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20 September 2006

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Attention: Mr. Greg Seymour

HYDROLOGICAL SCREENING REPORT FOR THE PROPOSED ESKOM PUMPED STORAGE PROJECT IN THE STEELPOORT RIVER: PROJECT LIMA.

Please find our screening report with regards to the hydrological characteristics for the above mentioned project.

Yours faithfully

André Pretorius
Hydrological Engineer

Mark Stewart
Project Manager

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REPORT NO BOH.06.121 S

SURFACE WATER SCREENING REPORT FOR THE PROPOSED ESKOM STEELPOORT PUMPED STORAGE SCHEME: PROJECT LIMA

HYDROLOGICAL SCREENING STUDY

PROJECT LIMA

REPORT NO: BOH.06.121 S

Client: Bohlweki Environmental (Pty) Ltd

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By

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EXECUTIVE SUMMARY

ESKOM is currently in the process of planning the construction of a 1 000 MW pumped storage scheme along the escarpment between the Nebo Plateau and the Steelpoort River valley, close to the town of Roossenekal in the Limpopo Province.

The hydroelectric power generation project will consist of an in-stream as well as an off-channel water storage dam. The locality as well as the storage capacity of these dams is not yet finalised, as a detailed feasibility study will be required in order to determine the optimum storage required with the relevant cost-benefit to the scheme.

It is proposed that the hydroelectric power generation process will be that of a pumped storage scheme. This is mainly because of the limited opportunities of generating hydropower from South African Rivers. Surplus electricity that the thermal power stations generate during off-peak periods (usually at night), and for which there is no other use and which otherwise would be wasted, is used to pump water to high elevations from where it is then released to generate electricity for the peaks in demand. The effective use of hydroelectric power stations require them to operate intermittently for only a few hours a day during the peak demand for electricity.

All hydrological data was based on preliminary desktop analyses for the purposes of the screening study. The "*Project Lima Supplementary Feasibility Study- Phase 1 Site Selection Study Main Report Volume 1*" conducted by BKS Palace Consortium during May 2006, was consulted for the purposes of this study. A number of potential sites was identified and ranked during this study.

This surface water screening report covers the potential surface water impacts that this proposed development may have on surface water resources at ach of the three candidate sites.

The following can be concluded with regard to the most favoured impoundment options from a hydrological point of view:

- For the Site A option, Option 3 is the most favoured, as both the upper and lower reservoirs will be off-stream. Less storage capacity than that suggested in option 4 implies a smaller surface area susceptible to evaporative losses. More run-off will also be available annually to sustain the hydrological regime, downstream of these impoundments.
- Site Options 1,3,5, and 7 are the more favourable Site B options as these impoundment options will contain less (10 hours) storage oppose to the other alternatives which will contain 20 hours.
- From the information provided, no distinction can be made between the four most favoured Site B options, but ultimately the option with the least upper reservoir storage capacity will be the most favoured, as it will impact the least on the

hydrological regime downstream. Also the reservoir with the smallest surface area will be least susceptible to evaporative losses.

- No distinction can be made between Site A3 and the various favoured B options.
- Site C is the least favoured of all three options as a result of the following factors:
    - the study area represents a lower MAR ($16.6 \times 10^6 m^3$) which will affect the hydrological regime more negatively, as it will be deprived of more available run-off.
    - On plan it appears that the lower reservoir Site C option will cover a much larger surface area than the A & B options, which will be more susceptible to evaporative losses.

1 INTRODUCTION

ESKOM is currently in the process of planning the construction of a 1 000 MW pumped storage scheme along the escarpment between the Nebo Plateau and the Steelpoort River valley, close to the town of Roossenekal in the Limpopo Province.

The proposed hydroelectric power generation project will consist of an in-stream as well as an off-channel water storage dam. The locality as well as the storage capacity of these dams is not yet finalised, as a detailed feasibility study will be required in order to determine the optimum storage required with the relevant cost-benefit to the scheme. Figure 1 below illustrates such a scheme

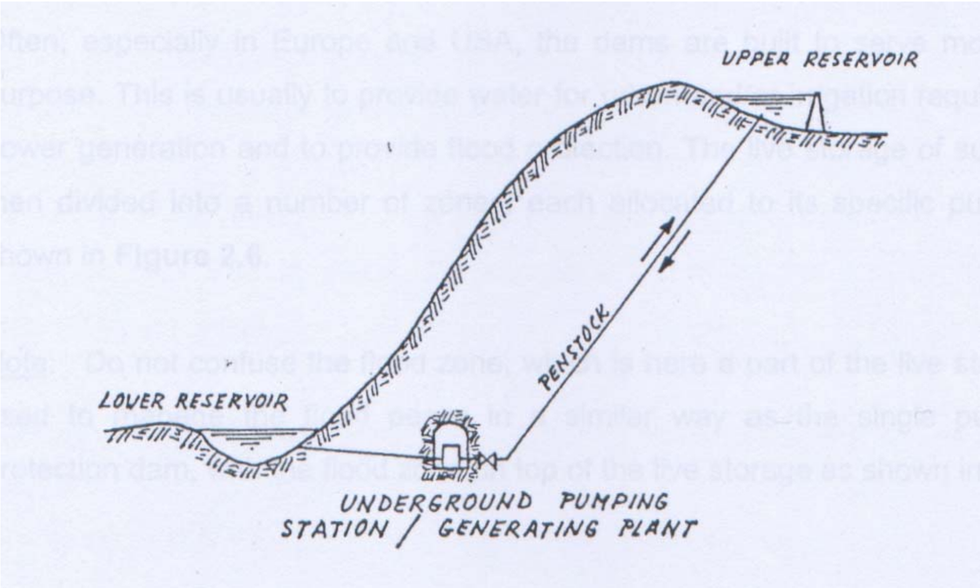

Figure 1

The screening study comprised a desktop study of available information. No field visits were conducted to obtain site-specific data, therefore no background data was obtained for the Steelpoort River and its tributaries. All hydrological data was based on preliminary desktop analyses for the purposes of the Screening Study. The "*Project Lima Supplementary Feasibility Study- Phase 1 Site Selection Study Main Report Volume 1*" conducted by BKS Palace Consortium during May 2006, was consulted for the purposes of this study. A number of potential sites was identified and ranked during the BKS study.

This screening report only covers potential surface water impacts that this development may have on water resources

1.1 Study Area

The study area comprises various properties, which is situated within the lower parts of the B41C Quaternary Catchment as well as within the middle to lower parts of the B41D Quaternary Catchment.

Catchment characteristics: -

- The general geology of these quaternary catchments comprises Bushveld Igneous Complex rocks and basic/mafic and ultramafic intrusives.
- Soils in this region vary from moderate to deep sandy loam, with steep relief.
- Vegetation for this area comprises of savannah (Simplified Acocks Veldt Types).
- The erodibility index is high (value between 3 and 5) and has an estimated sediment yield (Region 1) which is in the order of 40 000 tonnes per annum. Preliminary studies regarding the sediment yield conducted for the De Hoop dam indicate that the sediment yield for this region may be in the order of 250 $t/km^2/a$, for the Steelpoort River, and 300 $t/km^2/a$ for other minor streams.

Three possible sites[1] (Site A, B, and C) have been identified during the pre-feasibility study, and will be discussed for their significance.

1.2 Rainfall and Evaporation Data

Only preliminary desktop rainfall and evaporation calculations were conducted during the screening process. More detailed and site specific calculations and analyses should be made during the detailed design process.

The B41C Quaternary Catchment receives an annual average rainfall of 694 mm, the majority of which falls during the months of October to March, according to the *Surface Water Resources of South Africa report (Water Research Commission 1990*). The mean rainfall figures are given in **Table 1** and are illustrated in **Figure 2**. The month of January has the highest average monthly rainfall of 123.1 mm.

Mean annual evaporation for this region is 1500 mm, of which the monthly distribution is shown in **Table 1**. The mean monthly evaporation figures are illustrated in **Figure 2**.

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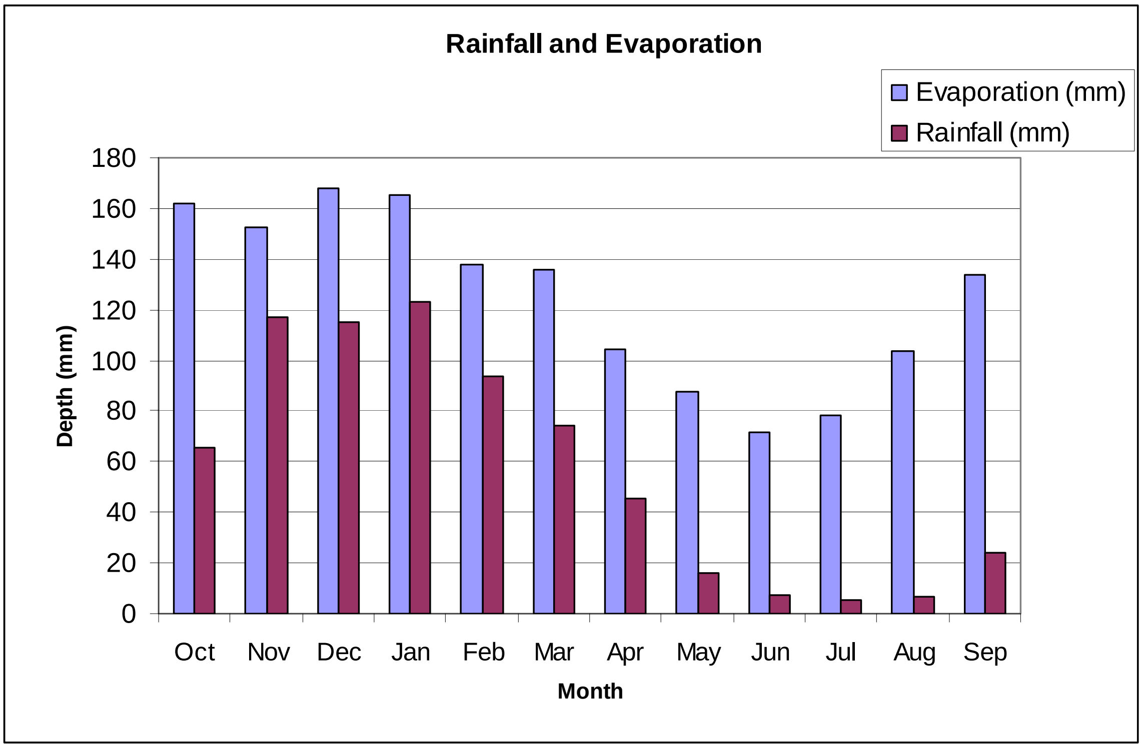
[1] The "*Project Lima Supplementary Feasibility Study- Phase 1 Site Selection Study Main Report Volume 1" report,* compiled by BKS Palace Consortium (May 2006) contains all relevant discussions and maps regarding the candidate sites.

Table 1: Mean Monthly Rainfall and Evaporation for the B41C Quaternary Catchment.

Month	Rainfall (mm) Surface Water Resources of South Africa (1990)	S- Pan Evaporation (mm) Surface Water Resources of South Africa (1990)
January	115.1	165.0
February	123.1	137.6
March	93.6	135.8
April	74.2	104.4
May	45.3	87.9
June	16.1	71.4
July	7.3	78.2
August	5.6	103.5
September	6.5	134.1
October	24.4	161.7
November	65.6	152.6
December	117.0	168.0
Mean Annual (mm)	**694**	**1500**

Figure 2: Mean Monthly Rainfall and Evaporation for the B41C Quaternary Catchment.

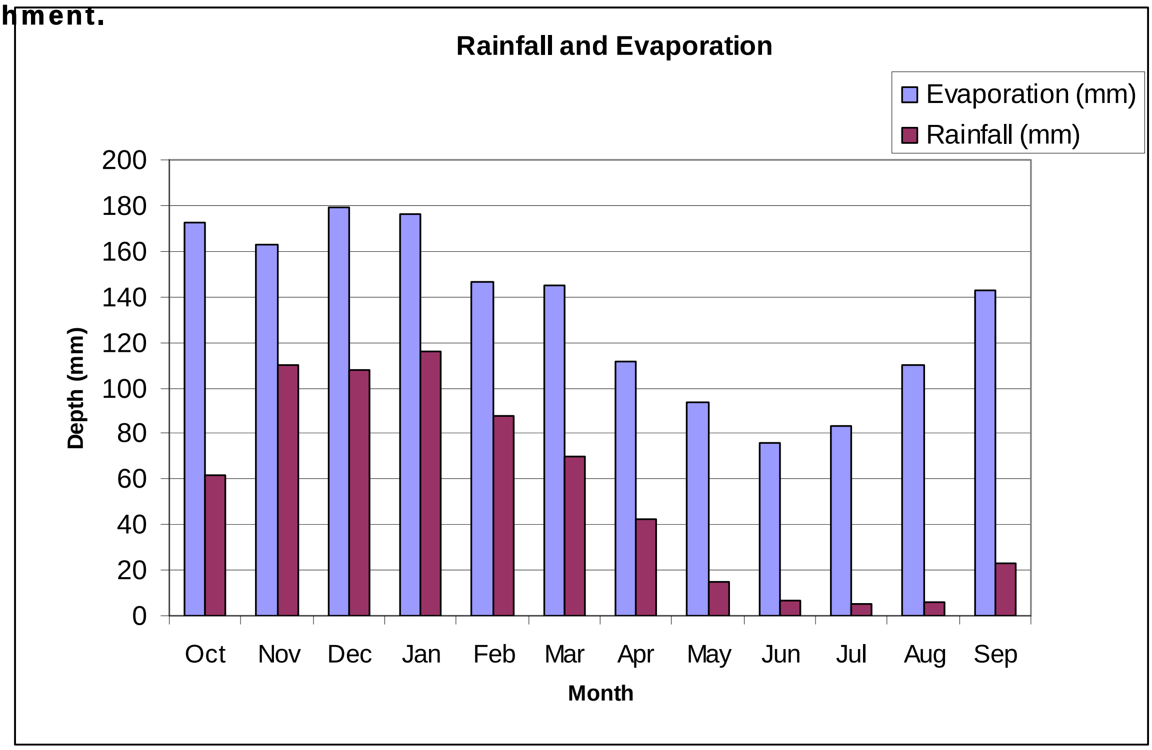


The B41D quaternary catchment receives an annual average rainfall of 652 mm, the majority of which falls during the months of October to March, according to the *Surface Water Resources of South Africa report (Water Research Commission 1990)*. The mean rainfall figures are given in **Table 2** and are illustrated in **Figure 3**. The month of January has the highest average monthly rainfall of 115.7 mm.

Table 2: Mean Monthly Rainfall and Evaporation for the B41D Quaternary Catchment.

Month	Rainfall (mm) Surface Water Resources of South Africa (1990)	S- Pan Evaporation (mm) Surface Water Resources of South Africa (1990)
January	115.7	176
February	88.0	146.7
March	69.7	144.8
April	42.6	111.4
May	15.2	93.7
June	6.8	76.2
July	5.3	83.4
August	6.1	110.4
September	22.9	143.0
October	61.7	172.4
November	110.0	162.7
December	108.1	179.2
Mean Annual (mm)	**652**	**1600**

Figure 3: Mean Monthly Rainfall and Evaporation for the B41D Quaternary Catchment.



Design rainfall depths for a 24-hour storm duration (1 day) was obtained from various weather stations, situated close to the study area, and are listed in **Table 3** for the various return periods.

Table 3: Design Rainfall Depths

Station Name	Altitude (m)	MAP (mm)	Return Period (years)						
			2	5	10	20	50	100	200
Roosenekal (SAWS no. 0553672 W)	1440	668	50	69	83	97	116	131	147
Tonteldoos (SAWS no. 0553859 W)	1807	762	56	74	87	100	118	132	147
Ga-Sekukuneland (SWAWS no. 0593015 W)	1260	552	49	68	81	95	113	129	145
Glen Cowrie Mission “Morg” (SAWS no. 0592560 W)	1478	637	48	66	79	92	111	126	141
Note: Values was obtained from Design Rainfall Depths at Selected Stations in South Africa (Smithers, J.C. and Schulze, R.E., 2000b.)									

1.3 Surface Water Quantity

1.3.1 Catchment Boundaries

The study area is located within the Steelpoort River Catchment and its tributaries. The Steelpoort River catchment drains into a northerly direction and eventually flows into the Olifants River. The boundaries of the catchment are occupied by some dense rural residential related activities, some small scale farming activities, as well as some game farming areas. The affected watercourse that would be impacted upon would be the Steelpoort River.

Identified sites are located towards the downstream western side of the Steelpoort River. This selection may be contributed to the plateau height (to the west of the river), which is required to achieve sufficient hydraulic head.

Site A, also known as the southern site, is located close to the current De Hoop Dam scheme. The site lends itself to both on- and off-channel options for the lower reservoir. Four different storage options have been identified for this site.

- Option 1
  As primary benchmark, the current scheme was designated as Option 1, with 10 hours storage

- Option 2
  The same as Option1, but with an off-channel storage reservoir

- Option 3
  Using the same upper reservoir as in Option 2, but with an off-channel lower reservoir

- Option 4
  Similar to Option 3 but with 20 hours storage

Site B, also known as the middle site, has one preferred location for an upper reservoir, with different locations for the lower reservoir. Eight different storage options have been identified for this site.

- Option 1
  This is the highest head option with 10 hours storage

- Option 2
  Same as Option 1, but with 20 hours storage

- Option 3 and 4
  Representing a more favourable location to the lower reservoir with relation to the Steelpoort fault

- Option 5 and 6
  Representing a lower pumping head, but influenced by the Steelpoort fault

- Option 7 and 8
  Options with a lower pumping head, and clear of the Steelpoort fault

Site C, also known as the northern site, is located opposite the western edge of the proposed De Hoop Dam, which would serve the common purpose as lower reservoir for the Pumped Storage scheme. Two options have been identified for this site.

- Option 1
  With the De Hoop Dam providing for the lower reservoir, and with an off-channel upper reservoir

- Option 2
  Similar to Option 1, but with an alternative upper reservoir for 20 hours storage

1.3.2 Virgin Mean Annual Run-off

The virgin mean annual run-off (MAR) for both quaternary catchment areas has been estimated. Water Research Commission publications *(Surface Water Resources of South Africa- Volume 1)* were used to obtain the MAR for each Quaternary drainage regions. The B41B Quaternary Catchment has an estimated MAR of 17.8 $x10^6$ m^3 per annum while the B41D Quaternary Catchment has an estimated MAR of 16.6 $x10^6$ m^3 per annum.

Note: No actual stream flow data was obtained during this study.

1.3.3 Flood Peaks and Volumes

Flood calculations will be determined as part of the feasibility process. Water storage reservoirs will be classified according to Chapter 12 of the National Water Act, 1998 (Act 36 of 1998) and relevant Government Notices, as dams with a Safety Risk. Social, economic, and environmental impacts will be used during the classification process. Freeboard and spillway sizes will be determined according to the relevant SANCOLD (South African Commission on Large Dams) publications. This will be done during the detailed design process.

1.4 Potential Impacts of Proposed Activities

The proposed water storage reservoirs will consist of concrete faced rock-fill dams. It is anticipated that the surface areas of the upper reservoirs will be in the order of 80 ha, while the lower reservoirs would be 50 ha. It is also anticipated that an initial start up volume of 15 $x10^6$ m^3 per annum would be required for these dams and that 2 $x10^6$ m^3 per annum would be required as top-up water due to evaporative and seepage losses. It is also anticipated that water would be supplied to local communities along the Nebo plateau from this Pumped Storage Scheme, but this has to be clarified. Water would be pumped from the De Hoop Dam in a pipeline to the water storage reservoirs.

Some potable water will be required for construction purposes as well as for the construction camp during the construction phase. These volumes will be abstracted over the whole length of the construction period for construction as well as for day-to-day operations in the camp. It is, however, still unclear what the workforce will consist off and what the level of service will be.

1.4.1 Potential Impacts on Hydrology

The hydrological implications for all sites will be similar for all identified options.

The damming up of small tributaries is expected to negatively impact on the current hydrological regime and future hydrological functioning. One of the main impacts of impoundments is that they change the timing, size and frequency of flow and flood events in the river. Altered flow patterns also lead to changes in sediment dynamics, habitat integrity, thermal and chemical (abiotic) conditions in rivers. Fluctuating discharges constantly change conditions through each day and season, creating mosaics of areas inundated and exposed for different lengths of time. The resulting physical heterogeneity determines the local distribution of species: higher physical diversity enhances biodiversity. The foreseen impacts on the Ecological and Basic human needs reserve will be neglectable, since water released by the relevant reservoirs will be intercepted by the De Hoop dam, and may be lost due to evaporation, seepage or releases from the dam.

Most water losses in the reservoirs would occur due to evaporation of water from the open water bodies. Some seepage and frictional losses will also occur. It is quite possible that water emanating from the dam wall as a result of seepage through the internal drainage system, will be measured and discharged back to the receiving water bodies. This volume may be small and can be considered as neglectable.

The impact on the Mean Annual Run-off (MAR) as well as on the yield of De Hoop Dam has not been determined yet, as no detailed design has been formalised.

1.4.2 Increased Run-off from surface areas

Increase in run-off and flow velocities are expected as a result of the increased impermeable surface areas and mitigation measures should be implemented to prevent the degradation of the watercourses. Soil conservation measures should be implemented at identified areas. Storm water collection and conveyance systems should be engineered designed.

1.5 Potential Impacts of hydrological factors on the proposed activities:

The Three possible sites (Site A, B and C) which have been identified during the pre-feasibility study, will be discussed for their significance from a hydrological point of view:

- Site A:

Option 1 is the least favoured as both the lower and the upper reservoirs will be located in-stream, which will result in high sedimentation yields which is a direct result of the high erodibility index for the study area. Both the in-stream options will also influence the hydrological regime for the streams they are located in negatively.

Option 2 is the second least favoured. For the same reasons as above, although the upstream reservoir will be off-stream, the lower reservoir will still be in-stream.

Option 4 is the third least favoured. Although both impoundments will be situated off-stream, a higher storage capacity (larger surface area) will be susceptible to higher evaporative losses. Less run-off will also be available to sustain the hydrological regime.

Option 3 is the most favoured. Both the upper and lower reservoirs will be off-stream. Less storage capacity than that suggested in option 4 implies a smaller surface area susceptible to less evaporative losses. More run-off will also be available annually to sustain the hydrological regime, downstream of the impoundments.

- Site B:

Site Options 1,3,5, and 7 are the more favourable Site B options as these impoundment options will contain less (10 hours) storage oppose to the other alternatives which will contain 20 hours. The former options will favour the hydrological regime more as less run-off will require to be stored. Smaller storage volumes that will occupy smaller surface areas will also be susceptible to evaporative losses.

- Site C:

Site C is the least favoured of the site options as the study area represents a lower MAR (16.6 x $10^6 m^3$) apposed to Site A & B which represents a MAR of 17.8 x $10^6 m^3$. This implies generally speaking sites A & B have more available run-off available to be stored, thereby influencing the hydrological regime less negatively than the Site C option. Secondly on plan it appears that the lower reservoir Site C option will cover a much larger surface area than the other two options, which will be more susceptible to evaporative losses.

2 CONCLUSIONS:

- For the Site A option, Option 3 is the most favoured, as both the upper and lower reservoirs will be off-stream. Less storage capacity than that suggested in option 4 implies a smaller surface area susceptible to evaporative losses. More run-off will also be available annually to sustain the hydrological regime, downstream of these impoundments.
- Site Options 1,3,5, and 7 are the more favourable Site B options as these impoundment options will contain less (10 hours) storage oppose to the other alternatives which will contain 20 hours.
- From the information provided, no distinction can be made between the four most favoured Site B options, but ultimately the option with the least upper reservoir storage capacity will be the most favoured, as it will impact the least on the hydrological regime downstream. Also the reservoir with the smallest surface area will be least susceptible to evaporative losses.
- No distinction can be made between Site A3 and the various favoured B options.
- Site C is the least favoured of all three options as a result of the following factors:
  - the study area represents a lower MAR ($16.6 \times 10^6 m^3$) which will affect the hydrological regime more negatively, as it will be deprived of more available run-off.
  - On plan it appears that the lower reservoir Site C option will cover a much larger surface area than the A & B options, which will be more susceptible to evaporative losses.

2.1 References

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