HYDROPOWER | WATER MANAGEMENT | ENVIRONMENTAL PROTECTION | INLAND NAVIGATION | ENERGY RECOVERY

# ENERGETYKA WODNA

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## RACIBÓRZ DOLNY RESERVOIR CAN CATCH **A MILLENNIUM FLOOD WAVE**

Page 38

## RACIBÓRZ DOLNY RESERVOIR **– CHALLENGES FOR SUPPLIERS**

Page 20

## DAM REMOVAL IN THE BALTIC STATES: **MISSION (IM)POSSIBLE**

Page 48

## RESTORATION OF SURFACE WATERS **– AN INVESTMENT AND CHALLENGE FOR HYDROTECHNICS**

Page 62

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# FROM **EDITORIAL OFFICE**

Dear readers, this year we have to publish the international issue of "Energetyka Wodna" in the unprecedented circumstances. At a time when the whole World has been absorbed with the struggle against COVID-19, the whole hydropower sector has had to adapt to new, pandemic realities. Among others, the organizers of exhibitions and conferences have suffered as they were forced to cancel planned events or change their format into the online one.

This is the reason why our editorial team also had to make appropriate changes and decided that this year the international, English-language issue of "Energetyka Wodna" would be available in an online version only. Admittedly, there is no substitute for business meeting and face to face discussions or reading a traditional, printed magazine, however, we also see positive aspects of this. The fully electronic distribution let us increase the range of the magazine and overcome physical barriers of its distribution, allowing the access to "Energetyka Wodna" to a much larger group of readers.

The current issue fluctuates around the topic of the dry, flood protection reservoir Racibórz Dolny. In the publications, the specifics of this largest hydrotechnical investment which has been completed in Poland in recent years, will be presented, as well as the course of its development from the perspective of drive and control systems for spillway and bottom outlet gates providers. Dr Włodzimierz Bramowicz in his article highlights the problems of comparing the characteristics of the equipment on the basis of various ISO standards with the example of corrosion protection requirements for hydraulic cylinders working in sweet-water environment.

The second section concerns the topics of inconsistency of the Water Framework Directive regulations and the Climate Policy towards hydropower. The European Union on one hand recognizes hydropower as an important tool in fighting against climate change and on the other hand, with the WFD hinders its development within Europe.

Dirk Hendricks, Secretary General of EREF, expresses his opinion on this topic in the context of the activities the European Renewable Energies Federation carries out for hydropower sector. In turn, Amina Kadyrzhanova, a Junior Specialist for Sustainable Development from the International Hydropower Association, demonstrates the main tasks for hydropower in the global energy transformation and shows tools for developers which can be used to facilitate new investments implementation.

We also present the Water Framework Directive impact on hydropower and water management in certain EU Member States. With the example of Estonia and Lithuania, dr Egidijus Kasiulis from the Vytautas Magnus University in Kaunas describes the movement for the dams removal and Ilona Biedroń, Mateusz Grygoruk and Paweł Pawlaczyk from Multiconsult Poland present the programme of surface waters restoration in Poland.

This is an important document which may have an impact on the future of the SHP sector and perhaps on the entire hydropower and water management in our country. The issue of demolishing some of the damming structures and decision not to unclog watercourses might be considered as particularly controversial. This document is of a directional nature and its preparation results from the implementation of the WFD. Detailed activities will be included in the 2nd update of the RBMPs.

Finally, I want to thank all the authors, advertisers and partners, who have enabled the edition of another international issue of our magazine, with diversified subject matters and a broad range of distribution. Wishing you interesting reading, I encourage all our readers to actively take part in creating next issues of the magazine and thus engage in the global dialog for hydropower development.

Michał Kubecki
Editor in Chief

# ENERGETYKA WODNA

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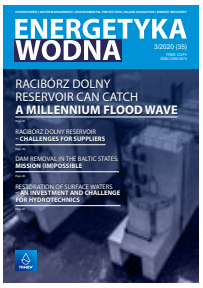


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# A NEW DRAFT OF ENERGY POLICY OF **POLAND UNTIL 2040**

**The Ministry of the Climate has presented a summary of the updates to the government's energy strategy called Energy Policy of Poland until 2040. The document retains the renewable energy goals set in its previous version presented a year ago.**

In the Energy Policy of Poland until 2040 (EPP2040) document published a year ago, the Ministry of Energy included a goal of increasing the share of green energy in Poland's energy mix up to 21% by 2030, along with a suggestion that reaching up to 23% may be possible as well – provided that more EU funding is granted.

If the goal of 23% share of renewable energy in the gross final energy consumption by 2030 were to be reached, 31.8% of net electricity would be produced by renewable energy sources. As far as the 2040 perspective is concerned, the goal established in the previous version of EPP2040 was to increase the share of RES in Poland's energy consumption to 28.5% (a level of 25.8% is expected in 2035). This includes increasing the share of renewable sources in the energy industry from the requested 22.1% by 2020 to 31.8% by 2030 and up to 39.7% by 2040.

The forecast in the last year's version of EPP2040 assumed increasing the installed capacity of photovoltaic power plants to 2285 MW by 2020, 4935 MW by 2025, 7270 MW by 2030 and 16062 MW by 2040. The total capacity of offshore wind farms was supposed to amount to 725 MW by 2025, 3815 MW by 2030, 5650 MW by 2035 and 7985 MW by 2040. On the other hand, onshore wind farm capacity in the 2020-2040 period was to remain at a level of about 9.5-9.7 GW.

Additionally, the last year's version of EPP2040 did not predict a significant increase in the installed capacity of hydroelectric power plants, which would maintain a capacity similar to the current one – 995 MW in 2020 and 1230 MW by 2040. The capacity of biomass power plants, as well as heat and power plants, was to increase from about 658 MW in 2020 to 1272 MW by 2040 while the capacity of biogas plants was to increase from 305 MW in 2020 to 1094 MW by 2040.

By 2040, the wind energy sector was to have the largest share in the national renewable energy mix (61.5%), compared to 59.9% in 2020), whereas the share of photovoltaic solutions was to increase to 16.5%, the share of biomass power plants was to decrease to 11.5% compared to 24.4% in 2020 while the share of biogas plants was to be 6.5% and hydroelectric power plants 3.5%. An additional 0.5%, i.e. as much as in 2020, would be provided by municipal waste used as a renewable energy source.

The previous edition of EPP2040 was prepared by officials from the Ministry of Energy headed by Krzysztof Tchórzewski. However, it is the Ministry of Climate headed by Michał Kurtyka that is preparing the latest version of EPP2040, the summary of which was presented yesterday.

The new version includes a target of at least 23% RES in the gross final energy consumption by 2030. Therefore, the possibility of increasing the target of 21% up to 23% if additional EU funding is provided is out of the question at this point. This includes reaching at least a 32% share of RES in electricity production by 2030. At the same time, heating and logistics are to reach a level of 28% and 14% of green energy use respectively. As such, the levels provided in the last year's EPP have been retained in the case of these sectors. The latest version of EPP2040 includes a goal of increasing the output of offshore wind farms to 5.9 GW, onshore wind power capacity to 8-10 GW and photovoltaic solutions to 5-7 GW by 2030.

The Ministry of Climate emphasizes that the implementation of offshore wind power and the establishment of Poland's first nuclear power plant will play a key role in forming the new electric energy system. They are supposed to become new, strategic industries for Poland. "This is an opportunity to help grow the national industry, develop specialised human resources competencies, create new jobs and generate added value for the national economy," said Michał Kurtyka, the Minister of Climate. Mr Kurtyka emphasizes that dispersed community-based electricity production supported by local capital will develop in parallel to the large-scale power engineering projects.

The new EPP2040 assumes that 300 areas of Poland will have reached energy sustainability by 2030 and that 1 million prosumers will contribute to energy production as well. As of today, there is about 260 thousand of them in Poland. Assuming the average power output of a prosumer photovoltaic installation at a level of 5.6 kW – the average power output of a domestic PV installation implemented as part of the "My Electricity" government programme – then given the figures provided by the Ministry of Climate, the total output can reach 5.6 GW.

Considering the Ministry's output forecast of 5-7 GW from photovoltaic solutions by 2030 and 5.6 GW from prosumer sources, 99% of which currently rely on this technology, the government's calculations leave little room for investment in such solutions as ground-based PV farms. The authors of the new EPP2040 assumed that by 2040 more than half of the installed sources will be zero-emission ones. The share of coal-powered energy sources in electricity production is expected to fall from the current level of about 70% to 37% by 2030 if the prices of $CO_2$ emission licences are high and 56% if they are low. Based on this, by 2040 the share of coal-powered energy sources is to decrease to 11% or 28% respectively.

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# SANTANDER BANK POLAND GETS POWER FROM **TAURON HYDROPOWER PLANTS**

**Santander Bank Poland has signed a green energy contract with TAURON. Thanks to this, 100% of the electricity used by Santander will be generated at TAURON's hydropower plants until 2021. The energy's source is guaranteed by a certificate issued by the Polish Association for Energy Certification (PTCE).**

The contract covers the sale of green energy to 538 power delivery points, i.e. branches and business support centres of Santander Bank Poland.

"More and more companies wish to have a choice when it comes to the sources of energy they use," said Wojciech Ignacok, CEO of TAURON Polska Energia. "I am glad that TAURON's Green Turn inspires our customers and our product offer responds to their needs by introducing specific and measurable ecological solutions," Mr Ignacok added.

EKO Premium is a service chosen by many of TAURON's business clients. The electricity offered as part of it comes mainly from TAURON Group's production facilities – 9 wind farms and 34 hydropower plants. TAURON purchased 5 wind farms with a total output of 180 MW in 2019.

Clients who choose EKO Premium not only gain certainty of receiving 100% of their electricity from RES (in commercial flow) but also the possibility of choosing the specific energy source they want. Santander Consumer Bank, part of the Santander Bank Poland Capital Group, has also decided to purchase energy produced at TAURON's hydropower plants.

"One of the cornerstones of Santander Bank Poland's responsible banking strategy is the so-called 'green finance.'" Not only do we wish to actively participate in the transformation of the Polish energy sector into a sustainable one by providing products and financial solutions that make it possible, but we also want to use environmentally friendly products ourselves. Reducing our carbon and environmental footprint is an important challenge for us. The decision to use green energy was a natural step towards achieving zero emissions. Therefore, from early 2020, we have been using only electricity produced wihout carbon dioxide emissions into the atmosphere," said Paweł Dziedzina, Director of the Work Environment Management Department at Santander Bank Poland.

TAURON's Green Turn Policy is aimed at both increasing the production capacity of green energy sources and offering clients a wide range of green products and services.

TAURON offers multiple ecological products and services for different client groups. They are available not only to the largest companies, but also the SME sector and individual clients.

Press Office
TAURON Polska Energia S.A.

# ENERGA OZE IMPLEMENTS **THE TETRA SYSTEM**

**TETRA – a modern digital communication system will be implemented in yet another Energa Group company to ensure reliable communication about the current business matters and emergencies related to energy security.**

Energa OZE will use this digital radio communication system on its premises in Włocławek, Żydów and Straszyn. Apart from digital voice communication, the service will also make it possible to record calls and transmit short text messages.

Energa OZE will be able to connect to fixed and mobile networks alike; connecting to such entities as Polskie Sieci Energetyczne and Energa Operator withing the TETRA network will be possible as well.

The service provider working for Energa OZE will be Enspirion, which offers a comprehensive dispatching service in the European TETRA standard based on the network infrastructure established by Energa Operator. Energa Operator chose TETRA because it is the most functionally advanced and technologically mature standard. Its implementation makes it possible to significantly improve power supply reliability for our clients (measured using SAIDI and SAIFI indicators). As of today, Enspirion is the only entity in Poland that provides commercial TETRA telecommunications services.

To support the communication needs of Energa OZE, the current range of the network will be expanded to include two additional base station locations: the Włocławek Hydropower Plant and the Żydów Pumped Storage Plant, both of which require reliable communication in crises and everyday work alike due to their significant impact on energy security.

Providing TETRA-standard critical connectivity for commercial applications is an example of the rational sharing of resources. The adopted business model is driven by economic considerations. It takes a large amount of money and a long time to build a communication network that meets the "Mission Critical" requirements. For smaller businesses, it is more profitable to use a proven system that is already available on the market.

Each subsequent entity that joins the TETRA network contributes to the improvement of both energy and public security, as well as the establishment of a nationwide critical communication network.

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# MODERNISED KACZORÓW RESERVOIR WITH **IMPROVED FLOOD PROTECTION**

**The renovation of the Kaczorów dry flood-control reservoir in the Lower Silesia region was completed in early July. The investment carried out by Polish Waters has improved the flood protection of towns located in the Kaczawa River valley. The works were wrapped up six months ahead of schedule.**

The contractor of the investment project carried out by Polish Waters, Wrocław Regional Water Management Board, was the ETP S.A. company from Katowice. The rehabilitation of the dry flood-control reservoir, capable of storing up to one million cubic metres of water, began in the second half of 2018 and was originally scheduled to last until the end of 2020. However, the works have already been completed and the renovated facility is ready for use.

During the modernisation works, the entire dam face was reinforced with concrete slabs and granite stone lining; additionally, a new spillway tower with a bottom plate and a new utility building on the dam crown were constructed. The works included the renovation of the dam's crown and replacement of the road surface, renovation of the footbridge and maintenance platforms for the servicing of the facility's machinery, renovation of stairs, slabs, lighting, drainage systems, the outlet tunnel of the tank's discharge facility and other elements of the structure.

The works also included changes to the Kaczawa riverbed on a 150-metre-long section upstream of the dam and another section of such length between the dam and a bridge downstream of it, as well as the renovation of cut-off ditches and piezometers, the creation of a control and measurement network and land development on the investment project's premises. The cost of the works was about 15 million zlotys. The works have also made the facility much safer for visitors as new fall protection systems have been added and the existing ones renovated.

The Kaczorów dry reservoir was built between 1929-1930 in a narrowed section

*Source: ETP S.A.*

of the Kaczawa River valley. The reservoir earthfill frontal dam is a nearly 175-metre-long trapezoidal structure with a crown width of about 4 metres. At its highest point, the facility is almost 15 metres high. In case of flooding, the reservoir can accumulate up to one million cubic metres of water while its total flood surface can reach more than 23 hectares.

Wrocław Regional Water Management Board
Social Communication and Water Education Team

# HOW TO PROVIDE THE FLOW CAPACITY OF THE VISTULA **ESTUARY? AN IMPORTANT DOCUMENT EMERGED**

**The technical documentation called "Estuary of the Vistula River – Modelling – 2019-2020" is ready. It has been prepared by the Department of Shore Mechanics and Engineering of the Institute of Hydroengineering of Polish Academy of Sciences. The works took a whole year. The model tests were related to ensuring the patency of the Vistula estuary (the Vistula Ditch) and its foreground in the waters of the Gulf of Gdańsk.**

In 2015 the reconstruction of the Vistula estuary was completed and model studies allowed assessing the effects of that investment and determining the possibilities of further works. They were carried out in the area of the Vistula Ditch and on the embankment cone forming in the waters of the Gulf of Gdańsk. According to the Gdańsk branch of the Polish Waters, mathematical models were constructed for various variants of activities within the Vistula estuary, in order to effectively maintain the expected depth of the mouth within a decade-long perspective. The reconstruction of the Vistula estuary, completed five years ago, was aimed at preventing the formation of congested floods: among other things, the western (550 m long) and eastern (600 m long; it was also extended by 200 m) steering wheels were rebuilt. Concrete segments filled with stones and sand (up to 6 m below the water level) were used for reconstruction, their size resembling small detached houses. The steering wheels, hence the name, direct the river current, and with it the material carried, further into the sea. Thanks to these buildings icebreakers can work in winter (the kraut flows freely).

As it was announced last year, when the contract to develop this documentation was signed, each year the Vistula carries from 0.4 to 1.5 million cubic meters of sediment, of which about 0.3 million cubic meters increases the embankment cone, which limits the flow capacity of the outlet. Now, after the completion of the study, it has been written that the elongation of the existing estuary, dredging works and the construction of a inspection chamber base unit were taken into account. In addition, the final report indicates solutions for planning new investments in the area of the Vistula estuary. It contains a qualitative and quantitative comparative analysis of the modelling results obtained for individual variants of technical activities in relation to the current situation.

The cost of conducting model tests is almost PLN 0.32 million.

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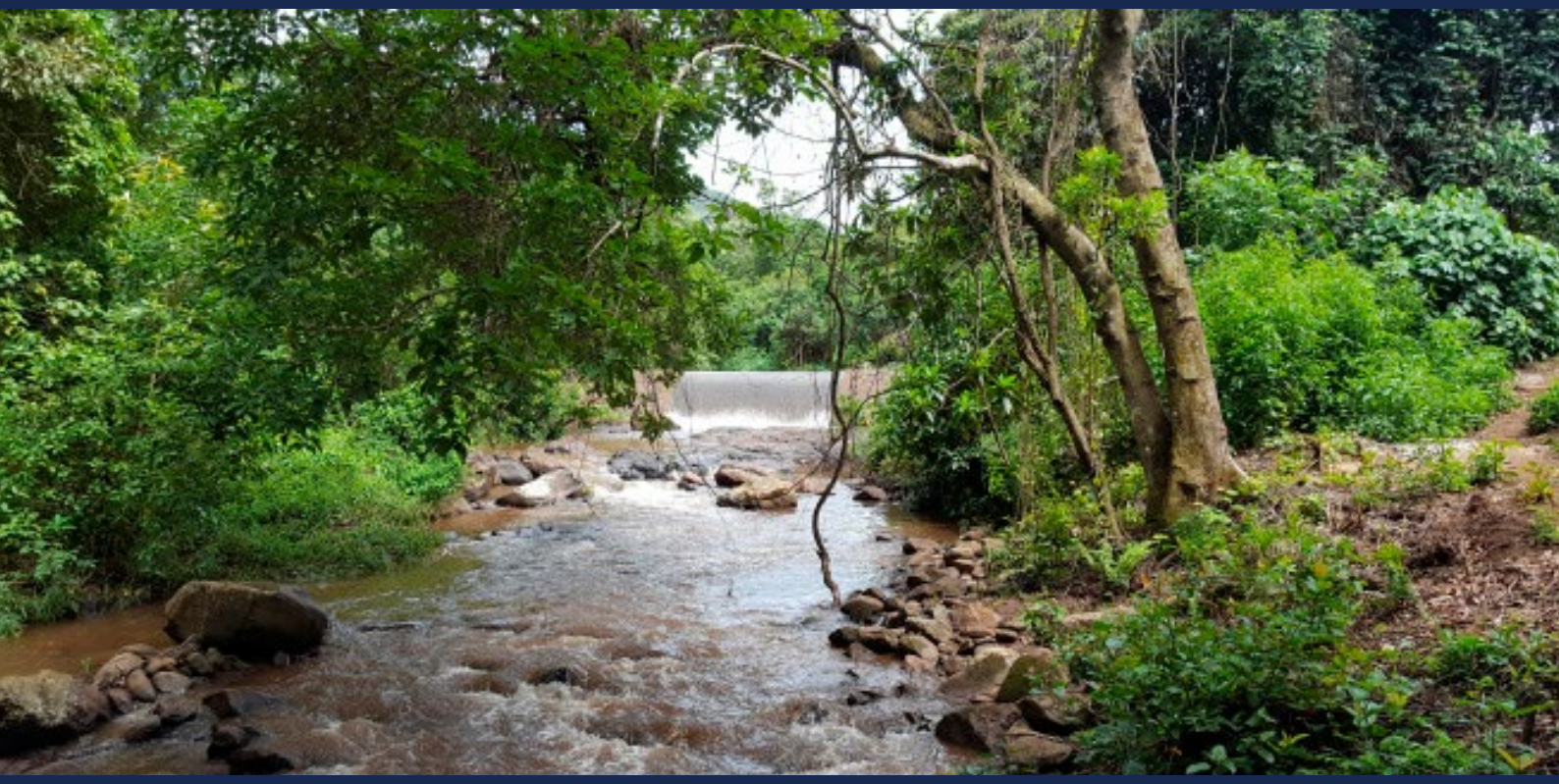

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# POLISH WATERS HAVE RECEIVED FUNDING FOR **DEVELOPMENT OF THE ODER WATERWAY**

**The State Water Holding Polish Waters has signed agreements for the co-financing of the modernisation of water locks and control rooms at the Krapkowice and Januszkowice water barrages, as well as the construction of a flap weir at the Ujście Nysy water barrage. The modernisation works will last from September 2020 to July 2023.**

As part of the project, multiple activities will be carried out within the next three years to improve the functioning of the three facilities. Importantly, the modernisation efforts will make the barrages more environmentally friendly as fish passes for migratory fish and other improvements will be added. The total value of the investment project exceeds half a billion złotys, with PLN 470 million being provided as part of EU funding.

*Source: State Water Holding Polish Waters*

"All investment projects being carried out with Polish Waters are an expression of a comprehensive outlook on tasks that not only improve shipping but also counteract the effects of drought," said Anna Moskwa from the Ministry of Marine Economy and Inland Navigation. Waterway modernisation works can help improve water balance by increasing river retention and thus also counteracting drought. "The investment projects underway prove that a huge leap in the quality of the Oder's transport infrastructure is upon us," Anna Moskwa added. Additionally, Ms Moskwa – Deputy Minister of Maritime Economy and Inland Navigation – expressed her gratitude for the quick and efficient preparation of all required documentation and meeting the procedural criteria, which made it possible to rapidly commence the works.

"Today's initiatives are not only river transport and safety improvement projects but also ones that improve river infrastructure and waterway conditions," said Małgorzata Jarosińska-Jedynak from the Ministry of Development Funds and Regional Policy. Krzysztof Woś – Vice President of Polish Waters for Flood and Drought Protection – also emphasized the comprehensive nature of the activities undertaken by Polish Waters regarding the projects implemented. "Polish Waters uses a comprehensive approach to waterways, taking action to improve sections that are vital to navigation conditions as soon as possible – something that is equally significant for waterways of international importance," Mr Woś said. "The financing obtained will allow Polish Waters to implement further investment projects to improve navigation conditions on the Oder Waterway," he added.

The control room and utility facilities at the Januszkowice water barrage will be refurbished. Moreover, the lower separator dam will be rebuilt, and the right riverbank will be altered. The outer ports will be modernised as well. Besides, ship berths and manoeuvring areas will be created. Most importantly, however, it is planned that a 190/12 m water lock chamber with intermediate mitre gates will be constructed and the existing 187/9.6 m barge lock will be altered. The scope of the project will make it possible to ensure continuity of inland navigation on the Oder Waterway even in case of a potential failure of one of the locks. Similar works are to be conducted at the water lock and control room of the Krapkowice water barrage.

On the other hand, the Ujście Nysy facility will be equipped with a hydraulic flap weir and automatic control system, which will replace the old trestle-needle weir. Nonetheless, a historic fish pass will be preserved during the trestle-needle weir's demolition. A new fish pass for migratory fish will be set up as well. The project also includes the construction of a footbridge and the reconstruction of the buildings near the barrage, the separator dam, the banks of the Oder River near the weir, as well as the downstream aprons, access roads and power and telecommunication facilities.

"In an era of progressing climate change, it is necessary to undertake intensive efforts to counteract drought and minimise the effects of flooding; investing in the development of inland waterways and maintaining the full efficiency of the existing inland transport facilities is equally important. Thanks to the implementation of three projects for which we have received funding today, i.e. the modernisation of locks and control rooms at the Krapkowice and Januszkowice water barrages, as well as the construction of a flap weir at the Ujście Nysy water barrage, navigation on the Oder will be more effective and safer for both the users and the maintenance personnel, whereas the waterway's administrator – the Polish Waters Gliwice Regional Water Management Board – will gain confidence in the efficiency and reliability of its infrastructure. EU funding will make it possible to utilise the section of the Oder Waterway managed by the Polish Waters Gliwice to its fullest extent, with utmost care being paid to the protection of the natural environment at the same time," said Marcin Jarzyński, Deputy Director for Flood and Drought Protection at Polish Waters Gliwice, when signing the agreements.

Press Office
State Water Holding Polish Waters

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# FUNDS FROM THE WORLD BANK FOR BUILDING **KĄTY-MYSCOWA RESERVOIR**

**In 2019, State Water Holding Polish Waters initiated works concerning creation of pre-project documentation for the Kąty-Myscowa Reservoir. Until present, developed projects include, among others: a hydraulic system, i.e. the predicted layout of individual buildings and the direction of the water flow. The works concerning wildlife inventory covering the full one-year growing period of fauna and flora is almost complete.**

Parallel to the activities related to the regulation concerning environment and modelling works, the Regional Water Management Board in Rzeszów, in 2019, commissioned two further studies: urban concept and resettlement concept, which aim was to select the optimal way of purchasing the land intended for the reservoir basin. This documentation made it possible to identify potential resettlement sites in the areas owned by the State Treasury.

In 2020 State Water Holding Polish Waters - Regional Water Management Board in Rzeszów, based on the aforementioned documents, prepared a work schedule until 2027 concerning the development of design documentation and construction works. The proposal was presented to the World Bank. The proposed solutions and the positive assessment of the progress of the works performed thus far have been accepted by the World Bank, which approved the inclusion of this task in the Odra-Vistula Flood Management Project. The confirmation of this decision is published on the website of the World Bank, the so-called "Procurement Plan", according to which (pp. 5-6 contracts from 5.8.1 to 5.8.7) allocation of funds for this project amounts to USD 10.738 million, i.e. over PLN 34 million.

The funds granted by the World Bank will allow commissioning further necessary studies, including, among others, the updated version of technical solutions concept, projects of local spatial development plans with the study of land use conditions and directions, the archaeological surface survey including determining the necessary scope of archaeological research, execution of Land Acquisition and Resettlement Action Plan, required by the World Bank policies, and finally, development of construction and working design, which will be the basis for applying for a permit for implementing the investment project.

The main aim of building the Kąty-Myscowa Reservoir is to counteract the effect of drought in 20 communes located in the valley of Wisłoka River. The result of the functioning of the reservoir should be the possibility of securing the guaranteed flows in the Wisłoka River for the period of 6 months. This will be of strategic importance when tackling the effects of drought taking into consideration the recurring water shortages. The flood management function of the reservoir is also crucial. After the reservoir is constructed, the flood flow in the dam section will be reduced 4 times. In cooperation with the accompanying investments projects already implemented, the construction of the Kąty-Myscowa Reservoir will allow to maximally reduce the flood risk in the Wisłoka River catchment area. In the case of the city of Jasło, the flood risk will be eliminated almost completely. The reduction of floodplain areas will also be noticeable in Dębica and Mielec.

Press Office
State Water Holding Polish Waters

# SIGNING THE CONTRACT FOR THE CONSTRUCTION **OF STORM GATES ON THE TUGA RIVER**

**State Water Holding Polish Waters signed an agreement for the construction of storm gates on the Tuga River. The contractor is B&W Usługi Ogólnobudowlane from Pruszcz Gdański. The value of the agreement is PLN 33 million. The construction is planned to be completed by the end of May 2022.**

"I am delighted that we are finalising the next phase of efforts made by Polish Waters to protect Nowy Dwór Gdański against floods. The construction of storm gates on the Tuga River is one of the most important investment projects financed from EU funds and implemented by the Regional Water Management Board in Gdańsk," said Director Aleksandra Bodnar after signing the agreement. The main objective of the investment project is to protect the town of Nowy Dwór Gdański and areas between the town and the storm gates against floods caused by storm surges coming from the Vistula Lagoon.

The storm gates in question will be a three-span structure, with two 6.5 m wide spans and one 3.0 m wide span. Under normal conditions, the storm gates will be open and the Tuga River water will flow through the gates. The gate mechanisms will control the gates both manually and automatically. When the storm gates are closed, causing the Tuga River section flowing to the Szkarpawa River to be closed as well, the plan is to direct the excess of water of the natural Tuga River flow to the Pryżnik canal through a transfer structure and further to the Chłodniewo pumping station through the Linawa Riverbed. To do so, a transfer structure (side spillway) has been designed on the left bank of the Tuga River.

The construction of storm gates on the Tuga River is one of the items of the project entitled "Comprehensive Flood Protection of Żuławy – Phase II – Regional Water Management Board in Gdańsk". The investment project is cofinanced (in 85%) by the European Union from the Cohesion Fund as part of the Operational Programme Infrastructure and Environment for 2014-2020. The total value of the project is PLN 130 million.

Press Office
State Water Holding Polish Waters

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# MODERNISATION WORKS AT THE ZEMBORZYCKI RESERVOIR IN LUBLIN HAVE COMMENCED

**The State Water Holding Polish Waters has signed a contract to perform a comprehensive modernisation of the Zemborzycki Reservoir in Lublin. The scope of the works includes the refurbishment of the frontal dam, including the construction of a fish pass. Desilting the reservoir is also necessary. Additionally, the plans include building a fore-reservoir, a pumping station and an Operations and Education Centre. The total cost of the reservoir's modernisation amounts to PLN 3.5 mln. The project documentation preparation and environmental approval stage is scheduled to be completed by the end of 2021.**

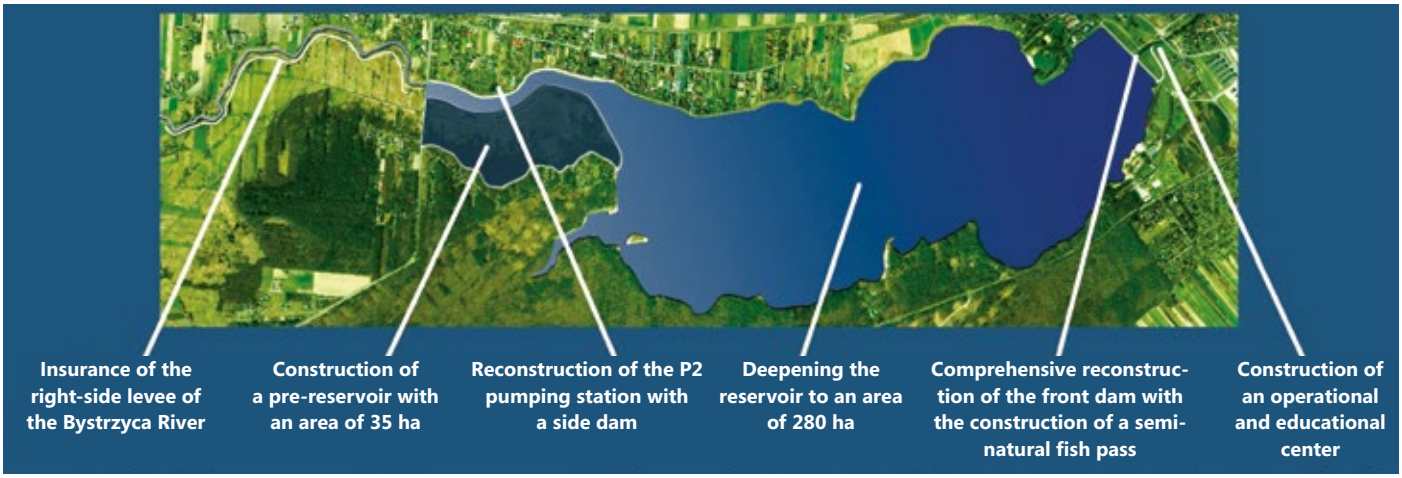
The renovation works are to start in early 2022 and are expected to last between 3 and 4 years, depending on the modernisation variant selected – the reservoir desilting method will be determined based on environmental aspects. The cost of revitalising the Zemborzycki Reservoir is estimated to be between 200 and 500 million złotys. The details of the project were presented by Przemysław Daca, President of Polish Waters, during a press briefing. The following guests participated in the meeting: Lech Sprawka – Voivode of the Lubelskie Voivodeship – Sebastian Trojak – Member of the Lubelskie Voivodeship Executive Board – as well as Blanka Rdest-Dudak – Deputy Director of the Environmental Protection Department of the Lublin City Hall – and Tomasz Pitucha and Piotr Popiel – Councillors of the Lublin City Council.

"The most important thing is to take all functions of the Zemborzycki Reservoir into consideration, i.e. its flood and drought protection, as well as recreational and natural functions," said Przemysław Daca. The reservoir revitalisation process includes all of that," he added. Polish Waters has been managing the Zemborzycki Reservoir since January 2018. Although the place has a high tourism and recreation value, neither residents nor tourists can take full advantage of it due to pollution. A team of experts from the Lublin scientific community investigated the cause of its deteriorating ecological state. It turned out that the main issue is the fact that the Bystrzyca River basin is being used for agricultural purposes, and as such, large amounts of phosphorus and nitrogen flow into the river and, consequently, the reservoir. In addition, there is approx. 6 mln m³ tonnes of peat and mud at the reservoir's bottom, which fosters the development of cyanobacteria. After hearing the opinion of experts and conducting public consultations, the management of Polish Waters has stated that it is necessary to clean and revitalise the Zemborzycki Reservoir. Works on the "Revitalisation and reconstruction of the Zemborzycki Reservoir" project have begun in mid-April 2019. Due to the wide range of the planned activities, Polish Waters had to announce and finalise several tenders. The first one, alloted at the end of April, was won by WTU Kraków. WTU Kraków is to prepare project documentation concerning such works as the reconstruction of the reservoir's frontal dam and the reconstruction of the left and right levees of the Bystrzyca River. Preparing the documentation and obtaining the building permit is expected by mid-December 2021. At the end of July of the current year, the winner of the second tender was selected. It concerned two investment project: deepening the reservoir basin on the area of 280 ha and construction of the Operation and Education Centre of State Water Holding Polish Waters "Lublin – Zemborzyce". The design documentation concerning deepening the reservoir basin will be prepared by Haskoning DHV Polska. When concerning cleaning the Zemborzycki Reservoir, State Water Holding Polish Waters consider two concepts: cleaning the bottom from sediment or both sediment and peat (then it should be decided what to do with peat). Both versions assume that an additional reservoir, which will collect the pollutants flowing into the basin, needs to be built in front of the main reservoir. It is not yet known which of the aforementioned concepts will be implemented. The State Water Holding Polish Waters authorities make the final decision dependent on the opinion of the Regional Director of Environmental Protection.

The tender for the design documentation of the Operation and Education Centre of State Water Holding Polish Waters "Lublin – Zemborzyce" was won by BIM Process Kraków. It is going to be a two-storey building of approx. 1,200 m². Preparing the documentation and obtaining the building permit is to be expected in mid-December 2021.

Press Office
State Water Holding Polish Waters

Fig. Implementation of the project "Revitalisation and reconstruction of the Zemborzycki Reservoir"




*Source: State Water Holding Polish Waters*

# COUNTRYSIDE WATER RETENTION PROGRAMME – **PLN 50 MLN FOR LOCAL GOVERNMENTS**

**Starting from 22 July, local government units can request funding for the improvement of water retention in rural areas. A total of PLN 50 million in subsidies was allocated for this purpose. Local governments can request subsidies reaching up to 70% of the eligible expenditure. Subsidies can be obtained until 17 December of next year or until the funding is exhausted.**

The subsidies are provided as part of the "Adaptation to climate change and limiting the effects of environmental threats" programme run by the National Fund for Environmental Protection and Water Management (NFEP&WM), which also assumes the financing of local government activities in the field of small-scale water retention in rural areas, including the construction of gates and small retention tanks. There are no financial limits for a single subsidy application, which ensures that both small and large investment projects can receive funding.

The recently announced rural retention funding programme is part of NFEP&WM's activities aimed at mitigating the effects of drought in Poland, as well as other improvements. The "Adaptation to climate change and limiting the effects of environmental threats" (financing rural retention) programme is one of 26 such programmes included in the so-called green investments package, which are addressed to various beneficiaries and amount to a total of nearly PLN 7.8 billion.

Press Office
State Water Holding Polish Waters

# FLOOD CONTROL RESERVOIRS FOR HALF A BILLION TO BE BUILT IN LOWER SILESIA

**The construction of four dry flood control reservoirs to reduce flood risk in the Kłodzko Valley will cost over half a billion PLN. The facilities in Krosnowice, Szalejów Górny, Roztoki Bystrzyckie, and Boboszów have been built for approx. two years now.**

The capacity of the reservoir in Krosnowice, built on the Duna Dolna mountain stream, will be 1.9 million m³, while the reservoir area at maximum water storage level will be 44 ha. The capacity of the reservoir on the Goworówka stream in Roztoki will be 2.7 million m³ (the dam will close the catchment with an area of 34.55 km²). The capacity of the reservoir built in Boboszów on the mountain section of the Nysa Kłodzka River will be 1.4 million m³ (the dam will close the catchment with an area of 18.03 km²) and will be slightly larger than the capacity of the Międzygórze Reservoir (1 million m³). The maximum capacity of the Szalejów Reservoir, located on the Bystrzyca Dusznicka mountain river, will be 9.9 million m³, while the reservoir area at maximum water storage level will be 118.7 ha.

The construction of the Krosnowice Reservoir will cost PLN 82 million. The agreement with the contractor was signed in April 2018, while the construction site was handed over at the end of August 2018. The site has already been prepared for the construction of the reservoir, the humus layer has been removed, and the riverbed has been moved. Currently, access roads in the reservoir basin are being built as well as excavation for the dam foundation and a working platform for the pile driver are being made. In addition, the construction of an anti-filtration barrier using the VDW technology has begun.

The cost of building the Roztoki Reservoir is PLN 175 million: the agreement was signed in December 2017, and the works began in February 2018. The current works include the formation of the dam body, while other works cover reinforced concrete works on the outlet structure, adjustments to the inflow channel, and the construction of an administrative building. The reconstruction of the district road and the construction of a watertight foundation barrier have already been completed.

The works related to the construction of the Boboszów Reservoir started in January 2018 (the agreement was initialled in December 2017) and will cost PLN 122 million. Excavations have already been made and related foundation works regarding piling (with the use of CFA) have been completed.

Currently, the reinforced concrete structure of the main spillway is being built; piling works for outlet structures are being carried out, and the first phase of the construction of a watertight barrier using low-pressure injection is being implemented.

Łukasz Madej
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## CALENDAR

| | | |
|---|---|---|
| **26-28.10.2020**<br>Online event | **International Trade Fair and Conference HYDRO 2020**<br>*Organizer – The International Journal on Hydropower & Dams* | www.hydropower-dams.com |
| **9-12.11.2020**<br>Online event | **Power Week Asia**<br>*Organizer – Infocus International* | www.power-week.com |
| **16-19.11.2020**<br>Online event | **Power Week Africa**<br>*Organizer – Infocus International* | www.power-week.com |
| **26.11.2020**<br>Salzburg, Austria | **RENEXPO INTERHYDRO Conference 2020**<br>*Organizer – Messezentrum Salzburg* | www.renexpo-interhydro.eu |
| **10.12.2020**<br>Gdańsk, Poland | **Polish Hydropower Conference HYDROFORUM 2020**<br>*Organizer – Polish Hydropower Association* | www.tew.pl |
| **15.12.2020**<br>Lublin, Poland | **XI Lublin Energy Fairs ENERGETICS**<br>*Organizer – Targi Lublin S.A.* | www.energetics.targi.lublin.pl |
| **15-18.02.2021**<br>Warsaw, Poland | **6th IAHR Europe Congress**<br>*Organizer – The International Association for Hydro-Environment Engineering and Research (IAHR)* | www.iahr2020.pl |
| **24-25.02.2021**<br>Kielce, Poland | **19th Fair of Renewable Sources of Energy ENEX New Energy and 22nd Environmental Protection and Waste Management Expo EKOTECH**<br>*Organizer – Targi Kielce S.A* | www.targikielce.pl |

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**Reidar Vestby,**
COO Enfini

"Our vision is ENFINI to be the world leader in supplying solutions to production of electricity from water in motion related to mobile micro- and small scale power plants. Due to their small size and light weight, our hydropower plants can be installed in locations where other solutions are unfeasible. Key differentiators are the power hub and plug-and-play capability of our plants. The plants are competitively priced and are built from high-quality components, requiring minimal maintenance over the course of a 15-year life expectancy. Our plants require minimal maintenance, are local, stable, sustainable and environmentally friendly"

Under the EEA&Norway grants, ENFINI can be the ideal bilateral partner when it comes to the development of project-focused innovative solution of mobile hydropower plants for off-grid areas. This power hub and plug-and-play capability of the hydropower plants are different from other solutions on the market with their cost-effectiveness, longer-term life expectancy and easy-to-install in various locations.

Astrid Green
**CEO**

Reidar Vestby
**COO**

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# FINANCIAL CHALLENGES OF MAINTAINING **SHP PLANTS**

**In Poland in October 2020 the support period has expired for around 400 small hydropower plants. The article describes the financial challenges these plants are facing and suggests some solutions to maintain the operation of these plants.**

Hydropower is often presented as an example of a low-cost source of electricity. According to IRENA's report on Renewable Power Generation Costs in 2019 the global weighted-average LCOE of hydropower was only USD 0.047/kWh and a vast majority of the capacity commissioned had costs lower than the cheapest new source of fossil fuel-fired electricity. However, it is worth noting that the costs of electricity generation in hydropower plants are highly dependent on numerous factors, including site location and conditions, plant's capacity and region of project development. According to the same IRENA's report, the weighted average country/regional LCOE of all hydropower projects, large and small range from a low of USD 0.038/kWh in Brazil to a high of USD 0.13/kWh in North America. In terms of the differences between small and large hydropower plants it is estimated that the LCOE of small hydro plants is usually higher than the LCOE of large hydro plants by 10%-40%.

## POLAND – VERY SMALL HYDROPOWER PLANTS WITH MANY OBLIGATIONS

Poland is the country where the majority of hydropower plants come into the category of small and micro hydro. In 2019, Poland had 766 hydropower plants, out of which 684 were up to 1 MW. Many of them are low head. Therefore, many factors set the Polish hydropower plants among the projects with highest LCOE.

Moreover, hydropower projects in Poland are obliged to provide additional services connected with water regulation and maintenance of State owned water facilities, channels and riverbeds as well as continuously adapt throughout the whole lifespan of the installation to more and more rigorous environmental requirements, such as building fish passes and fish barriers, increasing residual flow, etc. The situation is additionally exacerbated by the adoption of water pricing for hydropower since 2018 and the increase in fees paid for using damming structures and lands covered with water which are owned by the State. According to the Polish Hydropower Association's analysis an average cost of burdens connected only with water use and environmental protection imposed on Polish small hydropower plants with a capacity below 1 MW amounts to USD 0.042/kWh.

## POLISH SUPPORT SCHEMES FOR SMALL HYDRO

Since 2005 support schemes for RES in Poland have been based on green certificates (GC) and the period of support was established for 15 years for all renewable energy technologies regardless of depreciation time of the investment and the cost of electricity generation of each technology. Furthermore, since mid-2012, the GC system has been destabilized causing their value to decrease by 85 percent between 2012 and 2017. In 2018 FIT and FIP systems were adopted for small hydro plants below 1 MW both for new and existing projects which prevented many of them from bankruptcy.

## EXPIRY OF THE SUPPORT PERIOD FOR 400 SHPP PLANTS

Regrettably, as mentioned above, the total period of support is limited to 15 years and includes the time of support within the GC system. Due to the fact that the GC scheme was adopted in 2005, all plants which fell within it since that year have lost the right to FIT/FIP this year and the number of such installations amounts to 400.

The market wholesale electricity price, which was around USD 0,057/kWh in the last two years is not sufficient to cover the costs of power generation in the Polish small hydro plants, as these costs, according to the sector's analysis amounts to USD 0,137/kWh in case of plants with an installed capacity below 500 kW and USD 0,099/kWh in case of those up to 1 MW.

## DECOMMISSIONING OF EXISTING SHPPS?

The above numbers indicate that there is a risk of decommissioning of existing plants. This would lead to undesirable effects, including: reduction of distributed electricity sources, closure of small and micro enterprises and reduction of workplaces and State Treasury revenues. But first of all it would result in the reduction of renewable, zero-emission electricity generation in the Polish energy mix. This fact deserves even greater attention since Poland is one of the three EU Member States at severe risk of failing the 2020 RES target achievement. And what's equally important removal of small hydro plants would also lead to the reduction of water retention sites which is also very unwanted since Poland is among the countries with very low average water availability, very low rate of water reservoirs capacity and increasing draft problems

## CONCLUSIONS AND SOLUTIONS

As a conclusion it is worth to underline that although generally very low, electricity generation costs in hydropower plants may be still quite high depending on many factors. However, the plants with high LCOEs, may still be desired due to functions they fulfill (e.g. counteracting the effects of drafts, water management and grid services, maintenance of water facilities or even conservation of cultural heritage sites or creating places for recreation).

Therefore, the Polish small hydropower sector requests remedial measures to be implemented to the Polish law, including extension of the support period for small and micro hydro plants in order to adjust the support period to the depreciation time and generation costs of small hydro. Besides, other mechanisms are needed to maintain the small hydro installations after the support period. And they could include subsidies for existing plants' adaptation to environmental requirements, regulations on refurbishment for worked out hydropower installations and deregulation of direct sale of electricity from a plant to a final consumer or discounts on distribution fees in case of electricity sale to local consumers. Furthermore, the small hydropower sector in Poland highlights the need of some kind of operational, post-support period scheme for small hydro plants within the whole lifetime of the plant operation.

Ewa Malicka
President of the Polish Association
for Small Hydropower Development (TRMEW)

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# FROM THE WORLD

## 23.06.2020 STATKRAFT STARTS OPERATIONS **AT MOGLICË HYDRO PLANT, ALBANIA**

Commercial operations have started at the Moglicë hydropower plant in Albania, Statkraft has announced, with the project delivering power to the country's grid.

The power plant was officially opened on the 22th of June, with a site visit by Albanian Prime Minister Edi Rama and Minister of Infrastructure and Energy, Belinda Balluku.

Located on the Devoll River in the south-eastern part of Albania, Moglicë hydropower plant comprises a 167 m high asphalt-core rock-filled dam, a 10.7 km long headrace tunnel, an underground powerhouse with two main generators of 91.5 MW each and a 1 MW eco-flow unit at the foot of the dam.

Moglicë is the largest of the two hydropower plants in the Devoll hydropower project and will generate approximately 450 GWh per year.

International Water Power & Dam Construction

## 7.07.2020 MAJOR REFURBISHMENT OF HISTORIC **UK HYDRO STATION COMPLETE**

A 1.1m refurbishment of the historic Stonebyres hydroelectric power station on the banks of the River Clyde, near Lanark has been completed by energy company Drax Group ahead of the project's 100th anniversary.

The refurbishment of the Stonebyres power station – which is part of the Lanark Hydro scheme – was a complex task due to it being a category A listed building, the highest possible grading, as a result of it being designated as a site of national architectural importance. As part of the project, every original pane of glass and window frame in the building was painstakingly replaced using stronger, modern materials, but which retain the station's original design. The power station's exterior received a new concrete coating as well as a coat of mineral-based paint to protect the integrity of the building for decades to come. "Since the refurbishment, the station looks almost brand new – you would be forgiven for not realising it has been generating electricity for the area since 1927," added Ian Kinnaird, Drax's Head of Hydro. "Scotland has a long and proud history of hydroelectricity, and with this project Drax is ensuring these power stations play an important part in securing a net zero carbon future for our country."

Drax acquired the Lanark hydro scheme alongside the Galloway hydro scheme and the Cruachan pumped-hydro storage facility in Argyll in January 2019, helping to make the company a leading provider of flexible, low carbon and renewable power generation. The Lanark hydro scheme, which comprises both Stonebyres and Bonnington power stations, was the first large-scale hydroelectric scheme in Britain when it was completed in 1927 – producing enough electricity for around 17,000 homes.

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## 24.08.2020 USBR SAYS DAMS DEMONSTRATE VALUE OF HYDROPOWER **DURING RECENT WESTERN US HEATWAVE**

The US Bureau of Reclamation in the second half of August responded to unusually high energy demands across the western United States, with the situation demonstrating hydropower's integral role as a renewable, reliable, abundant, carbon-free source of electricity, it said in a statement.

Actions initiated by the USBR include:

- Glen Canyon, Morrow Point, Hoover, Davis and Parker dams ramping up power production in response to California's electrical emergency and to help stabilize the western electrical grid.
- Central Valley Project maximizing generation and reserves to make more energy available during peaks as well as shifting pumping operations to off-peak periods to reduce system load.
- Pacific Northwest federal dams generating enough electricity to meet load requirements for the Columbia River Basin and selling surplus power to California via the Bonneville Power Administration.

"Reclamation is the second largest hydropower producer in the Nation. Our multi-purpose dams are once again responding to the needs of the American people," said Dr. Tim Petty, Assistant Secretary for Water and Science for the Department of the Interior. "We are proud to provide this key domestic energy resource while fulfilling our mission to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public."

"The ability of hydroelectric dams to change output rapidly can offset fluctuations under extreme weather conditions and in wind generation or other intermittent resources, such as solar," said Reclamation's Hydropower Senior Advisor Max Spiker. "Without flexible backup generation, renewables could not match the energy needs of homes and businesses. In addition, hydropower can quickly compensate for other shortages in generation, such as California recently experienced and for which Reclamation provided emergency support and grid stability."

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## NEW STUDY BY IHA IDENTIFIES ASIAN HYDROPOWER PLANTS **THAT COULD BENEFIT FROM MODERNIZATION**

**1.09.2020**

A new study has identified decades-old hydropower stations across Asia that could contribute to the region's clean energy goals if they were significantly upgraded. The research by the International Hydropower Association (IHA), conducted for the Asian Infrastructure Investment Bank (AIIB), says that 66 hydropower stations across 19 countries could be ripe for modernisation, at an estimated investment value of up to US$13.7 billion.

Asia is home to around half the world's installed hydropower capacity, at almost 650 GW. Hydropower is therefore a major contributor to the region's electricity mix, accounting for around 14 per cent of total annual electricity generation. Countries such as Afghanistan, Bhutan, Cambodia, Georgia, the Kyrgyz Republic, Laos, Myanmar, Nepal and Tajikistan rely on hydropower for over half of annual generation.

IHA has estimated that more than a third of the continent's capacity will require, or have undergone, modernisation by 2030. Excluding China, which has a larger proportion of newer hydropower plants, this figure rises to around half of existing capacity.

The new research from AIIB and IHA, conducted over an eight-month period, found the countries with most hydropower capacity in need of modernisation and further investigation are India and Turkey.

The main drivers behind the need for hydropower modernisation range from upgrading ageing equipment, to improving energy performance, reducing environmental impacts, and complementing renewables like solar and wind.

International Water Power & Dam Construction

## ABD LOAN TO HELP FUND **HYDRO DEVELOPMENT IN UZBEKISTAN**

**8.09.2020**

The Asian Development Bank (ADB) has agreed to lend $60 million to Uzbekistan's state hydropower producer and developer JSC Uzbekhydroenergo to support implementation of the country's ambitious national energy strategy to generate a quarter of all electricity from renewable sources by 2030, including 3.8 GW of hydro energy.

The loan, agreed on a 25-year term, follows the recent announcement of a new 20-year, €55.8 million loan from the French Development Agency to support investment projects in Uzbekistan's hydropower sector. The ADB loan will be used towards the construction of three new hydropower plants on the Aksu River, with a total installed capacity of 24 MW – the 10.3 MW Tamshush project; 7.5 MW Chappasuy project; and the 6.2 MW Rabat project. Of the new $60 million from the ADB, $23.6 million will be used for procurement of machinery and equipment, $21.6 million has been allocated for construction and installation works and the remaining proceeds will be used to: manage the project and cover pre-project costs; create a high-voltage network; and finance the selection of general contractor through a tender organized with the ADB.

"We thank the Asian Development Bank for their continued confidence and support in our ongoing efforts to reform and modernise our energy sector," commented Abdugani Sanginov, Chairman of the Board of JSC Uzbekhydroenergo. "With the support of international partners such as the Asian Development Bank, we are making great strides towards our ambitious renewable energy goals for 2030 and meeting the ever-increasing demands for energy."

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## SNAKE RIVER DAMS TO STAY AS **RECORD OF DECISION SIGNED**

**1.10.2020**

The US Army Corps of Engineers, Bureau of Reclamation and Bonneville Power Administration signed a joint record of decision on 28 September which commits the agencies to implementing immediate and long-term actions related to the ongoing operations, maintenance and configuration of 14 federal dams that compose the Columbia River System. The decision means that four dams along the Lower Snake River – previously mooted to be removed – will stay.

The plan has been developed to balance the purposes of the dams, while specifically supporting ongoing and new improvements for species listed under the Endangered Species Act. The ROD sets out the reasons for selecting the preferred alternative published in the Columbia River System Operations final environmental impact statement as the alternative for implementation and affirms the agencies' commitment to implement the National Marine Fisheries Service and U.S. Fish and Wildlife Service 2020 biological opinions.

"This selected alternative provides the best balanced and flexible approach to meeting the needs of the human and natural environment in the basin, both now and into the future. Our decision benefits the public interest, treaty resources and iconic fish species of the Pacific Northwest," concluded Brig. Gen. D. Peter Helmlinger, commander of the Corps of Engineers' Northwestern Division.

Through her assessment, Reclamation Regional Director Lorri Gray has determined that, "The selected alternative meets the purpose and need of the action and a majority of the EIS objectives, balancing the co-lead agencies' abilities to meet statutory project obligations while also complying with the requirements of the ESA, Clean Water Act and other applicable laws."

International Water Power & Dam Construction

Photo 1. Reservoir Raciborz Dolny under construction
*Source: Budimex SA*

# RACIBÓRZ DOLNY RESERVOIR – CHALLENGES FOR SUPPLIERS

**The biggest civil engineering project in Poland recently put into operation – "Construction of the dry flood protection reservoir Racibórz Dolny" – has a goal to protect 2.5 million people living in 600 km² area in the south Poland from floods, like the one from year 1997, which killed 55 people and caused material losses worth over PLN 12.8 bn.).**

The goal of this paper is to present technical, organizational and logistic problems which were faced by suppliers of hydraulic drive and controls systems. Sky-high technical requirements defined by designers concerning durability, reliability and functionality of delivered systems are related to expectation of 7-year guarantee period, minimal price and short delivery time. Additional problems appeared because of unclear definition of many technical parameters and complicated procedures for receiving approvals of any deviations.

The paper puts special emphasis on corrosion protection requirements for hydraulic cylinders working in sweet-water environment. The question that will be discussed are:

1. which International Standards are most adequate for cylinders rods coatings protection evaluation?
2. whether it is possible to compare the test results conducted in accordance to different ISO Standards?

## BACKGROUND

The great floods are frequent phenomena on Odra River and its tributaries. Such tragic cases were noted 12 times in XX century. The biggest one took place in 1997 when 55 people were killed and the value of losses exceeded PLN 12.8 bn (over EUR 3 bn). Umbrella-like shape of the area above city of Racibórz caused a sudden raise of water level which together with lack of reservoirs and insufficient flood protection, especially in large cities located by Odra and Nysa Rivers, were the reasons of such tragic situation. Construction of Raciborz Dolny Reservoir on Odra River provides flood protection to 2.5 million people from number of cities between Racibórz and Wrocław as well as many villages in 3 Polish voivodeships. The goal is achieved through:

- Location of the polder in beginning parts of the river on Polish territory will assure water retention which significantly reduce river's flow and improve effectiveness of existing flood protection;

Table 1. The key parameters of Racibórz Reservoir

| | |
|---|---|
| Height of the crown of the dam | **197.5 m a. s. l.** |
| Maximum water levelling | **195.2 m a. s. l.** |
| Water volume by maximum water level | **185.0 million m³** |
| Maximum water area | **26.3 km²** |
| Maximum height of earth barriers | **11 m** |

*Source: State Water Holding Polish Waters*

- The polder will decelerate moment of culmination in the estuary of Nysa Kłodzka. It will also minimize probability of two culmination's waves overlapping – the one from Odra and the one from Nysa.

The construction program of the Reservoir Racibórz Dolny was initiated immediately after the flood in 1997. Conceptual and study work – much earlier. The first stage of construction (Buków polder) was completed in 2000. Civil works under the second stage were initiated in 2013, with

Table 2. Spillway

| | |
|---|---|
| Number of gates | **6** |
| Width of gate's span | **11.8 m** |
| Height of gate | **8,65 m** |
| Height of elevation of gate | **8.75 m** |
| Drive of gate | **2 hydraulic cylinders, each powered by separate Power Pack** |
| Dimensions of cylinder | **320 x 180 x 8800 mm** |
| Synchronization of cylinders | **duplicated electronic system located in piston rods** |
| Pulling force | **2 x 1000 kN** |
| Operating time – full lifting | **over 60 minutes** |
| Operating time – full lowering | **over 90 minutes** |

*Source: Haskoning DHV Polska*

Table 3. Bottom outlet

| | |
|---|---|
| Number of bottom outlets | **6** |
| Dimensions of span – height | **4.5 m** |
| Dimensions of span – width | **3.5 m** |
| Number of gates in outlet | **2 (main and emergency)** |
| Drive of gate | **1 hydraulic cylinder for each gate powered by separate PP Cylinder equipped with redundant electronic piston position measurement system** |
| Dimensions of cylinder | **400 x 250 x 4600 mm** |
| Pulling force | **1150 kN** |
| Operating time – lifting | **over 33 minutes** |
| Operating time – lowering | **over 48 minutes** |

*Source: Haskoning DHV Polska*

Photo 2. Spillways and bottom outlet gates building

*Source: Budimex SA*

a budget of PLN 2 billion, with financial aid from loans granted by the World Bank and the Council of Europe Development Bank, as well as financing from the Polish government, EU and the National Fund for Environmental Protection and Water Management. Investor was the State Water Holding "Polish Waters" - RZGW Gliwice and the general contractor of the project was the consortium of Budimex and Ferrovial Agroman.

The reservoir is prepared by construction of main front barrier and two side barriers forming the bowls of the reservoir. There is a spilllway construction equipped with 6 spillways gates and 6 bottom outlet gates located in the main barrier.

## THE REQUIREMENTS TO BE MET BY SUPPLIERS

The main parameters of technological equipment of spillway and bottom outlet building were designed by the designer of whole reservoir – Hydroprojekt, the subsidiary of Haskoning DHV Polska [3].

## TECHNICAL REQUIREMENTS FOR HYDRAULIC DRIVES

The requirements related to hydraulic drives set by the Project Designer were in general complying with market standards. Escalation of expectations was observed during technical discussions with Investor and it concerned mainly issues related to ecology and corrosion protection. Additional requirements included:

- Special requirements for cylinders rods corrosion protection;
- Requirement for application of biodegradable oil;
- Requirement for stainless steel in whole hydraulic installations;
- Requirement for 7-year long guarantee period;
- Necessity of approvals for all applicable products and materials.

To achieve compromise for all aforementioned questions it was necessary to provide a lot of correspondence and discussions.

## TECHNICAL REQUIREMENTS FOR CORROSION PROTECTION

According to the documentation prepared by the designer of gates systems, the technical requirements for hydraulic cylinders should be as follows:

- nominal pressure – 25 MPa
- type of hydraulic cylinder – double-acting
- piston rods of hydraulic cylinders should be covered with a ceramic anti-corrosion coating or other of similar mechanical and anti-corrosion durability; anti-corro-

sive coatings of external surfaces of the hydraulic cylinders should be resistant to river water and be characterised by long-term durability (minimum durability of the coating – 20,000 hours according to PN-EN ISO 4536);
- rods seals should be adapted to work in river water;
- piston rods of hydraulic cylinders should be equipped with dirt and ice scrapers;
- hydraulic cylinders should have double (duplicated) electronic position transmitters of piston rods;
- hydraulic cylinders should be provided with means for their de-aeration during exploitation and in the oil drain valves;
- spherical bearings of rods and bottom cylinders eyes should be made of corrosion-resistant materials and should be maintenance-free as well as have side seals of pins and bearings.

While most of the above requirements did not raise any doubts, the requirements for anti-corrosive protection of piston rods defined in such way required explanation. Therefore a question was asked to the Contract Engineer (the Representative of Investor with the decisive voice on all technical and organizational issues of the Project) on how to interpret the requirement. The answer was that Standard EN-ISO 4536 is the one that should be used to determine and prove the durability of the coatings of hydraulic cylinders' piston rods and this is due to the Designer's experience.

## CORROSION RESISTANCE OF CERAMIC COATINGS

Ruhfus, a supplier of hydraulic cylinders for the Racibórz Dolny Project, uses ceramic coatings with the parameters as shown in Table 4. Both author of this paper and Griekspoor Thermal Coatings, Ruhfus' business partner, professionally dealing with ceramic coatings of metal surfaces exposed to corrosion in various aggressive environments for years, were surprised by the requirement to confirm the anti-corrosive resistance of the ceramic coatings of piston rods with a test in accordance to EN-ISO 4536. Wide range of reports on resistance tests conducted by independent laboratories in the Netherlands and Belgium have been presented (Table 5), which unfortunately have not been approved by the Order maker. It forced the supplier of hydraulic cylinders to conduct an additional Saline Droplet (SD) test in the 720 hours range in accordance with EN- ISO 4536, which obviously ended with a positive result.

## THE ADEQUACY OF EXISTING STANDARDS FOR THE EVALUATION OF CORROSION PROTECTION

As it is well known, there are many international, as well as national (which are even preferred) standards used to prove corrosion resistance of particular coating. Objective interpretation of adequacy of these standards for the evaluation of various methods of corrosion protection, materials operating in various corrosive environments as well as comparison of their results is crucial. Stanley J. Dapkunas in his „Surface Engineering Measurement Standards for Inorganic Materials"[1] describes the areas of Norm ISO 9227 and ISO 4536 implementation:

"The standard ISO 9227 is intended to assess the corrosion resistance of metal-

Table 5. List of reports on corrosion resistance tests submitted for acceptance by the supplier of hydraulic cylinders

| # | Test's description | Data of Report | Test's duration | Test's performer | Result |
|---|---|---|---|---|---|
| **1** | EPQ acc. NBD 10300 and ASTM G61 | 21 Oct 2015 | 100h | C-CUBE NL | Coating meets requirements from NBD 10300 standard |
| **2.** | Test acc. ISO 9227 AASS Evaluation acc. EN-ISO 10289 | 17 May 2016 | 672 h | METALogic BE | Results of evaluation according to ISO 10289 shows Protection rating RP 10, meaning no degradation/corrosion on the basic material |
| **3** | EPQ acc. NBD 10300 and ASTM G61 | 15 Sep 2015 | 100h | C-CUBE NL | The potential of the measurement position starts at +0.05V. The potential shows an stable potential. After 100 hours the potential reaches a value of +0.05V. The corrosion stability test shows low current density, which indicates a low vulnerability to corrosion.<br><br>The test surface after the test showed no corrosion, which indicates that no porosity up to the steel surface is present.<br><br>The coating meets the requirements as stated in the NBD 10300 standard. |
| **4** | EPQ acc. NBD 10300 and ASTM G61 | 17 Apr 2014 | 24h | C-CUBE NL | On the Ceramic coating of the cylinder rod the ECP test shows values above the threshold of -0.35V after 24 hours, which indicates no permeability of the coating.<br><br>The corrosion stability test shows low current densities.<br><br>The test surface after the test showed no corrosion. |
| **5** | Coating testing, Singapore Sea Harbour | Feb 2016 – Aug 2017 | 13,500h | Griekspoor | The rods were hung on a steel wire in the tide zone for 18 months (February 2016 - August 2017). This means 18 months long a test cycle of 6 hours under water and 6 hours above the water line, with an average temperature of more than 30°C (18 months equals approx. 13,500 hours in salt water). No corrosion |
| **6.** | Test acc. EN-ISO 4536 | 21 Jul 2018 | 720h | C-CUBE NL | The coating shows no corrosion or anomalies during or after the saline droplet test of 720 hours |

*Source: Author on the base of Tests reports*

Table 4. Information on the anti-corrosive resistance of ceramic coatings used by RUHFUS

GRIEKSPOOR THERMAL COATINGS

**Product Specification Sheet**
**Standard TOPCOAT®**
**300µm 2-layer**
**Nickel Chromium / $Al_2O_3$ Ceramic coating**

| **Coating construction and composition (2-layer coating system)** | | | |
|---|---|---|---|
| Bond/intermediate coating | Plasma | Nickel/Chromium | > = 100µm (max. 900µm) |
| Topcoat | Plasma | $Al_2O_3$ $TiO_2$ | > = 200µm (max. 600µm) |
| **Key coating information** | | | |
| **Description** | **International standard** | **Minimum value** | **Griekspoor Standard** |
| Tensile Adhesive Strenght | EN 582 or ISO 41916 | Minimum value | > = 50 N/mm² |
| Corrosion test | DNV-C2 | > = 35 N/mm² | > 1000h |
| | Endurance test acc. NBD10300 | No corrosion visible after 500h<br>No permeability after 1000h (ECP-test > - 350 mV) | > 1000h (ECP-test > - 150 mV) |
| Corrosion resistance | DIN 50021-ESS ASTM G85 | No corrosion (10) after 1000h | >1000h |
| Porosity | | < 4% | < 3% |
| Chem. Resistance | | | |
| 1. NaCl (acid) | | 1. Very good | |
| 2. H2SO4 (acid) | | 2. Very good | |
| 3. HCl (acid) | | 3. Very good | |
| 4. NaOH (base) | | 4. Fair/good | |

*Source: Griekspoor Thermal Coatings*

lic materials with or without permanent or temporary corrosion protection. Useful for detecting of discontinuities such as pores and other defects in certain metallic, anodic oxide and conversion coatings. "

"The Standard ISO 4536 is intended for the evaluation of corrosion resistance where the droplets may be more severe condition than a continuously moving moisture film". Bearing the above in mind, it seems legit to evaluate the aggressiveness of both tests in relation to the ceramic-coated piston rods. The Saline droplet test can be more aggressive for non-passivating metals, where oxygen availability is of special importance. As the ceramics does not oxidize, any risk of corrosion in both types of salt tests, i.e. salt spray and saline droplet, is limited. The hardness of coating is at such a high level, that erosion is not expected. Only in the case of porosity, the coated metal is exposed to the test through the pores. It shows that the difference between SD saline droplet test and constant spraying with brine is insignificant since the exposure takes place through constantly moist pores. The only difference lies in availability of oxygen to the existing pores, while the higher concentration of oxygen in the case of droplet test is favourable for ceramic coating [5].

An interesting standard used by the Dutch Ministry of Waterways to assess the anti-corrosion resistance of hydraulic cylnders is NBD 10300 (2010). The non-destructive 24-hour EPQ test (Electrochemical Product Qualification) used in that case is based on 10-year research conducted at the Oosterschelde dam and enables 10x reduction of time needed for its completion compared to ISO 9227.4 A similar test is ASTM G61 carried out in the USA.

Summarizing the above brief overview of several popular Standards on the evaluation of anti-corrosion protection, the author allows himself to ask the following questions, answers to which would enable to solve the problem that occurred during the Racibórz Dolny Project and which is bound to be encountered by many other suppliers of systems operating in difficult corrosion conditions:

A. How to compare the results of tests carried out in accordance with various Standards?

B. How far can you objectively refer to a specific Standard as a tender requirement without infringement of the rules of fair competition?
C. How helpful it would be for the Association of Civil engineering Engineers to establish unambiguous guidelines containing criteria for assessment of corrosion protection in various environmental conditions?

## REQUIREMENTS FOR EXTENDED WARRANTY

In accordance with the terms of Contract on Finishing the construction of Racibórz Dolny Reservoir, concluded with the Investor, i.e. the State Water Holding "Polish Waters" RZGW Gliwice and the General Contractor of the Project – Budimex S.A. – the warranty period was agreed for 5 years, beginning from the completion of the investment, which was done in middle of 2020. Of course, expectations of the General Contractor in relation to Subcontractors and Suppliers are similar. In the case of Rockfin Sp. z o.o., which as a result of winning public tender received an order for the delivery of drive system for the spillways and bottom outlet gates, should give guarantees for all drive and control components for 6 and half years period. It required both determining and negotiating with the Client of economic, organizational and logistics conditions of the guarantee as well as implementing a number of assumptions to the designed constructions, aiming at increasing the durability and reliability of the supplied systems and facilitating their maintenance on the site.

Omitting the details of Warranty Terms agreed by Budimex and Rockfin (confidential data), I would like to briefly discuss a few solutions enabling extension of the guarantee period and also problems related to their implementation.

## DESIGN ASSUMPTIONS ADOPTED TO ENABLE EXTENSION OF WARRANTY PERIOD

Rockfin Sp. z o.o., as a supplier of hydraulic drive systems for closing the gates, together with its partner and subsupplier of all hydraulic cylinders – RUHFUS Systemhydraulik GmbH, in order to fulfill the terms of extended warranty decided at the design stage to add several Terms to Technical Requirementss imposed by the reservoir's Designer, namely:

- enabling improvement of the durability and reliability of the delivered systems, trying at the same time to further increase the load capacity and durability of designed elements and using materials and products from reputable suppliers with full confirmation of their quality;
- acilitating servicing and system regulation in conditions of difficult access on the site with appropriate construction solutions;
- extended testing and acceptance tests of the system.

As an example of designing activities aiming at lowering the load for system elements, I would like to present a problem related to spherical bearings of piston rods eyes in spillways hydraulic cylinders, which were designed by the reservoir's Designer for pins with diameter ϕ 140 mm. Designer of cylinders from RUHFUS, wanting to assure the maintenance-free bearings used bearings made of material called Deva Tex 552 despite its lower static load capacity.

To reduce the load coefficient of the bearing below 0.8

$$Fz / Fz.d. < 0.8,$$

where:
Fz is the max. existing bearing load calculated in accordance with DIN 18800-1;
Fz.d is the permissible bearing load calculated with the safety coefficient = 1.5;

he suggested increasing the size of the bearing and a pin to ϕ 160 mm. Unfortunately, the idea was rejected by the Investor, who was afraid of exceeding the budget. The supplier of cylinders, striving for maintaining a significant excess of load capacity of the bearing decided to agree with the supplier of bearing on delivery of a special customised bearing providing permissible static load for bearing with ϕ 140 mm at the same level as in case of bearing with ϕ 160 mm.

## ADOPTED ORGANIZATIONAL AND LOGISTICS ACTIVITIES

To secure warranty obligations, a number of organizational and logistics activities related to protection of spare parts, special philosophy of service and warranty inspection and the rules of possible repairs and renovations were undertaken. All of the above activities require detailed, complex and time-consuming arrangements both with the Ordering Party, i.e. Budimex, as well as the Investor and the future user of the system.

## SUMMARY

Presenting the above paper regarding the delivery of drive systems to Racibórz Dolny Reservoir, author would like to emphasize that the cited challenges and problems that relate (to a greater or lesser degree) to all civil engineering projects conducted in Poland and probably not only in Poland. To face those challenges not only knowledge, technical experience and familiarity with local reality is needed, but also a lot of perseverance and persistence in dealing with technical, organizational, logistics and communication problems. Bearing in mind constant necessity of renovation of hydrotechnical facilities in Poland as well as already started or soon-to-be-planned multi-million investments, such as shipping channel through the Vistula peninsula (worth over PLN 900 million) or implementation of the program to improve the navigability of Polish rivers in accordance with the AGN Convention signed by the Polish President on 24th March 2017 (worth over PLN 70 billion), discussion on those issues appears to be crucial.

Włodzimierz Bramowicz
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### The Author

Dr Włodzimierz Bramowicz has long-lasting experience in design and delivery of hydraulic drive and control systems. As a Managing Director of Bosch Rexroth Poland he was responsible for hydraulic systems delivery to a number of civil engineering projects implemented on Odra and Nysa Rivers. As of today, he runs a Consulting company providing advisory services to Polish and international companies. In the Project of Racibórz Dolny Reservoir he has been acting as an advisor to the companies supplying hydraulic drive systems – Rockfin Sp. z o.o. and RUHFUS Systemhydraulik GmbH.

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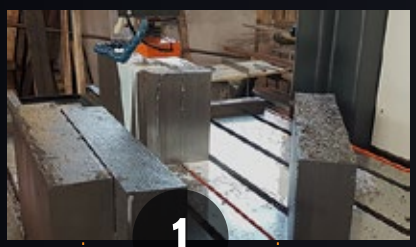


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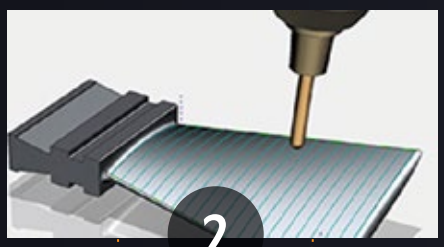


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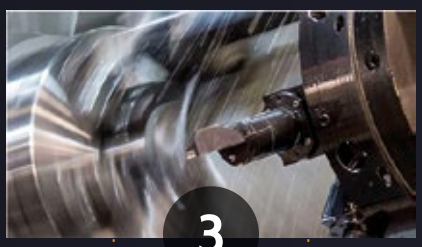


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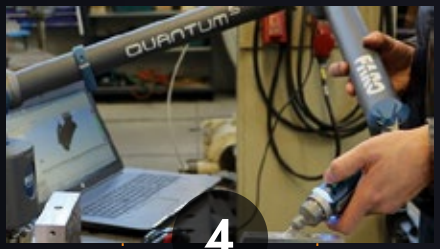


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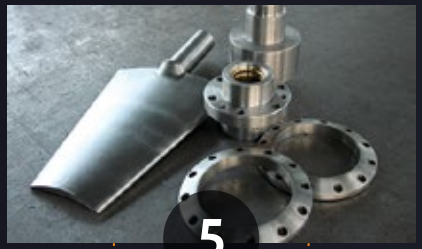


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# EXISTING LARGE HYDROPOWER **WAS LEFT OUT**

**If the Government does not improve the current revision of the Energy Act, Swiss hydropower will have a particularly difficult time in the future. Peter Lustenberger, Head of Asset Management Hydroenergy at Axpo, explains what it takes to ensure that hydroelectric power remains the strong backbone of Swiss electricity production.**

**The revision of the Energy Act provides for a doubling of contributions for the construction of new large hydroelectric power plants. That must make you feel optimistic.**
It is at least a clear sign. Policymakers believe that hydropower will play a central role in the electricity supply of the future. However, it must be said that contributions are only intended for new plants. Unfortunately, the potential for expanding large-scale hydroelectric power in Switzerland is limited. For us operators, the main concern is to keep the existing plants in good working order. And it is precisely large-scale hydropower that was forgotten in the revision of the Energy Act.

**What do you mean by that? As the Federal Council says, hydroelectric power is the backbone of Switzerland's electricity supply. Knowing that it has this backbone, isn't it justifiable to focus primarily on the expansion of new renewables?**
That's too easy. To stick with the analogy: a backbone that you don't train will degenerate. That's the risk for the existing large-scale hydroelectric power plants in Switzerland. Existing hydroelectric power plants that would need to be renewed will not receive any funding in the future. Because the risk of market prices is too high, no operator is able to make major investments in renewal. In other words, we will do only the bare minimum at our power plants. And to a certain extent we accept that reliability will suffer.

**Existing hydroelectric power stations are regularly refurbished. For example, Axpo completely renovated the Eglisau power plant a few years ago. This means that it can also be done without funding.**
A good example. It shows what is possible. In Eglisau, we have invested almost CHF 200 million in a plant that is now 100 years old, thereby increasing electricity production by 30 percent. There is similar potential for extension at many plants. However, the decision to renew was taken about 15 years ago, i.e. before the electricity market was opened up. Today, the decision would not be the same. In view of the market price risks, it would not be economically justifiable. We simply cannot assume that such an investment would pay off.

**What does it mean for the future of hydropower if only "the bare minimum" is done?**
It means that we limit ourselves to maintenance work and do not carry out total revisions. It also means that the condition of the plants will deteriorate in the medium term. In the long term, capacities could even be lost. One thing is certain: reliability suffers - which is a cause for concern. Hydroelectric power is our security in mitigating the volatility of the new renewables. It would be fatal if hydropower were suddenly to become volatile as well because of the neglected preservation of substance.

**What would it take to keep Switzerland's hydroelectric power plant park in good shape beyond what is absolutely necessary?**

Photo. Limmern pumped storage plant

*Source: Axpo*

The operators of the large hydroelectric power plants need a certain degree of security for renewal. No one is currently willing to make major long-term investments. Market prices are too volatile for that. At the same time, however, there is an overarching economic interest in reliable hydropower. Security of supply has its price, and that price must be paid collectively. No company can do this alone. This is why we are advocating a retroactive balancing of market risks as part of the revision of the Energy Act.

**What does that mean?**
If an operator invests in the renewal of a hydroelectric power station, he should retroactively receive back part of his investment - and only if the power station has not paid for itself. We assume a maximum of 60 percent of the costs. In this way, the market risk would be shared between the operator and the consumer. After all, both have an interest in strong large-scale hydropower. This would give more operators the courage to make long-term investments and also to take certain risks.

> *A backbone that you don't train will degenerate. That's the risk for the large-scale hydroelectric power plants.*

Peter Lustenberger
Head of Asset Management Hydroenergy
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# HYDROPOWER FRAMEWORK ANALYSIS IN A FEW **SELECTED AFRICAN AND LATIN AMERICAN COUNTRIES WITHIN HYPOSO**

**As readers of ENERGETYKA WODNA could have already read in previous issues of the magazine, HYPOSO is a research project funded under the H2020 programme with the aim to support the European hydropower industry while at the same time fostering a sustainable development in selected target countries in Africa and Latin America.**

One of the tasks advancing towards reaching the project objectives includes analysis of the hydropower sector framework in the target countries, namely: Bolivia, Colombia, and Ecuador (Latin America), Cameroon, and Uganda (Africa). This article summarizes some of the findings of this analysis and is based on the comprehensive report produced within the HYPOSO project.

Photo. The Muvumbe SHP, Uganda, 6.5 MW, project is expected to generate 31.4 GWh of electricity per annum.

*Source: HYPOSO project archive*

## BOLIVIA

Bolivia has a gross theoretical hydropower potential of 178,000 GWh/year (HP&D, 2019). The technically feasible potential has been estimated as 126,000 GWh/year, and the economically feasible potential is between 30,000 and 50,000 GWh/year. Hydropower plants generated about 2,500 GWh in 2018. Less than 2% of the technically feasible potential has been developed so far. A recent study based on GIS technologies identified the gross theoretical hydropower potential of 133 GW in Bolivia (Velpuri et al., 2016). Although protected areas were excluded from it, the real potential – technically or economically feasible potential remains still unknown. As of 2019, Bolivia had 16 large hydropower plants in operation with further 6 plants under construction (total capacity 659 MW).

The definition of small hydropower in Bolivia is up to 5 MW. So far, the small hydropower potential as expressed in real figures is not known as it is the case for all hydropower nor reliable inventory of SHP plants. After the highest estimate, there are 85 smalls, mini- or micro-hydro plants in operation, with individual capacities of up to 10 MW, and the total capacity of 153 MW, which generated 629 GWh in 2016. SHP plants belong to both private and public (ENDE) companies. Most of the SHPs in Bolivia belong to private companies. The energy tariffs for new projects are not defined yet, nor financial mechanisms exist. Regulations and investment frameworks are in the process of being implemented. Each project will have to be negotiated in order to establish the energy price through a purchase agreement according to ENDE's requirements, the interests of the investor, and authorizations.

There is an ambitious target to generate as much as 70 to 78% of domestic electricity from hydropower by 2025. The target of ENDE is to have 3,000 MW of hydropower capacity as soon as possible, which would allow the country soon to use about 1 GW for electricity export purposes. In the medium term, an estimated US$ 16.7 billion will be invested in new hydropower projects (HP&D, 2019, IHA, 2019). This plan is heavily reliant on two large hydropower schemes. The export to Brazil and Argentina is very attractive in terms of power price that is about seven times higher than the price established for the local market, which has been subsidized for energy production (WSHPDR, 2019). The Government's strategic plan includes SHP projects of approximately 30 MW for grid connection and another 20 MW for isolated networks, all of them in the progress of identification. Such projects as well as other endeavours can be studied, developed, and constructed by public or private investment. The Government is also working on the structure and rules to finance small hydropower and other renewable energy technologies, such as by assigning incentives to the local government departments when the installed capacity is below 2 MW; and to the municipalities or the indigenous authorities when the project is of an installed capacity less than 1 MW.

## COLOMBIA

Colombia has the second-largest hydropower potential in Latin America, after Brazil (OLADE, 2013). The gross theoretical hydropower potential of Colombia is about 1,000 TWh/year, of which 200 TWh/year is technically feasible. 140 TWh/year was economically feasible according to estimates made several years ago (H&D, 2019).

According to the data from Colombia's National Mining and Energy Planning Unit (UPME) and the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), the theoretical hydropower potential is estimated at 56 GW countrywide (UPME, 2015). This includes 8,113 MW at plants of 20 to 40 MW and 43,129 MW at plants larger than 40 MW. Of the total potential, 41.1% is in the Magdalena Cauca hydrographic basin, 23.7% in the Orinoco basin, 22.1% in the Amazon basin, 6.8% in the Caribe basin, and 6.4% in the Pacifik basin.

As of February 2019, the total installed hydropower capacity was 11,771 MW (including 22 plants of at least 50 MW

capacity), which is 68% of total installed capacity (H&D, 2019). About 55% of the hydro capacity is privately owned. Three main utilities EPM (public), Emgesa (mixed capital), and ISAGEN (private) account for 75% of installed hydropower capacity. In 2015, a comprehensive atlas of Colombia's Hydropower Potential was launched (UPME, 2015). This atlas indicates 4,947 MW hydro potential for plants of up to 20 MW capacity.

In Colombia, the definition of SHP was adopted, which involves a plant capacity less than or equal to 20 MW and that operates at run-off-river, with no water storage (Duque et al, 2016; Arias-Gaviria et al., 2017). There are some 35 SHP companies registered and trading energy through the stock market, with about 120 SHP stations and an installed capacity of 955 MW. Additionally, there are at least 200 smaller power plants, not registered at the stock market, and more than a thousand abandoned or dismantled SHPs. There is no comprehensive, centrally processed data for such power plants. In total, 125 hydropower projects are in the pre-feasibility stage according to UPME. These would add about 5,600 MW to the existing installed capacity. By comparison, over 300 solar and wind projects are also registered, representing 2,775 MW of additional installed capacity (IHA, 2018). Some 212 projects were registered by June 2016, with a total capacity of 7,585 MW, including 128 hydropower projects with a total capacity of 4,227 MW (H&D, 2019).

Despite the untapped large hydropower potential and the developed atlas of hydropower potential in the country, comprehensive data regarding small hydropower potential is not available. There is a Central Register Office for projects planned for construction. As of February 2019, there were thirty more small plants, with a total capacity of 285 MW, having their feasibility studies or designs ready (H&D, 2019).

## ECUADOR

Ecuador has a gross theoretical hydropower potential of 90,970 MW, equivalent to 638,000 GWh/year (H&D, 2019). The economically feasible installed capacity is 25,550 MW. CONELEC (2012) and IDB (2013) indicate a bit different estimates of theoretical and economically feasible hydropower potential – 77,000 and 21,520 MW, respectively. So far, about 19.7% of the technically feasible potential has been developed. Ecuador's total hydro capacity was 5,041 MW in August 2019.

The average annual generation from hydropower between 2006 and 2015 was 10,880 GWh, about 45% of total generation. In 2018, generation from hydro was 20,696 GWh (70.2%), a notable increase compared with the years mentioned above. There are 31 large hydro plants (>10 MW) in operation, with a total capacity of 4,973 MW. SHP definition in Ecuador is up to 10 MW. In practice, installations of slightly higher capacity are classified sometimes as small ones. There are 41 small, mini, or micro-hydro plants (<10 MW) in operation, with a total capacity of about 102 MW. Ecuador is one of the very few Latin American countries that implemented a feed-in tariff (FIT) scheme for renewable energy (Vargas et al. 2018). For small hydropower of up to 10 MW, the FIT rate is 0.0781 US$/kWh. Small-scale electricity producers (with a capacity smaller than 1 MW) do not require a permit for operation (Decree 1581 of 1999). Currently, the investment in hydropower projects focuses on projects of medium and large capacity, which are supported with foreign credits. For instance, large hydropower plants have been recently financed by the Chinese Exim Bank and built by the Sinohydro Corporation. Community opposition is manifested, particularly regarding private and large hydro projects.

ANDRITZ HYDRO, an EU based global supplier of electromechanical systems, has a long history in Ecuador. Since then this manufacturer delivered and rehabilitated more than 60 units with a total output of about 2,000 MW, representing an impressive 88% of the nation's hydropower capacity. At least 100 hydropower project studies were carried out in the country, which resulted in the total power capacity exceeding 4,150 MW. The country expects to meet the national domestic energy demand and export surplus energy to Colombia and Peru. The Ecuadorian Electrification Master Plan 2018-2027, developed by the MERNNR jointly with other relevant entities envisages 19 hydropower projects totaling 3.6 GW of new capacity by 2027, as well as an additional 550 MW of solar, wind, and other non-conventional renewables.

Dependency on large hydropower makes larger projects a priority for the Government and limits the interest in SHP investment. Some 40 SHP projects with a total capacity of 225 MW already completed the final design stages and are ready to go ahead for construction. Last summer in 2019, Ecuador's government started launching auctions for renewable energy projects, including small hydro installations, through which it intended to allocate around 500 MW of power generation capacity. Developers will be granted a 25-year PPA, while the sole off-taker of the generated energy will be state-owned utility Corporacion Electrica de Ecuador, S.A.

Photo. Ngassona SHP, Cameroon, 2.9 MW, plant under erection, but stopped for security reasons

*Source: HYPOSO project archive*

## CAMEROON

The country has the fourth-largest hydropower potential in Africa behind the Democratic Republic of Congo, Madagascar, and Ethiopia (Kenfack and Hamandjoda, 2012). The gross theoretical hydro potential of Cameroon is 294 TWh/year. Of this, 115 TWh/year is considered technically feasible, and 105 TWh/year economically feasible. Only about 4% of the technically feasible capacity has been developed. There was 816 MW of hydro capacity in operation (in 2017). The total installed capacity of all

power plants (as of 2017) is 1529 MW, of which 816 MW is hydro. Total production in 2017 was 6,973 GWh (latest available data), of which 5,090 GWh (73%) was contributed by hydro (H&D, 2019). As of 2019, only 8 hydropower plants are operational or under construction, out of which three are small schemes in the country. The upper capacity limit of SHP in Cameroon is 10 MW. The complete assessment of small hydropower potential is yet to be done. The country is still looking for funds to make an in-depth assessment of the small hydro potential. A very preliminary list of locations of sites for potential micro to small hydropower plants is freely accessible (ONUDI, 2019).

Mini-grids, powered by pico- and micro-hydropower plants, are a relatively new rural electrification strategy in Cameroon. Several of such mini-grids have been developed in the mountain regions of the country (Ministry of Energy, 2018). As of 2017, the installed capacity of SHP was at least 1 MW, however, comprehensive and accurate data on total installed capacity are not currently available.

The small hydropower potential is estimated to be at 970 MW (WSHPDR, 2019). Other sources provide SHP power generation potential estimated at 1.115 TWh, concentrated mainly in the Western and Eastern regions (Nematchoua et al. 2015). Substantial hydropower potential presents many investment opportunities for the future. Given this large hydro potential, the development of hydro plants could make the country a net electricity exporter in the future. Four neighbouring countries, Chad, Nigeria, Gabon, and Equatorial Guinea, have already expressed interest, and there are plans to build transmission lines between the four countries as soon as more hydro plants are developed (H&D, 2019). However, the negative effect of climate change should be underlined. So far persistent power outages used to take place throughout the country, especially in the dry seasons when water levels in reservoirs are low (Muh et al., 2018). Large hydro plants planning or construction is taking place in the country. E. g., the 420 MW Nachtigal scheme, the 398 MW Songdong scheme, the 600 MW Chollet scheme. A private developer is planning to implement the 485 MW Kpep scheme which could eventually have a total capacity of 850 MW, another one to construct the Makay complex (400 MW).

About 20 small schemes have been identified for the next 10 years. There are some plants (20 kW to 3 MW) abandoned due to grid extension and political instability. A very preliminary list of locations of sites for potential micro to small hydro plants is freely accessible (ONUDI). The Cameroonian government is struggling to cope with a low electricity access rate in the country. The lack of private investment is the root cause of the low electricity access rates in rural areas in Cameroon. Therefore, it has drafted policies favouring the participation of private investors in the sector that started working. Tens of memorandums of understanding (MoU) from a few MW to hundreds of MW in hydro capacity are being concluded. The companies are coming from almost all over the world.

## UGANDA

The gross theoretical hydropower potential of the country has not been fully assessed (H&D, 2019). The technically feasible potential of Uganda is 20,833 GWh/year and the economically feasible one - 12,500 GWh/year. About 15% of the technically feasible potential has been developed so far. In 2018, hydro plants generated 3,638 GWh, which was 89% of the total generation. Generally, the contribution of hydro each year is more than 80%. As of 2019, Uganda had 32 hydropower plants that were in operation, with a total installed capacity of 1,667 MW. This inventory comprises some 20 micro and small hydropower plants (up to 10 MW).

In Uganda, SHP is generally defined as hydropower plants with an installed capacity of up to 20 MW (ERA - the Electricity Regulatory Authority). These sites are located mainly in the Western and the Eastern regions of the country which are hilly and mountainous. About 50 potential small hydropower sites have been identified at the Ugandan rivers. So far SHP potential has not been fully assessed in the country, only rough estimates can be provided (some 1,250 GWh/year). Small schemes are generally privately owned and operated by the IPPs. To date, there is 20 SHP under operation, but access to their data is restricted. The Renewable Energy Feed-in Tariffs (REFiT) applies to systems of prescribed priority technologies (SHP and other renewables) of installed capacity in the range of 0.5 to 20 MW, as defined by the Electricity Act, 1999. In addition, to qualify for the REFIT, the projects must be connected to the national grid. Feed-in Tariff for micro hydro (<1 MW), mini (<9 MW), and small hydro (<20 MW) vary from 0.115 to 0.085 US $/kWh with a repayment period of 20 years.

Uganda Vision 2040 identifies electricity generation as one of the key strategic interventions for the social-economic transformation of the country. This includes increasing access to 30% in 2020 and 80% in 2040 (a 6% annual increase), with off-grid electricity playing only a minor role. While this is expected to be mainly low-carbon due to large hydropower resources, there is a potential to achieve 100% access cost-effectively by 2040 with a greater emphasis on small-scale off-grid renewable solutions (IHA, 2019). There should be also pointed out, that hydropower is sensitive to the climate-driven hydrological cycle thus necessitating proper management of the river catchment areas. The key challenges for hydropower development in Uganda, and most countries in Africa, include the need for substantial up-front investment capital which cannot easily be raised by the sector, as well as environmental and social concerns

Photo. Harca HPP, Zongo region, Bolivia

*Source: LHUMSS*

Table. Key indicators as of 2019

| No | Indicator | Bolivia | Colombia | Ecuador | Cameroon | Uganda |
|---|---|---|---|---|---|---|
| 1. | Population, mln. | 11.5 | 48.2 | 17.3 | 24 | 44.2 |
| 2. | Area mln km² | 1.098 | 1.142 | 0.256 | 0.475 | 0.242 |
| 3. | Access to electricity % | 91.8 | 97 | 97.05 | 63.57 | 50 |
| 4. | Installed hydro capacity MW | 735 | 11,771 | 5,066 | 947 | 1,004.2 |
| 5. | Share of generation from hydropower % | 30 | 86 | 70.5 | 73 | 80 |
| 6. | Hydro generation GWh | 1,715 | 58,300 | 20,678 | 5,090 | 3,638 |
| 7. | Economically feasible hydro generation potential TWh/year | 40 | 140 | 156.7 | 105 | 12.5 |
| 8. | Small hydropower potential MW | >2,000 | ca 5,000 | 297 | 630 | 400 |
| 9. | Small hydropower installed capacity MW | 153 | 955 | 120 | >15 | 145.3 |
| 10. | Specific hydropower potential (energy density) GWh/(year·km²) ** | 0.11 | 0.18 | 0.74 | 0.24 | 0.05 |

**For comparison, this specific indicator for Austria and Norway is around 0.66, Brazil – 0.15 GWh/(year·km²).

*Source: "Report on framework analysis and research needs in five target countries", HYPOSO project*

such as the resettlement and compensations of persons affected mainly by the large hydro projects, and inadequate local implementation experience and technical capacity.

To ensure the development of hydropower resources sustainably, in 2010 the government undertook a hydropower development master plan study (JICA, 2011). The study targeted sites above 50 MW mainly along the River Nile. In line with this hydropower master plan, the government is fast-tracking the development of the identified hydropower sites. It is currently implementing two key flagship hydropower projects namely, Isimba (183.2 MW) and Karuma (600 MW). Other large hydropower plants being packaged for development include Ayago (840 MW), Orianga (392 MW), Uhuru (350 MW), and Kiba (290 MW). (IHA, 2019). To address the challenge of financing, the Government of Uganda put in place the Energy Investment Fund which enabled to commencement of the construction of the Bujagali hydropower plant. The 250 MW Bujagali hydropower plant was developed under a public-private partnership arrangement with Bujagali Energy Limited (BEL). Additional investment capital has been attracted through bilateral financing with our development partners. The challenge of inadequate technical capacity has been addressed by putting in place a local content policy to ensure the participation of Ugandans during the construction of the projects.

A total of 59 mini-hydropower sites with a potential of about 210 MW have been identified through different studies. Some of the sites can be developed for isolated grids and others as energy supply to the grid (Fashina 2019). Regarding small hydropower projects, the current policy is that their development is undertaken by the private sector. The REFiT are in place to promote investment in small hydropower and other renewable power projects (IHA, 2019).

There are many unexploited potential SHP sites in Uganda, which could potentially supply electricity to areas not covered by the national grid. Their data are available at ERA and some of these sites are listed in WSHDR (2019).

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# HYDAC – **YOUR PROFESSIONAL PARTNER**

**Today, hydroelectric power stations make an important and sustainable contribution to the world's energy supply. HYDAC is determined to play its part in enabling people to gain maximum benefit from hydropower e.g. in opening flood gates and intake gates, and in efficiently regulating and protecting turbines and generators. HYDAC proves its expertise with hydraulic and filtration solutions in all sectors.**

HYDAC has decades of experience in oil hydraulics and process water treatment. With individual components constantly being added to the product range, such as filters, accumulators, valves, pumps, coolers and sensors, HYDAC has built up an extensive and complete product portfolio over the years that leaves nothing to be desi- red when it comes to designing systems for the hydropower industry. In addition to sup plying individual components, HYDAC also provides complete systems for almost all hy- dropower applications. These are compre- hensive systems which are specially tailored to suit the customer's needs. HYDAC was founded in 1963 as a company for hydraulic accessories and is today an international, family run company group with over 9000 employees, 50 subsidiaries and 500 sales and service partners worldwide. Our motto is: global yet local. HYDAC components and systems can be found in all sectors of industrial and mobile hydraulics.

## COMPREHENSIVE PRODUCT PORTFOLIO

In the hydropower industry, HYDAC is represented in the following applications for both large and small hydropower stations:

- Hydraulic steel structures and trash rack cleaners: hydraulic units and cylinders for gate, sluices, weirs and trash rack cleaners
- Shut-off devices: hydraulic systems for ball valves, shut-off valves and needle valves, piston and bladder accumulator stations for storing closing power and water-powered servo motors with corresponding protective filters
- Turbines: bearing lubrication systems, hydraulic turbine controllers, piston and bladder accumulator stations for the emergency shut-down function
- Process and cooling water treatment: for the filtration of seal water, cooling water and extinguishing water, the required components – e.g. the automatic back-flushing filter RF3 – are mounted on a compact frame (skid)
- Generators: lifting and brake cylinders, oil lubrication cooling systems and cooling water systems, high-pressure discharge systems (HP systems), brake lifting systems, oil mist separators.

For closed cooling circuits that work with water glycol, HYDAC has developed a compact system (WGK) that is made up of a motor-pump unit, an expansion tank, a mixing valve and sensors. In addition to customised hydraulic units, HYDAC supplies standard units in various sizes and versions with its Hydrobox system. This is especially suitable for small hydropower stations.

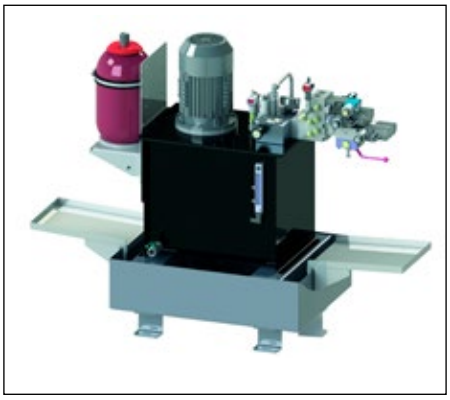
## WORLDWIDE SERVICES

HYDAC also supplies products for Condition Monitoring, such as sensors for monitoring water content (Aqua Sensor), metallic contamination (MCS Sensor) and the automatic monitoring oil cleanliness (CS Sensor) along

HYDAC sp. z o.o. is a Polish registered company; the company was founded over 28 years ago, and is a subsidiary of the Hydac Group in Germany. Since the company's foundation in 1992, it has steadily grown and now has its own network of technical offices within Polish, the Ukrainian and the Belarusian market.

Fig. For closed cooling circuits that work with water glycol, HYDAC has developed a compact system (WGK) that is made up of a motor-pump unit, an expansion tank, a mixing valve and sensors.

Fig. In addition to customised hydraulic units, HYDAC supplies standard units in various sizes and versions with its Hydrobox system. This is especially suitable for small hydropower stations.



with service instruments for maintenance such as dewatering units (FAM), offline filtration units (OLF), nitrogen charging units for accumulators (N2 server) and mobile units for measurement and data acquisition (HMG). The HYDAC portfolio is rounded off with extensive fluid engineering services which help to optimise your key components and fluid power systems. We are very happy to support you in areas such as energy efficiency, process and system reliability, conservation of resources and system availability.

Please contact us via our website or directly using the following e-mail address: info@hydac.com.pl The HYDAC team looks forward to receiving your enquiry!

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Photos and graphics come from the archives of HYDAC company.

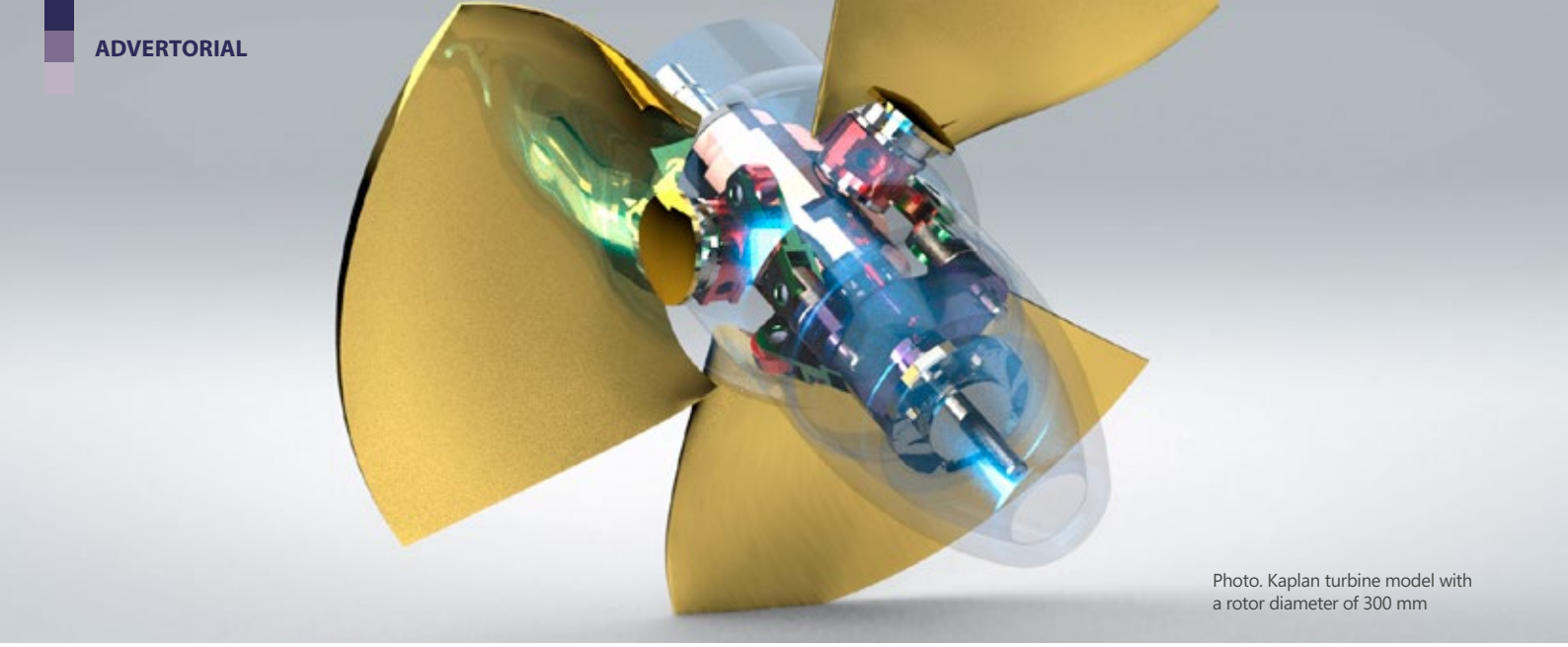


Photo. Kaplan turbine model with a rotor diameter of 300 mm

# WODEL REACHES A DEVELOPMENTAL MILESTONE **AND BUILDS ITS OWN RESEARCH LAB**

**Wodel, a manufacturer of highly efficient and reliable water turbines, will be the only company in Poland to launch its own laboratory for model tests of rotodynamic machines at the end of the year. In contrast to a CFD (computational fluid dynamics) analysis, energy and cavitation tests at a test station fully confirm whether the solutions chosen for a small hydropower plant (SHP) are appropriate.**

The technical design of the test station was prepared by Konrad Wawrzykowski, President of Wodel, based on the now-defunct laboratory of the Chair of Rotodynamic Machines and Fluid Mechanics at the Gdańsk University of Technology and with the assistance of the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences. The laboratory – currently still under construction at the company's headquarters in Nowa Sól – will be equipped with a test station that will enable conducting research projects and proprietary work on the hydraulic properties of rotodynamic machines. It will be used primarily for works related to the development of small hydropower solutions. The station will enable simultaneous testing of up to two machines.

## EXPERIENCE BUILT UP OVER THE YEARS

By today, Wodel already has nearly forty years of market experience. It employs thirty highly qualified specialists. It has three fully equipped production halls heavy machining and assembly, welding and metalworking and CNC machining, respectively. Additionally, Wodel has recently purchased five modern CNC machines, three of which are machining centers. The company provides services for the automotive industry as well. Wodel uses the ISO 9001:2015 quality management system and manufactures steel structures in accordance with the IS0 1090 standard. It also has an electrical and automation laboratory used for developing dedicated programs for turbine sets and other SHP equipment. It has been operating in the renewable energy source sector since 1986. It was then that Wodel manufactured its first machines, which are still operated by dozens of facilities across Poland and Europe. Currently, Wodel offers comprehensive solutions for SHP investments, including Kaplan, semi-Kaplan and Francis water turbines; mechanical gears and flexible connection drives; gated, flap-gate and slide gate weirs; chain and slat rake cleaning systems, steel hydro-technical structure elements; maintenance works and on-line facility supervision; SHP repair and modernisation; FEM and CFD analyses and control and automation solutions.

## WORKING WITH SCIENTIFIC INSTITUTIONS

Wodel worked with the Chair of Rotodynamic Machines and Fluid Mechanics of the Gdańsk University of Technology for about 20 years and all of its performance and cavitation research used to be performed at the Faculty's research stations. All turbine types produced by Wodel were tested using the Chair's facilities. Currently, Wodel works with the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdańsk (IMP PAN), where it is testing a semi-Kaplan turbine with a spiral-axial non-bladed distributor, as part of a project called "Development of a low-head modular hydroelectric power plant technology with high power performance and minimal environmental impact." Wodel's previous project carried out in cooperation with Fluid-Flow Machinery of the Polish Academy of Sciences was wrapped up in May 2020; it concerned a horizontal Kaplan turbine with a 3-vane rotor and high specific speed characteristics.

The idea of building a research centre at Wodel's headquarters was first proposed during that very project. "The research on the integrated semi-Kaplan turbine was to be carried out for us by the scientific unit. However, this cooperation did not materialise due to various reasons. As such, we have undertaken to set up our own test rig. We will integrate the entire system at our lab and then carry out tests with support of the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences," said K. Wawrzykowski.

## THE ADVANTAGE OF MODEL TESTS OVER COMPUTER ANALYSIS

Wodel has been using professional tools such as Auto Cad Mechanical, SolidWorks and Ansys in the design process for many years. "We perform MES and CFD analyses, which guide us in the design process. A CFD simulation provides you with some idea of how

things work, but it cannot be the only thing you rely on. The initial assumptions determine the results. Input data used for analyses is always simplified. A CFD assessment is purely theoretical. Since we are unable to predict the actual conditions, the results bear a large risk of measurement error. To ensure the validity of the solutions utilised, it is necessary to perform energy tests – and possibly cavitation tests – at a research station. Laboratory research is much more expensive than a CFD analysis and that is why few companies choose it, however, having 34 years of market experience, we would never risk choosing a turbine based only on computer analysis," said K. Wawrzykowski. Model tests eliminate design errors. They make it possible to measure universal characteristics based on which the specific turbine parameters can be selected – ones which are the most optimal for the hydrological conditions in both new and existing facilities.

## TESTED AND RELIABLE TURBINE SETS

The test rig that is being set up at Wodel has already drawn the interest of the academia and the RES industry. A university from Bydgoszcz has asked Wodel to use the station to support its students' hydropower plant-related PhD courses.

"This allows us to analyse rotors and various geometric shapes of the flow system to ensure the best parameters possible. While looking for the right shape, we also verify the given solution's mechanical properties. As such, we can avoid mistakenly choosing an expensive piece of equipment that does not work properly. We have been working in the industry for many years and we have achieved a lot while doing so. Our turbines have a good reputation; the very first ones we have made have been working in various facilities for decades and are still going strong. At this point, we have already reached our limits in certain design areas. Today we want to take another big step forward. This step is having a proprietary research laboratory. No other company in Poland has ever done this before," said K. Wawrzykowski.

Building our own laboratory is a response to the changing trends, technology, and customer expectations. Wodel has decided to meet these challenges head-on. "All of us – clients and producers alike – strive to keep the investment costs as low as possible and the energy production profits as high as possible," Mr Wawrzykowski emphasized. Laboratory-tested turbines, which Wodel has been offering for many years, also guarantee high durability, which ensures continuity of operation of the turbine sets and virtually eliminates downtime due to failures.

## CONSTRUCTION OF THE NEW SHP DOBROSZÓW IS UNDERWAY

The company has recently signed several new water turbine production contracts as well. Two new production halls will be built to fulfil all these orders. Apart from handling the multitude of new orders for turbines, Wodel is currently constructing a small hydroelectric power plant. Within a year, a new SHP will be built on the Bóbr River in Dobroszów Wielki, Nowogród Bobrzański commune; its estimated annual output is 6,600 MWh. Works related to this investment have commenced in early September. Wodel is the general contractor.

The scope of the works includes the construction of a gated weir and a control room, as well as the construction of the hydropower plant's chambers, plant building, inflow and outflow canal, reinforcement of the river bottom and slopes, construction of an earth embankment and a steel wall on the left bank, as well as the construction of a new fish pass and rock riffles. Additionally, a transformer station will be set up next to the SHP. The power plant will be equipped with automatic rake cleaning systems and, of course, turbine generators.

Photo. Flow A flow simulation for a vertical Kaplan turbine

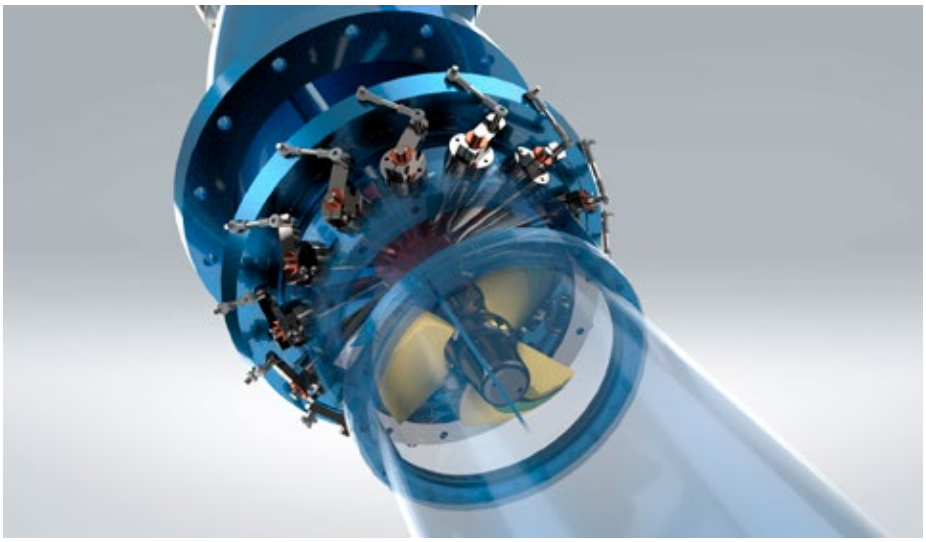


Photo. Kaplan 700 elbow draft tube turbine for industrial research

The turbine set parameters will be verified by the SCADA IT system used for supervising the production process. The system collects and archives current data (measurements) and visualises it, and it also controls the entire process and alerts employees of any issues (the relevant information is immediately sent to their phones, tablets and PCs). This solution is employed at all power plants using complete turbine sets supplied by Wodel. The turbines are compatible with each other. What does it mean? Let's assume that the river's water level is increasing and the efficiency of turbine No 1 begins to decrease. Upon reaching a certain efficiency value, the system turns on turbine No 2, then No 3 and so on. This makes it possible to use the watercourse to its fullest extent.

"Our goal is to continuously improve our products by using modern engineering design and part manufacturing methods. We constantly remain in contact with our clients throughout the design, service and installation phases, as well as during the subsequent operation of machines and equipment. We are firmly convinced that nearly 40 years of industry experience and our strong commitment will enable us to deliver every order at the highest quality level possible," K. Wawrzykowski emphasized.

Anna Karasiewicz
Wodel

Photos and graphics come from the archives of Wodel company.

# HYDROPOWER AT THE JUNCTION OF INCOHERENT UE POLICIES

**The final report of the Water Framework Directive (WFD) Fitness Check released by the European Commission last year concluded that the Directive was fit for purpose with some scope for improvement. Therefore, the subsequent revision of the WFD will not take place until 2027, with initial preparations for the revision taking place in 2024.**

The objectives of the Water Framework Directive were set in 2000, whilst the relevant objectives of European energy policy were fundamentally reformulated in 2018. This has led to major incoherency between the policy objectives. The Fitness Check failed to take into account the European Commission's Green Deal and the necessary expansion of renewable energy. As a result there are several outstanding issues and potential contradictions and ambiguities remaining in the final report of the Commission's WFD Fitness Check.

## WFD AND HYDROPOWER DEVELOPMENT

Hydropower is currently playing a crucial role in the energy transition; with their flexibility and large storage capacity, hydropower facilities of all sizes facilitate the integration of other renewables sources. Hydropower also provides all necessary services that are essential for security of supply and stability in the electricity grid. It is therefore crucial that EU policy and legislation supports the growth of hydropower over the coming years.

The WFD Fitness Check did not properly consider the implications on hydropower development, despite the fact that the WFD has the potential to play a pivotal role in the energy transition and climate protection. As a result the hydropower sector face continuous obstacles throughout the EU, with differing interpretation of the WFD leading to diverging hydropower development. The inherent flexibility of the WFD was never well implemented. It has become more and more constricted by jurisprudence and guidance documents. There is no cohesion between it and other climate and energy policy. Currently there is confusion at both a national and local level in situations where authorities attempt to apply the WFD when approving hydropower plants while also attempting to take into account the framework of the competing EU political goals such as the Renewable Energy Directive II. This confusion directly hinders the development of the hydropower sector. As there is no present opportunity to revise the WFD so that hydropower development is given proper consideration, it is crucial discover a working solution to these issues and contradictions which can be utilised by the hydropower sector over the coming years.

## OPPORTUNITY FOR IMPROVEMENT

It is important to identify opportunities to improve the interpretation of the WFD so that it is in line with current EU energy policy and supports the development of hydropower. The following paragraphs set out suggestions for this improvement:

The hydropower industry in particular has invested a great deal of money in the creation of fish possibility and in morphological improvements in order to meet the objectives of the Water Framework Directive. However, the ecological status of water does not reflect these improvements. It can therefore be assumed that other pressures stand in the way of achieving the objectives of the WFD (e.g. pollution from agriculture, river straightening, etc.).

The next phase of the WFD should focus on these areas. Only by assessing the quality of the water together can the objectives of the Directive be met by the most cost-efficient means. Particularly in the area of pollution from agriculture, a few measures have been implemented but must be followed up. Also with regard to "new pollutants" such as microplastics, airborne pollutants, etc., mitigation measures for these must be initiated as soon as possible so that the measures introduced by the hydropower sector can take effect. It is crucial to recognise the different national situations for member States throughout the EU. By recognising this difference, Member States should be allowed implement the WFD by taking into account their national specificities.

## RED II FIRST

In situations such as those described above in which there are conflicting interests arising from differing EU political goals, such as between the WFD and RED II, what is the best approach to remedy this?

The German Government currently assesses an idea for Germany that renewable energy rules should prevail over environmental ones in case of conflict between the two legislations. Though German politicians consider this proposal especially for the wind energy sector, it would also be very helpful for the development of the small hydropower sector which has been severely slowed from an excessive interpretation of the Water Framework Directive. The German EU Presidency plans to discuss this idea as well as with counterparts from EU institutions and fellow governments.

The Small Hydropower Chapter of the European Renewable Energies Federation (EREF) started already a discussion on this suggestion with the European Commission. Though staff from DG Environment seems rather sceptical about it, they signalled their openness for EREF's proposals on how to reduce problems for hydropower development in EU member States.

The ambitious goals for a fast and full decarbonisation of the European economy require the use of all existing renewable energy sources. Europe has developed nearly 50% of its small hydropower potential but 50% remains and it should be a major driver to the EU decarbonized energy strategy – for the sake of the climate and environment.

EREF European Renewable Energies Federation

Dirk Hendricks
European Renewable Energies Federation

# INDUSTRY CATALOG

Photo. Due to the increased flood risk, the Water Holding Polish Waters started the process of damming the Racibórz Reservoir for the first time at 14th of October
*Source: FB Czeska Fotografia*

# RACIBÓRZ DOLNY RESERVOIR CAN CATCH **A MILLENNIUM FLOOD WAVE**

**The construction of the Racibórz Dolny Reservoir had been completed at the end of June. It will protect 2.5 million residents living in three voivodeships through which the Oder River flows (Śląskie, Opolskie, and Dolnośląskie Voivodeships) against floods. Here is a discussion with Polish Waters expert Wojciech Skowyrski, who is the Director of the Investment Preparation and Implementation Department, about the construction of the reservoir and the way it operates.**

**Over 20 years ago, the Millennium Flood struck southern Poland, culminating with the flooding of 60% of the Racibórz area. Now that the reservoir has been built, can the residents of these areas feel safe?**

Yes, because it has been built to reduce the volume of flow in the river during a flood wave. The Racibórz Reservoir is a dry flood control reservoir and its task is to collect excess water and to reduce a flood wave so that it does not pose a threat to the residents. We know that the flood embankments located below the reservoir provide protection against water with a flow of approx. 2,300 m³/s. However, we will control the outflow so that the flow below the reservoir is reduced to 1,210 m³/s, i.e. the so-called 20-year flood level. The best way to explain this is to use an example: let us assume that the flow of water from the upper Oder River begins to increase. If it does not exceed 1,210 m³/s, we take no action. However, if it exceeds this value, we start reducing it, which we refer to as "choking the wave". To do so, we use forecasts prepared by IMGW and updated every few hours. It should be emphasised that when it comes to a flood wave, both its size and volume matter. When the inflow to the reservoir exceeds 2,400 m³/s, e.g. 3,120 m³/s (that was the flow recorded during the 1997 flood), we start to choke the wave more and more intensively until the outflow from the reservoir is lower than 1,600 m³/s, which is safe in terms of the capacity of the Oder River valley located below.

**What is chocking the wave?**

There are gates and bottom outlets in the reservoir or, to be exact, on the spillway structure. They form a system that we can control automatically. When water levels rise, we close the gates one by one – the entire procedure is described in the Water Management Instructions. This is to ensure that the outflow of water from the reservoir is not higher than we want it to be. We control the gates and close them in such an order to ensure that the water flow is safe. We are in a good position because we made accurate measurements of the 1997 flood wave; we know when it started, how long it was active, what its volume was, and when it started to move back. Wave choking is all maths: let us assume that a flood wave begins to lower and reaches 900 m³/s. The outflow is still 1,210 m³/s. The reservoir is slowly being emptied because the outflow of water is approx. 310 m³/s higher than the inflow.

**What happens to the water being emptied?**

It is reduced to the pre-flood level, i.e. it returns to the riverbed. The reservoir basin has a system of drains, which ensure that the water can flow to the riverbed even from isolated still water beds that could be formed outside the main riverbed.

**At present, the reservoir basin can store 185 million m³ of water but it will be deepened to store 300 million m³. How long can the deepening take?**

Approx. 10 years. The reservoir basin has rich deposits of very good quality gravel – 100 million m³ of the aggregate is estimated to be there. Given the price of gravel, there are billions of PLN to be extracted from the reservoir basin. There are currently several companies extracting it and, at the same time, deepening the reservoir basis and also increasing its the so-called water flood reserve, which is the amount of water that the reservoir can store and retain. We would like the gravel extraction to be completed when the reservoir is still of the dry type because we are planning to turn it into a wet reservoir, which will not only provide flood protection but also store water to be used in the case of droughts.

**In the frontal dam of the reservoir, there is a spillway structure, which the designers refer to as its "heart". Why "heart"?**

The spillway structure is a crucial part of the reservoir because it is responsible for controlling the outflow of water from the tank. It controls many processes like the human heart. Located in the frontal dam like heart valves, it controls the flow, while the reservoir basin is like heart chambers. When there is no tide, the reservoir basin is responsible for ensuring that water flows freely in the riv-

erbed. When the flow of water increases, however, it controls the outflow of water as required. The structure has been designed so that vessels can pass through it. In addition, the spillway structure ensures that the flow of water in the Oder River section flowing through Racibórz can be increased if necessary. The operation of this structure is a prerequisite for catching the flood wave effectively because it is not only about catching water; it is also important to do so at the right time and in a rational way.

**There are also two pumping stations, Lubomia and Buków, around the reservoir. What do they do?**
The pumping stations are located near the right side dam of the reservoir. There are watercourses that supply the Oder River with water there. When water levels in the Oder River start to increase, it is impossible to channel water by gravity so it moves back and causes local flooding. To prevent this, the pumping stations are started up. They increase the levels of water artificially to channel it to the main reservoir. The pumping stations do not operate continuously – they are started up only when necessary. Still, they provide additional protection for inhabitants of the areas surrounding the reservoir.

**Source information reveals that the idea to build a reservoir in Racibórz date back to the beginning of the 20th century. So the inhabitants had to wait a little bit for it. Why?**
Indeed, the construction of the reservoir was planned more than 100 years ago following a flood in 1880. The first plans were developed in the 1960s but were not implemented due to enormous investment costs. The idea to build the reservoir reemerged after the Millennium Flood. The first polder projects were prepared already in 2004 but encountered issues with land expropriation. When the special purpose Act on Flood Protection entered into force in 2010, it became easier to prepare the investment project. Racibórz was included in the Odra River Basin Flood Protection Project and became a flagship investment as part of this project. Funding was obtained from many sources including the World Bank, Council of Europe Bank, European Union, and the National Fund for Environmental Protection and Water Management.

**Speaking about the inhabitants, the construction of the reservoir here meant that over 700 people had to be relocated. This must have aroused a strong reaction...**
Situations like this are always difficult because you have to reconcile the interests of many parties. Public consultation took a lot of time. Representatives of the local government knew how important it was to build the reservoir right here; after all, the safety of not only Racibórz, but also Kędzierzyn Koźle, Opole, and Wrocław depends on it. In the end, the inhabitants agreed to expropriation and relocation – this is how the new village of Nieboczowy was established. It was built from scratch in areas, which had formerly been fields. The village has modern infrastructure - pitches, parks, a church. Even the cemetery was moved! The inhabitants themselves had the power to decide where they would like to be relocated as well as how their houses and the estate built for them would look like. Even though the idea seemed arduous at first, we have made it happen. Today, foreign delegations come to the new village of Nieboczowy (its construction began in 2014 and was completed in 2019) to see for themselves how to reconcile state interests and how to preserve local "small homelands" even if they have to be moved elsewhere.

**You have mentioned that the conversion of the Racibórz Reservoir from dry into wet is planned. How realistic is this plan?**
Climate forecasts do not leave any doubt: heavy rainfall causing floods will interweave with long periods of drought. That is why these phenomena must be considered as a whole – we must collect water when it falls and give it back when we run out of it. The only solution is to collect water in retention reservoirs and the Racibórz Reservoir will be perfect for this. Firstly, we can store water in it and channel it to the Oder River during periods of drought. This would have a positive effect not only on agriculture, but also on the economy because turning the Racibórz Reservoir into a retention reservoir would improve river navigability (currently, low water levels often make waterborne transport difficult). Secondly, the water stored in the reservoir could be used for energy purposes (hydropower). However, all this takes time. We cannot convert the reservoir for the next five years anyway because we are bound by the so-called project durability period, during which no reservoir modifications can be made. What is more, it takes a lot of work to convert a dry reservoir into a wet one. We would have to build a sluice because there are plans to build the Danube–Oder Canal, reinforce the barriers of waterside slopes surrounding the reservoir, build fish passes, etc. reservoir conversion is a complicated process that can take up to 10 years.

**The opponents of this investment claim that turning the Racibórz Reservoir from dry to wet will reduce its flood retention capacity. It is also alleged that the course of the Oder River was changed during the reservoir construction.**
The only change was to a section of the Oder River several hundred meters long and it was a slight change that did not in any way interfere with biological life in and around the river. Once the Racibórz Reservoir has been converted into a wet reservoir, its flood retention capacity will be maintained by adopting the appropriate water storage level (NWL). At the same time, we will be able to mitigate the effects of possible hydrological drought, which is also very much needed.

Interviewer: Jowita Hakobert
from the Social Communication Department
of State Water Holding Polish Waters

## Racibórz Dolny flood control reservoir

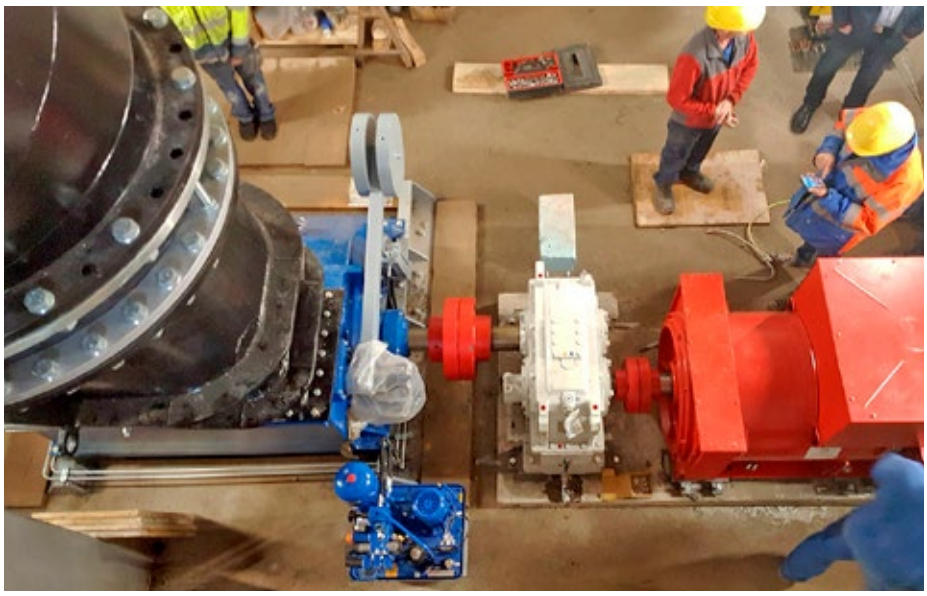
**Investment costs: approx.** PLN 2 billion
**Sources of financing:** World Bank, Council of Europe Bank, European Union, National Fund for Environmental Protection and Water Management, state budget funds
**Contractors:** consortium of Budimex S.A. (leader) and Ferrovial Agroman S.A.
**Reservoir capacity:** 185 million m³
**Polder surface area:** over 26 km²
**Length of dams surrounding the reservoir:** 22 km
**Flood protection area:** 600 km²
**Objective:** protection of 2.5 million inhabitants of three voivodeships (Śląskie, Opolskie, and Dolnośląskie) against floods
**Operation:** the polder flattens the flood wave and delays the time at which the Oder River wave reaches the Nysa Kłodzka River mouth, reducing the probability that two highest points of the wave overlap (this is what happened during the Millennium Flood in 1997).

# THE RECONSTRUCTED ALVIERWERK II HYDROPOWER PLANT
# TRIPLES CAPACITY WITH HELP OF OSSBERGER TURBINE

**The Alvierwerk II plant, which was built a few months ago, was connected to the network in the Bürs municipality, which is located in the state of Vorarlberg, Western Austria. The project was contracted by Getzner, Mutter & Cie., the network operator, which initiated the construction of a replacement structure as part of the municipal flood protection project.**

The entire installation was rebuilt from scratch – starting from the water intake, which is now connected directly to the Alvierwerk I upper station through an 800-metre underground pressure pipeline, which is also connected to the underground power station. In terms of electrical and machine equipment, the operators opted for a complete solution package offered by Ossberger, a German leader in the field of small hydropower plants. When fully loaded, the machine, which operates effectively in a wide operating range, reaches the power of more than 440 kW, which is almost three times higher than the previous solution.

Photo. Ossberger supplied all electrohydraulic and control equipment for the new Alvierwerk II replacement structure in Bürs, Vorarlberg. In March this year, the plant was successfully commissioned in a short time.



*Source: Ossberger*

Getzner Textil AG, which has been one of the largest private companies and employers in the region and the entire state of Vorarlberg for many years, is based in the Bürs municipality, southwest of the town of Bludenz. Established in 1818 "in the countryside", this traditional company is part of the internationally active Getzner, Mutter & Cie. holding (GMC), which is known throughout the world through its subsidiary Getzner Textil AG for high-quality processed cotton fabrics. Through its subsidiary Getzner Werkstoffe GmbH, the holding is also represented in smaller production plants in North America and Asia. In addition to its core activity, which is textile processing, Getzner is considered a competent specialist in terms of sound and vibration insulation – the "Sylomer" mats manufactured by Getzner Werkstoffe GmbH are well known and widely used in both construction and various industry branches. To meet its own electricity needs for production purposes, GMC in Bürs traditionally relies on renewable energy, especially hydropower. Thanks to two run-of-the-river plants on the Ill river and two diversion plants on the Alvierbach River, the company generates more electricity per year than it needs for its textile production.

Table. Technical data

| | | | |
|---|---|---|---|
| Flow rate | **2,5 m³/s** | Gear | **Spur gear** |
| Gross head | **24,5 m** | Gear ratio | **1:3,46** |
| Net head | **21,5 m** | Generator | **synchronous** |
| Derivation | **800 m** | Rated speed | **1000 U/min** |
| Material | **ductile cast iron** | Frequency | **50 Hz** |
| Diameter | **1280 mm** | Terminal voltage | **400 V** |
| Type of turbine | **Michell-Banki** | Efficiency | **0,9** |
| Rated speed | **289 U/min** | Cooling | **air** |
| Maximum capacity: | **443 kW** | Capacity | **455 kVA** |
| Manufacturer | **Ossberger** | Average annual production | **3 GWh** |

## PLANNED WELL AHEAD

About 11 years ago, GMC contracted the reconstruction of a pressure line and the revitalisation of the machinery of the Alvierwerk I power plant, which was built already in 1910. Then an even more comprehensive renovation of the Alvierwerk II lower station was planned. The plan was to build a new replacement structure, for which several variants were analysed in the project planning phase, as part of the municipal flood protection project. "The variant selected provided for several major improvements – in terms of both flood protection and electricity generation," says former plant manager Manfred Harrasser, who, as the GMC project manager, was responsible for the investment project concerning the hydropower plant renovation until he retired. The weir of the old plant, located in the centre of the town, was completely dismantled, leading to a significant improvement to the flood situation in this river reach. The new water intake was connected to the Alvierwerk I tailwater with relatively little construction effort. In addition, the penstock,

Photo. When fully loaded, the power of the Ossberger turbine, which is very efficient in a wide operating range, reaches 443 kW.

*Source: Ossberger*

Photo. The water supply, now completely underground, occurs entirely through a DN1280 pipeline made of cast iron.

*Source: Getzner, Mutter & Cie./B.Massimo*

which is now completely underground, replaced the previous open diversion channel. Harrasser explains that the redesign of the diversion reach, which is approx. 800-metre long, was a considerable challenge. "The majority of the pipeline route runs through built-up areas; in some cases, during the pipeline installation works, the distance from adjacent buildings was smaller than 5 m. Therefore, there were many things to consider in terms of construction and transport logistics". The penstock material was ductile cast iron, of DN 1280 mm diameter, while the pipeline itself was installed by Vorarlberg Hilti & Jehle GmbH in the third and fourth quarter of 2019. The selected penstock route was also based on the structure of the channel, which previously ran in sections as an aqueduct and whose stone structure was completely dismantled. A new design of the diversion stretch led to a significant improvement to the production technology. Since the flow of the old diversion channel was limited to 2 m³/s for safety reasons, it was impossible to use the entire licensed water volume of 2.5 m³/s for electricity generation. In addition, the usable head almost tripled when the location of the powerhouse was changed.

## CROSS-FLOW TURBINE INSTEAD OF KAPLAN TURBINE

The Alvierwerk II powerhouse was also built as an underground one. It was to remain next to a much bigger investment project by GMC, which was a new warehouse for Getzner Werkstoffe GmbH. While building the powerhouse, the highest priority was to avoid turbine noise and vibration emissions. This was ensured by a two-layer building structure and the use of Getzner's own insulation material.

Bernhard Massimo, who replaced Manfred Harrasser as plant manager in July last year, points out that the cross-flow turbine was an obvious choice for the new Alvierwerk II station for several reasons. "Originally, a Kaplan turbine, which is slightly more efficient, was planned. However, the most important thing is that the use of a cross-flow turbine is much more economical. The sheer costs of purchasing the cross-flow turbine and related equipment are half of the costs associated with the Kaplan turbine. Considering its simple and functional design, the cross-flow turbine consists of fewer parts, which leads to lower maintenance costs. Furthermore, the powerhouse for the cross-flow turbine, thanks to its space-saving size, could be smaller than the one for the Kaplan turbine and thus we were able to build it completely underground".

## SIGNIFICANT INCREASE IN POWER AND ELECTRICITY GENERATION

Ossberger, a South German supplier of comprehensive hydropower solutions, was the winner of the tender for the delivery of a complete electromechanical and control package. The heart of the system is a cross-flow turbine supplied from the top and designed for a gross head of approx. 21 m. When fully loaded, the power of the turbine, which is coupled with a horizontal synchronous generator via a spur gear, is 443 kW. This is an almost three-fold increase compared to the previous unit, whose power was limited to approx. 150 kW. Moreover, the machine, equipped with a two-chamber housing, offers very satisfactory efficiency in a partial load range. Ossberger's scope of delivery also included a cut-off butterfly valve and all auxiliary equipment necessary for installation, which was purchased exclusively from recognised manufacturers. As for control, the Germans opted for the PLC SIMATIC S7-1500 controller by Siemens, which has proven itself in the automation sector all around the world. The system is controlled using a touch panel integrated with the front part of the control cabinet. In addition, communication with the GMC central control room was established for remote access.

A few months after the plant commissioning in March, Harrasser and Massimo are both positive about the Alvierwerk II renovation: "The implementation was very smooth, mainly due to excellent cooperation between all investment project participants". It goes without saying that the former and current plant managers are very pleased with a huge increase in hydropower plant power, now able to generate approx. 3 GWh of green electricity per year on average.

OSSBERGER GmbH + Co. KG

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# SHP ZABRZEŻ – **THE RESULT OF OPTIMISATION WORKS**

**Construction and mechanical works on a new Polish hydropower plant are underway – both in the production hall and on a picturesque island located in a bend of the Dunajec River. This investment project is a testament to the fact that a holistic approach is required in the construction of SHP facilities. This is reflected in satisfactory production and economic results afterwards. We encourage you to read the SHP Zabrzeż case study.**

The formal history of SHP Zabrzeż began in 2011 when an application for environmental permission was submitted. After nearly 10 years, the investment project is in the final stretch and its launch is planned to take place by the middle of the next year. Nonetheless, several factors had to coincide to make it possible to reach such an advanced stage of works within this time. A facility building permit was issued as early as 2014; afterwards, the investor began looking for a general contractor. And this is where the difficulties began, as the quotations prepared by the bidders left little doubt – building the SHP in the original location for which permits were issued was too expensive and would result in a return on investment time that was unacceptable for the owner. The uncertainty of RES regulations was yet another obstacle at the time. Therefore, after several years of the project's development, the investor was close to giving up. The documentation gathered indicated that there is little chance of implementing it. It seems that the source of the problem faced by the investor was an impractical and non-market approach to designing technical solutions.

## LIGHT AT THE END OF THE TUNNEL

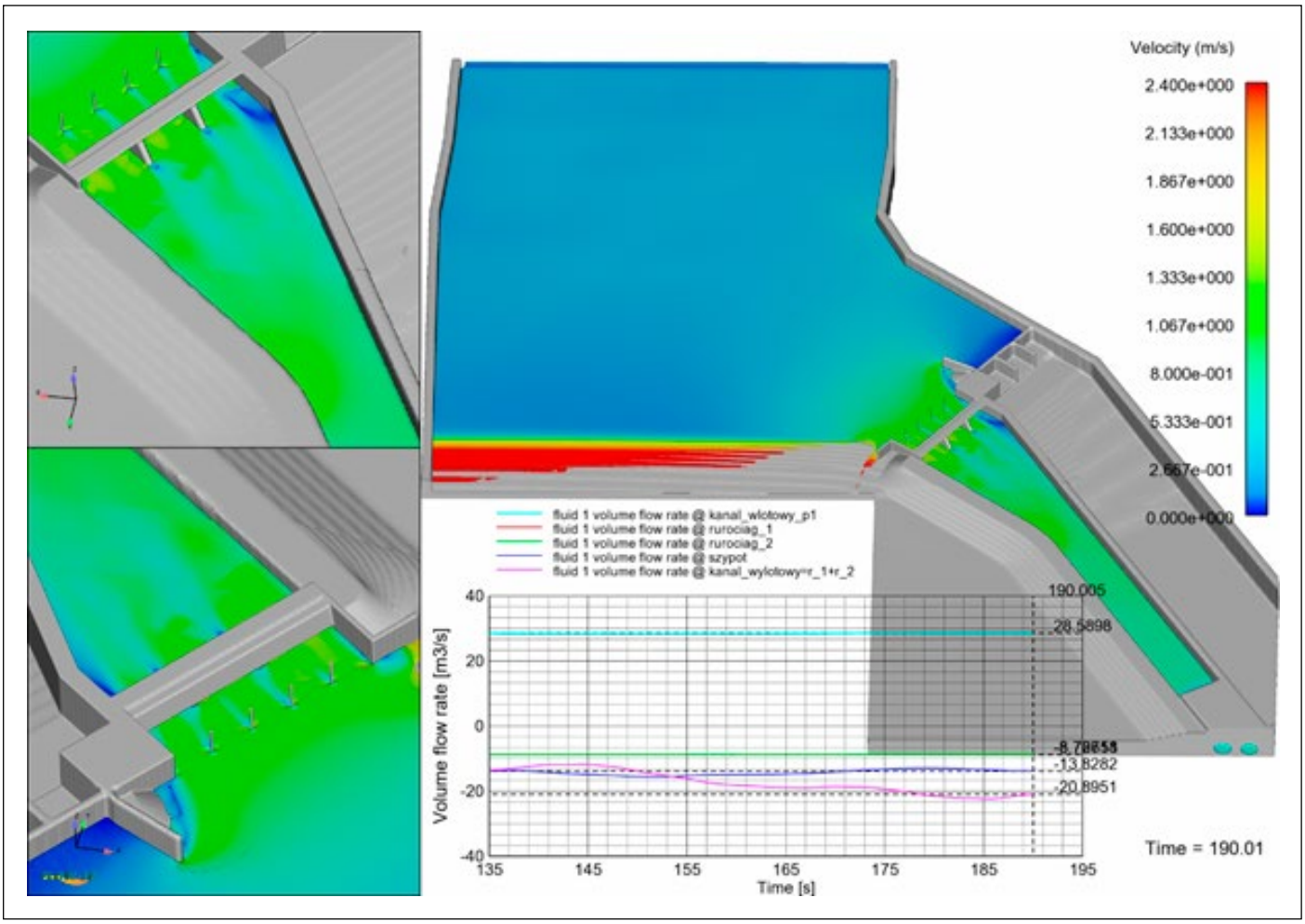
However, the belief that the decision to construct the SHP is right, as well as the perseverance of the company's shareholders, led to the cooperation with a design office capable of undertaking the project's technological and business optimisation based on a technical audit. The investor decided to employ the services of a company that works in the hydropower industry and has experience in rationalising the costs of such investments. The works began with a detailed formal and legal audit of the activities undertaken so far, the conditions in the area where the SHP was to be constructed and solutions proposewwd in the original construction and executive projects. As a result of the

Photo. The initial part of the power plant's inflow channel (the picture shows the exposed section made of reinforced concrete; the underground diversion channel consisting of two parallel pipelines is not visible).

## Investor's opinion

When choosing to work with IOZE, we needed someone to provide comprehensive services to support the project. Initially, we doubted that it would even be possible for a single company to provide all we need. Nonetheless, we are very pleased with our cooperation so far. The project's general contractor provided us with comprehensive services, assistance at every stage and in every situation, as well as legal, formal, financial and business consulting and the detailed technological solutions concerning all industries. We are convinced that we have entrusted the implementation of the project to the best industry professionals. – Dorota Chowaniec, President of the Management Board of the SHP Zabrzeż investment project owner.

Fig. A FLOW 3D simulation of water flow and water levels within the intake prepared by a CFD modelling specialist – provided by Instytut OZE Sp. z o.o., SHP Zabrzeż replacement design documentation contractor.




analysis, it was recommended that new project documentation be prepared to enable investment optimisation. The investor finally accepted the SHP Zabrzeż implementation offer based on the design-build method and could look to the future with optimism ever since – especially since the service also included obtaining project funding. For the investor, the most important thing is to get a chance to achieve the expected rate of return on financial expenditures, as well as ensure the technical and business coherence of the project while maintaining high safety and quality standards.

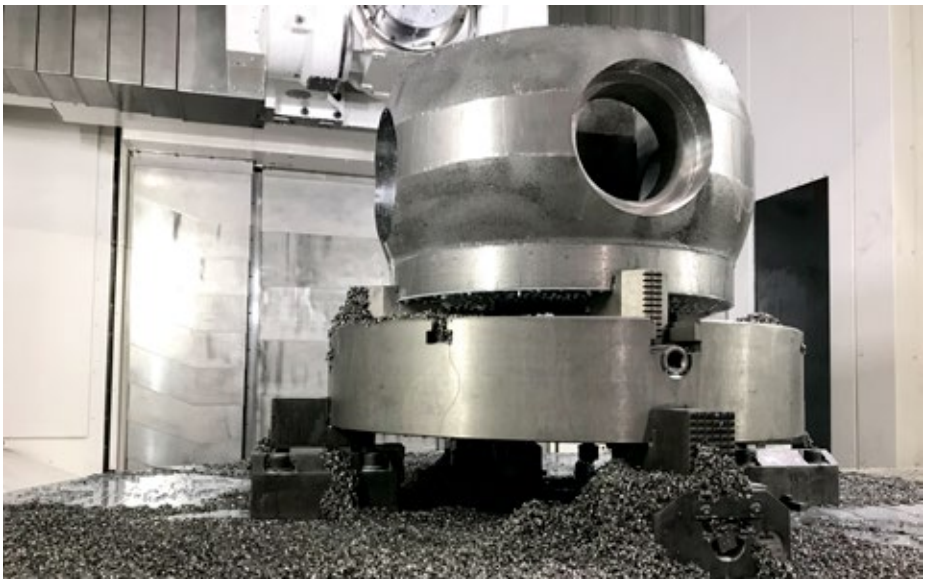
## OPTIMISED TECHNOLOGY

The new project reflected the designers' conviction that implementing the project in a profitable version is possible – a fact supported by their experience and multi-criteria hydrological and hydrotechnical analyses conducted. As part of the optimisation process, the SHP's entire hydraulic system was analysed, including the water intake, the inflow channel to supply water and the inflow chamber. The solutions used for this included the FLOW 3D software used to perform numerical simulations of liquid flow and water levels. The simulation made it possible to remodel the water intake's shape to make it more efficient (smaller energy losses; better adapted to the nature of a mountain river and the changing water levels in the different seasons). Water from the Dunajec will be directed to the intake using a stone groyne and then flow through an open canal. Importantly, the diversion canal changes its cross-section in 2 planes within the first 28 metres. The sloped bottom plate and narrowing walls enable slow and uniform water flow and eliminate turbulent water movements. The remainder of the canal has a constant cross-section. The main part of the system guiding the water into the turbines consists of two pipelines with a length of 142 m, a diameter of 2.4 m

## Basic advantages of the technology

A characteristic feature of a traditional vertical Kaplan turbine system – like the one designed for SHP Zabrzeż – is the low failure rate, which ensures stable, long-term operation of the facility. The turbine's design makes the number of parts that require maintenance very limited. At the same time, the turbine is easily accessible during any required maintenance works that the SHP might have to undergo. Furthermore, even while one turbine is undergoing maintenance works, the other can still operate and generate electricity. This is because each turbine has an autonomous energy generating system. All you need to do to shut down a turbine for its scheduled maintenance is to close the gates on the pipeline feeding water to it. Apart from the turbine, the RES installation includes a spiral, reinforced concrete inflow chamber (the first part of the chamber has a circular cross-section while the second a rectangular one), which, like all other elements, was modelled in specialised software to ensure the most efficient form. Another thing worth noting is the SHP's high level of flood safety. This includes the building itself, which will be capable of withstanding total submersion while preventing floodwater from getting inside thanks to special flood gates. The necessity of introducing such solutions stems directly from the nature of the river on which the project is located.

Photo. The hub of the Kaplan turbine, which will be installed at SHP Zabrzeż, during a five-axis CNC machining process



and a longitudinal slope of 0.35%. The total head possible to obtain for the SHP is up to 4 m, but this is also supplemented by a weir that supports the canoeing track. The constructional changes introduced (as a result of CFD – Computational Fluid Dynamics tests, among others) in the case of the intake's and diversion canal's designs, as well as the SHP building, the turbines and the drainage canal, were vital not only for the system's efficiency but also for the technical feasibility of the whole project. The heart of SHP Zabrzeż will be two vertical Kaplan turbines with a the runner diameter of 1670 mm, which are already being manufactured in the technology supplier's production hall. The facility's installed electrical power will be 0.5 MW and each turbine will be equipped with a four-blade adjustable pitch runner and 20 guide vanes, which make it possible to direct the water stream and control the turbine flow rate.

## PICTURESQUE LOCATION AND SMART DEVELOPMENT

The new small hydropower plant is being built in a bend of the Dunajec River, surrounded by the Beskid Wysoki, on an island separating the riverbed from a canoeing track which has been operating since the mid-1990s. The two facilities are expected to operate interdependently, which was one of the primary conditions provided for in the administrative decisions concerning the SHP. The power generating system will work around the clock throughout the cold season while between April and October it will allow for operation of the canoeing track. It is worth to emphasize the eco-friendly nature of the solutions utilised, such as the stone groyne used to divert water to the inflow canal, which is quite similar to natural structures. Obstructing the riverbed and disturbing the biological continuity of the Dunajec River – and putting the aquatic fauna at risk – is out of the question in this case. The facility, which is already partially completed, corresponds to the existing land use criteria and will exploit the previously unused hydropotential of this area. Sustainability in its pure form.

## FURTHER PLANS

The investment project, which has been under construction for several months, is in line with the general upward trend in hydroelectric power engineering. This is a direct result of both the stabilisation of the RES sector support system and the national and global policy of reducing the share of traditional fossil fuels in the energy sector. By using a Kaplan turbine designed individually based on the needs of the project, the SHP will be able to generate energy steadily and reliably. The launch of the facility in the first half of next year will enable the investor to take advantage of the recently introduced fixed energy sales prices under the FIT tariff. Considering the investments in the small hydropower plant sector in a slightly broader perspective, and in the context of the current economic situation and impact of the pandemic, one can surmise that banks and investment funds should be interested in seeking such investment alternatives to trading funds. This is especially since a well-designed facility makes a simple payback period of up to several years and an Internal Rate of Return (IRR) between a dozen and several dozen per cent achievable. To sum up, it is worth emphasizing that the broadly understood success in the case of such investments lies in using a comprehensive approach. It also involves using solutions developed based on experience gained in many projects – a successful power plant is not simply an engineering facility built according to a project, but rather a sequence of interdependent legal, formal, economic, technical and technological factors, each of which requiring that all others be taken into account.

However, it often happens that the start of an SHP investment is held up by administrative procedures, errors in the engineering documentation and unprofitable technological assumptions. In such situations, seeking the help of a professional design office is a great choice, as this can help identify optimisation opportunities and prepare an economically and technologically feasible investment project that meets all legal criteria and encourages the investors to proceed with its implementation.

## Holistic approach of the Instytut OZE

At our company, we utilise a holistic approach to projects and apply technically and financially optimal solutions, which ensures that the given project has a chance to achieve the rate of return expected by the clients. Scope of services:

- hydropower potential analysis,
- selection of optimal technology,
- SHP technical solution concepts,
- calculation of investment expenditures and operating costs; evaluation of the investment project based on profitability indicators (NPV, IRR, DPP).

The design office provides comprehensive services on the domestic market and shares both its good practices and extensive experience with such foreign entities as advisors, investors, design offices, general contractors and end clients. Instytut OZE is also capable of successfully transferring its vision of how to run an RSE business to foreign markets.

Instytut oze

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Photos and graphics come from the archives of Instytut OZE Sp. z o. o. company.

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- IOZE hydro offers **comprehensive** consulting services regarding investements in hydropower sector including **proprietary technology** supply and turn-key solutions.
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Stop Powodzi

Photo. Dikes on the Vistula River, Tarnobrzeg
*Source: State Water Holding Polish Waters*

# STOP FLOOD. STATE WATER HOLDING POLISH WATERS
# MINIMISE FLOOD RISK

**It is known that floods are natural phenomena and cannot be fully eliminated. However, the risk of negative consequences associated with floods can be effectively reduced. A number of activities and investment projects carried out by the State Water Holding Polish Waters serve this purpose in the most exposed to the flood risk areas in Poland. Moreover, since March 2020 State Water Holding Polish Waters in accordance with the Flood Directive and the Water Law Act update the Flood Risk Management Plans (PZRP).**

The enormous and tragic impact that water can have on the society as well as on the economy of a country can be illustrated by the example of two recent events – 1997 flood in Lower Silesia (the so-called Millennium Flood) and 2010 flood in regions of Podkarpacie, Lesser Poland, Lublin and in other cities located along the Vistula (when the culmination of flood wave on the Vistula was the largest in 160 years, i.e. since the measurements were first carried out). These two large floods caused losses that exceeded PLN 20 million. Tens of thousands of people got hurt (there were fatalities as well as mass evacuations from the flooded areas) and thousands of hectares of agricultural land were flooded. It became necessary to undertake intensive works related to the management of flood risk and other water resources. This situation coincided with the requirement to implement comprehensive flood planning and management imposed on EU countries by the Flood Directive (Directive 2007/60/WE). The directive indicated the need to prepare appropriate planning documents, start cooperation among institutions on border waters and develop coordination according to the Water Framework Directive. Poland initiated works concerning the implementation of the Flood Directive in 2011.

## PLANNING AND MANAGEMENT

According to the provisions of this document, the full planning cycle is completed with the flood risk management plans (PZRP) after drafting the preliminary flood risk, flood hazard maps and flood risk maps. Currently, all member states are in the process of reviewing and updating these documents, as a part of the 2nd planning cycle. In this respect, the key role in our country is played by State Water Holding Polish Waters.

## DOZENS OF INVESTMENT PROJECTS TO IMPROVE SECURITY

The scope of projects aiming at minimising the flood risk that are already implemented and that are still in various stages of implementation is impressive. Moreover, all those projects include both – the construction of new as well modernization of used or damaged hydrotechnical facilities and equipment that are of local and regional importance and that increase safety on a national scale. Below, you may learn about the examples of investment projects implemented by State Water Hold-

ing Polish Waters in the regions flooded in 1997 and 2010.

Due to its geographical location, **Podkarpacie** region is particularly vulnerable to floods. It is also a region where a number of activities of State Water Holding Polish Waters related to the modernisation and construction of flood protection infrastructure are taken. One of many results of such activities and efforts is e.g. the recently completed construction of 6km of new embankments of the Wisłoka River and the Kiełkowski Stream. This preventive measure covers the area of the municipalities of Mielec and Przecław. Moreover State Water Holding Polish Waters, apart from modernisation and building embankments on Wisłoka and Ropa Rivers near Dębica and Jasło, carry out the process of modernisation of flood protection infrastructure in the north of Podkarpackie Province. Over the last two years, in the Tarnobrzeg and Stalowa Wola counties, four investment projects related to rivers have already been complited are being implemented. Mentioned projects are realised at Vistula, Trześniówka and San. The total value of the works is PLN 140 million. Implementation of these projects will increase the level of flood protection in the area of 17,500 ha inhabited by over 28,500 people.

Several dozen investments were also implemented, which increased flood protection of the area **along the Vistula** in the Lublin, Mazovia and Kujawy-Pomerania provinces. This included, among others, construction and renovation of flood embankments, deepening the Vistula riverbed in many sections, repairs and reconstruction of pumping stations. The project "Improvement of Technical Condition and Flood Safety of Włocławek Barrage" was realized. The improvement of the technical condition of many facilities of the barrage as well as the improvement of flood safety for several thousand inhabitants and business entities are the result of these works.

State Water Holding Polish Waters also work on creating a comprehensive flood protection system on the Oder and the Vistula. The Odra River Basin Flood Protection Project (POPDO) and the Odra and Vistula River Basins Flood Protection Project (POPDOW) are financed from various sources, including the World Bank, the Council of Europe Development Bank and EC. The aim of these investment projects is to mitigate the flood wave and reduce the flood risk. It has been estimated that the areas surrounding places where these tasks and activities are proposed are inhabited by over 15 million people.

Among other things, the construction of flood embankments on the Central and Lower Oder (in Wrocław, Nowa Sól and Węzysko-Chlebowo) and the Upper Vistula (Sandomierz and Kraków) is being carried out. In June, the last finishing works concerning the Racibórz Reservoir were complited. The Racibórz Dolny investment project is a facility that will be filled with water in case of a flood only. When the wave comes, it will dam the water, securing an area of about 600 square kilometres from Racibórz, through Kędzierzyn-Koźle, Brzeg, Opole, Oława to Wrocław. The investment project will protect nearly 2.5 million inhabitants of the Silesia, Opole and Lower Silesia provinces. The investment projects which aim to protect the city of Słubice and Krosno Odrzańskie, as well as Kłodzko Valley, are being implemented. Numerous investment projects are also being carried out in order to increase flood safety of the inhabitants of Kraków and Skawina, municipalities of Sandomierz, Samborzec, Koprzywnia and the so-called Oświęcim Floodway System. As part of the POPDOW project, an IT system will be developed to monitor and manage the Oder and the Vistula River basins in southern Poland.

**Dolna Wisła and Żuławy Wiślane** (The Lower Vistula and the alluvial delta area of Vistula) are unique areas to our country and due to their specific character they require the implementation of appropriate hydrotechnical solutions related to the proper maintenance of proper hydrographic conditions both during drought and heavy rainfall. The project "Comprehensive Flood Protection of the Żuławy – stage 2" is of key importance for the Żuławy. It consists of five tasks: construction of storm surge gates on the Tuga River; reconstruction of the Przegalina barrage; reconstruction of the nineteen groynes on the Vistula; development of a flood risk monitoring system and evaluation of the effectiveness of the investment project "Reconstruction of the Vistula River mouth stage 1". Completion of the project is planned by the end of 2022. Its cost is PLN 126 million of which 85% is funded by EU.

## FLOOD RISK MANAGEMENT PLANS – A COMPREHENSIVE RESPONSE TO DILEMMAS CONCERNING FLOODS

State Water Holding Polish Waters are currently updating the flood risk management plans. The most important objective of this update is to reduce, through technical and non-technical actions, the potential negative effects of flooding on human life and health as well as on the environment, cultural heritage and economic activity. So far, preliminary flood risk assessment, flood hazard maps and flood risk maps have been drafted as a part of the 2nd planning cycle of the Flood Risk Management Plan. The aim of the preliminary flood risk assessment was to identify areas that are at risk of flooding, i.e. areas where there is a significant flood risk or where high risk is likely to occur. For such areas, flood hazard maps and flood risk maps have been updated. The need to update the maps resulted, among others, from the use of more accurate and up-to-date terrain data and updated hydrological data that includes the flows from recent years. These included, for the first time in Poland, maps concerning potential failures of damming structures. In total, the flood hazard maps will include about 29,000 km of rivers. In November as well as in December this year more Stop flood conferences is going to take place as a part of updating Flood Risk Management Plan. On 22 December 2020 six-months long public consultations of updated Flood Risk Management Plan will begin. Details and news are available at www.stoppowodzi.pl.

State Water Holding Polish Waters

# DAM REMOVAL IN THE BALTIC STATES: **MISSION (IM)POSSIBLE**

**Hydropower is unique amongst other renewable energy sources. When, for example, solar and wind energy farms serve sole purpose of electricity generation, hydropower can serve for several purposes. It creates additional social-economic benefits as dams and reservoirs can be also used for flood protection, irrigation, navigation, recreation, etc. On the other hand, dams are now also starting to be known as barriers.**

It is calculated that there is a dam or other hydraulic structure at almost every river kilometer in Europe. The reason that active movement for dam removal has started is that dams, which are closely associated with hydropower, block passage for fish migration and cause other environmental impacts. The number of dams that are scheduled for removal is constantly growing. Furthermore, sites with existing hydropower plants are no exception.

## ACTIONS WORLDWIDE

In Europe during last couple of decades from 3500 to 5000 various dams, weirs and culverts have been removed, mainly in France, Sweden, Finland, Spain and United Kingdom [1]. While in United States of America (USA) during the same time 1200 dams were removed (only during year 2018 – 82 dams) [2,3].

In Europe dam removal movement gained momentum after EU adopted Water Framework Directive in 2000 and will continue as only half of European rivers reached their environmental objectives. So far, the goal of the environmentalists is to remove old obsolete dams that are blocking considerable stretches of rivers for fish migration. In fact, in USA currently there are nearly 100000 dams and the average age of dam in USA is 60 years. Therefore, if it is more expensive to repair and maintain the dam in good condition than to remove it, it is going to be removed. For example, the biggest dam removal in European history began last year. 36 m high Vezins dam in France was built nearly a century ago to provide electricity generation. Instead of refurbishing the dam and hydropower plant the decision was made to remove it. Demolishing Vezins dam together with another dam will open a 90 km stretch of river for salmon migration, but the locals are now fearing possibility of future floods and loss of renewable electricity generation. Further, more smaller dams are scheduled for removal in the Netherlands, Denmark and Spain.

## ACTIONS IN ESTONIA

Estonia is the most active country of all three Baltic States in the dam removal actions. Currently in Estonia the project that will cost 15.2 mil. of Euros is carried out that will include removal of 3 dams in Pärnu River and 5 in its tributaries, including Sindi dam. The first Sindi dam on Pärnu River was built in 1832 for the wool factory, later was couple of times rebuild (last time in 1977). This 151 m wide and 4.5 m high dam was the first migration barrier within the river (located 14 km from its mouth into the Baltic Sea) so removing it will effectively open 3000 km of river network and 90 % of spawning areas in Pärnu River basin.

Discussions around removing Sindi dam has been in air for decades. But the project really started when in March 2015 Minister of Environment of Republic of Estonia decided to purchase the dam with land from the private owner. Previous owner had an idea to build a hydropower plant in Sindi, but the environmental laws had changed and currently it is prohibited to build or restore any hydropower plants on salmonid rivers in Estonia, so he decided to sell the dam to the government.

As the Sindi dam offered an artificial lake which local people enjoyed, project team came up with multiple visions for how the surroundings could look like once the dam was gone. The winner of final vision included excavation of the river to make it a bit deeper and easier to swim in. It also included plans to create pathways for walking along the riverbanks, leave a rapid for recreational kayaking. A favorable winter conditions for construction works in 2019 allowed to complete Sindi dam removal process and to start forming a rapid. Furthermore, two smaller dams, within the framework of this project, are also already removed.

## ACTIONS IN LITHUANIA

In Lithuania open debate on dam removal largely began in recent years concerning Belmontas dam in Vilnius. This dam is an old water mill site, built approximately 150 year ago and currently located in Pavilniai regional park where besides the environmental aspects, national industrial heritage

Photo. Sindi dam removal works in October 2019, completely removed dam in 2020

*Source: Ministry of Environment of the Republic of Estonia*

is also being preserved. The dam gradually went into disrepair and after one flood in 2016 it was badly damaged. As Vilnia River stretch in which Belmontas dam is located was also listed as ecologically and culturally valuable and is an important river stretch for migration of salmonid fish, robust calls from environmental NGOs and the Ministry of Environment started for the dam to be removed completely. Vilnius municipality and Department of Cultural Heritage under the Ministry of Culture stepped in, Belmontas dam was listed as national cultural heritage and was rebuilt in 2018.

Photo. Badly damaged Belmontas dam before reconstruction

*Source: Environmental Protection Agency of the Republic of Lithuania*

Bražuolė dam is the first dam that was removed in Lithuania during the summer of 2020. Bražuolė dam was a site of old water mill ruins. The initiative to remove this dam was started by environmental NGOs and the removal was financed by the funds raised by crowdfunding campaign. Bražuolė dam had no owner which meant that municipality was responsible for the maintenance of the dam and agreed that dam can be removed. The stretch of 25 km of free-flowing river was created for spawning habitats of salmonid fish after Bražuolė dam was removed.

The removal of second dam in Salantai is scheduled for 2021. Salantai dam is one of the hundreds of dams build in Lithuania during the Soviet times for agricultural and recreational purposes. The removal of this dam is planed following the Water area development program for 2017-2023 implementation action plan signed by Ministers of Environment and Agriculture of the Republic of Lithuania. The reasons for its removal are that after reconstruction in 1989 the original old water mill site dam was replaced with less environmentally friendly spillway that blocked the migration path of salmonid fishes and that formed Salantai pond already needs to be cleaned from sludge. The proposed solution is complete removal of the spillway, construction of small rapid and restoration of riverbed. Also, another much smaller pond will be built for the local community for recreational and fishing purposes.

Photo. Bražuolė dam before and after removal

*Source: Egidijus Kasiulis*

Photo. Salantai pond and spillway

*Source: Egidijus Kasiulis*

## FOOD FOR THOUGHT

Environmental NGOs that are working actively state that removal of dams is the only way of achieving good ecological status of waterbodies and that many countries in Europe are now removing dams as the economic, environmental and social benefits of doing it far outweigh the alternative of restoring the dams. The fact is also that many hydropower companies and specialists at the same time are failing to explain the multipurpose benefits of dams and reservoirs.

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# OPTIMAL OPERATION OF A LARGE HYDROPOWER RESERVOIR. **CASE STUDY OF KAUNAS HPP RESERVOIR**

**Operation of a large hydropower plant (HPP) does considerable impact to the environment. Many studies had shown that peaking hydropower plants, causing frequent and rapid changes in flow and water levels play and important role for aquatic organisms. Only way to mitigate the damage is to find optimal operation scheme of a reservoir that ensures environmental protection requirements and fulfills water users needs.**

The evaluation of the optimum hydropower plant operating policy is a nonlinear optimization problem with continuous variables. At this point no modern optimization techniques are used in order to optimize operation of Kaunas hydroelectric power plant and Kruonis pumped storage hydroelectric power plant. The main objectives of this paper are to analyze current operation scheme of Kaunas hydroelectric power plant, to identify its shortcomings and to suggest methods to improve it.

## OBJECT OF STUDY

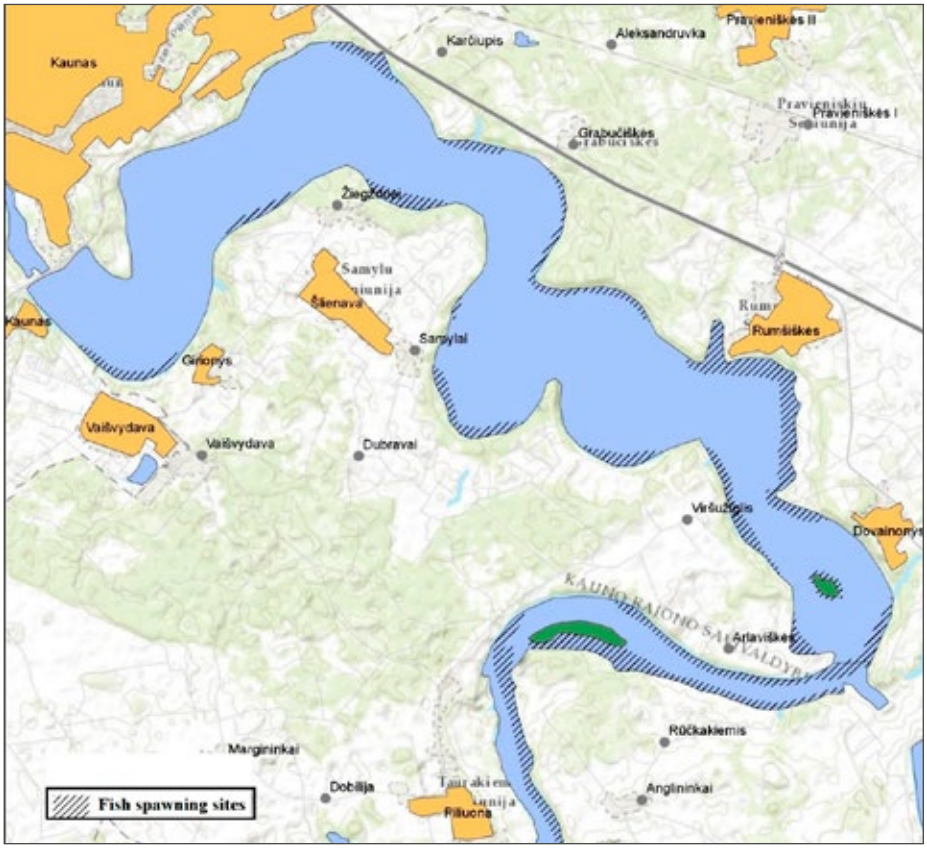
Kaunas HPP Reservoir is the largest artificial water body in Lithuania. Reservoir was made in 1959 by damming the Nemunas River. Area of Kaunas HPP Reservoir during normal water level (NWL) is 63.5 km² and the volume – 0.46 km³. Effective capacity of reservoir available for hydropower is 0.22 km³ [1]. Water resources of Kaunas HPP Reservoir are mainly used for generating power by Kaunas hydroelectric power plant (Kaunas HPP) and Kruonis pumped storage hydroelectric power plant (Kruonis PSP); recreation; navigation; irrigation; industrial water supply; industrial and recreational fishing. Water level dynamics of Kaunas HPP Reservoir is mostly dependent on operation of Kaunas HPP and Kruonis PSP. Kaunas hydroelectric power plant was built in 1960 on the Nemunas River. Power plant is located in the city of Kaunas, 224 km from the river mouth.

Current installed capacity of turbines is 101 MW, with average annual output of 351 GWh at 20.1 m water head [1]. Kruonis pumped storage hydroelectric power plant was built from 1978 to 1992. It's located on the southern part of the Kaunas HPP Reservoir near the small town of Kruonis. Upper basin area is from 306 ha at normal water level (153.5 m a.s.l.) to 292 ha at low water level (140.0 m a.s.l.). Volume of upper basin is – 48.78 mln. m³ at normal water level and 7.86 mln. m³ minimal water level. Depth of the upper basin is 15.5 m. Current installed capacity is 900 MW from four turbines. Water head is from 111.5 m to 93.6 m [1]. Average annual water flow of Nemunas River at Kaunas HPP is 284 m³/s, annual volume of water runoff – 8950 mln. m³. Average spring flood flow is 1045 m³/s [1].

## OPERATION RULES OF THE KAUNAS HPP RESERVOIR

Kaunas HPP and Kruonis PSP are trading on Nord Pool day-ahead market. "Gamybos optimizavimas" (Production optimization) Ltd. mediates with power plants and manages sales of electricity they produce on Nord Pool market. Operation schedules are made by analyzing Nord Pool day-ahead market. "Gamybos optimizavimas" Ltd. use real time data from Nemajūnai water measuring station, which is located 113 km upstream of Kaunas HPP. It takes about one day for the water flow from Nemajunai to reach Kaunas HPP and there's no significant inflow on the way, so they can make quite accurate estimations of the water flow by Kaunas HPP for the next day. With this data "Gamybos optimizavimas" Ltd. makes operation schedules for hydroelectric power plants. This method works, but they don't forecast water flow of the near future, which suggests that water resources are not used optimally. Power generation, environmental protection and fulfilment of other reservoir users needs are opposing tasks and multi-objective optimization models should be used in order to optimize operation of hydroelectric power plants. In further research multi-objective optimization models such as HEC-ResSim and MIKE HYDRO Basin will be used in order to check if Kaunas HPP and Kruonis PSP are run optimally. Operation of Kaunas HPP and Kruonis PSP are restricted by reservoir exploitation rules. Kaunas HPP Reservoir exploitation rules were established in 2016 by the Lithuanian Institute of Energy. Exploitation rules of the Kaunas

Fig. 1. Fish spawning sites of Kaunas HPP Reservoir [3]



HPP Reservoir state that normal operation levels of the reservoir are between 43.5 – 44.4 m a.s.l. During fish spawning period operation of Kaunas HPP is restricted. Fish spawning period is between the 1st of April and 30th of June. Reservoir exploitation rules state that during fish spawning period water level altitudes of Kaunas HPP Reservoir must be between 43.7 and 44.0 m a.s.l. Maximum difference of 10 cm between the highest and the lowest daily water level is allowed. Daily water level change of 20 cm is allowed if the owner of Kaunas HPP and the reservoir – "Lietuvos energijos gamyba" Ltd. fulfills research on the state of the environment according to the Environmental Research Program and compensates for environmental damage [1].

These rules are meant to protect the fish spawning and nursery grounds. There has been plenty of studies that were investigating water level fluctuation impact on the fish habitats. For example, study on the factors that influence stranding of wild juvenile brown trout show, that water level ramping rate speed up to 10 cm/h in an artificial stream does not have impact on the fishes. Water level ramping speed of 10-20 cm/h does have possible impact on stranded juvenile fishes and ramping speed higher than 20 cm/h has strong impact [2]. Current exploitation rules of Kaunas HPP Reservoir strongly limit operation of hydroelectric power plants. For this reason, further research on the impact of water level changes on the fish spawning and nursery grounds of Kaunas HPP Reservoir will be conducted.

## REMOTE SURVEY METHODS OF FISH SPAWNING SITES

During the fish spawning period, the main concern is the area of fish spawning sites. Previous research shows, that if water lever in Kaunas HPP Reservoir decreases by 0.1 m, total fish spawning area decreases about 3.96%, if water level decreases 0.2 m, total fish spawning area decreases by 7.91% and if water level decreases 0.3 m, total fish spawning area decreases by 11.9% [3,4]. The use of synthetic aperture radar (SAR) data is presently well established in operational services for flood management. In this case satellite images were used to track changes of the fish spawning site areas. During the research Sentinel-1 mission satellites images were used. Sentinel-1 satellites perform C-band imaging, which allows to acquire imagery regardless of the weather. With the vast database of satellite images every 2-4 days, it's possible to track and analyze changes of fish spawning areas that occur. In this study, dual polarized (VV and VH) of 5 × 20 m resolution (10-m pixel spacing) Ground Range Detected (GRD) Sentinel-1 SAR datasets were acquired in Interferometric Wide Swath (IW) mode. Ten cases with the various water levels of the Kaunas HPP Reservoir were analyzed. All images have been processed to generate calibrated and terrain corrected Sentinel-1 SAR images using Sentinel's Application Platform (SNAP). Processed images were classified using ArcGIS ArcMap software. After classification pixels that represent water were filtered and polygons of Kaunas HPP Reservoir water surface area created. Results show how fish spawning area changes when water level changes in the reservoir. For the second part of the

Fig. 2. Observed changes of the fish spawning site area using Sentinel-1 satellite images

*Source: Own figure*

research satellite images of Sentinel-2 were used. These images carry much more information than Sentinel-1 – images of Sentinel-2 has 13 bands in the visible, near infrared, and short wave infrared part of the spectrum. These images are sensible to clouds and their shadows, only three cloud-free images were obtained in the period of investigation. Sentinel-2 images allows much more research possibilities from the images. McFeeters (1996) introduced Normalized Difference Water Index (NDWI), which makes use of reflected near-infrared radiation and visible green light, for assessing quantity (e.g., surface area) and quality (e.g., turbidity) of water resources [5]. Xu (2006) modified NDWI by substitution of middle infrared for near-infrared in NDWI for enhancing open water features while efficiently suppressing and even removing built-up land noise as well as vegetation and soil noise [6]. Similar technique – Normalized Difference Vegetation Index (NDVI) was used in order to classify Sentinel-2 satellite images using QGIS application. Semi-automatic classification method was used as well, but NDVI gave the best results when classifying water surface. Using Sentinel-2 images it's possible to observe not just water surface area changes, but by calculating NDVI and NDWI it's possible to observe changes of water quality as well.

## FINAL REMARKS

Operation of Kaunas HPP and Kruonis PSP is yet to be optimized. Nord Pool dictates operation scheduling for both power plants, but without water flow forecasting water resources are not used optimally. Forecasting is most crucial when preparing for the flood periods. In further research optimization models will be used. As it stands for now, operation of Kaunas HPP Reservoir is strictly restricted by reservoir exploitation rules, especially in the fish spawning period. Various alternatives will be calculated, by letting power plants work in higher amplitude of water levels and assessing impact on the environment and electricity generation. Study of remote survey on the changes of the fish spawning site areas using satellite images will be continued after creating digital elevation model (DEM) of Kaunas HPP Reservoir and validating current results.

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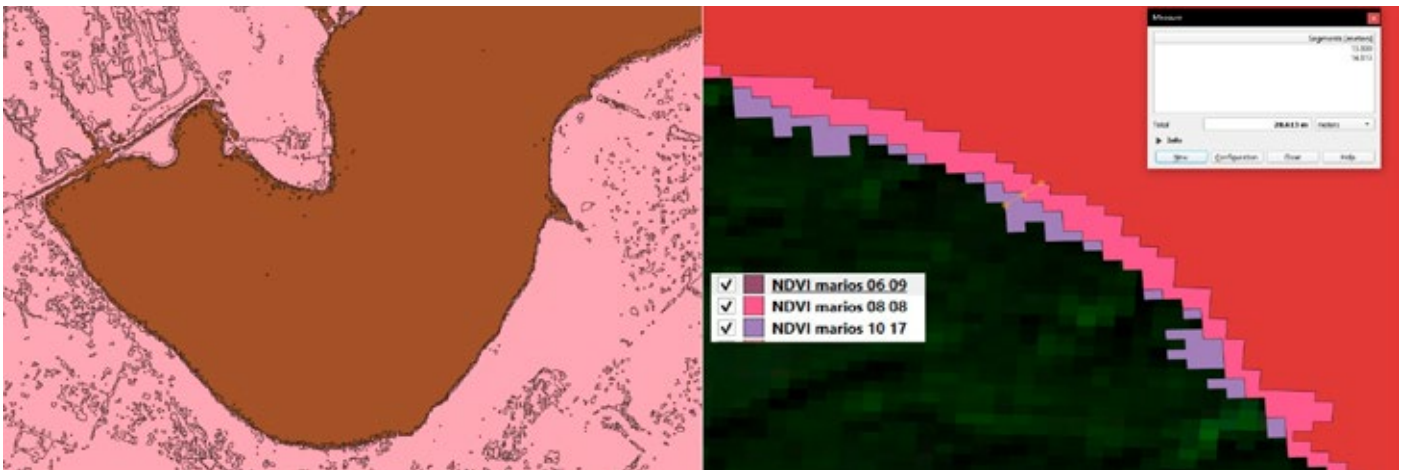
Fig. 3. Observed changes of the fish spawning site area using Sentinel-2 satellite images

*Source: Own figure*



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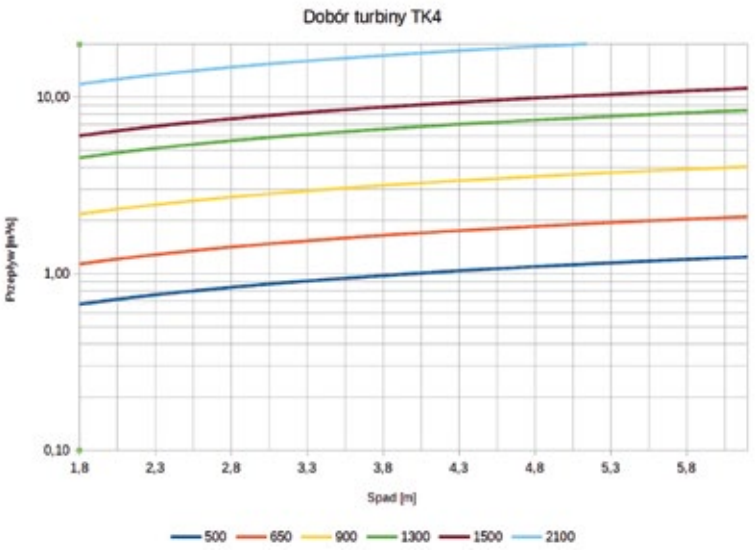


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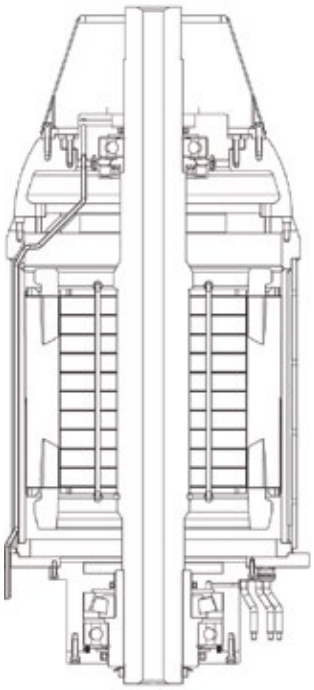

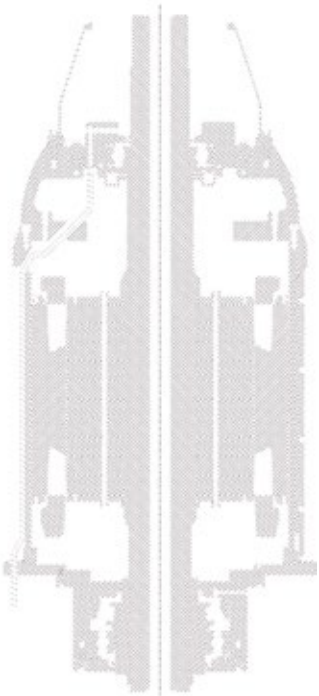

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# SUSTAINABLE HYDROPOWER TO ADVANCE **CLIMATE ACTION**

**Sustainable hydropower can help governments to limit the impacts of climate change, provided policy-makers and planners adopt the right tools. The year 2020 was supposed to be a milestone for climate action. It's the five-year landmark of the 2015 Paris climate agreement and the first test in countries' willingness to strengthen their targets for climate action.**

Governments were expected to put forward more ambitious short-term plans for 2030, and long-term targets for 2050, to decarbonise economies and keep global temperatures below 2°C.

As the world reels from the impact of the Covid-19 pandemic, it seems many vital climate initiatives have been put on hold. The UN Climate Change Conference (COP 26) and the negotiation sessions leading up to it have been postponed to 2021. While governments have justifiably focused their efforts to address the current health crisis, the climate crisis has not gone away. Decades of largely unabated carbon emissions continue to warm the atmosphere and increase surface temperatures. The events of the year should not be seen as an excuse to scale back climate ambition, but instead as an opportunity to accelerate the green economy transition.

*Source: iStock, DedMityay*

## THE PARIS AGREEMENT AND HYDROPOWER

In line with the Paris Agreement targets, governments should design environmentally sustainable recovery packages promoting cleaner and lower-carbon technologies. As the world's largest source of renewable generation capacity, hydropower has a key role to play in this transition. According to the International Renewable Energy Agency's recently released Global Renewables Outlook, an additional 850 GW of newly installed hydropower capacity is required by 2050 to support the carbon reduction commitments of the Agreement. Hydropower provides a double benefit in the fight against climate change. The first benefit is its contribution to climate change mitigation. Hydropower not only provides clean energy with significantly lower lifetime greenhouse gas (GHG) emissions than most other technologies, it also supports the increased integration of variable renewable sources through its flexibility services. It therefore reduces our reliance on fossil fuels, avoiding four billion tonnes of additional GHG emissions per year versus coal fired generation, according to IHA's 2020 Hydropower Status Report.

The second benefit is hydropower's ability to provide water services and act as a storage buffer against climate change, or in other words, its contribution to climate adaptation. Hydropower provides water storage capacity that can be used for irrigation, drinking water supply, flood control, navigation and other services. Increasing water storage capacities is imperative to adapting to a warmer world and meeting growing water demand. Although hydropower plants help tackle climate change, like other forms of infrastructure they can be vulnerable to variations in climatic conditions. Changes in regional rainfall, fluctuations in temperature, increasing frequency of droughts and extreme weather events all significantly impact river discharge. Increased or reduced river discharge affects water availability and regularity, and in turn, hydropower generation. Such uncertainty in future hydrological conditions pose conceptual challenges to hydropower managers.

## ASSESSING HYDROPOWER'S CLIMATE MITIGATION BENEFITS AND RESILIENCE

To support hydropower developers in coping with climate change, the internationally recognised Hydropower Sustainability Tools were updated in 2018. These now include a dedicated assessment topic on climate change mitigation and resilience, to bring greater clarity and guidance to the industry. The Tools were developed by a multi-stakeholder group of governments, companies, social and environmental NGOs and international financial institutions. The climate change topic defines international good and best practice and helps developers assess a project's ability to deliver climate mitigation benefits, its resilience to climate change and overall contribution to climate adaptation. For climate mitigation, the Tools require hydropower projects to assess their GHG emissions intensity. To meet good practice, the emissions intensity needs to be below 100 $gCO_2e/kWh$ over the lifetime of the asset. GHG emissions from a reservoir can be estimated using the G-res Tool – a web-based tool developed by IHA, UNESCO and the Université du Québec à Montréal for hydropower companies and researchers to estimate and report net emissions from a reservoir.

For climate resilience, good practice requires projects to assess climate change risks and implement structural and operational measures. Hydropower infrastructure must be designed, developed and operated to be resilient to a range of climate futures. Guidance on how to incorporate climate resilience into hydropower project planning, design and operations can be found in the Hydropower Sector Climate Resilience Guide.

## UNLEASHING HYDROPOWER'S POTENTIAL

Despite recognising the benefits of hydropower deployment, policy-makers and developers sometimes struggle to utilise

the full potential of hydropower in climate action. In fact, much of the world's hydropower potential remains untapped, especially in developing countries where reliable and affordable clean energy is in short supply. So what is hindering the development of hydropower where it is most needed? One of the biggest challenges is related to hydropower's high initial capital costs and long payback periods. Obtaining financing for hydropower projects is challenging, particularly at the vital early planning phase.

However, the rapid emergence of the green bond market offers hydropower an additional avenue for financing. In 2016, the Climate Bonds Initative established the Hydropower Technical Working Group, to develop a rigorous screening process for hydropower projects that provide climate mitigation and adaptation benefits in line with the goals of the Paris Agreement, to be eligible for green bonds. A key plank of the proposed hydropower-specific qualification criteria is the Hydropower Sustainability ESG Gap Analysis Tool.

The tool, which is governed by the Hydropower Sustainability Assessment Council, is used to check for gaps against good practice on relevant environmental, social and governance topics. It includes a gap management plan to improve processes and, in the context of climate change, enables project proponents to consider and address many of the challenges facing hydropower development. When developed responsibly and following international good practice, as demonstrated by the Hydropower Sustainability Tools, hydropower is an important technology for limiting the impacts of climate change. Regardless of the setbacks of 2020, governments should aim to accelerate their climate action efforts while taking into account the benefits of hydropower development. The contribution of hydropower in achieving the Paris Agreement needs to be considered not only in terms of avoiding GHG emissions, but also in promoting climate-resilient infrastructure that can provide a range of climate adaptation services.

## A SENSE OF URGENCY

As the Intergovernmental Panel on Climate Change (IPCC) reported, we have 10 years left before we reach an irreversible tipping point. The time window for effective climate action was always going to be tight; perhaps the Covid-19 pandemic is an opportunity to accelerate decarbonisation efforts to ensure that emissions begin to fall. The coming 15 months ending with COP 26 in Glasgow will be critical in mobilising the coordinated action needed in the fight against climate change. There isn't much time left to do the right thing, so let's start now. Sustainable hydropower is ready to play its part.

Amina Kadyrzhanova
Junior Sustainability Specialist
International Hydropower Association

# RESEARCH AND DEVELOPMENT WORKS AT **WTW POLAND**

**Due to rapid growth of the company's production, it was necessary to define a new development strategy. Its main objective is to construct and sell high-quality Kaplan turbines whose parameters are comparable to the products of the best companies that manufacture turbines for small hydropower plants.**

For this reason WTW Poland Sp. z o.o. is implementing a project under the name "Development of high-performance Kaplan's water turbines, designed for low, medium and high head". The project is co-financed by the European Union as part of the Intelligent Development Operational Programme 2014-2020 from the European Regional Development Fund. The project is implemented as part of the National Centre for Research and Development competition: Fast-Track Design.

## GUIDELINES FOR TYPE SERIES

The outcome of the planned research works will be the development of solutions enabling to increase the level of efficiency of a turbine equipped with a 3 or 4-blade rotor in all ranges by an average of 4 pp and the development of a turbine with a 5-blade rotor with the same degree of efficiency. Increasing efficiency of the new product by 4 percentage points in all ranges will result in achieving the maximum average efficiency of the new product by no less than 91%. As a result of conducted R&D works, WTW Poland Sp. z o.o. will introduce the results of these works to its own business activity by starting the production of innovative Kaplan turbines with increased hydraulic efficiency, increased speed and reduced cavitation coefficient.

As part of the project, the following types of Kaplan turbine series have been developed for the purpose of the driving head up to 24 m with an efficiency at a reference flow not less than 91% for 1m diameter rotor:

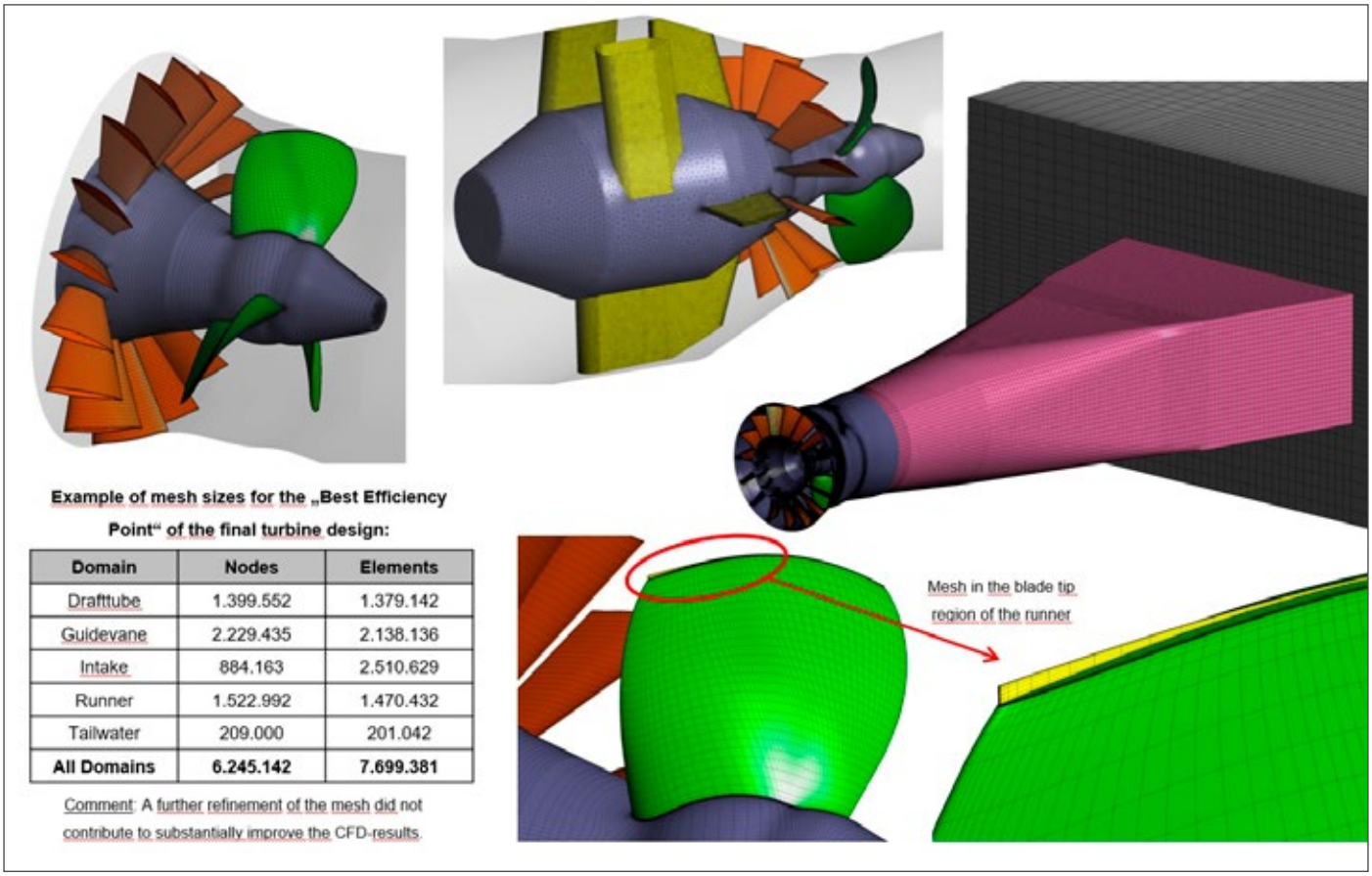
a) Turbines with axial guide vane and three-blade rotors for heads up to 5m
b) Turbines with axial guide vane and four-blade rotors for heads up to 12 m
c) Syphon tubular turbines with axial guide vane and four-blade rotors for heads up to 6 m
d) Turbines with radial guide vane and four-blade rotors for concrete spiral chambers for heads up to 12 m
e) Turbines with radial guide vane and five-blade rotors for steel spirals for heads up to 24 m.

Although the company's potential allows it to design a turbine of any rotor diameter in any configuration in a short time, it was nevertheless decided to develop series of types. The decisive factor was necessity of providing casting models of all elements for individual designs; it would prolong the turbine construction time and increase its costs. The series of types were designed in such a manner that the same casting models can be used for different types and different turbine configurations. It is needless to underline the advantages of this solution.

## IMPLEMENTATION

In order to obtain high parameters of the flow systems, including guide vanes and rotors, WTW has initiated cooperation with one of the most reputable institutes engaged in research of water turbines in

Fig. Observed changes of the fish spawning site area using Sentinel-1 satellite images



Western Europe - the HFM Institute in Graz (Austria). This institute successfully implements its objectives and for some types of turbines it indicates much higher efficiency parameters than it was originally planned (a turbine with a radial guide vane and a four-blade rotor at the best efficiency point BEP achieved efficiency of 93.1%).

## THE USE OF COMPUTER-AIDED DESIGN TO GENERATE DOCUMENTATION.

It is planned to stage the turbines in each series every 14% and develop 24 rotors for each type of turbine. It is easy to calculate that development of documentation for the rotors, their chambers and guide vanes would require piles of documentation for all types of turbines. This would be a big job for a big design agency. Application of the series of types will not reduce the number of rotor blade models - it will have to be provided for each type of turbine of the series. However, the number of models of hubs, documentation of chambers and guide vanes as well as their blades will be much smaller.

WTW has already used the idea of "intelligent" series and computer aided design in earlier projects. For the development of documentation of rotor blades, hubs and their mechanics, guide vanes, including blades and their bearings, computer programs developed by WTW to operate in the 3D software environment were used by the company. On the basis of the database that contained detailed information, such a program generates a set of 3D models for a given project. The parts are assembled by the program and as a result we get assemblies ready to be inserted into the design. After completion of this project, it will be possible to generate an entire rotor, its chamber and an entire guide vane in a 3D program for each of the turbines. In case of typical solutions, the automation will also include inlets and suction pipes of several types. The guidelines for the design of the remaining elements will also be precisely defined as a result of modifications to the existing solutions in WTW and interactive calculations of flow systems on individual turbine types made in consultation with the cooperating Institute.

Photo. Dispatch of inlets and suction pipes

## WORK PROGRESS

The following types of turbines have now been developed:

a) Turbines equipped with axial guide vane and three-blade rotors with a speed of nq = 270 and a cavitation coefficient lower than 1.5 for heads of up to 5 m - bulb-type and PIT turbines. Parameters of the turbines have obtained the expected values - the maximum efficiency of a turbine with rotor diameter d = 1 m is 91.1%.

b) Turbines equipped with axial guide vane and four-blade rotors with speed nq= 215 and cavitation coefficient less than 1.15 for heads from 3 to 7 m - bulb-type and PIT turbines. Parameters of the turbines exceed the design specifications. Maximum efficiency of a turbine with rotor diameter d = 1 m is 92.7%.

c) Turbines equipped with axial guide vane and four-blade rotors with speed nq = 165 and cavitation coefficient less than 0.75 for heads from 6 to 12 m - bulb-type, PIT, S and Z type turbines. Parameters of the turbines significantly exceed the design specifications - maximum efficiency of a turbine with rotor diameter d = 1 m is 92.8%.

d) Turbines equipped with radial guide vane and four-blade rotors for concrete spiral chambers with speed nq = 190 for heads up to 6 m and cavitation coefficient less than 0.95. Parameters of the turbines exceed the design specifications. Maximum efficiency of the turbine with rotor diameter d = 1 m is 92.0%.

e) Turbines equipped with radial guide vane and four-blade rotors for concrete spiral chambers with speed nq = 160 for heads from 6 to 12 m and cavitation factor less than 0.725. For this type of turbine the highest efficiency at BEP point of 93.1% is achieved - for turbine diameter d = 1 m.

For all the above mentioned turbines, computer programs have been written to enable automatic generation of:

- hubs, blades and all control elements of rotor with diameters according to the series of types
- bodies, blades and guide vane bearings
- rotor chambers
- casting models of rotor hubs and blades as well guide vanes.

A series of turbines with a radial guide vane and a five-blade rotor, powered by steel spirals with a speed of nq = 125 for heads from 12 to 24 m, is available. Preliminary calculations offer expectations of achieving maximum efficiency exceeding 93%.

## THE FIRST IMPLEMENTATION OF A NEW SOLUTION

A contract has been signed for the construction of the first six turbines with 1080 mm rotor diameter three-blade rotors as part of the new series. Works were commenced in February 2020. Casting models of the hub and rotor blades along with guide vane blades were made. Once all the castings were made, the machining began. Simultaneously, welded components such as turbine bodies, guide vanes and rotor chambers have been manufactured and processed. Suction pipes and water inlets to the turbines were delivered to the construction site as they will be concreted first. The commissioning of SHPP is planned in the first quarter of 2021 (location of SHPP - Opole Province).

Grzegorz Wiszniewski
The President of the Management Board of WTW Poland sp. z o.o.

Photos and graphics come from the archives of WTW Poland Sp. z o. o. company.

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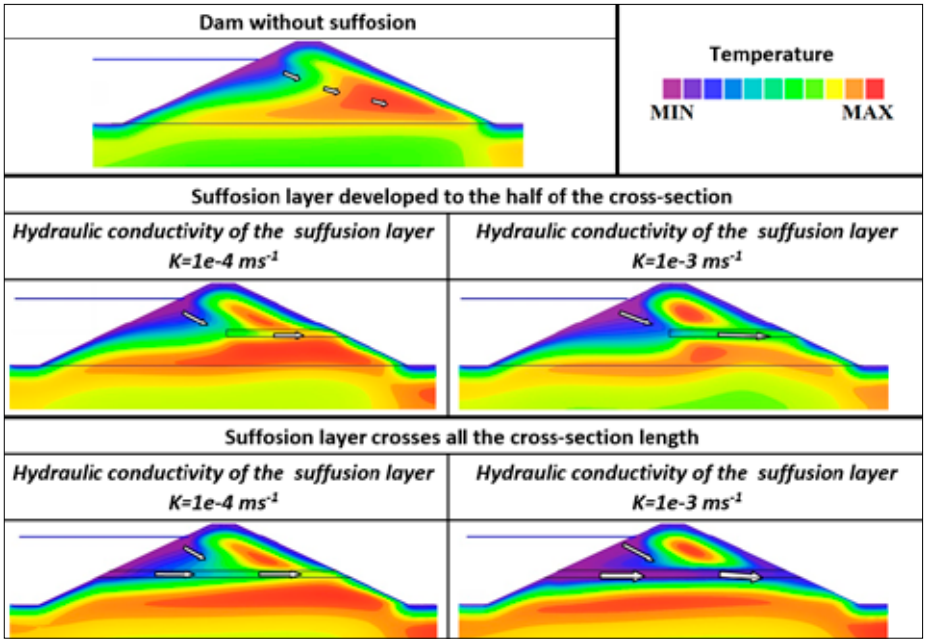
European Union
European Regional Development Fund

# THERMAL SENSING METHOD FOR DETECTION AND ANALYSIS OF LEAKAGES AND INTERNAL EROSION

**Innovative technology for thermal sensing of seepage, including leakages and internal erosion, in the soil has been developed by Neostrain for almost a decade as part of several R&D grants and implementations. Innovative MPointS and MCableS passive-active sensors, which are used for linear monitoring of structures, have been developed including advanced data analysis algorithms and algorithms for detection of destructive processes from such data.**

The technology may be used to monitor hydraulic structures, earth dams, levees, dikes of canals, and in geotechnics for the detection of leakages in deep excavations, leakages in pipelines, and scouring of foundations. A change in soil moisture, the occurrence of seepage, and increased water seepage velocity in the soil contribute to a very significant increase in thermal changes in the soil. As a result, thermal tests make it possible to analyse seepage in earth dams, dikes of canals, and levees. As the seepage velocity is affected by internal erosion, thermal tests are also used to obtain indirect information about the course and dynamics of internal erosion. Internal erosion generates characteristic thermal disturbances. There are two methods for the analysis of seepage, including leakage detection: passive and active.

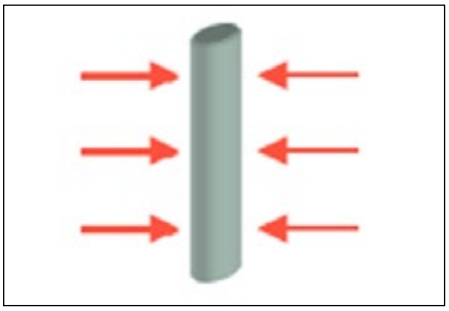
Fig. 1. Example of the impact of internal erosion development on the temperature field in an earth dam




## THERMAL PASSIVE METHOD

The passive method includes the measurements and analysis of natural soil temperatures. In the absence of seepage, there is only the heat conduction process. However, the change in soil moisture alone has a significant effect on the thermal front velocity and disturbs the local thermal soil field. When the seepage starts, the heat is transported with the flow of water. This process is referred to as advection and generates much more heat flow than that caused by the conduction itself. But the higher the water velocity, the more heat is transported (exponentially), generating more and more disturbances in the local thermal field. The occurrence of a seepage, causing a change in soil moisture and, especially, causing the flow of water or its acceleration, may, as a result, be easily detected. Depending on their analysis method, long-term measurements of natural soil temperatures – lasting from several weeks to several months – allow seepage velocity to be calculated at the sensor location.

Fig. 2. Passive method – measurements and analysis of natural soil temperatures



## THERMAL ACTIVE METHOD

The active method involves the analysis of the heating/cooling cycles measurements of the thermal passive/active sensor, which is integrated with the microheater. The higher the soil moisture or the higher the seepage velocity, the lower the sensor cooling and the lower the sensor temperature increase as a result of heating. The analysis of sensor cooling changes allows leakage locations to be detected. The current generation of MPointS passive/active sensors by Neostrain is also calibrated in the laboratory for different seepage velocitys and measurements with the active method allow the seepage velocity to be determined. Compared to the passive method, the active method is independent of changes in external thermal conditions. Measurements take only several hours. It requires an additional power source, e.g. a battery or connection to the mains.

> *The thermal method for analysis of water flow in the soil is based on coupled relations between the processes of heat and water transport.*

## MPOINTS – INNOVATIVE, MULTI-POINT THERMAL PASSIVE/ACTIVE MEASUREMENT SYSTEM

The MPointS (Multi Points Thermal Sensing) thermal passive-active sensing system is an innovative and optimised hardware and

Fig. 3. Active method - measurement and analysis of the heating/cooling cycle temperature of the sensor integrated with the microheater

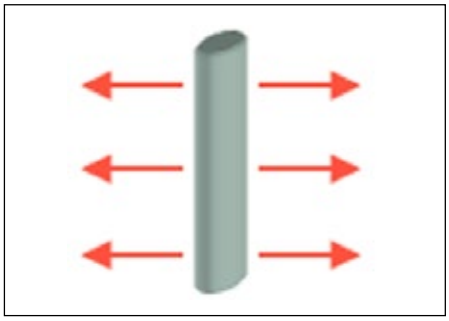


Fig. 4. Example of active measurements by MPointS sensors, (1) Leakage, (2) Increase in moisture, (3) Dry soil in the levee body

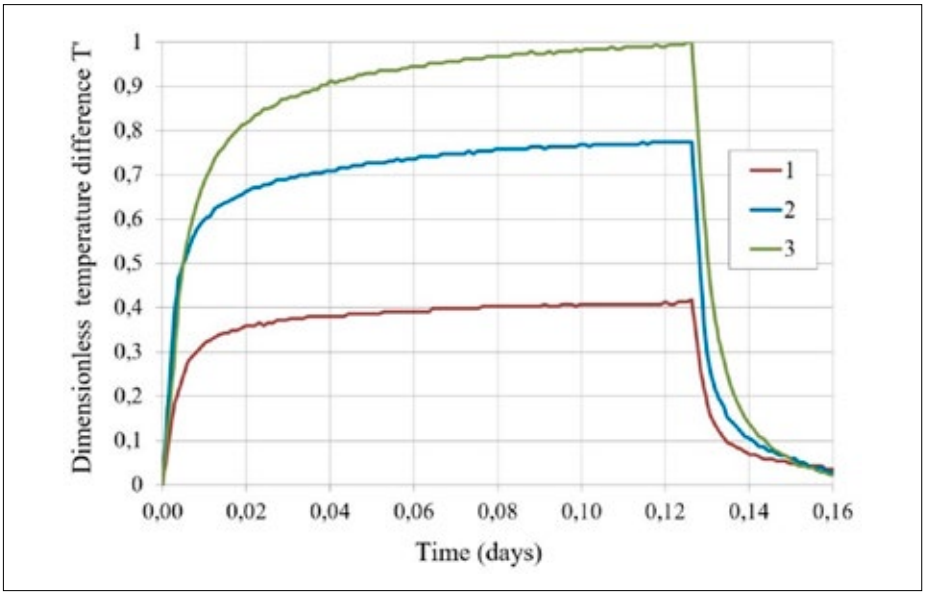



Fig. 5. Locations of MPointS sensors on the levee for linear thermal sensing of leakages, at two levels – levee body and levee foundation

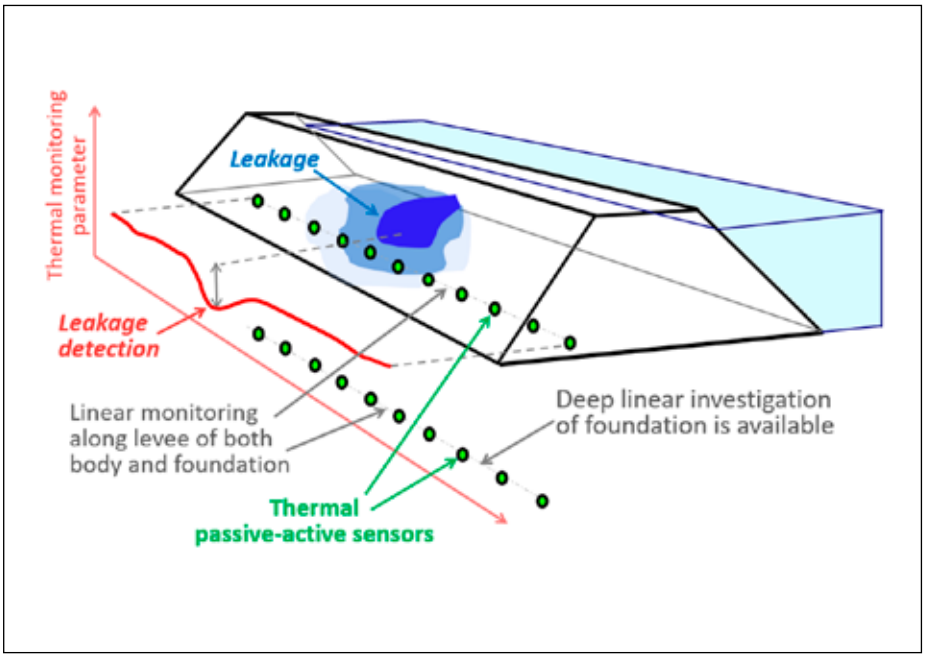
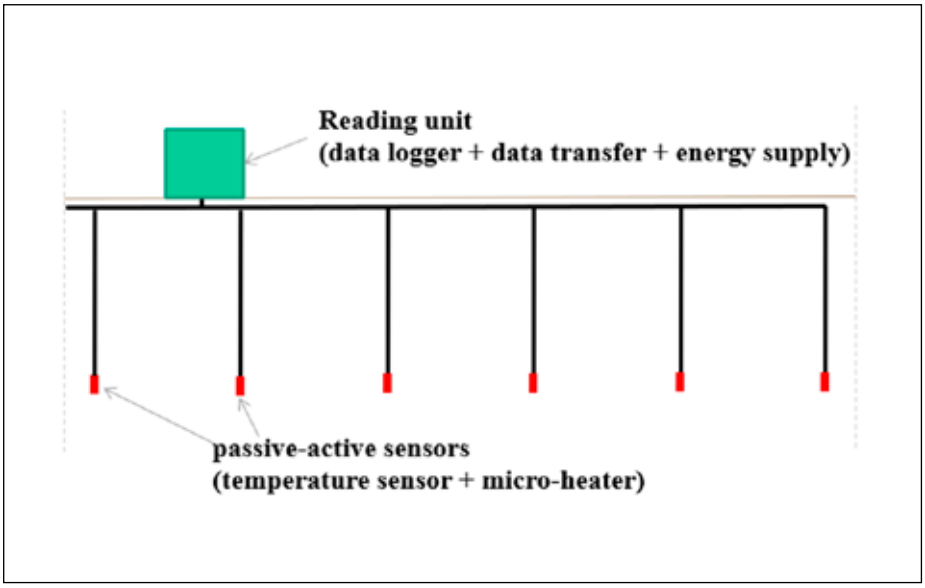



Fig. 6. Diagram of the MPointS system section, linear thermal sensing of leakages, at two levels – levee body and levee foundation




software solution for thermal detection of leakages and in-situ measurements of the seepage velocity. Its main features include:

- fast, structure-safe installation without excavations;
- linear measurements along a levee or in any other 2D or 3D arrangement;
- thermal passive-active sensors;
- detection of leakages and assessment of their intensity;
- seepage velocity measurement.

The characteristic feature of the MPointS technology is thermal passive-active sensors used to make thermal passive, and especially active, measurements. The sensor is equipped with a temperature sensor integrated with a specially designed heating system, which allows thermal passive and active tests to be carried out.

The current second generation of MPointS sensors was calibrated in the laboratory for different water seepage velocity values and offers the possibility of determining the local water flow velocity around the sensor in the soil. The installation of the MPointS sensing system does not require excavations and includes driving in successive sensors in a sequence, next to each other. This allows leakages along the structure length to be monitored linearly and quasi-continuously. Depending on the needs, MPointS sensors may also be installed based on any quasi-2D or quasi-3D arrangement.

The spatial resolution of the sensors is determined individually for each structure, including soil parameters and potential scenarios of internal erosion and seepage processes. This offers the possibility of optimising system costs while maintaining quasi-continuous measurements in the area. Sensor installation does not require excavations and is performed by simply driving sensors in or driving them in using vibration when the depth is up to several metres using lightweight drills and power hammers; no transport vehicle is needed. After installation, the diameter of the holes is very small, i.e. several centimetres. Once installed, the sensors are sealed with bentonite granules. As a result, the installation of the sensors does not cause discontinuities and leakages of the tight layers of the foundation. Therefore, it does not create any velocity seepage paths that could lead to the development of internal erosion, in particular piping.

Fig. 7. Installation of the MPointS system, making only a shallow ditch to hide the cables. The cables may also be led through cable trays located on the ground.

## MCABLES – MULTI-POINT THERMAL PASSIVE/ACTIVE MEASUREMENT CABLE

A multi-point thermal passive/active measurement cable is a system of passive-active sensors as well as power and communication lines integrated into one cable. Its main features include:

- passive/active measurement cable;
- linear measurement for vertical levee body and foundation testing;
- application in long-term thermal passive measurements in piezometers – their analysis makes it possible to detect leakage zones, while numerical modelling is used to determine the seepage velocity and detect erosion zones;
- fast measurements, taking only several hours, in boreholes filled with bentonite drilling mud make it possible to identify leakage zones in the soil.

It is used to make thermal passive measurements in existing piezometers or to make active measurements in deeper boreholes – up to several dozen metres deep. In the latter case, it may be used, for example, to detect zones with more intense water seepage and leakages during geological surveys. The MCableS cable is placed in a test borehole still filled with bentonite drilling mud after a geological survey and the heating/cooling cycle is performed. The measurement process takes several dozen minutes.

## EXAMPLES OF NEOSTRAIN PASSIVE--ACTIVE TECHNOLOGY APPLICATIONS

### Analysis of internal erosion in the Kozłowa Góra dam foundation and determination of seepage velocity

Fig. 8. MCableS - multi-point thermal passive/active measurement cable

Fig. 9. Kozłowa Góra dam and example of temperature measurements using MPointS sensors in piezometers

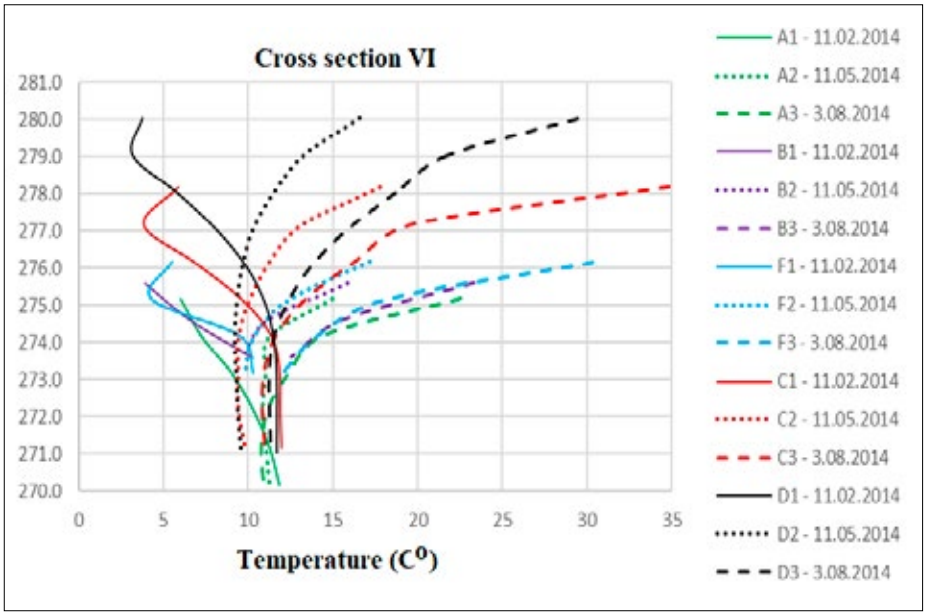



Fig. 9. Kozłowa Góra dam

The Kozłowa Góra dam is an earth dam located in Poland. A number of seepage and internal erosion problems were observed in the dam including the local lowering of the bank top, scouring of soil particles into the surrounding trench. MPointS sensors were installed on a 200-metre section with the highest intensity of seepage and internal erosion processes to detect a zone with the highest seepage intensity. In addition, MCableS sensors were installed in the existing piezometers to analyse seepage and internal erosion processes in the dam foundation. Passive measurements taken by the MCableS sensors were analysed using thermo-hydraulic numerical modelling. As a result, a leakage of the tight wall inside the dam foundation was found and the seepage velocity in the foundation was determined. At the same time, modelling excluded the existence of intensive internal erosion processes in the foundation. Virtual simulations of various scenarios of the development of internal erosion processes and their impact on the thermo-hydraulic field of the structure were additionally performed. These results were impossible to obtain with any other currently existing test method.

### Leakage detection in a Dutch sea levee

The MPointS technology was also used in 2018 for a Dutch North Sea levee. Measurement systems were installed in several locations along the levee with different cross-sections and geology. Each system included two MPointS vertical measurement profiles installed in the foundation on the landside side of the levee and a module for power supply, control, and data collection and transmission. Before that, the sea levee had had only single piezometers located 300-400 m apart.

A zone with more intensive seawater seepage was detected in the levee foundation. In addition, the technology made it possible to show the moment when the direction of water flow changes and an increase in the flow rate in correlation with tidal changes in the North Sea.

### Detection of leakages in deep excavation support

The MCableS technology was used to detect leakages in a deep excavation support on one of the construction sites in Poland in 2018. After building diaphragm walls over

Fig. 12. Dutch North Sea levee where MPointS measurement systems were installed

Fig. 10. Example of a numerical analysis of the thermal field of the Kozłowa Góra dam for the existing state, allowing us to conclude that there is no intense erosion process in the foundation at the moment

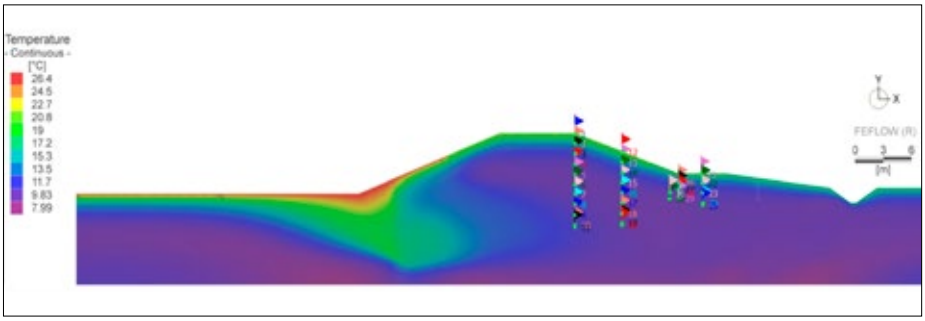



Fig. 11. Example of a simulation of a dam thermal field for a virtual scenario assuming that there is an internal erosion layer with increased permeability in the foundation.

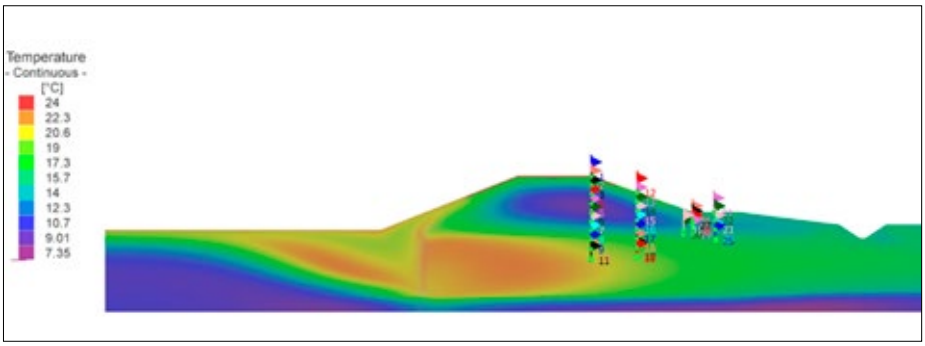



Fig. 13. Scheme of thermal leaks detection in the walls of the future deep excavation. Then injection of leaks from the surface is carried out and next safe execution of excavation

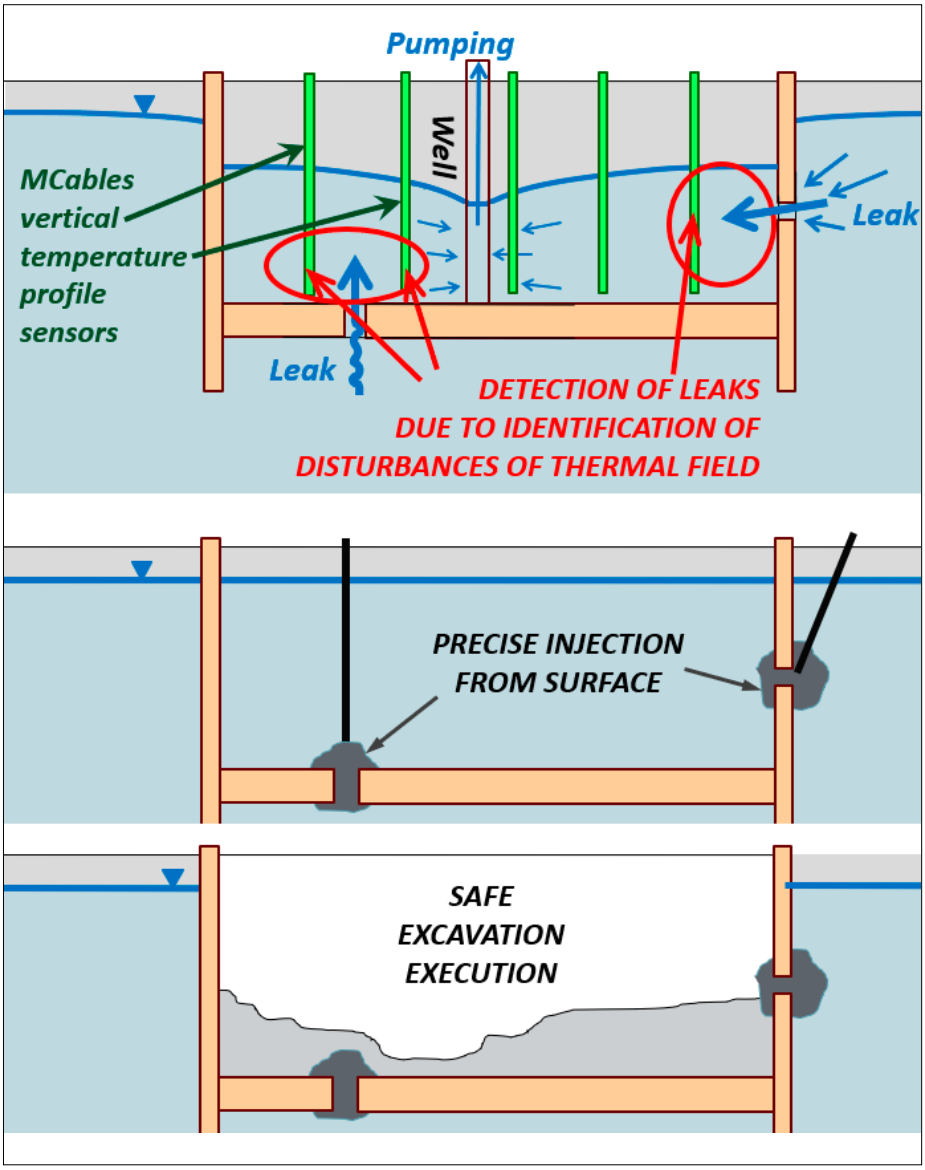
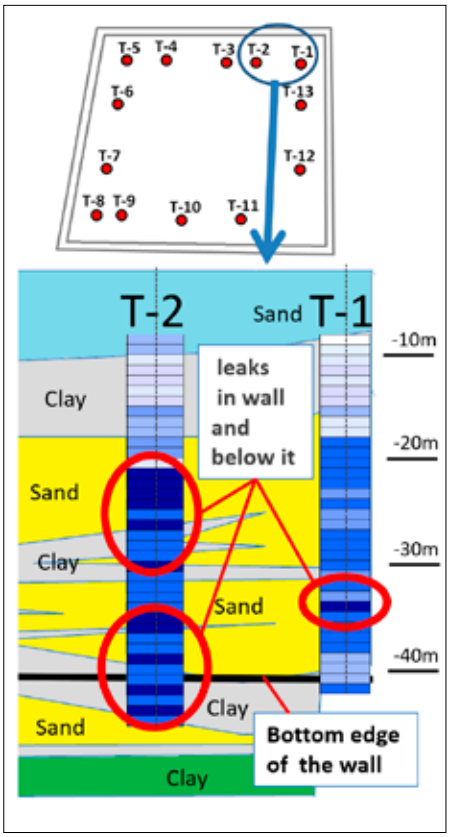



Fig. 14. Plan of the structure with the diaphragm wall as well as the thermal sensors (A) Measurement results provided by two selected MCableS sensors over the geological cross-section. Each colour bar on the profiles indicates the test result for separate measuring points with a spatial resolution of 1 m (B).




40 metres deep, the investor started to make an excavation. When the depth of the excavation was approx. 10 metres, water started to fill it intensively. This meant that there was a leakage in the excavation support. The flow of water was so intense that the excavation had to be filled in and construction works had to be stopped. Numerous geotechnical and geophysical tests did not detect any leakage locations. All leakages were only detected accurately after installing MCableS sensors from the inside of the diaphragm walls. These leakages were caused by leaks in the diaphragm walls and by leaks under these walls. The tests were performed to a depth of more than 40 m. The accurate and reliable information provided by the MCableS sensors allowed the investor to plan further construction activities effectively.

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Photos and graphics come from the archives of NeoStrain company.

# RESTORATION OF SURFACE WATERS – AN INVESTMENT AND CHALLENGE FOR HYDROTECHNICS

**Why are we talking about restoration? Why it is so much needed by surface waters of Poland and rivers especially? The national programme of surface waters' restoration is described by its authors from the Multiconsult Polska team, which was entrusted by the State Water Holding Polish Waters with its development.**

Until recently, it was widely believed that in order to increase the area of agricultural land it is worth draining marshes. It was also believed that to facilitate farming and to protect against flooding it is necessary to regulate rivers and make sure that they do not withdraw from their corridors. Activities in Poland were not fundamentally different from the remaining European countries. So, over the years, the area of Polish wetlands have been reduced and majority of rivers has been straightened and deepened in order to adapt them to the human needs of the time. Efforts have been made to prevent them from flooding by partitioning and piling up; building mills, sawmills and – later hydroelectric power stations. These changes affected entire river systems, from their springs to estuaries. At a time, the environmental consequences of this approach were not taken into account. Nowadays, more and more often there is talk about giving up space to rivers, and actions for water restoration are part of the canon of modern approach to water management.

Against the backdrop of climate change, which is increasingly resulting in long periods of droughts or sudden and intense torrential rainfalls, we are now clearly feeling the effects of these measures. These include accelerated drainage from catchment areas, reduced resistance of hydrological systems to droughts and floods, drastically reduced self-cleaning potential and the degradation of aquatic and riparian ecosystems. The river beds of many rivers have incised, causing the drainage of valleys and reduced water retention in the landscape. Although the regulation of rivers made their flooding less frequent in the case of "medium" floods, the danger of extreme floods did not change. At the same time the energy concentrated in a simplified waterbed has a greater destructive effect. Preventing natural flooding in their valleys has increased the risk of flooding and concentrated it in urbanised, built up for investment and industrial purposes. Maintained in a simplified form, river beds can drain excess water from agricultural land effectively, but in dry conditions they are equally effective at draining the last drops of water. Common simplifications of river channel structures have limited the retention capacity of watercourses. These transformations limited the resistance of water flow, i.e. they reduced the roughness of the channels and their valleys.

These problems are compounded in many places by the urbanisation of the catchment area - resulting in making of a significant part of its surface impermeable. Climate change has increased the unevenness of precipitation, making local, heavy rainfall more frequent, at the same time facing the prolonging rainfall-free periods. As a consequence, we experience recurring local episodes of 'flooding and destruction' interspersed with episodes of 'hydrological drought'.

These problems are often solved by means of investment activities, e.g. by aiming to increase retention by building weirs, valves, retention reservoir. However, the more we look for technical solutions, the clearer the problems related to them become. These methods have significant environmental disadvantages, which have serious social and economic consequences.

In the second half of the 20th century, in the light of progress in environmental engineering research, the need for intensive action to improve the state of the environment, which had previously been significantly transformed by human activity, began to be recognised. Aquatic and riparian ecosystems were among those most affected by human pressure. In response to this need, the European Union adopted directives protecting surface- and groundwater. Among these regulations there is the Water Framework Directive of 2000, in force in Poland since 2004. The directive sets an obligatory objective – to achieve the so-called 'good status' of all waters by 2027 at the latest, which means, among other things, good status of all biological elements - including aquatic, macroinvertebrates and ichthyofauna. In the case of Poland these are the hydromorphological transformations that seem to remain most serious barrier to achieving this objective. The revitalization and reconstruction of surface water is also becoming a way of restoring retention and consistent with the achieve of environmental objectives. In addition, if the entire river valleys are covered by this approach, the effect of delaying the flow affects the flattening of the intake flow waves[1].

## NATIONAL PROGRAMME OF SURFACE WATERS' RESTORATION

The development of National Programme of Surface Waters' Restoration (NPSWR) was one of the activities included in the current updates of the River Basin Management Plans (RBMPs), which implement the provisions of the Water Framework Directive in Poland. The programme is a response to the identified hydromorphological pressures and urgent needs to improve the condition of surface waters. The programme assumes the restoration of surface waters in Poland in relation to the needs resulting, among others, from the need to improve the condition of the Homogenous Surface Water Bodies (Pol: Jednolite Części Wód Powierzchniowych; JCWP). This document, developed by a group of specialists in water management, hydrology, ecology, engineering and environmental management indicates

Photo 1. Parsęta Valley. Title photo of the project of the National Programme of Surface Waters' Restoration

*Source: Archives of the Friends Society of the Ina and Gowienica Rivers, Marcin Budniak*

the directions of actions to be taken in individual JCWPs in order to achieve environmental objectives. It focuses at the actions influencing the improvement of hydromorphological condition.

Restoration should be referred to as the range of activities contributing to the improvement of the status of watercourses and reservoirs, which have been transformed by human, by bringing back selected natural functions and enabling to bring these ecosystems to a state close to the natural. The main objective of the programme was to propose priority areas with actions assigned to them, which should be implemented first, taking into account environmental and economic conditions. The final decisions on the planned activities and the timetable for their implementation will be taken at the stage of developing the second revision of the River Basin Management Plans (Pol. II aPGW).

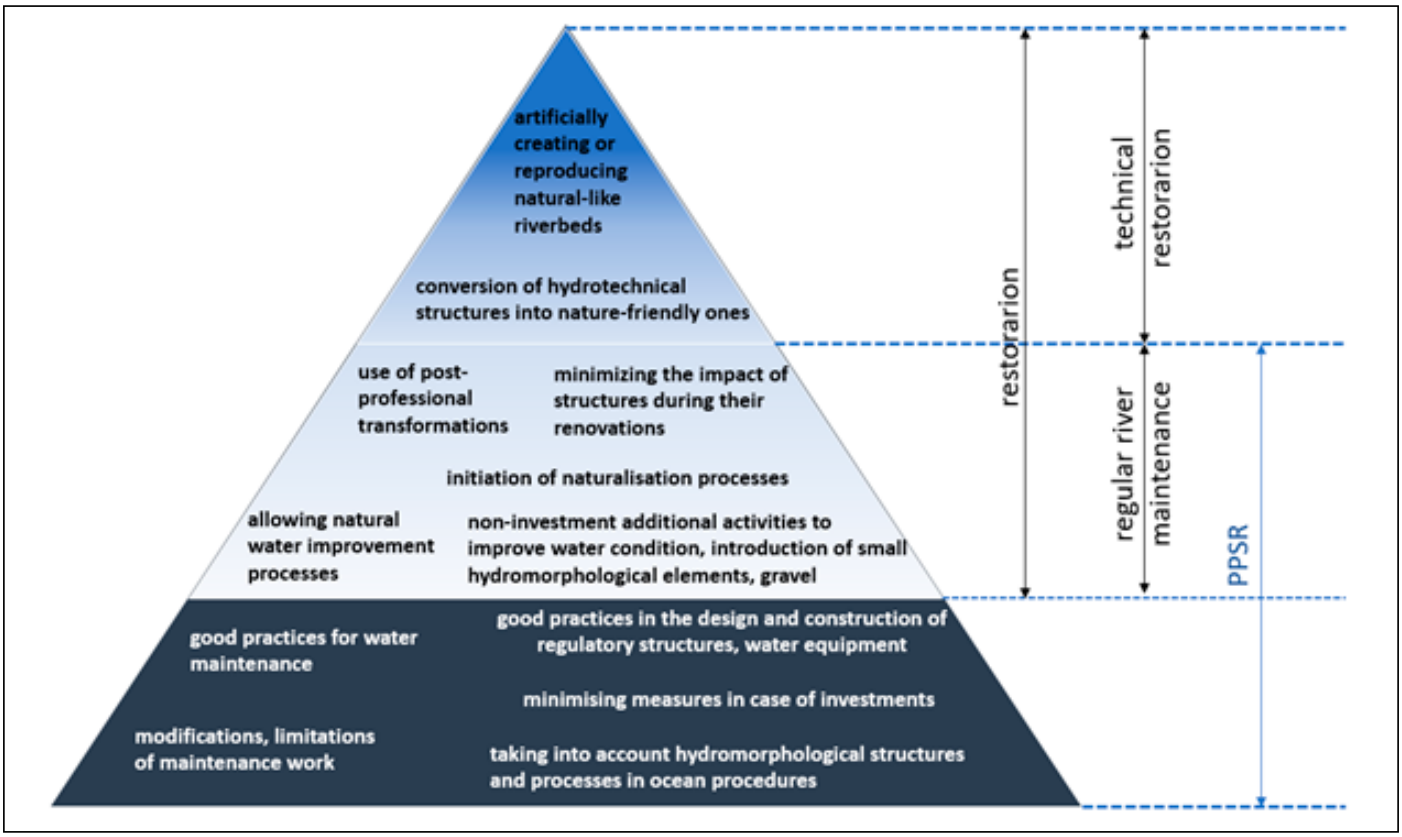
The scale of the need to restore Polish waters is considerably high. 91% of river and 57% of lake water bodies have been identified as areas requiring any restoration measures. It was diagnosed that over 1300 river water bodies - which constitutes over 40% of Polish waters – require urgent restoration. Interestingly, as a result of the research carried out, it is estimated that for 1/3 of Polish rivers it would be sufficient to introduce the simplest rehabilitation measures, consisting of limiting invasive maintenance works and enabling the spontaneous restoration of the good environment of the watercourses, or to modify the way the maintenance works have so far been carried out and developing them by adding simple measures, such as supplementing gravel substrate in the river bed or supplementing the resources of wood rum in the stream. It has been recognised that maintenance work can and should be carried out in order to reconstruct the curvature of river beds, develop riverside buffer zones and manage afforestation carefully. Restoration of surface waters consists not only in restoring the anthropogenically transformed ecosystem to a state (structures and processes) similar to the natural one existing before the transformation, but also in revitalisation, i.e. recreating (in the case of natural ecosystems) or creating (in the case of artificial water bodies) appropriate ecological functions of the ecosystem, which does not always mean restoring the state of the ecosystem before the transformation.

## WHAT DOES 'RESTORATION' MEAN?

Surface water restoration can be defined as a set of measures to restore - at least partially - lost natural features and reproduce natural processes of the ecosystems subjected to this process. These may be actions aimed directly at the removal of transformations (demolition of regulatory structures, bank fortifications, weirs, steps or dams that have ceased to perform their function). These can also be actions restoring damaged, removed elements of the river structure (e.g., appropriate introduction of gravels into the river, shaping of boulders, introduction of fallen trees into the riverbed. Sometimes these are also actions creating substitute structures (e.g., imitating the natural riverbed, a circulating channel in the role of a divider on a transverse septum, which for some reason should be maintained). Finally, sometimes it is not necessary to do anything, but rather to allow the river to recreate its chosen natural features by itself, It means acceptance for the development of bank breakdowns, the accumulation of shore and mid-district embankments, the differentiation of the

[1] Reinhardt, C., Bolscher, J., Ramelow, M., Wenzel, R., schulte, A., 2009. Alternatives in flood protection: the effect of decentralized measures in the Upper Floha watershed (Southeastern Germany). (w:) Brebbia, C.A., RIVER BASIN MANAGEMENT V, WIT Transactions on Ecology and the Environment 124, 93-103. DOI: 10.2495/RM090091

Figure 1: The place of water restoration in integrated water management from the environmental point of view.
PPSR = basic programme of restoration measures, the implementation of which will allow the environmental objectives for water to be achieved in a real time perspective.




*Source: Draft National programme for surfaces' water restoration, Krakow February 2020*

depth and width of the riverbed, the presence of dead trees in the river and the local coastal floods.

Due to the degree of hydromorphological transformations and the ability of aquatic ecosystems to regenerate spontaneously, the rehabilitation measures proposed in the NPSWR refers to three basic groups of measures (Fig. 2):

- natural regeneration - leaving the habitat to spontaneous regeneration of hydromorphological or biotic elements (in the case of a low degree of transformation of aquatic ecosystems);
- assisted regeneration - including natural regeneration, complemented by the need to carry out properly planned work within the framework of current water management (including the application of good practices in water maintenance and interventions aimed at supporting natural hydromorphological processes which favour naturalisation);
- reconstruction of ecosystems - including assisted regeneration, with the need to carry out technical actions (aimed at changing the current hydromorphological conditions resulting from the degradation of ecosystems) or ecological actions (aimed at supporting the development of natural diversity).

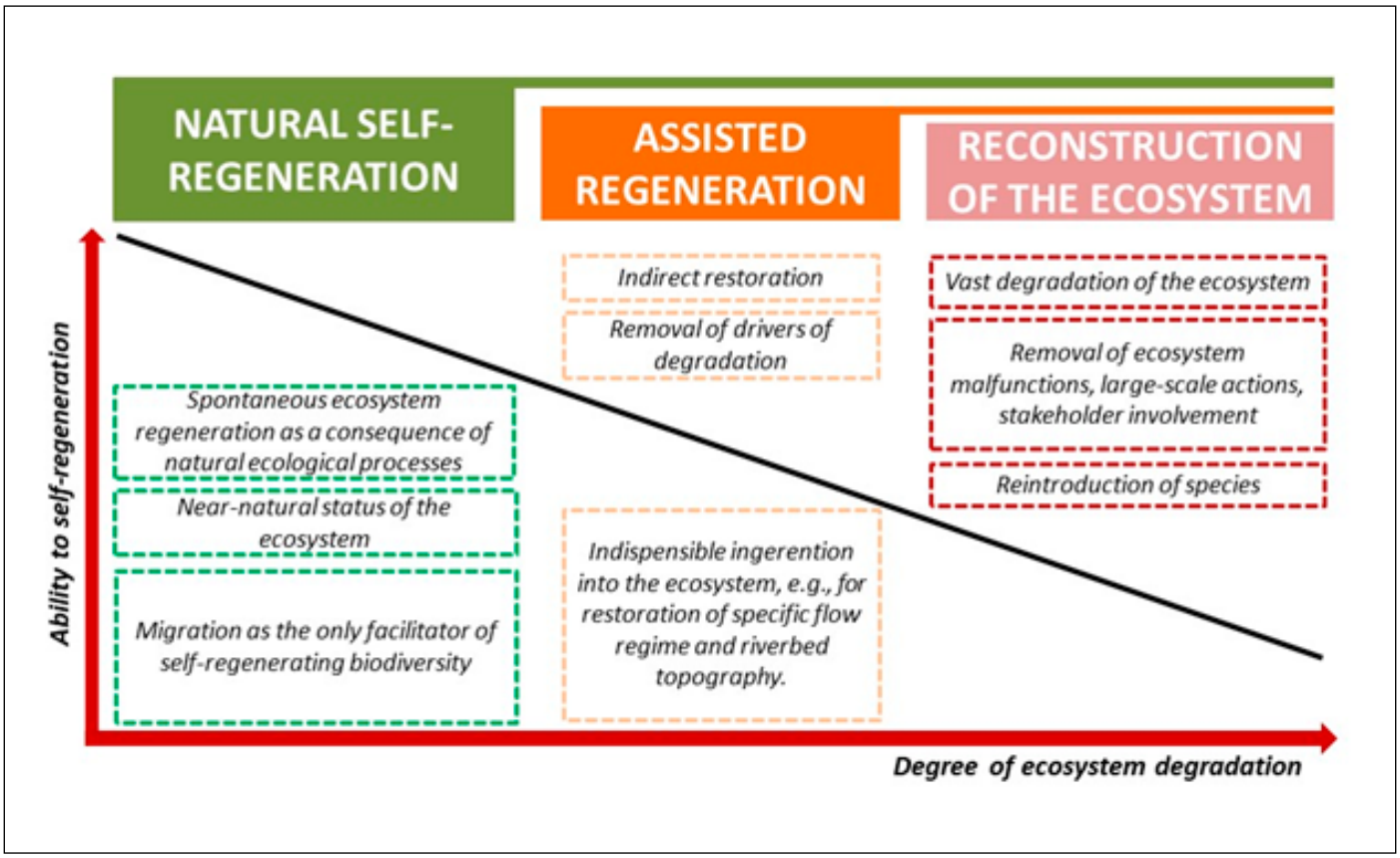
Photo 2. The valley of the valuable natural River Ina.

*Source: Archives of the Friends Society of the Ina and Gowienica Rivers, Marcin Budniak*

The restoration effect can be achieved both through the implementation of specific actions (restoration actions), as well as through the abandonment of certain actions (then restoration takes place as a result of spontaneous processes), or finally through modification of the methods of implementation of specific actions (e.g. maintenance works).

Restoration of surfaces' water should take place in the context of the catchment area (i.e. the area from which water flows into a given receiver, e.g. river or lake),, which is important in terms of making ecosystems more resistant to the effects of drought or flooding. Water restoration therefore also includes restoration of riparian wetlands and limiting surface sealing, or promoting the leaving of marshy buffer zones along rivers in order to filter the pollutants flowing into waters mainly from agriculture. . In many cases, and because it is not possible to direct water flowing from agricultural areas to a sewage treatment plant, restora-

Figure 2. Schematic approach to the restoration of water ecosystems illustrating the idea of the NPSWR




*Source: Draft National programme for surfaces' water restoration, Kraków February 2020*

tion is the only action that can be taken to improve water quality. Such activities usually serve the purpose of natural retention and improve the physicochemical and ecological quality of water, increase the resilience of ecosystems by adapting them more effectively to environmental change (including climate change) and ensure the continuity of the ecosystem services supply.

## DECISION MAKING IN PLANNING WATER MANAGEMENT PROJECTS

Restoration actions are part of good practice in water management, which is based on 4 decision-making steps developed in the "Catalogue of good practices in the field of hydrotechnical works and maintenance works recommended by the State Water Holding Polish Waters (https://www.gov.pl/web/klimat/katalog-dobrych-praktyk-w-zakresie-robot-hydrotechnicznych).

The basis for making good decisions in this area is to thoroughly study and understand the origins of the problem to be solved by a specific intervention in the river system. The key message here will be to understand the conditions of functioning of a particular river (including its hydrology and fluvial dynamics), taking into account the state of development of the catchment area and areas adjacent to the river, the occurrence and status of forms of nature protection, environmental objectives set for the JCWP and consideration of the application of alternative solutions. At an early stage of planning, the project should be examined to avoid legal and environmental conflicts. The aim of such an examination will be to propose a way of implementation that will ensure that the impact of the project is reduced to a negligible amount and that the work becomes acceptable.

The cost-efficiency of the intervention - checking whether the expected benefits will be significantly higher than the costs incurred - is the next decision-making step. At the end of this process, in order to finally optimise the work in terms of its negative impact on the environment, while maintaining the assumed effectiveness of the planned solution, it is necessary to select the appropriate forms, deadlines, technologies and to define the goal of the work, as well as to apply appropriate minimising measures and possible compensatory measures. The application of such 'good practice' in river management planning, among other elements, can effectively lead to the improvement of degraded ecosystems, the improvement of the quantity and quality of water resources and the mitigation of the effects of climate change, as well as increasing the efficiency of expenditures being covered by public funds. Ultimately, if there are no alternatives and the hydrotechnical investment has to be carried out, the restoration techniques should be used to mitigate its negative impact on the environment.

## BUILDING THE KNOWLEDGE BASE AND EXPERIENCE

The restoration of rivers has become an important and meaningful practical and research topic worldwide. Many textbooks and guidelines have been published, describing the most commonly used techniques. As part of the development of the national programme for the restoration of surface waters, a Polish manual of good practices for the restoration of surface waters, published on the Polish Waters website, has also been created, which refers the reader to further publications in this area: https://www.wody.gov.pl/nasze-dzialania/krajowy-program-renaturyzacji-wod-powierzchniowych

The idea of restoring aquatic ecosystems in our country has so far developed in a relatively modest quantities, but in terms of its substantive basis - without any delay in relation to its development worldwide. Already in the 90's of the twentieth century, actions were taken to restore the Rivers Wda and

Photo 3. The effect of removal of migration barrier one of the first dams in Europe. The newly built fish pass within the Project: LIFE13 NAT/PL/000009 LIFEDRAVAPL after 116 years of its existence the SHP Kamienna has made River Drawa usefull to allow upstream and downstream fish migration.

*Source: Archives of the Friends Society of the Ina and Gowienica Rivers, Marcin Budniak*

Trzebiocha in the Wdzydze Landscape Park in Pomerania in order to improve the habitat of the endemic form of lake trout (Salmo trutta m. lacustris) that occurs there. They consisted in cutting down selected coastal trees and leaving them in the riverbed as the deflectors of the river current, initiating erosion of the opposite bank and at the same time the formation of shallows in out-of-trend zones. The work undertaken was among the first examples in Europe of conscious use of dead trees to improve the diversity of habitats in the riverbed. Later on, in the vicinity of the Polesie National Park in the Lublin region, one of the first comprehensive programmes for the restoration of water and peat ecosystems was implemented in Poland, including the secondary modification of a kilometre-long section of the Piwonia riverbed, regulated in the 1960s. Significant steps in the area of surface water restoration in Poland were also taken in the Słupia River basin by the Słupia Valley Landscape Park or restoration sections of the Biała River in the urban landscape of Białystok.

In many places, initiatives have been taken to restore the possibility of fish migration (primarily by building passes) and local initiatives to improve the spawning conditions of salmonid fish by replenishing patches of gravel in poor spawning areas, and although the results of these projects have not been satisfactory everywhere, the same has been true of the growing social demand for river restoration, at least in some aspects. An important example of the restoration of rivers in Poland turned out to be the 'Upper Raba Spawning Grounds' project. As part of this project, good practices have been developed for the restoration of gravel rivers by recreating the sequence of rapids and pools. It was also pointed out that restoration should consist, among other things, in recreating the possibility of natural, periodic river flooding. In the Raba section, the concept of a 'free river migration corridor' was implemented, removing the remnants of artificial concrete embankments and strengthening the edges of flood terraces instead. This actions allowed the river to freely shape its changing riverbed within a wider zone. The experience from the Raba catchment area was later used in many other projects, e.g., in the upper part of the Bóbr River and in the Drawa River catchment area. Comprehensive measures to restore ecological continuity, in particular the conversion of dams into passable spillways were undertaken on a wider scale also in Wisłoka and Biała Tarnowska.

An important example of the restoration of the entire river valley is the project to rebuild the Oder dykes in the Domaszków-Tarchalice area. In place of the dyke, located in the close vicinity of the riverbed, a new flood protection dyke has been built away from the river, restoring the possibility of flooding several hundred hectares of forests and meadows. A similar measure is currently being implemented in another section of the Odra valley, downstream the Krosno Odrzańskie.

One of the important world trends in restoration is demolition dams. Several thousand dams have been demolished in the United States and several hundreds in Europe already. However, given the aging and decapitalization of hydrotechnical objects and the limitation of their functions (e.g. as a result of filling them with sludge), actions consisting in the demolition of dams will certainly soon be necessary. In Poland, especially in western and northern areas, we have several hundred examples of hydrotechnical structures that have been destroyed, giving us an opportunity to observe how much spontaneous restoration took place in these cases. Sometimes, the remnants of former river-banking dams are no longer an obstacle to the migration of aquatic organisms, but in other cases such ruins, even though they may already look 'natural' and picturesque, are still a significant ecological barriers. Therefore, as part of the restoration activities in our country, among other things, demolition of devastated, unused hydrotechnical structures will be carried out.

There is a number of examples of a spontaneous restoration of previously regulated Polish rivers as well. These experiences are different. In some cases, especially in the

Photo 4. The removal of migration barrier on the Drawa River at Stary Młyn in Głęboczek within the Project: LIFE13 NAT/PL/000009 LIFEDRAVAPL. Bypass channel - a similar to natural stream fish pass while maintaining the riffle-pool sequence.ca River made within the framework of the Project: LIFE13 NAT/PL/000009 LIFEDRAVAPL in the area of the old weir between Jaźwiny and Sówka.

*Source: Archives of the Friends Society of the Ina and Gowienica Rivers, Marcin Budniak*

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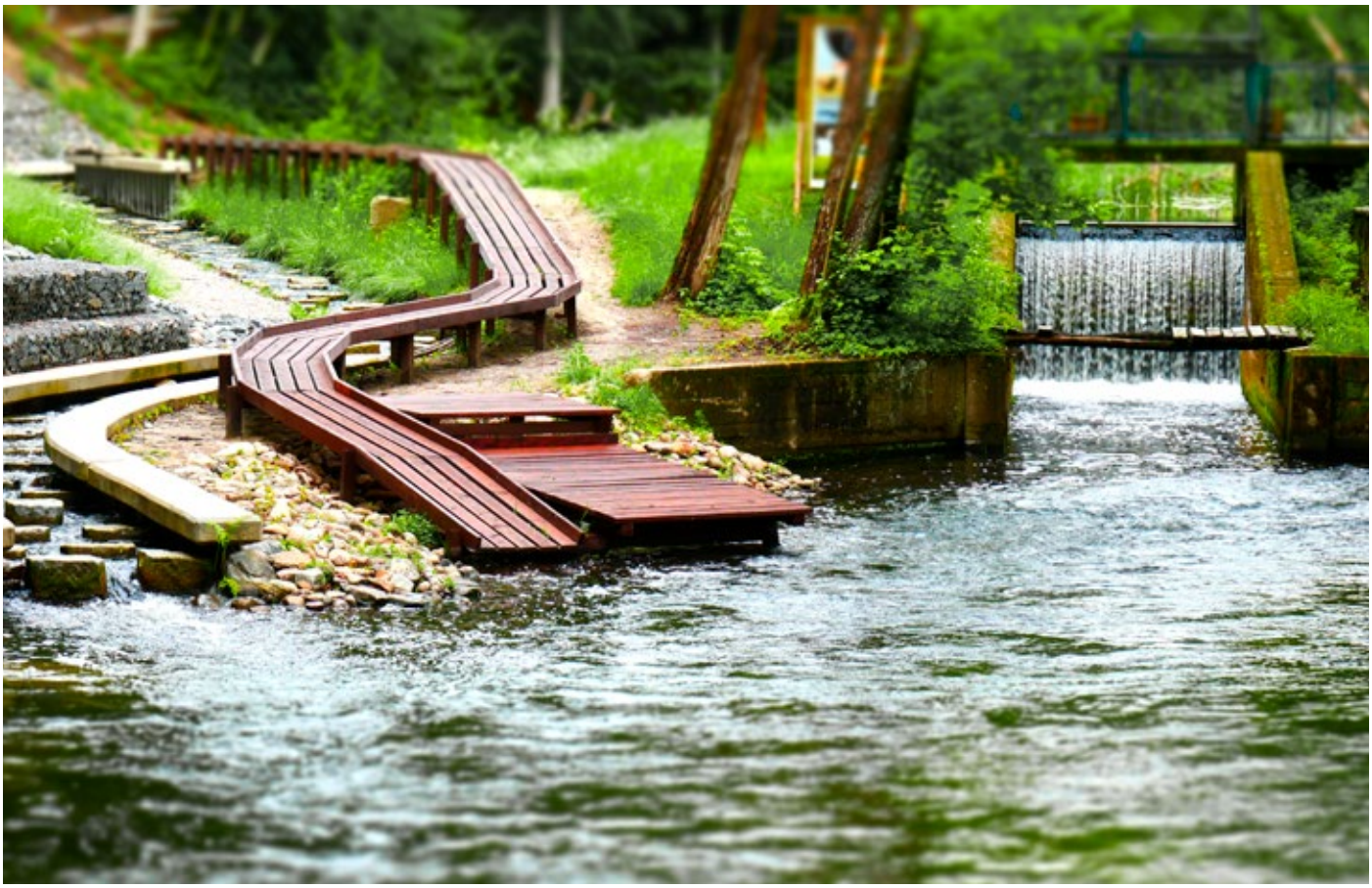
Photo 5. Seminatural river fish pass on the Korytnica River made within the framework of the Project: LIFE13 NAT/PL/000009 LIFEDRAVAPL in the area of the old weir between Jaźwiny and Sówka.



*Source: Archives of the Friends Society of the Ina and Gowienica Rivers, Marcin Budniak*

cases of high-energy mountainous rivers, river beds are becoming dynamically naturalised, Many lowland rivers are being restored by falling trees on the banks of the river, which initiates the differentiation of riverbed forms. On other rivers, however, spontaneous restoration can be very slow or even impossible - for example, once degraded gravel deposits in lowland landscapes cannot be restored without the significant help of a human.

Usually, the basic problem in restoration activities is the need to recover the space necessary for the functioning of the well preserved or properly reconstructed river ecosystems, including the natural migration of the riverbed. The need to restore the ecological continuity of rivers despite the conflict can be reconciled with the interests of damming and partitioning water, including the interests of hydropower. There are technologies of hydropower that do not require partitioning water. However, they are characterized by significant technical and performance limitations. Therefore, a compromise can be sought, especially in the case of barriers that already exist and are still in use, e.g. by building the most efficient fish passes. However, it will always be a compromise. Each fish pass requires water, which slightly reduces energy efficiency. On the other hand, a partition on a watercourse, even with the best possible barrier, remains a barrier that limits its continuity not only for aquatic organisms, but also for the transport of river debris. Relatively high environmental costs of these undertakings make it necessary for every investment of this type to be subjected to detailed analyses and include solutions that will allow for the most effective use of the river's energy potential, with the least possible negative conseqences on the environment.

The need to take the environmental objectives our waters seriously makes that we should think about restoration not as a revolutionary turn towards nature, but as a modern method of managing the surface waters of Poland. Aiming atsustainable water management, we should seek a compromise between restoration and maintaining these changes in the landscape - noting that restoration measures can be very helpful in adapting to climate change.

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