Mechanical rehabilitation of a horizontal filter well in Moers using the High Pressure Impulse-Process® brings about a sustainable improvement.

Figure 1: construction site "Vinn"

ENNI Energie & Umwelt Niederrhein GmbH in Moers operates a total of three water extraction plants with several vertical water wells and one horizontal water well. The peak demand of water in the summer months of up to 28,000 cubic meters per day is always sufficiently secured.

Every year, more than seven million cubic meters of drinking water leave the waterworks of the operator. Via a pipeline network of more than 690 kilometers it reaches the customers in guaranteed perfect quality. The water is characterized both in terms of its fresh taste as well as its special quality. Because it is fed by purest groundwater it does not require any further treatment. And all this at a price that has been significantly below that of other suppliers for years.

In total, ENNI is allowed to pump up to eight million cubic meters of drinking water annually while the customer demand is at around seven million cubic meters.

Preparatory measures

In the course of maintenance of the water extraction plants, the operator ENNI planned the purely mechanical rehabilitation of its horizontal filter well for 2013. The contract was awarded to the long-established company Robert Plängsken GmbH, which in turn cooperates exclusively in North Rhine-Westfalia with Etschel Brunnenservice GmbH, a specialist company with decades of experience in the application of the **HPI-Process®** (High pressure impuls process) according to DVGW W 130.

The rehabilitation of the seven horizontal filter strings at the well “Vinn” in Moers (North Rhine-Westfalia) presented the team of both companies with new challenges. At the client's request, the assembly of material and technology in the drained well shaft was performed without the use of divers. This meant that each individual string could be analyzed separately for yield, condition and solids transport.

In addition, this method has the advantage that no dissolved solids settle in the conveying shaft during rehabilitation, thus reducing the cleaning and disinfection effort of the shaft.

Inventory of the horizontal filter well “Vinn”

The well shaft with a diameter of 2.80 m is a 'wet' well shaft with a depth of 19.05 m (60 ft.), in which the water collects and is pumped out with two pumps each installed on DN 200/8” risers. The horizontal screens were drilled at a depth of 13.1 m (40 ft.) with a diameter of 470 mm and equipped with DN 250/10” slotted bridge filter pipes. The aquifer consisted of sand and fine gravel. The casing section at the beginning of each string extends over 5 m (15 ft.). The filter sections per string have a length of up to 40 m (120 ft.). The water pumped out for the drinking water consumption is led to the nearby waterworks via the pumping system. During the project work, Mr. Kamradt, head of the ENNI department, as well as Mr. Heimberg, master well constructor of the company Plängsken GmbH and Mr. Dipl.-Ing. Schmidt, technical engineer of the Etschel Brunnenservice GmbH, were on site as contact persons for the executing companies. During the entire rehabilitation, the highest level of safety was applied in the water protection zone of the horizontal well “Vinn” in order to avoid pollution of the ground water. For this purpose, fleece mats were spread out below the entire technical equipment and an emergency container was kept available.

The well was commissioned in 1979 according to information provided by the operators. The seven star-shaped strings were extended to a length of 45 m/150 ft each. The inflow is controlled a filter section of 40 m (120 ft.).

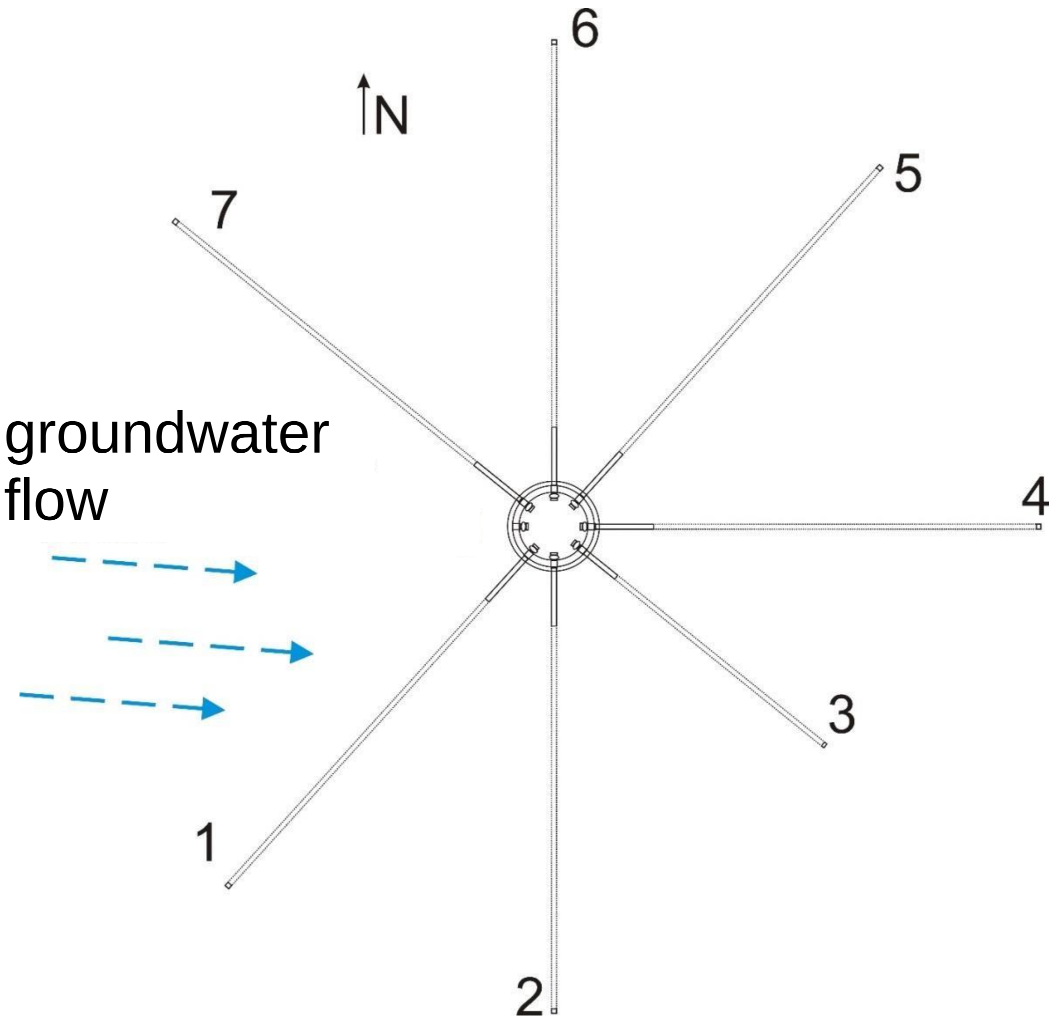
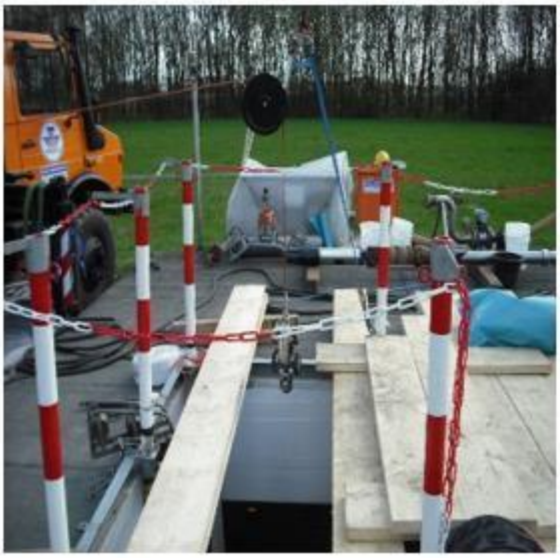


Figure 2: Schematic diagram of the construction of the horizontal filter well "Vinn" with indication of the groundwater flow direction.

When planning the well “Vinn”, the pumping capacity was designed for 800 m³ /h. In advance, the team of the Etschel Brunnenservice was informed that the well strings show no or little signs of ochre depositions, which is due to a low content of iron and manganese in the groundwater. The main reason for a decrease in yield and wear of material was attributed to a sand intrusion in the filter area.



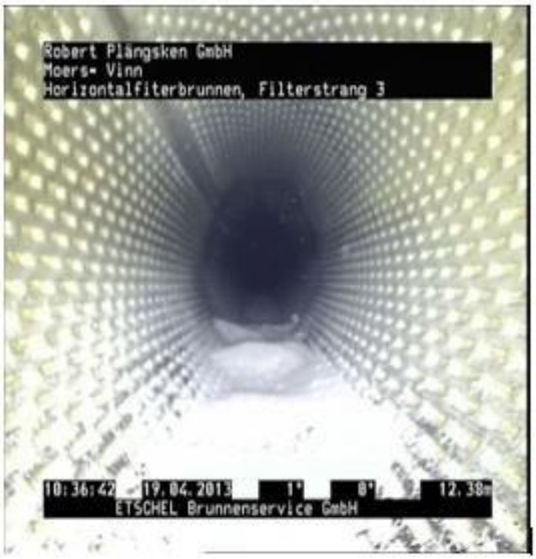


Figure 3: Retracting the horizontal TV Master Camera

TV before JET Master® rehabilitation shows silt and fine sand deposits on the screens and in the gravel pack

The well was developed conventionally during the new construction because of the technology available at that time. A deeply effective development in the sense of the **High Pressure Impulse-Process®** was never carried out. The operator attached importance to the application of a rehabilitation process that meets the requirements of the DVGW W 130 handbook: Separating - discharging - measuring at the same time completely fulfilled. The simultaneity of these steps is an extremely important requirement, since only then is it possible to immediately transport the separated particles out of the well and simultaneous and continuous control the progress and thus the definition of termination criteria.

Hydrogeological boundary conditions

The construction of a horizontal filter well has certain advantages. According to Houben and Treskatis (2012), the horizontal strings collect water from a hydro chemically homogeneous layer, so that the mixing of waters of different characteristics, one of the main processes that cause ochre formation, is less important. The sedimentation is also lower, so that the mixing-promoting vertical components in the flow process are lower. It should not be neglected, however, that with the very high flow rates, very large quantities of particles and dissolved substances flow through the well when the well development is not carried out deep enough. The strings were heavily to moderately sanded in the rear third of the filter section. According to the DVGW Regulations for Well Rehabilitation Worksheet W 130, sanding of water wells is attributed to the following causes:

- Incorrect grain gradation of the filter gravel pack to the existing rock, within multiple gravel packs or to gravel filters,
- a filter gravel pack that is too thin (annular space),
- faulty well construction (e.g. incorrect placement of the gravel pack),
- incorrect choice of material (filter tube construction, filter gravel),
- missing, insufficient or incorrect development of the newly constructed well,
- overloading of the well due to too high inflow velocities,
- flow rate too high when starting the pump,
- geological conditions in the layer structure,
- use of unsuitable rehabilitation methods.

First, the pumps were removed and the shaft was drained by Plängsken by removing the individual horizontal filter caps.

Figure 4: drained well shaft of a horizontal filter well

Preparation of the rehabilitation process

In preparation for the rehabilitation of the horizontal filter strings, Plängsken designed a pipeline which allowed the HPI equipment and the TV camera to be moved into the individual strings for inspection and carrying out the rehab process.

Figure 5: pipeline construction for installating and removing the rehabilitation equipment.

The simultaneous discharge of the dissolved solids during the application of the **HPI-Process®** was also ensured by this pipework. After reaching the finishing criteria, the piping system was moved to the next filter string.

In order to achieve the best possible results and to guarantee a continuously measurable and thus at any time controllable solids transport from the individual conveyor pipes, the Etschel **JET Master®** - technology of Etschel Brunnenservice GmbH was used, according to DVGW W130 and W 119 a **High Pressure Impulse-Process®** with high water pressure. A test run and the possibility of fine adjustment of the working pressure of the rehabilitation unit was of utmost importance for the client.

The direction of groundwater flow could be determined from the hydrogeological examination of the rest water levels of the individual strings. It could be observed that strings lying away from the flow direction showed less sand input. In contrast to this, an increased degree of ochre formation was documented on the strings facing the flow, in addition to the sand input. From the calculation of rest water level and groundwater lowering of the specific yield before, it was shown that strings 4 and 5, which point away from the groundwater flow, have the highest yields of up to 80 (m^3/h)/m. Strings 1, 6 and 7, facing away from the flow, were up to half as low.

Rehabilitation process

The rehabilitation process was carried out, after an obligatory camera inspection, by means of different high-pressure water nozzles. In order to transfer the effectiveness of the water pressure to the immediately adjacent filter gravel and the adjacent geology, the nozzle head is rotating and can thus mobilize undersized particles and precipitates in the grain structure by the force of the generated impulses of pressure waves. The underpressure generated by the high rotational speed caused the simultaneous suction of the dissolved solids into the horizontal string, from where they were pumped out simultaneously. The quantities of solids released in the process were clearly documented by measurements in Imhoff cones and in an overflow basin in accordance with the regulations.

During the rehabilitation process, other nozzle devices were also used, because of the penetration occurring mainly in the rear filter area. Due to the geological conditions and dimensioning of the gravel pack during the rehabilitation of the individual strings of the horizontal well “Vinn”, being technical sand free as a termination criteria was not aimed for. Thus, rehabilitation was carried out up to meeting said criteria for termination, i.e. the discharged solids could no longer be removed.

In the joint dialogue with the well operators of ENNI and Plängsken GmbH, reasons for the lack of proper well development during the insertion of the filter gravel or the failure of a complete well development may have been the reason for the fact that the strings tended to be more sand bound in some places. The main task was to activate the entire filter section and thus to relieve the drag forces in critical areas. Following the processing of each string, which took several hours, the condition after rehabilitation was documented using the latest submersible camera technology.

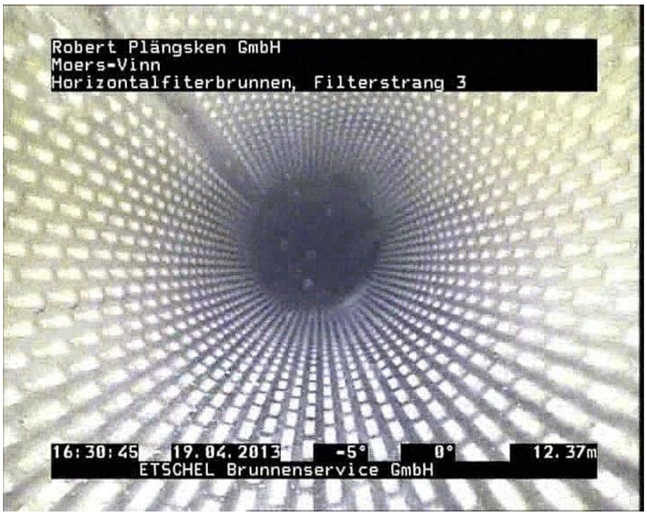


Figure 6:Cleaned string after JET Master® rehabilitation.

Rehabilitation documentation

During rehabilitation, samples were continuously taken and checked for solids content. On the basis of the values read and recorded by means of Imhoff cones, strong irregularities of the discharged particle quantity were found, but with a slightly decreasing tendency. It was exclusively a fine sand which could be declared as undersized sand within the gravel and silt from the aquifer. The proof that the use of the high pressure water nozzle with rotating head was able to cause a mobilization from the annular space and the existing geology was clear. Due to the positioning of the nozzle openings, the high pressure impulses can penetrate through the well screen and the gravel pack up to the borehole wall and even into the aquifer and generate impulses. The underpressure generated above and below each nozzle configuration while moving up and down within the filter screen transports the mobilized solids towards the well shaft. Through the pipeline construction, a submersible pump was used to pump out the loosened solids simultaneously. After a completed rehabilitation run, each string was analyzed for rehabilitation success by a final camera inspection. Although the pump for removing the dissolved solids with a delivery rate of 120 m³ /h was far beyond that of normal operation of each string, the rear area of the filter could be sufficiently activated. An essential proof of the optimization was the comparison of the operating water levels or the lowering before and after rehabilitation.

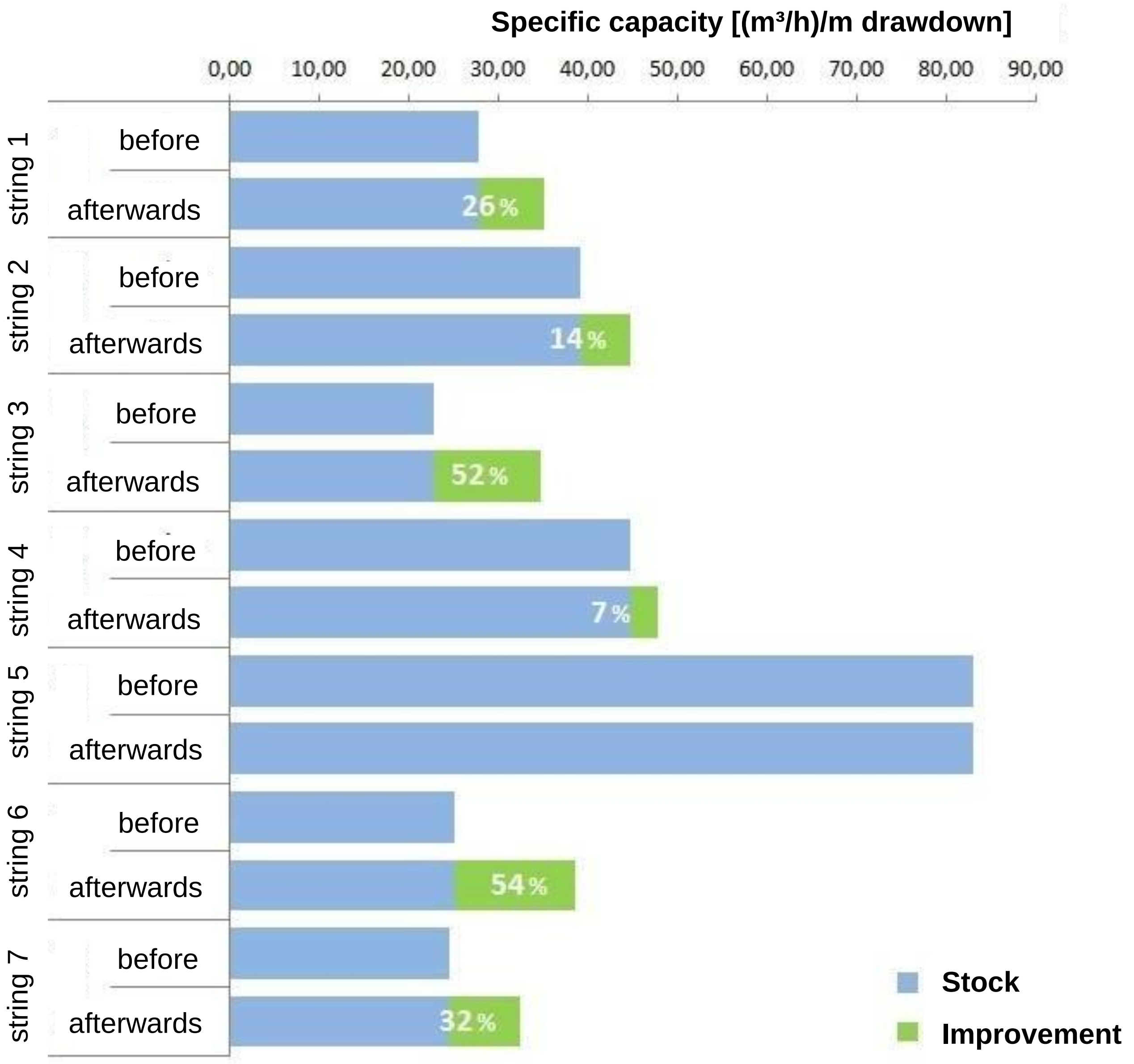


Figure 7: graphic representation of the specific yield before and after the JET Master® rehabilitation for each string

After rehabilitation using the Etschel **JET Master®** with the **UNINOZ®** rotary nozzle system, the performance of strings 1, 6 and 7 was increased by up to 50%. Strings that had a relatively high specific yield before rehabilitation could naturally only be optimized to a minor extent. After completion of the measure, the temporary installation parts were dismantled by the company Plängsken, the shaft disinfected and the operating pumps reinstalled. A final pumping test by the operator showed an increase of the Q spec. by 21% compared to the pumping test values before the rehabilitation.

Conclusion

With the execution and the result it could be shown that different parameters meet at horizontal filter wells. Finally, a professional statement about the well condition and the rehabilitation success can be made from the totality of the individual strings. It has also been shown that the use of the **HPI-Process®** with high water pressure, especially with the Etschel **JET Master®** technology, is very efficient in every respect for horizontal filter wells.

By treating the well with this technology, the entire job could be completed within 14 days, a particular advantage for the client as this minimized the shutdown downtime of the very productive well considerably. A large number of such horizontal filter wells date from the seventies of the last century. It can be deduced from this case of application that many of these wells could not be developed in the best possible way using the methods of well development available at that time. Even if there is not necessarily a need for rehabilitation due to ochre formation or decreasing performance of such well structures, a redevelopment of such wells can lead to considerable improvements in results.

Acknowledgement

The authors would like to thank ENNI Energie & Umwelt Niederrhein GmbH, in particular Mr. Kamradt, head of the water department, for the always goal-oriented and very cooperative cooperation and subsequent support in completing this publication.