MVM PAKS NUCLEAR POWER PLANT LTD.

Paks Nuclear Power Plant Subsequent Service Life Extension

PRELIMINARY CONSULTATION DOCUMENT

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OVERVIEW OF REVISIONS

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1. Introduction

1.1. Background

The Paks Nuclear Power Plant is a key component of Hungary's electricity system, with its primary function being the generation of electricity. Operated by MVM Paks Nuclear Power Plant Ltd., the nuclear power plant consists of four VVER-440/V-213 type reactor units, which were commissioned between 1982 and 1987. The nominal electrical capacity of the Paks Nuclear Power Plant is currently 2026.6 MW. As such, the nuclear power plant plays a crucial role in Hungary's electricity production, contributing more than 40% of the country's total electricity generation.

The Paks Nuclear Power Plant operates as a baseload power plant with relatively steady output. The turbines' condensers, associated with the plant's four units, use once-through cooling. The required cooling water is drawn from the Danube by the plant's water intake pumps, and the heated cooling water is returned to the river through a warm water channel. The electricity generated at the plant is connected to the national grid at 400 kV and 120 kV voltage levels.

According to the European Union's climate policy goals, achieving climate neutrality by 2050 is the objective, which has been reaffirmed by all member states who are firmly committed to its implementation. Nuclear energy and renewable energy sources are capable of producing electricity without carbon dioxide emission. The role of the Paks Nuclear Power Plant is decisive for the achievement of Hungary's climate neutrality goals.

Since its commission, the Paks Nuclear Power Plant has implemented safety-enhancing measures and modernization programs, the most significant of which were:

- AGNES (Advanced General and New Evaluation of Safety) project (1991-1994),
- safety enhancement program (1996-2002),
- seismic risk assessment and reconstruction (1993-2002),
- reactor protection system reconstruction (1993-2004),
- severe accident management (2008-2014),
- measures of targeted safety reviews (2011-2024).

In the early 2000s in accordance with international trends, the MVM Paks Nuclear Power Plant Ltd., with the involvement of technical-scientific and economic background institutions, began examining the possibility of extending the plant's originally designed 30-year service life. Based on the results of detailed feasibility studies, it was determined that there is a possibility of extending the service life by at least 20 years, thanks to the plant's operational and maintenance practices, the robust construction of its structures and systems, and numerous refurbishments and safety improvements. The decision to implement the first 20-year service life extension was made in 2003. One of the first steps in the permitting process was the environmental impact assessment procedure.

The environmental impact assessment study (EIAS) for the first service life extension of the nuclear power plant was completed in 2006, which concluded that the service life extension was feasible from an environmental protection standpoint. The environmental permit for operating the units of the Paks Nuclear Power Plant for 20 years beyond the originally planned 30-year service life was issued for the MVM Paks Nuclear Power Plant Ltd. on 25th October 2006, under reference number 100562-023-197/06 and registration number K6K8324/06, by the South Transdanubian Environmental, Nature Conservation, and Water Inspectorate.

The environmental permit currently in force for the units of the Paks Nuclear Power Plant, unified with amendments was issued under reference number 391-18/2017 per units, the validity of the permit thus expires between 2032 and 2037.

During the execution of the first service life extension project in 2013, the nuclear power plant's experts began considering the possibility of a subsequent service life extension beyond the 50 years (30+20) under authorization. The analyses conducted at that time confirmed the compliance for a total of 60 years (20+10), so it was already visible in the 2010s that the nuclear power plant might have the reserves needed for continued operation.

In 2019, under the Company's corporate strategy, an action plan was initiated to explore the possibility of a subsequent life extension, and in 2020, a study was conducted on the legal, technical, and economic feasibility, confirming the profitability for the additional 10 years of operation considered at that time. Although the economic and climate policy benefits of subsequent service life extension were evident, and several countries were already exploring the extension of the operational life of their nuclear power plants from 60 to 80, or even from 80 to 100 years, the decision to launch the Paks project was made only later.

The time required to prepare the service life extension of a nuclear power plant is around 10 years. Considering the fact that the service life of unit 1 expires in 2032, in summer 2022 the Hungarian Government decided to prepare for the subsequent service life extension of the Paks Nuclear Power. In a government resolution, it tasked the Minister of Technology and Industry with preparing the project for the subsequent service life extension of the nuclear power plant. Consequently, activities began in the Paks Nuclear Power Plant to establish the conditions for the subsequent service life extension.

In September 2022, MVM Paks Nuclear Power Plant Ltd., at the request of the owner, MVM Ltd., established the Subsequent Service Life Extension Priority Project. The tasks within this project include conducting the environmental impact assessment, including implementing specialized study programs that form the basis of the environmental impact assessment study, as well as carrying out the preliminary consultation and environmental permitting processes. The Project also encompasses technical analysis tasks aimed at a detailed assessment of the condition of the plant's structures, building elements, and equipment, reviewing current ageing management programs that effectively detect, prevent, or mitigate the impacts of ageing in time, and, if necessary, developing new programs. Based on the results of these studies, the execution program for the subsequent service life extension will be prepared also in the frame of the Project, along with the permit applications and the supporting documentation per unit, required for the nuclear authority permitting procedures.

The service life of the Paks Nuclear Power Plant as a facility is determined by those structures and system elements that cannot be replaced or refurbished (long-lived), or where the costs and downtime associated with such activities are so significant that replacement is not reasonable in technical and economic terms. Examples include the reactor vessel or steam generators.

Based on the available material examination, analysis, and maintenance results, the plant's experts have concluded that, during the extended 70-year (30+20+20) operational period of the power plant, none of the most important equipment from the point of view of nuclear safety will be inoperable or incur outlier cost. The safe operation of replaceable and refurbishable system elements can be maintained during the further operational period through the planned execution of ageing management and reconstruction programs, which are integral to the plant's operations.

In accordance with the above – and considering international practices related to the subsequent service life extension of nuclear power plants – technical and environmental studies for the further operation of the Paks Nuclear Power Plant are considering a 20-year subsequent service life extension, for a total operational life of 70 years. This period includes the originally planned 30-year operating life, the authorized and ongoing (first) 20-year service life extension, and the currently studied 20-year subsequent service life extension.

According to the current legislation, subsequent service life extension of an operating nuclear power plant (in the international practice sometimes referred as Long Term Operation (LTO) or licence renewal according to applied practice of a given country) does not require prior conceptual approval from the Parliament. However, the Parliament was informed before the commencement of the previous service life extension, and the Government has therefore decided to inform the Parliament in advance of the initiation of activities related to the subsequent service life extension of the Paks Nuclear Power Plant.

The Parliament, with a decisive majority (170 votes in favour, 8 against, and 1 abstention), adopted and acknowledged the subsequent service life extension of the nuclear power plant's existing units through the 56/2022. (XII. 8.) OGY Resolution. According to the resolution, this extension serves the country's energy sovereignty, climate protection, and supply security goals.

Under Article 41 of Chapter 4 of the Euratom Treaty concerning investments, the service life extension project must be notified to the European Commission. Following consultations involving the Hungarian Atomic Energy Authority and the Ministry of Energy, a document detailing the project was submitted to the European Commission Directorate-General for Energy Unit ENER D.2 – Nuclear energy, nuclear waste, and decommissioning on October 26, 2023. With this the European Commission was officially notified about of the subsequent service life extension of the Paks Nuclear Power Plant.

According to Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and integrated environmental use permitting procedures, extending the service life of the nuclear power plant is an activity subject to environmental impact assessment. Thus, the subsequent service life extension can only be carried out with a final environmental permit issued by the environmental protection authority. In order to further extend the service life of the nuclear power plant, it is necessary to issue an environmental protection permit for the MVM Paks Nuclear Power Plant Ltd. based on an environmental impact assessment procedure conducted by the Baranya County Government Office, as the competent environmental authority. The results of the environmental impact assessment must be presented in the EIAS.

For activities subject to environmental impact assessment, the Government Decree 314/2005. (XII. 25.) provides the opportunity for a preliminary consultation procedure. This allows the environmental user to gather opinions from the environmental authority, relevant administrative bodies, and the public, including those involved in the international environmental impact assessment procedure as stipulated by the Espoo Convention, promulgated by Government Decree 148/1999 (X. 13.). These opinions and feedback can provide additional guidance and perspectives for preparing the EIAS.

The MVM Paks Nuclear Power Plant Ltd. intends to initiate a preliminary consultation procedure with the environmental authority concerning the planned subsequent service life extension in order to taking into account the authority's closing opinion, the views of the involved administrative bodies, and the public's comments for the elaboration of the EIAS. To initiate the preliminary consultation, the applicant must prepare and submit documentation (Preliminary Consultation Document /PCD/) in accordance with the content requirements specified in Annex 4 of Government Decree 314/2005. (XII. 25.).

In 2023, MVM Paks Nuclear Power Plant Ltd. entered into a general contractor agreement for the tasks related to the environmental permitting procedure for the subsequent service life extension. These tasks include the development and implementation of underlying technical study programs, as well as the preparation of the PCD and EIAS. An independent project organisation was established for the execution of these tasks under the supervision of the environmental protection permitting working group operating within the framework of the Paks Nuclear Power Plant Subsequent Service Life Extension Priority Project. This project organisation led by MVM ERBE Ltd. as the main contractor, in collaboration with SOM System Ltd. and AFRY ERŐTERV Ltd., engineering companies. Additional specialized organisations and scientific institutions with the required references are involved in conducting studies and analyses related to various fields of the environmental impact assessment. For the supervision of environmental protection activities, MVM Paks Nuclear Power Plant Ltd. has established an Environmental Protection Expert Board, whose members are prominent Hungarian scientific experts in the relevant fields, to supervise the environmental protection professional tasks.

This document is the Preliminary Consultation Document (PCD) supporting the application for the preliminary consultation procedure of the environmental permitting for the subsequent service life extension of the Paks Nuclear Power Plant. It has been prepared in accordance with the content requirements outlined in Annex 4 of Government Decree 314/2005. (XII. 25.) titled “Content of the Preliminary Examination Documentation and Consultation Request.”

1.2. Definition, purpose, and justification of the planned activity

1.2.1. Identification of the planned activity, volume, start date, duration, and consideration of alternatives

The planned activity is the 20-year subsequent service life extension of the four VVER-440/213 type, pressurized water reactors with light-water moderation at the Paks Nuclear Power Plant, i.e., extension of the electricity generation activity. The subsequent service life extension of the power plant is classified under point 31 of Annex 1 of Government Decree 314/2005 (XII. 25.), which covers *“Nuclear power plant, nuclear reactor, and the extension of the service life of a nuclear power plant or reactor"* – regardless of size, making it subject to environmental impact assessment and requiring an environmental permit to start the activity.

The planned subsequent service life extension applies to all four units of the nuclear power plant, which is to be considered by units, taking into account the commissioning dates of each unit. The planned start date of the activity corresponds to the expiration of the currently valid environmental permit (with reference number 391-18/2017) for each unit, as shown in *Table 1.2.1-1.* The duration of the extension for each unit, according to the intent of MVM Paks Nuclear Power Plant Ltd., is until the end of the last year of the extended service life of the respective unit (*Table 1.2.1-1.*).

Table 1.2.1-1. Planned duration of the subsequent service life extension

Nuclear plant unit / system	Commissioning date	End of 50-year service life / start of 20-year subsequent life extension	Planned end of 20-year subsequent service life extension
Unit 1	14.12.1982.	14.12.2032.	31.12.2052.
Unit 2	26.08.1984.	26.08.2034.	31.12.2054.
Unit 3	15.09.1986.	15.09.2036.	31.12.2056.
Unit 4	09.08.1987.	09.08.2037.	31.12.2057.
Common systems		09.08.2037.	31.12.2057.

The nominal electrical output of units 1-4 of the Paks Nuclear Power Plant 508.6, 506.0, 506.0, and 506.0 MW, respectively, with a total nominal electrical output of 2026.6 MW for the facility. With the 20-year subsequent service life extension, the planned distribution of the available electricity generation capacity of the nuclear power plant over time is shown in *Table 1.2.1-2.* The power plant's operation during the subsequent service life extension period is planned to be as a baseload plant, with continuous and near-steady load, with scheduled and planned shutdowns only during periodic maintenance.

Table 1.2.1-2. The planned distribution of the available electricity generation capacity of the nuclear power plant over time during the subsequent service life extension

Period	Total nominal electrical output of the nuclear power plant [MW]	Operating units
14.12.2032. – 31.12.2052.	2 026.6	1-4.
01.01.2053. – 31.12.2054.	1 518.0	2-4. (unit 1 shut down)
01.01.2055. – 31.12.2056.	1 012.0	3-4. (units 1-2 shut down)
01.01.2057. – 31.12.2057.	506.0	4. (units 1-3 shut down)

Request for preliminary consultation regarding the extension of the service life of the nuclear power plant and the environmental impact assessment to be conducted in the second phase of the environmental permitting process applies to all four units of the plant. Accordingly, the assessments will be conducted with respect to the operation of the four units of the nuclear power plant.

The activity location is Hungary, Tolna County, within the administrative area of Paks town (H-7030 Paks, property registration number: 8803/17.), at the existing site of the Paks Nuclear Power Plant. Given that the subject of the assessment is an existing, currently operating facility, the planned activity does not include the use of additional areas, installation of new buildings, structures, facilities, or technological equipment, or any demolition work preceding such installations. Therefore, there are no other siting, technological, or other alternatives in this case. The only variant considered is the further extension of the service life of the existing nuclear power plant at its current site and with its existing technology. Besides implementing the subsequent service life extension of the nuclear power plant, the only alternative in accordance with the law is the shutdown of the units of the nuclear power plant at the end of their currently permitted 50-year operating life, and the cessation of electricity generation. Information on the decommissioning of the nuclear power plant is provided in *Chapter 7*.

1.2.2. Purpose and justification of the planned activity

The purpose of the planned activity is to maintain the commercial electricity production currently carried out by MVM Paks Nuclear Power Plant Ltd. through the operation of the existing four reactor units for an additional 20 years. The planned service life extension of the nuclear power plant serves Hungary's long-term energy sovereignty, climate protection, and energy supply security goals. Among the reasons for the government's decision to prepare for subsequent extension of the service life were the evolution of the international energy market, electricity prices and demands, and supply security risks in recent years.

The goal of Hungary's energy policy is to ensure supply security and achieve climate neutrality and energy sovereignty. To accomplish this, it is necessary to meet the country's electricity demand as much as possible from carbon dioxide emission-free domestic sources. Due to electrification and economic growth, the demand for electricity in Hungary is expected to continue to rise in the coming decades. Given that the Paks Nuclear Power Plant is a key source of domestically produced carbon-neutral electricity, the implementation of the subsequent service life extension will serve the long-term preservation of domestic base power generation capacity, thereby maintaining supply security, reducing energy import dependency and climate protection goals.

The environmental impact of technological societies is significant, and global warming is ongoing, with mitigation and halting being perhaps the most important challenges of our time. According to the climate policy goals set out in the Paris Agreement on climate change, the objective is to achieve climate neutrality by 2050 in the European Union. All EU member states, including Hungary, have signed and ratified the Paris Agreement, which entered into force in 2016. To meet these commitments, the Act XLIV. of 2020 on climate protection sets the goal of achieving full climate neutrality in Hungary by 2050, meaning that the remaining domestic emissions of greenhouse gases and their absorption must be balanced by 2050.

The EU is vulnerable to external suppliers in terms of natural gas as an energy carrier, and therefore, in the future, the priority will be the production of carbon-neutral, affordable, and high supply secure electricity, for which nuclear power plant units are fundamentally suitable.

The possibility of subsequent service life extension of the Paks Nuclear Power Plant is also included in the revised 2023 version of the National Energy and Climate Plan. The document states that the government's goal is for the majority of Hungary's electricity production to come from two sources: nuclear energy and renewable energy, primarily from solar power plants. These are not mutually exclusive or substitutive technologies but rather complementary solutions, and both are considered clean energy sources. Nearly half of Hungary's electricity generation comes from carbon-neutral nuclear energy. With the subsequent service life extension project of the Paks Nuclear Power Plant and the implementation of the Paks II. project, this ratio will be sustainable in the long term.

The subsequent service life extension of the Paks Nuclear Power Plant is a key project for achieving the 2050 climate neutrality target. Given Hungary's topography, hydrology, and natural conditions, carbon-neutral energy production in the country is inconceivable and unfeasible without nuclear energy. The use of nuclear energy significantly contributes to Hungary's energy security and independence by providing a clean, practical solution to the challenges of increasing energy demand.

According to the energy and climate plan, maintaining a high share of nuclear energy in electricity production is among the main electricity market goals. In addition to energy efficiency and renewable energy support programs, the long-term maintenance of nuclear capacities will have a significant impact on reducing greenhouse gas emissions.

If the service life of Paks Nuclear Power Plant is not extended further, the resulting electricity must be purchased from the electricity market, which, based on the forecasts, could mean significant additional costs compared to the continued operation of the nuclear power plant. The production of missing electricity using other technologies can result in significantly less favourable environmental impacts.

The examination of the possibility of subsequent service life extension of the Paks Nuclear Power Plant became relevant by mid-2022 for economic and political reasons. The Government of Hungary responded to the situation by making a decision to commence preparations for the subsequent service life extension of the nuclear power plant. This modifies the previous decision that after 50 years of operation, the Paks Nuclear Power Plant would be shut down, and domestic nuclear energy production would be limited solely to the electricity generation capacity of the new Paks units.

Preparatory activities include the current preliminary examination of the environmental impacts associated with the continued operation of the nuclear power plant, the purpose of which is to evaluate the environmental feasibility of the subsequent service life extension.

1.3. Introduction of the applicant MVM Paks Nuclear Power Plant Ltd., identification data, and data of the Preliminary Consultation Document preparers

1.3.1. Identification data of MVM Paks Nuclear Power Plant Ltd.

The applicant for the preliminary consultation procedure is MVM Paks Nuclear Power Plant Ltd., and the company's identification data are as follows:

Name:	
Short name:	MVM Paks Nuclear Power Plant Ltd.
Full name:	MVM Paks Nuclear Power Plant Private Limited Company
Registered office:	H-7030 Paks, property registration number: 8803/17.
Mailing address:	7031 Paks, P.O. Box. 71.
E-mail:	atomeromu@npp.hu
Website:	atomeromu.mvm.hu
Telephone:	+36 (75) 505-000
Company registration number:	17-10-001113
Tax number:	10742833-2-17
Main activity:	3511 Electricity generation
Environmental Client Identifier (KÜJ):	100 203 714
Environmental Area Identifier (KTJ):	100 294 388
Statistical number:	10742833-3511-114-17
Number of environmental permit for current electricity generation activity:	391-18/2017

The company operates an environmental management system certified according to the MSZ EN ISO 14001:2015 standard for its electricity generation activities since 2002. The adequacy of the system's operation is demonstrated by annual surveillance audits and triennial certificate renewal audits. The scope of the environmental management system extends to all the company's operational processes, all its employees, organisational units, and individuals in other employment relationships related to work performed, as well as the company's contractual partners and their employees.

1.3.2. Data of the preparers of the Preliminary Consultation Document

The specialized sections of the PCD were prepared by professional organisations involved in the preliminary investigation, under the collaboration and technical coordination of MVM ERBE Ltd. (H-1117 Budapest, Budafoki út 95.), SOM System Kft. (H-7030 Paks, Vadász utca 40.), and AFRY ERŐTERV Ltd. (H-1117 Budapest, Infopark sétány 3.). The PCD is compiled by the AFRY ERŐTERV Ltd. The professional organisations that participated in the preparation of the document and their areas of expertise are as follows:

- MVM ERBE Energy Engineering Office Ltd.:
  - Project management.
  - Technical direction of non-radiation-related (conventional) studies.
  - Air quality protection.
  - Noise and vibration protection.
  - Biodiversity protection survey.
- SOM System Engineering Office Ltd.:
  - Technical direction of radiation protection-related studies.
  - Site characterization.
  - Technical coordination related to the compilation of the PCD.
- AFRY ERŐTERV Power Engineering and Contactor Ltd.:
  - Power plant technology.
  - Technical coordination related to the compilation of the PCD.
  - Compilation of the PCD.
- HUN-REN Research Centre for Astronomy and Earth Sciences (HUN-REN CSFK):
  - Site characterization (geography, meteorology).
- GeoRisk Earthquake Engineering Ltd.:
  - Site characterization (geological, seismological-tectonic, geotechnical).
- NUBIKI Nuclear Safety Research Institute Ltd.:
  - Site characterization (external hazard assessment).
- National Center for Public Health and Pharmacy (NCPHP), Department of Public Health Laboratory and Methodology:
  - Air quality protection.
- NATURAQUA Environmental Protection, Designer and Service Ltd.:
  - Surface and groundwater protection.
  - Geological medium protection.
  - Management of non-radioactive waste.
- SCIAP Research and Development and Consulting Ltd.:
  - Protection of surface waters and aquatic ecosystems.
- Budapest University of Technology and Economics (BME):
  - Surface water protection.
- Kék Csermely Water Protection and Environmental Management Design and Organizing Ltd.:
  - Surface and groundwater protection.

- Isotoptech Nuclear and Technology Service Ltd.:
  - Examination of radiation exposure of living organisms.
  - Groundwater protection.
- HUN-REN Centre for Energy Research (HUN-REN EK), Institute for Atomic Energy Research:
  - Radiation protection, examination of public radiation exposure.
- SOMOS Environmental Development Service and Trading Ltd.:
  - Examination of environmental radioactivity.
- BioAqua Pro Environmental Protection, Service, and Consulting Ltd.:
  - Protection of living organisms and nature conservation.
- ÖKO Environmental, Economic, Technological, Trading, Service, and Development Ltd.:
  - Municipal environment and landscape protection.
- V-MED Education, Research, and Service Ltd.:
  - Examination of public health.

The list of experts and the verification of their professional credentials in alignment with the current data from the Hungarian Chamber of Engineers' public registry[1] and the Ministry of Agriculture's Register of Experts in Nature and Landscape Conservation[2], is provided in *Table 1.3.2-1.*

Table 1.3.2-1. Experts involved in the preparation of the PCD and their professional credentials

Organisation	Expert / field(s)	Chamber number(s) / licenses, permits codes
AFRY ERŐTERV Ltd.	Rozália Gátiné Magyar Radiation Protection	01-15651, 01-64695 EN-A, NSZ-3., NSZ-11., NSZ-17., NSZ-19. SVR-HA18098
AFRY ERŐTERV Ltd.	Péter Hayer Waste management, air quality protection, water and geological medium protection, noise and vibration protection	01-2861 SZÉM5, SZÉM6, EN-HŐ, EN-ME, EN-VI, SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4.
AFRY ERŐTERV Ltd.	Tamás Romenda Waste management, air quality protection, water and geological medium protection, noise and vibration protection, climate protection	01-12548, 01-64686 SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., K-Sz, NSZ-3., NSZ-11., NSZ-17., NSZ-19., NSZ-20. SVR-HA19197
BioAqua Pro Ltd.	Dr. Béla Kiss Hydrobiology, ecology	SZTV, SZTjV
MVM ERBE Ltd.	Dr. Zsófia Fehér Noise and vibration protection, biodiversity protection	13-11655 SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., SZTV, SZTjV
MVM ERBE Ltd.	Emőke Nagyné Juhász Water and geological medium protection	01-11964, 01-66916 SZKV-1.1., SZKV-1.2., SZKV-1.3., SZKV-1.4., SZVV-3.1., SZVV-3.9., SZVV-3.10., VZ-TEL, VZ-TER, ME-VZ, MV-VZ, VZ-VKG
MVM ERBE Ltd.	Dávid Pintér Air quality protection	07-01251 SZKV-1.1., SZKV-1.2., SZKV-1.3., K-Sz

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[1] www.mmk.hu/informaciok/nevjegyzek
[2] ttsz.am.gov.hu/szakertok/szemelyek

Organisation	Expert / field(s)	Chamber number(s) / licenses, permits codes
NATURAQUA Ltd.	Tamás Kerékgyártó Water and geological medium protection	05-01890 SZKV-1.3., SZVV-3.1., SZVV-3.5., SZVV-3.9., SZVV-3.10.
	György Maján Water and geological medium protection	01-3036 SZKV-1.3., VZ-TEL, VZ-TER, ME-VZ, MV-VZ, VZ-VKG
ÖKO Ltd.	Emőke Magyar Landscape protection, municipal environment	SZTV, SZTjV
SOM System Ltd.	Anita Puskás Nuclear environmental protection, radioactive waste management	17-06000 NSZ-19., NSZ-20.
SOMOS Ltd.	Dr. Gábor Nagy Radiation Protection	13-15382, 13-660 NSZ-10.2., NSZ-11. SVR-HA16235
V-MED Ltd.	Prof. Dr. János Sándor Human Health	Public health-epidemiology specialist exam, preventive medicine and public health specialist exam

1.4. The environmental impact assessment procedure and the planned activity

1.4.1. Legal framework for environmental impact assessment and environmental permitting

According to § 68. of Act LIII of 1995 on the general rules of environmental protection, an environmental impact assessment must be conducted, and an environmental permit must be obtained from the territorially competent environmental authority before commencing activities that significantly or are expected to significantly impact the environment. The scope of such activities, as well as the procedure, phases, and content requirements for documents to be submitted to the environmental authority during the environmental permitting process, are detailed in Government Decree 314/2005. (XII. 25.). According to the Government Decree, the environmental impact assessments apply not only to new facilities but also to modifications or changes in existing facilities, including the extension of service life of nuclear power plants.

For activities requiring an environmental impact assessment, the user of the environment (applicant) may initiate a preliminary consultation with the environmental authority under § 67. of Act LIII of 1995. According to section (2) of § 5/A of Government Decree 314/2005. (XII. 25.). The purpose of the preliminary consultation is for the environmental user to receive a written opinion from the environmental authority regarding the content requirements of the environmental impact assessment study covering environmental and nature protection, as well as other specialised issues outlined in Annex 12 of the Government Decree. The purpose of the preliminary consultation is also to allow the public to express their opinions on the proposed activity through the publication of relevant documents.

The environmental impact assessment procedure, following the preliminary consultation, is initiated by the environmental authority upon the request of the environmental user. The application must be accompanied by the EIAS, which complies with the opinion provided during the preliminary consultation and with the general content requirements specified in Annex 6 of Government Decree 314/2005. (XII. 25.).

The operation of nuclear power plants is an activity under the Espoo Convention (Appendix I), signed in Espoo, Finland, on 26th February 1991, and promulgated by Government Decree 148/1999. (X. 13.), concerning the assessment of transboundary environmental impacts, which is expected to cause significant transboundary environmental impacts. If significant transboundary environmental impacts are expected during the preliminary consultation, the Ministry responsible for environmental matters notifies the affected foreign parties about the planned activity and the ongoing environmental impact assessment procedure. If the foreign party expresses its intention to participate in the environmental impact assessment procedure in response to the notification, the procedure continues following the Espoo Convention's provisions (international environmental impact assessment procedure). During this process, the EIAS and related documents are sent to the affected foreign parties, and consultations are held with the relevant foreign stakeholders to inform them and gather their opinions. The environmental authority considers the opinions and comments received from foreign stakeholders during the international procedure when making its decision on the environmental permit.

1.4.2. Specifics of the environmental impact assessment for the planned activity

The environmental impact assessment for the subsequent service life extension of the Paks Nuclear Power Plant is considered unique compared to a conventional impact assessment for a new activity. These specifics, reflecting the legal requirements for the impact assessment, are as follows:

- The most important specificity from the perspective of the impact assessment is that the procedure pertains to an existing facility that has been in operation for decades. Generally, environmental reviews are used to assess and evaluate the environmental impacts of an ongoing activity. However, extending the service life of the nuclear power plant requires an environmental impact assessment. In this case, conducting an environmental impact assessment procedure is necessary, as opposed to an environmental review procedure, even though, methodologically, the examination of an existing facility is more akin to review expectations since the projections of future environmental impacts are largely based on real measurements and empirical results rather than estimates.
- Government Decree 314/2005. (XII. 25.) does not establish a separate or distinct set of requirements for conducting an impact assessment related to the modification of existing facilities. However, the content requirements for impact assessment established for new facilities are not fully applicable to modifications of operating plants. In the case of a new activity, a key question in the environmental impact assessment is whether the planned activity and its associated facilities can be integrated into the given environment. The content requirements of the legislation also focus on this issue. In present case, this question is irrelevant since the activity has already been integrated into its environment, the nuclear power plant is operating since 1982. Since the current environmental impacts and processes associated with the plant are expected to be the determining factors in the future, the acceptability of the plant's current environmental impacts will be crucial in evaluating future activities. Therefore, the focus of both the PCD and the subsequent EIAS will be on presenting the current state and evaluating and assessing current environmental impacts. (To present the current state as comprehensively as possible, a study program for assessing the environmental condition has been initiated alongside the PCD to better substantiate the EIAS, the details of which are presented in *Chapter 6.*)

  The environmental impact assessment, in this case, must focus on whether the current state is acceptable and how the cumulative environmental impacts of the extended operation of the plant will change due to the expected 20-year subsequent service life extension. It is also necessary to consider the expected changes in environmental characteristics (e.g., climate change, forecasted changes in the hydrological characteristics of the Danube, population, and human activities in the environment).

- Another specificity is that, since the subject of the assessment is a nuclear power plant, the evaluation must consider not only conventional environmental emissions but also radiological emissions. Therefore, both approaches must be applied for every environmental component, system. (Environmental impacts and areas not related to radioactivity or radiation protection will be referred to as “conventional” in the document.)
- In the case of existing facilities, the environmental impact factors and processes, as well as the resulting state changes, can be characterized and estimated for the extended operating period based on the results of monitoring activities carried out during previous operations. The current state of the environmental components, systems fundamentally determines the expected environmental condition during continued operation. This is also because the planned subsequent service life extension – according to the information available during the compilation of the PCB – does not require significant modifications, reconstructions, technological changes, or other major interventions in the operating plant. This activity primarily involves inspecting, reviewing, and maintaining the existing plant buildings, structures, facilities, and equipment, as well as replacing or refurbishing ageing components, which are also part of works necessary for the normal operation of the nuclear power plant (i.e., operation licensed until 2032-2037).
- When conducting conventional environmental impact assessments, the installation phase to be examined (i.e., according to legal interpretation, “creating the conditions necessary for the activity, particularly site occupation, preparation of the construction site, construction, installation of equipment”) can only be interpreted very narrowly (with the modernisation, refurbishment and replacement of certain equipment) in this case. However, since these activities are continuous during the normal plant operation, the examination of this phase is practically unnecessary, as it was addressed, evaluated, and approved as part of the EIAS for the first operational extension (considered as the continued operation of the nuclear power plant).

  As part of the preparatory phase for the subsequent service life extension of the Paks Nuclear Power Plant, environmental impacts exceeding regular operational maintenance work, such as larger scale, more frequent interventions or those requiring a campaign period and thereby causing additional environmental impacts, should be evaluated within this procedure. Alongside the elaboration of the PCD, detailed condition and structural assessments based on technical aspects, aimed among others determining the activities necessary for ageing management, have begun. If, based on the results of these assessments, activities causing additional environmental impacts are deemed necessary, they will be presented, examined, and evaluated in the EIAS.
- For most areas, a well-founded impact assessment can be provided for evaluating the impacts of continued operation, as data from detailed sectoral surveys related to the environmental permitting of the Paks Nuclear Power Plant's previous service life extension and capacity increase are available and can be used, just as the results of the mandated monitoring activities included in the environmental permit. Nearly a decade later, further surveys, measurements, and investigations were conducted in the presumed impact area of Paks II. for the environmental impact assessment necessary for the environmental permitting of the new nuclear units (Paks II.) to be built on the Paks site. Impact area of Paks II. overlaps to a significant extent with the impact area of Paks Nuclear Power Plant, therefore the data from there must also be taken into account when characterizing changes in baseline conditions. During the preparation of the PCD, based on the results obtained during the examined periods and the examination of their deviations, it is necessary to identify the causes of any potential changes and screen out those impact factors that operated independently of the Paks Nuclear Power Plant, and those that can specifically be linked to the plant's regular operation. For example, changes in main road traffic, changes in zoning classifications, the creation of new protected buildings or areas can be independent factors, but any visible changes in radiological measurements are fundamentally attributable to the nuclear plant’s activities.

- A specific aspect of this examination is that it is assumed that during the continued operation period, two new units of the Paks II. Nuclear Power Plant[3] will be built in the investment of Paks II. Nuclear Power Plant Ltd., a company independent of MVM Paks Nuclear Power Plant Ltd., adjacent to the area of the units 1-4 of the Paks Nuclear Power Plant. For the purposes of this study, it is assumed that by 2032, the starting point of the subsequent service life extension, Paks II. will be constructed, and its commissioning will begin. Accordingly, in this study, in addition to the independent examination of the impacts of the Paks Nuclear Power Plant, it is also necessary to assess the cumulative impacts arising from the joint operation of six units (four existing units of the Paks Nuclear Power Plant and two new units of Paks II.).
- In the case of nuclear power plants, decommissioning is an activity requiring a separate impact assessment according to Government Decree 314/2005. (XII. 25.), so in this environmental permitting procedure, this phase should only be presented at a conceptual level.
- Activities related to the disposal of excess spent fuel and radioactive waste generated during the extended service life will be subject to separate environmental permitting procedures and therefore (similarly to decommissioning) should be presented in this study only at a conceptual level.
- From the above, it follows that the delineation of the impact area must also differ from the usual. According to the law, *"the direct impact areas are the areas attributable to individual impact factors, which may include the areas of spread of certain substances or energy emissions into soil, water, or air within the affected environmental elements, as well as areas of direct use of soil, water, living organisms, built environment (site occupation), and areas of expected landscape changes".* The indirect impact areas, on the other hand, are *"the areas of spread of impact processes extending due to environmental condition changes occurring in direct impact areas, according to the environmental elements and systems affected by the impact process".* It can be seen from the legal quotation that the impact area is always associated with the spatial extent of a detectable environmental condition change. In this case, no significant spatially extensive condition change is anticipated. Thus, the determination of the impact area should basically be based on the detectable, calculable and modellable areas of change in the current state and the current operation. However, any calculable changes in environmental elements must also be considered during the impact assessment. If, for any environmental element, system, a different impact area than the current state needs to be considered during continued operation, it will be separately indicated when delineating the impact area.

In the study conducted for this preliminary consultation, the reference date for the baseline data and environmental information considered is 31 December 2023.

1.4.3. Technical feasibility of the subsequent service life extension, preparatory activities, ageing management

The management system of MVM Paks Nuclear Power Plant Ltd. is based on the requirements outlined in the volume 2 *"Management systems of nuclear facilities"* of the Nuclear Safety Code (NSC), which is annex to the 1/2022. (IV. 29.) HAEA Decree on the nuclear safety requirements of nuclear facilities and the related regulatory activities. This system covers the entire operation of the nuclear power plant, including the activities necessary for executing maintenance, testing, and supervision programs. The related activities are organized into processes, and the methods for executing the processes are described in procedures. The requirements of the management

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[3] The two new nuclear power plant units being built under the investment of Paks II. Nuclear Power Plant Ltd. will be marked with serial numbers 5 and 6, taking into account the already existing units 1-4 in Paks., regardless of whether they are operated by another company, the MVM Paks Nuclear Power Plant Ltd.

system ensure that the developed and applied procedures are regularly reviewed and validated based on operational experience and expected outcomes.

As part of the operation of nuclear power plant units, the plant operates a comprehensive work planning and management system to ensure the planned execution of tasks related to maintenance, testing, and supervision programs that must be performed on the units during operation and major outages. The operational processes of the work planning and management system, as well as the supply chain processes, are covered by the main process of work management. The main process covers the preparation of the Medium-term outage plan, the planning of the outage for the specific unit and the operational management of the works in the facility, from work requests, prioritisation of the work, work planning, safety assessment, through condition-related interventions, periodical implementation of programs defined by standards, manufacturer or internal regulations, and the execution of emerging repair and conservation tasks. The main process of work management includes the systems of material and services planning / tracking for work execution, in order to ensure that each task can be completed with urgency according to its priority, and no lack of materials or resources is experienced. The main process implements feedback through work week and outage assessment to ensure that performance is continuously improved.

The key elements of the condition-maintenance system are the monitoring the effectiveness of maintenance program, evaluating the achievement of maintenance goals, and thereby verifying the program's effectiveness and making necessary corrections.

The program has a significant technical impact on the management and execution of operational tasks, as well as on the technical decision-making mechanisms required for interventions necessitated by unplanned events occurring in the plant's technological equipment and systems.

Equipment-level lifetime management involves the operation of a complex management practice in which the company's management ensures that equipment with safety relevance and functions remains operational with the expected performance parameters throughout the entire service life. The current requirements for the system for maintaining the technical condition of the systems are identified, their technical content and daily practical implementation are up-to-date, and they are documented in the technical base document of the system.

To achieve the condition-maintenance goals, the established system plans and technically prepares the management of ageing processes, the medium-term and annual maintenance programs, as well as the preventive maintenance, testing, and supervision program to ensure that the systems, structures and components maintain characteristics that meet design requirements. It schedules and prepares technical reviews, condition monitoring activities, and determines the technical content and timing of refurbishments and replacements.

An ageing management system has been developed and is in operation at the nuclear power plant. During the development of the Ageing management program, all degradation mechanisms were identified for safety-critical equipment. The ageing management system is aligned with the maintenance processes and the qualification procedures of system components.

When establishing and operating the comprehensive ageing management program, environmental conditions, process conditions, operational cycles, maintenance plans, the planned operational period, and the scheduling of tests were taken into account.

The Paks Nuclear Power Plant's ageing management process includes measures necessary to prevent and detect the development of ageing mechanisms. To assess ageing effects, the operator carries out monitoring, testing, sampling, and inspection activities that ensure the timely identification of unexpected processes or deteriorations during operation and the necessary preventive or corrective actions.

The system of in-service inspections applied in the nuclear power plant complies with the requirements of the ASME Boiler & Pressure Vessel Code, Section XI: Inservice Inspection of Nuclear Power Plant Components, the 2001 version of which has been published as a Hungarian standard (MSZ 27011).

Maintaining a technically adequate condition does not require special preparation, as the comprehensive ageing management program is continuously updated and revised to ensure the reliable and safe, continuous operation of the plant.

Based on the above, it can be concluded that the condition of the equipment and structures at the Paks Nuclear Power Plant is continuously monitored as part of the operation, the necessary maintenance and refurbishments are carried out as planned, and these activities lay the foundation for maintaining the expected technical condition of the nuclear power plant, thereby ensuring the feasibility of the subsequent service life extension.

1.5. Methodology of the preliminary consultation document development

1.5.1. Logical process and phases of the impact assessment

The primary objective of the environmental impact assessment is to forecast and evaluate the changes occurring in various environmental elements, systems as a result of the examined activity based on changes observed in the final receptors. To achieve this, the first step is to review the plant's technology and related activities to identify specific environmental impact factors (e.g., environmental material and energy emissions, waste generation, noise pollution, etc.). With this knowledge, the most important task in impact assessments is to review the logical chain of "impact factor → direct impacts → indirect impacts, i.e., impact processes → directly and indirectly affected, i.e., receptors → final receptors." To carry out the impact assessment estimations, it is first necessary to identify the impact factors of the examined activity and the impact processes that originate from them, as well as to delineate the study area. The following steps are required to estimate the state changes:

- Review of the planned activity (technology, operational processes, material usage, related activities, environmental emissions).
- Identification of environmental impact factors.
- Mapping of impact processes.
- Preliminary delineation of the assumed total impact area, i.e., the study area.
- Description of the environmental status (determining the sensitivity of potential receptors).
- Estimation of impact processes and state changes.
- Evaluation of state changes, final delineation of impact areas by environmental elements, summarizing the delineated elementary impact areas, determining the total impact area of the planned activity.
- Proposals to avoid or mitigate adverse impacts.

As part of the development of the PCD, a preliminary analysis was conducted on the sensitivity of the planned activity to climate change (from both electricity generation safety and nuclear safety perspectives) and the exposure of the installation site and the assumed impact area to climate change.

The PCD examines the possibility of transboundary environmental impacts in terms of both radiological and "conventional" (non-radiological) environmental emissions.

In the context of the development of the PCD, a preliminary estimate was made of the expected environmental impacts and the impact area, based on currently available data and information. The results of these investigations will be refined in the EIAS following the completion of the ongoing sectoral study programs parallel to the document's preparation.

To survey the baseline condition of the nuclear power plant site and its surroundings, as well as to conduct the necessary investigations for the preparation of the EIAS, 13 sectoral study programs have been developed. As part of the study programs encompassing both radiological and conventional sectors, the results and documents of previous environmental studies conducted at the site – related to both the operation of the Paks Nuclear Power Plant and the implementation of Paks II. – has been collected, processed, and evaluated. The study programs also extend to the execution of sectoral investigations (on-site measurements and sampling, model calculations, data processing, and evaluations) that are indispensable for the preparation of the EIAS. The tasks to be performed within the investigation programs are presented in *Chapter 6*.

The implementation of the sectoral study programs is proceeding parallel with the preparation of this PCD and continues after the document is finalized, depending on the nature and scope of each investigation. As a result, the PCD relies only to a limited extent on the results of these programs. The investigation conducted for the preliminary consultation, with a few exceptions (e.g., meteorological characterization), is fundamentally based primarily on the existing results of previous studies. The preliminary estimates of the expected environmental impacts related to the subsequent extension of the service life are based on the environmental monitoring results, operational experience, and previous analyses and model calculations carried out during the plant's operation. These preliminary estimates will be refined and detailed in the EIAS using the investigation results that will become available after the execution of the sectoral study programs. These data and information provide an appropriate professional basis for the preparation of the PCD, based on their content and level of detail.

1.5.2. The main documents used

The following main documents were considered as primary data sources during the development of the PCD:

- The current environmental permit for the operation of the Paks Nuclear Power Plant and its amendments.
- Documents related to the environmental impact assessment of the first service life extension of the Paks Nuclear Power Plant:
  - Sectoral final reports of the site characterization program supporting the environmental impact assessment of the first operational period extension (2002-2006).
  - The Environmental impact assessment study (EIAS) related to the first operational period extension.
- The current Final Safety Analyses Report (FSAR) of the Paks Nuclear Power Plant.
- Annual reports (environmental, radiation protection) of MVM Paks Nuclear Power Plant Ltd., periodic reports submitted to the environmental authority, data submissions, and environmental monitoring data.
- Internal environmental regulations and procedures of MVM Paks Nuclear Power Plant Ltd.
- Documents related to the implementation of the Paks II. Nuclear Power Plant:
  - The Environmental impact assessment study (EIAS) and its supplements for the implementation and operation of the Paks II. Nuclear Power Plant.
  - Documents related to the nuclear safety site licensing of the Paks II. Nuclear Power Plant (Site Safety Report and its supplements).
  - Data submissions from Paks II. Nuclear Power Plant Ltd.
- Official statistics, databases (e.g., the HCSO's online databases, road data bank).
- Maps, satellite images.

1.5.3. Criteria for qualification of environmental impacts

The most important factors considered in the qualification of environmental impacts are as follows:

- Exceedance of a limit value or another accepted norm system.
- The spatial extent of the impact (a large area can increase the number of receptors and thus the significance of the impact).
- The temporal extent of the impact (its duration).

- The reversibility of processes.
- The possibility of preventing or reducing harmful / adverse impact processes.
- The certainty / uncertainty of the estimates.

The assessment of changes predicted due to the estimated environmental impacts in impact assessments cannot always appear numerically (e.g., changes within a living community). Therefore, it is generally necessary to introduce qualification categories. In this study the qualification categories related to internal state changes of environmental elements is used, that are applied in environmental impact studies. The general qualification of state changes used in this preliminary study is provided in *Table 1.5.3-1.*

Table 1.5.3-1. General qualification categories of state changes caused by environmental impacts

Qualification	Explanation
Eliminative	This includes changes where an environmental element, system or any of its independently considered components or the entire element, system ceases to exist. This also includes cases where the characteristics of the element, system that determined its classification are lost (e.g., arable land ceases to function as farmland during construction).
Damaging	This category assumes the simultaneous occurrence of two factors: one is exceeding the relevant threshold or requirement, resulting in a lower quality classification of the element. This does not necessarily involve legal thresholds. The second condition is the irreversibility of the change, meaning the consequences can only be corrected by human intervention (the internal processes, self-purification, and regeneration ability of the element no longer allow this). Irreversible and thus classified as damaging are changes that, while temporary, are periodic (e.g., daily peak loads).
Burdensome	This category includes two distinguishable cases: The first involves the irreversibility described earlier, but without exceeding thresholds or other classification limits. The second case involves threshold exceedance, but the impact is reversible without intervention due to its transient or negligible intensity. Either because the impact factor is one-time, discontinuous, or because the impacts occur continuously, but their intensity is negligible.
Tolerable	This applies when undesirable changes are detectable (e.g., occasional or slight near-threshold emissions) but do not affect any significant property of the examined unit. There should be no persistent or frequent threshold exceedance. These changes typically have a limited area of impact.
Neutral	This includes impacts where the existence is detectable, but the change caused is so small that it is imperceptible. Essentially, a neutral impact is not considered an impact and is only relevant to abiotic elements; for living organisms and systems, it is better to use terms like "no impact" or "undetectable".
Improving	This includes changes that positively affect any quantitative or qualitative characteristic of an environmental element, system. All improvements where existing values increase rather than creating new values are included here.

During the preliminary impact assessment, in addition to the qualification of state changes caused by various environmental impacts as outlined above, their duration and significance are also evaluated. The expected environmental impacts can be short-term (up to a few months), medium-term (up to 3 years), or long-term (longer than 3 years) based on their duration (durability). Impacts can be classified as minor, moderate, or major in significance. Burdensome and major significant impacts are considered significant impacts according to the Government Decree 314/2005. (XII. 25.).

1.5.4. Declaration on the implementation of associated activities

In accordance with point 1. bm) of Annex 4 of Government Decree 314/2005 (XII. 25.), the environmental user must declare whether, after starting the planned activity, the implementation of a new activity classified as an associated activity will occur, and whether the activity, combined with another similar activity conducted or planned on the site or neighbouring property, will reach the threshold specified in Annex 1 or Annex 3 of the Decree.

According to section 2 e) of § 2 of the Government Decree, activities listed in Annex 3 of the decree and those identical to the activities listed in Annex 1 or 3[4], which are planned to be commenced by the environmental user with the same or adjacent property for a common investment purpose, qualify as associated activities. Such activities are considered identical if they fall under the scope of Annex 3 or fall below the threshold values specified in Annex 3 but, when combined with the activity listed in Annex 1 or 3, they meet the threshold value specified in Annex 3.

The planned subsequent service life extension of Paks Nuclear Power Plant falls under Annex 1 of the Government Decree (point 31), meaning that regardless of size, it is an activity requiring an environmental impact assessment. Following the commencement of the subsequent life extension at the Paks Nuclear Power Plant site, no other activities listed in Annex 1 or 3 of the Government Decree are planned in connection with the operation of the nuclear power plant.

The following activities, subject to the Government Decree 314/2005. (XII. 25.), are being carried out or planned on properties adjacent to the Paks Nuclear Power Plant site:

- Spent Fuel Interim Storage Facility (SFISF) /operating nuclear facility/:
  - Classification according to the Government Decree 314/2005. (XII. 25.): Annex 1, point 17: "*Interim or final storage of spent nuclear fuel*" (no size restriction).
  - Licensee: Public Limited Company for Radioactive Waste Management (PURAM).
  - Valid permit registration number: 1363-15/2015. (environmental operating permit issued by the Baranya County Government Office on 6th July 2015).
- Paks II. Nuclear Power Plant /nuclear facility under construction/:
  - Classification according to the 314/2005. (XII. 25.) Government Decree: Annex 1, point 31: "*Nuclear power plant, nuclear reactor*" (no size restriction).
  - Licensee: Paks II. Nuclear Power Plant Ltd.
  - Valid permit registration number: 78-140/2016. (environmental permit issued by the Baranya County Government Office on 29th September 2016).

The activities carried out on the property adjacent to the Paks Nuclear Power Plant site are therefore subject to permits issued by the environmental authority, with the licensees being independent companies from MVM Paks Nuclear Power Plant Ltd. In the case of the adjacent Paks II. Nuclear Power Plant, as it is an identical activity, it is also subject to an environmental impact assessment regardless of size, with Paks II. Nuclear Power Plant Ltd. being the investor, holding a valid environmental permit for the facility.

Accordingly, no other identical activities are planned at the site or on adjacent properties that, when combined with the activity examined in this PCD, would reach the threshold value specified in Annex 1 or 3 of the Government Decree 314/2005. (XII. 25.). There is no planned new route-facility (e.g., overhead power line, road, railway track, channel) associated with the implementation of the planned subsequent service life extension.

In light of the above, no related activities associated with the subsequent service life extension of Paks Nuclear Power Plant will be implemented.

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[4] Annex 1 to Government Decree 314/2005. (XII. 25.) lists the activities subject to the environmental impact assessment, Annex 2 lists activities subject to integrated environmental use permit, Annex 3 lists activities subject to an environmental impact assessment, depending on the decision made by the environmental protection authority in the preliminary investigation.

1.5.5. Use of classified information and trade secret data

This PCD does not contain classified information or trade secret data. The data and information presented in the document are fully accessible to the public, and the document does not contain any segregated sections that are not to be disclosed publicly.

1.6. The international context and practice of nuclear power plant service life extension

Keeping in operation a production-capable and safely operable electricity generation capacity with production of significant national economic added value beyond its planned service life is a clearly rational decision from both technical and economic perspectives, especially when the capital costs have already been recovered. The necessary research and development work first began in the United States, considering that new nuclear power plants were not being built in recent decades, or only in certain parts of the world (e.g., China), and the operational units were approaching the end of their licensed service life. In the USA, where 100 nuclear power plants were in operation, the nuclear safety authority initiated a comprehensive ageing research program in 1985. The program aimed to identify and address technical safety issues related to the ageing of nuclear power plant equipment and to develop technical foundations for rulemaking on renewing operating licenses and evaluating the remaining service life of major nuclear power plant structures and equipment.

Under the 10 CFR Part 54 law issued in 1995, the Calvert Cliffs Units 1 and 2 were the first to receive a 60-year operational service life extension license in 2000. The technical-scientific foundation and legal framework for the second 20-year service life extension were also developed in the USA. Following the USA’s practice, many countries began systematically laying the foundation for managing the ageing of nuclear power plant equipment. The International Atomic Energy Agency (IAEA) also released its first ageing management guidelines during this period (Assessment and management of ageing of major nuclear power plant components important to safety), compiled by working groups of experts from member states.

This was also when the IAEA's SALTO (Safety Aspects of Long Term Operation) activities began, which were intended to review the safety of units with extended service lives. Since 2010, with the launch of the IGALL (International Generic Ageing Lessons Learned) program, the IAEA has been coordinating international cooperation, providing guidance for the plants' ageing management programs in compliance with requirements.

The concept of service life extension, and the necessary technical-scientific foundation for it, has been adopted and implemented by most operators worldwide, achieving extended operations within the framework of their national regulations. Due to geopolitical reasons, service life extensions, and even repeated service life extensions, are a relevant topic globally today.

In the case of nuclear power plant’s service life extension, the fundamental requirement is that the units must comply with current international requirements and national safety regulations. This compliance must be demonstrated not based on the current technical condition but by considering the partly manageable but theoretically unavoidable ageing of safety-critical structures, systems, and components, projecting the expected condition to the end of the extended service life. In this regard, the condition of replaceable or refurbishable system elements during the operational period is not the most important factor, as maintaining safety and operational readiness is a matter of cost for replacements and refurbishments. Instead, the condition of non-replaceable or economically unfeasible to refurbish structures, such as the containment building, the reactor, and the primary circuit equipment, is decisive. These must guarantee safe operation even at the end of the extended service life. It is the operator's responsibility to maintain the required state of the power plant through ageing management programs and ensuring the effectiveness of maintenance. For the VVER-440 type units operating at the Paks Nuclear Power Plant, their inherent safety design and reserves provide the foundation for this.

The safety of the currently operating VVER-440/V-213 reactors can no longer be judged based on the original designs. After the Chernobyl accident, the safety of all such units worldwide was subject to critical review, including national and international safety assessments and review programs, followed by costly and technically challenging safety enhancement programs. An example of this is the seismic safety program implemented at the Paks Nuclear Power Plant, during which nearly 4000 tons of steel structures were installed as reinforcements.

Thanks to these programs, the safety of operating VVER-440/V-213 nuclear power plants meet the requirements of the 2000s. This has been further improved by the periodic safety reviews and subsequent measures, and targeted safety reviews and measures following the Fukushima accident have prepared the units for extraordinary impacts and accident conditions.

These factors form the technical and moral basis for both the initial and renewed service life extensions, which are necessary because the VVER-440 units were commissioned between 1971 and 2000, and the operating countries have a fundamental interest in maintaining their capacity.

Regarding VVER-440 nuclear power plants, the four oldest units, initially licensed for 30 years, Novovoronezh 1-2 (Russia) and Kola 1-2 (Russia), received their first 15-year operational life extension licenses between 2001 and 2004.

In practice, VVER-440 units with fixed-term operating permits (Bohunice /Slovakia/, Loviisa /Finland/, Rovno /Ukraine/, Kola, Novovoronezh /Russia/) had their first service life extension aimed at a total operational life of 50 years. There are examples of other national regulations where the operating permit is indefinite, but periodic safety reviews (PSR) and their periodic safety analysis reports confirm it every ten years. However, even in such cases, there is a targeted extended operational life. For instance, between 2016 and 2017, the operating licenses of Dukovany 1-4 units (Czech Republic) were confirmed by the periodic safety review, while a 20-year service life extension was also considered in the technical basis for the operating permit.

In Finland, Ukraine, the Czech Republic, Slovakia, and Hungary, the validity of service life extension permits is also linked to the acceptance of plant reviews – such as the decadal comprehensive periodic safety reviews – reports, and approvals by authorities. Among the VVER-440 units, there are already some (Kola 1, Kola 2, Kola 4, Novovoronezh 4, Armenian 2) that have been granted operating permits with renewed service life extensions for nearly 60 years.

For the Loviisa units 1-2 (Finland), a request for a further 20-year service life extension (totalling 70 years) was submitted in 2022, after the successful completion of the periodic safety review of the units. The units now already have an operating permit for the extended operational life. For the Bohunice units 3-4 (Slovakia), the permitting of 60-year service life extension is also planned. For the boiling-water reactor (BWR) type Olkiluoto units 1-2 (Finland), the environmental permitting process for further service life extension has begun, totalling 70 years of operational life. The original planned operational life for Olkiluoto units 1-2 was 40 years, until 2018. The operational life was previously extended to 60 years, until 2038. Current plans aim to extend the operational life to 2048 and 2058.

Repeated service life extensions also follow the American model. According to 10 CFR Part 54, between 2019 and 2021, the U.S. Nuclear Regulatory Commission (NRC) issued additional 20-year operating licenses to six PWR units (Turkey Point 3-4, Surry 1-2, Peach Bottom 3-4), which totals 80 years of operational life for these units. Furthermore, the NRC is reviewing additional 20-year service life extension requests already submitted for nine PWR units from four other nuclear plants (St. Lucie 1-2, Oconee 1-3, Point Beach 1-2, North Anna 1-2). *Table 1.6-1.* summarizes the status of operating VVER-440 units and the U.S. PWR units involved in additional service life extension approvals.

In line with global trends and as part of the national energy strategy, preparations for another 20-year permit extension are also planned for the Paks VVER-440/V-213 units, extending their operational life to 70 years.

Table 1.6-1. Status of operating VVER-440 units and U.S. PWR units affected by authorising subsequent service life extension

First grid connection	Power plant unit	Type	Electrical power [MW]	First service life extension permit (years / issued / validity)	Additional life extension permit (years / issued / validity)	Current authorized (under approval) operational life (years)
28.12.1972.	Novovoronezh-4	VVER V-179	417	15 (2002) / 2017	15 / 2032	60
29.06.1973.	Kola-1	VVER V-230	440	15 (2003) / 2018	15 (2018) / 2033	60
09.12.1974.	Kola-2	VVER V-230	440	15 (2004) / 2019	15 / 2034	60
08.02.1977.	Loviisa-1	VVER V-213	531	20 (2007) / 2027	20 (2023) / 2050	70
05.01.1980.	Armenian-2	VVER-270	451	10 / 2016	20/2036	56
04.11.1980.	Loviisa-2	VVER V-213	531	20 (2007) / 2030	20 (2023) / 2050	70
22.12.1980.	Rovno-1	VVER V-213	420	10 (2010) / 2020	10 (2020) / 2030	50
24.03.1981.	Kola-3	VVER V-213	440	15 (2010) / 2026	no data	55
22.12.1981.	Rovno-2	VVER V-213	415	10 (2010) / 2021	no data	40
28.12.1982.	Paks-1	VVER V-213	509	20 (2012) / 2032	20 (Owner's intent for 70-year service life)	50
20.08.1984.	Bohunice-3	VVER V-213	500	10 / 2024	20 (Owner's intent)	40
06.09.1984.	Paks-2	VVER V-213	506	20 (2014) / 2034	20 (Owner's intent for 70-year service life)	50
11.10.1984.	Kola-4	VVER V-213	440	25 (2014) / 2029	No data	55
24.02.1985.	Dukovany-1	VVER V-213	500	Indefinite (2016 PSR)	(Indefinite, tied to PSR, Owner's Intent for 60-year service life)	41
09.08.1985.	Bohunice-4	VVER V-213	500	10 / 2025	20 (Owner's intent)	40
30.01.1986.	Dukovany-2	VVER V-213	500	Indefinite (2017 PSR)	(Indefinite, tied to PSR, Owner's Intent for 60-year service life)	41
28.09.1986.	Paks-3	VVER V-213	506	20 (2016) / 2036	20 (Owner's Intent for 70-year service life)	50
14.11.1986.	Dukovany-3	VVER V-213	500	Indefinite (2017 PSR)	(Indefinite, tied to PSR, Owner's Intent for 60-year service life)	41
11.06.1987.	Dukovany-4	VVER V-213	500	Indefinite (2017 PSR)	(Indefinite, tied to PSR, Owner's Intent for 60-year service life)	40
16.08.1987.	Paks-4	VVER V-213	506	20 (2017) / 2037	20 (Owner's intent for 70-year service life)	50
04.07.1998.	Mohovce-1	VVER V-213	500	No data		30
02.12.1999.	Mohovce-2	VVER V-213	500	No data		30
U.S. PWR units, which permit renewal application for another 20-year service life has been approved by the NRC						
02.11.1972.	Turkey Point-3	PWR	829	20 (2002) / 2032	20 (2019) / 2052	80
21.06.1973.	Turkey Point-4	PWR	829	20 (2002) / 2033	20 (2019) / 2053	80
04.07.1972.	Surry-1	PWR	890	20 (2003) / 2032	20 (2021) / 2052	80
10.03.1973.	Surry-2	PWR	890	20 (2003) / 2033	20 (2021) / 2053	80
18.02.1974.	Peach Bottom-3	PWR	1412	20 (2003) / 2033	20 (2020) / 2053	80
01.09.1974.	Peach Bottom-4	PWR	1412	20 (2003) / 2034	20 (2020) / 2054	80

First grid connection	Power plant unit	Type	Electrical power [MW]	First service life extension permit (years / issued / validity)	Additional life extension permit (years / issued / validity)	Current authorized (under approval) operational life (years)
U.S. PWR units, which permit renewal application for another 20-year service life under evaluation by the NRC						
07.05.1976.	St. Lucie-1	PWR	1045	20 (2003) / 2036	20 (2023?) / 2056	80
13.06.1983.	St. Lucie-2	PWR	1050	20 (2003) / 2043	20 (2023?) / 2063	80
06.05.1973.	Oconee-1	PWR	891	20 (2000) / 2033	20 (2023?) / 2053	80
05.12.1973.	Oconee-2	PWR	891	20 (2000) / 2033	20 (2023?) / 2053	80
18.09.1974.	Oconee-3	PWR	900	20 (2000) / 2034	20 (2023?) / 2054	80
06.11.1970.	Point Beach-1	PWR	640	20 (2005) / 2030	20 (2023?) / 2050	80
02.08.1972.	Point Beach-2	PWR	640	20 (2005) / 2033	20 (2023?) / 2052	80
17.04.1978.	North Anna-1	PWR	990	20 (2003) / 2038	20 (2023?) / 2058	80
25.08.1980.	North Anna-2	PWR	1011	20 (2003) / 2040	20 (2023?) / 2060	80

Source: Á. K. Bíró – Dr. T. J. Katona – S. I. Rátkai: Bíró Á. K. – Dr. Katona T. J. – Rátkai S. I.: VVER-440 type nuclear power plants, Service life extension, Mérnök Újság, Vol. XXIX, Issue 10, October 2022, updated to reflect the status as of August 2024.

2. The service life extension and the nuclear power plant site, the nuclear energy production technology

2.1. The nuclear power plant site and its environment

2.1.1. Geographic location of the site

The site of the Paks Nuclear Power Plant is located in the southern Transdanubia region, on the eastern border of Tolna County, 1 km west of the Danube River, at the 1527 river kilometre section, and 1.5 km east of main road No. 6. The site is situated 118 km south of Budapest, 83 km from the regional centre of Pécs, 30 km northeast of Szekszárd, and 5 km south of the centre of Paks. The nearest national border section is to the south, 63 km in a straight line and 94 km along the direction of the Danube, with the border lying at the 1433 river kilometre section. The area designated for the broader environmental assessment of the power plant site, with a radius of 30 km, includes parts of Bács-Kiskun, Fejér, and Tolna counties, covering a total of 282 742.1 hectares, which is shown in *Figure 2.1.1-1.* The broader 30 km radius environment of the power plant site is illustrated in *Figure 2.1.1-2.*

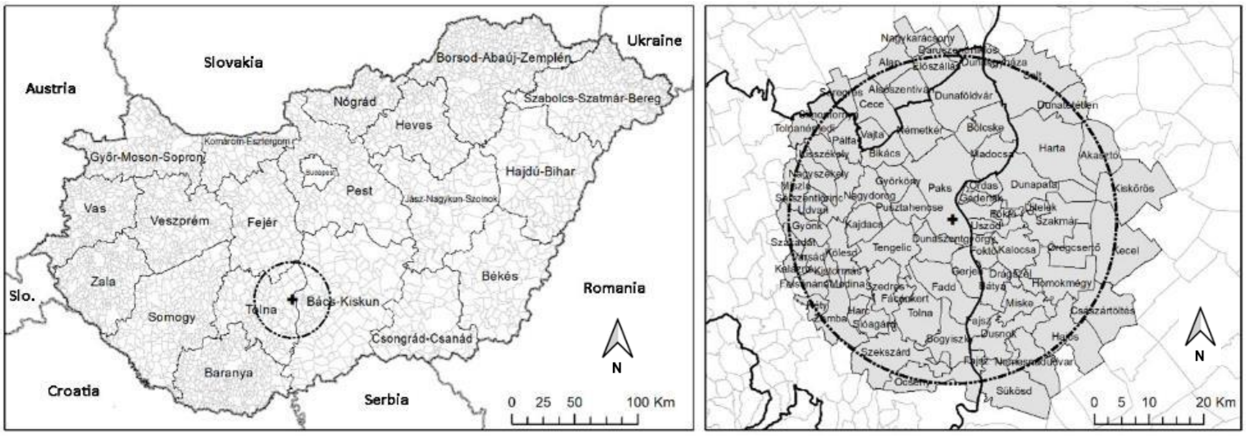


Figure 2.1.1-1. Geographic extent of the study area

The designated area (Paks region) is divided into two parts by the Danube. The section located in the Danube-Tisza Interfluve, along with its eastern and central Transdanubian areas (Mezőföld), belongs to the flat, lowland Great Plain region, while its western unit is part of the hilly Transdanubian Hills region, as shown in *Figure 2.1.1-3.*

The two mentioned major regions (Great Plain and Transdanubian Hills) are essentially made up of mosaic-like smaller regions that are similar but differ in some parameters. The Great Plain includes smaller regions such as the Solti Plain (16 385 ha), Kalocsa Sand Ridge (89 790 ha), Bugac Sand Ridge (6 636 ha), Central Mezőföld (29 310 ha), South Mezőföld (50 157 ha), Tolna Sand Ridge (33 923 ha), and Sárvíz Valley (16 174 ha). The part of the Transdanubian Hills here includes the Tolna Hills (36 341 ha) and the Szekszárd Hills (4026 ha). The site is located on the boundary between the South Mezőföld and Tolna Sand Ridge small regions.

In terms of topography, the study area (Paks region) features a flat, slightly undulating lowland landscape. Exceptions include the west and northwest, loess-covered plains, where the highest point is at Györköny (214 m), and the hilly areas, where the highest point is at Szekszárd (255 m).

Source: National Geospatial Base Map (NTA), Lechner Knowledge Center

Figure 2.1.1-2. The site of the Paks Nuclear Power Plant and its broader (30 km radius) environment

In the 30 km radius area (Paks region), significant expanses of Natura 2000 and nationally protected areas are present. The territory of Special Protection Areas (SPAs) /protected areas for birds/ within the Natura 2000 network covers 26 603 ha, while the territory of Special Areas of Conservation (SACs) is 42 495 ha. Due to overlapping areas, the extent of Natura 2000 sites in the studied region is 50 937 ha. The total area of national parks and other protected areas is 20 243 ha. Due to overlaps with Natura 2000 areas, the total area of nationally protected areas is 51 765 ha, which constitutes 18.3% of the total area. Protected natural areas around the site are shown in *Figure 2.1.1-4.*

There are three nationally significant protected areas in Paks, only one of which, the Paks loess cliff geological basic section natural monument (2 ha), is entirely within the administrative boundary. The South Mezőföld Landscape Protection Area and the Dunaszentgyörgy Marsh Forest Nature Conservation Area cover a total of 603.5 ha in Paks. The Natura 2000 sites within the municipal boundary cover 2318.6 ha. The combined area of nationally protected and Natura 2000 SACs within the Paks municipality totals 2496.2 ha.

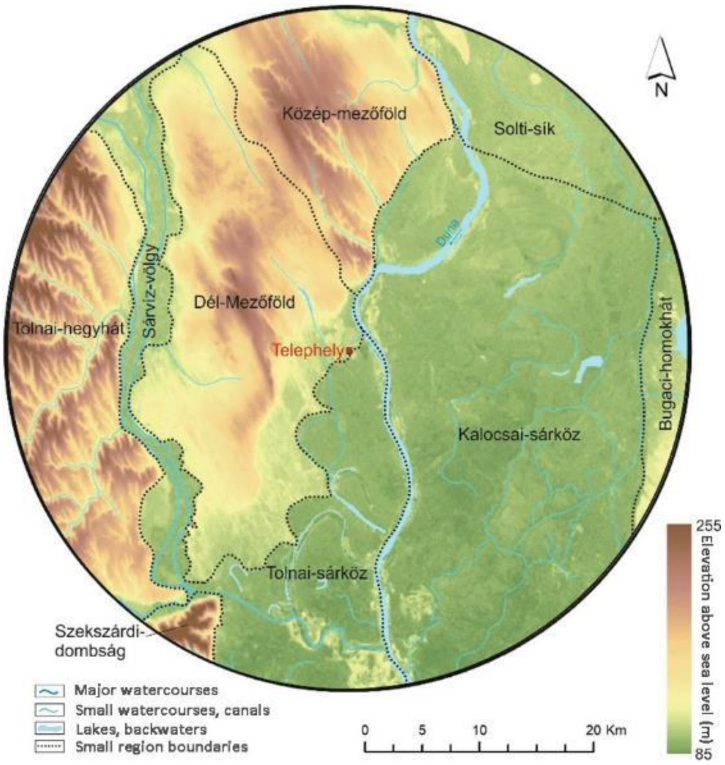
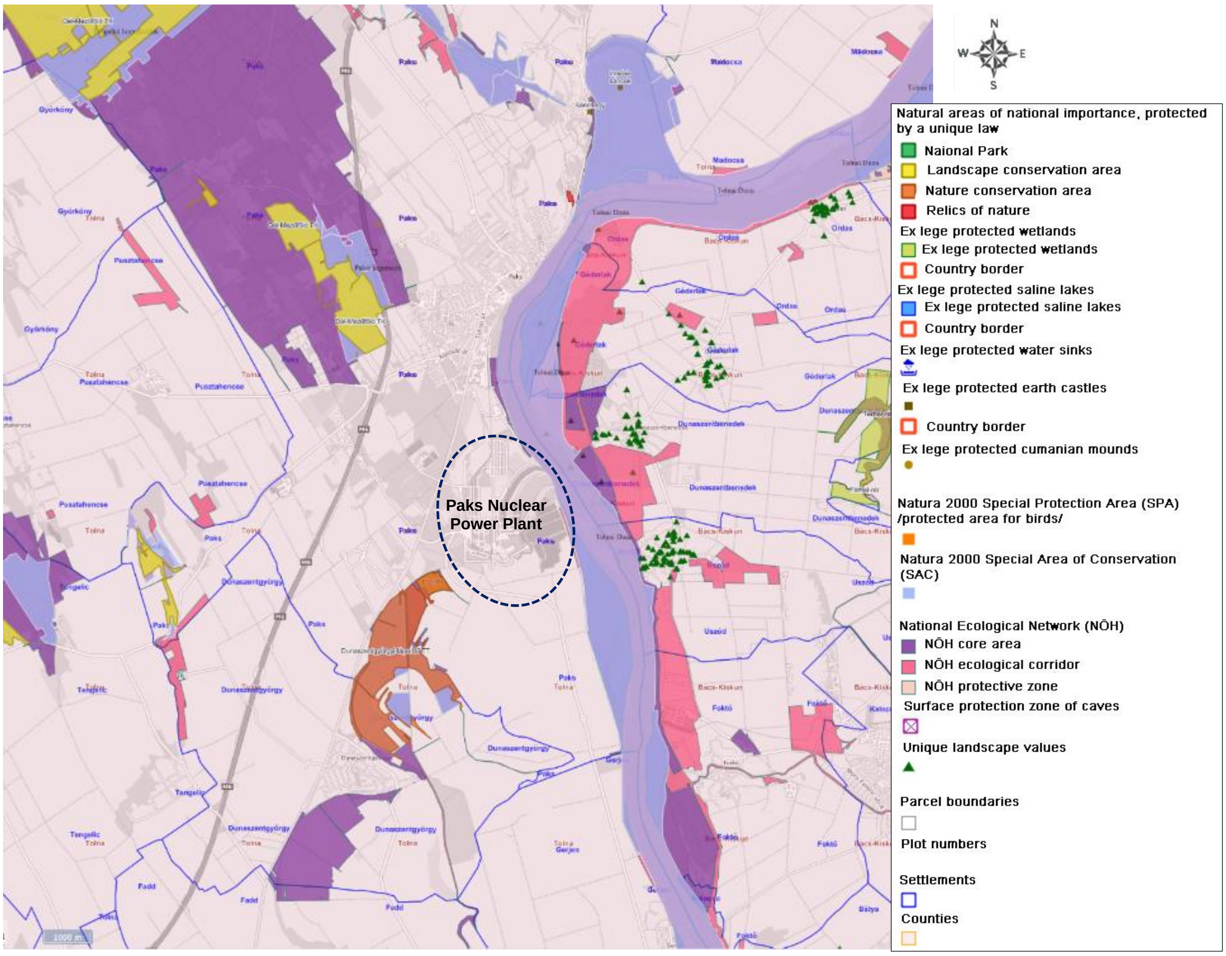


Figure 2.1.1-3. Natural geographic conditions of the study area



Source: Nature Conservation Information System

Figure 2.1.1-4. Protected natural areas surrounding the Paks Nuclear Power Plant

2.1.2. Land use of the site and its immediate surroundings

Site structure and land requirements

The Paks site is located within the administrative boundaries of the city of Paks, in an inner area, and is divided into the following three main sections:

- Operational Area of Paks Nuclear Power Plant units 1-4 (plot number 8803/17): This area houses units 1-4 operated by MVM Paks Nuclear Power Plant Ltd., including the related turbine hall, water intake facility, and auxiliary equipment, systems, office, maintenance, and storage buildings.
- Area of Paks II. Nuclear Power Plant units 5-6 (plot number 8803/16): This area, located north of the existing units 1-4, is designated for the construction of the new Paks II. Nuclear Power Plant (units 5-6) under the investment of Paks II. Nuclear Power Plant Ltd. Construction work for units 5-6 is currently underway in this area.
- Operational area of the Spent Fuel Interim Storage Facility (SFISF) (plot number 8803/2): Located southwest of the units 1-4 operational area, this area includes the SFISF maintained by the Public Limited Company for Radioactive Waste Management (PURAM), along with related buildings and structures.

The central EOV coordinates of the Paks Nuclear Power Plant site are X: 136667.09 m, Y: 635005.39 m. The operational area includes the hazardous and industrial waste operational collection area, the slurry ponds, and cold and warm water channels. Satellite imagery of the site and its surroundings, indicating the Paks II. construction area and the SFISF area, is shown in Figure *2.1.2-1.* The site layout is illustrated in *Figure 2.1.2-2.*, showing the buildings, structures, and facilities of the ongoing Paks II. Nuclear Power Plant construction, new hot water channel, new substation, and the construction and erection base. As shown in the layout, most of the area between the existing cold and hot water channels will be allocated to the operational area of the Paks II. warm water channel and related facilities.

The operational area of units 1-4 is owned by MVM Paks Nuclear Power Plant Ltd., and the plot number 8803/16 area for Paks II. is owned by Paks II. Nuclear Power Plant Ltd. The external boundaries of the Paks Nuclear Power Plant areas and the outlined areas within the operational sites are shown in *Figure 2.1.2-3.* Besides the actual operational areas, reserve operational areas, fishing ponds, access roads, and forests are considered external areas. Their distribution by size, representing the land requirements of the examined activities, is shown in *Table 2.1.2-1*.

Only nuclear energy production and related activities are conducted within the Paks Nuclear Power Plant site. No other activities affecting operational safety are present.

The Paks Nuclear Power Plant site is surrounded by a safety zone, designated by the Hungarian Atomic Energy Authority (HAEA) according to Government Decree 246/2011. (XI. 24.) on the safety zone of nuclear facility and radioactive waste repository. The safety zone extends 500 meters from the plane of the outermost technological protection wall of the plant, as shown in *Figure 2.1.2-2.* The referenced government decree allows for overlapping safety zones of the nuclear facilities. At the safety zone boundary, individuals continuously present during the plant's proper operation should not be exposed to a higher dose than 100 µSv/year of radiation from radioactive material emissions or releases into the environment.

A 500-meter safety zone is also designated around the adjacent SFISF and Paks II. Nuclear Power Plant areas (*Figure 2.1.2-2.*). The restrictions according to the referenced government decree apply in these safety zones.

Due to the subsequent service life extension of the Paks Nuclear Power Plant, there will be no change in the land requirements, and no new technological buildings or structures are planned within the operational area, thus the current extent of the safety zone will not be affected by the planned activities.

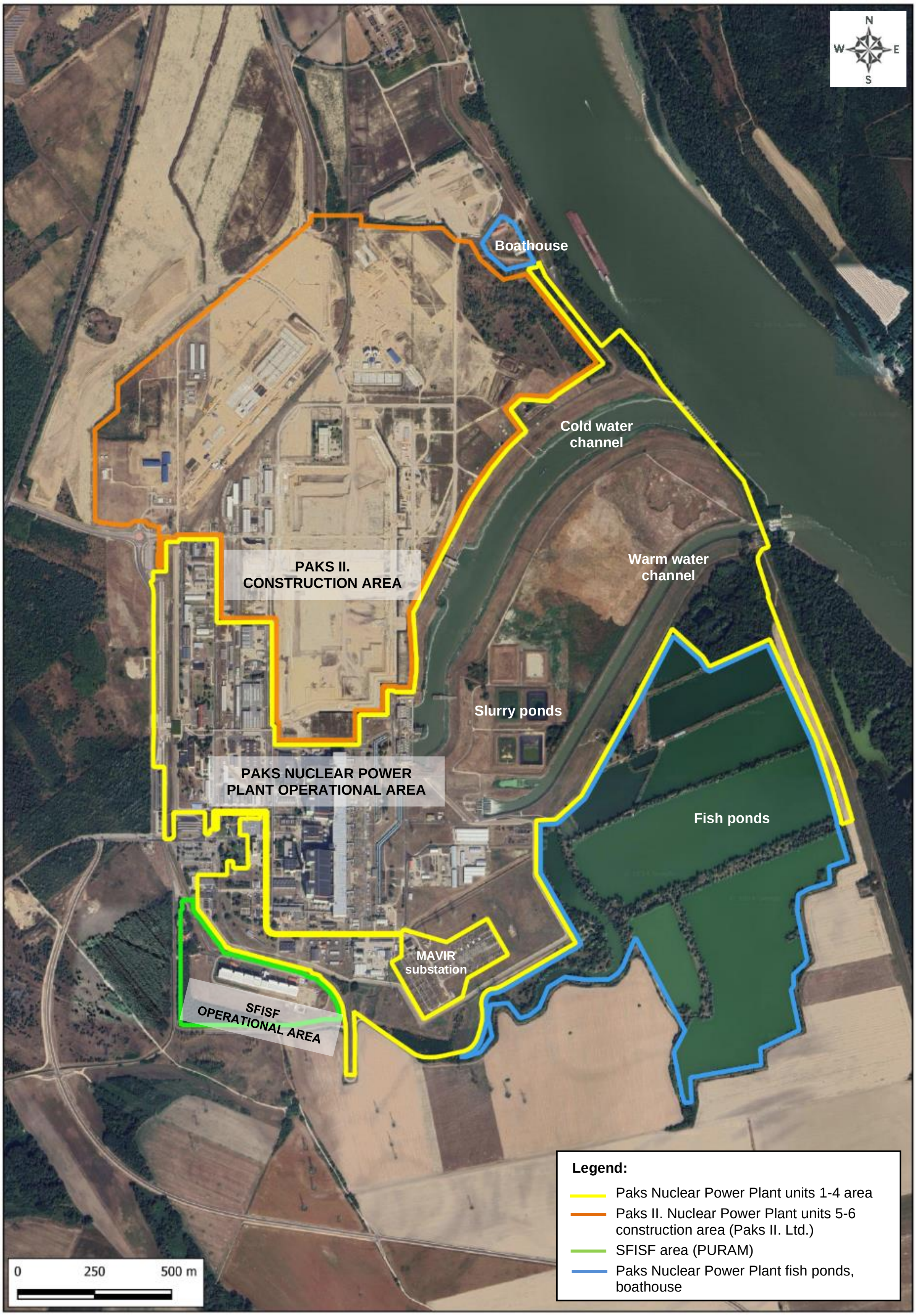


Figure 2.1.2-1. Satellite image of the Paks Nuclear Power Plant site and its surroundings, indicating the Paks II. Nuclear Power Plant construction area and the SFISF area

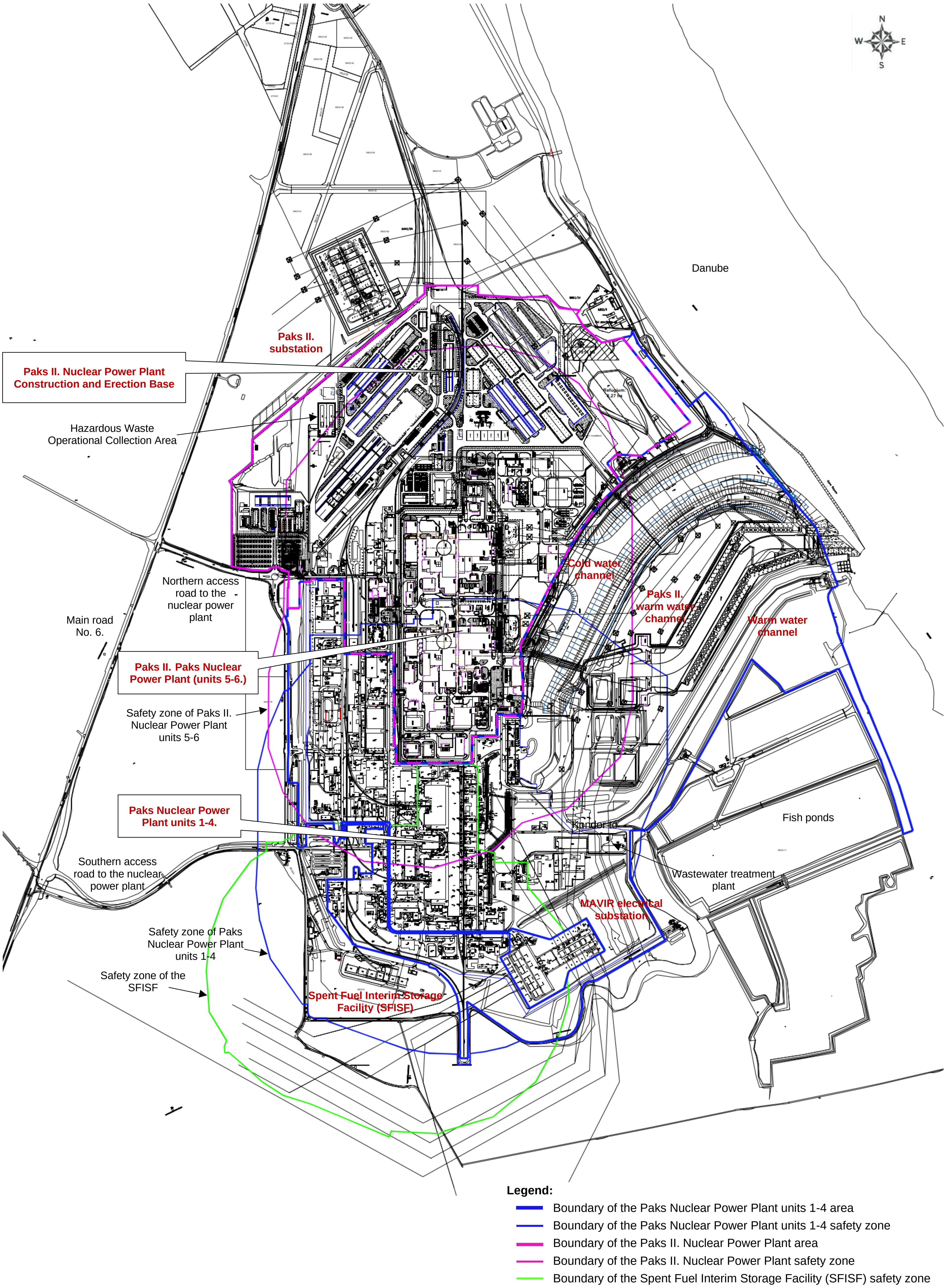


Figure 2.1.2-2. Layout of the Paks Nuclear Power Plant and its immediate surroundings, including the planned buildings and structures of the Paks II. Nuclear Power Plant

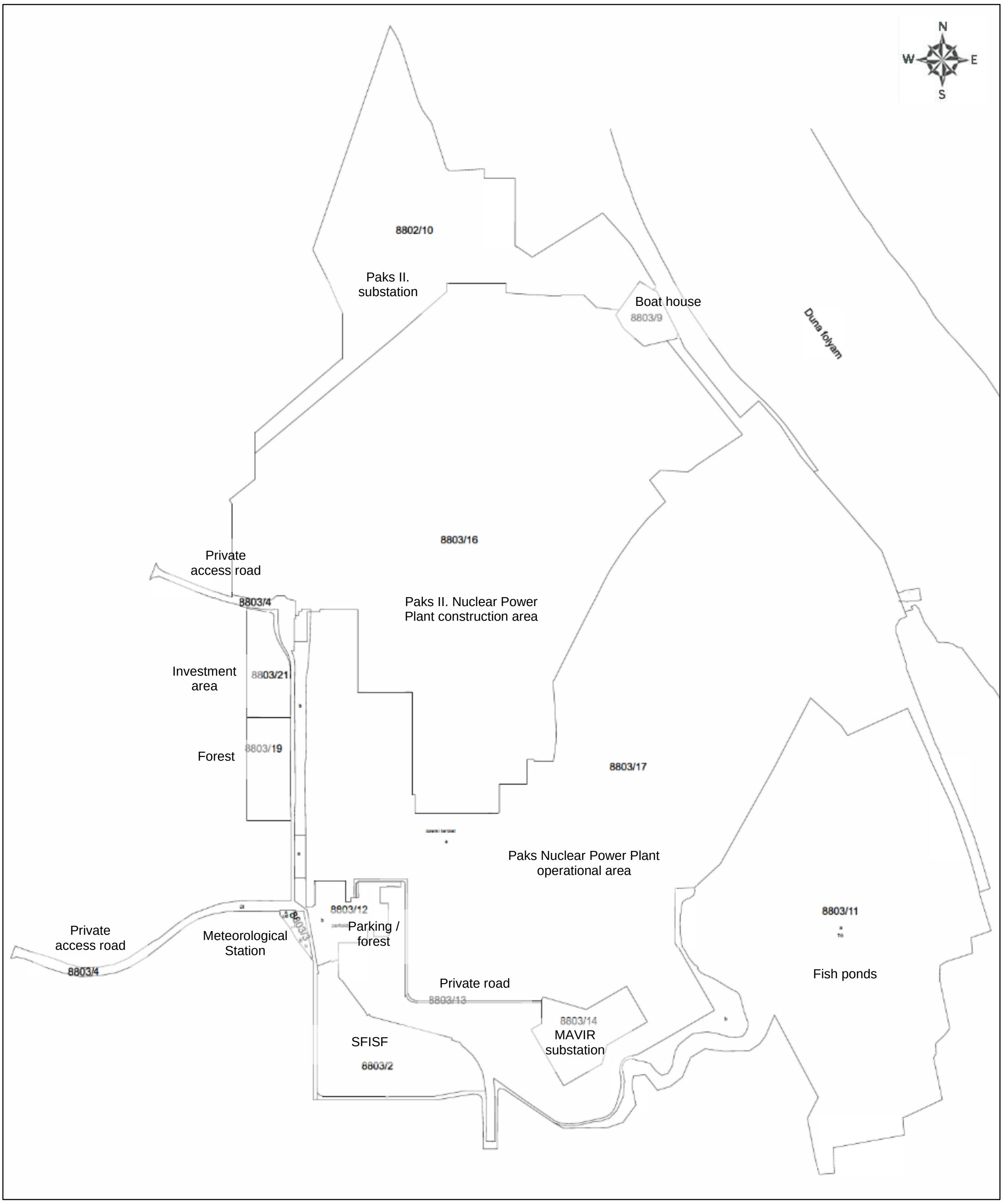


Figure 2.1.2-3. Plot boundaries and distribution of internal areas of the Paks Nuclear Power Plant

Table 2.1.2-1. Data on the operational area of MVM Paks Nuclear Power Plant Ltd. and adjacent properties according to the land registry

Plot number	Denomination		Area [ha]
8803/2	a sub-area	Excluded operational area (operational area of SFISF maintained by PURAM)	11.3742
	b sub-area	Forest	2.4119
8803/3	Excluded unbuilt area (meteorological station)		0.7191
8803/4	Excluded private access road (access road /northern, southern, connecting/)		6.6368
8803/20	Excluded investment area		0.2538
8803/21	Excluded investment area		4.2682
8803/19	Forest		4.7664
8803/9	Boat house		2.5271
8803/11	a sub-area	Fish pond	93.1596
	b sub-area	Excluded operational area	5.8775
8803/12	b sub-area	Excluded parking	5.3354
	c sub-area	Forest	0.5057
8803/13	Excluded private road closed for public traffic		0.6556
8803/16	Excluded operational area (Paks II. Nuclear Power Plant units 5-6 area, owned by Paks II. Nuclear Power Plant Ltd.)		157.8856
8803/17	a sub-area	Operational area (Paks Nuclear Power Plant units 1-4)	214.2264
	b sub-area	Excluded investment area	2.4532

Land use, examination of compliance with urban planning regulations

For characterisation of land use of the power plant site and its immediate surroundings and to assess compliance with urban planning regulations, the national and county-level land planning documents and the Local Building Code were considered. The analysis includes the presentation of the zones according to the Local Building Code and the following regulations:

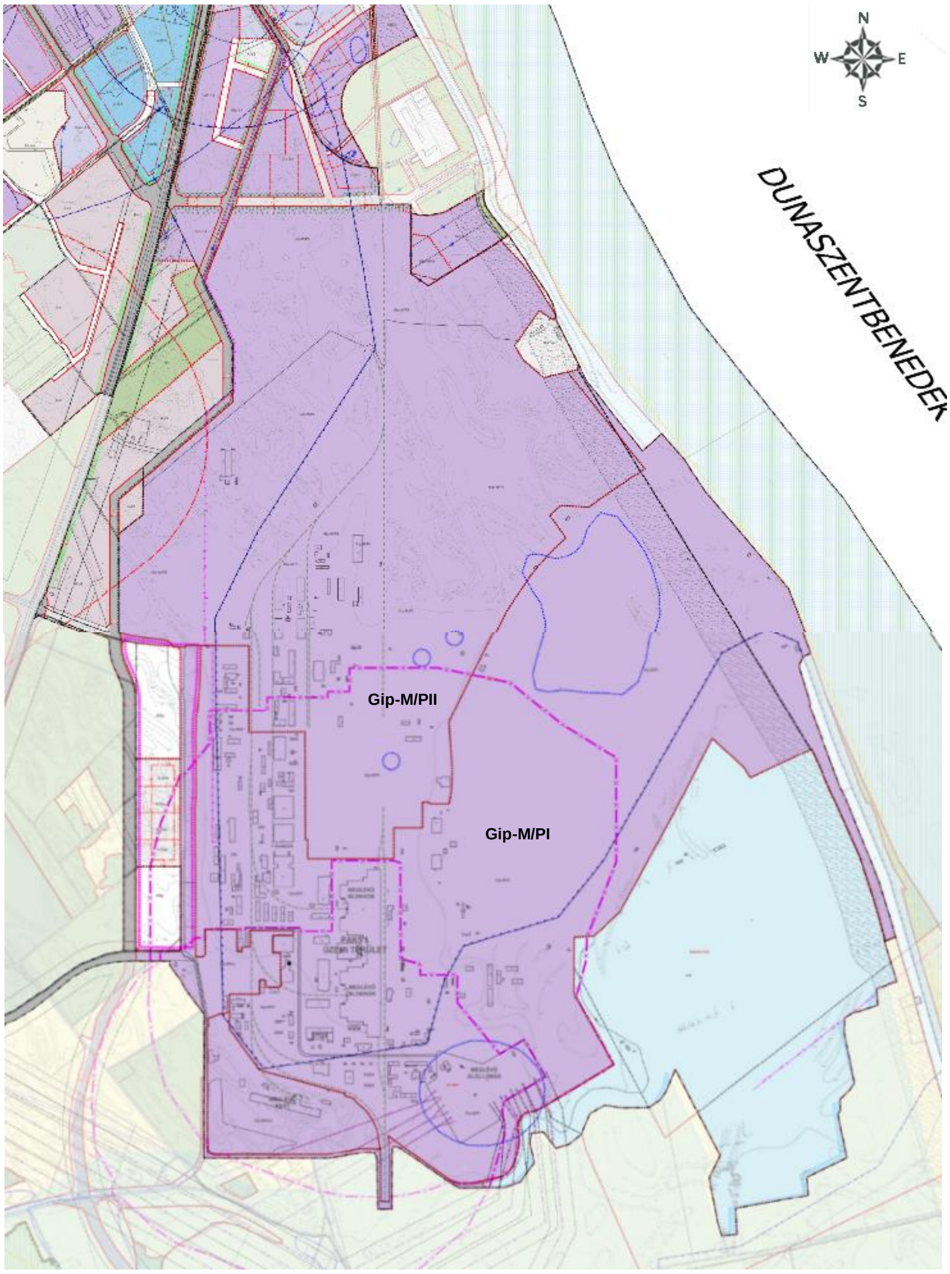
- Act CXXXIX of 2018 on the Spatial Planning Plan of Hungary and Certain Priority Regions of Hungary,
- The 8/2020. (X. 29.) municipal decree of the Tolna County Assembly on the land use planning of Tolna County,
- The 33/2016. (VIII. 22.) municipal decree of the Paks City Council on the Local Building Code of Paks City,
- The repeatedly amended Decision No. 92/2016. (VIII. 17.) ÖK. of the Paks City Council on the review of the Paks City Settlement Structure Plan.

According to point 1.13 of Appendix 4/7 of Act CXXXIX of 2018, "Paks I." is listed as an existing nuclear power plant site, which is also indicated in Annex 2 (The National Structural Plan) of the Act. The continued operation of the power plant is therefore in accordance with the National Spatial Plan and the National Structural Plan.

The 8/2020. (X. 29.) municipal decree of the Tolna County Assembly on the land use planning of Tolna County lists "Paks I." as an existing nuclear power plant with a capacity of 2000 MW within the Tolna County technical infrastructure networks and individual buildings system, which is also indicated in Annex 2 (Regional Structural Plan) of the decree. The continued operation of the power plant is therefore in accordance with the land use planning regulations of Tolna County and the Regional Structural Plan.

According to the Annex 1 – (Paks City Regulatory Plan, Annex 1/a: internal regulation plan, sections B26-B27) 33/2016. (VIII. 22.) municipal decree of the Paks City Council on the Local Building Code of Paks City, the operational area of the Paks Nuclear Power Plant is located within the Gip-M/PI designated industrial-economic zone (*Figure 2.1.2-4.*). The Gip-M zone includes nuclear power plant industrial-economic areas (existing and new nuclear power plants, existing and new substations, transport areas, interim spent fuel storage, and additional industrial-economic areas related to the nuclear power plant). The Gip-M zone is subdivided into the following building zones:

- Gip-M/t: Industrial-economic area not directly related to the nuclear power plant,
- Gip-M/PI: Area of the existing nuclear power plant and existing substation,
- Gip-M/PII: Area of the new nuclear power plant and new substation,
- Gip-M/kkát: Area of the interim spent fuel storage facility,
- Gip-M/kö: Transport area of the nuclear power plants.



Source: Appendix 1 of the 33/2016. (VIII. 22.) municipal decree of the Paks City Council on the Local Building Code of Paks City (Paks City Regulatory Plan), Appendix 1/a, Paks City Regulatory Plan, sections B26-B27

Figure 2.1.2-4. The site of the Paks Nuclear Power Plant in the Paks City Regulatory Plan

According to the provisions of the Local Building Code, the Gip-M/PI building zone includes the area of the existing nuclear power plant, as well as the existing substation and the electrical overhead lines (power lines and cables) directly associated with it. The site can accommodate the existing and new nuclear power plants, as well as the existing and new substations, and the required functions for the construction of the new nuclear power plant.

The land use types existing or planned in the vicinity of the power plant site, as listed in the urban planning documents, are as follows:

- To the North: Gip-M/PII – Industrial economic area: Area of the Paks II. Nuclear Power Plant and its related substation.
- To the East: Danube River – water management area.
- To the South: Fishing ponds – water management area, Má-á – general (typically arable) agricultural zones, Má-k – restricted use agricultural zones.
- To the West: Ev – protected forest areas, KÖp – parking areas for transport, Má-k – restricted use agricultural zones.

Based on the above, it can be concluded that the current land use by the Paks Nuclear Power Plant is consistent with the land use defined in the spatial planning documents. Implementation of the subsequent service life extension of the nuclear power plant is in accordance with the spatial planning tools.

Examining the relationship between the nuclear power plant and the city of Paks, it can be concluded from the area and urban development documents (Tolna County Area Development Concept and Program 2021-2030 (2021), Central Danube Region Area Development Concept 2021-2035 and Strategic Program 2021-2027 (2021), Integrated Urban Development Strategy of Paks City Volumes I-II (2014)) that the formulated strategies clearly account for the Paks Nuclear Power Plant and its extension, resulting in significant long-term social, economic, and infrastructural relationships.

Existing and planned nuclear facilities on the Paks site

The currently applied strategy for handling spent fuel elements at the Paks Nuclear Power Plant is to place the spent fuel in interim storage for a longer period until a decision is made about its reprocessing or final disposal. After the spent fuel is removed from the reactor, it is placed in a water-filled "spent fuel pool" within the nuclear power plant for 3-5 years. After the prescribed cooling period, the fuel assemblies are transported from the power plant to the SFISF (*Figure 2.1.2-5.*). For transportation, the spent fuel assemblies – up to a maximum of 30 at a time – are placed into a water-filled transport container at the nuclear power plant. The container is then transported by rail to the SFISF.

Source: PURAM website (www.rhk.hu)

Figure 2.1.2-5. The SFISF and the main buildings of the Paks Nuclear Power Plant

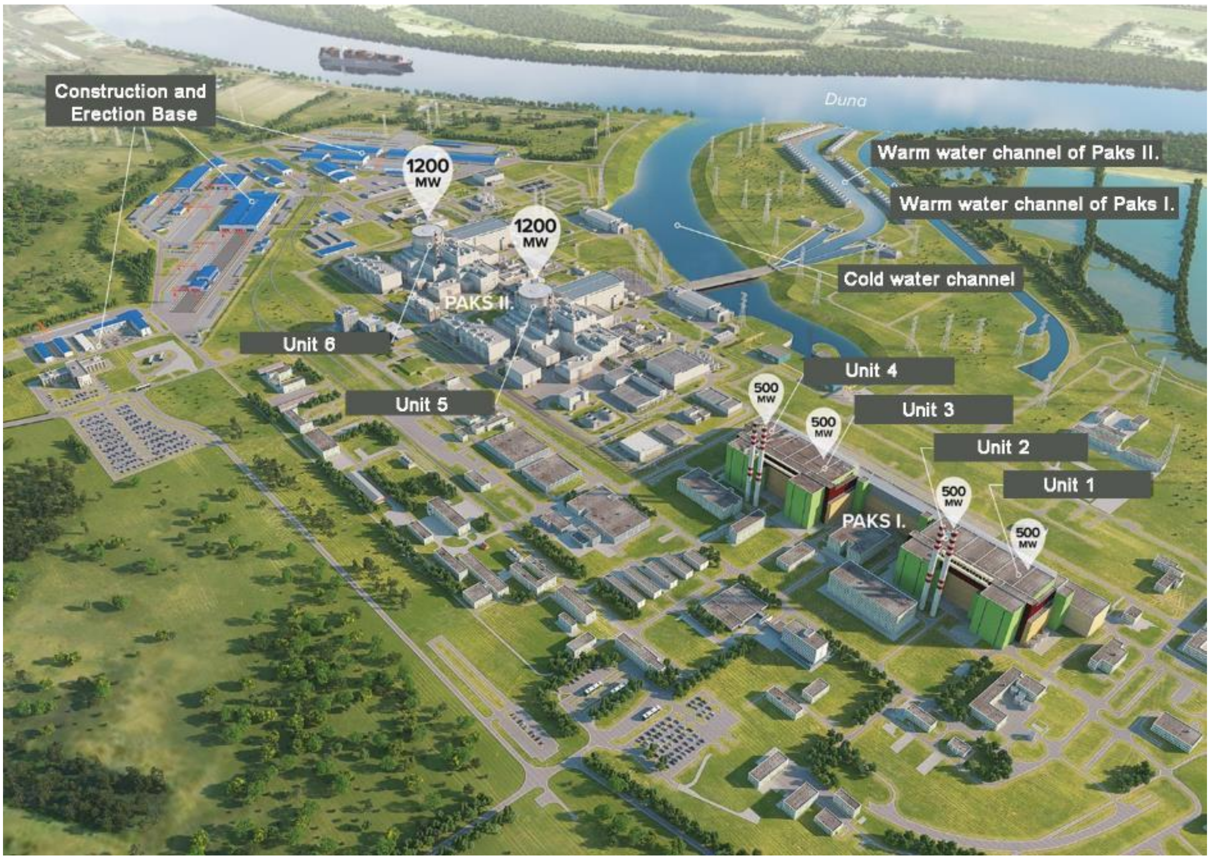
The SFISF is a modular, vault-type facility, specifically a Modular Vault Dry Storage (MVDS) system by GEC Alsthom. It operates on a passive cooling principle and provides dry storage for spent fuel assemblies. The interim storage is currently planned to last at least 50 years. The facility is a surface building where the assemblies are removed from water-filled containers, thoroughly dried using a drying system, and then placed individually into sealed storage tubes with the help of a transfer machine. The storage tubes are arranged in vertical positions within vaults surrounded by reinforced concrete walls, providing nearly 2 meters of shielding against radioactive radiation. Storage occurs under dry conditions, with the residual heat removed by a cooling system based on natural air convection. The cooling air flows between the storage tubes, without direct contact with the assemblies. As of 2023, the facility stores 10 567 spent fuel assemblies. The planned and approved storage capacity of the facility has been determined by taking into account the number of spent fuel assemblies generated during the first 20-year service life extension of the Paks Nuclear Power Plant. Accordingly, with the planned 33-vault configuration, the storage capacity of the facility will be 17 743 assemblies.

According to the agreement between the Government of Hungary and the Government of the Russian Federation on cooperation in the peaceful use of nuclear energy, the design, construction, commissioning, and decommissioning of two new VVER-1200, V-527 type reactor units (Paks II. Nuclear Power Plant, units 5-6) with a nominal thermal power of 3200±128 MW_{th}, capable of providing district heating, will be implemented at the site adjacent to the site of the Paks Nuclear Power Plant.

For the two units of Paks II. Nuclear Power Plant, a similar once-through cooling system from the Danube is planned for cooling the condensers, as used for units 1-4 of the Paks Nuclear Power Plant. The necessary cooling water is extracted by pumps from a common cooling water channel shared with the Paks Nuclear Power Plant, and the warmed cooling water is returned to the river through Paks II.'s own warm water channel. The possibility of cooling the warmed water before its return to the Danube is ensured by a peak cooling system consisting of cooling tower cell rows. The electricity produced by Paks II. Nuclear Power Plant will be delivered to the national electricity grid via one of the following two delivery routes at a voltage level of 400 kV: either towards the new Biritó electrical substation being built for Paks II. or towards the existing Paks substation. The main technical characteristics of the new Paks II. Nuclear Power Plant are as follows:

Gross electrical power:	1262 MW_e / unit.
Net nominal output power:	1184 MW / unit.
Reactor nominal thermal power:	3200 MW / unit.
Operational power range:	20-100%
Maximum temperature rise in condenser cooling water:	8°C.
Cooling water use (extracted from the Danube:	132 m^3/s.
Planned lifetime:	60 years.

The visual plan of Paks II. Nuclear Power Plant, showing the buildings of the Paks Nuclear Power Plant, is shown in *Figure 2.1.2-6.*



Source: Paks II. Nuclear Power Plant Ltd. website (www.paks2.hu)

Figure 2.1.2-6. Visual plan of Paks II. Nuclear Power Plant

2.1.3. Hydrological characteristics

Within a 30 km radius of the Paks Nuclear Power Plant site, surface waters (watercourses and lakes together: 6287 ha) and wetland / riverine areas (5953 ha) cover a total of 12 240 ha. The most significant watercourse in the study area is the Danube, with its north-south segment measuring nearly 71 km in length. The surface area of the main channel is 4048 ha, which, when including the smaller branches found in the floodplain, totals 4287 ha. Alongside the Danube, significant watercourses include the Sió-Sárvíz system on the Transdanubian side, which is predominantly canalized and flows into the Danube in the southern part. The associated watercourses (Sió and Sárvíz) enter the northwest part of the study area and flow southward in parallel through the Sárvíz valley. After traveling nearly 50 km along this parallel section, the Sárvíz river joins the Sió River below Sióagárd. The combined watercourse then also receives water from the Völgységi stream, which enters from the southwestern part of the area and travels 9 km to the Sió. The Sió River is approximately 70 km long within the study area. The three watercourses together cover an area of 451 ha.

Other smaller waterways are found on both sides of the Danube. On the Transdanubian side, water is transported from various smaller valleys in hilly and meadow areas into the Sió-Sárvíz system or the Danube. On the Great Plain side, smaller watercourses are also mainly found in canalized beds, except for natural watercourse sections using former backwaters. The combined surface area of the smaller watercourses in the entire area is approximately 105 ha. The lakes in the area are mostly created by damming streams or filled former backwaters, with a total area of 1444.7 ha. The former are typical of the Transdanubian region, while the latter are more common along the Danube and in the lowland areas.

2.1.4. Demographic characteristics

The demographic overview relies on previous similar studies (environmental and site permitting documents for Paks II. Nuclear Power Plant), data from the 2022 census, and comparisons between the 2011 and 2022 census data. The analysis of the current demographic situation primarily focuses on the Paks region, consisting of 75 municipalities (the broader area within a 30 km radius of the Paks site), but also highlights significant regional differences at the municipal level in some cases.

Since 1990, the population in the Paks region has been steadily decreasing, which mirrors the national trend (*Table 2.1.4-1.*). However, the population decline in the region is more pronounced than the national average. The decrease is partly due to natural population decline (decreasing birth rates) and partly due to negative migration balance.

Table 2.1.4-1. Population changes in Hungary and the Paks region, 1990-2022

Area	Population [persons]				Change 1990-2022 [persons]	Change Rate 1990-2022 [%] (1990=100%)
	1990	2001	2011	2022		
Paks region	242 746	241 642	223 947	203 961	-38 785	-16.0
Hungary	10 354 842	10 174 853	9 931 925	9 599 744	-755 098	-7.0

Source: Hungarian Central Statistical Office (HCSO) census data

Previous studies on the gender and age composition of the population in the Paks region have highlighted two important trends: 1) continuous ageing of the population, and 2) a decreasing proportion of younger people. Both trends have continued into the 2010s for the following reasons:

1. The increase in life expectancy at birth is accompanied by a rising proportion of the elderly population (over 65 years).
2. The decline in birth rates results in a reduced proportion of children and adolescents in the medium term.

Based on gender composition, the Paks region shows a male surplus up to age 60, with a significant female surplus in old age (HCSO 2022 census). This is explained by higher mortality rates among middle-aged men and the longer life expectancy of women. The proportion of different age groups within the total population in the Paks region (2022) indicates that the proportions of middle-aged and elderly people are the same (29.5%), while the proportion of the 20-39 age group (22.3%) is nearly 20% higher than that of the 0-19 age group (18.7%). Conversely, the proportions of the 40-59 and 60+ age groups (29.5% each) exceed the 20-39 age group by 32%.

The distribution of several key demographic indicators among municipalities in the Paks region highlights regional differences based on the 2022 census data (*Table 2.1.4-2.*). There are notable differences between cities and villages, primarily according to the size categories of the municipalities.

The trends observed in the Paks region are consistent with demographic phenomena observed in Hungary and Europe concerning family status, with fewer marriages each year. The increase in the number of families in the region is primarily influenced by construction and relocations associated with the Paks II. project.

Table 2.1.4-2. Distribution of some demographic indicators in the municipalities of the Paks region, 2022

Municipality	Population [persons]	Ageing index * [%]	Live births [persons]	Deaths [persons]	In-migrations [persons]	Out-migrations [persons]
Foktő	1 409	145.7	9	31	75	105
Vajta	791	107.6	9	8	62	55
Sáregres	687	97.6	11	9	47	50
Miszla	255	229.2	3	7	16	23
Fajsz	1 532	170.1	17	20	97	100
Bogyiszló	1 982	139.0	20	40	106	103
Géderlak	864	158.2	9	18	61	78
Kistormás	272	117.4	4	5	30	27
Dusnok	2 671	149.3	15	36	110	122
Paks	***17 827***	***153.0***	***157***	***179***	***796***	***1 016***
Gerjen	1 151	138.2	9	19	52	50
Kalocsa	14 619	201.3	96	250	761	834
Bölcske	2 593	136.5	26	34	169	158
Varsád	337	151.2	1	4	23	19
Nagyszékely	380	105.1	2	5	20	28
Tengelic	2 013	176.9	17	30	160	164
Nagykarácsony	1 308	133.5	12	22	100	104
Drágszél	288	293.5	4	8	46	40
Dunapataj	3 017	199.0	15	49	235	208
Öregcsertő	708	193.0	2	14	66	50
Őcsény	2 213	140.8	14	35	189	158
Kiskőrös	13 320	166.1	92	228	586	552
Pálfa	1 435	156.1	12	26	117	69
Dunaszentgyörgy	2 434	117.6	27	30	151	154
Kölesd	1 322	109.1	16	21	72	109
Császártöltés	2 115	216.3	11	28	107	103
Tolnanémedi	922	168.1	7	15	57	69
Dunaszentbenedek	714	145.8	5	17	37	45
Bátya	1 825	176.1	16	39	135	120
Bikács	381	150.0	2	5	31	35
Györköny	985	134.4	12	12	76	58
Cece	2 529	105.7	30	35	163	133
Kajdacs	1 062	111.4	19	20	110	75
Harc	769	102.3	5	15	60	67
Dunatetétlen	510	160.6	4	5	31	23
Németkér	1 539	145.2	18	30	90	106
Szakadát	214	331.8	1	2	14	22
Felsőnána	570	88.2	4	12	26	43
Ordas	427	151.4	9	7	27	32
Uszód	846	168.0	4	15	86	92
Szedres	1 974	148.9	18	37	129	133
Nagydorog	2 462	117.9	22	34	152	130
Harta	3 368	208.5	28	48	155	179
Hajós	2 700	238.4	8	37	113	126
Fadd	4 012	123.5	35	61	279	260

Municipality	Population [persons]	Ageing index * [%]	Live births [persons]	Deaths [persons]	In-migrations [persons]	Out-migrations [persons]
Szakmár	1 082	179.3	7	25	97	94
Kecel	7 932	153.0	77	125	336	358
Pusztahencse	917	95.5	10	14	60	84
Előszállás	2 419	125.5	22	36	185	156
Simontornya	3 581	185.1	29	66	225	216
Sárszentlőrinc	954	128.6	6	13	69	63
Dunaegyháza	1 458	122.7	12	25	160	124
Sükösd	3 340	176.6	17	77	200	194
Udvari	268	200.0	4	6	9	20
Zomba	1 849	181.4	13	22	91	115
Kéty	631	99.0	6	9	25	38
Akasztó	3 138	138.4	31	43	206	194
Szekszárd	30 057	212.6	215	484	1 826	2 073
Kalaznó	132	177.8	1	2	7	13
Fácánkert	664	95.2	5	6	76	55
Tolna	10 697	158.9	92	152	528	613
Alsószentiván	543	195.2	6	12	62	51
Sióagárd	1 183	154.3	4	19	95	78
Alap	1 856	116.3	23	44	124	92
Kisszékely	290	506.7	1	6	37	26
Homokmégy	1 191	197.9	11	18	104	90
Solt	5 990	160.6	59	93	340	348
Madocsa	1 746	119.3	18	24	74	95
Gyönk	1 648	329.9	9	82	167	98
Medina	688	112.0	4	13	63	42
Miske	1 609	121.3	19	25	151	179
Dunaföldvár	8 176	135.4	59	136	533	485
Nemesnádudvar	1 636	161.3	16	24	51	71
Újtelek	364	346.4	1	11	34	22
Daruszentmiklós	1 072	85.6	14	17	126	114

* A measure of population aging, which also projects future trends, shows the ratio of the elderly (aged 65 and over) to the population aged 14 and under.

Source: HCSO Census 2022

2.1.5. Site-specific external hazards of human origin and combinations of the external hazards

Specific human-induced hazards threatening the nuclear safety of the Paks Nuclear Power Plant

To establish the basis for assessing the existing environmental conditions and the environmental impacts of the facility, the investigation also addressed whether possible events related to human activities among the external hazards would pose a risk to the plant during the extended operational period to a degree that would significantly impact the plant's environment. This investigation was conducted based on the available knowledge and forecasts, using the information included in the current Final Safety Analyses Report (FSAR) of the Paks Nuclear Power Plant. For each activity that may induce a hazard, an overview of the analyses related to the site characterization of the Paks Nuclear Power Plant and the protection against individual hazards was reviewed, and their validity for the extended operational period was assessed, relying on the available information.

In the initial step of examining the man-made external hazards characteristic to the site, human activities and their groups in the site and its surroundings that may pose a threat were identified. Aiming for completeness, the following hazardous activities are related to the present analysis area:

- road transportation,
- water transportation,
- railway transportation,
- airspace usage,
- parking lot usage,
- forest usage,
- operation of industrial facilities (excluding Paks II. Nuclear Power Plant):
  - nearby industrial facilities,
  - industrial facilities located on the site of the Paks Nuclear Power Plant,
- operation of Paks II. Nuclear Power Plant,
- operation of military facilities.

The review also included a systematic assessment of human-induced hazards resulting from the operation of the planned new units, as well as a methodical investigation and evaluation of the likelihood of these hazards occurring and their impact on the existing four units. This enabled an assessment of how the new units, operating during the extended operational period, would influence the environmental impact of the facilities on the site of the Paks Nuclear Power Plant. These investigations were part of the tasks supporting the implementation permit application for the new units.

Based on the evaluation of the impacts of accidents assumed during the execution of the studied activities in the vicinity of the nuclear power plant, it can be stated that the plant is adequately protected against these impacts and there is no need to anticipate the formation of hazardous situations related to these activities. Available forecasts did not indicate any future changes that would significantly alter the impacts or the frequency of accidents. Consequently, the impacts of hypothetical accidents from hazardous external human-induced activities during the extended operational period will not pose a risk to the plant to a degree that would significantly affect its environment.

Site activities with environmental impact

Non-nuclear accidents associated with site activities related to the operation (electricity generation) of the nuclear power plant can also have an impact on the environment. MVM Paks Nuclear Power Plant Ltd. has prepared a safety report in accordance with Governmental Decree 219/2011. (X. 20.) on protection against serious accidents involving hazardous substances, which includes the assessment of hazardous activities on the site of the Paks Nuclear Power Plant, evaluation, and presentation of the safety management system. The preliminary assessment of non-radiological environmental impacts and environmental demands resulting from human-induced external hazards was based on this safety report.

Hydrazine is the only hazardous substance required for plant operation that is considered an important hazard source due to its quantity under the aforementioned government decree. Taking into account all relevant factors, it can be determined that the risk from serious accidents involving environmental impacts at the Paks Nuclear Power Plant site is acceptable. The plant is adequately prepared to handle such havaria events, including possible accidents involving hydrazine hydrate. Available forecasts did not indicate any future changes that would significantly alter the consequences, so the environmental impact of these hazards remains negligible during the extended service life. Furthermore, the licensee will continue to ensure that the risk from serious accidents involving environmental impacts remains acceptably low and that the plant is always prepared to handle potential havaria events.

Combinations of external hazards threatening nuclear safety of the nuclear power plant

In addition to single hazards, combinations of external hazards can also be characterized by a targeted evaluation of the available investigation results. To consider external hazard combinations in the design basis – consistent with the investigation steps for single external hazards – the following main analysis and evaluation tasks have been completed:

1. selection of hazard combinations,
2. screening of hazard combinations,
3. definition of design basis load combinations,
4. evaluation of plant protection.

After screening hazard combinations, the following combinations were selected for detailed assessment:

- external hazards from human activities in extreme meteorological conditions,
- High wind *and* extreme precipitation *and* lightning (storm),
- High wind *and* extreme snow,
- extremely high air temperature *and* high cooling water temperature,
- extremely low air temperature *and* surface ice (*and* icing *and* snow),
- simultaneous accidents in multiple industrial facilities nearby (e.g., due to earthquakes),
- occurrence of an earthquake when the ambient temperature is extremely high or extremely low,
- combinations of hydrological hazards,
- combinations of potential hazards in the field of geosciences.

Based on the investigation results, it can be concluded that the Paks Nuclear Power Plant is adequately protected against the impacts of the hazard combinations specified in the design basis. Available forecasts did not indicate any future changes that would significantly alter the consequences. Consequently, combinations of external hazards will not pose a risk to the plant during the extended operational period to a degree that would significantly affect its environment.

2.1.6. Geological, tectonic, seismological, and geotechnical characteristics of the site

The evaluation of the geological characteristics of the site is not the subject or purpose of the environmental permitting procedure. Nevertheless, the question was re-evaluated, given that several additional investigations related to the Paks II. project have been carried out in the vicinity of the site in the last decade, which confirmed the findings of the geological investigations that have been carried out at the Paks site for 50 years now. The Paks site is the most thoroughly researched areas in the country. The detailed research and investigation program of the geological, tectonic, and seismological characteristics of the current site hosting the two operating nuclear facilities – the Paks Nuclear Power Plant and the SFISF – as well as the entire Paks site accommodating the new nuclear units, has recently been conducted as part of the preparation for the site permit for the new units. Based on the referenced programs and subsequent additional investigations and analyses, the information about the site relevant to the extended operational period of the Paks Nuclear Power Plant can be summarized as follows:

Based on current scientific knowledge, the characteristics of the risks arising from earthquakes and earthquake-induced surface displacements, as well as soil liquefaction, do not differ from those considered in the safety analyses of the nuclear power plant. The Paks Nuclear Power Plant is adequately protected against these risks. Considering the time scale of geological processes, no future changes are expected that would significantly alter the risks and consequences.

Geological and tectonic characterization

In the broader area, six significant geological horizons can be distinguished, each marking distinct evolutionary units. These were identified based on geophysical and drilling data specific to the region. The description of Quaternary formations was achieved through the evaluation of approximately 1500 drill cores. The dominant structural feature of the area is the “Kapos line," which is oriented SE-NW and can be traced for about 100 km in the pre-Cenozoic basement. While the eastern segment of this line shows significant neotectonic activity, the western segment is essentially inactive from a neotectonic perspective. The structural pattern of the area is predominantly characterized by NE-SW trending fault systems, most of which have steep dips (70-90°). Additionally, a smaller number of faults with NNE-SSW and N(N)W-S(S)E orientations, also with steep dips, are associated with these. Among the NE-SW faults, the Dunaszentgyörgy-Harta fault zone, which branches off from the Kapos line near Dunaszentgyörgy and passes under the site and its southern forefield, is particularly significant for the site. Together with the eastern segment of the Kapos line, this fault zone represents the most intense neotectonic activity in the area.

Based on the available geological and tectonic information, the faults identified at the site and its surroundings cannot be classified as capable according to nuclear regulations (NSC 7.3.1.0900), and the IAEA's SSG-9 (Rev.1) definition. The deformations and signs of soil liquefaction observed in the loose sediments in the research trenches and in the wider surroundings of the site could be the result of paleoquakes of magnitude up to 4-5, which based on the dating, occurred in the late Pleistocene.

The hazard curve used to characterize the surface displacement hazard caused by faults in and around the site indicates that the risk of permanent surface displacement is practically negligible, even at 10^{-7}/year frequency. Additionally, the possibility of cliff-edge phenomenon can be excluded.

Seismological characterization

Hungary is situated between the seismically active Mediterranean region and the nearly aseismic Northern Europe. The seismic activity in Hungary is moderate, with earthquakes being rather diffusely distributed, classified as intraplate seismicity. Earthquakes often cannot be clearly associated with specific tectonic structures due to inaccuracies in seismotectonic and geological knowledge and uncertainties in earthquake localization, making it difficult to determine which fault caused which quake.

In the entire Pannonian region (44-50°N, 13-28°E), an earthquake of magnitude six or greater occurs approximately every 3.8 years; earthquakes of magnitude five or greater occur three times a year on average; and earthquakes of magnitude four or greater earthquakes occur 36 times a year on average.

Earthquakes near Paks have been monitored with a high-sensitivity network since 1995. It can be stated with high confidence that during the observation period, no earthquake with a magnitude of 1.0 or higher occurred in the immediate vicinity of Paks. Thus, the recent activity of the structures here can be increasingly ruled out, and no seismically active faults have been identified in the vicinity of the Paks site. Even the faults identified or presumed near the site, based on other geophysical, geological, and geomorphological observations, do not show seismic activity even within the magnitude range of 0.75-1.

Space geodetic survey results over the last 25 years indicate that the local relative present-day horizontal crustal movement velocities in the 30 km radius around the Paks site are below 0.5 mm/year. Vertical surface movements in the area are below 1 mm/year. GPS data also clearly show no significant present-day lateral movement along the mapped faults in the area, relative movement between the two major structural units is essentially non-existent or is below 0.1 mm/year.

Earthquake hazard and soil liquefaction

For the Paks Nuclear Power Plant site, the characteristics of a safety earthquake should be evaluated according to Nuclear Safety Code regulations at a 10^{-4}/year exceedance probability level. Taking into account the lessons and results of the geological research program conducted in preparation for the construction of the new units, it has been confirmed that the seismic hazard results obtained in 2016 as part of the program are consistent with previous analyses, both in terms of bedrock and surface characteristics. The expected value of free-field acceleration calculated at a 10^{-4}/year exceedance probability is 0.26 g.

The potential for global soil liquefaction was examined for the safety earthquake of 10^{-4}/year probability. The results indicated that at the 10^{-4}/year probability level, global soil liquefaction affecting the entire stratigraphic sequence does not need to be considered. Due to possible local liquefaction, the largest subsidence at the safety earthquake level (10^{-4}/year probability) is expected at the northwest corner of the reactor building, with a conservatively estimated magnitude of 5.08 cm, which does not pose a safety risk.

2.1.7. Hydrogeological characteristics of the site

Regarding the subsurface water table, the impermeable layer of the groundwater reservoir is formed by Pannonian lake clay deposits located at a depth of 30-40 meters below the current surface level, generally eroded by riverine erosion. However, older Pleistocene layers, which are of eolian origin or their transformed variants, can also be found in some places.

The most significant deposits for groundwater storage and conductivity are the Late Pleistocene fluvial sediments, which formed in a young subsidence zone extending from Paks to the mouth of the Sió River. These deposits are regionally extensive and about 20 meters thick. The lower section is 10-15 meters thick and consists of poorly graded, cobbly, sandy gravel, and gravelly sand, with intercalated sand layers in some areas. Based on experimental pumping, the average permeability coefficient of this deposit is $1.1 \cdot 10^{-3}$ m/s. This is the best water-conducting formation in the region, primarily determining the movement and storage of groundwater. The upper 5-10-meter section of the Late Pleistocene fluvial sediment likely originated from flood deposits and consists of fine sand with scattered gravel. Its average permeability coefficient is $2.7 \cdot 10^{-4}$ m/s. This layer is directly connected to the Danube's riverbed, where the present-day medium- and low-water channels of the Danube have developed.

Holocene layers are deposited over the Pleistocene aquifer layers, with a thickness of 5-10 meters. In the 1-3 km wide strip along the Danube, the cover consists of the Danube's Holocene alluvial deposits, including fluvial gravel, sand, alluvial silt, alluvial clay, and loess silt. The permeability coefficient of this formation, according to calculations, ranges from 10^{-5} to 10^{-9} m/s. Further away, the top layer consists of wind-blown sand derived from the Danube's sediments, which in some areas contains buried fossil soil layers. In these areas, the magnitude of vertical water movement does not exceed 1 meter per day.

Due to groundwater level fluctuations and variable stratification, a more precise value cannot be provided (v = 0.2-0.8 m/day). In the windblown areas, the morphological forms include 6-8 meter thick, partially consolidated sand dunes, where wind furrows and residual ridges can be recognized. Despite its eolian origin, the material is relatively poorly graded, and its good permeability allows a significant portion of surface precipitation to infiltrate into the soil. North-Northwest of the power plant, a loess plateau elevated to 160-180 meters above sea level extends toward the northwest. The younger upper sections of the loess are loosely deposited and, due to their large pore volume, have relatively good water conductivity. This enables the infiltration of rainwater into deeper layers. At the boundaries of the loam (clay) layers, the water flows toward the base of erosion (the Danube).

The described geological structure is modified by two factors:

1. The strip along the Danube is crisscrossed by former meanders that significantly alter the general geological picture and can also influence flow conditions.
2. During the construction of the area, the original morphology and soil conditions were significantly altered, with the original surface being covered by 0-7 meters of fill material sourced locally. Near the surface level within the power plant area, the speed of vertical infiltration varies between 0.6-0.8 meters per day. Where the fill consists of fine sandy silt, the permeability coefficient is around $3 \cdot 10^{-6}$ m/s, meaning the speed of vertical water movement is a few decimetres per day. The construction may also alter groundwater flow

in the vicinity of deep foundations and underground structures. However, these changes are only effective in the immediate vicinity of the facilities, with no detectable impact over a larger area.

Groundwater in the Quaternary (Upper Pleistocene, Holocene) porous sandy-gravel deposits flows toward the draining live stream of the Danube. Based on the properties and direction of the flow, the seepage of groundwater can be divided into three characteristic zones.

The first zone, where the seepage direction is consistent, points towards the active watercourse of the Danube. Its direction remains unchanged, and the value of the hydraulic gradient varies only slightly. It is in direct seepage-hydraulic connection with the background groundwater fed by precipitation infiltrating in the Mezőföld area.

The second zone is the transitional or stagnant zone, where the characteristic seepage direction remains towards the draining Danube. However, the hydraulic gradient of the groundwater decreases significantly, and in certain seepage-hydraulic situations, its value becomes zero.

The third zone is the Danube impact zone, where the characteristic seepage direction of the groundwater can be bidirectional, influenced by the prevailing water level of the Danube. During high and prolonged flood waves, the seepage direction of the groundwater points towards the background, and during this period, the pressure level of the groundwater rises. During prolonged medium and low water periods of the Danube, the seepage direction of the groundwater changes, pointing towards the active watercourse of the Danube, the drainage direction. During this period, the pressure level of the groundwater decreases.

The flow direction and speed of groundwater are important primarily from the perspective of contaminants entering the soil, as potential contamination can be traced by understanding the flow. A portion of the contaminant entering the soil in liquid form, due to a havaria event, adheres to the surface of soil particles, while another portion reaches the groundwater after vertical seepage, disperses, mixes with the groundwater, and then moves with it. The movement speed is specific and varies uniquely depending on the type of contaminant.

The examined area can be divided into two characteristic zones: the background area and the strip accompanying the surface water flow of the Danube. A transitional zone lies between them. The groundwater in the area of the power plant and its surroundings is fed from the western side – by horizontal seepage of groundwater from the higher terrain of Paks-Mezőföld.

The direction of groundwater flow in the examined area is determined by two main factors: one is the water level of the Danube, and the other is precipitation infiltrating from the background. The water level of the Danube can change the groundwater level and flow direction in both directions. The suction effect of the Danube on groundwater is less significant regarding the background, so a larger groundwater reserve remains in the aquifer in the background area.

The characteristic direction of groundwater flow is W-E, which locally modifies to SW-NE in the area near the cold water channel extending into the power plant area, and perpendicular to the channel bank. The average hydraulic gradient in the area is 2.5-3 m/km. At low and medium Danube water levels, the suction effect of the river prevails, while at high water levels, it causes the groundwater to back up. Therefore, the water level in the observation wells changes according to the Danube's water regime, but this effect gradually weakens as one moves away from the river. The propagation speed of pressure waves formed in the groundwater due to flooding is approximately 100 m/day.

The groundwater levels measured in monitoring wells closely follow the Danube’s water level changes and the passage of flood waves. Their effects are noticeable within a 1 km band from the Danube line, and these effects significantly decrease and are time-shifted as one moves further away.

During the subsequent service life extension of the Paks Nuclear Power Plant, no activities are planned that would affect or change the above-described characteristics of the subsurface water body.

2.1.8. Hydromorphological characteristics of the site

The Danube is the dominant watercourse in the immediate vicinity of the Paks Nuclear Power Plant and the broader region. The plant's cooling water supply is ensured through a cold water channel branching off from the Danube at 1526.6 river kilometers. The heated cooling water is returned to the river via the warm water channel.

In the river section between Dunaföldvár and the southern national border, the average bankful width of the channel is 400-600 m, 430 m at the power plant (1527 river km), and the floodplain width is 1.1-1.2 km. According to regulation plans developed in the late 1970s, the river section between Dunaföldvár and the southern national border can be considered partially regulated. As a result, mean water regulation has stabilized the main riverbed. However, both the velocity increase caused by narrowing and the slope increase due to shortening have led to an increase in the river's sediment transport capacity, initiating a riverbed incision process. To halt the process of water level decline, regulation structures have been built at a lower level and with a modified site plan over the past 20 years.

North of the power plant's water intake site, just above the town of Paks, the Danube makes a sharp turn from a westward to a southward direction. As a result, the thalweg shifts towards the right bank, and the outer bank along the town's shoreline is protected with stone revetment against lateral erosion. As part of the stabilization of the main channel, groins were constructed every 600-750 meters along the outer bank between 1530-1533 river km. Formation of side bars continues along the left bank up to 1525.5 river km.

At 1526 river km, the thalweg shifts closer to the left bank. Below the warm water channel return of the power plant, where the right bank floodplain gradually widens, a shoal island approximately 2 km long extends near the right bank. This unfavourable shoaling for navigation was regulated with spurs several decades ago to enable the continuous natural filling of the embayment. Simultaneously with the right bank stabilization, short groins were constructed every 400 meters on the opposite bank at Uszód, completely stabilizing the left bank.

The flow rate of the Danube is primarily determined by snowmelt in the Alps and precipitation patterns. Its floods are typically associated with early spring snowmelt and the early summer precipitation peak and glacier melt. At the 1527.0 river km section of the power plant, water level changes can be characterized based on the Paks gauge station (1531.3 river km), which has been operating since January 1, 1868. The height of the gauge "0" point is 85.38 m BES. The lowest water level recorded since observations began was -97 cm (84.41 m BES, 26 October 2018). The highest ice-free water level was +891 cm (94.29 m BES) and was observed on 11th June 2013. The highest iced water level was recorded on 27th February 1876, with a water level of +1006 cm (95.44 m BES). The absolute annual water level change primarily depends on the flood peak levels: usually 6-7 m, but in some extreme hydrological years, it approaches 9 m.

The fil level established at the nuclear power plant site is 97.00 m BES. This is nearly 3.0 m higher than the design flood level (94.05 m BES) and about 1.4 m higher than the 10 000-year return period (0.01% calculated probability of occurrence) ice-free flood level, as well as higher than the 96.60 m BES crest elevation of the left-bank flood protection level in the plant section. Considering all these factors, the power plant site is considered safe from a flood protection perspective. Given the current runoff conditions, the formation of a flood wave that would inundate the power plant site can be ruled out.

In the area of the nuclear power plant, the average depth of the Danube riverbed is 4 m below the low water level, and 5-6 m in the thalweg. The riverbed material mainly consists of gravelly sand and sandy gravel. Below the confluence of the warm water channel, the increased water velocity and turbulence have resulted in significant deepening of the riverbed. At the same time, the height of the right bank shoal (Uszódi shoal) has increased, permanent vegetation has established on its surface, and fine-grained flood deposit has started to accumulate over the gravelly sand. The deepening of the low water bed also explains the formation of a thin, long side bar along the left bank between 1525.6-1526.1 river km.

2.2. Facilities and technological process of electricity production

The operation of the nuclear power plant during the subsequent service life extension is planned with the currently used plant technology, production capacity, and material use characteristics, utilizing the existing energy production equipment and infrastructure. The main technological equipment and their functions, as defined in Annex 1 of the currently valid environmental permit for the Paks Nuclear Power Plant (reference number 391-18/2017), will not change due to the subsequent service life extension, but their operational duration will be extended. The technical conditions for the continued operability of the equipment are ensured by the maintenance and reconstruction activities currently being carried out, as presented in *Chapter 2.3.*

2.2.1. Technology and main technical characteristics of the Paks Nuclear Power Plant

The Paks Nuclear Power Plant operates four VVER-440/213 type reactors. The acronym "VVER" stands for "Water-Water Energy Reactor," and the number "440" indicating the original nominal electrical capacity of each reactor unit, which was 440 MW. Thus, the total electrical capacity of the plant was initially 1760 MW. Over time, due to modernization efforts, the electrical capacity of units 1-4 was first increased to 470 MW each. With further power upgrades, the capacity was increased to 508.6; 506,0; 506,0; 506,0 MW respectively for the units, bringing the facility's total nominal electrical capacity to 2026.6 MW.

The reactor units are pressurized water-cooled, light water-moderated[5] thermal reactors, operating within a saturated steam cycle system. Each unit has a dual-loop design, consisting of a radioactive primary circuit and a non-radioactive secondary circuit. The fundamental technical parameters of the reactor units are summarised in Table *2.2.1-1.* A schematic diagram of the main equipment and the conceptual operation of the plant's cycle is shown in *Figure 2.2.1-1.*

Table 2.2.1-1. Main technical parameters of the reactor units at the Paks Nuclear Power Plant

Reactor type	**Pressurized water-cooled, water-moderated energy reactor, model number: V-213**
Thermal output of the reactor	1485 MW
Number of primary circuit loops per reactor	6
Total volume of the primary circuit	237 m^3
Primary circuit pressure	123 bar
Average coolant temperature	284±2°C
Number of turbines per unit, per reactor	2

The energy produced from the fission of ^{235}U isotopes, caused by thermal neutrons within the uranium dioxide fuel rods located in the reactor's active zone, is absorbed by the coolant in the primary circuit (water at 123 bar and 266°C). The water in the primary cooling circuit is kept at a very high pressure (123 bar), preventing it from boiling even at the high operational temperature. The water, heated to 297°C in the primary circuit, is then directed to the steam generator, where it transfers its heat to the water in the secondary circuit through narrow tubes.

In the secondary cooling circuit, the pressure is much lower (46 bar) than in the primary circuit, causing the water in the steam generator to boil. After separating the steam, it is sent to the high-pressure and then low-pressure turbines, where the saturated steam powers the turbines. The generators, driven by the turbines, produce electricity. The steam exiting the turbines condenses in the condenser and is then reheated and returned to the steam generator. The water in the primary and secondary circuits does not mix, ensuring that any radioactive substances in the coolant remain confined to the primary circuit and do not reach the turbines or condenser.

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[5] For the chain reaction, the fast fission neutrons need to be slowed down, the moderator serves this purpose.

The secondary circuit vapour phase coolant cools down as the heat is converted into mechanical energy, and the residual heat is released by heating the river water in the condensers, which is then cooled using water from the Danube River. The warmed cooling water is then returned to the Danube.

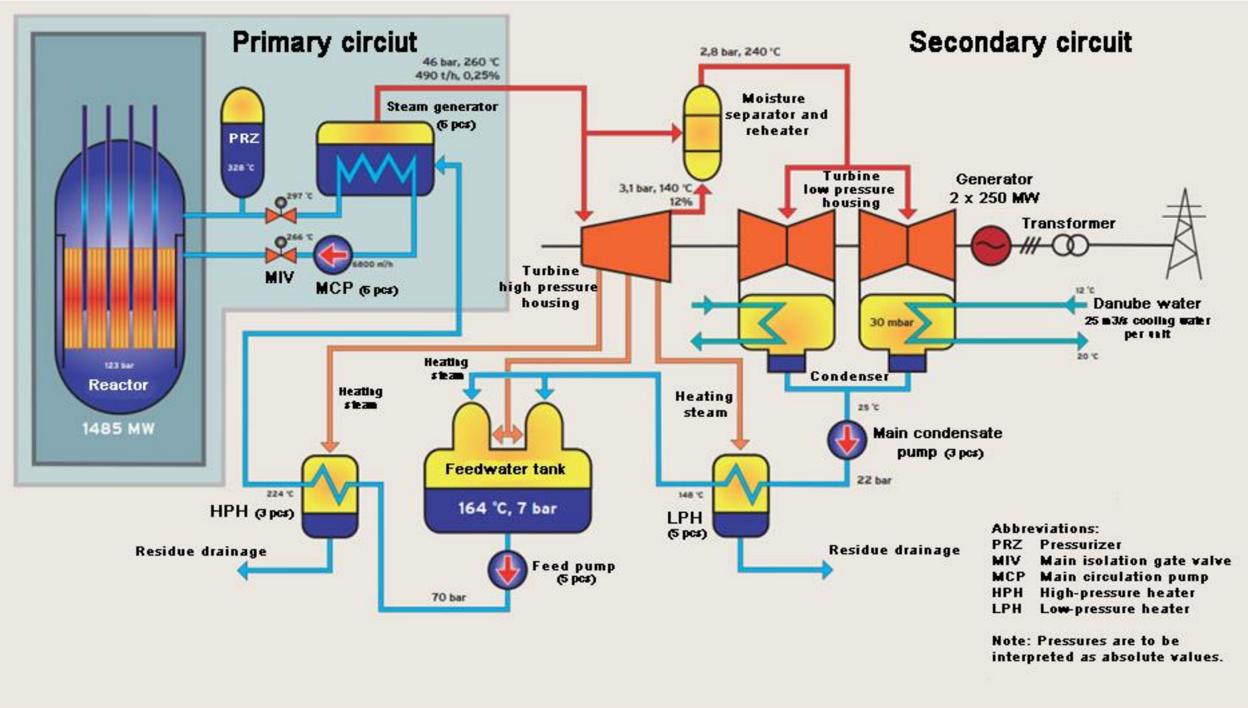

Figure 2.2.1-1. Schematic diagram of the main equipment involved in power generation

The primary and secondary circuits include the following key technological equipment:

- Primary circuit:
  - reactor vessel and upper unit,
  - main circulation pipeline and main isolation gate valve (MIV),
  - main circulation pump (MCP),
  - steam generator,
  - pressurizer (PRZ).
- Secondary circuit:
  - saturated steam turbine,
  - generator,
  - condenser,
  - low-pressure pump,
  - low-pressure heaters (LPH),
  - degassing feedwater tank,
  - high-pressure heater (HPH),
  - feed pumps,
  - moisture separator reheater (MSR).

The nuclear power plant operates as a baseload power plant, with relatively constant loading. The generated electrical energy is connected to the national power grid at 400 kV and 120 kV voltage levels. The power supply system is designed to ensure the operation of the units' vital safety equipment even in the event of disconnection from the national grid.

Design and equipment of the primary circuit

The primary circuit consists of a vessel-type reactor, six parallel-connected loops, and a pressurizer connected to one of the loops. Each loop contains a main circulation pump, a steam generator, two main isolation gate valves, and a connecting pipeline made of 500 mm diameter stainless steel. The reactor consists of the following structural units:

- Reactor vessel: Its purpose is the safe generation and transfer of heat energy produced by the controlled, self-sustaining nuclear chain reaction in the active zone to the primary circuit. To perform this function, the vessel must accommodate the necessary structural elements for the heat generation process, ensure their proper fixation, and provide biological protection. It must also allow for the necessary maintenance conditions required for fuel replacement during operational cycles. The reactor vessel is a vertically placed cylindrical container with an elliptical lid and bottom. The vessel is made of high-strength alloyed carbon steel, with the inner surface and the partition plane surface covered with a corrosion-resistant stainless steel coating (cladding) to reduce corrosion.
- Internal reactor equipment: The internal reactor equipment (including the shaft, shaft bottom, removable basket, protective tube unit, and intermediate rod) is used to secure the active zone within the reactor vessel and direct the flow of the coolant within the reactor.
- Active zone: The active zone is the part of the reactor where a large amount of heat energy is released through the controlled nuclear chain reaction. The active zone consists of 349 hexagonal fuel rod bundles (assemblies), 312 of which are fixed fuel assemblies and 37 are movable control and safety rods (CSR). The equivalent diameter of the zone is 2.66 m, and its height is 2.5 m. The fuel assemblies are fixed at the bottom by the basket bottom and at the top by the lower plate of the protective tube unit, ensuring their vibration-free holding.

  In VVER-440 power plants, low-enriched ceramic uranium dioxide fuel is used. The fuel assemblies are the nuclear fuel units used in nuclear power plants operating with VVER-440 type reactors. The primary task of the fuel assemblies is to produce heat energy through the fission of nuclear material. The Paks Nuclear Power Plant currently operates on a 15-month operational cycle.
- Upper unit with control and safety protection system (CSR) drives: Its purpose is to seal the reactor vessel from above, as well as to house the control and safety system drives of the reactor, the cables and connectors of the internal measurement system, and the conduits and sealing of the measuring cables, along with the protective tubes. The upper unit prevents the reactor shaft from moving upwards. The main elements of the upper unit include the cover, CSR drive housings, CSR drive cooling circuit collectors and pipelines, degassing collector and pipelines, traverse structures, and metal structures of the cover's thermal insulation units.
- Reactor main partition sealing elements: The function of the reactor main partition sealing elements is to ensure the seal between the reactor vessel and the upper unit.

Additional equipment in the primary circuit:

- Main circulation pipeline and main Isolation gate valve: The main circulation circuit's task is to transport the heated coolant from the reactor’s active zone to the steam generator, and from there, direct the cooled coolant to the main circulation pump and back to the reactor's inlet nozzle. The main isolation gate valves, located in the cold and hot legs of the loops, are designed to isolate the part of the loop containing the steam generator and MCP from the reactor, if necessary.
- Main circulation pump (MCP): Its purpose is to circulate the coolant in the primary circuit through the reactor, loops, and steam generators, thereby ensuring the transfer of the heat energy generated in the reactor to the steam generator, as well as cooling the fuel assemblies. The circulation of the primary circuit water is carried out by one pump per loop, which is located in the loop’s cold leg.

- Steam generator: Its function is to transfer the heat energy produced in the reactor to the secondary circuit's coolant, thus generating the dry saturated steam needed to drive the turbines. The steam generator is a horizontally arranged, suspended cylindrical heat exchanger with heat transfer tube bundles and elliptical covers at both ends. The primary circuit coolant flows within the tube bundles, ensuring the production of dry saturated steam on the secondary side by transferring heat from the primary to the secondary coolant while hermetically separating the radioactive primary circuit from the secondary circuit.
- Pressurizer: The pressurizer and volume control system's function is to create pressure when the unit is started and to maintain constant pressure during stationary operation, as well as to limit pressure fluctuations during transitional modes. Besides pressure control, the pressurizer is also responsible for regulating the water volume in the primary circuit. The pressurizer is a vertically arranged, insulated carbon steel tank with an austenitic cladding on the inner walls.

The auxiliary systems connected to the primary circuit are as follows:

- Make-up water and boron control system: This system’s role is to compensate for organized and unorganized leaks in the primary circuit, ensure the water balance in the primary circuit, and compensate for slow reactivity changes by altering the concentration of boric acid solution. In case of an incident, the system introduces boric acid into the primary circuit as part of the reactor protection function, ensuring adequate subcriticality.
- Primary circuit water purification systems: The purity of the primary circuit coolant is crucial for the safe and proper operation of the primary circuit's technological equipment, achieved through continuous water purification. Six independent systems handle the water purification tasks connected to the primary circuit. The purification systems perform the following tasks:
  - cleaning a portion of the primary circuit coolant,
  - purifying water from organized leaks and drainages in the primary circuit, providing purified boric acid solution of appropriate concentration for other technological systems in the primary circuit,
  - purifying floor waters in the primary circuit,
  - purifying boric acid solutions in the spent fuel pool, transfer pool, incident boric acid tanks, and bubble condensers,
  - cleaning the secondary side blowdown of the steam generators,
  - recovering concentrated boric acid from the coolant drained during startup and boron control.
- Organized leaks system and leak detection Systems: These systems are responsible for maintaining the amount of the primary circuit coolant by collecting and returning the primary circuit water that has leaked from the main water circuit equipment in a planned manner. The leak detection system allows monitoring the sealing of flanged joints in the main water circuit equipment and continuously provides information to the operating personnel on the status of these joints.
- Intermediate cooling circuits: Some elements of the primary circuit's main equipment require continuous cooling. Since these pieces of equipment come into direct contact with the primary circuit water, a closed intermediate cooling circuit is introduced between the cooling environmental water and the equipment to be cooled. The radioactivity of the demineralized water in the closed circuit is continuously monitored. The drives of the control and safety rods, the main circulation pumps, and the emergency zone cooling system pumps are equipped with intermediate cooling circuits.
- Special drain and floor water system: Its purpose is to collect and pre-purify the floor waters from the main and auxiliary building rooms from mechanical contaminants through sedimentation and filtration. All rooms in the reactor building are equipped with special drains to collect any liquid that falls on the floor. The water flows by gravity through pipes into sump tanks, from where it is directed to the water purification system.

The secondary circuit

The secondary circuit's task is to remove heat from the primary circuit through the steam generators, deliver the 46 bar dry saturated steam produced in the steam generators to the two turbine-generator units, and return the resulting condensate to the steam generators. During cooling and in the event of an incident, it ensures heat removal from the primary circuit through the steam generators. The systems fulfilling the heat removal function on the secondary side can be divided into the following:

- Main steam system: Its function is to deliver fresh steam produced in the steam generators to the turbines, thus meeting the turbines' working steam demand and transferring the heat generated in the primary circuit to the secondary circuit. Additionally, it supplies the internal steam systems and participates in cooling and heating the unit. The steam produced in the 6 steam generators reaches the main steam collector via separate steam pipes from each steam generator. Each main steam pipe is equipped with safety valves, a quick-acting pneumatic sectional gate valve, and a main steam gate valve.
- Turbine and generator: The heat and kinetic energy of the steam produced in the steam generators must be converted into mechanical rotary motion to drive the generator, thereby producing electricity. In this energy conversion process, the steam turbine's role is to convert the thermal energy of the saturated steam produced in the steam generators into mechanical energy (rotary motion), contributing to the secondary circuit's heat removal process. Each unit has two turbines, which are three-casing designs consisting of one high-pressure and two low-pressure casings. The generators are two-pole, three-phase synchronous machines, with a rotor directly cooled by hydrogen and stator windings directly cooled by water, while the heat removal from other active parts (laminated core) is done through surface (indirect) hydrogen cooling.
- Moisture separator and reheater: The nuclear power plant's steam turbines operate with dry saturated steam. The initial moisture content of the steam entering the high-pressure casing is approximately zero, which steadily increases due to successive expansions in the turbine. The moisture content of the steam exiting the high-pressure casing is already so high (about 12%) that it is no longer suitable for further work. Therefore, a moisture separator is installed before each low-pressure casing. The moisture separator first mechanically separates the water droplets, and then, in two reheater stages, the steam is superheated to remove the remaining moisture content.
- Main condensate system: It transports the water formed by the condensation of steam in the condenser to the feedwater tank, and from the feedwater tank, the feedwater system supplies the steam generators. Each of the two turbines belonging to a unit has its own main condensate system with the same design.
- Feedwater system: Its task is to deliver the feedwater stored in the feedwater tanks to the steam generators, preheat the feedwater in high-pressure heaters, and participate in cooling and heating the primary circuit. The operational feedwater system consists of 2 deaerator feedwater tanks, 5 feed pumps, 6 high-pressure heaters, and 6 steam generator level control valve groups, as well as the connecting pipes and fittings.
- Demineralized water system: The function of the demineralized water system is to provide the feedwater reserve for the units, make up for secondary circuit coolant losses by supplying the condensers or feedwater tanks, and supply sealing and cooling water to the cooling pumps, as well as supply feed pumps in case of a main condensate system failure. The demineralized water system is a shared system for each unit pair (separate systems are implemented for units 1-2 and 3-4). The production of demineralized water is handled by the make-up water preparation plant from Danube water. The demineralized water reserve is stored in three 1000 m³ tanks per unit pair. The tanks are vertical cylindrical structures located in the yard area beside units 1 and 3.
- Cooling system: It serves to cool the primary circuit and remove residual heat through the secondary circuit. The system's function is to cool the primary circuit at the

appropriate rate through the secondary circuit during planned or emergency shutdowns, remove the residual heat generated in the non-operational reactor, and assist in heating the primary circuit during startup. The cooling system is only operated during emergency or normal cooling.

Cooling water systems

Operating various systems and equipment in a nuclear power plant requires an adequate supply of cooling water. The plant's cooling water system consists of the following subsystems: the safety cooling water system, the technological cooling water system, and the condenser cooling water system. Each of these subsystems has different technological requirements, but they all ultimately source their cooling water from the Danube River. The intake structures for units 1-2 and 3-4 ensure the necessary water extraction.

The safety cooling water system supplies cooling water to equipment that requires safe, continuous cooling during normal operation of the plant and supports the cooling of the unit both in normal and emergency conditions. Considering that the emergency cooling system for the core consists of three independent systems in line with the plant's safety philosophy, the safety cooling water system is also designed with three independent branches to maintain the principle of independence. The cooling water for the safety cooling system is provided by pumps located in the intake structure.

The technological cooling water system supplies the cooling and other water needs of normal operational consumers involved in the plant's energy production process. Its consumers do not belong to the category of vital equipment (i.e., equipment important for nuclear safety during normal operation). This system branches off from the condenser cooling water supply, using booster pumps and filtering equipment.

The condenser cooling water system provides the cooling water necessary for condensing the steam that has performed work in the turbines, as well as for the operation of some auxiliary systems of the turbine and generator. The source of the cooling water is raw Danube water, which reaches the intake structure through the cold water channel. The condenser cooling water system receives water from the intake structure's main pipeline through four connections.

Water delivered by the condenser cooling water pumps enters the raw water reservoir and flows through subsequent sections by gravity. From the raw water reservoir, the water passes through four drum filters. The filtered water from the drum filters enters the filtered water reservoir, and from there, it is directed (one per unit) into the main pipelines. Each main pipeline has four connections to the turbine condensers. Water reaches the technological pump house from the two main pipelines via a branch connection. The heated cooling water from the condenser is discharged into enclosed reinforced concrete channels and then flows into the Danube through the warm water channel and overflow weir.

Ventilation and air conditioning systems

The purpose of the ventilation and air conditioning systems is to ensure the proper extraction and treatment of air from potentially contaminated areas, as well as to provide the necessary operating conditions for equipment operation and personnel occupancy.

The ventilation systems serve the operational rooms within the controlled area of the nuclear power plant and the rooms housing electrical and control systems located outside the controlled area. The ventilation systems for the controlled area and those outside it, are physically separated from each other. In exhaust systems where air contamination with radioactive aerosols is possible, the extracted air passes through filters. Air from the controlled area is only released into the environment through controlled emission points via the ventilation chimney.

Emergency systems

The emergency systems of the nuclear power plant are designed to meet safety requirements. They must ensure the safe shutdown of the reactor core in the event of any malfunction of normal operational equipment and must be able to prevent the release of radioactive materials into the environment beyond permissible levels. To meet these requirements, safety-critical protection systems are designed with redundancy. The emergency systems include:

- Emergency core cooling systems: These are the primary protective devices for the reactor unit, intended to prevent severe damage to the reactor core by injecting borated cooling water in the event of an accident involving coolant loss, thereby avoiding unauthorized radioactive releases.
- Emergency systems for steam generators: To ensure the reliable water supply of the steam generators, emergency feedwater pump systems and auxiliary emergency feedwater pump systems are available. The emergency feedwater system ensures water supply to the steam generators from the deaerator feedwater tank in case the operational feedwater pumps fail. The auxiliary emergency feedwater system supplies water to the steam generators from the demineralized water tanks during major emergencies in the feedwater supply, which could lead to the risk of the steam generators drying out. Each unit has two auxiliary emergency feedwater pumps. The pumps and the auxiliary emergency feedwater pumps of the other identical unit are connected via a common suction line to three 1000 m^3 demineralized water tanks.

  In order to mitigate the consequences of steam generator heat transfer tube or collector break accidents (PRISE), a secondary-side blowdown system has been installed. The system, which consists of five valves placed beneath each steam generator, can blow down sufficient medium to ensure that pressure does not exceed the opening value of the steam generator safety valves even in the event of the largest cross-sectional break. With this system, the activity release during a PRISE accident is reduced to practically zero.

Containment systems

The plant's overpressure-proof containment, i.e., its hermetic area, is the structural building housing the primary circuit. Its purpose is to prevent the release of radioactive medium into the environment during accidents involving coolant loss. The building structure is designed to withstand the pressure that would occur during the design basis accident. The containment system includes:

- Passive pressure reduction System (localisation tower): Its purpose is to reduce the pressure of steam generated during the expansion of the overheated coolant in the event of an emergency in the primary circuit by condensation. The localisation tower consists of two main parts: the bubbler condenser and the air traps. In the event of a pipe break accident, the steam condenses as it bubbles through the water layer in the bubbler condenser trays, and the air is driven into the air traps by the pressure difference.
- Sprinkler system: This is the active element of the containment pressure reduction system. Its purpose is to reduce pressure in the hermetic space during an accident, bind iodine present in the atmosphere of the hermetic rooms, and cool the atmosphere.
- Containment isolation system: This system's purpose is to isolate the hermetic rooms and the technological systems within them from the environment during an accident involving the release of radioactive materials within the hermetic area.
- Hydrogen management system: This system is responsible for removing hydrogen from the hermetic space during an accident.

Electrical equipment

The four units of the power plant generate electricity for the National Power Grid as a baseload power station. Accordingly, the first part of the plant's electrical systems consists of the equipment that generates electricity and transmits it to the national grid. The electricity generated by the plant's steam turbine-generator units is carried to the main transformers via busbars through generator circuit breakers, where it is stepped up to 400 kV. The two main transformers for each reactor unit connect to the 400 kV substation, which is part of the national grid, via a 400 kV unit line. Another significant part of the plant's electrical equipment is the in-house electrical systems, which supply auxiliary power to the technological systems necessary for their operation.

Part of the plant's technology is dedicated to maintaining nuclear safety. These technologies require what is known as safety electrical power supply to perform their safety functions. The interruption time for the electrical power supply of certain technologies must not exceed a fraction of a second. Uninterruptible power supply systems are used to power such equipment.

In the event of unexpected failures, voltage drops, or frequency drops in the internal power network, the diesel generator units associated with the specific unit automatically start up, and by connecting to the safety power supply network, they ensure the electrical power supply to the affected technological systems as an independent energy source. Due to the triple redundancy of the safety systems, each unit is equipped with three independent diesel generators.

Instrumentation and control technology

A comprehensive control system is in place to monitor the technology, nuclear and mechanical processes, and equipment of the nuclear power plant, ensuring safe and economical operation. The control system's task, in all operational states of the unit, is to ensure the necessary protective and automatic operations, provide operator intervention capabilities, supply information characteristic of the given operational state, monitor the fulfilment of the safety functions, and prevent unauthorized interventions.

Radioactive waste management

At the Paks Nuclear Power Plant site, radioactive waste generated during operation is temporarily stored. Radioactive waste can be in solid, liquid, or gaseous form. Based on activity concentration and dose rate, radioactive waste is categorized as low, intermediate, or high activity. The main sources of solid radioactive waste generated during the operation of the nuclear power plant include:

- fatigued and activated or surface-contaminated equipment, fittings, insulation etc.
- construction materials from modifications (concrete debris, wood etc.).
- metal waste, shavings, and worn-out tools generated in maintenance workshops.
- "soft" waste generated during maintenance and operation (clothing, personal protective equipment, wiping rags, films etc.).
- components removed from the reactor (absorbers from control assemblies, intermediate rods, thermocouples, etc.).

Temporary storage of low- and intermediate-level waste is provided on the power plant site by reducing the volume and preparing the waste packages for final disposal. After temporary storage, this radioactive waste is transferred to the National Radioactive Waste Repository (NRWR) in Bátaapáti, operated by PURAM. The preparation of waste packages suitable for final disposal is ensured at the plant through appropriate waste processing and conditioning technologies.

The collection and processing technologies for low- and intermediate-level solid radioactive waste are designed to meet the waste acceptance criteria. They are stored in the main and auxiliary buildings of the power plant until they are handed over to PURAM. The following specific waste types can be distinguished:

- waste that can be placed in 200-liter barrels.
- large-sized waste that cannot be placed in 200-liter barrels:
  - after cutting, these can be placed in larger containers and filled with cement paste for final disposal.
- borax from the Liquid Waste Water Processing (FHF) technology:
  - metaborate of a quality that can be released is produced by the FHF technology, and the recovered borax is disposed of as hazardous waste after release.
- various filter cartridges:
  - cesium filters produced by the FHF technology are to be packed in containers without treatment after activity measurement.

The schedule for handing over the waste packages considers that there should always be at least one year of reserve capacity at the plant site for potentially reclaimed radioactive waste packages or waste generated in unexpected events.

Through the cooperation of MVM Paks Nuclear Power Plant Ltd. and PURAM, a waste package system was developed that allows cost-effective utilization of the storage spaces being implemented at the NRWR in Bátaapáti while maintaining the same level of safety. Rigid metal containers are used for the disposal of low- and intermediate-level solid waste, in which 1 or 4 pcs of 200-liter barrels are placed. The free voids in the waste packages are filled with radioactive cement paste made from liquid radioactive waste (additional radioactive waste can be placed with this process). The compact waste packages are produced at the nuclear power plant site, and their transportation to the NRWR is carried out by road using specially designed and authorized trucks.

Liquid radioactive waste (evaporation residues, evaporator acid solutions, spent primary circuit ion exchange resins) is collected in temporary liquid radioactive waste storage tanks in the auxiliary building. Before transportation to the final repository, liquid radioactive waste is solidified at the nuclear power plant because only solid waste can be placed in the final repository.

The regular operation of the FHF technology for processing liquid waste has begun. Operating this technology frees up storage capacity, ensuring long-term temporary storage of liquid radioactive waste, considering the commissioning of the cementing technology used for solidifying liquid waste. The solidification of liquid radioactive waste is done tank by tank, with the cementing recipe tailored to the chemical composition of the waste in the tanks, which can be applied following individual regulatory approval. The scheduling of the processing and conditioning of liquid radioactive waste considers that there should always be at least two years of reserve capacity for waste generated in unexpected events.

High-level solid radioactive waste is temporarily stored in special wells designed for this purpose at the nuclear power plant site. Large-sized waste that cannot be placed in storage wells can be collected in lead containers. According to the management concept for high-level waste, it will be temporarily stored on-site until the decommissioning of the nuclear power plant. At the time of decommissioning, the waste will be handled and disposed of together with other high-level waste by PURAM in a final repository[6] that will be operational by then for the disposal of high-level waste.

During the operation of the nuclear power plant, a portion of the gaseous radioactive waste is purified by the filtration systems of the ventilation systems. The hydrogen burner system regulates the dilution and burning of gases (hydrogen, noble gases, oxygen, etc.) dissolved in the primary circuit coolant and the medium added as make-up water. Special gas purification systems continuously receive and clean the high- and low-activity gas mixtures generated in the units, which, after purification, are released into the ventilation chimney.

Handling and storage of fuel assemblies

The management and storage of fuel assemblies used as fuel in the nuclear power plant can be divided into two parts. The first involves handling and storing the fresh fuel assemblies arriving at the plant. Before being used in reactors (irradiated), these do not require radiation shielding or cooling. However, for irradiated or spent fuel assemblies that are no longer used in the reactors, radiation shielding and the removal of residual heat generated in the assemblies must be ensured during both handling and storage while maintaining a subcritical state. Consequently, there is a significant difference between the handling and storage of fresh and spent fuel assemblies.

The role of the fresh fuel storage facility is to store the quantity of fresh fuel required for the economical operation of the plant. Each twin unit has a designated room for storing fresh fuel assemblies.

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[6] https://rhk.hu/timeline/investigation-in-the-west-mecsek-mountani

For the internal storage of irradiated fuel within the plant, each of the four reactor units has a spent fuel pool located directly adjacent to it. The purpose of the spent fuel pool is to store spent fuel assemblies after they have been removed from the reactor for the duration necessary for the specific activity and heat generation of the fuel to decrease to a level that allows for the safe transport of the spent fuel out of the plant using the available transportation equipment. The spent fuel pool is connected to the upper part of the reactor shaft, the transfer pool, by a transfer channel. The spent fuel pool has its own cooling circuit to ensure the removal of residual heat from the fuel assemblies.

After 3-5 years of storage in the spent fuel pool, the spent fuel assemblies are transported by rail in specially designed transport containers to the SFISF, ensuring the availability of free storage capacity in the spent fuel pool necessary for the continuous operation of the reactors.

Communication and telecommunication systems

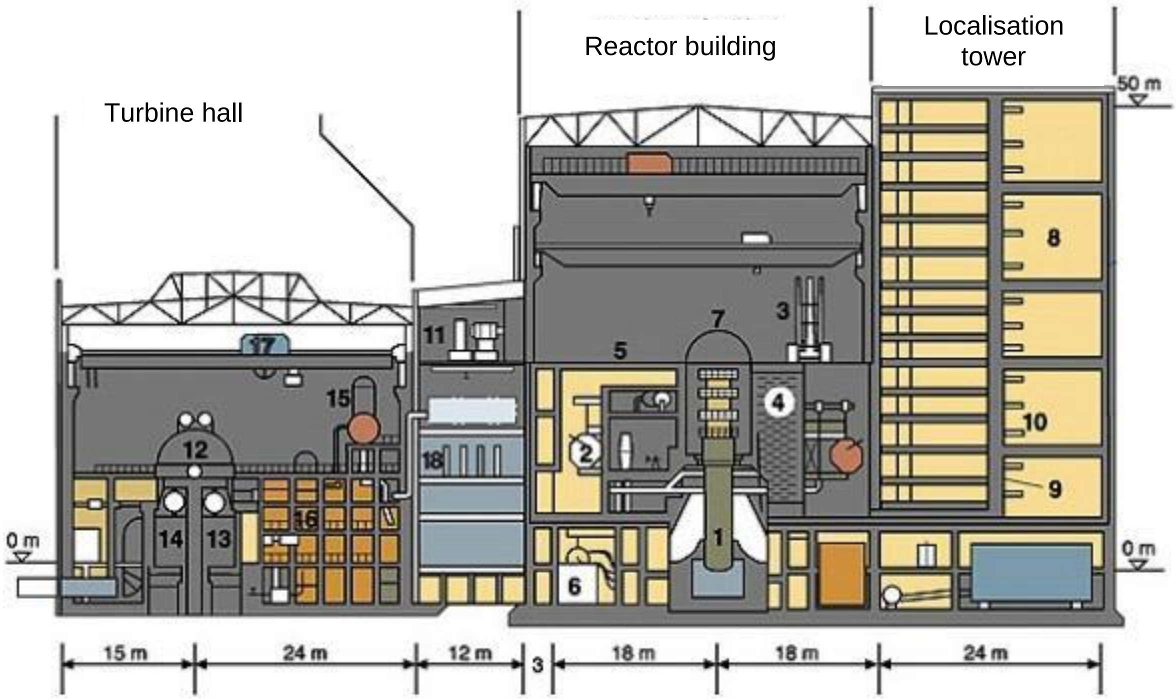
The nuclear power plant is equipped with all the necessary wired and wireless communication devices to ensure operational communication, the handling of telephone traffic, the execution of measurement and signal data transmission, and the voice and data connection with the power industry telephone system. These systems also facilitate the communication with employees, authorities, and the public, including alerting them in case of emergencies.

2.2.2. Facilities of the energy production

The individual reactors are housed in twin-unit buildings (building-up I: units 1-2, building-up II: units 3-4). The twin unit that houses two reactors is shown in *Figure 2.2.2-1.* The upper part of the reactor buildings is a conventional industrial structure with general mechanical equipment. The reactor, primary circuit, and steam generators are located in the lower part of the building. The reactor is surrounded by radiation shielding. The lower part of the reactor building forms a separated, enclosed space for each reactor. These separated parts (so-called hermetic spaces) are connected to the reactors' own emergency and containment systems. A hermetic space is a pressure-resistant area that can withstand the thermal and pressure loads and ensures the containment of radioactive substances also in an accident situation.

Figure 2.2.2-1. View of the twin units of the Paks Nuclear Power Plant

The safety systems of the Paks Nuclear Power Plant follow the principle of "defense in depth", as part of this there are multiple radioactive emission-preventing systems (defense barrier) between the environment and the nuclear fuel assemblies. In addition to these passive defense barriers, there are also active safety systems. Adequately sized systems are in place to cool the reactor during and after accidents. In the event of a power outage, backup diesel generators are activated. A cross-section of the building complex including the main building and the main equipment of the power plant is shown in *Figure 2.2.2-2.*



1. Reactor
2. Steam generator
3. Refuelling machine
4. Spent fuel pool
5. Biological protection
6. Supplementary feedwater system
7. Reactor hall
8. Localisation tower
9. Foam dispersing tray
10. Air trap
11. Air-shaft
12. Turbine
13. Condenser
14. Turbine hall
15. Feedwater tank
16. Pre-heater
17. Turbine hall crane
18. Instrument place

Figure 2.2.2-2. Cross-section of the building complex containing the main equipment of the power plant

All four reactors share a common turbine hall, located adjacent to the reactor buildings. Each reactor is paired with two turbines, making a total of 8 turbines in the power plant. The main transformers are positioned directly beside the turbine building, while the switchyard is located at a safe distance from the turbine building. This ensures that, in the event of a fire, the switchyard and the turbine hall do not endanger each other. During normal operation and maintenance, the Paks Nuclear Power Plant is completely independent of any external services from an infrastructural perspective.

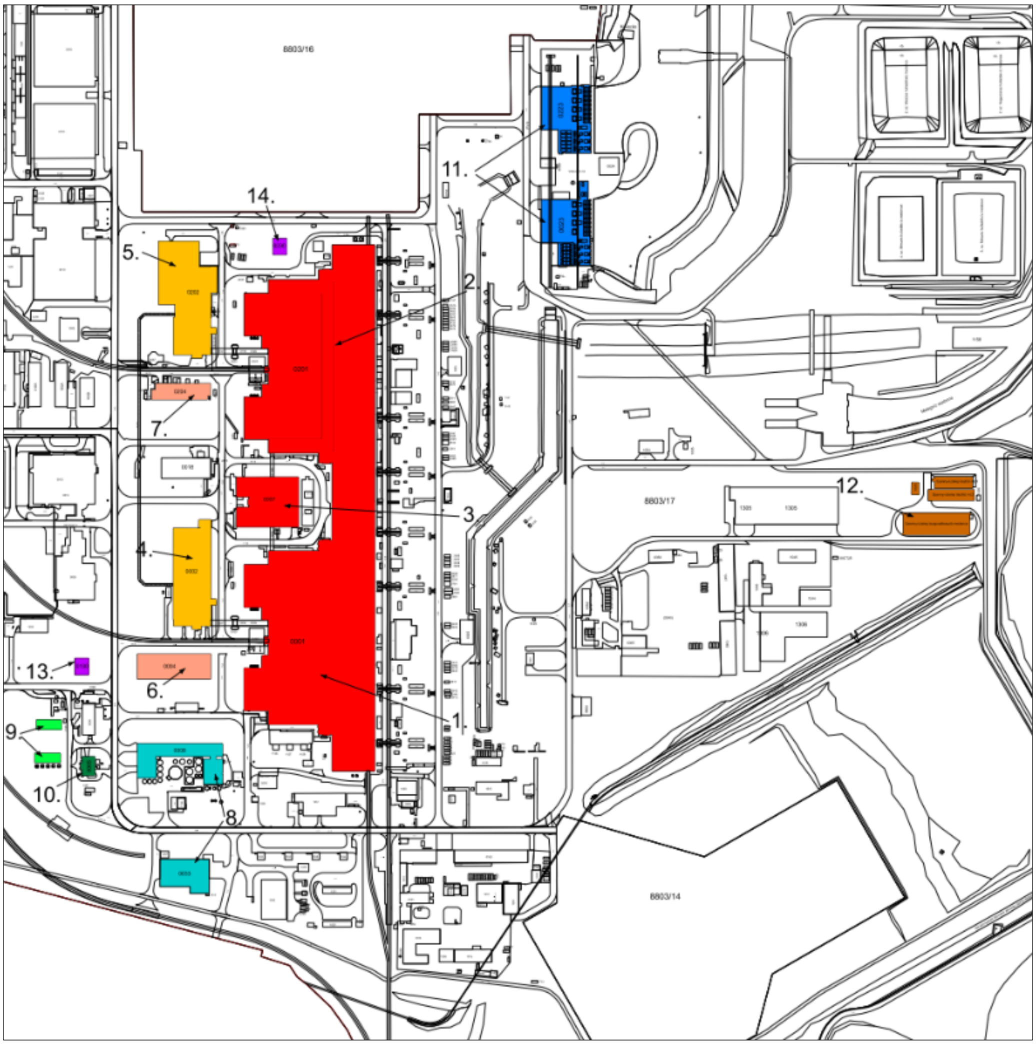
In terms of design and layout of the power plant, the following main buildings, structures, and architectural elements should be distinguished (the list does not include offices, warehouses, and other buildings located on the site):

- Main operational buildings: These are the centres of the energy production. From a design perspective, the buildings are divided into units consisting of two units each, which are essentially identical. The main operational buildings are divided into sections that include the primary and secondary circuits, as well as electrical switchhouses, according to the technology in use.
- Auxiliary buildings: Each auxiliary building is designated for housing water purification equipment and storage facilities for radioactive liquid and solid waste generated within the controlled zone, as well as technological systems related to waste management. The auxiliary buildings are connected to the main buildings by bridges and tunnels and are also interconnected by a pipe bridge used for transporting liquid waste.
- Diesel generator buildings: The two diesel generator buildings each house 6 diesel generator units, which serve as the power source for the plant's 6 kV safety distribution boards in the event of an accident.
- Medical and laboratory building: This building was constructed to serve units 1-4. It is located between the two main operational buildings and is connected to them by

two-story pedestrian bridges, which facilitate personnel movement between changing rooms and workplaces in the main building, as well as light freight traffic between laundries and laboratories. The facility, which has a complex function, effectively acts as a "lock" between the controlled zone and the operational area. In the controlled zone of the building, there are primary circuit changing rooms, washrooms, showers, laundries, the Dosimetry Service, the radiation protection control room, radiochemical and emission monitoring laboratories, and material testing laboratories.

- Chemical and makeup water preparation building: This building is used for producing the demineralized water necessary for operation and for housing the technological and support systems that supply chemicals to the primary and secondary circuits. An external storage tank park has been established in the courtyard. The technological connections are made through a pipe bridge and reinforced concrete technological channels.
- Water intake structure and water dispatching centre: The water intake structure, which ensures the cooling water supply for the plant, is divided into three units. Separate water intake structures serve units 1-2 and units 3-4. A common control building has been constructed for both water intake structures to house equipment responsible for the operation, monitoring, and regulation of electrical systems. Two pumping stations, located at the end of the cold water channel, lift the required amounts of condenser and safety cooling water. The safety cooling water is directly supplied to the consumers, while the condenser cooling water is pumped to the raw water pool located at the discharge side of the pump operation. The mechanical equipment, as well as the raw and filtered water storage pools, are located in the filter house, which is integrated with the filtered raw water pools.
- Level control weir: Its function is to ensure the necessary water level for the gravitational operation of the cooling water circulation, as well as to allow for the possibility of warm water recirculation into the cold water channel. The reinforced concrete structure is located between the closed-section concrete part and the open-section earth channel of the warm water channel.
- Warm water channel: Its function is to discharge the cooling water heated during the plant's operation into the receiving water body, the Danube. The warm water discharge is managed by a closed-section concrete channel, partially constructed with a twin-section, a weir structure, and an adjoining lined open-section channel. The warm water channel connects to the Danube via a chute and an energy-dissipating reinforced concrete structure. The cold water channel's de-icing and emergency water replenishment system connects to the warm water channel before its outlet.
- Unit ventilation chimney: The ventilation chimneys are responsible for discharging filtered air from the ventilation systems of the plant's primary circuit areas. One 100-meter-high, twin-shaft reinforced concrete chimney was built to serve units 1-2 and units 3-4. Both chimneys have two shafts and operate with natural draft.
- Hydrogen and Nitrogen tank park: Its function is to store the hydrogen gas for cooling the generators delivered by tanker trucks, and the nitrogen gas also delivered by tanker, which is used for emergency draining of the generators, displacing primary circuit technological waters from the system, and servicing the measurement systems. In the event of failure of the 15 gas-phase hydrogen tanks or the 10 gas-phase and 4 liquid-phase nitrogen tanks, the protection of the site's technological facilities and offices is ensured by reinforced concrete walls.

The main buildings and structures on the site of the nuclear power plant are shown in *Figure 2.2.2-3.*



1. I. Main operating building (0001)
2. II: Main operating building (0201)
3. Health and laboratory building (0007)
4. I. Auxiliary building (0002)
5. II. Auxiliary building (0202)
6. I. Diesel generator building (0004)
7. II. Diesel generator building (0204)
8. Chemical water preparation (0008) and makeup water preparation (0033)
9. Hydrogen and nitrogen tank park
10. Building of hydrogen plant (0005)
11. I-II. Water intake facilities (0023-0223)
12. Wastewater treatment plant
13. Southern emergency diesel generator building (0130)
14. Northern emergency diesel generator building (0230)

Figure 2.2.2-3. Major buildings and structures on the Paks Nuclear Power Plant site

2.2.3. Related activities and facilities

2.2.3.1. Water supply, wastewater treatment

Water use and supply

The facility's water use can be categorized into two main groups based on function:

- For cooling purposes, the power plant withdraws water from the Danube via an open cold water channel, which is completely returned to the receiving body through an open-channel warm water channel after use.
- Industrial water for replacing technological water losses comes from the Danube water intake. The source of anti-fire water provision is the shore-filtered well site (with reserves in the warm water channels), while drinking water and service water sources are at the Csámpa well site with 9 deep wells (groundwater).

The annual allocated water demand from waterworks wells is 200 000 m³/year, and from surface water intake is 2.9 billion m³/year. The theoretical water requirement for the condenser cooling water system is 25 m³/s for a single reactor unit, and 100 m³/s (360 000 m³/h) for simultaneous operation of four units. The water requirement for units 1-4 is 2.5-3.1 billion m³/year, including 72 million m³/year for safety cooling water. The annual contingency is influenced by maintenance shutdowns and the effect of recycling reduction.

Municipal wastewater treatment and disposal

The Paks Nuclear Power Plant has a constructed wastewater sewage network. The municipal wastewater, wastewater from the health and laboratory building, and occasionally the excess water is collected and treated by the power plant's 1870 m³/day capacity municipal wastewater treatment plant. The treatment plant consists of two units of TABTA type structures with 670 + 1200 m³/day installed hydraulic capacity. Both units use a mechanical and total oxidation activated sludge system for full biological treatment. The excess sludge is directed to sludge dewatering beds. In operation, the unit II. is used, with the unit I. as backup.

The unit I. (670 m³/day) ensures adequate oxygen concentration in the tanks with surface aeration devices (rotors). The suction effect of the rotors automatically ensures sludge recirculation. The unit II. (1200 m³/day) uses a deep aeration system. In the pre-aeration tank, there is 1 pc. Jet aerator, and in the aeration storage tank, there are 1+1 Jet aerators. Fine-bubble deep aeration ensures the proper oxygen concentration and mixing in the aeration tanks. The aeration tanks have 2+2 sludge thickening units and pumps for sludge recirculation.

Treated wastewater from the municipal wastewater treatment plant is discharged through a steel pipeline into the warm water channel directly before the energy dissipator. A sampling shaft is located before the channel inlet, which is the power plant's V3 sampling location.

Excess sludge from the secondary clarifier is transferred to a sludge thickener, where sludge water and sludge are separated. The thickening time is 4-6 hours. The thickened sludge is transported through a sludge pipeline to a sludge bed of 1200-1300 m^2 for further dewatering. The dried sludge is disposed of after radioactive concentration checks – depending on the result, either as radioactive waste or, if not classified as radioactive, as hazardous waste, following hazardous waste regulations.

Industrial wastewater treatment and disposal

Wastewater from filter backwashing at the water intake facilities, waste removed by washing from clarifiers, and other wastewater from the water intake operation are received by the warm water channel directly after the weir.

The treatment of water softener wastewater is part of the power plant's industrial sludge system. It involves receiving, treating, and discharging treated water into the receiving body. Water softener wastewater treatment occurs in two stages. The first stage is spontaneous neutralization in the pumping suction pit. The second stage is the sludge reservoir, which performs phase separation and sedimentation. The two 10 000 m³ sludge reservoirs are used for treating and settling water softener wastewater. Treated (cleaned) water leaves the sludge reservoir through an overflow into the warm water channel. Observation wells are implemented around the sludge area to monitor leakage and groundwater quality.

Technological oil wastewater

Oil wastewater is treated at its source. At the car wash, treated wastewater is directed into the power plant's municipal wastewater system. At other sources (fire station car wash, drum oil storage, truck wash), it goes into the plant's rainwater drainage system.

Rainwater drainage

Rainwater channels collect roof runoff and precipitation from roads and green areas and direct it into external ditches surrounding the plant. The Paks Nuclear Power Plant site has 5 main rainwater collection channels. The rainwater drainage system within the plant is connected to the off-site catch drain system. The rainwater transported by Northern catch drain gets into the cold water channel, while the rainwater conveyed by Southern catch drain is received by the warm water channel.

2.2.3.2. Freight and passenger transport necessary for the activity

The power plant site can be approached by road from the north and south via main road No. 6, from which two branches (northern and southern entrance) lead to the power plant area (*Figure 2.2.3.2-1.*). The site is also accessible from the south via the Paks – Gerjen connection road, which connects to the southern entrance road of the plant. The site can be approached from the M6 motorway by exiting at the Paks-south junction at the 113 km section, then traveling through Paks (Kölesdi Road – Dankó Pista Street), and finally accessing it from the north via main road No. 6. under Paks.

From the Paks railway station, only dedicated trains can reach the plant site via the industrial track, exclusively for cargo transportation, no passenger transport by rail. Railway transport is occasional and has negligible environmental impact.

The plant site is also accessible by water, with a heavy cargo dock on the cold water channel. Water transport is also occasional and solely for cargo, with negligible environmental impact.

To determine the volume of cargo and personnel transportation related to the operation of the Paks Nuclear Power Plant, the transportation routes shown in *Figure 2.2.3.2-1.* Personnel and cargo transportation associated with the plant primarily occur by road was used. Considering the available entrance data for vehicles to the plant, the typical daily utilization of parking spaces, and public bus traffic, road vehicle traffic related to the operation of the Paks Nuclear Power Plant is characterized by the data in *Table 2.2.3.2-1.*

Table 2.2.3.2-1. Road vehicle traffic related to the operation of the Paks Nuclear Power Plant

Vehicle type	**Average daily traffic* [vehicles/day]**		
	Daytime	**Nighttime**	**Total**
Freight traffic			
Average daily traffic of freight vehicles (typically light trucks)	450	40	490
Passenger traffic			
Passenger cars	1 920	220	2 140
Buses	316	58	374
Motorcycles	90	–**	90

* Vehicle numbers were determined with simplifications in favour of overestimation.
** Negligible amount.

For the given vehicle numbers, one trip per day is considered, including arrival at the plant, various waiting periods, and departure. It is assumed that approximately 2/3 of the vehicles coming to and leaving the plant travel in the northern direction, and about 1/3 travel in the southern direction. About 10% of the traffic continues to the M6 motorway, while 90% stays on main road No. 6.

For the subsequent service life extension of the Paks Nuclear Power Plant no significant changes in the current cargo and personnel transportation needs have been anticipated. Given that the frequency and volume of material, equipment, and other goods deliveries to the plant are expected to remain as currently experienced, and there is no significant forecasted change in operational or maintenance personnel, the magnitude of transportation related to the activity is estimated to be similar to the current level during the extended operating period.

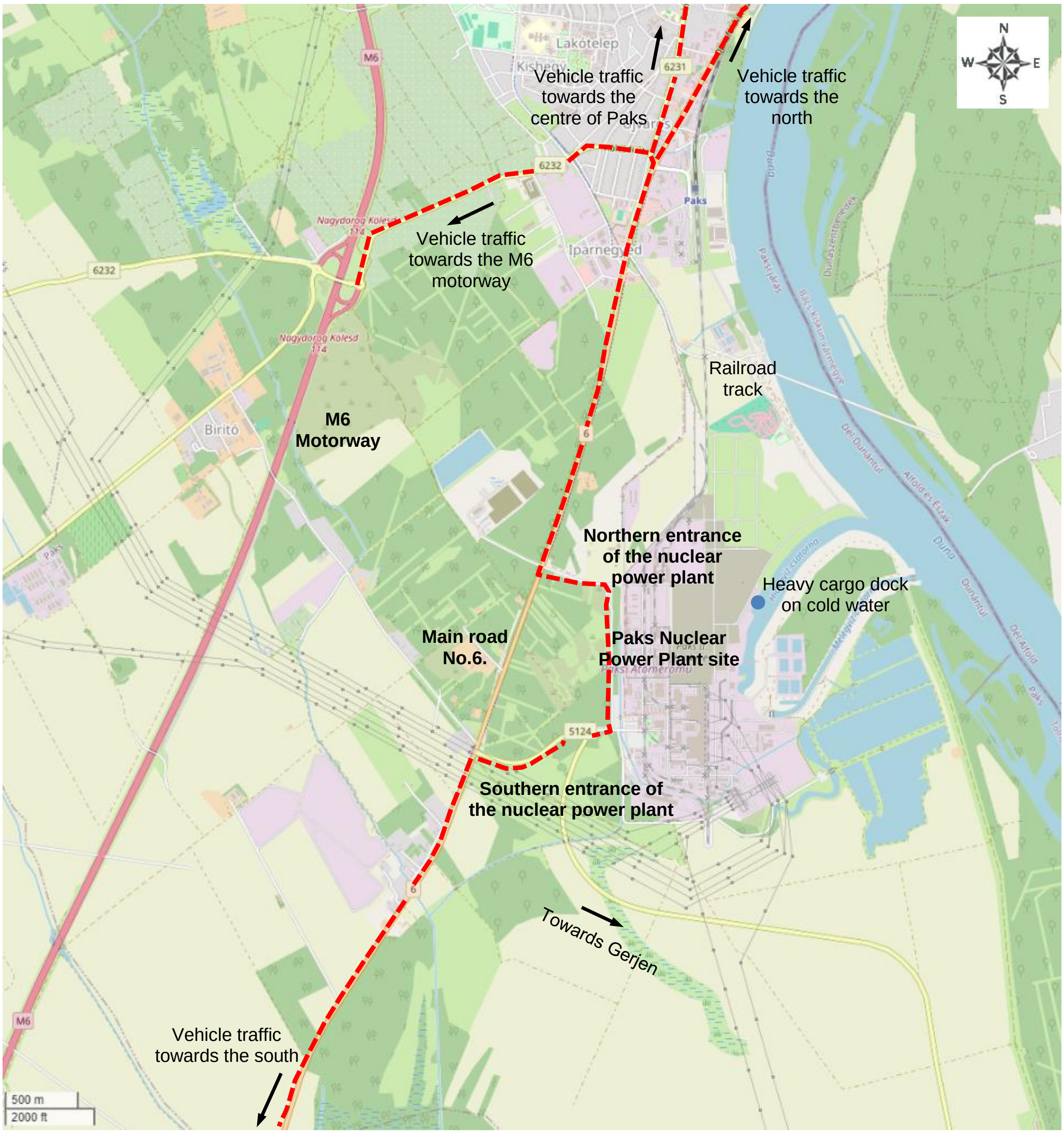


Figure 2.2.3.2-1. Approach routes to the power plant

2.2.3.3. Environmental facilities and measures, emission and environmental monitoring

The Paks Nuclear Power Plant operates under the conditions specified in the unified environmental permit issued by the Baranya County Government Office under file number 391-18/2017 on 9th June 2017, and its amendments. The nuclear power plant is a facility that has been in operation for several decades, the environmental impacts associated with its operation are known. Activities carried out to monitor the state of the environment ensure traceability of the plant's environmental impacts by providing detailed and up-to-date information on the state of the environment. The plant's activities are regulated by rules and procedures related to environmental protection, some of which are approved by the environmental authority in accordance with jurisdiction and legal requirements.

For the subsequent service life extension period, no modifications or technological, operational changes are expected that would significantly alter the current environmental emissions or impact factors. Therefore, no new environmental facilities or measures beyond those already implemented and the existing measures, procedures and checks are anticipated. The existing environmental monitoring activities should of course be continued for the period of subsequent service life extension.

Based on current knowledge, the plant’s procedures, regulations, measures, and environmental monitoring activities will be adequate for ensuring the plant’s compliance with environmental regulations and the monitoring of its environmental impacts during the continued operation period. However, this requires that in the event of legal changes, significant alterations affecting the plant’s systems, or changes in environmental conditions, the plant’s environmental measures, procedures, and practices must be reviewed and, if necessary, revised or supplemented. To ensure this, the nuclear power plant operates a certified Environmental Management System according to the MSZ EN ISO 14001:2015 standard.

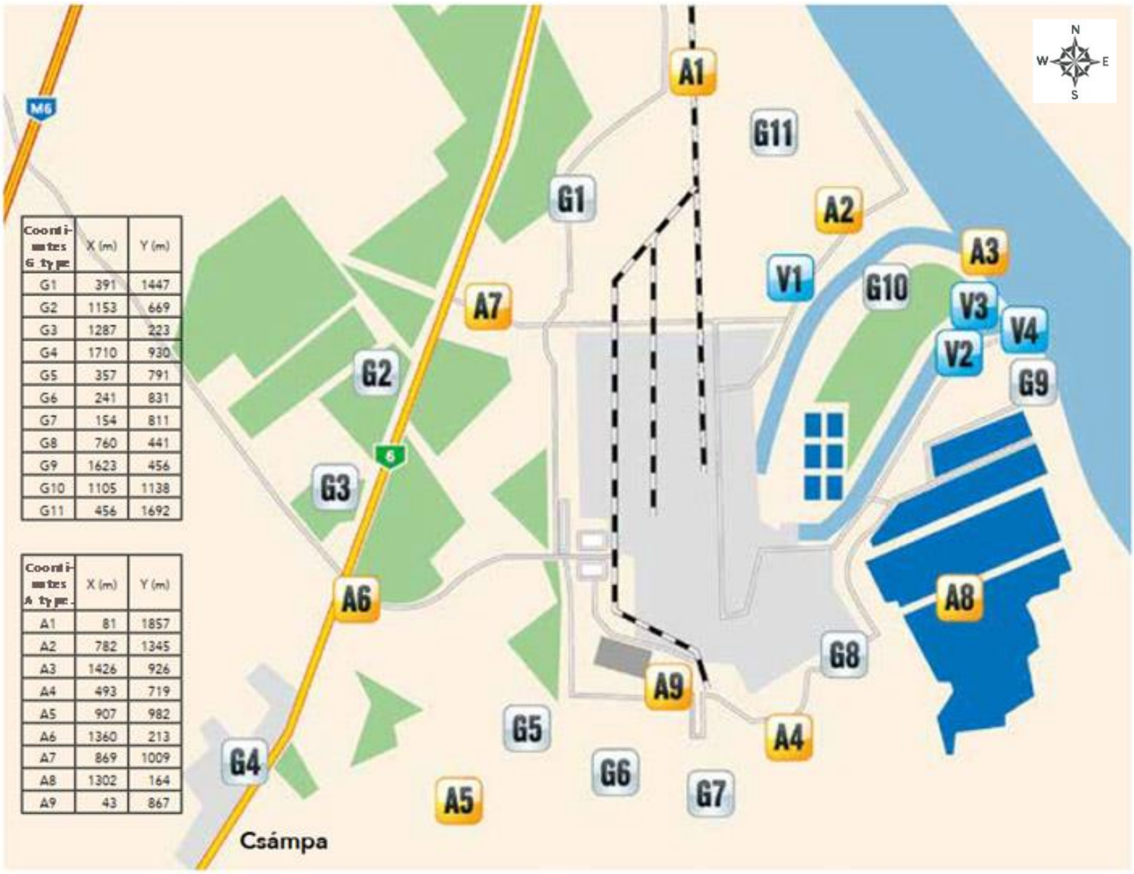
The key measures and environmental monitoring activities required by the nuclear power plant’s environmental permit are as follows:

- Protection against radioactive radiation:
  - Examination of radiation exposure to living organisms: sampling and gamma spectrometry measurements every 5 years.
  - Gamma spectrometry measurements of soil and Danube sediment every 5 years.
  - An emission control system must be operated to determine radioactive emissions. The plant’s radioactive emissions must be monitored according to the currently applicable Emission Control Regulations.
  - An environmental monitoring system must be operated to check the environmental impact of radioactive emissions. The monitoring of the plant’s environment must be carried out according to the currently applicable Environmental Monitoring Regulations.
- Water protection:
  - The impact of the plant’s heated cooling water and wastewater on the Danube’s water quality and aquatic life must be monitored with a system in line with the Water Framework Directive’s requirements. Monitoring examinations must be carried out seasonally every three years.
  - To protect the Danube’s aquatic life from thermal pollution, the temperature of the Danube water used for cooling and the discharged heated cooling water (at the discharge point) must be continuously measured. If the Danube water temperature reaches or exceeds 25°C, a temperature check of the 30°C limit must be performed by a measurement vessel using manual measurements at a reference cross-section 500 m downstream from the discharge point.
  - The plant must operate a monitoring system for the protection of riverbank water sources of operational and future significance affected by the discharge of used water (monitoring impacts on groundwater) as specified in the valid water rights permit.
  - The condition of the Danube riverbed and the riverbank must be monitored by repeating previously conducted examinations every 10 years.
  - In the event of failure, the results of the inspection program related to the ageing of Class 4 systems according to the Plant Systems and Components Safety Classification, the associated maintenance (rehabilitation) schedule, and the environmental impact assessment program must be submitted to the environmental authority every five years.
- Waste management:
  - The plant’s waste management goals – such as reducing the quantity and hazard of generated waste, maximizing waste utilization, and further developing the selective waste collection system – must be achieved according to environmental and economic considerations in a scheduled manner.
- Air quality protection and operation of point sources of air pollution:
  - The operational time of safety diesel generators must be below 50 hours per year.

  - Only low-sulfur (below 0.05 m/m%) diesel fuel can be used.
  - The emission limit values for air pollutants specified in the permit must be determined by standardized emission measurements conducted by an accredited measurement organisation every five years.
- Noise protection:
  - Noise limit values specified in the applicable regulations must be adhered to.

The primary task of nuclear environmental monitoring is to continuously control the release of radioactive materials from the plant and to extensively investigate their direct environmental presence. The monitoring is two-tiered: remote measurement networks constantly measure and monitor key emission and environmental radiation quantities, as well as meteorological characteristics, while sensitive laboratory tests complement and refine the remote measurement results. The number of continuous and, if possible, representative samples taken annually is nearly 10 000, with the number of data obtained through analysis, mostly nuclide-specific, being two to three times that amount. The assessment of the plant's nuclear environmental impact is primarily based on comparisons with isotopic selective radioactive emission limits.

The task of the Operational Environmental Radiation Monitoring System (OERMS) is to demonstrate through direct environmental measurements that the plant does not have a greater impact on the environment than permitted during normal operation. Environmental radiation protection monitoring of the plant is based partly on remote measurement systems and partly on sampling laboratory examinations. The locations of sampling and remote measurement stations around the Paks Nuclear Power Plant are shown in *Figure 2.2.3.3-1.* Laboratory tests cover both environmental media and elements of the food chain. This involves processing and measuring approximately 4000 samples annually.



Coordinates G type	X (m)	Y (m)
G1	391	1447
G2	1153	669
G3	1287	223
G4	1710	930
G5	357	791
G6	241	831
G7	154	811
G8	760	441
G9	1623	456
G10	1105	1138
G11	456	1692

Coordinates A type	X (m)	Y (m)
A1	81	1857
A2	782	1345
A3	1426	926
A4	493	719
A5	907	982
A6	1360	213
A7	869	1009
A8	1302	164
A9	43	867

Figure 2.2.3.3-1. Location of "A", "G", and "V" type remote monitoring stations in the vicinity of the nuclear power plant

For measuring environmental gamma radiation dose rates, all measurement points use dosimeter systems that are type-tested and calibrated. The "A" and "G" type stations are located within a 1.5 km radius, while the B24, L25, and "C" type stations are situated within a 30 km radius around the power plant. The "C" type stations and the L25 measurement point use environmental dosimeters with Al_2O_3 pellets (POR TL), whereas the "G" type stations are equipped with BITT RS03/232 type measuring probes. At stations A1-A9 and B24, POR TL environmental dosimeters and BITT RS03/232 type measuring probes for continuous monitoring provide data in parallel.

The determination of public radiation exposure is based on calculation methods derived from radioactive material emissions and dispersion, specifically for critical public groups (Csámpa /atmospheric emissions/ and Gerjen /liquid discharges/).

Regarding non-radioactive emissions and environmental impacts, the power plant performs the following monitoring activities:

- For the protection of surface waters:
  The plant’s water usage categories are:
  - cooling water, which is returned to the receiving Danube without residues,
  - technological make-up water,
  - social water supply,
  - fire water supply.

  The power plant's cooling water and raw water used in the technological make-up preparation are sourced from the Danube, drinking water needs are met by wells in Csámpa (groundwater), and the fire water system is supplied from riverbank-filtered wells.

  The V4 sampling point in the warm water channel’s outlet energy-dissipating structure (*Figure 2.2.3.3-1.*) serves both regulatory and self-monitoring purposes. This sampling point represents the quality of all used water and treated wastewater discharged into the Danube. (Sampling point V1, located along the cold water channel, monitors the radiometric characteristics of the Danube, and the V2 sampling point, located at the end of the warm water channel continuously monitors the radiometric characteristics of the discharge condenser, essential and technological cooling water, the water transferred from the slurry ponds, and the rainwater transferred from the Southern catch drain. The combined characteristics of the treated faecal wastewater leaving the discharge line and the over-balance water are measured by the devices at V3 sampling point. Continuous sampling is performed at each station for laboratory testing.) Under the valid monitoring program, all parameters specified in the water rights permit are checked.
- For the protection of groundwater:
  The plant’s impact on groundwater and soil is monitored using an extensive groundwater observation well system. The monitoring system includes 42 groundwater observation wells examining various parameters depending on the technology being monitored. To track the movement of groundwater and possible contaminants, the water levels of 118 wells are recorded, with automatic water level recording devices installed in 18 of these wells.

  To control potential sources of environmental pollution, monitoring is carried out around the following facilities:
  - waste operational collection area,
  - industrial sludge deposit,
  - underground oil tanks,
  - municipal wastewater system.
- For the protection of aquatic life:
  The impact of the plant's heated cooling water and wastewater on the Danube’s water quality and aquatic life is monitored every three years with a system that meets the requirements of the Water Framework Directive. Examinations are conducted during the vegetation period as stipulated in the environmental permit.

- For air quality protection:
  The operating time of air pollutant point sources is recorded, and their emissions are also measured in accordance with the parameters specified in the environmental permit, with measurements performed every five years.

2.2.3.4. Other related activities, technological systems

The nuclear power plant has several technological systems that, based on their safety classification, do not impact nuclear safety or are not directly related to production. These systems are necessary for the general operation of the plant. Their tasks involve the handling, transport, and storage of hazardous materials and conventional hazardous wastes, which could lead to environmental contamination if they fail. These include:

- industrial wastewater collection, pumping, and disposal systems,
- industrial sludge ponds (lime sludge, chemical and oil ponds),
- chemical treatment and specialised chemical preparation systems,
- chemical transfer and dosing systems,
- chemical wastewater discharge pipes,
- turbine oil systems,
- oil discharge stations and emergency drainage systems,
- machine room and auxiliary pump oil systems,
- safety diesel generators' lubrication oil, used oil, and diesel systems,
- municipal wastewater pipeline network,
- oily wastewater pipelines,
- chemical storage.

2.2.4. Operational states of the nuclear power plant

The determination of the nuclear power plant's operational states and the requirements for nuclear safety analyses are detailed in the 1/2022. (IV. 29.) HAEA Decree on nuclear safety requirements for nuclear facilities and related regulatory activities, as well as in the Nuclear Safety Code (NSC) as its appendices.

According to the requirements of NSC Volume 3, conditions other than normal operation are categorized into design basis and design basis extension operational states. Normal operation and the events leading to the states considered as part of the plant’s design basis are assigned to operational states according to their frequency of occurrence, as specified in *Table 2.2.4-1.*

Design basis accidents at the units of the Paks Nuclear Power Plant are characterized by a frequency greater than 10^{-5} events/year/unit. As a result of the principles and technical solutions applied during the design and operation of the plant, and the safety protection systems implemented, no significant release of radioactivity exceeding nuclear safety criteria into the environment occurs.

Table 2.2.4-1. Events leading to operational states considered as part of the plant’s design basis and their frequencies

Operational State*	Description	Event Frequency (f [1/year])
DBC1	Normal operation	–
DBC2	Anticipated operational occurrences	$f \geq 10^{-2}$
DBC4	Design basis accidents	$10^{-2} > f \geq 10^{-5}$

* The DBC3 category for infrequent design basis accidents ($10^{-2} \geq f \geq 10^{-4}$) is only applicable to newly constructed nuclear power plant units, and accordingly, the frequency of occurrence for DBC4 events is an order of magnitude lower, i.e., ranging up to $f \geq 10^{-6}$.

Events with a lower frequencies of occurrence than design basis accidents may result radioactive releases causing doses exceeding the limits of the design basis conditions. As an extension of the design basis, regulations distinguish between complex accidents (DEC1) and severe accidents (DEC2). In these cases, emergency and accident management measures must be implemented to prevent and reduce the consequences.

According to national regulations, the operational states of the Paks Nuclear Power Plant can thus be categorized as follows:

- normal operation (DBC1),
- anticipated operational occurrences (DBC2),
- design basis accidents (DBC4),
- complex accidents (DEC1),
- severe accidents (DEC2).

The NSC specifies different acceptance criteria for conditions deviating from normal operation, in accordance with their differing frequencies. The relevant criteria for the preparation of this PCD are as follows.

For processes resulting from initial events leading to DBC2 and DBC4 conditions, it must be demonstrated that the dose to the population reference group per person does not exceed:

a) the dose constraint value for processes resulting from initial events leading to DBC2 conditions, and
b) the 5 mSv/event value for processes resulting from initial events leading to DBC4 conditions.

Taking into account all design operating conditions and assumed initial events, except sabotage, the frequency of core damage leading to a severe accidental release shall not exceed 10^{-4}/year.

The summed frequency of severe accident event chains with large or early releases, aggregated for all initiating operating conditions and effects – excluding sabotage and earthquakes – must not exceed 10^{-5}/year, but should be approached as closely as possible to 10^{-6}/year with all reasonable modifications and interventions.

Safety analyses are used to demonstrate compliance with the relevant acceptance criteria for all initiating events belonging to the design basis and design basis extension operational states. Probabilistic safety analyses are conducted to determine the overall risk posed by the nuclear power plant, verify compliance with the acceptance criteria, evaluate the balance and robustness of the plans, and assess the suitability of the design basis extension. Probabilistic safety analyses are used to ensure that adequate reserves are available to avoid cliff-edge effects.

The fulfilment of these requirements must be demonstrated in a Final Safety Analysis Report (FSAR) with content defined in the NSC and must be approved by the regulatory authority responsible for nuclear safety, the HAEA. The FSAR must include the characteristics of the nuclear power plant, the description of modifications made, new regulatory and safety requirements, and any information that might affect safety analyses. Updates must be made as soon as new information becomes available and can be incorporated into the FSAR. The licensee must consolidate the FSAR annually to reflect changes in the nuclear facility.

When interpreting and comparing analytical results, it should be considered that environmental analyses generally use the best estimate method, while deterministic nuclear analyses use a conservative or Best Estimate Plus Uncertainty (BEPU) approach. Acceptance criteria are provided so that the conservative or BEPU results can be compared with these criteria.

2.3. Activities supporting the subsequent service life extension

The technical conditions for the subsequent service life extension are based on ongoing technical reviews, planned ageing management activities, refurbishments, equipment and tool replacements, and maintenance at the nuclear power plant. The planning of ongoing maintenance and condition-maintaining activities is based on the following plans, programs, and other records:

- The medium-term major repair plan, which identifies tasks that could affect the major repair plans in terms of duration, resource allocation, or special organisation.
- Maintenance programs for equipment groups and individual pieces of equipment that define the maintenance tasks to be performed and their scheduling during a specific period.
- Monitoring programs for individual systems, equipment groups, and individual pieces of equipment, which include technical and structural preparation of the plant's systems, structures and components.
- Recording of failures occurring during operation and associated technical decisions, specifying necessary interventions and execution conditions.

The multi-level (long-term, medium-term, campaign plans) planning practice developed for the implementation of maintenance, testing, and monitoring programs aims to provide the system with adequate flexibility for execution organisation. Another important point is that the control points built into the compilation of the campaign plans ensure the gradual clarification of the resource needs and the control of their availability.

Considering design and manufacturing specifications, operational, testing, and maintenance experiences, the long-term and campaign maintenance plans are developed, updated, and campaign volume is determined.

2.3.1. Ageing management of mechanical, electrical, instrumentation and control systems and plant structures

The systems, structures and components of the nuclear power plant age due to operation, which leads to gradual changes (deterioration) in their characteristic parameters. These parameters include material properties (e.g., strength), geometric dimensions (e.g., wall thickness, diameter), and other characteristics describing the fulfilment of safety functions by system components. Ageing is caused by normal operational loads, potential operational disruptions, improper commissioning, maintenance, or other effects induced by failures. Ageing processes (mechanisms) include all material structure changes caused by:

- static, dynamic, constant, variable, and cyclic mechanical and / or thermal loads,
- environmental factors (radioactive radiation, moisture, temperature, corrosive media),
- maintenance and inspections (and associated disassembly and reassembly).

Ageing management is a key activity in the lifecycle management of a nuclear power plant and is essential for the long-term safe operation of the plant. The goal of ageing management is to ensure that through systematic performance of analysis, operational, maintenance, periodic inspection and testing, monitoring, repair, and reconstruction activities related to identified ageing processes on designated system components, the system remains capable of performing its function while maintaining the minimum necessary safety reserves. Its necessity is independent of the owner’s and operator’s strategy regarding operational lifetime, whether the plant is intended to operate beyond the planned lifetime or not.

Requirements related to considering structural material ageing processes are defined in the NSC. During the preparation for the first service life extension, both the operator and the authority have expressed the need for a comprehensive review of ageing management programs and, where necessary, their modification.

The lifetime of the nuclear power plant as a facility is determined by structures and system components that cannot be replaced or refurbished (e.g., reactor vessel, steam generators), or where the costs and required shutdown time for replacement are such that execution is not justified from a technical-economic perspective.

Based on available material inspection, analysis, and maintenance results, there should be no expectation of infeasibility or excessive costs for the planned additional 20 years of operation for the most critical equipment (e.g., reactor vessels, steam generators). The safe operation of replaceable and refurbishable system components is maintained through ageing management and reconstruction programs as part of plant operations during the extended service life period.

In the development of the ageing management program operated by the Paks Nuclear Power Plant, the expected ageing processes and their effects for safety-critical equipment were identified and assessed. The progression of ageing processes was estimated, and this was considered when determining the necessary inspection cycles, ensuring that the ability of systems, structures and components to perform their safety functions is preserved.

There is a monitoring program for observing and controlling the ageing of reactor vessel materials, consisting of both reactor vessel and so-called sample string[7] material inspection documents.

During the operational period, ageing management is primarily conducted within the framework of periodic safety reviews. The Paks Nuclear Power Plant has developed a comprehensive ageing management program for the plant. As part of this, ageing management programs required for the degradation processes have been developed, the scope of ageing management has been determined and the ageing management programs for the systems, structures and components relevant to the first service life extension have been reviewed. As a result of this review, new programs have been developed, and existing programs have been modified as necessary.

For passive system components, the ageing management review of mechanical system components is carried out with consideration of specific ageing management programs. For major equipment, except for control rod drives (active system components), independent programs have been developed, and their ageing management is handled individually. For other (non-major) equipment, groups of system components have been formed based on similar ageing processes, allowing for similar management approaches. The grouping of system components was determined by factors such as construction, structural materials, and operating environment.

For architectural structures, system component groups have also been formed, categorized into main groups based on material and structure. The grouping principle was that within each group, identified ageing effects and damage processes should be similar, and thus their management methods should also be similar. Two types of programs have been developed for ageing management: structural programs and facility programs. Both types of programs use the same groups and main groups of system components. Structural programs include all identified ageing effects, damage processes, and their management for system component groups, while facility programs define the specific conditions for implementing the structural programs.

For electrical and control system components classified under the 2-3+ categories according to the Plant Systems and Components Safety Classification, the continued capability to perform safety functions is mostly verified through environmental qualification. However, for certain system components, cables, and equipment types, it has been more practical to develop ageing management programs.

For active system components, ageing management is conducted through a program designed to maintain the qualified state and a program for evaluating and verifying maintenance effectiveness. These programs have been developed and implemented.

2.3.2. Planned equipment and device replacements, renovations, and reconstructions

The activities listed below are necessary regardless of the plans for subsequent service life extension, and they also form the basis for its implementation. In the coming years, the replacement of several pieces of equipment will become inevitable due to the lack of spare parts or the wear and obsolescence of the equipment. The responsible departments of the nuclear power plant have outlined the following equipment and tool replacements, renovations, and reconstructions for the coming years:

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[7] Inside the reactor vessel, the so-called sample string contains samples identical to the material of the reactor vessel, which are subjected to greater stress than the vessel. By examining these samples, the future condition of the vessel can be estimated

- Renovation and reinforcement of operational main buildings, auxiliary buildings, diesel engine rooms, health and laboratory buildings, hot water channels, and other facilities. The necessity of the work is generally estimated based on condition assessment reports.
- Replacement of reactor internal equipment, pumps, heat exchangers, valves, compressors, and filters, and renovations related to the spent fuel pool and transfer pool.
- Replacement of telecommunications system components due to obsolescence of hardware and software and technological changes.
- Partial or full renovation of radiation monitoring systems, including replacement of data collectors and computers due to obsolescence.
- Replacement and renovation of control system equipment, with a full renovation anticipated considering the extended operational lifetime. The replacement of turbine performance control system components is currently difficult, with maintenance needs increasing, requiring full reconstruction. Control equipment and tools installed in water intake facilities are mostly original, with increasing maintenance needs, necessitating full reconstruction.
- Renovation of radioactive waste qualification system components, including complete renovation of the gamma-spectrometry measurement system, as the system units become irreparably obsolete approximately every 15 years.
- Periodic renovation of the radioactive waste compaction press and cementation equipment due to wear. This includes modification of ^{60}Co removal and complex dismantling equipment and operational safety upgrades.
- Renovation of fire alarm system components, including replacement of fire alarm and suppression control system elements, due to technical amortization and parts supply issues. (Note that some electronic and digital devices are expected to be replaced again during the extended service life.)
- Other reconstruction-related activities include:
  - Evaluation of replacement for high-pressure zone emergency cooling system pumps due to potential failure modes in the pump construction and frequent maintenance needs (or alternatively, retrofit of the pumps and renovation of the hydraulic part).
  - Reconstruction of the hermetic carbon steel plate lining, including repairs of defects found during hermetic space integrity work (hermetic space monitoring and repair program), with reconstruction work possible during long-term major outages.
  - Replacement of fans due to expiration of their operational lifetime.
  - Replacement of liquid nitrogen storage tanks and evaporators.
  - Replacement of high-pressure nitrogen generators due to discontinued parts supply.
  - Replacement of diesel generator engines in units 1-2, with the development of a long-term strategy for the emergency diesel generators of the built-up I. (units 1-2) considering full or partial replacement options.
  - Replacement of external operational distribution network transformer stations due to limited parts supply and increasing maintenance needs.
  - Replacement of steam generator blow-off system components due to increasing failure frequency.
- Renovation of electrical, building systems, water units, sewage lift stations, and replacement of instruments and generators.
- Replacement of chemical sampling system components, including chemical analysers and ion chromatographs.
- Renovation, reconstruction, and replacement of lifting equipment, lighting fixtures, and electric motors.

The above-listed renovations and equipment replacements will be scheduled and carried out as part of ongoing nuclear power plant operations.

2.4. Uncertainty and availability of basic data for the planned activity

Considering that the Paks Nuclear Power Plant is an existing facility that has been operating for decades, the technical data and information presented are derived from documents reflecting the actual design and current state of the plant (e.g., Final Safety Analysis Report). The technical data and operational characteristics of the Paks Nuclear Power Plant are well-known, fully available, and there are no uncertainties regarding them. During the extended operational period, the plant will continue to operate with the existing energy production technology, with unchanged technical and operational characteristics.

For the Paks II. Nuclear Power Plant, the data considered are from the currently available technical plans and other documents. Major technical characteristics of the facility are expected to change only to the extent that it will not significantly affect the nature or extent of the environmental loads estimated in this preliminary review.

3. Definition of impact factors and the area under study

3.1. Definition of impact factors and impact processes

The primary goal of assessing environmental impacts is to predict and evaluate changes in specific environmental elements, systems due to the planned activity, based on changes observed in the final receptors. To carry out impact assessments, it is first necessary to identify the impact factors of the planned activity and the potential direct and indirect impacts that may result from them, known as potential impact processes.

During environmental impact assessments, the identification of impact factors and impact processes is linked to specific phases of the planned activity (construction, operation, decommissioning). In this case, the meritorious preparatory activities are conducted during the operational phase that precedes subsequent service life extension of the nuclear power plant, as part of the prescribed maintenance and upkeep activities of the plant's systems, under the scope of the environmental permit valid for this period and activity. Therefore, no separate preparatory phase can be distinguished for the subsequent service life extension of the nuclear power plant. The decommissioning and dismantling of the nuclear power plant, according to legal requirements, is an activity that requires a separate impact assessment, thus the assessment of decommissioning impacts is addressed conceptually in *Chapter 7*.

Based on the above, the operation of the nuclear power plant must be thoroughly analysed concerning influencing factors and impact processes. Given that this impact assessment pertains to an existing and operational facility, the impact factors and impact processes during operation are practically identical in the current state and the case of subsequent service life extension. The potential environmental impact factors of the nuclear power plant operation include:

- Land occupation and use – no changes are expected during the extended service life, and land use will not be modified.
- Existence of the facility (electricity generation activities, retention effect on the settlement, landscape impact).
- Operation – includes all exposure (radiological and conventional), emissions (exposure of part of the environmental, quantitative changes).
- Transport (movement of operating personnel, auxiliary materials for operation, equipment, machinery, delivery of devices, waste removal, resulting in air pollution, noise emissions, and disturbances).
- Process water extraction from the Danube (quantitative changes in surface water).
- Potable water extraction from the Csámpa waterworks (quantitative changes in groundwater).
- Cooling water extraction and discharge of heated cooling water back into the Danube (thermal load, hydraulic, and hydromorphological changes).
- Generation and treatment of wastewater and rainwater (quantitative and qualitative changes in the recipient)
- Generation, temporary on-site storage, removal, and treatment of waste (conventional and radioactive waste).
- Handling of spent fuel assemblies.

The potential environmental impact factors of possible accidents, havaria events during operation include:

- Failures of operational systems and equipment, which may lead to the release of radioactive and conventional pollutants into the environment (e.g., rupture of pipes transporting radioactive media, leakage of contaminants /oils, chemicals/ onto the soil, geological medium due to failure of the turbine oil system, transformer, tanks, pipelines).
- Failures in operational systems and equipment (industrial wastewater, improper operation of municipal sewage treatment system) leading to the release of pollutants into surface water, groundwater, and soil.

- Emission of air pollutants and noise during the operation of diesel generators due to power outages.
- Soil / geological medium contamination during waste storage, handling, and transport.
- Contamination of geological medium due to failures or accidents during the transport of hazardous materials.
- Waste generation during remediation (excess beyond normal operation).

The key impact factors, direct and indirect potential impacts associated with the existence and operation of the nuclear power plant, as well as potential accidents or incidents, are outlined in *Table 3.1-1.*, categorized according to the affected environmental elements and systems (air, water, geological medium, biota, artificial environment).

Table 3.1-1. The environmental impact factors, direct and indirect potential impacts of the Paks Nuclear Power Plant's operation

Affected environmental element, system	Impact factor	Potential direct impact	Potential indirect impact
Air	Emissions of radioactive substances into the atmosphere in the course of normal operation	Changes in environmental radioactivity, exposure of population, living environment	Health – ecological risk growth
	Conventional air pollutant emissions (power plant and transport) during normal operation	Changes in air quality in the closer environment and on access roads	Health impacts, changes in living conditions for humans and wildlife
	Heat emissions to the atmosphere (normal operation)	Changes in air temperature in the immediate environment	Microclimatic change, change in living conditions
	Existence of the power plant (coverage of built-up area)		
	Accidental (radioactive), havaria (conventional) air pollution	Increase in environmental radioactivity above background exposure levels	Increase of health risk, deposition of radioactive substances on soil, surface water
		Increase in concentrations of conventional pollutants in ambient air	Health – ecological effects
Surface and subsurface waters	Water extraction (to meet cooling, process and other water needs)	Change in the quantities of surface and subsurface waters	Use restriction
	Emissions of radioactive substances (liquid)	Changes in the quality of surface water	Health risk growth, use restriction
	Conventional wastewater generation – pollutant emissions	Changes in the quality of surface water	Use restrictions, health – ecological risk
	Emission of heated cooling water	Rise in temperature of receiving water body, hydraulic, hydro-morphological changes, changes in the structure of aquatic life	Intermittent disturbance of uses, spillover effects of changes in material cycle processes in biotic communities, gradation of invasive species, microclimatic changes

Affected environmental element, system	Impact factor	Potential direct impact	Potential indirect impact
	Water pollution by havaria	Pollution in the receiving water body or groundwater, changes in aquatic habitat conditions	Temporary restrictions on certain uses,
Soil / geological medium	Havaria related to the management of conventional waste (e.g., spills)	Soil pollution	Use restriction, health risk, change in living conditions
	Spillage of pollutants (e.g., hazardous substances stored on site) in havaria event	Soil pollution	Use restriction, health risk, change in living conditions
Biota and ecosystems	Existence (built-up coverage of the area) and operation of the power plant, impact factors on other environmental elements (pollutant emissions, noise, etc.)	Change in living conditions	Migration, degradation, biodiversity loss, changing conditions for nature conservation
	Releases of contaminants (into air, water, soil) in case of havaria	Damage to wildlife and habitats	Degradation, biodiversity loss
Municipal environment	Existence and operation of the power plant, related activities (e.g., transportation)	Impacts on the functioning and development of the settlement	Possible changes in uses
		Changes in the condition of built elements (roads, infrastructure elements)	Change in living circumstances
	Noise and vibration emissions	Disturbance, health risk, deterioration of buildings and structures	Use restriction, deterioration in the quality of life
Landscape	Existence of the power plant (coverage of built-up area)	Land use restrictions, landscape disturbance	Use restriction

3.2. Delimitation of the area under study

The delimitation of the study area follows the approach used in previous similar environmental impact assessments conducted for the facilities at Paks site (the first service life extension of the Paks Nuclear Power Plant, implementation of Paks II.). Regarding the independent operation of the Paks Nuclear Power Plant, no technological or other modifications are anticipated that would result in significant changes in the current environmental impacts. With the commissioning of the Paks II. Nuclear Power Plant, the combined impacts of both facilities must be considered, and the impact assessment should address this, which must also be taken into account when delineating the study area. The simultaneous operation of both facilities has already been considered in the Paks II. environmental impact assessment, thus providing a suitable basis for the subsequent service life extension of the Paks Nuclear Power Plant.

The study area is distinguished based on the expected impact area under normal operational conditions and in the event of accidents, havaria events. The study area delineation considers the threefold territorial division defined by the radiological field, namely the 500 m zone (safety zone area, immediate surroundings), the 5-10 km zone (closer environment), and the 30 km zone (broader environment).

For the baseline condition assessment, the general characteristics of the 30 km zone should be considered when presenting the receiving region, while the study area should be focused on the closer or immediate surroundings for more detailed presentation in specific fields. In the case of transboundary environmental impacts, the study area may exceed the generally considered 30 km radius of the broader zone for certain environmental influencing factors.

Based on the above aspects, the study area considered in the impact assessment covers the following regions:

- The site and its immediate surroundings (the safety zone of the nuclear power plant, a distance of 500 m from the outermost technological protective wall).
- Closer environment, the region to which conventional pollutant emissions and environmental loads and stresses are estimated to spread under maximum conditions. This is approximately the 5-10 km zone around the plant.
- Broader environment, the area estimated to experience detectable changes due to radiological impacts in the event of accidents, or where accumulation might potentially be anticipated. This is up to a 30 km radius.

Beyond the above, if indicated by field-specific studies (e.g., transboundary impacts), the study area is defined in line with the objective of the study.

4. Characterization of environmental radioactivity and expected changes due to the service life extension

4.1. Characterization of environmental radioactivity

4.1.1. Radioactive releases from the Paks Nuclear Power Plant

During the operation of the Paks Nuclear Power Plant, radioactive substances are released into the atmosphere and surface water (River Danube). A key difference between liquid and gaseous releases is that various types of radioactive wastewaters are collected in storage tanks within the plant and are released periodically after preliminary checks, allowing for operational intervention (retention, concentration, dilution etc.), whereas gaseous releases and their monitoring are continuous.

The amount of radioactive nuclides that may be released is regulated by strict regulatory limits, which are monitored multiple times by both the plant and authorities. The operator of the Paks Nuclear Power Plant has implemented more extensive emission monitoring from the outset than required by regulatory standards. Primarily, the scope of nuclide-specific tests has been expanded, which is fundamentally important for calculating public radiation exposure. The results of emission monitoring are summarized in MVM Paks Nuclear Power Plant Ltd’s monthly, quarterly, and annual reports.

The current emission limitation system prescribed by 15/2001. (VI. 6.) KöM Decree on radioactive releases into the atmosphere and water and their monitoring during the use of atomic energy compares both liquid and gaseous releases to isotope-specific emission limits derived from the dose constraint specified for the nuclear power plant (90 μSv/year). The aggregated emission data for 2022, characterizing the normal operational radioactive releases of the nuclear power plant, along with the associated emission limit utilisation criteria, are grouped in *Table 4.1.1-1*. The values of radioactive substances released from the nuclear power plant, normalized per unit of electricity generation, are shown in *Table 4.1.1-2*.

Table 4.1.1-1. Summary data on annual radioactive releases from the nuclear power plant in 2022

Isotope groups	Total emission [Bq/year]	Utilisation of emission limit value
Gaseous releases		
Corrosion and fission products	$7.63 \cdot 10^{8}$	$7.06 \cdot 10^{-5}$
Radioactive noble gases	$2.80 \cdot 10^{13}$	$3.76 \cdot 10^{-4}$
Radioionides	$7.41 \cdot 10^{7}$	$2.46 \cdot 10^{-5}$
Tritium	$4.10 \cdot 10^{12}$	$2.36 \cdot 10^{-5}$
Radiocarbon	$7.30 \cdot 10^{11}$	$2.62 \cdot 10^{-4}$
Total:		$7.57 \cdot 10^{-4}$
Liquid releases		
Corrosion and fission products	$1.09 \cdot 10^{9}$	$5.68 \cdot 10^{-4}$
Tritium	$2.89 \cdot 10^{13}$	$9.98 \cdot 10^{-4}$
Radiocarbon	$2.57 \cdot 10^{9}$	$8.28 \cdot 10^{-4}$
Alpha-emitters	$9.96 \cdot 10^{5}$	$1.18 \cdot 10^{-6}$
Total:		$2.40 \cdot 10^{-3}$

The emission limit value criterion is the ratio of the emission limit value to the quantity emitted for a given isotope and emission method, calculated as:

$$\sum_{ij} \frac{R_{ij}}{El_{ij}} \leq 1$$

where:

El_{ij} – emission limit value (Bq/year) of radionuclide *i* for emission mode *j*,
R_{ij} – the annual emission value (Bq/year) of radionuclide *i* for emission mode *j*.

Table 4.1.1-2. The values of radioactive substances released from the nuclear power plant, normalized per unit of electricity generation

Radionuclide	Paks Nuclear Power Plant [$GBqGW_e^{-1}year^{-1}$]	
	2022	**1983-2022**
Gaseous releases		
Corrosion and fission products in aerosol	$4.5 \cdot 10^{-1}$	$6.7 \cdot 10^{-1}$
^{131}I equivalent	$2.9 \cdot 10^{-2}$	$1.1 \cdot 10^{-1}$
Total noble gases	$1.6 \cdot 10^{4}$	$1.2 \cdot 10^{5}$
Total tritium	$2.4 \cdot 10^{3}$	$2.1 \cdot 10^{3}$*
Total radiocarbon	$4.3 \cdot 10^{2}$	$4.8 \cdot 10^{2}$**
Liquid releases		
Corrosion and fission products	$6.4 \cdot 10^{-1}$	$1.5 \cdot 10^{0}$
Tritium	$1.7 \cdot 10^{4}$	$1.1 \cdot 10^{4}$

* Average of 1985-2022.

** Average of 1988-2022.

Overall, it can be concluded that the nuclear power plant, throughout its entire operational period, has consistently adhered to the limits for radioactive releases with substantial reserves in all respects. In 2022, the plant utilized 0.32% of the emission limit (utilization of the emission limit criterion: $3.15 \cdot 10^{-3}$), with 0.24% from liquid releases and 0.08% from gaseous releases. The utilization of the emission limit criterion in previous years was 0.28% in 2019, 0.30% in 2020, and 0.38% in 2021, indicating that the usage of the limit has been of a similar magnitude in recent years.

Based on the evaluation of the 2022 results of nuclear environmental monitoring, it can be established that the operation of the nuclear power plant did not have a directly measurable impact on the environmental radiation conditions in 2022. The dose rate measurement probes of the "A" and "G" type stations, as well as the TL-detectors placed at all stations, indicated dose rates and doses characteristic of natural gamma radiation in the environment.

The estimated average annual increment of radioactive materials discharged into the Danube River, observed in the Danube's water after complete mixing, was less than 1.0 Bq/dm^3 for tritium and less than 0.1 mBq/dm^3 for all other radionuclides combined.

Regarding the appearance of the released radioactive isotopes in the direct environment, no artificial isotopes were detectable in surface air samples at the A-type stations located 1-2 km from the plant, even with highly sensitive test and measurement methods. The environmental activity concentration of noble gases in the same locations was estimated to be around 100 mBq/m^3. No isotopes of artificial origin were detectable in fall-out samples throughout the year.

No radionuclides originating from the nuclear power plant were found in any soil and grass samples taken from the vicinity of the stations, nor in any sediment samples from the Danube. Radioactive isotopes originating from emissions were not detected above the detection limits in water and sediment samples either from fish ponds or in milk and fish samples. Summarizing the 2022 measurements of nuclear environmental monitoring, it can be concluded that, similar to previous years, the impact of the nuclear power plant on the environment was negligible from a radiological protection perspective.

4.1.2. Data from radiological environmental monitoring of the nuclear power plant

4.1.2.1. Data sources and radiological monitoring of the nuclear power plant's environment

The objective of radiological environmental monitoring of the nuclear power plant is to track the exposure caused by radioactive materials released into the environment from the plant. This can verify that the use of nuclear energy does not expose the population to radiation doses exceeding the regulatory limits.

Environmental monitoring encompasses the entire chain of radionuclides from the point of release to humans. The first link is the determination of emissions; thereafter, nuclides can spread in the air or surface waters, causing radiation exposure either directly or through the food chain.

Within the framework of examining environmental radioactivity, the characteristics determining the spread of radioactive substances in the atmosphere, surface, and groundwater on the site and its surroundings are reviewed. Furthermore, the radiological characteristics of the environment are examined and evaluated within a 30 km radius of the site.

The examination was carried out based on the comprehensive processing of annual reports and official measurements available for the period 2011-2022 (supplemented by accessible data from 2023). The data processing covered the following:

- Activity concentration of near-ground air (aerosols, radioiodines, radioactive noble gases, tritium, and radiocarbon),
- Activity concentration of soil and grass samples (gamma-emitting isotopes, radiostrontium),
- Activity concentration in water and sediment samples from the Danube (gamma-emitting isotopes, radiostrontium, tritium),
- Activity concentration in fish, water, and sediment samples from fish ponds (gamma-emitting isotopes, radiostrontium, tritium),
- Activity concentration in groundwater (gamma-emitting isotopes, tritium),
- Activity concentration in fish milk samples (gamma-emitting isotopes),
- Gamma radiation dose rate in the environment.

The primary data sources used for the measurements were:

- Annual reports of the National Environmental Radiation Monitoring System (NERMS),
- Annual reports of the Joint Environmental Radiation Monitoring System (JERMS),
- Annual environmental and radiation protection reports of MVM Paks Nuclear Power Plant Ltd.

The NERMS is responsible for the nationwide collection, registration, and evaluation of the environmental radiation conditions and activity concentration results of certain radionuclides measurable in the environment, which determine the natural and — excluding medical radiation exposure — artificial radiation exposure of the population. NERMS also coordinates regulatory inspection programs related to the radiation protection of the environment around significant facilities. Members of NERMS include central administrative bodies and other professional organisations involved in collecting environmental radiation data.

The authorities and radiological laboratories conducting the radiation protection monitoring of the Paks Nuclear Power Plant's environment report the results and findings of the given year in a joint report annually. The activities of ministries of the sectors involved in the inspection, their cooperation with each other and with the plant's operational environmental monitoring system are conducted within the framework of JERMS developed in coordination with the HAEA. The geographical location of the power plant, monitoring stations, and sampling locations of participating authority laboratories are shown in *Figure 4.1.2.1-1.* The figure also shows the north-western and south-eastern semicircles, as well as the 10 km and 30 km boundary lines, which appear in the reports.

Since 2015, JERMS has been a part of NERMS, supervised by the HAEA, and measurement results are now included in the NERMS report rather than a separate document.

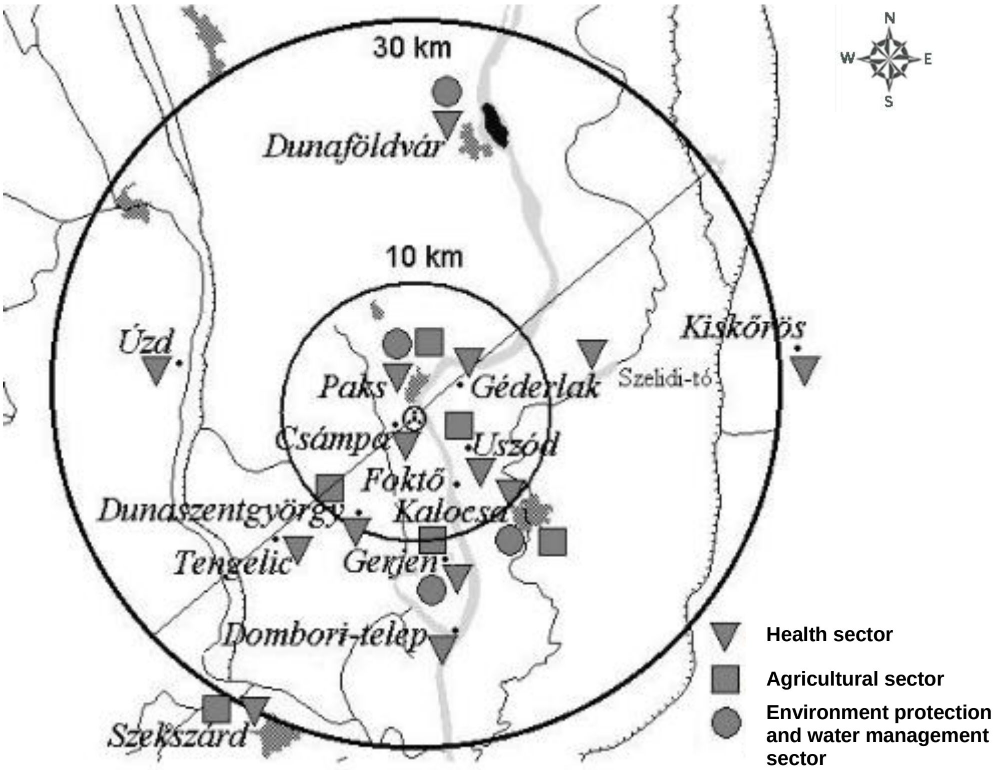


Figure 4.1.2.1-1. Regulatory measurement and sampling locations

The radiation protection organisation of the Paks Nuclear Power Plant issues a report annually detailing the previous year's data related to workplace radiation protection and nuclear environmental protection. The report also includes the environmental measurement results of the Environmental Monitoring Laboratory (KEL laboratory) of the Paks Nuclear Power Plant. KEL laboratory conducts radiation protection monitoring of the nuclear power plant's environment based on its own methodology. The location of remote monitoring stations surrounding the power plant is shown in *Figure 2.2.3.3-1.* in *Chapter 2.2.3.3.*, which details emission and environmental monitoring. The task and objective of the nuclear power plant's environmental radiation protection monitoring are to demonstrate through direct measurements that, during normal operation, the plant places a lower burden on the environment with radioactive isotopes and their radiation than the levels established as acceptable. Another task is to contribute – primarily through measurements conducted in the operational area – to identifying technological anomalies that may pose a risk to the environment and, after their elimination, to verify the cessation of environmental endangerment.

In this evaluation, the occurrence of radioactive isotopes released under normal operation in significant environmental media and the average annual dose rate of environmental gamma radiation per station will be summarized to establish any potentially detectable contributions from the power plant. The analysis is based on comparisons with what are called baseline values, taking into account the fallout effects of the Chernobyl accident. Unlike emission restrictions, no "normal operational" limits are established for radioactive concentration in environmental components.

The most important documents for determining the baseline are *”The current level of environmental radiation and radioactivity in the surroundings of the Paks Nuclear Power Plant under construction”* published in 1980 (Status Report), and its supplement, *”The baseline level of environmental radiation and radioactivity in the surroundings of the Paks Nuclear Power Plant under construction (1981-1982)”*. These documents present the average radiation exposure levels from natural and artificial radiation sources for the population living in the vicinity of the Paks Nuclear Power Plant.

For some sample types, no baseline values are available. For samples where the above documents do not contain average values or ranges, the processed values can be compared to the national average of the given year.

4.1.2.2. Activity concentration of near-ground air

The radioactivity of our atmosphere is formed by the decay of radionuclides from natural and artificial sources. Natural radioactivity can be of terrestrial and high-atmosphere origin. Nuclear activities that cause artificial radioactive air pollution include isotope production, various industrial, research, medical applications and energy production. In the course of electricity production, atmospheric pollution in the form of gases, vapours and aerosols may be released into the atmosphere through the chimneys of the nuclear power plant. The concentration of the emitted pollutants decreases with high dilution during the flow.

Activity concentration of aerosols in atmospheric samples

The ^{7}Be is a natural isotope of cosmogenic origin. The results measured by different laboratories did not show significant changes within the examined period, falling within the measurement range of national results.

The artificial ^{137}Cs isotope was detected by JERMS, NERMS, and the Paks Nuclear Power Plant KEL laboratory in 2011. Its reason was the spread of contamination released into the atmosphere during the Fukushima nuclear power plant accident in 2011. The maximum values measured in 2011 were 0.05 mBq/m^3 in the JERMS laboratory, 0.11 mBq/m^3 in the NERMS laboratory, and 0.059 mBq/m^3 in the KEL laboratory. There were no significant differences among the values measured between 2012 and 2022, and the average values measured by the laboratories remained well below the average values measured in 2011.

The ^{134}Cs isotope is also of artificial origin, similar to ^{137}Cs, resulting from the Fukushima accident and was detectable above the detection limit only in 2011.

Similarly, the ^{131}I isotope is of artificial origin and can be traced back to two events in 2011. It can be associated with the Fukushima accident on the one hand and with a release during ^{131}I isotope production in Hungary on the other. The maximum values measured in 2011 were 0.89 mBq/m^3 in the JERMS laboratory and 0.82 mBq/m^3 in the KEL laboratory of Paks Nuclear Power Plant.

The total-beta activity concentration of aerosol in air samples remained well below the baseline value established in the 1980 Status Report (10 mBq/m^3) in every year of the period under study.

Activity concentration in atmospheric fallout samples

The activity concentration of the isotope of cosmogenic origin, ^{7}Be, did not show significant changes during the study period.

The ^{137}Cs isotope, originating from the Fukushima and Chernobyl accidents, was also detectable in the fallout samples. The average ^{137}Cs activity concentrations of the samples taken at sampling points around the power plant is of the same order of magnitude as or lower than the national averages.

In March and April 2011, the Paks Nuclear Power Plant KEL laboratory, using gamma spectrometry, detected artificial isotopes ^{131}I and ^{134}Cs in fallout samples, which originated from the Fukushima accident.

Since the testing results of the fall-out samples are significantly influenced by the general contamination of the airspace around the sampling stations and the current meteorological conditions, the total beta activity concentration values of the baseline survey were within the range of 10-70 Bq^2/m^2/month. During the study period, total beta activity concentration remained within this range in each year.

Tritium activity concentration in air samples

The KEL laboratory of Paks Nuclear Power Plant measures tritium activity concentration in air, both in the HTO (water vapor) and HT (hydrogen) fractions. The B24 station is considered to be the background value for these measurements, as its distance and direction suggest it is unaffected by emissions from the Paks Nuclear Power Plant.

Except for stations A3 and A4, samples from all other stations closely followed the values observed at the B24 station. The higher tritium activity concentration values at station A3 are attributed to the proximity of station V3, where tritium concentration and evaporation rates are higher at the emission point. The higher concentrations observed in samples from station A4 are due to the prevailing wind direction from the power plant.

Radiocarbon activity concentration in air samples

For several years, the KEL laboratory of Paks Nuclear Power Plant has been annually determining the ^{14}C activity concentration from monthly collected air samples of CO_2 (inorganic) and CO_2+C_nH_m (inorganic and organic) fractions at stations A1-A9 and reference station B24 as part of a monitoring program.

Based on the ^{14}C values measured at stations around the nuclear power plant, no nuclear power plant contribution, or only a small amount, can be detected. An increase is observed at station A3. It is due to the higher ^{14}C concentration and increased evaporation at the emission point of station V3. At station A4, the higher values observed (in the CO_2+C_nH_m fraction) may also be influenced by decomposition processes occurring in the nearby Kondor Lake.

In summary, the tritium and radiocarbon content measured at type A stations closely followed the values measured at the B24 reference station during the study period. The HTO activity concentration measured at station A3 is higher than at other stations for the reasons described.

4.1.2.3. Activity concentration in soil and grass samples

Two factors can cause radioactivity of the soil. There can be radionuclides of natural origin and also of artificial origin. Natural nuclides can be of crustal or cosmic origin. Artificial radionuclides are introduced into nature by human activity. Emissions from the use of nuclear energy primarily contaminate the atmosphere, but a significant proportion is released to the surface through fall-out and contributes to soil radioactivity.

Soil samples

The KEL laboratory does not conduct total beta activity concentration measurements, but the results of regulatory measurements show good agreement with national measurement results.

The ^{40}K isotope measurement results obtained through gamma spectrometry indicate that both regulatory and KEL laboratory measurements fall within the baseline value of 379 Bq/kg (range: 305-504 Bq/kg) set in 1980.

The ^{137}Cs isotope activity concentration, also determined through gamma spectrometry, is below the national average and lower than the baseline value of 10 Bq/kg (range: 4.2-15.8 Bq/kg) from 1980.

For ^{90}Sr, values lower than the baseline value of 6 Bq/kg (range: 1.3-20 Bq/kg) set in 1980 have been measured every year, and the annual data from different laboratories fall within a similar range.

Grass samples

Measured concentrations have been lower each year than the baseline value range of 300-1060 Bq/kg for ^{40}K set in 1980. At the B24 station used as reference station all laboratories involved in the study measured lower values.

Although the ^{137}Cs values measured by the KEL laboratory of Paks Nuclear Power Plant are higher than regulatory values, the values measured at type A and B24 stations closely follow each other, remaining within the same range. The measured values have remained within the baseline range of 1.6-15.2 Bq/kg each year.

For ^{90}Sr, the baseline range is 3.5-26.3 Bq/kg. All laboratories involved in the study measured much lower values than this.

In summary, based on the measurement results for artificial isotopes in soil and grass samples for the study period, no local impact from the plant can be identified.

4.1.2.4. Activity concentration in water and sediment samples from the Danube

The radioactivity of natural waters comes from radionuclides released into the environment naturally and through human activities. Radioactive materials entering the ecosystems of rivers and lakes can be incorporated into sediments, aquatic plant and animal organisms due to various natural processes and then dissolved again.

Danube water

The ^{137}Cs activity concentration in Danube water was higher above the nuclear power plant section than the national average and the baseline level. In 2011, 2012, and 2013, measured values downstream of the power plant exceeded the baseline level, likely originating from fallout from the Fukushima accident.

Throughout the study period, ^{3}H activity concentration remained well below the 1980 level and closely aligned with the national average.

Except for the outliers observed in 2014 and 2016, ^{90}Sr activity concentration remained below the national average and baseline level throughout the study period. Both outliers were from samples collected upstream of the nuclear power plant.

The total beta activity concentration of the water in the Danube section downstream of the power plant was lower than the baseline level and national average each year.

Danubian sediment

For ^{90}Sr, the baseline range from the 1980 survey was 0.84-1.48 Bq/kg, with an average value of 2.3 Bq/kg reported by the then National Water Office. The average values measured by the KEL laboratory of Paks Nuclear Power Plant were lower than these values each year, regardless of the sampling location.

For ^{137}Cs, the baseline concentration range was 4.6-11.9 Bq/kg in 1980. The measured values were higher than the baseline during the study period, likely due to the Chernobyl and Fukushima accidents.

In general, no downstream trend in measurement results can be observed for activity concentration in Danube water and sediment samples. Results from samples taken near the nuclear power plant fall within the same range as the national average. Some outlier concentration values were observed, primarily indicating uncertainties in sampling and the sampled medium.

4.1.2.5. Activity concentration in fish, water, and sediment samples from fish ponds

The sources of radioactive contamination of fish, water and mud samples from fish ponds are the natural processes described for water and mud samples.

Fish samples

No artificial radioactive gamma-emitting isotopes exceeding the detection limit of 0.5 Bq/kg were measured in fish samples from the fish ponds near the nuclear power plant (*Figure 2.1.2-1.* in *Chapter 2.1.2.*), between 2011-2022.

Within the NERMS framework, fish sampling is conducted in the Danube section downstream of the power plant. The ^{137}Cs activity concentration in fish samples exceeded the detection limit in only a few cases, with these measurements ranging from 0.02-0.64 Bq/kg.

The total beta concentration in fish samples showed virtually no change during the study period, with similar values measured each year (average: 76.5 Bq/kg, minimum: 32 Bq/kg, maximum: 120 Bq/kg).

Radiostrontium activity concentration exceeded the detection limit in a few cases, with these measurement results ranging from 0.2-1.5 Bq/kg.

Water samples from fishponds

No artificial radionuclides from the power plant were detectable during gamma spectrometry examinations from 2011-2022 in either JERMS or the Paks Nuclear Power Plant's KEL laboratories. In a few cases, the NERMS reports included ^{137}Cs isotopes above the detection limit, with a maximum of 0.13 Bq/dm^3.

Except for the outlier reported in the 2011 JERMS report, similar tritium concentrations were observed throughout the study period. Reported values are in the lower range of the national value spread (0.2-7.8 Bq/dm^3).

Radiostrontium examinations showed outlier values in 2018, but these were still below the nationally measured maximum value (0.03 Bq/dm^3).

The total beta activity concentration in the samples remained below the national average each year.

Sediment samples from fishponds

Apart from a single outlier in 2022 (potentially due to materials concentrated in the sediment from Chernobyl or Fukushima fallout), measured values fell within the same range throughout the study period. The ^{137}Cs activity concentrations in fish pond sediment samples were significantly lower than those measured in Danube sediment.

Apart from ^{137}Cs radionuclides, only ^{90}Sr isotopes could be detected above the detection limit in 2011, with an average value of 0.11 Bq/kg and a range of 0.043-0.18 Bq/kg on a dry weight basis.

4.1.2.6. Activity concentration in groundwater

To protect subsurface water, the impact of the power plant on groundwater is monitored by an extensive groundwater monitoring well system. Tritium activity concentration in groundwater wells shows a declining trend. The relatively high initial value can be traced back to a malfunction detected in 2006. Due to the successful management of this malfunction, average tritium activity concentration has dropped year by year. By 2022 and 2023, it closely approached the background value measured in 1979-1980, which was 8.7 Bq/dm^3 (range: 7.2-13.1 Bq/dm^3). The fluctuations may be due to the water levels of the Danube and the amount of precipitation.

Based on the gamma spectrometric analysis of samples from groundwater wells, it can be concluded that no artificial isotopes from the nuclear power plant were detectable in any of the years of the study period. The samples mostly contained cosmogenic radionuclides and gamma-emitting isotopes from natural decay series, all below permissible limits.

There are also sampling wells outside the facility. Not all of these wells were operational throughout the entire monitoring period, but the measured results indicate that tritium concentrations outside the site are comparable to those of other groundwater and surface water concentrations.

4.1.2.7. Activity concentration in milk samples

Milk is a nutritionally important food item and, in particular, one of the key sources of ^{90}Sr incorporation. Regular radiological monitoring of milk is carried out.

The KEL laboratory of the Paks Nuclear Power Plant only conducts gamma spectrometric analysis on the prepared samples. During the study period, no radioisotopes of either Chernobyl or nuclear plant origin were detected above the detection limit.

The activity concentration values of the ^{137}Cs isotope in milk samples ranged between 0.01-0.25 Bq/l in the JERMS and NERMS measurements. According to NERMS reports, higher concentrations originate from milk powder, often not even produced in Hungary. Between 1976 and 1980, baseline surveys measured ^{137}Cs content in the range of 0.04-1.2 Bq/l.

Gamma spectrometric analysis confirmed that the total beta activity measurable in milk samples originates from the natural ^{40}K isotope. For the baseline, the status report provided a value of 43.3 Bq/l for the 1975-1979 period. The results indicate that the measurement results near the plant are below this value every year and even below national levels almost every year.

^{90}Sr measurements typically exceeded the detection limit but remained below the lower value of the baseline range. The baseline was taken as the range of average values measured between 1976 and 1980, which was 0.5-2.3 Bq/l.

In summary, it can be said that the measurement results of milk samples from around the Paks site did not exceed national averages and were lower than the averages from pre-1980 surveys. No nuclear plant effect was detectable in the milk samples.

4.1.2.8. Gamma radiation dose rate in the environment

The external radiation exposure of the population can be determined from the dose rate of environmental radiation. Dose rate results include the natural background radiation component and the impact of the nuclear facilities (Paks Nuclear Power Plant and SFISF) operating on site.

It can be stated that the values measured in the vicinity of the Paks Nuclear Power Plant are lower each year than the national annual average values (NERMS). The measured values fall close to the baseline value of 80 nSv/h established in the status report in 1980. Values measured in the 1.5 km and 30 km radius correspond to dose rates resulting from natural background radiation fluctuations. During the examined period, no nuclear plant-related increment was detectable in the environmental gamma dose rate.

4.1.2.9. Summary of investigation results

Based on the comprehensive processing of annual reports on radiation protection activities prepared by MVM Paks Nuclear Power Plant Ltd. and official measurements for the period 2011-2022 (and partly for 2023), the following conclusions can be made regarding the environmental radioactivity around the power plant site.

Based on the measurement results of gamma-emitting isotopes mentioned in the reports, it can be concluded that, with a few exceptions, the observed values remained below the 1980 baseline every year or were very similar to the values measured at the reference station 30 km away or to the national values. Activity concentrations attributable to the nuclear power plant above the detection limit occurred only on a few occasions in air, fallout, soil, and fishpond sludge samples.

Regarding isotopes of artificial origin (e.g., ^{131}I, ^{134}Cs, ^{137}Cs), deviations are primarily linked to the 2011 Fukushima accident and the domestic emission during isotope production in 2011. It should be noted that increases in ^{90}Sr and ^{137}Cs are not contributions from the Paks Nuclear Power Plant but are presumably consequences of the Chernobyl accident.

As there are no national measurements for air tritium (^{3}H) and radiocarbon (^{14}C) content, station B24, located 30 km away, has been designated as the reference station. These measurements are only carried out by the KEL laboratory of the Paks Nuclear Power Plant. The results show good agreement between the A-type stations and the B24 station.

The average ^{3}H activity concentration in sampling wells within the plant site has shown a continuous decline. Measurement results from wells outside the site are consistent with the ^{3}H activity concentration in nearby fishponds and in the Danube. No artificial gamma-emitting isotopes from the power plant above the detection limit could be detected.

The environmental dose rate values show good agreement with the baseline and national average values. No increment from the nuclear power plant was detectable.

In summary, based on the evaluations presented above, it can be stated that during the study period, no additional radiation exposure from the normal operation of Paks Nuclear Power Plant affecting the population or the environment could be detected.

4.1.3. Examination of radiation exposure of wildlife in the vicinity of the nuclear power plant

The general radiation protection framework developed by the International Commission on Radiological Protection (ICRP) aims to ensure compliance with human and environmental radiation protection requirements without unnecessarily restricting the human activities that can be associated with exposure effects.

According to the ICRP, it is not advisable to establish dose rate limits for wildlife, even though guidelines used in radiation protection and the assessments based on them require quantitative values for risk assessment. A convenient basis for comparison can be the dose rate resulting from natural background radiation for individual organisms. Thus, if the incremental dose rate associated with human activities is only a fraction of the natural level, it certainly does not affect the functioning of environmental systems in any way. For the environment around the Paks Nuclear Power Plant, the dose rate from natural background radiation for most reference organisms is mostly considered as known. This provides a good basis for directly comparing the incremental dose rate from isotopes released into the environment from the nuclear power plant with the dose rate resulting from natural background radiation, and, on that basis, for assessing the plant's impact and immediate area of influence.

The ICRP recommendation states that the reference level for radiation exposure caused by human activities for a given habitat should apply to all anthropogenic sources acting in that area. Thus, the impact of a planned new source must be evaluated together with the existing ones. In addition to the operational contribution of the Paks Nuclear Power Plant, contributions from nuclear weapons testing and fallout from Chernobyl must also be considered.

4.1.3.1. Natural radiation exposure of wildlife

Terrestrial habitats

An extensive database of measurements spanning 20-25 years is available for the environment of the A-type measurement stations of the Paks Nuclear Power Plant. Based on the analysis of hundreds of measurement results, the isotopic concentrations characteristic of soils surrounding the power plant (U-series, Th-series, and ^{40}K) and the natural ^{7}Be, ^{3}H, and ^{14}C concentrations in the atmosphere have been determined.

The radiation exposure of typical terrestrial organisms in the area (lichens and mosses, grasses, shrubs, trees, snails, soil-dwelling invertebrates, decomposing invertebrates, flying insects, amphibians, reptiles, birds, bird eggs, small mammals, large mammals) was studied using the ERICA (Environmental Risk from Ionising Contaminants: Assessment and Management) program. The dose rates obtained for the A1-A6 station environments fall in the range between nGy/h and a few µGy/h. It is characteristic that, except for some very “close-to-ground” organisms, external radiation exposure is about an order of magnitude lower than internal exposure. In summary, it can be stated that the background radiation exposure for terrestrial organisms living in the vicinity of the nuclear power plant is below 0.5 µGy/h for most species. Organisms that accumulate lime, as well as mosses, show significantly higher values, even exceeding the reference levels suggested by the ICRP.

Aquatic habitats

In the case of aquatic habitats (phytoplankton, vascular plants, zooplankton, molluscs, snails, crustaceans, insect larvae, benthic fish, pelagic fish, amphibians, birds, mammals), the dominant living environment is the water itself and the sediment. Natural waters generally contain only small amounts of dissolved materials from the Earth's crust, especially true for U- and Th- series.

Therefore, the external exposure from natural waters is low. This is also true for aquatic habitats that can be examined in the Paks environment. However, the dissolved material originally comes from the solid Earth's crust material bordering the water (mostly the sediment), and thus, if the radioactivity of the sediment is known, then based on the distribution coefficient (K_d) of the element in question, the activity concentration appearing in the water can be calculated.

For the subsequent service life extension of the nuclear power plant, the most affected area is the Danube, especially the section a few hundred meters downstream of the warm water channel. The data necessary to estimate the natural radioactivity-derived radiation exposure of aquatic life can also be primarily obtained from archived measurement results of operational and regulatory control studies spanning several decades. The radiation exposure of aquatic organisms characteristic of the area was studied using the ERICA program by placing them in designated habitats. Regarding the ratios of external and internal radiation exposure, aquatic life shows great variability. While the estimated external radiation exposure for benthic fish is similar to terrestrial organisms, for pelagic (open water) fish, external radiation exposure is practically negligible compared to internal exposure, given that they typically move in aquatic media with low solute content. This is mainly due to water acting as a radiation absorber. Those typically living "far" from the bottom are almost only exposed to radiation from radioactive substances that have entered their bodies, due to the radiation shielding effect of the extensive water mass. This also explains the negligible external radiation exposure for phytoplankton and zooplankton communities and for amphibians. As for waterfowl, the reason why this value is almost an order of magnitude lower than the previous one is that these creatures spend most of their lives on the surface of the water or in the air.

4.1.3.2. Artificial radiation exposure of the wildlife

As a result of atmospheric nuclear weapon tests, fission and activation products can be found in the environment surrounding the Paks Nuclear Power Plant. Among these, tritium and radiocarbon contributions are no longer significant today, with only isotopes like ^{137}Cs, ^{90}Sr, as well as ^{239}Pu and ^{241}Am being present, primarily in the soil and sediment. Due to the Chernobyl accident in 1986, additional artificial radiation exposure from ^{137}Cs contamination in the soil and river sediment must also be accounted for. The radiological impact of the nearly 40-year-old Paks Nuclear Power Plant on the wildlife, due to continuous atmospheric and liquid discharges, is also present and must be considered in the inventory of artificial radiation exposure. These three sources together constitute the current anthropogenic radiation exposure of species within the wildlife.

Terrestrial habitats

For assessing the artificial radioactivity in soil, data from the plant's Operational Environmental Radiation Monitoring System (OERMS) and JERMS can be used. Even after a critical analysis of the available data, there was a sufficiently large dataset available to statistically reliably characterize ^{137}Cs and ^{90}Sr activity concentrations in individual areas. Layer-by-layer soil samples provided the opportunity to determine the inventory of the isotopes in question (expressed in Bq/m²) at the sampling site. As in undisturbed areas this showed acceptable agreement with model calculations, contamination of the soil with ^{239}Pu and ^{241}Am could also be estimated. The estimation was confirmed by radioanalytical measurements of the samples.

The data for soil essentially represent the residual activity concentrations from global and Chernobyl fallout, to which the contribution of the Paks Nuclear Power Plant is negligible as the continuous operational nuclear environmental monitoring has only sporadically detected minimal ^{137}Cs fallout around the monitoring stations since the beginning. This also implies that the atmospheric emission of ^{90}Sr, which is roughly two orders of magnitude lower than that of ^{137}Cs, is also undetectable in the soil, given the residual ^{90}Sr contamination from global fallout. The half-life of activation products that regularly appear in the annual emission inventories is relatively short; therefore, their accumulation is not expected even when their total emitted activity occasionally compares to that of ^{137}Cs in a given year.

The power plant also affects terrestrial wildlife through its constant atmospheric radioactive emissions. Direct effects arise from the radioactive cloud as an external source of radiation. Furthermore, the inhalation of radioactive isotopes must be considered (also in the case of animals). Some of the radioactive material reaches the ground as aerosols through dry or wet fallout, where it acts as an external source, primarily through its gamma radiation, and also incorporates directly through the food chain or indirectly through the soil.

The A-type monitoring stations around the plant have only sporadically been able to detect plant-originated radioactivity in the air, and the deposition is negligible, so the plant's impact is not detectable in the soil. This implies that the contribution of radiation exposure from the plant can only be estimated through modelling, for which the ERICA toolkit provides the necessary capabilities. Using the aggregated annual KEL data for Paks Nuclear Power Plant and the activity values determined for each isotope, an atmospheric emission inventory was created to estimate the radiation exposure of the wildlife concerning different habitats. In the inventory for an 11-year period, the total emitted activity of tritium, radiocarbon, noble gases, activation, and fission products (^{54}Mn, ^{58}Co, ^{60}Co, ^{110m}Ag, ^{90}Sr, ^{131}I, ^{134}Cs, and ^{137}Cs) served as the starting point.

Using the measurement data from the Paks meteorological tower, the average annual emission rate towards the given terrestrial habitats was determined for each isotope (in Bq/s). The concentration of radioisotopes released through the chimneys and carried away by the wind decreases progressively with distance from the emission point, both due to dispersion and deposition. Under average atmospheric conditions (Pasquill D), the highest activity concentration of plant-originated isotopes in the near-ground air is expected to be around the examined terrestrial habitats. Despite this “exposure”, direct measurements at the stations only rarely succeed in detecting radioisotopes emitted from the plant into the atmosphere. An estimation of the artificial radiation exposure to the biota was performed using the ERICA program. Comparing the dose rates obtained for reference organisms in a breakdown of “northern” and “southeastern” directions compared to the longitudinally extended plant site, it can be established that the contribution of the plant is practically negligible compared to global and Chernobyl-originated radiation exposure. There is no significant difference in dose rates obtained for various groups of flora and fauna, with values generally falling within one order of magnitude. The only noticeable “grouping” is perhaps the slightly higher values observed for certain higher-order animals, likely due to their dietary habits and vertebrate nature (Sr and Pu accumulation).

Practically the same can be said about the current artificial radiation exposure estimated for the southeastern terrestrial habitat from the power plant, as well as its components. Regarding the baseline for artificial sources, it should also be noted that it is applicable to the entire area around the plant, including the area between main road No. 6 and the Danube, as the soil activity concentrations used as the basis for the estimation did not show significant differences according to the relevant measurement results. The radiation exposure values obtained for different species groups, which do not show significant differences and account for only about 1% compared to the natural background, indicate that no species require special attention due to their exposure.

Aquatic Habitats

The current radiation exposure of the aquatic biota from anthropogenic sources, similar to that of the terrestrial biota, originates primarily from isotopes like ^{137}Cs, ^{90}Sr, ^{239}Pu, and ^{241}Am, mostly from fallout due to atmospheric nuclear weapon tests, as well as ^{137}Cs isotope deposition during the Chernobyl reactor accident. In addition to these two contamination events, the radioactivity from the liquid emissions of the Paks Nuclear Power Plant must also be considered at the Danube.

To estimate the radiation exposure of aquatic life from the above sources, it is necessary to know the currently measurable activity concentrations of the isotopes in question in the sediment of the Danube, as well as the regular liquid emissions from Paks. These are regularly monitored as part of the plant’s emission and environmental monitoring, with measurements conducted on the Danube water and the warm water channel. Therefore, there is a sufficient archive of data available. At the same time, it was possible to identify the radioisotopes that contribute to the anthropogenic radiation exposure of aquatic life.

For assessing the isotope concentrations of the warm water channel and the Danube of global and plant-origin, the default transfer coefficient values were used for reference organisms. Deviations from the default residence factors were made only in a few cases. Model calculations were performed for phytoplankton, vascular plants, zooplankton, mussels, snails, crustaceans, insect larvae, benthic fish, pelagic fish, amphibians, birds, mammals organisms. The resulting dose rates typically fall within the range of 10^{-7} to 10^{-3} μGy/h. Therefore, it can also be said that the radiation exposure of aquatic life from artificial sources is orders of magnitude below the 10 μGy/h reference level proposed by the ICRP.

4.1.4. The impact of the nuclear power plant on the population's additional radiation exposure

4.1.4.1. Doses of gaseous and liquid radioactive emissions

The normal operational radioactive releases of the Paks Nuclear Power Plant so far have resulted in negligible environmental impact, consistent with analytical and measurement results. The presence of any radionuclide was only occasionally detectable in environmental media samples, and even then in low activity concentrations. No measurements exceeding the detection limit were observed in measurements conducted on elements of the food chain. Based on sample measurement results and investigations aimed at measuring the dose of additional environmental gamma radiation, it is not possible to provide an accurate estimate of the additional radiation exposure affecting the population. Since most measurements yielded results below the detection limit, these could only provide an upper, very conservative limit for the population's radiation exposure. Instead of direct measurement data, the magnitude of the exposure can be determined through calculations based on discharge data using dispersion models, taking into account various exposure pathways.

The doses of gaseous radioactive releases from the power plant to the public were established using atmospheric discharge and meteorological data, and taking into consideration a number of other parameters (e.g., food production and consumption data, population habits, geographical characteristics etc.). They were taken into account in a program capable of modelling the environmental transport of radioactive contaminants released into the atmosphere and of determining their doses to the population as part of analyses conducted in recent years.

The dispersion modelling program calculating several intermediate results and other data as outputs. The simulation results relevant to public radiation exposure are the calculated values of committed effective doses for adult and child population groups in the surrounding settlements, resulting from gaseous releases. These are annual effective doses, including both external doses and committed doses from internal radiation exposure due to radioisotopes incorporated into the human body, meaning integrated values over 50 years for adults and 70 years for children. The annual radiation protection reports also include the distribution of doses by isotope groups, soft beta emitters, activation-corrosion and fission products, radioiodines, and noble gases.

In Csámpa, the nearest settlement to the discharge point, the average dose from gaseous releases over the past 10 years (2013-2022) was 16 nSv/year for both children and adults. Annual exposures were of the order of nSv, with a maximum of just over 50 nSv in the last 10 years, which is less than 0.1% of the 90 μSv dose constraint set for the nuclear power plant.

The doses to the population from liquid radioactive releases from the nuclear power plant have been determined from the liquid discharge data, using hydrological characteristics that determine the dispersion characteristics, in particular the water flow of the Danube. Furthermore, the calculations – similar to atmospheric modelling – considered additional parameters, such as population lifestyle and consumption habits.

In the annual radiation protection reports, the calculated data on external and internal radiation exposure from radioactive isotopes discharged into the Danube are shown both for adult and child groups of the most affected population in Gerjen. It is also worth noting here that the internal radiation exposures represent doses committed over 50 and 70 years for adults and children, respectively. The program estimates the dose from liquid discharges only for the population of Gerjen (the first settlement located 10 km south of the nuclear power plant, directly on the right bank of the Danube), as in other settlements, no doses or only several orders of magnitude lower doses result from the discharge of liquid contaminants.

Based on the doses estimated for the population of Gerjen from liquid discharges over the past 10 years (2013-2022), it can be established that the average annual dose was 59 nSv for children and 64 nSv for adults. The vast majority of dose contributions calculated from liquid discharges are due to internal radiation exposure caused by the incorporation of ^{3}H and ^{14}C.

4.1.4.2. Residential doses from nuclear power plant's releases

For the assessment of the radiological impacts of the nuclear power plant – in addition to the general criteria outlined in *Chapter 1.5.3* – the numerical limits used during the first service life extension and the environmental impact assessment of Paks II. Nuclear Power Plant were applied, and the classification categories accordingly specified. The classification of environmental impacts induced by direct and scattered radiation and by radioactive releases can be performed using the qualification categories listed in *Table 4.1.4.2-1*.

Table 4.1.4.2-1. Qualification categories of the radiological impacts from the nuclear power plant

Qualification for change of state	Radiation exposure levels (E= effective dose) [μSv/year]
Neutral	E ≤ 90
Tolerable	90 ≤ E ≤ 1 000
Burdensome	1 000 ≤ E ≤ 10 000
Damaging	10 000 < E

The interpretation of the qualification categories in *Table 4.1.4.2-1.* is as follows:

- Neutral: The impact of the activity does not exceed the value set by the authority – meaning it does not significantly exceed the reasonably achievable lowest level, which is a dose constraint of μ90 μSv/year.
- Tolerable: The upper limit of the impact is 1000 μSv, which is in line with the 2/2022. (IV. 29.) HAEA Decree on protection against ionizing radiation and the related licensing, reporting, and inspection system, stating that the radiation exposure of the public from all approved activities in a given year must not exceed the effective dose limit of 1 mSv, i.e., 1000 μSv.
- Burdensome: The upper limit of the impact can be considered the value at which protective measures are required. The impact does not reach half of the annual dose limit (20 mSv, or 20 000 μSv) applicable to workers in occupations with radiation hazard.
- Damaging: To mitigate the potential consequences of the impact, some form of action is required based on the National Nuclear Accident Management Action Plan (OBEIT) – such as sheltering, evacuation, iodine prophylaxis, or temporary or permanent relocation.

The total radiation exposure to the population from the nuclear power plant's discharges is made up of the combined gaseous and liquid radioactive releases. The dose given for the hypothetical critical population group, provided (as a conservative assumption) by the National Public Health and Medical Officer Service, is derived as the aggregated doses calculated for children in Csámpa from gaseous releases and in Gerjen from liquid releases. The public doses thus determined over the past 10 years (2013-2022) and the utilization of the dose constraint applicable to the nuclear power plant site are presented in *Table 4.1.4.2-2*. Over the past 10 years, the maximum population dose was 115 nSv, which represented only a maximal 0.13% utilization of the dose constraint. This value is roughly equivalent to the effective dose caused by natural radioactivity received during one to two hours spent outdoors, thus posing virtually no health risk.

Table 4.1.4.2-2. Summary of external and internal radiation exposures from gaseous and liquid releases

Year	Csámpa from gaseous releases and Gerjen from liquid releases		Utilization of dose constraint based on public doses set for children [%]
	Adult residential doses [nSv]	Child residential doses [nSv]	
2013	$5.14 \cdot 10^1$	$4.83 \cdot 10^1$	0.054
2014	$6.30 \cdot 10^1$	$5.99 \cdot 10^1$	0.067
2015	$9.23 \cdot 10^1$	$8.77 \cdot 10^1$	0.097
2016	$7.50 \cdot 10^1$	$6.96 \cdot 10^1$	0.077
2017	$9.16 \cdot 10^1$	$8.58 \cdot 10^1$	0.095
2018	$1.04 \cdot 10^2$	$9.65 \cdot 10^1$	0.107
2019	$6.73 \cdot 10^1$	$6.11 \cdot 10^1$	0.068
2020	$7.21 \cdot 10^1$	$6.49 \cdot 10^1$	0.072
2021	$8.80 \cdot 10^1$	$8.11 \cdot 10^1$	0.090
2022	$1.15 \cdot 10^2$	$1.10 \cdot 10^2$	0.122
Minimum	$5.14 \cdot 10^1$	$4.83 \cdot 10^1$	0.054
Maximum	$1.15 \cdot 10^2$	$1.10 \cdot 10^2$	0.122
Average	$8.19 \cdot 10^1$	$7.65 \cdot 10^1$	0.085
Deviation	$1.96 \cdot 10^1$	$1.90 \cdot 10^1$	0.021

Based on the data presented above, during the normal operational period of the Paks Nuclear Power Plant, no adverse health effects associated with additional radiation exposure to the public have been observed. The environmental impacts caused by the radioactive releases from the nuclear power plant are rated as neutral according to the impact classification categories introduced earlier.

4.2. Expected impacts during the subsequent service life extension

4.2.1. Anticipated releases of radioactive substances

The radioactive releases of the Paks Nuclear Power Plant, considering the current operational characteristics, will remain unchanged during the remaining period of the currently licensed operational time and a period of the subsequent service life extension. This is because no modifications are planned to the plant's technological process or operational characteristics that would affect the nature of radioactive releases in connection with the subsequent service life extension. Accordingly, it can be stated that the current radioactive releases detailed in *Chapter 4.1.1.* are expected to characterize the period of the subsequent service life extension. This means that the nature, quantity, and method of gaseous and liquid radioactive releases are expected to remain unchanged compared to the current state.

Considering past experiences, it can be concluded that the magnitude of gaseous and liquid radioactive releases during the subsequent service life extension of the plant will remain in a similar range as before.

4.2.2. Anticipated change of environmental radioactivity

Impacts of the Paks Nuclear Power Plant’s independent operation

The results of the radiological monitoring of the Paks Nuclear Power Plant's environment for the period 2011-2022 were presented in detail in *Chapter 4.1.2*. To continuously monitor the radiation levels in the environment, examinations are conducted not only by the plant's own environmental monitoring laboratory but also by regulatory laboratories that check the activity concentration of various environmental media. It can be stated that, for the examined period, the level of background radiation in the vicinity of the Paks site falls within the same range as typical national data. Artificial radionuclides originating from the nuclear power plant were only detectable in environmental samples in a few cases.

The measurements for the period 2011-2022 were conducted regarding the plant's normal operational emissions. Similar results were also achieved in the investigations preceding the Paks Nuclear Power Plant’s first service life extension, which were also conducted under normal operational emissions. Based on the assumption that the plant's normal operational emissions will remain within similar ranges, it can be assumed that the further independent operation of the Paks Nuclear Power Plant will not pose a higher radiological risk to the environment than before.

Combined impacts of the nuclear facilities operating and planned on the site

According to the implementation licensing documentation of the Paks II. Nuclear Power Plant, the plant is designed so that the impacts of radioactive radiation on the environment and on the public will not exceed public dose constraints or the radioactive material content from the environment during continuous normal operation of the units and expected operational events. As a verification thereof, dose calculations were performed in the surrounding of the site for the impact of Paks II. during its operation. The results received are entirely similar to the calculation results for the normal operational emissions of the Paks Nuclear Power Plant’s units.

During the examination of the expected normal operational environmental impacts of the Paks II. Nuclear Power Plant, calculations showed that during the normal operation of the two Paks II. units, the actual doses expected for the public from gas-aerosol emissions and liquid discharges (radioactive wastewater) will be significantly lower than the dose constraint of 90 μSv/year established for the facility alone. Moreover, the actual emissions will be much lower than the limits.

The power plant's plans also detail how the environmental and radiation monitoring system of Paks II. will cooperate with the emission and environmental radiation protection monitoring system of the existing units, i.e., of the Paks Nuclear Power Plant. Some existing stations will need to be relocated, and some need to be rebuilt to ensure the most appropriate spatial coverage.

Based on the above, it can be concluded that the combined normal operational activities of the Paks Nuclear Power Plant and the planned Paks II. Nuclear Power Plant on the site are expected to result in negligible environmental radiological exposure.

4.2.3. Estimation of radiation exposure of wildlife

Impacts of the Paks Nuclear Power Plant’s independent operation

The additional radiation exposure of wildlife can be attributed to radioactive materials released into the air and water from the operating nuclear power plant. Based on the analysis of detailed emission data covering the period between 2011-2022, it can be assumed that the further operation of the nuclear power plant will not result in significantly increased radioactive emissions.

To assess the impact, it is advisable to consider what is called background radiation exposure affecting the wildlife from natural sources. According to the results of the model calculations conducted, the magnitude of this exposure can be estimated to range from a few tenths of μGy/h to a few μGy/h, depending on the species and habitat. Since the concentration of naturally occurring radioactive isotopes that determine background radiation in the domestic geological environment fluctuates within a relatively narrow range, similar radiation exposure is expected from the above-mentioned dose rate in other habitats. In comparison, the ICRP's current recommendation considers an incremental increase of nearly one order of magnitude up to the 10 μGy/h threshold to be still tolerable. In contrast, the contribution of the nuclear power plant to the radiation exposure of terrestrial and aquatic wildlife is estimated to be only

10^{-3}-10^{-6} µGy/h. This negligible additional exposure will remain unchanged during the further operation of the Paks Nuclear Power Plant, as the extent of atmospheric and water emissions is not expected to change. Therefore, it can be concluded that the subsequent service life extension of the Paks Nuclear Power Plant will not impact wildlife.

Combined impacts of the nuclear facilities operating and planned on the site

The anticipated impact of the two new units of Paks II. Nuclear Power Plant being under construction at the Paks site can currently only be modelled by using what are called design parameters while taking into account the actual (expected) local impact factors. Its anticipated impact on the environment, specifically on the wildlife in the Paks area was estimated, taking into consideration that all four units of the Paks Nuclear Power Plant are also operational. The two nuclear power plants combined are supposed to meet currently recommended impact ceiling (10 µGy/h), therefore it must be studied whether it will be achieved.

To model the impact of atmospheric emissions the PC-CREAM 08 program was used, which allows examination of fallout rate, cloud dose rate, and radioactive concentration in the near-ground air for relevant isotopes in up to 32 sector directions and at multiple distances.

Based on the expected annual emission inventory of the Paks II. Nuclear Power Plant and eight years of meteorological data from Paks, the assumed spatial distribution of radioactive material in the terrestrial environment surrounding the operational area was estimated. This includes the radioactivity of the surrounding air and the study of the soil as a receptor. For both media, locations characterized by maximum concentration was identified and used the data for these locations in the second phase of the impact study as input data for the ERICA program to estimate the radiation exposure of reference organisms placed there.

Meteorological data included annual average data generated from 10-minute measurements of wind speed, wind direction, Pasquill category, and precipitation at the 120 m and 50 m levels measured at the Paks meteorological tower, with a resolution of 32 sectors. The fallout rate, cloud dose rate, and radioactive isotope concentration of the near-ground air for each isotope at a resolution of 100 m were examined.

Using annual average meteorological data distributes rainy periods evenly throughout the year, resulting in a monotonic decrease in air activity concentration and fallout as the distance from the source increases. The maximum impact of emissions regularly concentrates over a smaller zone within the area under the influence of the dominant wind direction. Decades of meteorological data from Paks point out such a location, with the most exposed direction being southeast, and its narrow surroundings.

Therefore, during modeling, the pattern of impact appearance in the area around the power plant by proportionately dividing the year into rainy and rainless periods were examined. The results of the simulations for dry periods clearly highlighted the prominent role of sectors 12, 13, and 14 *(Figure 4.2.3-1)*.

Figure 4.2.3-1. Illustration of the combined impact of Paks Nuclear Power Plant and Paks II.

The cloud dose rate for this area: 5%: 22,4 pGy/h, average: 65,8 pGy/h, 95%: 193 pGy/h for large mammals, with other organisms generally experiencing different values based on size and habitat. Estimates based on 10 000 randomized sampling were made for lichens and mosses, grasses and herbaceous plants, shrubs, trees, snails, soil-dwelling invertebrates, decomposing invertebrates, flying insects, amphibians, reptiles, birds, bird eggs and mammals for a continuous release period of multiple years. The dose rate for these organisms typically falls in the range of 10^{-4} µGy/h, with a maximum risk factor of 10^{-4} to 10^{-5}.

It is advisable to compare these results with the maximum contribution of the operating nuclear power plant to the baseline level. This was estimated similarly to the method described above but using the emission inventory determined by the MVM Paks Nuclear Power Plant Ltd. for the given year as atmospheric emission data. Since the meteorological data matched those used for modelling the impact of Paks II., logically the sectors 12-13-14 and the 500-1000 m range had the maximum impact here. Data showed that the planned new nuclear power plant's impact is not significantly different from that of the existing one.

The estimated dose rates from the new units tend to be higher roughly by a factor of 2 due to the conservative design emission data while the larger installed capacity also contributes to the greater impact. The combined operation of the two nuclear power plants would only increase global radiation exposure by 20-30%. Therefore, it can be concluded that the subsequent service life extension of the Paks Nuclear Power Plant, even with the combined operation of Paks II., does not affect terrestrial wildlife.

Based on the available data, the planned process water treatment for the new units will result in the generation of 29 000 m³ of wastewater per year, which will be collected in tanks and then periodically discharged in a controlled way into a new warm water channel, and eventually to the Danube. Based on the isotope inventory regarding water discharge per unit, tritium accounts for 99.99% of the total emitted activity. This proportion and magnitude closely align with the liquid emission inventory of the Paks Nuclear Power Plant, supported by regular measurements. The data also show that the planned emission is predicted to be well below the threshold level.

However, there are several isotopes, especially those with longer half-lives, for which the newer data may be an order of magnitude higher than the previous ones, obviously resulting in higher estimated dose rates.

On the other hand, in estimating the combined impact, the new cooling water discharge plan for the new units, with radioactive emissions into the aquatic environment, will be conducted through a new warm water channel, which has an impact of reducing the exposure. Its discharge point into the Danube will be about 100-150 m upstream of the operating warm water channel. This means that, due to dilution, only a portion of the activity from units 5 and 6 will add to the radioactivity of the water released into the Danube from the operating plant.

Despite some isotopes showing such differences in estimated emissions from the two sources that can be regarded significant, this is expected to cause only minimal increase / decrease in the radiation exposure of the aquatic ecosystem. This will be presented as the result of detailed modelling to be performed during the environmental impact assessment.

Since the sum of the estimated dose rates (from the four units of the Paks Nuclear Power Plant and the units of Paks II.) is by nearly two orders of magnitude below the background radiation estimated for the aquatic ecosystem, and even lower by one more order of magnitude than the 10 µGy/h reference level recommended by the ICRP, it can also be stated that the Paks Nuclear Power Plant's subsequent service life extension will have a neutral impact on the ecosystem, and thus no direct impact area can be identified.

4.2.4. Expected radiation exposure to the population

Impacts of the Paks Nuclear Power Plant's independent operation

When evaluating radiological impacts, direct and indirect radiological impacts are distinguished as follows. Residents in the vicinity of the site may be exposed to direct radiation from several sources, of which the following are worth highlighting in connection with impacts associable with the operation of the Paks Nuclear Power Plant:

- transport of fresh fuel to the site
- transport of spent fuel to the neighboring interim storage, SFISF,
- transportation of radioactive waste from the site,
- movement of equipment and radiation sources containing radionuclides on their surface within the area of the site,
- use of high-activity radiation sources for different industrial radiographic inspections.

Based on calculations considering the results of regular dosimetric measurements and evaluations, it can be concluded that radiation exposure to the population from direct impacts, even under very conservative scenarios, does not reach a fraction of the 90 µSv/year value, thus it is considered neutral according to the impact qualification system.

Due to the similarity of activities and their resulting direct impacts, it can also be stated that changes in direct radiological impacts are not expected during the extended operating life of the nuclear power plant compared to the current operation.

Indirect radiological impacts refer to doses resulting from gaseous and liquid releases of the nuclear power plant. The values for radiation exposure to the population from the normal operation of the nuclear power plant are listed in *Chapter 4.1.4*.

During the subsequent service life extension, significant changes in radiation exposure to the population are not expected. Based on all this, it can be stated that the normal operational radiological impact area of the nuclear power plant's subsequent service life extension will not differ significantly from the current impact area, remaining within the operational area.

Combined impacts of the nuclear facilities operating and planned on the site

The environmental impact study of Paks II. also includes statements regarding the combined operation impact of the Paks Nuclear Power Plant, Paks II., and the SFISF. To estimate the combined radiological impact, radiation exposures from normal operation must be aggregated.

The doses from gaseous emissions of the three facilities (Paks Nuclear Power Plant, Paks II., and SFISF) are shown in *Tables 4.2.4-1.* and *4.2.4-2.* for two age groups (1-2-year-old children and adults) in Csámpa and at different distances from the discharge point. *Table 4.2.4-3.* shows the maximum combined impact of liquid releases in Gerjen. The provided data indicate that the total dose does not reach 1 μSv, which is by nearly two orders of magnitude below the upper limit of the neutral range.

Table 4.2.4-1. Total doses to children aged 1-2 years from Paks Nuclear Power Plant, Paks II. and the SFISF [nSv/year]

Plant / area	Csámpa	Surrounding of the site		
		<5 km	5-10 km	10-30 km
Paks Nuclear Power Plant	$8.40\cdot10^{1}$	$4.00\cdot10^{1}$	$6.50\cdot10^{0}$	$1.00\cdot10^{0}$
Paks II.	$6.90\cdot10^{1}$	$3.90\cdot10^{1}$	$9.00\cdot10^{0}$	$1.50\cdot10^{0}$
SFISF	$1.40\cdot10^{0}$	$4.00\cdot10^{1}$	$6.60\cdot10^{-2}$	$1.00\cdot10^{-2}$
Total	$1.54\cdot10^{2}$	$7.94\cdot10^{1}$	$1.56\cdot10^{1}$	$2.51\cdot10^{0}$

Table 4.2.4-2. Total adult doses from Paks Nuclear Power Plant, Paks II. and the SFISF [nSv/year]

Plant / area	Csámpa	Surrounding of the site		
		<5km	5-10km	10-30km
Paks Nuclear Power Plant	$6.00\cdot10^{1}$	$2.90\cdot10^{1}$	$4.70\cdot10^{0}$	$7.30\cdot10^{-1}$
Paks II.	$5.90\cdot10^{1}$	$3.30\cdot10^{1}$	$7.50\cdot10^{0}$	$1.30\cdot10^{0}$
SFISF	$7.00\cdot10^{-1}$	$2.10\cdot10^{-1}$	$3.40\cdot10^{-2}$	$6.60\cdot10^{-3}$
Total	$1.20\cdot10^{2}$	$6.22\cdot10^{1}$	$1.22\cdot10^{1}$	$2.04\cdot10^{0}$

Table 4.2.4-3. Maximum combined annual impact of liquid releases in Gerjen [nSv/year]

Gerjen	
1-2 year-old child	Adult
$1.54\cdot10^{2}$	$2.04\cdot10^{2}$

Based on the studies conducted, it can be stated for both direct and indirect impacts that the combined impact area does not exceed the dose constraint value at the boundaries of the safety zone(s) (500 m). The boundary of the impact area under combined normal operation is considered the boundary of the safety zone(s), therefore the issue of potential transboundary impacts does not arise in these cases either.

4.2.5. Impact of accidents on public radiation exposure

The Final Safety Analyses Report of the Paks Nuclear Power Plant provides a detailed overview of nuclear safety analyses, including analyses performed for design basis accidents. One of the objectives of these accident analyses is to determine the anticipated level of radioactive releases and the resulting radiation exposure to the public during various types of accidents. The presentation of these analyses includes the methodology for managing the release and dispersion of accident-related activity and describes the calculation results. For accidents where the integrity of the primary circuit and / or some of the fuel rods are compromised, doses inside the building and the extent of radioactive material releases, along with the environmental doses comparable to the established criteria, have been determined.

Various initial events that fall under the design basis were investigated from the perspective of possible discharge pathways. To determine releases into the environment, emissions through the containment, bypassing the containment, from a shutdown and open reactor, and from the spent fuel pool were analysed. On that basis, the following discharge pathways were identified:

- from the primary circuit through the containment into the reactor hall and adjacent rooms, then into the environment through the active ventilation at an effective release height of 120 meters,
- through a damaged steam generator into the secondary circuit and then into the environment via the discharge line at an effective release height of 44 meters,
- from a shutdown and open reactor into the reactor hall and then into the environment through active ventilation,
- from the spent fuel pool into the reactor hall and then into the environment through active ventilation.

The extent of discharge is primarily influenced by three factors:

- the number of damaged fuel element,
- the quantity and enthalpy of the medium escaping from the primary circuit into the containment,
- the time during which the containment pressure drops below atmospheric pressure.

The quantity and enthalpy of the medium escaping from the primary circuit increase with the diameter of the broken pipe. However, the time to achieve containment depressurization is dependent in a complex way on these quantities. The delay and overall process of the discharge affect the isotopic composition of the discharge since radionuclide decay depends on half-lives. Based on these factors, it is not expected that the extent of the release will increase monotonically with the diameter of the broken pipe.

Due to the proper design of the pipelines and valves passing through the containment wall, no incident resulting in containment bypass would compromise the cooling of the reactor core, thereby preventing fuel rod damage in such cases. However, the decrease in primary circuit pressure triggers the iodine spiking process, causing the iodine activity in the primary circuit coolant to increase by approximately two orders of magnitude. In case of a PRISE incident (primary-to-secondary leakage) managed by blowdown on the secondary side, some of the discharge bypass the containment. The active primary circuit coolant flows to the secondary side of the steam generator and exits into the environment via the discharge line.

In most accidents occurring in a shutdown, open reactor or the spent fuel pool, fuel cladding damage does not need to be considered. In these incidents, the cooling water boils (or evaporates), leading to discharges through the open water surface. In case a fuel assembly drops, fuel cladding damage must be considered, potentially resulting in more significant discharge.

Environmental dose calculations were conducted using the CARC code according to the methodology detailed in the FSAR. The calculations were performed for a receptor point 1 km from the power plant (Csámpa), using meteorological, consumption, and lifestyle parameters characteristic of the Paks Nuclear Power Plant site, focusing on the adult population group. Based on the analysis results, it can be concluded that in the event of design basis accidents (processes initiated by initial events leading to DBC4 operating conditions), the dose for the reference group of the public will not exceed the 5 mSv per accident limit. Interpreting the criterion as a committed effective dose, it can be stated that even under the conservative assumptions used, the criterion is met with a high degree of certainty. For a significant number of other initial events analyzed as part of the nuclear power plant's design basis, it was evident that they were far below of the values prescribed by regulatory criteria.

Based on the results, the highest values were observed in the event of a break in the 492 mm hot leg pipeline, with the maximum committed effective dose over 50 years being 2.75 mSv, the committed dose over 2 days being 0.381 mSv, and the committed dose over 7 days being 0.428 mSv. The distribution of the effective dose over 7 days for the reference individual by exposure pathway is as follows: 26% from groundshine exposure, 65% from inhalation, and 9% from cloudshine exposure. For the same scenario, most (>70%) of the reference individual’s committed effective dose over 50 years received from the food chain.

Based on the results of earlier calculations (primarily aimed at nuclear safety analyses) and the considerations applied during the analyses, the following conclusions can be drawn:

- during the service life extension period of the nuclear power plant, no considerable change in the magnitude of gaseous and liquid radioactive releases compared to previous levels is expected,
- the radiological impacts on the ultimate bearer of the effects are expected to remain below regulatory limits in the future, and thus no change is foreseen compared to the current state.

In the analyses presented, it was conservatively assumed that all fuel assemblies would be damaged in accidents resulting from large diameter pipe break. With advancements in analytical methods and tools, the latest analysis results suggest that a significantly lower percentage of fuel assembly damage than 100% can be expected, which would likely lead to a significant reduction in doses. The analyses made for an amendment to the environmental permit due to the new type of fuel assemblies assumed 33% fuel assembly damage in case of large diameter pipe breaks.

Based on the results of previous calculations and the considerations applied during the analyses, the following statements can be made:

- During the service life extension period of the nuclear power plant, no considerable change or increase in the magnitude of gaseous and liquid radioactive releases compared to previous levels is expected.
- In recent years, alongside the development of models, the input data have also changed, justifying a repetition of analyses. Preliminary calculations suggest that the repeated analyses are expected to lead to reduced doses.
- The radiological impacts on the ultimate bearer of the effects are expected to change favorably due to the reduction of analytical conservatisms.

In the environmental impact study prepared for the first service life extension of the Paks Nuclear Power Plant in 2006, it was established that the tolerable effects of design-basis incidents could be expected up to a distance of 6.3 km from the discharge point, with neutral effects expected beyond that. However, based on the results of calculations performed in recent years for other purposes, it is expected that the population dose values determined at these distances will be lower than the results obtained during the environmental impact study. As a result, the impact area is highly likely to decrease as a result of the new analyses to be carried out. The safety analyses and investigations conducted during the preparation of the environmental impact study for the first service life extension also concluded that the impact of accidental liquid discharges is by several orders of magnitude lower than the atmospheric releases. Considering the above, in the current preliminary phase, a distance of 6.3 km is considered the impact area for design basis accidents using a conservative approach.

4.3. Generation and management of radioactive waste and spent fuel

4.3.1. Generation and disposal of radioactive waste

According to section 1 of § 38 of Act CXVI of 1996 on atomic energy, during the licensing procedure for subsequent service life extension, it must be demonstrated that the safe disposal of the resulting radioactive waste and spent fuel is ensured, in accordance with the latest verified scientific results, international requirements and experiences. Activities related to the final disposal of radioactive waste and the interim storage of spent fuel fall within the responsibilities of PURAM, an organisation designated by the government.

During the operation of the nuclear power plant, solid and liquid low- and intermediate-level radioactive wastes are generated, which are temporarily stored at the nuclear power plant until their transfer to a final repository. Most solid radioactive waste is placed in 200-liter steel drums in compressed form (uncompressed for non-compressible waste). Liquid radioactive wastes are collected in tanks at the nuclear power plant. Radioactive wastes can only be disposed of permanently in solid form, so liquid wastes are also solidified at the nuclear power plant before being transferred to the final repository.

An overview of the low- and intermediate-level radioactive wastes generated in connection with the operation of the nuclear power plant is provided in *Table 4.3.1-1.*, reflecting the state as of 1st January 2023. The annual waste generation rate from normal operation, as shown in the table, indicates that approximately 90 m³ of solid waste (around 450 pieces of 200-liter drums) is generated annually, with an additional 10 m³ (50 drums) expected from the operation of the FHF technology. Thus, approximately 500 drums are expected to be generated annually. Large-sized solid waste is also included among the solid wastes. These radioactive wastes cannot (or are not advisable to) be placed in 200-liter drums, and their annual generation is not substantial. Among the solid wastes are caesium and other filter cartridges, which will be placed in storage containers of special circular profile in the future. The amount of this waste form is also minimal over the entire operational period, and therefore the quantity generated annually is not specified.

Table 4.3.1-1. Inventory of low and intermediate-level radioactive waste generated at the Paks Nuclear Power Plant

	Waste flow	**Stored quantity (01.01.2023) [m^3]**	**Annual generation [m^3]**	**Management**	**Waste to be disposed of till the end of the 50 (30+20) operation time**	
					Waste package	**Volume* [m^3]**
Solid	Compacted waste (stored in reinforced concrete containers)	0	0	None	Reinforced concrete container	967
	Compacted non-historical waste stored in drums	0	55	None	Barrel	626
	Compacted non-historical waste in compact waste packages	902		Placing in compact waste package	Compact waste package	3 152
	Non-compacted waste	846	33			2 858
	Sludges blotted up and dewatered with diatomaceous earth	158	3			449
	After-filter to remove Co	50	10			729
	Large-sized waste	–	–	None	Container (4 m^3)	200
	Container to store Cs-column	19	na	None	Container (1,7 m^3)	53
Liquid	Normal operation evaporation residue	3 853	200	FHF technology	–	3307
	Emergency evaporation residue (including sludge)	2 685	na	Cementing into compact waste-package (volume increase by 1.6 to 1.8 times)	As cement paste in compacted waste package	
	Sedimentation sludge and evaporation residue sludge	710	20			
	Evaporator acid cleaning solution (including sludge)	211	0			
	Decontamination solution (including sludge)	543	0			

	Waste flow	Stored quantity (01.01.2023) [m^3]	Annual generation [m^3]	Management	Waste to be disposed of till the end of the 50 (30+20) operation time	
					Waste package	Volume* [m^3]
	Ion exchange resin	295	5	Cementing into container (volume increase by 3.8 times)	Container (identical with compacted waste package)	1934

na – not applicable.

* This does not take into account the 20-year subsequent service life extension. The subsequent service life extension would increase the total volume to be disposed of by nearly 2000 m^3.

Annually, about 225 m^3 of liquid radioactive waste is expected, most of which (200 m^3/year) is evaporation residue (concentrate). Other liquid wastes include evaporator acidizing solutions, ion exchange resins (5 m^3/year without transport water), sludge (20 m^3/year), and decontamination solutions. Decontamination solutions are generated periodically, and therefore their quantity generated annually is not specified.

The above data are derived from trend analysis of waste quantities generated in previous years and take into account the impact of the implemented 15-month-long campaigns. The implementation of the 15-month fuel cycle will reduce the number of annual major overhauls to 3, and the generated quantities of waste will also drop. The anticipated quantity of waste can still be considered as a conservative value.

The amount of additional radioactive waste generated during the 20-year subsequent service lifetime extension is currently estimated to increase by approximately 2000 m^3, from approx. 14 000 m^3 to approx. 16 000 m^3, in terms of the final disposal volume of conditioned operational radioactive waste.

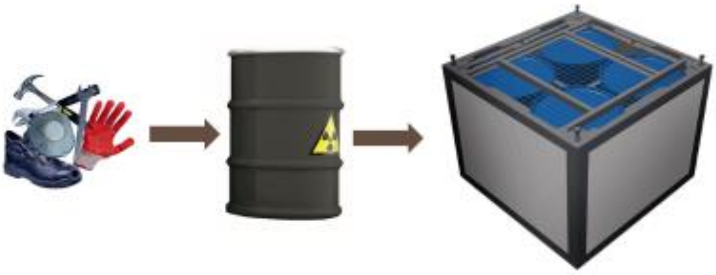
The utilization rate of on-site interim storage capacities for low and intermediate-level solid and liquid radioactive waste is approximately 90% based on the 2023 data, but by operating the volume reduction technology for liquid radioactive waste and the cementation technology (and by continuously transporting waste packages suitable for final disposal), the interim storage of both types of waste can be ensured for an additional 20 years of operation.

The final disposal of low and intermediate-level radioactive waste from the Paks Nuclear Power Plant is provided at the National Radioactive Waste Repository (NRWR), operated by PURAM, which features subsurface storage chambers (*Figure 4.3.1-1.*). Final disposal of radioactive waste occurs in storage chambers constructed 200-250 meters below the surface. According to the original storage concept, waste packaging (placing drums into reinforced concrete containers and filling such containers with inactive concrete) was carried out at the NRWR until 2017. The storage chamber marked I-K1 of the NRWR (*Figure 4.3.1-1.*) was filled in May 2017. In the future, the NRWR will receive and handle the so-called compact waste packages produced at the Paks Nuclear Power Plant, accommodating them in further storage chambers.

Source: PURAM's website (rhk.hu)

Figure 4.3.1-1. The surface facilities of the National Radioactive Waste Repository (NRWR) in Bátaapáti and filling the storage chamber marked I-K1 with reinforced concrete containers

In the compact waste package (*Figure 4.3.1-2.*), 200-liter metal drums are placed in fours into a thin-walled, reinforced steel container. The space between drums is filled with cement paste mixed with liquid radioactive waste, thus utilizing the dead space of containers for radioactive waste as well.



Source: PURAM's website (rhk.hu)

Figure 4.3.1-2. Compact waste package formed with a steel container

The total capacity of the Bátaapáti NRWR, with storage chambers designed according to the original plans, is sufficient for the low and intermediate-level radioactive waste generated during the 50-year (30+20 years) operational period and decommissioning of the nuclear power plant.

The final disposal of low and intermediate-level solid radioactive waste generated during the subsequent service life extension of the Paks Nuclear Power Plant can be resolved by expanding the storage capacity of the NRWR.

During the operation of the Paks Nuclear Power Plant, relatively small quantities (net 5 m³/year) of high-level radioactive waste are generated annually, which are temporarily stored in designated storage wells on-site. As of 1st January 2023, 107.62 m³ of waste was stored within the 222.8 m³ storage capacity. By the end of the 50-year operational period, additional 65 m³ of high-level radioactive waste is expected to be generated, leaving approximately 50 m³ of storage capacity available for the period of the subsequent service life extension.

For the purpose of final disposal, the waste with high activity level is collected in containers and encased in concrete. Considering the rate of generating radioactive waste with high level activity, the final disposal needs to be addressed only during the decommissioning phase of the nuclear power plant, as outlined in the technical design.

According to widespread international consensus, the safe final disposal of high-level waste can be achieved safely in deep geological repositories. Such a facility is constructed several hundred meters deep, protected from surface impacts and processes, where, along with human-made technical structures, the stable geological environment guarantees long-term safety. There is also a unified position among the relevant international organisations that a deep geological repository is equally suitable for the direct disposal of spent nuclear fuel and for the disposal of residuals from processed spent fuel.

In Hungary, a research program to identify a potential repository site began at the end of 1993, utilizing the galleries opened from the Mecsek uranium mine to study the Boda Claystone Formation. The research focusing on the final disposal of high-activity-level waste is currently ongoing. In 2018, PURAM compiled the site investigation framework program for the Boda Claystone Formation, outlining tasks until 2032. According to the planned timeline, the repository facility is expected to be operational by 2064.

4.3.2. Interim Storage of spent fuel assemblies

Spent fuel generated at the Paks Nuclear Power Plant is stored for a longer period (currently 50 years) in an interim storage facility, called SFISF, until a decision is made about its reprocessing or final disposal.

According to PURAM's current plans, the approved construction of SFISF using Modular Vault Dry Storage (MVDS) technology with 33 vaults can accommodate the temporary storage of

VVER-440 type spent fuel assemblies generated during the 50-year (30+20 years) operational period of the Paks Nuclear Power Plant.

PURAM is investigating options considering several aspects, including the commissioning of new units at the Paks plant, to handle spent fuel from both the subsequent service life extension of the Paks Nuclear Power Plant and the new Paks II. Nuclear Power Plant:

- The first alternative involves increasing the storage capacity of SFISF's current MVDS technology to accommodate the additional spent fuel from the subsequent service life extension of the Paks Nuclear Power Plant. For that purpose, the construction of a five-vault module on both the western and eastern sides of the storage facility has been envisaged.
- The second alternative involves a technical concept utilizing dual-purpose metal or concrete cask for storing the additional spent fuel generated during the extended operational period of the Paks Nuclear Power Plant.

If cask storage is chosen for the interim storage of spent fuel generated during the additional service life extension, modifications to handling and pre-shipment preparation activities for spent fuel in the nuclear power plant will be necessary to meet the requirements of the new technology. This means from a technological viewpoint that the cask as storage units will be prepared for storage purposes within the power plant, using the power plant's systems. Then the cask, in its closed and hermetically sealed state, will only need to be delivered to the SFISF storage area.

From an environmental perspective, if a shift to cask storage technology occurs, the emissions associated with drying the spent fuel assemblies for storage will be linked to operations performed in the reactor hall within the power plant, rather than to SFISF. These emissions are already significantly below the limits in the current SFISF technology and are expected to be even more favourable with cask technology, albeit not significantly so. A detailed assessment of the environmental impacts resulting from the adoption of cask technological process will be conducted following the decision on the technology transition, and these will be detailed in the environmental impact assessment study.

For both the MVDS and cask storage alternatives, the interim storage of spent fuel generated during the additional 20-year operational period can be ensured within the current area of the SFISF, meaning that interim storage will not require additional land.

The concept plan for the new units of Paks II. includes dual-purpose casks for the interim storage of spent fuel. According to current plans, the amount of spent fuel generated during the nearly 40 years of operation of Paks II.'s two units can be stored within the legal boundaries of the SFISF site. Future capacity expansions associated with the operation of Paks II. can be ensured in the future by extending the site.

5. Current status of conventional environmental characteristics and expected changes due to service life extension

5.1. Impacts on air quality

5.1.1. Description of the base state

For the baseline air pollution state of Paks, the average values of air quality measurements conducted in 2019-2023 in the surroundings of the city can be taken into account as the most recent available data (*Table 5.1-1-1.*).

Table 5.1.1-1. Base load of ambient air taken into account in the Paks area

Year	NO_2 [μg/m^3]	NO_x [μg/m^3]	CO [μg/m^3]	O_3 [μg/m^3]	Particulate matter (TSPM) [g/m^3]	Particulate matter (PM_{10}) [μg/m^3]	Sedimenting dust [g/m^2 x 30 day]
2019-2023	12.6	15.4	487.0	74.6	23.7	15.5	4.6

Based on the above base load data, the load capacity values of the air for the area are shown in *Table 5.1.1-2.*

Table 5.1.1-2. The load capacity of the air in the area of Paks

Air pollutant	Base load of the air	Air pollution limit value	Load capacity	Reference period
	[μg/m^3]			
Nitrogen oxide (NO_2)	12.6	100	87.4	Hourly average
Nitrogen oxides (NO_x)	15.4	200*	184.6	Hourly average
Carbon monoxide (CO)	487.0	10 000	9 513.0	Hourly average
Particulate matter (TSPM)	23.7	200*	176.3	Hourly average
Particulate matter (PM_{10})	15.5	50	34.5	24 hour average

* Design guidance value.

5.1.2. Impacts expected from subsequent service life extension

During the environmental impact assessment phase, a detailed description of the air pollutant sources operating at Paks Nuclear Power Plant site and planned air pollutant sources of the Paks II. Nuclear Power Plant will be provided. Additionally, a more accurate and detailed evaluation of the impacts on air quality will be carried out based on the results of atmospheric dispersion model calculations.

Impacts of the Paks Nuclear Power Plant's independent operation

There are some diesel generators operating as backup power sources at the Paks Nuclear Power Plant site, whose exhaust outlets function as point sources of air pollution. Under normal operating conditions, these diesel generators are only run in test mode. The operator of the nuclear power plant conducts independent test runs periodically throughout the year, as specified, ensuring they do not operate simultaneously. In total, there are 31 air pollutant sources located at the nuclear power plant's site.

Since the air pollutant sources at the nuclear power plant site do not operate continuously and simultaneously, the study will focus on one of the most powerful diesel generators, identified as P13, and its associated point source because the operation of such a point source is responsible for the highest environmental impact among the air pollutant sources operating at the site.

The impact area of the air pollutant point source associated with the safety diesel generator selected for the study was determined according to section 14 of § 2 of Government Decree 306/2010. (XII. 23.) on the protection of air. The analysis focused on nitrogen oxides emissions as the key component, and the results indicate that there is no exceedance of limit values or of absorption capacity.

During the subsequent service life extension, it is expected that these same point sources will operate intermittently, therefore, the air environmental load and impacts will be similar. The impacts and impact area resulting from the operation of the selected air pollutant point source are taken into consideration as the impact on air quality for the service life extension of the Paks Nuclear Power Plant (*Table 5.1.2-1*).

The air quality impacts of the nuclear power plant's operation during the subsequent service life extension are assumed to be tolerable within the impact area. The impact area will likely cover the plant site and its immediate surroundings (*Figure 5.1.2-1.*).

Table 5.1.2-1. Summary of the estimated air quality impacts of the operation of the Paks Nuclear Power Plant

	Nitrogen oxides (NO_x) – hourly value
Air pollution concentration maximum	~79 μg/m^3
Design guidance value	200 μg/m^3
Design guidance value exceedance	None
Load capacity of air	184.6 μg/m^3
Load capacity exceedance	None
Criteria for determining the impact area*	„a)”
Concentration value determining the impact area	20 μg/m^3
Impact area	The area of diesel generator P13 within a radius of 1079 m: on-site and off-site areas

* The requirements for determining the air quality impact area are set out in criteria a), b), c) of section 14 of § 2 of Government Decree 306/2010 (XII. 23.).

Figure 5.1.2-1. Assumed air quality impact area of the Paks Nuclear Power Plant operation

For the preliminary estimation of the expected impacts of transportation activities associated with the independent operation of the Paks Nuclear Power Plant, the data from the environmental impact study of the plant's first service life extension was considered. The impact of road traffic arises from two sources: one from main road No. 6 and the other from the traffic on the northern and southern access roads leading to the power plant. The latter includes the inbound and outbound traffic around the entrance. The available data need to be reviewed for the current period and for the subsequent service life extension.

It must be taken into account the M6 motorway and the Danube bridge between Paks and Kalocsa and its access roads has been constructed, which diverts significant traffic from main road No. 6. Therefore, the air quality impacts resulting from transportation are shared between the routes. It is also notable that, over the past nearly 20 years, the vehicle fleet has become more modern, and the vehicles are presumably operating with lower specific pollutant emissions.

As a result of the subsequent service life extension of the nuclear power plant, no increase in traffic is expected. Based on the results of previous studies, the air quality impacts of the nuclear power plant during the subsequent service lifetime extension, concerning transportation, are likely to fall into the neutral category. The impact area is the immediate vicinity of transportation routes.

Combined impacts of the nuclear facilities operating and planned on the site

In addition to the air pollutant sources operating at the Paks Nuclear Power Plant site, 62 air pollutant sources at the Paks II. Nuclear Power Plant site are planned to be installed. These are predominantly diesel generator exhaust outlets.

The study of the impact of combined operations consists of two parts: firstly, considering the nitrogen oxide components emitted by the safety diesel generator (P13) at the Paks Nuclear Power Plant, and secondly, for Paks II., considering the total NO_x emissions as NO_2 components from the exhaust outlets of the EPSS diesel generator (0009) and the exhaust fans of a heated garage.

The part of the combined operations that is related to the Paks Nuclear Power Plant has been detailed under the independent operation section above, while the impacts of the Paks II. operations, which constitute the other part, are summarized in *Table 5.1.2-2.*, and the impact area is illustrated in *Figure 5.1.2-2.*

Table 5.1.2-2. Summary of the estimated air quality impacts of Paks II. operations

	Nitrogen oxides (NO_x) as nitrogen dioxide (NO_2) – hourly value
Air pollution concentration maximum	~40 µg/m^3
Limit value	100 µg/m^3
Limit value exceedance	None
Load capacity	87,4 µg/m^3
Load capacity exceedance	None
Criteria for determining the impact area*	„a)”
Concentration value determining an impact area	10 µg/m^3
Impact area	The zone of emissions within a radius of 600 m: on-site and off-site areas

* The requirements for determining the air quality impact area are set out in criteria a), b), c) of section 14 of § 2 of Government Decree 306/2010 (XII. 23.).

The available analyses for examining the air quality impacts of the combined operation of the two nuclear power plants have approached the assessment of these impacts in different ways. In the analysis of the Paks Nuclear Power Plant's impacts, the nitrogen oxides (NO_x) component was examined, while in the case of Paks II., the total amount of NO_x was taken into consideration as nitrogen dioxide (NO_2).

As a result, merging and jointly evaluating the results for the Paks Nuclear Power Plant and Paks II. in this preliminary evaluation phase is not yet possible. The different approaches in the available information influence the fulfilment of carrying capacity and the extent of the impact area differently. To accurately assess the air quality impacts arising from the combined operation of the two nuclear power plants, a more precise and detailed evaluative study must be conducted within the framework of the environmental impact assessment for the subsequent service life extension.

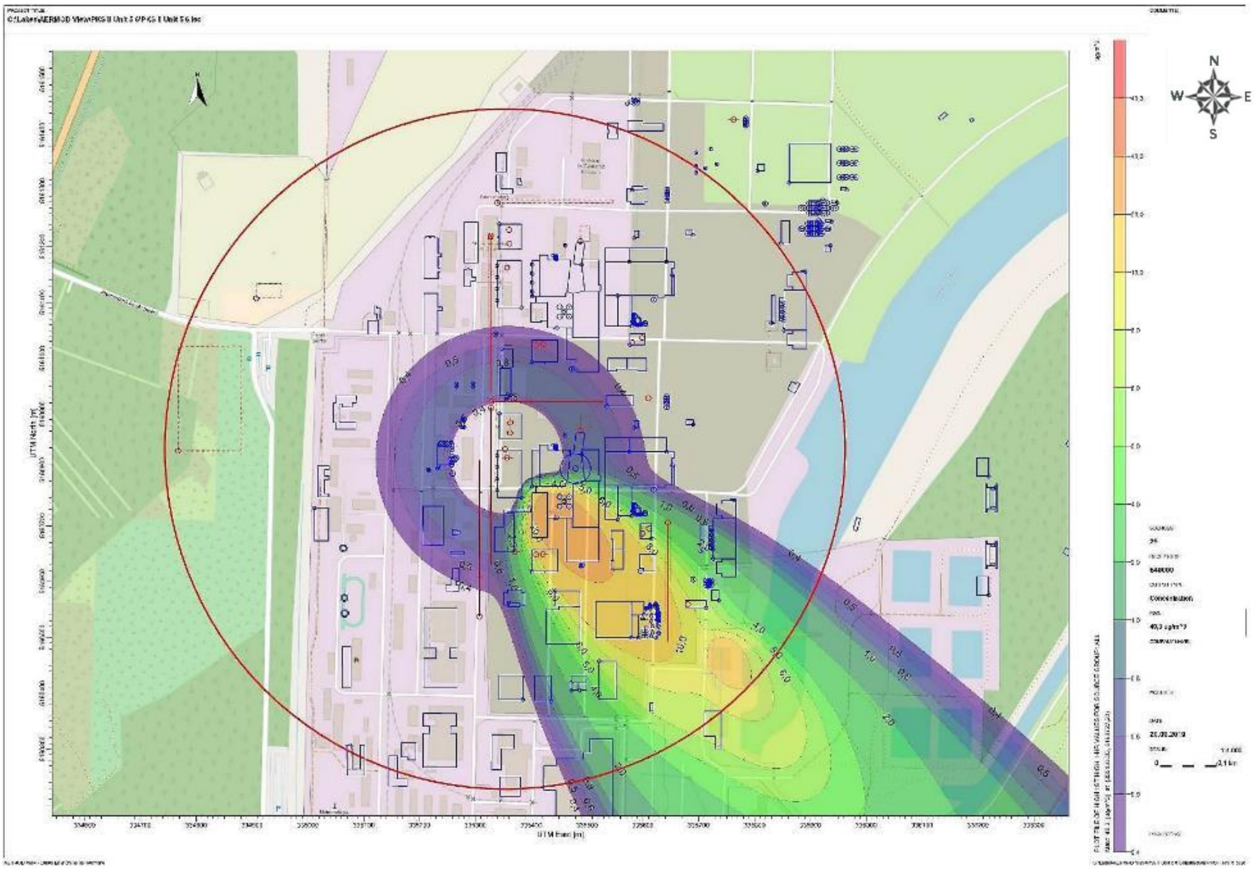


Figure 5.1.2-2. The assumed impact area of estimated air quality for Paks II. operations

Despite uncertainties, it is assumed that the air quality impacts of the combined operation of the Paks Nuclear Power Plant and Paks II. will be tolerable within the impact area during the service life extension. The impact area is expected to cover the nuclear power plant site and its immediate surroundings. One component of the air quality impacts related to transportation associated with the combined operation of the Paks Nuclear Power Plant and Paks II. is the impact of existing traffic on main road No. 6 (including the additional traffic related to the operation of the nuclear power plant). No concentrations exceedance of the limit values has occurred.

The impacts associated with the transportation for the future operation of Paks II. will add to the existing transportation impacts on main road No. 6. The operation of Paks II. should be considered as an additional load on the affected road sections. During the transportation activities associated with the operation, it is highly unlikely that the limit values will be exceeded.

The air quality impacts related to transportation associated with the combined operation of the Paks Nuclear Power Plant and Paks II. during the subsequent service life extension are assumed to fall into the neutral category.

5.1.3. Impacts of havaria events

In the event of operational disturbances, diesel generators will operate in the required number and for the necessary duration. The diesel generators will burden the air environment with emissions typical of combustion equipment, including nitrogen oxides (NO_x), particulate matter, carbon monoxide (CO), and sulphur dioxide (SO_2).

The air pollution levels caused by possibly operating multiple equipment items simultaneously may be higher than those that occur during the maintenance or test operation of a single diesel generator under normal operating conditions. Based on preliminary assumptions, air quality impacts during havaria events will remain within a tolerable range in the impact area. The impact area is expected to cover the nuclear power plant site and its immediate surroundings.

5.1.4. Transboundary impacts

In the case of environmental impacts on air quality – given the assumed extent of the air quality impact area – the possibility of transboundary effects does not arise.

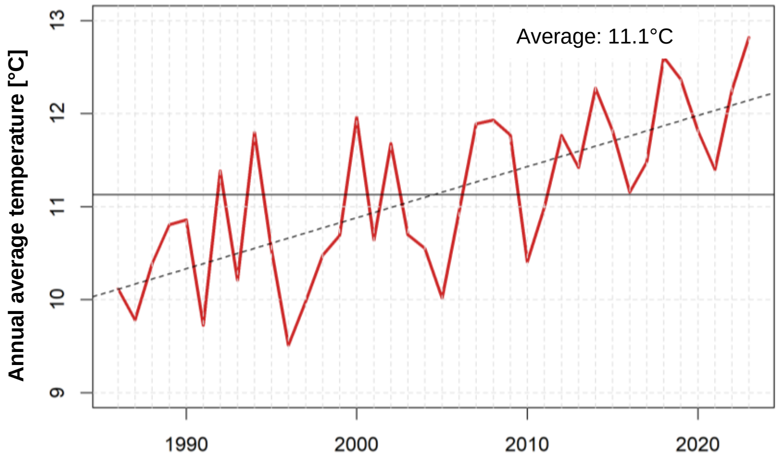
5.2. Climatic Conditions, exposure and sensitivity to climate change

5.2.1. Meteorological characteristics of the site's environment

Meteorological conditions fundamentally influence the operation of industrial facilities. In the case of the Paks Nuclear Power Plant, the air temperature is the main regulator of the water temperature of the Danube, making the study of basic meteorological variables crucial. The climatological / meteorological characteristics of the Paks Nuclear Power Plant site are summarized by updating the results of the period from 1981 to 2010, which were processed for previous studies by the Hungarian Meteorological Service (the predecessor of HungaroMet Zrt.).

Temperature, precipitation

During the period from 1981 to 2010, the average annual mean temperature at the Paks meteorological station was 10.7°C, while in the period from 1991 to 2020, it was 11.1°C. In the period from 1986 to 2023, also shown in *Figure 5.2.1-1.*, the average annual mean temperature was 11.1°C. The past decades have been characterized by significant warming (an average temperature increase of 0.55 °C per decade). The highest daily maximum temperature during the 1986-2023 period was measured on July 20, 2007 (40.6°C), and the lowest on 13th January 1987 (-13°C).



Note: The value in the figure means the average between 1986 and 2023.
The dashed line represents the matched trend

Figure 5.2.1-1. Annual average temperature data (°C) for Paks meteorological station for the 1986-2023 period

A “heatwave day” refers to days when the daily average temperature exceeds 25°C. The average annual number of heatwave days at the Paks station for the entire period of 1986-2023 was 12.5 days, with the highest value recorded in 2021 (29 days) and also high values in 2015 with 28 days. There is a significant increase in the number of heatwave days.

A "hot day" refers to days when the daily maximum temperature exceeds 35°C. The average annual number of hot days over the whole period 1986-2023 was 5.9, with a maximum in 2015 (19 days). There is an increasing trend in the time series, but the significance level is low, indicating that the increase is not definitive.

In the period 1981 to 2010, the average annual precipitation was 599 mm, while between 1991 and 2020 it was 596 mm. No trend can be observed in the annual precipitation totals in the 1986 to 2023 period. The average annual number of days with heavy precipitation (>30 mm) ranged from 0 to 5 days at the nuclear power plant area, with an average of 1.66 days per year. No trend can be observed in this data series. The average number of extreme high precipitation days (>44 mm) per year at Paks was 0.36 days between 1986 and 2023, with the highest number of days in 2010 (3 days). No trend can be observed in this data series.

Wind conditions, atmospheric stability

In the period 1996-2023, the relative frequency of wind directions was similar to that of 1981-2010, with north-west (11.1%) and north-north-west (10.8%) being the most common, and the second maximum being north (8.7%) and south (8.6%).

The annual average wind speed was 1.7 m/s in the 1991-2020 period, and 1.8 m/s in the 1986-2023 period. The highest wind gust recorded during the 1986-2023 period was 27.5 m/s on 27th February 1990. Extreme wind gust days (wind speed >85 km/h) occurred ten times in total according to measurements at the Paks Nuclear Power Plant in the entire 1986-2023 period.

For atmospheric dispersion calculations, along with wind speed and direction, stability conditions also need to be provided. The most important parameter characterizing atmospheric stability is the vertical change in air temperature. Vertical stratification is influenced by inbound radiation and ground outbound radiation ratio, as well as wind speed. Atmospheric conditions are typically categorized for stability purposes. For environmental calculations at nuclear power plants, the Pasquill classification is commonly used, as recommended by the International Atomic Energy Agency (IAEA). This classification ranges from "A" to "F", where "A" represents highly unstable atmospheric conditions, "B" represents moderately unstable, "C" represents slightly unstable, "D" represents neutral, "E" represents slightly stable, and "F" represents stable conditions.

In the period 2013-2022, the category occurring most frequently was "C" (34.2%), followed by "D" (24.2%). The next most common was "B" (20.6%), then "A" (11.7%) and "E" (7.3%), with "F" being the least common (2%).

5.2.2. Climate change projections

In the context of climate change, projections for the future can only be made based on certain assumptions about anticipated social, economic, and political decisions. For this study, results from two Representative Concentration Pathways (RCP) scenarios were used (RCP4.5 and RCP8.5). RCP8.5 is the most pessimistic scenario, assuming high greenhouse gas emissions without climate policy, while RCP4.5 is a more optimistic scenario, assuming successful emission reduction efforts. According to RCP4.5, the national average temperature is expected to rise by 1.5-2.9°C by the end of the century, while RCP8.5 predicts a rise of 3.5-5.3°C compared to the end of the 20th century. Changes in annual precipitation by the end of the century are projected to be between -5% and 16% (RCP4.5), and 0% and 24% (RCP8.5).

Source of meteorological data

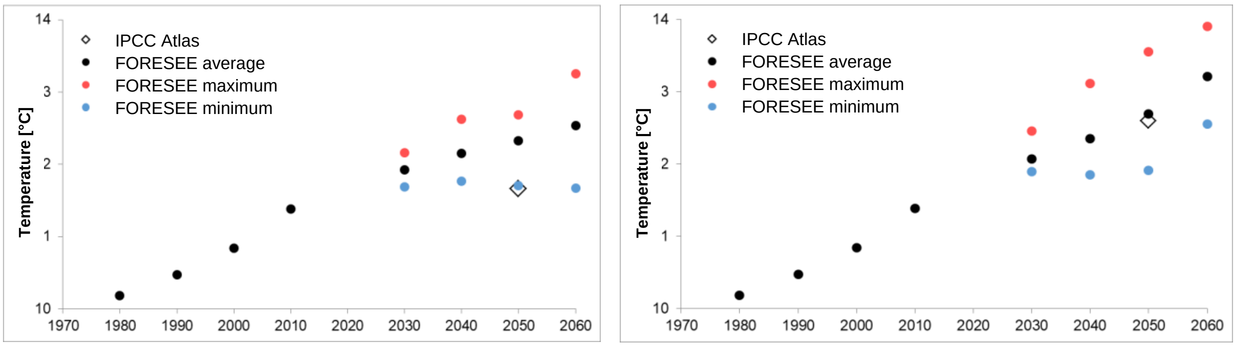
The meteorological data used for assessing climate change impacts are not based on measurements, but on calculations relying on modern climate models. Climate projections are presented using an ensemble (multi-model) approach. An average is derived from the ensemble data, which is interpreted as the most likely scenario based on the models used and provides the most probable future scenario. It is important to note that this is based on current knowledge, meaning that it does not provide certainty, but rather what appears to be most likely based on the projections used. Future social, economic, and political changes / decisions will fundamentally influence future climate, and precise forecasts are inherently not possible.

The variables were derived for four past periods (1971-1990, 1981-2000, 1991-2010, 2001-2020) and four future periods (2021-2040, 2031-2050, 2041-2060, 2051-2070). The most probable future scenario, based on the available data, is based on the average of 14 models from the FORESEE database, and the derived trends were estimated accordingly. The trends were determined in two ways: by fitting a linear trend function to the longest possible period (1971-2070) and to a shorter period covering the recent past and near future (2001-2060). The matching the two periods of different lengths was justified by the fact that the rate of change significantly depends on the selected period. The IPCC Atlas results are used as supplementary information, and the relevant projections are indicated as a supplement to the FORESEE results.

The projections are discussed separately for the RCP4.5 (more optimistic) and RCP8.5 (more pessimistic) scenarios. It is important to mention that some research results indicate that current regional climate model projections for Europe might be overly optimistic and may underestimate the expected changes, at least regarding temperature increases and the frequency of summer heatwaves. Therefore, in addition to examining the anticipated ensemble average, it is advisable to consider uncertainty, particularly focusing on estimates with higher-end values.

Annual average near-surface air temperature

According to FORESEE, it is expected that the annual average near-surface air temperature will increase compared to the current ~11.4°C value for the years 2001-2020. For the whole period, warming between 1971 and 2070 is projected, with a decadal rate of ~0.3°C in the more optimistic scenario and ~0.4°C in the pessimistic scenario (*Figure 5.2.2-1.*). Looking only at the period 2001-2060, the expected rate of warming is more moderate, ~0.2°C/decade in the optimistic scenario and ~0.3°C/decade in the pessimistic scenario. For the period 2041-2060, the optimistic scenario projects an annual average near-surface air temperature of ~12.3°C, while the pessimistic scenario projects ~12.7°C. The IPCC Atlas forecasts a lower temperature increase compared to the FORESEE average for the period 2041-2060, with an annual average near-surface air temperature of ~11.7°C for the optimistic scenario and ~12.6°C for the pessimistic scenario.



(a) (b)

Note: The symbols in the figure represent 20-year averages, indicating trends rather than specific years. The FORESEE database's average, minimum, and maximum values are represented in black, blue, and red, respectively. The black rhombus shows the average projection from the IPCC Atlas for the period 2041-2060.

Figure 5.2.2-1. Projected annual near-surface air temperature in the vicinity of the Paks Nuclear Power Plant (a) based on the optimistic scenario and (b) based on the pessimistic scenario

Seasonal average near-surface air temperature

According to FORESEE, the average near-ground air temperature is expected to rise in both winter (December, January, and February) and summer (June, July, and August) compared to current conditions. The results for seasonal near-surface air temperatures closely resemble those for annual values.

Based on the FORESEE mean, the average winter near-surface air temperature between 1971 and 2070 is projected to increase from the current value of ~1.1°C, by approximately 0.3°C/decade under the optimistic scenario and by approximately 0.4°C/decade under the pessimistic scenario. Considering the periods between 2001 and 2060, both the optimistic and pessimistic scenarios anticipate a warming rate of about 0.4°C/decade. The IPCC Atlas projects a smaller increase compared to FORESEE the expected winter average near-surface air temperature will be around 1.5°C under the optimistic scenario and approximately 2.3°C under the pessimistic scenario.

Based on the FORESEE average, the average near-surface air temperature during the summer between 1971 and 2070 is projected to increase by about 0.4°C/decade for both the optimistic and pessimistic scenarios, compared to the current temperature of approximately 21.3°C. Focusing on the periods between 2001 and 2060, the expected warming rate is about 0.3°C/decade in both scenarios. The IPCC Atlas projects a smaller increase compared to FORESEE for the 2041-2060 period, estimating an average temperature of around 21.8°C under the optimistic scenario, while the pessimistic scenario predicts a summer average near-surface air temperature of approximately 22.7°C.

Number of spring days with minimum temperatures below 0°C

Consistent with the warming trend results mentioned earlier, the predicted number of frost days during spring is expected to decrease. Based on the FORESEE average, this decrease is projected to be ~1 day/decade for both the optimistic and pessimistic scenarios, considering the periods between 1971 and 2070. Compared to the current annual average of approximately 16.6 days, the expected number of spring frost days for the 2041-2060 period is projected to be ~14.4 days/year and ~12.6 days/year on average. Examining the periods between 2001 and 2060, a statistically significant decrease at the 0.1 significance level is anticipated, amounting to ~0.5 days under the optimistic scenario and ~1 day under the pessimistic scenario. The IPCC Atlas projects a smaller decrease compared to the FORESEE average for the 2041-2060 period, projecting ~17.2 days/year under the optimistic scenario and around 15 days/year under the pessimistic scenario for annual spring frost days.

Number of days with maximum temperatures above 35°C

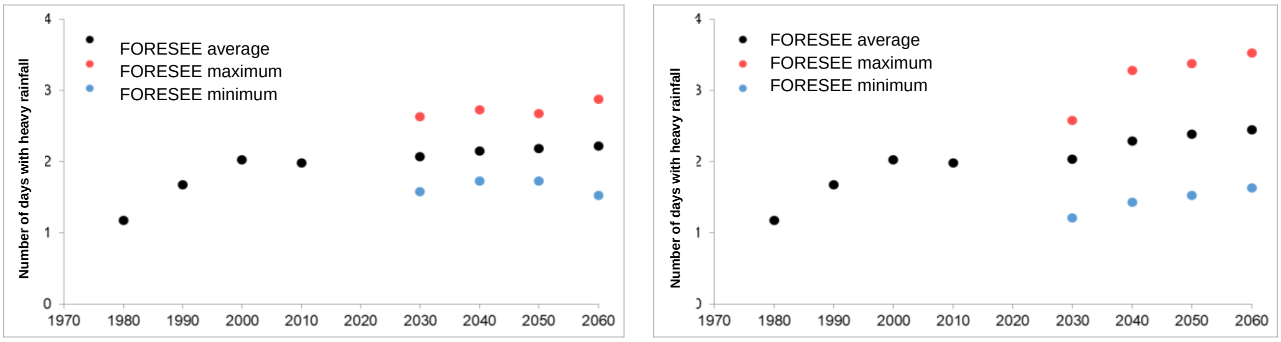
Based on FORESEE, the number of days with maximum temperatures exceeding 35°C is projected to increase by ~1.7 days/decade between 1971 and 2070 under the more optimistic scenario and by ~1.8 days/ decade under the pessimistic scenario. Focusing only on the shorter period between 2001 and 2060, the number of days with maximum temperatures above 35°C is expected to increase by ~1.9 days per decade for both scenarios, compared to the current value of ~6.2 days/year, resulting in an estimated 13.7-13.9 days/year for the 2041-2060 period. The IPCC Atlas, under the optimistic scenario, projects a significantly smaller increase compared to the FORESEE average for the 2041-2060 period, estimating only ~8.8 days/year, while the pessimistic scenario anticipates a similar value to the FORESEE average pessimistic scenario, predicting around 14 days/year with maximum temperatures exceeding 35°C.

Number of heatwave days (daily average temperature above 25°C)

According to the FORESEE average, the number of annual heatwave days is projected to increase by ~3.4 days per decade under the optimistic scenario and by ~4 days per decade under the pessimistic scenario, regardless of whether considering the periods between 1971 and 2070 or between 2001 and 2060. From the current value of around 13,3 days per year, the number of heatwave days is expected to rise to ~26.3 days per year under the optimistic scenario and to ~29.1 days per year under the pessimistic scenario for the 2041-2060 period. (The IPCC Atlas does not provide a variable for the number of heatwave days.)

Number of days with heavy rainfall

The number of heavy rainfall days – defined as days with precipitation exceeding 30 mm – is projected to show an increasing trend of ~0.1 days/decade, according to the FORESEE average in both the optimistic and pessimistic scenarios, based on both periods from 1971 to 2070 and 2001 to 2060 (*Figure 5.2.2-2.*). Currently, there are ~2 heavy rainfall days per year, and this number is expected to remain roughly the same during the 2041-2060 period.



(a) (b)

Note: The symbols in the figure represent 20-year averages, indicating trends rather than specific years. The FORESEE database's average, minimum, and maximum values are represented in black, blue, and red, respectively.

Figure 5.2.2-2. The number of days with heavy rainfall, i.e., the number of days with precipitation exceeds 30 mm in the Paks area in (a) the optimistic and (b) the pessimistic scenario

Number of days with extremely heavy rainfall

The number of extremely heavy rainfall days – defined as days with precipitation exceeding 44 mm – is projected to show an increasing trend according to the FORESEE average under both the optimistic and pessimistic scenarios, based on both periods from 1971 to 2070 and from 2001 to 2060. Currently, the number of extremely heavy rainfall days is about 0.36 days/year, which is expected to increase between 2041-2060, but at a rate of only ~0.1 days per decade. (The IPCC Atlas does not provide a similar analysis.)

Number of days with wind gusts exceeding 85 km/h

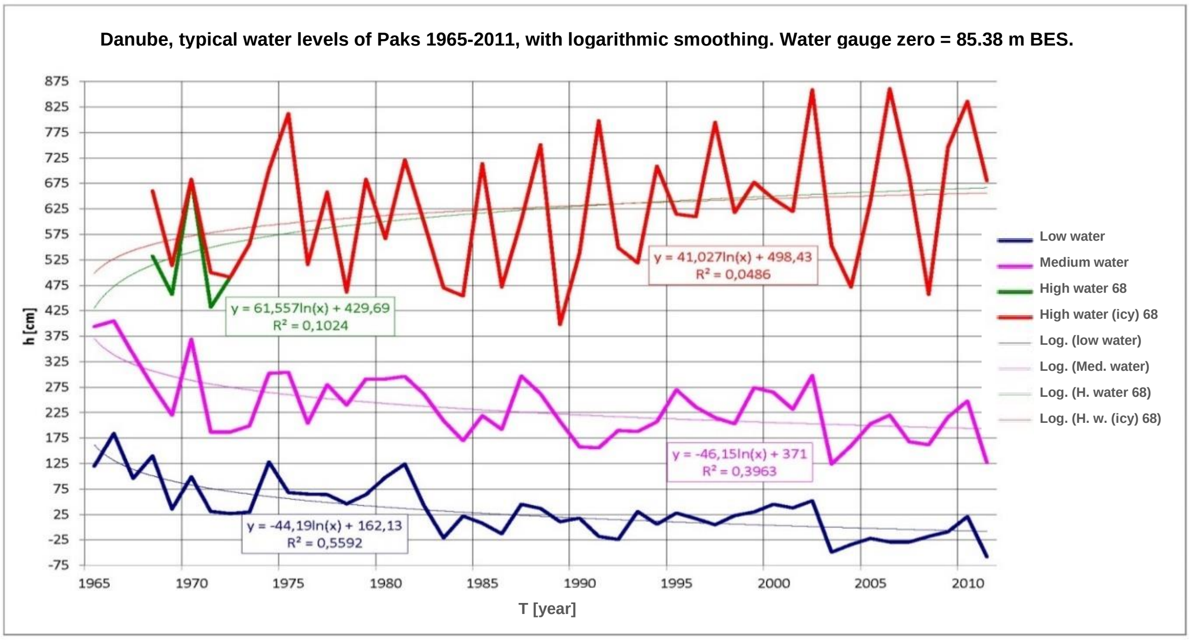
Days characterized by very strong wind gusts – specifically those with peak gusts exceeding 85 km/h – show only negligible decadal variations according to the averages of the non bias-corrected Euro-CORDEX models, based on both optimistic and pessimistic scenarios, for periods between 1991 and 2060. The uncertainty of projections is underscored by the fact that, on the average, the models typically estimate the number of such days to be between 0 and 1 during the period from 1991 to 2060.

Trends of discharge and water level of the Danube upstream of Paks

Climate change affects the hydrological cycle of the Danube River Basin, which in turn influences the discharge and natural water levels observed upstream of the Paks Nuclear Power Plant. The impacts of climate change on the Danube River Basin may vary across different regions but remain fundamentally important for several sectors, including agriculture, forestry, navigation, hydropower, and water management. The total catchment area of the Danube exceeds 800 000 km², encompassing a complex hydrological system.

The most significant findings concerning discharge and water levels, as determined in the 2012 environmental impact assessment of the Paks II. Nuclear Power Plant, can be summarized based on the available data and trend analysis results. Between 2000 and 2010, both extreme low and high levels increased in frequency. From 2003 to 2009, water levels of -17 cm (85.21 m BES) or lower were recorded every year. Conversely, in 2002, 2006, and 2010, flood peaks approached previous record high water levels, reaching between +836 and +861 cm (exceeding or equalling 93.74 m BES). Taking these into account, the site of the nuclear power plant was considered to be safe from a flood protection perspective at the period under review.

The hydrological characterization conducted as part of the final report of the environmental impact assessment preparatory investigation program for Paks II., completed in 2013, examined critical low, medium, and high stages using statistical methods, considering events recurring every 20 000 years. The forecast horizon for water levels corresponded to the end of the planned operational period of Paks II. (2120) at 1531.3 river km (Paks gauge), utilizing water level data from 1876 to 2011. *Figure 5.2.2-3.* illustrates the logarithmic smoothing applied in the study.



Source: Compilation and execution of sectoral investigation and evaluation programs underpinning the environmental impact assessment study, Final report, Hydrological characterization of the site, condition of the Danube riverbed and banks (11 June 2013)

Figure 5.2.2-3. Logarithmic smoothing of changes in low, medium, and high water levels at 1531.3 river km of the Danube

Based on previous forecasts of the study, a decreasing trend was predicted for low and medium water levels up until 2060 at all probability levels, while an increasing trend was estimated for high water levels (Figures *5.2.2-4.* and *5.2.2-5.*). By 2060, the estimated low water level returning every 20 000 years (p=0.005%) was estimated to be ~83.00 m BES, the estimated mean water level was ~89.54-84.40 m BES, while the estimated high water level not affected by ice was estimated to be ~97.34 m BES based on the inspection results at the time.

Independent forecasts of changes in water flow were made by Stagl and Hatterman (2016)[8]. Five different global climate models were used in their study. The reference period for the changes projected for the period 2031-2060 is 1971-2000. For the three different scenarios they inspected (RCP2.6, RCP 4.5, RCP 8.5), the projected annual runoff in the Paks section will show a decrease of around -10% and -15%, respectively, compared to the reference period from 2031 to 2060 (*Figure 5.2.2-6.*). For low water discharges (Q90%) a decrease of ~ -10% is expected, while for high water discharges (Q2%) a change of ~ -15% may happen in the power plant section, but in some Hungarian sections of the Danube a decrease of up to -50% can also be observed. In the Paks section, the seasonal variation for spring, summer and autumn is in a similar range (-10% to -20%), but for the winter the variation is close to 0%.

Low water levels can be significantly influenced by dredging activities, which are expected to decrease. Projections indicate that both low and high flows will show a declining trend compared to the reference period (1971-2000), with reductions ranging from -2% to as much as -50% between 2031 and 2060.

The results of the studies regarding the discharge and water level predictions are going to be revised and updated if needed in the following study program.

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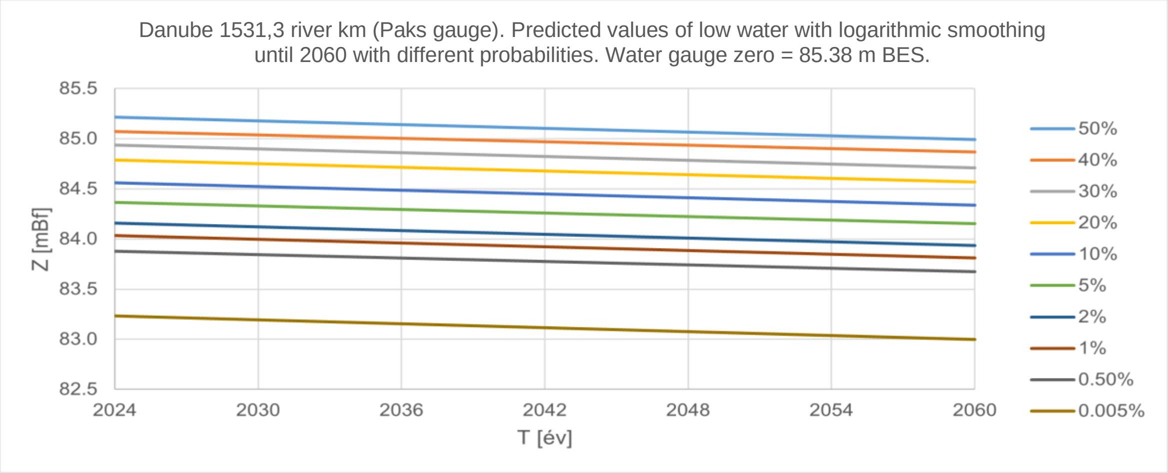
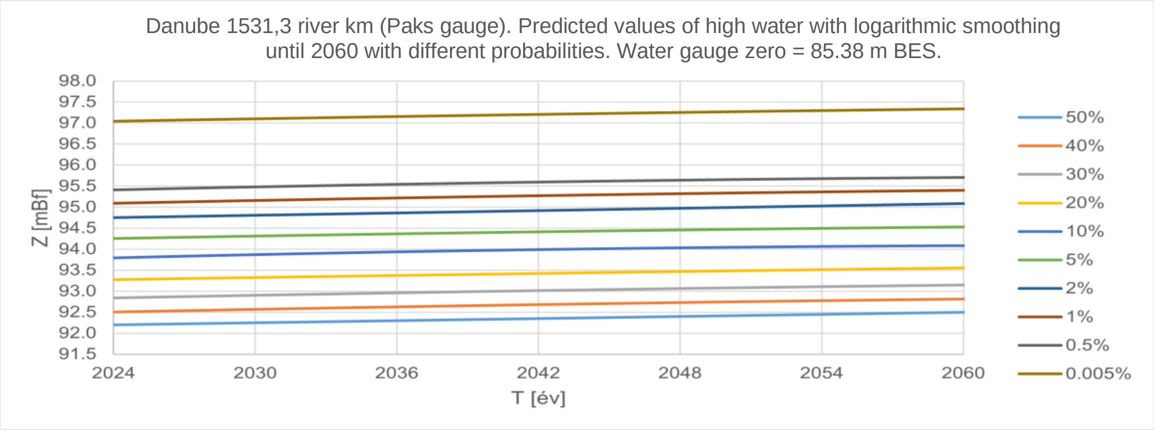
[8] Stagl, J. C. and Hattermann, F. F. (2016) ‘Impacts of Climate Change on Riverine Ecosystems: Alterations of Ecologically Relevant Flow Dynamics in the Danube River and Its Major Tributaries’, Water (Switzerland), 8(12). doi: 10.3390/w8120566.



Source: Compilation and execution of sectoral investigation and evaluation programs underpinning the environmental impact assessment study, Final report, Hydrological characterization of the site, condition of the Danube riverbed and banks (11 June 2013)

Figure 5.2.2-4. Forecast of low water levels at 1531.3 river km of the Danube



Source: Compilation and execution of sectoral investigation and evaluation programs underpinning the environmental impact assessment study, Final report, Hydrological characterization of the site, condition of the Danube riverbed and banks (11 June 2013)

Figure 5.2.2-5. Forecast of high water levels not influenced by ice at 1531.3 river km of the Danube

Trend of water temperature in the Danube upstream of Paks

While the withdrawal of freshwater from the Danube for use in the power plant does not cause significant changes in water quantity, the return of used cooling water impacts flow and sediment conditions, water quality, ecological conditions, and water temperature in the Danube.

According to the final report[9] of the hydrological characterization prepared under the investigation program establishing the environmental impact assessment of Paks II., the water temperature of the Danube can reach 25°C in summer. Observations of the climatic state at the time of the study showed that the highest annual maximum was 25.4°C, with a 1% exceedance probability, i.e., would have occurred once every 100 years. However, since the study of 2013, there have been more observations when the water temperature reached above 25°C between 2018 and 2024. Due to climatic variability, a maximum water temperature exceeding this value may occur with an increasing trend. The increase in annual maximum water temperature is consistent with the rise

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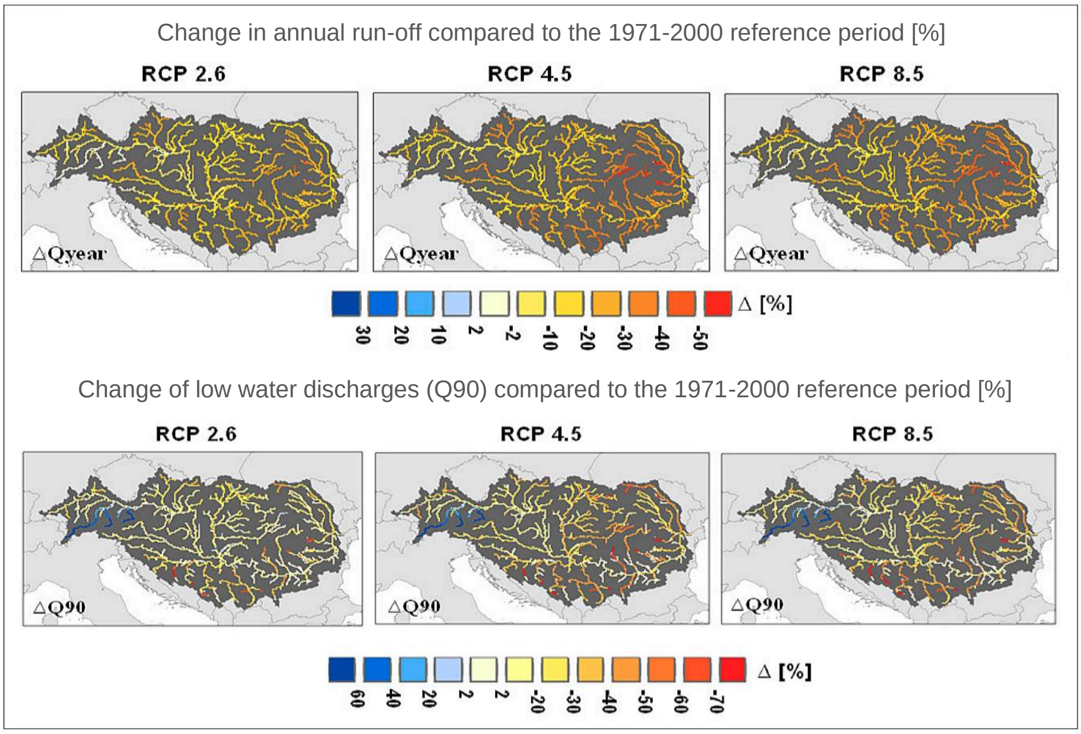
[9] Compilation and execution of sectoral investigation and evaluation programs underpinning the environmental impact assessment study, Final report, Hydrological characterization of the site, condition of the Danube riverbed and banks (11 June 2013)

in air temperature. If the climate warms by 1.5°C, the annual maximum water temperature with a 1% exceedance probability could rise from 25.4°C to 27.0°C between 2020 and 2040 according to the study, with further increases expected by 2060.


Change in annual run-off compared to the 1971-2000 reference period [%]

Change of low water discharges (Q90) compared to the 1971-2000 reference period [%]

Note: The maps show the relative changes in the near future (2031-2060).
(Source: Stagl and Hatterman, 2016)

Figure 5.2.2-6. Anticipated Changes in Annual and Low Flow Rates for the Main Rivers of the Danube Basin Compared to the 1971-2000 Period (%)

At the time of the study, historical coincidences of low discharges (Q<1100 m^3/s) and high water temperatures could rarely be observed. The probability of coincidence between discharges below 1100 m^3/s and Danube temperatures above 22-25°C was low, at 1-3%. Danube water temperatures exceeding 25°C rarely occurred before 2013, but are nowadays increasingly more often observed.

Strong turbulent fluctuations in water temperature can be detected near the discharge of the warmed cooling water returned into the Danube. The higher volume of cooling water and thus the heat load, the lower the cooling of the plume up to a given section (+500 m). At low water discharge (800 m^3/s) and hot water input of 100 m^3/s, the cooling rate is reduced (to 2.5°C) due to the low water level and the low velocity in the plume. New model studies will be performed to determine the relevant hydro-meteorological conditions.

5.2.3. Impacts of subsequent service life extension of the Power Plant on the meteorological and climatic conditions

The climatic impact of the nuclear power plant on the air environment is determined by two factors. One is the plant's heat load (heat emissions through the cooling system, water vapor resulting from water cooling, heat load due to the higher temperature of the Danube). The other is the existence of the site itself, more precisely the so-called urban (city) effects due to the built-up areas. The first component is typical of all thermal power plants, while the second is characteristic of any facility with extensive built-up areas.

5.2.3.1. Impacts arising from the heat load on the Danube

Theoretical impacts of heat load

Heat and water vapour emissions through the cooling systems of once-through cooled thermal power plants can cause local variations of some climatic elements. The frequency of local fog formation can depend on the cooling process. The extent of the impacts is determined by the type of source combined with meteorological parameters. The results of measurements carried out in the framework of the site description program for the first service life extension, which targeted mesoclimatic effects, show that these effects locally only affect the immediate surroundings of the nuclear power plant and the close river valley due to the thermal load of the Danube. This is also confirmed by the fact that continuous meteorological measurements since the construction of the nuclear power plant have not shown any characteristic changes in the measured parameters compared to the nationally observed trends.

Independent operation of the Paks Nuclear Power Plant

In the environmental impact assessment related to the first service life extension of the nuclear power plant, the potential meteorological impact of the heat load on the Danube was examined on two spatial scales and using two methods:

- Local microclimate impacts, which can be felt above the water and directly along the shore. The detectability of these impacts was assumed in terms of air temperature and humidity. The study examined how big and significant these impacts are.
- The environmental meso-climatic impacts are those (potential) climatic impacts that may occur beyond a few kilometres from the arrival and persistence of the heat surplus in the Danube as a line source. It was assumed that if these impacts occur at all, they would be closely related to the weather conditions, large-scale wind direction, stability etc. These impacts were studied even by modeling.

It was established as a result of the measurement program completed that the heat load of the nuclear power plant is only detectable near the warm water channel. In most measurements, the temperature differences measured upstream and downstream of the warm water channel remained below 1°C. At the measurement station set up 200 meters downstream of the warm water channel, the monthly and annual temperature data did not show any impact of the heat load.

Based on the conducted measurements and modelling, it was established that the heat load caused by the return of heated cooling water from the nuclear power plant into the Danube, although detectable, does not represent a level of change in the atmospheric environment that would necessitate intervention. The differences pointed out:

- in climatic averages near the right bank of the river, even near the mouth, are smaller than the natural climatic differences often observed between two lowland stations within the country.
- The largest observed and modeled impacts, for most of the year, are smaller even on the right bank of the river than the daily temperature variation that characterizes typical weather variability, and certainly smaller than the largest day-to-day weather changes.
- No warm water impact could be detected on the left bank by measurement, and the breakdown according to weather conditions showed that the detected impact could not be attributed to the crossing impact of warm water but to other, independent microclimatic factors.
- The modeled warm water impact, which can be observed even a few kilometers from the river in certain weather situations, can at least partly be attributed to the idealized, flat surface. It would probably be smaller alongside the protective and alternative microclimate-creating impact of natural vegetation cover, as it exceeded the impact in question on the left bank and, at measuring points further from the mouth, even on the right bank.

These circumstances indicate that the surrounding ecosystems have had to adapt to far greater differences in both climatic and weather terms for their survival than the warm water impact detected by direct measurements and modelling. At the same time, the observed experiences and the more significant differences with the idealized surface strongly indicate that in the region, it is necessary to protect the natural vegetation that also filters and reduces climate-modifying impacts, regardless of the existence of the nuclear power plant.

The study conducted using two independent methodologies provided a clear determination of the magnitude of the heat load caused by the return of heated water from the operation of the nuclear power plant. The resulting impact is lower than three natural effects (regional climatic differences, daily weather changes, and certain competing microclimatic differences) to which ecosystems have so far been able to adapt. Based on the study results, no further investigations were justified regarding the heat load caused by the warm water.

Regarding the independent operation of the Paks Nuclear Power Plant, no changes in the meso-climate characteristics resulting from the Danube heat load during the extended service life of the plant are anticipated based on currently available information.

The combined operation of Paks Nuclear Power Plant and Paks II. Nuclear Power Plant

Paks II. Nuclear Power Plant will have an once-through cooling system similar to the Paks Nuclear Power Plant. The plan is to establish what is called a peak cooling system that will provide after-cooling for the heated water along the new warm water channel of Paks II. The peak cooling system is designed to ensure that, in the event of high water temperatures in the Danube, the temperature of the cooling water returned is reduced at the discharge point to the upper temperature limit of 30°C specified by regulations for the cross-section located 500 m downstream of the discharge point. The cooling tower cells of the peak cooling system will not operate continuously, they will be activated only during critical periods and gradually. Their total operating time is expected to be limited to short periods within a year. However, it should be considered that the planned peak cooling system will emit large amounts of water vapor during heat wave periods, which is expected to influence the microclimate. The emission of water vapor is likely to periodically affect the amount of solar radiation, promote fog formation (although this is less typical in summer when the cooling system operates in warmer periods), and affect temperature and temperature fluctuations.

The climatic effects resulting from the heat load on the Danube due to the return of heated cooling water from the two nuclear power plants will likely continue to be detectable locally at the power plant site and in the immediate vicinity of the warm water channels. However, no meso-climatic changes are expected to result from this, even with the doubled amount of heated cooling water being returned. The detectability of the impact is likely to remain small, similar to the current state.

5.2.3.2. Thermal impact due to built-up areas

The construction of the Paks Nuclear Power Plant and its associated facilities significantly altered the terrain surface at the time of their establishment. Former agricultural areas and biologically active surfaces were built in, which notably affected the area’s albedo, evaporation conditions, and biological activity.

As a consequence of the differences in energy balance between urbanized areas (generally “urban”) and natural surfaces, the average temperature in these areas is higher than in neighbouring areas. During the environmental impact assessment for the first service life extension of the Paks Nuclear Power Plant, this temperature difference was estimated to be negligible, just a few tenths of a degree Celsius.

Activities conducted at the site and its surroundings (such as vehicle movement, emissions of air pollutants, heat release etc.) and the facility's operations acted as additional influencing factors. The variation in surface topography and the different thermal properties compared to surrounding areas could also result in changes in local air circulation and movement, which could consequently alter evaporation and air humidity conditions on a sub-regional scale.

Given that the Paks Nuclear Power Plant has been in operation for decades, it is likely that the power plant will not trigger any previously unobserved effects, meaning there is no need to anticipate changes in the state and functions of the area. In case of the independent operation of the Paks Nuclear Power Plant with an extended service life, no increase in current land use or new constructions can be expected. The additional independent operation of the Paks Nuclear Power Plant will not significantly affect the site's meteorological and climatic conditions due to the nature of the infrastructure. This will not change even as climate change progresses. However, the strengthening of the urban heat island effect, which is already present, can be expected due to general warming.

With the implementation of the Paks II. Nuclear Power Plant, the unbuilt and vegetation-covered area on the Paks site will further decrease, thus intensifying the urban heat island effect, even outside the context of climate change. It is important to note that the reduced evaporative capacity of the soil-vegetation system is also a clear consequence of increased built-up areas, which makes the surroundings of built-up areas drier. In this context, however, the evaporation-based cooling system planned for Paks II. could partially be interpreted as compensating for some of the evaporative deficit resulting from the increased urbanisation.

5.2.4. Assessment of the exposure and sensitivity to climate change

5.2.4.1. Methodology of the study, applied approach

It is a general principle that adaptation to a more extreme climate resulting from the climate change process, i.e., conscious adaptation to the future climate, must be enforced during the planning and implementation of various projects. Of all project types, the infrastructure development projects – primarily due to their planned lifespan – are perhaps the ones the most exposed to future climatic conditions.

The expectation at the European Union level is that a climate resilience assessment be conducted for all infrastructure investments planned for a time horizon of at least five years. The assessment helps identify infrastructure developments that involve significant greenhouse gas (GHG) emissions or are particularly vulnerable to future climatic conditions, thereby allowing project planners to integrate, by taking into account the anticipated effects and risks of climate change, such supplementary measures into their projects that are indispensable to ensure that the created infrastructure can operate cost-effectively and fulfil its intended function in the long term.

The study on the Paks Nuclear Power Plant's exposure and sensitivity to climate change, related to its subsequent service life extension, was conducted on the basis of the Climate Resilience Guidelines prepared and issued on behalf of the Prime Minister's Office (February 2022), using the standard climate resilience assessment method and steps defined therein. The study comprises two interrelated but distinct parts:

1. Climate neutrality sub-assessment: evaluating the expected changes in GHG emissions resulting from the project.
2. Climate adaptation sub-assessment: assessing the project's adaptation to climate change.

The objectives of these assessments are to identify high-risk infrastructure developments that involve significant GHG emissions or are particularly vulnerable to climatic impacts, and to encourage the integration of climate protection and adaptation considerations during project planning and implementation. Both sub-assessments of the standard climate resilience assessment consist of two interrelated phases: a screening phase and a detailed analysis phase. The latter is only required if deemed justified based on the results of the screening phase.

According to the guidelines, infrastructure includes network infrastructures indispensable for the functioning of the economy and society, including energy infrastructure, such as power plants. Since the planned subsequent service life extension of the Paks Nuclear Power Plant, which is part of the national electricity infrastructure, is for 20 years, a climate resilience assessment (standard version) has been conducted based on the guidelines.

The goal of the climate neutrality sub-assessment is to determine whether the expected change in annual GHG emissions due to the planned development aligns with the emission reduction targets set by the European Union and Hungary as part of the EU. Due to the nuclear technology employed, no GHG emissions are released into the atmosphere from the Paks Nuclear Power Plant's electricity generation activities. Traditional combustion equipment is not used, nor are any fuels burned that would result in large amounts of exhaust fumes or the accompanying GHG emissions into the atmosphere. From this perspective, the subsequent service life extension will not result in any changes regarding GHG emissions compared to the current situation.

However, related to the operation of the nuclear power plant, several devices that primarily serve for safety purposes (e.g., diesel generators for emergency power) and result in GHG emissions can be found on the power plant site. These devices operate for limited hours annually, primarily for testing purposes. Therefore, no significant change (increase) in GHG emissions in relation to such sources is expected during the period of the planned service life extension compared to the current situation.

Other significant GHG emission sources related to the nuclear power plant's operation include road transportation (passenger and freight transport). The demand for road transport is not expected to grow considerably from 2032 onwards for the extended service life of the nuclear power plant, considering that no significant increase in passenger and freight transport needs is assumed.

The climate neutrality sub-assessment was completed in consideration of the above, based on the GHG emissions that can be taken into account from the current operation of air polluting point sources included in the nuclear power plant's effective environmental permit and its amendments on the one hand, and from the current vehicle traffic related to the operation of the plant on the other.

5.2.4.2. Climate neutrality sub-assessment

The climate neutrality assessment consists of the following two stages with varying levels of detail:

1. Screening phase: As part of the screening, it can be determined, based on a preliminary list (Annex 1 of the Climate Resilience Guidelines) whether, in the knowledge of the project's sectoral classification and purpose, the infrastructure developments implemented under the project are likely to result in significant changes in GHG emissions.
2. Detailed climate neutrality analysis: This is only required if the results of the screening phase suggest that the extent of GHG emissions directly or indirectly caused by the infrastructure development could exceed 20 000 tons of CO_{2eq}/year.

The nuclear power plant' service life extension is not among the activities listed in Annex 1 of the guidelines, which would result in significant changes in GHG emissions, and thus, a detailed climate neutrality assessment is not required. But to verify this, activities associated with the plant's operation that result in GHG emissions were identified, and the emissions from such activities were calculated.

Related to the Paks Nuclear Power Plant's operation, GHG emissions result from the annual test runs of diesel generators (air pollutant point sources) located on the plant site as well as road passenger and freight traffic associated with the plant's operation, involving vehicles with internal combustion engines.

The total annual GHG emissions (CO_2) from the power plant's operation are as follows: 101.26 t/year (air pollutant point sources) + 10 038.83 t/year (transportation) = 10 140.09 t/year. A similar value is likely for the years of the nuclear power plant's subsequent 20-year service life extension. Since the global warming potential (GWP) value for CO_2 is 1 (t_{CO2}/t_{GHG}), the value expressed in carbon dioxide equivalent (CO_{2eq}) is: E_{total} (t CO_{2eq}) = $GWP_{CO2} \cdot E_{CO2}$ (t) = 10 140.09 t/year.

Therefore, no GHG emission value exceeding the threshold of 20 000 t CO_{2eq} per year, as specified in the guidelines, is expected from the current operation of the nuclear power plant or its operation following the implementation of the subsequent service life extension project.

Based on the above, the subsequent service life extension of the Paks Nuclear Power Plant will not result in a significant change in GHG emissions, and thus, no further studies or detailed climate neutrality analyses are required.

5.2.4.3. Climate adaptation sub-assessment

The climate adaptation assessment consists of the following two stages:

1. Screening phase (examining the Impact of climate change on infrastructure):

   The purpose of the screening phase is to determine what kind and extent of impacts climate change is expected to have on the infrastructure development implemented within the project.

   The screening itself is divided into three subprocesses which are:

   1.1. Examination of climate exposure of the project site.

   1.2. Determining the sensitivity to climate change in terms of the project’s content and expected outcomes.

   1.3. Identifying the impacts of climate change on the given infrastructure development and its sustainability based on the results of the previous two sub-assessments.

2. Detailed analysis phase (risk assessment of infrastructure against climate change, identification of adaptation measures):

   This phase is only required if the screening phase results suggest that climate change may have a significant impact on the project’s implementation and the operation of the created infrastructure. The assessment includes examining the likelihood of the occurrence of significant climate change impacts identified during the screening phase and defining adaptation measures necessary to improve resilience.

Out of the methodology and specific implementation criteria of the climate adaptation sub-assessment conducted for the Paks Nuclear Power Plant's service life extension, the following ones can be highlighted:

- As it is an existing facility, there are no significant construction activities to consider, and therefore, there are no associated GHG emissions.
- As there is no need for high-cost construction works, the project’s return on investment is assured even under extremely unfavorable conditions.
- The nuclear power plant's detailed site assessment and evaluation were carried out using site-specific data, in accordance with nuclear regulations, and with the work conducted during the preparation of the PCD.
- As a result of the detailed site evaluation required for nuclear licensing, during the examination of the site’s exposure, several climate change impacts can be excluded from further study based on a justified “irrelevant" classification.
- In addition to the climate change impacts identified in the Guidelines, further nuclear power plant-specific climate change impacts were also examined.

During the screening phase, the following climate change impacts were found to be relevant for the site’s climate exposure assessment, with low expected current and future impacts:

- Based on the examination following the criteria outlined in the Climate Resilience Guidelines:
  - expected change in the average annual temperature (slow increase),
  - expected change in summer average temperature,
  - expected change in the number of hot days,
  - increase in the number of heatwave days.

- Based on specific nuclear plant specific considerations:
  - decrease in the water flow of Danube River due to the increased length of dry periods in the catchment area.
  - increase in the temperature of Danube River.

Based on the above, two impact groups were identified, and the following conclusions could be drawn during the sensitivity analysis of the facility:

- The facility is not sensitive to the group of climate change impacts related to increasing air temperatures. These impacts have been managed during the operation of the facility, and available forecasts do not indicate changes that would hinder the management of these impacts in the future.
- An ultraconservative estimate was made for the group of climate change impacts related to the reduction in the cooling potential of Danube River, classifying the potential risk to the facility as "small," using the categories provided in the guidelines, based on current operational practices.

The assessments conducted as part of the screening phase show that none of the expected impacts have high consequences, and therefore, no further detailed climate adaptation analysis is required, following the guidelines' recommendations.

While the study confirmed the nuclear power plant's climate adaptation compliance, individual analyses also indicated that, from an economic perspective, significant differences could still arise in the management of climate change impacts classified as "small" because of the high specific performance of the nuclear power plant units and the exceptional efficiency of the subsequent service life extension. Therefore, in the case of appropriate cost-benefit ratios, it may be advisable to prepare for managing extreme situations beyond the climate adaptation study’s acceptance criteria if it is economically justified and technically feasible. Considering these factors, the following optimization recommendations can be made:

- For the group of climate change impacts related to increasing air temperatures, it is recommended to create, review, or optimize operational continuity plans that optimize technological cooling capacities for extreme high air temperatures, especially when coupled with extreme high water temperatures in Danube River, ensuring the necessary climatic conditions for the operation of the equipment.
- For the group of climate change impacts related to the reduction in the cooling potential of Danube River, it is recommended to conduct analyses and to implement measures to optimize the number and extent of power reductions required to protect the Danube from thermal stress.

Overall, it can be stated that the subsequent service life extension of the nuclear power plant is justified from a climate protection perspective since, in line with EU and national energy and climate strategies, the nuclear power plant's subsequent service life extension, also including related activities, involves low GHG emissions during its implementation, as it extends the production capability of an existing facility. Besides, it is also significant from a climate protection perspective that the nuclear power plant, even during the extended service life, can continue to operate as a facility with outstanding climate protection characteristics, thanks to the very low carbon footprint per unit of electricity generated by the nuclear power plant. The analysis conducted confirms that the facility's climate adaptation characteristics are exceptional, and the robust construction of the nuclear power plant and its significant safety reserves are also crucial for adapting to the impacts of climate change, alongside other human and natural hazards.

5.2.4.4. Impact of the planned activity on the adaptability of the presumed impact area to the climate change

Adaptability to climate change refers to a system's ability and preparedness to prepare for climate change, mitigate potential damages, manage the consequences of occurring events, and adjust to changes. In evaluating the impact of a planned activity on the adaptability of a given area, it is essential to assess whether the activity studied affects the vulnerability and adaptability of the assets and infrastructure in the vicinity. A specific activity may alter the microclimate, modify wind channels, or impact surface or groundwater resources. It is crucial to examine whether the planned investment project may increase the frequency of risks related to climate change or the severity of their consequences.

The presumed impact area of the environmental effects resulting from the operation of the Paks Nuclear Power Plant (within approx. 10 km radius) extends across Tolna and Bács-Kiskun Counties. The affected area is predominantly agricultural, with the agricultural sector being the primary land user, and sylviculture and forest management as the second most significant sector. The majority of the affected settlements are villages with populations ranging between 450 and 4000 inhabitants, characterized by rural, single-family housing with a high proportion of green areas. Exceptions include two small towns, Paks, with a population of 17 827, and Kalocsa, with a population of 14 619. Even in these towns, large urbanised areas with densely built-in areas, high buildings or extensive paved surfaces are not typical, with the exception of a few housing estates, a small-town, suburban environment is predominant. In terms of infrastructure and industry, the town of Paks, the power plant site, and the Paks Industrial Park are noteworthy. Additionally, agricultural processing industries are significant in the region. The area is characterized by transport infrastructure (primarily the road network, including main road No. 6 and the M6 motorway, railroads, and the Danube as a waterway) and the electric transmission network.

The objectives and envisaged measures for adapting to climate change are outlined in the county climate strategies, taking into account the sensitivity and vulnerability of each county's territory to the consequences of climate change.

According to Tolna County’s climate strategy, factors contributing to the county's vulnerability to climate change include drought (impacting agricultural production), heatwaves (affecting society and healthcare), storms (threatening built environments), water-related hazards (e.g., flash floods, water erosion), and threats to natural assets (biodiversity loss).

The climate strategy also highlights that the investment related to the extension of the Paks Nuclear Power Plant can significantly influence the anticipated negative processes associated with climate change in Tolna County into a positive direction, thanks to the positive effects on the county's socio-economic situation.

As part of the climate strategy, Tolna County's comprehensive climate protection objectives include establishing a county-level climate protection institutional system and securing its financing. The mitigation goals, aimed at reducing the emission of GHG causing climate change, include:

- Increasing energy efficiency to reduce emissions,
- Increasing the share of renewable energy sources in the local energy structure,
- Reducing CO_2 emissions that originate from from transportation,
- Expanding forested areas.

The adaptation and preparedness goals of the county’s climate strategy include:

- Comprehensive adaptation and preparedness objectives (e.g., increasing the proportion of areas protected against drought, reducing vulnerability to water damage, protection against heatwaves, reducing the vulnerability of built environment, expanding green areas).
- Special adaptation and preparedness objectives (e.g., assessing the vulnerability of natural and landscape values, creating conditions for adapting to climate change in wine regions).
- Climate awareness and educational goals (forming climate-conscious consumer behavior, expanding knowledge on adaptation, raising awareness about reducing GHG emissions, strengthening the climate-conscious communication of county government.

According to the climate strategy of Bács-Kiskun County, climate change primarily manifests through increasing water shortages and intensifying summer heat in the county, affecting mainly the sectors and fields that are highly sensitive to these changes, such as agriculture, forestry, water management, disaster management, nature conservation, and public health. The climate strategy sets the following climate protection objectives:

- Emission reduction and decarbonization objectives (reducing GHG emissions from building operations, transportation, agricultural cultivation, and the waste sector).
- Adaptation and preparedness objectives (e.g., developing a heatwave action plan in settlements reduce public health risks, maintaining the natural condition of habitats under nature protection, water management practices aimed at water retention, soil tillage methods to improve soil organic content and water balance, ensuring that the health status of forests, partially renewing or comprehensively renovating the building stock.)
- Awareness-raising, climate-conscious, and institution development goals (e.g., improving the availability of up-to-date knowledge on climate change, preparating strategic plan that examines the anticipated local impacts of climate change and sets tasks for their prevention and adaptation to them, increasing the number of businesses engaged in environmental and/or climate protection research and development activities, sharing knowledge related to climate-conscious consumption and lifestyle with the population).

Regarding the additional service life extension of the Paks Nuclear Power Plant, it can be stated that the currently existing environmental impacts are expected continue. The planned activity does not require the acquisition of additional land, the construction of new structures or buildings, and thus, the area of built-up and paved surfaces will not grow. The planned activity does not involve the use of green areas or forests, meaning that the plant's continued operation will not affect the region’s GHG absorption capacity.

The nuclear power plant site is not located in an urbanised, densely built-up environment where the effects of climate change would pose significant problems, and therefore the heat island effect typical of a built-in site is not considered significant. As no new structures are required, the area’s wind conditions and shading characteristics will not change compared to the current situation. The climatic impacts of the plant's operation are detectable but remain local, and meso-climatic changes are not anticipated.

Regarding water usage, withdrawals, and water resources, the plant's service life extension will not result in any changes compared to the current state. The subsequent service life extension will not change the run-off conditions at the power plant site and its surroundings, given that the planned activity will be carried out on the existing site, with the existing structures, equipment and infrastructure elements.

The nuclear power plant's electricity generation technology does not result in any GHG emissions to the atmosphere, thus the continued operation of the nuclear power plant will contribute significantly to the long-term sustainability of electricity generation without GHG emissions.

The sensitivity of regional infrastructure elements (transport, electricity transmission lines, other industrial activities) and their adaptability to climate change will not be affected by the subsequent service life extension of the nuclear power plant.

However, the continued operation of the plant provides reliable, stable, and predictable baseload electricity generation to meet the growing demand for electricity. By continuing to operate, the Paks Nuclear Power Plant will contribute to increasing the ability to adapt to the anticipated impacts of climate change at national level, and through its industrial activity and social engagement, the company can also take part in raising awareness and maintaining the economic strength of the region in the long term.

The service life extension of the Paks Nuclear Power Plant does not conflict with the above objectives and measures for adaptation set out in the Tolna and Bács-Kiskun County climate strategies, it does not hinder their implementation, and it does not have a negative impact on the climate change adaptation capacity of the assumed impact area.

5.3. Assessment of impacts on surface waters

This chapter presents the impact of the nuclear power plant on surface waters. It characterises the Danube between Dunaföldvár and Hercegszántó and the ecological baseline status of the surrounding surface water bodies. It then assesses these according to the Water Framework Directive (WFD) criteria based on available data. An assessment of the expected environmental impacts, with emphasis on the thermal stress on surface waters, has been carried out in the light of both the physical, chemical and biological characteristics of the water.

5.3.1. Description of the base state

The WFD (Water Framework Directive) entered into force on 22 December 2000 (Directive 2000/60/EC). Hungary has transposed the provisions of the WFD and related directives and regulations into the Hungarian water management and water protection legislation, thus providing an important framework for environmental impact assessment and environmental evaluation. The measures needed to achieve the objectives are summarised in the River Basin Management Plans (RBMP) for all river basin districts. Hungary's current third RBMP (RBMP3) for the period 2022-2027 was approved by the Government Decision 1242/2022. (IV. 28.). The Danube River basin district is one of the four districts in Hungary, and its particular importance is due to the fact that the Danube is the largest river in Central Europe, and its ecological status is shaped by the impacts of the eight Danube countries concerned. Accordingly, cooperation between the member countries in the Danube river basin is governed by the international Convention on cooperation for the protection and sustainable use of the Danube River, promulgated by Government Decree 74/2000 (V. 31.) on the proclamation of the Convention on cooperation for the protection and sustainable use of the Danube River, created in Sofia on 29 June 1994. The Danube River Basin District Management Plan is developed and coordinated by the ICPDR (International Commission for the Protection of the Danube River).

Within the Hungarian sub-basin of the Danube, 378 river and 73 lake water bodies have been designated. The water bodies potentially affected by subsequent service life extension of the Paks Nuclear Power Plant are presented in *Table 5.3.1-1.*

5.3.1-1. Table: Water bodies potentially affected by the subsequent service life extension of the Paks Nuclear Power Plant

Name of water body	Water body VOR code	Type of water body
Danube, between Dunaföldvár and Sió mouth	AOC754	River
Danube, between the Sió mouth and the border	AOC755	River
Bogyiszlói-Holt-Danube (oxbow lake)	AIH051	Lake
Faddi Holt-Duna (oxbow lake)	AIH066	Lake
Tolnai-Északi-Holt-Duna (oxbow lake)	AIH136	Lake
Tolnai-Déli-Holt-Duna (oxbow lake)	AIH135	Lake
Grébeci-Holt-Duna (oxbow lake)	ANS503	Lake

The hydromorphological characterisation of the Danube section near the Paks Nuclear Power Plant as well as the physical, chemical, bacteriological and ecological characteristics of the potentially affected water bodies have been carried out. The WFD based assessment of the ecological status of the potentially affected water bodies were estimated by the biological elements such as phytoplankton, phytobenthos, macrozoobenthos and fishes. The data assessment was also carried out for zooplankton, as zooplankton are an important part of the food webs of both rivers and lakes, furthermore, they are good indicators of changes in nutrient regime (*Figure 5.3.1-1*).

Figure 5.3.1-1. Overview map of historical data of the chemical and biological elements under study

Hydromorphological characterisation of the Danube section near the site

The water level trends of the Danube, constructed using the time series of the annual characteristic water levels determined from the data observed at the Paks gauging station, are presented in *Figure 5.3.1-2.* for the period 1950-2023. The figure demonstrates that while the annual trend of the high-water levels remained relatively stable, there has been a notable decline in the low and medium water levels. The data revealed that the average of the minimum values over the last 10 years was -52 cm, and -18 cm over the 10 years previous to the past 10 years. This demonstrates a clear trend towards lower water levels, with the relevant values becoming increasingly smaller. The downward trends already observed for high, medium and low water levels seem to be gaining momentum. The trend line for medium and low waters has fallen by approximately 1.5 metres over the last 70 years of data.

The detailed study of the riverbed data available from 2005 show that the values of the wetted cross-section areas of the main river bed show an increase over the whole section and that the annual average of the calculated river bed level changes shows a slight decrease over the whole section. These results indicate a slight slowing of the deepening process. However, this process has the opposite sign in the Danube section upstream of the power plant, i.e., the deepening of the river bed in this section shows a slightly accelerating trend.

Based on available data, no dredging has taken place in the Danube stretch between 1560 and 1510 river km since 2011. Regulations on dredging remain unchanged. The positive impact of the cessation of dredging on the abstraction of water by power plants is supported by the available data, as the cessation of dredging reduces the rate of the steady sinking of the riverbed.

The status of the water bodies under examination, based on historic physical, chemical and bacteriological data

The heated water emissions from the Paks Nuclear Power Plant are a key factor in the environmental impact assessment process. The water temperature of the Danube is regularly measured at the 1531.3 river km gauging stretch at the Paks boat station, closest to the power plant site. The long-term (1946-2023) annual water temperature curve of the Danube is presented on the basis of available historical data (*Figure 5.3.1-3*). The highest measured water temperature in the period before the construction of the nuclear power plant was 25.2°C on 8th August 1971.

Since then, the Danube water temperature has continued to rise, with the current peak measured in 2018, when the annual maximum base temperature of the Danube was 27.03°C (*Figure 5.3.1-4*).

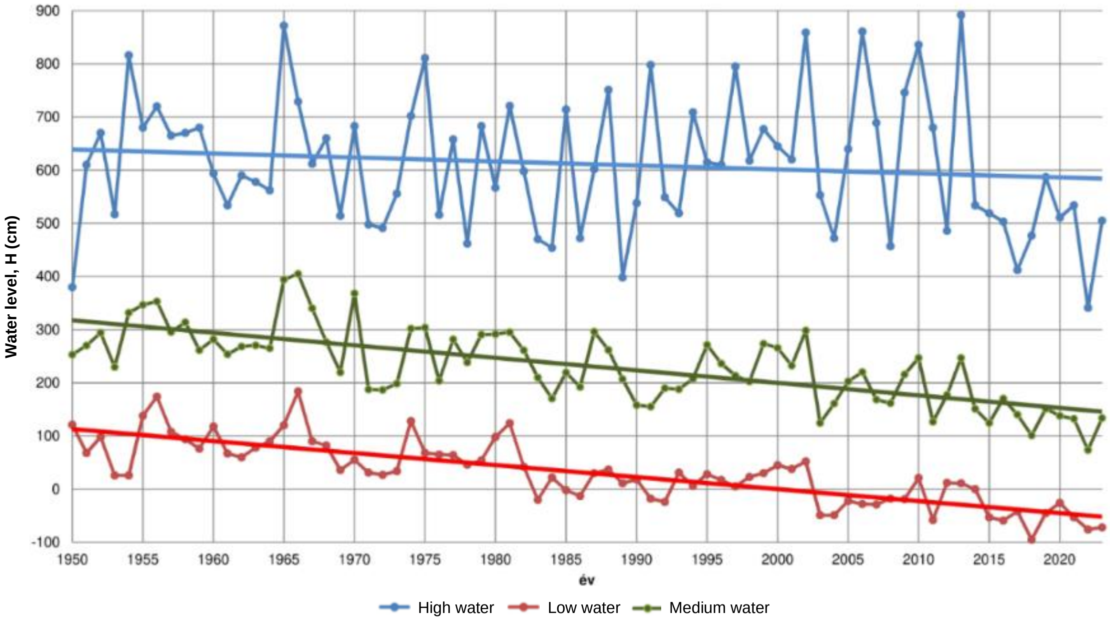


Figure 5.3.1-2. Trend lines of water levels based on data from the Danube at Paks gauging station

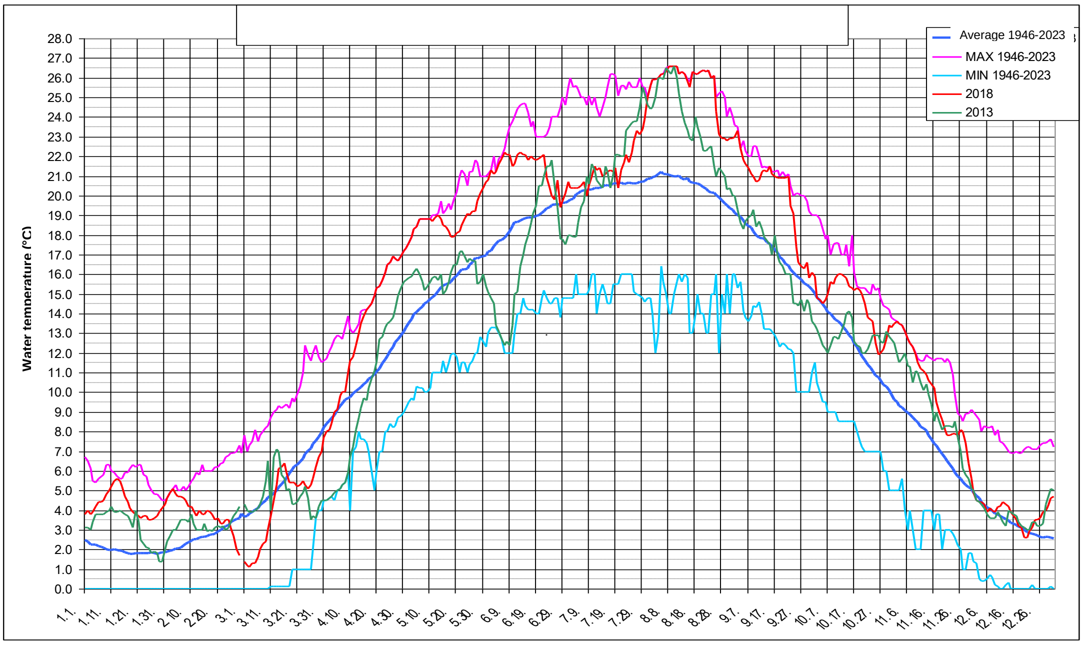


Figure 5.3.1-3. Statistical comparison of daily water temperature data for the 78-year period of the Danube at Paks with the years of 2013 and 2018

The chemical status of the Danube water bodies can be classified according to the WFD on the basis of available previous data. The two Danube water bodies being studied (VOR codes: AOC754 and AOC755) namely the Dunaföldvár-Sió Mouth and the Sió Mouth-Hercegszántó sections can be divided into four segments from classification point of view, from the discharge point of the warm water channel (warm-water channel) (*Table 5.3.1-2.*).

The evaluation of the historical data shows that the Danube sections studied were in excellent status in terms of salinity, metals, and specific pollutants, and good in terms of acidification status and oxygen balance. Differences were observed in terms of nutrients, with water body values in AOC755 in moderate status, which is due to the high nutrient content of the Sió River.

Sporadic information is available on the bacteriological status. The examined Danube sections (AOC754) is Class II (good) for Clostridium count, Class III (tolerable) for Coliforms and Class III-IV (tolerable-contaminated) for thermotolerant Coliforms.

The results did not show any correlation with the emissions from the Paks Nuclear Power Plant, the values in the upstream and downstream sections indicating a similar situation.

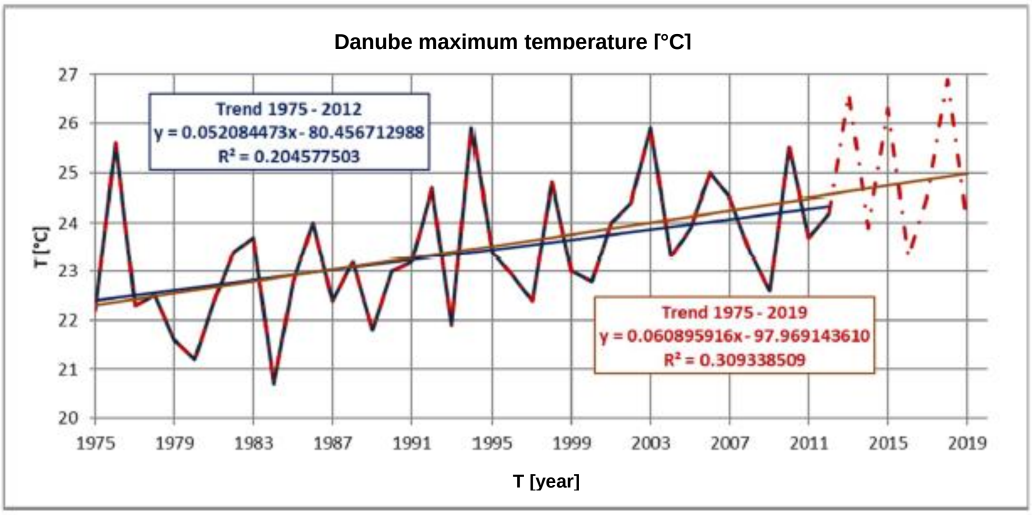


Figure 5.3.1-4. Maximum water temperatures of the Danube, 1975-2019

Table 5.3.1-2 Summary of physical, chemical status of the Danube according to criteria of WFD, based on previous monitoring results over the last decades

Danube segments concerned	Acidification status	Salt content	Oxygen balance	Plant nutrients	Metals	Specific pollutants (hazardous chemical elements)
Upstream segment 1560.6-1533.4 river km	good	high	good	good	high	high
Immediate- and medium-distant downstream segment 1526-1516 river km	good	high	good	good	high	high
Distant downstream segment 1506-1478 river km	good	high	good	moderate	high	high
Country border 1433 river km	good	high	good	moderate	high	high

Ecological status of the water bodies assessed based on existing previous data on biological elements

The phytoplankton-based ecological status of the potentially affected water bodies of the Danube is good, based on the assessment of previous data. Before 2009, the phytoplankton composition was only recorded on the basis of the percentage of higher taxonomic categories, which does not allow for a classification from a WFD point of view. However, the data leads us to assume that there has been no change in the level of higher taxonomic groups of phytoplankton. Centric diatoms (Centrales) remain dominant, while green algae (former Chlorococcales order), cryptomonads and pennate diatoms (Pennales) are subdominant. The results also show that there is considerable intra-annual variability in the ecological status. However, the potential for eutrophic, sometimes hypertrophic conditions to develop has decreased since 2010. Summer peaks have disappeared, with the highest biomass conditions developing in mid-spring. The nutrient level of the river has decreased significantly. Research on the impact of the Paks Nuclear Power Plant cooling water on phytoplankton has been carried out by providing metrics of phytoplankton biomass and phytoplankton composition. The results of the studies clearly show that the cooling water discharged has no detectable effect on the recipient phytoplankton communities. No trend-like changes were observed in the four pre-determined segments (1. upstream, 2. immediate downstream, 3. medium distant downstream, 4. distant downstream). The long-term changes observed for phytoplankton can be explained by decreasing nutrient level and water discharge. The results of the phytobentos analyses indicate that the two Danube water bodies in question are in good ecological status, based on multi-year averaged data values (AOC754=0.67; AOC755=0.68). The annual taxon composition of the community is significantly influenced directly (e.g., water velocity, flow conditions, etc.) and indirectly (e.g., transparency, nutrients etc.) by the annual flow conditions, in addition to the available nutrients and light. The year-on-year analysis demonstrates a persistent decline in the ecological status of the Danube section between Dunaföldvár and the Sió mouth (AOC754) throughout the early 2010s. The diatom-based ecological status has declined from a good to a moderate status. In the second half of the decade, no trend-like changes in water body were detected. The ecological condition of the studied Danube section ranged from good to moderate on an annual basis. Over the section between the Sió mouth and the country border (AOC755), the water body also generally qualifies as moderate to good status year on year. The data from previous studies on the effects of the nuclear power plant for the period 2008-2023 allows for a more detailed and comprehensive assessment. Based on multi-year averages, both the upstream and downstream segments are in good ecological status. Statistical evaluation of the historical data confirms that the impact of the discharge in the immediate downstream segment is detectable with regard to phytobentos. However, the impact does not extend beyond immediate segment (sample site at Uszód, the extent of the detected impact is around 2 km, which may be considered as a local effect.

Sporadic data is available on zooplankton in the Danube. The available data from the former studies on the river demonstrate that community structure indicators show a high degree of similarity in terms of spatial and temporal distribution of species abundance. The number of species present is almost identical, with a predominance of species that prefer eutrophic waters typical of the Danube. There is no clear trend in the number of individuals either in spatially or temporally different samples. Based on an analysis of previous research reports and historical data, it can be reasonably assumed that the discharge from the nuclear power plant has no discernible impact on the downstream zooplankton community in the Danube River. Local effects may occur at the point of discharge if emissions exceed 30°C.

The historical aquatic macroinvertebrate data indicate that the ecological status of the two examined Danube water bodies is moderate. A time-series analysis of the data revealed that water body AOC755 has a stable moderate status with minor fluctuations. In contrast water body AOC754 shows much greater variability, and despite an overall moderate status, several instances of poor and/or bad classifications have been recorded. The finer resolution, segment-level analysis carried out to assess the impact of the Paks Nuclear Power Plant did not show any class-level change in the downstream segments. However, the ecological analysis confirms that there is a significant difference among the community structure indicators of the upstream and immediate downstream segments in terms of abundance and diversity. This difference is not persistent, as it only occurs during certain periods. Overall, the impact of the heated cooling water from the nuclear power plant can be considered as local, with an extent not exceeding 2 km in the right-hand areas of the segment. The results also highlight that differences found using community structure indicators may be completely masked by abiotic environmental effects (water level, background water temperature) and variability in habitat conditions at the microhabitat level.

The results of the investigations show that a significant proportion of the macroinvertebrate taxa detected in the Danube sections studied are invasive, strongly and aggressively spreading alien species. This can be considered as one of the most important indirect effects of heated water discharge. At the same time, the number of protected species is also high, emphasising the importance of environmental protection on these lower reaches of the Danube, which is further highlighted by the advance of invasive species. The following protected species have been detected in previous investigations: *Borysthenia naticina (Valvata naticina)*, *Calopteryx virgo*, *Fagotia esperi*, *Gomphus vulgatissimus*, *Orthetrum brunneum*. The examined Danube section (AOC754) is part of the Natura 2000 network as a site of Community Interest (SCI) with the site code HUDD20023. Among the macroinvertebrate species, the *Unio crassus* is included in the site's conservation plan as a species of community interest listed in Annex II of Directive 92/43/EEC. Investigations prove that the species is present, but rare in the section.

Based on the assessment of the long time series data of the fish assemblages, it can be concluded that the ecological status of the Danube water body AOC754 directly affected by the discharge varies between good and moderate. Results clearly demonstrate that the moderate values are consistently associated with the years that can be characterized by low water levels. The next, downstream water body of the river (AOC755) shows similar wobbling of ecological status between good and moderate. The finer resolution analyses carried out on segment level prove that the discharged heated cooling water from the Paks Nuclear Power Plant into the Danube downstream of the discharge point does not cause statistically significant changes neither in the species composition nor in abundance of fish assemblages in the whole cross-section of the river. At the same time, the discharged warm water does not result a class-level change in the ecological status evaluated by fish assemblages even in the immediate segment downstream of discharge. However, the impact of the warm water discharge on the fish assemblages can be detected as a result of finer resolution ecological analyses, the abundance values show gradient-like changes in the downstream segments of the discharge in the affected right bank areas. The extent of this change justified in a statistical way is 2 km, however in the periods with exceptionally high background temperatures together with low water level, the length of the affected segment significantly enlarged, typically doubled. Overall, these analyses demonstrated that the effect of heated water discharge up to Δt_{water} =2.5°C has a detectable effect on the structure of the fish assemblages. The warm water discharge also represents a detectable change at the species level according to previous studies. The immediate downstream segment, mainly areas with lower flows and shallower water including oxbow lakes, can be a hotspot for releasing of several invasive, pioneer fish species as an indirect effect of the heated cooling water discharge.

Based on its species composition, the Danube section below Paks can basically be classified as a barbel zone, but due to certain structural features, a special fish assemblage, unique to Danube is existing. The abundance (number of individuals per 1000 m) typically shows low to medium values in this middle reach of the Danube. Based on the previous studies can be stated that the natural value of the Danube at Paks is significant due to the number of protected fish species present, but even more so due to the structure of the fish assemblage. At the same time, the number of invasive species is high and their relative abundance is increasing, especially in warmer years with low water levels. The natural value of the studied Danube section is continuously and demonstrably eroded by indirect (e.g., climate change) and direct (e.g., hydromorphological interventions, point source, and diffuse pollution) impacts, independent of the heated water discharges from the Paks Nuclear Power Plant. The number of protected species identified from this Danube section in previous investigations are 12 (*Cobitis elongatoides, Eudontomyzon mariae, Gymnocephalus baloni, G. schraetser, Leuciscus leuciscus, Misgurnus fossilis, Rhodeus amarus, Romanogobio vladykovi, Rutilus virgo, Sabanejewia balcanica, Zingel zingel, Z. streber*), of which Zingel zingel, and Z. streber are strictly protected. The examined Danube section (AOC754) is part of the Natura 2000 network as a site of Community Interest (SCI) with the site code HUDD20023. All fish species of the 9 indicator species of community importance, except the European mudminnow (*Umbra krameri*) were found during the previous studies.

Based on the available data sourced from previous studies, an ecological status assessment of the potentially affected water bodies under the scope of the WFD was made, taking into account the "*one out all out*" principle (*Table 5.3.1-3*).

Table 5.3.1-3. Overall ecological status/potential of water bodies assessed on the basis of available data according to the criteria of the WFD

Name of water body	Water body VOR code	Ecological status / potential
Danube, between Dunaföldvár - Sió mouth	AOC754*	Moderate
Danube between Sió mouth - country border	AOC755*	Moderate
Bogyiszlói Holt-Duna	AIH051*	Bad
Faddi Holt-Duna	AIH066*	Moderate
Tolnai-Északi-Holt-Duna	AIH136*	Poor
Tolnai-Déli-Holt-Duna	AIH135*	Poor
Grébeci-Holt-Duna	ANS503	Poor

*Highly modified water bodies.

5.3.2. Potential Impacts expected from subsequent service life extension

Based on the findings of the available documents, the analyses and classifications based on existing data as well as the relevant literature, the following can be identified as potential impacts on surface water from the subsequent service life extension of the Paks Nuclear Power Plant:

- water abstraction from the Danube (hydraulic, hydromorphological impacts),
- discharge of heated cooling water into the Danube (thermal load, hydraulic and hydromorphological impacts),
- the discharge of process wastewater, treated municipal wastewater and treated rainwater into the Danube (polluting impact).

Based on the evaluation of the available data, the operation of the nuclear power plant and operation in combination with Paks II. could potentially affect the water bodies AOC754, AOC755, while the potential impacts of the plant do not extend to the surrounding back waters such as follows lake water bodies: the Bogyiszlói-Holt-Duna (AIH051), the Faddi-Holt-Duna (AIH066), the Tolnai-Déli-Holt-Duna (AIH135), the Tolnai-Északi-Holt-Duna (AIH136) and Grébeci-Holt-Duna (ANS503).

Water abstraction from the Danube

Currently, the Danube water is abstracted via the cold water channel to provide cooling water. The amount of water abstracted equals the amount of heated water returned through the warm water channel, so that the water abstraction does not have a significant impact on the hydraulic regime of the Danube and does not represent a significant intervention in the river section concerned, even during low flow periods. The direct upstream and downstream segments of the cold-water channel are equipped with a bank protection stone spreader, while the section of the surface water intake is equipped with a float trap. The planned cooling water intake for Paks II. will be provided through an extension of the existing cold water channel.

In the current operational state of the Paks Nuclear Power Plant, the water withdrawal per unit is 25 m^3/s, in total 100 m^3 /s, which is not expected to change in case of stand-alone operation. During the combined operation of the Paks Nuclear Power Plant and Paks II., the maximum amount of water withdrawn and discharged will increase to a total of 232 m^3 /s, taking into account the cooling water demand of the two new units of Paks II. of 132 m^3/s altogether. The potential impact of cold water abstraction for the Danube aquatic organisms studied is expected to be the altered hydraulic and hydromorphological effects.

With regard to water abstraction, it is important to note that possible changes in the boundary conditions on the Danube side could have an impact on the operation of the plant. Two phenomena with a direct impact on operation need to be investigated. On the one hand, the future development of abstraction potential may be influenced by changes in the hydromorphological conditions of the Danube. The expected reduction in low flows due to climate change and the possible deepening of the river bed may require the installation and use of auxiliary pumps to ensure a continuous supply of cooling water to the safety systems. On the other hand, decreasing low flows and rising water temperatures may increase the thermal load on the Danube, which may require additional measures. In order to assess the environmental impacts of further service life extensions, a coupled climate and catchment area level hydrological model will be developed to provide a more reliable estimate of future water runoffs and water temperatures. Basin changes will be verified on the basis of real river bed relief studies, which can also take into account the erosion-resistant rock layers in the river bed. These refined models lead to a refinement of the above numerical estimates.

Discharge of heated cooling water into the Danube

The cold water channel supplying the cooling water to the power plant branches off from the Danube at 1526.6 river km, and then, passing through the technological systems, the heated cooling water enters the main riverbed about 400 m downstream, at 1526.2 river km, at a temperature generally 8-10°C above the prevailing Danube water temperature. The temperature gradient (Δt) can be as high as 11.0-13.9°C during the winter months.

The available data indicate that the Danube water temperature is increasing in the long term due to climate change, with a clear increase in the number of days per year with water temperatures exceeding 25°C. Still however, warming does not pose safety issues. Too high inlet water temperatures mean high outlet temperatures. Because of this, it is increasingly common that the water temperature of the Danube in the reference section 500 m from the discharge outlet would exceed the maximum temperature limit for the thermal load of the power plant as specified in the plant's operating instructions. In addition to this, the Paks II. development will reduce the efficiency of the mixing with the undisturbed waters of the Danube at the Paks Nuclear Power Plant's discharge point, and thus the temperature decreases up to the reference section.

In order to prevent exceeding the temperature limits, to the necessary degree, the power output of the nuclear power plant units can be decreased. Another option is to explore technical solutions to increase the efficiency of mixing, with a view to avoiding having to decrease the power output of the nuclear power plant units and reducing the environmental impact of the heated cooling water.

Discharge of process wastewater, treated municipal wastewater and treated stormwater into the Danube

The total daily capacity of the Paks Nuclear Power Plant wastewater treatment plant is 1870 m^3/day (657 thousand m^3 /year). In addition to the treatment of municipal wastewater, the plant also treats wastewater from the laboratory, laundry and shower rooms contaminated with radioactive isotopes. The treated municipal wastewater is discharged directly into the warm water channel, from where it is discharged into the Danube together with cooling water, treated industrial wastewater and rainwater. Rainwater run-off from the operational area is collected in the north and south rainwater ditches, from where it is discharged to the cold water channel in the north and the warm water channel in the south. The flow conditions in the area are characterised by the fact that the Danube is a groundwater drainer for most of the year, and is therefore a natural recipient of precipitation in the area. The operation of the Paks Nuclear Power Plant alone generates 240-280 thousand m^3 of municipal wastewater per year. During the combined operation of the Paks Nuclear Power Plant and Paks II., based on available documents Paks II. will have its own wastewater treatment plant. The quality of the wastewater discharged from both the existing and the new plant will have to comply with the requirements of the 28/2004. (XII. 25.) KvVM Decree on some regulations regarding limit values applicable to the discharge of water-contaminating substances, and their implementation.

5.3.3. Assessment of the impacts of operations in the light of the River Basin Management Plan

During the operation of the Paks Nuclear Power Plant, the most significant actual environmental impact on the Danube aquatic organisms is the discharge of heated cooling water into the Danube. Analyses have shown that under current operating practices, this impact is not an acute lethal or sublethal one, but a long-term impact. Therefore, the significance of the thermal exposure is caused by the persistence of the exposure. Analyses have demonstrated that the impact of warm water is at the limit of detectability even under optimal sampling conditions, which may be exceeded by the natural variability of the Danube abiotic environmental factors. However, it should be taken into account that, in addition to the thermal load on the Danube, other effects, in particular hydraulic and hydromorphological changes and increased nutrient concentrations, combine to shape the structure of each aquatic communities. Rising background temperatures and the increasing frequency and depth of the low water levels of the Danube further modify the ecological status of the biological elements.

The maximum thermal load at the point of discharge is typically below the temperature that would be lethal for biota, but previous research has shown that under extreme hot weather conditions, some vagile organisms such as fishes are already avoided at the point of release. In relation to thermal load, it is a fact that the typical heat gradient is relatively large: within 500 m, Δt decreases to ~4°C, while further decreases take place over a longer distance. It is also an important fact that the run of the thermal plume stays on the right bank and opens only slowly, reaching the midline only at around Foktő town.

Statistical analysis of available data shows that the effect of heat stress on phytobenthos, macrozoobenthos and the fish assemblages is demonstrable. Calculations based on the fish assemblage indicated that its extent up to a temperature difference of Δt=2.5°C comparing the upstream water temperature. This is considered to be the detectability value for the investigated biological elements. The heated cooling water discharge has no detectable impact on the structure of planktonic organisms either phytoplankton and zooplankton.

Of the operational scenarios, the combined operation of the Paks Nuclear Power Plant and Paks II. clearly has the most significant environmental impact due to the increased amount of heated cooling water discharge. According to the currently available thermal load models, the extent of the impact area in the case of stand-alone operation of the Paks Nuclear Power Plant is ~2.5 km in the right bank riparian areas, while the same value during combined operation is ~12.5 km downstream of the Danube discharge. This point is located at 1514 river km on the Danube at around Gerjen town. It should also be emphasized that during periods of extreme heat and low water levels, previous measurements have shown that the impacted distance can increase significantly, temporary even up to double the distance, estimates suggest. Even under these extreme weather and water level conditions, the heat load only affects the right bank areas and not the entire cross-section of the Danube. On this basis, it can be concluded that no transboundary environmental impact is expected in terms of thermal load. The new heat load model to be created will be used to refine the extension of effected areas by heated cooling water discharge.

Based on the analysis of the currently available data, the directly affected biological elements will be the phytobenthos, the macrozoobenthos and the fish communities. Indirectly, the most likely to be affected are the consumer organisms. The strongest indirect impact of the introduction of heated cooling water into the Danube will be the role of warm water in the spread of invasive species, but the potential indirect impact may be a stronger than expected local degradation of the structure of the community due to the above mentioned cumulative impacts along the food web. The impact of thermal load is long term, strong and significant in the impact area, and it means the major load on the aquatic communities. However, based on the results of the ecological analyses, it can be concluded that the impact of the thermal load will not cause a class-level degradation to any of the biological elements of the downstream sections evaluated on the basis of the WFD. At the same time, the same conclusion applies to the overall ecological status. On the basis of the information available, it can also be concluded that the achievement of the environmental objectives of the affected water body (AOC754) of the Danube is not obstructed even by the joint operation of Paks Nuclear Power Plant and Paks II. However, the relevant parts of the River Basin management plan and results of the available data and analyses show that achieving the good ecological status for the whole domestic section of the Danube, including the water body AOC754, will only be achievable through the complex rehabilitation of the entire upper sections of the Danube, with strong coordination of the various current uses, and in some cases with restrictions. In this context, the continued operation of the Paks Nuclear Power Plant will not prevent the achievement of good ecological status of the Danube water body concerned in the long term.

Based on the results of previous ecological analysis, it was found that the impact of the Paks Nuclear Power Plant's heated cooling water discharge could be detected up to a temperature difference of +2.5°C ΔT downstream comparing to the unaffected upstream water temperature. These results were confirmed by the analysis of the existing previous data. Based on the currently available heat load models, the detectable impact area for biological elements, with a focus on fish, macrozoobenthos and phytobenthos is the right bank area of the Danube 2.5 km downstream from the discharge point of heated cooling water during the stand-alone operation of the Paks Nuclear Power Plant, while the impacted area for combined operation is 12.5 km (*Figure 5.3.3-1.*).The impact areas will be refined by updating the thermal load models and by further assessment of the impacts on each biological elements.

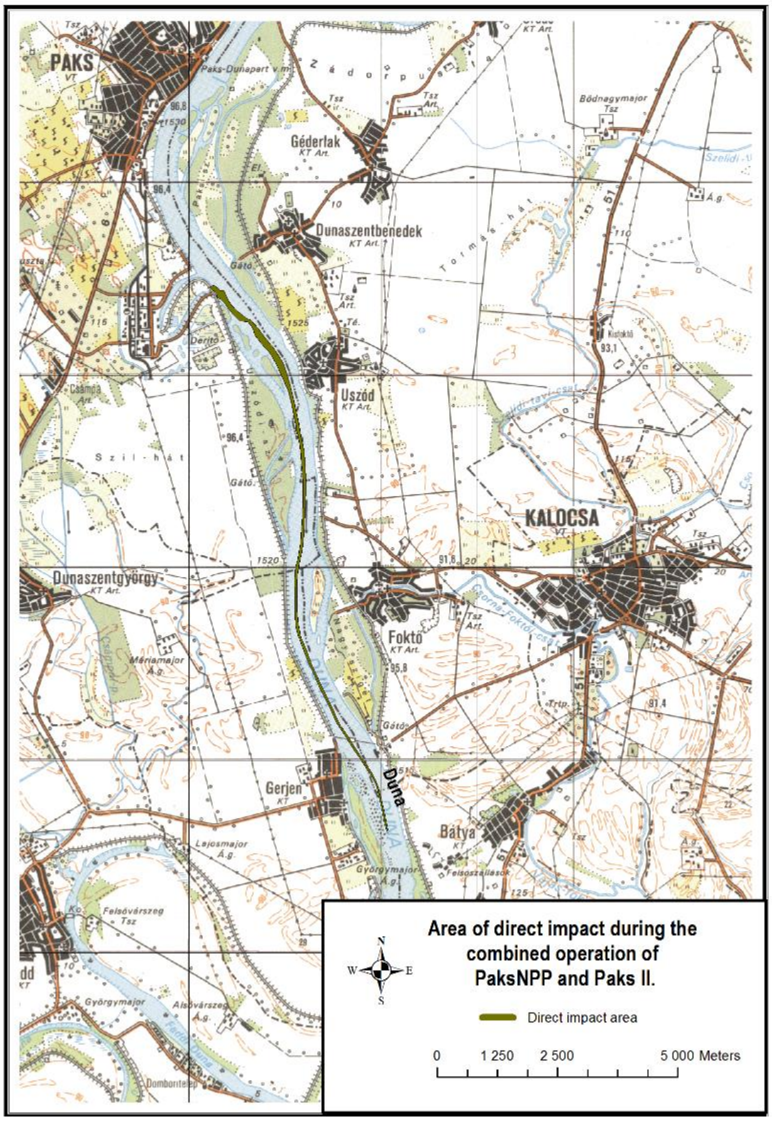


Figure 5.3.3-1. Area of direct impact on the biological elements during the combined operation of the Paks Nuclear Power Plant and Paks II., based on the current thermal load model

5.3.4. Impacts of havaria events

When examining the havaria events, it is important to highlight that the water rights operation permit with reference number 35700/6161-7/2019.ált. of the Paks Nuclear Power Plant requires the regular review of the water quality damage mitigation plan approved by the environmental authority. MVM Paks Nuclear Power Plant Ltd. maintains and regularly updates its damage mitigation plan in accordance with the Environmental Management System. The effective date of entry into force of the updated version of the current Operational Water Quality Damage Mitigation Plan is 15th December 2021, prepared on the basis of the content-related requirements stipulated in the Government Decree 90/2007. (IV. 26.) on the procedure for the prevention and mitigation of environmental damage. Section 12 of the Operational Water Quality Damage Mitigation Plan of the nuclear power plant describes the Emergency Response Plan, which is the applicable plan in a havaria event.

It should be noted that the environmental impact assessment of the Paks II. Nuclear Power Plant examined the spread of pollutants in the Danube during havaria events. These modelling studies can be considered analyses analogous to havaria events in the Paks Nuclear Power Plant. The study showed that the nature of non-radiological pollution in a havaria event is a shock-type load for the recipient medium: a finite amount of pollutant flows into a point in the river system over a short period of time. The pollution wave or cloud is drawn off relatively quickly, which, in the case of the Danube means 1-2 days up to the country border. The data also indicate that the dilution of pollutants potentially entering the Danube as a result of a havaria event in a warm water channel is still effective enough to preclude significant damage to aquatic organisms or a deterioration of an order of magnitude of the ecological status of the river based on WFD criteria. For this reason, no distinction is made between the impact and the impact area in a baseline situation and in a havaria event from the point of view of biological elements of the Danube.

5.3.5. Transboundar impacts

On the basis of the specified impact area, no transboundary environmental impacts on surface waters are expected, including impacts on aquatic organisms, from the thermal load on the Danube from the return of the heated cooling water, during the simultaneous operation of the six units.

5.4. Impacts on subsurface waters and the geological medium

5.4.1. Description of the baseline

Status of regional subsurface waters

In the Danube valley, groundwater is stored in the alluvial Pleistocene-Holocene gravel and sandy formations. The groundwater forms an interconnected system and is in direct contact with the more highly positioned groundwater infiltrated from precipitation in the Holocene loess plateau of Mezőföld forming the border of the Danube Valley to the west, such groundwater building up on the loam strata. This area ensures the resupply of groundwater reserves for the Danube Valley from the west. The general direction of groundwater flow follows the sloping morphology of the surface, from north-west to south-east on the right bank of the Danube, while on the left bank the flow is from east to west. The highest groundwater levels are found on the loess plateau west of Paks. The hydraulic gradient decreases significantly from the Mezőföld towards the Danube. The background groundwater level is higher also on the left bank than in the river valley, so the general flow direction is from east to west, i.e., towards the Danube. The left bank is topographically less fragmented, so the hydraulic gradient values are lower. The water levels in the wells *outside* the hydrodynamic reach of the Danube move almost parallel to each other, i.e., the hydraulic gradient in this area does not vary significantly between low and high water periods. In contrast, within the hydrodynamic reach of the Danube, the hydraulic gradient increases or decreases at high water levels and may even become reversed.

The shallow porous water bodies (sp.1.10.1., sp.1.10.2. and sp.1.15.2.) are only partially affected spatially. The impact processes occur within the boundaries of the water bodies in a much narrower area.

To determine the baseline environmental status, the area between 1534-1498 river km along the Danube was investigated. On the eastern side, an artificial border extending 3.5-9.5 km from the left bank of the Danube is considered. The vertical boundary of the study area is determined by hydrogeological conditions. The study of the various impacts can be restricted to the Quaternary formations, shallow porous water bodies in which groundwater forms a coherent flow regime between the loess reefs of the Mezőség region and the Homokhátság sand ridges as two infiltration areas and the Danube as main tapping area. This particular evolutionary history has resulted in the formation of a coherent sandy-gravel aquifer complex that gradually thickens towards the east. The Quaternary formations in the hills of the Mezőség region are dominated by loess tens of metres thick and quicksand a few metres thick. Both formations also store groundwater, and play a role in transmitting hillslope infiltration, firstly to the Danube valley groundwater and, secondly, to the Pannonian artesian waters (confined water). The substratum of the sandy-gravelly aquifer complex of good aquiferous qualities is formed by a regionally widespread layer of Pannonian silty clay, clayey rock silt, occasionally with a rocky silt layer, several metres thick, which, at some points, is absent or features poor aquiferous parameters. That layer is called the Upper Pannonian Tengelic Formation. Its importance lies in the fact that it provides a barrier between the Quaternary and Upper Pannonian aquifers, protecting the water bases established on upper Pannonian artesian water from surface contamination. The Csámpa Waterworks located 2.8 km south-west of the Paks nuclear power plant, supplying water to the Paks nuclear power plant, was similarly built on Pannonian artesian water.

The protection of the artesian water is also ensured by the pressure conditions in the aquifers. Below the hilly areas ensuring re-supply, the levels of potential decrease with depth, i.e., there is also the possibility for deep infiltration as enabled by anisotropy or forced by geological conditions. In the Danube valley in its natural state unaffected by industrial activity, the artesian water’s level of potential increases downwards, i.e., the subsurface water here flows upwards, which means an upwelling area.

The general direction of groundwater flow is towards the Danube, the main drain factor, from northwest to southeast on the right bank and from east to west on the left bank. The groundwater flow patterns are determined by the erosion base of the Danube and partly by the spatial position of the depressions.

The Mezőség region, i.e., the west/north-western part of the area under study is an infiltration area where the hydraulic rise of the layers close to the surface is significantly higher than the deeper layers, and the vertical hydraulic gradient of the subsurface water points downward. The area around the Danube, however, is already a draining area, where the hydraulic rise of the deeper artesian waters exceeds that of the shallower layers, and the vertical hydraulic gradient of the subsurface water points upwards.

The Danube valley, and thus the area under the Paks Nuclear Power Plant and Paks II., is a hydrogeologically upwelling area. This upwelling character provides protection for the deeper layers of the geological medium and the subsurface water stored in them against aqueous solutions of contaminants seeping down from the surface.

State of local subsurface waters

Water level data from monitoring wells on and around the site were processed for an assessment of the current conditions. Groundwater fluctuations from 2011 to 2023 range from 1.51 m to 7.77 m, with groundwater levels showing a steady decline. The general direction of groundwater flow is towards the Danube, the main tapping factor.

Water chemistry data from the monitoring wells show that the oil tanks and the area around the hazardous and industrial waste collection area are free of contamination. At the site of the Paks Nuclear Power Plant, ammonium and nickel contamination above the contamination limit value "B" according to 6/2009. (IV. 14.) KvVM-EüM-FVM Joint Decree on the limit values for the protection of the geological media and subsurface water against pollution and on the measurement of pollution was detected in the period 2011-2023, which did not require any action. The results of the tests of the wells in the vicinity of the main grid of municipal wastewater show that no pollution has been released from the grid into the environment.

Monitoring system of the region

Water level and water quality data from monitoring systems can be used to track natural processes in the area and to detect changes in response to human activity. Water level data from monitoring systems also provide information on groundwater flow. The area has several complementary monitoring systems for monitoring the groundwater system. The monitoring systems operating in the area are as follows:

- the monitoring system located within the MVM Paks Nuclear Power Plant Ltd. site (160 groundwater and 4 artesian water monitoring wells),
- the environmental monitoring system of bank filtered subsurface waters along the Danube operated by the MVM Paks Nuclear Power Plant Ltd. The monitoring system is currently operating in six sections. In the sections, 4 horizontal and 8 vertical basin probes are installed in the active flood plain. A further 6 monitoring wells are installed on the protected side moving further away from the Danube. Measurements in four sections are made using instruments, and manually. The instrumental measurements include pressure and temperature. In four sections, manual measurements are taken monthly, and in five sections, in 12 objects instrumental measurements are carried out. Water quality analyses are carried out manually once a month (temperature, pH, specific conductivity, dissolved O_2 , saturation). Laboratory measurements are carried out with 2-3 times per year for general water chemistry, microbiology, toxicology, bacteriology, and tritium components. The returning of cooling water back into the Danube and the subsurface water along the Danube is a factor of environmental significance the impact of which is monitored by MVM Paks Nuclear Power Plant Ltd., pursuant to an official decision, through continuous operation of the monitoring system "in order to protect the bank-filtered water bodies of long-term importance on the Danube section concerned".
- the core network and other monitoring wells operated by the Water Management Directorates: in the study area, on three shallow porous water bodies (Sp.1.10.1, Sp.1.10.2, and sp.1.15.2, on the left bank) there are, respectively, 4, 2, and 7 monitoring wells in operation. These wells generally provide measure groundwater levels once a day / once a week to characterise the hydrodynamic movement of the Danube valley in the region.

For the baseline assessment of the tritium content of subsurface water, the data provided by MVM Paks Nuclear Power Plant Ltd., regulatory and study documents, and long-term background databases was used, which will be presented in detail in the EIAS. The baseline data were processed using data for the period 2005-2024 for the close environment of the site.

Evaluation has focused on elements that may have an impact on groundwater flow dynamics. With the exception of the Danube river, practically all of these are architectural, and engineering structures. The current water level of the Danube and the cold water channel have the greatest influence on groundwater flow and the spreading of loads. Precipitation feeds groundwater through the priority infiltration area of the Mezőség region, whereas this is not the case on the site due to the built-up area and drainage system.

The trend of the water levels in the cold water channel and monitoring wells was examined, as well as the amount of precipitation. The monitoring system, consisting of more than 100 monitoring wells, was spatially divided into the following sections:

- the far west side of the main building,
- the south side of the main building (the SFISF and its surroundings),
- the immediate surroundings of the Danube, the cold and warm water channels and fish ponds,
- the west and east sides of the immediate surroundings of the main building.

The data show a downward trend in water levels. In general, the further away from the Danube, the less the water level fluctuates. The influence of the Danube is noticeable up to about 500 m, with a slight shift over time. In the vicinity of the SFISF, an area of lower groundwater seepage velocity has developed. The groundwater from the west is held up by the artificially maintained water level in the fish ponds, diverting it towards the cold water channel. 8-10% of the precipitation can recharge down to re-supply groundwater. The water level fluctuation of the cold water channel can reach 10 m, while the average water level fluctuation of the monitoring wells is 3-4 m.

Tritium activity concentration values measured in monitoring wells are available from a total of 62 wells. The locations of the wells relevant for modelling the spread of the exposure are shown in *Figure 5.4.1-1.*

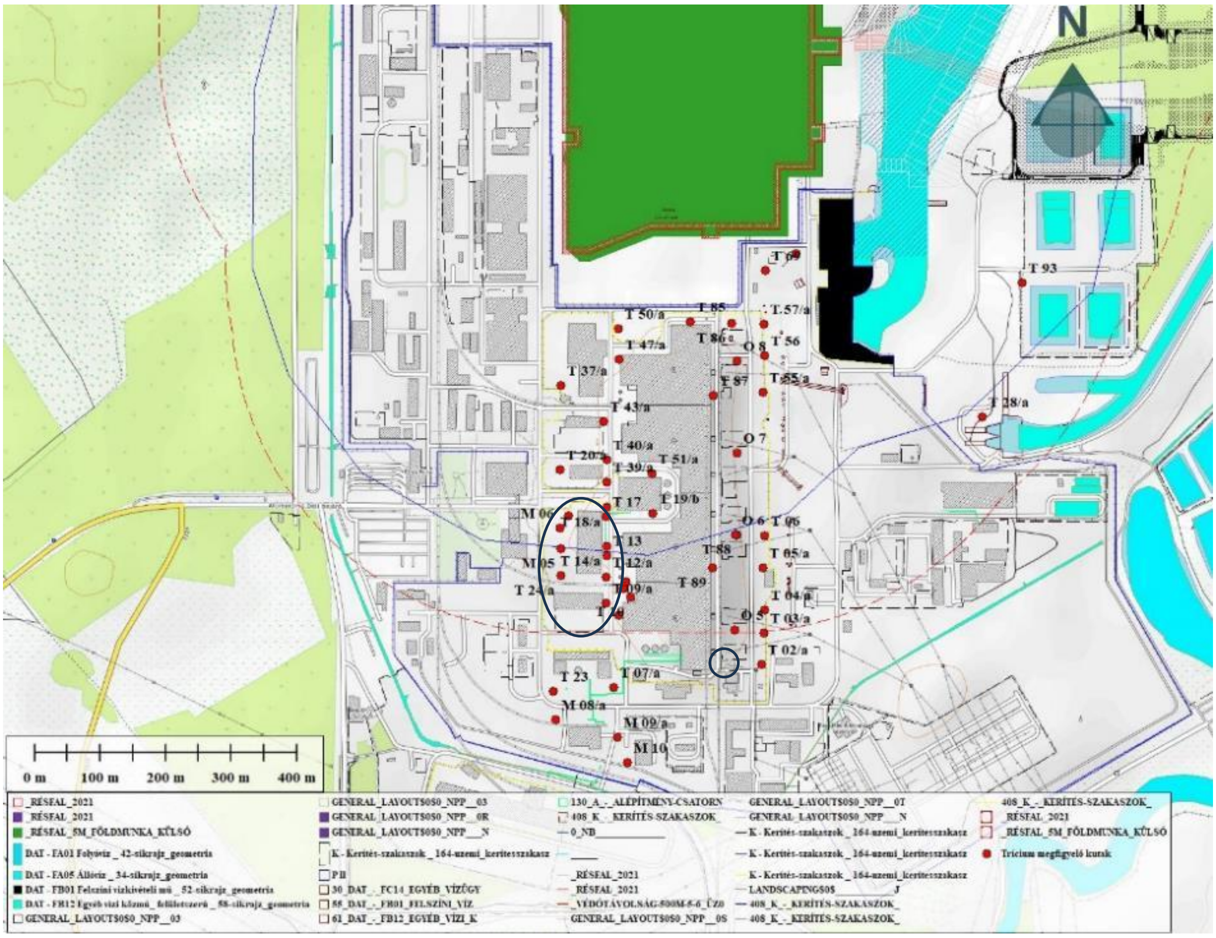


Figure 5.4.1-1. Location of monitoring wells relevant for simulating the spreading of the load

MVM Paks Nuclear Power Plant Ltd. pays extra attention to monitoring the tritium load, as the discharge of contaminants into subsurface water is not permitted. As a conservative pollutant, tritium is well suited for monitoring unplanned discharges. The area marked on the map with the black ellipsis is the location of auxiliary building I, the low-activity canal and the given sections of the sewer pipe. The area marked by the black circle is the transfer pump of the TM-55 pipeline. In both areas, active sources appeared before 2005. The highest value (10 kBq/l) was measured in well O5, located northeast of the TM-55 pipeline. The changes of ^{3}H values over time measured in well O5 is shown in *Figure 5.4.1-2.*

At the Paks Nuclear Power Plant site, all the identified outflows and sources of leakage have been eliminated between 2006 and 2011, and the half-life of tritium (12.32 years) has also contributed to the reduction of the load. The third factor is the thickness of the unsaturated zone. Since the load is introduced close to the surface (2-3 m deep), it still has to travel 5-6 m down before it reaches the groundwater. There are fluctuating values in the time series due to the infiltrating effect of precipitation (0.4-2 Bq/l) and the scouring effect of groundwater.

Unplanned ^3H emissions have been estimated over the years using a variety of methods and its amounts are gradually decreasing as sources are phased out. Given all these trends, it can be said that ^3H load on groundwater is on a downward trend.

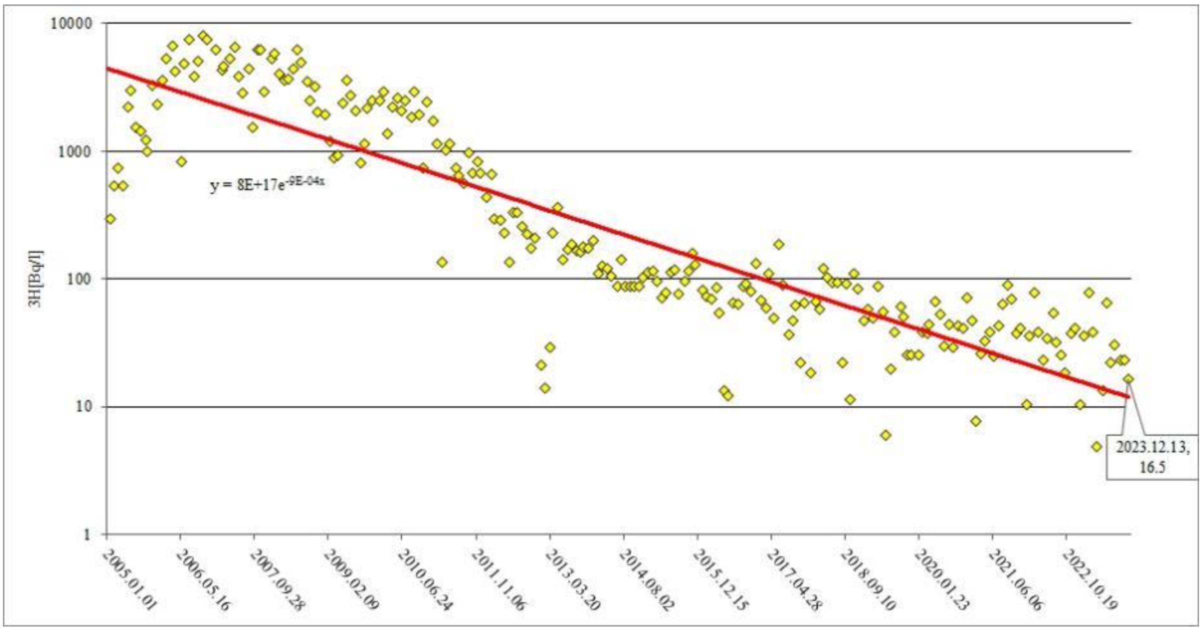


Figure 5.4.1-2. Tritium activity concentration in well O5 from 2005 to the end of 2023

The state of soil and geological medium on the site and in its immediate vicinity

The contamination status of the geological medium at the site and its immediate surroundings was presented for the period 2007-2023, following the environmental impact assessment of the first service life extension of the power plant. It included the processing of events affecting the quality of the soil and the geological medium. The results show that there was no permanent environmental contamination and that minor, localised contamination was short-lived due to rapid intervention and remediation.

5.4.2. Impacts expected from subsequent service life extension

Impacts of the Paks Nuclear Power Plant's independent operation

The impact of Danube's thermal load on groundwater is expected to fade away fully at the "connection point" of surface water and groundwater, the so-called "colmated zone". Groundwater is tapped and replenished mostly through the Danube riverbed (colmated zone), where the rate of infiltration into subsurface water is significantly reduced. The interaction between the warmed Danube water and subsurface water will be investigated later in the environmental impact assessment using hydrodynamic and heat transport models. Based on our experience to date, it can be provisionally concluded that the thermal load on the Danube is not expected to have a negative impact on the functioning of the basin. The operation of the nuclear power plant does not have a significant impact on the Csámpa Waterworks, because the study area is located in an upwelling zone, so that the impact of near-surface changes is not felt.

For the impact of the subsequent service life extension of the Paks Nuclear Power Plant, the current baseline is considered to be the distribution of the plant's unplanned discharges and the modifying effect of the deep-foundation buildings on groundwater flow. The leaks detected since 2006 were stopped by 2011. The current tritium distribution shows a decreasing trend, with a continuous depletion from the geological medium towards the Danube. Future leaks may occur but can be detected by the monitoring network in time. The tritium distribution has no impact on the groundwater for the subsequent service life extension.

With the construction of the Paks II. Nuclear Power Plant, the deep foundations will have a perceptible impact. The path of tritium depletion under the current units will not be altered by the effect of the depression funnel. The hydrodynamic impacts of the construction and operation of the Paks II. Nuclear Power Plant have been assessed on the basis of a hydrogeological model calibrated and validated for the existing Paks Nuclear Power Plant compound.

In the light of the findings described herein there is no reason for examining the impact of dewatering the construction pit of the Paks II. Nuclear Power Plant in connection with the subsequent service life extension.

The operation of the nuclear power plant will not result in any discharge of pollutants into the geological environment or subsurface water. Waste generated by the plant will be disposed of in certified, regularly inspected and properly insulated containers. Even during the period of the subsequent service life extension, the release of pollutants to the ground will only take place in the event of an accident. The nuclear power plant is prepared for such events and has the necessary equipment, trained personnel and established procedures for the mitigation operation.

Combined impacts of the nuclear facilities operating and planned on the site

The combined impact of the Paks Nuclear Power Plant and Paks II. on the subsurface waters of the Danube Valley can only spread indirectly via the Danube. The relationship between the Danube river and the groundwater system is complex, with the Danube affecting groundwater in different ways and to different degrees depending on its regime.

Under natural conditions of potential, the Danube is a tapping factor on subsurface water coming from the direction of the background. The Danube controls riparian groundwater levels by very rapid changes of its own level relative to changes in groundwater levels. Under natural seepage conditions, the spreading of the pressure is rarely accompanied by an actual inflow into the groundwater storing formations. The Danube pressure wave typically causes a backflow in groundwaters rather than pushing them back into the formation.

Based on on-site, and laboratory investigations and measurements carried out in the framework of the operation of the environmental monitoring system for subsurface water in the Danube basin, long-term test results can be analysed in terms of hydrodynamics, heat transfer and water quality changes, which have also served as a basis for the validation of the hydrodynamic and heat transport model.

The impact of the combined operation of the Paks Nuclear Power Plant and Paks II. on groundwater temperature is of minor importance, since the effect of the warmed Danube water temperature may be so small in the colmated zone that it is not detectable in groundwater.

The combined operation has no significant impact on the Csámpa Waterworks because the study area is in a discharge zone, so the impact of near-surface changes is not felt. The impact of unplanned discharges that may occur in the future during the combined operation is expected, which may have a tolerable impact on groundwater.

The combined operation of the Paks Nuclear Power Plant and the planned Paks II. will have no impact on the geological medium, and contamination will only occur in a havaria event.

5.4.3. Impacts of havaria events

Subsurface waters can typically become contaminated indirectly by pollution of the geological medium. Experience to date suggests that subsurface water has not been affected by the havaria events between 2007-2023 due to the application of appropriate operating procedures. It is expected that Paks II. will also apply the Paks Nuclear Power Plant operating procedures, so that the monitoring system installed and operated will be able to monitor and predict the possible contamination and its movement, allowing timely planning of appropriate neutralisation.

The potential havaria events do not have a negative impact on the operation of the Csámpa Waterworks because the study area is part of a hydrodynamically discharging system, so the probability of contamination entering drinking water wells is negligible.

The safety requirement for the operation of a bank filtered water source is that in the event of pollution in the Danube, the waterworks' operation will be suspended until the pollution has moved away. In a havaria event, both at the Paks Nuclear Power Plant alone and in combination with Paks II., the rapid response required by the Paks Nuclear Power Plant operating procedures and the safety requirement for the bank-filtered aquifers should not cause any negative impact.

Based on experience to date, contamination of the geological medium can only occur as a consequence of havaria events, for which a monitoring and response system is in place.

5.5. Impacts on wildlife and the ecosystem

5.5.1. Description of the base state

The preliminary assessment of impacts on wildlife and ecosystems is based on the results and data from the following three previous series of studies:

- The studies carried out in the framework of the site description program (1999-2004) for the environmental and water right licensing of the Paks Nuclear Power Plant for the previous service life extension and the power increase, and the documentation presenting them and the evaluation of the data generated.
- The biomonitoring studies (2012-2013) of reference value that formed the basis of the environmental impact assessment for the environmental licensing of the new nuclear power plant units (Paks II.) to be built at the Paks site, and part of the environmental impact assessment titled "Habitat, Ecosystem", which was mainly based on the evaluation of these data.
- Reports on the studies (2009, 2012, 2015, 2018, 2021) carried out in the framework of the implementation of the monitoring program to characterise the ecological state of the Danube, as required by the environmental license of the previous service life extension of the Paks Nuclear Power Plant, and the evaluation of the resulting data.

In the preliminary assessment of the impacts on the biota and ecosystem, the results of the above assessments were compared by organism group to establish a baseline. However, due to differences in methods and/or locations, comparisons could not be made in an objective manner. Therefore, conclusions on the expected impacts on the biota and ecosystem during the period of the further extension are mainly drawn from the impact assessment chapters of the two periods.

5.5.2. Impacts expected from subsequent service life extensions

In assessing the impacts on biota and the ecosystem of the further extension of the Paks Nuclear Power Plant's service life, relying on the fact that radiation measurements and modelling results show that the additional exposure (max. ~10^{-4} μGy/h) of the four units in operation for almost 40 years is negligible compared to the global and Chernobyl radiation (~10^{-3} μGy/h), and both are far below the background radiation (0.5 μGy/h) of terrestrial organisms living in the vicinity of the plant. The assessment has been carried out taking into account protected natural areas, ex lege sites, special areas of conservation (SACs) and protected species irrespective of the site's environmental protection status.

Impacts of the Paks Nuclear Power Plant's independent operation

The impacts are assessed based on the results of 8 groups of organisms. The impacts that can be considered for each organism group are:

- maintenance works of the artificial environment,
- discharge of cooling water into the Danube,
- the emergence of sources of infection from invasive species,
- deposition of air pollutants,
- the effect of the electric field of transmission lines.

Overall, the impacts on groups of organisms are very weak and mostly unmeasurable.

Based on the assessment results from 2002-2003 and 2011-2012 and the expert findings in the habitat impact assessment chapters of the environmental impact assessment for the previous service life extension of the Paks Nuclear Power Plant and the new Paks II. Nuclear Power Plant units, it is not expected that subsequent service life extension of the plant will lead to significant changes in the habitat of the different groups of organisms related to the operation of the plant. There is no reason to expect changes in the quality and quantity of groups of species directly or indirectly related to the operation of the Paks Nuclear Power Plant and the potential impacts resulting from it. The assessment of the likely impacts for each group of organisms based on the impact qualification system is shown in *Table 5.5.2-1.*

Table 5.5.2-1. Qualification of the expected impacts for each group of organisms for the Paks Nuclear Power Plant's independent operation

Name of organism group	Impact qualification
Vegetation	Neutral (not detectable)
Macroscopic aquatic invertebrates (macrozoobenton)	Neutral (not detectable)*
Orthoptera	Neutral (not detectable)
Lepidoptera	Neutral (not detectable)
Soil arthropods, saproxylophagous insects	Neutral (not detectable)
Fishes	Neutral (not detectable)
Amphibians and reptiles	Neutral (not detectable)
Birds	Neutral (not detectable)
Mammals	Neutral (not detectable)

* The impacts on aquatic macroinvertebrate groups of species in the Danube stretch affected by the thermal load are assessed in the stretch on surface water impacts in *Chapter 5.3.*

Combined impacts of the nuclear facilities operating and planned on the site

In assessing the impacts on biota and the ecosystem of the extended service life of the Paks Nuclear Power Plant and the planned new nuclear power plant units, relying on the fact that according to relevant studies the overall exposure of biota will be lower during the period of combined operation, as the global and Chernobyl-related exposure will continuously reduce due to the half-life of the isotopes. Overall, the combined effects of the Paks Nuclear Power Plant and Paks II. on groups of organisms are also very weak, mostly not measurable.

Based on the 2002-2003 and 2011-2012 assessment results and the experts' findings included in the impact evaluation chapters of the impact assessment study on biota, completed as part of the previous service life extension of the Paks Nuclear Power Plant, and of the environmental licensing of the new units of Paks II., no meaningful changes are expected that could be directly or indirectly related to potential impact factors associated with the normal operation of the Paks Nuclear Power Plant and the planned new nuclear units.

It could be concluded that the planned extension of service life and the combined operation will not lead to any appreciable changes in the coming service life. The assessment of the expected impacts for each organism group based on the impact qualification system is shown in *Table 5.5.2-2.*

Table 5.5.2-2. Qualification of expected impacts for each biota for the combined operation of the Paks Nuclear Power Plant and Paks II.

Name of organism group	Impact qualification
Vegetation	Neutral (not detectable)
Macroscopic aquatic invertebrates (macrozoobenton)	Neutral (not detectable)*
Orthoptera	Neutral (not detectable) - tolerable
Lepidoptera	Neutral (not detectable)
Soil arthropods, saproxylophagous insects	Neutral (not detectable)
Fishes	Neutral (not detectable)
Amphibians and reptiles	Neutral (not detectable)
Birds	Tolerable
Mammals	Neutral (not detectable)

* The effects on aquatic macroinvertebrate groups of species in the Danube stretch affected by the thermal load are assessed in the stretch on surface water impacts in *Chapter 5.3.*

5.5.3. Impacts of havaria events

In the assessment of the impacts of the havaria events on the biota and ecosystem, only those havarias were considered that have a significant probability of occurrence, taking into account the safety systems of the plant. Typically, these would be primarily small-scale, localised events.

Overall, small, localised, but significant non-radioactive release hazards (e.g., oil spills, fires) with a significant probability of occurrence can cause damage to individual groups at the site of a fire or other emergency. Indirect impact of non-radioactive release events (e.g., air pollution) may also affect the living groups, but it is difficult to imagine an event with indirect effects that would reach the limit of detectability. Based on the impact qualification system, the assessment of the likely impacts for each organism group are shown in *Table 5.5.3-1.* The expected impact depends on the size and extent of the havaria.

Table 5.5.3-1. Qualification of the expected impacts for each group of organisms in the event of a non-radioactive release havaria

Name of organism group	Impact rating
Vegetation	Low probability of an impact stronger (reaching the detectability level) than neutral
Macroscopic aquatic invertebrates (macrozoobenton)	From neutral (not detectable) to damaging*
Orthoptera	Neutral (not detectable) - tolerable
Lepidoptera	Tolerable
Soil arthropods, saproxylophagous insects	Low probability of an impact stronger (reaching the detectability level) than neutral
Fishes	*
Amphibians and reptiles	Tolerable
Birds	Tolerable
Mammals	Neutral (not detectable) - tolerable

* The effects on aquatic macroinvertebrate groups of species and fish communities in the Danube stretch affected by the thermal load are assessed under the impacts on surface waters in *Chapter 5.3.*

5.5.4. Impact area, transboundary impacts

As in previous years, the investigations are carried out in a previously specified potential impact area. The actual impact areas will be defined following the completion of the study program that will form the basis for the final environmental impact assessment, after the comparison of the actual data resulting from the implementation of the study program with the assessment results of previous years, and after the impact assessment. In the light of the results, the actual biota protection area will be delineated within the study area as a potential biota protection area on the basis of the actual impacts detected. *Figure 5.5.4-1.* shows the study area as a potential biota protection area.

In view of the extent of the pre-specified biota protection area, and as well as on the results of previous evaluations, no transboundary environmental impacts were identified for terrestrial wildlife.

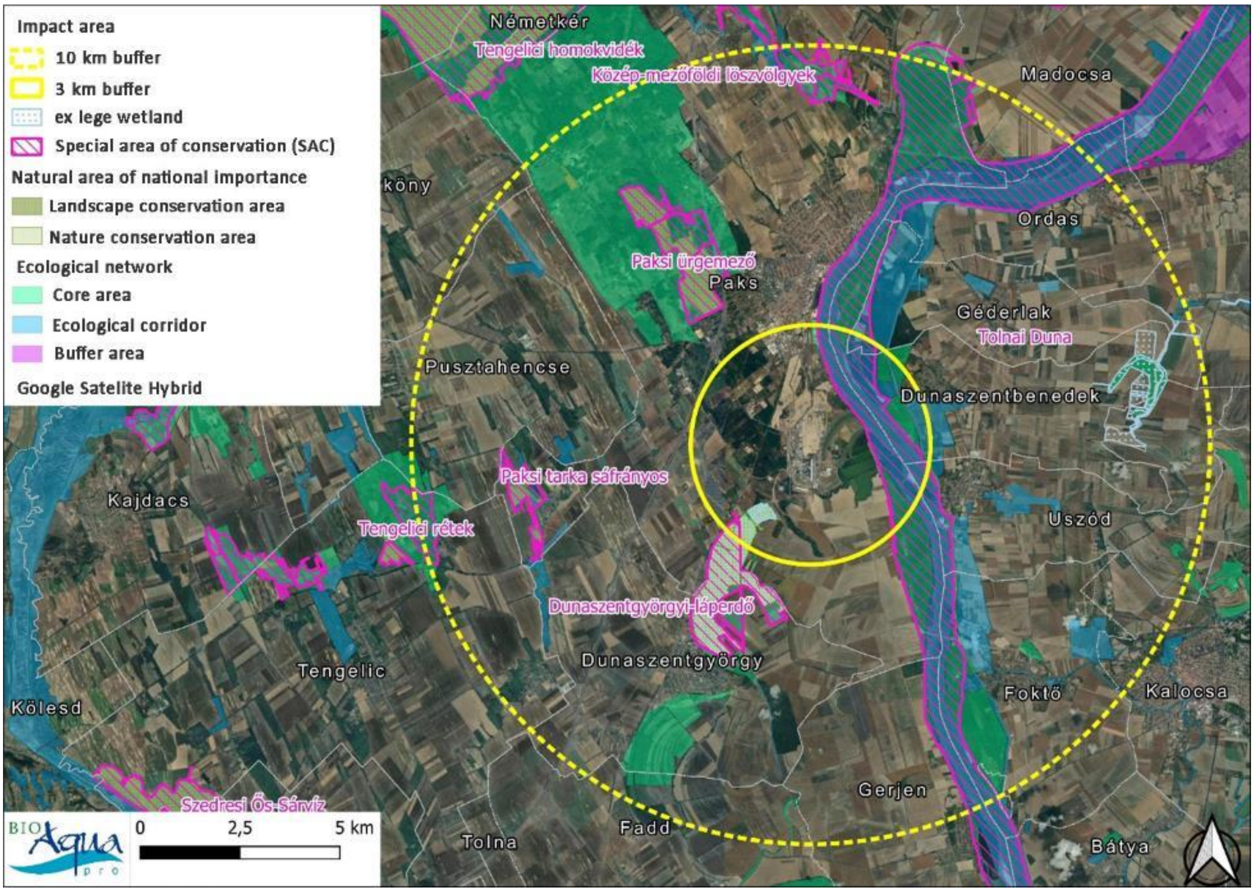


Figure 5.5.4-1. Delineation of the study area as a potential impact area

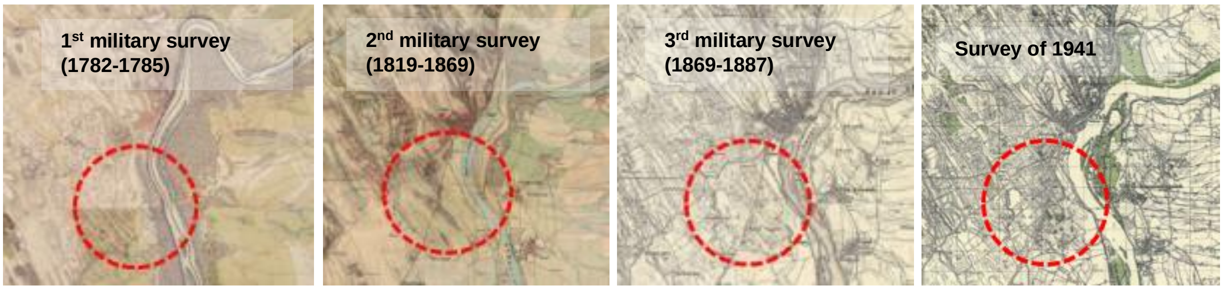
5.6. Impacts on landscape and land use

5.6.1. Description of the base state

The area within a 30 km radius of the Paks nuclear power plant is part of the large area of the Danube-Tisza basin, large area sections of the Great Plain, and the medium areas of the Transdanubian hills, Mezőföld, the Danube lowland and the Tolna hills. The power plant is located on the border between southern Mezőföld, and the Tolna Sárköz. The 30 km natural environment also affects areas called Közép-Mezőföld, Tolnai-Hegyhát, and Kalocsai-Sárköz. According to the vegetation map by Bálint Zólyomi (1989), before human changes to the landscape typical habitats included by tatarian maple and loess oak forest, floodplain forests and swamps, sand oaks and sandy scrub.

The history of the nuclear power plant and its surroundings cannot be separated from the history of Paks. Paks has been inhabited since prehistoric times, thanks to its favourable geographical location (the Danube, a flat river bank with loess hills). The earliest archaeological finds are the Sánchegy carved Stone Age tools. In the 1st century AD Paks was part of the Roman Empire's province of Pannonia. In the Middle Ages Paks was a typical agricultural settlement. From 1730 onwards, it developed into a market town, and, in addition to agriculture, guilds were established in the settlement, which contributed to the growth of the area removed from cultivation, but vine-growing and wine production were also typical. 18th century maps show extensive arable and vineyards, wetlands, marshes and bogs south of the town.

Draining the marshes that once stretched across the site of the present power station began in the mid-19th century. The bend between Imsós and Várszeg were cut through, between Paks and Ordas, as part of the Danube regulation project. This shortened the Danube by about 40 km. This brought the mainstream of the Danube to the immediate vicinity of the town, which boosted trade. The development was also helped by the emergence of a fleet of ship mills and a miller's guild, and the construction of a ship station. The economic boom was later curbed by the fact that the Danube bridge was built in Dunaföldvár instead of here, and the construction of the Paks-Tolna-Mözs-Szekszárd railway line was eventually given up for the same reason. In addition, the Danube ship mills were gradually replaced by steam mills. The changes in the history of the landscape can be clearly seen on the maps of the military studies shown *in Figure 5.6.1-1.*



Source: https://maps.arcanum.com/hu/

Figure 5.6.1-1. Historical maps of the wider area surrounding the nuclear power plant (1782-1941)

From the beginning of the 19th century, the decisive trend was a slow rising of the bourgeoisie, then, despite the world economic crisis, industrialisation (e.g., the predecessor of a cannery) in the period between the two world wars. After the Second World War, economic development (canning, brickworks and agriculture) was booming, but by the 1960s it had come to a halt, the population was declining and the demographic ageing process set in.

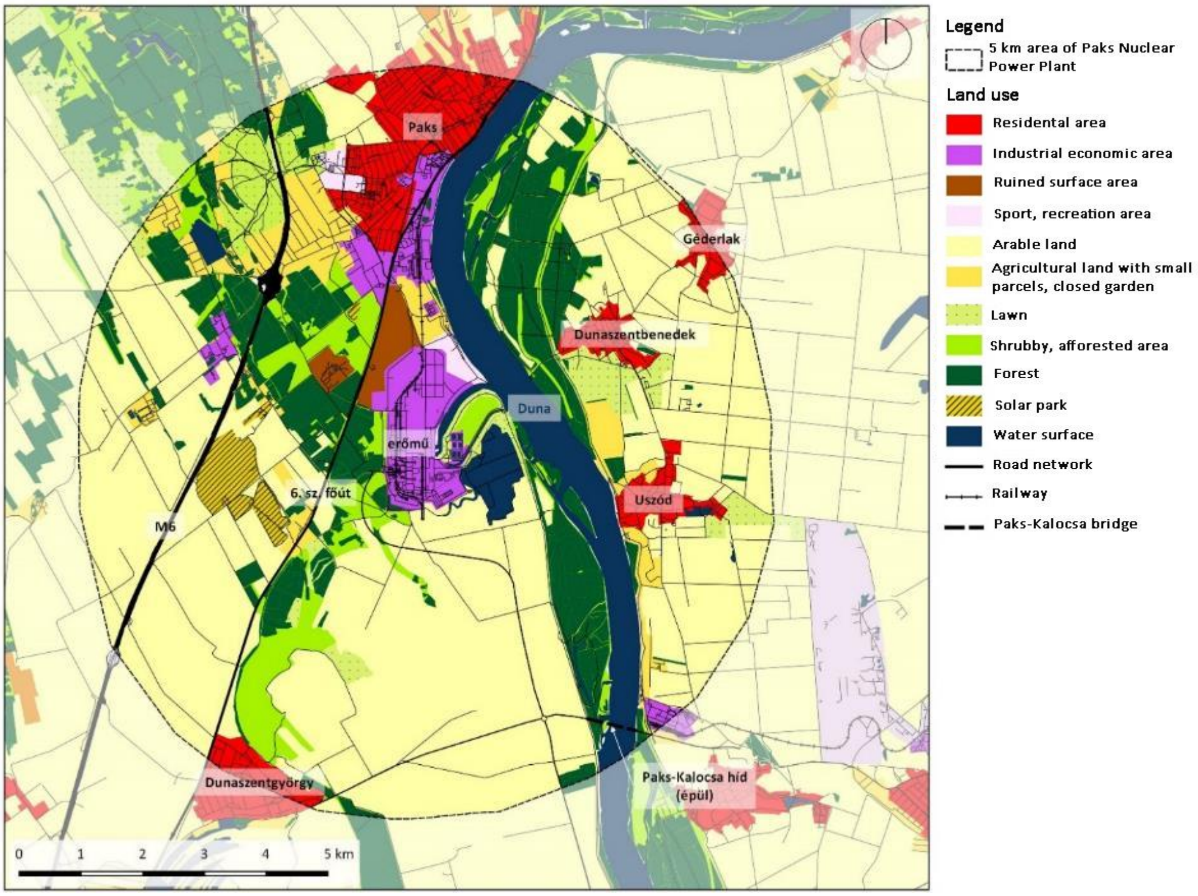
The construction of the four reactor units of the Paks Nuclear Power Plant between 1973 and 1987 gave a new impetus to the economic and social development of the town, which is still continuing today. As a result of the project, the population of Paks grew from 13 000 to 21 000 in just a few years. In parallel with the population growth, the municipality underwent significant changes and was granted town status on 1st January 1979. The construction of the power plant made Paks the most dynamically developing municipality in the country, with the opening of a number of new functions, such as a theatre, a sports ground, new health facilities and other community facilities.

Changes in the landscape over the last three decades were assessed by evaluating changes in of land cover/land use ratios. This was characterised on a three-way scale (3-5, 10, 30 km), similar to previous environmental impact assessments of the nuclear power plant. The assessment shows that the extent of built-up areas, degraded areas and forest areas in the wider area has increased slightly. At the same time, the area of arable land, vineyards and orchards, as well as marshes and bogs, has decreased. The construction of the new units of the Paks II. Nuclear Power Plant will not change these proportions, as the site has been designated as an industrial and economic area.

The dominant land use in the area around the power plant is large-field cultivation. There are significant areas of broad-leaved woodland, urban areas and watercourses (mainly due to the Danube's water surface). In recent decades, the area of grassland has been decreasing. An updated land use map of the 5 km surrounding the nuclear power plant is shown in *Figure 5.6.1-2.* Land use for tourism, e.g., Ürgemező, and the educational trail, the hiking trails

(Mária-út, red-marked hiking trail of local significance) and the Information and Visitor Centre of the nuclear power plant are to be highlighted.

The landscape potential ("landscape performance") of the region shows that it has a high ecological potential due to its natural features and a high agricultural and forestry potential due to various types of land use. The industrial potential of the municipality is also high due to the nuclear power plant and the adjacent Spent Fuel Interim Storage Facility (SFISF), as well as the industry park, and will be further enhanced by the improved road accessibility of the new Paks II. Nuclear Power Plant and the new Paks-Kalocsa Danube bridge (Tomori Pál bridge). The tourism potential is considered medium.



Source: Open Street Map 25.03.2024., Corine Land Cover 2018, Google Earth 2023 aerial photo and 2024 field study with the author's updates

Figure 5.6.1-2. Landscape use in the 5 km vicinity of the Paks Nuclear Power Plant

Landscape values also include natural landscapes, protected natural areas, conventional land uses and built heritage. These are summarised in *Table 5.6.1-1.* in an inventory of values according to the three territorial subdivisions.

No unique landscape value west of the Danube has been recorded either in the Nature Conservation Information System or in the settlement development plans. Such sites were registered in the settlements of Uszód, Dunaszentbenedek, Géderlak within a 5 km radius (most of them are residential houses, crucifixes, draw wells, country houses, wetlands, monuments, public sculptures). In Paks, the field study also identified the memorial site of the 1887 ferry accident in the immediate vicinity of the power plant.

In addition to a summary of the landscape values, it is important to describe the current land use conflicts associated with the operation of the power plant and the landscape values associated with the power plant. The following have been identified as conflicts:

- sections of the power transmission network in protected natural areas,

– above-ground district heating pipelines in the streets of Paks between the power plant and the housing estate.

Table 5.6.1-1. Main landscape values within 30 km of the site

Type of landscape value	**List of landscape assets by location**		
	The nuclear power plant's		
	10-30 km radius	**5-10 km radius**	**0-5 km radius**
Landscape values included in the county inventory	Several values in Tolna and Bács-Kiskun counties are included	Tolna county: Madocsa, Paks, Tengelic Bács-Kiskun county: Uszód, Kalocsa	Paks: churches and chapels, statues, houses, mansions, cellar village, Danube bank, Uszód: Péter Benedek Memorial House
Areas and values of national importance under natura conservation	Duna-Dráva NP, Kiskunsági NP - Miklapuszta, 5 NA (Bölcskei-nő-szirmos, Szelidi lake, Császár-ridge Vörös-swamp, Hajósi-hayfield and loess banks, Kapszeg lake NA), ex lege protected marshes, saline lakes, mounds, earth castles	Ex lege protected earthwork castles, Terhel-meadow, ex lege protected marsh, Paks loess wall geological base section NM	South-Mezőföld LA, Dunaszentgyörgyi marsh forest NA, ex lege protected marshland in the northern part of Dunaszentgyörgyi marsh forest NA
Areas of local importance under natura conservation	Includes a number of protected natural areas of local importance, mainly in the case of settlements in Tolna and Bács-Kiskun counties	Paks: 3 NA (Imsós forest, Vineyards as part of Prelátus, Cseresznyés marshes NA) Tengelic: Arboretum and Bogárzó Lake NA	Paks: Deák Ferenc Street Primary School front garden NA, garden of Municipal Museum NA, Paks Roman Catholic Church garden and Templom Square NA
Natura 2000 sites	10 nature conservation and 4 bird protection areas	Conservation areas: Central Mezőföld loess valleys, Paks multicoloured saffron, Tengelic meadows	Conservation areas: Tolna River Danube, Paks Meadows, Dunaszentgyörgyi wetland forest
National Ecological Network	Core area, ecological corridor, buffer area	Core area, ecological corridor, buffer area	Seed area, ecological corridor
UNESCO Biosphere Reserve	Mura-Drava-Danube cross-border Biosphere Reserve	–	–
Ramsar sites	Rétszilasi fish ponds, Upper Kiskunság saline lakes, Gemenc	–	–
Landscape conservation zone areas	The landscape conservation area overlaps significantly with protected natural areas of national importance, Natura 2000 sites, forest areas and water bodies		
Nature parks	Őrjeg and Vineyard hills, Nature Park, Kapos-Hegyhát Nature Park	–	–
Areas of high natural value	Sárvíz Valley AHNV, Homokhátság AHNV	Danube Valley Plain AHNV	–
Planted forest areas	Large forest blocks in the South-Mezőföld LA and Danube-Dráva NP	Approx. 4910 ha (including 1570 ha within 5 km)	About 1570 ha
Forest reserve areas	There is no forest reserve within 30 km of the power plant (the nearest one is located in Decse, which is the Buvat Keszeges Lake Forest Reserve, about 34 km away)		
Excellent/good arable land	Excellent and good ploughland also in significant proportions	Excellent and good ploughland in significant proportions	Smaller proportion S-W of the power plant (approx. 580 ha)
Orchards	Typically, vineyards, orchards: Alsószentiván, Dunaföldvár, Harta, Nagyszékely, Miske, Hajós, Kecel, Kiskőrös	The only orchard within a 10 km radius of the plant is at Fad (along the M6 motorway)	–
Wine-growing areas, vineyards of protected origin	Szekszárd wine region, Hajós-Baja wine region, Kunság wine region, certain settlements of Tolna wine region	Tolna wine region: Paks (in the north: Sánchegy and Hideg-valley), Dunaszentgyörgy, Tengelic, Madocsa, Bölcske, Dunaföldvár	Tolna wine region: areas south of Paks (gardens, enclosed gardens) classes I. and II. in the vineyard register

Note: NP – National Park, NA – Nature conservation area, NM – Natural monument, LA – Landscape conservation area, AHNV – Areas of high natural value

In principle, Kalocsa airport could also be one, but it is currently used for civilian (sports) purposes and the airspace of the nuclear power plant is currently off limits to civil aviation, so there is no conflict.

The land use value associated with the nuclear power plant is identified as the transfer of water to ensure good water quality and water levels in the Fadd-Holt-Duna oxbow lake, the supply of fresh water to the fish ponds with the condenser cooling water used, and the supply of district heating to the housing estate on the small hill using waste heat from the power plant.

The landscape is primarily defined by topography, vegetation cover and land use types. In the region, the water surfaces (primarily the Danube), the vegetation accompanying the watercourses and the extensive grasslands are of outstanding landscape value. These are generally protected and are also included in the environmental protection area designated in the National Spatial Plan. Landscape scars occur in the study area (e.g. the construction of the Paks II nuclear power plant), but these are temporary, short or long term. Distinctive, unfavourable landscape features are existing power lines, mobile phone towers and radio towers.

According to the mapping of the National Landscape Character Areas, the landscape area under study lies at the junction of the Central and Lower Danube Basin and the Mezőföld landscape character areas. Here, the following landscape character types are common: “ploughland-dominated homogeneous lowland landscape”, “forest-water-dominated river landscape’, “forest-dominated mosaic lowland landscape” and “ploughland-dominated mosaic undulating lowland and hill landscape with watercourses and forest patches”. The power plant itself, together with the town of Paks, falls within the landscape character type of “municipal landscape on the waterfront”.

The reactor buildings of the Paks nuclear power plant – with a maximum height of 77 m – can be seen from a distance of up to 5-10 km in good visibility conditions, as the plant is built on a nearly flat, low-lying area. At a distance of 10 km, however, the outlines of the individual buildings are difficult to discern, with the roofs of the reactor buildings being visible as point-like objects. Within the study area, it is not unimportant from which vantage points the view is revealed. The expected changes in the landscape were examined from 19 different vantage points. It was found that, based on the location of the viewpoints and the view limiting elements, the actual visibility is around 8 km with the naked eye in clear weather conditions. From the residential area closest to the plant – the inner area of Uszód – the power plant buildings are not visible due to the flood protection embankment and the extensive forest areas. However, a clear view is offered from the inner area of Paks (especially from local viewpoints such as the Gárdonyi lookout and the high points of the residential areas), the road network connected to the Paks-Kalocsa Danube bridge.

5.6.2. Impacts expected from subsequent service life extension

Impacts of the Paks Nuclear Power Plant’s independent operation

The benchmark for the assessment of the independent operation of the Paks Nuclear Power Plant is the abandonment of operation, the abandonment of electricity generation. In terms of landscape use, the usual, decisive impact factor is the land use. In the present case, the existing plant will continue to operate, no land expansion is required. In terms of land occupation, the activity does not therefore cause any change and the impact is neutral.

The current spatial structure was established during the construction and/or operation of the nuclear power plant and its associated facilities, so the impact/influence on the use of the surrounding land materialised in the past (except for the construction of the Paks II. Nuclear Power Plant, which is dealt with in the next chapter). Thus, the impact on the spatial structure is also neutral. This is also true for the relationship between the power plant and the town and its landscape structure. In other words, the positive impacts (fish pond, water supply to the Fadd-Holt-Duna oxbow lake, district heating) and negative impacts on uses remain unchanged (this also applies to forest use and forest cover, which will be a key focus of the environmental impact assessment).

Any minor changes are basically assessed as a consequence of general socio-economic changes, both in the past and in the future. The longer-term expected impact in spatial structure is also assessed as neutral. Indirectly, of course, an industrial installation of major importance will also have an impact on the development of its surroundings, i.e., the development of the host municipality and the direct or indirect presence of associated plants, facilities and service provider businesses, which may also have environmental effects. In our opinion, the continued operation will no longer have such an impact.

Based on the unchanged land-use spatial structure presented, no new conflicts beyond the current land-use conflicts are expected to arise from the continued operation. In the longer term, only the use of Danube water and the thermal load could cause conflicts, if climate change leads to a decrease in the discharges of low water and an increase in water temperature, which may require a limitation of the operation of the plant in accordance with the legal requirements during the period of the subsequent service life. This is a low frequency and short duration event, the adverse environmental consequences of which can be managed through operational measures.

The preservation of the landscape values to be protected is not expected to be affected by the planned operation, as will be discussed in the chapter on wildlife and the municipal environment. The impact on landscape values is therefore assessed as neutral.

No change in landscape character is expected during operation, the landscape character of the installation will be the same as at present during the period of continued operation (no change in the character, the overall mass or appearance of buildings and structures). In this respect, the impact is also considered to be neutral. The visibility of the plant will not change, unless significantly altered by other circumstances (e.g., additional construction, planting, vegetation removal) unrelated to the nuclear power plant. It is expected that even in such a case there would be only minor visual changes (e.g., obscuring from view or even reappearance) from one point to another. No substantive change is expected as a result of such interventions.

Landscape potential refers to the total economic capacity of a landscape, i.e., the landscape assets that provide some environmental benefit or advantage to society. The existing power plant represents an economic potential in Paks. From this point of view, if the further extension of the plant's service life is achieved, continued operation can be considered more beneficial in terms of exploiting its potential than abandoning the plant or stopping power generation.

Combined impacts of the nuclear facilities operating and planned on the site

The impacts of the combined operation of the Paks Nuclear Power Plant and the Paks II. Nuclear Power Plant were already assessed during the environmental licensing of Paks II., but at that time (based on the information available at that time) the combined operation could only be assessed for a relatively limited period of time, until 2037, as the existing units of the Paks Nuclear Power Plant were expected to operate until that date. The subsequent service life extension adds 20 years to that period. Taking this longer period into account, the aspects examined in the previous section are reviewed below for the combined operation of the two plants.

From the point of view of land use and landscape use, no significant changes are expected during joint operation, since the Paks II. site was previously designated as an industrial area. However, with the construction of Paks II., the largely undeveloped site will become a heavily built-up, paved, intensively used area, where the functionality will be substantially changed to accommodate the electricity generation. In addition, the installation of facilities and infrastructure directly and indirectly related to the operation of Paks II. (e.g., transport links, electricity network lines, warm water channels) will also change. In addition to these elements, other indirectly related facilities, such as service sites and business offices/facilities, are expected to be built. In view of the combined operation of the two nuclear power plants, there will also be a need to expand the storage capacity of the SFISF, which will also entail land requirements. As both the additional land requirements and the change in land use will take place in an industrial environment, the effects of the combined presence and operation are considered to be acceptable.

No significant changes are expected in the spatial structure of the wider region as a result of the joint operation. (In this respect, other investments in the region may cause significant changes (e.g., the new Kalocsa-Paks Danube bridge and the related economic boost).

The combined operation of the two nuclear power plants could have a positive impact on the life of the town. While the number of operators is not expected to double, additional staffing will be needed for operation. The needs of the employees of the two plants, whether for housing, shopping, recreation, health care, education, will be met, which will also help the town to develop and strengthen its economy to a certain extent. The impact is considered to be positive.

No increase in land-use conflicts is expected in the immediate vicinity, as a nuclear power plant has already been operating in the area, so the surrounding uses could adapt earlier, knowing and acknowledging the effects of this. The combined operation of the two power plants is expected to lead to neutral to tolerable land use conflicts. However, the combined operation of the two nuclear power plants could lead to increased conflicts due to water use, i.e., the discharge of heated cooling water into the Danube. This is not a land use issue, but an operational issue that can be addressed by technical solutions.

No detectable change in landscape values is expected with the combined operation of the two nuclear power plants, thus the impact is considered neutral. Of the landscape changes, the construction of the Paks II. Nuclear Power Plant is perhaps the only one considered to have relative significance. The visual plan of the Paks II. Nuclear Power Plant shown *in Figure 5.6.2-1.* shows that the height and overall mass of the two new units are similar to those of the existing Paks nuclear power plant. Thus, the visibility is not expected to change significantly from more popular vantage points, and the new elements in the visual appearance of the two nuclear power plants together are expected to have a tolerable effect (possibly disturbing from some locations). The exploitation of the landscape potential will be further enhanced if the two nuclear power plants operate together, subject to the conditions described for the independent operation of the Paks Nuclear Power Plant.

Source: website of Paks II. Nuclear Power Plant Ltd (www.paks2.hu)

Figure 5.6.2-1. Visualisation of the Paks II. Nuclear Power Plant showing the buildings of the Paks Nuclear Power Plant

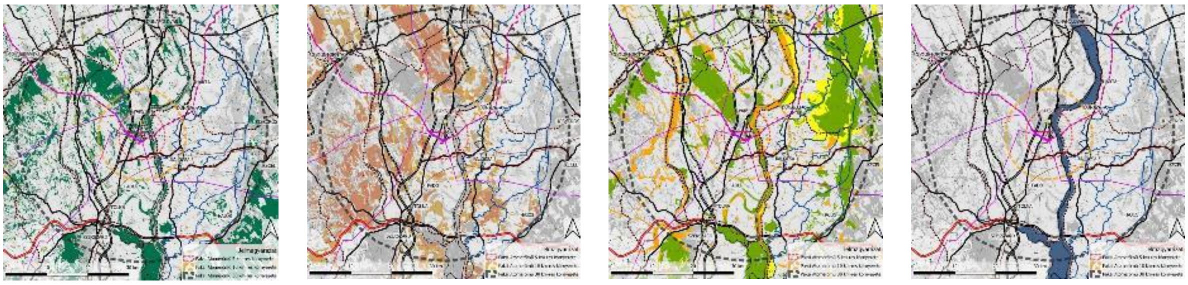
5.7. Impacts on the municipal environment

5.7.1. Description of the base state

The assessment of impacts on the municipal environment, as with the assessment of impacts on landscape and land use, has been carried out on a three-way scale. The wider context is important when examining spatial development and spatial planning, and in determining the role of the town and the power station in the county's spatial structure. The narrower context is relevant for the presentation of the town, the analysis of the relationship between the town and the nuclear power plant and the definition of values.

Both the National Concept for Development and Spatial Planning and the Regional Development Concept and Program of Tolna County consider the new nuclear power plant units at the Paks site as a spatial development asset. In this context, they emphasise the boost to the construction industry, its special role in vocational and higher education, innovation and research, which could be even more significant if the two nuclear power plants are operated jointly. The strategic role of the town of Paks in the economic life of the county and the fact that the production of electricity from the nuclear power plant will have a positive impact on the economic indicators of the county are also noted.

As regards the spatial planning aspects of the site and its surroundings, the currently effective structure sheet of the National Spatial Plan identifies both the existing and the planned new nuclear power plant, and includes existing and planned infrastructure elements (roads, bridges, transmission lines etc.). The nuclear power plant is a key element in the regional electricity supply, shaping the structure of the electricity network in a centric way. *Figure 5.7.1-1.* illustrates the system of National Zones of relevance within a 30 km radius of the nuclear power plant.

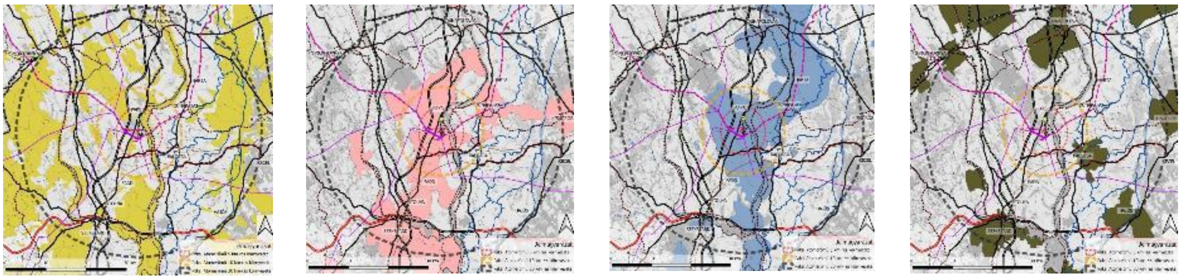


Zone covered with forests (dark green) or recommended for forestation (light green)

Ploughland of excellent (darker brown) and of good fertility features (lighter brown)

Zones of the National Ecological Network (green – private land, orange - walkway, yellow buffer zone)

Zone of riverbed during high water levels (dark blue)



Zone of landscape protection area

Zones of hopeful World Heritage site communities

Zone of the water quality protection area

Zone of settlements affected by defence and military zones

5.7.1-1. Cuts from the National Zoning Plan Sheets (regional zones) in the 30 km vicinity of the Paks Nuclear Power plant

Within a 30 km radius of the nuclear power plant, there is a high proportion of forests and arable land with excellent and good soil conditions, but also large natural areas and elements of the ecological network. The zone of the basin during high water levels extends along the Danube and the Gemenc area. There are a significant number and extent of settlements which are classified as landscape protection, world heritage sites and water quality protection zones. There are also several settlements within a 30 km radius affected by defense and military zones.

The county level, i.e., Tolna County's spatial development plan is in line with the national spatial development plan. South of the power plant, an extensive mosaic is included in the zone of inland waterways (a former Danube floodplain – called "muddy swamp" in the 1st military survey). The county spatial development plan includes the following among the supported target areas:

- almost the entire study area with tourism development,
- the settlements of Paks and Dunaföldvár with innovation and technological development,
- Paks, Dunaföldvár and Tolna settlements with logistics development.

The urban planning aspects of the site and its surroundings are described in *Chapter 2*, under the presentation of the site. It is important to highlight that the subsequent service life extension of the nuclear power plant does not entail any change in land use or the creation of technical infrastructure elements that would require changes to the urban planning instruments.

The most important features of the settlement development planning of Paks are briefly described in *Chapter 5.6.1.* From a settlement environment perspective, the following should be highlighted:

- The settlement's heyday began in the period 1820-1830, as evidenced by the numerous monuments and historic buildings. The settlement, of which the Danube formed an integral part at the time, was characterised by a lively commercial life, which reached its peak at the turn of the 20th century and lasted until the Second World War. This bustling municipal life is reflected in the merchant houses in the town centre, the former hotel and inns, the cellar rows, the busy ferry and the harbour.
- The Second World War caused a significant decline in the life of the town. The Jewish bourgeoisie, which had established the commercial character of the town, disappeared. The population of Paks continued to decline steadily since the First World War, and with no industry coming to the town the urbanisation process slowed down considerably. Thus, in the period following World War II, the community of Paks continued to slowly decline (characterised by, among other things, further population decline, deterioration of the age structure, and unfavourable changes in economic characteristics).
- From the early 1970s, the process of designing, then building and commissioning the nuclear power plant halted this negative trend. The resident population increased significantly, first with the arrival of the construction workers and later with the arrival of the workers who operated the plant. In ten years the population almost doubled. The age composition has also changed, with both the construction workers and the nuclear plant operators coming mainly from younger age groups. However, the development was not really organic, as a housing estate was built "above" the town, and new residents came to work here. The change in the character of the settlement brought both advantages and disadvantages to the "original settlement".
- The development of the town over the last 40 years is inseparable from the nuclear power plant. The Paks Nuclear Power Plant has played and continues to play an important role in the development of the community. The majority of the population is directly or indirectly linked to the plant.

The main general characteristics of the settlement environment are summarised as follows:

- The administrative area of the town is 154.08 km^2, with a population of nearly 18 thousand people.
- The town of Paks is the seat of the Paks district, which comprises 15 settlements.
- The town is essentially "single-centred", with services and various urban functions also concentrated on the Dózsa György út – Tolnai út axis.
- Paks has not been able to expand its medium level municipal functions in line with its population growth. Beyond meeting the local educational needs of the power plant, Paks has not dynamically increased its role in the medium level settlement network. At the same time, the municipal infrastructure coverage of the town is qualitatively better than towns of the same size, and the basic infrastructure is considered complete.

The demographic and age distribution characteristics of Paks from 2012 are shown in *Table 5.7.1-1.* Over the last almost 10 years, the population has decreased by almost

1600 persons, i.e., by 8.5%, and the ageing index has also deteriorated (the number of persons aged 65 and over significantly exceeds the number of persons under 14). However, the population decline is largely due to the migration differential, not to natural attrition.

The unemployment rate in Paks is much lower than in the surrounding settlements (1.77% in 2022) due to the absorption capacity of the nuclear power plant and related service companies.

Table 5.7.1-1. Demographic characteristics of the town of Paks (2012-2022)

Year	Population	Number of 0-14-year olds	Number of persons 65 and over	Number of persons 15-64	Population density [persons/km^2]	Ageing index
2012	19 481	2 672	2 830	13 979	126	105.9
2013	19 387	2 634	2 927	13 826	126	111.1
2014	19 305	2 661	3 034	13 610	125	114.0
2015	19 117	2 640	3 147	13 330	124	119.2
2016	18 970	2 624	3 323	13 023	123	126.6
2017	18 788	2 611	3 426	12 751	122	131.2
2018	18 623	2 608	3 504	12 511	121	134.4
2019	18 489	2 639	3 672	12 178	120	139.1
2020	18 224	2 617	3 790	11 817	118	144.8
2021	18 019	2 636	3 792	11 591	117	143.9
2022	17 827	2 583	3 838	11 406	116	148.6

Source: Hungarian Central Statistical Office (HCSO)

Cultural and historical sites protected or to be protected in the wider and narrower environment include:

- There are no world heritage sites in the studyed settlements according to the relevant regulation and the National Spatial Plan. However, Paks, Dunaszentgyörgy and Fadd is expected to become a world heritage site under the name of “The borders of the Roman empire – The Hungarian stretch of the Danube limes”, and Györköny, Uszód and Dunapataj expect the same under the name of “The network of Hungarian folk museums”.
- According to nationally available and local databases[10] , there are 55 nationally important monuments in 8 settlements within 10 km radius of the nuclear power plant, of which 24 are in 5 settlements located within 5 km. More than 40% of the nationally important monuments are ecclesiastical/sacral, 20% have a residential building character, less than 20% are institutional and 20% are buildings or compounds of other origin.
- Local authorities have the possibility to place worthy built and natural assets under local protection. According to the available data sources, there are 70 locally protected buildings within 5 km of the nuclear power plant in Paks, 39 in Dunaszentgyörgy, 4 in Uszód, 39 in Dunaszentbenedek and 37 in Géderlak (189 in total). These built assets are typically residential, religious and sacral buildings and monuments, and to a lesser extent press houses, institutional and other buildings.
- There is no site or area designated as a national monument within 30 km of the nuclear power plant.
- A total of 336 archaeological sites are recorded within 10 km of the nuclear power plant.
- The values of the municipal environment deserving protection include the green spaces within 5 km of the nuclear power plant, typically in downtown Paks. These are the Paks loess wall, Ürgemező, Táncsics Park, the old Reformed and Virág Street cemeteries, the sports grounds of the nuclear power plant and the green areas of the institutional and residential areas, the cemeteries of Uszód and Dunaszentbenedek.

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[10] Local Artificial Asset Register, annexes to the municipalities' local building code, muemlekem.hu website.

5.7.2. Impacts expected from subsequent service life extension

Impacts of the Paks Nuclear Power Plant's independent operation

The impacts of the Paks Nuclear Power Plant operating on its own can be compared with the impacts of abandonment, i.e., the question may be what changes in the urban settlement/environment can be expected if the Paks Nuclear Power Plant is decommissioned, i.e., no further electricity is generated at the plant. The facility itself, due to the specific decommissioning and abandonment of the nuclear power plant, is expected to stay in place in the longer term, but the consequences of this are not examined in detail, this should be addressed in the environmental impact assessment conducted for a decommissioning.

In terms of spatial and urban planning aspects of the site and its surroundings at the national, county and municipal level, no significant changes in land use and spatial planning are expected as a result of the extension of the service life. The spatial development objectives already defined as a result of the existence of the nuclear power plant are essentially in line with the long-term or planned elements identified in the spatial and town-planning plans. However, developments in the zoning plans that are independent of the nuclear power plant may indirectly influence the conditions for further extension of the nuclear power plants' service life (e.g., the realisation of the new Kalocsa-Paks Danube bridge, easy accessibility, new source of workforce).

Among the general urban characteristics of Paks, the natural geographic and spatial position of the town is not expected to change as a result of the extension of the plant operation. No change in these characteristics is expected even if the power generation at the plant ceases. Such a change can only be estimated if power generation at the Paks Nuclear Power Plant ceases and the new units of Paks II. fail to start operating. In this case, if no new investment is made to compensate for terminated jobs in town, emigration and economic decline in can be expected. This could lead to changes not only in economic but also in social characteristics. The outward migration may involve mainly younger, more skilled people, which may also lead to negative changes in demographic conditions (total population, age composition, skills). In the event of the subsequent service life extension, a situation similar to the present situation can be expected in both economic and social terms, with a neutral impact. No change is expected either in the characteristics of technical and other infrastructure and institutional services.

It is hoped that the good relationship between the nuclear power plant and the town will not change and will remain unbroken during the period of further extension of the plant's service life. The impact is environmentally neutral, but the favourable situation for the town may remain stable. In the case of the expected impacts on the municipal environment, the impact area has been predefined as contiguous urban and industrial areas with buildings, structures and other infrastructure elements in interior area of Paks.

The status of the protected values (see the previous section on status) in the municipal environment, both in the wider and narrower surroundings of the power plant, will not change in the context of the further operation of the power plant, their conservation and maintenance potential will remain unchanged. The vulnerability of these values will not be affected by the continued operation. Continued operation will therefore have a neutral impact on the protected values (but a more favourable situation than in the case of abandonment is expected).

Combined impacts of the nuclear facilities operating and planned on the site

The existence of the Paks nuclear power plant and the construction of the new nuclear power plant mean that the spatial development objectives already defined are essentially in line with the long-term or planned items indicated in the spatial and urban development plans. Further spatial planning elements are directly expected to be implemented as a result of certain prepared and advanced or already implemented developments. The territorial extent of these may even be extended (e.g., new residential areas, infrastructure) in connection with the construction or operation of the new units.

In the case of joint operation, for example, an increase in labour demand cannot be ruled out, which may require the involvement of labour from more distant areas, which may entail infrastructure development, i.e., changes in the spatial structure.

Among the general characteristics of the municipal environment of Paks, the natural geographic position of the town will not change during the combined operation. However, the spatial structural position of the town may improve in parallel with the economic growth of the town (i.e., the joint operation of the two power plants may bring further economic boost to the town with the emergence of the necessary skilled labour force, additional developments to meet their needs, from housing to recreation), as confirmed by the Tolna County Regional Development Program (2021-2030).

If the two nuclear power plants are operated together, these impacts could be even more significant. The new Danube bridge also enables the movement of labour from Kalocsa, as the distance between the two cities reduced to about 15 minutes, so the development and further operation will have a positive, improving impact on other counties and districts.

The demographic situation could also improve, as the combined operation of the two power plants will certainly create a need for additional labour. This may not double the number of people working at the two plants, but it will certainly mean that hundreds or thousands of skilled workers, most of them young people, and their families will have to be provided for in the area. This can be provided partly by inward migration and partly from the surrounding settlements. Improvement may be expected not only in number, but also in age composition. The further extension of the service life and the joint operation of the two power plants could bring about beneficial changes in both economic and social conditions, and the impact is assessed as favourable.

It is also true for the characteristics of technical and other infrastructure and the availability of necessary institutions that the emergence of additional labour can bring positive impacts, and strengthen the likelihood for implementation and expansion. Joint operation can further strengthen the good relationship between the nuclear power plants and the town, and further improve the situation in the town.

As it was also stated in the discussion of the impacts of the stand-alone operation, the status of the protected and to-be-protected values in the municipal environment, both in the wider and narrower surroundings of the power plant, is not expected to change in connection with the combined operation, their possibility of their conservation and maintenance will remain unchanged, and the vulnerability of the values will not increase.

The built heritage is not expected to become an affectee as a result of the joint operation. Rather, the realisation of other land use aspirations linked to the joint operation (e.g., residential, economic and other special areas to be developed in the long term) may have consequences which, if realised, would clearly not exclude the possibility of unfavourable effects on the built heritage, but these are not essentially linked to the present activity.

5.8. Impact on the health of the population

Ionising radiation is a natural consequence of the use of nuclear energy. Ionising radiation is present throughout a person's life, partly from natural and partly from artificial sources. Radiation can be harmful, causing serious illnesses, for example, resulting in DNA mutations that can lead to diseases that develop over time. The higher the dose of low-dose ionising radiation (which does not cause radiation related sickness but damages DNA), the more likely it is to cause disease (tumours or genetic disease).

All living organisms on the Earth's surface are constantly exposed to ionising radiation. The average effective dose of this radiation is 2.4 mSv/year on Earth and 3.0 mSv/year in Hungary. In many parts of the world, the natural background radiation is an order of magnitude higher than in Hungary, which is not reflected in the incidence of cancer, i.e., exposure variations in the range of 2-3 mSv/year effective dose do not cause a detectable increase in cancer risk. (The average dose of ionising radiation from artificial sources on Earth is 0.4 mSv/year.)

The study to assess the environmental impacts of the subsequent service life extension of the Paks Nuclear Power Plant should evaluate the incidence of potentially ionising radiation-related diseases in the population living within 30 km of the plant. The analyses should answer the question whether the observed pattern of illnesses raises the suspicion that there is an additional risk of certain diseases associated with the radiation exposure related to the operation of the Paks Nuclear Power Plant.

The health status of the population living in the vicinity of the nuclear power plant has recently been the subject of two comprehensive studies:

- Lévai Project, Preparation and implementation of the technical assessment and study programs for the compilation of the environmental impact assessment, Final report, Determination of the health status of the people living in the vicinity of the site, MVM Ltd., contract number: MVM TEVH/11C00039, MVM ERBE Ltd. contract number: S 11 122 0, ERBE document reference number: S 11 122 0 007 v0 25, 12 June 2013.
- MVM Paks II. Ltd., Construction of new nuclear power plant units at the Paks site, Environmental Impact Assessment, MVM Paks II. Ltd. contract no: 4000018343, MVM ERBE Ltd. contract number: 13A380069000, Chapter 20: Environmental radioactivity – exposure of the population in the vicinity of the site.

The investigation establishing a position was carried out in two phases. In phase 1, relevant Hungarian health statistics were processed. (Demographic data were provided by the Central Office for Public Administration and Electronic Public Services, the number of deaths per year in settlements and indicators of socio-economic status of settlements by the Hungarian Central Statistical Office, the National Registry of Congenital Malformations provided the database of registered malformations, and the National Health Insurance Fund provided the performance data on outpatient and inpatient specialised care.) In phase 2, a study based on primary data collection was performed, which enabled risk assessment adjusted for other (not ionising radiation) risk factors at individual level.

No environmental load involving health risks have been previously observed in the vicinity of the nuclear power plant, as confirmed by the test results referred to above.

The study area was defined as a 30 km circle around the Paks Nuclear Power Plant, in line with the scope of other environmental impact assessment tasks. Within this area, measurements and model calculations based on the results of measurements could be used to confirm that no ionising radiation capable of causing significant biological effects was emitted from the nuclear power plant. The study area represents a potentially exposed population. The studies therefore create separate evaluations of the population within a 10 km radius (as the primary potential affectee), the population within a 10-20 km band (as the secondary potential affectee) and the population within a 20-30 km band (as the reference population reflecting local conditions).

5.8.1. Phase 1 studies

The assessment of mortality and morbidity ratios essentially looked at the relationship between the number of expected and observed cases. The first step in this analysis was to produce ratios standardised by age, sex and study year using indirect standardisation to obtain frequency data that show risk independent of the disturbing effect of demographic composition. A distance trend analysis was then used to examine whether the location of the Paks Nuclear Power Plant was a point-source of health effects (increased risk in the vicinity of the Nuclear Power Plant and decreasing risk moving away from it). The latter analyses were complemented by an assessment of the effect of socioeconomic status on the development of the diseases studied.

Overall, the study found that at almost all endpoints, the population in the study area was characterised as being in good health or in a similar health status to that observed in the reference populations.

The possibility of an increase in risk associated with the power plant, based on the Phase 1 statistical indicators, arose at the following endpoints:

- deaths from malignant tumours of the colon,
- deaths from hypertension,
- the prevalence of developmental abnormalities of the gastro-intestinal tract,
- morbidity from colorectal malignancies,
- morbidity due to hypertension,
- morbidity from ischaemic heart disease,
- morbidity from cerebrovascular diseases,
- morbidity from diseases of the circulatory system,
- morbidity from other musculoskeletal disorders,
- morbidity from muscular atrophy of spinal origin.

In relation to the above, it is important to emphasize the following:

- The morbidity from diseases of the circulatory system summarises the cases of hypertension, ischaemic heart disease and cerebrovascular disease. Therefore it should not be considered as a distinct endpoint.
- The excess risk registered in specialist care for certain diseases of the circulatory system could be explained by the fact that the specialist care provider can play a greater role in the care of patients living close to Paks, and the primary care general practitioners play less active. On the other hand, the more unfavourable pattern of cardiovascular risk factors (smoking, obesity, sedentary lifestyle) of patients living close to the plant could also explain the increase in local risk. Altogether, the decrease in local risk as a function of distance from Paks raises the likelihood of an explanation based on easier access to specialist care.
- Ionising radiation is not included as an aetiological factor for cardiovascular disease, which also supports the view that the increase in local risks (by any Phase 1 indicator) is not attributable to exposure to ionising radiation.
- Among the 82 Phase 1 endpoints examined, 8 summary indicators (total cancers, total cardiovascular diseases, total digestive tract diseases, total violent deaths) were included. Of the 74 distinct indicators, 6 dealt with chronic cardiovascular diseases whose etiological factors did not include low doses of ionizing radiation. These were taken into account and statistical evaluations were performed on 68 relevant endpoints. The number of statistical artifact results at this number of analyses was 68 × 0.05 = 3.4. This implies (assuming equality in the number of tests with apparent significant differences in the positive and negative directions) 3.4 (1.7 increase in risk and 1.7 decrease in risk) as the expected number of statistically significant differences with a risk distribution that can be explained by chance.
- Mortality from colorectal malignancies (high risk in Paks based on 63 cases), morbidity from spinal muscular atrophy (high risk in Paks based on 8 cases) and morbidity from colorectal malignancies (high 0-10 km zone risk based on 136 cases) were highlighted based on 1 statistically significant increase in risk, and morbidity from alimentary canal malformations and other musculoskeletal malformations were highlighted based on 2 significant statistical tests (high risk in Paks based on 13 and 1936 cases and high 0-10 km zone risk based on 17 and 2599 cases respectively). There were certainly statistical artifacts among these. (7 significant increases in risk were observed compared to 3.4 expected). However, it is not possible to distinguish between statistical artifacts and endpoints showing true risk elevation on the basis of the available data in Phase 1. This requires an assessment of the aetiological relationships of the diseases and knowledge of the intensity of risk factors observed in the study area. The latter was particularly important in the case of colorectal cancer, which showed a local increase in risk in both mortality and morbidity analyses recorded in specialist care.
- The reliability of data for the endpoints showing the increase in risk is variable. Some of the diseases registered in specialised care are referral diagnoses (registered only on the basis of suspicion of disease). The reporting effectiveness for developmental disorders shows spatial variability. A diagnosis of cancer death based on histological diagnosis is

considered the most reliable data. This consideration has also underlined the need for a more accurate exploration of the elevated incidence of colorectal cancer.

5.8.2. Phase 2 of the study involving general practitioners

In order to further investigate the observed increased risk associated with the power plant identified in Phase 1 studies, Phase 2 studies were conducted with the involvement of general practitioners.

Lifestyle risk factors at the individual level cause difficulties of interpretation when the prevalence of individual diseases cannot be adjusted for the impact of lifestyle-related confounders (e.g., smoking, alcohol consumption, accumulation in the family etc.). Therefore, analyses based on aggregated data had to be completed by primary data collection in the study area, describing not only the health status of the residents but also their risk factor profile. To this end, a collaborative general practitioner service had to be organised, as general practitioners are familiar with the basic risk factors that have a significant impact on the development of the diseases studied in the program. With their help, both the health status and the risk profile can be recorded, while respecting data protection rules, providing the full coverage and quality required for the study.

Education (as an approximate indicator of general socioeconomic status), regular smoking, occupational exposure to radiation, diabetes, prevalence of ischaemic heart disease and hypertension, and family history of cancer were the confounders included in the analyses. In selecting the control group, adults without cancer who were age, sex and education matched were asked to participate by their general practitioners. The (potential) residential exposures could be approximated by the distance of the study participants' residence from the plant. Residents living more than 20 km away from Paks were considered unexposed and those living closer were considered (potentially) exposed.

The study sought to determine whether there is a correlation between the incidence of cancer and the distance from home to the power plant correlated with potential exposure to nuclear power plants. The calculated measure of the correlation was the odds ratio, a measure of how many times higher the incidence of cancer is among people living near a power plant than in the reference population living further away.

The aim of the study was to assess the prevalence of biological effects associated with ionising radiation in principle among people living in the vicinity of a nuclear power plant.

An analytical approach was used that allowed the quantification of the influence of exposure from the power plant alone on cancer risk by adjusting for the effects of risk factors on the development of tumours. The exposure under study (the dose of ionising radiation in the environment from the power plant) was estimated by the distance between the subjects' residence and the power plant, rather than by direct measurements. The induced health damage was the incidence of cancer as recorded by the general practitioner. Other risk factors controlled were age, sex, education, smoking, occupational exposure to radiation, family history of cancer, diabetes, hypertension, and ischaemic heart disease. The study involved data collection by general practitioners in settlements in 3 counties closer than 30 km to the power plant. Data were analysed by tumour type. A description of the case and control populations was made, and the role of each risk factor in influencing risk was determined using multivariate logistic regression.

As an overall result, it could be stated that the study found no increase in cancer risk among people living near the nuclear power plant.

5.8.3. Impacts expected from subsequent service life extension

In normal operation, the radiological impact is neutral with respect to atmospheric and water emissions, because the combined maximum total doses of the three facilities (Paks II., Paks Nuclear Power Plant and the SFISF) are two orders of magnitude below the neutral value for normal atmospheric emissions during operation.

The maximum combined effect of liquid emissions is 0.154 µSv/year for children aged 1-2 years and 0.204 µSv/year for adults. On the basis of the highly conservative approximations used, the normal operation of the plant does not give rise to a risk to the population exceeding 90 µSv.

For this reason, the same health impacts are expected during the subsequent service life extension of the Paks Nuclear Power Plant and after the commissioning of the Paks II. as during the operation of the Paks Nuclear Power Plant so far. In other words, the operation of the Paks Nuclear Power Plant and the SFISF to date has had a neutral impact on the health of the population living in the vicinity, which will not be affected if Paks II. starts operating as planned.

There was no evidence of any health loss in the exposed population that was not present in the control groups and could be attributed to ionising radiation. Based on measurements and conservative model calculations, the environmental impact of the Paks Nuclear Power Plant and the SFISF was orders of magnitude lower than the regulatory maximum dose. According to the model calculations, the commissioning of Paks II. will not change this situation. The very small exposure of the population compared to the maximum permissible dose means that it is not even possible to define an impact area in the usual way in environmental epidemiological studies. There is simply no excess exposure to which the geographical extent of the impact area of exposure could be adapted.

The stochastic adverse health impact of low-dose ionising radiation have a significant latency for tumours and genetic diseases. In the case of developmental disorders, however, the impacts are manifested within a time span corresponding to the length of pregnancies. For this reason, it is important to carry out a systematic risk assessment for developmental disorders and therefore to have a continuous monitoring system to detect health impacts with long latency. This is why health monitoring covers a long period of time in the vicinity of the nuclear power plant.

The majority of diseases caused by ionising radiation are life-threatening or cause significant loss of quality of life even with treatment. For this reason, it is not possible to pursue strategies in this field that focus on the subsequent mitigation of the manifested damages. It is therefore justified that the maximum permissible dose should be very strict. (Even compared to the average effective dose of 0.4 mSv/year as a side effect of medical treatment, the dose constraints per plant are very low at 90 µSv/year.) And for this reason, it is very positive that the Paks Nuclear Power Plant has a very low impact on the environment during its operation compared to the dose constraints.

5.9. Generation and treatment of non-radioactive waste and wastewater

5.9.1. Description of the base state

The operation of a nuclear power plant generates both wastes similar to household waste (municipal) and production-related (non-hazardous and hazardous) inert solid waste. In addition to solid waste, municipal wastewater from the use of sanitary equipment, inert wastewater and oily water from technology is generated. These wastes are collected at designated collection areas at the plant in an organised manner.

5.9.1.1. Waste generation and management

Wastes similar to household waste (municipal)

Waste similar to household waste is generated in all the units of the nuclear power plant and in their work areas (offices, workshops, social rooms, canteens, laboratories etc.). Waste is collected at the place of its generation in collection containers, bins or designated storages. Municipal waste is handed over to an organisation with a valid waste management license and is collected in a contractually compliant manner following the route and according to the collection plan specified in the contract. Waste such as household waste, which generates a volume of several hundred tons per year is disposed of in the municipal landfill of the town of Paks.

Paper and plastic waste is collected separately at the nuclear power plant site and all organisations are obliged to collect it separately and place it in the designated containers. The separate collection of plastic and paper waste shall be carried out in colour-coded, hot-dip galvanised containers with a capacity of 1.1 m^3 placed on the site of the nuclear power plant. These containers are also emptied by the municipal service provider under a contract in accordance with the weekly emptying route plan.

Non-hazardous production waste

Non-hazardous production waste is collected separately from waste such as household waste and hazardous waste at the Non-Hazardous Production Waste Collection Area or at designated storage facilities.

The different types of production waste generated during plant maintenance, sometimes in large quantities, are collected separately and selectively. The most common non-hazardous production wastes at the nuclear power plant are paper, metal, wood, rock wool, cable, glass and plastic. The majority of the paper waste collected from the nuclear power plant's industrial waste storage and the majority of the metal waste is recycled.

The annual generation of non-hazardous production waste at the Paks Nuclear Power Plant has been close to 700-760 tons over the last two years, which corresponds to the normal operating conditions.

The non-hazardous production waste is transferred to an organisation with a valid waste management license for transport, further utilization or disposal.

Hazardous production waste

The collection of hazardous waste at the workplace is separated by type, in closed containers, in a closed place and in a non-polluting manner. Hazardous waste is transferred from the designated workplace collection areas to the Hazardous Waste Workplace Collection Area, except for those (e.g., waste oil, containerised oil absorbents etc.) that are transported directly from the collection area for disposal or utilisation. The design of the Hazardous Waste Collection Area is in compliance with the legal requirements and its operating rules have been approved by the environmental protection authority.

The annual amount of hazardous waste generated is mainly determined by the volume of planned maintenance and renovation work in a given year. Hazardous waste generated at the power plant typically includes oil-contaminated waste (rag, sludge, waste oil, oily water), packaging waste and general packaging material contaminated with hazardous substances (e.g., paint, oil, packaging of chemical substances), foaming agents, borax waste, electronic waste).

The annual generation of hazardous production waste at the Paks Nuclear Power Plant has been around 290-310 tonnes over the last two years, which corresponds to the normal operating conditions.

Hazardous production waste is transferred to an organisation with a valid waste management license for transport and disposal.

5.9.1.2. Wastewater generation and treatment

Disposal of treated municipal wastewater

The municipal wastewater of the power plant, the wastewater of the sanitary and laboratory building and occasionally water on top of expected amounts is treated in the municipal wastewater treatment plant (*Chapter 2.2.3.1.*) with a capacity of 1870 m^3/day. The water used by the power plant is discharged into the Danube via the cold water channel. Before the launching the system, a sampling shaft was constructed, which is the sampling point for the power plant V3. In 2022, the amount of treated municipal wastewater generated equalled 36 667 m^3.

Depending on the radioactive concentration, the dried sludge from the treatment process is treated or released and disposed. Municipal sewage sludge released from control by the radiation supervisory authority is classified as hazardous waste and disposed of in accordance with the relevant legislation.

Industrial wastewater treatment and disposal

The plant generates the following inert wastewater (*Chapter 2.2.3.1.*):

- Slop from the water extraction facility:
  The combined volume of sewage water discharged is 0.5 m^3/s (1800 m^3 /h) at its peak. The pollutant is waterborne, suspended solids filtered from the Danube water (held up in filters with a mesh size of 0.4-5.0 mm). The suspended solids content of the effluent discharged at concentrations depending on the pollution of the Danube is about 40-50 times higher than that of the Danube water in the filtration range.
- Wastewater from water treatment:
  From September 2020, the demineralised water is produced by the new, modern make-up water preparation plant of the nuclear power plant, based on a more economical and environmentally friendly technology. The majority of the inert industrial wastewater is obtained during the demineralisation process through neutralisation and settling of suspended solids in 2 clay-lined slurry ponds of 10 000 m^3. The high salinity of the industrial wastewater discharged from the sludge ponds, which is cleaned of suspended solids, is a source of environmental pollution. Most of the salinity is sodium chloride, i.e., table salt, formed by the reaction of hydrochloric acid and sodium hydroxide regenerates. The volume of wastewater from the water softener is 500-700 m^3/day at any one time.
- Technological oily wastewaters:
  The oily wastewater is treated at source and then discharged into the plant's municipal wastewater system or rainwater drainage system.
- Wastewater from the secondary circle:
  Secondary circuit wastewater is generated in the engine room as follows:
  - Condensate wastewater and mopping water: these waters are collected in the basement sump, from where they are pumped to the warm water sewer from the -6.5 m level.
  - The emergency cooling water system and any failure of the condenser cooling water system – emergency water – also collects in the -6.5 m deep sump. They are removed by a submersible pumping system to the warm water drain. Waters containing oily or suspended impurities are discharged through an oil trap.
  - Rinsing water for magnetic filters. Total volume 100 m^3/week at an intensity of 20 m^3/h, once a week. It is drained into the warm water channel.
  - Wastewater of full-flow drainage of chemical residues, regeneration solutions. A system was built dedicated to collecting these. The water activity concentration in the secondary circuit systems is monitored at several points by continuous telemetry and sampling. Pre-discharge monitoring (collection in a control tank and discharge after activity concentration monitoring) is only carried out for the regenerates of the full-flow condensate treatment plant and in some cases for the water discharged from the steam generators.

  There are several options for their placement:

  1. If the regenerate is radioactively contaminated, it is disposed of in primary circuit containers.
  2. If radioactively pure (max. 3 Bq/l measured by total beta) into the calcareous sludge pools. Wastewater from secondary circuit treatment is piped into the industrial wastewater system. Supplied medium: solutions of acids, alkalis.
  3. For water discharged from steam generators, the emission limit can be between 3 Bq/l and 30 Bq/l depending on the discharge pathway.
- Wastewater from supplementary addition of chemical, tank cleaning effluent: these are very small amounts of wastewater, and are placed in a collection tank and pumped to the calcareous sludge ponds.

- Periodic wash waters:
  Primary and secondary circuit systems are chemically preserved during annual maintenance. The wastewater from the conservation of the steam generators is discharged into two 10 000 m^3 wastewater basins with a geoelectric sensor network (monitoring system) covered by an insulating film, from where it is discharged into the Danube via the warm water channel in compliance with the criteria provided in the water systems operation license (if accredited laboratory tests show that the wastewater meets the discharge criteria).

In the year 2022, 754 965 thousand m^3 of industrial wastewater was generated, which, compared to the annual volume of cooling water, was discharged into the Danube after dilution by about 18 000 times in the warm water channel.

The MVM Paks Nuclear Power Plant Ltd. has a Self-Monitoring Plan for its discharges of used and wastewater, as required by law, which is approved by the water management authority and is reviewed every five years (or in case of a change in the discharge). The Self-Monitoring Plan, prepared on the basis of 27/2005. (XII. 6.) KvVM Decree on the detailed rules for monitoring the discharge of used water and wastewater, defines the method and scope of water quality monitoring.

To assess the quality of the water used, the water from the warm water channel shall also be sampled at the time of sampling water from the cold water channel. The quality of all used water discharged into the Danube and the combined (resulting) treated wastewater shall be ensured by testing the water sample from the warm water channel estuary outlet structure at sampling station V-4. Sampling is carried out on a quarterly basis.

The results of the measurements must not exceed the limit values of the national territorial limit values for "Recipients of general protection category 4" in Annex 2 of 28/2004. (XII. 25.) KvVM Decree on the limit values for emissions of water pollutants and certain rules for their application. The results of the emission monitoring show that the nuclear power plant complies with the regulatory limits.

5.9.2. Impacts expected from subsequent service life extension

Solid waste

During continued operation of the nuclear power plant, the amount of different types of waste generated is expected to be similar to the current level, and the type of waste generated is not expected to differ either. Waste collection systems and on-site storage facilities are in place and are capable of handling waste in accordance with the legislation without major modifications.

Waste generation is an impact factor for which the extension of the plant's service life causes cumulative quantities, i.e., overall, the additional 20 years of operation will increase the amount of waste generated during the plant's service life, even if the plant is able to reduce the annual waste quantities generated compared to previous periods.

The operation of the Paks II. Nuclear Power Plant will have no impact on the characteristics and quantity of non-radioactive waste generated by the Paks Nuclear Power Plant as Paks II. will have its own waste management system, independent of that of Paks Nuclear Power Plant.

The subsequent service life extension of the Paks Nuclear Power Plant's service life is not expected to result in significant changes in the type and annual amount of non-radioactive waste generated compared to the current situation, but an overall increase may be seen in the amount of waste over the service life of the plant.

The areas affected by the operational and accidental generation of non-radioactive waste during the operation of the nuclear power plant are the nuclear power plant site, the hazardous waste collection area, and the non-hazardous industrial waste collection area and their immediate surroundings. The extension of the impact area includes the waste collection areas, storage facilities and their immediate surroundings, i.e., the impact area remains within the site boundary of the power plant site.

Wastewater

Wastewater discharged from the nuclear power plant into the living water (municipal wastewater, treated oily wastewater, wastewater from the water preparation plant, water from periodic washing) is discharged after treatment into the warm water channel upstream of the estuary and from there, after control, into the Danube. No significant changes are expected in the sources, types and quantities of wastewaters from the operation of the Paks Nuclear Power plant during the subsequent service life extension period, based on the information currently available. However, an overall increase in the volume of wastewater generated is expected over the service life of the plant.

5.9.3. Impacts of havaria events

In the context of the waste management system applied at the nuclear power plant, non-radioactive waste incidents are defined as spills and leaks occurring during the storage of waste at the workplace, at the plant collection area and during the movement of waste (loading, transport). During the transport of waste from the plant and in the event of an accident involving a transport vehicle, waste may also be dispersed or spilled along the affected section of the route. These events may cause changes in the geological medium due to the contaminating effects of the waste.

By following the nuclear power plant's waste management procedures, training workers, and using state-of-the-art equipment and vehicles, the likelihood, risk and danger of such incidents can be greatly reduced.

The detailed rules for the collection, treatment and transportation of non-hazardous and hazardous waste generated at the power plant are laid down in regularly revised procedures, which must be followed by all employees working at MVM Paks Nuclear Power Plant Ltd. In order to mitigate any damage that may occur, it is necessary to stock and use absorbent materials (sand, perlite, etc.) that can be used to soak the waste.

A havaria related to waste generation and waste management can also be mentioned as an event if an unplanned type and amount of conventional waste is generated during some other activity in the power plant, the handling and removal of which must be ensured in the power plant's waste management system. The impact of the excess waste generated will be felt as extra on-site land use, the area of impact remaining within the plant site.

Overall, the generation and management of non-radioactive waste is in practice a rare havaria event. The environmental impact of such incidents can be mitigated by compliance with the regulations, by stocking the necessary equipment and materials to deal with the incident, by providing trained personnel and by intervening in a timely manner. This way the impact can be short-lived and significant environmental impacts can be prevented.

5.10. Impacts on noise and vibration conditions

5.10.1. Description of the base state

The baseline noise load for the years 2006-2012 is assessed taking into account the studies related to the Paks Nuclear Power Plant and Paks II., within the assumed direct impact area – Paks, Paks-Csámpa, Uszód, Dunaszentbenedek. The following are the residential buildings / neighbourhoods closest to the site, and thus requiring noise protection, and applying maximum permissible noise levels to them with the relevant noise load limit values:

1. Paks, area for the location of a special health centre (plot no. 8802/34).
2. Paks, workers' hostel in a mixed institutional area (plot no. 4703/45).
3. Paks, near the entrance of Paks Nuclear Power Plant, residential building in economic industrial area (plot no. 057/9).
4. Paks, Csámpapuszta 22. Csámpai Fenyvestanya, in a rural residential area (plot no. 0292/2).

5. Paks, Csámpapuszta 33. Csámpai Faluház, in a rural residential area (plot no. 0191/23).
6. Dunaszentgyörgy Béke tér 22. residential building, in a rural residential area (plot no. 112/1).
7. Uszód, Béke u. 15. residential building, in a rural residential area (plot no. 044).
8. Dunaszentbenedek, Zöldfa u. 3. residential building, in a rural residential area (plot no. 581/2).

The traffic noise load was considered along the main traffic routes related to the nuclear power plant, the main road No. 6 and the M6 motorway within a maximum distance of 25 km from the site of the core activity in the settlements of Paks, Dunaszentgyörgy, Dunaföldvár, Tengelic, and Fácánkert.

For the operational assessment of the Paks Nuclear Power Plant, the "current" environmental base state is the noise situation in 2024, which also provides the basis for determining the plant's operational background load. The background load of the operational road traffic was determined on the basis of the annual average daily traffic data for the road sections concerned, minus the traffic associated with the operation of the Paks Nuclear Power Plant.

Based on the available information, the environmental noise impact of the Paks Nuclear Power Plant on the surrounding residential areas is not detectable and measurable independently of the background noise. Based on the assessment results, it can be concluded that the environmental noise load of the Paks Nuclear Power Plant is below the noise load limit values at all assessment points and measuring surfaces that can be evaluated, i.e., it is adequate.

The baseline road noise load is considered for the road sections where an impact area will have to be defined and for which road sections an impact area is potentially assumed to be created. For the sections of main road No. 6 and M6 motorway potentially affected by power plant-related traffic, the traffic data of the latest available road database (2022) (data of Hungarian Public Roads Nonprofit Ltd.[11]) were taken into account. The background load is given net of the traffic associated with the operation of the Paks nuclear power plant.

Based on the information processed, the noise load values at the reference points to be protected along the M6 motorway are below the limit values at all test points. At the reference points to be protected along main road No. 6, with the exception of Dunaföldvár and Paks Csámpapuszta 22, the test points show a few dB excess during day and/or night hours.

In the framework of the environmental impact assessment of the Paks II. Nuclear Power Plant, vibration measurements were taken in the vicinity of the Paks Nuclear Power Plant at the cold water channel and at the boundaries of the areas adjacent to the Paks Nuclear Power Plant, and vibrations from traffic were also investigated. During the study period, Paks Nuclear Power Plant and the vibration generated by road and rail traffic were considered to be the source of vibration. Thus, these base state results also characterised the environmental vibration impact of the Paks Nuclear Power Plant. The results of the historic studies indicate that the load to vibration is not likely to be critical, either for the base state or for the Paks Nuclear Power Plant.

In view of the results of the previous studies referred to above, and the considerable distance of the Paks Nuclear Power Plant from residential areas and its insignificant contribution to traffic-related vibration, it is not justified to carry out further environmental vibration load studies.

5.10.2. Impacts expected from subsequent service life extension

Impacts of the Paks Nuclear Power Plant’s independent operation

Based on the environmental impact assessment of the first service life extension and its review, the dominant sources of noise at the plant are: 8 steam turbines (in main buildings I-II), transformer plant equipment, cooling plant building, submersible pumps of the water intake plant,

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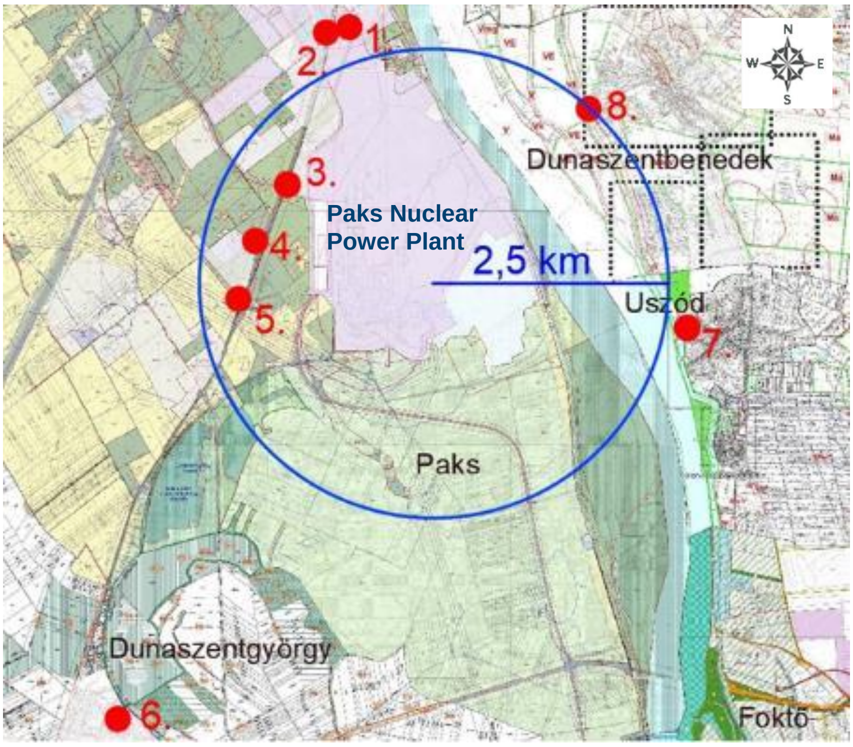
[11] www.kozut.hu/kozerdeku-adatok/orszagos-kozuti-adatbank/forgalomszamlalas/

firewater pumps (in-doors), outdoor transformers, high pressure compressor (in-doors), level control weir, energy-dissipating structure, maintenance and machining shop, hydrogen building.

A comparison with historical data shows that the plant's noise emissions have not increased since 2006. Looking at the time since the start of the first service life extension, there have been improvements in the equipment operating during a havaria, but the impact area (night is the larger) is not affected by the havaria operating noise sources tested during the day. Compared to 2012 data, the operational noise load of the Paks Nuclear Power Plant has not increased in the 12 years since data collection started. The operational noise impact area of the Paks Nuclear Power Plant can be assumed to be within a circle of approximately 2.5 km radius, to be marked east of the plant centre due to the intake and return structures (noise sources) associated with the plant (*Figure 5.10.2-1*).



Note: The red marking means the sites and objects to be protected closest to the nuclear power plant (numbered according to *Chapter 5.10.1*)

Figure 5.10.2-1. Impact are of Paks Nuclear Power Plant's normal operatin from noise protection aspects

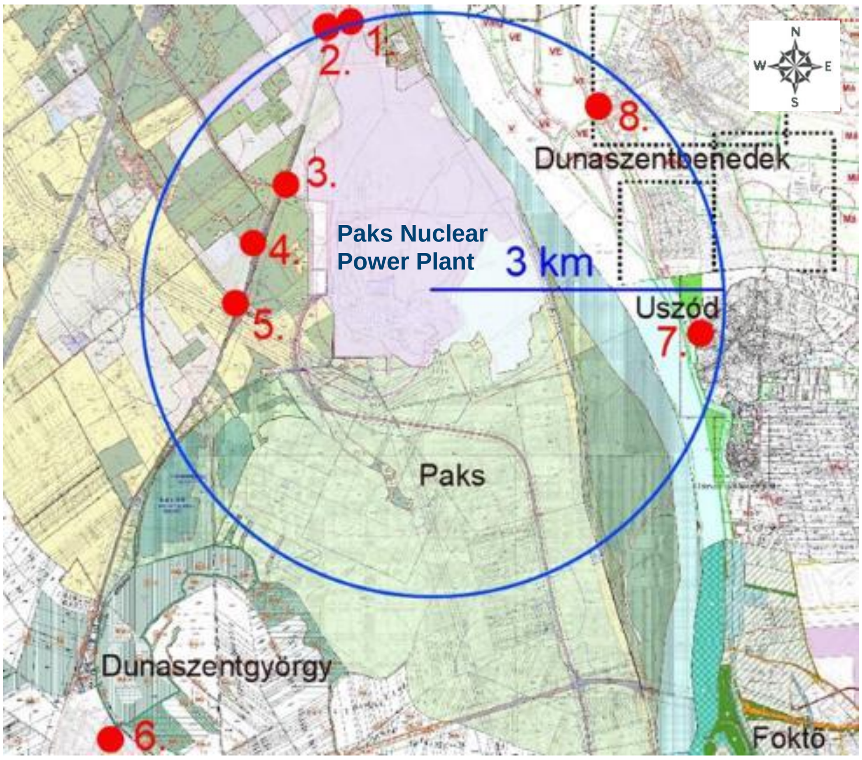
The impact area covers the administrative areas of Paks, Dunaszentbenedek and Uszód. There will be no transboundary impact due to the noise emissions from the nuclear power plant. No change is expected in the noise sources of the nuclear power plant for the whole duration of the planned extension of the service life. No significant change is expected compared to the current operational emissions of the plant, and therefore the current noise load is expected to continue. Noise modelling will be carried out as part of the environmental impact assessment to refine the noise impact area. The operational noise load of the Paks Nuclear Power Plant is expected to be long-term and in the neutral to tolerable categories for the qualification of environmental effects.

Based on the passenger car traffic data related to the operation of the Paks Nuclear Power Plant, higher loads are expected to occur between Dunaszentgyörgy and Paks on related to main road No. 6, no increase in noise pollution is expected on the M6 motorway in connection with power plant traffic. No indirect impacts are expected on the affected road sections. Noise impacts from traffic associated with the operation of the nuclear power plant (*Section 2.2.3.2.*) will be modelled in the environmental impact assessment study. The traffic noise load of the Paks Nuclear Power Plant is expected to be long-term, in the neutral category for the purposes of environmental impact assessment for the facilities and areas to be protected. In 2006, the traffic load was lower for the power plant, but since then traffic patterns have changed, road traffic and power plant traffic have increased accordingly and proportionally. Looking at the long term forecast, it is unlikely that there will be any future impact area for the power plant along the affected roads. The new Tomori Pál bridge between Paks and Kalocsa is not expected to have a significant impact on the noise load from traffic related to the Paks Nuclear Power Plant.

Based on the baseline historical vibration measurements carried out in the context of the Paks II. environmental impact assessment, the Paks Nuclear Power Plant's environmental vibration load is below the limit value. The vibration load from traffic related to the operation of the Paks Nuclear Power Plant is not expected to be significant, as the traffic on the main road No. 6 is not significantly affected by the traffic of the Nuclear Power Plant. No impact area can be defined for vibration. Vibration from the combined operation of the Paks Nuclear Power Plant and Paks II. is expected to be a long-term impact in terms of the qualification of environmental impacts on the assets to be protected and can be qualified as neutral. No change is expected for the vibration sources for the duration of the additional service life extension, the current exposure can be taken into account for the duration of the additional operation.

Combined impacts of the nuclear facilities operating and planned on the site

The environmental impact of the combined operation of the Paks Nuclear Power Plant and Paks II. is expected to be close to, but not exceeding the zonal noise load limits in the nearest residential areas. The cumulative noise impact area of the operation of the Paks Nuclear Power Plant and Paks II. is assumed to be within a radius of approximately 3 km, to be marked east-southeast of the centre of the power plants due to the intake and discharge structures (noise sources) associated with the power plants (*Figure 5.10.2-2.*). There will be no transboundary impacts. The operational noise load of the Paks Nuclear Power Plant and Paks II. is expected to be long-term and in tolerable to burdensome categories for the qualification of environmental impacts in terms of the objects to be protected. Noise modelling will be carried out as part of the environmental impact assessment study to refine the noise impact assessment.



Note: The red marking means the sites and objects to be protected closest to the nuclear power plant (numbered according to *Chapter 5.10.1*)

Figure 5.10.2-2. Impact are of combined operation of the Paks Nuclear Power Plant and Paks II. from noise protection aspects

The traffic noise impact of Paks II. Nuclear Power Plant was estimated based on the data of the Paks II. environmental impact assessment (2014). The road noise impact of Paks II. is not detectable on either main road No. 6 or the M6 motorway, therefore it is assumed that no definable traffic impact area will be created by the combined operation of the two nuclear power plants. The traffic noise impact of the Paks Nuclear Power Plant and Paks II. is expected to be long-term in terms of the qualification of environmental impacts and to be in the neutral category in terms of the objects to be protected. The noise impacts will be modelled in the environmental impact assessment study.

5.10.3. Impacts of havaria events

For the purpose of this study, the black-out event of the Paks Nuclear Power Plant was considered as the event of a havaria. It is estimated that noise emissions during the havaria event will be close to the limit value at the nearest protected objects. The magnitude of the impact area is not significantly different from the impact area during the operational period, estimated to be within a circle of approximately 2.5 km (*Figure 5.10.2-1.*). The noise impact area, supported by noise modelling, will be presented in the environmental impact assessment study.

6. Study programs establishing the basis for the development of the environmental impact assessment study

6.1. Description of the site

Analysis of geographical location, population size and distribution

The purpose of the site characterisation of the Paks Nuclear Power Plant is to provide a summary description of the Paks region (a 30 km radius around the site), which consists of 75 settlements, in terms of geography, land use and land cover, demographic characteristics, economic characteristics, water use, transport characteristics. Projections, forecasts and projections up to 2060 are made for land use and land cover, demographic characteristics, economic characteristics and transport.

The description of the geography of the Paks nuclear power plant and its wider surroundings includes an explanation of the geographical situation, which essentially places the site and the area within a 30 km radius (the Paks region) at the junction of two large areas, the Great Plain and the Trans-Danubian hills. This has important consequences for the land cover and land use of the area under study. In other words, natural factors play an important role in the economic life of the region (e.g., agriculture) or in its transport (e.g., through traffic). The geographical location is presented in addition to the geomorphological and landscape characteristics, which are also described and evaluated. The data on each landscape component will be used to produce a map-based digital database, which can also be used to capture results from other disciplines (e.g., land use). With regard to geographic location, forecasting is not relevant. The results of studies on land use and land cover change forecasting are used to illustrate possible future changes.

Forecasts on land use and land cover change are made using LCM, Land Change Modeler for ArcGIS software, relying on a so-called multi-layer perceptron (MLP) artificial neural network, based on CORINE land cover data from 1990 and 2018. Preliminary calculations, which assume no change in trends and therefore do not take into account factors that inhibit and drive land use conversions, indicate that 9000-12000 ha of land cover change could occur, which is about 3.2-4.2% of the 30 km study area. The main drivers could be the expansion of settlement areas and forest areas and, in particular, the loss of arable land and natural or semi-natural watercourses. The increase in artificial surfaces is expected mainly in the context of the Paks II project, due to the industrial and residential land demand in the area. However, the land use of the whole study area (Paks region) will not change significantly by 2060 and will remain essentially an agricultural landscape with forests and valuable natural areas.

Further studies on water use will aim to map small streams, lakes and waterlogged areas in terms of water use and to enter the results into the digital database. This digital database will thus contain not only natural geography (e.g., geomorphology, small area etc.) elements and information on geographic location, but also useful and up-to-date data on water use (surface and subsurface waters). In addition, the water use assessment will include detailed information on urban water and wastewater services. This information will also be used, for example, in land use and land cover studies.

The results of the demographic situation assessment of the Paks region so far and further details (e.g. migration, natural population movement, actual reproduction etc.) prepare the demographic forecast for the region. The population projection methodology used to forecast the demographic trends in the study area combines a cohort component and an agent-based modelling approach, which allows for the detailed spatially resolved projection of migratory trends in addition to the natural population movement projections. The methodology has been used successfully in the past and has provided data for the National Adaptation Geo-information System (NAGiS). The starting point for the projection is the data from the 2022 census, disaggregated into 5-year age groups at settlement level. The model run, adapted to the initial data set, works with 5-year cycles, looking at the changes in population numbers, age composition and population movement processes at the municipal level up to 2060. Six scenarios are developed: three low, baseline and high scenarios with different natural population movement assumptions, and a variant of these assuming the realisation or non-realisation of further extensions of the service life. In the development of each scenario, the hypotheses of the most recent national projections of the Population Research Institute of the HCSO are taken into account, as well as the population projections of the Paks II. environmental impact assessment, which include the estimation of the additional population associated with the construction of Paks II. The expected results, in line with the baseline scenario of the Paks II. environmental impact assessment population projections, predict a significant decline and ageing of the study area population over the period under consideration, but the construction of Paks II. and subsequent service life extension in the narrower vicinity of the Paks Nuclear Power Plant are expected to significantly influence these trends in a more favourable direction.

The transport forecast for the Paks region takes into account the results of the demographic and economic forecast scenarios for the study area and its settlements. The long-term traffic forecast uses available traffic count data on the road sections concerned (i.e., the Paks region) and includes an indicator for the total number of vehicles passing through the study area in a day. The result of the trend calculation is extrapolated to the following decades, i.e., the evolution of the traffic data from 2001 to 2022 is projected for the future (up to 2060).

The number of traffic accidents is linked to traffic intensity trends. In this case, the data available since 2005 are extrapolated on the basis of trends in traffic changes (trend calculation), since the number of accidents and their ratio to the population are indicators of the risks arising from traffic, which provide information on the characteristics of transport in the region.

In addition to the assessment of the economic situation in the Paks region, it is also necessary to carry out an economic forecast for the area under study. For the forecast of long-term economic trends the recent projections of the European Commission based on the background data of "The Ageing Report 2024" (2023) and extrapolate its nationally estimated results to the study area will be used, based on suitable regional data[12]. The basic model for the economic projections assumes that the GDP per capita of the less developed EU Member States converges to the EU average in the long run. This convergence process can be supported by an increase in capital intensity (capital stock per person employed) and rising production efficiency (total factor productivity) in the first part of the period up to 2060, but labour input cannot contribute sufficiently due to the expected adverse demographic trends (declining birth rate, shrinking population). The long-term projection assumes that the trends in the study area follow national trends in proportion, but several scenarios are considered (baseline, low and high variants).

Investigation of the geological, tectonic, seismological and geotechnical characteristics of the site

In the fields of geology, tectonics, seismology and geotechnics, the site characterisation is based on the results of nearly 50 years of investigations. A summary description will be prepared of the geological structure of the site and its wider surroundings, in line with the geological description of the Pannonian Basin. The quantitative characterisation of the surface displacement hazard is carried out in the form of a hazard curve based on calculations and publications carried out after the completion of the Paks II. Geological Research Program. A complex recalculation of the seismic hazard associated with the development of the environmental impact assessment is not justified. It has been confirmed that the new data do not change the model parameters used for the calculation of the hazard (PSHA) and thus the hazard results, especially for the UHRS (Uniform Hazard Response Spectra) with a frequency of 10^{-4}/year.

In the seismological description and characterisation of the site, all earthquake statistics, tables and figures will be updated and recalculated based on the latest monitoring results. The a priori conclusion is that, although a considerable amount of new data and knowledge has been generated over the past 10 years, this does not fundamentally change the earthquake hazard on the site.

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[12] https://economy-finance.ec.europa.eu/publications/2024-ageing-report-underlying-assumptions-and-projection-methodologies_en

It is also confirmed that the geotechnical measurements made since the update of the Paks Nuclear Power Plant FSAR do not change the model parameters used for the surface hazard calculation and thus the values of the free-surface hazard curve and UHRS.

Assessment of external hazards due to human activities specific to the site

In the area of external hazards from human activities, one of the main objectives of the assessment is to demonstrate that, among the external hazards, the possible events related to human activities do not endanger the nuclear power plant during the subsequent service life extension to an extent that would have a significant impact on the environment of the plant. To this end, the first step is to characterise, on the basis of the available information, the impact on the plant of potential man-made hazards in the vicinity of the site and their expected evolution over the period under consideration, including possible changes. Then, on the basis of the plant design basis, its protection against man-made hazards and the expected effects of man-made hazards during the period under consideration, it should be ascertained whether the plant will continue to have a high level of safety and thus whether the plant will continue to pose a negligible risk to the environment from external man-made hazards. In addition to single hazards, combinations of external hazards should be characterised by means of a targeted assessment of the available analysis results.

Preliminary results are already available for most of the above tasks, together with the preparation of the PCD. The implementation of the study program will focus on one hand on a detailed analysis through an extensive review of background documents, and on the other hand on an assessment of the available forecasts and a summary of lessons learned. For the latter part of the work, the results of the economic and transport forecasts already available and those of the site characterisation study program will be reviewed and compared, and the main lessons will be drawn based thereon.

6.2. Review of climatic characteristics

The climate characteristics review study program aims to assess the current and projected future climate of the Paks Nuclear Power Plant and its 30 km surrounding area. As part of this, the aim is to supplement and update the climate characterisation previously carried out in the framework of the studies for the environmental and site licensing of Paks II. with data from the last 10 years or so, and to analyse projections to the current state of the art using available databases and modelling.

The study is also intended to provide information for a climate change sensitivity analysis of the facility under study in terms of meteorological characteristics and their expected changes due to climate change, i.e., the exposure of the site.

Historical characterisation of temperature conditions is carried out on different time scales, as part of which monthly, annual and summer mean temperature trends are investigated. The necessary baseline data are provided by station observations and the FORESEE databases. In addition, emphasis will be placed on the assessment of temperature extremes, where daily and monthly maximum and minimum temperatures will be investigated.

To characterise past precipitation patterns, monthly, annual, winter and summer semi-annual precipitation totals are calculated from station observations and the FORESEE database. For the analysis of extreme precipitation values, the daily maximum and the monthly precipitation totals (maximum, minimum) are analysed on the basis of station observations and the FORESEE database. Furthermore, the evolution of daily rainfall totals, intensity and frequency, especially during the summer period, will be investigated.

Historical wind patterns are investigated at different altitudes. The study includes an analysis of wind direction frequencies (16 directions) for 10 m height, broken down into annual, summer and winter half-yearly frequencies. In addition, the same temporal resolutions are used for the processing of stronger air currents (daily average winds exceeding 3 m/s) and for the daily maximum wind gust.

In line with international practice, the Pasquill categorisation is used to characterise atmospheric stratification and stability. For the propagation calculations, the analyses of the relative frequency of wind speed and wind direction according to the Pasquill index are based on the measurement data of the meteorological measurement tower of the Paks Nuclear Power Plant. The study also includes the analysis of additional meteorological variables such as pressure at sea level.

The historical number of intense convective events is based on observations from the Paks meteorological station. For the period 1994-2018, the daily and monthly number of heavy convective events is determined, with the number of days with quiet rain, snowy days, snowy days, thundery days and showery days separately defined using synoptic codes.

For the characterisation of storms and studies of atmospheric instability in extreme weather conditions, temperature and specific humidity at 500 and 850 hPa and convective precipitation are used mainly from regional climate model data and global climate models.

To investigate the co-occurrence of drought and heat wave (known as compound extreme event), observations and FORESEE data are used. The occurrence of other extreme weather events will be examined mainly on the basis of CORDEX data. The extreme weather event values considered are those corresponding to the 10^{-4}/year return frequency required for the site investigation of existing nuclear installations.

New study results generated during the implementation of the study program will provide additional data to clarify or refine the results in this PCD. Compared to the results presented in the PCD, the study program will present information on meteorological variables with more temporal resolution, including heavy weather events (e.g., 10-minute maximum precipitation totals). Results from station data will also be presented in more detail for the data needed for climate resilience studies. Gumbel distribution based data for 10 000 years return period will be derived for some meteorological variables (e.g., maximum wind gust return values). The study of compound events will also be part of the study program. In this context, the co-occurrence of heat wave and drought will be investigated, considering the more pronounced effects that occur together. Remote sensing based fire detection will also complement the work based on MODIS sensor data (Terra and Aqua satellites) in the vicinity of the nuclear power plant.

The results of the study program will provide more detailed information on the expected trends for the period of the subsequent service life extension, with probability values (25 and 75 percentile probability of change, further refining the possible uncertainty interval, which are the FORESEE-based minimum and maximum possible changes). Convective susceptibility will be investigated for future expected severe weather events, based on GCM and CORDEX data. These data indicate the expected trends in atmospheric stability by examining and analysing the weather conditions that are conducive to the development of severe weather events (e.g., supercells) based on monthly data.

The Danube’s upstream water temperature, discharge and water level are modelled as part of the study program. The discharge is calculated using a distributed hydrological model. The climatic data required for the calculation of the discharge are not statistically scaled due to the resource requirements of running the model, but they are directly from the model results corrected using the measured data. Due to the transient nature of the climatic data, extremes in hydrological variability (e.g., low and high discharge values and water levels that are rare compared to the length of the prediction) are estimated by extrapolation from the discharge and water level distributions. Water temperature is modelled using the “equilibrium temperature” principle. This assumes that each weather condition has a water temperature at which the water body is in radiative equilibrium with its environment. The actual water temperature of a watercourse will tend to this value over time, i.e., as the water flows down in its bed. Since the majority of the Danube's discharge “travels” for several days before reaching the Paks area, it is reasonable to assume that the water temperature observed there is determined by the meteorological conditions experienced in the few days before arrival and that the equilibrium water temperature is not closely dependent on the hydraulic boundary conditions. Therefore, data from the meteorological stations along the Győr-Paks stretch and the relevant climate model predictions are used in the study. From the weather data, equilibrium water temperatures for the past and the future are calculated. Based on past water temperature measurements, the potential range of convergence rates is estimated, which depends on both discharge and thermal regime of the riverbed. Then, the future equilibrium temperatures can be used to investigate the water temperature of the upstream waters under different flow conditions. Because of the dependence of the rate of convergence to equilibrium temperature on discharge (through water depth), the relationship between water temperature and discharge can also be investigated, i.e., the probability of low discharge and high temperature coincidences is analysed.

6.3. Description and characterisation of the status of subsurface water environment (and the geological medium)

During the study program, 20 accredited monitoring wells will be sampled, analysed in a laboratory, the results evaluated and incorporated into the archive monitoring results and the results will be evaluated together. To investigate the impacts, a hydrodynamic and heat transport model will be built and different scenarios will be run. The monitoring wells will be sampled 4 times per quarter, the monitoring wells to be sampled are O1, O2, O3, O4, O5, O6, O7, O8, T23, T07/a, M09/a, M10, T55/a, T53/a, T90, T91, T92, T93, T94, T95. *Figure 6.3-1.* shows the locations of the wells to be sampled.

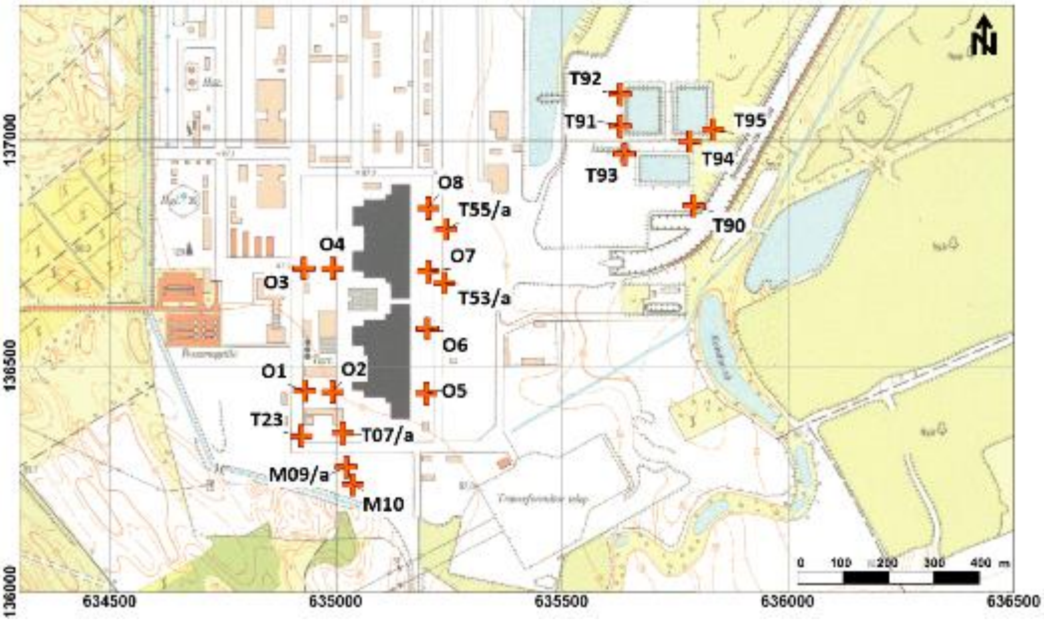


Figure 6.3-1. Location of monitoring wells to be sampled at the site

Sampling techniques are defined by standards. In all cases, the sampling should follow the requirements of the standard for the particular sampling. Based on the results of monitoring wells to date, the following laboratory tests will be carried out on groundwater samples:

- General water chemistry (pH, specific electrical conductivity, COD_{ps} , bromide, fluoride, chloride, nitrate, nitrite, sulphate, phosphate, ammonium, p-alkalinity, m-alkalinity, carbonate ion, bicarbonate ion, hydroxide ion, hardness, Ca, Fe, K, Na, Mg, Mn),
- 1. Metals ("all" leachable) and semi-metals (Cr. Cr(VI). Co. Ni. Cu. Zn. As. Se. Mo. Cd. Sn. Ba. Hg. Pb. Ag. Sb. B), in accordance with 6/2009. (IV. 14.) KvVM-EüM-FVM Decree,
- Aliphatic hydrocarbons (TPH) in accordance with 6/2009. (IV. 14.) KvVM-EüM-FVM Decree,
- Benzene and alkylbenzenes (BTEX) in accordance with 6/2009. (IV. 14.) KvVM-EüM-FVM Decree,
- Polycyclic aromatic hydrocarbons (PAH) in accordance with 6/2009. (IV. 14.) KvVM-EüM-FVM Decree.

The results will be used to carry out an assessment of groundwater quality and update information on groundwater flow.

The contamination of the geological medium can be attributed to possible havaria events that may occur during the activity under investigation. The management of these incidents and the prompt clean-up of the contamination demonstrate that the current control and intervention system is working, and that the prevention of further contamination is adequate. The study program will present the experience of the control and response system and of the occurrence of the incident.

6.4. Hydromorphological characterisation of the site

The aim of the study program can be divided into three main groups:

1.) characterisation and long-term forecasting of the hydromorphological conditions of the site,
2.) investigation of the mixing of cooling water from the power plant in the Danube,
3.) investigation of the spreading of tritium load in the aquifer beneath the power plant.

The analyses of water flow characteristics, water temperature and bed alteration processes will be carried out for the Danube between Dunaföldvár and the southern border. Thermal plume propagation and contaminant migration studies will be carried out at different scales using 1D/2D and/or 3D hydrodynamic and transport modelling from the site in the downstream direction furthest to the country border. The surface boundary of the study area is limited to the Paks Nuclear Power Plant site and the construction and staging area of Paks II. The vertical boundary of the study area extends from the surface to the first aquifer. Using the boundary conditions defined by the extreme low and high Danube water levels identified in the available data, time-constant simulations are run and projections are made for the period up to 2060.

In terms of the study method, it will be analysed how the bed morphology has evolved along the length of the Danube by analysing past riverbed relief data. It will be also examined the longitudinal and temporal evolution of annual low water levels, which can also be used to infer changes in the riverbed. A 1D hydromorphological model is built for the Danube stretch between Dunaföldvár and the country border, using the riverbed topography data of the study area, and the model is verified with archive river bed elevation data. The model will be used to make predictions for the period of the subsequent service life extension, resulting in an evaluation of the expected changes in the bed and the changes in the low water level caused by the bed changes. The mixing of fictitious Danube pollution discharges is also investigated through numerical modelling. The simulations are carried out for different power plant operating conditions, hydrological conditions in the Danube and pollutant ingress scenarios. In addition, detailed model studies will be carried out to analyse the evolution of the thermal plume in the immediate vicinity of the power plant. The aim of the modelling is to calculate the transport of the thermal plume under unmeasured or unmeasurable (e.g., future) conditions (changing (critical) hydrological and/or operating conditions). A simulation study of tritium loading is performed using a 3D hydrodynamic model.

Within the framework of the work carried out in the study program, relying on the results of several previous studies and it will be refined and revised them in the light of 1.) new(er) measurement and monitoring data, 2.) the improved modelling methodology and 3.) the results of related study programs (e.g., the changed Danube water flows and water temperatures estimated as a result of the climate characteristics study).

6.5. Status of the Danube and other surrounding surface waters

The primary objective of the Danube and surrounding surface waters status study program is to evaluate the status of the Danube and other surface waters in accordance with the Water Framework Directive (WFD). Additionally, the program evaluates the environmental impacts anticipated as a result of the subsequent service life extension of the Paks Nuclear Power Plant, including the joint operation with Paks II. with a particular focus on the impact of the heated cooling water. In addition, the present study will assess the ecological status of the relevant biological elements and analyse the impacts of the subsequent service life extension on these aquatic communities.

For the physical and chemical elements, Danube water and river sediment sampling has been carried out using accredited sampling and analytical processes. The study segments, sites, sampling period and frequency are given in *Table 6.5-1.* For water and sediment samples, analyse for targeted compartments will be carried out according to the requirements of the relevant standards.

Table 6.5-1. Summary table of planned sampling of physico-chemical, biological and isotopic elements

Elements examined	Number of segments examined	Number of sampling sites in a cross-section	Name of sampling sites in the cross-section	Number of repetitions	Sampling period
Physical and chemical characteristics	8	3	Riparian zone right bank, left bank, Medial zone	4	April, June, August-September, October
Physical and chemical characteristics, sediment samples	8	2	Riparian zone right bank, left bank,	4	April, June, August-September October
Isotope elements	3	3	Riparian zone right bank, left bank, Medial zone	4	May, July, September, December
Phytoplankton	8	3	Riparian zone right bank, left bank, Medial zone (with warm water downstream)	4	April, May-June, July-August, September-October
Phytobentos	8	2	Riparian zone right bank, left bank	3	April-May, July-August, September-October
Zooplankton	8	3	Riparian zone right bank, left bank, Medial zone (with warm water downstream)	4	April, May-June, July-August, September-October
Macrozoo-bentos	8	2	Riparian zone right bank, left bank	3	April-May, July-August, September-October
Fish	6	3	Riparian zone right bank, left bank, medial zone	2	July-August, September-October

The sampling sites for the biological elements were selected based on the specific objectives of the study and in consideration of the sample sites used in previous studies conducted to monitor the Paks Nuclear Power Plant and Paks II. as well as assess their environmental impact. The studied segments, sampling sites, period and frequency of samplings are presented in *Table 6.5-1.*

In addition to the above mentioned sampling on the Danube, all biological elements will also be sampled and analysed at one sampling site on four backwater and oxbow lake (Uszódi mellékág, Grébeci-Holt-Duna, Rezéti-Holt-Duna [ANS503], Vén-Duna), according to the sampling frequency of each taxa on the Danube.

Phytoplankton quantitative sampling is carried out according to the MSZ EN 16698:2016 standard. Species identification and the counting of the number of individuals is carried out by using the standard MSZ EN 15204:2006. The estimation of biomass is based on Hillebrand et al. (1999). The dominant centric diatom species in the phytoplankton samples are also identified (MSZ EN 14407:2014). The analysis of a-chlorophyll is performed according to the national standard (Kl-a - µg L-1, MSZ ISO 10260:1993). The EQR (Environmental Quality Ratio) based assessment of the results will be carried out according to the draft EU standard CN TC 230 and the recommendations developed for the domestic application of the Water Framework Directive.

Phytobentos sampling and sample processing are carried out according to the standard MSZ EN 13946:2014. The taxa identification is performed according to MSZ EN 14407:2014. In all cases, the identification shall be made at the lowest taxonomic level that can be accurately determined (species, subspecies, varietals, form etc.).

The zooplankton sampling will be carried out in accordance with the MSZ EN 15110:2006 standard for the sampling of zooplankton in lake, while the sampling will be adapted to the river conditions in the Danube sampling. Sampling will be carried out by taking a submerged sample from the upper water column equal to twice the Secchi transparency. The sample is compressed to 100 ml by filtering 100 litres of water through a 50 µm mesh plankton net and preserved with 4% formalin solution. The sample is counted and determined by light microscopy. During sample processing, taxonomic and quantitative analysis is performed according to the Rotatoria, Cladocera and Copepoda communities. The quantitative analysis includes the number of individuals per unit volume and biomass estimation. Biomass estimation is based on the specific data described by Németh (1998).

The theoretical basis for the sampling of macrozoobentos the Danube is the EU-STAR/AQEM protocol, which has been modified for the Hungarian conditions by National Biodiversity Monitoring System (NBmR) for macroscopic aquatic invertebrates. The sampling method is in line with the MSZ EN ISO 10870:2013 and MSZ EN 16150:2012. The sampling methodology for the oxbow lakes is the same as for the Danube. The processing of the samples will cover a total of 10 macroscopic aquatic invertebrate groups, preferably at species level. These include the taxa required by the NBMS protocol: Gastropoda, Bivalvia, Hirudinea, Malacostraca, Ephemeroptera, Odonata, Plecoptera, Heteroptera, Coleoptera, Trichoptera. Groups outside these taxa are also counted and identified to the lowest possible taxonomic category.

Planning the fish sampling, the objectives of the study, the provisions of 31/2004. (XII. 30.) KvVM Decree on certain rules of observing, and evaluating the state of surface waters, EN 14011:2003 Water quality – Sampling of fish with electricity, the chapters on fish sampling of the project "Preparation of monitoring in accordance with the birds (79/409/EEC) and habitats (92/43/EEC) Directives" (2006/18/176.02.01), the methodological guidance on fish monitoring of the Water Framework Directive have been taken into account. In addition, the methodological chapters and results of the impact assessments carried out of the Paks Nuclear Power Plant have been also taken into account in the design. Accordingly, the sampling methodology complies with the requirements of the WFD. Sampling with high performance, aggregator driven electric device with handheld anode at riparian zones of Danube and oxbow lakes is quantitative, partial, fragmented and stratified. The total length of the Danube sampling units is 2000 m in each segment. In the oxbow lakes, the sampling unit length is 300-300 m, partial, continuous or fragmented depending on the sampling site. Sampling will be carried out by boat. An electric trawl net is used to investigate the medial zones of the six sampling segments. The sampling units are 1500 m long. The sampling time is daytime in both cases. The sampling with electric fishing device on daytime is defined by the relevant standard and also justified by the appropriate results of the previous studies. To evaluate the results, the species found are identified and their numbers per sampling sub-unit are recorded. Young of the Years (0+) are also identified and listed separately from adults.

The sampling for the isotopic element analysis will be performed by Isotoptech Ltd. in the test segments and plummet listed in *Table 6.5-1.*, with the given sampling period and frequency. From the water sample, tritium (^3H) and radiocarbon (^{14}C), from the sludge sample, tritium (^3H), radiocarbon (^{14}C) and strontium contents will be measured. The samples are measured for isotopes that are difficult to measure (^{14}C, ^3H, ^{90}Sr) after isotope selective radiochemical separation.

For the gamma spectrometric analysis of samples, evaporation is used for water samples and the evaporation residue is measured for activity. For mud samples, dried and homogenised samples are prepared. Activity measurements are performed in a low background laboratory with a Canberra HPGe detector with lead shielding. Sample amounts and measurement times will be chosen to achieve a minimum lower limit of 0.01 Bq/kg for isotopes of potential plant origin (^{54}Mn, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs).

6.6. General characterisation of environmental radioactivity

The aim of the study program is the general characterisation of the environmental radioactivity of the Paks Nuclear Power Plant, based on the review of the characteristics determining the atmospheric, surface water and subsurface water radioactivity dispersion of radioactive substances at the site and its surroundings, and the investigation and assessment of the radiological characteristics of the environment within a 30 km radius of the site.

The task will be completed partly by a full processing of the available annual reports and official measurements for the period 2011-2022 (supplemented by available data for 2023) and partly by an environmental assessment of the presence of artificial isotopes at 5 potential accumulation sites, to be carried out in the growing season of 2024.

In the first phase of the study program, the presentation and assessment of the environmental radioactivity, i.e., the preliminary impact assessment, can be ensured by processing existing data. (Detailed data processing is included in *Chapter 4.1.2.*)

In the second phase of the task implementation, the following accredited investigations and sampling will be carried out at the potential accumulation sites identified during the first service life extension of the nuclear power plant and identified in the Paks II. environmental impact assessment:

- in-situ gamma-spectrometry measurements (a total of 50 measurements in 10 time points),
- dose rate measurements (a total of 50 measurements in 10 time points).

Dose rate measurements and in-situ gamma spectrometry measurements are performed simultaneously. Topsoil and plant material (e.g., grass, sedge and bark) will also be sampled at the same time as the measurements. The following tests are carried out on the samples taken in an accredited laboratory:

- measurement of soil activity concentrations (measurement of a total of 50 samples taken from the top 0-5 cm of soil for gamma-emitting isotopes and 90Sr, and determination of total beta),
- measurement of the activity concentration of plant substances (measurement of a total of 50 samples for gamma-emitting isotopes and 90Sr, and determination of total beta).

Finally, all available measurement data and information from the study program will be used to assess the radiological conditions of the site environment and the characteristics (processes) determining the atmospheric, surface water and subsurface water dispersion of radioactive substances at the site and its surroundings.

6.7. Environmental noise assessment of the Paks Nuclear Power Plant

Within the framework of the study program, the following tasks are performed:

1. Measurement of the environmental noise load of the site and its surroundings in relation to the plant at the following points:
    - At residential building / area in zone to be protected from noise nearest to the nuclear power plant:
        - PKS ZT1 – Paks, Vi-M/10 on a workers' hostel in a mixed institutional area (plot no. 4703/45).
        - PKS ZT2 – Paks on the boundary of the site for the Paks Special Health Care Centre (plot no. 8802/34).
        - PKS ZT3 – Paks, near the northern entrance of Paks Nuclear Power Plant, at the facade of the residential building (plot no. 057/9).
        - CSP ZT1 – Paks, Csámpapuszta 22. in front of the facade of Csámpai Fenyvestanya (plot no. 0292/2).
        - CSP ZT2 – Paks, Csámpapuszta 33. in front of the facade of Csámpai Faluház (plot no. 0191/23).
        - DSG ZT1 – Dunaszentgyörgy Béke tér 22. in front of the facade of a residental building (plot no. 112/1).
        - DSB ZT2 – Dunaszentbenedek Zöldfa u. 3. in front of the facade of a residential building (plot no. 581/2).
        - USD ZT1 – Uszód In front of the facade of the residential building at Béke u. 15. (plot no. 044).
    - At typical points on the site boundaries of a nuclear power plant:
        - ZP1 – Southeastern site boundary – next to the substation,
        - ZP2 – Eastern site boundary – near to the fishing lake,
        - ZP4 – North-eastern site boundary – end of Island, energy breaker,
        - ZP5 – Northern site boundary,
        - ZP6 – Northern site boundary – opposite reactor halls 3, 4,
        - ZP7 – North-western site boundary – corner of reception building F3,
        - ZP8 – Northern site boundary – northern gate,
        - ZP9 - Western site boundary – parking lot,
        - ZP10 – Western site boundary – corner of reception building F2,
        - ZP11 – Southwestern site boundary,
        - ZP12 – Southern site boundary – next to railway overrun.
    - At the not-to-be-protected reference points (TB1, TB2, TB3) and rooms to be protected from noise (TB4, TB5) of the Paks Nuclear Power Plant site:
        - TB1 – in front of the eastern facade of the nitrogen plant office,
        - TB2 – In front of the eastern facade of the central office building,
        - TB3 – Between office buildings,
        - TB4 – In front of the eastern facade of the medical practice,
        - TB5 – In front of the eastern facade of the fire barracks.
    - At the not-to-be-protected reference points in the vicinity of the nuclear power plant (currently not considered to be protected, but can be used as a reference for archive studies):
        - TK1 – In front of the eastern facade of the SFISF office (plot no. 8803/2),
        - TK2 – In front of the northern facade of the fishing guest house (plot no. 8803/11),
        - TK3 – Fishing guest house – parking lot (plot no. 8803/11),
        - TK4 – Danube dam residential building (plot no. 0108/2),

  - TK5 – Nuclear Power Plant SC boathouse (plot no. 8803/9),
  - DSB ZT1 – Dunaszentbenedek Pillangó buffet (plot no. 0135).
2. Comparison of measurements and results with archive data.
3. Determination of the noise emission impacts of the Paks Nuclear Power Plant, both individually and in combination with Paks II., and assessment of compliance with the requirements of legislation and standards.

Noise emissions, indirect and direct impact areas will be specified in the environmental impact assessment study through noise modelling. The road traffic noise baseline is determined from a road traffic database. This includes the traffic of the Paks Nuclear Power Plant, therefore the difference is also determined.

6.8. Air quality assessment

A program of on-the-spot measurements will be carried out with the involvement of the National Center for Public Health and Pharmacy (NCPHP) to determine the level of air pollution in the vicinity of the site.

Baseline air pollution data are generated from measurements taken at 6 monitoring points within a 30 km radius of the site. Three of the measurement points are located on the power plant site, and one measuring point each in Paks, Csámpa and Dunaszentbenedek, as follows:

- at 1 point on the power plant site (LMp1 – Nuclear Power Plant site),
- at 1 point along the northern access road (LMp2 – along the northern access road),
- at 1 point along the southern access road (LMp3 – Meteorological station),
- in the settlement of Paks-Csámpa, at 1 point at the residential properties next to road No. 6 (LMp4 – Csámpa, Kis u.),
- at 1 point on the left bank of the Danube (LMp5 – Dunaszentbenedek, 2/3 Dike reeve house),
- at 1 point in the town of Paks, in the vicinity of Kölesdi út (LMp6 – OVIT site, Dankó Pista u. 1.).

The parameters measured are:

- particulate matter (PM_{10}),
- particulate matter (TSPM),
- settling dust,
- nitrogen-dioxide (NO_2),
- nitrogen-oxides (NO_x),
- sulphur-dioxide (SO_2),
- carbon-monoxide (CO),
- ozone (O_3).

The measurements started on 16 January 2024. Measurements will be carried out at each measurement point once a season for two weeks. The expected date of completion of the full series of measurements is early January 2025.

The measurement results are used as a baseline air pollution data for the environmental impact assessment. The environmental impact assessment will include modelling of the dispersion of air pollutants, the results of which will provide a more accurate picture of the air quality impacts of the further extension of the plant's service life.

6.9. Characterisation of radiation exposure to living organisms (excluding human exposure)

The main objective of the study program is to assess the current radiological status of terrestrial and aquatic biomes in the direct and indirect impact area of the Paks Nuclear Power Plant, based on sampling and radioanalytical analyses, and to compare and evaluate the results of previous similar investigations, and to estimate the impact of exposure on organisms using modelling based on measurement results, habitat types and typical taxa.

As part of the investigation, the following tasks will be carried out:

- Processing of the results of the investigations carried out in accordance with the environmental license for the extension of the service life issued on 25 October 2006.
- Processing data generated during the environmental licensing of Paks II.
- Evaluation of data on exposure of living organisms from the international radiological protection organisation and EU research programs.
- Estimation of radiation exposure for typical habitats and species.
- Estimation of baseline exposure levels for reference animal and plant habitats around the site according to ICRP / ERICA.
- Collecting and measuring biological samples from 5 selected habitats.
- Monitoring of the environmental accumulation of radioactive isotopes potentially released from the Paks Nuclear Power Plant by sampling (spring, autumn).
- Determination of the activity concentrations of isotopes (^{3}H, ^{14}C, ^{54}Mn, ^{58}Co, ^{60}Co, ^{134}Cs, ^{137}Cs) regularly emitted from the plant in the environment and in living organisms.

The radiological impact from the following sources should be considered as the current baseline for the impact of the subsequent service life extension:

- the external and internal dose rate resulting from naturally occurring radioactive isotopes (^{40}K, members of the U-series, members of the Th-series, atmospheric ^{3}H and ^{14}C, ^{7}Be) in the environment,
- the dose rate contribution from nuclear weapons tests and the Chernobyl accident, ^{241}Am and ^{239}Pu alpha emitting isotopes, ^{90}Sr and ^{137}Cs isotopes, and the contribution of radioactive isotopes released into the environment from the Paks Nuclear Power Plant.

A significant proportion of the radiation exposure of the living world comes from natural primordial radionuclides. As a reference level, the calculation of the total (natural and anthropogenic) dose is required, in line with international methodology.

The results of the radioanalytical analysis, past and projected changes in state, presenting their likely effects will be evaluated and the associated model calculations will be performed.

The ERICA project (Environmental Risks from Ionising Contaminants: Assessment and Management) is an approach for assessing the environmental risks of ionising radiation to wildlife. The software developed in the framework of ERICA project can be used to estimate the risk to living organisms from exposure to radiation. Historical data and model calculations are evaluated together in the current study program.

The PC-CREAM Gaussian plume model is used to calculate the activity concentrations of each radioisotope in the near-surface air at the most relevant distances for environmental impact, as well as the soil contamination from the fallout. During the assessment of the study program, the available transferred and measured ambient medium activity concentration values for the habitat will be entered into the ERICA/FASSETT database, as well as the ambient radioactivity data obtained using PC-CREAM. By associating the former with the target species, the risk quotient for that species can be determined. In the case where no suitable value can be given for a given species, a species similar in size, lifestyle and feeding habits is selected.

6.10. Completing sample biomonitoring studies

The main immediate objective of the study program is to generate a biotic dataset for the habitats and associated communities on the nuclear power plant site and its immediate surroundings (3 km radius circle), and for the habitats and associated species of importance for their communities within the wider Natura 2000 network of habitats to be studied (10 km radius circle), which is suitable for objectively describing and characterising their current status. In addition, it should be suitable for describing and analysing any changes in the status of the habitats concerned since the previous studies, in comparison with the results of previous studies of the habitats concerned, and thus for assessing the likely effects of the further extension of the service life of the nuclear power plant.

The field sampling, studies and data evaluation planned in the sampling areas and study units defined in the study program will be carried out with the following direct objectives:

- Flora and vegetation:
  - the preparation of a taxon list of vascular plant species,
  - display of protected species on maps,
  - group share diagrams,
  - narrative description and evaluation of the vegetation types present in the area,
  - the preparation of a vegetation map of the site based on the habitat types of the Á-NÉR 2011 (General Hungarian Habitat Categorization System of Habitats) and the NBmR habitat mapping guide, highlighting the vegetation units,
  - study and assessment of plant species of community interest, that the designation of special areas of conservation is based upon within 10 km of the power plant,
  - study and assessment of natural habitat types of community interest, that the designation of special areas of conservation is based upon.
- Zoology:
  - compiling taxon lists for the groups of organisms included in the study program for the areas to be assessed with priority given to species of conservation and community importance among the species present,
  - characterisation of each habitat type based on the animal species of community interest, that the designation of special areas of conservation is based upon,
  - the designation of species that can be used as indicators of habitat types,
  - a study of animal species of community interest, that the designation of special areas of conservation is based uponin special areas of conservation within 10 km of the power plant,
  - narrative assessment of endangeredness by species (on a species-specific scale).

As part of the environmental impact assessment for the subsequent service life extension of the Paks Nuclear Power Plant, the wildlife and nature conservation studies in the study program will evaluate the data from the field surveys carried out in the study year 2024 and present the current status of the wildlife in the study area, broken down by the groups of organisms and study areas. The current status will then be compared with the status in previous periods of operation since the plant was built, which is defined in the introductory section of *Chapter 5.5.*

6.11. Determining the radiation exposure of the population

The aim of the study program for determining the exposure of the general public is to describe the exposure of the population living within a 30 km radius of the site and to use the results to assess the effects of the nuclear power plant on members of the public. The primary objective of the studies is to assess the potential changes in the environmental impact due to the effects of changing characteristics (e.g., meteorological data or lifestyle and consumption habits of the local population) that may affect the exposure of the population during the subsequent service life extension. Accordingly, while no new analyses were carried out during the preparation of the PCD, but the results of the analyses carried out previously were processed and evaluated, the implementation of the study program will involve both new analyses using the latest available data and a detailed analysis of the likely changes during the further extension of the service life, taking into account the available data.

In addition to the analysis of the consequences of radioactive releases, the study program also includes an estimate of the exposure of the public to direct and scattered radiation. The scope of this study program has been defined to ensure that the results of the study programs provide sufficient quantity and detail of up-to-date information to assess the environmental impact of the continued operation of the nuclear power plant.

A relevant circumstance for the scope of the study is that the categorisation of normal operation and accidents in the current legislation on nuclear safety regulations (1/2022. (IV. 29.) HAEA Decree) has changed significantly compared to the categories considered in the previous service life extension of the Paks Nuclear Power Plant. The environmental impacts associated with the continued operation of the plant will be assessed on the basis of normal operation and design basis accidents.

In the course of the implementation of the study program, the exposure pathways for the population living in the vicinity of the nuclear power plant will be analysed and the extent and characteristics of the exposure from these pathways will be described in detail. The analysis takes into account that the scope of the analyses required for environmental permitting is somewhat different from the scope and assessment criteria of the nuclear safety analyses. The following exposure pathways are considered to determine the doses of atmospheric releases:

- the dose from the radioactive cloud,
- the dose from contaminated soil,
- the dose from inhalation,
- the dose from the food chain.

The analyses use site-specific real meteorological measurement data series covering several years.

In determining the exposure of the population from liquid discharges, it is assumed that the liquid releases from the nuclear power plant will eventually be discharged into the Danube as a receiving water body. Contamination discharged into the river water is diluted as it disperses and its concentration decreases. For radioactive materials, radioactive decay also causes a decrease in activity concentration. The analyses determine the activity concentrations of the released radioisotopes at the receptor points and then calculate the exposure of the population taking into account the exposure pathways.

As part of the analyses, sensitivity studies will be carried out to determine the extent to which changes in the Danube water flow will affect doses to the population, and whether changes in hydrological characteristics are expected to have a significant impact on the level of exposure to the population.

As part of the implementation of the tasks, it will be determine which events of design basis accidents need to be taken into account for the assessment of environmental impacts, which are required for the subsequent service life extension.

The analyses for normal operating conditions are carried out taking into account the normal annual operating emissions, the average dispersion conditions for the site based on meteorological measurements and the lifestyle and consumption data determined on the basis of previous studies of the local population.

For the analysis of the design basis events the emission source term is available from the deterministic and probabilistic safety analyses as described in the Final Safety Analysis Report of the nuclear power plant. As part of the tasks carried out so far in the study program, the previous analyses have been reviewed and it has been found that, mainly due to the development of analytical tools, the conservatism in the calculations that have been forced to use can be significantly reduced. The degree of damage to the fuel rods, the value of the change of the source term assumed during the accidents will be assessed as part of the review of the assumptions and input data considered in the analyses. Based on the preliminary results of the implementation of this exercise, it is expected that a significantly lower amount of damage to the fuel rods of 33% can be expected in the analysis of accidents caused by large diameter pipe breaks, instead of the previous very conservative damage to the fuel rods of 100%.

It will be analysed whether there is a change in the scope of the analyses compared to previous studies and whether there is a substantial change in the characteristics of the environmental release (release location, physico-chemical characteristics of the release, time frame of the release, nuclide vector direction).

As part of the preparation of the studies, it was determined that no new additional field measurements are required to carry out the task, neither in the field of meteorological data nor in the field of lifestyle and consumption data of the population, and that the studies can be carried out by processing the existing data. However, it is also taken into account that some of the parameters considered for the determination of the exposure may change in the period up to 2060, in particular climate characteristics influencing the dispersion of radioactive contaminants or the lifestyle and consumption habits of the population influencing the exposure. These changes will be identified and assessed as part of targeted study programs, and their potential impact will be demonstrated by carrying out sensitivity analyses. As part of the sensitivity analyses, the sensitivity of the results for public exposure to meteorological data and the lifestyle and consumption habits of the local population will be assessed. It will also be determined which parameters (e.g., the extent of outdoor exposure and shielding, local food consumption) have the greatest influence on the results of dose calculations. It will be investigated whether their change is likely to result in significant deviations in the magnitude and nature of population exposure in the period up to 2060.

In addition to the airborne, liquid, direct and scattered radiation sources from the plant, the potential changes in public exposure from other activities and other man-made sources (e.g., transport of fresh and spent nuclear fuel and radioactive waste, radioactive sources for industrial radiography) will be reviewed to determine the exposure of the public.

In carrying out this task, it will be also separately assessed the impacts of the combined operation of the nuclear facilities currently operating at the Paks site and those planned for the Paks II. site. As part of this, studies will be carried out on how the operation of the SFISF and Paks II. Nuclear Power Plant can be taken into account alongside the operation of the four units currently in operation.

In addition to the radioactive release data of the operating nuclear facilities on site (Paks Nuclear Power Plant and SFISF) and the direct and scattered radiation dose rates, the investigations for the determination of the exposure of the public also include the analysis of the nuclear environmental monitoring data. No additional field measurements are required to perform this task, the assessment will be carried out by analysing and evaluating existing data. This will include an assessment of the results of the study program ”general characterisation of environmental radioactivity”, based on the results of measurements at environmental monitoring stations and on environmental samples. Based on the results of the analyses carried out, it will be assessed the extent to which the fulfilment of the radiological requirements for the environmental impact assessment (knowledge and characterisation of the baseline exposure of the population) may change taking into account national legal requirements and relevant international recommendations.

6.12. Determining the health status of people living around the site

The aim of the planned study is to evaluate the occurrence of diseases potentially related to ionising radiation in the population living within 30 km of the Paks Nuclear Power Plant. The primary question to be answered by the analyses is whether the observed pattern of illnesses suggests that there is an increased risk of disease associated with the radiation exposure associated with the operation of the Paks Nuclear Power Plant.

The methodology used is based on the results published in the international literature. From a technical point of view, the investigation should identify or exclude the spatial clustering of certain diseases and their consequences. The investigation will be structured in a stepwise approach following the principles of searching for a cluster:

- The first step is to process relevant data of sufficient quality that exist independently of the investigation as tasks of phase 1. This approach can establish a cluster suspicion.

- Individual-level data can then be used to determine the pattern of disease prevalence, taking into account the risk factor patterns of the individuals studied (phase 2).
- If the cluster suspicion is confirmed in phase 2, an investigation should be performed to provide a definitive answer, which can be planned and performed on the basis of the suspicion as a phase 3.

In phase 1 of the study program, the health status of the population living in the impact area will be characterised by aggregated risk measurements based on the processing of data from the databases maintained by various public institutions. The results will be compared with similar observations from previous studies. The indicator groups used are the following for 5 years:

- cause-specific mortality,
- morbidity based on use of specialist care for cancer,
- the prevalence of congenital anomalies.
- the prevalence of non-cancerous diseases with a genetic component based on the use of specialist care,
- morbidity based on hospitalisation for cardiovascular diseases.

The investigation is carried out in the following way:

1. Producing and statistically evaluating standardised risk measures for the settlements in the impact area.
2. Examination of the spatial distribution of threatened status within the impact area.
3. Distance trend analysis, examining the role of the Paks Nuclear Power Plant as a potential point source.
4. Correction of risk profiles by socio-economic parameters.
5. Comparing the results with those of previous periods.
6. Assessment of whether the results of the tests are suitable for:
   a.) ruling out with sufficient precision the status of the nuclear power plant as a point source of health hazards,
   b.) proving with sufficient precision the status of the nuclear power plant as a point source of health hazards,
   c.) establishing that it is not possible to take a sufficiently precise position on the situation.

In phase 2 of the study program, health status will be assessed by analysing individual-level data, using indicators adjusted for confounding factors, among people living in the impact area. In this phase it is necessary to clarify how the incidence of diseases theoretically related to ionising radiation is associated to location within the exposure area, when disease risks are adjusted for the influence of other pathogenic factors and other risk factors (lifestyle factors, accumulation in the family and occupational exposures).

Phase 2 is technically a survey based on the voluntary participation of general practitioners covering the population within a 30 km radius of the nuclear power plant to collect data from newly diagnosed cancer patients in the 3 years preceding the study.

The study is carried out in the following way:

a) organising a network of collaborating general practitioners,
b) general practitioners register new cancers diagnosed in the last 3 years and match them with a control person, and describe the family history of the persons examined, their lifestyle risk factors, occupational risks,
c) processing the case-control database to evaluate the status of the nuclear power plant as a potential point source.

6.13. Examination of potential transboundary impacts

During the preparation of the PCD the possibility of transboundary environmental impacts from the planned extension of the service life of the Paks Nuclear Power Plant was assessed. As part of the service life extension, the assessment should target the impacts of the continued operation of a plant which has been in operation for more than 40 years, rather than the introduction of a new activity. The primary objective of the assessment is to evaluate the changes in the impacts identified in relation to the current operation.

According to the environmental impact assessment for the first service life extension of the Paks Nuclear Power Plant, no significant transboundary impacts were expected for conventional pollutants and radioactive discharges, including events falling under the categories of normal operating and design basis accidents. Even for the latter, it is true that the impacts are already reduced to a neutral level within the national borders.

A review of the potential transboundary impacts due to the subsequent service life extension will be carried out by reviewing the analyses carried out in the past period and by assessing the characteristics assessed in the separate study programs as part of the extension of the service life.

The potential transboundary impacts of conventional non-radiological effects are assessed in the framework of the individual study programs. The assessment of radiological impacts is subject of a separate study program, which also includes a summary of the results of the analyses carried out to assess conventional non-radiological impacts.

The need to assess the potential transboundary impacts of radiological impacts as a separate program arise from the planned review of the results and impacts of the analyses previously carried out for design basis accidents as well as complex accidents and severe accidents falling in the category of design basis extension.

The nuclear safety legislation has changed in such a way that the assessment of accidents and their consequences, previously excluded from the scope of the design basis, has become essentially part of the design basis with the introduction of the extension of the design basis. Consequently, there is a need to characterise also the environmental impacts of the events considered as an extension of the design basis, which essentially means a review and repetition of the analyses previously carried out.

During the implementation of the tasks, the analyses will be repeated and completed to the extent necessary. Even without knowing the results of the calculations, it can be stated in advance that significant, favourable changes can be expected compared to the results of the calculations carried out previously. One of the reasons for this is that the technical modifications made to the plant have changed the process of accidents and severe accidents, which leads to changes in the release characteristics. It should also be noted that recent developments in the last years have led to less conservative models being used in the calculations and less conservative assumptions being required in the analyses.

The assessment of potential transboundary impacts and the criteria for their acceptance can be derived essentially from the nuclear safety requirements for nuclear installations. Compliance with these criteria ensures that the exposure of the population living in the vicinity of the plant remains below the limit values both during normal operation and in abnormal operational conditions. During the implementation of the study program, potential transboundary impacts will be identified and their significance assessed on the basis of the impact processes and the sensitivity of the areas.

A transboundary impact is defined as an impact that extends across the border and qualifies as significant also for that part of the estimated area of significant impact. According to professional practice, it is appropriate to apply the significant impact to the most sensitive affectee according to domestic practice, unless contrary circumstances are known for the territory of the country concerned. An impact is considered to be significant if it causes a permanent change or a long-lasting deterioration. The scope of the study program has been defined taking into account the need to ensure that the results of the programs provide sufficient quantity and detail of up-to-date information on the existing state of the environment and to provide a basis for the assessment of the environmental effects associated with the operation of the nuclear power plant.

In order to assess the transboundary impacts, the implementation of the study program will focus on determining the radiation exposure from radioactive discharges and the doses to the population. For radioactive discharges, the exposure pathways with potential significant transboundary impacts will be identified. An estimate will be provided on whether the impacts triggered by the exposure factors considered could reach beyond the national boundary, and the expected area of impact must also be estimated. An investigation will be conducted into how the impacts are spread and cumulated with any existing exposure, which locations are the most exposed (receptor points) to potential impacts. A detailed analysis will be made of the possibility of impacts that could be amplified further away from the point of release. As part of the analysis, it will also be considered whether the transboundary spillover is a consequence of the subsequent service life extension or whether it could already occur as a result of current operations.

While no new analyses were carried out during the preparation of the PCD, but the results of the analyses carried out earlier were processed and evaluated. During the implementation of the study program, new analyses are carried out using the latest available data, and a detailed analysis is made of the changes that are likely to occur during the subsequent service life extension, taking into account the available data.

The choice of receptor points (settlements), operating conditions and hypothetical scenarios to be analysed will be made taking into account the historical results and the expected impacts. The scope of the calculations will be defined. As part of that task the baseline events to be considered for the assessment of the environmental impacts due to the need for subsequent service life extension will be determined.

The source terms associated with the environmental release are selected in accordance with the initial events and releases considered in the 11. study program “Determining the radiation exposure of the population”. The analyses for the operational conditions and for the cases defined as extensions of the design basis will be carried out taking into account the emission source terms defined for each emission case in the safety analyses, meteorological data for past years and lifestyle and consumption data specific to the local population at the receptor point.

In the analyses, dose estimates should, as far as possible, be carried out using the same models as those used to determine the exposure of the population living in the vicinity of the plant. Where deviations from the methods presented therein are necessary (either in the assumptions used in the analyses or in the values of the parameters used in the models or calculations), justification will have to be given, showing to what extent the deviations are responsible for the differences between the results obtained through the different analyses performed.

The analyses are carried out using meteorological data specific to the site and its surroundings. The large distance between the release point and the receptor point– more than 100 km – significantly increases the uncertainty of the results. Due to the long distance between the release point and the receptor point, the plume model used in the safety analyses cannot be used directly and the analyses required further development of previously developed and validated models, which have been used in practice on several occasions.

In determining the transboundary impacts from liquid discharges, it is assumed that liquid releases from the nuclear power plant will eventually be discharged into the Danube as a receiving water body. The contamination discharged into the river water will be diluted and its concentration will decrease during the dispersion process. For radioactive materials, radioactive decay also causes a decrease in activity concentration. The analyses determine the activity concentrations of the released radioisotopes at the receptor points and then calculate the exposure of the population taking into account the exposure pathways.

In the analyses the national data for the population at the receptor point will be used and the resulting uncertainties will be assessed. Before detailed model calculations are carried out, a proposal will be made on which operating conditions, which hypothetical scenarios need to be analysed and which receptor points (settlements) need to be calculated.

It should be taken into account that the input data and parameter values needed to determine the exposure, such as meteorological and climate characteristics affecting the propagation of emissions and the lifestyle and consumption habits of the population, may change in the period up to 2060. The studies will therefore include sensitivity analyses and the identification of parameters and data, changes in which could significantly affect transboundary impacts.

In the framework of the study program, sensitivity analyses will be carried out to determine the extent to which changes in the hydrological characteristics of the Danube, in particular its water flow, affect the doses to the population.

7. Environmental consequences of the abandonment (decommissioning of the nuclear power plant)

7.1. Planning the decommissioning of the nuclear power plant

Decommissioning of the nuclear power plant represents the final phase of the facility's existence, beginning with the cessation of operational activities. Decommissioning involves administrative and technical measures implemented to terminate partial or complete regulatory oversight of the facility.

The goal of decommissioning is to dismantle the portion of the power plant designated for decommissioning, restore the site condition, which includes decontaminating the facility and site from radiological contaminants, dismantling structures, decommissioning installed infrastructures, removing generated waste, and performing all necessary verification activities to ensure that decommissioning is carried out according to authorized plans.

According to general practice for nuclear power plants, planning for decommissioning of the Paks Nuclear Power Plant began as part of the plant's operation. Nuclear safety regulations require that potential decommissioning solutions and their impacts are examined and evaluated during the operational phase. These analyses are regularly updated during the plant's operational life and also before the commencement of decommissioning activities.

The planning, preparation, and regulatory approval of decommissioning are governed by detailed regulations. According to Act CXVI of 1996 on Atomic Energy, the nuclear safety licensing and oversight of activities related to plant shutdown and decommissioning fall under the jurisdiction of the Hungarian Atomic Energy Authority (HAEA). Based on the regulation 1/2022. (IV. 29.) HAEA on the nuclear safety requirements of nuclear facilities and on related regulatory activities – which also details the requirements for decommissioning – decommissioning requires HAEA's authorization.

The licensee of the nuclear power plant prepares a Preliminary Decommissioning Plan, which is continuously updated during the operational phase and submitted to the HAEA for information after each review. The decommissioning plan is reviewed every five years to account for changes in the plant and ensure appropriate adherence. This review includes an assessment of the environmental impacts based on the current plan version. Currently, the plan version from 2021 is in effect, which does not account for the additional 20 years of service life extension. After obtaining permits for subsequent service life extension, the next review of the decommissioning plan will incorporate the additional 20 years of operation.

According to Act CXVI of 1996, the government-designated body, the Public Limited Company for Radioactive Waste Management (PURAM) is responsible for tasks related to the final disposal of radioactive waste, temporary storage of spent fuel, closure of the nuclear fuel cycle, and also decommissioning nuclear facilities. The financing of decommissioning preparation and execution is provided from the segregated state Central Nuclear Financial Fund according to Section 62 of the referenced law.

Abandonment (decommissioning) of the nuclear power plant) is subject to an environmental impact assessment according to the Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and the integrated environmental permitting procedure. This is specified in Section II. 6.5. of the Paks Nuclear Power Plant's environmental permit (file number 391-18/2017, included in a unified structure), which states: *"The cessation of activities (decommissioning of the power plant) is an activity requiring an independent impact assessment."* Accordingly, an environmental impact study must be prepared, and an environmental permit must be obtained from the competent environmental authority. The detailed analysis of decommissioning activities and their expected environmental impacts will be part of an independent environmental impact assessment for the decommissioning, to be prepared by the responsible organisation and to be authorized before the end of the extended operational period.

7.2. Implementation of decommissioning and its activities

According to the current Preliminary Decommissioning Plan reviewed in 2021, decommissioning work can be divided into three essential phases:

Phase 1: Preparation for the protected storage of the primary circuit.

Phase 2: 20 years of protected preservation of the primary circuit.

Phase 3: Decommissioning / dismantling of primary circuit technologies and buildings.

In terms of environmental impacts, the activities conducted in Phases 1 and 3 are the determinants. The scheduling of the decommissioning process and typical activities for each phase are illustrated in *Figure 7.2-1.*

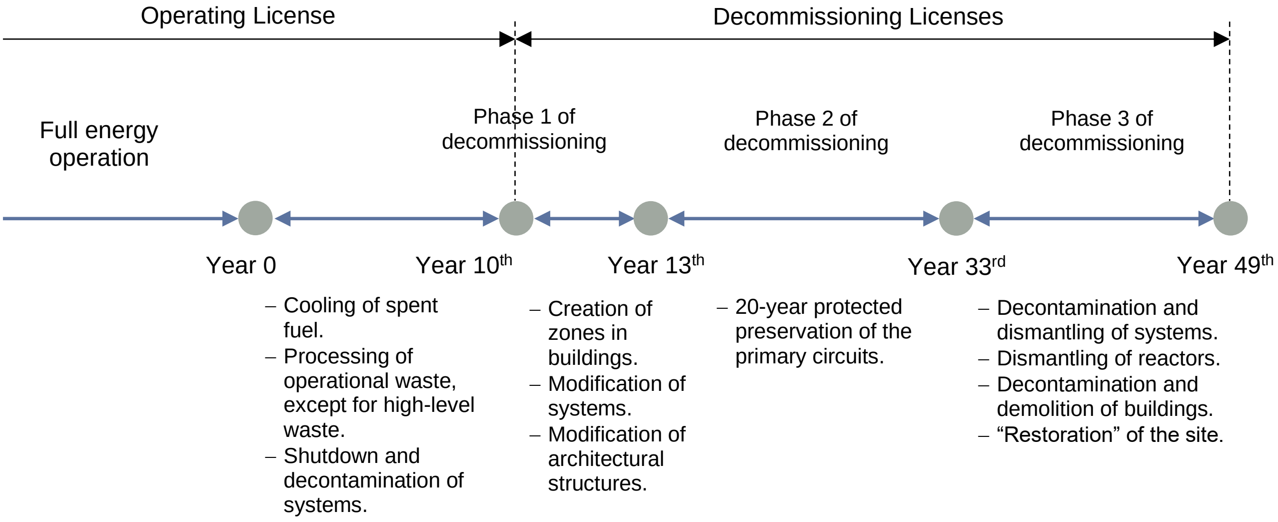


Figure 7.2-1. Time schedule for the decommissioning of the nuclear power plant assuming a 20-year protected preservation of the primary circuit

7.3. Overview of expected environmental impacts of decommissioning

Based on the decommissioning plan, the most important work processes for decommissioning the nuclear power plant are as follows:

- technical preparation (preparation for decommissioning, establishing decommissioning infrastructure, procurement, draining operational media, waste removal),
- decommissioning of technological systems,
- dismantling of buildings and structural elements,
- waste management activities (collection, sorting, storage, packing, disposal),
- radiological surveys,
- decontamination of contaminated surfaces and equipment,
- transport activities (to and from the site),
- decommissioning infrastructure removal, site restoration.

The potential impacts of dismantling are reviewed below by environmental element and system, with a brief description of each. For each impact, it will be noted whether it presents a conventional or radiological effect for the respective environmental element or system, which will be detailed in the environmental impact assessment for dismantling. The potential environmental impacts of the plant dismantling can be summarized as follows:

- Air: Dismantling involves activities such as demolition of buildings, crushing of debris, and disassembly of technological systems and machinery etc. These activities will involve large and heavy vehicles and machinery. Air quality is the primary factor affected by the dismantling process, taking into account the regional meteorological characteristics, as such activities can emit radioactive and non-radioactive gases, aerosols, and dust. High-efficiency mobile extraction and filtration equipment is assumed to be used for dismantling more contaminated equipment, as well as modified operational systems to minimize the release of contaminated and non-contaminated aerosols. During the dismantling period, conventional (non-radioactive) air pollutants are expected from two sources. Equipment that will continue to operate from the operational period, such as a diesel generator used as an emergency power source, and new sources of air pollution, including emissions from transportation, mobile equipment engines, dust from demolition activities, and emissions related to on-site processing of waste. Overall, both conventional and radiological effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.

- Surface and groundwater: The effects of the dismantling process on these environmental systems depend on the site's hydrological and hydrogeological characteristics. During dismantling, radioactive wastewaters are discharged from controlled tanks. The category of liquid radioactive waste mainly includes solutions from pre-dismantling and post-dismantling decontamination, as well as decontamination of building surfaces, and condensates and wash waters from waste processing technology systems. As for conventional discharges, technological wastewater is not expected beyond the municipal wastewater discharge, except possibly for cooling waters from certain machines, which may represent minimal impact. Therefore, potential contamination of surface and groundwater should be considered, which can be caused by the pollutant components of the discharged and dissolved substances. The removal of non-natural surfaces (such as roads and buildings) alters the flow of surface waters, site drainage, and infiltration of runoff into groundwater. Overall, both conventional and radiological effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.
- Noise: Noise impacts during dismantling need to consider operational noise sources, access routes and areas required for dismantling, and the distance from protected objects. Noise sources include demolition machinery and equipment (trailers, excavators, crushers, cutters), freight vehicles moving within and outside the site (road, rail), and vehicles used for transporting personnel involved in the demolition (road). Overall, conventional effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.
- Land and soil: The importance of impacts in this category varies depending on the selected dismantling strategy. Buildings must be demolished according to the chosen strategy, and then controlled debris is removed. Land changes may result from levelling, compaction, and removal of underground structures. During demolition, contaminated particulate matter released into the air may settle on the soil, though such contamination is expected to remain within the site. Overall, conventional effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.
- Flora and fauna: Impacts on plant life are caused by dust released during work, which settles on surrounding farmland and plant leaves. Impacts on animal life may be caused by increased noise levels (affecting certain species' habitats and behaviour), and secondary impacts may arise from changes in plant life (e.g., disappearance or appearance of food plants or changes in shelter). Overall, conventional effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.
- Landscape: Changes to the landscape during decommissioning, following the selected decommissioning strategy, are expected to lead to positive changes. The fact of dismantling and demolition may affect recreational and tourist landscape use, tourism

development, industrial site availability, changes in industrial land use, unused land, and road use rights. All of this naturally depends on the operational timelines of other facilities on the site and the planned dismantling schedule. Overall, conventional effects are anticipated, and adherence to relevant environmental protection limits and requirements can be ensured through appropriate technology and administrative regulations.

Regarding the social, sociological, and economic impacts of decommissioning, it is important to note that only conventional effects are considered. A fundamental factor is that the impacts arising from the dismantling of the four reactors at the Paks Nuclear Power Plant cannot be separated from those related to the two neighbouring nuclear facilities, the Spent Fuel Interim Storage Facility and the two new power plant units under construction. A detailed examination, determination, and assessment of all these aspects will be carried out as part of the development of the dismantling plans for the facilities.

Considering the fact that the continued operation of Paks Nuclear Power Plant is planned to use the existing power plant technology and the existing buildings and structures, the extended service life is not expected to affect the forecast environmental impacts of decommissioning as described above.

The Preliminary Decommissioning Plan also examines potential havaria, operational incidents. The results of the analysis of significant events indicate that the maximum radioactive releases into the environment during such incidents will remain several orders of magnitude below the annual limits.

Based on the results of environmental studies conducted as part of the preparation and regular updates of the decommissioning plan, it can be concluded that the decommissioning of the Paks Nuclear Power Plant will be feasible while adhering to the environmental protection regulations in force at the time of decommissioning.

The dismantling of the four reactor units at the Paks Nuclear Power Plant, including the partial or complete cessation of regulatory oversight of the facility will be carried out taking into account the decommissioning strategies and plans of the operating Spent Fuel Interim Storage Facility and the new reactor units under construction. The specific determination and implementation of the decommissioning of the four units, assessment of their environmental impacts, and the nuclear safety and environmental regulatory authorization will be ensured as part of the processes described above.

8. Summary of environmental impacts, delimitation of the impact area

For the estimation of the actual environmental impact factors and the resulting impacts associated with the continued operation of the nuclear power plant, accidents, havaria events, the potential impact factors and assumed impacts considered in *Chapter 3.1.* were used.

The basic assumption of the assessment of the expected environmental impacts related to the further extension of the plant's service life is that the current environmental impacts and impact processes related to the plant will continue to be dominant in the future, so the current impact factors should be considered, but their "operational" duration will be extended by the 20-year period of further operation.

In the preliminary impact assessment carried out, each environmental impact has been classified according to the criteria described in *Chapter 1.5.3.* The area of impact is defined as the area where the impact can be detected or estimated.

The preliminary estimated impact areas related to the further extension of the service life of the Paks Nuclear Power Plant, i.e., the environmental impacts resulting from the continued operation without significant changes to the existing technology and operating characteristics and related to the assumed accidents and havaria events are presented in a tabulated form. *Tables 8-1.* and *8-2.* provide the spatial extent of environmental impacts for each environmental element / system, broken down by impact factor, for normal operating conditions and for the accident / havaria event. The impact areas for each environmental element / system are shown on maps in *Figures 8-1.* to *8-5.* The total impact area, shown in *Figure 8-6.*, which is the sum of the areas of direct and indirect impacts, concerns the settlements listed in *Table 8-3.*

Based on the data reflecting the environmental impacts of the Paks Nuclear Power Plant's operation to date, and on the PCD prepared on the basis of an assessment of the monitoring results, it can be concluded that no overriding environmental, nature conservation and landscape protection reasons have been identified that would disable the planned subsequent extension of the nuclear power plant's service life.

The total area of potential environmental impacts associated with the subsequent extension of the service life is the area surrounding the site within a radius of 10 km, which covers 14 settlements in addition to the town of Paks where the activity is located.

Table 8-1. Extent of impact areas of the previously assessed environmental impacts resulting from the subsequent service life extension of the Paks Nuclear Power Plant under normal operating conditions

Impact factor / activity	Impacts / impact processes	Affectee	Impact area	Nature of impact
Radiological impacts				
Controlled (atmospheric and liquid) radionuclide emission	Radiation exposure of the population	Reference person	Safety zone of the Paks Nuclear Power Plant	Change in state: neutral Durability: long-term Importance: minor
	Radiation exposure of biota	Reference organism	None	Change in status: neutral Durability: long-term Importance: minor
Conventional impacts				
Impacts on air quality				
Air pollutant emissions from the operation of point sources of air pollution (diesel generators)	Changes in air quality	Ambient air	1.079 km radius circle around the air pollution point source (EOV 635680, 136715)	Change in state: neutral Durability: short-term Importance: minor
Air pollutant emissions from the related road transport	Changes in air quality	Ambient air	The immediate environment of the transport route	Change in state: neutral Durability: long-term Importance: minor
Meteorological / climate impacts				
Air temperature increase resulting from built-up of the area	Impacts on climate factors (urban effect)	Atmosphere	Paks Nuclear Power Plant operational area boundary	Change in state: neutral Durability: long-term Importance: minor
Discharge of heated cooling water into the Danube	Danube water temperature change	Danube River, atmosphere	None	Change in state: neutral Durability: long-term Importance: minor

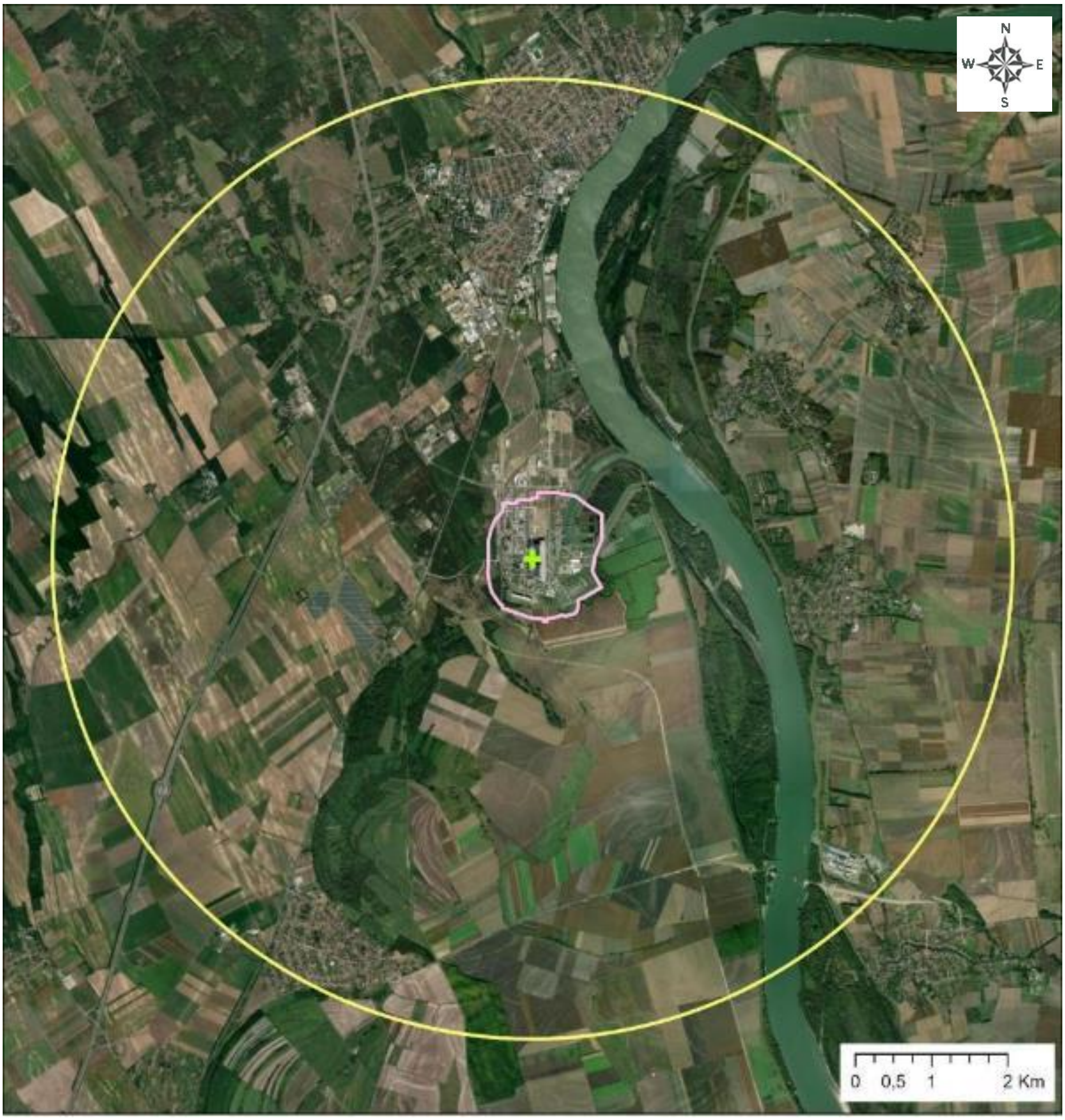
Impact factor / activity	Impacts / impact processes	Affectee	Impact area	Nature of impact
Impacts on surface water				
Discharges of industrial, municipal treated wastewater and rainwater	Changes in the water chemistry of water discharged into the Danube via the cold water channel	Danube River	Approximately 2.5 km downstream of the point of discharge on the Danube	Change in state: neutral Durability: long-term Importance: minor
	Water quality change	Aquatic biotic communities	None	Change in state: neutral Durability: long-term Importance: minor
Discharge of heated cooling water into the Danube	Changes in the hydromorphological characteristics of the Danube	Danube River	In the Danube, 300 m longitudinally from the point of discharge, a maximum of 200 m in the transverse direction	Change in state: neutral Durability: long-term Importance: minor
	Hydraulic, hydromorphological effect	Aquatic biotic communities	500 m downstream of the point of discharge on the Danube	Change in state: tolerable Durability: long-term Importance: minor
	Danube water temperature change	Aquatic biotic communities	Approximately 2.5 km downstream of the point of discharge on the Danube	Change in state: burdensome Durability: long-term Significance: great
Impacts on subsurface waters				
Discharge of heated cooling water into the Danube	Local impacts within the site: increase in groundwater temperature	Subsurface water environment (site)	Local within the Paks Nuclear Power Plant operational area	Change in state: neutral Durability: long-term Importance: minor
	Off-site, regional impacts (zone 1.: stronger Danube impact /ΔT>5°C/): increase in groundwater temperature	Subsurface water environment (wider environment)	The stretch of the Danube between 1526-1525 river km, downstream of the warm water channel and the Nagysarkantyú	Change in state: neutral Durability: long-term Importance: minor
	Off-site, regional impacts (zone 2: weak Danube impact /ΔT<2,5°C/): increase in groundwater temperature	Subsurface water environment (wider environment)	The stretch of the Danube between 1525-1523,8 river km, stretch of the boundary downstream of Nagysarkantyú and Uszód	Change in state: neutral Durability: long-term Importance: minor

Impact factor / activity	Impacts / impact processes	Affectee	Impact area	Nature of impact
Impacts on biota and ecosystems				
Existence and operation of the facility (including impact factors on other environmental elements)	Changes in living conditions	Biota, living communities	10 km radius circle around the site (potential impact area)	Change in state: neutral Durability: long-term Importance: minor
Impacts on landscape, and landscape use				
Existence of the facility (buildings, structures)	Restrictions in landscape use, landscape disturbance	Surrounding population	A 10 km radius circle around the site	Change in state: neutral Durability: long-term Importance: minor
Impacts on the municipal environment				
Existence and operation of the facility (buildings, structures)	Impact on the functioning and development of the settlement	Settlement, surrounding population	Downtown area of the town of Paks (contiguous, urban, industrial areas)	Change in state: neutral Durability: long-term Importance: minor
Waste generation and treatment				
Generation, on-site transport and loading of non-hazardous and hazardous waste	Land use	Soil	Paks Nuclear Power Plant operational area boundary (waste collection and storage areas, immediate surroundings)	Change in state: tolerable Durability: long-term Importance: minor
Impacts on noise and vibration conditions				
Industrial noise emissions, noise emissions from related road transport	Disturbance, deterioration of quality of life	Surrounding population, biota	2.5 km radius circle around the centre of EOV 635680, 136715 (dominant noise source)	Change in state: neutral-tolerable Durability: long-term Importance: minor

Table 8-2. Extent of impact areas of the previously assessed environmental impacts resulting from the subsequent service life extension of the Paks Nuclear Power Plant in the event of an assumed accident / havaria

Impact factor / activity	Impacts / impact processes	Affectee	Impact area	Nature of impact
Radiological impacts				
Controlled (atmospheric and liquid) radionuclide emissions	Radiation exposure of the public	Reference person	6.3 km radius circle around the point of emission	Change in state: tolerable Durability: short-term Importance: medium
Conventional impacts				
Impacts on air quality				
Air pollutant emissions in "black out" condition, when several diesel generators are operating simultaneously	Changes in air quality	Ambient air	The nuclear power plant operational area and its immediate surroundings	Change in state: tolerable Durability: short-term Importance: minor
Impacts on surface waters				
Industrial, municipal wastewater and polluted rainwater run-off	Changes in the water chemistry of water discharged into the Danube via the warm water channel	Danube River	Approximately 2.5 km downstream of the point of discharge on the Danube	Change in state: neutral Durability: short-term Importance: minor
	Water quality change	Aquatic biotic communities	Approximately 2.5 km downstream of the point of discharge on the Danube	Change in state: neutral Durability: short-term Importance: minor
Impacts on subsurface water				
Pollutant discharge	Local pollution	Subsurface water environment (site)	Local within the Paks Nuclear Power Plant operational area	Change in state: tolerable Durability: short-term Importance: minor
Impacts on soil, geological medium				
Discharge of pollutant, waste	Local pollution	Soil, geological medium on the site	Local within the Paks Nuclear Power Plant operational area	Change in state: tolerable Durability: short-term Importance: minor
Impacts on biota and ecosystems				
Discharge of pollutants (into air, water, soil), fire	Damage to biota and their habitats	Biota, living communities	10 km radius circle around the site (potential impact area)	Change in state: neutral Durability: short-term Importance: minor

Impact factor / activity	Impacts / impact processes	Affectee	Impact area	Nature of impact
Waste generation and treatment				
Generation of unplanned types / amounts of waste	Land use	Soil	Local within the Paks Nuclear Power Plant operational area	Change in state: neutral Durability: short-term Importance: minor
Impacts on noise and vibration conditions				
Noise emissions in "black out" condition (simultaneous operation of noise sources at power plant and multiple diesel generators)	Disturbance, deterioration of quality of life	Surrounding population, biota	2,5 km radius circle around the centre (noise sources) of EOV 635680, 136715	Change in state: neutral-tolerable Durability: short-term Importance: minor



Legend:

✚ Paks Nuclear Power Plant
▭ Radiological impacts (normal operation: safety zone of the nuclear power plant)
▭ Radiological impacts (accident: 6.3 km radius circle)

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Figure 8-1. Radiological impact area estimated for the period of subsequent service life extension of the Paks Nuclear Power Plant

Legend:

✚ Paks Nuclear Power Plant
▭ Impacts on air quality (normal operation: 1.079 km radius circle)
┅ Impact on environmental noise condition (normal operation, havaria: 2.5 km radius circle)
▭ Impacts on soil, geological media (havaria: operational area)
▭ Meteorological / climate impacts (normal operation: operational area)
▭ Waste generation and treatment (normal operation, havaria: operational area)

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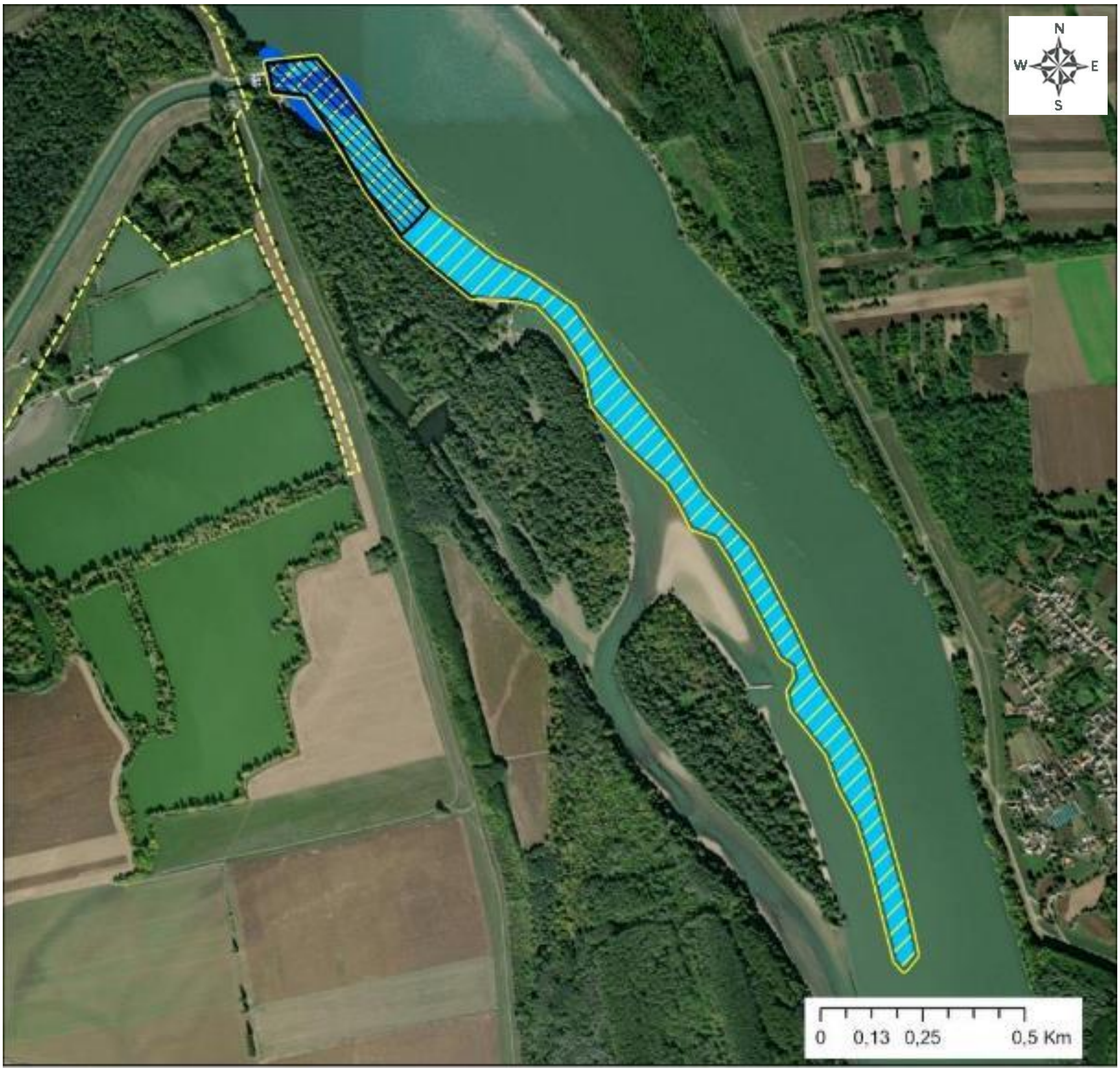
Figure 8-2. Impact area on air quality, climate, soil and non-radioactive waste generation estimated for the period of subsequent service life extension of the Paks Nuclear Power Plant



Legend:

⬚ Operational area of Paks Nuclear Power Plant

🟦 Hydromorphological impacts on surface waters (normal operation: 300 m, transverse up to 200 m from the point of discharge)

▨ Hydraulic, hydromorphological impact of warmed-up cooling water discharge (aquatic biotic communities) (normal operation, 500 m from the point of discharge)

▨ Impact of Danube heat loads on aquatic biotic communities (normal operation: 2.5 km from the point of discharge)

🟦 Impact of wastewater discharge (normal operation, havaria: 2.5 km from the point of discharge)

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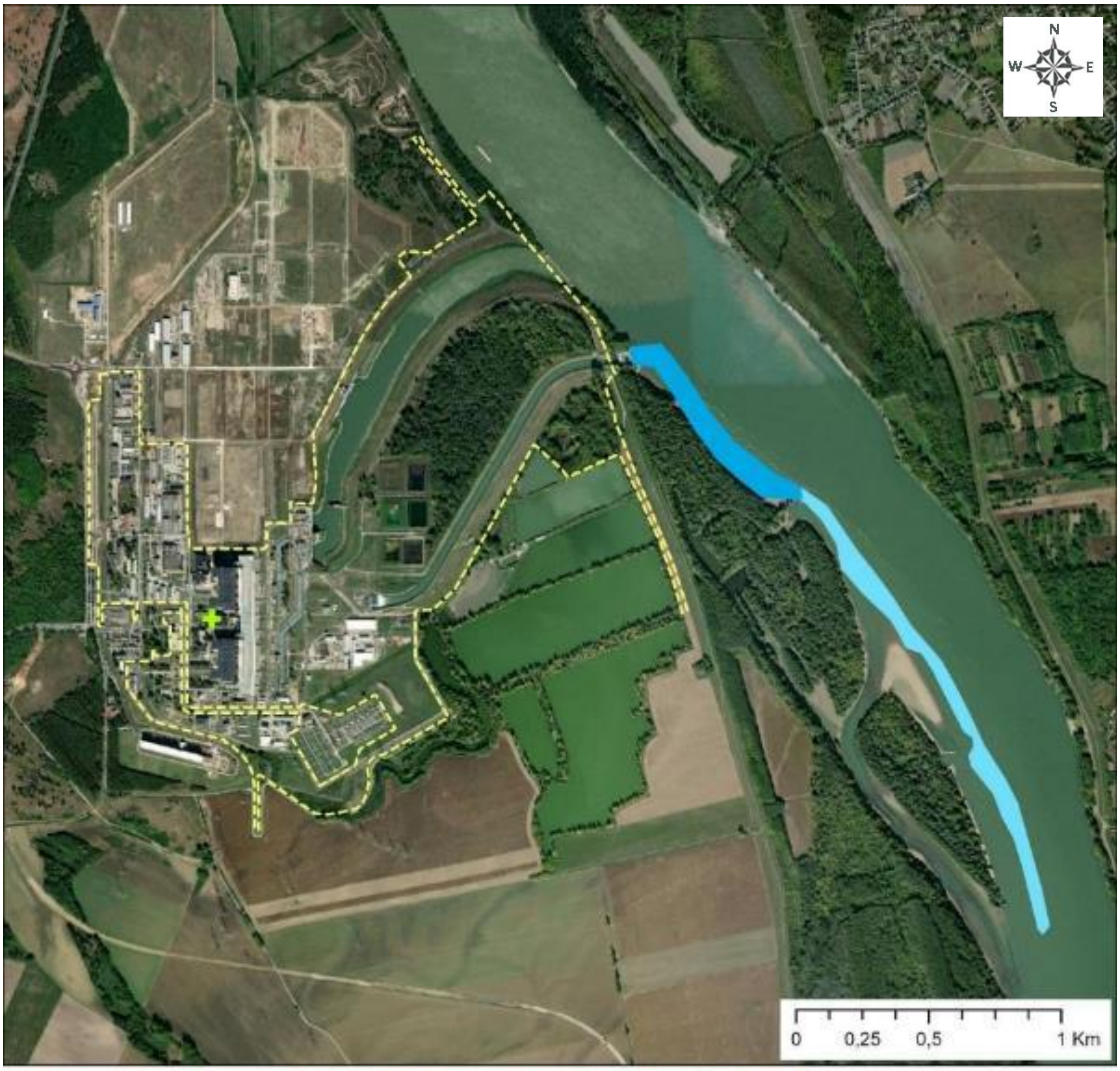
Figure 8-3. Impact area on surface waters estimated for the period of subsequent service life extension of the Paks Nuclear Power Plant



Legend:

- ✚ Paks Nuclear Power Plant
- ⬚ Heated cooling water discharge: increase in groundwater temperature (normal operation: operational area), contaminant leakage (havaria)
- 🟦 Regional impacts of heated cooling water discharge (zone 1 /ΔT>5°C/): the Danube between 1526-1525 river km, the boundary section downstream of the warm water channel and Nagysarkantyú
- 🟦 Regional impacts of heated cooling water discharge (zone 2 /ΔT<2,5°C/): the Danube 1525-1523.8 river km, the boundary between Nagysarkantyú and Uszód

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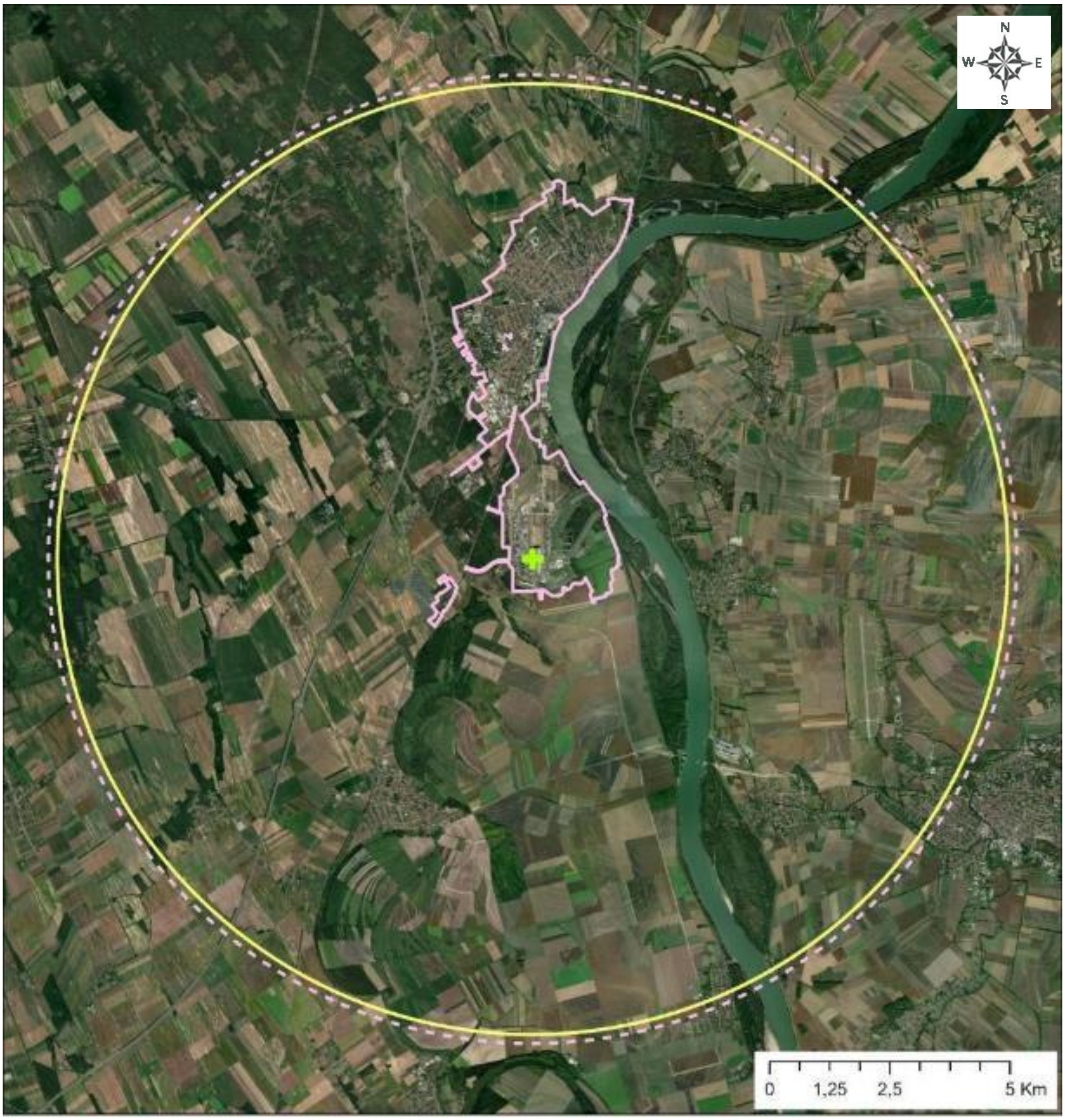
Figure 8-4. Impact area on subsurface water estimated for the period of subsequent service life extension of the Paks Nuclear Power Plant



Legend:

✚ Paks Nuclear Power Plant

▭ Impacts on biota and ecosystem (normal operation, havaria: 10 km radius circle /potential/)

⬚ Impacts on landscape, landscape use (normal operation: 10 km radius circle)

▭ Impacts on municipal environment (normal operation: inland parts of the town of Paks)

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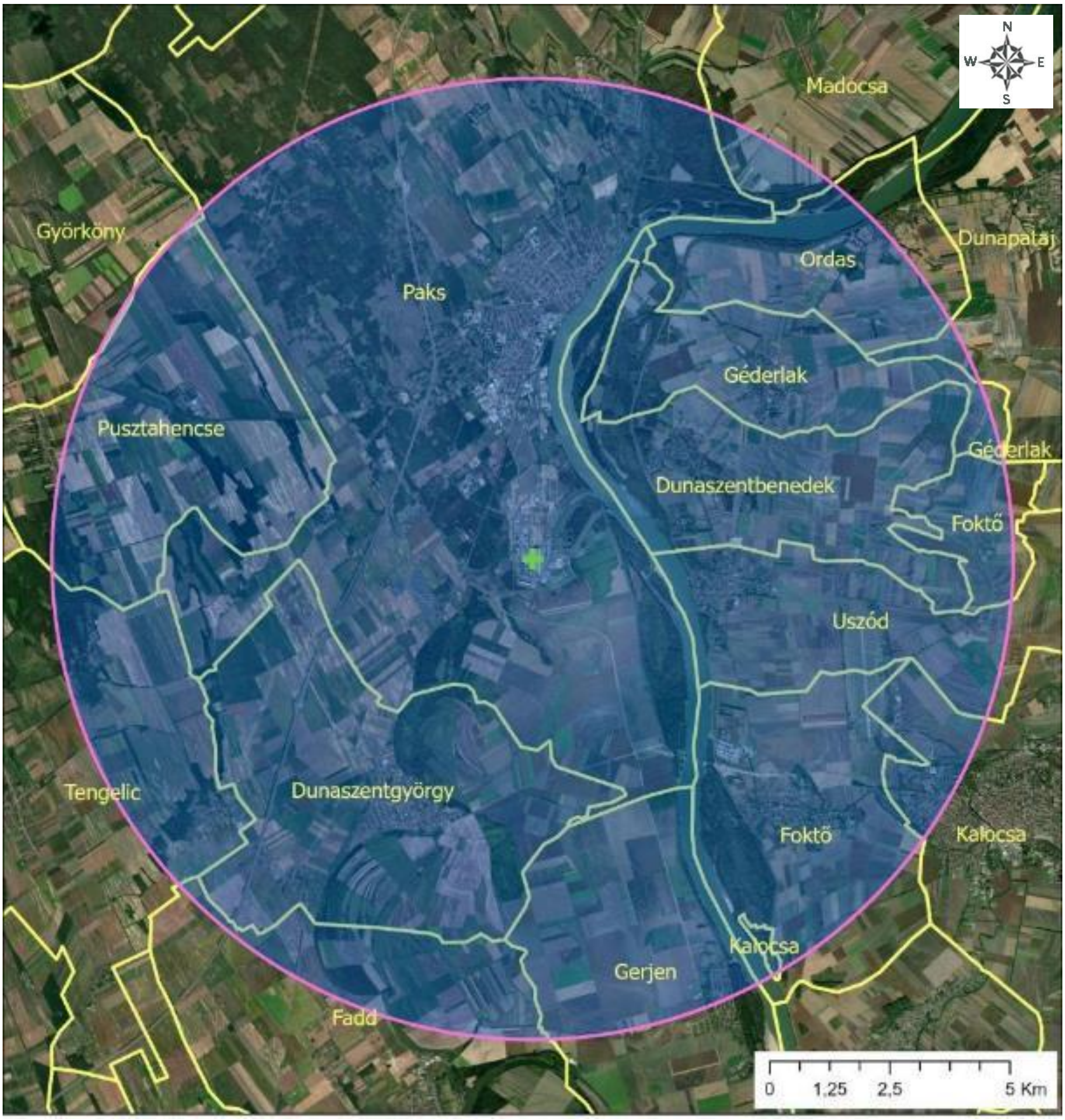
Figure 8-5. Impact area on biota and ecosystem, landscape and municipal environment estimated for the period of subsequent service life extension of the Paks Nuclear Power Plant



Legend:

✚ Paks Nuclear Power Plant

☐ Public administration boundary of settlement

🟦 Total impact area for the subsequent service life extension

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Figure 8-6. Total impact area preliminary estimated for the environmental impacts from the operation of the Paks Nuclear Power Plant for the period of subsequent service life extension

Table 8-3. Settlements affected by the assumed total impact area of the preliminary assessed, expected environmental impacts from the subsequent service life extension of the Paks Nuclear Power Plant

No.	Settlement	Settlement status	District	Area [km^2]	Population* [inhabitants]	Population density [inhabitants/km^2]
Tolna County						
1.	Dunaszentgyörgy	Municipality	Paks	37.63	2 434	65
2.	Fadd	Large municipality	Tolna	67.54	4 012	59
3.	Gerjen	Municipality	Paks	36.28	1 151	32
4.	Györköny	Municipality	Paks	31.60	985	31
5.	Madocsa	Municipality	Paks	43.33	1 746	40
6.	***Paks***	***Town***	***Paks***	***154.08***	***17 827***	***116***
7.	Pusztahencse	Municipality	Paks	31.71	917	29
8.	Tengelic	Municipality	Paks	70.93	2 013	28
Bács-Kiskun County						
9.	Dunapataj	Large municipality	Kalocsa	90.47	3 017	33
10.	Dunaszentbenedek	Municipality	Kalocsa	23.24	714	31
11.	Foktő	Municipality	Kalocsa	31.46	1 409	45
12	Géderlak	Municipality	Kalocsa	18.94	874	46
13.	Kalocsa	Town	Kalocsa	53.18	14 619	275
14.	Ordas	Municipality	Kalocsa	16.31	427	26
15.	Uszód	Municipality	Kalocsa	24.46	846	35

Source: HCSO Census 2022

9. Assessment of potential transboundary environmental impacts

9.1. Aspects for assessment of transboundary impacts

Pursuant to the provisions of the Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and the integrated environmental permitting procedure it is necessary to indicate, already at the preliminary consultation stage, whether the activity under consideration is likely to cause significant transboundary environmental impacts.

The operation of nuclear power plants is covered by the Espoo Convention on Environmental Impact Assessment in a Transboundary Context and Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the Assessment of the effects of certain public and private projects on the environment, as amended by Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014. The mandatory application of the Espoo Convention in Hungary is provided for by Government Decree 148/1999. (X. 13.) on the proclamation of the Convention on Environmental Impact Assessment in a Transboundary Context, signed in Espoo (Finland) on 26 February 1991. Appendix I to the Convention lists the activities to which the provisions of the Convention apply. For these activities, countries that consider themselves to be concerned may request the international impact assessment procedure, irrespective of whether, based on the analysis conducted, the impact area includes that particular country.

Hungary shares borders with seven countries – Austria, Slovakia, Ukraine, Romania, Serbia, Croatia and Slovenia. Serbia is the closest country to the site of the nuclear power plant, at a distance of about 63 km, followed by Croatia at about 75 km, then Romania at 120 km, Slovakia at 130 km, Slovenia at 170 km, Austria at 180 km and Ukraine at 320 km.

The concept of transboundary impact is defined in Government Decree 148/1999. (X. 13.) as follows: any impact of a non-exclusive global nature on an area under the jurisdiction of a party[13] caused by a planned activity the physical origin of which is wholly or partly within the jurisdiction of another party. The definition of the impact area is presented in *Chapter 8.*, and the results are used to assess the potential for transboundary impacts associated with the subsequent service life life extension of the nuclear power plant. Laws do not specify content requirements in this regard. These impacts are to be estimated and assessed in the same way as other impacts, with the proviso that their transboundary nature is to be analysed in a later stage. Taking into account the expectations, with regard to nuclear power plant it will be presented which environmental elements and systems as transboundary environmental impacts are realistic at all. In order to identify transboundary impacts, the following questions need to be clarified:

- Are there, or can there be, impact factors and impact processes liable to spread beyond the country borders?
- What are the impact factors for which such a possibility does not exist or has only very low likelihood?
- How do the individual impacts and impact processes for a potential load spread and add up?

Some of the questions are general, while others are activity and region-specific. The following three factors play a crucial role in assessing the transboundary impacts:

- impact factors that assume the possibility of spreading over a larger area,
- the potential for the impacts to spread and the sensitivity of the area of impact,
- characteristics of the impact area, which conduct or inhibit the spread.

Information had to be collected on these three factors to assess the impacts. The significance of the transboundary impacts of an activity can be assessed based on an investigation completed

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[13] Parties: Contracting Parties to the Espoo Convention.

in preparation for a preliminary consultation and through a regulatory assessment by carrying out the following steps.

Based on the location of the installation, the nature of the activity and the technology used, it is necessary to decide whether a transboundary impact can theoretically occur. From among the impact factors and impact processes of the activity in question those should be selected for which there is a realistic likelihood of triggering adverse transboundary environmental-ecological processes.

The mode of spreading and potential of the impact processes triggered by the impact factors taken into account must be estimated, and on this basis it must be judged whether they can reach the neighbouring country (i.e., the expected area of impact must be approximately defined). If it is established that spillover impacts are possible, the characteristics of the affected area of impact must be identified, i.e., it must be determined how sensitive the given area is to the impact processes. On this basis, the truly transboundary impacts must be selected, and the significance of the transboundary impacts must be assessed by comparing the impact processes and the spatial sensitivity.

In what follows, the possibility of transboundary spill-over is assessed in response to these questions regarding the subsequent service life extension of the Paks Nuclear Power Plant. A “significant” impact implies that the change in status is not temporary but permanent, or that it causes long-lasting environmental load.

The Paks Nuclear Power Plant site is located in the "interior" of the country, a considerable distance from the national borders. This means that, given its location, transboundary impacts can only be envisaged in exceptional cases. The expected impacts and impact processes during the operation of the nuclear power plant and their spatial extent have been identified in the previous chapters.

9.2. Radiological impacts

In preparing the PCD, it was assessed which environmental elements and systems could be considered to have transboundary environmental impacts. Based on the analyses carried out previously and the assessments carried out as part of the present assessment, it can be concluded that all environmental impacts during normal operation of the Paks Nuclear Power Plant and during design basis accidents will neutralise before they reach the national border, so that no significant transboundary impacts are expected during the originally planned service life, during its extension and during the subsequent service life extension of the Nuclear Power Plant. This is also supported by the fact that no such impact has occurred during the almost 40 years of operation to date.

Radioactive emissions into the air

The normal operation of a nuclear power plant results in some 10^{11} Bq/day of radioactive noble gas activity and about $1.5 \cdot 10^{10}$ Bq/day ^{3}H activity discharge to the atmosphere. The amount emitted will be diluted to one millionth according to the most conservative estimates, so that the expected concentrations of noble gas are 1 Bq/m^3, while those of tritium are orders of magnitude lower. This estimated activity can be detected by current instrumental methods, but the increment, i.e., the contribution of the Paks Nuclear Power Plant, cannot be distinguished from the background level. The radiological health impacts on humans and biota will be reduced to below evaluable and detectable levels much closer – within 10-12 km of the nuclear power plant – and will be classified as neutral in the environment as a whole.

The above applies to ^{3}H and noble gases. Atmospheric release of isotopes with a longer half-life, and thus possibly accumulating in the environment, are characterised by values of 10^4-10^7 Bq/day, which makes activity concentrations at the boundaries likely to be in the range of tenths of mBq/m^3, which is practically below the detection limit even for the very sensitive measurement methods used today.

The dispersion of releases calculated during the design basis accidents will result in detectable concentrations of 10^4-10^5 Bq/m^3 of radioactive noble gases at the national boundary, but their health impacts will be reduced to neutral levels even in the vicinity of the power plant, within the country's border.

On the basis of the above, the atmospheric releases of radioactive effluents outside the national boundary are expected to be neutral even in the event of a design basis accident and therefore not significant.

Radioactive releases to surface water

During normal operation, less than 1.5 GBq/year of fission and corrosion product activity is discharged to surface water. Calculated with the minimum observed water flow this results in activity concentrations of 50-60 mBq/m^3 in the Danube, which cannot be detected by direct instrumental measurements, but can sometimes be detected by sensitive radioanalytical methods.

Accumulation of longer-lived components on suspended or rolled sediments is a well-established phenomenon (in some cases, higher activity concentrations are measured in the Danube stretch above Paks than below the plant), but it migrates with the sediment, with negligible impact on humans and biota in the vicinity of the plant.

The nuclear power plant emits about 20 TBq ^{3}H per year, the final recipient of which is the Danube. Under low water conditions, this emission is present in the boundary section in measurable quantities (about 300-600 Bq/m^3), but has no radiological health impact.

As a result of the liquid releases in the context of the consequence elimination of a large diameter cold branch pipe break in the category of design basis accidents, fission and corrosion product activity concentrations of 170-200 mBq/m^3 are expected to occur in the Danube under low water conditions in the boundary stretch, which is of the same order of magnitude as the normal operational release.

Based on the above, there is no significant transboundary radiological impact on the water environment, as the impact of radioactive contaminants discharged to surface water is neutral at the boundary.

Accidental releases

In the course of implementing the transboundary impact study program, new analyses will be carried out for accidents interpreted as an extension of the design basis, using the latest available data, and a detailed analysis of the likely changes in the subsequent service life extension will be carried out, taking into account the available data.

In recent years, the nuclear power plant has undergone significant technical improvements to increase safety, which have led to a reduction in the probability of severe accidents and the assumed amount of radioactivity released. Significant improvements have also been made in the analytical tools used for the calculations, one of the results of which is that the analyses can be performed using less conservative assumptions. Taken together, these should lead to the results of the analyses planned during the implementation of the study program for the subsequent service life extension being significantly favourable than the results of the previous calculations.

9.3. Conventional environmental impacts

Based on the preliminary assessment of the conventional environmental impacts and the extent of the impact areas presented in *Chapter 8.* for each environmental element / impact, it can be concluded that all environmental impacts will be neutral well before the national border, both during normal operation of the Paks Nuclear Power Plant and during the havaria events associated with conventional environmental emissions. No significant impacts beyond the national boundary are expected to occur in terms of conventional environmental impacts during the subsequent service life extension of the nuclear power plant.

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Abbreviations

AGNES	Advanced General and New Evaluation of Safety
Á-NÉR	General Hungarian Habitat Categorization System of Habitats
BEPU	Best Estimate Plus Uncertainty
BES	Elevation above Baltic Sea level
BME	Budapest University of Technology and Economics
BTEX	Benzene, toluene, ethylbenzene, xylenes
CERTA	Centre for Emergency Response, Training and Analysis
COD_{ps}	Chemical oxygen demand (permanganate)
CORINE	Corine Land Cover, the land cover database of the European Environment Agency
DBC	Design Basis Condition
DBC1	Normal operation
DBC2	Anticipated operational occurrences
DBC4	Design basis accidents
DEC	Design Extension Condition
DEC1	Complex accidents
DEC2	Severe accidents
EIAS	Environmental impact assessment study
EOV	Unified National Projection System
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EQR	Environmental Quality Ratio
FHF	Liquid Waste Water Processing technology
FSAR	Final Safety Analyses Report
GDP	Gross domestic product
GHG	Greenhouse gas
GPS	Global Positioning System
HAEA	Hungarian Atomic Energy Authority
HCSO	Hungarian Central Statistical Office
ICPDR	International Commission for the Protection of the Danube River
ICRP	International Commission on Radiological Protection
IPCC	Intergovernmental Panel on Climate Change
JERMS	Joint Environmental Radiation Monitoring System
KEL	Environmental Monitoring Laboratory of the Paks Nuclear Power Plant
LCM	Land Change Modeler
MLP	Multilayer perceptron
MVDS	Modular Vault Dry Store
NAGIS	National Adaptation Geo-information System
NBmR	National Biodiversity Monitoring System
NERMS	National Environmental Radiation Monitoring System
NPP	Nuclear Power Plant
NRWR	National Radioactive Waste Repository
NSC	Nuclear Safety Code
OBEIT	National Nuclear Accident Management Action Plan
OERMS	Operational Environmental Radiation Monitoring System

PAH	Polycyclic aromatic hydrocarbons
PCD	Preliminary Consultation Documentation
PM_{10}	Particulate Matter 10 – particles with a diameter of 10 micrometres or less
PRISE	For primary circuit to secondary circuit leakage
PSHA	Probabilistic Seismic Hazard Assessment
PURAM	Public Limited Company for Radioactive Waste Management
SAC	Special Areas of Conservation
SFISF	Spent Fuel Interim Storage Facility
SPA	Special Protection Area
TPH	Total petroleum hydrocarbon
TSPM	Total Suspended Particulate Matter
UHRS	Uniform Hazard Response Spectra
VOR	Water object identification
WFD	Water Framework Directive
VVER	Water-cooled water-moderated energy reactor

Definitions

Ageing management	Engineering, operational, and maintenance activities aimed at keeping systems, structures and components degradation due to ageing within acceptance limits.
Ageing management program	An integrated procedure designed to identify degradation effects on nuclear power plant systems, structures and components, analyse and monitor ageing, and implement and document corrective actions.
Anticipated operational occurrence	A process triggered by an initial event presumed in the design basis and analysed based on the single failure principle, with significant likelihood of occurring during the operational lifetime of the nuclear facility, covered by these analyses.
Cliff edge effect	In a nuclear power plant, a severely abnormal process where a small change in parameters causes a sudden, large negative shift in the plant’s state.
Containment	A pressure-resistant, hermetically sealed structural enclosure that includes the nuclear reactor and its directly associated systems, structures and components. Its function is to prevent or limit the release of radioactive materials into the environment during normal operation, anticipated operational occurrences, and design basis accidents.
Decommissioning	Administrative and technical measures taken to end partial or complete regulatory oversight of a nuclear facility.
Decommissioning plan	A preliminary or final document that provides information on the concept of decommissioning a nuclear facility and the scheduling of activities, depending on the facility's current life cycle phase.
Decontamination	The partial or complete removal of radioactive contamination using physical, chemical, or biological methods.
Defense-in-depth	A multi-layered defense strategy involving principles, measures, and technical solutions that build on each other to ensure the desired level of nuclear safety. A key component at the physical level is the system of multiple barriers.
Design basis	The characteristics of a nuclear facility and its systems, components, and the functions they must perform to manage presumed initial events under specified radiological protection requirements. It includes a) requirements derived from the analysis of the effects of presumed initial events against which systems, structures and components are designed, b) parameter values or ranges, constraints, or limits defining the scope of the plan, c) anticipated operational occurrences, presumed initial events, and the resulting accident conditions, including key assumptions and specialized analytical methods generally accepted for ensuring the implementation of safety functions according to current scientific knowledge, and d) anticipated operational occurrences during which safety protection functions may fail.
Design basis accident	An operational state analysed based on the principle of single failure, triggered by an initial event presumed in the design basis, and covered by these analyses, occurring with a low probability during the operational lifetime of the nuclear facility, which only results in fuel damage of the type and extent specified in the plans.
Design basis earthquake	The maximum earthquake considered in the design basis, for which the nuclear facility's load-bearing capacity, integrity, and stability are demonstrated, and the operability of system components is assessed to ensure the achievement of fundamental safety functions.

Design extension condition (DEC)	Design basis extensions include operational states resulting from events or event combinations that were not considered in the original design basis but are now required to be addressed according to newer requirements.
Emission limit	The level of environmental or specific element loading defined by law or regulatory decision, exceeding which could cause environmental damage based on current scientific knowledge.
Emission limit criterion	The ratio of the emission limit to the emitted quantity for a given isotope and emission mode, calculated as follows: $$\sum_{ij} \frac{R_{ij}}{El_{ij}} \leq 1$$ where: El_{ij} – the emission limit for isotope *i* and emission mode *j* (Bq/year), R_{ij} – the annual emission of isotope *i* for emission mode *j* (Bq/year).
Environment	Environmental elements, their systems, processes, and structure.
Environmental element	Land, air, water, living organisms, and the human-made (artificial) environment, as well as their components.
Environmental impact	The change in the environment resulting from environmental load or the use of the environment.
Environmental impact factor	The part of the examined activity that causes a change (impact) in the state, which may be single, recurring, continuous in time, and can be decreasing, increasing, constant, or variable in intensity.
Environmental load	The direct or indirect release of any material or energy into the environment.
Environmental use	Activities involving the use or load of the environment or any of its elements.
Environmental user	An individual or entity that applies for or conducts activities defined in the annexes 1-3 of the Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and integrated environmental use permitting procedures. (Extending the operational lifetime of a nuclear power plant or reactor without size restrictions is included in point 31 of annex 1 of the Government Decree, among activities requiring environmental impact assessments.)
Final disposal	The final, authorized placement of spent fuel and radioactive waste without the intention of recovery.
Fuel element	A structural component that contains nuclear fuel, along with its associated fuel element cladding.
Havaria	Generally defined as an unexpected, significant, non-intentional event caused by a natural disaster or human activity that could endanger human health or the environment. In environmental protection terminology, it refers to an unplanned event involving environmental release or impact due to a technology or equipment failure, unintentional human error, or a natural event. In this examination, a havaria refers to events, potential failures, or assumed incidents that involve conventional (non-radioactive) environmental emissions. Operational disruptions and serious accidents are understood as those operational states defined in the Nuclear Safety Regulations, which are annexes to the 1/2022. (IV.29.) OAH Decree on nuclear safety requirements and related regulatory activities.
Hazard curve	A curve calculated during the site evaluation of the nuclear power plant, describing the site's vulnerability. It determines the annual exceedance probability of a specific characteristic of the hazard based on that characteristic.
Impact area	The area or space where the environmental impact, defined by law, occurs or may occur during environmental use.
Impact process	A process initiated by environmental factors that creates environmental impacts (interpreted when multiple environmental elements or systems are affected).

Interim storage	The temporary storage of spent fuel and radioactive waste in a facility designed for this purpose, isolated from the environment, intended for later retrieval or, based on future decisions, for final disposal in a permanent storage facility.
Normal operation	The operation of a nuclear facility under the approved Operating Conditions and Limits set by the nuclear safety authority, including changes in load, shutdowns, startups, fuel bundle exchanges, maintenance, testing, and other planned operations.
Nuclear facility	A nuclear power plant or a facility for the interim storage of spent fuel.
Nuclear fuel	The fuel used in a nuclear reactor that contains nuclear material.
Nuclear fuel cycle	All stages of the nuclear fuel's lifetime, including manufacturing, utilization, interim storage, and closure of the nuclear fuel cycle.
Nuclear power plant	An energy conversion facility that generates electrical power using nuclear fission reactions
Nuclear power plant unit	A nuclear reactor with its associated systems, structures and system components, necessary for safe electricity generation.
Nuclear reactor	A device designed to sustain and control a nuclear chain reaction.
Off-normal condition	Conditions other than normal operation, categorized into design basis and design basis extension operational states. Events leading to these states are assigned based on their frequency to the following operational states: a) DBC2 – anticipated operational occurrences, event frequency (f): $f \geq 10^{-2}$ 1/year b) DBC4 – design basis accidents, event frequency (f): $10^{-2} > f \geq 10^{-5}$ 1/year. Design basis extension categories include: a) DEC1 – complex accidents, b) DEC2 – severe accidents.
Operational state	The operational states within the design basis are: a) normal operating state (DBC1), b) anticipated operational occurrences (DBC2), c) design basis accidents (DBC4). Operational states exceeding the design basis (design basis extension) include: a) beyond design basis accidents (complex accidents) (DEC1), b) severe accidents (DEC2).
Population reference group	A group of individuals whose radiation exposure from a specific source is reasonably evenly distributed and represents those most exposed to radiation.
Postulated initiating event	An internal or external event specified during the design phase and considered in the safety analyses, with its associated initial and boundary conditions, leading or potentially leading to a DBC2-4 or DEC1-2 operational state.
Project	The totality of tasks required to obtain environmental permits for the extension of the subsequent service life extension of the Paks Nuclear Power Plant.
Radioactive waste	Radioactive material no longer intended for further use, which cannot be managed as ordinary waste due to its radiological characteristics.
Radioactive waste repository	A facility for the final and interim disposal of radioactive waste.
Related facility	A facility that supports, complements, or services the main facility at the installation site.
Severe accident	An operational state of a nuclear power plant unit involving fuel melting and causing off-site impacts more severe than those in a DEC1 state.

Single failure	A random failure of a system or system component that results in the partial or complete loss of function of that system component or the system containing it. Any subsequent failures resulting from the initial failure should be treated as part of the single failure.
Spent Fuel	Nuclear fuel that has been irradiated in a nuclear reactor and permanently removed from the reactor. It is not considered waste due to its potential for reprocessing outside the reactor; if not reprocessed based on a decision, it is classified as radioactive waste and must be disposed of permanently.
Storage of spent fuel or radioactive waste	The preservation of spent fuel or radioactive waste in a facility designed to isolate it from the environment, with the intention of future recovery.
Transboundary impact	Any impact not solely global in nature affecting an area under one jurisdiction caused by a planned activity whose physical origin partially or fully lies in another jurisdiction.
Use of environment	The induction of changes in the environment or the use of the environment or its elements as natural resources.