptations

Based on the information available to inhabitants prior to the floods it becomes interesting to assess what kind of preparations and coping measures that were taken.

During interviews with farmers and individuals in the area a couple of reported preparation strategies were reported. Farmers at the community meetings on the Northern Islands however emphasized how there was no way to prepare for a flood like this besides getting good early warnings and information about it. Reported preparations and coping strategies by large scale commercial farmers in different areas on the other hand include:

- Taking workers out of low lying lands
- Stacking up with food
- Strengthening flood walls with sand bags
- Continual assessment and monitoring of damages and leakages
- Opening up sections of private emergency walls to let water enter lands and build up on both sides of remaining emergency and diversion walls, thus reducing the pressure on them as there is water on both sides. In this way, walls were kept intact.
- In anticipation of the flood some grapes were harvested earlier at lower ballings (sugar content) resulting in lighter wines (Jordaan 2012)

And the main wine cellar in the region focused on making more high quality wine in this season due to lower yields (ibid.). The only proposed adaptation strategies for future flood events that came up during interviews and community meetings were strengthening of the flood walls. Concerning further risk reduction measures and adaptation strategies, one of the previously cited impact assessment reports proposed the following (SRK 2011:21):

- Determining indicative flood lines in low lying areas
- Carry out risk assessments to find houses at highest flood risk
- Implementation of flood levees
- Relocation plans to higher grounds for some households
- Risk awareness campaigns

An official at the local DoA office also proposed improved storm water management through improved drainage canals, as there were reported problems of water during the flood pushing up through the drainage canals and thus easily reaching farm lands (DoA 2012a).

5.3. Post-disaster assistance

At the time of the conducted field studies, in April and May 2012, 14 months after the floods hit, neither compensation nor post-disaster recovery assistance had been provided to the affected areas. Shortly after the floods hit in 2011 South Africa's President promised ZAR 900 million to be allocated to victims of the disaster, an amount which was later reduced to ZAR 280 million, and which has still not reached the affected areas. Apparently a pay out compensation program was initiated and some farmers in the area did receive compensation, however this program was quickly stopped due to mismanagement allegations on how the recipients were chosen. Farmers from the community meetings claimed that some households received more than intended while some did not receive anything. After its ending the program has to this day not been taken up again.

Several farmers at one of the community meetings in the Northern Islands expressed deep concerns about having lost their homes and money during the flood, and now not knowing what to do or who to contact.

After much political struggle the DoA finally managed to get a ZAR 132 million funding to be used for repairs of the flood walls in the Northern Cape Province (ibid.). For the crop losses there have never been any considerations of governmental compensation, the compensation and recovery programs only concern infrastructure. At the time of writing, DoA is busy with taking registrations from farmers on damages to flood emergency and diversion walls on and adjacent to their lands. Each wall will then be assessed by engineering teams before reparation and construction is initiated. The current conditions given for the funding is that subsistence farmers will pay 10% of the reparation costs, emerging farmers 20% and commercial farmers 50%. However, as several officials at DoA expressed as well, it is unreasonable to expect subsistence and emerging farmers to be able to get the capital to pay for 10 or 20% of the reparation costs for a flood wall, which could easily have a total cost of ZAR 1 million (ibid.). Construction and reparation is especially expensive in Keimoes as the area mainly lies on rocky grounds with little good soil available for these purposes (ibid.). Proper construction soil therefore has to be transported from other areas. Another issue that came up was that as walls had been left damaged for so long, some farmers had started to repair them on their own, and DoA was now concerned that these walls had been repaired poorly, and would had to be taken down before reconstruction could begin, thus increasing the repair costs (ibid.). During the flood wall registration meeting in Keimoes, where farmers were invited to come and report damages to walls on their lands so that they would get funding to rebuild it, officials from DoA reported that apparently no large scale commercial farmers showed up, only emerging and subsistence farmers (DoA 2012b). In Machant, another farming area outside of Kakamas, emergency walls had already been repaired on some commercial farms lands repaired with funding support from the government. For this reconstruction, walls were built to take the flood of 2011, approximately 5 000 m^3/s. One farmer from the Middle Islands in Keimoes had already organized farmers to rebuild smaller walls in the area, while bigger walls were still left damaged. These are all examples of local farmers taking matters into their own hands instead of waiting for government support and funding.

After the floods Keimoes municipality's office formalized a relocation program with the aim of getting some households to move out of the flood struck islands. One of the governmental impact assessment reports also recommended this together with construction of new houses as a risk reduction measure for the city (SRK 2011:23). The program was still to be finalized at the moment of the field studies, but some households had allegedly already moved out of the islands to informal settlements in town.

6. Dam management analysis

As stated earlier the Orange River has several large dams upstream of Keimoes and the Northern Cape Province and the management of these will therefore have large impacts on the hydrology in the area. Concerning flood management for downstream areas it thus becomes relevant to assess the upstream dam management during the time prior to and under the floods, which is what this section will do. More specifically the purpose is to assess whether the dams could have been managed differently to reduce the flow levels in the flood struck areas, and if this is so, why they were not at this time.

6.1. Institutional context

There are three main objectives for dam management in the South Africa (DWA 2011a):

- Minimization of damages (by minimizing flow in the system during floods)
- Ensuring the safety of the structures
- Ensuring that the dams are 100% full at the end of floods

South Africa is also recognized to be a water scarce country and retaining and releasing water for irrigation purposes is thus another crucial aspect for the dam management. Some large dams are also used for hydropower production, which requires and is benefitted by high dam levels. The public power production company ESKOM, which generates 95 % of the electricity used in South Africa, has a stated goal of trying to reduce its environmental and carbon footprint by for instance producing more electricity through hydropower (ESKOM 2011b). At the moment 92.8% of its electricity production is from coal based power plants and only 0.8 % is from hydropower (ibid.). Some of these objectives and aspects are conflicting. Ensuring that dam levels are at 100% after floods, for hydropower production or water scarcity reasons, can under some circumstances conflict with the objective of minimizing flow in the system. For example prior to expected heavy rainfall water could be released from dams to increase storage and flow attenuation capacity for the upcoming rainfall. But this might, depending on the accuracy of rainfall predictions and on the amount of water released, increase the risk that dam levels will not be full after the rain event has passed. Within the uncertainty that working with weather and hydrology predictions implies, it will thus be necessary to prioritize one of the two objectives. For dam management in the country water scarcity and hydropower production aspects are thus under some circumstances in conflict with flood reduction.

6.2. Infrastructure in the river systems

Figure 11 shows the rivers and dams in the Vaal and Orange River system.

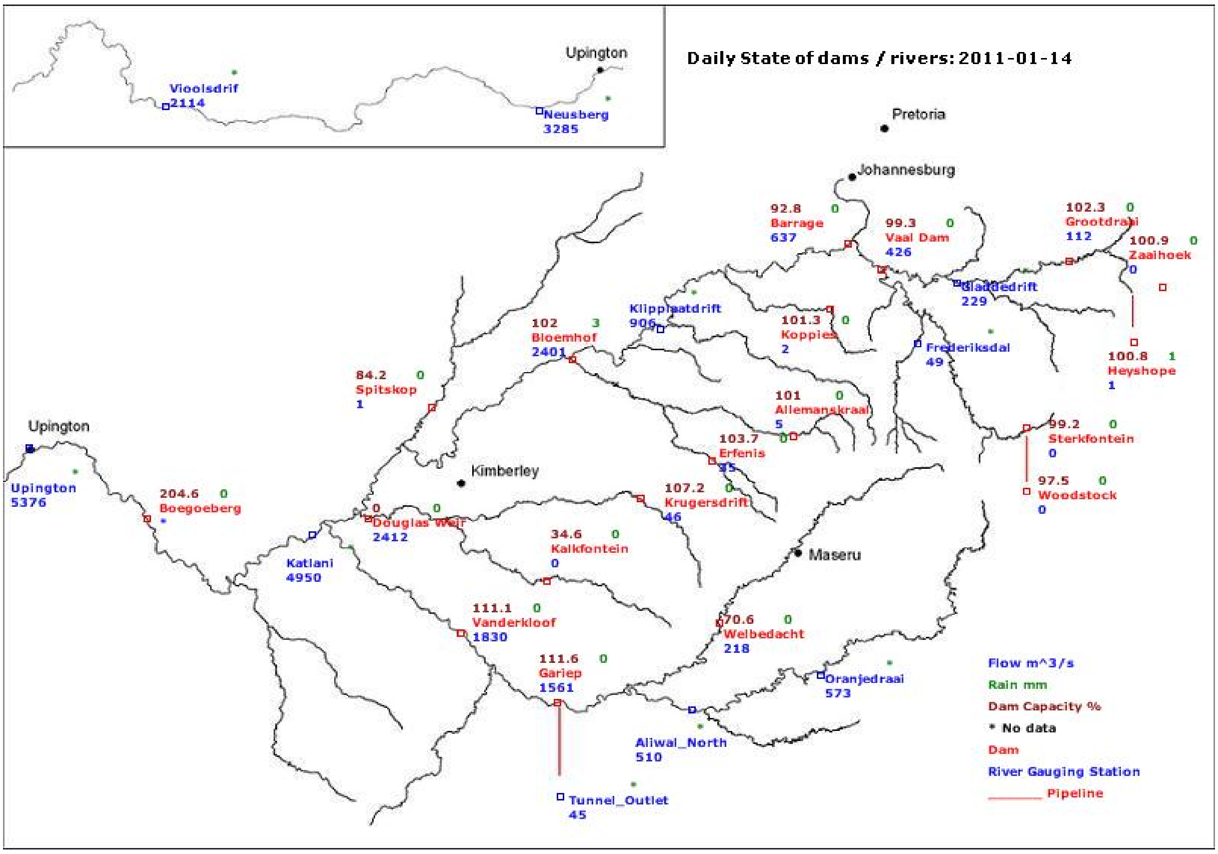

Figure 11 – Streams and dams in the Vaal and Orange River systems (DWA 2012a)

Figure 11 is a print screen of the state of dams and rivers in the Orange River Basin as they are presented on the DWA webpage. In the Vaal River system there are three main dams: Grootdraai Dam, Vaal Dam, and Bloemhof Dam (ORASECOM 2008:17). The Vaal- and Bloemhof Dams both have spillway gates and no uncontrolled spillways (DWA 2011). There are also several smaller dams in the Vaal system, but the only ones with gated structures are the Vaal Barrage and Vaalharts Weir (ibid.).

The main dams in the Upper Orange River system are the Gariep Dam and Vanderkloof Dam. Both of them are hydroelectric power plants which generate electricity for the stately owned energy company ESKOM. The Gariep Dam, completed in 1977, has a storage capacity of 5 670 million m^3 and a full load station capacity of 360 MW (ESKOM 2011a). From the Gariep Dam there is a tunnel that transfers water to catchments located just south of the dam (ORASECOM 2007:17). The Vanderkloof Dam, located 130 km downstream of the Gariep Dam and also completed in 1977, has a storage capacity of 3 236 million m^3 and a full load station capacity of 240 MW (ESKOM 2011a). The Vanderkloof dam also has a transfer scheme, providing water for the Riet River (ORASECOM 2007:17). For these two dams, management is a joint operation between DWA and ESKOM. If the capacity levels of the dams are below 80% DWA decides how to release the water, but when the capacity level rises above 80% it is ESKOM that manages the dams for hydropower production (DoA 2012a, ORLU 2012).

The Orange River basin (Vaal and Orange River) thus has several flood control structures which gives authorities flood management possibilities. These possibilities and options enable management authorities to give priority to different outcomes which, if managed properly, will reflect the ideological basis and politics of the authorities.

The confluence of the Vaal and Orange River is at Katlani. Upstream of this point Bloemhof Dam is the last large dam on the Vaal River and Vanderkloof Dam is the last one on the Orange River. To assess the flow contribution of tributaries downstream of the Bloemhof Dam and Vanderkloof Dam, which are the last points of intervention for dam management, before Upington (just upstream of Keimoes) the outflows from these dams were compared to the flow in Upington. These charts are shown in figure 12.

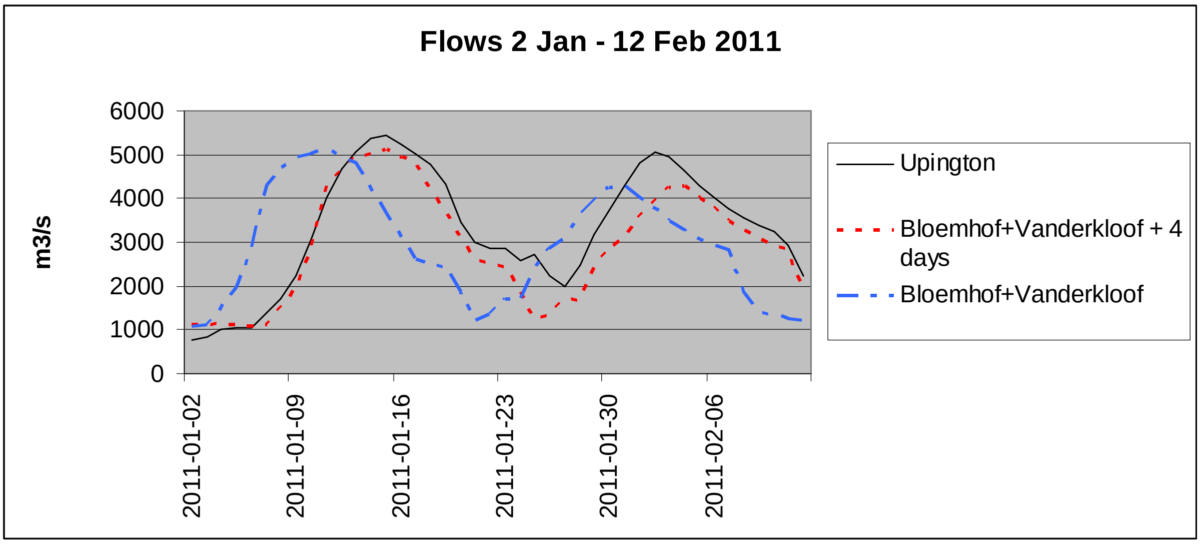

Figure 12 – Flows for Bloemhof Dam, Vanderkloof Dam and Upington (data from DWA 2012e)

The graphs show that for the first peak the flow in Upington is well approximated by adding the Bloemhof Dam and Vanderkloof Dam flows. For the second peak the graphs are a bit further apart, with around 800 m^3/s difference at its most, but are still similar. Figure 12 also shows that there is an estimated 4 day time lag needed for these graphs to fit each other, which is equivalent to the time it takes for the water to travel from the dams to Upington. It should however be noted that Bloemhof Dam and Vanderkloof Dam are two different measuring points and the flow travelling time to Upington is thus not necessarily the same for both of them. On the other hand figure 12 shows that the Upington flow can be well approximated by using the 4 day time lag for the sum of them, which implies that they might each on their own have similar flow travelling times to Upington. With specifically adjusted travel times for each of the dam flows the graphs might fit each other even better. As the Upington flow is so well explained by the added Bloemhof Dam and Vanderkloof Dam flows it can also be concluded that the flow contribution from tributaries downstream of the dams until Upington is negligible. The absolutely majority of the flow that eventually reaches Upington, and Keimoes, thus passes these dams.

6.3. Water releases for flood attenuation

Several commercial farmers in Keimoes claimed that dams upstream were kept closed for too long, and that water should have been released earlier to attenuate the flood. In the middle of December, members of the farmers union in the province saw that weather forecasts predicted heavy rains in the catchment area and contacted DWA to advise them to release water from the dams to prepare for the upcoming rains and possible floods, but they were told that no water would be released on these premises, and that the dams were not built for flood reduction (ORLU 2012). Furthermore, development plans for Kai!garib Municipality have identified inefficient management of water releases from Vanderkloof Dam as one of the main constraints in the area concerning management of surface water, and stresses the need to implement flood management measures in collaboration with upstream water management areas (Kai!garib Municipality 2011b:22). What is also worth noting is that prior to 1990 there was an agreement between farmers unions and DWA to keep dam levels at a certain point to have storage capacity to attenuate possible floods (DWA 2012b). This agreement was however eventually cancelled as water restriction measures were adopted in the country resulting in policies forcing dam levels to be kept full at all time (ibid.).

In January before the flood, the dams in the Orange and Vaal River system were already full and could not hold any more water (ibid.). According to officials in dam management in the country, there were never any considerations to release water earlier in expectations of upcoming floods (ibid.). Within the current dam management framework, water can only be released for flood prevention based on calculations on water that is already measured in the catchment area (ibid.). As such, weather and rainfall predictions are not used as inputs for flood management, but only data that is received from measurement stations in the catchment areas and in the water bodies.

Officials in dam management in the country also claimed that even if the dams were emptied prior to the floods the amount of rainfall and water under this period was still so high that it would not have made any differences for the flood levels in the country (ibid.). It is claimed that lower initial dam levels would only have delayed the flood a couple of days, but would not have altered its magnitude (ibid.). It was also claimed that the Vanderkloof Dam for instance released three times its storage capacity during four months over the floods (ibid.). Based on this, the dam management officials claimed to have done all they could to minimize flood impacts (ibid., DWA 2012c).

Two opposing perspectives are thus presented. On one side there are farmers in the flood struck areas claiming that water should have been released earlier from dams to have space to attenuate the flood. And on the other side there are the dam management officials claiming that all possible flood reduction measures were taken, that the dams were well managed, and that a prior release of water would not have reduced the flood impacts. To assess these contrasting claims this study will make a brief assessment of the management of the dams based on hydrological data during that period.

6.4. Flows and dam levels previous to and during flood

For a complete assessment of the dam management previous to and during the 2011 flood, and also to know what the management options were, the following hydrological data would be required: daily flows in and out of dams, daily dam levels, dam storage capacities, amount of water in the catchment areas, information about dam management decision making, predicted rainfalls and hydrological models relating dam discharges to downstream flows and water levels. During the data gathering for this study only part of this information was acquired, and as such only an initial assessment can be done for the dam management. What was not acquired was reliable data on water availability in the basin, information about dam management decision making and access to the hydrological models used to calculate flows and water levels for different dam discharges in the area. Despite these limitations, sufficient data is still available to make reliable assumptions about actual and alternative dam management during the floods.

Figure 13-16 below gives the discharge and dam levels for the Vaal Dam, Bloemhof Dam, Gariep Dam and Vanderkloof Dam.

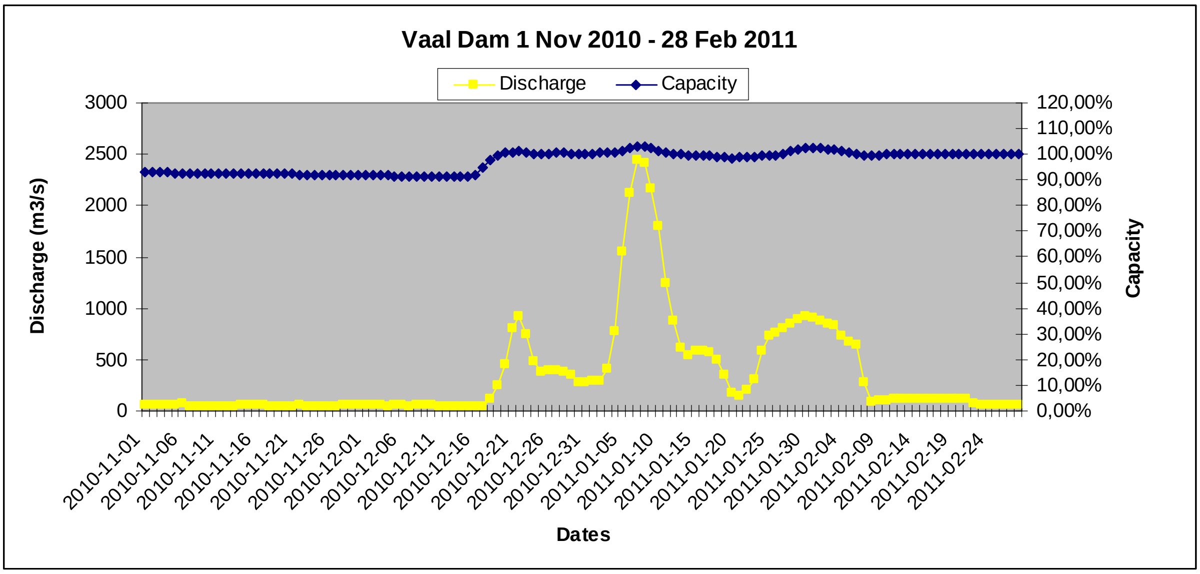

Figure 13 – Vaal Dam flow chart for 1 Nov 2010 – 28 Feb 2011 (data from DWA 2012e)

Figure 13 shows that capacity levels are high and discharges low for this period but with a distinct discharge increase in the end of December, middle of January and beginning of February. As the capacity level rises during discharge increases it can be concluded that there was a high inflow at this point in time. Figure 13 shows that despite high capacity levels discharge is kept very low prior to the floods, which peaked in Keimoes around 15 January and 3 February. Only when the capacity levels start increasing does the discharge increase.

Downstream of the Vaal Dam on the Vaal River is the Bloemhof Dam, which is the last large dam on this river before the confluence with the Orange River. Figure 14 presents the flow chart for this dam.

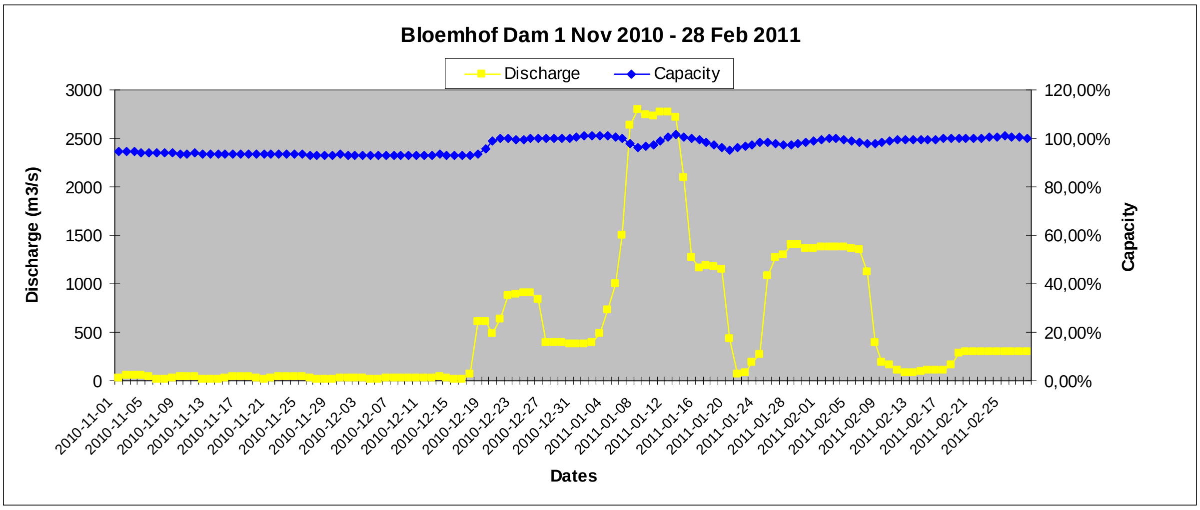

Figure 14 – Bloemhof Dam flow chart for 1 Nov 2010 – 28 Feb 2011 (data from DWA 2012e)

As for the Vaal Dam the Bloemhof Dam has constant high capacity levels and low discharges for this period. For Bloemhof Dam the capacity level also stays somewhat stable around 90-100% over this period. Discharge levels are kept very low prior the floods and only rise sharply in the end of December, beginning of January and end of January. As capacity levels are kept fairly constant during these increased discharges it follows that inflows were high for this periods.

The most upstream dam in the Upper Orange basin is the Gariep Dam. Its flow chart for the assessed period is presented in figure 15.

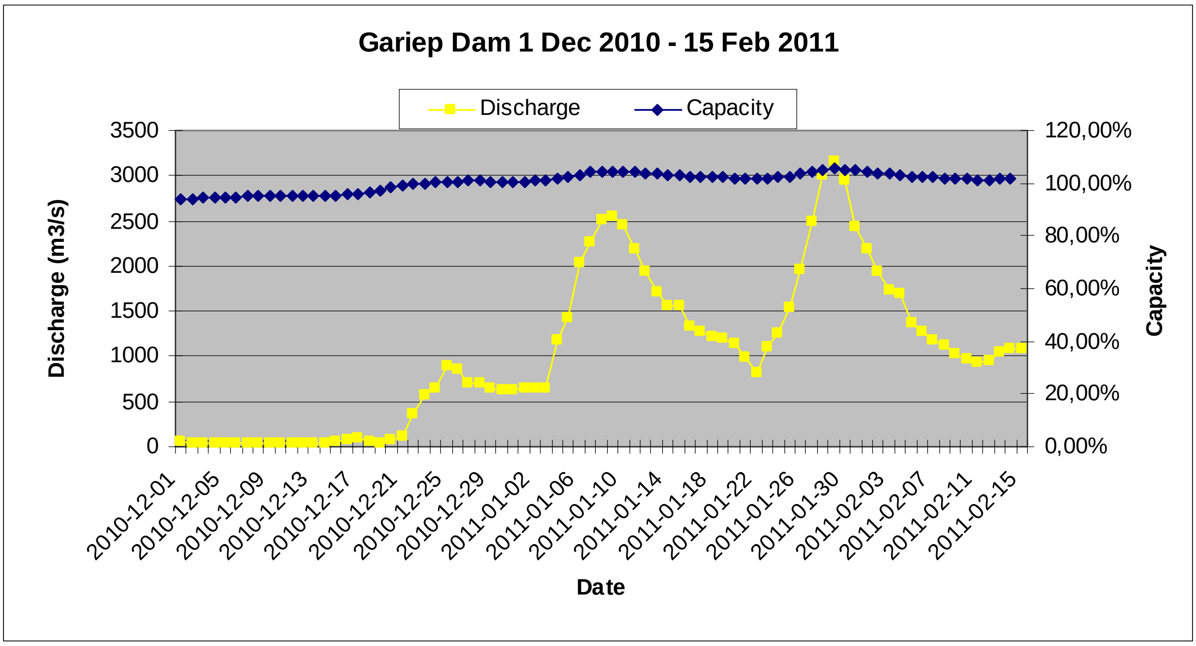

Figure 15 – Gariep Dam flow chart for 1 Dec 2010 – 15 Feb 2011 (data from DWA 2012a,e)

As for the previous dams, capacity levels are constantly high and discharges are low in December but with major peaks in the end of December, beginning of January and end of January. It also shows that Gariep Dam also has a stable capacity level throughout this period, which indicates that inflows were high during high discharges. Of notice is also the very low discharge levels in December when capacity levels are stable between 90-100%.

The final dam is the Vanderkloof Dam which is the last large dam in the Upper Orange basin before the confluence between the Vaal and Orange Rivers. Figure 16 presents the discharge and capacity levels for this dam.

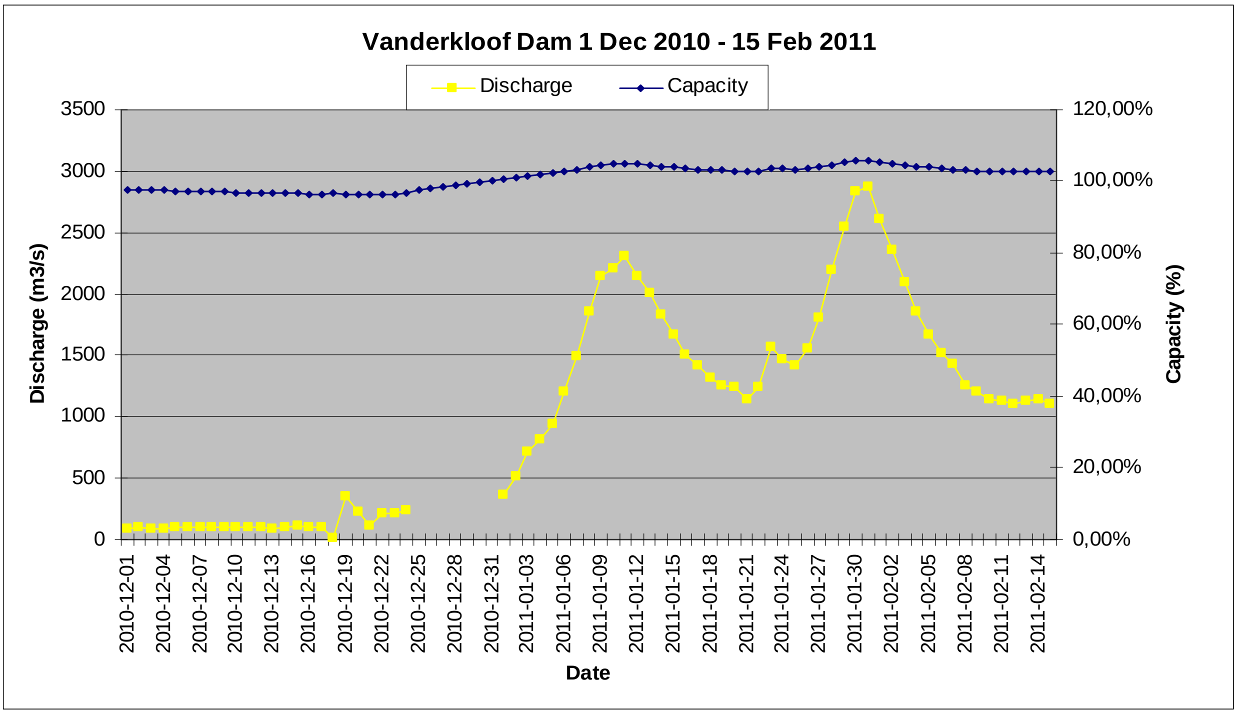

Figure 16 – Vanderkloof Dam flow chart for 1 Dec 2010 – 15 Feb 2011 (data from DWA 2012a,e)

The gap in the end of December for the discharge graph is due to missing data. Just as for the other dams, the capacity level is stable throughout the period, in this case kept between 96 – 106 %. Discharge is low in December (not zero) and only rises in the beginning of January and February. The stable capacity level during increased discharges means there are high inflows at these times.

Flow data in figures 13-16 above clearly show that all dam capacity levels were high (90-100%) and discharge levels continuously low several weeks before the floods hit. It is thus apparent that no water was released to create space to attenuate the upcoming floods. Seeing that no real preemptive measures were taken it now becomes relevant to try to assess whether any flood reduction measures were possible under this hydrological scenario.

6.5. Alternative dam management and water release scenarios

To assess the flood attenuating capacity of the dams it must first be decided how much water that would have had to be retained for there not to be a flood situation in the downstream areas. This is complicated by the fact that a flood situation is not just a matter of a one time peak flow but instead a matter of receiving a certain amount of water over a certain period of time. To simplify matters this assessment it is assumed that a flood scenario in the area only is a matter of high peak flows. Figure 17 gives the flows in Keimoes prior to and during the flood period as the average between the measured flow in Upington, 40km upstream, and Neusberg, 20 km downstream.

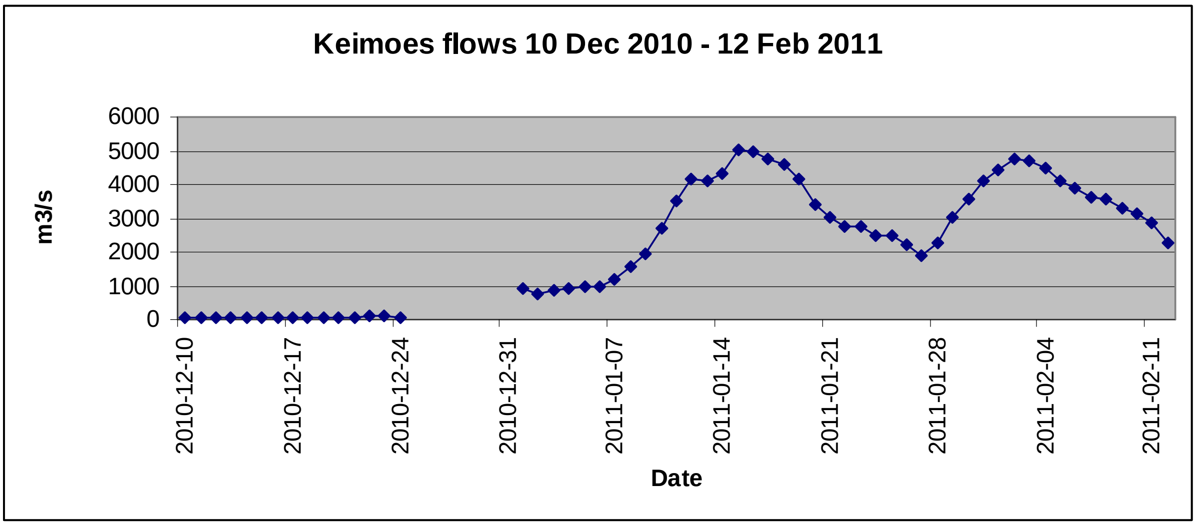

Figure 17 – Flows in Keimoes prior to and during 2011 flood (Data from DWA 2012a)

In the middle of December the flow is very low, around 60-90 m^3/s and starts to rise in early January. The gap in late December is due to missing data. The graph shows that Keimoes could have received substantially more water from upstream dam releases water during December without risking flood scenarios at this time.

To calculate how much water that had to be retained at upstream dams during the flood it must be decided what the highest acceptable "no-flood" flow is. For the flood in 2011, the peak was around 5 100 m^3/s. In previous years the lowest flows for which the DWA has sent out flood warnings is for 2 400 m^3/s and 3 300 m^3/s, which occurred in 1996 and 2010 (DWA 2011b). A model has been created to calculate how much water that would have to be released from dams and under what period of time for the flow in Keimoes not to exceed a certain flow. Aspects taken into account and assumption in this model are:

- To reduce flood peaks in Keimoes water has to be released earlier from dams which will generate a higher pre flood flow in Keimoes.
- The required increased dam storage capacity volume is equal to the required reduced flow volume at Keimoes for a "no-flood" scenario
- Only the four major dams (Vaal Dam, Bloemhof Dam, Gariep Dam and Vanderkloof Dam) are incorporated in the model

- A time lag of 4 days, as indicated in figure 12, is used for the flow time between Bloemhof Dam and Vanderkloof Dam to Keimoes.
- The pre flood release period has been set to start on 10 December as this was when farmers prior to the floods contacted DWA to suggest water releases from dams due to the upcoming floods. It is set to end on 3 January as this date seems to be the final date where water can be released from dams without increasing the flood peaks in Keimoes in January. The additional discharge period is thus 25 days. Necessary water releases are set to be constant during this time. It is thus assumed that sufficiently accurate rainfall predictions were available at this time to be incorporated into dam management models
- Additionally required storage capacity is set to be equally shared between the 4 dams. As the dams have different storage capacity a more complex model might be able to produce and assess more optimal scenarios.
- Evaporation losses are neglected. As these are neglected higher than actual flows is calculated with.
- As Vaal Dam and Bloemhof Dam are located on the Vaal River and Gariep Dam and Vanderkloof Dam on the Upper Orange River discharges from dams upstream of another dam are assumed to reach the downstream dam unaltered, i.e. added discharge from Vaal Dam = added inflow to Bloemhof Dam, and the same for the Upper Orange River. As this neglects water extraction and losses between dams a higher than actual flow is calculated with
- Discharge from the most downstream dams on each river, Bloemhof Dam and Vanderkloof Dam, are assumed to reach Keimoes unaltered. As this neglects water extraction and losses between the dams and Keimoes a higher than actual flow is calculated with
- Data used for the calculations are: storage capacities for the dams, measured discharge from the dams prior to and during the floods, and measured flow in Keimoes prior to and during the floods. The following storage capacities are used (DWA 2012e):
  - Vaal Dam – 2 603 000 000 m^3
  - Bloemhof Dam – 1 240 000 000 m^3
  - Gariep Dam – 5 670 000 000 m^3
  - Vanderkloof Dam – 3 236 000 000 m^3

- Daily flows and discharges (given in m^3/s) are assumed to be the daily averages. In this was daily total flows and discharges are acquired by multiplying the given data with the respective time period
- The gap in data for the Keimoes flows for the last week of December (see figure 17) have been filled by extrapolating data from the nearest available measurements.

More detailed information about the calculations for this model is presented in Appendix A.

<u>Alternative Scenario 1 – Max Keimoes peak flow 3 000 m^3/s</u>

The first max flow to be tested for is 3 000 m^3/s. To reduce all daily flows in Keimoes below 3 000 m^3/s (see figure 17 for data) an additional 2 100 Mm^3 of storage capacity has to be created at the upstream dams prior to the floods. This means that the dams must have the following constant additional discharges under the discharge period (10 December – 7 January):

- Vaal Dam and Gariep Dam– 246 m^3/s each
- Bloemhof Dam and Vanderkloof Dam – 493 m^3/s each (= upstream dam * 2 due to increased inflow as upstream dam discharge increases)

With these modifications and additional discharges, the flow in Keimoes will be the following:

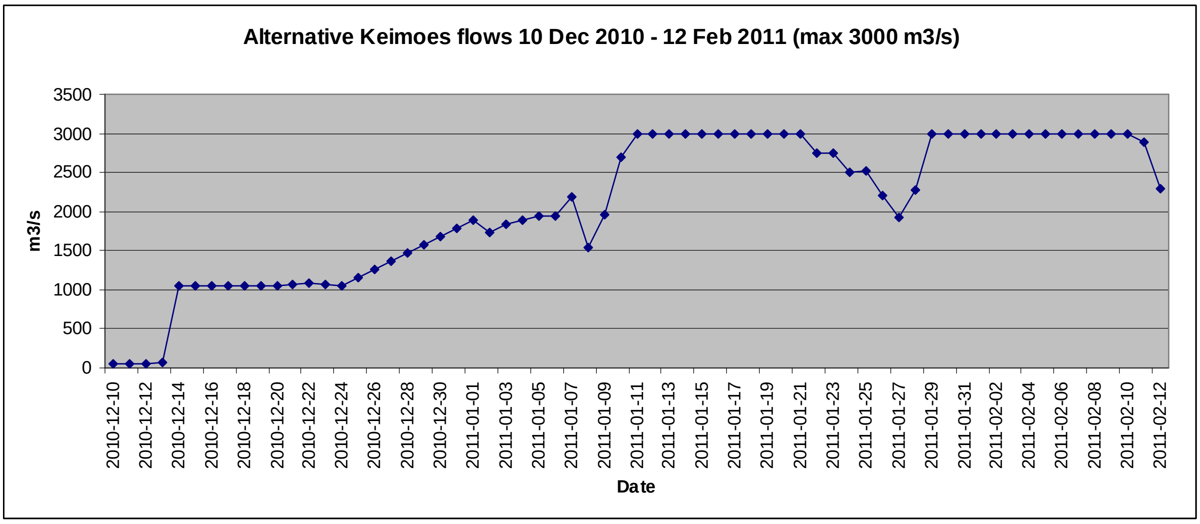

Figure 18 – Flow in Keimoes for alternative dam management scenario 1

The figure shows that the peak flow can still be reduced somewhat without raising the December flows above the critical limit. Besides a new flow situation in Keimoes the alternative scenarios also has to be assessed for the discharge from the dams. As indicated in the discharge and capacity charts for the dams (figure 13-16) the actual discharges are very low for the pre flood period (10 December – 7 January) compared to the additional discharges under this alternative scenario (246 and 493 m^3/s). Therefore, these additional discharges are assumed to pose no issues for the dams and no further assessment will be done on this matter. As there seems to be capacity to increase the pre flood discharges and thus lower the peaks a new scenario is tested for a max peak flow of 2 500 m^3/s.

Scenario 2 – Max Keimoes peak flow 2 500 m^3/s

To reduce all daily flows in Keimoes below 2 500 m^3/s (see figure 17 for data) an additional 3 300 Mm^3 of storage capacity has to be created at the upstream dams prior to the floods. This means that the dams must have the following constant additional discharges under the discharge period (10 December – 7 January):

- Vaal Dam and Gariep Dam– 377 m^3/s each
- Bloemhof Dam and Vanderkloof Dam – 755 m^3/s each (= upstream dam * 2 due to increased inflow as upstream dam discharge increases)

In the same sense as for scenario 1 the additional discharges (377 and 755 m^3/s) are comparatively small enough to not pose any problems for the discharge limits for the dams. With these additional discharges, the flow in Keimoes will be the following:

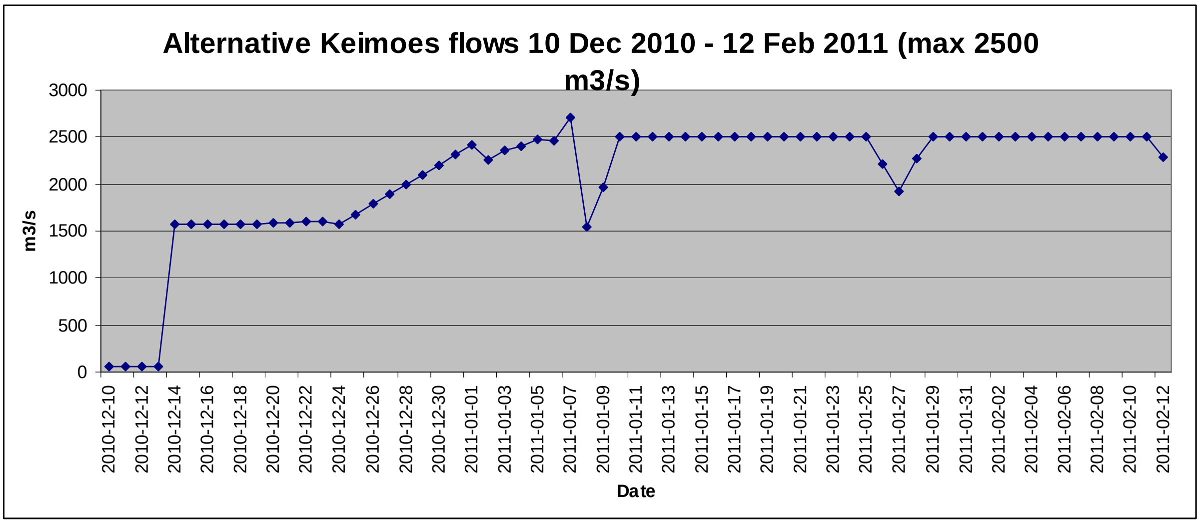

Figure 19 – Flow in Keimoes for alternative dam management scenario 2

It is now seen that the peak flow is higher than the set max flow of 2 500 m^3/s for the last day of the pre flood period (7 January). The limit of the flow level to which the peak flow can be reduced in Keimoes might thus be around 2 500 m^3/s. However by using a more complex discharge model where more water was released earlier during the pre flood period and less later on it is evident that all peaks could be under 2 500 m^3/s. The assessment here will not go any deeper and incorporate more complex discharge models and will thus conclude here by stating that alternative dam management scenarios with substantially reduced peak flows in Keimoes seem to have been possible.

Power production losses under alternative scenarios

As dam discharges will increase under the alternative scenarios the storage levels will decrease. For the hydropower producing dams, Gariep Dam and Vanderkloof Dam, this will reduce the power production. But this power production will only be temporally affected, as capacity levels will increase with the incoming flows that under the actual scenario caused the floods and which are now retained by the dams. Depending on what capacity levels that is required for hydropower production at the respective dams, which is information that was not attained for this study, power production losses will range between nothing to no production under two weeks in the end of December. This production loss and its cost implications should be compared to the impact caused by the floods as presented in the previous sections which an alternative dam management scenario would spare. For irrigation purposes by the dam reservoirs no negative effects should be noticed under the alternative dam management scenarios as there will still be water available throughout the whole analyzed period and as dams would still be full in the end.

7. Discussion

The results section covers a wide range of aspects of the flood impacts. This impact assessment will now form the foundations of a vulnerability assessment with subsequent proposals for possible flood and disaster management improvements and for the involved stakeholders. Despite the very large amounts of water that the area received and the seemed helplessness of society when facing it, there are still some tangible improvements that this section will outline. Dam management issues, which were a large part of the previous results section and which directly relates to the amount of water downstream areas receives, will be discussed and presented separately from the vulnerability assessment.

7.1. Vulnerabilities and improved flood reduction measures in Keimoes

Although the impacts of the floods were extensive throughout the whole Keimoes certain areas and groups were especially affected, which this vulnerability assessment will highlight.

7.1.1. Location

The first and most obvious aspects that define the impacts in the area are topography and location. Low lying areas adjacent to the river have the highest water levels for the longest period of time. They are also the areas that are cut off for the longest time. In this sense location has direct effects on access to work, education, farm lands, medical services and social life. A major issue for Keimoes is that most of the farmers live on or have lands in these low lying areas close to the river. As stated before extensive farming and settlements in these areas is due to the fertile soils and easy access to irrigation. But at the same time it is a major vulnerability aspect for the area. The relocation program initiated by the municipality is one attempt to tackle this. However, farmers' livelihoods are connected to their lands and the idea of relocating people from these areas is a complex issue which must address many different aspects of livelihoods and dependencies if it is to be successful, such as schools, work and social life. And as some farmers expressed it during the community meetings on the Northern Islands, "farmers have been here for generations and will never leave". The spatial dependencies are thus very strong for some of the farmers. Irrespective of the possibility for success of the relocation program, it being proposed as a measure bear witness of the severity of the floods and shows that the impacts is not just a matter of temporary hardships or loss of revenue, but that it can be a deeply subversive event for some groups of society. Furthermore, as the whole idea of a relocation program is to reduce the negative impacts of future floods, risk perception of future floods and future climate predictions become relevant aspects. As stated in the initial climate sections very little is known about future hydrology in this region and the only thing that can be expected with some certainty is increased variability. More precise knowledge on this matter might alter which flood reduction efforts that are feasible or not, but at the moment the best approach seems to be to keep basing flood risk assessments on historic flow data but to prepare for increased variability.

Construction of flood walls is one alternative that just as relocation programs addresses location as a cause of vulnerability to floods. By having high and strong enough walls farmers can keep farming safely even in low lying areas adjacent to the river. As given in the results section the conditions of the flood emergency walls in the area when the floods hit were generally bad. Another complicating aspect is that flood walls are public goods in the sense that they affect and benefit everyone in the area. In the same sense an emergency wall in a bad condition can put large areas at risk. Their conditions are therefore a communal matter. Different reasons came up explaining why the conditions of the walls were so bad prior to the floods. Lack of capital for farmers in some areas is one aspect and unclear institutional structures and responsibilities was another. Some large scale commercial farmers in the area had walls that were in good conditions prior to the floods and provided maintenance to them during and after the floods. Other areas, especially in areas with subsistence and emerging farmers in the Northern and Middle Islands had walls in very poor conditions that broke during the floods and that still (14 months later) have not been repaired. The institutional issue in this matter is that the government owns the land on several of the islands and has farmers renting the land. Under these arrangements, there is a lack of incentives for farmers to invest in their lands by for instance building emergency walls. And instead they expect the government to do this, who does not really address the issue. The result over the past few years is clear: emergency walls in these areas were in a very bad state when the flood hit. Until the concerned government bodies become more active in the matter the best approach might be private and cooperative engagements and responsibilities for the area.

Given the high cost damage estimates due to the flood (R 3.9 billion) and the distress experienced during the floods for many inhabitants, expensive investments in emergency walls to reduce future impacts in the area are well motivated. Large scale farmers with access to capital seem to have realized this, and the issue rather rests with the poorer farmers who lack this capital. Government funds, which now seem to have been made available for wall construction through the DoA in the flood struck areas, is another way to fund these walls. The extent of funding and its allocation to different areas is however largely a political issue. This thesis will not address the political context for this further, but will conclude that funding and efforts comparable to the cost damage estimate are justified for reduction of future similar flood impacts.

7.1.2. Infrastructure

Several infrastructure aspects are identified as improvable in Keimoes. The extensive usage of gravel roads quickly renders transportation difficult with increased water levels. A further aggravating aspect is that it is generally the poorer sparsely populated areas which have worse road quality, making these groups even more vulnerable to flood impacts. Poverty together with a sparse population explains why there are so many gravel roads in these areas. Paved roads, besides resisting water better than gravel roads, also simplifies storm water management, which there is none of in the farming areas of the islands.

Bridges and transportation between the islands were also severely affected during the floods. One possible improvement that was discussed here was raising bridges. However, just raising bridges when the rest of the area or transportation network is submerged will not do much good for the area. Only for situations with lower water levels, when only low lying bridges are submerged, will a potential raising of bridges bring any benefit and increased resilience. For a flood of the size of the one in 2011 there does not seem to be much to do concerning submerged bridges and cut off islands on this matter.

Sparsely populated areas with long travel distances also makes local livelihoods further vulnerable. As stated in the results section schools had difficulties getting both students and teachers to the schools given that many of them had to travel over long distances that were now inaccessible due to the floods. There was no specific data for how this affected access to work, but it can be safely assumed that the same would apply there, namely that sparse population and long travel distances made it impossible to reach work for some inhabitants. In this way sparse populations and livelihoods depending on long daily travelling are other relevant vulnerability aspects for this area.

7.1.3. Access to information prior to floods

The results section shows that there seems to be a wide difference in terms of access to information and preparedness among inhabitants in Keimoes. Large scale farmers came off as well informed while some smaller farmers had very poor or no information about the upcoming flood. The main explanation for this was that different groups had access to different information sources. This lack of information within some groups is something that can be improved by the disaster management and water authorities in the area. By knowing this, more focus can be put on disseminating precise information to these areas prior to future floods. More precise information on what areas that would be flooded and to what level was requested by some small scale farmers. This is however difficult to provide for the moment as no inundation or flood line studies have been done in the area. Until such studies are conducted past floods can always be used to compare with, and this flood in 2011 with its flow characteristics can now come to serve as one such comparison for potential future flood events. But if water levels for specific areas are not documented during the floods this information will rest solely with the inhabitants, possibly being forgotten or eventually lost if they leave the area or pass away.

7.1.4. Harvesting time

The impacts on the agricultural sector in both Keimoes and the whole province was severe as the floods hit just prior to or during harvesting time. Besides damages to lands this resulted in that only little of the annual yield could be harvested and immense crop losses became unavoidable. In this way, time of the year is another vulnerability aspect for this area, meaning that the agricultural sector in this case was especially vulnerable prior to and during the harvesting time. Generally this implies that maybe certain measures can be worth taking during certain times of the year. On a local level this does not change anything. The main protection against a flood of this magnitude is to build and maintain flood walls, which is a long term investment and with continuous status over time. However, the time aspect, and the increased impact risk that comes with it, becomes more relevant when it comes to dam management and in the assessment of what kind of measures that might be worth taking for flood attenuation at certain times. Concerning water releases from dams prior to floods, which were discussed previously, maybe special attention and caution should be given to this during these especially vulnerable times each year, namely prior to and during harvesting time. As a major part of the impact on agricultural was due to crop losses (ZAR 2.5 billion out of a total ZAR 3.9 billion), which to a large extent seems time dependent, this issue deserves special attention by dam and flood management authorities.

7.2. Dam management and flood reduction

From the previous dam management assessment several important aspects were pinpointed:

- Dam levels were high (above 90%) for all major dams several weeks prior to the floods

- No water was released prior to floods in order to be able to have increased attenuation capacity
- The four major dams together have sufficient storage capacity to attenuate large floods as the one in 2011
- The alternative dam management scenarios presented previously are such that increased discharges prior to floods would only lead to dam levels being temporarily lowered and they would still be full after the floods due to the high inflows which under the actual scenario caused the floods

The dam management assessment points to the conclusion that downstream flood reduction aspects have a very low priority within the dam management framework in the country. Given the major impacts, both monetizable and not, of the floods downstream of the confluence between the Vaal and Orange Rivers these priorities might need to be revised, and especially so prior to and during harvesting time. The dam management assessment that was made here was however only initial and more data and analysis are needed to be able to confidently conclude whether dam management can be improved along these lines or not. As such, the findings presented here should only be seen as preliminary and to be used as a foundation for further studies. However, besides dam levels, water releases and flood attenuation aspects, some other important points support the claim that the dam management does not give downstream flood impacts the attention it deserves, namely that:

- Hydropower production is identified as an important contribution to the country's sustainable energy production goals
- Hydropower production is favored by continuous high dam levels, and consequently disfavored by their lowering
- South Africa is identified as a water scarce country and early release of water in anticipation of floods risks "wasting" water depending on the accuracy of weather and rainfall predictions

So even without more and deeper access to dam management information in the country these points together with the flood attenuation capacity assessment still build up a strong case supporting the claim that downstream flood reduction aspects might be prioritized unjustifiably low. And by adding the increased hydrological variability that is expected for the area in the future new and adapted dam and flood management frameworks might become increasingly important.

These matters consequently become a political issue, where hydropower production, water availability, and flood impact aspects have to analyzed and weighed against each other before any management and regulatory changes can be proposed. The incorporation of weather and rainfall predictions, which for the moment are not used in the dam management models, must also be analyzed and assessed further, and especially prior to and during harvesting time for downstream communities. These are tasks which are outside the scope of this study. The facts and argumentations in this thesis however justify that such analysis with all their cost and resource implications are initiated.

7.3. Compensation and post disaster governmental assistance

The compensation programs from the government have been disastrous. At the time of writing, no compensation has been handed to the affected areas. There have on the other hand been many promises of compensations which have resulted in widespread disappointment and anger within the affected areas. A further aggravating matter is that compensation and support measures might be as most efficient briefly after the floods when the impacts and needs are highest. Even though being a highly political and complex matter, it is evident that the compensation issues were managed poorly and slow by the responsible authorities, with the false and unsupported compensation promises creating unnecessary disappointment in the affected areas.

8. Conclusion

The research questions for this study were:

- What were the impacts of the flood in 2011 in Keimoes and the Northern Cape Province?
- What can be done to improve flood management and reduce future negative flood impacts in this region?

The answers to these questions were outlined in the previous sections and are summarized here.

The impact assessment concluded the following:

- The total cost implication estimate due to the floods for the Northern Cape Province is ZAR 3.9 billion
- The agricultural sector was especially affected by the floods as it is widespread in low lying areas along the Orange River. Furthermore, the floods struck during harvesting time which resulted in major crop losses and hampered yields. The crop loss cost estimate was ZAR 2.5 billion.
- The extent and duration of the floods meant that large areas in Keimoes were completely cut off and many individuals had to be evacuated. This disrupted local livelihoods as no transportation was available for several weeks. Some families were separated as students and adults in some cases were taken to different hostels to facilitate access to school for students.

Based on the impact assessment, the following local vulnerabilities were pinpointed:

- The location and topography of the areas where people live and farm makes them vulnerable to floods
- Large areas with only gravel roads are easily affected by raised water levels
- Access to information and anticipation of floods were good for some individuals but very poor for others. Generally, individuals using the internet as a source of information for this seemed to be well informed. Many small scale farmers requested better and more accurate flood information and warnings.
- The fact that it was harvesting time when the floods hit substantially increased the community's vulnerability to floods. In this way the timing of the flood is identified as another factor that makes these communities further vulnerable.

Some possible recommendations for improvement were discussed. The main ones are:

- Flood walls conditions were bad prior to the floods. The extent and severity of the impacts justify expensive investments and efforts in flood wall construction in the area
- Access to information about the floods prior to impact was in some areas poor and can easily be improved by knowing which areas are in need of improved information access for these events
- Dam management seems to prioritize downstream flood impact low and major improvements might be possible. Further studies are however necessary on this matter before any further conclusions can be drawn and recommendations for capacity building can be outlined. But given the severity of the impacts, the possible increased hydrological variability in the near future and the potential improvements to dam management, such studies should be given high priority.

As a final point it is worth emphasizing that the impact and vulnerability assessments made here reaffirms what is intuitively apparent and what is so often stressed in literature in social sciences, namely that vulnerability has a deep positive relationship to poverty. Consequently, an extreme and subversive event as the floods studied here generally affect the poorest hardest, thus pushing them into further and deepened poverty.

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Appendix A – Detailed methodology for the alternative water release scenarios

The daily flow in Keimoes for the alternative scenarios is calculated by in the following steps:

- Decide on a maximum “no-flood” flow. 2 500 and 3 000 m^3/s were used for the two runs of the model
- Calculate how much volume of water that exceeds these flows in Keimoes under the set flood period. This is then the amount of water that has to be held at the dams and thus the necessary additional storage volume
- This storage capacity is then equally divided between the 4 dams, which means that enough water has to be released from each dam under the set water release period (25 days) to increase its storage capacity by ¼ of the calculated total storage capacity
- Dams located downstream of other dams (Bloemhof Dam downstream of Vaal Dam and Vanderkloof Dam downstream of Gariep Dam) will besides the ¼ of the total storage capacity also have to release an additional ¼ of the total storage capacity as they each receive an extra ¼ of the total storage capacity from their respective upstream dam. Bloemhof Dam and Gariep Dam thus have to release ½ of the total storage capacity under the set water release period.
- The calculated additional outflow from the Bloemhof Dam and Gariep Dam, which are the two last dams (each on their own tributary) before Keimoes, is then added to the already given flow in Keimoes
- The flow in Keimoes is then acquired by using the actual flows plus the additional discharges with a 4 day time lag period from Bloemhof Dam and Gariep Dam for the water release period and by using the modified flows with reduced peaks to the set maximum “no-flood” flow for the flood period.