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Municipal Failure, Unequal Access and Conflicts Over Water: A Hydrosocial Perspective on Water Insecurity of Rural Households in KwaZulu-Natal, South Africa

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ABSTRACT: Despite South Africa's modern water legislation and commitment to the Sustainable Development Goals, over three million South Africans, most of whom live in rural areas, still lack access to a basic supply of safe drinking water. This case study examines the implications of unequal levels of household water insecurity (HWI) among rural households and communities; it considers the effects on their health and productivity and on their power relations with other households. We first ask whether municipal water services have succeeded in improving water access and reducing HWI for served households in the study area; we then investigate misuse and vandalism of municipal water infrastructure – the reason it occurs and how it interrelates with unequal access and HWI. We understand HWI in both a physical and a relational sense and employ the hydrosocial cycle as a lens to explore its relational dimension. Our research indicates that the District Municipality responsible for water services has largely failed to improve water access and reduce HWI for users of standpipes and users of unimproved sources/surface water, with adverse effects on health and productivity; only users of illegal yard taps benefit from water services. Partial coverage, incremental infrastructure development, neglect of infrastructure maintenance and corruption have produced uneven power relations that result in conflicts over water, vandalism and misuse of water infrastructure.

KEYWORDS: Household water insecurity, water services, vandalism, water infrastructure, power relations, South Africa

INTRODUCTION

A reliable supply of safe and adequate water to households is the foundation for good health, hygiene and food production. Around the globe, 844 million people still lack even a basic water service (UN Water, 2018). Target 6.1 of the United Nations Sustainable Development Goals (SDGs) is to "achieve access to accessible and safe drinking water", with the special commitment to "leave no one behind". This calls for a particular focus on disadvantaged and indigent rural households and on redressing inequalities in drinking-water services.

South Africa has committed itself to the SDGs and has modern and aspirational water legislation that grants the constitutional right to a basic supply of safe water to all (Republic of South Africa, 1998); yet, over three million South Africans still lack access to this basic supply, most of whom live in rural areas. Since the 1990s, there has been some progress in provisioning water infrastructure. Currently, 89% of households in South Africa have access to water supply infrastructure; its reliability, however, has declined to only 64% nationally and 42% in the priority district municipalities (Department of Water and Sanitation, 2019). There are two main reasons for this low level of reliability: first, backlogs in water infrastructure were tracked and local governments held accountable, which put pressure on them to quickly provide new infrastructure, while neglecting maintenance of existing infrastructure (Eales, 2011); second, national infrastructure grants incentivise the building of new infrastructure but do not include funding for maintenance. As a result of this poor maintenance, an estimated 35% of water is lost through leakage (Department of Water and Sanitation, 2019).

The provision of water to underdeveloped rural areas and former homelands – which are made up of dispersed settlements and where there are high levels of poverty – is particularly challenging. The Free Basic Water Policy of 2001 aims to ensure access to water for all households regardless of their ability to pay. In accordance with this policy, because 77% of rural households are classified as indigent they are not required to pay for the basic water supply of 25 litres per capita per day; as a result, local or district municipalities responsible for water services receive no revenue from this large sector of the population. The distribution of water resources in rural areas is highly uneven; only 3% of the country's total water resources are used for municipal/domestic purposes in rural areas, while 66% is used for agriculture, irrigation, afforestation, watering of livestock and nature conservation (Department of Water and Sanitation, 2019). Rural households that do not have access to formal municipal services depend on rivers, streams and springs for their domestic use; these water sources, however, have been deteriorating in quality, partly due to high levels of raw sewage and untreated effluents from unmaintained wastewater treatment works and industries. An estimated 56% of South Africa's wastewater treatment works are dysfunctional (Department of Water and Sanitation, 2019).

District and local municipalities have been struggling to overcome decades of underdevelopment in water services, and, in their effort to quickly reach development targets, they have chosen a technocratic, top-down approach to service delivery (Eales, 2011); they often, however, lack the skills needed for such an approach (Mukheibir, 2007). Next to dysfunctional infrastructure, the major challenges to water security are lack of technical capacity and skills within the water sector, and lack of transparency and citizen trust in water service delivery (Sershen et al., 2016). Poor financial management and widespread nepotism and patronage have rendered municipal water service delivery inefficient (Muller, 2007; Eales, 2011) and political interests are often prioritised over the needs of local communities (Munzhedzi, 2020). Due to the lack of capacity in local municipalities, provision of municipal services by means of contracting and tendering is common practice, which is prone to corruption. Vandalism of municipal water infrastructure is another widespread phenomenon in South Africa (Haarhoff and Rietveld, 2009; Majuru et al., 2012; Rietveld et al., 2009). Hove et al. (2019) relate vandalism to frustration with the failure of water service delivery and to disillusionment resulting from broken promises. Vandalism of standpipes is a manifestation of prevailing conflicts over water, which in turn are a symptom of water stress and insecurity (Calow et al., 2010).

Household water insecurity (HWI) is an emerging research field (Jepson et al., 2017); it reorients the wider water security discourse to the household level and can thus help in working towards the targets of SDG 6. This reorientation is important because theoretical frameworks and scientific contributions to the SDGs have thus far tended to focus on larger scales and forget local needs (Tortajada and Biswas, 2018), while many solutions to clean water and sanitation are to be found at a local scale (Tortajada and Biswas, 2018). Case studies within the scope of HWI can thus provide insights for SDG implementation and monitoring at the local level, where relevant information is urgently missing.

Previous case studies have addressed issues of water insecurity and lack of municipal water services in rural communities in South Africa. In their case study of rural areas of Limpopo, Mothetha et al. (2013) identified the challenges of municipal water supply, including poor operation and maintenance of infrastructure, illegal yard connections, and the interference of political interests in water infrastructure development. Sinyolo et al. (2014) studied the link between irrigation water security and rural household food security along the Tugela River in KwaZulu-Natal. Edokpayi et al. (2018) sampled domestic water and studied water-use practices, water treatment methods and perceptions of water quality of rural households in Limpopo. Bulled (2017) analysed the interrelations between water insecurity, emotional distress and civic engagement to improve access to water services. In a participatory action research study in rural Mpumalanga, Hove et al. (2019), together with co-researchers from rural communities, analysed the lack of water supply to households, the causes of water shortages, and their health and social impacts; from there they developed priorities for action. Similarly, Rankoana (2020) used a participatory approach to investigate community-based practices for adaptation to climate change, drought and associated water insecurity.

No study has so far evaluated existing water services in terms of their ability to reduce HWI for served households; the implications of partial coverage and unequal water access for health, productivity and uneven power relations within and among rural communities have also not been explored in depth. With our case study of HWI in a rural area in KwaZulu-Natal, we contribute to filling this gap. We aim to bring light to the interrelations between shortfalls of municipal water services and infrastructure, unequal access to water, uneven levels of HWI and the associated shifts in power relations among households and communities; we look at the potential of this dynamic to give rise to conflicts and vandalism. A deepened understanding of these interrelations may help to guide municipal water services in rural areas and prevent future conflicts around water and vandalism of infrastructure. Our study is guided by the following research questions: 1) to what degree have municipal water services succeeded in improving water access and reducing HWI for served households in the study area; and 2) what are the reasons for misuse and vandalism of municipal water infrastructure and how are they related to unequal access and HWI.

Water insecurity can be understood in both a physical and a relational way. The physical dimension is reflected by, among others, Webb and Iskandarani (1998): "Water security can be defined as access by all individuals at all times to sufficient safe water for a healthy and productive life". In this sense, Jepson (2014) defines household water insecurity as inadequate, unreliable and unaffordable water for a healthy life. We address our first research question – the degree of improvement of water access and reduction of HWI following from municipal water services – by comparing households that use municipal water services to those which are unserved; we compare them quantitatively and qualitatively in terms of different aspects of HWI, including availability and quality of water, access to water, and water-related health and productivity. We measure these aspects against the water security indicators of the Joint Monitoring Programme (UNICEF and WHO, 2018) and SDG 6 (UN Water, 2017) and against the National Norms and Standards for Domestic Water and Sanitation Services (Department of Water and Sanitation, 2017).

Wutich et al. (2017), in regarding HWI as a "concept that comprises both a state and a relation", move beyond its physical understanding to acknowledge political, economic and sociocultural dynamics as *relational* dimensions of HWI that may produce water-related inequities. In this paper, we take on this relational conceptualisation and explore HWI through the lens of the hydrosocial cycle, which Linton and Budds (2014) define as "a socio-natural process by which water and society make and remake each other over space and time". Water shapes (disrupts or stabilises) social power and institutions, which in turn shape technology and infrastructure and thus the quantity and quality of water flows (Linton and Budds, 2014). The hydrosocial cycle thus gives us a lens through which to investigate the interrelations among water services and infrastructure, unequal access and levels of HWI, uneven power relations among households and communities, and the manipulation of infrastructure and alteration of flows in the form of illegal yard connections and vandalism of public standpipes.

MATERIAL AND METHODS

Study area

The study area lies within the former homeland of KwaZulu; it is now officially state-owned land under tribal authority. Most of the study area lies within Ward 1 of the Umvoti Local Municipality; it covers an area of 52 km² which includes land at elevations of between 350 and 950 metres above sea level (masl). Greytown, the town closest to the study area, is 29 km to the northwest. The area is mainly covered by pastures, dispersed settlements and their associated small-scale cropland, and some forest or shrub land close to watercourses. Smaller roads connect most of the settlements to the main road network, though some settlements are only accessible via footpaths. The closest marketplace and hospital are located west of the study area, in Matimatolo. Based on aerial imagery by Google Earth, we estimated there to be between 1255 and 1385 households within the study area. The people living in the area speak isiZulu. An *inkosi* (king) is responsible for an area that extends well beyond the study area, while an *induna* (headman, tribal leader) is in charge of each village (tribe or community). Within the study area are the villages of Vikindlala, Embulwane, Dube, Mabomveni, Bhekizwe and Makhabeleni. The mean annual rainfall at the closest weather station (Mistley station, 22 km west of the study area) is 805 mm. The temperature in Greytown ranges from a mean daily minimum of 11°C to a mean daily maximum of 24°C.[1] The Umzinyathi District Municipality (DM) is responsible for providing water to the study area.

Field research and household survey design

This study draws on two research phases, an exploratory field trip between September and November 2014 and a household survey in January and February of 2018. During the field trip in 2014, the first author carried out over 30 semi-structured and unstructured interviews with farmers and water users and with municipal and traditional leaders on water-related problems in the Upper and Lower Umvoti River Basin. She attended meetings of the Upper and Lower Umvoti Catchment Management Forums (CMF) and participated in a community meeting in Vikindlala and in subsequent group discussions; together these formed the basis for choosing this specific study area as the site for a study of household water insecurity.

In order to investigate the factors for household water insecurity, we designed a household survey drawing from the core questions on drinking-water and sanitation for household surveys developed by the WHO/UNICEF Joint Monitoring Programme (WHO and UNICEF, 2006). Survey items were further informed by the National Sanitation and Hygiene Knowledge, Attitudes and Practices (KAP) Survey of the Department of Rural Health Care and the Ministry of Rural Development, Cambodia (DoRHC and MRD, 2010) and the Water, Sanitation and Hygiene Household Survey, Gaza (UNICEF and PHG, 2010).

The household survey was subsequently carried out with 67 households, the first and second author working in two teams of one researcher and one translator each; the translators helped translate the survey items into isiZulu. After a short pilot phase of three days, we identified problematic survey items and adapted the survey. To sample households in this remote setting, we used convenience sampling (Etikan, 2016), that is, we picked households that seemed representative of their group of neighbouring households. In two cases, we were not invited in. We visited only households that were less than 15 minutes by foot from a road; such households were therefore overrepresented in the sample. We spent between 35 and 60 minutes with each household, though in a few cases we spent longer. During the

[1] We calculated mean annual rainfall (1968-2016) and mean maximum and minimum temperatures (1993-2016) from data provided by the South African Weather Service.

survey, we noticed possible sources of uncertainty and bias in the responses: for example, the presence of other people at the interviews probably influenced responses; also, in a few cases, we were not able to speak to the person who was responsible for water collection because they were busy collecting water at the time; we also observed that responses were affected by time of day and weather. For questions on water collection, we asked the interviewee to show us the containers used for water collection and, with their permission, we took photos of these containers; these photos were later used to verify responses on collected water volumes. In some cases, we asked interview questions that went beyond the survey items. The translators undertook the survey and interviews entirely in isiZulu; during interviews, they translated responses into English so that the researcher could fill in the survey form, take notes and ask further in-depth questions based on the responses.

Survey and interviews were conducted in line with the principles of good fieldwork as laid down by the American Anthropological Association (2012). The overall research plan was introduced to the participants, the purpose of the study was explained, and it was made clear to participants that their privacy would be protected; we then made sure that the participants had understood this and asked for their oral consent, which we recorded. In response to the question of whether we would "bring them water", we said, we were "not in the place of authority to bring about change", but that we hoped "that the research would be able to speak to those who do have authority to bring on real change in the community".

During the second field trip, we conducted further interviews and attended more meetings. Among those interviewed were the councillor and programme manager of the local office of World Vision, an international humanitarian organisation; these interviews were conducted in English by the researcher. Towards the end of our research stay, we participated in a large community meeting on conflicts over water within the study area. The meeting was attended by women and men from the community and surrounding communities, the mayor of the DM, the king and traditional leaders from different villages; it was held in isiZulu, and one of the translators took meeting minutes in that language which she later translated into English.

Data analysis

Processing data on water collection

Questions on water collection were only directed at users of standpipes and of informal water sources. In order to estimate the average water volume collected per capita per day, we recorded the volume and number of water collection containers filled in one day, the weekday availability of water (i.e. on how many days in a week water was available) and the number of household members. For most households we estimated a minimum and maximum water volume, since there could be variation in the volume collected in one day and the number of days in a week that water was available. We defined water collection time as the total time needed for a round trip to the water source, including queuing. This was not the same each day but depended on various factors such as season and time of day; many users therefore indicated a range – minimum and maximum – of water collection times. Because of the large variety of different unimproved and improved water sources and because of our limited time in the field, we did not locate each primary water source or gather data on the distance of each household from their source; we instead asked for the time needed for a round trip. This approach is recommended by the Joint Monitoring Programme (UNICEF and WHO, 2018).

Statistical data analysis

The households were grouped according to their primary water source: 1) users of yard taps (n = 12), 2) users of public standpipes (n = 13), and 3) users of unimproved sources/surface water (n = 36). The three groups were contrasted pairwise in terms of survey responses. All statistical analysis was performed in the open-source software R (R Core Team, 2017), using Bayesian regression models via the 'brms' package (Bürkner, 2017) as an interface to the Bayesian inference engine Stan (Stan Development Team, 2019) for the analysis of continuous response variables.

For categorical response variables such as weekday water availability, we tested their dependence on the primary water source by calculating the probability of the independence hypothesis H0 and the probability of the dependence hypothesis H1 from a Bayesian analysis of the respective contingency table as follows: we used a multinomial model for the cell counts (as total counts were fixed by the sample size) and a uniform prior cell count so that the total prior weight was 1 compared to the data weight of 67 (Aitkin, 2010). The probability of the independence hypothesis vs. the dependence hypothesis was calculated via the deviance difference. A positive deviance difference indicates that there is support for the dependence hypothesis, while a negative deviance difference means support for the hypothesis that the two variables are independent. In the results section, the posterior probability of one category, or the difference between the posterior probabilities of two different categories, is always summarised by the central 90% credible interval (CI) and the median, i.e. the 0.05 quantile, the 0.5 quantile and the 0.95 quantile.

Continuous response variables were log transformed and modelled as a function of primary water source in a Bayesian version of variance analysis (normal response distribution after log transformation). Competing model variants were ruled out based on predictive performance of the models, specifically leave-one-out cross-validation using the expected log pointwise predictive density (ELPD) (Vehtari et al., 2016). For the average response for each primary water source (the intercepts of the model), we used a uniform prior over the real numbers. As prior for the common standard deviation, a t-distribution with 3 degrees of freedom and scaled by 2.5 was used. Both are uninformative choices.

Strictly speaking, our sample is only representative for communities within a 15-minute walk from the roads; this limitation is due to the typical logistical constraints we found in the field. The relatively small sample size translated directly into wide uncertainty distributions for the effects under investigation in the Bayesian framework, so it is properly accounted for. With information on the demographic characteristics of the wider population in the area we could have even extrapolated our findings using post-stratification, but obtaining those demographics was beyond the scope of this study. We expected that those households further away from the roads would have very limited access to water resources from public standpipes and would be even more water insecure than the households portrayed here. Even within our sample, the largest group of households was that which relied on unimproved sources or surface water.

We compared the three groups of households in terms of different aspects of HWI: water availability and quality, water access, health, income, and productivity. In addition to the results from the statistical analysis, we used qualitative data from individual responses of community members and from interview partners outside the community, as well as field observations and meeting notes. In a similar case study in Ethiopia, MacAllister et al. (2020) compared the performance of different types of water sources during drought. We measured aspects of HWI against indicators of the Joint Monitoring Programme (UNICEF and WHO, 2018), SDG target 6.1 (UN Water, 2017), the regulatory framework laid out by the *Water Services Act* (Department of Water Affairs and Forestry, 2001) and the National Norms and Standards for Domestic Water and Sanitation (Department of Water and Sanitation, 2017). Specifically, we measured our results against thresholds for water collection time and water consumption, and against water services standards.

RESULTS AND DISCUSSION

Availability, seasonality, and quality of different water sources

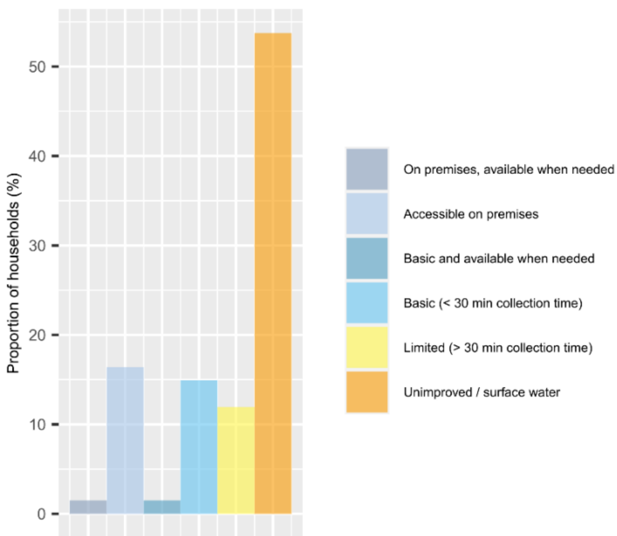
Households in the study area depended on a variety of different water sources. Table 1 shows the proportional use of sources as primary and secondary water sources during summer and primary water source during winter. During the dry season (winter), 84% of all households (n = 67) switch to a different primary water source.

Table 1. Percentages of different sources used as primary source in summer, secondary source in summer, and primary source in winter.

	Primary water source in summer (n = 67)(%)	Secondary water source in summer (n = 64)(%)	Primary water source in winter (n = 66)(%)
Unimproved source/ surface water	54	6	30
Public standpipe	28	1.5	
Yard tap	18		
Rainwater		84	34
Waterkan*		4.5	12
Umvoti River (by car/taxi)			7.5
Standpipe in distant village			15

Note: * Waterkan refers to water trucks administered by the District Municipality.

Figure 1. Proportion of households with different levels of service (primary water source), following the Joint Monitoring Programme drinking-water service ladder.



Since its 2017 report, the Joint Monitoring Programme (JMP) uses an updated drinking-water service ladder to enhance global SDG monitoring (UNICEF and WHO, 2019). Figure 1 shows the proportion of households with different levels of service in accordance with the JMP service ladder for drinking water. Improved water sources are those that have the potential to deliver safe water. The first two categories are improved water sources that are accessible on the premises but with different levels of availability; in our case study these correspond to yard taps, that is, illegal yard connections to public pipes. 'Basic service' is drinking water from an improved source with a water collection time (round trip) of less than 30 minutes. We added another category of 'basic and available when needed'; this makes clear that most households with basic service do not have continuous water availability. 'Limited' service is an improved water source with a water collection time of more than 30 minutes. In our case, both basic and limited levels of service correspond to public standpipes. In the last category, we combined households with unimproved sources (such as unprotected springs) with households that use surface water from streams or rivers; we did so because many surveyed households did not clearly differentiate between springs and streams when asked about their primary water source.

The statistical analysis shows clear support for a correlation between water availability and type of primary water source. Weekday availability, hours of availability and seasonality of water all depend on whether a household uses an unimproved source/surface water, a public standpipe or a yard tap (Table 2); moreover, availability and water quality are interlinked.

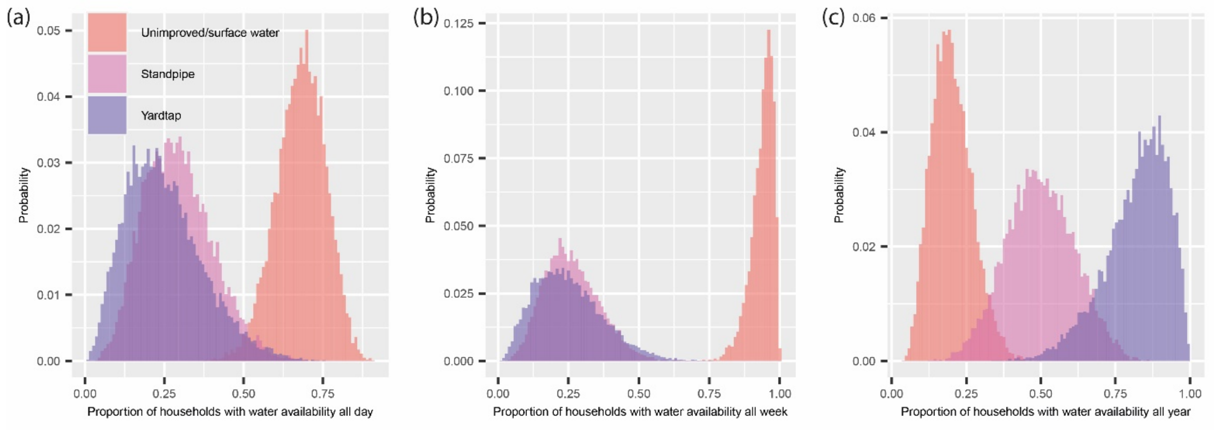
Table 2. Reliability and seasonality of water sources.

	Unimproved sources/surface water (%)	Standpipe (%)	Yard tap (%)
Weekday availability (n = 64)			
Continuously/seven days a week	94	28	25
4 to 6 days a week	3	22	58
2 to 3 days a week	0	39	17
Once a week	3	11	0
Hours of availability (n = 64)			
Continuously/all day	69	29	25
More than 12 hours per day	6	0	17
5 to 12 hours per day	20	71	58
Less than 5 hours per day	6	0	0
Seasonality of primary water source (n = 65)			
Use it all year	20	50	83
Use it all year but flow/pressure decreases greatly in winter	51	11	17
Use it only in summer	29	39	0

The proportion of users of unimproved sources/surface water who have water available every day of the week is 0.68 [0.49, 0.83][2] higher than the proportion of standpipe users who have the same; it is also 0.7 [0.46, 0.87] higher than the proportion of users of yard taps with water all week (Figure 2b). Similarly, the proportion of users of unimproved sources/surface water who have water available all day is 0.4 [0.16, 0.59] higher than the proportion of standpipe users who have the same; it is also 0.44 [0.18. 0.65] higher than the proportion of yard tap users with water all day (Figure 2a). The proportion of yard tap users who have water all year is 0.63 [0.39, 0.8] higher than the proportion of users of unimproved sources/surface water who have the same; it is also 0.33 [0.05, 0.3] higher than the proportion of standpipe users with water all year (Figure 2c).

[2] We present all estimates as medians [90% credible interval].

Figure 2. Proportion of households with water available all day (a), all week (b), and all year (c), among users whose primary water source is unimproved sources/surface water, standpipes or yard taps.



Unimproved sources/surface water

The numerous springs and streams in the mountainous area of this study serve as primary or secondary water source for almost all households. Bushland (natural vegetation) covers the streambanks and meadows along and around these water sources and serves as a habitat and corridor for wildlife. The largest surface watercourse in the area is the Umvoti River; it offers a continuous supply of water to nearby households throughout the year, and in winter it also serves as water source to households that live further away. There are irrigated community gardens on the floodplains of the river but no public standpipes close to the river. In accordance with the JMP classification, we refer to springs, streams and the river as 'unimproved/surface water' (Figure 1).

During summer, the majority of users of unimproved sources/surface water have water from their source all day and every day (Table 2); however, after intense rainfall events and at very high temperatures, availability is limited by low water quality. Heavy rainfalls may cause resuspension of sediments and can flush debris into watercourses; after rain events, water users thus need to wait for the mud to settle before being able to collect water. The water quality in highly used streams and springs is best in the morning; as a member of household R8[3] said, "Throughout the day, the water becomes more and more unusable due to cows and other livestock drinking and defecating in the water". The programme manager of World Vision indicated that their NGO has protected some springs from pollution. Compared to streams, the water quality in the Umvoti River is low; this is due to multiple sources of pollution within the large catchment area (such as raw sewage from Greytown) as well as direct water use. Members of households close to the river wash themselves and their clothes directly in the river and large numbers of livestock drink from it.

Half of the households that rely on unimproved sources/surface water stated that the flow decreased greatly in winter. A member of household R8 said that, "In winter there is very little but we still collect even though it's dirty and we compete with the cows". In the dry season, some streams fall dry; this means that a reduced number of springs and streams provide water to an increased number of households, likely reducing water quality further. Some households indicated that the decrease in flow during the winter was linked to the drought that the region had experienced between 2014 and 2017. In the winter, more households compete for water from the streams that have not fallen dry. A member of household R15 told us that,

[3] We numbered the studied households, and refer to them as R (user of unimproved source/surface water), S (user of standpipe) or Y (user of yard tap).

> In winter it's not enough for all, only for a few households. It wasn't like this before but in the past few years it is becoming like this because of the droughts. In winter we go at 5 a.m. so we get water before the neighbours get it.

Public standpipes

The DM provides free public groundwater-fed standpipes to water users. Groundwater is pumped from boreholes to reservoirs and from there to the standpipes, in most cases in a rotating water-shedding system. Daily management of valves by the service provider ensures that water from one reservoir reaches different standpipes on different weekdays. Water shedding is a technical attempt to distribute the limited amount of water evenly among communities that rely on standpipes, as the available groundwater is not sufficient for a continuous supply to all standpipes. Public standpipes are dispersed along the main roads at irregular distances.

To some extent, low weekday water availability at standpipes is a purposeful outcome of the rotational water-shedding system. Households collect large amounts of water on the days when it is available and store it at home for the rest of the week. Various factors, however, limit the water volume that a household can collect from a standpipe in a single day (see below), and households with a low weekday availability usually cannot collect enough water to compensate for the days of the week on which no water is available and thus need to store large amounts of water in their homes for the rest of the week; this can lead to bacterial growth which reduces water quality. Levels of bacterial contamination in storage containers are generally associated with the water storage period, with how well and how often storage containers are washed, and with hand contact with drinking water (Too et al., 2016; Edokpayi et al., 2018). Many respondents also told us that standpipes sometimes ceased to function even during the regular water-shedding schedule and water was lost through leaky or broken pipes. A member of household Y1 explained that, "When water in the standpipe is shut down, there are two possible reasons: diesel for the generator has run out, or the pipes are broken". Other case studies in rural South Africa have reported a similar lack of maintenance of water infrastructure (Hove et al., 2019; Mothetha et al., 2013).

For 71% of users of standpipes, water is available for only 5 to 12 hours per day. A member of household S17 described the unreliability of the public standpipe she was using, saying that,

> It comes in the morning. Around 11 am, there is no water left. Then it comes back later in the afternoon and the neighbours tell us that the water is back. It disappears again at any time. Taps are on and off. The people with yard connections always have water. It is difficult to ask them for water because they paid for the connections.

The service provider does not treat groundwater that feeds into public standpipes; the DM therefore advises households to treat their drinking water with bleach. The National Groundwater Archive South Africa contained no data on groundwater quality in the study area, so we assumed that groundwater quality was not being monitored. This meant we could not rule out geogenic and anthropogenic contamination of groundwater and related health hazards. Use of groundwater instead of surface water does not necessarily guarantee good water quality (Mackintosh and Colvin, 2003). Availability of water from public standpipes in winter is limited because the groundwater table drops and the pressure in the borehole is not sufficient to sustain the flow at the standpipe. A member of household S2 told us that, "In winter, water from the standpipe is unavailable. The engine pumps up mud". Mothetha et al. (2013) showed comparable results; the boreholes in their case study were unable to meet the demands of the community, and households used additional water from springs, or bought water from households with private boreholes.

Yard taps

Some households had installed taps in their yards and had connected them to the pipe system that feeds the public standpipes. Such yard taps are deemed illegal by the municipality because they divert water from public standpipes. The main requirement for a yard connection is that the household has the financial means to pay a qualified plumber for installing and connecting it, which usually takes place in the dark. Yard connections divert water from pipes before it reaches the public standpipe. On certain days of the week, water can still be available to upstream yard taps but not sufficiently to downstream public standpipes. A member of household S17 told us that, "Sometimes there is no water in the standpipe. I suspect that it is because of the people with yard connections. Water gets finished in their homes". Poor water services and low coverage and reliability of standpipes have triggered the installation of numerous illegal yard taps, which in turn further compromise the reliability of the standpipes. In the perception of yard tap users, the water source is very reliable; the only reason for the water flow to cease would be vandalism. A member of household Y6 said, "Water is only unavailable if the pipes are broken. This is due to my neighbours vandalising my yard tap. It takes a day or two to fix the pipes". We have no data on the water volumes used in a home with a yard tap; our observations of water use in the field, however, suggest that the water volumes used by yard tap users exceed the free basic water volume of 25 litres per capita per day. A strong indicator for our assumption is the use of water from yard taps for irrigation.

The waterkan

The National Norms and Standards for Domestic Water and Sanitation specify that an interim level of water supply service is provided "within reasonable walking distance (…) while repairs and/or reconstruction of a water services failure/interruption/breakdown are in effect" (Department of Water and Sanitation, 2017). The goal is to "[meet] people's need for potable water for domestic use within 24 hours of disruption or breakdown in existing services". In the study area, this interim level of service was expected to be provided in form of the *waterkan*, or water lorry. The waterkan (in Afrikaans, literally 'water tanker') refers to one or several water trucks administered by the DM which fill the community tanks on the DM's behalf. Rural residents in need of water contact the local councillor, who then has to ask the municipality to send for a waterkan (from an interview with householders R4 and R8).

Due to intermittent water supply, community tanks provided by World Vision and filled by the waterkan are an important secondary water source (Table 1). World Vision is an NGO which works to support children and their families who live in poverty. In the study area, one of the priorities of World Vision is to improve access to safe drinking water; it works in partnership with the DM to provide large community tanks along the main roads. Some tanks are also placed within fenced yards and accessible to the public from there.

The surveyed households reported experiencing the waterkan as being highly unreliable. As a member of household R8 said, "These tanks are filled depending on the mood of the people that deliver and they come irregularly". Reported intervals between water deliveries by the waterkan ranged from two weeks (R16) to six months (S12). A representative from the DM stated that communities in the area could count on the waterkan to be there within one day after the councillor's request; community members, however, said that the councillor did not pass on the request to the District Municipality in time (R4, R8). The unreliability of the waterkan is allegedly linked to the relatively small number of water tankers that serve a large area and numerous communities. The councillor suggested that there was only one waterkan for the whole DM; other interviewees involved in water provision objected to this and spoke of several water tankers. One interviewee added that the number of trips per day was limited by the long travel time between the rural communities and Greytown, where the water tankers fill up.

Six interviewees said that the waterkan had ceased to provide water to their household altogether (R6, R7, R19, R23, R29, Y5). A member of household R7 told us that, "We were given water tanks to store water. We were promised that Waterkan will come but it hasn't in a very long time". In the past, households that were not accessible by the waterkan would place large drums next to the road that the waterkan could fill; they then carried the water from the drums to their homes in buckets (R29). The waterkan, however, has now stopped filling these drums; as a member of household R29 said, "The Waterkan hasn't been here for more than one year. When it does come, it only puts water into Jojo® tank [large polyethylene storage container] for people who have tanks. It doesn't come down here".

Water from the waterkan is supposed to be "of an adequate quality from a health point of view" (Department of Water and Sanitation, 2017); some households, however, reported it to be of very low quality. One interviewee (R16) told us that, "The water from the Waterkan does not look clean, but red. We put vinegar in it, but we got sick anyway. (…) In June/July the water from the Waterkan was muddy but we paid for it anyway because we needed the water". Another interviewee (R13) said that, "Since they put the water into my Jojo-tank the water in the tank is green". An interviewee from outside the study area stated that waterkan drivers often did not drive all the way back to Greytown to fill up, but instead filled up by the river or its tributaries; this would explain the low water quality reported by some households. We did not speak to waterkan drivers to verify this.

The waterkan service is characterised by mismanagement and corruption. A member of household R16 reported that, "When the Waterkan comes, it passes by the tanks on the road without filling them with water. I suspect that the Waterkan only puts water in households with people they know or are friends with". Whether or not the waterkan provides a specific community tank with water is supposedly linked to the political orientation of the households that rely on that tank. According to one interviewee (R7), "The Waterkan used to come, but it doesn't come anymore because of politics. We did not vote for the services, so it doesn't come anymore to us". The interim level of water services temporarily replaces the regular Free Basic Water Supply services and therefore ought to be free of charge; yet households are often asked to pay for water from the waterkan. A member of household R16 told us that, "Although water from the Waterkan was previously free, people of the Waterkan had told me that to fill up my tank was going to be too much as the tank itself is too big. This is when Waterkan water deliverers started charging me ZAR250". Two interviewees (R25 and R26) said that they would be willing to pay for water from the waterkan. A councillor confirmed that service providers of the waterkan often made a profit from the water by selling it to households and that waterkan drivers were thus "double-dipping". This is a case of the kind of petty corruption that can alienate citizens from municipal leadership (Pillay, 2016). In the case study by Hove et al. (2019) as well, community members reported corruption of waterkan drivers. At the large community meeting in 2018, the mayor of the DM instructed the community not to buy water privately from the waterkan; he said that this water was meant for everyone, referring to the waterkan's function to fill community tanks along the road.

Water collection

Women and children generally carry the brunt of collecting water from distant and often unreliable water sources (Bakker and Hemson, 2012). In 91% of the households (n = 55), water is collected by women only, while in 45% of the households (n = 56) children take part in the collection of water. Members of 90% of households (n = 59) walk to the water source and carry containers of water in their hands or on their heads. Only two households primarily used cars for collecting water and 7% used wheelbarrows. Two households used cars as their secondary means of transport, for example when they needed to travel to a more distant water source in the dry season. Unlike public standpipes, which are close to roads, most unimproved sources/surface water sources are not accessible with wheelbarrows or cars. One interviewee (R29) said that, "The standpipe is far away but I use it sometimes because the terrain is flat".

The JMP defines a basic drinking-water service as an improved source with a total collection time of not more than 30 minutes (UNICEF and WHO, 2018). The collection time is an important indicator for SDG target 6.1 (UN Water, 2017); according to the National Norms and Standards for Domestic Water and Sanitation, the maximum walking distance to a public standpipe should not exceed 100 metres at the lowest level of water supply ("intermittent provision of water at a minimum level of water supply services") (Department of Water and Sanitation, 2017). For this reason, public standpipes should be dispersed at regular distances of 200 metres apart along the roads; however, this was not the case in the study area and, instead, we took note of only a few functional public standpipes at irregular intervals. The average minimum water collection time is 30 minutes [7, 121], while the average maximum water collection time is 37 minutes [9, 146]. Water collection time is determined by the distance to the available water source, its characteristics (flow/pressure) and the number of households that depend on that same water source; these factors account for the large variation in water collection times. There is no clear support for a correlation between water collection time and type of water source; that is to say that users of standpipes – though they do have access to an improved water source – do not spend less time collecting water than do users of unimproved sources/surface water. 50% [41, 59] of households have a *minimum* water collection time greater than 30 minutes, and for 60% [51, 69] of the households the *maximum* water collection time is greater than 30 minutes.

Households collect an average water volume of between 12.4 litres per capita per day (l/cap/day) [2.8, 55] and 16.6 l/cap/day [4.7, 59.2]. There is no clear support for a correlation between collected water volume and type of water source; the large variation in collected water volume is related to large differences in availability, water collection time and household characteristics. The number of household members, their age, gender and health status all determine the capacity of a household to collect water. The *Water Services Act* regulates basic water supply; it states that, "3) The minimum standard for basic water supply is (…) b) a minimum quantity of potable water of 25 litres per person per day or six kilolitres per household per month" (Department of Water Affairs and Forestry, 2001). The National Norms and Standards for Domestic Water and Sanitation specifies the minimum volume for the most basic level of supply, which is the "intermittent provision of water at minimum level of water supply services" (Department of Water and Sanitation, 2017); it states that, "A minimum volume of 1500 litres of potable water shall be made available to a household per week". This corresponds to an amount of 6000 l/household/month and gives an indication of the required weekly availability. Among the households, 70% [61, 78] collected a *maximum* volume of less than 25 l/cap/day and 78% [70, 85] collected a *minimum* volume of less than 25 l/cap/day; hence, for a large majority of households that do not own yard taps, the collected water volume does not meet the requirements of the *Water Services Act* and the National Norms and Standards for Domestic Water and Sanitation, regardless of their water source. (Here we assume that most of these households are not able to significantly top up their collected volume of water with secondary sources such as rainwater or water from the waterkan.)

Shortfalls of the District Municipality in water provision to households

The above findings show that households served by standpipes do not collect larger volumes of water per person per day than do unserved households, nor is the water collection time for served households less than for unserved households. In contrast, the weekly and hourly water availability from unimproved water sources/surface water is significantly higher than the availability from standpipes or yard taps; provision through public standpipes has thus failed to improve water access in the study area compared to access to unimproved sources/surface water. Municipal water supply is irregular, coverage is only partial and households are not equally served. The rotational water-shedding system differentially limits households' water availability. For a large majority of the surveyed households, municipal water services do not fulfil the criteria for intermittent provision of water at a minimum level of water services laid out by the Department of Water and Sanitation (2017); the department calls for a minimum volume of 1500 litres of water per household per week, a walking distance of no more than 100 metres from the farthest household to the standpipe and water availability for 52 weeks a year; it further specifies that water must comply with the South African National Standard (SANS) 241 quality standards. Neither are the criteria fulfilled for an interim level of water services in case of disruption or breakdown of existing services.

The DM does not manage groundwater abstraction in a sustainable manner that prevents depletion of aquifers and preserves groundwater resources for future generations. The service provider regularly overpumps boreholes to meet the rising water demand of the growing rural communities; as a consequence, boreholes have collapsed, aquifers are at risk of depletion and the service provider has had to drill new boreholes at much deeper levels (up to 200 metres). During the 2014 to 2017 drought, many streams and springs in the area fell dry; this led to a further increase in demand for the decreasing number of remaining groundwater sources – what Calow et al. (2010) have termed the "drought spiral".

At a community meeting in 2014, an engineer from the DM presented plans for new (groundwater-based) water infrastructure in the area and promised that the DM would implement the new plans within the next two months, thereby raising expectations within the community. During our second field research in 2018, it became clear that only a small part of the plans that the DM had announced in 2014 had actually been implemented and large parts of the area were still lacking functional water infrastructure. Our interview partners were not clear about the whereabouts of the funds that were meant for water infrastructure, though one interviewee reported that the DM had paid it out to contractors, but that they had not carried out the work. According to this interviewee, a private donation from a commercial farmer close by had enabled the municipality to pay another contractor to provide at least part of the area with the promised water infrastructure. It is likely that this is a case of corruption where the DM and the contractors colluded in rent seeking. Apparently, the DM has lost accountability for, and oversight of, contracting in water services (Pillay, 2016).

Although public standpipes do not nearly serve all households, the engineer from the DM denounced the users of unimproved sources/surface water; he made it clear that community members should not themselves be responsible for sourcing and that water provision should be left to the DM. He stated that, "the water we give you is potable water, it's safe water (…) and you are not supposed to drink water from the river, and you are not supposed to even go and bath in the river because you get waterborne diseases". The Umvoti River has been subjected to continuous point-source pollution from Greytown and the town's sewage treatment plant has been dysfunctional for more than seven years; this has been due partly to the repeated failure of the generator and partly because the sewage entering the plant long ago exceeded the plant's capacity. The responsible municipality has not expanded the plant to meet the town's growing population and increased housing development; as a result, a continuous overflow of untreated sewage enters a tributary of the Umvoti.

To summarise, the DM has failed in its provision of water services in manifold ways; these include low and unequal coverage and poor reliability, questionable and unmonitored water quality, unsustainable management of groundwater resources, weak accountability in contracting and negligent pollution of surface water. The DM has failed to improve household water security in the form of adequate, accessible and reliable water, and where households do have reliable and adequate water access it is through self-supply by illegal connections. Unequal access to water resources has important implications for health, productivity, and the dynamics of power relations among households.

Implications of unequal water access for health and productivity

Health

Households that lack access to adequate water supply in terms of both quality and quantity are at risk of disease (Hove et al., 2019). Five households reported incidences of diarrhoea and vomiting in infants in the previous two weeks, which is indicative of health hazards related to water quality (Fink et al., 2011). In four of these cases, other members of the households were also affected; three of these households were users of unimproved sources/surface water and two were users of standpipes. Four of the households treated their drinking water using bleach or chlorine, and one household (R27) treated the water for consumption by infants by adding small amounts of sugar. Two households also reported waterkan-related health problems; a member of household S5 told us of a funeral where all participants fell ill after drinking water from the waterkan. Water treatment and sanitation do not explain differences in health among the groups of water users; there was, however, no indication of health issues related to water quality in households that used yard taps.

Apart from health hazards related to water quality, the actual collection of water puts collectors at risk. Geere et al. (2010) found that water-carrying has the potential to produce musculoskeletal disorders and related disability. In the study area, collecting water from streams or springs is more strenuous and hazardous than collecting water from a public standpipe along the road; users of streams often need to walk down steep hills and carry heavy water containers back uphill, and some water users recounted having been bitten by snakes next to their primary water source. One interviewee told us that in order to get enough clean water, it was important to be at the stream early in the morning (between 5 and 6 am) before other water users came and before livestock arrived and dirtied the water. However, going to the stream early in the morning increases safety risks related to criminals or wildlife. Hove et al. (2019) reported similar findings, specifically safety risks for women collecting water at night or early in the morning. In one of our meetings with community members, they told us that schoolchildren were required to bring 5 litres of water to school each day in order to receive a cooked meal, and parents worried about their children collecting water at the stream so early in the morning. As pointed out by the interviewee at World Vision, children can also be put at risk when left at home alone while their mothers are out collecting water for long periods of time.

Income and productivity

Water access, water marginality and the poverty of rural households are interlinked (Adeyeye et al., 2020). In a study that was based on 2009 General Household Survey data from South Africa, Matshe et al. (2013) found a direct link between water poverty and economic poverty for rural households; similarly, Calow et al. (2010) found links between water security, productivity, income and livelihood security; and Dungumaro (2007) reported a strong relationship in South Africa between the socio-economic status of households and the availability of domestic water.

Although households should receive a basic water supply of 25 l/cap/day under the Free Basic Water Policy, income plays a large role in water access and vice versa: to be able to install a yard tap, a household needs to have the financial means to pay a plumber for the installation; a rainwater harvesting tank is also costly; and, in many cases, households are asked to pay for water from the waterkan. In turn, productivity and income can be enhanced by the higher water availability that comes along with yard taps, rainwater harvesting tanks, or water from the waterkan. Our field observations suggest that households with better access to water have more income than households with little access, while our quantitative analysis does not show clear support for a correlation between type of water source and income. Of the surveyed households, 64% receive their main income from the state in the form of pension, child support grants, disability grants and money for sick leave; 28% derive their main income from unskilled (24%) or professional (4%) employment; and 6% receive their main income from farming or home production. In general, household size is a significant factor for poverty among rural households (Sharaunga and Mudhara, 2020); we therefore based our analysis on per capita income instead of household income. On average, minimum per capita monthly income is 493 rand (ZAR) [124, 1953] and maximum income is 582 ZAR [145, 2314]. Our analysis of poverty is based on the poverty lines in South Africa in April 2018: the food poverty line of 582 ZAR/cap/month; the lower-bound poverty line of 785 ZAR/cap/month, and the upper-bound poverty line of 1183 ZAR/cap/month (Statistics South Africa, 2018). When we look at maximum income (Table 3), we see that 42-58% of the households are below the food poverty line and only 13-26% are above the upper-bound poverty line. The large majority of households in the study area lives in poverty and is thus excluded from enhanced water access through yard taps, rainwater harvesting tanks or the waterkan, all three of which come at a certain cost.

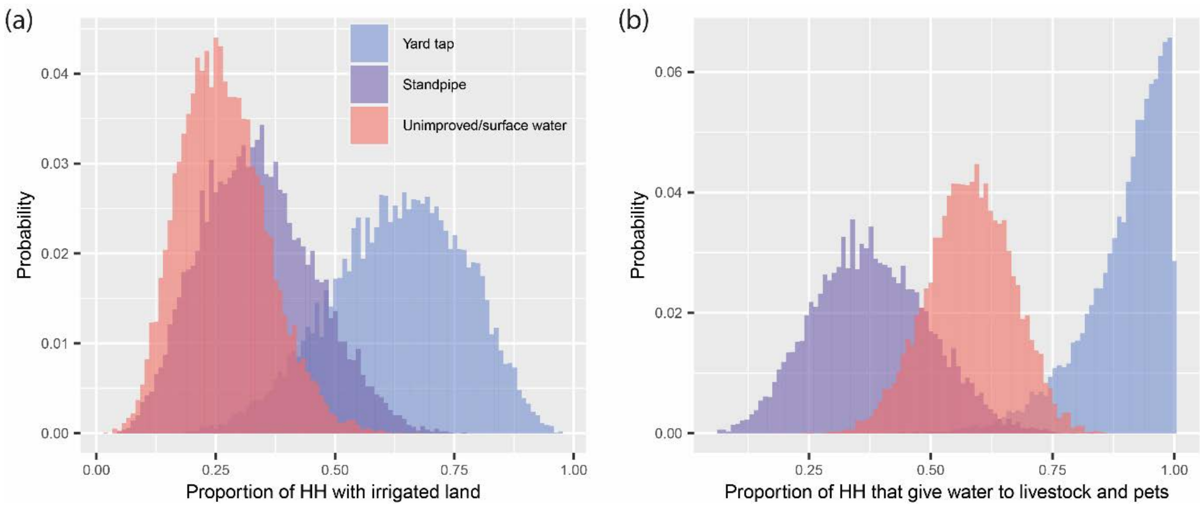
Table 3. Percentages of households for minimum and maximum income per capita per month at different levels of poverty.

	Percentage of households earning minimum income (%)	Percentage of households earning maximum income (%)
Below food poverty line	60 [52, 68]	51 [42, 58]
Between food and lower-bound poverty line	10 [8, 11]	14 [12, 16]
Between lower and upper-bound poverty line	11 [9, 13]	16 [14, 19]
Above upper-bound poverty line	19 [13, 26]	19 [13, 26]

Note: We present all estimates as medians [90% credible interval].

Although the municipal infrastructure is meant for domestic water use, water resources in the study area are used for multiple purposes, including irrigation and livestock. These multiple uses of water services in rural South Africa have been gaining attention and recognition (Smits et al., 2010 ; van Koppen et al., 2020). Among households that own livestock or pets (n = 58), 59% give them water. There is some support for a correlation between watering of livestock and the type of water source (Figure 3b); of households with a yard tap, a much higher proportion give water to their livestock and pets compared to households that depend on a standpipe (difference 0.53 [0.27, 0.74]) or households that use an unimproved source/surface water (difference 0.32 [0.09, 0.50]). Among households that grow crops (n = 49), 37% irrigate them; however, there is no clear support for a correlation between irrigation and the water source type (Figure 3a). Of those households with a yard tap, a much greater proportion irrigate their crops compared to households that use a public standpipe (difference 0.3 [-0.02, 0.58]) or an unimproved water source/surface water (difference 0.38 [0.08, 0.63]).

Figure 3. Among households with yard taps, standpipes and unimproved sources/surface water, (a) shows proportion with irrigated land, and (b) shows proportion of households that give water to livestock and pets.



Note: HH = households.

Overall, users of yard taps utilise their improved water access to enhance their productivity and income through watering of livestock and irrigation; moreover, households with yard taps do not need to collect water, which saves time and creates opportunities for productive activities and income. Water security and high levels of productivity or income were interlinked in an upward spiral; we suggest that, by contrast, the poverty of many households is partly caused and manifested by their water insecurity. In general, users of standpipes or unimproved sources/surface water do not have enough water available for productive purposes; furthermore, they spend a large part of their day collecting water, leaving little time for productive activities, education, and income opportunities such as land preparation or paid labour; in addition, they may suffer from health issues related to the collection of water, which further restricts their ability to work.

Uneven power relations, conflicts around water, and vandalism of water infrastructure

From the perspective of the hydrosocial cycle, new infrastructure channels water in new directions, to the disadvantage of some water users and the benefit of others. This reconfigures power relations among households and communities, not least in terms of the income opportunities discussed in the previous section; it also affects relations among communities, traditional leaders, the councillor and the municipality. Power is shifted towards those who have more access to, or control over, the flow of water, tending to accrue to communities that have better water access. When resources become scarce in the dry season or during a drought, equal relations among households and communities can turn into uneven relations. This shift in power relations can lead to conflicts and ultimately to vandalism, or to the misuse of water infrastructure such as the installation of illegal yard connections, which then alter the flows of water one more. This again reshapes power relations, and so the cycle continues.

Illegal yard connections and vandalism of yard taps

The issue of illegal yard connections is complex and not easily resolved. We found diverging perspectives on this issue among users of yard taps, users of other water sources, the councillor, traditional leaders and the DM.

We have shown that yard tap users strongly benefit from their improved water source; the demand in the study area is clearly for yard connections. Members of households without yard connections often said that they wished for a yard tap and water metering. One interviewee (R33) told us that, "They [the municipality] have promised to put taps in the yards, they promised a long time ago and it hasn't happened. I don't believe it will happen and if it does, I will be long gone". In connecting yard taps to public pipes, yard tap owners are acting on a decision to "take what the government has promised to them" (Interviewee Y3). Most users of yard taps spoke openly about them; a member of household Y1 said to us candidly that, "We are aware that it is illegal, but we want to tell it to you to point out that we need water in the house". Only once did an interviewee try to hide the fact that they had a tap in the yard. Traditional leaders usually have yard connections.

At the community meeting in 2014, the then councillor of Embulwane said that,

> This just shows that they undermine what is rightfully belonging to the whole community because they want (…) supply to their own homes. I had a detailed explanation with them and told the chief that what they are doing is not right because I see that the reason why water is not coming out of the taps (…) is because water pipes are burst here, it ends up being closed where water pipes are supposed to go! (…). Personally, I have decided that if a person has (…) a tap at their home, we put a meter. Then only will they stop stealing the water because they are now paying for it.

In line with the water legislation, the DM aims to provide rural households with improved water sources in the form of metered yard taps. At the community meeting, the engineer from the DM told those in attendance that,

> When we have the bulk scheme working, then we have the yard connections. (…). You must disconnect it. You can connect it again when there is a lot of water and pump the water, we like to sell water it means we

> get money for the municipality but (…) we don't want your money. We want to give people a basic level of service for everybody and the moment is wrong if you are denying somebody of water.

He declared yard taps to be illegal and threatened to charge yard tap users and disconnect their tap by police force, saying that, "It's illegal and the water is not owned by the people, the water is owned by the national municipality". He further blamed yard taps users for the low availability of public standpipes. "It's because people are stealing water, some people are not getting water. Don't blame uMzinyathi, you blame the community".

Despite these statements, access to infrastructure is still not properly controlled; on the contrary, public standpipes allow private misuse of the infrastructure. By privately paying for a yard tap when it is illegal, more resourceful households opt out of the community system; this leads to unfair outcomes and to conflicts with other water users. These conflicts manifest themselves in the vandalism of yard taps by neighbours who depend on the downstream standpipe. Occasionally, owners of yard taps allow neighbours to use them. A member of household Y6 indicated that she shared the water from their yard tap with others, saying, "Neighbours come to do washing at my tap in the yard". In some cases, yard taps significantly reduce the water availability for standpipe users. One interviewee (S17) told us that,

> There was no water in the standpipe at all so I and my neighbours go to people with yard connections and beg them for water. Sometimes when they are not there we even go and steal water from their yard tap. (…). These people have no right to the water. It belongs to the municipality. (…). We are scared to call out people with yard connections and tell the municipality because they might get angry. We don't want to die.

Vandalism of yard taps, in turn, can enhance water availability from standpipes. This same interviewee (S17) went on to say that,

> We thought that with a standpipe we are in a better situation than the people down the road who rely on the river. But the standpipe is not a reliable source. Last year there was no water in the standpipe for several months. Because certain people up the road had vandalized yard taps and taken out pipes that lead to yard taps, the water started flowing again.

Our findings suggest that unlimited and uncontrolled use of water from yard taps undermines groundwater resources; the proposition of community members and the former councillor thus seem sensible, that an appropriate way to deal with the problems arising from illegal yard taps would be to legalise them and start metering water use. Yard tap users would then need to pay for volumes that exceed the Free Basic Water Supply of 25 l/cap/day; this would arguably prevent overuse and thus increase reliability of water in standpipes. An important requirement would be to expand the infrastructure and to improve maintenance on existing infrastructure. Legalisation and metering of yard taps would seem an important step towards the targeted improvement of the level of water service in the study area.

Conflicts among communities and vandalism of standpipes

Vandalism of public standpipes has contributed to their unreliability and has the potential to revert the incremental water infrastructure development in the study area. Interviewee S2 told us that, "Sometimes there are conflicts over water, then people cut the pipes. The tap is new in the community". In principle, we found two different scenarios with the potential to cause water conflicts among communities or households, and which could possibly lead to vandalism of standpipes.

First, conflicts arise among communities with different levels of water services. In the study area, some communities had been provided with new water infrastructure, while others were still waiting for water services that had been promised to them; such uneven development produces inequality in service, with the potential for conflict. In an attempt to resolve a conflict over water, traditional leaders in the study area called a meeting in February 2018, which we attended. Many community members, traditional leaders, a councillor and the mayor of the DM were present. At this meeting, the inkosi (king) said that, "These people will end up fighting because of water as there are some people who are receiving water while others are not. This becomes a problem because if development comes to a community, it should come to everyone". This is in line with what Mothetha et al. (2013) found in Limpopo, where, "villagers decided that the other side of the community will not get water services if the entire community does not get"; similarly, in the case study by Hove et al. (2019), municipal provision of water had increased, rather than decreased, conflicts over water. By contrast, in the case study by Rankoana (2020), neighbouring communities did not fight over scarce water resources; instead, they appointed a water committee to monitor water use and maintain the resources, and then agreed to follow the restrictions laid down by the committee.

The second scenario with the potential to lead to conflict and vandalism was one where new infrastructure and services improved water access for some but, at the same time, reduced it for others. At the meeting, one of the traditional leaders said that, "The people complain and tell me, 'Water is being pumped from our area to another area, leaving us with mud to drink'. The pumping decreases water from their streams". Certainly, households that live close to a new borehole can also access water from this borehole; however, due to the rotational water-shedding system they can only access it on certain days of the week, whereas they may have had a continuous water supply before the new borehole was drilled. Pumping water to distant standpipes can also ignore or overrule the perceived power of traditional leaders to grant water rights; this power is *perceived* rather than actual because, by law, it does not lie within the power of a traditional leader to grant permission to collect water from a public standpipe (Republic of South Africa, 1998). We observed, however, that this notion of the traditional leader's power is still widely shared among rural households; a household that wishes to collect water from a public standpipe, stream or spring in a village other than their own needs first to ask the responsible induna in that village for permission. Households that live close to a new borehole thus feel that water has been taken away from them to distant places (standpipes) without permission of their induna.

Seen through the hydrosocial cycle, vandalism is a form of protest and a measure of retaliation by water users who lack access to basic water supply, against new infrastructure from which they do not benefit. It aims to reverse the change in water flow caused by the new infrastructure and thereby also reverse the shift in power relations and control over water.

CONCLUSION

Our household-level analysis has shown that rural communities are far from homogeneous and that, for the most part, unequal access to water and uneven levels of household water insecurity are exacerbated, rather than reduced, by municipal water provision. Our results suggest that users of yard taps are water secure in terms of access and the beneficial effects that their improved water source has on their health and productivity; indeed – unintended by the service provider – users of illegal yard connections benefit most from water services. By contrast, the District Municipality has largely failed to reduce HWI for users of standpipes and users of unimproved sources/surface water, a failure which continues to have adverse effects on their health and productivity.

Our case study illustrates the hydrosocial cycle in operation, that is to say the cyclical relations of water, infrastructure and power. Shortfalls in municipal water services and infrastructure produce unequal access to water and uneven levels of HWI, which shapes power relations and provokes conflicts among households and communities; these, in turn, give rise to manipulation of infrastructure and alteration of flows. When infrastructure development is slow and incremental and coverage only partial, it risks causing conflicts over water as well as misuse and vandalism of newly installed standpipes; this result may nullify any progress that is made in improving water service delivery. The particular dynamics of the hydrosocial cycle can have important consequences for HWI, in that households that may be water secure in a physical sense – such as those with yard taps – can still be water insecure in a relational sense;

this relational insecurity may take the form of recurring conflicts with their neighbours, fear of losing access to their water source, or worry about being penalised by the District Municipality.

In order to substantially improve the water security of rural households and break the disruptive cycle, a strong focus on equal water service delivery to all is crucial. The aspirational targets and actions for service delivery proposed in the National Water and Sanitation Master Plan (Department of Water and Sanitation, 2019) need to be implemented without delay. Involving communities in planning processes (Rankoana, 2020) would shed light on traditional notions of water rights and would help prevent conflicts. A sustainable solution for handling illegal yard connections is needed in order to maintain reliability of public standpipes and end misuse and vandalism. Springs and surface water need to be protected from pollution and recognised as the important secondary water sources that they are. A diversification of water sources (such as by rainwater harvesting and formal treatment and use of surface water) would relieve pressure on groundwater resources and would support sustainable groundwater management in the face of climate change and drought. Water providers and contractors need to be held accountable for their practices and for how they spend budgets that are meant for water infrastructure. The communities we studied share common characteristics with other rural areas, especially in terms of their water issues. While we cannot generalise from our rich but geographically constrained case study, we believe our results to be replicable in other indigent communities in rural South Africa.

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REFERENCES

Adeyeye, K.; Gibberd, J. and Chakwizira, J. 2020. Water marginality in rural and peri-urban communities. *Journal of Cleaner Production* 273: 122594.

Aitkin, M. 2010. *Statistical Inference: An integrated Bayesian/likelihood approach*. Boca Raton: CRC Press.

American Anthropological Association. 2012. *Statement on ethics: Principles of professional responsibility*. http://ethics.americananthro.org/category/statement

Bakker, K. and Hemson, D. 2012. Privatising water: Bott and hydropolitics in the new South Africa. *South African Geographical Journal* 82(1): 3-12.

Bulled, N. 2017. The effects of water insecurity and emotional distress on civic action for improved water infrastructure in rural South Africa. *Med Anthropol Q* 31(1): 133-154.

Bürkner, P.-C. 2017. brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software* 80(1).

Calow, R.C.; MacDonald, A.M.; Nicol, A.L. and Robins, N.S. 2010. Ground water security and drought in Africa: Linking availability, access, and demand. *Ground Water* 48(2): 246-256.

Department of Water Affairs and Forestry. 2001. *Water Services Act: Compulsory national standards and measures to conserve water regulations*. www.gov.za/sites/default/files/gcis_document/201409/223550.pdf

Department of Water and Sanitation. 2017. *National norms and standards for domestic water and sanitation services*. https://www.gov.za/sites/default/files/gcis_document/201709/41100gon982.pdf

Department of Water and Sanitation. 2019. *National water and sanitation master plan: Ready for the future and ahead of the curve 1*. https://cer.org.za/wp-content/uploads/2019/02/Volume-1-Call-to-Action.pdf

DoRHC and MRD. 2010. *National sanitation and hygiene knowledge, attitudes, and practices (KAP) survey*. Department of Rural Health Care, Min. of Rural Development Phnom Penh, Cambodia. https://bit.ly/39r3GWu

Dungumaro, E.W. 2007. Socioeconomic differentials and availability of domestic water in South Africa. *Physics and Chemistry of the Earth, Parts A/B/C* 32(15): 1141-1147.

Eales, K. 2011. Water services in South Africa 1994-2009. In Schreiner, B. and Hassan, R. (Eds), *Transforming water management in South Africa: Designing and implementing a new policy framework,* pp. 33-71. Dordrecht: Springer Netherlands.

Edokpayi, J.N.; Rogawski, E.T.; Kahler, D.M.; Hill, C.L.; Reynolds, C.; Nyathi, E.; Smith, J.A.; Odiyo, J.O.; Samie, A.; Bessong, P. and Dillingham, R. 2018. Challenges to sustainable safe drinking water: A case study of water quality and use across seasons in rural communities in Limpopo Province, South Africa. *Water* 10(2).

Etikan, I. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics* 5(1): 1-4.

Fink, G.; Gunther, I. and Hill, K. 2011. The effect of water and sanitation on child health: Evidence from the demographic and health surveys 1986-2007. *International Journal of Epidemiology* 40(5): 1196-204.

Geere, J.A.L.; Hunter, P.R. and Jagals, P. 2010. Domestic water carrying and its implications for health: A review and mixed methods pilot study in Limpopo Province, South Africa. *Environmental Health* 9(1): 52.

Haarhoff, J. and Rietveld, L. 2009. Public standpipe design and maintenance for rural South Africa. *Journal of the South African Institution of Civil Engineering* 51(1): 6-14.

Hove, J.; D'Ambruoso, L.; Mabetha, D.; van der Merwe, M.; Byass, P.; Kahn, K.; Khosa, S.; Witter, S. and Twine, R. 2019. 'Water is life': Developing community participation for clean water in rural South Africa. *BMJ Glob Health* 4(3): e001377.

Jepson, W. 2014. Measuring 'no-win' waterscapes: Experience-based scales and classification approaches to assess household water security in colonias on the US-Mexico border. *Geoforum* 51: 107-120.

Jepson, W.E.; Wutich, A.; Colllins, S.M.; Boateng, G.O. and Young, S.L. 2017. Progress in household water insecurity metrics: A cross-disciplinary approach. *Wiley Interdisciplinary Reviews: Water* 4(3).

Linton, J. and Budds, J. 2014. The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum* 57: 170-180.

MacAllister, D.J.; MacDonald, A.M.; Kebede, S.; Godfrey, S. and Calow, R. 2020. Comparative performance of rural water supplies during drought. *Nature Communication* 11(1): 1099.

Mackintosh, G. and Colvin, C. 2003. Failure of rural schemes in South Africa to provide potable water. *Environmental Geology* 44(1): 101-105.

Majuru, B.; Jagals, P. and Hunter, P.R. 2012. Assessing rural small community water supply in Limpopo, South Africa: Water service benchmarks and reliability. *Science of the Total Environment* 435-436: 479-86.

Matshe, I.; Moyo-Maposa, S. and Zikhali, P. 2013. Water poverty and rural development: Evidence from South Africa. *African Journal of Agricultural and Resource Economics* 08(2): 21.

Mothetha, M.; Nkuna, Z. and Mema, V. 2013. The challenges of rural water supply: A case study of rural areas in Limpopo Province. In *Third Southern African regional YWP conference*. Stellenbosch.

Mukheibir, P. 2007. Water resources management strategies for adaptation to climate-induced impacts in South Africa. *Water Resources Management* 22(9): 1259-1276.

Muller, M. 2007. Parish pump politics: The politics of water supply in South Africa. *Progress in Development Studies* 7(1): 33-45.

Munzhedzi, P.H. 2020. An evaluation of the application of the new public management principles in the South African municipalities. *Journal of Public Affairs*.

Pillay, P. 2016. Ethics and accountability in South African municipalities: The struggle against corruption. *African Journal of Public Affairs* 9(2).

R Core Team. 2017. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. www.R-project.org

Rankoana, S.A. 2020. Climate change impacts on water resources in a rural community in Limpopo province, South Africa: A community-based adaptation to water insecurity. *International Journal of Climate Change Strategies and Management* ahead-of-print(ahead-of-print).

Republic of South Africa. 1998. *National Water Act 36 of 1998*.

Rietveld, L.C.; Haarhoff, J. and Jagals, P. 2009. A tool for technical assessment of rural water supply systems in South Africa. *Physics and Chemistry of the Earth, Parts A/B/C* 34(1-2): 43-49.

Sershen, S.; Rodda, N.; Stenström, T.A.; Schmidt, S.; Dent, M.; Bux, F.; Hanke, N.; Buckley, C.A. and Fennemore, C. 2016. Water security in South Africa: Perceptions on public expectations and municipal obligations, governance and water re-use. *Water SA* 42(3).

Sharaunga, S. and Mudhara, M. 2020. Analysis of livelihood strategies for reducing poverty among rural women's households: A case study of KwaZulu-Natal, South Africa. *Journal of International Development*.

Sinyolo, S.; Mudhara, M. and Wale, E. 2014. The impact of smallholder irrigation on household welfare: The case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa. *Water SA* 40(1).

Smits, S.; van Koppen, B.; Moriarty, P. and Butterworth, J. 2010 Multiple-use services as an alternative to rural water supply services: A characterisation of the approach. *Water Alternatives* 3(1): 102-121.

Stan Development Team 2019. *Stan User's Guide*. Version 2.24.

Statistics South Africa. 2018. *National Poverty Lines*.

Too, J.K.; Kipkemboi Sang, W.; Ng'ang'a, Z. and Ngayo, M.O. 2016. Fecal contamination of drinking water in Kericho District, Western Kenya: Role of source and household water handling and hygiene practices. *Journal of Water and Health* 14(4): 662-71.

Tortajada, C. and Biswas, A.K. 2018. Achieving universal access to clean water and sanitation in an era of water scarcity: Strengthening contributions from academia. *Current Opinion in Environmental Sustainability* 34: 21-25.

UN Water. 2017. *Integrated Monitoring Guide for Sustainable Development Goal 6 on Water and Sanitation – Targets and global indicators*. https://www.unwater.org/publications/sdg-6-targets-indicators/

UN Water. 2018. *Sustainable Development Goal 6: Synthesis Report 2018 on Water and Sanitation*. New York. https://sustainabledevelopment.un.org/content/documents/19901SDG6_SR2018_web_3.pdf

UNICEF and PHG. 2010. *Water, Sanitation and hygiene household survey Gaza*. www.unicef.org/opt/final_wash_report.pdf

UNICEF and WHO. 2018. *JMP Methodology 2017. Update & SDG Baselines*. https://bit.ly/2M222BZ

UNICEF and WHO. 2019. *Progress on household drinking water, sanitation and hygiene 2000-2017: Special focus on inequalities*. New York https://www.who.int/water_sanitation_health/publications/jmp-report-2019/en/

van Koppen, B.; Hofstetter, M.; Nesamvuni, A.E. and Chiluwe, Q. 2020. Integrated management of multiple water sources for multiple uses: Rural communities in Limpopo Province, South Africa. *Water SA* 46(1).

Vehtari, A.; Gelman, A. and Gabry, J. 2016. Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Statistics and Computing* 27(5): 1413-1432.

Webb, P. and Iskandarani, M. 1998. *Water insecurity and the poor: Issues and research needs.* Bonn, Germany: Center for Development Research: ZEF.

WHO and UNICEF. 2006. *Core questions on drinking-water and sanitation for household surveys.* Geneva. https://apps.who.int/iris/bitstream/handle/10665/43489/9789241563260_eng.pdf?sequence=1

Wutich, A.; Budds, J.; Eichelberger, L.; Geere, J.; Harris, L.; Horney, J.; Jepson, W.; Norman, E.; O'Reilly, K.; Pearson, A.; Shah, S.; Shinn, J.; Simpson, K.; Staddon, C.; Stoler, J.; Teodoro, M.P. and Young, S. 2017. Advancing methods for research on household water insecurity: Studying entitlements and capabilities, socio-cultural dynamics, and political processes, institutions and governance. *Water Security* 2: 1-10.