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Hydrological processes in the middle Mohlapitsi Catchment/ Wetland, Capricorn district of Limpopo Province, South Africa

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Abstract

The hydrology of the Mohlapitsi Wetland, Limpopo Province of South Africa was studied from November 2005 to April 2006. This paper presents the results of an investigation of the hydrology of the wetland and its contribution to dry season flow in the Mohlapitsi River. Forty piezometers were installed along seven transects and water levels monitored in order to understand water table level characteristics with time. The northern part of the wetland is affected by artificial drains and the piezometers closest to the river channel showed the lowest variations. The relationships between rainfall, groundwater, and surface water shows that stream flow did not respond quickly to precipitation as expected. Also the groundwater levels did not show fluctuations, indicating that groundwater responds gradually to precipitation, and that the relationship between rainfall, groundwater and surface water is complex.

Keywords: Wetlands hydrology, Piezometers, Transects, Groundwater Surface Water Interactions

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1. Introduction

Wetlands are important ecosystems of river basins world-wide and are also important from economic point of view in that they support agricultural activities (Ehrlich et al., 1997). IUCN (2008) proposed that wetlands are an important support system on the planet. The formation, persistence, size and function of wetlands are controlled under natural conditions by hydrological processes (Carter, 1996). The distribution and differences in wetland type, vegetative composition, and soil type are caused primarily by geology, topography, and climate (Fetter, 1994). According to Carter (1996) such differences are the product of the movement of water through or within the wetland, water quality, and the degree of natural or human-induced disturbances. In turn, the wetland soils and vegetation alter water velocities, flow paths, and chemistry. The hydrologic and water-quality functions of wetlands, that is, the roles wetlands play in changing the quantity or quality of water moving through them, are related to the wetland's physical setting (Carter, 1996). Wetlands are therefore sensitive natural environments and if they are to be used in a sustainable manner, knowledge of wetland hydrology and quantification of water inputs and outputs are necessary prerequisites to understanding wetland environments and determining their vulnerability to change resulting from man’s activities (Roulet, 1990).

South African inland wetlands are hydrologically complex and cover approximately 20% of the landscape and play a very important role in ecosystem functioning (Masiyandima et al., 2006). These wetlands play provisioning, regulatory, and habitat roles in the landscape. McCartney et al. (2005) demonstrated that wetlands are vital for attenuating floods, regulating river flow, recharging groundwater sources, biodiversity protection, tourism, environmental education, grazing, and subsistence agriculture and as a source of food and plant materials for rural communities. Wetland ecosystems, including rivers, lakes and marshes, provide a number of services that contribute to human well-being and poverty alleviation (Millennium Ecosystem Investment, 2005). Conservation and management of freshwater resources are also roles that wetlands play. In addition, wetlands play important roles in maintaining environmental quality, supporting immense biodiversity, sustaining livelihoods and mitigating unemployment. Recreational and aesthetic qualities and their role in local and regional hydrology, by serving as water-storage areas and reducing flooding, are other important values of wetlands (McCartney et al., 2005).

Flow generation processes in wetlands are important in determining the role of the wetland in relation to river flows as well as for managing land uses, especially agriculture-related, that impact on the functioning of the wetland (Hughes, 2010). In spite of their considerable value, some 50% of wetlands in South Africa have already been destroyed due to unsustainable development and land use/cover changes upstream and within the wetlands caused by human activities (Kotze, 2005). Examples of mechanisms leading to their destruction include draining wetlands for crops or housing developments, pollution, building upstream dams, and overgrazing (McCartney et al., 2005).

2. Study area

2.1. Location and general description

This study was conducted at the Middle Mohlapitsi Wetland, which lies in the former homeland area of Lebowa in the Capricorn District and in the middle part of the Limpopo basin. The wetland is a riverine system covering an area of 120 ha (Kotze, 2005). The wetland is located in the B71C quaternary catchment (according to South African designation) and geographically on coordinates 24^{0}6'0" South and 30^{0}6'0" East. Agricultural activities have extensively modified the ecological status of the wetland system under study (Jogo and Hassan, 2010). The valley is narrow and confined; with steep hill slopes on the edges of the valley bottom.

The Mohlapitsi River is in Limpopo Province of South Africa and drains southwards from the Wolkberg Mountains into the Olifants River (Figure 2.1). The upper part of the Mohlapitsi Catchment in Olifants Catchment (in Limpopo Catchment) is mountainous with peaks above 2050m and mainly covered by natural forest, whereas the lower reaches are alluvial valleys (Kotze, 2005). At the confluence with the Olifants River, the Mohlapitsi catchment is 49000 km^2 and upstream of the wetland it is approximately 263 km^2.

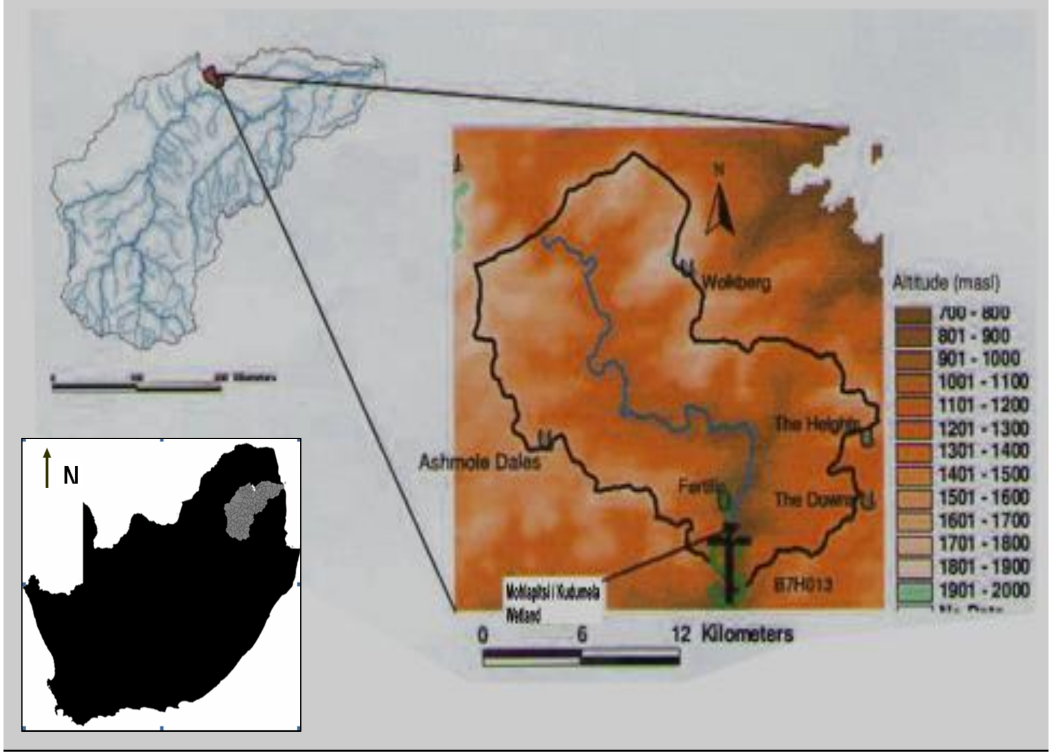

Figure 2.1. Map showing the location of the study area within the Olifants catchment (Mekiso, 2011)

2.2. Hydrology of the wetland

The hydrology of the wetland has also been adversely affected by artificial drainage of water by wetland farmers aimed at removing excess water to create favourable growing conditions for maize, the main crop grown in the wetland (Jogo and Hassan, 2010). Besides crop production, the wetland provides other services that support people's livelihoods, such as dry season livestock grazing and watering, domestic water supply, fishing and natural products (reeds, sedges and other edible plants). The hydrological and ecological functions of the study site are driven by wetland activities, and the magnitude of these impacts is not well understood (Kotze, 2005).

2.3. Climate of the study area

The entire Middle Mohlapitsi Wetland has a typical valley climate with warm to hot summers (October-April) and cool winter days with cold nights. Temperatures at the study site vary from an average monthly maximum and minimum of 30.2 ^{0}C and 18.0 ^{0}C for January to 22.0 ^{0}C and 5.2 ^{o}C for June respectively (Nell and Dryer, 2005). The climate of this part of South Africa is highly variable and the study site has experienced alternating droughts and floods for many years (Nell and Dryer, 2005). In 2000 a devastating flood a lot of community's property was destroyed, including the irrigation infrastructure.

The Middle Mohlapitsi River basin is within the summer rainfall region of South Africa and receives rain between October and April. Mean annual rainfall in the valley bottom, where the wetland is located, is typically 500-600 mm (Jogo and Hassan, 2010). The mean annual potential evaporation for the B71C quaternary catchment is 8.33 mm/day (Midgley et al., 1994). Rainfall information on Figure 3.2 is based on all available gauged data; Potential Evapotranspiration (PE) as regionalized data and stream flow as simulated natural flow using a rainfall-runoff model.

2.4. Stream flow

The river is gauged just below the Middle Mohlapitsi wetland, at station B7H013 and stream flow records are available for the periods 1970 to 2008.The flow shows both seasonal and inter-annual variation, with mean annual flow is 37.96 Mm^3, equating to about 144 mm of runoff (McCartney et al., 2005). The coefficient of runoff for the catchment (i.e., the proportion of rainfall converted to runoff) is 0.18, which compares to an average of 0.06 for the whole of the Olifants catchment (McCartney et al., 2005).

2.5. Geology and soils

The geology of the region comprises sediments of the Transvaal Sequence and the study area is underlain by the Malmani Subgroup of the Chuniespoort Group (Nell and Dryer, 2005) which are Early Proterozoic dolomitic rocks of between 2,100 million years and 2,000 million years old (Miyano and Beukes, 1996).

The soils in the wetlands are a mix of fine-textured, poorly drained areas away from the river bank, and less extensively sandy soils located close to the channel (Kotze, 2005). During floods, the Mohlapitsi River carries fine and coarse sediments from the steep catchment slopes with high velocity until it reaches the wetland with gentler slopes. A sudden reduction in flow velocity in the valley has created a changing pattern of braided channels, where it spreads and deposits coarse sediments or bed load (gravel, cobbles and boulders) during very high flood stages. These deposits are located near the base of the alluvium. Suspended load (fine materials or sediments such as sands, clays and silts) are deposited at the surface as well as in the interstices of the deeper coarser sediments (Kotze, 2005). Soils of the study area are hydric-wetland soils, which have grayish, dark brown to reddish brown, sandy loam top soils and strongly sub-angular structured, sandy clay loam sub soils because of the long periods of saturation (Nell and Dryer, 2005).

3. Methodology

3.1. Piezometer installation and groundwater monitoring

The study wetland is divided into seven transects with a total 40 piezometers. Piezometers were made from PVC with an internal diameter of 65mm, and no bottom and top caps were provided. In November 2005, piezometer holes were made using a Dutch Auger and all tubes were installed at different time. Piezometers were installed at a spacing of 50m along transects, the lateral distance between transects differs due to the wetland orientation (left bank and right bank position). Groundwater monitoring started in November 2005 and water table levels were recorded daily following rain events. During other days (summer and winter seasons) recording was made every other day.

3.2. Stream flow measurements

Daily stream flow was measured at the only gauging station on the Mohlapitsi River (B7H013), located about 1 km downstream of the wetland. The gauging station weir is maintained by the Department of Water Affairs (DWA) and has been in operation since August 1970. Mean daily stream flow data available from the DWA website (www.dwaf.gov.za) were used in the analysis. For the current study, historical records from June 1970 – September 2008 (Figure 3.2) were used for all the analyses.

4. Results

4.1. Rainfall and stream flow

The rainfall data plotted are averages of the 10 day accumulations measured at the five rain gauges installed as part of the project (Figure 4.1). There were very small differences between the rainfalls measured at the five gauges suggesting low spatial variability of rainfall inputs over the wetland area.

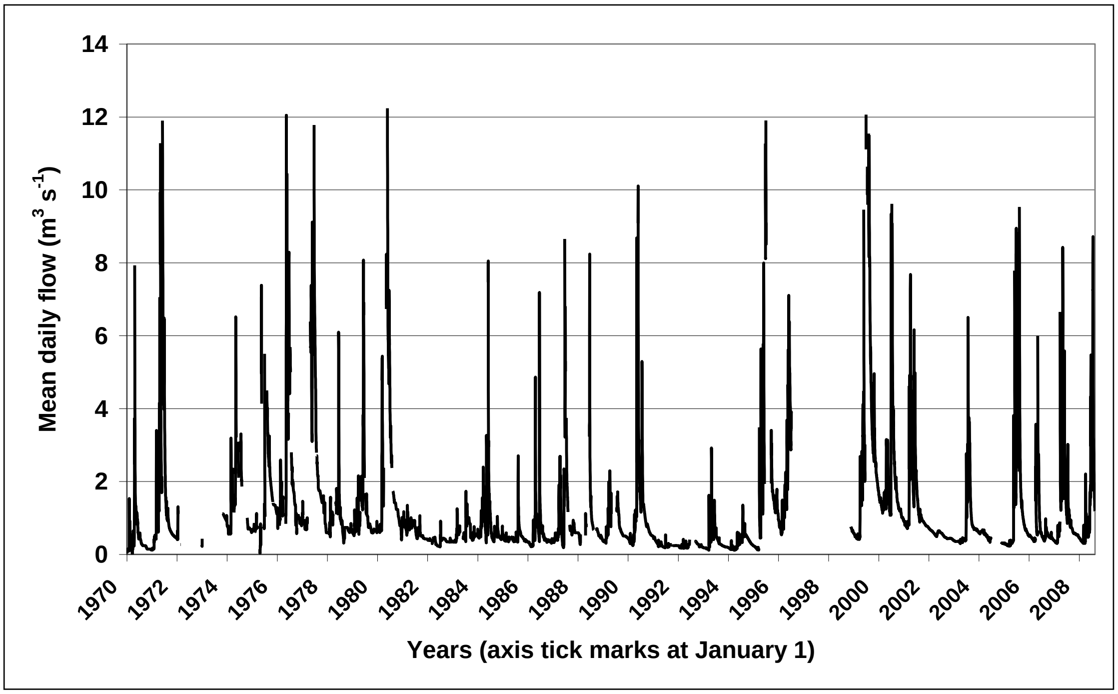

Figure 3.2. Time series of observed stream flow for gauge B7H013 for the period 1970 to 2008 (Mekiso, 2011)

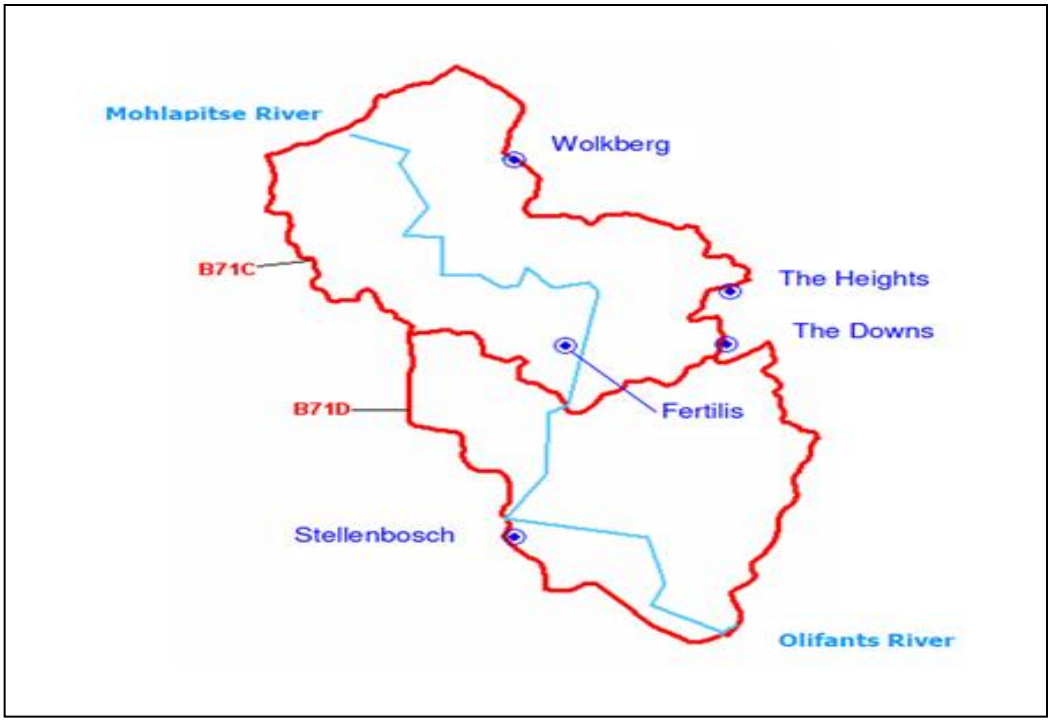

Figure 4.1. Location of rain gauges and flow gauging station in the Mohlapitsi catchment (Mekiso, 2011)

Figure 4.2 illustrates the relationship between rainfall measured over the wetland and stream flow at the DWA gauging station (B7H013) downstream. The accuracy of the measured flow data at the hydrological station B7H013 is expected to be about 5% in the range 0 – 5 $m^3 s^{-1}$ and 10% for flows higher than 5 $m^3 s^{-1}$. Moreover, when the water level exceeds 1 meter at the gauge (which corresponds to 12.8 $m^3 s^{-1}$), water overtops the weir and no stage-discharge relationship is available. Therefore, no high flow data are available and such a situation appears as observation gaps in the records (Troy et al., 2007).

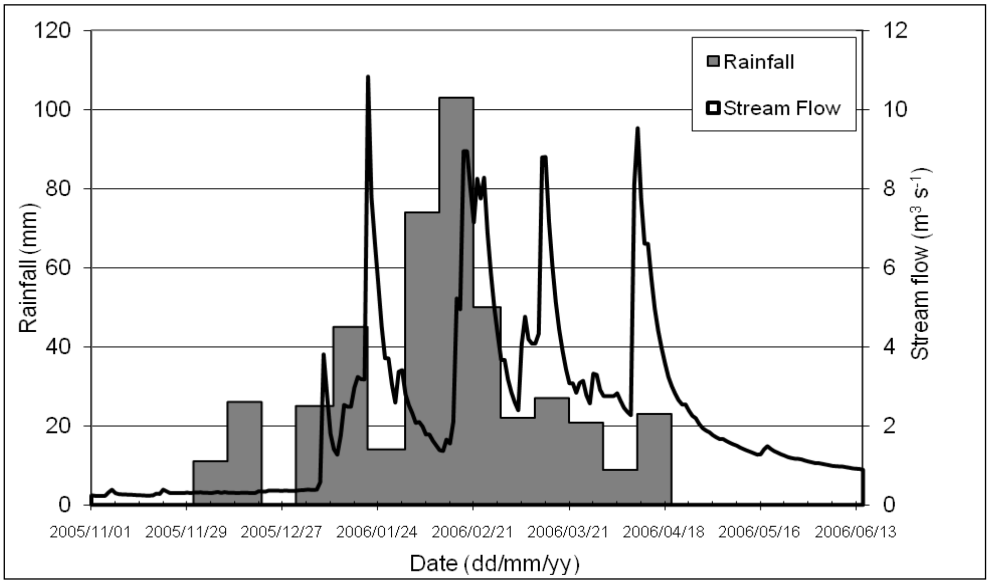

Figure 4.2. 10 day accumulations of rainfall over the wetland and daily stream flow observations at B7H013

The limited programme of stream flow observations from upstream and within the wetland area suggests that the Mohlapitsi River can lose approximately 50% of its flow after the gabion dam (Figure 4.3) during moderate to low flows (Fetter, 1994). For example, in November 2007 the flow upstream of the study site was measured as 4.2 $m^3 s^{-1}$. At a site 300m upstream of the bridge the discharge had reduced to 2.2 $m^3 s^{-1}$, while downstream of the wetland the discharge was estimated to be 2.5m^3s^{-1}.

Figure 4.3. Gabion dam structure at the head of the valley

4.2. Piezometer observations

All piezometers were installed 24 hours after augering to allow for the equilibration of water levels after initial disturbance. It was not possible to auger all the holes and install all piezometers on the same day. The graphical rainfall and stream flow data from Figure 4.2 have been added as a background image to all the piezometer elevation time series graphs to facilitate comparisons. It should be noted that the stream flow data are sourced from the Department of Water Affairs (DWA) gauge (B7H013) that lies downstream of the wetland and that the variations in flow could reflect variations in discharge from the catchment area upstream of the wetland, as well as inputs from some of the tributary channels within and downstream of the wetland. Groundwater level data are available for a seven month period that includes the 2005/2006 wet and dry seasons and show the short term variation in the water levels in the shallow aquifer associated with the wetland. Due to no significant fluctuations in the water tables, the monitoring period after May 2006 has not been included in the analysis.

4.2.1. Transect T1

Except for MRB101 (the piezometer closest to the river), the water levels showed a rapid response at the start of the wet season (Figure 4.4). However, there is very little correlation with the patterns of local rainfall during the main part of the wet season. The early season increases in water level are approximately 0.75m, which would imply a 'storage coefficient' of approximately 5% if the increase is to be attributed to the local rainfall of 37mm. In this context 'storage coefficient' refers to the material pore space available before saturation. This would seem to be somewhat too low for un-compacted surface soils, the implication being that the increase in water levels is likely to be caused by other inputs. Although not explicitly part of the measurement programme, other possibilities include diversions from the upstream main channel or inflows from the valley side slopes or minor tributaries. A further possibility is a rise of the regional groundwater level, although the relatively rapid response at the start of the wet season would tend to negate this as an option.

None of the piezometers responded to the large amounts of rainfall recorded during the first three weeks of February 2006 (10 day accumulations of 74 and 103mm) (Figure 4.2). MRB103 and MRB105 show some response to the final stream flow event of the season (end of March 2006), but no clear responses to any of the other stream flow fluctuations during the wet season. Variations in groundwater levels in MRB101 (Figure 4.4) show the closest relationship with variations in stream flow, an expected result given that this piezometer is closest to the channel. The assumption is that the groundwater is draining towards the channel and that the wetland is probably contributing to stream flow, however, the source of the increments to wetland groundwater is not very clear from the available data.

It is interesting to note that most of the piezometers do not show a great deal of variation at the end of the wet season and yet the groundwater levels (and hydraulic gradients toward the river) are substantially higher than at the start of the 2005/2006 wet season (Figure 4.4). Without recent rainfall data it is difficult to reach firm conclusions, and unfortunately the data for B7H013 are missing during the 2004/2005 season.

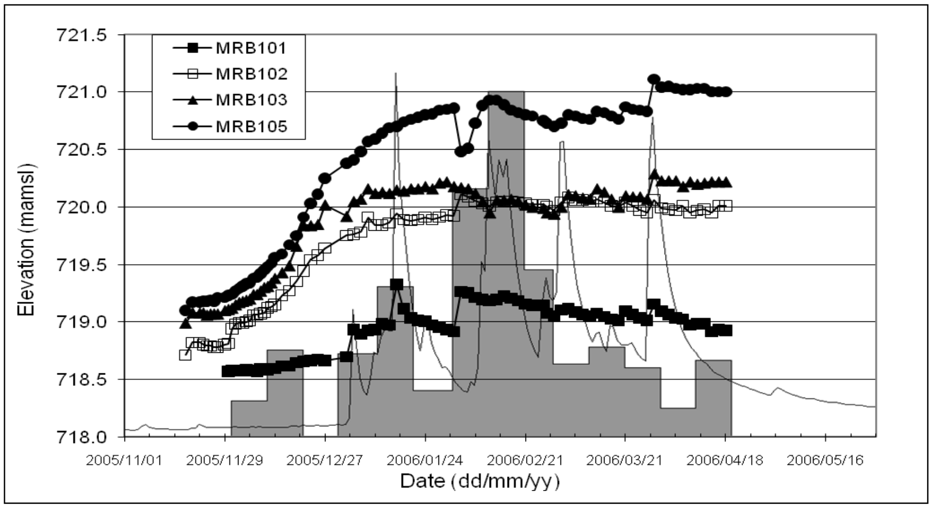

Figure 4.4. Groundwater table fluctuations November 2005 to May 2006 for T1

4.2.2. Transect T2

Most of the piezometers in T2 show a relatively small response throughout the wet season, although MRB206 responds rapidly to the high rainfalls that started at the beginning of February 2006 and, as with the T1, the piezometer closest to the river (MRB201) approximately follows the patterns of stream flow variation (Figure 4.5). MRB206 also shows a response at the same time as the last flow event of the year (at the end of March 2006). If the increase in water elevation of 0.89m in MRB206 in early February is caused by local rainfall a 'storage coefficient' of 22.7% would be required. While this might seem reasonable for the type of soil, there is no explanation for the lack of response in the other piezometer.

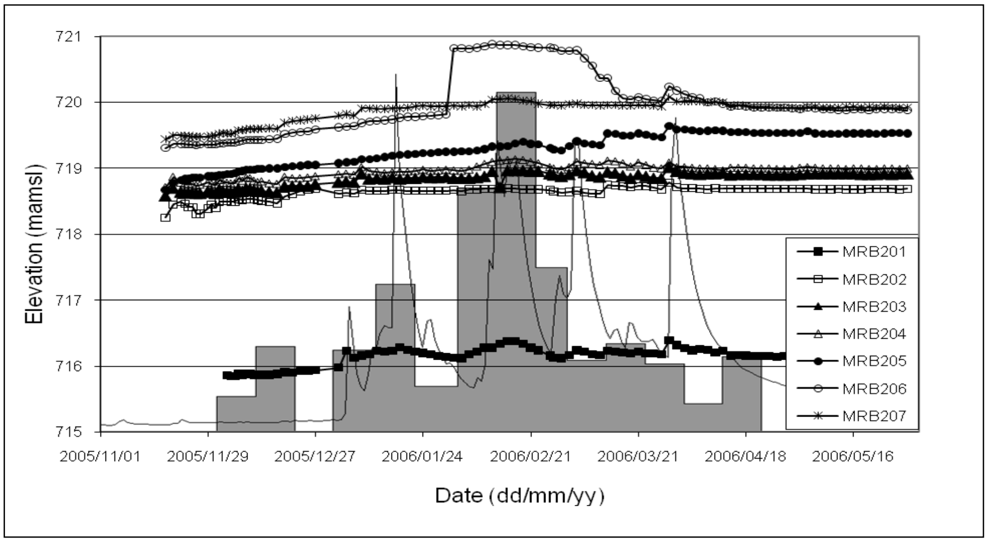

Figure 4.5. Groundwater table fluctuations November 2005 to May 2006 for T2

4.2.3. Transect T3

Piezometers MRB304 and MRB306 are the quickest to respond at the start of the wet season, with the water level in MRB304 increasing by 0.28m (Figure 4.6). Except for MRB302 and MRB301, all the sites respond quite rapidly to the rain at the start of January 2006 and continue to respond to the rainfall later in the season. Despite the data gap between the end of February and early April 2006, there are indications that these more remote (from the channel) sites respond to rainfall at the end of the season that is missing from the local records. MRB303 is the most responsive piezometer and this may be related to its position within a depression (Figure 4.6).

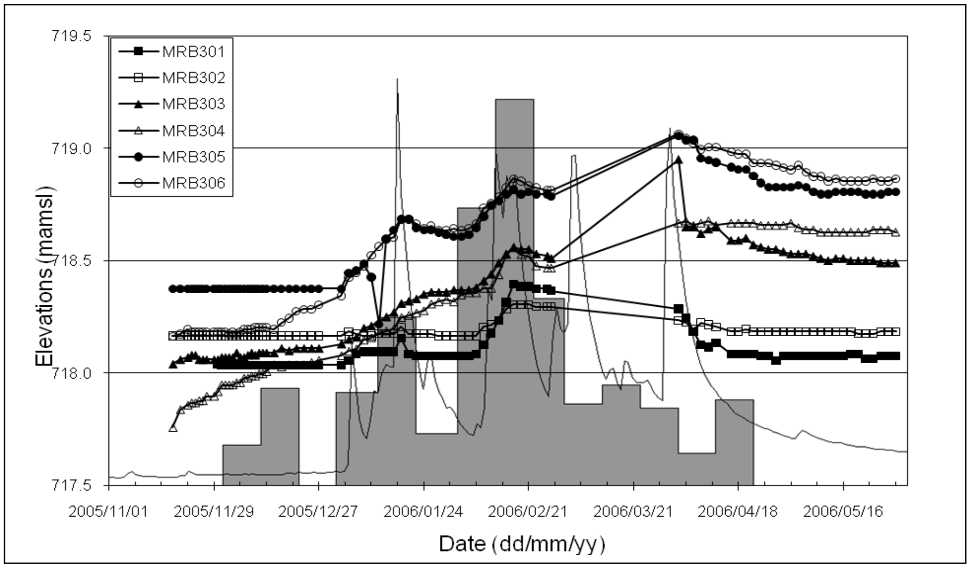

Figure 4.6. Groundwater table fluctuations November 2005 to May 2006 for T3

4.2.4. Transect T4

T4 is the widest transect in the study area, with a width of 597m and is the only transect that the river crosses (Figure 4.7). A total of 11 piezometers were installed, two were removed by vandals and nine were operating until the end of the study period (Figure 4.7). The river at T4 environment is known to be migrating within the valley bottom, branching and braiding after every flood event. For example, the river's current flow channel is approximately 150 m to the east of the location before the 2000 flood. Unlike any of the other transects, many of the piezometers at the right bank on T4 show a drying tendency at the start of the wet seasons and water levels only start to rise at the beginning of January 2006. There is no obvious explanation for this phenomenon. For most of the remainder of the wet season all the sites exhibit fluctuations that are partly a reflection of the variability in the stream flow and local rainfall. There is one unexplained rise in water level at site MLB409, but this could be related to data collection errors.

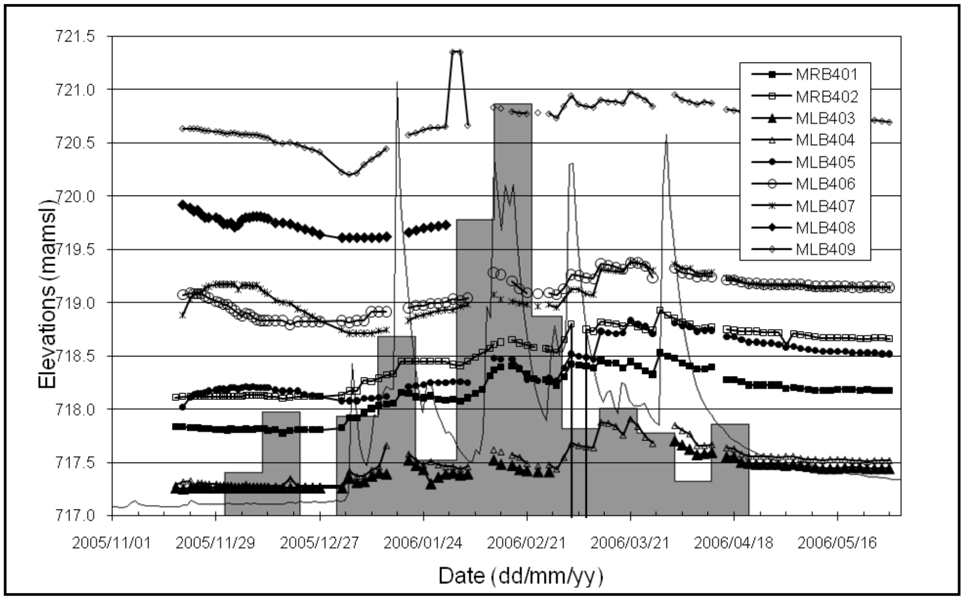

Figure 4.7. Groundwater table fluctuations November 2005 to May 2006 for T4

4.2.5. Transect T5

Figure 4.8 shows that T5 is located at the left bank and is 451m wide with eight piezometers. This portion of the wetland is located at the foot of a dolomite hillside and is within approximately 20ha of marshy land. Several springs were observed to exist at the foot of the hillside, even during dry seasons. Alike T4, some of the piezometers (MLB502, 504, 505, 506 and 508) show a drying tendency at the beginning of the wet season.

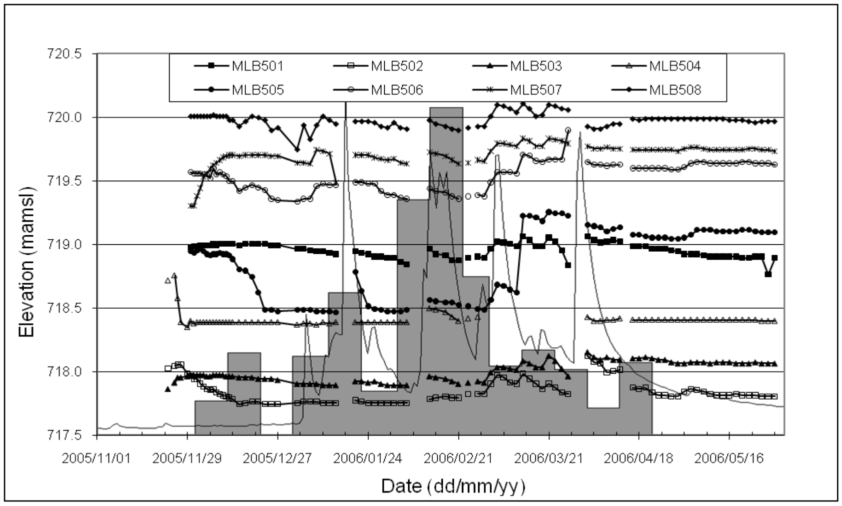

Figure 4.8. Groundwater table fluctuations November 2005 to May 2006 for T5

However, MLB507 shows a strong initial wetting and these differences are difficult to explain. In other respects most of the water levels show variations which are weakly related to the variations in stream flow and local rainfall. Site MLB505 has the greatest fluctuations, but does not seem to correlate particularly well with any known driving forces. T5 was flooded in early February (08/02/2006) and again in late March (29/03/2006) and it was not possible to record any readings. Only MLB502 and 503, show any significant reaction to the second flooding event, while most piezometers show at least some reaction to the first. However, none of the piezometers show any signs of complete saturation soon after these events, suggesting that either the flood waters do not fully penetrate into the subsurface material, or that rapid drainage occurs soon afterwards.

4.2.6. Transect T6

Figure 4.9 shows that the water levels across this transect fluctuate more than many of the other transects. These fluctuations are also quite well correlated with the variations in stream flow downstream at the gauging station, except at the start of the wet season. Part of this result may be related to the fact that the gauged stream flows are a better reflection of flows in the channel at the transect than in some of the upstream transects, but this is impossible to confirm without more data. Figure 4.9 also suggests that there may have been a wetting influence before the study started collecting data and this was followed by a drying period immediately after the first period of observed rainfall.

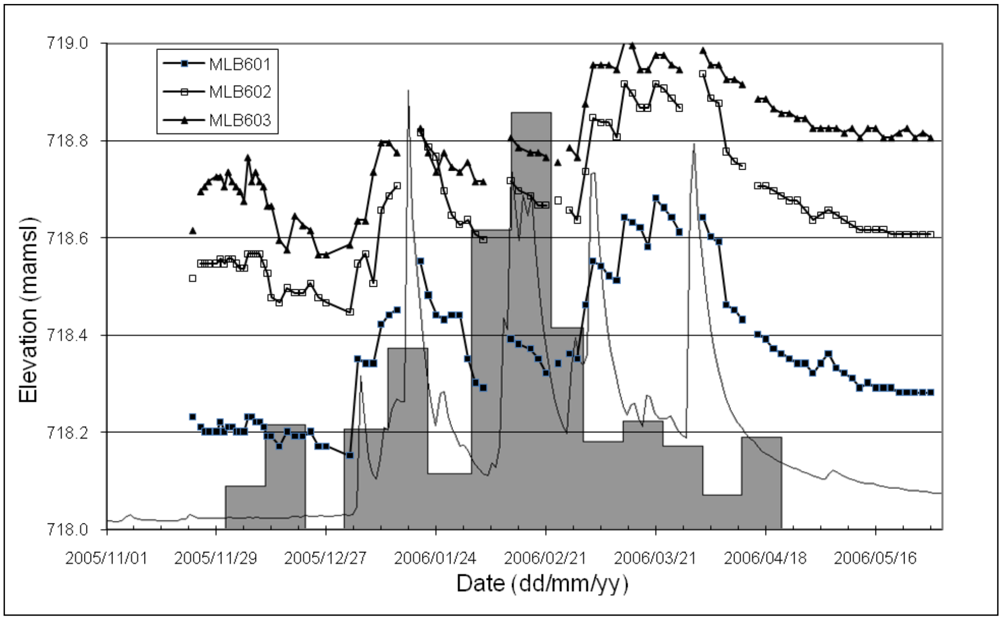

Figure 4.9. Groundwater table fluctuations November 2005 to May 2006 for T6

The response to the second rainfall period (early February) was more or less immediate with water levels rising between 0.4m in MLB601 and a little more than 0.2m in MLB603 (Figure 4.9). Because of 70mm of rain that was measured during this period, 'storage coefficients' of between 18% and 35% would be required to account for these increases in water level (Mekiso, 2011). These values are within the range that might be expected for the type of material that is present. The responses to later events in the wet season are also relatively immediate, but not always as clear and there appears to be a gradual accumulation of groundwater during the whole period, despite frequent, but relatively short periods of drying. These could be caused by drainage or evaporation, or a combination of these two processes. The recession in groundwater levels at the end of the wet season also reflects the pattern of stream flow recession, a result that is not as evident in all the previous transects. The implication is that the groundwater in this transect has a greater connection to the channel than in the other transects (Mekiso, 2011).

4.2.7. Transect T7

The water levels in transect T7 (Figure 4.10) show similar patterns of variation to transect T1, rising gradually during the start of the wet season and then remaining high with relatively minor fluctuations that do partially reflect patterns of stream flow and local rainfall. As with some of the other transects, the water levels during the 2006 dry season are much higher than the levels at the end of the 2005 dry season.

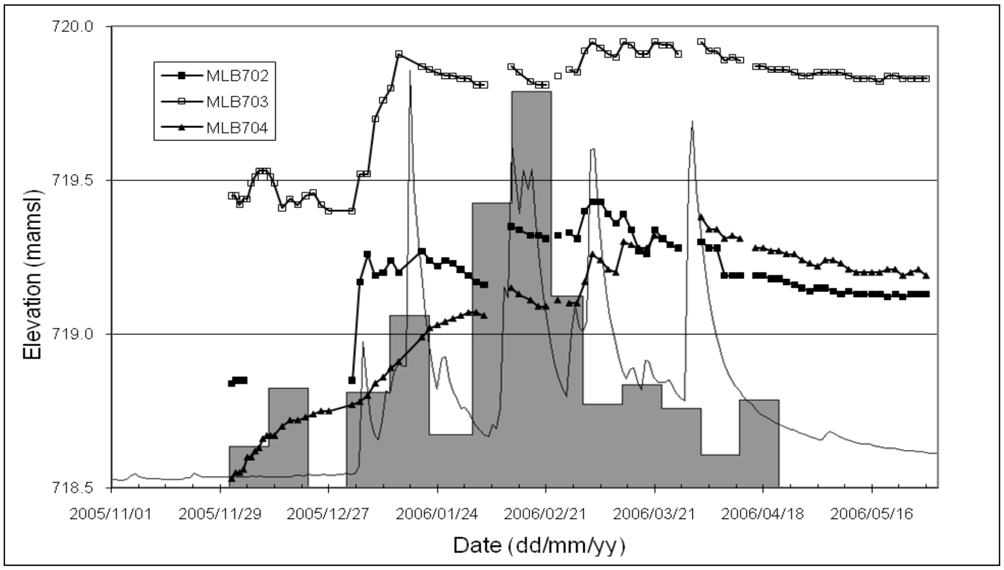

Figure 4.10. Groundwater table fluctuations November 2005 to May 2006 for T7

5. Discussion

Groundwater monitoring on all piezometers did not commence on the same day due to the fact that drilling all holes manually could not be achieved the same day. In addition, boulders beneath the soil did not allow some holes to penetrate as deeply as others. However, these constraints have not affected the interpretation of the results as the main wet season groundwater response has been captured within all transects. The deepest piezometer (3.19m) is MRB306 (farthest from the river), which is located at the end of T3 (Figure 4.6); while the shallowest (0.75m) one is MLB404, located at the left bank of T4 (Figure 4.7).

One of the first observations is that some of the interpretation of the results is hampered by some problems with the experimental design. The author was very reliant upon the field technicians to collect the data accurately and while this appears to have been generally successful, there are some gaps that impact on the interpretation of the data. Specifically, there is some evidence to suggest that the local rainfall did not end at the beginning of March 2006 and the records have been extended using the more distant (1 km from the wetland area) observations from the Agricultural Extension office. While there were insufficient resources available to the study to measure channel flow at each transect at the same time as the groundwater level observations, in retrospect it would have been useful to measure channel water levels at the same time as the piezometer water levels were monitored. This information would have helped to better understand the variations in flow in the channel through the wetland during the whole of the wet season.

At the start of the 2005/2006 wet season the variation in water levels across some of the transects was relatively low, while the variation at the end of the season was much greater (T1 and T3). However, in other transects (T2, T4 and T5, for example) the variations during the wet season were relatively minor. Most piezometers showed a gradual increase in water table level at the start of the wet season, while some others showed a drying tendency. The fluctuations in the water level varied from transect to transect as well as within transects. Transect 1 showed the greatest variations (between 1.1 and 2.0m, with the exception of MRB101 next to the channel), while T5 showed the lowest range of variation (mostly between 0.3 and 0.6m). Most of the sites closest to the river channel showed the lowest variations. The soils near the river channel are sandy and well drained in nature (Kotze, 2005) and these smaller variations in water level possibly reflect the presence of rapid lateral flow processes.

The fluctuations in water level appear to be more strongly associated with the stream flow variations reflected at the gauge (B7H013) located downstream of the wetland. The lower part of the wetland is characterized by sandy and more permeable soils, allowing for more rapid movement of water, both vertically and laterally. In this part of the wetland, any increase in storage in the wetland due to rainfall may be lost shortly after the event through lateral flow to the river. This may be one explanation for some of the rapid water table surface elevation changes observed for T6 (Figure 4.9). A further possibility that is difficult to explore in more detail without more data is that the river flow from upstream is influencing the water tables in some of the transects. It has already been noted that some of the moderate to low flows generated upstream of the wetland are diverted at the gabion dam (Figure 4.3). This water is assumed to infiltrate into the wetland environment through boulder beds and then flow back to the river through drains or subsurface flow.

These processes could have affected water levels in some of the upstream transects (notably T1 and T2). There are also many small tributaries that flow into the main channel across the wetland and depending on the spatial patterns of rainfall over the surrounding hill sides, these could have runoff responses that are very different to those reflected at the B7H013 gauge. These tributary inflows could also be affecting the water levels in some of the transects.

The mean water table surfaces in all transects (Figures 4.4, 4.5, 4.6, 4.7, 4.8, 4.9 and 4.10) show gradients in the water table along the transects towards the channel, suggesting inflow from the slopes. Whether this inflow is derived from surface runoff onto the wetland surface, or as subsurface flow is difficult to determine from the available data. The upstream part of the wetland is affected by artificial drains, although the exact location of these with respect to the transects has not been recorded. The influence of these drains could be partly responsible for the relatively low degree of variation in most of the piezometers of T2 (Figure 4.5).

This investigation has attempted to show whether there are relationships between groundwater, surface water and rainfall at the study area. Very few of the piezometers show any clear relationships with the measured local rainfall inputs, suggesting that other processes are playing equal or more important roles. These processes could include inflows from the adjacent hill slopes (either surface or subsurface or both), interactions with flow in the channel and the effects of artificial drains. There is some evidence within the data for all of these processes, but it is not conclusive. One of the important observations that have been made is that the research resources required satisfactorily quantifying and understanding wetland processes are substantial. Many valuable lessons have been learned from this study. While the wetland is relatively small, it is apparent that the hydrological processes within it are quite complex.

6. Summary

To improve the understanding of the hydrology in the Middle Mohlapitsi Catchment/ Wetland, monitoring water table levels were analyzed. The results of these analyses, a critical assessment of the gaps in data and understanding and interpretations of the data with respect to the dominant hydrological processes in the wetland are summarized below.

- Tracing shallow water table levels for 7 months indicate that there is no strong correlation with the rainfall data recorded in the wetland during the study period. The relationship between water level fluctuations and rainfall data collected from five rain gauges in the wetland during the study period did not show a strong correlation. Rather the fluctuations of water levels appear to be strongly associated with the stream flow variations reflected at the gauge (B7H013) located downstream of the wetland.
- Most transects showed a gradual increase in water table at the beginning of the rainy season, while some of them indicate a drying tendency which is difficult to explain without more information about events that occurred immediately prior to the study period.
- The water table in the vicinity of transects T1 and T2 rises quickly but does not recede during periods after rainfall events (Figures 4.4 and 4.5). This observation suggests a component of lateral flow from

the valley side. The water level responses in piezometers close to the river bank do tend to more closely follow patterns of rainfall, showing increases when it rains and decreases following storm events. However, this may also be a reflection of changes in channel flow closely following changes in rainfall and that the water table levels close to the channel are mainly affected by relatively rapid exchanges with channel water. The soils close to the river bank are sandy and well drained (Kotze, 2005 and Nell and Dryer, 2005) which supports the concept of rapid lateral flow exchanges with the channel. More rapid water level responses are observed in the lower part of the wetland (Figures 4.10), and these appear to be more strongly related to rainfall. This part of the wetland is characterized by sandy and permeable soils, leading to rapid movement of water vertically and horizontally. In the area of transect T6, any increase in storage due to rainfall is lost shortly after the event through lateral flow to the river, as demonstrated by the rapid water table surface elevation changes observed.

- Some of the river flows generated upstream of the wetland at the gabion dam (Figure 4.3) are assumed to contribute to the wetland environment through both channel overflows (largely caused by the artificial gabion dam) and infiltration through boulder beds. At least part of this water flows back to the river through drains or subsurface flow. There is some limited evidence to suggest that this process is influencing the water tables at T1 and T2, but it is not conclusive.

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