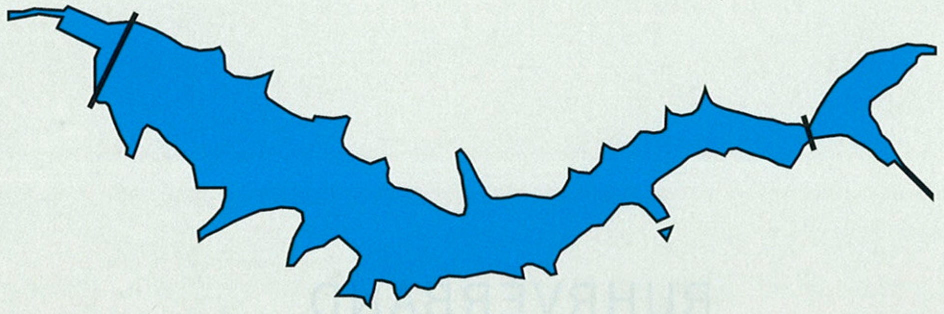
RUHRVERBAND

Sorpe Dam

Ruhrverband
Kronprinzenstraße 37
45128 Essen



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1 General data

Rivers
Sorpe, Hespe, Röhr, Bönkhauser Bach, Setmecke

Nearest city
Sundern, Hochsauerland District, North Rhine-Westphalia

Purpose
Low flow augmentation,
supply of drinking and industrial water,
flood control,
power generation

Dam type/Sealing element
Earthfill dam with concrete core

Construction period
Original construction period:
1926 – 1935
Construction of further drainage and collecting systems in adjacent areas 1957 – 1960
1st rehabilitation 1958 – 1962
2nd rehabilitation 1996 – 1997

Start of operation
1934

2 Technical data

2.1 Hydrology

Extended catchment area	100.32	km²
Original catchment area	52.67	km²
Mean annual discharge (1961-1993) (with extended collecting system)	44,000	10³ m³

2.2 Reservoir

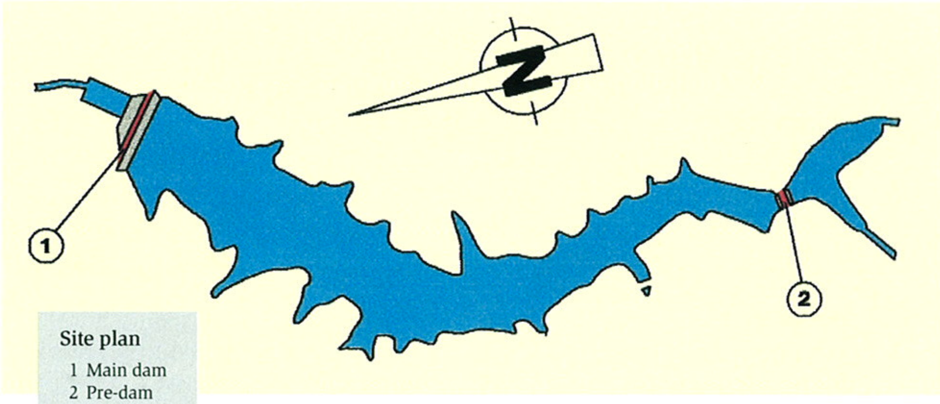
Maximum water level	283.30	m a sl
Normal water level	283.03	m a sl
Minimum operating water level	239.88	m a sl
Minimum water level	224.53	m a sl
Gross capacity	70,800	10³ m³
Storage	70,000	10³ m³
Effective storage	69,240	10³ m³
Surcharge flood storage	800	10³ m³
Flood storage	0	m³
Active storage	66,400	10³ m³
Inactive storage	2,040	10³ m³
Dead storage	1,560	10³ m³
Reservoir surface at maximum water level	3,380	10³ m²
Storage/Mean annual discharge (with extended collecting system)	1.62	

2.3 Utilities

Power installed capacity (2 Francis turbines, 1 Kaplan turbine)	7.4	MW
Average energy output	11.5	GWh/year
Average annual discharge for low flow regulation	44,830	10³ m³
Average annual abstraction for water supply (1995-2000)	640	10³ m³

2.4 Main dam

Height above lowest foundation	69.00	m
Height above valley bottom	60.00	m
Crest length	700.00 m	
Crest width	10.00	m
Dam volume	3,250	10³ m³
Dam volume/Gross capacity	1:22	
Dam slope upstream face	1:2.25	
Dam slope downstream face	1:1.50/1:3.00	



Site plan
1 Main dam
2 Pre-dam

3 Spillway

The overflow structure consists of a 100 m-long spillway (283.03 m a sl), located on the right side of the valley, and a 7-m-wide masonry spillway channel (cascade) that leads to the tailwater bay.

4 Intake structures

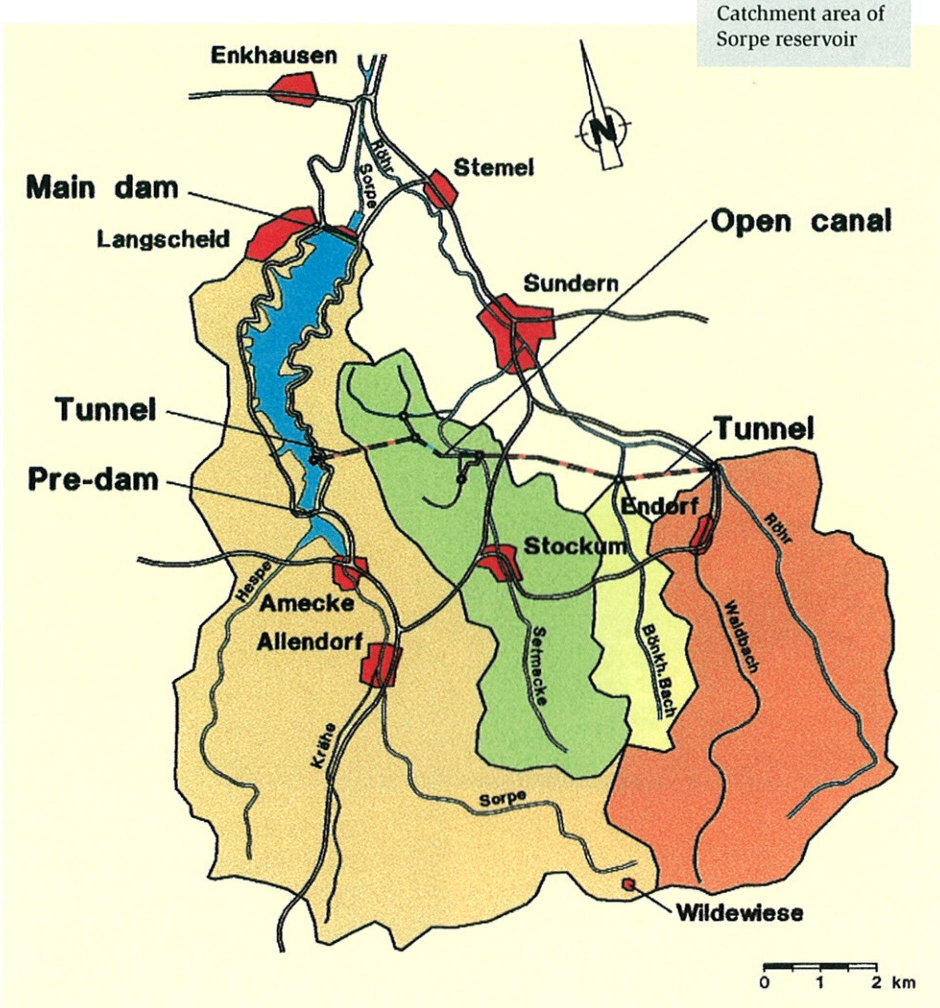
There are two galleries that were driven through the dam at valley bottom level. The left tunnel, serving as bottom outlet, is provided with a concrete-encased steel pipeline of size ND 1,400 on the upstream side of the concrete core. The tunnel intake is designed as shaft with an opening, covered by a screen rack, that is situated at about 11 m above valley bottom level.

In the section where the gallery traverses the core wall, the bottom outlet is split up – by means of a bifurcation – into two lines of size ND 1,000 leading to an open channel.

The penstock is on the right side of the valley. Its intake is designed similarly to that of the bottom outlet tunnel. The transferring steel pipeline is of size ND 2,500. In the gallery section within the core wall, it branches into two lines of size ND 1,600 which are reconnected on the downstream side into a single pressure pipe of size ND 3,000 that leads to the power station.

The shutoff facilities for both pipes are in the valve houses located behind the dam core: a sphere valve with hydraulic control and an annular valve with electric motor serve as shutoff units in the direction of flow. The penstock is closed by means of two butterfly valves. The discharge capacity of bottom outlet and penstock adds up to 36 m³/s (bottom outlet: 20 m³/s; penstock: 16 m³/s).

Catchment area of Sorpe reservoir



5 Secondary dam

A pre-reservoir was constructed at the upstream end of the impoundment, where the Sorpe river flows in. It is separated from the main reservoir by the Amecke dam which is provided with a massive spillway structure. Integrated into the dam, there are two bottom outlets of size ND 900. The pre-reservoir has a storage capacity of 1.5 million m³. It stores the water at a constant level independently of the water levels in the main basin. The pre-reservoir holds back, for one thing, the sediments carried along by the water courses, and for another, the nutrients that would otherwise pollute the main basin.

Pre-dam

The Amecke dam was built in 1934 and – as far as it is known – it was the first embankment dam in Germany to be waterproofed with a 6-cm-thick layer of asphaltic concrete at the upstream face. After no less than 60 years of operation, the sealing layer had to be replaced in 1995, due to wear and embrittlement. The thickness of the layer was increased to 12 cm on that occasion. At the same time, new bottom-outlet and regulating valves with hydraulic control were installed.

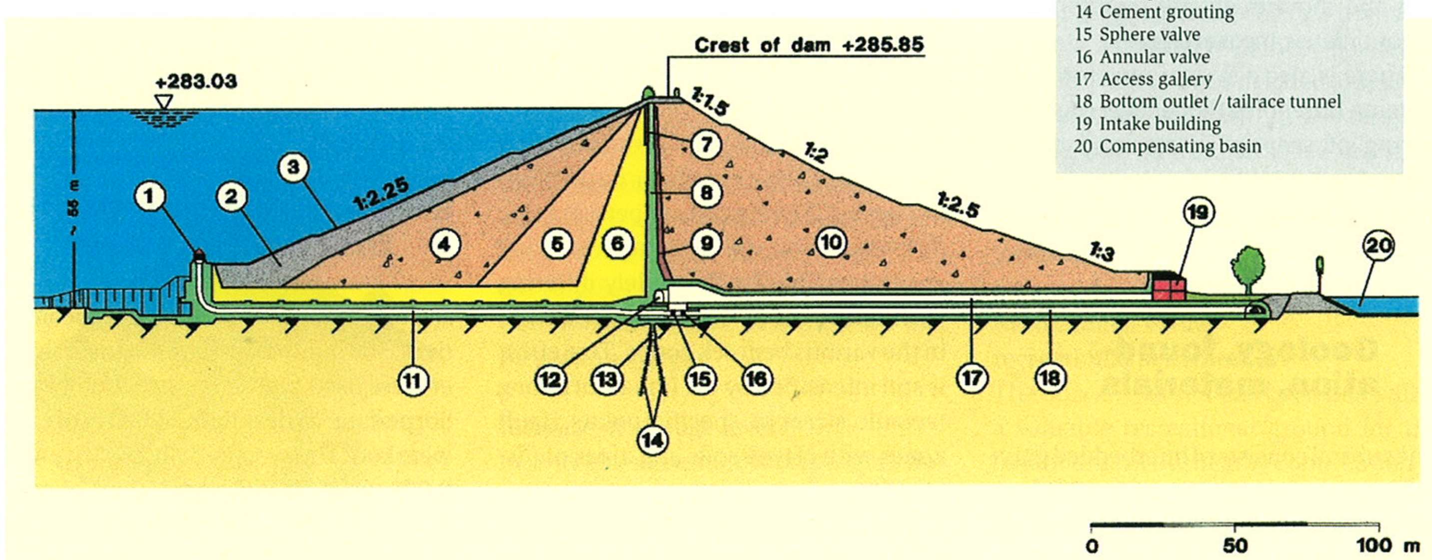
Compensating basin

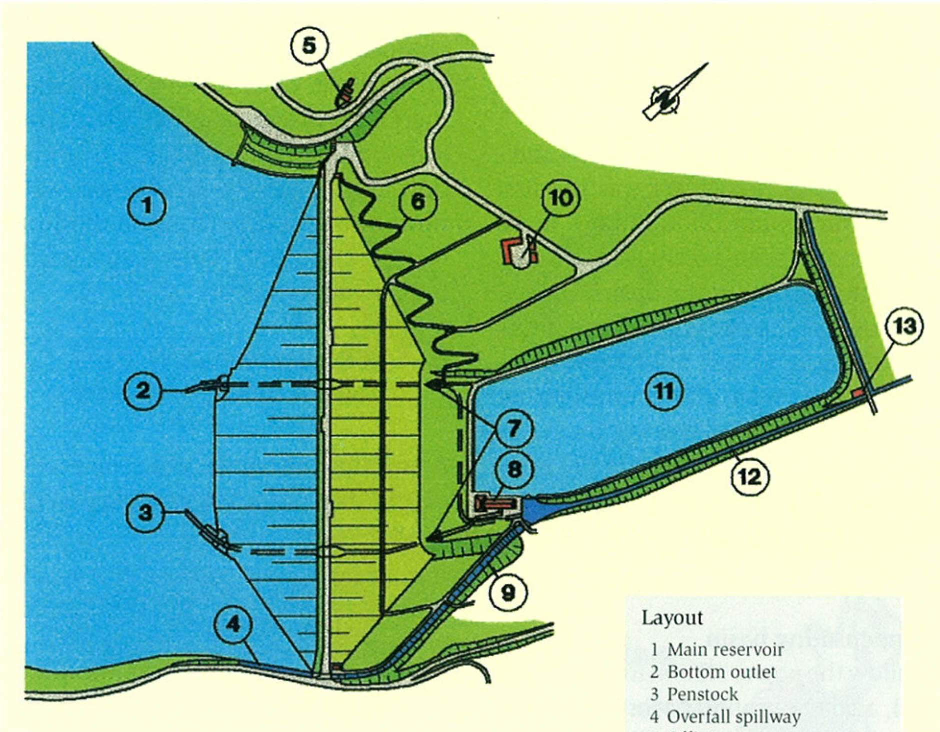
To allow the power station to run at peak load, a compensating basin with a storage capacity of 0.374 million m³ was built. It serves as buffer basin for both the controlled discharge into the downstream reaches of the Sorpe river and the pumped-storage operation of the hydropower plant. Close to the power station, there is the discharge and spillway structure with bottom outlet and five overflow openings. The discharged water flows into the stilling basin of the Sorpe reservoir and from there into the controlled Sorpe river.

6 Measurement and monitoring devices

Apart from the regular visual inspection of the dam structure, possible settle-

Cross section of the Sorpe dam
1 Intake structure
2 Compacted rockfill
3 Masonry facing
4 Rockfill with low content of loam
5 Loam with stones
6 Clay sealing
7 Jet grouting
8 Concrete core
9 Drain curtain
10 Rockfill
11 Bottom outlet line
12 Inspection gallery
13 Deep gallery
14 Cement grouting
15 Sphere valve
16 Annular valve
17 Access gallery
18 Bottom outlet / tailrace tunnel
19 Intake building
20 Compensating basin





Layout
1 Main reservoir
2 Bottom outlet
3 Penstock
4 Overfall spillway
5 Office
6 Footpath
7 Access buildings
8 Power station
9 Spillway channel (cascade)
10 Owner's yard
11 Compensating basin
12 Sorpe river
13 Gauging station

ments are controlled by precision levelling and movements are monitored by trigonometric measurements.

There is also a system of control and gauging boreholes that allows the monitoring of seepage water and of the ground-water table.

Precipitation, inflow and outflow, as well as storage levels are routinely measured at regular intervals.

7 Geology, foundation, materials

The subsoil consists of interbedded graywacke and of slate/clay strata with fractions of coarse, medium, and fine sands striking from West-South-West to East-North-East, which were formed during the non-coal bearing upper Carboniferous period. The significant petrographic differences and the resulting fracturing are responsible for the widely differing weathering and permeability conditions in the various bedrock zones. This effect is still intensified by the impact of strong tectonic stress at specific points (fault zones with clayey soils and areas of distortion).

The concrete core is deeply founded in the bedrock, reaching down to 3 to 4 m, and it is provided with an additional toe cutoff wall on the upstream side. The foundation work for the upstream dam section (impervious body) began upon removal of the loose soils from the underlying bedrock. The downstream dam section (shell body) was built up on the coarse gravel ground found in situ upon removal of the fertile soil. In addition, the core toe area was reinforced by injections of cement grouting to improve subsoil conditions on the upstream side.

The dam core sealing consists of concrete with the following mixture: 180 kg/m³ of blast furnace cement, 60 kg/m³ of aggregate with a grain size of up to 60 mm. The core wall is divided into 26-m-wide segments by vertical expansion joints.

A course of loam without gravel is applied directly on the foundation base on the upstream side of the dam core. This is followed by a layer of loam with coarse gravel and a layer of rock-fill with a low fraction of loam. The final fill on the upstream side consists of coarse rock and a layer of pavement.

The supporting body is built of different rockfill materials that were available in the valley (gravel, boulders, Grauwacke cuts).

8 Construction process, first impoundment

A track system with along 28 locomotives, 300 dump wagons and a track shifter were used for the construction of the Sorpe dam. No less than 24,000 m of rails were laid. The average daily capacity was 9,000 m³ of rockfill and 250 m³ of concrete. The diversion of the Sorpe river during the construction period was effected through the bottom outlet gallery that was the first tunnel to be completed.

10.11.1932 Test impoundment
03.11.1934 Final impoundment

9 Engineering, construction

Planning:
Ruhrtalsperrenverein
(Ruhr Reservoirs Association)
Construction:
Contracting joint venture Sorpedamm
(overall control: Hanebeck)

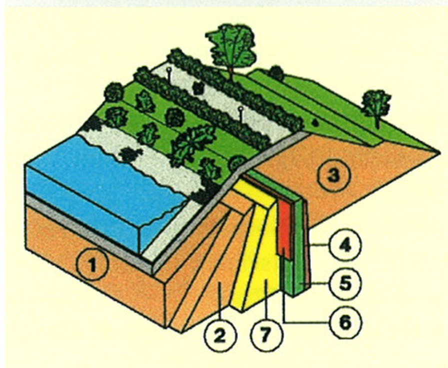
10 Comments

1st Rehabilitation
The Sorpe dam was the target of several air raids during World War II. Even though the dam was hit by 11 bombs, it did not collapse. After the war, just the most severe damages could be repaired gradually.

In January 1951, a sudden and steady rise of seepage water was observed (max. 180 l/s) which contained soil fractions of up to 34 cm³/l. These internal erosions resulted in a massive ground settlement that reached 1.40 m on the left upstream embankment. Responsible for the problem was the damage of the concrete core caused by the bombs of World War II.

Between 1958 and 1962 an extensive rehabilitation project, mainly consisting of injection work in the subsoil zone and in the concrete core of the dam, was implemented. As a first measure a working gallery was driven through the underground beneath the left bottom outlet. Another measure was the construction of a completely new drainage and inspection system.

Three-dimensional sketch of the crest area
1 Compacted rockfill
2 Rockfill with low content of loam
3 Supporting rockfill
4 Drain curtain
5 Concrete core
6 Jet grouting
7 Clay sealing



Increase of storage level
In 1963 the maximum storage level was elevated by 60 cm, so that the overall storage capacity could be increased to 70 million m³.

2nd Rehabilitation
In the mid-80s, another rise of seepage water was observed and, finally, in 1994 more than 30 l/s were registered at normal water level. Evidently the water was seeping through the uppermost 5 to 6 metres of the concrete core. As it was not possible to precisely identify particular seepage points, it was decided to seal the complete core wall within the range of the upper 8 metres. All loose materials and possible cavities were sealed and stabilised by high-pressure concrete injections.

Recreational value, recreational activities
The Sorpe reservoir has been and still is a valuable recreational ground for the inhabitants of the nearby conurbation of the Ruhr District. It offers a wide range of recreational uses, with sports prevailing on the western bank and quiet recrea-

Forest around the reservoir

tion on the eastern bank. With its surrounding forests, the reservoir enjoys a high status as green refuge that attracts the people. The forests, serving the conservation of water resources, are managed in a way that is adequate to nature. In the course of the last years, great efforts have been made to practice an environmentally sensitive bank protection. The dam itself has been optimally integrated into the natural landscape with a planting concept adapted to the region's typical vegetation.

The Sorpe reservoir is located in a protected landscape area, whereof the ground below the dam structure has been classified as nature preserve.

Flora and fauna

Fluctuations in the water level – as they are typically found in waterbodies like, for instance, reservoirs with alternating 'dry or wet' bank – are absolutely detrimental to the development of a stable litoral flora with rooted macrophytes and benthic algae. The major primary producers are essentially represented by planktonic algae.

So there is also a lack of spawning ground for many fish species. For this reason, the Ruhrverband has been pursuing an environment-conscious fishery policy (with stocks of perch and pike-perch) to promote the growth of zooplankton which, in turn, helps to create and maintain a self-regulating natural balance. The major fish groups are pike, perch, pike-perch, eel, carp as well as roach.

The phytoplankton in the reservoir is dominated by diatoms, in particular, synedra acus, fragilaria crotonensis, melosira italica and gran. var. agust, as well as asterionella formosa, and by chlorophytes, in particular, eudorina elegans and chlamydomonas spp.. The zooplankton in the reservoir mainly consists of crustaceans of the genera eudiaptomus, cyclops, daphnia, bosmina and eubosmina.

Spillway channel (cascade)

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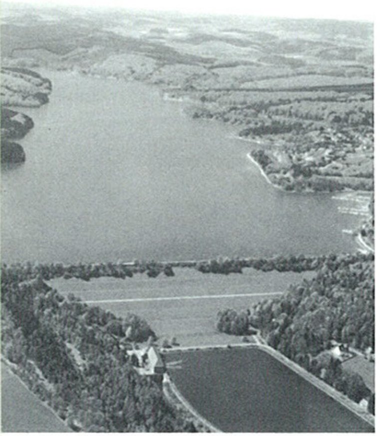
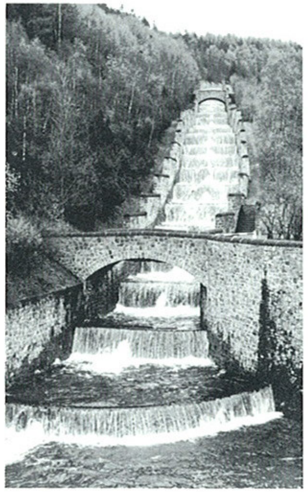
SORPE DAM

Test planting for lakeshore protection

Sorpe Dam and Reservoir   Technical data

Ruhrverband





Water management

Storage capacity	70 million m^3
thereof pre-reservoir	1.5 million m^3
Normal reservoir level	283.03 m above mean sea level
Catchment area	
Sorpe	52.7 km^2
Collecting works (neighbouring valleys)	47.6 km^2
	total 100.3 km^2
Average annual inflow (1961-1993)	
Sorpe	28.2 million m^3
Collecting works (neighbouring valleys)	15.8 million m^3
	total 44 million m^3
Storage ratio	1.59
Reservoir surface at normal reservoir level	3.30 km^2
Storage capacity of the afterbay reservoir	0.374 million m^3
Normal reservoir level of the afterbay reservoir	224.43 m above mean sea level

Dam (rockfill dam with concrete core wall)

Height of crest above foundation	69 m
Height of crest above valley bottom	60 m
Length of crest	700 m
Breadth at bottom of valley	307 m
Width of crest	10 m
Volume of dam	approx. 3.25 million m^3
Volume of concrete for core wall	approx. 0.13 million m^3

Bottom outlet (left side)

Steel pipe set in concrete as far as gate chamber behind core (subsequent open adit), diameter ___ 1.40 m

Maximum discharge ___ approx. 20 m^3/s

(regulation of water charge by means of needle valves)

Powerhouse penstock/bottom outlet (right side)

Steel pipe set in concrete as far as core, diameter ___ 2.50 m

subsequent exposed pipe, diameter ___ 3.0 m

Maximum discharge ___ approx. 16 m^3/s

(regulation of water charge by means of turbines)

Spillway

Overflow weir on the right slope upstream of the dam

Length of the overflow sill	100 m
Discharge at overfall of 35 cm	46 m^3/s

Pumped storage scheme

Two Francis spiral case turbines and pumps with horizontal axle and three-phase current synchronous generator

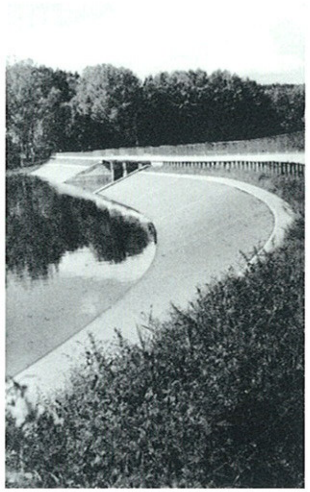
Generator operation:	
Average head	56 m
Turbine discharge	8.1 m^3/s
Output per turbine	3600 kW
Pump operation:	
Pump discharge	4 m^3/s
Input per pump	3200 kW
Kaplan turbine with generator:	
Average head	7.5 m
Turbine discharge	3.6 m^3/s
Output	220 kW
Average annual power generation	11.5 million kWh

The pumped storage scheme is operated by the Lister- und Lennekraftwerke GmbH (Lister and Lenne power stations ltd.) in Olpe, a 100 % subsidiary of the Ruhrverband.

Pre-reservoir

Earthfill dam with asphalt membrane

Normal reservoir level	283.03 m above mean sea level
Height of crest above foundation	17.30 m
Length of crest	200 m
Breadth at bottom	63 m
Width of crest	12 m



Collecting works

Röhr-tunnel	Length: 1600 m
Clear height	2.30 m
Clear breadth	1.76 m
Bönkhauserbach-tunnel	Length: 2470 m
Clear height	2.30 m
Clear breadth	1.92 m
Channel in the Setmecke valley	Length: 1160 m
triangular shape	6.50/2.05 m
Setmecke-tunnel	Length: 1950 m
Clear height	2.25 m
Clear breadth	2.30 m