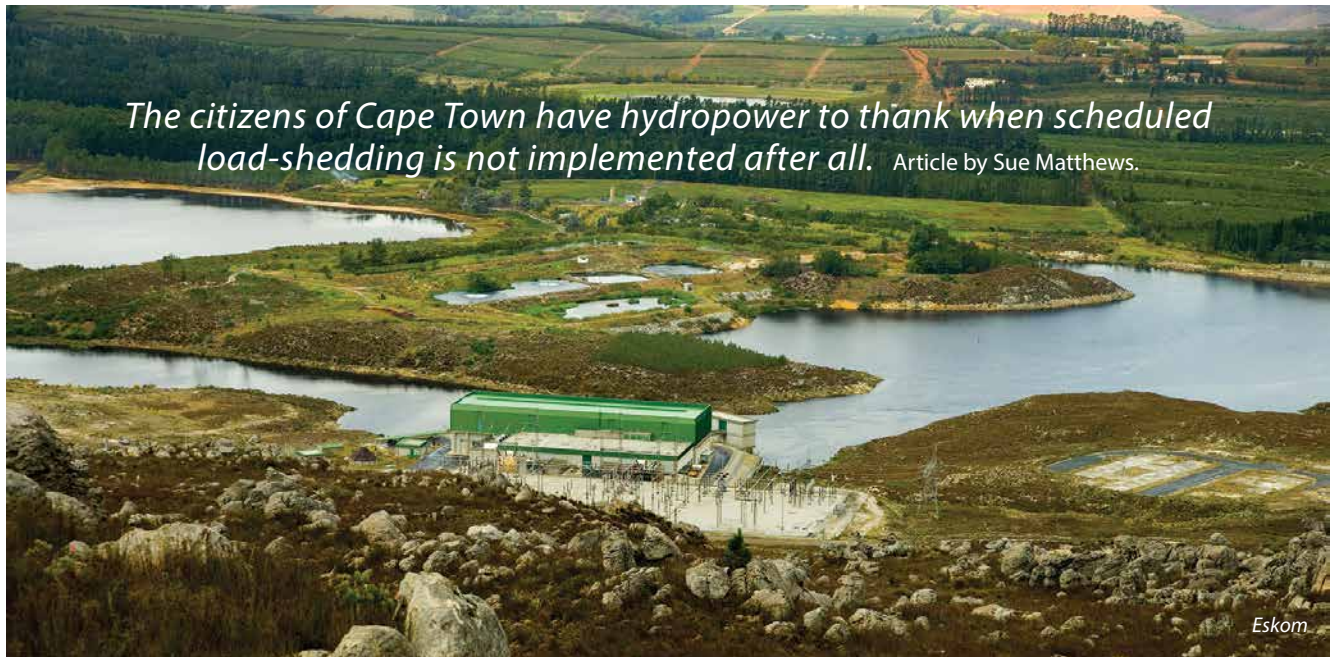


Water and energy

Hydropower – keeping the lights on in the Mother City



The citizens of Cape Town have hydropower to thank when scheduled load-shedding is not implemented after all. Article by Sue Matthews.

The Palmiet Power Station lies next to the Kogelberg Dam on the Palmiet River.

Mention pumped-storage hydroelectricity to most Capetonians and they'll either look at you blankly or say, "Ah yes – that Eskom place at the top of the pass." They're referring to the Palmiet Pumped Storage Scheme, which they've probably noticed while driving over Sir Lowry's Pass, the section of the N2 national road that crosses the Hottentots-Holland mountains separating the Cape Flats from the Overberg beyond.

All that can be seen from the road is the visitors centre, some power lines and – in the distance – the Rockview Dam wall and an incongruous-looking tower, which is actually a surge tank preventing excessive fluctuations in pressure when water flow suddenly stops or starts. Out of sight in a valley is the Kogelberg Dam on the Palmiet River, and the 400 MW power station with its two reversible pump-turbines, which

act as a pump-motor in one mode and a turbine-generator in the other. Power is generated during periods of peak energy demand, when water is allowed to flow down an underground tunnel from the Rockview Dam to the Kogelberg Dam. When demand is low, water is pumped back up the tunnel to the Rockview Dam, so it can be used again. But for every 10 hours of electricity generation, approximately 15 hours are needed for pumping.

"We don't get all the water back up every night so water steadily accumulates in the lower dam during the week," says Liesel Sherwood-Adcock, information officer at the visitor's centre. "At weekends we must pump, using electricity from the grid, to build up reserves for the coming week."

This is why Eskom sometimes says load-shedding is being done at the weekend to 'replenish reserves' – they need to

provide enough electricity to pump all the water back up to Rockview Dam so that it's available for generating during the week, when demand is high.

Commissioned in 1988, this was the second pumped storage scheme developed by Eskom in a joint venture with the Department of Water Affairs. The 1000 MW Drakensberg scheme was put into commercial operation in 1981. But the first pumped storage scheme in the country – in fact the first on the African continent – was the 180 MW Steenbras Power Station constructed by the City of Cape Town. It was commissioned during 1979, and has been in operation ever since, yet few Capetonians even knew of its existence until it saved them from load-shedding a few times this past winter!

From the outset, the Mother City was at the forefront of the hydropower field. Although two 6 kW hydroturbines were

in use in the gold mines of Pilgrim's Rest as early as 1892, the Graaff Electric Lighting Works inaugurated in 1895 on the lower slopes of Table Mountain is considered South Africa's first hydro-electric power station. Built next to the Molteno Reservoir, its two 150 kW generators could be driven either by steam or by water flowing from the Woodhead Reservoir on the 'table top'. It was closed in 1920, after coal-fired power had become the mainstay of the city's electricity supply.

In 1974 the city entered into a long-term bulk-supply agreement with Eskom, but this electricity is expensive during peak periods because the 'night-save' tariff means that the city is charged according to the maximum demand attained in any given month. The possibility of a pumped storage scheme to augment the city's power supply had been bandied about since the 1950s, so it was decided to construct one to reduce the amount of electricity purchased from Eskom at peak rates – a process known as 'peak lopping'.

There was already a dam on the Steenbras River, which – like the neighbouring Palmiet River – drains the Hottentots Holland mountains and flows under the N2 on Sir Lowry's Pass.

Completed in 1921, it initially delivered water to the Molteno Reservoir through a 64 km-long cast-iron pipeline. The dam wall was raised in 1926 and again in 1954, and during this period two additional pipelines were laid to the Newlands Reservoir, just over 50 km away.

A second dam was built upstream of the existing Steenbras Dam, and the intake works for the pumped storage scheme sited in this 'upper' dam. A small reservoir and the power station were constructed on the mountainside some 300 m below, and the two water masses were connected via a series of tunnels and a steel penstock that splits just behind the power station to deliver water to the four 45 MW pump-turbines.

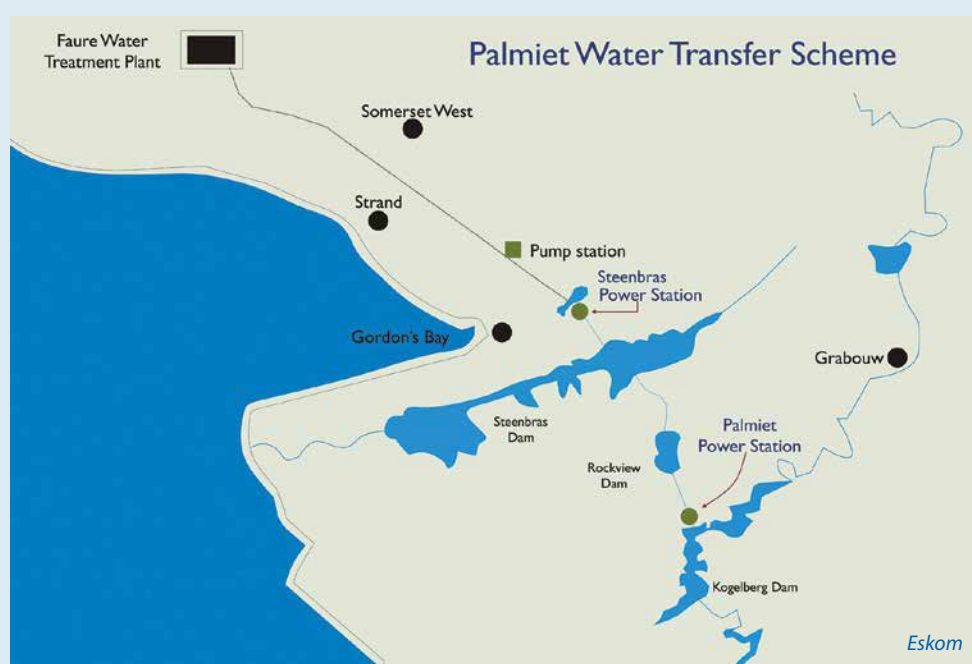
Operation is essentially the same as in the Palmiet scheme, generation taking place during periods of peak demand around sunrise and sunset, and pumping of water from the reservoir back to the upper Steenbras Dam at night and weekends, using comparatively cheap Eskom electricity. The power station is used as the regulating station on the city's electricity distribution network, ensuring that the feed from Eskom is kept within a predetermined level. The beauty of such installations is that they

can be brought online within a few minutes – compared to about eight hours for a coal-fired power station – so generating can begin as soon as that level is reached on any particular day.

Their output is of course constrained by the time taken to pump water back up, but while management of the Palmiet scheme is largely dependent on the storage capacity of the upper Rockview Dam, the opposite is true at the Steenbras scheme. Only about 10% of the capacity of the upper Steenbras Dam is required for the pumped storage scheme, and its daily operation causes the water level to rise and fall by less than a metre when the dam is full.

"In our case, the bottleneck is the lower reservoir," explains Bongani Sithole, head of electricity generation at the City of Cape Town. "If we ran all four units for about 12 hours without pumping any water back up, the reservoir would be full."

The storage capacity of the reservoir was increased slightly in 1988 so that the power station could meet weekly energy requirements, given the limited pumping time available during weekday nights. The reservoir reaches a maximum level by Friday night, but by 6 am on Monday



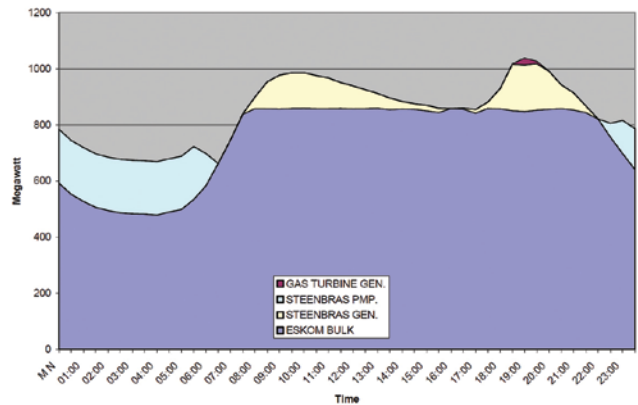
The Palmiet and Steenbras pumped storage schemes are linked by the Palmiet Water Transfer Scheme, which allows excess winter flow in the Palmiet River to be pumped from the Kogelberg Dam to the Rockview Dam, from where it is released to the upper Steenbras Dam. After being used for electricity generation at the Steenbras Power Station, the water is piped to the Faure Water Treatment Plant to augment Cape Town's water supply.

morning it should be empty, ready to start receiving water from the upper dam.

Typically, generating is done for four to five hours per day during the winter months, but this can be extended to eight hours depending on the level of the reservoir. By having its own generating capacity, the city can sometimes also avoid load-shedding implemented by Eskom, or reduce from Stage 2 to Stage 1. Electricity can also be provided to priority installations such as key hospitals and some large factories that cannot risk a power cut.

“We can’t do it for too long, because we must always keep enough space available in the reservoir for the water required for routine generating,” explains Sithole. In essence, it would not make financial sense to fill the reservoir to a level that would compromise the peak-logging function, because the city would not be able to recover the funds spent on the more expensive Eskom supply when the baseload limit is exceeded.

The exception to the rule of pumping water back to the top of the mountain occurs when the upper and lower Steenbras Dams are overflowing. The sluice gates of the power station’s



Electricity demand and supply components for a typical winter's day in Cape Town in June 2005, showing electricity generation by the City of Cape Town's Steenbras Power Station once the baseload limit is reached during the day, and electricity usage for pumping water back to the upper Steenbras Dam overnight. If necessary, gas turbines at Roggebaai and Athlone are brought into operation too, but fuel costs make this an expensive option. Nowadays, 'peak-logging' is implemented at around the 920 MW mark, and the total demand may reach 1200 MW. (Source: City of Cape Town)



A rocky ridge of the Hottentots Holland mountain range separates the upper and lower Steenbras Dams from Gordon's Bay. The Steenbras Water Treatment Plant is perched on the mountain slope in the foreground, while the reservoir for the Steenbras pumped storage scheme can be seen in the distance.



*Bongani Sithole, head of electricity generation at the City of Cape Town, in front of the Steenbras Power Station's SCADA system.
(Credit: Sue Matthews)*

reservoir are then opened, and generation can take place without being constrained by the capacity of the dam, and without the need to pump water back, which saves on electricity costs. Originally this 'free' water was discharged to the sea at Gordon's Bay, but the commissioning of a pump station below the power station in late 1997 allowed it to be piped instead to the Faure Water Treatment Plant, some 18 km away.

This is the largest of the city's 12 water treatment plants, capable of treating 500 Mℓ per day. It also receives water from the Riviersonderend-Berg River Government Water Scheme, while water from the Steenbras Dam actually forms part of a water transfer scheme associated with the Palmiet Pumped Storage Scheme. In February 1995, the then Department of Water Affairs (now the Department of Water and Sanitation) approved Palmiet Phase 1, which allows the annual transfer of 22 Mm³ from the Palmiet River – via the Kogelberg and Rockview Dams – to the upper Steenbras Dam.

"Palmiet water is only transferred to Steenbras during the winter rainfall months," explains Sherwood-Adcock. "The Department monitors flow coming

down the Palmiet River, and advises us when to pump additional water from Kogelberg to Rockview."

The Rockview Dam lies on the watershed between the Palmiet and Steenbras catchments, so the water flows under gravity when it is released to the Steenbras Dam, less than 3 km away. While this water augments Cape Town's water supply, it is of relatively small importance, making up only 5.6% of the city's total allocation from the Western Cape Water Supply System. The upper and lower Steenbras Dams together contribute 40 Mm³, representing 10% of the city's allocation.

Apart from the water transferred to Faure for treatment, the Steenbras Water Treatment Plant built below the lower dam in 1946 treats up to 150 Mℓ per day. Even here, hydropower has been innovatively used. Way back in 1948, two turbines with a combined capacity of 340 kW were installed on the inflow pipes. Although only one is operated at a time, this generates enough electricity to meet all the needs of the water treatment plant.

There are similar installations at the city's Faure, Wemmershoek and Blackheath

water treatment plants, although at the last-mentioned the turbines are run off the flow of treated water entering a reservoir, rather than raw water from the supply dams.

The city has also been exploring the use of conduit micro-hydropower for remote pressure management instrumentation. Controlling pressure in a water distribution system, for example, is vital in preventing pipe damage and reducing leakages, which can result in costly repairs and water losses. Normally this is achieved with pressure reducing valves, installed at specific points along a conduit to dissipate excess energy, but conveying the water through a turbine instead allows this energy to be converted to usable power. The associated savings in electricity can offset operational costs significantly.

For more information on this aspect of hydropower, refer to the *Conduit Hydropower Development Guide* published by the Water Research Commission in 2014 (WRC Report No. TT 597/14).