PAPER 16

BULK WATER JOURNEY: THE DEVELOPMENT & DIVERSIFICATION OF NMBM'S WATER SUPPLY

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ABSTRACT

The then City of Port Elizabeth, now Gqeberha, developed its first water source roughly 30 years after its settlement. This would be a well which was sunk in 1850. It was 5 feet deep and 6 feet wide. This, along with local streams and rainwater harvesting quickly proved insufficient for an expanding city.

All efforts were then directed west, towards surface water development. For the next century the Nelson Mandela Bay Municipality (NMBM) would be almost exclusively dependent on these sources.

Following this period, the NMBM would then spend three decades to greatly diversify water sources. Most of the development driven by fierce droughts. The current drought started in 2015 and has entered its eighth year with some of the lowest rainfall measured in recorded history. These events would accelerate the diversification even more with the municipality becoming less dependent on the sources it relied on for so long.

A majority of the NMBM's water would now be coming from the east, which also meant big changes in infrastructure to convey this water. An infinite work stream branded internally as the "Maximisation of Nooitgedagt". This project was a conglomeration of new developments and modifications to existing infrastructure. It highlighted how institutional knowledge of infrastructure allows a municipality to repurpose existing assets for maximum benefit.

This paper will explore the journey of NMBM's bulk water supply. How pipelines built 60 years ago for gravity supply are now the rising main life veins of the city with their flow in reverse. How old forgotten assets were brought to life and are now indispensable for the continued existence of the city.

This diversification of supply would make NMBM more resilient against future droughts as it would not rely only on surface water from the same catchment area. NMBM is moving towards a sustainable system that will be more responsive to the visible effects of climate change experienced in South Africa.

1. INTRODUCTION

The Nelson Mandela Bay Municipality (NMBM) has continuously needed to develop new sources to keep up with demand. According to the NMBM master planning a new source was required to be developed roughly every 10 years. Figure 1 clearly indicates a period between 1993 and 2018 where a new source was not developed. The consumption continued to climb above available licensed water, which meant over abstraction from the western dams was the only way to secure continued supply. This over abstraction would frustrate other users on shared systems and would increase the rate at which these dams dropped during periods of little to no rainfall.

Once again severe drought, commencing in 2015, would change the situation permanently with multiple dams reaching their lowest levels since construction. Most of the water would now be coming from an independent source.

NMBM has allocation of 404.73Ml/d and a treatment capacity of 551.25Ml/d, however during the current drought some systems have been restricted as heavily as 85%.

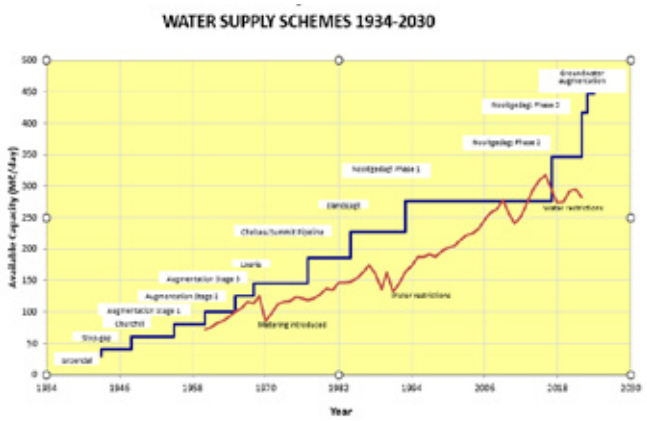

FIGURE 1: *NMBM Bulk water supply scheme development & ave daily consumption trend*

2. HISTORY

2.1 Springs

Before amalgamating with NMBM, Kariega (Uitenhage) was a local municipality formed in 1841. Sometime before that, during 1804, farmers settled in the area as there were fertile riverbanks and a reliable source of water. This same water is still supplying certain areas of NMBM to this day.

The Springs is an artesian basin with 9 perennial eyes that deliver roughly 6Ml/d. Historically this water would run down to the water course to the town situated roughly 8km South. Some improvements were done over time to improve efficiency. Stone embankments were built to keep the eyes clean of debris as well as pipelines to concentrate the water and avoid high losses due to seepage. Water treatment was introduced during the early 1900's but due to excellent raw water quality only stabilization and disinfection are required.

FIGURE 2: *Springs artesian well*

Port Elizabeth at the time often tried to secure supply from Uitenhage but due to a bitter rivalry between the two municipalities they could never come to an agreement. This resulted in the Port Elizabeth Municipality pursuing the Van Stadens scheme. Uitenhage municipality would also end up building the arched Groendal dam (11 638Ml) in 1934 due to further failed negotiations with Port Elizabeth.

2.2 Shark river water company

In 1863 a masonry dam was constructed across the Sharks river which before then was mostly used as a wool washery. It was called the Frames dam and was developed from capital funds raised in shares. The scheme would fail not long after commissioning and required financial support from the municipality. The scheme was abandoned as soon as another reliable source was developed due to condemned water quality.

3. HEADING WEST FOR 100 YEARS

3.1 Older Dams system

FIGURE 3: *Diagrammatic layout of NMBM's Bulk water systems*

The Older Dam scheme consists of the Upper Van Stadens, Van Stadens Gorge and the Sand and Bulk River Dams with the first water arriving in the city during 1880. An amazing engineering feat at the time when travel to site took 3 days by horse. Cement was shipped from England in barrels and the city did not have a harbour yet. This made offloading and transport to site troublesome. These four dams were constructed from about 1880 up until the early 1900's and received various upgrades up until the late 1920's. The municipality would fully rely on this system until low rainfall and water restrictions during 1935 forced councillors to consider the development of the Kromme river scheme. The city had been hesitant to initiate such an ambitious project up until this point, however, extensive surveys during 1935 indicated that the older dams were fully developed.

3.2 Linton water treatment works

Up until the mid-1930's the water from the older dams were filtered at the source with the exception of the Van Stadens Gorge dam. The water from all four storage dams was then chlorinated upon arrival at the Linton Reservoir. At the time the City Engineer was requested to investigate a solution due to complaints that were received regarding the quality of the water.

A report dated 13 November 1934 indicated that it would be better to treat all the raw water at one central location in accordance with the latest technology rather than at each source.

The works was commissioned in September 1937 and comprised an inlet mixing weir, flocculation chamber, two horizontal flow sedimentation tanks with hoppers and six rapid gravity sand filters. The administrative building housed three dry chemical feeders, a laboratory, office, chemical store and the filter backwash tank. The final water is disinfected with chlorine gas prior to entering the Linton Reservoir from where it is reticulated.

Over time as larger schemes were developed the importance of this works dwindled and it would draw the short end of the stick when competing for resources. Many of the controls were made redundant creating operational challenges for staff. Majority of the processes were not efficient or even functional. Production at the works had steadily decreased over years and at one stage was left dormant for the greater part of 3 years.

During the current drought it became critical to resurrect this works to reduce the demand on NMBM's largest supply zone. It would also come with the added benefit of preserving the history of the works.

Phase 1 included the emptying, cleaning and unblocking of clarifiers. Upgrades to the lime dosing pipework. Refurbishments of filter gallery including all filter control valves. Phase 2 would be for replacing filter media. The peak production rate currently is 10Ml/day with potential to still increase.

FIGURE 4: *Filter module before refurbishment*

FIGURE 5: *Filter modules after refurbishment*

The works has a mechanically automated control system that has been made redundant roughly 20 years ago. The institutional knowledge of these control systems was lost, however they have been made operational once again and a control philosophy captured so that this info is never lost again.

3.3 Churchill water scheme

Initial investigations to develop a water source from the Kromme river started during 1928. Up until this point the city was fully reliant on the Older dams scheme, however, frequent droughts would make supply from these sources unreliable for an expanding city. Due to the size of the project, it was only considered much later when the city had no alternative options.

Construction commenced in 1939 and the multi arched Churchill dam (33 282ML) would be completed in October 1943. Due to delays experienced by World War 2, the scheme was not fully commissioned until 1947. The 124km of 700mm steel pipes had to be delivered from the UK by ship, at the time most available steel went to the war.

An unprecedented drought during 1941 meant that the older dams were once again struggling to provide the necessary water security. An emergency scheme was initiated where completed sections of the Churchill pipeline were connected with smaller diameter pipes that were sourced from existing pipelines. This could supply an additional 8Ml/d to the existing Linton wtw. Similarly, to the current drought, the municipality would find a creative solution for utilizing existing available raw water before the treatment capacity has been completed.

Hardly one year after the scheme was fully operational the municipality started planning augmentation of this scheme. This included various works including increased treatment capacity at the Churchill wtw, reservoir, pipeline and pump station construction projects. Most of this infrastructure still plays a vital role in service delivery to this day and assisted in developing the city into its current state.

The biggest section of the contract would be to build a second Churchill pipeline. Another 120km pipeline became operational in 1962. This time locally manufactured prestressed concrete pipes would span the distance. Various diameters ranging from 800mm up to 1300mm followed the route of the first pipeline. For 30 years there would be no redundancy and the municipality would be fully reliant on water from the Churchill pipeline. From the 1940's until the late 1980s all development of water sources would be intended of being supplied via the Churchill pipeline, with the exception of the Summit Chelsea pipeline in 1977 that provided some redundancy when the Churchill pipeline is not available.

3.4 Kouga water scheme

Water development did occur in the Gamtoos valley during the early 1900's already, although mostly for irrigation. In 1955 the Government announced plans of a dam being built on the Kouga river. Opportunistically the municipality negotiated an agreement for an allocation from this scheme. Initially the municipality secured a 140Ml/day allocation, however, during 1973 the Minister of Water Affairs announced that the Government had reduced the allocation to 100Ml/day. This happened without consulting the Municipality. The allocation would then be further reduced during 1989 when the municipality negotiated an exchange volume with DWS to develop a new source for the same volume from the Orange river system. The reduction was 37Ml/d leaving the municipality with an unrestricted abstraction volume of approximately 62Ml/d.

The scheme comprised of the Kouga dam (133 000Ml), a 72km canal, the Loerie balancing dam (3055Ml), a 100Ml/day Water treatment works (wtw), a 4.9km rising main and the 45Ml Summit reservoir.

At the time the majority of the city's bulk water was still supplied via the Churchill pipeline. Therefore, water from the summit reservoir at 285msl had to be injected in the Churchill pipeline with a top water level of 146m. To do this a break pressure tank was constructed which would break about 12bar pressure to atmosphere.

This would be the standard operations until 1977 when the Summit Chelsea pipeline was constructed. Loerie water could now go directly to the Chelsea reservoir for further distribution. The construction of the Elandsjagt wtw meant that there was even less need to supply Loerie water into the Churchill pipeline. This led to the ultimate neglect of this break pressure tank facility. Malfunctioning equipment caused a disastrous wash away which also created a big fear with using the facility again.

It would only be once the municipality was able to utilise the full Nooitgedagt allocation that the Loerie water would return to its initial supply philosophy, to join the water from the Kromme system in the Churchill pipeline. This once abandoned facility is now providing permanent augmentation.

3.5 Elandsjagt water scheme

This source was developed in conjunction with Government which delivered a 106 000Ml dam and water treatment works that could contribute another 105Ml/day peak supply by 1985. Roughly 100 years after the city constructed its first surface water dam in the Van Stadens river. This would also be the last dam to be constructed before all efforts were directed at developing Orange river water.

It was anticipated that this dam would take up to 5 years to fill, however heavy rain during 1983 caused it to overflow within 72hours. This rainfall would then be the start of another dry period, worse than any previous drought.

The position of the wtw was chosen as to be able to connect to the existing Churchill pipeline via gravity supply. This unfortunately meant that the raw water intake pumps could only draw the dam down to 16%.

During the 1989 drought NMBM built a floating barge pump station that could further abstract dead storage from the dam. This was utilized before rain eventually filled the dam again towards the end of 1989. The barge was dismantled and put into storage. The low dam levels of the current drought required it to be installed again during 2020.

This time around NMBM would rely more heavily on the barges to abstract water as the Churchill dam reached dead storage level and could not contribute to the daily water production. This necessitated various upgrades to the existing barge as well as building a new one with an output of 60Ml/d. River basin surveys were done to determine deep spots as the dropping dam level would continuously risk grounding the barge. A 7km 800mm HDPE pipeline was constructed and floats from the barge's final position.

FIGURE 6: *Barges on the Impofu dam access the dead storage*

4. CHELSEA TO MOTHERWELL

The city now started expanding towards the north and required a system to divert supply from its western sources. Initially called the Greenbushes

scheme, it commenced in 1964 and was developed in multiple phases with various pipe sizes and material. Water would be pumped out of the Churchill pipeline at Seaview and then be supplied to the Chelsea reservoir. From here it would be gravity fed down the various pipeline sections to supply the neighbouring local municipalities at the time as well as provide the required supply to allow the development of areas all the way through the Northern areas to Motherwell. This would be the case for almost 30 years. This pipeline would not be considered critical at the time as it was just an ancillary system meant to extend the supply zone of the Churchill pipeline.

At this point the importance of the Churchill pipeline could not be exaggerated as all bulk water supply was prioritised through it and its ancillary systems. Redundancy was only available from 1977 after the construction of the Summit Chelsea pipeline made it possible to take Loerie water straight into Chelsea.

5. MAXIMISATION OF NOOITGEDAGT

5.1 Orange river history

During the early 1900's most of the eastern cape irrigation schemes were struggling with water security. Unreliable inflow and high sedimentation would cause irrigators to press the Government for the diversion of Orange river water to the eastern cape. The Government accepted a white paper on the Orange river development project in 1971.

Then followed a massive civil engineering project that would include the building of the Gariep dam and the diversion of that water via tunnels, river systems and canals with a total distance of over 400km before it is available for use in NMBM. The Orange Fish river tunnel is the longest enclosed aqueduct in the southern hemisphere at 83km. Many large projects needed to be completed before this water could become an option for NMBM, therefore it wasn't considered until the late 1980's.

5.2 Nooitgedagt water treatment works

This is where the true diversification started for NMBM's water system. For the first time in 100 years, it could develop a major water source completely independent from the existing ones. Up until this point the droughts affected all NMBM's existing sources at the same time as catchment areas are relatively close together and usually get replenished from the same rainfall events.

Once again severe drought during 1989 would require emergency plans to avoid disaster. NMBM would negotiate an exchange volume with the Department of Water & Sanitation (DWS) that would see NMBM receiving 37.5Ml/d treated water from the Orange river scheme by forfeiting the same volume from the Kouga dam on a permanent basis.

An emergency scheme commenced, however most of the components where part of the permanent scheme. These included the Scheepersvlakte balancing dam, Nooitgedagt wtw, Grassridge reservoir (23Ml) and the bulk pipelines which now connected this scheme to the Motherwell reservoir. This meant that the Nooitgedagt system was now connected to the Motherwell Chelsea pipelines that had been constructed since 1964 to supply water from the Churchill pipeline to the North.

The treatment works was designed with an ultimate capacity of 280Ml/d to be constructed in 4 modular phases of 70Ml/d each. The first phase was completed in 1993. NMBM master planning would indicate the need for phase 2 by 2007, however this phase was only completed in 2017. Due to rapidly decreasing dam levels NMBM had to fund phase 2 itself. This increased the treatment capacity to 140Ml/d whilst increasing the pumping capacity to 210Ml/d. This would be the ultimate pumping capacity required when phase 3 of the wtw is completed. The extra pumping capacity was opportunistically utilised to resurrect the emergency Grassridge wtw.

FIGURE 7: *Nooitgedagt phase 3 settling tank*

The construction of Nooitgedagt phase 3 was funded by DWS who appointed Amatola water as the implementing agent. It was commissioned in 2022 and can supply NMBM with 210Ml/d. That is roughly 60% of NMBM's current daily demand.

5.3 Grassridge emergency wtw

Phase 3 of the Nooitgedagt water treatment works would not have been completed in time for the imminent failure of the western supply sources. Drastic measures were required to avoid disaster and it would be institutional knowledge that provided the necessary direction. Under normal conditions the Grassridge reservoir receives potable water via a pump station at the Nooitgedagt water treatment works, however, with a surplus of raw water available from the Orange river transfer scheme, this 23Ml reservoir was converted into an emergency water treatment works that could provide an additional 40Ml/day to the drought stricken areas of NMBM.

The reservoir itself was constructed 30 years prior to this activity during the 1989 drought. This was part of the emergency scheme that provided NMBM with water from the Gariep dam for the first time. The emergency scheme was commissioned in 1992 and it included the temporary wtw at Grassridge reservoir, a 50Ml/d emergency pump station situated at the Nooitgedagt wtw site and a booster pump station on the Motherwell Chelsea pipeline.

FIGURE 8: *Emergency dosing facility at Grassridge*

FIGURE 9: *Emergency pump station at Nooitgedagt*

Using information from the past, this emergency facility would once again be erected using modern treatment technology. Firstly, a 600mm uPVC pipeline was built to bypass the Nooitgedagt wtw so that raw water could be connected to the High lift water pump station. Modifications were needed to keep the pumpstation cooling water on potable supply to avoid blockages.

The Grassridge reservoir is split into two compartments which are about 24m wide, 70m long with a water depth of 7m. A flocculation chamber was created just after the raw water inlet by constructing a HDPE curtain on a cable rail. Three mechanical mixers per side assisted with floc formation. The rest of the reservoir would serve as a sedimentation tank. The reservoirs outlet pipework was converted into launders which collected the settled water. Disinfection was done by means of chlorine gas on automatic controls. The two Nooitgedagt bulk pipelines then connect at Motherwell reservoir where the temporary wtw water would then blend with the 140Ml/d potable water from Nooitgedagt.

The facility was also equipped with a laboratory, operators office, chemical storage and dosing facilities.

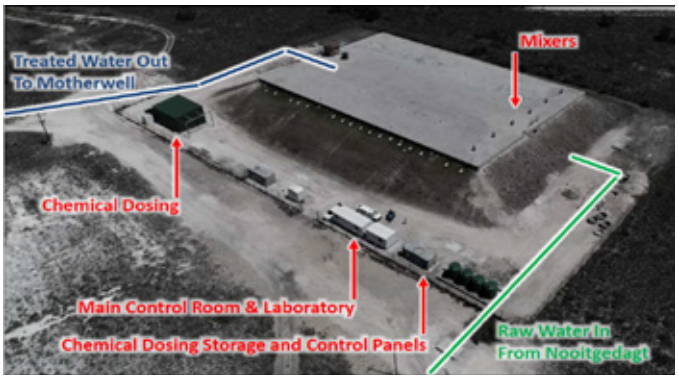

FIGURE 10: *Aerial view of the modern emergency Grassridge wtw*

FIGURE 11: *Launders inside the reservoir to collect settled water*

6. REVERSING SUPPLY DIRECTION

6.1 The forgotten pipeline

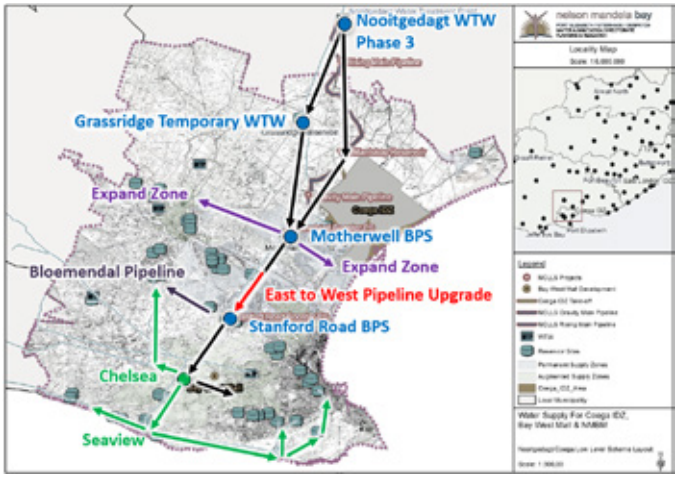

FIGURE 12: *Maximisation of Nooitgedagt water*

Critical sections of this pipeline were left dormant after spates of vandalism meant they would require complete refurbishment. The section in question supplies the suction side of the Stanford road pump station. This meant that even though the pumps could transfer 100Ml/d, there wasn't sufficient suction conditions as only a 700mm pipeline remained operative. Chambers had to be made vandal proof and advanced condition assessment techniques were used to identify and pinpoint trouble sections for repairs. A new pipeline of roughly 1000mm is currently entering design phase which would increase redundancy by removing the reliance on the old 500mm.

6.2 Motherwell & Stanford Road pump stations

These two booster pumpstations were constructed during 2013 as part of the Nooitgedagt phase 2. For 30 years NMBM would only be able to pump 20Ml/d in this direction when enough storage was available in Grassridge reservoir. Now these stations would send about 100Ml/d over the hill into the drought-stricken areas previously exclusively supplied from the western dams.

Very soon after completion it would become clear that the stations would require further upgrades. All pumps constantly run at peak capacity and down time of a single pump would mean water disruptions if not restored within a few short hours.

Contracts were awarded for various upgrades at both stations that include additional pumps. This would increase redundancy as well as increase transfer capacity from 100Ml/d to 120Ml/d.

6.3 Chelsea pump station

The majority of Kwanobuhle received dedicated supplied via the Loerie system. Therefore, they were at high risk of disruptions when there is maintenance or operational challenges on this system.

The municipality had to quickly establish an alternative supply for this area. A 7Ml/d pump station was erected at the Chelsea reservoir in 1986 that would be able to reverse the flow back up the Loerie system far enough to reach the Kwanobuhle reservoir. The pump station was built on ground level next to the reservoir which meant it could only run if the reservoir was at least 70% full. Considering that the reservoir has 90Ml storage and strict restrictions on the western sources meant that it would be near impossible to always keep the reservoir full enough to have a reliable supply in case of disaster.

For this reason, the municipality would construct a new pump station during 2022. The new one would be dropped to reservoir floor level which meant it could operate at low storage levels. It is envisaged that the new pump station would run permanently as the Chelsea reservoir would receive surplus supply once the Nooitgedagt maximisation projects were complete.

6.4 Seaview pump station

The Seaview pump station was originally built in 1953 with four 7Ml/d pumps which lifted the water from the Churchill pipeline to the Greenbushes reservoir. The supply zone is small, however, this station serves as a back up to transfer water to the Chelsea reservoir when supply from the Loerie system is unavailable.

The pump station was upgraded in 1967 with four new pumps which delivered a maximum output of 50Ml/day. In 2018 the pump station was once again upgraded. This time a new pump building was constructed with new pump sets delivering 60Ml/d. The pump station was completed during the drought which meant there was not much water available for transfer, however, the commissioning came at a vital time for its small

supply zone as there was no water available from the Loerie system due to the critically low levels of the Kouga dam at the time. For a period, this pump station would be the dedicated supply for the Greenbushes reservoir which comprises of residential, commercial and industrial zones including the St Albans prison.

The situation would then change once again. With water becoming available from Loerie, the pumps could be rested which would reduce the demand on the Churchill pipeline. During the 2018 upgrades a pipeline was installed around the new pump station that would bypass the supply from the Greenbushes reservoir into the Churchill pipeline. Energy dissipaters are required to break the 18bar head from this reservoir to balance with the 2 bar operational pressure on the Churchill pipeline.

The completion of the Chelsea pump station and all the other interventions brought Nooitgedagt water to this point, where it is now on an almost permanent basis injected into the Churchill pipeline.

6.5 Chatty pump station

The larger transfer volumes through the Motherwell Chelsea bulk pipelines caused slightly lower operating pressures. This would prove to be troublesome for the Despatch water tower which was fed directly out of the bulk pipelines. Frequent disruptions were starting to occur in the tower zone, so the municipality built a containerised pump station at the Chatty reservoir that could deliver about 4Ml/d. The reservoir had surplus storage as the supply zone was still being developed. Two pumps were placed in the container along with all the equipment that would make it run autonomously.

Many of the reservoirs supplied by the Motherwell Chelsea pipeline required modifications on the inlets to accommodate the new operating conditions.

6.6 Bloemendal pipeline

This 5.5km 450mm pipeline was constructed to further supply Nooitgedagt water into the Kwanobuhle zone. As previously mentioned, this area was exclusively fed via the Kouga system and there was a high risk of failure. This pipeline was completed during October 2021.

7. FURTHER DIVERSIFICATION

7.1 Groundwater

NMBM has been investigating groundwater utilisation for the last decade and has drilled approximately 200 boreholes around the city to determine suitable sites for development. An implementation plan was developed that would see the possible addition of roughly 35Ml/d from these sources.

FIGURE 12. *Identified borehole sites*

The sites that were developed include:

- Coegakop wellfields - The largest biofiltration plant in South Africa.
- Bushy Park wellfields - Requires only disinfection and is injected directly into the Churchill pipeline
- Moregrove Fault wellfields - Various wellfields developed next to existing reservoirs in order to blend water and offset the reservoir's demand on existing sources.

Further areas have been identified for developing more groundwater which will continue to diversify sources.

8. CONCLUSION

NMBM currently has an integrated water system with many redundancies. However, it took multiple great engineering projects to achieve, many of these were considered very ambitious at the time. NMBM has always been expanding and required major water projects every decade to keep up with increasing demand.

Supply sources are now more diverse with NMBM no longer relying completely on rainfall events in relatively the same area. Sources are far apart so it is unlikely that they would experience a drought concurrently. The Churchill pipeline was initially supplied with 100% Kromme River water, today it receives a split of 40% Kromme, 25% Loerie, 25% Nooitgedagt and 10% Groundwater.

However, the new norm is energy intensive and requires continues uptime to avoid water disruptions whilst the abstraction from dams is still severely restricted. Energy dissipation is also required, which does mean there is future potential for power generation.

This diversification of supply has allowed NMBM to stay within the severely restricted allocations of the western supply dams, meaning that there is less risk of rapidly depleting these sources again once they fill. NMBM would then also not be reliant on 100% uptime from the Nooitgedagt supply system. There is sufficient capacity to augment supply from the west for short periods which will allow more time for maintenance.

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