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MVM HUNGARIAN ELECTRICITY Ltd.

IMPLEMENTATION OF NEW NUCLEAR POWER PLANT UNITS

PRELIMINARY CONSULTATION DOCUMENTATION

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OVERVIEW OF REVISIONS

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Revision “A” includes all modifications in accordance with said and written remarks made by MVM Paks Nuclear Power Plant Ltd. and MVM Hungarian Electricity Ltd. during the design jury on 24th February 2012.

Revision “B” includes the modifications and additions executed according to the technical decisions made in course of the elaboration of the documentation.

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1. Introduction

1.1. Introduction of the planned activity and the project

In order to maintain the safe electricity supply of Hungary it is required to establish new power plant capacities since the shut-down of significant part of the currently existing capacities can be expected in medium and long-term. Basically because of the obsolescence of the domestic power plant fleet and secondly because of the increase of consumer needs – even in case of the temporary recession caused by the economic crisis – approx. 5000 MW new generation capacity is going to be necessary until 2020 and further 4000 MW until 2030. The construction of a new nuclear power plant is an advantageous solution for replacing a part of the missing resources since the electricity generation by nuclear power plants makes economically efficient, safe power supply possible that can be applied in long-term, as well as its fuel can be purchased at a steady, predictable price from several resources and it can be stored for longer time.

The construction of a nuclear power plant is preceded by a political decision and an extremely thorough, many years' preparation and licensing. The MVM Hungarian Electricity Group has carried out preliminary expert examinations at the site in Paks since 2007 related to the construction of new nuclear power plant units by analysing technical, economical, commercial, legal and social aspects. Based on the preliminary professional analyses, on 30 March 2009 the Parliament gave its approval in 95.4% ratio to start the activity that serves as preparation for the implementation of the new units at Paks site (parliamentary decision 25/2009. (IV. 2.)).

The decision of the Parliament does not mean actual decision about the construction of new nuclear power plant units. The professional work started after the principled approval shall answer for several assumptions, for example for the question of financing and investment construction, technical characteristics, competitiveness, adaptability to the system, impact on environment, type of the unit and the supplier. Following the parliamentary decision – based on the executed preliminary activities – the actual preparations started and as a part of this the preparation for the necessary licensing procedures began.

The supplier and the type of the units to be constructed – in accordance with the international practice – is chosen on the basis of a tendering procedure, which is a complex process including several phases. On the basis of the consideration of both the global trends and the domestic professional experience with nuclear power plants, it can be clearly defined that a Generation 3, pressurized water nuclear power plant should be built in Hungary. There are more of these types and suppliers present in the market, and all of these multinational corporations have recognised expertise and relevant experience in building nuclear power plants. The range is quite well-balanced, there are not any outstandingly good or weak versions. According to the analysis and references so far, all of the possible types are sufficiently safe and technically advanced.

Following the decision of the Parliament, the MVM Hungarian Electricity Group founded the Lévai Project on 8 July 2009 in order to prepare for the implementation of the planned new nuclear power plant units. The project is named after the late Professor Dr. András Lévai, who was a key figure in the domestic energy sector, who adopted a comprehensive energy-related attitude combining technical, environmental and national strategic considerations. From September 2012 the tasks related to the preparation for the implementation of the new nuclear power plant units are executed by MVM Paks II. Nuclear Power Plant Development Ltd., the new project company established by MVM Hungarian Electricity Ltd.

The planned activity is the implementation and operation of two nuclear power plant units with 1000–1600 MW net electric power at the site of the Paks Nuclear Power Plant for commercial electricity generation. The time of implementation is 11–12 years, of which the preparation phase takes 5–6 years and the construction is 6 years. As is to be expected, the first new nuclear power plant unit would be commissioned until 2025 and the second one would start until 2030, and the units are designed for 60 years operational time. The construction place of the new units is the area owned by MVM Paks Nuclear Power Plant Ltd. about 5 km to the south from the centre of Paks in the administrative area of the town of Paks in Tolna County.

The planned investment is expected to have favourable social and economic impacts on local and regional level (e.g. significant improvement in employment, development of public education and the role of increasing personal and municipal income in economic recovery) in both the construction and the operational period.

The first phase of the environmental licensing procedure is the non-mandatory preliminary consultation according to the several times amended Government decree 314/2005. (XII. 25.) on the environmental impact assessment and IPPC (Integrated Pollution Prevention and Control) procedures. In course of the preliminary consultation, by the involvement of competent administrative authorities the Inspectorate gives an opinion on the content requirements of the environmental impact assessment study to be submitted in the second phase of the licensing procedure. Following the submission of the environmental impact assessment study, with full knowledge of all data and analysis results related to the planned activity the territorially competent South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate (hereinafter Inspectorate) adopts a decision by involving the concerned specialised authorities. In this decision the Inspectorate will grant the environmental protection licence, if the power plant units to be installed are adequate from the point of view of environmental protection.

Present document is a documentation of the application for preliminary consultation, which was prepared by PÖYRY ERŐTERV Co. and its subcontractors on behalf of the MVM Hungarian Electricity Ltd. The expert institutions and companies involved in the preparation of the Preliminary Consultation Documentation and the parts of the work they executed are the following:

ÖKO Environmental, Economic, Technological, Commercial, Service and Development Co. Ltd.:	The description of environmental state and the assessment of potential impacts in the conventional (non-nuclear) fields (air quality, noise condition, wildlife communities, settlement’s environment, landscape and land use).
Hungarian Academy of Sciences Centre for Energy Research:	The description of nuclear energy generation technology and the versions of new units taken into account, the characterisation of radioactivity in the environment, the assessment of potential radiological impacts.
Golder (Associates) Hungary Ltd.:	The description of aquatic environment and the environmental state of surface and subsurface waters, the presentation of geological and hydrogeological conditions, the assessment of expected environmental impacts.
Hungarian Meteorological Service:	Regional and local meteorological characterisation, the preparation of climate study.
SOM NET Co.:	The examination of environmental impacts related to the decommissioning.

1.2. Licensing procedures related to the implementation of the new nuclear power plant units

According to the current legislation, for the implementation of new nuclear power plant units the following are necessary: execution of environmental, nuclear safety and electricity industrial licensing procedures, fulfilment of other additional licensing obligations, as well as acquisition of authority’s licences.

According to the Article (1) of 66. § of Act LIII of 1995 on the general rules of environmental protection, in case of activities falling within the scope of environmental impact assessment, the environmental use can only be started after the **environmental protection licence** issued by the environmental authority becomes final. The activities liable to environmental impact assessment are determined by the Government decree 314/2005. (XII. 25.) on the environmental impact assessment and IPPC procedures. The activities falling within the procedure are included in the Appendix 1 and 3 of the decree. The planned activity, namely the implementation of new nuclear power plant units occurs in the item 31 of Appendix 1, consequently it belongs to the activities that are liable to environmental protection licence, and therefore the environmental protection licence must be obtained as part of the licensing process. In present case the authority tasks are carried out by the Inspectorate.

According to the Government decree 314/2005. (XII. 25.), in case of the activities listed in Appendix 1 of the decree that are liable to environmental impact assessment, the environment user can initiate preliminary consultation in order to:

- on the one hand, ask the opinion on the content requirements of the environmental impact assessment study of the Inspectorate and of the authorities that later will be involved in the environmental licensing procedure as specialised authorities,
- and on the other hand, to know the comments of the public and to take them into consideration in course of the execution of the environmental impact assessment.

In present case the applicant of the environmental protection licence has decided to initiate the preliminary consultation. For this the Preliminary Consultation Documentation (PCD) complying with the content requirements of the Appendix 4 of Government decree 314/2005. (XII. 25.) has to be prepared. The Inspectorate sends the submitted documentation and the application for preliminary consultation to the administrative bodies defined in the Appendix 12 of the decree and to the notaries of the affected settlements for an opinion, and it publishes a notice about the receipt of the application. The notice can be commented on within 21 days, and the affected administrative bodies have 15 days to form their opinion. In course of the preliminary consultation procedure it is possible to conduct verbal consultation by the participation of the involved administrative bodies (future specialised authorities) and the environment user. As a result of the preliminary consultation, the Inspectorate expresses its opinion on the content requirements of the environmental impact study by taking into account the Appendix 6 of the Government decree. The environment user can submit an application for the environmental protection licence within two years after the expression of the opinion.

Since the implementation of the nuclear power plant is falling within the scope of the Government decree 148/1999. (X. 13.) on the publication of the agreement on the transboundary environmental impact assessment signed on 26 February 1991 in Espoo (Finland), and the European Community Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment as amended by Council Directive 97/11/EC, 2003/35/EC and 2009/31/EC, therefore the execution of international impact assessment procedure is also necessary. The Inspectorate shall notify the Ministry of Rural Development about the necessity of international procedure in the preliminary consultation phase. The Ministry informs the supposedly affected parties about the planned activities by sending the documentations translated into the language of the affected party or into English. If the affected party wishes to participate in the environmental impact assessment procedure, then the Ministry – by the involvement of the Inspectorate and the environment user – will conduct a consultation with the affected party as part of the procedure. The comments received during the consultation and the public’s comments of the affected parties are considered and taken into account according to necessity by the Inspectorate.

In present case the content elements of the environmental impact assessment, the necessary examinations partially differ from the usual general expectations referring to the majority of activities. One of the important differences arises from that the environment user does not consider the planned new units as the extension of the existing nuclear power plant, but it implements new units as a stand-alone facility at a location, where the adjoining land user is another, already operating nuclear power plant.

Another important peculiarity is the management of decommissioning. In case of most of the conventional activities, there is only little information available about this in the design phase. In present case, this work process is approximately the same order of magnitude as the construction volume, and its environmental impacts can be also significant. Because of the environmental risk of complex impacts, the decommissioning of a nuclear power plant is an activity liable to independent environmental impact assessment by itself according to the Government decree 314/2005. (XII. 25.). The primary reason of the separate licensing procedure is to promote the implementation of environmentally optimal solution possibility (possibilities) in course of the decommissioning of the power plant. This period will be in such a distant future (after many decades, even after 100 years) that the then up-to-date technological solutions cannot be yet predicted in the current design phase, and its environmental impacts cannot be estimated in detail. At present stage, the separate impact assessment requirement of the decommissioning of the nuclear power plant means that this phase has to be discussed in the study, but its depth does not have to achieve the elaborateness needed for the environmental licensing.

The acquisition of **nuclear safety licences** necessary for the implementation and operation of nuclear power plants can be realised according to the regulations of Act CXVI of 1996 on nuclear energy and the Government decree 118/2011. (VII. 11.), which is amended by the Government decree 37/2012. (III. 9.), on the nuclear safety requirements of nuclear facilities and the related authority activities, as well as the Nuclear Safety Requirements considered as its appendices:

- facility-level licences (site licence, construction licence, commissioning licence, operating licence),
- system-level and system element-level licences (production (type) licences, procurement (type) licences, installation licences, operating licences, building licences, utilisation licences, etc.).

In course of the nuclear safety licensing, the authority tasks are carried out by the Hungarian Atomic Energy Authority (HAEA) and the licensing procedures are executed by the Nuclear Safety Directorate (NSD) of the HAEA.

According to the regulations of Act LXXXVI of 2007 on electric energy and the Government decree 273/2007. (X. 19.) on the execution of certain provisions of Act LXXXVI of 2007 on electric energy, the implementation of the nuclear power plant also requires the acquisition of **electricity industrial licences** falling under the competence of the Hungarian Energy Office (HEO). On the basis of legislation, the implementation of new units, as a power plant significantly affecting the operation of the power system, requires principled licence, and the implementation of the power plant and the production transmission line[1] has to be licensed during the procedures. In course of the licensing of the power plant's implementation, the authority issues – in two steps – the power plant implementation licence and then the producer's operating licence.

The authority licensing of the nuclear power plant's implementation also covers several **other specific fields of interest** (examination of the site and the geological adequacy, designation of the safety zone of the facility, physical protection and fire protection of the facility, monitoring emissions and the environment, etc.). The authority licensing procedures, whose execution is necessary for the implementation of the nuclear power plant, and the most important legislations related to the procedures, are summaried in *Table M-1.* of the *Appendix.*

[1] According to the regulations of Act LXXXVI of 2007, the licensing obligation of the production transmission line's establishment does not exist in that case, when the production transmission line is exclusively used for the connection of the power plant and it does not used for the supply of other users. Accordingly, it can be assumed that during the implementation of the new nuclear power plant units the licensing of the production transmission line under the competence of the Hungarian Energy Office will not be needed.

1.3. Reasons of the implementation of new power plant units

1.3.1. Domestic electricity demand forecast

In 2011 the Hungarian power system's total electricity consumption was 42.63 TWh, of which the gross electricity generation (calculated by taking self-consumption into account) was 35.98 TWh, and the net electricity generation (fed to the network) was 33.50 TWh. Approx. 44% of the (gross) electricity generated by the domestic power plants in 2011 came from fissile material, 30% from natural gas, 18% from coal and 8% from waste and renewable energy sources. [1]

As an effect of the economic crisis, the annual peak load of the system decreased, but in 2010, with 6560 MW it came near to the 6602 MW load of 2007, which is the largest load ever measured. In 2011 the value of the annual peak load was 6492 MW. Regarding the development of net electricity consumption, 1.5% annual growth rate can be considered as a benchmark. The forecasts consider the 1% rate less likely and they make the 2% annual growth the least probable.

The gross installed capacity of domestic power plants was 10109 MW in 2011 (of which 8637 MW was the installed capacity of big power plants). By analysing the medium and long-term changes and forecasts of installed electrical capacity, it can be concluded that the fate of existing domestic power plants, their expected decommissioning in the time and way according to the owner's will, will follow the capacity market developments. In the next two decades the new power plants will be needed primarily because of the replacement of decommissioned units, and only secondarily because of the increase of electricity demands. The necessity of source establishment is demonstrated by *Figure 1.3.1-1.*

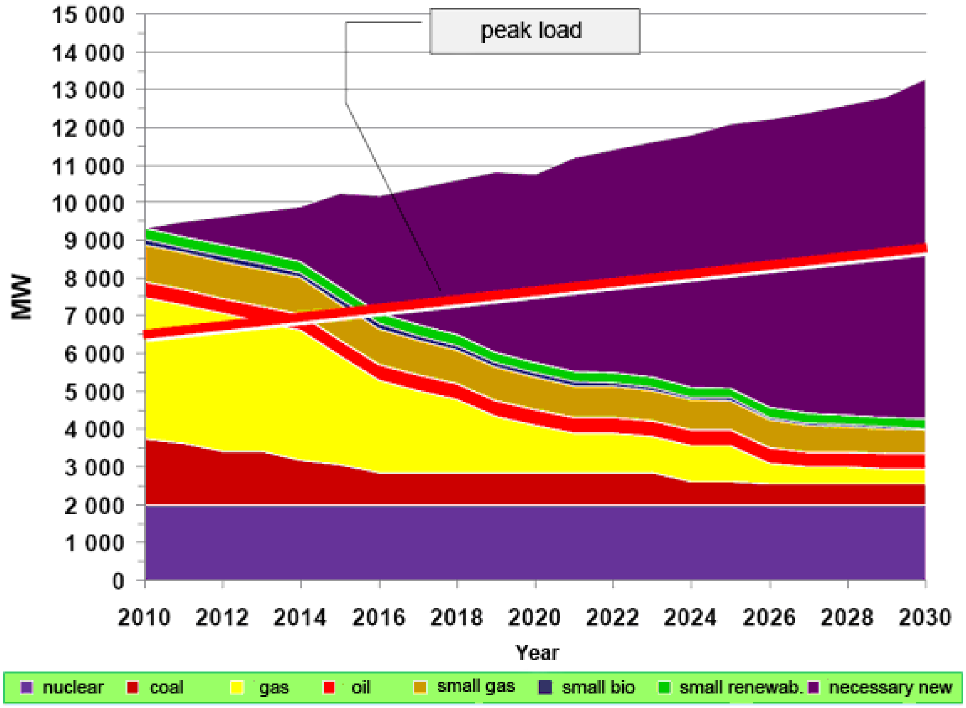


Figure 1.3.1-1. The necessity of source establishment

The power plant construction between 2010 and 2020 will be expected to be determined by the implementation of combined cycle units (CCGT[2]) and by the development of small power plants. In the early 2020s until the planned commissioning of the first new nuclear power plant unit, the necessary resources seem to be providable only by new CCGT units. However, during this period, it

[2] Combined Cycle Gas Turbine Power Plant

is also needed to start building the tertiary reserve gas turbine park, whose capacity matches to the capacity of the new nuclear power plant unit. This capacity shall be already available at the test run of the first new nuclear power plant unit to be able to replace the capacity loss for any reason within the stipulated time. [2].

With the gas turbine construction typical of the next period the ratio of natural gas as primary energy source may increase to near 50% in Hungary. This cannot be compensated effectively by the power plants based on renewable energy sources, the reduction of the ratio of natural gas can be expected from the implementation of nuclear power plant with large units. Although parallel to the construction of big power plant the construction of small power plants still continues, but the capacity value of wind power plants giving the main ratio and the biomass-fired power plants tied to their heat supply can be still very moderate. Therefore by 2030, overall the 53% of the gross electricity consumption can come from nuclear sources, 28% from natural gas, 4% from coal and 15% from renewable energy sources.

The ratio of import balance may increase in the 2010s, mainly due to the low regional offer price, which can be further strengthened by the nuclear power plant units that are expected to be commissioned in the region. However, in the 2020s the decrease of import balance can be expected. The commissioning of the nuclear power plants with large units may cause temporary overbuilding in the domestic system. The utilization of excess capacity will be able to be solved only by export or pump-storage hydropower plant.

The excess capacity can be mainly a problem in low-load periods, when in addition to the power plants that are weather dependent or not controllable because of other reasons there are controllable machine units still in operation (typically with high unit capacity) that have to ensure the regulatory capacity in the way down. This is the reason why the new units have to be able to be controlled in the range of 50–100%, which is significantly higher than the present range, and this is made possible by the current Generation 3 nuclear power plant technology without further ado, and it is also prescribed as requirement by the Grid Code of the Hungarian Power System.

1.3.2. Comparison of power generation alternatives from environmental point of view

A separate study [3] was carried out for the life cycle assessment of the Hungarian energy sector's electricity generation. The life cycle assessment examines the environmental aspects and potential impacts in course of the life cycle of a product, process or service, in each life cycle stage. The subject of the life cycle assessment is usually such product, process or service, in case of which we have an option between the systems that have the same function but different impact on the environment. The studied potential alternatives of electricity generation are the following: nuclear energy, fossil energy sources (lignite, brown coal, black coal, natural gas, oil), alternative energy sources (waste) and renewable energy sources (wood burning, biogas, ethanol, water, wind and solar power).

The system includes the LCA (Life Cycle Assessment) model of all the electric production technologies current used in Hungary, from the fossil energy sources, through the utilization of nuclear energy to the renewable sources. It should be emphasized that the assessment concerns only the electricity generation.

For the evaluation the EcoIndicator '99 and the CML 2001 methods were used that have been developed at the University of Leiden in the Netherlands [3]. The EcoIndicator '99 characterizes the environmental performance of a technology by an aggregate, dimensionless value, while the CML 2001 indicators refer exactly each emission to the quantity of reference materials by providing easily understandable units of measurement. The system boundaries of the assessment spread from the fuel extraction to its restructuring, where the final product will be the functional unit. During the analysis of the use of nuclear energy not only power generation was assessed but the loads related to the construction and decommissioning of the power plant and to the waste management as well.

The comparative analysis was carried out on the basis of the Hungarian energy mix. The Hungarian energy mix is a system, where the modelled technological systems contribute to the functional unit, i.e. to the production of 1 MJ electricity, to a real extent, so at the analysis their emissions were taken into account in real proportion. The various power production alternatives were compared on the basis of the energy mix, and since the analysis applies only to electricity, therefore heat recovery was omitted from the analysis. *Figure 1.3.2-1.* shows the results of the analysis, for which the following indicators of the CML 2001 method have been used:

- Acidification potential (kg SO_2-Equiv.), i.e. how the given system contributes to the pH change of the environment.
- Eutrophication potential (kg Phosphate-Equiv.), i.e. the characterization of the enrichment of nutrients in the environment referred to in phosphate.
- Global warming potential (kg CO_2-Equiv.), i.e. the contribution to the global warming effect referred to in carbon dioxide.
- Human toxicity potential (kg DCB-Equiv.), i.e. the toxic effect on humans, which is referred to in dichlorobenzene.
- Photochemical ozone creation potential (kg ethylene-Equiv.), i.e. the role of the process in the contribution to the creation of low atmospheric ozone, which is referred to in ethylene.

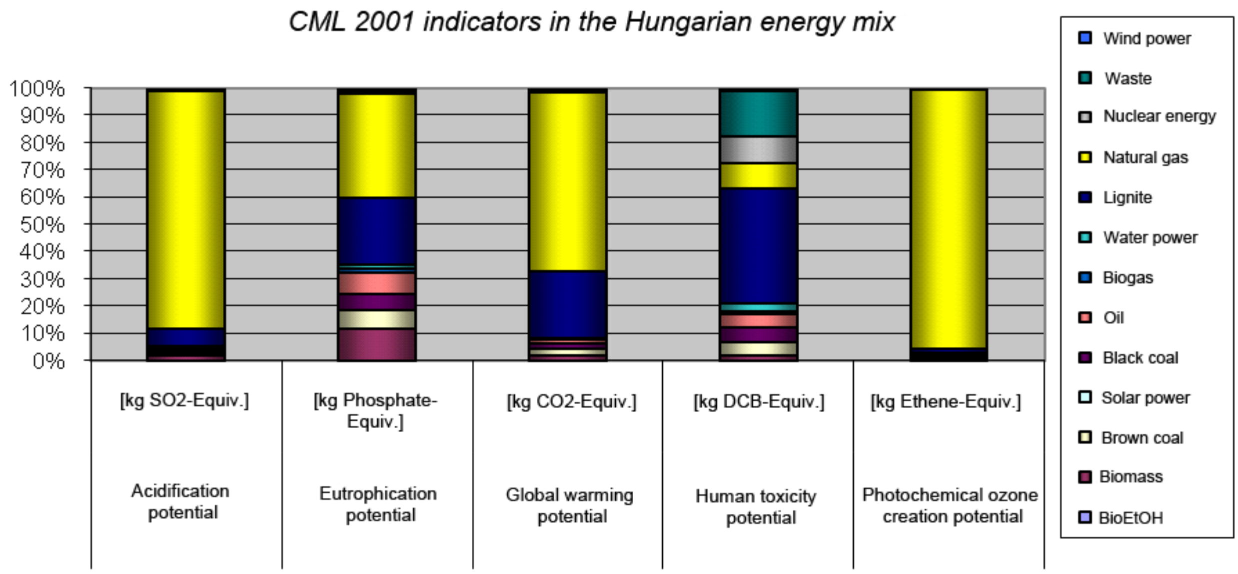


Figure 1.3.2-1. The environmental indicators of the distribution by the Hungarian energy mix (CML 2001)

The natural gas combustion plays a major role in the acidification potential, but this is understandable, since it covers the 35% of energy supply. The effect of lignite also occurs, which is responsible for the 15% of energy supply.

In case of the enrichment of nutrients, the lignite combustion also occurs, almost to the same extent as it can be observed in case of the gas combustion, whose ratio is 35%, despite the fact that lignite combustion's ratio in the energy mix is only its half, approx. 15%. The effects of two other fossil fuel technologies, the oil, as well as the black coal and brown coal, can be seen as well, although their ratio is only 1–2%. In addition to them, the biomass (firewood) combustion also has an evaluable effect with its 3.7% ratio in the energy mix.

In the distribution in case of global warming potential, natural gas occupies the largest place, which may also be the impact of its important role in the energy service. It is followed by lignite, then by the other "fossil technologies".

More power generation methods occur in case of human toxicity potential. Lignite is present in the highest ratio, and it is followed by waste incineration. Here the importance of gas decreases, its extent is almost equal to nuclear energy's, which is in accordance with their role in power production (about 35–35%), although nuclear energy could not be detected valuably in any indicators so far.

In the photochemical ozone creation potential natural gas combustion plays a role in almost 100%. It shows that the further increase of the ratio of lignite and natural gas combustion in the Hungarian power generation would not be beneficial in terms of environmental performance. Nuclear energy occurs detectably only in the human toxicity potential, therefore this technology has the best environmental load in the analysed Hungarian energy mix.

The environmental load data is summarized by *Figure 1.3.2-2.*, which presents the EcoIndicator ’99 values of each electricity generation technology.

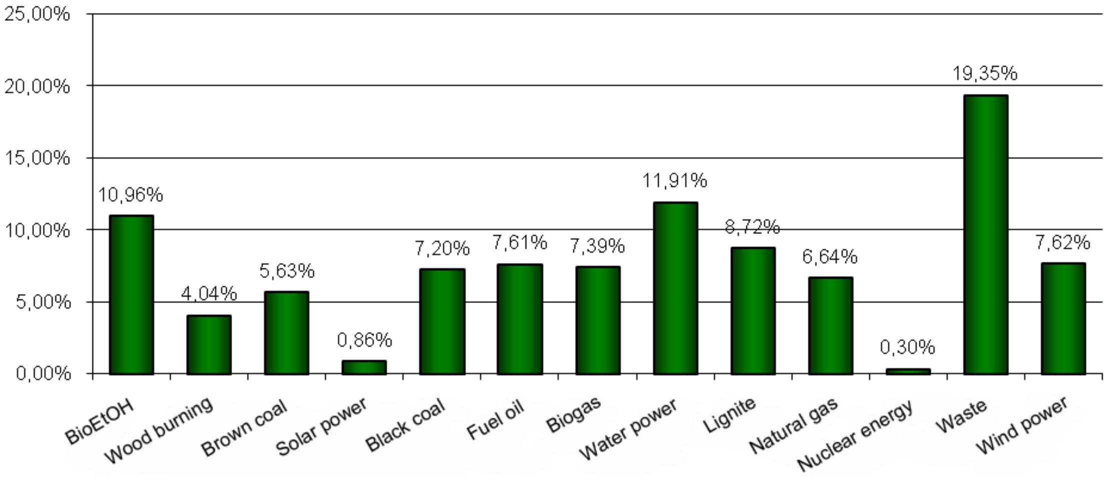


Figure 1.3.2-2. The EcoIndicator ’99 values of each power generation technology

Among the assessed procedures the waste incineration is classified as the procedure that has the most environmental loading effects, since the applied hierarchist approach within EcoIndicator takes the carcinogenic effects into account and the higher heavy metal and dioxin emission of waste incineration belongs into this category, so the indicator value will be higher. The fossil fuel technologies are almost at the same level, minor differences can be due to the ways of fuel production. In this category the best value was reached by natural gas combustion. Wood burning is the best combustion technology, but it requires a properly working forest management system, which can always deliver the fuel material.

The situation of water power is interesting, since it has the worst performance after waste incineration. This is due to the massive use of construction materials, and then we have not even accounted for the problems occurring at the different dam types, such as emissions due to the decay of sediment along the dam, and the damage of the ecosystem. The combustion of ethanol has the same level of load as the natural gas combustion, which is mainly due to the environmental impacts of agriculture. Wind power is at the same level as ethanol, but it requires less work, since it is not needed to produce agricultural raw materials every year. Among the renewable energy sources the solar power was the best as it had lower environmental load by order of magnitude than the others.

Nuclear energy had the best performance, its performance was much better than others. The impact of waste treatment cannot be seen in this figure, but the other processes do not include it either. So as in case of solar power the treatment of spent solar cells or in case of coal the treatment of fly ash is not included (which is also more or less radioactive, since the combustion functions as a selection, where the radioactive isotopes of fuel elements remain in the solid residual and they are enriched), it is not included in this case either. The disposal of radioactive wastes means much rather a risk, they can be safely disposed in appropriately designed storages. The reason of the good performance of nuclear energy is the direct power production’s low or zero “traditional” pollutant emissions, and on average 2–3 orders of magnitude less amount of fuel is required in case of the same volume electricity generation.

2. Characteristics of the site, the nuclear energy generation technology and the variations of the planned new units taken into consideration

2.1. Description of the site

2.1.1. Location of the site

The site in Paks is located in Tolna County, 118 km from Budapest to the south, 5 km from the centre of the town of Paks to the south, 1 km from the river Danube to the west and 1.5 km from the main traffic road No. 6 to the east. The southern border of the country lies 63–75 km away from the site, it is 94 km away downstream on the Danube (the existing power plant at 1527 rkm, the border of country at 1433 rkm). The area of the new power plant is located directly in the neighbourhood of the operating Paks Nuclear Power Plant, within the site boundary of the power plant. The location and immediate neighbourhood of the site is shown by *Figure M-1.* of the *Appendix*, in which it can be seen that the wider environment of the site (30 km radius area) is divided into two by the Danube. Its western part is situated in Transdanubia, while its eastern part can be found in the Danube-Tisza Interfluve. [4]

The site of Paks Nuclear Power Plant is currently an about 5.8 km^2 area. The site is divided into the following two parts in terms of function as well as protection and surveillance:

- The operating area of Paks Nuclear Power Plant:
  It includes the existing power plant’s four units and the related turbine engine room, water intake structure, and for their service: the auxiliary equipment and systems, office, maintenance and storage buildings. The Interim Spent Fuel Storage (ISFS) owned by the Public Limited Company for Radioactive Waste Management (PURAM) is connected to the operating area.
- The investment area of Paks Nuclear Power Plant:
  Currently the maintenance workshops, storage rooms and office buildings of external institutions and companies, which are necessary for the operation of the power plant, can be found here.

The area of the planned site of the new nuclear power plant units is 106 ha, which is planned to occupy approx. 29.5 ha from the current operating area of Paks Nuclear Power Plant and 76.3 ha from its so-called building yard. The location of the site in Paks, with indicating the location of the new units’ construction, can be seen in *Figure M-2.* of the *Appendix.*

The planned site of the new units can be also divided into two parts according to function. The operating area is where the power plant units, the service auxiliary equipment and systems as well as other buildings are placed, while the building yard provides adequate building area in the construction phase. In these areas there are currently the systems, offices, maintenance and storage buildings serving the operating power plant. Now the area of the new units can be found within the lot number 8803, according to the Local Building Regulations of the Town of Paks (Local Government decree 24/2003. (XII. 31.)), it is the construction zone, industrial economic area marked as Gip – M.

2.1.2. Infrastructure connections of the site

2.1.2.1. Grid connections

The current four units of Paks Nuclear Power Plant as a base power plant produce electricity for the Hungarian Power System. The electricity generated in the power plant’s turbo generators is transformed to 400 kV voltage level by the main transformers. The two main transformers of each reactor unit are connected by a 400 kV transmission line to the 400 kV substation, which is part of the national base network and located in the southeastern part of the site in Paks. The transmission lines connecting into this 400 kV substation are the main routes of the generated electricity's transportation. Via two transformers the 400 kV station is connected to the 120 kV substation situated next to it, which is part of the national main distribution network, and thus to the 120 kV transmission lines starting from there.

For the grid connection of the planned new nuclear power plant units, the implementation of a new 400 kV switch yard and transformer station is required at the site.

2.1.2.2. Road, railway and shipping connections

The accessibility of the site in Paks is good both by road, railway and on the river Danube as an international water way. The section of the main road No. 6 between Dunaföldvár, Paks and Szekszárd can be found approx. 1 km away to the west from the site. Approaching the site on the main road No. 6 from the direction of Budapest, there are two service roads after the town of Paks (the northern one is the freight entrance, the southern one is the passenger entrance). On 31 March 2010 the section of M6 motorway between Dunaújváros and Pécs, which passes by Paks too, was opened. Its route lies to the west from the site in about 3 km distance and parallel to the main road No. 6. From the motorway the site can be accessed via Paks South junction and by returning to the main road No. 6.

By railway, the site can be approached via Budapest–Pusztaszabolcs–Dunaújváros–Dunaföldvár–Paks, the terminus of the Pusztaszabolcs–Dunaújváros–Paks branch line No. 42 is in Paks. From the branch line, an industrial railway goes to the site of the power plant, the nuclear power plant can be only reached by target trains. The track is currently out of use, reconstruction and maintenance is required for its re-commissioning.

The river Danube is an important national and international water transport route, in the area of Paks it is easily navigable, slow-moving and the setting of navigable waters is good. The site of the nuclear power plant is situated 1 km to the west from the Danube. The site has a river harbour on the cold water channel, which is appropriate for the accommodation of heavy loads arriving on ships and barges to the power plant.

In 50 km radius of the site there is no public, civil airport. A private airport can be found in Dunaújváros, Kalocsa-Foktő and Őcsény. (Of these, however, the former military airport in Kalocsa-Foktő is currently out of use.)

2.1.2.3. Water supply and sewage disposal

The water supply of power plant facilities can be provided from two sources: on the one hand, from water intake from the Danube, and on the other hand, from subsurface water and deep drilled wells. In case of the four existing units of Paks Nuclear Power Plant, once-through cooling system is used currently. For that the water to be used is taken out from the Danube, through the cold water channel by the water intake structures, and after the use it returns to the recipient through the hot water channel.

Now the nuclear power plant takes out 100–110 m^3/s water from the Danube for the cooling of turbine condensers. The current amount of water taken out from the Danube is approx. 15% of the lowest water discharge of the Danube, and nearly 5% of the average water discharge. The conceptual water demand of the cooling water systems of Unit 1–4 is 2.5–3.1 billion m^3/year, the value tied to water consumption is 2.9 billion m^3/year (authority limit). The heated cooling water is returned to the Danube through the lined, free surface hot water channel. At the entering of hot water into the Danube an energy dissipation structure was constructed.

The industrial and fire fighting water necessary for the operation of the power plant also comes from the water intake from the Danube. Its source is the bank filtration well site, which was established on the north side of the cold water channel. 9 pieces of large and medium-diameter water extraction wells belong to the bank filtration industrial waterworks. The bank filtration wells are connected to the power plant's industrial and fire fighting water networks. The water pipe network covers the power plant's current operating area and the planned new units' area.

The source of drinking water and domestic water is the well site in Csámpa. In the interest of the water supply of Paks Nuclear Power Plant, 9 deep drilled wells have been established, of which four wells operate currently and two wells are available as stand-by. One well functions as a monitoring well and the other two have become clogged. The amount of water authorized to be used from the waterwork wells in Csámpa is 300000 m^3/year.

The waste water of the so-called investment area situated north to the northern access road is conducted to the sewage plant of the town of Paks by the sewer network. Its estimated amount is 1200 m^3/month. The municipal waste water of the areas situated south to the investment area, i.e. the entire operating area, is transported to the sewage treatment plant of the power plant. The purified municipal waste water is conducted into the Danube by the hot water channel.

After the treatment and purification, the final recipient of industrial waste water produced by the technology in the power plant (water of preparatory and auxiliary processes, waste water of the water-treatment plant, technological oily waste water and periodic washing water) is the Danube via the hot water channel.

2.1.3. Connections with spatial plans, settlement development plans and local plans

Whether the planned site of the new nuclear power plant units is consistent with settlement development provisions should be investigated at the following levels and based on the following legal regulations:

- Act XXVI of 2003 amended by Act L of 2008 on National Spatial Plan:
  The project site of the Paks Nuclear Power Plant is identified in the Annex "Nuclear power plant and other power plants" No. 1/8. of the National Spatial Plan and marked on the map named "Hungary's Structural Plan".
- Local Government Decree 1/2005. (II. 21.) of Tolna County Local Government on Spatial Plan of Tolna County:
  Although the County Spatial Plan was prepared earlier than the amendment of the National Spatial Plan, in many cases it contains more elaborated map annexes. Furthermore, in some places there are differences between the two spatial plans. The site of nuclear power plant is indicated on the "The plan of the County's Spatial Structure" just like in the National Spatial Plan.
- Local Government Decree 24/2003. (XII. 31.) of Paks Local Government on Local Building Regulations (Consolidated Structure) and the Lay-out Plan belonging to the Decree:
  The settlement development concept of Town of Paks was endorsed by Decree 55/2010. (V. 26.) by the body of representatives of Paks Local Government. The existing nuclear power plant site was regulated in the structural plan of the town (*Figure M-3.* of the *Appendix*).

  According to the Local Building Regulations of Town of Paks (Local Government Decree 24/2003. (XII. 31.)), the site of the power plant is located in an industrial economic building zone for nuclear power generation purposes (signed Gip – M). During the planning and construction of the facilities the requirements set for the facilities of power plant site in the Local Building Regulations should be met.

2.1.4. Summary of the characteristics of the site in Paks

In terms of the implementation of the new nuclear power plant units, the site in Paks has a number of favourable conditions, which can be exploited by establishing the new units here. The favourable conditions can be summarized as follows:

- it is an already existing, operating nuclear power plant site,
- there is no need for a new site, which can be only developed by significant expenditures (maybe by greenfield investment),
- since the beginning about 30 years ago the site has been examined by the use of substantial investments, according to numerous safety and environmental aspects, and as a consequence of this it is one of the most carefully excavated, explored areas in Hungary,
- in the surroundings of the site the infrastructure is built and available,
- the surroundings of the site is flat land area, and due to the soil characteristics the filling and foundation works can be carried out easily,
- due to the special design of ground level, the flood and inland water protection is provided in the area,
- by taking into account the already operating power plant’s water intake, the reserves remaining in the Danube’s water discharge can be used for cooling purposes,
- the meteorological parameters are favourable, the prevailing wind direction is north-west, so the wind is not directed from the power plant towards the town of Paks, which is situated to the north,
- in 30 km radius of the power plant, with the exception of Paks, the population density is lower than the national average,
- the site can be economically connected to the already developed national transmission line network,
- due to its favourable location, the power plant improves the electricity supply of the southern part of the country as well as the distribution of performance among the parts of the country,
- part of the construction materials and large equipment can be transported by water,
- the operating area is easily accessible and it is easy to ensure its connection to the main road and railway lines,
- the existence of the adjacent power plant assumes a special expertise and work culture that can be used at the new units as well,
- among the surrounding population the existence and operation of Paks Nuclear Power Plant is accepted, which may serve as a promising basis for the power plant development efforts,
- the settlement of Paks – due to its natural and infrastructural conditions – provides a good opportunity to accommodate the operators,
- the further development of the town of Paks can be solved, if necessary,
- the investment has crucial significance in terms of the further industrial development of the agricultural Tolna County.

2.2. Description of the technology of nuclear energy production

The basis of nuclear energy production is the controlled and self-sustaining chain reaction based on nuclear fission. The heat produced in the chain reaction is transferred to the coolant and after its conversion it is used for electric energy production.

2.2.1. Description of the types of nuclear power plants

The development of nuclear power plants up till now could be divided into four well defined sections. The Generation 4 reactors are still under development, basically aiming at further increasing their nuclear safety, so we do not deal with them any further.

Generation 1 – Demonstration and prototype reactors

Generation 1 included low capacity demonstartion or prototype units that were built in the 1950s and 1960s and with the exception of some reactors they were all shut down and decommissioned. These units were operated on the basis of different technological methods: Obninsk (Soviet Union, 1954): graphite-moderated and water-cooled reactor, Shippingport (the USA, 1957): light water-cooled thermal breeder reactor, Dresden 1 (the USA, 1960): the first commercial boiling water reactor, Fermi 1 (the USA, 1957): fast breeder reactor, Magnox (England, 1956): graphite-moderated and carbon dioxide-cooled reactor.

Generation 2 – nuclear power plants operating today

The experience gained in the Generation 1 prototype reactors was taken into account in the design of Generation 2 reactors developed in the 1970s and 1980s. In course of the development more standard designs were created such as Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR) and CANada Deuterium Uranium (CANDU), which is a heavy water-moderated reactor that uses natural uranium as fuel. Most of the reactors operating today (therefore also the four VVER-440[3] type units in Paks) belong to this category.

Generation 3 – nuclear power plants that can be built today

After the nuclear accidents of Three Mile Island (the USA, 1979) and Chernobyl (Soviet Union, 1986), besides improving the safety of the operating reactors, significant efforts were made worldwide in order to develop new reactor types with better safety indicators than the previous nuclear reactors have. Generation 3 nuclear reactors were developed in the 1990s with evolutionary improvements of Generation 2 reactors. Improvements in Generation 3 reactors have aimed to reduce the probability of severe accidents and to mitigate the consequences of severe accidents occurring with very low probability.

The so-called Generation 3+ reactors intensively apply passive safety systems. Their operations rely only on natural resources such as gravity, natural circulation and compressed gas energy; therefore they do not require emergency energy supply.

Among the operating reactors today, the followings are considered as Generation 3 (or 3+) reactors: the Advanced Boiling Water Reactor (ABWR) that began operation in Japan at the end of the 1990s, the Mitsubishi Advanced Pressurized Water Reactor (APWR), the Areva Evolutionary Pressurized Water Reactor (EPR), the Toshiba-Westinghouse Advanced Pressurized Water Reactor 600 (AP600) and Advanced Pressurized Water Reactor 1000 (AP1000), the new designs of VVER-1000 (AES-2006 / MIR.1200), the South Korean APR1400 and the Areva-Mitsubishi ATMEA1 reactor design.

[3] The VVER units operating in Paks are pressurized water reactor types.

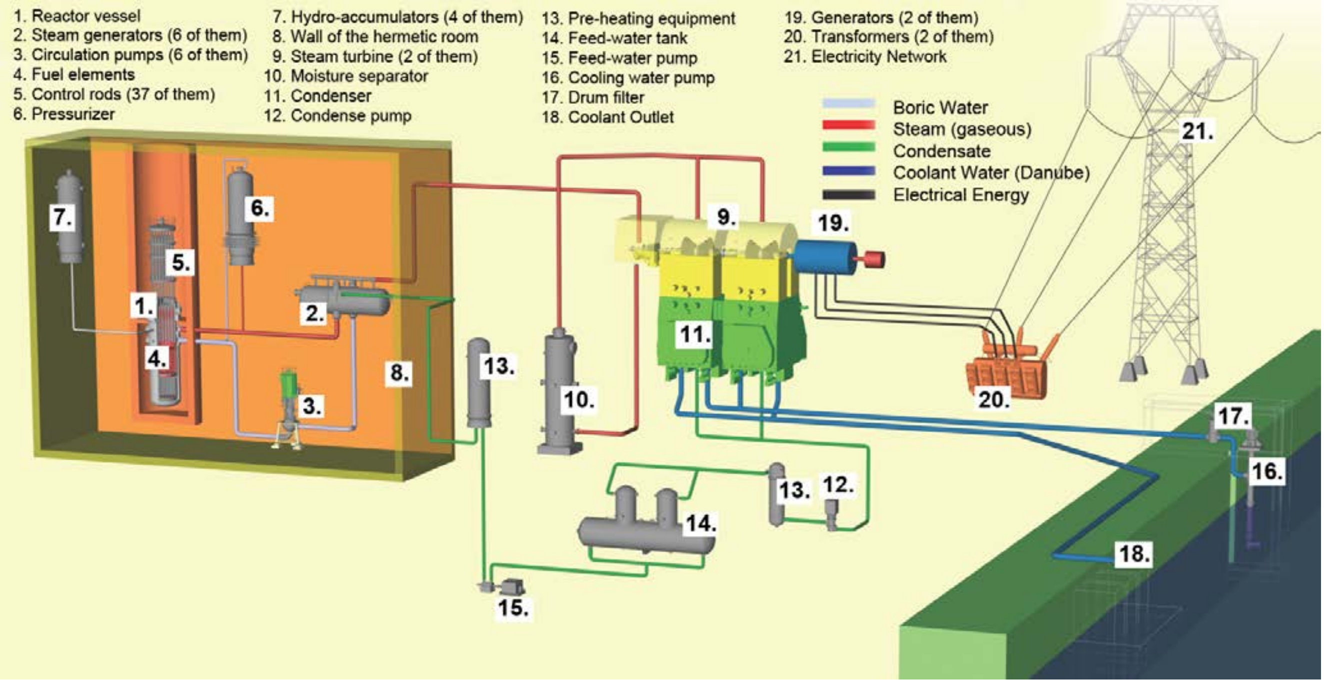
2.2.2. Operation of the pressurized water reactors (PWR) and the Generation 3 pressurized water reactors

2.2.2.1. The process of electricity generation

In case of pressurized water reactors the heat transfer is provided by a three-loop system from the reactor to the final heat absorber. In the active zone the high amount of heat generated by nuclear fission is transferred by the purified water circulating in a closed system, the so-called primary circuit. Due to the water pressure in this primary circuit the cooling water will not boil even at high temperature either; therefore, this type of reactor is named “pressurized water” reactor. The heat transferred from the reactor generates steam in the large heat exchangers (Steam Generators), in another closed water circuit, the so-called secondary circuit. The pressurized steam makes the steam turbine rotate. Due to magnetic induction this rotation generates electricity in the electrical generator. The generated electricity gets into the national network via switch gears and transformers.

The steam that has already done its work goes to the condenser where it is condensed and becomes water again by the cooling effect of the final heat absorber (it can be water of a sea or river or air in case of a cooling tower). This is the third water circuit, the so-called tertiary circuit. It is open since the large quantity of coolant taken out from the sea or river is let back to its origin into the water of the sea or the river.

In addition to this, there are several technological auxiliary systems connected to the nuclear steam generator. They have safety functions; they improve the power plant’s power efficiency and continuously clean the water circuits. The operation of a pressurized water reactor is shown by *Figure 2.2.2.1-1*.



Source: Publication of Paks Nuclear Power Plant Ltd.’s Visitors Center titled as How does it work?

Figure 2.2.2.1-1. Operation of the pressurized water reactor

2.2.2.2. Primary circuit

The reactor core is located in the vertically placed cylindrical steel reactor pressure vessel. In it there is an inner stainless steel plating (clad lining) as corrosion prevention. The inlet and outlet pipe connections for the coolant are located at the upper part of the vessel (*Figure 2.2.2.2-1.*).

Transport of the heat generated in the reactor core is performed by the cooling loops, which surround the reactor. The number of the cooling loops depends on the rector construction; thus 2, 3, 4 or 6 loops are applied usually. A four-loop primary circuit can be seen in 3D in the *Figure 2.2.2.2-2.* The primary circuit pressure is controlled by a pressurizer, which is connected to one of the loops. If necessary, the pressurizer increases the pressure of the primary circuit by switching on the electric heaters located in the vessel, or decreases the pressure of the primary circuit by injecting cold water taken from the cold leg.

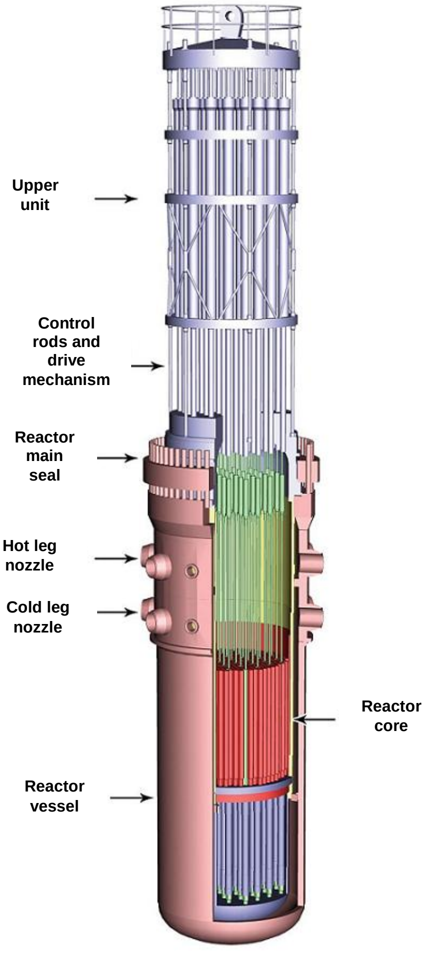


Figure 2.2.2.2-1. Figure of a VVER-440 type reactor vessel

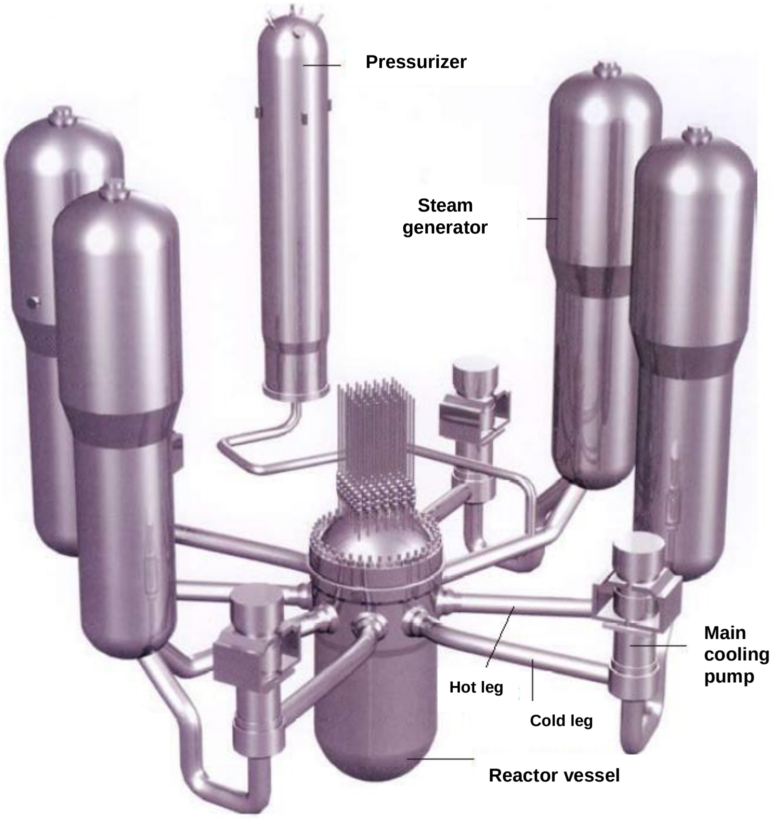


Figure 2.2.2.2-2. Figure of a four loop reactor's primary circuit (Mitsubishi APWR)

The cooling water flows into the reactor vessel on the so-called cold legs, while the water warmed up to the temperature between 300 and 320 ºC in the reactor core discharges from the reactor on the hot legs and gets to the steam generators located around the reactor vessel. In the steam generators part of the heat of primary circuit water is transferred to the secondary water, while the secondary circuit water boils in the steam generator (transforms to steam). The cooled down coolant returns to the reactor on the cold leg. Water in the primary side is circulated by the main cooling pumps.

In the primary circuit of the pressurized water reactor the value of the nominal primary pressure is between 123 and 156 bars, depending on its type. This high pressure ensures that the high temperature coolant leaving the reactor core does not boil.

2.2.2.3. Secondary circuit

The conversion of the heat released from the reactor to kinetic and then electric energy is done in the secondary circuit. On the secondary side the circulating feed water is heated and boiled by the 300–320 ºC water of the primary circuit circulating in the small tubes of the steam generators.

The steam leaves the steam generator and flows towards the turbine, where, by its kinetic energy, it rotates the turbine blades. In the turbine a single shaft connects the high pressure case, the two low pressure cases as well as the generator rotor. In the high pressure case the temperature of the steam decreases and thus its moisture content increases significantly. Therefore, before it enters the low pressure case, it must go through the so-called moisture separator re-heater, which removes the drops that are harmful to the turbine blades.

2.2.2.4. Tertiary circuit, the final heat absorber

The (spent) steam that has already done its work goes to the condenser, where in thousands of thin tubes cooling water flows. The steam condenses at about 25 ^{o}C on the cooling tubes. The condensed coolant is brought back to the steam generator by feed water pumps after it gets through cleaner and pre-heater equipment. Preheating is mainly necessary because in this way higher overall plant efficiency can be achieved.

The final heat absorber provides the removal of the heat generated in the reactor, which is not converted to electric energy, the ratio of that is approx. 65–67%, which depends on the efficiency of the process. Several solutions are possible for the construction of the final heat absorber depending on the features of the site. In case of a nuclear power plant located next to a river with high rate of flow, a big lake or the sea, the cooling water taken out from them is used as final heat absorber. This method is applied in case of the Paks Nuclear Power Plant as well. At those sites, where "fresh water" is not available in adequate amount to feed the tertiary circuit, cooling towers are applied.

2.2.2.5. Main buildings of the pressurized water nuclear power plants

We illustrate the typical buildings of the pressurized water nuclear power plants by the buildings of the EPR reactor design (*Figure 2.2.2.5-1.*). There might be some differences between each reactor design, though these buildings compose the power plant. The name and the functions of each building:

1. **Reactor building (containment):** it contains the equipment of the Nuclear Steam Supply System, including the reactor vessel, the primary circuit and the steam generators. The containment is a pressure resistant, hermetically constructed (usually double-walled) structure, which blocks and constrains the release of radioactive materials into the environment.
2. **Fuel building:** is the building where fresh and spent nuclear fuel is managed and stored.
3. **Safeguards buildings:** due to the multiple redundancy, several safety systems are included in the nuclear power plants such as the Emergency Cooling System. For the sake of their appropriate physical separation, they are usually located in different buildings. In case of emergency, one properly operating system is enough.
4. **Diesel buildings:** the diesel generators providing emergency AC power supplies are located in several separate buildings for the sake of the appropriate physical separation.

5. **Auxiliary building:** the main auxiliary systems related to the primary and the secondary circuits can be found in this building.
6. **Waste building:** the function of this building is the treatment of liquid and solid radioactive waste generated during the operation of the reactors.
7. **Turbine building:** it contains the turbine, the generator and their auxiliary systems.

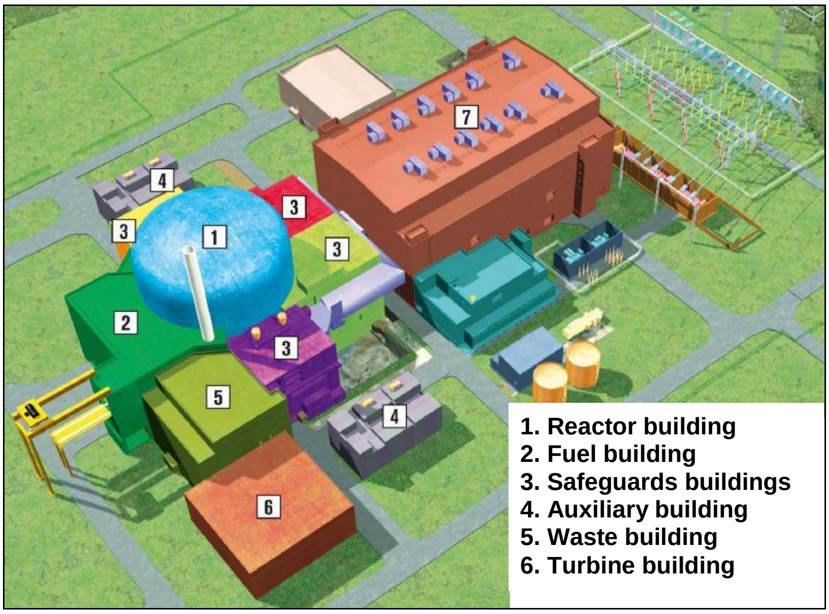


Figure 2.2.2.5-1. The main buildings of the EPR reactor design [5]

2.2.2.6. Safety philosophy – the defence in depth principle at the new nuclear power plants

The defence in depth principle

The release of radioactive materials into the environment is prevented by the following four physical barriers:

1. fuel matrix (the material of the fuel tablet),
2. fuel cladding,
3. primary circuit boundary (reactor vessel and primary circuit pipelines),
4. the hermetically sealed, usually double-walled containment system.

The defence in depth principle was already applied at the first nuclear power plant designs. On the one hand, it ensures the prevention of the so-called postulated events and on the other hand, it is appropriate for mitigating the consequences of a possible accident. The levels of defence in depth were defined according to the progressive worsening of accident: should one level fail, the subsequent level comes into play. The original concept of defence in depth ([6], [7], [8]) contained three levels, which were further developed; therefore, in the early 1990s the class of "Beyond Design Basis Accidents" (BDBA) was launched. This category contained those accidents, which were not included originally in the Design Basis (for example, multiple failure leading to events and severe accidents). For managing events in this new category two more levels of defence in depth were introduced. The main objective of the defence in depth principle is to keep the integrity of the physical barriers by the help of automatic or manually operated safety and protection systems in case of the occurrence of internal or external events dangering them. The integrity of the barriers, besides the inherent physical processes, in normal operation, in case of events or accidents is enhanced by automatic or manual operated Safety and Protection Systems. The five levels of defence in depth, the four physical barriers as well as the relation between the automatic and manual interventions are shown by *Figure 2.2.2.6-1.*

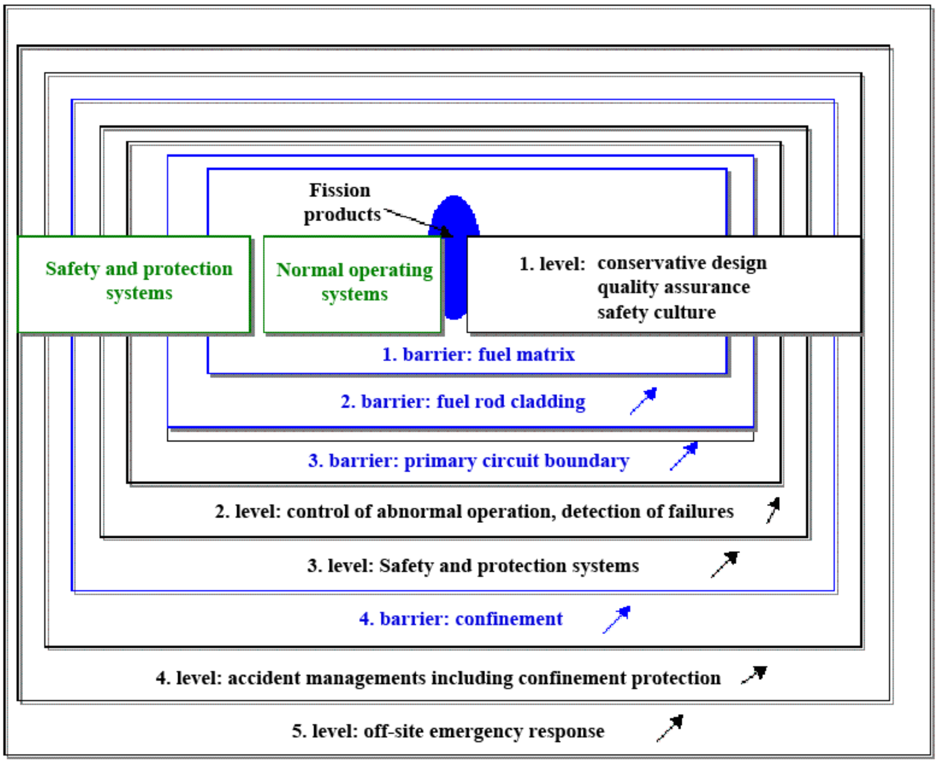


Figure 2.2.2.6-1. The hierarchy of physical barriers, levels of protection in defence in depth interventions [6], [8]

Implementation of defence in depth on the new reactor designs

The concept of defence in depth applied to the new reactor designs contains five levels showed by *Figure 2.2.2.6-1.* [7] The new reactor designs include those accidents such as multiple failures and severe accidents leading to core meltdown in the design basis, which in case of the current power plants are classed into the "beyond design basis" accidents. It shows that the category of "beyond design basis accidents" is different regarding the new and the operating reactors. Further distinction is that in case of presently operating reactors the defence in depth manages those nuclear fuel conditions when nuclear fuel is in the reactor, while the new reactor designs cover all possible conditions of the nuclear fuel (for example, the case when the spent fuel assemblies are stored in the spent fuel pool).

If a safety function is ensured by more safety subsystems (three or four usually) operated in parallel and their operation is based on the same principle, we call it as redundant method. These systems should be physically separated for that reason that the potential external hazards (e.g. fire, flood) could not cause the loss of the parallel operating subsystems at the same time.

If a safety function is implemented by more safety subsystems and their operation is based on different principles, we apply the diverse method.

A function is "single failure tolerant", if it is implemented by redundant systems and a single failure occurrence[4] at one of the redundant systems does not lead to the loss of the function.

[4] The single failure is the random failure of a system component arising from one error and as a result the system component and/or the function of the system containing it will be lost.

2.2.2.7. The special characteristics of Generation 3 reactor designs

One of the main objectives of the Generation 3 reactor types' development was the prevention of the hypothetical severe accidents and the mitigation of the consequences of extremely low probability severe accidents. The new designs contain those technological solutions which prevent the radioactive release into the environment even during severe accidents. So even in case of the occurrence of severe accidents, Generation 3 units do not have a substantial impact on the population and the environment of the power plant.

One of the prevailed constructions is the “core catcher”, which is a device provided to catch the molten core material of a nuclear reactor in severe accidents. It is used to prevent the molten core from attacking the concrete under the reactor vessel by establishing compartments at the bottom of the cavity that helps the melt spreading or by placing such materials under the vessel, which prevent the molten core material from trickling through. This solution is applied by the EPR, ATMEA1 and MIR.1200 reactor designs. A different method is applied to severe accidents at the AP1000 reactor design to mitigate a postulated severe accident such as core melt. The “in-vessel retention philosophy” of the Westinghouse aims to keep the molten core within the reactor vessel. In these cases, they can flood the reactor cavity space immediately surrounding the reactor vessel with water to submerge the reactor vessel. A similar method is applied to the standard version of the South Korean APR1400 reactor design; however, the “core catcher” design has been already started to satisfy the European market demand.

The containment is an important part of the defence in depth, which represents the last barrier between the radioactive materials and the environment of the power plant. Therefore, many innovative solutions have been developed in order to enhance the containment of the Generation 3 reactors and to maintain the integrity of its structure for long term. One of the impressive solutions is the so-called passive containment of the AP1000 reactor design. The inner wall of the passive containment, made of stainless steel, extracts the heat from inside the containment and then natural circulation transfers it further. If necessary, the outside surface of the inner steel wall is started to be water cooled passively, by the gravity of water from the large water tank located on the top of the containment.

In order to keep the containment undamaged, processes for the handling of the generated hydrogen are also applied to severe accident sequences. When the recombination of hydrogen and oxygen is reaching a certain concentration level it could be exploded. In the passive process catalytic recombiners are used to remove the hydrogen released into air. The active method, which applies the hydrogen as a glow plug igniter to fire the hydrogen gathered in the top of the containment, before it would exceed the dangerous concentration in order to reduce the quantity of the hydrogen in the containment.

In most countries today's regulations require that the containment shall resist even a large passenger aircraft crash despite the fires derived from the large amount of kerosene dispersed.

2.2.3. Nuclear energy generation around the world, the references of nuclear energy generation

The nuclear energetics developed rapidly in the 1960s and 1970s around the world, but this development came to a sudden halt after the Three Mile Island accident (the USA, 1979), and it basically stopped after the Chernobyl Nuclear Power Plant accident (USSR, 1986). The situation changed at the beginning of the 21st century, mainly due to two important circumstances. One of the circumstances is the present high oil and gas prices, which are going to remain persistently high according to the energy market analysts, and they can even increase because of the impacts of political crises. The other circumstance is the concerns and international obligations related to the global climate change. For the “clean” energy production (resulting zero CO_2 emission) required by sustainable development, the new energy sources (renewable and fusion) and the new energy carriers (e.g. hydrogen) certainly do not mean a solution in the short term, but they do not surely mean a solution even in medium term. Therefore, the use of nuclear power plants has come to the fore again around the world, especially because the nuclear power plant technology has progressed significantly in the meantime, so the Generation 3 unit types currently available in the market have such technical-safety indices that the operation of even a large number of nuclear power plants can be considered safe. [9]

The change of world trends has had an impact on the European Union as well. The union is highly sensitive to the fossil energy carrier-related problems, since its own gas and oil production covers only a fraction of consumption.

On the basis of the data of *Figure 2.2.3-1.* showing the distribution of operating nuclear reactors by country, it can be found that nearly 25% of the total of 435 operating reactors is located in the United States. In the second place there is France, the 58 French nuclear reactors gave approx. 75% of the country's energy production (as of 31 December 2009). In China there are only 16 operating nuclear power plant units currently, which give insignificant part of the country's energy production. [10] The quantity and distribution of reactors under construction show a very different picture. Approx. 44% of the reactors under construction can be found in China, so the dominance of Asian countries is clear. The number of reactors under construction (a total of 63 pcs) by country is shown by *Figure 2.2.3-2.*

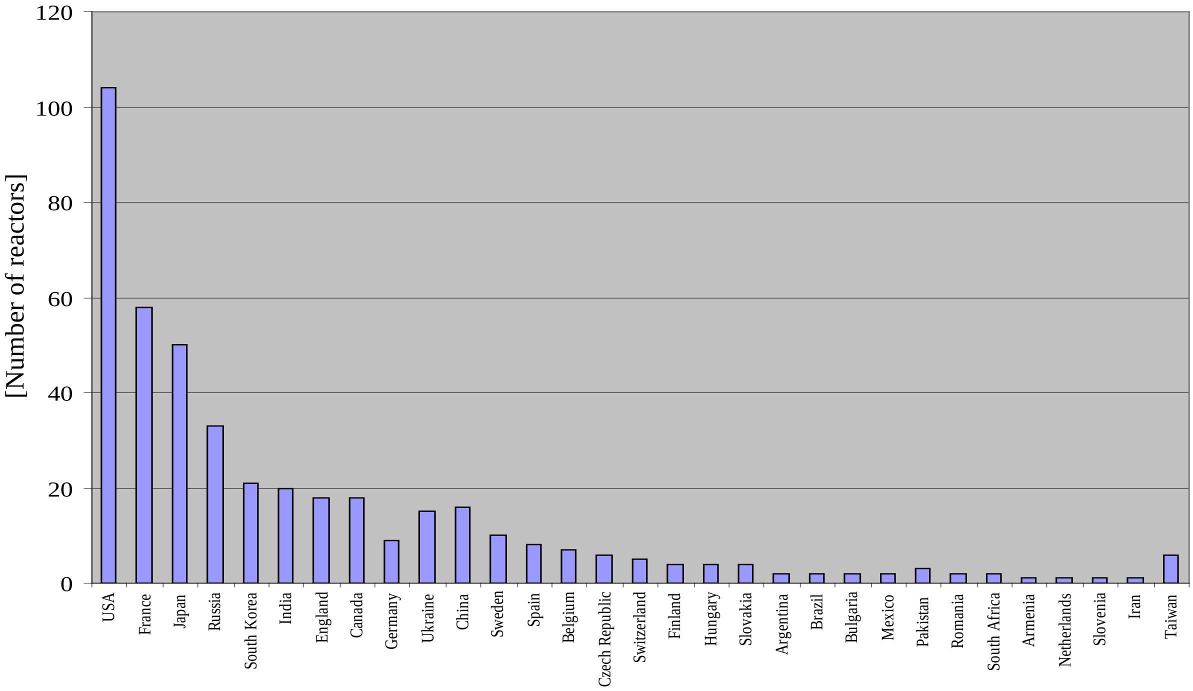


Figure 2.2.3-1. Distribution of operating reactors by country (January 2012) [10]

At the beginning of 2012 the vast majority of the world’s 435 nuclear power plant units providing approx. 373 GW electric power belonged to the pressurized water (PWR) and boiling water (BWR) type, but a lot of units operated by the Canadian CANDU heavy water technology as well [10]. There are also some reactors operating by the RBMK technology (this is the “Chernobyl” boiling water type: water-cooled and graphite-moderated), and there are some gas-cooled reactors still in operation as well.

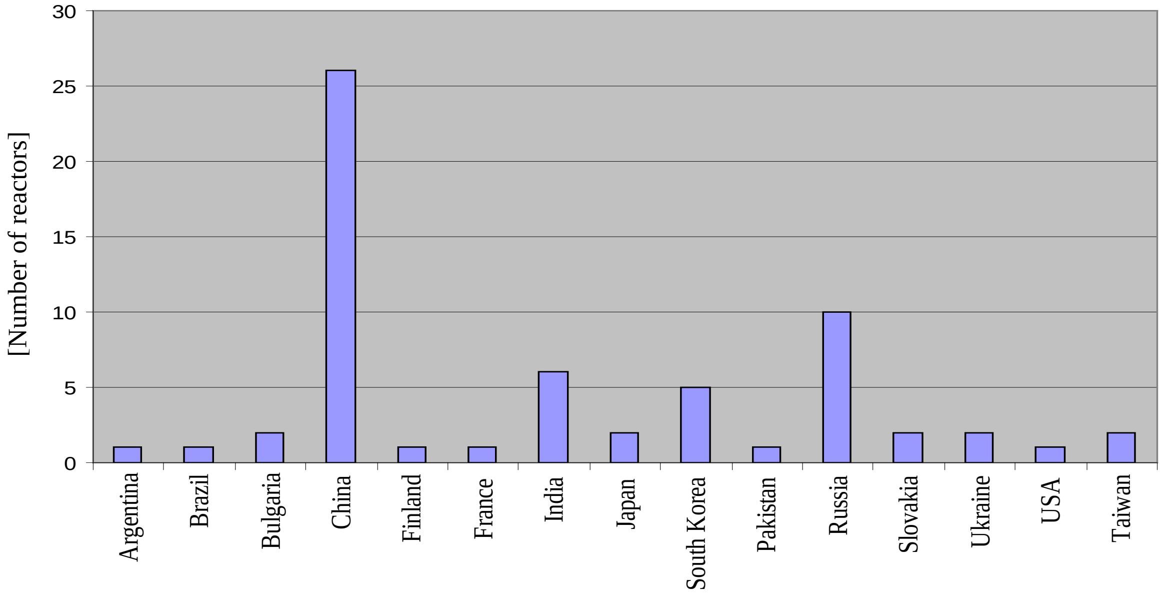


Figure 2.2.3-2. Distribution of reactors under construction by country (January 2012) [10]

Basically the following major suppliers are present in the current market, that recommend the different versions of Generation 3 units: Areva, AECL (Atomic Energy Canada Ltd.), Atomstroyexport, General Electric (GE), Hitachi, Mitsubishi, Toshiba-Westinghouse and the South Korean KEPCO (Korea Electric Power Corporation). These large enterprises – in addition to being tough competitors to each other – cooperate in certain projects, and they have common developments as well. The advanced pressurized water reactors come from five manufacturers (Areva, Toshiba-Westinghouse, Atomstroyexport, Mitsubishi and KEPCO). In addition, in 2007 the Areva-Mitsubishi joint venture, called ATMEA, started, whose aim is to develop a Generation 3 unit with 1000–1100 MW_e capacity.

At reviewing the ongoing nuclear power plant constructions (*Table 2.2.3-1.* and *2.2.3-2.*), the dominance of pressurized water type is striking, more than 80% of the new units belongs to this type, while the proportion of boiling water type is less than 10%. India that aspires for nuclear independency is an exception because mostly self-developed pressurized-tank (PHWR) units are built there.

Table 2.2.3-1. The ongoing reactor constructions by reactor types (January 2012) [10]

Type	Number of units under construction [pcs]	Total capacity [MW]	Proportion [%]
Boiling water (BWR)	4	5250	8.6
Fast breeder (FBR)	2	1274	2.1
RBMK* (LWGR)	1**	915	1.5
Pressurized heavy water (PHWR)	4	2582	4.2
Pressurized water (PWR)	52	51011	83.6
Total	63	61032	100.0

* Boiling water reactor, graphite-moderated and light water-cooled.

** The construction of the Unit 5 of the Russian Kursk Nuclear Power Plant was started in 1985, the construction was later suspended, and the preparedness of the unit is currently 70%. In the Power Reactor Information System [10] database of the International Atomic Energy Agency it occurs as a unit under construction and the intention of the construction's final suspension is not indicated.

Table 2.2.3-2. The ongoing Generation 3 reactor constructions (January 2012) [10]

Type	Manufacturer	pcs
PWR, EPR	Areva	4
ABWR	Toshiba	4
PWR, AP1000	Westinghouse	4
PWR, APR1400	South-Korea	2
VVER, AES-2006	ROSATOM	4
VVER, AES-92 (V-466)	ASE	2
	Total:	20

To a decisive extent, the advanced Generation 3 reactors are built in Asia, primarily in China. While Japan and South Korea build self-developed reactors, China decided on Areva and Westinghouse. The ongoing reactor constructions by country are shown by *Table 2.2.3-3.*

Table 2.2.3-3. The ongoing reactor constructions by country (January 2012) [10]

Country	Number of units under construction [pcs]	Type of units under construction	Total capacity [MW]	Proportion [%]
Argentina	1	Pressurized heavy water	692	1.1
Brazil	1	Pressurized water	1245	2.0
Bulgaria	2	Pressurized water	1906	3.1
China	26	Pressurized water	26620	44.0
Finland	1	Pressurized water	1600	2.6
France	1	Pressurized water	1600	2.6
India	6	3 press. heavy water 1 fast breeder 2 pressurized water	3766	6.2
Japan	2	Pressurized water	2650	4.4
South-Korea	5	Pressurized water	5560	9.3
Pakistan	1	Pressurized water	300	0.5
Russia	10	8 pressurized water 1 fast breeder 1 RBMK*	8203	13.6
Slovakia	2	Pressurized water	782	1.3
Ukraine	2	Pressurized water	1900	3.1
USA	1	Pressurized water	1165	1.9
Taiwan	2	Boiling water	2600	4.3
Total	63		60589	100.0

* The construction of the Unit 5 of the Russian Kursk Nuclear Power Plant was started in 1985, the construction was later suspended, and the preparedness of the unit is currently 70%. In the Power Reactor Information System [10] database of the International Atomic Energy Agency it occurs as a unit under construction and the intention of the construction's final suspension is not indicated.

Due to the large earthquake occurred in Japan in March 2011, the planned nuclear power plant developments, the ongoing licensing procedures and the schedule of nuclear power plant constructions are likely to be reviewed worldwide. On the basis of the directive of the Council of the European Union, in the countries operating nuclear power plants the safety review of the currently operating nuclear power plant units has been executed. The review reports have been assessed by the competent national authorities, and they have prepared the National Report to the European Commission on the safety of nuclear power plants operating in the given country. On these reports an independent and mutual review is carried out by the International Working Group that consists of members delegated by the EU Member States' safety authorities.

By the deadline of 31 October 2011, MVM Paks Nuclear Power Plant Ltd. has sent the report on the results of the targeted safety reassessment of Unit 1–4. to the Hungarian Atomic Energy Authority (HAEA). The HAEA has accepted the report and on the basis of its evaluation, by the end of December 2011 it has defined those tasks that have to be executed by the power plant in order to further improve its safety. The National Report[5] compiled about the results of the reassessment was issued on 29 December 2011, and it was submitted to the European Commission by the HAEA.

On the basis of the targeted safety reassessment, in the National Report the HAEA has stated that Paks Nuclear Power Plant's design basis is appropriate and it is in accordance with the requirements specified in the legislation and with the international practice. The safety systems and functions fulfil the requirements considered in the design basis and no immediate measure is required. The authority review also pointed out that there are some options for change, whose implementation can further increase the safety of the power plant.

2.3. Summary introduction of the nuclear power plant currently operating at the site and the Interim Spent Fuel Storage

2.3.1. Main technological characteristics of the existing nuclear power plant

Paks Nuclear Power Plant consists of VVER-440/213 type pressurized water reactor units with originally 440 MW electric power each, which started the operation between 1982 and 1987, since then the power plant has operated continuously as planned. The units were originally designed for 30 years operational time, which will be increased by further 20 years, if the planned lifetime extension is realised. Due to the modifications, which were executed in order to increase the economy efficiency of operation and which comply with the safety requirements, each unit has reached the nominal electric power of 500 MW, so the nominal electric capacity of the power plant is currently 2000 MW. The nuclear power plant operates as a base power plant with a relatively constant load.

Figure 2.3.1-1. View of the Paks Nuclear Power Plant units

The individual reactors are installed in twin-unit buildings. The twin-units containing two reactors each are shown by *Figure 2.3.1-1.* The reactor units of Paks Nuclear Power Plant have two-circuit design, accordingly, they consist of a radioactive primary circuit and a non-radioactive secondary circuit. The power plant is a pressurized water type, in its water cooled and moderated energetic reactors the heat transfer circulates in a closed primary circuit, which also includes the reactor, and it has no direct connection with the outside world.

In the planned and verified way and by complying with the prescribed limits, radioactive isotopes may get into the environment from the nuclear power plant through the ventilation chimneys and the hot water channel, and radioactive waste is produced in course of the normal operation and maintenance. The air exhausted by the ventilation systems or coming from the technological blow-down is purified by the gaseous emission control systems by the use of aerosol and iodine filters and then it gets into the environment through the 100 m high

[5] National Report of Hungary on the Targeted Safety Re-assessment of Paks Nuclear Power Plant, Hungarian Atomic Energy Authority, Budapest, 29 December 2011

chimney of the units and through the 30 m high chimney of the healthcare-laboratory building. The generated waste water is collected in control tanks and its discharge is preceded by strict chemical and radiological classification in each case. From the control tanks the water classified as dischargeable gets into the Danube, as the receiving water, via the hot water channel by complying with the emission limit values.

The resulting low and intermediate level solid radioactive wastes are processed (sorted, compressed, the sludge is stabilized), and they are temporarily disposed in the power plant's main and auxiliary buildings. The final disposal of the low and intermediate level radioactive wastes generated in course of the Paks Nuclear Power Plant's operation and future decommissioning will take place in the National Radioactive Waste Repository (NRWR) implemented in the region of Bátaapáti.

The high level solid radioactive wastes are disposed in storage wells, in packages guaranteeing recovery. The final disposal of wastes stored in the wells should be arranged at the decommissioning of the power plant. The spent fuel leaving the power plant's reactors is temporarily disposed in the Interim Spent Fuel Storage (ISFS), in the facility built specially for this purpose and operated by PURAM.

2.3.2. Interim Spent Fuel Storage

The spent fuel assemblies generated during the operation of the nuclear power plant – annually 400 pcs on average – are temporarily stored before any possible further processing or before the final disposal without processing. The storage is provided by the spent fuel pool that is situated next to the reactor; consequently, it has limited storage capacity, for that period of 3.5 years, until the specific activity and thermal evolution of the fuel leaving the reactor decreases to such value, which allows to dispose the spent fuel in the interim storage. After the decay period the spent fuel elements are placed in the Interim Spent Fuel Storage (ISFS), which is an interim storage facility located next to the power plant that can store the spent fuel assemblies for at least 50 years.

The ISFS that can be seen in *Figure 2.3.2-1.* is a modular vault dry storage (MVDS). It is a reinforced concrete structure, which includes storage wells arranged in a matrix, which are suitable to accommodate fuel assemblies. The proper shielding and protection is provided by concrete structures. Heat dissipation is executed by circulating air on the outer surface of the fuel elements and storage wells, and then the air is led directly into the atmosphere. In the air flowing through the chamber the driving force and hereby the proper cooling without active mechanical systems and personal supervision is provided by the chimney effect (air thermosiphon) maintained by the heat abstracted from the stored fuel elements.

Figure 2.3.2-1. The Interim Spent Fuel Storage in Paks

The facility's first module consisting of 3 chambers and the service building were completed in 1997, the ISFS began the operation at that time. A module consisting of 4 chambers were taken over in 2000 and 2003, and then the construction of a new module consisting of 5 chambers was completed in 2007, so the storage's 16 chambers became suitable to accommodate a total of 7200 assemblies. On 31 December 2010 a total of 6547 pcs of spent fuel assemblies were stored in the ISFS. The new storage module of ISFS consisting of 4 chambers was taken over in December 2011, by this the facility's storage capacity increased to 9308 assemblies.

2.3.3. Safety zone of the nuclear power plant and the Interim Spent Fuel Storage

Currently the boundaries of nuclear facilities' safety zone, as well as the restrictions to be applied in the safety zone should be determined on the basis of the regulations of the Government decree 246/2011. (XI. 24.) on the safety zone of nuclear facility and radioactive waste storage. According to the decree, in case of both nuclear power plants and interim spent fuel storages, the terrestrial distance of the safety zone is at least 500 m from the plane of the facility's wall, which means the outermost technological protection. In course of the proper operation of nuclear facilities, the person permanently residing at the boundary of the safety zone cannot be exposed to a radiation greater than 100 μSv/year by the radiation of radioactive materials emitted or emerging into the environment. The Government decree imposes various restrictions related to the safety zone (e.g. prohibition of the construction of residential buildings and holiday resorts, the storage of hazardous materials, human activities hazardous to the safety of nuclear facilities).

The boundaries of Paks Nuclear Power Plant's safety zone reviewed according to the Government decree 246/2011. (XI. 24.) were designated by the Hungarian Atomic Energy Authority by the decision HA5538 issued on 2 August 2012. The extent of the safety zone can be seen in *Figure M-4.* of the *Appendix.* The boundaries of the Interim Spent Fuel Storage's reviewed safety zone were designated by the Hungarian Atomic Energy Authority by the decision HA5540 issued on 31 July 2012 according to the regulations of the Government decree 246/2011. (XI. 24.).

According to the Local Building Regulations of the Town of Paks (Local Government decree 24/2003. (XII. 31.)), the areas in the safety zone of the nuclear power plant and the ISFS are all affected by building ban.

2.4. Description of the considered types of new reactors to be implemented

2.4.1. Basic data of the considered new reactor designs

The preliminary evaluation executed during the preparation of the implementation of new nuclear power plant units [9] highly recommends the pressurized water Generation 3 reactor types due to the below mentioned reasons. More than 80% of the presently built nuclear reactors around the world belong to the PWR type. The selection of the PWR type is promoted by the Hungarian professional background and by the many years of favourable operational experience gained with the pressurized water reactors of the Paks Nuclear Power Plant. The Feasibility Study [9] comparing and evaluating the technological, safety, operational, maintenance and installation features and the subsequent analysis of the APR1400 proposed that the following reactor types can be implemented:

- AP1000 – Advanced Pressurized Water Reactor 1000 (Toshiba-Westinghouse),
- AES-2006 (Atomstrojexport, the name of this type is MIR.1200 in the international market),
- EPR – Evolutionary Pressurized water Reactor (Areva),
- ATMEA1 (Areva-Mitsubishi),
- APR1400 – Advanced Pressurized Reactor (KEPCO – Korea Electric Power Corporation).

The main technical and safety parameters of each reactor type are summarized in *Table 2.4.1-1.*, while the safety targets, the design solutions applied to their achievement as well as the consequence mitigation processes are summarized in *Table 2.4.1-2.*

2.4.1.1. AP1000 – Westinghouse Advanced Passive PWR

Technical characteristics

The AP1000 reactor (*Figure 2.4.1.1-1.*) is a simple, fully developed and safe construction. Due to the higher than medium installed capacity, the specific investment costs are favourable, the duration of the unit's overhaul due in every ten years is approx. 40 days. The U.S. Nuclear Regulatory Commission (NRC) has issued the type approval for the unit; the unit is in compliance with the EUR[6] (European Utility Requirements for LWR Nuclear Power Plants) requirements.

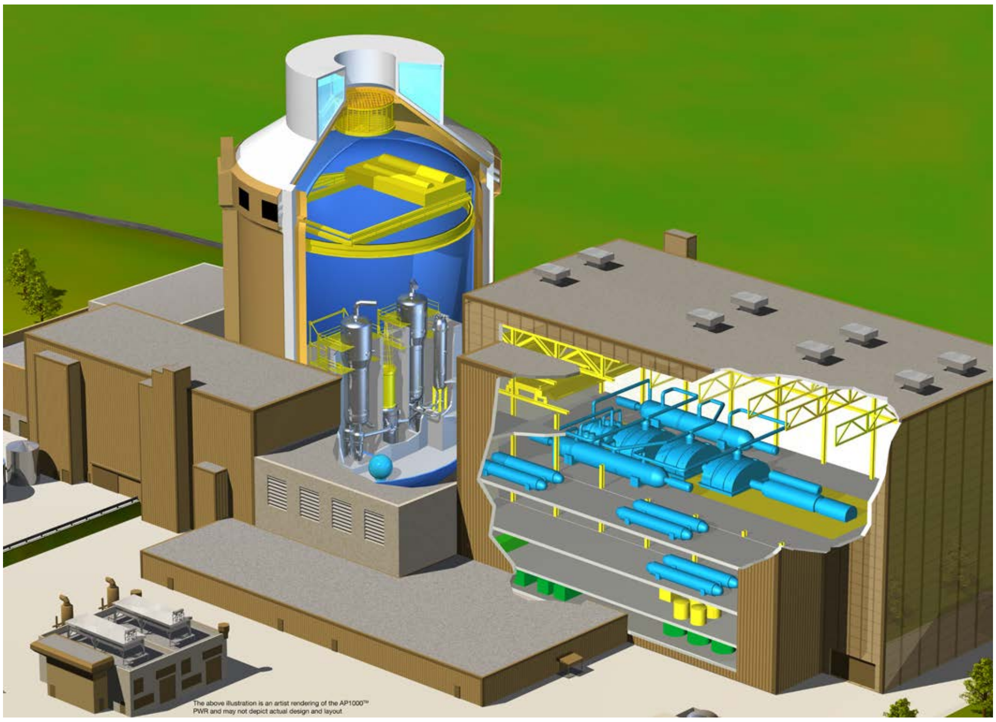


Figure 2.4.1.1-1. Layout of the AP1000 reactor [11]

There are 157 pieces of standard PWR fuel assembly containing 17×17 positions in the core, from which 69 pieces are regulating assemblies. At the end of the fuel cycle 43% of the core is replaced by fresh fuel. [12], [13], [14]

The primary circuit has 2 loops, with 1 hot leg and 2 cold legs on each loop. There are in total 4 main cooling pumps in the cold legs, directly mounted on the bottom outlet nozzles of the vertical steam generators. The reactor vessel is identical to the earlier widely used Westinghouse vessel. The reference unit's secondary circuit contains a slow rotated (1800 rpm) 60 Hz turbine, the design of the slow rotated (1500 rpm) 50 Hz turbine has not completed yet.

Safety characteristics

The AP1000 unit uses the principle of passive safety: its safety systems do not contain any active components (e.g. pumps), for their operation there is no need for safety classified auxiliary systems (e.g. alternative current supply or cooling water). There are four passive safety systems used: the emergency core cooling system, the safety injection and pressure relief system, the residual heat removal system and the containment cooling. The passive systems satisfy the requirements of the

[6] A comprehensive system of requirements developed by the owners and operators of nuclear power plants in Western Europe in the early 1990s.

principle of single failure tolerance. Their reliability was tested within comprehensive experimental programs on two power levels (600 MW and 1000 MW).

Very little operator's intervention is required for the operation of safety systems; in this case the principle was the exclusion of necessity of interventions instead of the automatization of interventions. All of the safety systems are located either within the containment, whose design basis overpressure is 4.1 bar, or in an auxiliary building; these are situated on a common earthquake-proof foundation.

2.4.1.2. MIR.1200

Technical characteristics

The two VVER types, which are presently on the offer palette by the Russian supplier, are the AES-92 belonging to the Generation 3 reactors [13], and its further developed version, the AES-2006 (*Figure 2.4.1.2-1.*). It is scheduled to build 17 AES-2006 type units in Russia until 2020 (with the total capacity of 20000 MW_e). The basic technology has not changed: four primary circuit loops with horizontal steam generators.

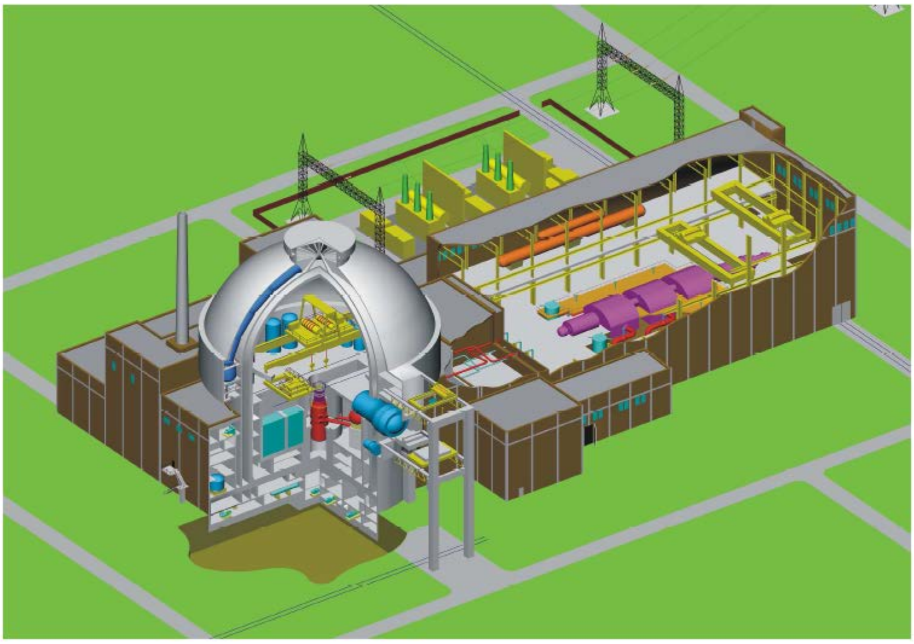


Figure 2.4.1.2-1. Layout of the MIR.1200 reactor design [15]

The MIR.1200 reactor design is the version of the AES-2006 reactor type for the international market. Compared to the AES-92 reactor type, the developments were mainly oriented to improve the economical features (unit capacity, efficiency) and the availability (e.g. achieving the capacity load factor of 92% and the 60-year operational lifetime). Beside the safety changes, a number of technological developments took place as well: e.g. improvement of the operation of main cooling pumps (by the elimination of oil lubrication), improvement of the reliability of steam generators and introduction of new fuel containing burning poisons[7]. According to the plans, the MIR.1200 reactor design will be appropriate for MOX fuel application. In case of the new units, integrated, digital based instrumentation and control is used. Its secondary circuit contains a fast rotated (3000 rpm) turbine; however, they plan the application of slow rotated (1500 rpm) equipments as well. By the consistent application of internationally accepted safety standards and the EUR requirements, the

[7] Reactor poisons are the elements that absorb neutrons (thereby reducing the multiplication factor), without contributing to the chain reaction.

MIR.1200 reactor type has been substantially raised to the level of the AP1000 and the EPR. This was confirmed by that the AES-92 reactor type was qualified and considered as appropriate by the EUR organization.

Safety characteristics

In case of emergencies the long term cooling of the reactor and the primary circuit is solved without the operator's interventions. This is assured by means of four high-pressure and eight low-pressure hydro accumulators together with the core cooling systems operating in automatic mode.

The nuclear systems of the unit are located within double-walled containment. The containment is designed for 4 bar emergency overpressure; the inner steel casing has a passive cooling mode. The safety systems, each having 100% capacity, are incorporated into four channels that are independent from each other. The power supply of each safety channel is provided by a diesel generator with capacity of 6.3 MW. The bottom part of the containment operates as a core catcher.

2.4.1.3. ATMEA1

Technical characteristics

The ATMEA1 reactor design (*Figure 2.4.1.3-1.*) was created by means of the further development of proven pressurized water technologies of Areva and Mitsubishi. The unit is based on the Mitsubishi's 3-loop PWR type but several solutions of the EPR have been also integrated. The design of the unit complies with the requirements of the EUR. In case of its implementation a 5-year construction time might be taken into account. Due to the higher than medium installed capacity (1000–1150 MW), the specific investment costs are favourable. The fuel assemblies contain 17×17 positions, they are practically identical to the assemblies that could be loaded into the EPR core, but they are shorter. Overhaul is due in every ten years. The capacity of the unit might be changed with the maximum change speed of 5%/minute. The unit is capable to operate in automatic frequency-regulating mode as well. [16], [17]

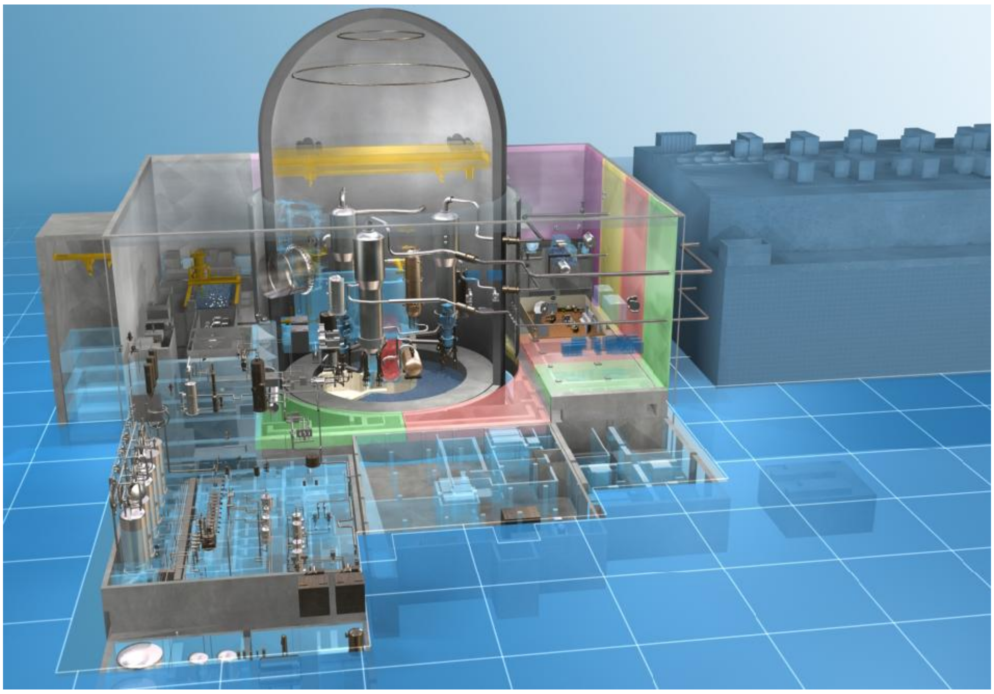


Figure 2.4.1.3-1. Layout of the ATMEA1 reactor design [18]

Safety characteristics

The safety systems contain 3 independent active legs of 100% redundancy, with the possibility of on-line maintenance. For managing the consequences of severe accidents the following solutions are applied that can be deemed as standard in case of the Generation 3 units: core catcher for the localization and cooling of the molten core, hydrogen recombiners and igniters for the localization of hydrogen accumulated within the containment and for the decrease of the H_2 concentration, as well as filtered drainage and cooling for the long-term preservation of the integrity of the containment. The containment is a double-walled structure, it is protected even against the crash-impact of a large passenger aircraft. The unit's earthquake protection makes possible that it can be constructed even in seismic areas.

2.4.1.4. EPR – Evolutionary Pressurized Water Reactor

Technical characteristics

The EPR ("European Pressurized Water Reactor", which was changed to "Evolutionary Pressurized Water Reactor" when it was introduced in the U.S. market because of marketing reasons) (*Figure 2.4.1.4-1.*) was created by developing further the proven pressurized water technology of the French Framatome and the German Siemens-KWU. The unit's designs have been already licensed by the Finnish, French and Chinese authorities and they are currently investigated by the authorities of the USA and the UK. The unit is in compliance with the EUR requirements. [19]

Figure 2.4.1.4-1. Layout of the EPR reactor construction in Finland [19]

Due to the high installed capacity, the specific investment costs are favourable, but under the conditions of the Hungarian network, the high unit-capacity is a great disadvantage of the unit. However, if regional cooperation is postulated for the construction of reserve capacities, then the competitiveness of the EPR unit will not be significantly worsened by the necessary additional investments. The duration of the core-refueling with preventive maintenance is 16 days. The overhaul that is due in every 10 years lasts for approx. 40 days.

There are 241 fuel assemblies in the reactor core; each assembly contains 17×17 positions. The regulation of reactivity is performed by means of 89 control rods.

The primary circuit is made up from four loops, with a main cooling pump and a steam generator on each loop. The secondary circuit was created by further developing the secondary circuit of the well-proven German Konvoi units, which is operating with excellent availability factors. The steam-condensate-feed-water system has been optimized, as well as the high- and low-pressure turbine stages, and this led to the significant increase of efficiency.

For normal operational conditions the systems performing regulation and providing protection were made with double redundancy, these are protected against single-mode failures. For managing the expected operational transients two plus two redundant, diverse system is applied, while for managing the postulated emergencies four redundant system is used. The emergency power supply is provided by four diesel generators, which are located in a separate building. It is very important from the point of view of maintenance that one of the systems established with quadruple redundancy might be taken out any time during the operation for maintenance or repair.

Safety characteristics

The important safety indicators of the unit (core melt frequency, probability of the release of great amount of radioactivity, etc.) are excellent. The safety systems have quadruple redundancy, each of the subsystems has 100% capacity.

There is no high-pressure injection, there are only medium- and low-pressure injection systems. The In-containment Refueling Water Storage Tank (IRWST) is situated at the bottom of the reactor building and it alloys the coolant storage and sump functions. The handling of severe accidents with core meltdown is promoted by a special construction, the so-called “core catcher”. The melt is flooded by the water stored in the IRWST tank in passive (gravity) manner.

The inner wall of the double-walled containment is made of pre-stressed reinforced concrete; there is a 6 mm steel lining on the inner wall. The outer wall made of normal reinforced concrete serves as protection against external events and it is sized to bear the consequences of the crash-impact of a large passenger aircraft.

In case of severe accidents passive hydrogen management (catalytic recombiners) is used. The passive hydrogen removal system using catalytic recombiners, as well as the cooling system reducing the pressure of the containment serves for the mitigation of the consequences of severe accidents.

2.4.1.5. APR1400 – Advanced Pressurized Reactor

Technical characteristics

The South Korean KEPCO (Korea Electric Power Corporation) company developed the APR1400 reactor design (*Figure 2.4.1.5-1.*) based on the improvements of the OPR1000 (Optimum Power Reactor) reactor type with electric capacity of 1000 MW. Both reactor models are based on the System 80+ reactor developed by Combustion Engineering in the early 1990s in the USA. The reactor design has been licensed by the South Korean nuclear regulatory body. The application is under preparation in order to acquire the NRC type approval. The reactor design has not got the EUR certification yet.

The safety indicators of the unit are good, and all the internationally accepted solutions are applied to prevent severe accidents and to mitigate their consequences. Under the conditions of the Hungarian network, a great disadvantage of the unit is its high unit-capacity. However, if regional cooperation is considered, the same can be stated here as at the EPR design.

The reactor core consists of 241 fuel assemblies. The fuel assembly is arranged like the standard PWR assembly in a 16×16 array, and it is manufactured by the KNF (KEPCO Nuclear Fuel) company. The reactor can also be operated if maximum one third of the fuel is MOX.

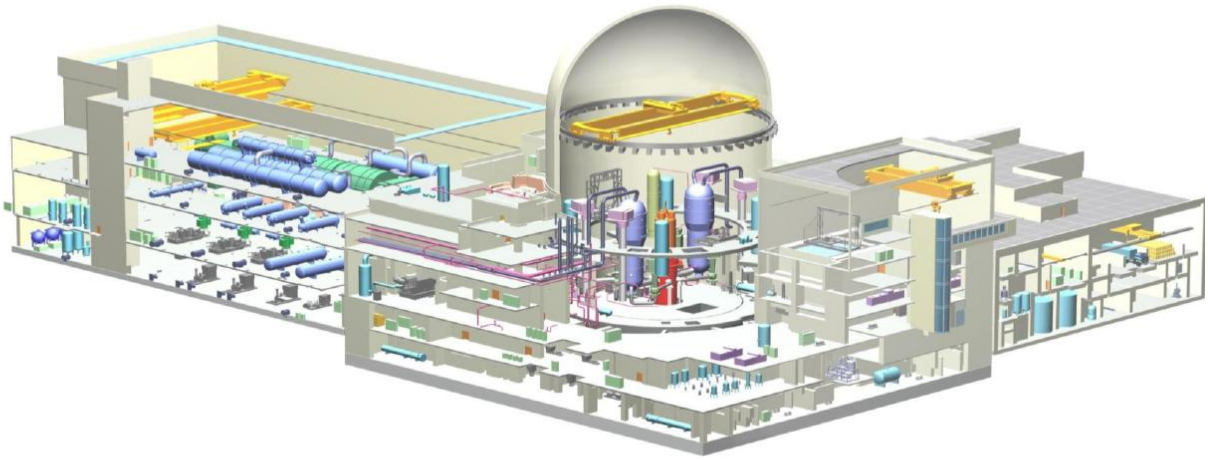


Figure 2.4.1.5-1. Layout of the APR1400 reactor design [18]

The primary circuit of the APR1400 reactor design contains two loops, each of which consist of one hot leg and two cold legs and both cold legs have a main cooling pump (the construction is similar to the Westinghouse AP1000 reactor design). Both hot legs have a large size, vertical steam generator: each steam generator provides 2000 MW thermal power. The amount of feed water in the secondary circuit is enough to able to secure the steam generator dry-out time (at least 20 minutes) in case of Total Loss Of Feed Water accidents.

Only one high-capacity turbine generator belongs to the APR1400 reactor design, which is composed of a high-pressure turbine and three low-pressure turbines, and it operates at 1800 rpm (to the 60 Hz network). In case of load dropping, in operation of 100% the turbine by-pass system is calibrated to remove the steam without the emergency shut-down of the turbine or the reactor. The APR1400 units under construction in the United Arab Emirates are going to be equipped with 1500 rpm turbine operating in 50 Hz network for the first time.

Safety characteristics

The reactor protection systems are installed four times redundant, and both active and passive safety systems are applied in order to achieve the safety objectives.

The large size IRWST (In-containment Refueling Water Storage Tank) is located in the containment building (cubic extent: 2500 m^3) and supplies large amount of injected cooling water into the reactor vessel via four nozzles providing direct injection. Each train has the capacity of 50%, which means 4×50% redundancy. In addition to the safety injection pumps, each train has one large size, passive safety injection tank (accumulator) as well.

The primary containment of the APR1400 reactor is made of pre-stressed reinforced concrete, and a hermetic steel line fits to the interior surface layer of the reinforced concrete shield. The outside of the primary containment is covered by the secondary containment structure, which provides appropriate protection against external hazards (e.g. aircraft crash). The containment spray system (CSS) is composed of two independent trains and their pumps are connected to the IRWST. Its function is to reduce the temperature and pressure of the containment. The volume of the containment is so large that after the occurrence of a hypothetical severe accident, up to 24 hours the pressure is kept below the limit and the hydrogen concentration does not exceed the dangerous value anywhere.

In case of severe accidents leading to significant core damage, the molten core shall be kept within the reactor vessel by cooling the outside surface of the reactor vessel. For the European implementations an EU-APR1400 version is designed, which includes core catcher as well. The generated hydrogen is treated by recombiners and additionally hydrogen glow plug igniters are also applied. [20]

Table 2.4.1-1. The main technical parameters of the considered reactor designs

Reactor design	AP1000	MIR.1200	ATMEA1	EPR	APR1400
Electric capacity (net)	1117 MW	1150 MW	1000 MW	1600 MW	1400 MW
Designed operational lifetime	60 years	50 (60) years	60 years	60 years	60 years
Planned capacity load factor	93%	92%	92%	92%	at least 92%
Annual off time due to scheduled overhaul	17 days	20 days	16 days	14 days	17 days
Self-consumption	6.9%	7.0%	5.8%	7.0%	3.8%
Applicable fuel type	UO_2, MOX	UO_2	UO_2, MOX	UO_2, MOX	UO_2, MOX
Source of the applicable fuel	Westinghouse	TVEL	Areva and MHI	Areva	KEPCO Nuclear Fuel
Fuel cycle	18 months	18–24 months	12–18–24 months	12–18–24 months	18 months
Fuel demand	43.2 t UO_2 / 18 months	43.0 t UO_2 / 24 months	42.7 t UO_2 / 24 months	64 t UO_2 / 24 months	44.7 t UO_2 / 18 months
Number of fresh fuel assemblies at refueling	68 pcs (per 18 months)	82 pcs (per 24 months)	60 pcs (per 18 months)	120 pcs (per 24 months)	92 pcs (per 18 months)
Average enrichment of the fresh fuel assemblies	4.8%	4.0%	4.95%	4.4%	4.09%
Maneuverability	in the range of 25%–100%, 100%–50%–100% /day	in the range of 30%–100%, annually max. 250 pcs Δ70%	in the range of 30%–100%	in the range of 20%–100%, 100%–25%–100% /day	in the range of 20%–100%, 100%–25%–100% /day
Primary circuit pressure	155.2 bar	157 bar	155 bar	155 bar	155 bar
Reactor inlet temperature	280.6 °C	291.0 °C	290.9 °C	295.5 °C	290.6 °C
Reactor outlet temperature	321.1 °C	320.0 °C	326.3 °C	328.0 °C	323.9 °C
Steam generator outlet steam pressure	57.6 bar	62.7 bar	>70 bar	78.0 bar	69.0 bar
Amount of the used cooling water	136000 m^3/h	140000 m^3/h	122000 m^3/h	190000 m^3/h	173000 m^3/h

Table 2.4.1-2. Design solutions and consequence mitigating processes to achieve the target

Safety targets to be achieved	Design solution and consequence mitigating process to achieve the target				
	AP1000	MIR.1200	ATMEA1	EPR	APR1400
Management of the extended design basis accidents	– Passive safety systems – In-vessel retention – Containment flood and passive containment cooling system – Hydrogen recombiners and glow plug igniters	– Double-walled containment – Passive cooling mode – Containment passive cooling system – Hydrogen recombiners – Core catcher	– Great volume pre-stressed concrete containment – Long term containment cooling – Hydrogen recombiners – Core catcher	– Double-walled containment – Containment cooling system – Hydrogen recombiners – Core catcher (molten spreading and cooling)	– Large volume, pre-stressed concrete containment – Long term containment cooling – Hydrogen recombiners – In-vessel retention (optional core catcher)
Prevention of the high pressure sequences leading to early containment damage	Automatic primary circuit depressurization valves	– Depressurize valves – Passive cooling system	– Fast, redundant depressurizer valves	– Manually operated primary circuit depressurizer valves	– Manually operated depressurizer valves – Containment spray system
Management of the generated hydrogen	– Passive recombiners (in case of pipeline breaks) – Hydrogen glow plug igniters (in case of severe accident)	– Passive recombiners	– Passive recombiners	– Passive recombiners	– Passive recombiners + hydrogen glow plug igniters
Stabilization and cooling of molten core	– In-vessel retention – Containment flood and passive containment cooling system	– Core catcher	– Ex-vessel molten core stabilization	– Ex-vessel molten core stabilization	– In-vessel retention – Containment flood and passive containment cooling system (European version includes core catcher)
Depressurization of the containment	Passive containment cooling system	– Passive, large-surface coolers (between 0–24 hours) – Mobil equipment (between 24–72 hours)	– Containment spray	In-vessel air cooling: – By flooding the molten from above and its cooling from below – Manually started containment spray cooling	Containment spray + shut down heat removal system

2.4.2. Description of the planned cooling system

The analysis of cooling options applicable at the new nuclear power plant units planned at the Paks site were carried out in course of separate examinations [21], [95]. The aim of the analysis was to choose that cooling method that under the circumstances and environmental conditions can be economically executed and operated by the best possible technical solution and efficiency and that complies with the environmental requirements during the planned operational life. Based on the results of the executed analysis – similarly to the cooling system currently used at the four existing units – fresh water cooling system was selected.

During the operation of the fresh water cooling system the industrial and condenser cooling water supply required for the operation of the units is executed by water intake from the Danube. The use of fresh water cooling system is limited by the environmental requirements related to the thermal load caused by the recirculation of heated cooling water. After the new units were put into force, in order to meet the valid limit values, even under extreme conditions (high water temperature of the Danube, low water discharge), as technical measures, the heated cooling water discharged from the units should be mixed with fresh cold water, and in exceptional cases, it is necessary to not operate the units at full capacity.

In case of the utilisation of once-through, fresh water cooling that operates by the use of raw water taken out from the Danube, raw, chemically untreated water is used after it is mechanically treated (screened) from the floating and suspended sediment. The cooling water demand of the units' condensers, i.e. the amount of raw water needed to be taken out from the Danube in case of the analysed units' capacities is shown by *Table 2.4.2-1.* Following the use, the total amount of heated cooling water will be returned to the Danube. The layout of the fresh water cooling system can be seen in *Figure 2.4.2-1.*

Table 2.4.2-1. **The basic data taken into account at the analysis of the fresh water cooling system**

	In case of 2×1200 MW capacity	In case of 2×1600 MW capacity
Heating of the cooling water in the condenser [°C]	8	8
Nominal water demand of the condensers [m^3/s]		
Per unit	66	86
Total	132	172

The Danube feed water pumping station will be placed over the mouth of the existing cold water channel of the power plant. The water supply line includes two stages, at the first stage the feed water pumping station lifts raw water from the Danube to the new cold water channel, at the second stage the condenser pump station transfers the cooling water from here to the condensers. The new cold water channel is approx. 4 m deep, 12–20 m wide at the bottom – depending on the unit type – and approx. 1000 m long.

From the screening house to the condenser cooling water pump station the water goes through a closed reinforced concrete channel. The pump station' task is to drive the required amount of cooling water through the condensers from the intake cold water channel to the outlet hot water channel. From the main building the hot water drainage is executed through reinforced concrete channels, which are connected to the power plant's existing hot water channel via water level maintaning structure. According to the previously conducted hydraulic calculations [21], the existing hot water channel can drain not only the 100–110 m^3/s (max. 120 m^3/s) water quantity of the current units' operation, but the 172 m^3/s water quantity of the 2×1600 MW capacity new unit as well.

For draining the cooling water into the Danube another outlet shall be established, which is planned to be situated about 1000 m to the south from the existing Danube inlet. The new channel section branches off from the existing channel in front of existing arched section bending towards the Danube, on the downstream side of the existing channel, in a new equalising basin (*Figure 2.4.2 1.*). (In the future, water recuperation power plant is planned to be constructed on the hot water channels.)

The south bank of the new hot water channel section – instead of the section of the existing hot water channel's south bank from the new channel branch to the mouth – will function as a permanent flood protection structure as well.

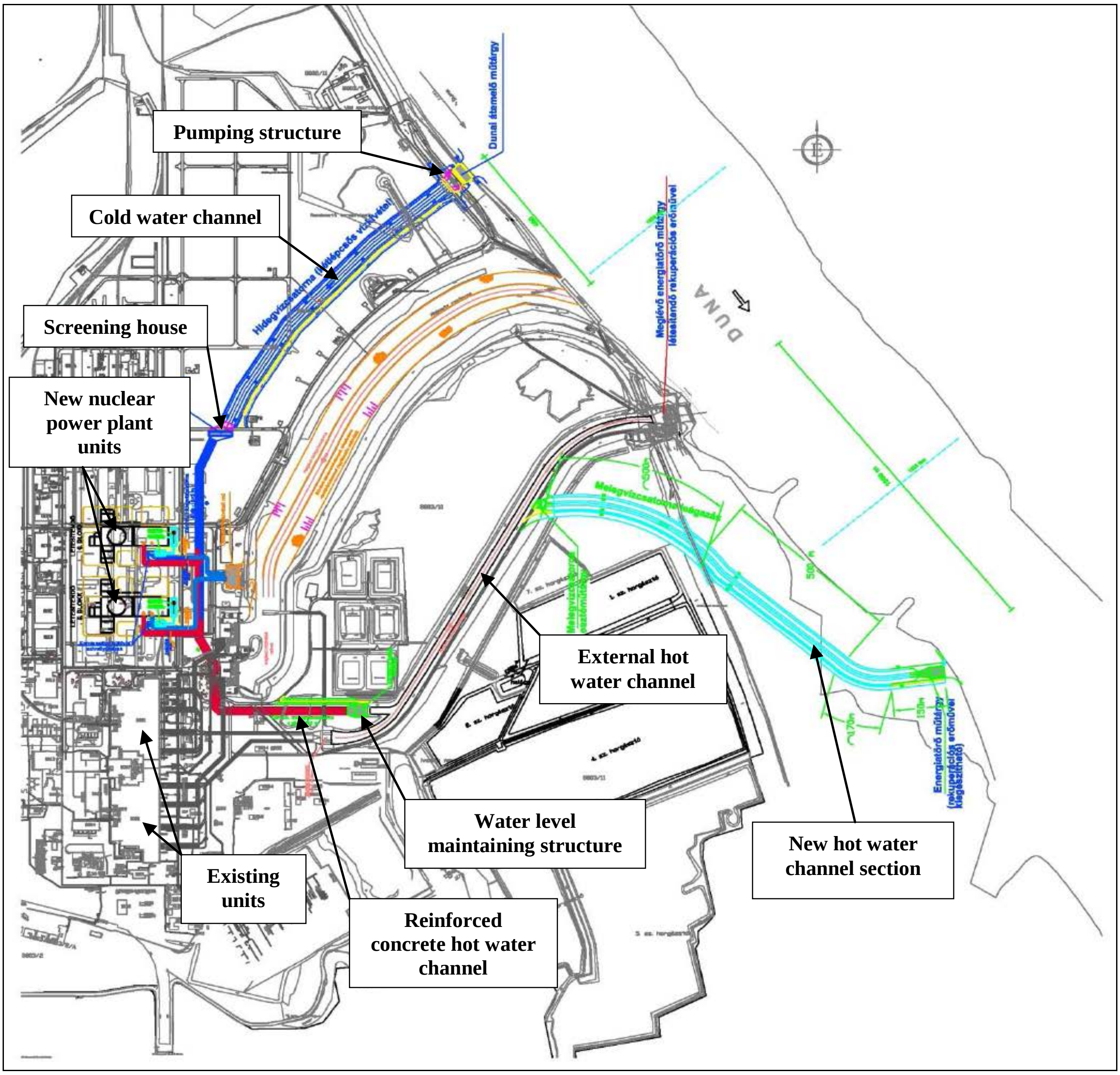


Figure 2.4.2-1. Parts of the two-stage fresh water cooling system and its layout

2.4.3. Additional facilities and related operations necessary for the implementation of activities

The currently operating units of Paks Nuclear Power Plant are connected to the Hungarian Power System by the 400 kV switch gear of the 400/120 kV substation owned by MAVIR Hungarian Transmission System Operator Company Ltd. as transmission network licensee. In terms of connection the site in Paks is a 400 kV node with appropriate conditions, however, the integration of the new power plant units to the electricity system can only be solved by the establishment of new network connections. Until the supplier is selected, various types of units shall be reckoned with, and for installed capacities of various sizes, different levels of network improvements are needed.

In course of the preparation for the implementation of new nuclear power plant units, preliminary network calculations [22] were made to investigate that in case of units with 1000–1600 MW net capacity, under which conditions the generated power can be delivered in normal operational and breakdown states. The results verified the need of the following improvements in the studied capacity range:

- The construction of the double-circuit Paks–Albertirsa transmission line is fundamental and essential condition of the commissioning of the new units.
- Because of the double deficiency state related tests' results and the new power plant's reserve supply, it is justified to install the third 400/120 kV transformer into the existing (Paks-I.) substation.
- Depending on the size and dynamic characteristics of the unit to be implemented, the transient stability needs to be strengthened by constructing a second transmission line connection directed towards Litér or Martonvásár. This issue has to be further investigated in the future with knowledge of the more accurate parameters of the unit.

For the grid connection of the new units a new 400 kV switch yard (Paks-II.) will be implemented, whose location has not been designated yet. [23] The possible location can be found along the transmission line routes running towards the north-west, in the area between the roads from Paks towards Nagydorog and Kölesd, about 6 km from the planned location of the new units.

To connect the reserve auxiliary supply of the units a 120 kV cable connection has to be established between the planned location of the new units and the 120 kV switch gear of Paks-I. substation.

Infrastructure (water, sewage and road system, telecommunications, etc.) is normally available at the site for the implementation of the new units, but it is expected that its expand and upgrade will become necessary in the future. The available infrastructural connections of the site in Paks are detailed in *Subchapter 2.1.2.*

It is expected that a new sewage treatment plant has to be constructed to receive and purify municipal waste water generated by the operation of the planned new units, waste water of the healthcare and laboratory building and sometimes water above balance.

2.4.4. Description of the international references of the unit types taken into consideration

2.4.4.1. AP1000 (Westinghouse)

Currently, there are already three AP1000 units under construction in China (Sanmen 1 and 2 – *Figure 2.4.4.1-1.*, Haiyang 2 – *Figure 2.4.4.1-2.*), and they are planned to be taken over between 2013 and 2014. It is expected to start the implementation of AP1000 type units in the USA as well, there are already construction preparations underway at two sites (Georgia, Vogtle Nuclear Power Plant) now, but according to the predictions, application will be submitted for the implementation of a total of 12 AP1000 units at 6 sites. The Chinese units are planned to be built in 5–6 years, the reference AP1000 can be constructed in 5 years according to the designers.

Figure 2.4.4.1-1. Placing the third containment ring at the site of Sanmen 1

Figure 2.4.4.1-2. Construction of Haiyang 2

2.4.4.2. AES-2006 (MIR.1200) (Atomstrojexport)

The construction of two AES-2006 (MIR.1200) type units is in progress in Leningrad Nuclear Power Plant (Sosnovy Bor – *Figure 2.4.4.2-1.*) in Russia, and two AES-2006 units are under construction in Novovoronezh Nuclear Power Plant as well. In Russia the major expansion of nuclear capacity is planned by AES-2006 type units: according to the plans, 20000 MW_e capacity (17 units) will be constructed until 2020.

Figure 2.4.4.2-1. The power plant units under construction in Sosnovy Bor

2.4.4.3. ATMEA1 (Areva-Mitsubishi)

The basic designs of ATMEA1 unit were completed by the end of 2009, after that the preparatory works necessary for licensing started. Presumably there will be no difficulties with the licensing of the unit and the justification of its compliance with EUR, since the designs have been already prepared in accordance with the EUR by taking into account widely the NRC's regulations.

The participants of Areva-MHI joint venture have great experience in implementation; jointly they constructed 123 nuclear power plant units till now. Their production capacity is also significant; they are able to produce nuclear devices at 12 sites around the world.

2.4.4.4. EPR (Areva)

Currently the implementation of two EPR units is in progress in Europe: the first is constructed at Olkiluoto site in Finland [24], the second at Flamanville site in France [25]. The OL-3 unit's construction began in 2005, the construction of the Flamanville-3 unit in Normandy (*Figure 2.4.4.4-1.*) started in the summer of 2006. The take over of the units is delayed as compared to the original schedules. Areva has concluded a contract to implement two EPR units in China (Taishan 1, Taishan 2), they are also already under construction (*Figure 2.4.4.4-2.*) and they are scheduled to be connected into the network in 2013 and 2014.

Figure 2.4.4.4-1. Construction of Flamanville-3

Figure 2.4.4.4-2. Construction works of Taishan 1–2

2.4.4.5. APR1400 (Korean Hydro and Nuclear Power)

Currently, a total of four APR1400 units are constructed at two sites (Shin-Kori – *Figure 2.4.4.5-1.* and *2.4.4.5-2.* and Shin-Ulchin) in South Korea. The United Arab Emirates also signed a contract with the South Korean KEPCO-led consortium at the end of 2009 to implement four units.

Figure 2.4.4.5-1. Work in the containment building in Unit 3 of Shin-Kori Nuclear Power Plant

Figure 2.4.4.5-2. Construction works of Shin-Kori Nuclear Power Plant

2.5. Presentation of the construction phase, description of the construction technology and other characteristics

2.5.1. Description of the characteristic data of construction

Expropriation of land by the facilities to be constructed

The area of the new nuclear power plant units' planned site is approx. 106 ha, which is planned to occupy 29.5 ha from the current operating area of Paks Nuclear Power Plant and 76.3 ha from the so-called building yard. The location of the site in Paks, with indicating the location of the new units' construction, can be seen in *Figure M-2.* of the *Appendix.* The area requirement of each examined unit type's buildings, structures and other facilities specified in the supplier data supplies is summarized by *Table 2.5.1-1.*

Table 2.5.1-1. Expropriation of land by each unit type

Unit type	Characteristic area requirement	Area requirement of two units
AP1000	Overall dimensions of the operating area covered by one unit: 250×233 m, which means 5.825 ha. The building yard is calculated by using the whole, approx. 100 ha area. [26]	≈ 12 ha
MIR.1200	The expropriation of land by one unit's building is 2.6 ha, and together with the connected facilities and paved surfaces the double of this area is considered as space demand. The building yard requirement is calculated by the total available area in this case as well. [27]	≈ 10 ha
ATMEA1	Based on the available diagrammatic drawing, approx. 12 ha area is required for one unit. For the building yard the entire area shall be used in this case as well. [28]	≈ 24 ha
EPR	Overall dimensions of the operating area occupied by one unit: 384×283 m, i.e. 10.867 ha per unit. The building yard is calculated by using the whole, 100 ha area. [29]	≈ 22 ha
APR1400	The placement of two units requires 36 ha area. The building yard requirement is calculated by the total area in this case as well. [30]	≈ 36 ha

During the construction the damage and disappearance of current vegetation and green area should be expected in the construction area and presumably in the entire building yard as well. Its environmental significance is limited since both the construction area and the building yard are situated within the existing site in industrial zone. Following the completion of construction, the "rehabilitation" of areas between the built-up areas has to be performed in the building yard and operating area.

The duration of construction works

The expected duration of the construction activities specified by the suppliers is included in *Table 2.5.1-2.* by unit types.

Table 2.5.1-2. The duration of construction works regarding each unit type

Unit type	The specified construction phases
AP1000	Time requirement for the site preparation is 18 months. The construction is 4–5 years until completing the execution of commissioning tests. [26]
MIR.1200	It is 60 months from the pouring of first concrete until putting it into operation. [27]
ATMEA1	The construction of one unit is less than 40 months from the pouring of first concrete until the placing of fuel element. The test run lasts 8.5–10.5 months. [28]
EPR	It is 62 months from the pouring of first concrete until putting it into operation. [29]
APR1400	The complete construction duration of the implementation of two APR1400 units is 58 months from the pouring of first concrete until the connection in parallel. This period includes the construction, installation and commissioning until the commercial taking over. [30]

The labour demand of construction, the necessary number of construction workers

The number of workers necessary in the average and peak periods of the construction process is summarized by *Table 2.5.1-3.* by unit types, on the basis of the data supply received from the suppliers [26 – 31]. Three-shift work schedule should be taken into account in the construction period. [32]

Table 2.5.1-3. The number of construction workers by unit types in the average and peak periods

	AP1000		MIR.1200	EPR		ATMEA1		APR1400
	Average	Peak	Max.	Average	Peak	The specified lower value (peak)	The specified higher value (peak)	Max. (monthly number)
Number of construction workers [people]	3000	4300	5600	800	2400	6000	7000	1200

The actual labour demand of the new units' construction (approx. 5000–7000 people in the peak period of construction) depends largely on the investor to be selected because there are fundamental differences between the five possible technical solutions regarding the labour demand of the pre-construction and construction period.

Multiple solutions are possible to accommodate the participants of the construction process in Paks and in the surrounding settlements. If new houses are built to accommodate the construction workers, they can be sold for the local population following the completion of the construction period or they can be used by the power plant operators. It is possible to buy or rent existing apartments and houses or temporary workers' accommodations may be established near the construction site or in the nearby settlements. Its advantage is that after the temporarily employed labour completes the works, the temporary residential containers can be reused; they can be transported to a new construction site. [32] [33]

Tools and site machinery

In the construction period the movement of simultaneously more and different types of machineries and several trucks carrying out transportation within the site has to be reckoned with. According to the data supply of the APR1400 unit type's supplier [30], the use of the following machineries and vehicles is necessary during the construction:

1. Very heavy lift crane (main construction equipment)

   For the installation of the large and heavy main components of the power plant (reactor vessel ≈ 530 t, steam generator ≈ 775 t) a heavy lift crane is essential. In case of the construction of the Shin-Kori Nuclear Power Plant's Unit 3 and 4, regarded as a reference for the APR1400 unit type, a 1350 t capacity heavy lift crane was used to move the major equipment.

2. Other machineries and equipment

   - During the preparatory works (landscaping, foundation, etc.) the following machineries work: tugboats, barges, trailers (100 t), backhoes, grabs (0.2; 1 and 8 m^3), graders, tire rollers, vibration rollers, core drills, tower crane (50 t), hydro crane, crawler crane (200 t), pay loaders, dump trucks (15 and 25 t), dozers (32 t), mixer trucks, cargo trucks and compressors.
   - During the superstructure works the operation of the following machineries is expected: tower cranes (5, 10–12 and 20 t), truck cranes (90, 200 and 300 t), creter cranes (35 and

50 t), hydro cranes (35 and 50 t), crawler cranes (100 and 150 t), pump cars (80 m^3/hour), concrete pumps, hydro brooms, trailers (25 t), water trucks (6000 l), flat bed trucks (25 t), air compressors (100 and 210 m^3/min), tractors (10 t) and forklift trucks (5–10 t).

- In course of the installation of mechanical engineering equipment and during other construction/installation works (e.g. pipelines, electrical equipment installation) the following machineries are in operation: the major construction crane (1350 t), hydro cranes (30, 50, 100, 150, 300 and 400 t), forklift trucks (7.5 and 10 t), truck cranes (140 and 300 t), trailers, electric hoists (2 t) and diesel generators.

Considering the similarity of the construction activity and the individual work phases and processes, tool and machinery types similar to the above mentioned (mainly earth moving machineries, lifting and loader machines, transport vehicles, cranes, etc.) can be taken into account in case of the implementation of the other unit types as well. However, the number, parameters and type of the machineries may be different in case of the different versions, so they can be determined more precisely at a later stage of the design by considering the site-specific characteristics.

At the construction site multiple machineries and transport vehicles work simultaneously, when the impacts have been estimated 50 machines were taken into account, but later, as works progress, a much lower number can be expected.

Special work phases (foundation, dewatering)

The currently operating reactor units' foundations have been prepared by flat foundation, on coherent monolithic foundation plate at a depth of 6.5 m. The machinery rooms rest on monolithic strip foundations, the depth of foundation plane is 7.0 m. The foundation of turbine sets was executed by either monolithic foundation plate (flat foundation) or deep foundation (6–7 m long Franki piles), the depth of foundation is 7.5 m. The low-load buildings and facilities (diesel generator stations, auxiliary buildings, cooling house, compressor house, access and technological bridges) were prepared by flat foundation, with monolithic foundation plate, and the depth of foundation varied between 3 and 7 m. Under the main buildings the maximum soil load is of the order of 700 kN/m^2 (= 0.7 MPa), while under the low-load facilities it is 250–450 kN/m^2 (0.25–0.45 MPa).

Similar foundation methods will be taken into account in case of the foundation of the planned investment's facilities due to the similar geotechnical conditions. The foundation works of the reactor units – regardless of the type of units – mean the excavation and movement of several hundreds of thousands of m^3 of soil per each unit.

The exact locations and dimensions of the foundation trenches are not known yet. The load of the turbine engine rooms to be established is expected to be higher than of the currently operating ones, therefore their foundation will be executed by deep foundation.

If the ground water level is higher than the foundation's lower plane, then the dewatering of the trench will be required. It is likely that the trench can be deepened until approx. –7 m without lowering the ground water level; however, at the further deepening of trenches, it is required to lower the ground water level. The most effective method of lowering the ground water level may be the use of vacuum well points. This solution was applied at the construction of the existing four reactor units and the related facilities as well, in course of which for the dewatering of trenches two batteries of wells were constructed around the trenches when the –6.8 m and –9.0 m depth was reached. The maximum depth of the trench reached 12.1 m at the western side of the construction site.

It is advisable and economical to execute the dewatering works in a period, which is dominated by lower ground water levels. The amount of water to be drained depends on the ground water level occurring at the construction and the water level of the Danube as well. The quality of water generated during the dewatering requires constant monitoring, after the sedimentation and oil separation in addition to the possibility of desiccation, the extracted water can be entered into the Danube.

2.5.2. The method and volume of transportations related to the construction

Construction materials can be transported in and excavated soil and wastes can be transported out by road, railway and water way. The main road No. 6 and the M6 motorway are appropriate for road transportation. At the moment the construction site can be accessed from the motorway only by passing through the town of Paks. According to the data supply of the Client [32], it is possible that a direct – not going through the town of Paks – access road will be designated from the Paks-South exit of the M6 motorway towards the construction site.

The transportation of people working at the construction site can be executed by road, mainly by buses from Paks and the surrounding settlements. The number of construction workers may vary between 800 and 7000 people depending on the unit type and the actual construction phase. Assuming the proportion of people arriving by bus and by car for 80% / 20%, the arrival of 16–140 buses and 80–700 cars per day can be estimated.

The anticipated duration of the construction activity will be much longer (5–6 years) than the usual duration in case of other investments. During this period a significant amount of transportation (soil, concrete, technological equipment, etc.) should be expected.

The amount of soil to be moved is 4–6 million m^3 in case of the implementation of two units according to the data supply of the MIR.1200 unit type's supplier [27], and it is nearly 3 million m^3 also in case of the construction of two units on the basis of the data of the APR1400 unit type's supplier [30]. Depending on the site conditions there will be several hundreds of thousands of m^3 of moved soil based on the data provided by the EPR unit's supplier in case of the construction of one unit [29]. The size, design and expropriation of land of each unit version's buildings are different, so the amount of soil to be excavated during the construction of the AP1000 and ATMEA1 units can be estimated – by taking into consideration the data provided by the other suppliers – in the range from several hundreds of thousands to 4–6 million m^3 in case of the construction of two units.

The transportation may affect the southern edge of the town of Paks and its areas along the main road No. 6, possibly the western edge of Dunaszentgyörgy and the settlement of Csámpa. In order to minimize the disturbance it is advisable to transport the most construction materials possible by water way. Transportation by railway is also a more favourable solution than by road, the railway connection is given, but the Dunaföldvár–Paks branch line certainly needs reconstruction. It is worth considering the execution of the majority of transportations by water way, especially if the transportation of building construction modules – due to their size – can be carried out only that way.

If all material transportation is executed by road, then based on the required amount of materials the estimated size of traffic related to the material transportation is approx. 80 heavy goods vehicles per day on average and about 130 heavy goods vehicles per day in the peak period of construction. The material transportation is carried out 12 hours per day.

2.6. The planned environmental protection facilities, equipment and measures

In present phase of the preparation for the implementation of new nuclear power plant units, already planned facilities and measures with environmental goals do not yet exist. However, on the basis of the operating experience of the operating nuclear power plant, a number of facilities and measures can be named that will be also basic conditions of the new units' construction. These types of measures shall include both the period of construction, operation and decommissioning.

The nuclear power plant has no conventional (non-radioactive) air quality loading emissions in normal operation. Air pollution shall be reckoned with only resulting from cargo and passenger transport, and in case of the test run and possible emergency operation of diesel generators. In order to reduce the loads it is recommended to use the most advanced vehicles and equipment both in the construction and operational period. In case of passenger transport to the new site, preference should be given to public transport both in course of construction works and operation, by developing a bus service with adequate density of service and route.

The construction and operation of the power plant requires significant additional drinking water intake. In terms of volume, the existing water resources are expected to be able to provide this additional water quantity. However, the protective area of water resources extends by the increase of water demand. The redesignation of the hydrogeological protection zone is necessary to protect the water resources.

At the selection of technological solutions, preference should be given to the solutions based on water saving and recycling. At the new site rainwater's collection, and if necessary, its treatment and discharge in the receiving water must be resolved so as not to cause any surface or subsurface water loads.

In connection with the implementation and operation of the new units the generation of waste water shall be also reckoned with. The largest volume of municipal waste water is expected in the construction period. The power plant's existing sewage treatment plant will not be enough for the purification of municipal waste water generated during this period, therefore, a new, modern sewage treatment plant will be needed to be constructed. The receiving water of the new facility can be the Danube. In order to maintain the good water quality of the river according to the Water Framework Directive (WFD), the most up-to-date facility is recommended to be constructed.

In addition to municipal waste water, the generation of industrial waste water also can be expected in the planned facility. Industrial waste water is needed to be pre-treated, and only water pre-treated according to the legislation can be entered into the recipient.

It is expected that significant soil excavation will be required for the construction of the units. At the planned site it is likely that its one part will not be soil material, but landfill, namely rubble, inert waste. Their treatment and disposal according to the laws and regulations must be provided. In addition to this special bulky waste produced during the construction, municipal wastes, as well as non-hazardous and hazardous industrial wastes are generated in course of both the construction and the operational phase. Their treatment, storage and disposal have to be executed in accordance with the laws and regulations. This means that it will be necessary to establish storage and treatment areas and in-plant collection places at the new site as well. The collection should be carried out selectively.

Special attention should be paid to waste recycling, waste reduction and to dispose only a minimum amount of waste. Therefore already at the selection of technologies, then at the choice of materials to be used an effort shall be made to use low-waste technologies and recyclable materials.

The new site's landscaping is essential not only to fit it better into the environment, but in order to improve the workers' mood as well. Besides, it is proposed to plant a protective forest at the boundary of the new site too.

Due to their size the planned facilities cannot be fitted entirely into the landscape. However, by architectural solutions (building lines, colouring, etc.) the buildings can be made more harmonious and less striking.

In course of the operation, the environmental impacts of the new facility – both radiological and conventional – have to be monitored by the development and operation of emission and environmental monitoring system. The environmental monitoring system shall provide data continuously regarding the environmental condition changes related to the operation of the planned power plant units. On the one hand, this enables to verify the reliability of constructed environmental models and forecasts, and on the other hand – in case of possible adverse impacts and adverse condition changes – it makes possible quick intervention and to avert and even prevent adverse processes as well.

2.7. Uncertainty of the presented data

In present preparatory phase of the implementation of the new nuclear power plant units, detailed designs and building plans are not yet available and the concrete type and the supplier of the units to be installed have not yet been selected from the five possible unit types described in *Subchapter 2.4.1.* The technical solutions and data presented in present Preliminary Consultation Documentation are based basically on the preliminary data supply and published data of power plant equipment manufacturers/suppliers, as well as on the reference data of similar units already implemented or under construction.

By the progress of the design process, as a result of the tendering procedures of suppliers the data presented here will be updated in the next phase of the environmental licensing procedure, but the main data related to technology and the preliminary estimated environmental load data will be modified only slightly.

3. Description of the environmental impacts

The basic purpose of environmental impact assessment is to assess and classify changes in certain environmental elements/systems occurring as a result of the planned activity based on the changes in the final impact bearers. In impact assessments it is the most important to follow the logic chain impact factor → direct impacts → indirect impacts, i.e. impact processes → directly and indirectly affected ones, i.e. impact bearers → final impact bearers. In order to estimate the impacts, impact factors of the planned activity and impact process they potentially launch should be identified. These are called potential impact processes, because all impact processes possibly occurring during the activity are taken into consideration. In later phases, when local conditions are already known, the scope of the assessment can be reduced to the really occurring processes.

In case of investment impact assessments, for determining the potential impact processes, the preparation of impact process diagram is a well-applicable method. The impact process diagrams are principled, which means that in the light of the designs these environmental processes can be expected. The structure of the impact process diagram (*Figure M-5.* of the *Appendix*) related to the construction phase of the new units is the usual structure used in case of impact assessments. The first column indicates the relevant environmental element or system. The second column includes serial numbers, the expected impact factors of the planned activity can be found in the third column. The given impact factor always appears at that environmental element, on which it has a direct impact. One impact factor may have a direct impact on more environmental elements at the same time, but in a different way, so it should be indicated at all the relevant environmental elements. The expected direct impacts are included in the fourth column, the indirect impacts are in the fifth column. The arrows indicate the forward linkage of impacts in the direction of the final impact bearers. Forward linkage can occur through a number of phases, mostly with decreasing, rarely with increasing efficiency. In general, the intensity of impacts has a decaying tendency during forward linkage. The final impact bearer is usually the ecosystem and/or human. The latter one is highlighted in the diagram and it appears separately, in the last column, as the impacts on the environment, i.e. the changes in the state of environmental elements/systems can be interpreted and evaluated essentially from human perspective.

The most important, environmentally dominant impact factors of the implementation of the new power plant units and the construction works are the following:

- construction works (dust, exhaust gas of transportation and construction machineries, noise and vibration load, disturbance, a number of construction workers),
- transportation of workers and building materials to the construction site (dust, exhaust gas of transportation and construction machineries, noise and vibration load, disturbance, deterioration of roads),
- permanent and temporary land take, relatively large-scale built-up (urban effect, changes in the structure of soil, changes in the amount of subsurface water),
- establishing and exploiting raw material deposits,
- waste generation during construction works (communal, hazardous and non-hazardous industrial wastes),
- sewage, waste water generation,
- appearance of new structures at and near the site of the power plant.

The method of determining the impact processes related to the operation of the planned new units is the same as described in case of the construction phase. First the impact factors, and starting from these the potential impact processes have been determined by the preparation of impact process diagram. The dominant impact factors of operation are the following:

- radioactive releases during operation (air, water),
- heat emissions into the Danube (microclimate modification),

- passenger and freight traffic (air pollution, noise and vibration load, disturbance),
- radioactive and conventional waste generation,
- water intake (social water demand),
- sewage generation, water pollution in accident (quality change of receiving water),
- existence of built-up and paved surfaces (quantity and quality change of ground water and subsurface water),
- existence of the power plant (landscape, landscape structure, urban effect).

The flowchart (*Figure M-6.* of the *Appendix*) summarising the environmental impact processes of the nuclear power plant's operation outlines the key impact factors related to the existence and operation of the power plant and to its possible incident events, as well as their direct and indirect impacts and it shows how they can presumably get to the final impact bearer, to the human.

The state of the environment prior to the construction of new power plant units serves as baseline data for predictions of expected environmental impacts. In the impact assessment process, when changes in state are to be predicted, the whole lifetime should be investigated and this could be achieved by presenting tendencies. When predicting the effects of the operation of new units, excess loads caused by the currently operating power plant as a baseline should be taken into consideration. If possible, it should be made clear to what extent the baseline conditions are influenced by the nuclear facilities operating next to the present project site.

The chapter starts with the general description of the geographical environment, covering landscape geography demarcations and the latest characteristics available of the receiving environment. Then – breakdown by environmental elements/systems – the expected environmental impacts of the construction and operation of the new units, the joint operation of the existing and new units (impact processes are shown by *Figure M-7.* of the *Appendix*), the possible incidents and accidents are described, and the radiological and conventional impacts are discussed separately.

3.1. General description of the geographical environment

The approx. 30 km region of the site hosting the existing nuclear power plant and the new nuclear power plant units is part of the Great Hungarian Plain macroregion, and within that especially of the Dunamenti Plain and the Mezőföld mesoregion. Within the Dunamenti Plain it is included in the Solt Plain, the Kalocsai-Sárköz and the Tolnai-Sárköz microregions, and within the Mezőföld region in the Central and South Mezőföld and the Sárvíz Valley microregions. The town of Paks itself is situated in the north part of the South Mezőföld microregion. The microregions affected with the largest area are the following [34]:

- The Kalocsai-Sárköz (It is situated in the area of Bács-Kiskun- and Tolna County, its area is 992 km^2 and it is a floodplain with heights from 89.4 to 125.6 maBsl[8]. Its northern part is a high floodplain and its southern part is a low floodplain. Mainly in the north-east the high floodplain is divided by alkaline flats, its middle part by oxbow lakes and low floodplain flats. The peatland stretching long along the Vörös Swamp in the immediate vicinity of the Kecel-Baja steep bank is the lowest part of the microregion. The partially wind-blown sand covered high floodplain on the right bank of the Danube (Madocsa Terrace) towers over the environment as a wide, oval promontory.)
- The Tolnai-Sárköz (It is located in Tolna and Bács-Kiskun County, its area is 680 km^2 and it is a floodplain with heights from 88.1 to 162 maBsl. The area has the risk of inland water, until the river control the seasonally flooded swampy surfaces occupied major moorlands, their remains is the Gemenc Forest. Its northern part is a continuous low floodplain, while its southern part is a high floodplain, where terrace islands can be found

[8] Meter above Baltic Sea level.

and at the western edge there are alluvial cones accumulated by the streams coming from the direction of the Tolna-Baranya Hill Country.)

- The South Mezőföld (It is located in the area of Fejér and Tolna County, its area is 503 km^2 and it is a wind-blown sand and loess covered alluvial cone plain with heights from 90 to 213 maBsl. It is separated from the surroundings by sharp orographic[9] boundaries towards the west and east. In the microregion two orographic levels can be separated: an indented plain with an average height of 180–200 m, which is surrounded ring-like by the wind-blown sand surface of the slightly indented plain with an average height of 150–160 m. The surface is partly covered by fixed wind-blown sand dunes.)
- The Sárvíz Valley (It is situated in the area of Fejér and Tolna County, its area is 344 km^2 and it is a terraced river valley with heights from 89 to 161 maBsl. On the surface three characteristic height levels can be distinguished. The Sárvíz Valley has been formed by erosion-accumulation, so the development of landforms is also linked to that. The topographic view is given variety by the wind-blown sand dunes of high floodplains and the erosion-derasion forms of loess covering the terrace.)

3.2. Description of the radioactivity of the environment

3.2.1. Description of the basic state

Continuous environmental monitoring is an essential condition of the operation of a nuclear power plant. As data basis for forecasting the environmental impacts of the planned new units the condition before the implementation of the new nuclear power plant units should be considered. For its determination the results of the measurements taken in the past 10 years (2001–2010) were available, as well as the annual reports issued as “Radiation protection activities in Paks Nuclear Power Plant” summarizing these results [35]. Beside the environmental radiation dose rate, the activity of various environmental media was examined.

Describing the environmental condition, we tried to determine the effects on the trend of the basic status of the operating nuclear facilities near the planned new facility. For the evaluation, we used widespread investigations taken before the installation of the Unit 1 of Paks Nuclear Power Plant in order to assess the environmental radiation dose rate and the concentration of radioactive isotopes of different media, so called basic levels. For better evaluation, we compared these results with the national data measured by the National Environmental Radiological Monitoring System (NERMS) [36].

In many cases, the results remained below the detection limit (LD); however, we used highly sensitive equipments and methods in the measurements. In these cases, the detection limits were recorded and used for the analysis.

The scattering of individual measurements is generally below 10%. The sampling procedure introduces a significantly greater error, if the sampled medium has inherent inhomogeneity. Due to non-normal distribution of data [35], the scattering was not determined parallel to counting the average. However, in these cases, we give the minimum and the maximum value.

3.2.1.1. Dose rate of the environmental radiation

The basic level of dose rate of the environmental radiation[10] was determined by data sequences measured in the period 2001 to 2010 at the telemetry stations. The measurements were taken with

[9] Orography: branch of geography describing the landforms of the Earth.

[10] The measured value of environmental radiation is the sum of environmental gamma radiation and cosmic radiation. Since the latter is fairly constant, it is not taken into account in the comparisons. We adapted the term “gamma

passive dosimeters, such as ALNOR and PorTL thermoluminescence dosimeter system, as well as with active dosimeters, such as BITT RS03/232 type dose rate meter.

On the basis of measurements taken by passive dosimeters, the average ambient dose equivalent was 76 nSv/h. Concerning 1 month’s time, the minimum value measured was 46 nSv/h and the maximum value was 118 nSv/h [35] in course of the measured 10-year period. Data measured by the BITT dose rate meters are equivalent with data measured by TL dosimeters: the average ambient dose equivalent was 77 nSv/h. Concerning 1 month’s time, the measured minimum value was 58 nSv/h and the maximum value was 109 nSv/h. Data measured in the period 2001 to 2010 are in line with the national values, as well as with the 67±8 nGy/h value, obtained in the period 1980 to 1982 by the 23 measuring stations located within 30 km of the site [37]. The fluctuation of values can be explained by the soil type, the quantity of natural radioisotopes occurring in the soil and by the changes of weather.

3.2.1.2. Results of in-situ gamma spectrometric measurements

In-situ gamma spectrometric measurements were taken by portable semiconductor detectors located near the telemetry and sampling stations. On the basis of measurements characteristic of the upper level of soil, it can be stated that apart from natural radioactive isotopes (^{40}K, uranium series, and thorium series), ^{137}Cs, from the atmospheric nuclear test explosions and from the release of Chernobyl, is also easily measurable in the spectrums. *Table 3.2.1.2-1.* shows the measurement results (average, minimum and maximum value) from the past 10 years [35].

Table 3.2.1.2-1. Radioactive concentration of the upper level soil nearby the “A” type measuring stations in the period 2001 to 2010 based on the in-situ gamma spectrometric measurements [35]

Activity concentration based on the in-situ gamma spectrometric measurements	Average (min-max) [Bq/kg]
^{40}K	240 (182–348)
^{137}Cs	3.7 (0.49–13.3)
U series	17.7 (8.0–31.0)
Th series	14.9 (8.4–26.6)

3.2.1.3. Airborne activity concentration

For describing the airborne radioactivity of the examined area approx. 500 samples are evaluated every year. The detection limit of the method for each isotope is between 10^{-5}–10^{-6} Bq/m^3.

On the basis of the results of large-volume aerosol and fall-out samples, it can be stated that the activity concentration of each isotope reaches the detection limit only <1% of the samples. The results are similar to country data [36] [38], and it is likely that the measured isotopes were released as the result of global fall-out.

The activity concentration of ^{14}C in air was determined on a monthly basis, the average value was 43 mBq/m^3.

radiation” dose from the source documents; however, we emphasize that it includes the contribution of the cosmic radiation as well.

3.2.1.4. Activity of soil and grass samples

In the period 2001 to 2010, soil and grass samples were taken regularly. The ^{7}Be, ^{40}K, ^{60}Co, ^{110m}Ag, ^{134}Cs and ^{137}Cs content of the samples, as well as the activity of the uranium and the thorium series were determined by gamma spectrometric measurements. In addition, the ^{90}Sr content of the samples was also determined. The data shows the low activity concentration generally characteristic of sandy soil and it is similar to the country average [36] and to the values of basic level measured in the 1980s [39].

3.2.1.5. Radioactive isotope concentration of surface water

Water samples are taken regularly near the operating units of the Paks Nuclear Power Plant. The goals of the sampling are mainly to detect radioactive isotopes released to the environment due to the operation of the units and to make a determination of radiation exposure. However, measurement results can also be used for environmental condition assessment. The characteristic gross beta activity concentration of water samples is between 0.06–0.55 Bq/dm^3. The measured activity concentrations are neutral, because approx. half of the measured activity comes from isotope ^{40}K. Artificial radioactive isotopes could be detected only a few times with low activity concentration (with the detection limit in the range of 10–20 mBq/dm^3 in case of ^{137}Cs and ^{60}Co). The results fit into the gross beta activity concentration range of natural surface water and to the values of basic level measured at the beginning of the 1980s. [39]

The tritium activity concentration of 70 water samples is measured generally in every year on average at the site and in its neighbourhood. Except for some cases the tritium activity concentration was below the range of 3.5–10 Bq/dm^3 in each year, and the values beyond this were in the range of 15–22 Bq/dm^3. The measured values assumed at most 2 to 3 times the tritium activity concentration of natural surface water [36], and are a little below the range measured during the basic level determination in the Paks Nuclear Power Plant.

3.2.1.6. Activity of the sludge of surface waters

Samples from the beds of surface waters (the Danube, fish ponds and fish breeder) are regularly taken. Besides the natural radionuclides, isotope ^{137}Cs and ^{90}Sr could also be detected in almost every sludge sample taken from the Danube. It can be assumed that as a result of the Chernobyl fall-out, small amounts of ^{137}Cs could be measured in the sludge samples taken from the fish ponds. In the sludge samples, the average activity concentration of ^{90}Sr is in the range of 0.3–0.5 Bq/kg, which fits into the basic level range. In some cases, artificial isotope ^{131}I was measured at one of the sampling points of the Danube. The value of the measurement was near the detection limit; therefore, further samples were taken and an assessment was carried out. From the detailed studies that conclusion could be drawn that the Danube was also contaminated. The measured artificial radionuclides cannot be linked to the operation of the nuclear power plant, the long half-life radionuclides are derived from Chernobyl, and the short half-life isotope ^{131}I is probably derived from medical therapy.

3.2.1.7. Radioactive isotope concentration of fish samples

Fish samples are taken quarterly from the fish ponds located next to the Paks Nuclear Power Plant. No artificial radioactive isotope could be detected from the samples in the period 2001 to 2010 (detection limit: 0.5 Bq/kg), which is line with that neither the water in the fish ponds nor their sludge contain artificial radioactive isotopes. The artificial radionuclide concentrations measured in fish taken from the Danube section below the power plant are very low and below the detection limit in most samples. Between 2005 and 2010, the maximum measured isotope ^{137}Cs activity concentration was 1.3 Bq/kg and the maximum measured isotope ^{90}Sr activity concentration was 0.99 Bq/kg. The gross beta activity was about 50–60 Bq/kg, which is mainly derived from isotope ^{40}K. [36]

3.2.1.8. Ground water activity

The status of ground water at the site and in its surroundings can be concluded from the samples taken before the construction of Paks Nuclear Power Plant and from the analysis of monitoring wells established especially for ground water observation. However, tritium of technology origin has been detected since the mid 1980s at the site of Paks Nuclear Power Plant, mainly in the ground water underneath and around the main building and service buildings, but its effect can only be felt in a small area and its impact is negligible on the new site ([40] [41]). As a result of the repairs executed up until 1998, significant decrease of the concentration of tritium could be detected in the ground water wells. Based on the above mentioned facts, it can be stated that the tritium-contaminated water of technology origin is not able to reach into the ground water anymore. In case of some wells, the activity concentration of isotope ^{14}C is beyond the natural background limit, which refers to power plant origin. However, it means significantly less environmental load even than that caused by the tritium.

3.2.1.9. Radioactive concentration of milk samples

Milk samples are bought monthly south of the nuclear power plant alternately from dairy farms in nearby villages Dunaszentgyörgy and Gerjen. The measurements are taken with a gamma spectrometer equipped with a semiconductor detector. In the samples, radioisotopes neither of Chernobyl origin nor of nuclear power plant origin can be detected due to the detection limit of 0.5 Bq/dm^3. The activity concentration of isotope ^{110m}Ag and ^{137}Cs were below the detection limit in all cases. The activity concentration of isotope ^{40}K is in the range of 40–60 Bq/dm^3, its average activity concentration is 51.1 Bq/dm^3, which is line with the national values.

3.2.1.10. The environmental radiological monitoring

It is prescribed by the decree 15/2001. (VI. 6.) of the Ministry of Environment on radioactive emissions into air and water in course of the use of nuclear energy and their monitoring, that Paks Nuclear Power Plant shall monitor the levels of environmental radioactivity related to the power plant's emissions, both in air and water. In all operating conditions of the nuclear power plant the system should provide data in adequate quantity and with appropriate reliability in order to assess environmental impacts, and if necessary, to take all the required measures. The main areas of monitoring are the following:

- measurement of atmospheric and water emissions in the ventilation chimneys, water collection tank park and drainage channels,
- measurement of the Danube's hydrological characteristics,
- radioactive concentration measurement of air, fallout, soil, ground water and natural vegetation (grass) in the environment,
- activity measurement of the different samples (water, sludge, fish) of surface waters (the river Danube and fish ponds) and rainwater collection channels,
- activity concentration measurement of certain food samples (milk),
- measurement of environmental gamma radiation dose and dose performance.

The control has two levels, it is carried out partly by telemetry systems, partly by sampling, laboratory tests, and in course of the control annually approx. 4000 sample analyses are executed. The telemetry system provides on-line data, usually by measuring the total radiation.

In case of normal operation, the task of measuring stations is to verify that no significant amount of radionuclides gets into the atmosphere from the power plant. In case of breakdown, their most important task is that they will continue to provide data about the most important components of environmental radiation, even if the emission does not occur through the chimney. This information must be able to establish the measures to be taken to protect the population living in the neighbourhood.

- In the 1–1.5 km radius circle around the power plant 9 "A" type measuring and sampling stations were placed with the following main functions:
  - measurement of gamma radiation dose performance,
  - measurement of gross beta activity concentration of aerosols,
  - measurement of the prime or prime and organic phase of radioiodine,
  - aerosol and iodine sampling for laboratory measurements.
- The so-called control station (B24) that has been built in accordance with the "A" stations operates in Dunaföldvár.
- In the interest of better spatial coverage, further 11 gamma radiation dose performance measuring "G" type stations were installed among the "A" type stations in course of the reconstruction.

The signals of telemetry detectors are complemented by the laboratory test of samples taken at the places of emission and at different points of the environment (environmental monitoring stations and other places). These analyses are very sensitive and they can be applied to all radionuclides.

At the "A" type stations aerosol and iodine, fallout, soil and grass samples are taken in order to execute high sensitivity nuclide-specific laboratory tests. At 5 of the stations air, tritium (in the form of hydrogen gas (HT) and water vapour (HTO)), CO_2, C_nH_m sampling is done as well. Nuclide-specific analysis of water, sludge and fish samples is carried out from the surface waters around the power plant (the Danube, fish ponds, belt channel). To monitor the radioactive contamination of ground water, ^{3}H measurement is carried out in 40 of the wells in the operating area, and in 20 wells gamma-ray nuclides bound to ion exchange columns and isotope ^{14}C is determined by using automatic samplers.

The Joint Environmental Radiation Monitoring System (JERMS), which is operated by the official bodies and radiological laboratories executing the radiation control of the power plant's environment, works parallel to the measurements of the nuclear power plant. Every year approx. 2–3000 samples are analysed. In course of the official control, in addition to the control of atmospheric and water emissions, sampling laboratory tests are executed as well, and during these Danube water and sludge, soil, plant, and milk samples are analysed.

3.2.2. Radiological impacts related to the operation of the new units

There are three sources of public exposure as a result of the operation of nuclear power plant units:

- direct and scattered exposure originating from the installation,
- atmospheric release (external exposure, internal exposure via inhalation, ground contamination, ingestion via the food chain),
- liquid discharges (drinking water, fish consumption, usage of the surroundings of the Danube).

The critical group (representative group)[11] living in a village near the installation is a group of individuals characterized by their location, age range, consumption or other features (living habits), that receives the highest dose from the facility. In order to determine the representative group the features of meteorology, hydrology, demography, agriculture production, consumption and living habit valid for the neighbourhood of the facility were used. A group like this may be hypothetical, in the sense that specific characteristics of different groups are linked in order to ensure conservative assumptions. Similarly to the analysis applied for the existing units, calculations were performed for children of 1–2 years of age and adults.

In accordance with the previous analyses [42], [43], group of children of 1–2 years of age living in the village of Csámpa can be considered as critical group or reference person in case of atmospheric releases, as well as direct and scattered gamma and neutron radiation originating from the installation. On the basis of the analysis detailed in study [42] the members of this group may be exposed to the highest dose consequences as a result of releases from the on-site facilities. The adult population of the village of Gerjen near the Danube can be considered as the group the most exposed to the dose consequences of liquid release. In course of the analysis in order to achieve conservative estimation, the groups of Csámpa and Gerjen were "united" and the amount of the dose of the two reference persons were taken into account.

3.2.2.1. Effects of the direct and scattered radiation

Based on the EUR [44], the target value of the direct radiation of the population originating from one nuclear power plant is 0.1 mSv/year (100 μSv/year), which is independent from the performance of the unit(s). This is practically the same as the dose constraint of the authority[12]. In case of each reactor type, we often have only few data for the population dose caused by direct radiation of the reactors, and many of them are estimated with significant conservatism.

Regarding the AP1000-type reactor, the exposure of the representative group from direct and scattered radiation was estimated as 4 μSv/year, which is a highly conservative upper estimation.

Regarding the EPR-type unit, in accordance with the dose projection (0.2 pSv/h) set at the distance of 1000 m, the external exposure does not exceed 2 nSv per year.

Regarding the APR1400-type reactor, at the distance of 700 m 50 μSv/year is set as the upper limit. This value is not calculated or measured; therefore it would be an exaggeratedly conservative estimation to accept this value for the potential exposure of the nearest population group (Csámpa, 1300 m). By correcting the data on the basis of the distance-dependent data set for the EPR unit, the external exposure at the distance of 1300 m is estimated as 0.5 μSv/year.

The value provided for the AP1000-type reactor at the distance of 100 m, even by taking into account the APR1400-type unit, is considered as a bounding (covering) case. Thus it can be stated that the exposure of the nearest (Csámpa, 1300 m) population group will surely not exceed the value of 4 μSv/year. [42]

[11] In recent years, in international recommendations the concept of critical group has been replaced by the concept of typical (representative) individual: *"... a person, whose dose is typical of individuals who received the highest radiation..."*. Since the dose factors, consumption and lifestyle characteristics are not expected to differ from the characteristic values of the critical group according to the method applied so far, therefore, in practical calculations, it will not mean any changes.

[12] Dose constraint is a planned and source-related restriction on the possible individual dose from defined sources. It is used at the planning stage of radiation protection, for optimization. Its value is determined by the Office of the Chief Medical Officer of the National Public Health and Medical Officer Service.

3.2.2.2. The estimation of radionuclide discharge of the new units

The European Utility Requirements (EUR) document determines requirements and target values for the discharge of nuclear power plants in normal operation, in case of anticipated operational occurrences and in case of an accident [44]. Based on these requirements, during normal operation the annual value of liquid discharge, except tritium, should not be greater than 10 GBq. The annual atmospheric release of radioactive noble gases should not be greater than 50 TBq, and that of radiohalogens and aerosol-bond radioactivity should not be greater than 1 GBq. Values of the EUR mentioned above refer to 1500 MWe (electric) capacity units. In cases where the performance of the unit is below 1500 MWe, the above mentioned values are proportionally lower according to the performance. In addition to these release limits there is a further requirement that these values should be “as low as reasonably achievable” according to the ALARA[13] principle.

The study [42] prepared for the establishment of dose constraint contains the data of atmospheric and liquid release in normal operation for each reactor type. The given values of liquid discharges do not list radionuclides having half-life of 1 hour or less, because from the aspect of public exposure, by taking into account the possible routes, the dose contribution from these radionuclides are negligible.

The release data of anticipated operational occurrences, whose frequency exceeds 10^{-2}/year, are also set in the study [42] for each reactor type. Only the anticipated operational occurrences associated with atmospheric release could result in emission, which exceed normal operational levels. The anticipated operational occurrences associated with liquid discharge could not result in radioactive discharges beyond normal operational level.

The surface water (in our case this is the water of the Danube) could be theoretically contaminated as a consequence of the following anticipated operational occurrences:

a) direct contamination of the surface water,
b) indirect contamination of the surface water via ground water,
c) indirect contamination of the surface water via atmospheric discharge, caused by anticipated operational occurrences via deposition into the surface water and via leaching from the ground surface.

All potential types of reactor units taken into account assure that liquid discharges during anticipated operational occurrences would comply with discharge norms in a controlled manner. Based on our experiences, direct and uncontrolled contamination of the surface water can be excluded. There is no reference in the description of anticipated operational occurrences of the potential reactor types on ground water contamination; therefore this pathway can also be excluded in this phase of the design. Indirect contamination of the surface water via the pathway of “Indirect contamination of the surface water via atmospheric discharge caused by anticipated operational occurrences via deposition into the surface water and via leaching from the ground surface,” would not pose significant addition compared to the atmospheric component. In conclusion it can be stated that no anticipated operational occurrences resulting in liquid discharges can be assumed which are not manageable in the normal operational constraint system. [42]

3.2.2.3. Public exposure as a consequence of the new units

Regarding all five reactor types, we determined the exposure value originating from atmospheric and liquid release in normal operation. According to the international and national radiation protection requirements, the dose consequences in case of anticipated operational occurrences shall not exceed the value of the dose constraint; therefore we also analysed releases of anticipated operational occurrences.

[13] “As Low As Reasonably Achievable”

We determined the dose contribution of releases on the basis of internationally accepted models. Calculations were made by the PCCREAM program [45] for normal operation and by the PCCOSYMA program [46] for anticipated operational occurrences.

The assumed emission point was in the middle of the planned site; at the determination of the residence of the representative group, we took into account the nearest residence home of the surrounding settlements.

The assumed emission height was defined with respect to the different reactor types: for MIR.1200 and ATMEA1 we took 100 m, and for EPR, AP1000 and APR1400 we took 60 m. We took into account ten years of meteorological data obtained between 2000 and 2009. We made the calculations using the typical value of agricultural area for the surface roughness that has influence on dispersion. During the calculations we take into account the following exposure pathways:

- external exposure originating from cloud and radionuclides deposited on the ground,
- internal exposure via inhalation,
- internal exposure via food consumption.

We determined the committed dose originating from external exposure integrated for one year and from internal exposure for one year exposure (intake). The calculations were made for one-year-old children and adults as well. We assumed that the reference person spends 90% of the time in the building and the shielding factor for the building is 0.2 from cloud shine and 0.1 from ground shine. We assumed, as a conservative approach, that the population consumes all their food from local products (from that sector and distance). We applied the data of Tolna County for age-related food consumption survey in the area of Bátaapáti. This data would also apply for the area of Paks site.

It can be stated on the basis of the calculations executed for *atmospheric release in normal operation* that

- the largest value of exposure from normal operational release is 2.0 μSv/year,
- for the two age groups considered the exposure of the one-year-old children is approx. 50% higher than that of adults,
- of the residences the population of Csámpa is exposed the most,
- meteorological data of 2003 resulted the maximum exposure,
- the highest public exposure in normal operation may originate from the EPR-type reactor' atmospheric release and the lowest one from ATMEA1-type reactor's atmospheric release.

The same three radionuclides are responsible for dose contribution ≥1% for all types of reactors. Moreover, radionuclide ^{14}C was the most significant in all the cases. The reason of the high contribution of ^{14}C was that in the lack of information on the chemical form, we conservatively assumed the form of CO_2 entirely in the calculations [38].

Regarding the exposure pathways, food consumption is determining. The weight of internal exposure via inhalation is slightly beyond 1%, the contribution of external exposure is negligible.

During the PCCOSYMA calculations made on the *atmospheric release of the anticipated operational occurrences*, we assumed neutral (Pasquill "D") atmospheric stability (5 m/s wind speed, dry weather), because this is one of the most typical meteorological categories in the area. In addition, we also executed calculations for Pasquill "F" category. In the assumed duration (0.5 h) of the release, we considered permanent meteorological conditions, and we executed the calculations for the village (Csámpa) nearest to the release.

We determined the exposure for one year following the anticipated operational occurrence originating from cloud shine, ground shine and inhalation. In case of food consumption, one year intake was taken into account during the calculation of the committed effective dose. For the calculation of exposure delivered from food-chain we did not take into account conservatively the consumption of exported food products. We assumed that consumed food was produced completely within a 5 km^2 symmetrical circle.

Based on the results it can be stated that the highest public exposure originates from the atmospheric release of the AP1000-type reactor during anticipated operational occurrences (14 μSv/year), while the lowest one originates from the ATMEA1-tpye reactor (0.71 nSv/year). In case of release during anticipated operational occurrences the adults are exposed the most, and isotope ^{134}Cs and ^{137}Cs has the highest dose contribution.

To determine exposure originating from *liquid discharges* we applied the model based on Safety Reports Series 19 of the International Atomic Energy Agency (IAEA) [47], taking into account that the lateral mixing of the discharge into the Danube is only partially achieved even far from the inflow. The decreasing effect of the sedimentation on activity concentration was neglected in the calculations [47], and we considered exposure via the following pathways:

- external exposure originating from contaminated water, from contaminated water banks and from the irrigated ground,
- internal exposure originating from drinking water, fish, irrigated vegetables and consumption of food from animal origin contaminated by watering animals and feeding of irrigated vegetables.

We determined the committed dose originating from external exposure integrated for one year and from internal exposure for one year intake. The calculation was made for one-year-old children and adults of the first village (Gerjen, 10 km) downriver on the right side of the Danube. Based on the analysis the following conclusions can be made:

- In case of the APR1400-type reactor the dose contribution of isotope ^{106}Ru, ^{134}Cs and ^{137}Cs is the highest, in case of the other reactors isotope ^{3}H or ^{14}C has the highest dose contribution. Beside them only isotope ^{60}Co, ^{63}Ni, ^{131}I has dose contribution near 1% or slightly greater in some units.
- Similar to the exposure originating from atmospheric release in normal operation, the internal exposure has dominance.
- Based on the lack of available information, the comparison of total doses is not realistic. At the same time, it can be stated that in case of the given parameters, the liquid discharges of the EPR-type reactor would result in the highest public exposure (4.4 μSv/year).

On the basis of our experience so far and of the data provided by suppliers, *liquid discharges* originating from *anticipated operational occurrence* can be supposedly managed within the limits of normal operation.

On the basis of the executed measurements, in case of one unit, the effect of normal operational atmospheric and liquid discharges cannot exceed the 6 μSv/year value; the 4 μSv/year dose contribution of direct and scattered radiation should also be added to this value thus the result is 10 μSv/year per unit. If we assume that besides the annual normal operational discharges an anticipated operational event will also occur, the dose contribution will increase with a value of 14 μSv/year under the most unfavourable meteorological conditions. This value would be added to the value of normal operation (10 μSv/year) thus the dose contribution for one unit is 24 μSv/year. Thus, regarding two units and assuming one anticipated operational occurrence per unit beside the normal operational dose, the dose contribution is 48 μSv/year.

3.2.2.4. Flora and fauna exposure

The "Environmental Risks from Ionising Contaminants: Assessment and Management" (ERICA) project is also included in the 6th Research Framework Programme of the European Union. By the program [48] prepared as a result of this project, the potential exposure to the flora and fauna (ecosystem) can be determined in the surroundings of a nuclear power plant. Furthermore, the risk related to some highly sensitive species could also be calculated. The most important conclusions of the ERICA project are the following:

- Regarding the radiation sensitivity to continuous environmental release, there is no difference between the continental, marine as well as freshwater ecosystems.
- There is one dose criterion applicable to all investigated ecosystems; if the exposure does not exceed this criterion, the environmental effect will be negligible. [49]

It has to be mentioned that the definition of equivalent dose applies only the human exposure, so this dose term shall not be applied to the biological dose (D_b) of the flora and fauna. Instead of that, according to the recommendations of the ICRP[14] in the international practice the following formula should be used for dose calculations:

$$D_b = \sum_R D \times w'_R \qquad (3.2.2.4\text{-}1)$$

In the *Equation (3.2.2.4-1), R* index represents the radiation type, w'_R is the radiation weighting factor for radiation type *R. R* is 10 for α-radiation, 3 for soft β-radiation, 1 for medium and high energy β- and γ-radiation.

The FREDERICA [50] database was elaborated in course of the ERICA program, which includes a large number of plant and animal species, as well as radionuclides delivering the highest specific dose to them.

The basis of calculations is the definition of “Predicted No-Effect Dose Rate” (PNEDR) to the species of flora and fauna; this is used to derive the value of the Environment Media Concentration Limit (EMCL) for different radionuclides. EMCL values are different in terms of radionuclides released from nuclear installation into the environment and of the four “environmental media” (water, sediment, soil/ground, air).

The ERICA is a graded program that consists of three steps (Tier 1, 2 and 3) with ascendant details as well as complexity. In the present phase of our work, using the available data, we conducted the first step (Tier 1) of the ERICA program. We analysed the possible radioactive discharge into the air originating from the planned installation to terrestrial species of flora and fauna living at the fence of the site.

In the ERICA program, we used covering data of the five investigated reactor types calculated from the values of maximum discharge. As a result of the first step of the ERICA program, which is the most conservative, the risk factor turned out less than one. Assuming two operating units, the sum would not exceed one either.

3.2.3. Common radiological impacts of nuclear facilities operated at the site

In the course of the assessment of the new environmental radiological situation derived from putting into operation the new units, the starting point of the application of conservative approach should be that the current four VVER-440 units with extended lifetime, the new nuclear power plant with maximum two units and the interim spent fuel storage will operate simultaneously for a certain period of time. Therefore, it is necessary to investigate the cumulative radiological effects of the nuclear facilities operated at the Paks site.

The description of the cumulative radiological environmental effects of the nuclear facilities operated at the Paks site is based upon the studies on the proposed dose constraints for the planned new units as well as the analysis presented in the previous chapters, the previously established dose constraints for the operating facilities and the actual airborne and liquid release.

Dose constraint for the operating facilities and the new planned units at the Paks site

The 90 μSv/year dose constraint was established for Units 1–4 of the Paks Nuclear Power Plant in permit No. OTH 40-6/1998 of the National Public Health and Medical Officer Service (NPHMOS) Office of the Chief Medical Officer of State, while 10 μSv/year dose constraint was established for

[14] International Commission on Radiological Protection.

the ISFS. The total number of 33 storage vaults was envisaged in the construction design of the ISFS facility. If it is constructed, it would provide a maximum storage capacity of 16200 spent fuel assemblies. The ISFS is operated by Public Limited Company for Radioactive Waste management (PURAM). The ISFS has the same geographical conditions such as the Paks Nuclear Power Plant; however, its licensee is different. The respective discharge (release) limits for each installation and pathway of release were calculated from these dose constraints.

The planned new units at the Paks site are likely to be different types than the existing ones; therefore, different installation-specific dose constraints should be established for each installation. The authors of study [42] for substantiating dose constraints of the new planned units state that dose constraints established for the operating units could also be applicable for the planned two units given similar electric power; therefore 90 μSv/year dose constraint would be appropriate.

The release limits for radioactive material should be derived from the dose constraint. The licensee should initiate release limits and verify them with calculations in order to represent that they are in compliance with these limits and the members of the critical groups (and the representative person) will not be exposed more than the established dose constraint. The following criteria should be assessed to that:

I. The exact location (for example, stack, channel, etc.) and the physical and chemical condition of discharge.
II. The distance between the place of discharge and the place of the representative person.
III. Meteorological, geographical and geological features determining the dispersion of the radioactive release between the two places.
IV. All "anthropomorphic" factors which could have influence on the dispersion (for example, agriculture, usage of water, etc.).
V. Factors which could have influence on exposition of the representative persons (inhalation, intake and immersion dose conversion factors, consumption data and residence time, etc.)

Cumulative radiological effects of the planned and operating units at the Paks site

The dose contribution of the new units are taken into account on the basis of the results presented in Subchapter *3.2.2.3.* The release data of the operating units was taken out from the latest radiation protection report of the Paks Nuclear Power Plant [35], while the release data of the ISFS was taken from the study [51] that was provided in the latest review. In the latter one the total construction of the facility was assumed during the calculations, and a special so-called composite source was applied, which was the most unfavourable as regards the burn-out level of spent fuel and the composition of radioisotopes from radiation protection point of view.

The children of 1–2 years of age, living in the village of Csámpa, which belongs to the territory of Paks town, could have the maximum dose originating from the atmospheric releases of the new units. The largest value of exposure from normal operational release is 2 μSv/year, while the releases of anticipated operational occurrences result maximum 14 μSv/year dose. The effect of the atmospheric releases of the operating units does not exceed the value of 1 μSv/year, the effect of the ISFS is even lower. The cumulative effects of the atmospheric releases of the operating and planned facilities at the Paks site can be assumed as 33 μSv/year.

The population of Gerjen is assumed to be the representative group that is the most exposed to the dose consequences of liquid discharge. In case of both children of 1–2 years of age and adults, the dose value of 4 μSv/year can be calculated from the discharge of the new units. According to the report [35], the estimated dose consequence of liquid discharges of the presently operating units is approximately 1 μSv. The study [51] associates 0.4 μSv/year dose for the liquid discharge of the present ISFS facility with maximum load. Thus the cumulative liquid discharge from the operation of present and planned installations could cause a total of 10 μSv dose to the representative person.

In case of the new units, the component originating from direct and scattered radiation was estimated as 4 μSv/year value, which is a highly conservative upper estimation. The effect of the direct and scattered radiation of the operating units does not reach the order of magnitude of μSv/year. According to the study [51], because of the movement of fuel bundles this dose contribution is maximum 5 μSv/year in case of the ISFS. On the basis of the above mentioned, the effect of the direct and scattered radiation of the facilities at the Paks site is 13 μSv/year.

Summing up these calculations it can be stated that the estimated value of the dose of the representative person derived from the simultaneous operation of six units and the ISFS at the site is 56 μSv/year (*Table 3.2.3-1.)*. Regarding the new units, in this amount conservative upper estimation was applied to the calculations of effect of the airborne and liquid discharge in normal operation and originating from one anticipated operational occurrence per year. The conservatism of results is implied by that the present discharge of Paks Nuclear Power Plant of the radionuclides having the highest dose contribution is much less, even by the orders of magnitude, than the values provided by the suppliers for the new units. Consequently it means that the presented values of the designers of the new reactor types constitute conservative upper estimation of the expected values instead of expected average discharges. Although these results do not exceed the 90 μSv/year value either, but later for more detailed assessment the data provided by the suppliers is needed to be updated, and in some cases, its critical control will also be necessary.

Table 3.2.3-1. Cumulative radiological effects of the planned and operating nuclear facilities at the Paks site

Atmospheric discharge [μSv/year]			Liquid discharge [μSv/year]			Direct and scattered radiation [μSv/year]			Sum [μSv/year]
PNPP	New	ISFS	PNPP	New	ISFS	PNPP	New	ISFS	
<1	32	<<1	1	8	<1	<<1	8	5	56

PNPP – operating Unit 1–4 of Paks Nuclear Power Plant
New – planned new units
ISFS – Interim Spent Fuel Storage

3.2.4. Impacts of incidents and accidents

In case of new nuclear power plant units, according to Nuclear Safety Requirements (NSR) Volume 3, which is the annex of the Government Decree 118/2011. (VII. 11.) on the nuclear safety requirements of nuclear facilities and the related authority activities, conditions are defined as below (name of condition, abbreviation used in the NSR, and abbreviation used in the EUR):

a) normal operation condition = TA1 (design basis) = DBC1 (Design Basis Condition 1),
b) events in design basis:
    ba) anticipated operational appearances = TA2 = DBC2,
    bb) low frequency design basis accidents = TA3 = DBC3,
    bc) very low frequency design basis accidents= TA4 = DBC4,
c) design extension conditions = TAK (beyond design basis),
    ca) beyond design basis accidents DEC1 (Design Extension Condition – complex sequences category),
    cb) severe accidents = DEC2 (severe accidents category).

3.2.4.1. Design basis accidents

On the basis of Section 3.2.4.0100. of NSR in case of new nuclear power plants the dose of the representative group of the population should not exceed the 1 mSv/event value in a process starting from an initiating event resulting TA3 operation condition and the 5 mSv/event value in a process starting from an initiating event resulting TA4 operation condition.

AP1000-type reactor

Design basis accidents of AP1000-type reactors are listed in the document [53]. Albeit the terms are different from the identifications of the EUR standards, it can be seen from the list of accidents that the categories listed are in line with EUR categories EUR DBC1–DBC4.

According to the document [53], the power plant fulfils the EUR requirements; and their fulfilment was checked by applying estimated values. The data was obtained by multiplying the adequate data of the EPR reactor, which is considered to have maximum release indicators in the document [42] for substantiating dose constraints of the new units, by the quotient of the gross output of the two reactor types. This is a conservative process; therefore, it provides safe estimation regarding the compliance of the EUR criteria. Based on the executed analysis, the requirements are fulfilled.

MIR.1200-type reactor

The MIR.1200-type reactor was designed according to the Russian regulation in force, which is slightly different from the EUR categorizations. There is no difference in categories DBC1 and DBC2 (TA1–TA2). The difference occurs at accidents, because the Russian regulation does not make any difference between the frequency and the severity of the accidents. In case of design basis accidents, the whole body dose limit of 5 mSv shall be applied to the public at the boundary of the health zone, which is in compliance with the 5 mSv/event requirement for EUR category DBC4 (TA4). The compliance was investigated with the same methodology as applied to the AP1000-type reactor design, according to this, the MIR.1200-type reactor design is in compliance with the criteria.

EPR-type reactor

At the design of the EPR-type reactor the different operational conditions, transients and accidents were categorized into classes DBC1 to DBC4 regarding to the EUR requirements [56]. The comparison of the compliance with the criteria was also carried out in this case, and we found that the conditions are fulfilled.

ATMEA1-type reactor

In case of design basis accidents, the Table of the Attachment 4 of the document [57] includes the maximum dose rates at the border of the health zone.

This unit type was designed in accordance with the American regulation (US Regulatory Guide 1.183, July 2000), which prescribes maximum 250 mSv dose consequence for accidents. However, the requirements of EUR are stricter, therefore in the course of the completion of data provided by the supplier, the fulfilment of the EUR target values has to be verified. Assuming the given release through the stack, it can be stated that the requirements of EUR are fulfilled.

APR1400-type reactor

Documents [58] and [59] are the sources of the data regarding the APR1400-type reactor design. It is obvious, that also the designers of the APR1400-type reactor applied the American regulation (10 CFR) as the source document. With the knowledge of further data the compliance with the EUR criteria can be later verified. We investigated the criteria, and based on the analysis with the release data provided by the supplier the criteria are fulfilled.

3.2.4.2. Extension of the design basis

The events belonging to the extension of the design basis can be classified into two categories: complex processes and severe accidents. The former one includes those processes which may result in release of significant radioactive materials due to multiple failures. Some low-probability chains of events may result in core damage and release of significant radioactive materials, they are called severe accidents. The selection of chains of events is carried out by PSA (Probabilistic Safety Assessment) methods.

The release from the primary circuit to the containment shall be considered as source term. Based on the sequences identified by PSA, a Reference Source Term (RST) shall be determined by the best approximation method, and this shall be used to justify the compliance with the release criteria. In the level 2 PSA sequences having similar releases shall be classified into source term categories. Those sequence groups that are beyond the RST shall be investigated separately. It has to be verified that their probability does not exceed the target value of 10^{-7}/year. Moreover, the cumulative probability of all groups generating releases beyond the RST shall not be larger than 10^{-6}/year.

Based on the EUR, the objective is that the release does not exceed the value

- that would justify early emergency actions (evacuation) beyond 800 m distance from the nuclear reactor,
- that would justify provisional actions (temporary evacuation) beyond 3 km distance from the nuclear reactor,
- that would require subsequent actions (final evacuation) beyond 800 m distance from the nuclear reactor,
- that would lead to significant economic consequences (nutrition and feeding bans would be required limited in time and space at the worst).

AP1000-type reactor

The documentation [53] prepared for the AP1000-type reactor design contains a special analysis that verifies the compliance with release limits of severe accidents of the EUR. According to that, it can be stated that the AP1000-type reactor design fulfils all release criteria.

MIR.1200-type reactor

The severe accidental releases of the MIR.1200-type reactor were investigated for severe core damage with break of the largest diameter (850 mm) line and station blackout, which was considered as “reference severe accidents” [55]. The MIR.1200-type reactor design fulfils the release criteria.

EPR-type reactor

Document [62] includes calculations on the EPR-type reactor design. Although the calculation methods are only partially comply with the EUR requirements, but even based on these it can be stated that the EPR-type reactor fulfils the criteria.

ATMEA1-type reactor

The document on severe accidents [57] provides release data on severe accident sequences involving station blackout in 48 hours just after the beginning of the accident. According to this data, a very small part of core inventory is released; however, suppliers should provide further data in order to execute the evaluation.

APR1400-type reactor

The values provided in the documentation [59] cannot be compared with the EUR criteria without further information. The values given in documentation [58] are lower than the relevant EUR dose criteria, further data should be provided by the supplier for a comprehensive verification of the compliance.

3.2.4.3. Probabilistic characteristics of beyond design basis accidents and severe accidents

As part of the safety analyses, besides deterministic assessments, probabilistic safety assessments shall be conducted. By taking into account all initiating events and operation conditions (output operation, shut down operation conditions) the core damage frequency should be less than 10^{-5}/year. Large accidental release can be assumed in case of core damage and containment function break. The frequency of severe accident should be less than 10^{-6}/year by taking into account all possible initiating events. The construction equality shall be verified by showing that there are no events, which contribute to the cumulative frequency of severe accidents with more than 10^{-7}/year frequency.

AP1000-type reactor

The probabilistic description is based on the results of analysis provided in document [66]. Considering all initiating events and operation conditions, the value of the cumulative core damage frequency is $5.1 \cdot 10^{-7}$/year. This is by more than one order of magnitude lower than the acceptance limit values.

Considering all initiating events and operation conditions, the value of the cumulative frequency of severe accidents is much less than 10^{-7}/year, therefore, the criterion is satisfied with significant reserves.

MIR.1200-type reactor

The probabilistic description is based on the results of analysis provided in document [67]. Considering all investigated initiating events and operation conditions, the value of the cumulative core damage frequency is significantly less than 10^{-7}/year. This is by more than two orders of magnitude lower than the acceptance limit values.

The value of the cumulative frequency of severe accidents is of the order of 10^{-8}/year. Thus, the criterion is satisfied with significant reserves.

EPR-type reactor

The probabilistic description is based on the results of analysis provided in document [68]. Considering all initiating events and operation conditions, the value of the cumulative core damage frequency is less than 10^{-6}/year. This is by more than one order of magnitude lower than the acceptance limit values.

Since the core damage frequency is of the order of 10^{-7}/year, therefore the acceptance criterion for the cumulative frequency of severe accidents is satisfied obviously with significant reserves.

ATMEA1-type reactor

The probabilistic characteristics of this reactor design can be derived on the basis of the preliminary probabilistic safety assessment for the basic design [69]. According to the available results, the value of core damage frequency is of the order of 10^{-7}/year. Thus, the reactor design satisfies the acceptance limit value of the core damage frequency with significant reserves.

Based on the level 1 probabilistic safety assessment (PSA) the value of the frequency of severe accidents is of the order of 10^{-7}/year at the most. Thus, the acceptance criterion for the frequency of severe accidents is satisfied.

APR1400-type reactor

The probabilistic description is based on the results of analysis provided in document [58]. Considering all initiating events and operation conditions, the upper estimation of the cumulative core damage frequency is $3 \cdot 10^{-6}$/year. This is less than a third of the acceptance limit values.

According to the results of level 2 PSA, the cumulative frequency of severe accidents to the evaluated risk components is $2.84 \cdot 10^{-7}$/year, thus the criterion is satisfied with significant reserves.

3.3. Air quality

3.3.1. Description of the basic state

Describing the baseline conditions currently available data was used. Though the conventional air pollution of the new nuclear power plant is negligible during operation except the passenger and freight transport, but significant loads are expected in the construction period, therefore, the characterization of the baseline conditions by measurements is proposed until the impact assessment work phase.

3.3.1.1. Present state of air pollution

In the absence of measurements, the present state can be described by the following characteristics:

- *Zoning:* Hungary's territory is classified into air pollution zones by the Ministry of Environment and Water Decree 4/2002. (X. 7.) on the Designation of Air Pollution Agglomerations and Zones. Town of Paks and the vicinity of the nuclear power plant do not belong to the highly polluted areas, and are in group 10, the zone called "the rest of the country". This category consists of the least polluted areas of Hungary, where pollution (except $PM_{10\,(BaP)}$[15]) is classified into the two lowest categories.
- *Air pollution measurements:* Dust immission in Paks has been measured manually since 1987 by the National Air Quality Monitoring Network (OLM). Based on the data of 2011, the settlement is classified into category excellent from the point of view of pollution. The nearest automatic measuring station can be found in Dunaújváros, where in 2011 the results were excellent as regards sulfur dioxide, nitrogen oxides and carbon monoxide pollution, good as regards nitrogen dioxide and benzol pollution, and appropriate as regards settled dust pollution. The trends are improving.
- *Regional background pollution:* Air quality (background pollution) values – not influenced by local pollution sources – are regionally low in the area, based on data of the background pollution measuring network managed by the Hungarian Meteorological Service and measurements carried out in similar areas.

3.3.1.2. Environmental sources of pollution

In the area of the power plant roads, residential and industrial emissions and the power plant itself can be the source of air pollution:

- *Emissions of road transportation:* Local pollution source is the national main road No. 6 and the two access roads to the nuclear power plant beacuse of their significant passenger, truck and bus traffic. In course of the environmental licensing of the nuclear power plant's lifetime extension [37], calculations were made concerning air pollution caused by the traffic of main road No. 6. According to traffic data of year 2004, in the vicinity of the nuclear power plant the volume of all traffic was 11059 vehicles/day. The concentration caused by the traffic of main road No. 6 in a 50 m range from the road's centerline in the peak hour is 850 $\mu g/m^3$ in case of carbon monoxide and 26 $\mu g/m^3$ in case of nitrogen dioxide, that is below the limit value. In 2010, after the opening of M6 motorway the

[15] PM_{10}: flying dust, fine particle materials dispersed in the air (particles with a diameter of less than 10 micrometres). $PM_{10\,(Bap)}$: benzo(a)pyrene content of flying dust.

traffic of main road No. 6 changed to 7279 vehicles/day, i.e. it decreased by 28%, therefore emissions decreased as well.

- The last measurements were made in 2003 along the northern and the southern access roads and at the site of the power plant. According to these measurements, nitrogen dioxide and carbon monoxide concentrations were not significant, far below the threshold values. Concentration of fine particulates PM_{10} occasionally slightly exceeded the health threshold value.
- *Air pollution from residential, utilities and industrial sources:* For heating and heat production approx. two third of the apartments uses natural gas, a third of them uses district heating from the nuclear power plant. It is worth providing this possibility at the construction of the new units.There is no industrial facility causing significant emissions in Paks and its vicinity.
- *Air pollution sources of the existing nuclear power plant:* At the site of the nuclear power plant conventional air pollutants are emitted only during the temporary operation of immovable emergency power sources (diesel generators). In 2006, a propagation model was prepared for the emission of air pollutants of diesel generators [37]. Based on this, the impact area is a circle with a radius of 590 m around these devices. Their running times and size of their emissions have not changed significantly since then, so it is estimated to match the present state. This impact area does not affect any residential areas.

Summarising, based on earlier measurements carried out in the vicinity of Paks Nuclear Power Plant and on estimates on present conditions, concentration of “conventional” (not nuclear) air pollutants does not reach the level causing health damage. Settlements and residential areas are located at such a distance from the nuclear power plant that no conventional (not nuclear) air pollution impact of the nuclear power plant is expected.

3.3.2. Impacts of the construction

The conventional air pollution of the planned reactor units is expected to be significantly larger during its construction and decommissioning than during operation. The following baseline data should be considered in the assessment of impacts of the construction phase:

- Distance of the nearest residential areas from the border of the construction area is 1100–1300 m.
- Duration of construction activity will be longer (5–6 years) than usual. During this period, there will be significant incoming and outgoing transporation. According to data supply of the Client [32], the average truck traffic is expected to be 80 trucks/day, 130 trucks/day in the peak phase.
- At the construction site the simultaneous work of 50 machines in the preparatory (peak) phase and of 15 machines later (construction and transportation) is estimated.
- In the peak phase 1200–7000 workers work at the construction site, depending on the reactor type to be constructed [26 – 31]. Transportation of working staff to the site generates significant traffic. In our calculations 80% public transport (bus), 20% individual transport (car) were taken into consideration.

Air pollutants emitted during the construction phase:

- Pollution caused by *construction site activities* is expected to be irrespective of the type of unit to be built, rather it depends on the number and type of machinery moving on the site simultaneously. According to our calculations, significant excess pollution can be expected at the construction site due to the operation of construction and transportation machinery. Considering the distance of areas to be protected, no significant excess pollution can be expected on them. This impact is needed to be specified in a later phase.

- Emissions originating from *technological operations* (e.g. welding, soldering, gluing, and insulation) are expected to have no traceable impacts even in the vicinity of the construction site. Their magnitude can hardly be predicted in present phase.
- The most significant air pollutant of construction is expected to be dust. (No toxic dusts would be emitted.) Weather conditions, soil characteristics, and its momentary water content largely influence the extent of dust emission. Large volume of earth is needed to be moved for the construction of the power plant. According to our experience, in this case significant dust load may occur in the 500 m radius area of the construction works. In residential areas, taking into account their great distance (1100–1300 m), no significant extra dust load is expected from the construction works despite the fact that dust load is near the limit value in baseline condition.
- Road, railway and water transportation can be suitable for delivering construction materials to the site, and carrying away earth and wastes. Concerning air pollution, road transportation is critical, since by train and by ship a lot more goods can be transported with one turn. Main road No. 6 and M6 motorway are suitable for road transportation. Transportation related pollution load, considering the baseline and the excess loads, can be significant in the immediate vicinity of transportation routes. Due to the increased population (number of construction workers) traffic increase and extra traffic loads are expected in the inner city areas. Therefore, the excess immission of transportation related to residential areas should be calculated later on by taking the transportation routes and their baseline load into consideration.

In the lack of detailed data, our predictions currently are based on assumptions. The loads of construction works, the probable concentrations and the impact area of dust can be more precisely calculated with standardized procedures in the environmental impact assessment process when concrete base data are known.

3.3.3. Impacts related to the operation of the new units

During operation, emissions of conventional air pollutants of a nuclear power plant are both specifically and in absolute values minor compared to the emissions of power plants using other energy sources. The emissions arise from technology to a minimum extent and from transport to a more significant extent:

- The almost only sources of *technological emissions* of the new units are the diesel generators of the emergency power source and pumps. According to the data supply [26 – 31], 2–4 diesel generators of 4–7.5 MW thermal power is needed by each unit. In case of any types of units, the operational time of this equipment is not expected to reach the annual 50 hours, therefore no threshold value needs to be determined as regulated by paragraph 2.8.3. of Annex 7 of Decree 4/2011. (I. 14.) of the Ministry of Rural Development. However, the preparation of an air quality report is compulsory. Emissions are not expected to be higher in case of the modern equipment to be installed than the emissions of the current diesel generators. Thus according to the previous calculations, the impact area is a circle with a radius of 500–600 m around the place of emission. (If the operational time is more than 50 hours, then equipment capable of complying with the threshold value should be installed.)
- Sulphur dioxide emission of diesel generators is likely to be insignificant, if low sulphur diesel oil is used as required by the regulations. Employing catalytic converters can reduce the relatively higher nitrogen oxide emissions. The impact resulted by emissions from diesel generators are not expected to be significant taking the short operation time, the usually high emission point (chimney) and the distance to sensitive residential areas into consideration.

- Besides the air pollution of diesel generators, conventional air pollutants (e.g. formaldehyde) can be emitted during restarts after shutdowns for *maintenance and overhauls*. From formaldehyde carbon monoxide may be formed ($H_2CO \rightarrow CO$), if insulation gets heated, and ammonia can be emitted from steam generators during restarts. These gases will be ventilated and emitted through high chimneys. This type of technological emissions may occur once in every 0.5–2 years, and excess pollution is reduced to minimum values in a few (2–4) days. Because of the high emission place, the amounts just slightly influence the atmospheric concentrations, and their impact area is likely to remain within the site's immediate vicinity. At present no information is available on support plants (e.g. painting workshop).
- In the operation phase the *transportation of employees* will be the dominant impact factor. Operational staff for two units varies between 330 and 1000 according to data supply of the supplier [26 – 31]. So in the peak hour the necessary number of bus services is 10–30, and 70–200 cars are expected to arrive. According to our previous calculation, significant pollution from peak hour emissions is expected only in the immediate vicinity of roads, in a max. 25–50 m wide belt. Only a relatively small number of buildings to be protected is located within this belt (e.g. along main road No. 6 in Csámpa).

During the operation of the planned units, air pollution from the power plant will increase slightly in the direct and indirect impact area. The size of the impact area can be determined by propagation calculations, if concrete emission values are known.

3.3.4. Common impacts of nuclear facilities operated at the site

The currently operating nuclear power plant and the Interim Spent Fuel Storage (ISFS) are located within the air pollution impact area of the new units. After the construction of the new units, the three industrial facilities will be operating simultaneously in the same impact area until the currently operating units are shut down between 2032 and 2037. Concerning environmental impacts, this period seems to be critical, i.e. the most significant environmental impacts are expected then:

- Cumulation of conventional air pollutants emitted by the *technologies* of the three facilities is not expected since the emissions of the employed diesel generators will last for a few hours a month, and in case of maintenance works for a few days once in every half to two years. If the industrial facilities cooperate properly, these emissions can be scheduled in a way that the test of diesel generator and its unit's restart after maintenance is carried out in only one unit at the same time.
- During *transportations*, however, the cumulation of pollution is almost unavoidable. (Pollution in case of this impact factor can be mitigated, if shifts start at different times in the old and new reactor units.) Depending on the reactor type, the combined transportation traffic in peak hour is 75–95 bus services and 550–700 cars. The combined loads are detectable and are expected to be significant. It can be stated that significant load is expected to affect the immediate vicinity of the roads only, where immissions exceeding threshold values are expected to occur on occasions. The impact area is estimated to be in the 50–100 m wide belt along the roads. In this area the number of facilities to be protected is low.

3.3.5. Impacts of incidents and accidents

Incidents and accidents causing air quality deterioration occur due to fire or explosion. The estimated impact area of such breakdown is 1–3 km. Fire can take place in the following cases:

- Oil fire in case of breakdown of the oil system of turbines, the transformer, the oil system of support plants and cutouts,

- Breakdown of gas bottle store or gas bottle,
- Interim transportation of hazardous substances,
- Fire in the hazardous waste and industrial waste store.

Explosion is possible at tanks located in the hydrogen unit and at the nitrogen tanks. These impacts occur once, they may also have significant emissions, but if appropriate measures are taken, significant extra load on residential area will be unlikely.

3.4. Regional and local climate-meteorological characteristics

3.4.1. Description of the basic state

The regional and local climate-meteorological characteristics of the surroundings of the Paks site are summarized according to the data processing and analysis carried out by the Hungarian Meteorological Service (HMS) regarding the 30-year period between 1981 and 2010 [70]:

- The *average annual mean temperature* (1981–2010) at the station in Paks is 10.7 °C, which exceeds the national average. The hottest month of the region is July, while the coldest one is January. The average annual temperature range, which is the difference between the mean temperature of the hottest and coldest month, is 21.7 °C.
- Since 1951 the driest year in Paks was 1961 (285.9 mm), while the wettest year was 2010 (990.9 mm). The wettest month is June (72.3 mm) and it is followed by the two other summer months and May. We can observe a secondary maximum in November (54 mm). The driest month is March (31.7 mm), but there is usually little *precipitation* in January and February as well.
- Precipitation falls in the form of *snow* on an average of 30 days a year and continuous snow cover can be observed on an average of 29 days a year. The most snowy days were recorded in 1986 and 1996, while the most snow-covered days were observed in 1996. It is snowing the most frequently in January, but it is followed closely by February and December. The first snowfall can be usually expected from mid-November and the average date of the last snowfall is late-March. The average thickness of maximum snow cover is approx. 20 cm in the region, the thickest layer of snow was 53 cm, which was measured in November 1999.
- In the area of Paks there are an average of 27 *thunderstorms* a year, which is slightly above the national average (20–25 thunderstorms). During the examined period (1997–2010) the maximum number of thunderstorms observed a year was 36 (in 1998 and 1999). The thunderstorm season lasts from April to October, and the main season is the May-August period, when an average of 5–6 thunderstorms can be expected a month, but over the last years even 9–10 have been reported.
- The poorest month in sunlight is December, when the average monthly *sunshine duration* is 53 hours. In the May-September months an average of over 250 hours sunshine a month is typical. July is the most cloudless with nearly 300 hours sunshine.
- In the area of Paks the annual average sea level *pressure* is 1017.5 hPa. Its annual course is similar to the national course, the highest values are usually in January (1021.9 hPa) and the lowest ones occur in April (1014.1 hPa). The average air pressure of the summer half-year is lower than in case of the winter half-year.
- The actual *evaporation* (the amount of water really evaporating from the surface of the earth) is the lowest in the November-February period and it is the highest in the May-August period. The potential (possible) evaporation is the lowest in winter, but from spring to autumn it exceeds the actual evaporation by far, since then there is no adequate amount of water available to be evaporated.

- Of the *wind directions* on an annual basis the north-west (11.6%) and the north-northwest (11%) winds are the most common, and the southern direction occurs as a secondary maximum (8.1%) (*Figure 3.4.1-1.*). The summer half-year is dominated by the north-northwest direction (12.7%), and then it is followed by the north-west (12.2%) and the northern direction (8.9%), so the southern direction falls back to the fourth place (6.7%). In the winter half-year the prevailing wind direction is the north-west (10.8%), however, in this period the southern direction advances to second place (9.6%) and the third is the north-northwest (9.1%).
- The annual average wind speed was 1.9–2 m/s at the beginning of the examined period (1997–2010), then in recent years 1.6–1.7 m/s averages could be seen (downward trend). The highest wind speed values can be observed in March–April, while the lowest values are in the August–October period. Windless period occurs on average in 2.2% of the year, but there is a large fluctuation between the years. (0.3% in 1997 and 2002, 4.5% in 2007.) A windless period can be expected with the highest probability in August–October and with the lowest probability in March–April. 1.1–2 m/s winds blow the most often, they are followed by the 0.1–1 m/s and then by the 2.1–3 m/s range. The 5.1–6 m/s wind speeds occur in a smaller percentage, while wind speeds over 6 m/s can be registered very rarely.

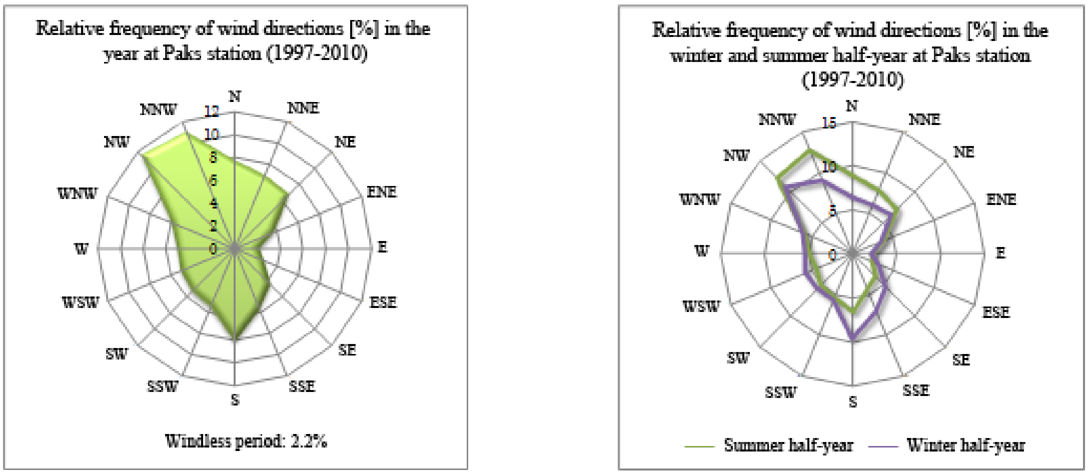


Figure 3.4.1-1. Relative frequency of wind directions [%] at the station at Paks between 1997 and 2010

The nuclear power plant is located to the south-east of Town of Paks, therefore pollution from the town is transported into the environment of the power plant by the very frequent north-western winds. Also frequent south-eastern winds carry pollution from the power plant towards the town. Emissions from the power plant spread towards the settlements on the other side of the river Danube (Dunaszentbenedek, Uszód) by the prevailing winds. The river Danube as a ventilation corridor dilutes and carries away local emissions.

In case of conventional air pollutants the town’s impact is dominant in the close vicinity of the power plant. The emission of conventional air pollutants of the power plant is minor. From main road No. 6 westerly winds carry pollutants emitted by traffic towards the power plant. Turbulent northerly and westerly winds promote the dilution of pollutants, but laminar southerly winds and calm periods favour the accumulation of air pollution.

The relief and the vegetation are major factors in ambient air pollution of the area. The area between the power plant and the town is flat; the relief does not obstruct the dilution and propagation of air pollution. During the construction of the power plant a forest buffer of significant size was planted. Its cleaning and filtering effect significantly contributes that air pollution caused by traffic is little in the site. The forest shelters the power plant from the air polluting effect of main road No. 6.

3.4.2. Impacts of the construction

The climatic effect as a result of the construction of new reactor units originates from “urban effect”[16]. It is caused by the changed temperature and humidity as a consequence of the increase of built-up areas. The existing power plant and the connecting facilities when being built already significantly had modified the character of the surface. The former agricultural arable land, the biologically active surfaces got built-up. It significantly modified e.g. the albedo[17] of the area, evaporation and biological activity as well.

As a consequence of the difference between the energy balance of the urban (here: built-up area) and the natural land surface, in urban areas the average temperature is higher than in the neighbouring areas. The degree of this difference can be relatively low (only couple of tenth of °C). In Budapest, for example, according to measurements, the difference in the annual mean temperature between the downtown and the outskirts (Pestlőrinc) is 1.2 °C (Szász-Tőkei, 1997.)

The two new units will be built on disturbed grassland, not on agricultural land or area of high biological activity. The size of the site affected by temporary or permanent built-up is a bit over 100 ha. Within this, built-up, paved and recultivated areas will be created instead of biologically active surfaces. In this way the unfavourable urban effect could partially be compensated. Planting protecting forest around the site can also have a balancing effect. The forest is useful not only from climatic aspects but also for screening other environmental loads (air pollution, noise) as well as for mitigating visual impacts.

It can be stated that the construction of the two new units and associated facilities is not expected to cause significant microclimatic impact.

3.4.3. Impacts related to the operation of the new units

Because of the existence and operation of the nuclear power plant the urban effect is needed to be examined. It is related to the heat load from fresh water cooling and – as it was above mentioned – it emerges in the environment of a built-up area. The first effect is generally characteristic of thermal power plants, while the second one is characteristic of any facilities involving extensive built-up area.

3.4.3.1. Impacts of heat load

In order to detect the mesoclimatic impact of current heat load, measurements were taken related to the meteorological parameters associated with heat load between 2002 and 2004, in course of the preparation for the environmental licensing of the existing units’ lifetime extension. The heat load of the nuclear power plant was only traceable next to the hot water channel. In case of the majority of measurements, the difference between the temperature values measured upstream and downstream of the hot water channel remained below 1 °C. At 200 m downstream of the hot water channel the effect of heat load was not clearly traceable. The monthly air humidity average values were higher than the values of the reference measurement point (1–3%) but it may be explained mainly by the proximity of the Danube. In case of situations that are cooler, brighter, vertically more stable than average, as well as in case of calm, anticyclonic situations, the differences were somewhat more significant, but they did not exceed 1.5 °C (mostly below 1 °C) and the 5% (usually below 3%) humidity difference.

The new units’ cooling would be executed by fresh water cooling, but water would be drained into the Danube at two points instead of the current one point. In this case, the heat load recipient is

[16] It is called urban effect, because it mostly occurs in cities.
[17] Albedo is a measure of the degree to which a surface reflects electromagnetic radiation (Earth’s average albedo: 39%, the fresh snow surface: 80–90%, grassland: 20–30%, forest: 5–10%).

partly directly the Danube, partly the air. The heat is transferred into the recipient, but only to the compliance level of temperature limits previously established for the Danube. Instead of the water amount currently used (100–110 m^3/s), the water amount used for fresh water cooling will be 172 m^3/s in case of the two new 1600 MW units and $\Delta t = 8$ °C, in the operational period of the new units (after the decommissioning of the existing units). Assuming a linear relationship between the amount of heat and the meteorological characteristics change, the temperature difference of 1 °C measured in the environment of the hot water channel will increase to 1.7 °C, while the relative humidity will increase from 1–3% to 1.7–5.1%. So the change of temperature in the environment of the hot water channel is still not significant, but the change of humidity is traceable according to our opinion.

3.4.3.2. Urban effect

The urban effect due to the significant built-up in the construction phase may increase further as a consequence of the operation of the facility (car movements, air pollution, heat emission etc.). The excess heat may intensify the conditions of rain shower formation. Surface distribution and the difference in heat balance from the neighbouring areas may cause modifications to local air convection resulting altered evaporation and air humidity conditions. There is also a negative feedback mechanism decreasing the urban effect, for example, more cloudiness, greater wind speed. Planting protecting forest or green surface with greater biological activity near the power plant can decrease the urban effect.

As a result of the operation of the new power plant and the couple of tenth of °C possible excess heat, no significant microclimatic impact is likely. Along hot water channels the increase of relative humidity may be traceable to a minimum extent.

3.4.4. Common impacts of nuclear facilities operated at the site

If both two sites operate with fresh water cooling, instead of the current 100–110 m^3/s, a total of max. 272 m^3/s water will be required. Assuming a linear change, in the environment of the hot water channel the currently detectable temperature difference of 1°C [37] will increase to 2.7 °C, while relative humidity will increase from 1–3% [37] to 2.7–8.1%. This is a significant, well-detectable change in case of both factors.

In case of the joint operation of all facilities, major change in the urban effect is not expected compared to the present state, since the majority of built-up and paved surfaces are not new, but already existing facilities.

3.5. Surface waters

3.5.1. Description of the basic state

The river Danube is a determinant stream of both the direct environment of Paks Nuclear Power Plant and the wider area (*Figure M-8.* of the *Appendix*). Cooling water supply of the nuclear power plant is provided through the cold water channel branching out of the Danube at the 1526.6 rkm. Water returns into the main bed primarily through the hot water channel, causing a significant direct environmental impact (mainly thermal loading).

The creek of Csámpa, which is located 2 km to the west from the site in the right-side river basin of the Danube, flows into the Paks-Fadd main channel. During last years the creek of Csámpa dried up for most of the year. Therefore, through a diversion implemented in 1996, water is regularly transmitted from the office building air-conditioning equipment of the power plant into the Paks-Fadd main channel in order to provide water supplementation to the main channel and, through it, to the system of Fadd-Tolna-Bogyiszló dead branches. Surface waters of the left side of the Danube do not belong to the direct impact area of the power plant.

The Kondor Lake located directly to the south-east of the power plant is also a rest of the formerly wide-ranging system of dead branches of the Dunamenti Plain. At 1 km to the east-southeast of the power plant, within the area surrounded by the Kondor Lake, the hot water channel and the Danube bed, angling lakes have been created from side burrows used during construction of the power plant, the total area of these lakes is 75 ha. Water supplementation to the Kondor Lake and the angling lakes is ensured by means of periodical supplying of used service water of the power plant. The angling lakes have a depth of a few meters, their water is connected with the Danube through the local sedimentary set. At 5 km to the north-west of the power plant, the fishponds of Biritó were previously created by means of submerging the creek of Csámpa. However, since drying of the creek occurred with increasing frequency, the system of lakes practically ceased for today.

According to Appendix 2 of the Ministry of Environment and Water Decree 28/2004. (XII. 25.) determining the water quality-protection areal categories of surface waters, surface waters of environment of the site, both the Danube-section concerned and the other flowing and dead waters, belong to the generally protected category.

In accordance with the European Parliament and Council Directive 2000/60/EC (the Water Framework Directive – WFD), the River Basin Management Plan of Hungary, which separates 42 planning subunits, was issued as appendix of the Government Decree 1042/2012. (II. 23.). The environment of Paks Nuclear Power Plant belongs to the 1-11 Sió river basin planning subunit, and is located at the Eastern margin of it.

The Water Framework Directive originally prescribes completion of the environmental target condition by the year of 2015, however, but in consequence of disproportionately high economic loads and financing problems, the good condition has to be reached by 2021.

General features of the Danube-section concerned

There are 32 bends having varying curves on the river section with a length of 127 km between Dunaföldvár and the southern country border. The average width of the mean-stage river bed is 400–600 m. The stream gradient is 6–8 cm/km until Fajsz, and 4–5 cm/km after that. Except the right-side elevated river banks between Dunaföldvár–Bölcske, Paks and Dunaszekcső–Bár, the river is accompanied by stop banks at both sides. At the Paks Nuclear Power Plant (1527 rkm) the width of the mean-stage river bed is 430 m, while the width of the high-water river bed is 1.1–1.2 km

According to the regulation plans, elaborated at the end of the 1970s, the river section between Dunaföldvár and the southern country border can be considered as partly regulated. As a result of this the mean-stage regulation stabilized the main bed. However, both the increase of speed due to narrowing and the increase of stream gradient due to shortening enhance the debris-transportation capability of the river, therefore as a result of both intervention types a bed deepening process started. In order to stop the water level lowering process, during the last period of 20 years the river-training structures were constructed with a lower level and a modified alignment survey.

To the north of the water-intake installation of the nuclear power plant, immediately upstream of the town of Paks, the Danube turns from western direction to southern direction with a large bend. Consequently, the current line swings towards the right-side bank. Therefore, this concave bank is protected by a stone coverage against side erosion along and downstream of the bank line next to the town. In course of the stabilization of the mean-stage bed of the river, on the convex side, between 1530–1533 rkm, groynes were created per section of 600–750 m. Along the left-side bank formation of fringing reefs is also currently in progress up to 1525.5 rkm.

At the 1526 rkm the current line moves next to the left-side bank. Downstream of the hot water channel of the nuclear power plant, where the right-side bank foreshore gradually widens, there is a cay with a length of approx. 2 km next to the right-side bank. This reef-formation, which is disadvantageous from the point of view of river navigation, was regulated by groynes already several decades ago so that it is possible for the embayment to be continuously naturally filled up. Simultaneously with the right-side bank protection, at the opposite bank, at Uszód, short groynes were constructed per a distance of 400 m. By means of them also the line of the left-side bank was stabilized.

River regime of the Danube

The stream flow of the Danube is always mainly determined by thawing of snow and precipitation circumstances in the Alps. Its floods typically connect to thawing of snow at early spring, as well as to precipitation maximum and thawing of glaciers at the beginning of summer. Long low-water periods mainly occur between November and February.

For lack of more significant tributary, the average river regime of the Danube barely changes from Dunaújváros to Mohács. Measured between 1960 and 1989, the minimum daily stream flow was 780 m^3/s; the average daily stream flow of many years was 2350 m^3/s; the maximum daily stream flow was 8870 m^3/s.

In the section of power plant at 1527 rkm the change in water level can be featured on the basis of the measuring station of Paks (1531.3 rkm), which has been operated since 1st of January 1868. The height of “0” point of the water post is 85.38 maBsl. The lowest water level measured since the beginning of observations is –58 cm (84.80 maBsl), which occurred on 3rd of December 2011. The highest ice-free water level is +872 cm (94.10 maBsl), which was observed on 19th of June 1965. The highest icy water level was observed on 27th of February 1876 with a water stage of +1006 cm (95.44 maBsl). The annual absolute change in water level primarily depends on the summit level of floods: it is usually 6–7 m, but during years with extreme river regime it approximates the value of 9 m.

During the last 10 years the frequency of both extreme low stages and high stages increased. Between 2003 and 2009 a water stage of –17 cm (85.21 maBsl) or lower than that occurred in every year. However, also in 2002, 2006 and 2010 there was a flood wave, which approximated the earlier highest water level and peaked at a level between +836 and +861 (reaching or exceeding the value of 93.74 maBsl).

The measuring station of Paks is simultaneously an authoritative flood gauge. According to Amendment 2010 of the Ministry of Transport, Communication and Water Management Decree 10/1997. (VII. 17.) on flood control and land-drainage operations, at the right-side bank of the Danube the protection grade for the flood control section of Siótorok–Paks has to be determined on the basis of data of the water post at Paks. The alarm level of the currently valid Grade III readiness is higher than the highest ice-free water level observed so far at the right-side bank. However, in case of the left-side bank embankment opposite to the power plant, the decree requires significantly lower readiness levels for the flood control section of Uszód–Solt. The abovementioned facts well show that the two banks are endangered by flood to different extent.

According to the Ministry of Environment and Water Decree 11/2010. (IV. 28.) on authoritative flood level of rivers, at the Danube-section concerned the height of flood-control works has to be determined so that it has to be 1.0 meter higher than the authoritative flood level specified in the Appendix of the decree. The authoritative flood level for the section of 1527.0 rkm of the power plant is currently 94.05 maBsl

In the section of the nuclear power plant (at 1527 rkm) the water levels are 0.3–0.6 m lower than the level read at the measuring station of Paks in accordance with the different grade circumstances of periods of rising and lowering of water level.

The filling level created at the site of the nuclear power plant is 97.00 maBsl. It is almost 3.0 m higher than the authoritative flood level and approx. 1.4 m higher than the level of ice-free flood with a recurrence period of 10000 years (with a calculated occurrence probability of 0.01%). The filling level is higher than the crest of 96.60 maBsl of the flood-control dike at the left-side bank of the Danube in the section of the nuclear power plant. Considering all of the abovementioned facts, the site of the nuclear power plant can be considered as safe from the point of view of flood control. Under current flowing circumstances, it can be excluded that such a flood wave occurs, which would cause direct pollution of the Danube by means of flooding the site of the nuclear power plant.

In order to ensure the safe operation of Paks Nuclear Power Plant it is essential to provide suitable fresh water cooling. During design of the plant the lowest water level of +27 cm (85.65 maBsl) observed till that time at the measuring station of Paks was considered as a basis, and the authoritative low stage level for the section of the plant was specified as 85.24 maBsl. In accordance with it, the value of 84.74 maBsl was prescribed for the original minimal suction side level of cooling water pumps of the plant. However, already in the year of commissioning of Unit 1, in autumn 1983, a water stage of –27 cm was observed at the water post of Paks, which was lower than the earlier lowest water level, and resulted in a water level of 84.77 maBsl at the branch-off point of the cold water channel.

On the basis of assessments performed in that time it was unambiguous that lowering of low stage levels was caused by the industrial-aimed gravel dredging works executed in the bed of the Danube to an extent significantly exceeding the natural supplementation, therefore these works were forbidden.

The low stage stream flows were detected under steadily decreasing water level in the last 25 years, which is the consequence of incision of the low stage bed. [71], [72].

The cooling water demand of the Paks Nuclear Power Plant is provided through the cold water channel branching out of the Danube at the 1526.6 rkm. The quantity of fresh water intake approved by the authority is currently 98 m^3/s, 2.5 billion m^3/year. The annual quantity of fresh water actually used was 2.1–2.4 billion m^3 for the period of 1997–2008. Under normal operation of the four units the water quantity necessary to cool the turbine-condensers is 100–110 m^3/s. The cooling water demand exceeding the fresh water quantity approved to be taken out is ensured by means of recirculation of water within the technological system.

The fresh water taken out is 4–4.5% of the mean stage stream flow of the Danube, while almost 14% of the average lowest Danubian stream flow of 700 m^3/s. Almost full quantity of the used cooling water is returned into the Danube through the baffle structure of the hot water channel about 450 m downstream of the water intake point. Consequently, the water use of the plant does not cause significant change in the quantity, however recycle of the used cooling water affects the flowing and bed circumstances, the water quality of the Danube, the temperature of water and the ecological conditions.

Flowing and bed circumstances of the Danube

Detailed hydrometric[18] survey in the environment of Paks Nuclear Power Plant was performed several times. The first one was performed in 1967 [73], then the next one in 1983 at a stream flow of 2900 m^3/s, when the quantity of cooling water taken was 55 m^3/s. In 2003 the measurements were performed at a stream flow of 1600 m^3/s, and the quantity of cooling water taken was nominally 110 m^3/s. In the range of mean stage the effect of the hot water tail was lower to the flowing area, the current line ran along the right-side of the bed even at 1525.0 rkm. In case of lower stream flow, due to the direction-deflecting effect of the groynes, the current line already runs in the left-side area of the bed at 1525.0 rkm.

In the region of the nuclear power plant the average depth of the Danube bed is 4 m during low stage level, while 5–6 m in the current line. The material of the bed mainly consists of gravel and sand and sandy gravel.

General deepening of the low stage bed stopped in the narrower environment of the nuclear power plant and it can be considered as relatively stable. However, in consequence of a significant

[18] Hydrometry: discipline dealing with the measurement of rivers and lakes' important technical characteristics (e.g. flow velocity).

decrease in supplementation of bed load, the Danube section concerned is deficient in debris, therefore the current sensitive balanced situation may easily break up.

The increased water velocity and turbulence resulted in significant deepening of the bed downstream of mouth of the hot water channel (*Figure M-9.* of the *Appendix*). However, the height of the fringing reef along the right-side bank (reef of Uszód) increased, permanent vegetation appeared on its surface and deposition of fine-grained alluvial covering sedimentary started over the gravel and sand. The fact that a thin long fringing reef started to develop along the left-side bank, between 1525.6 and 1526.1 rkms in the last five years can also be explained with the deepening of the low stage bed.

Water quality of the Danube

Owing to the fact that the environmental protection regulation becomes more and more rigorous, as a result of significant decrease in the industrial and communal sewage loading, water quality of the Danube continuously improves in recent decades. *Figure M-10.* of the *Appendix* shows, as a function of time, the annual values with 90% durability of some typical water quality parameters measured at water quality sampling network points of the Danube-section between Dunaföldvár and Hercegszántó. As it visible, in the period between 1979 and 2004 the change in time is much more significant than the change in concentration according to streamline of the tested parameters.

Water quality of the Danube within the area of Paks is currently classified into the water quality categories of I–II (excellent–good) according to the standard MSZ 12749:1994 on the basis of the indexes of oxygen regime and of the organic-material content, while on the basis of the plant nutrient content into the water quality categories of II–III (good–tolerable). With respect to organic and inorganic micro-polluting materials, the water quality is currently classified into the categories of I–II on the basis of anionic detergents and toxic metals concentration, into the categories of II–III on the basis of phenols, while, in spite of the significant improvement, into the category of IV (polluted) on the basis of petroleum oil and its products.

It is generally true that the water quality is not worse at the sampling places downstream of the nuclear power plant (Fajsz, Baja, Mohács, Hercegszántó) than at one upstream of it (Dunaföldvár). Consequently, water quality of the Danube does not change considerably due to used water discharge of the nuclear power plant.

Water management and water quality examinations for the water systems of Paks Nuclear Power Plant have been performed since 1983 [74]. Within the frame of the onsite monitoring the water quality of the Danube is examined upstream of the branch-off point of the cold water channel at 1527.0 rkm, as well as downstream of the mouth of the hot water channel at 1526.0 rkm.

Conclusions drawn on the basis of water examination performed by the sampling network stations were confirmed by these samplings: impact of used waters of the nuclear power plant along the longitudinal section of the Danube could primarily be detected with respect to the water temperature and the indexes of oxygen regime, as well as to certain micro-pollutants, petroleum fractions and the components typical to the household sewage. However, the concentration of pollutions exceeded to a small extent only the average value typical for the Danube-water.

A communal sewage quantity of 240–280 thousand m^3 is annually generated in the nuclear power plant. The plant's own sewage treatment works operate with a technology of total oxidation, activated-sludge, and its capacity is 1870 m^3/day (657 thousand m^3/year). The treated sewage is directed via a pipeline into the hot water channel, to the section upstream of the baffle structure, where, mixing with the used cooling water, returns into the Danube with several thousand times dilution.

The water taken from the Danube is used not only as cooling water, but as industrial make-up water, as well. A desalinated water quantity of approx. 1 million m^3 is annually produced in the nuclear power plant by means of ion exchange water treatment. During this process an industrial waste water quantity of 140–160 thousand m^3 is generated annually (acidic and alkaline pollution), neutralization and sedimentation of which is performed in sludge ponds of 10000 m^3 in the area between the cold water channel and the hot water channel. Water quality and discharge of these ponds are regularly subject to operating and regulatory control. Water is discharged from these ponds via the collecting pipeline of treated communal sewages with an inflow upstream of the baffle structure of the hot water channel.

Water temperature values of Danube

The temperature of the Danube water is regularly measured, nearest to the site, in the water post section at the boat station of Paks at the 1531.3 rkm. The highest water temperature value was 25.2 °C during the years before the construction of the nuclear power plant (8th of August, 1971). During the period of operation the highest value was measured in 2006 (26.7 °C), and before that time a value of 25.9 °C was detected in the summer of 1994 and 2003. *Figure M-11.* of the *Appendix* shows the annual water temperature values of the Danube for the period of 1990–2009.

According to section (1) of § 10 in the Ministry of Environment Decree 15/2001. (VI. 6.) on radioactive releases into air and water during the use of nuclear energy and about their monitoring: the difference between the temperature of water discharged from the nuclear power plant and the temperature of the receiving water (ΔT) is not allowed to be more than 11 °C, or more than 14 °C in case of a receiving water temperature of less than +4 °C; and the receiving water temperature is not allowed to be more than 30 °C (T_{max}) at any point of the section being at a distance of 500 m calculated in streamline from the discharge point.

The water temperature of cooling water channels is hourly measured within the operation monitoring system of the Paks Nuclear Power Plant. The filtered water lifted out of the cold water channel, after passing through the technological systems, gets back into the Danube with a temperature of 7–9 °C (11–12 °C during winter months) higher than the actual Danube-water temperature.

Examination of collective occurrence probability and durability of water temperatures and stream flows showed that two authoritative situations have to be considered: one of them can be featured with the highest water temperature in summer, and the other with the lowest stream flow in autumn. In summer, when water temperature of the Danube exceeds the value of 24 °C, complying with the limit for the maximum temperature (T_{max}) is primarily authoritative. The most critical is the low stage period occurring in summer due to the durably warm and dry, canicular weather. During these periods the nuclear power plant took measures in order to ensure water quality protection, providing compliance with temperature limits. In the autumn-winter low stage period, when the relative thermal loading is significant due to low stream flow of the river, complying with the limit for the temperature difference (ΔT) shall be primarily ensured.

In order to examine mixing of warmed cooling water in the Danube, six thermal imaging measurements were performed during the period of 1983–2005 [75] (*Figure M-12.* of the *Appendix*). According to the images taken, independently of stream flow and water temperature of the Danube, the heat tail on the section of 1–2 km downstream of the inflow is relatively homogeneous and, excluding the inflow turbulence, mixing hardly occurs. The heat tail goes touching the right-side bank and also enters into water areas between reefs. Mixing of the heat tail greatly occurs on the section of 4–5 km calculated from the inflow point, and it is not possible to observe it on the basis of the surface water temperature in a distance of 10 km.

In order to examine the mixing occurring under the surface in the dept and temperature differences in the depth, the temperature distribution according to depth was examined in 8 sections between the 1527–1499 rkms of the Danube [76]. On the basis of their measurements, the water temperature at the bridge of Szekszárd, that is 27 km downstream of the inflow point, is 1.1–1.3 °C higher in the full depth section of the Danube than the left-side bank water body. However, this difference is not relevant for the final receptors (certain species of aquatic wildlife).

On the river section concerned by the heat tail, the increased water temperature locally accelerates organic-matter decomposition in the river, which involves increasing oxygen consumption, de-oxidation. Due to inflow of the hot water all biomasses occurring in the Danube are higher than in the upper sections. The aquatic wildlife of the section of a few kilometres downstream of the inflow point belongs to the richest species composition ones within the area. In consequence of the higher temperature the density of the fish stock exceeds the average value, particularly in the winter months. Upon the whole it can be stated that the water chemistry and hydro-biological impacts of the hot water inflow comply with the regulatory requirements and exceeding of the water quality limits did not occur at all.

The mixing process of warmed water was examined with help of numerical models [77]. On the basis of calculation results they made recommendations on development of the monitoring and the operation management. They assessed the possible impact of change in climate by means of analysing potential changes in climate pertaining to the year of 2050. It was stated that the background Danubian water temperatures of more than 24–25 °C, which are critical from the point of view of complying with the environmental protection requirement for the reference section at a distance of 500 m downstream of the inflow point, currently on an average occur for a period of 2–5 days annually to a maximum. Under the supposed scenario of change in climate, the durability of critical situations may increase almost threefold, a period of 8–16 days, however uncertainty of these estimations is significant.

3.5.2. Impacts of the construction

During the implementation and construction of the planned new units – beyond impact of the units currently operated, the surplus load concerning surface water bodies was examined from the point of view of the following direct and indirect impacts: provision, treatment and removal of service water and cooling water; treatment and removal of communal sewage; treatment, removal of water taken out during foundation works; treatment, removal of waste water and other sewage; interventions concerning bed and bank of the Danube, surface water pollution occurring in consequence of dust emission.

3.5.2.1. Water intake for domestic water and service water

Service water demand

The service water demands are provided by means of water intake from the Danube. It can be assumed that large quantity ion-exchanged water will be needed in the stage of test operation, and it will be provided from the make-up water plant to be constructed for the new units. The precise water demand of each construction process is not yet known in the current phase of the design. On the basis of data provided by the supplier of the different unit types, water demands vary between 400 m^3/day and 1300 m^3/day, the average water demand is 1000 m^3/day [27-30].

Provision of fire water

Fire water is provided by means of water intake from the Danube, from bank-filtered wells, also in case of operation of the new units. The maximum fire water demand can be estimated as 47 l/s, while the average demand per month can be estimated as 1000 m^3/month [26], [27].

3.5.2.2. Sewage discharge

The impact originated from water draining after treatment during construction concerns the Danube. Also for the new units it is necessary to comply with the discharge limit values specified in Appendix 2, titled as “Discharge limit values determined according to water quality protection areal categories, pertaining to direct drainage of sewages into receiving water" of the Ministry of Environment and Water Decree 28/2004. (XII. 25.).

Foundation engineering dewatering

Water generated during dewatering of the building pit, due to its quality, high sediment content, as well as possible oily pollution, demands a continuous control. Beyond the possibility of desiccation, it can be drained into the Danube after, as demanded, treatment, sedimentation, oil separation, with consideration of the limit values according to Appendix 2 of the Ministry of Environment and Water Decree 28/2004. (XII. 25.). The disadvantageous impacts can be restricted for the period of foundation works and, with due foresight, as well as under compliance with the discharge limit values, can be decreased.

Rainwater

In order to drain the rain falling onto the construction and operating area of the new nuclear power plant, as well as the waters originated from thawed snow, a system for draining and treating rainwater will be established. The cold water and hot water channels may be the receiving water of collected waters, after oil separation. At the beginning of construction works, independently of unit type, it is necessary to create a temporary rainwater draining system to be developed during progression of works, in accordance with their demands. The rainwater may contain, particularly during the phase of construction, debris, oil and pollutants originated from air, therefore the appropriate control, treatment has to be continued to ensure before draining it into the receiving water.

Communal sewage

Construction of the new units involves a significant labour force demand, hereby increases the quantity of communal sewage generated, therefore, before start of works, a new sewage purification plant will be built in order to treat communal sewage originated at the construction area. The receiving water of the purified sewage, through the hot water channel, is the Danube. [78]

The labourer number can be significantly different in the different phases of construction. According to data provided by the suppliers, it varies between 1200–7000 people. Calculating by the value of 140 l/day/person the daily communal sewage discharge is 168–980 m^3/day [26 – 30].

By complying with the limit values, the sewage discharge does not change significantly the quality of the receiving Danube, its impact remains within 5 km.

3.5.2.3. Other impacts

The nuclear power plant has a river harbour established on the cold water channel. By means of establishing a temporary harbour at the Danube bank, it is possible to reduce impacts caused by road transport.

In case of implementation of a cooling system with two-stage once-through fresh water cooling, water supply of the new cold water channel with suspended valley ensuring cooling water supply of the new units, is planned to be provided by means of establishing a pumping station at the bank of Danube. Construction of the pumping structure has a direct impact on water quality and hydrodynamic condition of the Danube. Periodical impacts of the construction directly concern both of the Danube bank and the Danube bed, a detailed examination is required for morphologic, water quality changes in flowing circumstances.

3.5.2.4. Indirect pollution impacts

Deposition of dust generated during construction works onto surface waters has to be examined as an indirect impact. The dusting can be minimized, if the area is wetted during dry periods, the main transport roads are covered with a temporary (dust-laying) surface and minimization of dusting originated from cargo of transporting vehicles is ensured for example, so that it is kept in constant earth-damp condition or it is covered. Requirements specified in the Government Decree 306/2010. (XII. 23.) on protection of air have to be complied with during the periods of design, construction, operation and decommissioning.

In order to prevent ground, ground water and surface water pollution caused by hydrocarbon products possibly escaping from machines, it is important to select appropriate machines and continuously maintain them. Repair/maintenance workshop, filling station, park of tanks, drum oil storage shall be constructed for the machines. In case of these facilities it is particularly important to minimize drip and leakage.

3.5.3. Impacts related to the operation of the new units

3.5.3.1. Provision of cooling water

During the examination of cooling options [21] in case of the use of fresh water cooling, water demands shown in *Table 2.4.2-1.* of *Subchapter 2.4.2.* were considered. The Danubian pumping structure applied in the two-stage water intake supplies the new cold water channel with 132–172 m^3/s water. The issue of the pumping station's impact on speed conditions of the Danube, water traffic and local morphological conditions is a local and long-term issue to be examined, as water intake is executed near the current line pressed to the right-side bank. Water demand in case of the operation of the new units is approx. 25% of the average lowest Danubian stream flow, and approx. 7.5% of the medium stream flow. Impact area of the cooling water intake is the Danube section between the cold water and hot water channel.

3.5.3.2. Other service water intake

According to information specified by the suppliers, during normal operation the average daily ion exchanged water demand is 430 m^3/day, the maximum value is 3000 m^3/day. The expected minimum and maximum value of untreated water demand is 315 m^3/day and 4000 m^3/day [26], [28], [29], [30].

The fire water is provided from the bank-filtered wells in case of operation of the new units, as well. The maximum fire water demand can be estimated as 20–47 l/s, the annual average demand can be estimated as 3000 m^3/year [26], [27], [29].

3.5.3.3. Discharge of treated sewage

During operation of the plant, sewage is generated as result of the following processes: water treatment, water softening; blow-down of steam generator; cleaning, regeneration of condensate-treatment system; discharge of oil-polluted (and pre-terated) and other service sewage, as well as communal sewage.

Beyond treated sewages, generation of used waters which do not demand treatment shall also be considered. Sewages requiring treatment shall be collected and they are solely allowed to be drained into the Danube via the sewage-purification plant, which was already built during the period of construction. The quality of sewage discharged has to comply with the limit values specified in the Ministry of Environment and Water Decree 28/2004. (XII. 25.) on the limit values for discharges of water-pollutant materials and certain rules of their application.

Communal sewage

After the prominently high communal sewage discharge of the construction, generation of essentially less sewage has to be considered in the operation phase. The estimated amount of communal sewage discharge can be expected between 50 m^3/day and 160 m^3/day, the average value is 100 m^3/day.

Other sewage discharges

In addition to discharge of communal sewage, sewages are generated during water treatment (blow-down of sedimentation basin, regeneration of ion-exchanger, backwashing of filters), cleaning of buildings and halls, as well as other technological procedures. Sewages possibly polluted with oil are allowed to be drained via oil and mud collector into the channel system of the site.

Drainage of rainwater

Although rainwater may contain debris, oil and pollutants deposited from air particularly in the period of construction, appropriate inspection, treatment before drainage into the receiving water shall be provided in the operation phase, as well. During establishment of the rainwater-draining system, oil filters shall be installed and rainwater storage basins shall be constructed in order to ensure that it is possible to retain the water quantity collected even in case of an intensive precipitation.

Water supplementation of the Kondor Lake and the angling lakes is ensured by means of periodical draining of used service water of the nuclear power plant. It can also be provided during operation of the new units under complying with the discharge limit values specified in Appendix 2 of the Ministry of Environment and Water Decree 28/2004. (XII. 25.) on discharge limit values (determined according to water quality protection areal categories) for direct draining of sewages into receiving water.

The Danubian impact area of sewage discharge originating from rainwater and other waste waters remains within approx. 5 km. It shall be examined hereinafter by mixing model whether the water quality class will change and to determine its exact impact area.

3.5.3.4. Discharge of warmed-up cooling water

In the fresh water cooling system, the warmed-up cooling water is returned into the Danube and it transfers its heat content directly to the water of the river. For the intensive mixing of cooling water warmed-up during the joint operation of the old and new nuclear power plant units, a new hot water channel section will be constructed, i.e. hot water is planned to be drained at two inflow points.

According to the currently valid regulations, using water of the Danube for cooling is limited regarding the recirculation of used cooling water and the resulting thermal load. The following 2 decrees are normative: Government Decree 220/2004. (VII. 21.) on rules of protection of surface water quality and Ministry of Environment and Water Decree 28/2004. (XII. 25.) on the limit values for discharges of water-pollutant materials and certain rules of their application. Thermal load of Paks Nuclear Power Plant is currently regulated by Ministry of Environment Decree 15/2001. (VI. 6.) on radioactive emissions into air and water in course of the use of nuclear energy and their monitoring. This decree prescribes (a) the temperature difference between the water to be discharged and the receiving water – which is also currently monitored by MVM Paks Nuclear Power Plant Ltd. – and (b) the maximum temperature limit value of 30 °C in the section being at a distance of 500 m calculated in streamline from the discharge point. [79]

If the Danube water temperature is high, additional technical measures (mixing with cold water, not operating the units at full capacity) are required to be taken to comply with the discharge limit.

In the receiving watercourse (the Danube, 1526.2–1510 rkm), water temperature, induced by the inflow of hot water, water depth integrated and averaged, calculations were performed according to the Directive *MI-10-298-85 – Determination of the spread of pollutants in watercourses*. Our calculations can only provide an estimate for temperature distribution, assuming that the discharged water's maximum temperature is 30 °C, the average water speed is 1.1 m/s and the average water depth is 4.5 m:

(1) In case of 2×1200 MW units, at approx. 4.5 km from the hot water channel, in case of 2×1600 MW units, at approx. 8.5 km, increment of temperature caused by inflows decreases below 1 °C.

(2) Complete transverse mixing of heat tails occurs at approx. 30 km away from the inflows.

Impacts and impact area of the new units can be estimated on the basis of impact assessments, field measurements, numerical models and laboratory measurements executed for the currently operating units [37]. Impact area of the thermal load caused by the operation of the new units is approx. 4.5–8.5 km.

3.5.3.5. Assessment of impacts on surface waters in accordance with Water Framework Directive (WFD)

Based on the River Basin Management Plan of Hungary (RBMP), the following water bodies can be separated in the environment of Paks Nuclear Power Plant: the Danube, creek of Csámpa, Paks-Fadd main channel, Faddi-Holt-Duna (dead branch of the Danube), Paks Angling Clubs ponds and Szelidi Lake nature conservation area belonging to Kiskunság National Park.

In terms of the inflow of industrial and communal sewage and cooling water, operation of the new units may have an impact on reaching the environmental goals set for the water of the Danube. In case of the inflow of industrial and communal sewage in quality according to the regulations, it should be examined whether the discharge under construction and normal operation will cause the deterioration of the water quality category.

The technical measures program of the RBMP includes measures related to the point source discharges into surface waters. The RBMP formulates only expectations, it does not determine the control cross-section of discharged hot water temperature measurement. In case of the Danube, the discharged hot water temperature is T_{max} = 30 °C; the temperature difference is ΔT_{max} = 10–12 °C, if the water temperature of the Danube is below 4 °C, and ΔT_{max} = 5–8 °C, if the water temperature of the Danube is over 4 °C. The temperature difference is ΔT = 3 °C after total mixing. With the knowledge of planned development parameters, these values are met.

In case of creek of Csámpa, Paks-Fadd main channel, Faddi-Holt-Duna, Paks Angling Clubs ponds and Szelidi Lake, implementation and operation of the new units has no significant impact on the measures specified in the RBMP.

3.5.4. Common impacts of nuclear facilities operated at the site

For cooling the four units of the existing power plant, water of 100–110 m^3/s (max. 120 m^3/s) is taken from the Danube. The cooling water demand of the new units, depending on their capacity, is added to this water amount. The combined cooling water demand of the existing and new units is maximum 292 m^3/s, which is approx. 42% of the average lowest Danubian stream flow (700 m^3/s), and approx. 12.5% of the medium stream flow.

In the existing power plant 240–280 thousand m^3 communal sewage is generated annually, which is treated in the power plant's own 1870 m^3/day (657 thousand m^3/year) capacity sewage treatment works. Quality of the sewage discharged from both the existing and the new power plant should comply with the limits according to Ministry of Environment and Water Decree 28/2004. (XII. 25.).

In case of the joint operation of the old and new nuclear power plant units, a total of maximum 292 m^3/s warmed-up cooling water is drained into the Danube from the existing, as well as the new hot water channel section, which will be constructed for more intensive mixing. On the basis of the water temperature distribution calculation described in *Subchapter 3.5.3.4.* – water depth integrated and averaged calculation of distribution of water temperature induced by the inflow of hot water in the receiving watercourse (the Danube, 1526.2–1510 rkm) – the following observations can be made:

(1) In case of the operating units and the 2×1200 MW new units, at approx. 20 km from the existing hot water channel, in case of 2×1600 MW units, at approx. 25 km, increment of temperature caused by inflows decreases below 1 °C.
(2) Complete transverse mixing of heat tails occurs at approx. 30 km away from the inflows.

The cooling water intake from the Danube is significant considering the common water demand of the existing and new units. If fresh water cooling is taken into account in case of both the existing and new power plant, the impact area of the combined thermal load is approx. 18–24 km.

3.5.5. Impacts of incidents and accidents

During the environmental impact assessment of incidents and accidents involving non-radioactive pollution the amount of stored liquid hazardous materials should be taken into account. Due to there is only a small amount of ammonium chloride, lithium hydroxide, sodium molybdate, sodium bromide, polyphosphates / orthophosphates / phosphoric acid, zinc acetate, and ethylene / propylene glycol stored within the building, therefore, they do not mean a significant risk to surface waters even in case of a possible accident.

Except diesel oil, the materials are stored in the turbine building, so their spill does not affect any surface water bodies. Diesel oil will be supposedly stored besides the diesel generators, therefore, a possible oil spill into surface water should be examined in detail. The impact of oil contamination largely depends on the speed of the localization of contamination and the mitigatory actions. There are different separation and collection techniques for mitigation: baffle, floating baffle and separator.

If the diesel oil stored at the site of the nuclear power plant gets into subsurface environment, it may affect the surface water bodies as well. The large amount of diesel oil discharged to the surface forms a circular lens reaching the ground water. Groups of hydrocarbon compounds leaching from the oil lens may reach the cold water channel and the Danube as well. Its detailed examination can be carried out by hydrodynamic transport model.

If the communal sewage treatment system does not operate properly, untreated sewage may cause pollution by entering into the Danube. Due to leaching, particularly during wet period, high concentration of suspended matter, conventional communal organic matter, nutrients, various toxic substances and coli bacteria may get from the sewage treatment plant into the recipient.

In case of incidents, it is the task of the cooling system to remove the residual heat released after the shut-down of units, which gradually decreases after shut-down. In case of the breakdown of units, the thermal load caused by warmed-up cooling water returned into the Danube will remain below the load possible in normal operation.

3.6. Subsurface waters

3.6.1. Description of the basic state

In the investment area the average ground water level is at a depth of 7–8 m, the flowing direction is W-E in case of average water stage. The extent of average ground water level fluctuation – depending on the distance from the Danube – is 3.0–6.5 m.

The ground water level and ground water regime is affected by the following: natural impacts (rainfall quantity, flow from background, water level of the Danube), operation of artificial facilities (channels, reservoirs), draining of rainwater (belt canal), the extent until the area is filled and public utilities network (e.g. water pipe and drainage failures). Chemical composition of ground water is calcium hydrogen carbonate.

Conventional environmental pollution concerning the place of the future power plant units was solely revealed on the deposit of building rubbish of the existing units [80]. Traces of periodical ammonium-, nitrate-, sulphate-, TPH- and zinc pollution were only detected in ground water. Since the pollution did not endanger the living environment, therefore it was not necessary to apply a damage clearance intervention. Recultivation of the deposit was completed in 2004.

3.6.2. Impacts of the construction

Impacts of dewatering of foundation building pits on ground water

Ground water's level, flowing direction and speed are all affected by the dewatering of foundation building pits. The great extent decrease of ground water level caused by dewatering is likely to be observed only in the immediate vicinity of the extended area, and its duration is limited. After the completion of dewatering, it returns to the equilibrium state. The impact area extends towards the east until the line of the Danube. Hydraulic modeling should be done to refine the impact area.

Creation of building pits is performed in two phases from the point of view of dewatering. Deepening of the building pit until the depth of –7 m, in case of average and low ground water levels, can be executed without ground water lowering. During further deepening of the building pits it is already necessary to lower the ground water level.

Compaction of water-bearing formations is an indirect impact of dewatering. The volume decrease occurred on account of compaction may cause non-uniform subsidence on the surface. After completion of dewatering volume increase of water-bearing layers has to be considered.

Dewatering may have an indirect adverse impact on the existing artificial environment (buildings) as a consequence of changes in volume of water-bearing layers (ground motions).

Impact of built-up density on ground water

The built-up density restricts surface infiltration of rain waters, and it in principle may reduce the ground water level. However, due to decrease in evaporation, an increase in water level can be expected. These two impacts neutralize each other.

Under the investment area the ground water is supplemented side-wards (depending on the water stage from the direction of the background or of the cold water channel). Consequently, the built-up density has no significant impact on ground water levels.

Estimation of impacts concerning subsurface waters

The investment may have a direct impact on the shallow subsurface waters only, it does not affect the thermal waters at a depth of more than 500 m. The impact of intensive water intakes already appears during the construction, but the impact reaches its maximum extent during simultaneous operation of the existing reactor units and the new ones to be constructed.

At the construction of the new units the communal water demand varies between 112 and 980 m^3/day, depending on the reactor type. The capacity of the Waterworks of Csámpa is 2500 m^3/day (approx. 900000 m^3/year), which is sufficient for simultaneous serving communal water demand of both the existing units and the new ones. During water right licensing process of the new units the protecting areas of the water base of Csámpa have to be determined again.

Disadvantageous impacts of the intensive subsurface water exploitation are as follows:

- Stationary water levels of subsurface waters decrease even more.
- On account of water level decreases the energy demand of water producing increases.

- Due to possible change in flowing paths and pressure circumstances of subsurface waters, the current positive vertical hydraulic gradient may turn into negative, consequently surface pollutions may get down into even the subsurface water-bearing layers.
- Due to decrease in water potential the chemism of subsurface waters may change.
- In consequence of decrease in pore water pressure an additional compaction may occur in the water-bearing layers which, in extreme cases, may result in even lowering of the surface [81].

A decrease in stationary levels of subsurface waters necessarily occurs. In consequence of this fact also the energy demand of water exploitation increases independently of unit types. It is expectable that lowering of the water level will not exceed the value of some meters.

With respect to communal water demands of the different unit types, it is expectable that the extent of water exploitation will not affect disadvantageously the subsurface water resources.

3.6.3. Impacts related to the operation of the new units

During normal operation of the plant units to be constructed, subsurface waters are not affected by any pollutions, it is fully eliminated due to the technologies used. Such pollutions originated from technology may occur solely in case of incidents.

Impact of deep foundations on ground water

It is expected that the datum surface of certain facilities (containment, turbine) will always be under the ground water level. Therefore, the deep foundations, by means of forming an obstruction, may deviate the natural flowing direction of ground waters.

Bed-colmation caused by operation of bank-filtered wells

10 pieces of bank-filtered well are currently available at the plant-side bank of the cold water channel. [82] It is expected that the water taken out of the bank-filtered wells will solely be used for the purpose of fire water supply. The increased service water demand related to operation of the new units can also be provided by means of intensive operating of the bank-filtered wells, which may involve more intensive siltation of bed of the cold water channel at the infiltration area of the channel, that is the phenomenon of bed-colmation may occur. The harmful impact of the colmation can be reduced by regular dredging of the bed.

Impacts of operation on subsurface waters

Impacts of operation on subsurface waters do not deviate from ones described during construction. On the basis of current knowledge, it is expected that subsurface waters during operation will be subject to less impacts from every aspect than impacts of construction. Therefore, the impacts described in *Subchapter 3.6.2.* are, with respect to the kind of impacts, fully the same as ones occurring in operation, however the extent of impacts will be lower in every case (the construction can be considered as an upper envelope when examining impacts of the operation).

During the period of the new power plant units' operation the daily drinking water demand varies between 46.2 and 380 m^3 depending on the unit type.

3.6.4. Common impacts of nuclear facilities operated at the site

During normal operation of both the existing plant units and the ones to be constructed, subsurface waters are not affected by any pollutions, it is eliminated due to the technologies used. Such pollutions originated from technology may occur solely in case of incidents.

During the period of common operation of the existing and new units, the impact concerning subsurface waters is represented by the increase in quantity of water intake from wells of the

Waterworks of Csámpa. In case of simultaneous operation of wells currently operated, they have a capacity in principle of approx. 5500 m^3/day (approx. 2 million m^3/year); however, the actually removable water quantity is determined by the capacity of the de-ironing and de-manganizing equipment of the waterworks. Considering this restriction, the capacity of the waterworks is 2500 m^3/day (approx. 900000 m^3/year), which is sufficient for simultaneously serving the communal water demand of both the existing units and the new ones.

3.6.5. Impacts of incidents and accidents

As a consequence of abnormal operation, in case of accidents and incidents various (non-radioactive) pollutants may be emitted into the environment, therefore, into subsurface waters as well. Due to subsurface pressure circumstances only the ground water may be concerned, the subsurface waters are currently not affected by surface pollution. The extent of possible pollutions is judged in accordance with Appendix 2 of the KvVM-EüM-FVM Decree 6/2009. (IV. 14.). (Ministry of Environment and Water, Ministry of Health and Ministry of Agriculture and Rural Development).

At the planned area of the new units diesel oil storage can be named as the most probable potential source of ground water pollution. The infiltration of diesel oil into the ground can be considered as an incident, and as a consequence of this there may be a potential pollution of the Danube through the polluted ground water body. Knowing exactly the amount of diesel oil stored at the site and the location of the storage, later it is necessary to examine the possibility of the occurrence of incident event and the possible impacts of diesel oil infiltrating possibly into the ground.

3.7. Soil, geological agent

3.7.1. Description of the basic state

Thanks to the large number of archive data, the geological structure of the environment of Paks Nuclear Power Plant is very well known. The database of the former State Geological Institute of Hungary contains 1989 pieces of boring, 271 of which reached the Pannonian formations, while 27 of which reached the pre-Pannonian ones. Particularly important information was provided by the deep boring named “Paks-2” implemented with continuous coring at the area of the planned new units. In 2006 a 3D geological-hydro-geological spatial model was prepared for the area of 15×15 km of the power plant.

In the area of the power plant the surface of the basement is at a depth of approx. 1600–1700 m. The base of basin is composed of metamorphic granitic formations with lower-coal age belonging to the Complex of Mórágy. To the north-west of the site the crystalline formations in the base of basin are covered by Permian sandstones and lower-middle Trias fragmentary-carbonate sediments.

In the area of the power plant deposition of sediments filling the basin started at the beginning of Miocene period. Partly fragmentary sediments and partly volcanites deposed with a thickness of approx. 1000 m, a part of which is terrestrial, another part of which is fluvio-marine. The main rock types are as follows: rhyolite, rhyolitic tuff, andesite, clay marl, lime marl, sandstone, limestone.

Evolution of the Pannonian set with a thickness of totally 600–700 m started 12 million years ago. The lower-Pannonian sediments with a thickness of approx. 100–150 m are shallow-sea formations mainly consisting of aleurit clay marl and clay marl aleurit. The upper Pannonian series of strata with approx. 500 m thickness is alternately formed by sand, clay marl and marl aleurit strata in the whole area. Their bedding is uniform, near horizontal, however traces of significant structural impacts can be observed in some borings. The quaternary sediments depose onto the upper Pannonian sediments with erosion discordance.

In the environment of the nuclear power plant the surface is composed of quaternary formations everywhere (*Figure M-13.* of the *Appendix*). The Pleistocene loess evolution was one of the most typical sediment evolution momenta during the Quaternary period. On the bottom of the loess series with a thickness of approx. 70 m, there are Pliocene-lower-Pleistocene terrestrial red clay layers deposed onto the upper Pannonian sediments (Red Clay Formation of Tengelic).

To the north-west of Dunakömlőd–Paks and Dunaszentgyörgy Szőlőhegy, the loess forms plateaus with shapes of north-north-west – south-south-east, with combs with heights of 140–180 maBsl, and with wide and plain derosion valleys. Between these two loess runs, to the north-west of the nuclear power plant, along the valley of the creek of Csámpa, there is a 4–6 km wide alluvial cone flat covered with Pleistocene-Holocene sheet sand with sand-hill reliefs with typically 100–130 maBsl.

The Paks Nuclear Power Plant is constructed onto the upper Pleistocene fluvial terrace running at western edge of the Danube Valley. The original relief of 93–95 maBsl was raised at the area of the power plant with a filling of 2–4 m thick silty sand up to the level of 97 maBsl. Under the filling, in a thickness of 12–18 m, there is the layer of medium- and fine grained sand and aleurit, and the base layer consisting of gravel and sand and sandy gravel is generally under the level of 78–83 mBf. The underlaying[19] of the gravel layer is at the level of 70–72 maBsl. The layers, verging to the east-south-east, of clay, clay marl, silty sand and weakly adherent sand rock of the upper Pannonian set can be found under the underlaying mentioned above (*Figure M-14.* of the *Appendix*).

Eastwards the upper Pleistocene terrace segregates mainly with sharp, unambiguous, lobate edge from the Holocene-aged low flood zone of the Danube. The surface running at the height of 89–93 maBsl of the low flood zone is rendered slightly wavy by the old dead branches, as well as by the lobate point bar structures.

The low flood zone is formed by the Holocene-aged sediments of the present-day Danube. The upper part is almost everywhere composed of alluvial silt, aleurit and fine-grained sand with a thickness of few meters. Under that there is a layer of cross-bedded fluvial fine- and medium grained sand until a depth of 12–16 m from the surface, while downmost there is a layer of gravel and sand and sandy gravel with a thickness of 5–25 m, which deposes onto the upper Pannonian clay.

The lower layer of gravels under sand of the low flood zone is probably not part of the Holocene sediment-formation cycle, but it has a direct connection with base gravel of the upper Pleistocene terrace.

The seismicity of the site was researched thoroughly during the period of 1986–1996. According to the relevant international recommendations, the horizontal and vertical acceleration components of the earthquake with a return period of 10000 years were determined. It was stated that the value of horizontal peak ground acceleration caused by the authoritative earthquake with return period of 10000 years is 0.25 g, while the value of the vertical component is 0.20 g.

In the wider environment of the Paks Nuclear Power Plant, in accordance with recommendations of the International Atomic Energy Agency (IAEA), a micro-seismic observation network was constructed in 1995. Currently 8 pieces of advanced digital measuring station operate within the environment with a radius of approx. 100 km of the power plant. In the period of 1995–2005 the network totally registered 708 earthquakes.

The distribution of quakes is quite diffuse, the hypocentres[20], excluding some cases, can with difficulty be connected to known lines of breakage.

The spatial distribution of earthquake epicentres[21] with respect to the area examined is shown in *Figure M-15.* of the *Appendix*. It can be seen that the active areas definable on the basis of historical

[19] Name of sections under the layer that serves as reference.
[20] The centre of earthquake, the point inside the Earth where seismic energy is released and where the earthquake originates.
[21] The location of epicentre is the orthogonal projection of hypocentre on the Earth’s surface.

quakes coincide with the present-day epicentres. In the environment of Paks Nuclear Power Plant, on the basis of the 15-year observation, there is no change in the level of seismicity, it can be considered as low nowadays, as well.

Beyond determination of the authoritative earthquake, a further more important result of the geological research performed in the period of 1986–1996 was that it was possible to exclude possibility of a fault, active in the last 100000 years, running out to the surface, furthermore to assess the possibility of soil liquefaction and the stability of soil on the basis of geotechnical survey program of the site. According to the geotechnical examinations performed, only the layers between the depths of 10 and 20 m are susceptible to soil liquefaction.

3.7.2. Impacts of the construction

At the beginning of construction of the investment, the settling and the creation of foundation pits significantly, and at large areas, concern the geological formations. The real size of foundation pits is determined by, beyond sizes of buildings, the position of traffic and transportation roads and the circumstances of dewatering, as well. In the present stage of design this data is not yet known, therefore quantities of grounds excavated from the foundation pits during construction of each unit type, can be estimated with difficulty in this phase. According to the data provided by the suppliers, the amount of ground to be excavated is estimated to be in the range of several hundred thousand to 4–6 million m^3 for the construction of two units. Foundation depth of maximum 14 m is expected.

Terrain preparation, settling, relocations of public utilities

The investment area covers a rectangular area of approx. 400 m × 600 m in the northern adjacent of Unit 4 of the operating plant. The area has already previously been filled up to the design level of 97.15 maBsl.

Currently there are no buildings at this area section, but remains of building foundations can be found at some places. The whole area is plain, a part of it is covered by large-sized concrete slabs, while remaining part of it is covered by herbaceous vegetation (locally there are young trees), and the vegetation is regularly mown. The underground public utilities (channel, fire water network) are still in existence.

The building yard (76.2 ha) of the planned investment connects to the construction area directly northwards. Also this area section has been filled up to the design level. To the west there are single-floor lightweight construction halls of companies serving the nuclear power plant and industrial rail-tracks. Eastern and northern parts of the prospective building yard are un-built, grassy, timbered, plantation natured. A series of bank-filtered wells is located at the bank of the cold water channel.

More serious, more significant volume works, and consequently their impacts, are not expectable in the design stage. Only tree felling and smaller excavation works involving relocation of the public utilities network are expectable. At both the investment area and the building yard there are more ground water monitoring wells for removal/relocation of which measures have to be taken.

Certainly features of the construction site are fully independent of each unit type. Consequently, an impact estimation of the construction for the local terrain circumstances and the existing public utilities network, which is more detailed than the above mentioned one, is only possible, if the precise detailed designs are available.

Soil dusting

With construction of foundation building pits, slopes, access roads also dusting of soils comes into prominence. This impact appears only until the depth of 20 cm from the surface. The average authoritative grain size of soils revealed by the building pits changes between 0.1 and 0.3 mm, therefore these soils are prone to dusting due to their granulometric composition.

This impact appears particularly in the dry, hot summer period. During the winter half-year, due to the lower temperature and the higher relative humidity, these phenomena are less considerable. The dusting of soils, as an impact, is adverse regarding the air quality, particularly in the closer environment of excavation works, and the impact area depends on the size of building pits. The phenomenon of dusting is periodic and it is only related to open building pits.

Watering of the area is one of the methods possibly usable for protection against dusting. A water content of 3–4% is already capable of reducing the extent of dusting to its fraction. Another, less expensive, possibility is to sprinkle transportation routes with sandy gravel.

Erosion of slopes of building pits due to rainwater (sheet erosion)

Stability of building pits of foundations, over the ground water, is mostly endangered by an intensive rainfall. Sandy soils are very sensitive to erosion, therefore the appropriate condition of building pits can solely be ensured by means of workmanlike draining of rainwater (ditches, shafts, ground stabilization).

Impact of foundations on underlying soil

At the area of constructions an increase in layer load is expectable on account of weight of the facilities. As a consequence of the increasing layer load soils are gradually compacted.

The volume of uniform grain sized sandy sediments may decrease by 20% already after deposition by means of simple redistribution of grains. Extent of the compaction is the most significant at fine-grained pelitic sediments containing organic material, while more coarse grained fragmentary sediments (sandy gravel) are compacted to the smallest extent. All of these formations are available at the investment area, but it is expected that the loading impact of the facilities will primarily concern the sand sediments [83].

With respect to the operating reactor units it was experienced that majority of the compaction (consequently subsidences due to decrease in volume) occurred relatively soon during some years under the foundations. The extent of subsidence by the end of the 1980s was 55.5 mm under Unit 1 and 2, 58.1 mm under Unit 3 and 72.6 mm under Unit 4. After the early period (some years) the velocity of subsidences significantly decreases, but the full consolidation will occur after decades only. According to the relevant calculations, the limit depth of stresses causing subsidences and originating from weight of the facilities can be defined as 47 m at the area of the nuclear power plant. [83]

The loading data of the new reactor units and the precise location of buildings and facilities respectively are currently not known, not to mention the detailed geotechnical data necessary for calculations.

3.7.3. Impacts related to the operation of the new units

It is probable that further impacts, which are considerable compared to the current situation, have not to be considered during the operation of the new reactor units. During the operation of the new reactor units, given full compliance with technological requirements, soil pollution has not to be taken into account. Soil pollutions may solely be caused by incidents.

Loading impact of facilities on subsurface

After completion of constructions, already in the period of operation, consolidation of the load-bearing soil under foundations continues to increasingly slowing extent. Compaction of soil due to loading is an irreversible process. The impact of consolidation processes is similar to the ones occurring in the construction phase, but duration of the impact is longer.

Vibration impacts of turbine foundations (engine foundations) on soils
Soils under foundations continue to consolidate, moreover also the phenomenon of liquefaction may occur in an extreme case. Consequently, very careful geotechnical examinations shall be performed before foundation works. In disadvantageous case soil solidification or soil stabilization has to be executed. The vibration impacts may improve certain features of the subsurface; however, the non-uniform soil subsidence possibly occurred may be harmful on facilities.

3.7.4. Common impacts of nuclear facilities operated at the site

During the simultaneous operation of the old and the new power plant units further impacts on the geological agent need not to be reckoned with. There are similar impacts (loading impact of facilities on subsurface, vibration impacts of turbine foundations) on the geological agent during the simultaneous operation of the old and the new units, but these impacts are entirely separated from each other in space and time. Soil pollutation may occur only in incidents.

3.7.5. Impacts of incidents and accidents

In case of accidents and incidents, due to the abnormal operation, different (non-radioactive) pollutants may get into the environment, consequently into the geological agent, as well. Harmful impact of the pollutant depends on the extent of the given pollution, the features of the pollutant discharged and the environmental conditions (soil capabilities, configurations of terrain, ground water situation, weather conditions, etc.). The water-soluble, mobile compounds are the most dangerous because they may reach even the ground water. At the planned area of the new units the diesel oil storage can be considered as potential pollution source. The event of infiltration of a diesel oil quantity of 30 m^3 into the soil during oil storage was considered as an incident condition. In actual practice occurrence of this incident has an extraordinarily low probability, due to the obligatory preventive protection requirements (double-walled underground vessels equipped with leakage detectors). In case of incident events a portion of the oil infiltrating into the soil absorbed at the soil grains (absorption), a portion of it evaporates (vapour phase), certain components are dissolved in water. Infiltration of a diesel oil quantity of 30 m^3 into the soil would reach the ground water level in a short period of time in the absence of intervention, hereby causing the pollution of a soil quantity of 150–500 m^3. The extent of possible soil pollutions is judged in accordance with Appendix 1 of the KvVM-EüM-FVM Decree 6/2009. (IV. 14.).

3.8. Wildlife and living communities

3.8.1. Description of the basic state

3.8.1.1. Nature conservation importance of the wildlife around Paks

The nature conservation importance of the wildlife of an area can be primarily measured in scope and characteristics of the protected areas. In the immediate vicinity of the new power plant the semi-natural vegetation is present in smaller and larger patches, especially near watercourses and on hills to the northwest of Town of Paks. Most of the natural, semi-natural patches are under nature conservation protection. Within a 30 km range of the project site there are 2 national parks, 1 area belonging to landscape protection area, 7 nature conservation areas, a few nature conservation areas of local importance, as well as several Natura 2000 sites and areas belonging to the National Ecological Network. Of the areas belonging to the Natura 2000 network the following can be found in the surveyed area: 4 special bird protection areas (Special Protection Area – SPA), 16 priority conservation areas (Site of Community Importance – SCI). Of these in the 8–10 km vicinity of the project site the following SCIs can be found: Paksi ürgemező SCI, Dunaszentgyörgyi láperdő SCI, Paksi tarka sáfrányos SCI, Tengelici rétek SCI and Tolnai Duna SCI. The latter one is practically adjacent to the area of the existing and the new power plant at the bank of the Danube. The different types of protected areas are presented in *Figure M-16.* of the *Appendix.*

Core areas of the National Ecological Network can be found at three different locations in the area. They include the forests on the hills to the northwest of Paks, one region of Kiskunság National Park and Gemenc region of the Duna-Dráva National Park. Besides these, watercourses and riversides serve as continuous ecological corridors.

3.8.1.2. Wildlife and living communities in the vicinity of the site

Condition of water ecosystems

The qualification of the Danubian living world's condition for organism groups in accordance with Water Framework Directive (WFD) (bacterio-, phyto- and zooplankton[22], macroscopic invertebrate species and fish fauna) was performed on the basis of the results of the examinations executed between 1999 and 2003 on the Danubian section between Paks and Mohács in 8 cross-sections. Based on this it can be stated that the impact of the thermal loading caused by the operating power plant is barely detectable. Difference that is worth mentioning between the sampling locations affected and non-affected by the thermal impact was only in the macroscopic invertebrate species group, this species group responded to the higher temperature by the increase of species and individual number.

The fish stock was surveyed at the sections upstream and downstream of the warmed-up cooling water inflow point, as well as within the area of the power plant in the cold and hot water channels. Due to temperature increase, in the direct vicinity of the warmed-up cooling water inflow point a strong increase in production can be observed, which was detectable to a decreasing extent until 2 km distance from the inflow point. The fine structure of the fish community changed only in this section. During fish faunistic examinations occurrence of totally 34 fish species was detected in the Danube section next to the power plant, of which 1 was particularly protected species and 6 were protected species.

The qualification according to WFD (standard draft CN TC 230 EU) executed on the basis of the results of the latest hydrobiological examinations performed in 2009–2010 classifies the species group as follows: ecological condition of phytoplankton is good-average, of phytobenton[23] is excellent in 3%, good in 48%, poor in 49%, of macrozoobenton is good, of fish community is average. Overall the examined river section can be classified into the ecological category of "good".

Flora of the surveyed area

In 2002 detailed surveys were carried out covering the full vegetation period, focusing on mosaics of the most precious vegetation patches in the approx. 10 km environment of the operating nuclear

[22] Plankton: all aquatic organisms, whose displacement is determined by primarily water flow and not muscle function, their groups:
Bacterioplankton: constitute of bacteria and archaea, they have an important role in decomposing organic materials in water, mainly in the lower part of the water column.
Phytoplankton: they live near the water surface, so the light helps their photosynthesis. Their major groups are diatoms, cyanobacteria and green algae.
Zooplankton: consisting of uni- and multicellular animal organisms, e.g. a variety of sea animals, fish, shell fish, inferior crustaceans and segmented worms eggs and larvae.

[23] Benthos: community of organisms living at the bottom of water, their groups:
Phytobenton: plant organisms in water, fixed at the bottom (water-solid phase boundary)
Macrozoobenton: invertebrate animals, animal communities visible to the naked eye living in water, at the bottom. (Their sensitivity to organic pollution and hydro-morphological changes is one of the methods of biological classification of water quality.)

power plant. These areas surveyed in detail are the followings: the area to the north of the power plant stretching to the main road No. 6, Kisbrinyó and Nagybrinyó, Dunaszentgyörgyi égerláp (alder swamp) and Uszódi-sziget (Uszódi Island). The habitats, the protected and non-protected, but valuable and typical species in the vicinity of the power plant are presented in *Table 3.8.1.2-1.* and *3.8.1.2-2.*

The typical vegetation types in the immediate and wide vicinity of the power plant are shown in map format in *Figure M-17.* of the *Appendix.* The following vegetation types can be found in the immediate vicinity of the planned new nuclear power plant:

- sandy grassland (degraded – *in yellow*, semi-natural – *in pink*),
- fen meadows (*light green with orange stripes*) and wet meadows,
- semi-natural riverine woodlands and mire woodlands,
- mud vegetation,
- planted woodlands (*Robinia pseudoacacia – in purple,* pine – *in green* and poplar – in *brown*).

The river Danube and its both banks are parts of Tolnai-Duna (HUDD20023) SCI of the Natura 2000 Network. Typical habitats are tall herb communities (6430), wet meadows (6440), riverine woodlands (91E0, 91F0) and mud banks (3270). Besides the formerly mentioned protected areas, there are mosaics of the Dél-Mezőföld Landscape Conservation Area near the new project site. The most extensive one lies to the north-west of Town of Paks. Most of them are Natura 2000 SCIs: Paksi ürge-mező (HUDD20069) lies close to the power plant, Paksi tarka sáfrányos (HUDD20071), Tengelici rétek (HUDD20070), Szenes-legelő (HUDD20050) and Közép-mezőföldi löszvölgyek (HUDD20020) can be found further away. In this landscape conservation area of mosaic-like structure, the valuable vegetation patches (sandy grasslands and closed steppe on loess) survived as ecological refuges surrounded by cultivated lands.

Table 3.8.1.2-1. Habitats, flora

Valuable species Latin name (common name)	Protection	Note
Pannonic sandy grassland (habitat code 6260) in close vicinity to the site and in the area of the ecopark		
– *Dianthus serotinus*	protected	They were registered species in the area before the opening of the ecopark. They probably disappeared due to the grazing. In other areas they are displaced by common milkweed (invasive species).
– *Stipa borysthenica*	protected	
– *Ranunculus illyricus*	protected	
– *Corispermum nitidum*	protected	
 ***Dianthus serotinus***	 ***Stipa* grassland in Felső-Csámpa in 2002**	 ***Stipa borysthenica***
– *Ornithogalum refractum*	protected	It can be found on both sides of main road No. 6, near the power plant and within the site.
– *Asplenium adiantum-nigrum* (Black spleenworth)	protected	Protected species that were found during the botanical surveys undertaken in the vicinity of Town of Paks during the planning of the route of M6 motorway.
– *Orchis morio* (Green-winged orchid)	protected	
– *Alkanna tinctoria* (Alkanet)	protected	
– *Epipactis palustris* (Marsh helleborine)	protected	

Valuable species Latin name (common name)	Protection	Note
 **Black spleenwort**	 **Green-winged orchid**	 **Marsh helleborine**
Fen meadow (habitat code 6410) – unique, highly valuable habitat located to the north-west of the power plant in some places		
– *Blackstonia acuminata*	protected	The area is endangered by growing shrubs, drying and invasive plant species – common milkweed *(Asclepias syriaca)* in dry places and giant goldenrod *(Solidago gigantea)* in more humid areas.
– *Dactilorhiza incarnate* (Early marsh orchid)	protected	
– *Equisetum variegatum* (Variegated horsetail)	protected	
Swamp and fen meadow (habitat code 6440 and 6410) on former floodplains of Régi-Brinyó and Új-Brinyó and in hollows among arable lands		
– *Blackstonia acuminata*	protected	The place is drying and getting weedy; the primary invasive weed is giant goldenrod *(Solidago gigantea)*.
– *Cephalanthera damasonium* (White helleborine)	protected	
– *Cirsium brachycephalum*	protected	
– *Leucojum aestivum* (Summer snowflake)	protected	
– *Gentiana pneumonathe* (Marsh gentian)	protected	
– *Hottonia palustris* (Water violet)	protected	
– *Orchis laxiflora* subsp. *elegans*	protected	
– *Listera ovate* (Common twayblade)	protected	
– *Senecio paludosus* (Fen ragwort)	protected	
– *Pseudolysimachion longifolium*	protected	
– *Sonchus palustris* (Marsh sowthistle)	protected	
– *Lathyrus palustris* (Marsh pea)	protected	
– *Peucedanum palustre* (Milk parsley)	protected	
 **Régi-Brinyó: Mixed poplar and alder woods**	 **Marsh gentian**	 **Új-Brinyó: “Turján” meadow and softwood forest patch**
Riverine woodlands, **swamp woodland** (91E0) with old growth alder trees in the area of Régi-Brinyó and Új-Brinyó, and Dunaszentgyörgyi láperdő (HUDD20072), which is part of the Natura 2000 Network, between Paks-Faddi főcsatorna (main canal) and Paks-Kölesdi-vízfolyás (watercourse)		
– *Leucojum aestivum* (Summer snowflake)	protected	It is almost completely dried-out. As a result of drying, European dewberry *(Rubus caesius)* and common nettle *(Urtica dioica)* became more abundant and they can endanger protected species.
– *Thelypteris palustris* (Marsh fern)	protected	
– *Dryopteris carthusiana* (Narrow buckler fern)	protected	
– *Dryopteris filix-mas* (Common male fern)	non-protected	
– *Cirsium brachycephalum*	protected	Natura 2000 priority species

Valuable species **Latin name (common name)**	**Protection**	**Note**
 **Dunaszentgyörgyi legelő (pasture) and láperdő (swamp woodland); power plant in the background**	 **Summer snowflake**	 ***Cirsium brachycephalum*, priority species of the Natura 2000 site**
Riverine woodlands, mud vegetation (habitat code 3270) on the widening floodplain of Uszódi-sziget (Uszódi island) (Tolnai Duna (HUDD20023), part of the Natura 2000 Network)		
– *Lindernia procumbens* (Prostrate false pimpernel)	protected	Natura 2000 priority species
– *Carex bohemica*	protected	Planted woodlands, but along water surfaces there are willow shrub vegetation and riverine willow woodlands and mud vegetation, which is made of natural pioneer species, if water levels are low. Number and abundance of non-native species are significant: various *Aster* species, giant goldenrod *(Solidago gigantea)*, *Bidens frondosus.* On the floodplain there are “woody” weeds such as maple ash *(Acer negundo)* and desert false indigo *(Amorpha fruticosa)*.
– *Eleocharis carniolica*	protected	
– *Limosella aquatic* (Water mudwort)	non-protected	
– *Dichostylis micheliana*	non-protected	
– *Chlorocyperus glomeratus*	non-protected	
– *Veronica catenata* (Pink water-speedwell)	non-protected	
 **Danube’s floodplain at Dunaszentbenedek**	 **Old English Oak on the floodplain**	
Riverine oak-elm-ash woodlands’ remains to the north of the power plant, on the east bank of the river Danube and in the middle of Uszódi-sziget (Tolnai Duna (HUDD20023), part of the Natura 2000 Network)		
– *Scilla vindobonensis*	protected	Remains of oak, elm, ash woodlans on higher grounds along the rivers.
– *Galanthus nivalis* (Common snowdrop)	protected	Natura 2000 priority species.
Open sandy grasslands with smaller-larger patches of fen meadows between sand dunes in Paks Ürge-mező (HUDD20069, part of the Natura 2000 Network). In wet meadows of the protected area there are 486 plant species registered, 28 plants out of which are protected		
– *Apium repens* (Creeping marshwort)	protected	Natura 2000 priority species.

Fauna of the surveyed area

The survey of the fauna was carried out in years between 1998 and 2002 by the Hungarian Natural History Museum. Most of the surveyed area near the power plant was found to be moderately degraded closed sand steppe under strong anthropogenic influence, shrubby grasslands of the higher floodplains dominated by invasive species of common milkweed (*Asclepias syriaca*) and giant goldenrod (*Solidago gigantea*), and cultivated arable land or not long ago abandoned land. From nature conservation's point of view, these habitats are less valuable except for Brinyó Forest located to the south of the power plant, and riverine willow-poplar forests, islands, sand banks and ponds lying along the river Danube. Even on degraded areas there are still sand steppe and loess steppe animal species occurring, mainly of great tolerance and typical of steppe fauna of the Great Plain.

Table 3.8.1.2-2. Fauna

Valuable or typical species Latin name (common name)	Protection	Note
Riverine softwood and oak-elm-ash woodlands in Uszódi-sziget and Brinyói-erdő		
– *Aegosoma scabricorne* (Grain support beetle)	protected	With old trees it is a paradise for insects.
– *Aromia moschata* (Musk beetle)	protected	
– *Carabus granulatus*	protected	
– *Catocala fraxini* (Blue underwing)	protected	
– *Catocala electa* (Rosy underwing)	non-protected	
– *Cucujus cinnabarinus*	protected	
– *Apatura ilia* (Lesser purple emperor)	protected ►	
– *Apatura metis* (Freyer's purple emperor)	protected	
– *Papilio machaon* (Common yellow swallowtail)	protected	
– *Edwardsiana tersa* (Cicada species)	non-protected	It was found here first time in Hungary.
 **Cicada**  **Grain support beetle**  ***Cucujus cinnaberinus***  **European penduline tit**  **Eurasian wryneck**		
– *Picus viridis* (European green woodpecker)	protected	Old willow trees are nesting trees for them.
– *Dryocopus martius* (Black woodpecker)	protected	
– *Dendrocopos major* (Great spotted woodpecker)	protected	
– *Jynx torquilla* (Eurasian wryneck)	protected	
– *Ciconia nigra* (Black stork)	protected	
– *Remiz pendulinus* (European penduline tit)	protected	
Mire and swamp forests in Brinyói-erdő		
– Owlet moth (*Noctuidae*) species	protected	
– *Panurus biarmicus* (Bearded reedling)	protected	
– *Acrocephalus arundinaceus* (Great reed warbler)	protected	
– *Emberiza schoeniclus* (Reed bunting)	protected	
– *Rallus aquaticus* (Water rail)	protected	
– *Circus aeruginosus* (Western marsh-harrier)	protected ►	
Planted poplar and pine plantations		
– *Panolis flammea* (Pine beauty)	non-protected	Most of their species are common and frequent, and several of them are forest pests. Only a few represent faunistic
– *Dendrolimus pini* (Pine tree lappet)	non-protected	

Valuable or typical species Latin name (common name)	Protection	Note
– *Bupalus piniarius* (Bordered white)	non-protected	value such as certain Catocala species. Planted pine plantations are an alien vegetation type and their fauna largely differs from the native fauna.
– *Rhagium inquisitor* (Longhorn beetle species)	non-protected	
 **Dead nettle-leaf beetle**  ***Rhagium inquisitor***	 ***Chlorophorus varius***  ***Anomala vitis***	 ***Etiella zinckenella***
Planted Robinia pseudo-acacia plantation		
– *Chrysolina fastuosa* (Dead-nettle leaf beetle)	non-protected	These are usually widespread species, less interesting from a faunistic aspect and often polyphagous[24].
– *Chlorophorus varius* (Variabler widderbock)	non-protected	
– *Polyphylla fullo* (June beetle)	non-protected	
– *Anomala vitis* (Vine chafer)	non-protected	
– *Amphimallon solstitiale* (European june beetle)	non-protected	
– *Etiella zinckenella*	non-protected	
Wet meadows, fen meadows, mire and swamp forests		
– *Lycaena dispar* (Large copper)	protected	They host many postglacial relict[25] species.
– *Hyles gallii* (Bed-straw hawk moth)	protected	
– *Lamprotes c-aureum, Diachrysia zosimi* (Owlet moths)	protected	
– *Lygephila pastinum, Calyptra thalictri* (Owlet moths)	non-protected	
 **Large copper**  **Bed-straw hawk moth**	 **Small yellow underwing**	 **Whinchat**
– *Lacerta agilis* var. *rubra* (Red backed subspecies of sand lizard)	protected	
– *Motacilla flava* (Yellow wagtail)	protected ►	
– *Saxicola rubetra* (Whinchat)	protected	
– *Gallinago gallinago* (Common snipe)	protected	
– *Clossiana selene* (Small pearl-bordered fritillary)	non-protected	
– *Panemeria tenebrata* (Small yellow underwing)	non-protected	
– *Proserpinus proserpina* (Willowherb hawkmoth)	protected	
Waters, shores, reeds and large sedges		
– *Emys orbicularis* (European pond turtle)	protected	
– *Triturus cristatus* (Great crested newt)	protected	
– *Bombina bombina* (European fire-belled toad)	protected ►	
– *Pelobates fuscus* (Common speadfoot)	protected	
– *Rana dalmatina* (Agile frog)	protected	
– *Hepialus humuli* (Ghost moth)	non-protected	
– *Mononychus punctumalbum* (Weevil species)	non-protected	

[24] Living creatures feeding on many kinds of food of organic origin.
[25] Postglacial, warm period relic species.

Valuable or typical species **Latin name (common name)**	**Protection**	**Note**
– *Hyla arborea* (European tree frog)	protected	
– *Natrix natrix* (Grass snake)	protected	
The river Danube, the Danube’s embankment (Tolnai Duna Natura 2000 area)		
– *Barbastella barbastellus* (Barbastelle)	highly	They have outstanding natural value.
– *Myotis myotis* (Great mouse-eared bat)	protected	
– *Myotis dasycneme* (Pond bat)	highly	
– *Lutra lutra* (European otter)	protected	Natura 2000 priority species.
– *Aspius aspius* (Predator asp)	non-protected	
– *Gymnocephalus schraetzer, G . baloni* (Striped ruffe, Balon’s ruffe)	protected	
– *Rutilus pigus*	protected	
– *Zingel zingel, Z. streber* (Common zingel, streber)	highly	
– *Eudontomyzon mariae* (Ukrainian brook lamprey)	highly ►	
– *Unio crassus* (Thick shelled river mussel)	protected	Near threatened.
Steppe mosaics		
– *Acrida ungarica*	protected	Their characteristic insect fauna preserves the remains of zonal forest steppe fauna used to be typical in the inner part of the Carpathian Basin.
– *Colias chrysotheme* (Lesser clouded yellow)	protected	
– *Arctia festiva* (Hebe tiger moth)	protected	
– *Ocnogyna parasita*	protected	
– *Hemaris tityus* (Narrow-border bee hawk-moth)	protected	
– *Periphanes delphinii* (Pease blossom)	protected	
– *Schinia cardui*	protected	
– *Eresus cinnabarinus*	protected ►	
– *Lycosa singoriensis*	protected	
– *Lacerta viridis* (European green lizard)	protected	
– *Spermophilus citellus* (European ground squirrel)	highly	Natura 2000 jelölő faj – Ürgemező.
Open grasslands		
– *Falco tinnunculus* (Common kestrel)	protected	
– *Falco cherrug* (Saker falcon)	highly	
– *Buteo buteo* (Common buzzard)	protected	
– *Burhinus oedicnemus* (Stone curlew)	highly ►	
– *Anthus campestris* (Tawny pipit)	protected	
– *Alauda arvensis* (Eurasian skylark)	protected	
– *Lanius collurio, L. minor* (Red-backed shrike, lesser grey shrike)	protected	
– *Upupa epops* (Hoopoe)	protected	
– *Falco subbuteo* (Eurasian hobby)	protected	
Grassland-bush mosaics		
– *Mantis religiosa* (European mantis)	protected	
– *Pyronia tithonus* (Gatekeeper)	protected	
– *Maculinea arion* (Large blue)	protected ►	
– *Lycaena thersamon* (Lesser friery copper)	protected	
– *Satyrium w-album* (White letter hairstreake)	protected	
– *Acherontia atropos*	non-protected	
– *Merops apiaster* (European bee-eater)	highly	
– *Alcedo atthis* (Common kingfisher)	protected	
– *Riparia riparia* (Sand martin)	protected	
– *Coluber caspius* (Caspian whipsnake)	highly	On a loess bank over Paks.

<table>
<tr><th colspan="5">Valuable or typical species
Latin name (common name)</th><th>Protection</th><th>Note</th></tr>
<tr><td colspan="5">– Dorcadion aethiops, D. pedestre</td><td>non-protected</td><td></td></tr>
<tr><td colspan="5">– Pezotettix giornae</td><td>non-protected</td><td></td></tr>
<tr><td>
Antlion</td><td>
Acrida ungarica</td><td>
Dorcadion pedestre</td><td>
Pezotettix giornae</td><td colspan="3">
European bee eater</td></tr>
<tr><th colspan="7">Agricultural cultivations</th></tr>
<tr><td colspan="5">– Buteo buteo (Common buzzard)</td><td>protected</td><td rowspan="2">Good feeding areas.</td></tr>
<tr><td colspan="5">– Falco tinnunculus (Common kestrel)</td><td>protected</td></tr>
<tr><td colspan="5">– Alauda arvensis, Galerida cristata (Eurasian skylark, Crested lark)</td><td>protected</td><td></td></tr>
<tr><td colspan="2">
Common buzzard</td><td colspan="3">
Common kestrel</td><td colspan="2">
Crested lark</td></tr>
</table>

3.8.2. Impacts of the construction

3.8.2.1. Impacts on terrestrial wildlife

In the construction phase, terrestrial wildlife is being affected by direct (land take) and indirect (dust emission, air pollution and noise load, and impacts resulted by pollution of groundwater and changes in its level) impacts. Places affected by permanent or temporary land-take during construction are presented in *Figure M-18.* of the *Appendix.* The affected area can be divided into four zones:

- The operating area of the “new nuclear power plant” (*purple*) – permanent built-up,
- Building yard (*pink*) – partly permanent, partly temporary during construction phase only,
- The whole territory of the currently operating nuclear power plant (*yellow*) – already built-up,
- Areas outside of the nuclear power plant’s site – building of associated/auxiliary facilities.

In the lay-out plan of Town of Paks all areas to be occupied or built-up, except for the last one, are designated as industrial or reserve industrial areas. In the affected area (the operating area and the building yard) currently industrial activities and auxiliary activities ensuring the operation and maintenance of the existing power plant take place. Thus the area to be taken cannot be called good habitat for terrestrial wildlife.

Impact of land take on wildlife

The size of the necessary operating area is 10–36 ha depending on the type of unit. In this area present patches of vegetation (secondary, degraded grasslands) will disappear by the built-up, and the fauna will also disappear or migrate. There is an expectation that not built-up surfaces will be parked and green surfaces will be produced during the construction and landscaping. It is also essential from the point of view of ensuring the continuity of ecological corridors.

During the construction phase, flora and fauna present in the building yard will disappear as in case of the operating area, but after construction there is the possibility of creating new, extensive green surfaces there. It is estimated that the available 100 ha area will be fully utilized by the building yard. This area has no significant value from the point of view of nature conservation, therefore, the disappearance of its wildlife will not cause significant deterioration in the state of the region's wildlife.

Land take of two elements of the planned power plant's cooling system, the water intake plant and the new hot water channel section, involves a significant interference into the flora and fauna of the area. Territories on the bank of the Danube are part of the Tolnai Duna Natura 2000 area, good, valuable riparian areas are located along the route of the planned hot water channel section. Of representing habitats the habitat type code 3270 (Rivers with muddy banks with Chenopodion rubri pp and Bidention pp vegetation) occurs. Nowadays this habitat complex with willows, islands, reefs and side branches exists only in a few places in the floodplain of the Danube, and the concerned channel route is just one of them. The relevant Natura 2000 management plan's[26] main objectives include the following in the first place: *"Keeping the foreshore natural and semi-natural willow-poplar woodlands and reef willows in good naturalness state, maintaining the permanent forest cover for the protection of its associated living communities"*. This will be significantly broken, if the channel is realized here. Therefore, after the detailed design and modeling of heat emission it is necessary to strive for implementing as low land take as possible. Natura impact assessment is required in the next, environmental impact assessment phase.

Areas 1, 2 and 3, lying in present power plant's operating areas, over the fence and marked in red in Figure *M-18.* of the *Appendix*, have values, whose protection is of high importance. Their permanent or temporary use and disturbance should be avoided to the greatest extent as far as possible.

Indirect impacts of construction

Indirect impacts can be called disturbance. It is primarily caused by air pollution, noise, intense human presence and appearance of wastes. Wildlife of areas affected by construction and staging, as well as their environment is basically poor; therefore, this impact does not cause loss. Disturbance to an area results in the appearance and dominance of ruderal[27] and invasive plant species. The spreading and invasion of these species in more valuable grasslands is damaging, thus weed control of the building yard is necessary.

Subsurface construction works may cause local depression in ground water levels. Therefore, the seasonal change of local ground water gradient and its possible modification should be modelled in relation with the change in water flow of the river Danube. It is essential in maintaining the good conditions of Dunaszentgyörgyi láperdő (alder swamp), a Natura 2000 site of community importance (SCI). The further operation of the belt canal has a positive effect, since it provides water for the long dried-out Csámpai-patak (creek) and neighbouring canals.

The construction of new reactor units is expected to have a significant impact on the town's development. The town certainly will have to expand if up to 5000–6000 workers are needed to be

[26] http://www.termeszetvedelem.hu/_user/browser/File/Natura2000/SAC_Celkituzesek/DDNPI_SAC_celkituzesek/HUDD20023.pdf/

[27] Weeds living in neglected, disturbed, non-cultivated areas.

accommodated. Therefore, in order to protect valuable pieces of terrestrial wildlife, areas with no nature conservation value should be designated in order to site further auxiliary developments.

3.8.2.2. Impacts on aquatic ecosystems

The new nuclear power plant units and especially their associated investments affect the wildlife of the Danube water bodies as well. (Adverse effect of land take has been already described.) As part of the fresh water cooling technology the implementation of new cold water and hot water channel sections is required. Their construction at the meeting point of the channels and the Danube involves also the intervention into the living space of the Danube (dredging, riverside planning works). Establishment of a temporary harbour to solve waterway transportations may have similar impacts. The impacts of dredging-riverside planning on the species groups named by WFD are the following:

- *Phytoplankton*'s structure is temporarily modified. The suspended particles getting into the water may reduce the transparency of water along the bank, thus the density of algae is reduced. This impact is expected to be limited to a short section of the river, so the phytoplankton community can recover in a few days.
- Due to these works the *diatom* community disappears in the affected riverbed areas. The local impact does not involve the destruction of outstanding natural values. Within a short period of time the formation of the same diatom community could be expected at the banks.
- Of the typical groups of *zooplankton* – the rotifers and plankton crustaceans – filter of most species may be clogged by disturbed mud, which may result in their destruction. However, this does not threaten the populations, since most of them reproduces by parthenogenesis, so the next generation grows in 7–10 days. Most of the slower cycle zooplankton (oar-footed crustaceans) are carnivorous, clogging is not a problem for these. Zooplankton return rapidly from water bodies not affected by the works.
- Regarding feeding, m*acroscopic invertebrates* (aquatic insects, mussels, snails) can be grazing, filter, carnivorous and ectoparasitic[28]. Most of them are settled at the river bank section of about 1.5–2 rkm with fine-grained sediment, downstream of the mouth of the hot water channel. Dredging causes the local destruction of species with small-scale mobility. However, due to their excellent colonizing ability, they can re-take possession of the disturbed bed sections soon.
- During the dredging it is expected that the river bed base is stirred, which locally reduces the oxygen saturation of the water body, and it may have short-term negative impact on *fish stocks*. The protected amur bitterling (*Rhodeus sericeus*) should be mentioned, which, due to its special reproductive strategy, is sensitive to the decrease of shellfish stocks, as this species spawns in mussels. During construction the periodic noise and vibration waves can have frightening impact as well.

In terms of aquatic ecosystems the impacts of construction are temporary, the period of dredging is very short compared to the total construction time. In order to prevent adverse processes that may occur, efforts should be made to change the current bed formations to the lowest extent possible.

[28] Parasite organism that lives on the body surface and lives from the body of the host.

3.8.3. Impacts related to the operation of the new units

3.8.3.1. Impacts on terrestrial wildlife

During operation, in the operating areas and in the related, complementary areas no additional direct impact is expected in terms of wildlife and their habitats. The only indirect factor causing significant impact on the wildlife of the surrounding area is the fresh water cooling. We consider this to such extent to be able to comply with the current emission limit values (temperature difference, maximum temperature). The maximum allowable heat load is expected to be approached by the power plant more frequently, but this is not expected to cause increased load on the terrestrial wildlife.

From the wildlife point of view it is favourable that some activities related to the current power plant can be continued (e.g. water supplementation of the creek of Csámpa via the belt canal, existence of the fish ponds or Dunaszentgyörgyi láperdő (alder swamp) is less disturbed due to the presence of the nuclear power plant).

According to experience gained so far, certain valuable representatives of flora typical of this region (e.g. *Corispermum nitidum*, *Centaurea arenaria*, *Stipa borysthenica*, *Dianthus serotinus*) can find their living conditions at the site of the power plant. The same is expected to happen in the un-built areas of the new site in the course of time.

3.8.3.2. Impacts on aquatic wildlife

One of the most important conventional environmental impacts of the new nuclear power plant is thermal load of the Danube, which is the only impact factor reaching the aquatic wildlife. Cooling of the existing four units of the operating power plant is executed by fresh water cooling as well, i.e. the most important technical-environmental limit of Paks site is the finite thermal load capacity of the Danube. The living conditions of aquatic ecosystems may be modified by the amount of water, as well as by significant change in water quality. (Under the current thermal load of the Danube critical states have occurred at times, i.e. in summer, high water temperature and low stage period, the permissible temperature difference was reached, and there were nearly maximum thermal load states.) In case of the planned new units, at the most, more than one and a half times the current amount of warmed-up cooling water will be drained into the receiving water at two points. The increase of thermal load should be planned carefully, by modeling critical states and with full knowledge of stream flow, which determines load capacity, and meteorological conditions.

The increased amount of hot water discharged into the receiving water and the water temperature caused by this locally accelerates organic-matter decomposition in the river, which involves increasing oxygen consumption, de-oxidation. However, the Danube is still able to compensate this due to its hydraulic, mixing relations and the typically high dissolved oxygen content. Due to the higher water temperature, in the Danube under downstream of Paks the total biomass still remains higher than in the upper sections. Regarding species composition, aquatic wildlife of the section of a few kilometres downstream of the inflow point may be rich similarly to the current one. In consequence of the higher temperature the density of the fish stock increases, particularly in the winter months. The finer structure of the fish community, due to the two inflow points, is expected to change detectably in an about 3 rkm long section downstream of the mouth of the existing hot water channel. Thus, the impact of independent operation may be nearly the same as the current state, this is a detectable change for each group of species.

These changes can be assumed in that case, if the requirements related to the permissible thermal load of the operating power plant are complied with during the operation of the new units as well.

Surface mixing of the heat tail usually occurs on the section of 4–5 km calculated from the inflow point, but it can be tracked until the Gerjen-Bátya line (10 rkm). In terms of aquatic wildlife, this is the impact area. (Subsequently, this should be updated on the basis of the modeling of the two heat tails' water temperature modifying impacts.)

In case of incident, i.e. if water temperature exceed the current limits, the following may occur: destruction, decrease of the number of species in the affected river section, decrease of stock size. (For the majority of fish species typical in the Danube, the final, lethal temperature is about 31 °C. The most resistant species are the following: carp /35.6 °C/, amur bitterling /35.4 °C/ and common sunfish /35.3 °C/.)

In addition to thermal load, bypass effect also should be mentioned, which occurs in case of the fish fauna and it is caused by the noise emission of pumps, compressors and mechanical equipment. Due to this there is a low decrease of the number of species in a short river section.

3.8.4. Common impacts of nuclear facilities operated at the site

In case of the simultaneous operation of the six units, if the warmed-up cooling water draining limits are met by applying technical measures (e.g. in critical periods, not operating the unit at full capacity, shut-down of unit), then the impacts described in *Subchapter 3.8.3.* will be expected, that is the state resulting from the impacts of simultaneous operation will not significantly deviate from the present state, either.

3.9. Environmental noise and vibration

3.9.1. Description of the basic state

The nearest inhabited areas are located 2–2.5 km away from the centre of the site of the new units. These areas are Paks, Csámpa and Dunaszentbenedek, on the other bank of the Danube. The demarcation of impact area of the planned site should be carried out in compliance with the Government Decree 284/2007. (X. 29.) on certain rules of protection from environmental noise and vibration, depending on the background load of neighbouring areas, their building zone classifications and the noise emission of the planned facility.

3.9.1.1. Noise load in the area

In the surveyed new site primarily the noise emitted during the operation of the Paks Nuclear Power Plant can be expected. Major sources of noise are the power plant's steam turbines, devices of the transformator plant, diesel generators, cooling house, pumps, high-pressure compressor and the maintenance and cutting workshops.

During the environmental impact assessment of the lifetime extension of the nuclear power plant [37] noise measurements were carried out at the site and at certain characteristic points at the border. Average noise emission values estimated from the measurements made at the northern border of the site towards the studied area are $L_{A,ki}$ = 50–55 dB.

The studied site is being affected by traffic generated noise, which is caused by M6 motorway located approx. 2 km away from the site, by main road No. 6 situated approx. 500 m away and by the passenger and heavy traffic of the operating power plant. Due to the traffic of M6 motorway the estimated noise load at the planned site is 40–41 dB[29] in daytime (6–22h) and 32–33 dB at night (22–6h). In 2009 the noise load caused by the traffic of main road No. 6 was 41–42 dB in daytime and 34–35 dB at night. (The traffic of 2010 decreased by 28%, this presumably means about 1 dB or less noise level reduction in the area.)

[29] The noise levels are given in L_{Aeq}.

The traffic on the southern and northern access road is directly connected to the operation of the power plant. According to our calculations, noise load approx. 100 m away from the road is 35.4 dB in daytime and 30.0 dB at night. Total roadway noise load of the new site is 43–45 dB in daytime and 36–38 dB at night.

Currently there is no railway passenger service in the area of Paks. Noise load from freight services is insignificant due to low traffic.

3.9.1.2. Areas and facilities to be protected near the surveyed area

There are agricultural and forest areas (according to the lay-out plan of Town of Paks around the power plant there are protecting forests /signed “Ev”/, forests for economic purposes /signed “Eg”/, and general agricultural lands /signed “Má”/) located in the vicinity of the studied area. In these areas no noise load threshold value applies to the environmental noise sources.

The studied area itself and the site of the neighbouring nuclear power plant, as well as the area lying towards Paks are in the economic zone of the lay-out plan (as industrial economic area /signed “Gip”/) together with areas located near the administrative border of Paks (commercial economic area /signed “Gksz”/). Therefore, the most important facilities to be protected against noise are residential buildings in residential areas. These are the followings:

- residential buildings at the southern border of residential area of Paks, along main road No. 6 (called suburban residential area /signed “Lke”/), along Dankó Pista Street,
- residential buildings in Csámpa, in the line of the southern entrance of the nuclear power plant on the other side of main road No. 6 (“Lf” – rural residential area),
- built-up area of Dunaszentbenedek on the other bank of the river Danube.

In residential and economic areas there are noise load threshold values to protect facilities against noise. In areas to be protected against noise residential noises are dominant in Paks and Dunaszentbenedek. In Csámpa, however, the roadway noise caused by the traffic of main road No. 6 is dominant. Noise levels are not available for these areas due to the absence of measurements. Therefore, in case of facilities to be protected against noise loads caused by both traffic and operational noise, the noise load for the condition before the start of the investment is needed to be determined by on-site measurements prior to the start of the environmental impact assessment.

3.9.1.3. Current vibration loads

We do not have vibration measurement data in the area of the power plant, so current state of the area in this respect is not known. Based on our previous experience, however, it can be said that no vibration problem will be expected in the facility to be protected due to vibration travelling through the soil, if the distance between the source and the facility to be protected is more than 80–100 m. (This applies to vibrations caused by traffic and technology as well. Passenger car and pickup truck traffic does not usually cause any problems even within the above mentioned distance of 80–100 m.) Therefore vibration impact area is much smaller than the impact area of noise examinations.

In the 100 m zone outside the site border of the nuclear power plant there is no building to be protected, such buildings are only located more than 1 km away from the site border. Thus, vibration impact of the power plant’s machinery and equipment is not expected on the buildings to be protected that are situated outside the site of the plant.

Transport (road, railway) loads should be examined within this relatively narrow (80–100 m) belt but in a much more extended area: in case of road, until the closest settlement at least, while in case of railway, until the nearest major railway junction (Előszállás). For the survey of current state, vibration measurements are reasonable in these areas until the start of environmental impact assessment.

3.9.2. Impacts of the construction

The places to be protected against noise and vibration load nearest to the construction area/building yard are located more than 1 km away from the border of the new site.

3.9.2.1. Impacts of noise load

In the absence of more detailed basic data, forecast can only be made on the basis of assumptions for the construction works. Construction works are expected to take place in three shifts, transportations, however, in day shift only. During earthworks, the operation of maximum 50 construction machines is expected simultaneously. The position of machinery is unpredictable, accidental, but we calculated that near site borders located towards the facilities to be protected 15 machines at the most will be working simultaneously in the daytime, and 5 machines and 3 other equipment at the most at night.

Presumed noise emission of earthwork machineries (according to findings of earlier measurements) is L_{5m} = 85–95 dBA. During freight transportation, primarily the use of M6 motorway and 24 rides per hour were presumed. Noise emission of heavy trucks causes an $L_{7.5m}$ = 62–65 dBA noise load. Passenger transportation causes $L_{7.5m}$ = 50–57 dBA noise load at the speed of 50 km/h during the day depending on the different passenger transportation need of the certain unit types. Under these conditions, in case of the nearest facilities to be protected the expected noise load value caused by constructions works and traffic is L_{AM} = 42–47 dB, 38–42 dB at night (by taking into account the attenuation of distance, air and soil). The latter value is at the nearest residential buildings of Dunaszentbenedek and it does not comply with the relevant threshold value of 40 dB. Calculations need to be refined in the environmental impact assessment and if the threshold value cannot be met, the adverse condition should be avoided by technical intervention (e.g. reduced machine chain, avoiding earthworks at night). If the threshold value cannot be met in certain construction phases even by the use of the above mentioned solutions, then an application should be submitted to the competent environmental inspectorate for the temporary exemption from the threshold value.

Based on the presumed basic data, the impact area of constructions works and traffic is expected to be between 900 m and 3100 m, and between 19 and 41 m along the transportation routes. Within this area the facilities to be protected are certain residential buildings of Paks, Dunaszentbenedek and Csámpa up to 3100 m from the site border and up to 41 m from the road’s centreline.

3.9.2.2. Impacts of vibration load

Vibration loads may result in structural problems (adversely affecting structure and condition of buildings) and environmental problems (disturbing people staying within a building with vibrations of the floor/ceiling). Vibration problems are always connected to buildings. Therefore, when studying vibration impacts, it should be decided first whether there are buildings to be protected within the impact area and if so, what kind of buildings are these. As it was mentioned in case of the current state, the general impact area of vibration load is max. 80–100 m from the source.

Direct vibration load: Construction works are expected to cause a lot bigger vibration load than the subsequent operation. Working processes causing significant vibration loads are e.g. pile driving, sheet piling, demolition works or possibly excavation with explosions. Within the impact area the only facility to be protected is the operating nuclear power plant, whose safety must not be adversely influenced by the vibration load of construction. Therefore, it is important to monitor vibration load continuously.

Indirect vibration load: During construction of new reactor units there is a sudden rise in the volume of materials transported and of passenger transportation. In case the total volume of materials is planned to be transported by road vehicles, it may mean the traffic of even a thousand of heavy trucks a day and several hundreds of bus rides transporting workers would be added to it. It would be twice as much as the annual heavy truck traffic of main road No. 6 in the vicinity of Paks. In our opinion, this significant traffic growth is not feasible in practice.

Deterioration of condition due to vibration load of traffic depends on the distance between the transportation route and the facility to be protected, the axle load, speed of passing vehicles, the quality of road surface and the structural condition of the building to be protected. The primary cause of rise of structural vibration load is not the increasing number of passing heavy trucks, but rather the resulted deterioration of the road surface, as well as the increasing axle load.

Due to significant traffic growth vibration levels rocket (instead of vibration speed of some tenth mm/s and some mm/s, vibration speeds of several 10 mm/s) and it can cause damage even in buildings of good condition and structure.[30] Therefore, it is recommended to carry out an inventory of the buildings of poor condition at least along critical section of transportation routes prior to the construction of the new units in order to assess professionally the real and the putative damages occurring to buildings. In order to prevent structural vibration problems, materials in large quantities should be transported primarily by water or – to a smaller extent – by train.

Direct vibration impact area of the construction is an approx. 100 m wide belt outside the present site border of the power plant and the section of road and railway transportation routes crossing residential area. A 100 m wide belt should be considered here as well. After a site visit it can be stated that there about 300 buildings in this area that can be potentially damaged – to different extent – during construction related transportations. It is recommended from the point of view of vibration (and environmental) protection to establish a connection between the M6 motorway and the construction site that runs outside residential areas.

3.9.3. Impacts related to the operation of the new units

3.9.3.1. Impacts of noise load

According to the data provided [32], regarding the operation of the power plant units to be newly implemented, environmental noise impacts of similar type and order of magnitude have to be expected as in case of the operating power plant. Therefore, at the prediction of impacts the main sources of the operating power plant and in case of their noise levels the results of our previous measurements were taken for basis:

- noise caused by the turbines located in the main building does not get out of the building, the vents on the walls of the building's facade can be considered as source of noise: L_{5m} = 60–62 dBA,
- diesel generators are also located in the engine room, there is L_{5m} = 77–80 dBA noise emission next to the building,
- the outdoor transformer station causes a noise level of about 60 dBA at the site border,
- noise from the pumps causes a noise level of L_{5m} = 68–70 dBA,
- next to the compressor building the typical noise level is approx. L_{5m} = 60 dBA.

In case of fresh water cooling only the water intake structure and the baffle structures of the hot water channels are sources of noise. In case of traffic load, taking the current traffic for basis, at 7.5 m away from the road’s centreline passenger transportation causes 53–57 dBA load in daytime,

[30] In case of buildings with poor structural condition, heavy vehicle traffic may cause vibration damage even at 1 mm/s maximum speed of vibration. In case of well-built, massive buildings, damage is only caused over the speed of 20–30 mm/s.

and 48–53 dBA load at night. Freight transportation is expected only in daytime, the average value is 15 vehicles/hour, its emissions is $L_{7.5m}$ = 56 dB.

Taking the above mentioned assumptions, noise load from the operation of the new nuclear power plant units at the nearest facilities to be protected (Paks, Dankó Pista street, Csámpa, residential area opposite to the southern access road, Dunaszentbenedek, Petőfi Sándor street), both regarding the operational and the traffic noise, complies with the requirements.

According to our estimation, in case of operational noise the impact area is 300–500 m, in case of traffic noise it remains within 50 m from the road's centreline. Within the latter area there are facilities to be protected in the residential areas of Paks and Csámpa.

3.9.3.2. Impacts of vibration load

Direct vibration load: Vibration travelling through the soil may cause detectable problem within 80–100 m from the source, but in the 100 m vicinity of the new power plant site there are no facilities to be protected.

Indirect vibration load: Independent operation of two new units can be executed with fewer staff than at present, resulting in lower road loads. The volume of freight transportation is not expected to exceed the current one. Vibration problem may occur only at the closest buildings with already poor structural condition.

3.9.4. Common impacts of nuclear facilities operated at the site

In connection with operational noise load it can be stated that due to the location of the existing and the planned sources of noise and the distance of the site of three facilities, no significant cumulated impacts can be expected. I.e. statements concerning the new development may refer to the combined noise load as well.

Transportation traffic, especially passenger car traffic, is significantly higher concerning the planned units and the existing 2 facilities (operating power plant and ISFS). The daytime noise emission calculated this way, 7.5 m away from the road's centreline, varies between 60 and 62 dBA depending on the type of reactor unit and the number of operational staff of the particular types of units.

In case of the combined operation of the three facilities, noise levels along roads (assuming that all traffic uses the same route) exceed noise levels resulted by the operation of the planned new units by 5–7 dB. Thus total traffic can cause exceedance of threshold values near residential areas. Therefore the noise impact of passenger and freight transportation in the not too large residential areas along the access roads (territories of village of Csámpa located along the main road No. 6, inbound road to Paks) is expected to be significant. In the environmental impact assessment process this issue needs to be investigated in details: distribution of traffic has to be defined, then estimated noise levels have to be refined, and if necessary, possible solutions should be proposed to prevent exceedance of threshold values.

In case of vibration load, those written in the previous section refer to the combined operation of the facilities as well, since there is no significant source of vibration at the currently operating facilities. Regarding the loads caused by transportation, in case of normal combined operation of the six units, the volume of transportations into the plant, goods to be transported and passenger transportations is estimated to be twice the current quantity. This is a significant amount (about 30–40%, considering natural traffic development as well) compared to the heavy truck traffic of main road No. 6, which may influence the vibration condition of the buildings situated along the route. So the condition survey of the buildings along the transportation routes is essential taking into account the impacts of combined operation as well.

3.10. Wastes

3.10.1. Description of the basic state

According to the available data and information, disposal site of the existing units' construction waste has been excavated at the place of the future power plant units. Based on the complete environmental review executed by FTV Ltd. in 2002 [80], no hazardous materials were found at disposal site, and pollution of the disposed solid waste was not shown by laboratory tests. If the area is concerned by building, the disposed waste will need to be excavated and handed over to an organization having effective waste management licence.

3.10.2. Impacts of the construction

3.10.2.1. Types and quantities of wastes

During the construction period a significant quantity of waste is generated. Types of wastes are essentially the same in case of the different units, however their quantity may differ from each other per reactor type. According to the valid regulation, the earth excavated from the construction area – in case of its contamination – has to be considered as waste, generation of this type of waste has to be taken into account in the largest quantity. The other wastes generated are shown by *Table 3.10.2.1-1*. If a main group or subgroup is indicated, the generation of several types of wastes should be reckoned with from the group.

Table 3.10.2.1-1. Wastes generated during construction

EWC code	Denomination
08 01 subgroup	Wastes from manufacture, formulation, supply, use and removal of paint and varnish
17. main group	Construction and demolition wastes
17 05 03*[1]	Soil and stones containing dangerous substances
17 05 04[1]	Soil and stones other than those mentioned in 17 05 03
15. main group	Waste packaging
20 02 01	Biodegradable waste
20 03 01	Mixed municipal waste

[1] Emphasized due to the amount.

The amount of construction waste may be different depending on the type of unit to be implemented, especially in case of excavated soil, since its volume is also determined by the selected foundation method. During the construction of fresh water cooling system the generation of the same type of construction waste is expected as during the construction of the units.

The quantity of communal wastes will change depending on the number of labourers, considering an average number of 1000 people, a waste quantity of 500–700 kg per day has to be treated, during the peak period (7000 people) this number may reach even the value of 4000 kg/day.

3.10.2.2. Collection, utilization, disposal of wastes

If the upper layer of the excavated soil is not backfilling, then the surface-soil has to be separately collected and used at the field after completion of the construction, or, as surface-soil, handed over for utilization. Only small part of the additional excavated earth quantity of several hundred thousand m^3, a part of which is backfilling, is allowed to be used at the area, its remaining part has to be tried to utilize during road construction, regional planning. If the earth can not immediately be transported, then an interim storing area has to be assigned for its storage. If the utilization is not possible, then the mixed construction waste shall be handed over to an organization having effective waste management licence. If a disposal place with appropriate capacity is not available in the reachable proximity, then it is recommended to enlarge the communal waste disposal site of Paks [78].

In case of construction wastes efforts have to be made during the whole period of the construction that as large fraction of wastes as possible are selectively collected in order to utilize them. In order to do so an appropriate collection area, near the construction or at the building yard, has to be ensured for certain wastes generated in big quantity (brick, concrete, ceramic, wood, iron). Also wastes of paper and plastic packaging materials have to be separately collected in titled containers. These materials shall be handed over for utilization. The utilizing organization may be one of current providers of the MVM Paks Nuclear Power Plant Ltd.

Also hazardous wastes have to be collected separately per kind. Since in case of these wastes the danger of environment pollution exists, therefore the collection place shall be established in accordance with requirements for a plant collection place specified in the Government Decree 98/2001. (VI. 15.) on terms of execution of activities related to hazardous waste. The utilization or disposal is allowed to be performed by an organization having licence to do it, consequently the waste shall be handed over to a company (companies) having such licence. The necessary burning and depositing, respectively capacity is available in the country. Requirements specified in the abovementioned decree shall be complied with during the processes.

The communal waste is currently disposed into the settlement solid waste disposal site of Paks, the capacity of which will run out, therefore a regional disposal site will be constructed with contribution of 7 settlements. An agreement for taking over of waste generated during the construction has to be made with the consortium operating the regional disposal site, if it is necessary, then another disposal place shall be sought.

The vegetation waste generated during settling can be composted or utilized in biogas production. It has to be assessed whether the composting is possible at the composting site to be installed during construction of the Regional Waste Management System of Paks or not.

A log of construction wastes shall be continuously filled out during the construction in accordance with the Government Decree 191/2009. (IX. 15.) on the building industrial construction activity, and it, after completion of the construction activity, together with the take-over confirmation issued by the operator of waste, shall be submitted to the locally competent environmental protection authority. The Inspectorate, in accordance with the Common Decree of Ministry of the Interior, Ministry of Environment and Water 45/2004. (VII. 26.) on detailed rules for management of construction and demolition waste, makes its professional regulatory statement during the construction licensing process.

3.10.2.3. Impacts of the generated wastes

The areas where waste is generated and disposed, respectively during construction, operation and decommissioning, are considered as receptors from the point of view of waste management. During the period of construction the placement of wastes and the storage of them until transportation may cause a change in condition of the geological agent, impacts on surface waters and subsurface waters can be eliminated. The impacts may appear in the form of temporary area use by waste storage places, of spreading of wastes during movement, transportation and of possible draining. The pollutant source is well specifiable in these cases, the pollution is single. The source can be ceased in a short period and the pollution can be removed from the earth. The impacts can be decreased and avoided, respectively if during construction of the plant appropriate collection and storage of wastes generated are provided in accordance with the valid statutes, requirements, and if the rules for waste management are complied with. In such case the impacts will be minimal.

3.10.3. Impacts related to the operation of the new units

3.10.3.1. Radioactive waste generation, management and storage

Low, intermediate and high level radioactive waste is generated in liquid and solid forms during the operation of nuclear power plants. Categorizations of radioactive waste can be different in each country, which should be taken into account in their comparison. In all five reactor types, low and intermediate waste is categorized separately, with management and storage needs having different technical methods, at the same time in four cases (AP1000, ATMEA1, EPR and APR1400) only the spent fuel is regarded as high-level waste – control rods and filters belong to the category of intermediate waste; however these are high level waste in the Paks Nuclear Power Plant. Consequently, only in case of MIR.1200 out of the five investigated reactor types was provided estimation for the quantity of high level waste generated in normal operation.

The planned new units are pressurized water reactor types, therefore, similarly to the currently operating reactors, liquid radioactive wastes shall be considered: evaporation sludge, acid for evaporation, used ion exchanger resin, decontamination liquid, radioactive sludge, rest of radioactive chemicals and used boric acid. Only solid radioactive wastes can be delivered into the disposal facility, therefore the liquid waste should be conditioned at the site, for example, by cementation or embedding in polymer.

According to the national practice, low and intermediate level solid wastes are those which are generated during the operation (for example, clothes, personal protective equipment, used tools, mountings, aerosol filters), reactor tank and its structural elements; and some activated equipment. Short-lived isotopes are dominant in low and intermediate level wastes.

There is no shielding needed for the storage of low level waste, it is enough to separate it in a selected storage area with limited access by nature. The design of the storage facility of intermediate level waste is based on radiation protection considerations though, on the contrary to high level waste, heat generated in the waste should not be taken into account. It is worthy to distinguish the low and intermediate level waste based also on the half-life of isotopes in them: The half-life of the isotopes in short lived waste does not exceed 30 years.

During the operation of the new units, low and intermediate level waste shall be temporarily stored at the site and solid waste shall be compacted by applying appropriate technology. According to the plans, it could happen by grinding, by compacting or by burning (e.g. in case of EPR-type unit) too. It is estimated that 200 litre steel drums are needed for storing low and intermediate level waste in most of the new units, but regarding the AP1000-type reactor, $3m^3$ storage container units would be used for this purpose.

3.10.3.2. Spent fuel management and interim storage

Two types of fuel are planned to be used in the new reactors: uranium dioxide, which is currently used in the Paks Nuclear Power Plant or MOX (Mixed Oxide) fuel, which is the mixture of uranium dioxide and plutonium dioxide produced by reprocessing of the spent fuel. The composition of isotopes in spent fuel covers almost all elements of the periodical system from the low atomic number elements to the highest atomic number elements.

The mass and activity of spent fuel, the heat production generated by nuclear decay, as well as radiotoxicity, which is typical of biological damage, are significant factors in terms of disposal and reprocessing of the spent fuel.

In the beginning, the activity of spent fuel is mainly due to the short-lived fission products, after hundreds of years, plutonium, uranium and other actinides[31] are significant. At the end of the

[31] Common name of 14 elements following actinium with atomic number 89 in the periodic system of elements.

operational lifetime the specific activity is 10^7 TBq/kg, this value will reduce to1/1000 in the first ten years, after 600 years it is reduced by 1/100000 (100 TBq/kg). The heat production is reduced in parallel with the activity of the spent fuel.

The radiotoxicity of spent fuel expresses what amount of potential harmful health effects it could have if the radioactive isotope is absorbed into the human body[32]. After decades from the end of the operational lifetime, a large part of radiotoxicity of spent fuel is originating from actinides, the radiotoxicity of spent fuel will decrease to the level of natural uranium after more than 100000 years.

During 60 years lifetime approximately 1300–2200 tons of spent fuel will be generated in a reactor regarding the provided data (*Table 3.10.3.2-1.*).

Table 3.10.3.2-1. The quantity of spent fuel generated during the whole lifetime of each reactor type

Reactor	Thermal performance[MW]	Fuel burn-up [MWd/kgU]	Load factor [%]	Weight of spent fuel [t]
AP1000	3400	60	93	1334
MIR.1200	3200	55.5	90	1403
ATMEA1	3138	51.5	92	1450
EPR	4300	55	92	1861
APR1400	3983	44.6	92	2126

Due to heat production the fuel assemblies are stored in the spent fuel pool next to reactor core for several years. The activity of the short lived isotopes and the decay heat decrease significantly with time here.

The capacity of the spent fuel pool of the new units allows storing the spent fuel for ten or more years in the spent fuel pool. During this time decay heat is reduced to the value appropriate for storing in dry storage (*Table 3.10.3.2-2.*)

Table 3.10.3.2-2. The storage of spent fuel in the spent fuel pool

Reactor	Storing time [year]
AP1000	max. 18
MIR.1200	10
ATMEA1	6–10
EPR	11–18
APR1400	max. 16

After certain time, the spent fuel should be removed from the spent fuel pool and it is put into the interim storage, where the spent fuel is stored for several decades. The decay heat should be dissipated; however, less intensive heat transfer can be appropriate as such natural circulation. In some countries like Slovakia, wet interim storage is applied, which is similar to the spent fuel pool; however, dry interim storage is more widely used. The widely used types are:

- Appropriate shielding of cask and isolation for radioactive materials are provided by the material of the cask. To improve the heat removal, the surface of the casks has impact fins on it. Some casks are appropriate for the transport of spent fuels as well.

[32] In mathematical sense, radiotoxicity is the weighted sum of the activity of radioactive isotopes in spent fuel by dose conversion factor characteristic of isotopes.

- Storage halls are large size cast iron structures, where fuel assemblies are stored in slim-wall steel containers. A slight crack is left between the concrete wall and steel container in order to intensify the heat removal. The biological protection is the concrete wall.
- Vaults are in a large encapsulating building, which contains the network of the vaults. The decay heat is removed by the circulated air between the vaults containing the spent fuels, the natural circulation is enhanced by a chimney.

3.10.3.3. Options for disposal of radioactive waste and spent fuel

It is assumed that, as a result of technological development, there will be less radioactive waste generated by Generation 3 nuclear power plants to be built in the future, during unit electric power production, than with the currently operating units; however, much less reduction should not be considered. During the operation of the planned new units and after their decommissioning, storage and final disposal shall be provided for several thousand m^3 of low and intermediate level radioactive waste. According to current knowledge, it is likely to be solved by the expansion of the National Radioactive Waste Repository (NRWR) to be realised in the area of Bátaapáti.

In direct disposal of spent fuel (in the so-called open end fuel cycle), spent fuel removed from the reactor can be delivered into the disposal facility without reprocessing. In this case, valuable fissile materials are not used further; however its quantity is not negligible. Disposed spent fuel without reprocessing is high level waste and has significant heat production.

The most appropriate solution for spent fuel disposal is the deep geological disposal facility, which is established deep under the surface in appropriate geological formations. At waste disposal multiple protective barriers are used. Packaging of waste (i.e. the use of appropriate storage containers), the use of gap filling materials, together with the geological features of the disposal site guarantee the isolation of radioactive waste from the biosphere. This kind of disposal facility can be used for direct disposal of spent fuel and it is appropriate for disposal of other high level waste of reprocessing, reactor operation and decommissioning.

The research for appropriate rock of high level waste disposal started with the investigation of the Boda Aleurolite Formation (BAF), which belonged to the then abandoned uranium mine in the Mecsek Hill. Amount of available information on the appropriate rock and its geological environment is by far more than any other documentation on other potential areas. Because of exploratory tunnelling and drilling detailed investigation could be conducted, there are not any circumstances that exclude the appropriateness of the location for deep geological disposal facility. If the spent fuel of the currently operating VVER-440 units is disposed in the location of Boda, the spent fuel of the new units could be considerably disposed there as well with expansion of the tunnel system.

In the closed fuel cycle the spent fuel is reprocessed, then new fuel is manufactured from it and only the waste of reprocessing is disposed finally. The reprocessing of spent fuel is not possible in Hungary.

3.10.3.4. Impacts of construction and other wastes generated during operation

Information on wastes generated during operation was provided by, on the one hand, the suppliers of the new units, on the other hand, the MVM Paks Nuclear Power Plant Ltd. with respect to the units currently operating. Operation of the new units does not fundamentally result in other type of wastes, their specific quantity will be less than the current one, since they are more advanced equipment.

Types and quantities of waste

Conventional wastes generated during operation of the new units qualitatively only slightly differ from wastes of an industrial commercial plant. The most significant difference is that wastes have to be treated separately from radioactive wastes. The wastes may be inert construction wastes of construction and modification works during operation, communal, hazardous and non-hazardous wastes. Using data provided by the suppliers and data of the operating units of Paks Nuclear Power Plant, production wastes of the planned new units are reviewed, the result is shown in *Table M-2.* of the *Appendix*.

With respect to waste management related to the operation of units, the hierarchy of waste management shall be considered: prevention of generation of waste – reduction of generation of waste – reuse – utilization – utilization for energetic purpose – disposal. Where it is possible wastes shall be prepared for reuse. It may include used oil, batteries, metals, glass and paper. A supplier having suitable licence is allowed to be commissioned to transport the waste for the purpose of utilization or disposal at a licensed site. The environmental risk of transportation can be reduced, if it is possible to transport waste to a near place.

The residual solid material (screening waste) of screening of raw water taken from the Danube shall be considered as waste generated related to the operation of the fresh water cooling system. Communal waste is generated in all departments and work areas of the power plant (offices, workshops, social areas, canteens, laboratories, etc.).

Collection, storage of wastes

Collection of wastes shall be ensured so that it is possible to eliminate, but at least to reduce to minimal extent, the possibility of environmental pollution and to provide conditions of utilization. Consequently, if it is not possible to avoid generation of waste, then an appropriate selective collection shall be established. The selective collection has to be implemented, if it is possible, already at the place of generation by means of adequately establishing workplace collection areas. Simultaneously, labelled, well differentiable collection receivers have to be provided at the collection area, in case of hazardous wastes at the site collection areas of hazardous wastes, in which the same types of waste can be collected from workplaces.

Industrial non-hazardous wastes

The industrial non-hazardous wastes, particularly utilizable, marketable wastes, shall be collected so that they do not contain pollutants, which would impede further use. Therefore, it is not allowed to them to contain, for example, communal and hazardous waste. Warehouses, storing rooms in acceptable number shall be ensured for storage of them. Different metal wastes, cable wastes, non-hazardous electronic and electro-technical wastes, wood wastes, as well as paper and plastic packaging material wastes are included in this group. For non-utilizable industrial wastes it is practical to assign a separate collection area, possibly to separate a dedicated section from the area of the site collection place(s) of hazardous wastes.

Construction inert wastes

This type of waste is generated in larger quantity, therefore a particular attention has to be paid to wastes generated during constructions. Not only workers of the power plant are responsible for the task of ensuring suitable selectivity, but, since such works are most frequently performed by external companies, it is obligatory to all constructors. The construction-demolition waste shall be collected in containers located by the given construction in case of smaller quantity, but during a larger construction a separate area suitable for collection of wastes generated shall be assigned.

Hazardous wastes

Hazardous wastes have to be collected at the place of generation, at workplace collection areas, in storage devices with name and EWC code (container, drum, sack). Used oil generated in large quantity is also allowed to be collected in vessels with adequate protection. Solid wastes, which do not contain liquid even in the form of residue (for example, oiled cloth, packaging material of paints), are allowed to be collected in plastic sacks.

Since it is directly not possible to transport the collected waste from the workplace collection areas, hazardous waste collection place/places have to be established at the site. The collection place in question shall be created in accordance with requirements of Appendix 3 of the Government Decree 98/2001. (VI. 15.) on conditions of performing activities related to hazardous waste, furthermore the document of Operational Rules for the collection place shall be elaborated and it has to be submitted to the locally competent environmental inspectorate.

Communal wastes

Communal wastes are conventionally collected at their generation places, in refuse receivers, containers and in storage units assigned for this purpose. It is not necessary to establish a separate storage place, transportation can be executed by means of replacing the containers.

Clearance of wastes

The different types of waste may be generated in both the controlled area and the supervised area. Also wastes generated in the controlled area shall be selectively collected by type, however, they have to be qualified before removal from the site, and they are solely allowed to be removed after a clearance procedure. During the clearance procedure it shall be confirmed that the individual radiation exposure, originated from managing the waste as non-radioactive one, does not exceed the effective dose value of 30 μSv. Wastes are allowed to be cleared on the basis of the Ministry of Health Decree 16/2000. (VI. 8.). Wastes are allowed to be removed from the controlled area on the basis of the requirements specified in the above mentioned decree, considering the clearance levels approved by the authority, after activity measurement. After clearance, the waste removed from the controlled area is allowed to be stored and managed commonly with one generated in the supervised area.

Utilization, disposal

On the basis of profitability and environmental protection aspects, considering the hierarchy of waste management, the decrease of quantity of wastes generated and, by means of establishing a selective system of collection of wastes, the implementation of high utilization ratio of wastes shall be specified as one aim of the investment.

Consequently, utilization, disposal of wastes listed above shall primarily be provided during waste management. On the basis of experience and opportunities, out of non-hazardous industrial wastes the metal, wood, paper, card and plastic wastes can easily be marketed for the purpose of utilization, but, on account of the increase of domestic processing capacity, it will be possible to utilize construction wastes, as well. With respect to hazardous wastes, oiled wastes (used oil, oiled cloth, packaging materials of oils, oiled sludge), batteries and dry batteries can be utilized [84]. A part of the other hazardous waste may be thermally utilized with burning (for example, sewage sludge), for which the necessary burning capacity is available. The final method for the placement of non-utilizable waste is disposal at a waste disposal site. Disposal of hazardous waste – due to its relatively low amount – is possible and feasible at a hazardous waste disposal site.

Impacts of the generated wastes

The impacts of operation differ from ones of construction from the aspect that generation of more types of waste, which are more hazardous from the point of view of the environment, has to be considered. At the same time the impact may last for a longer period, identification of the source, detection of the pollution may possibly be prolonged, therefore also the quantity of pollutant getting to the surface may be more significant. Also in the period of operation the geological agent may be the impact receptor, the impacts on surface and subsurface waters can be eliminated. The direct impact is pollution of the geological agent, which may occur during storage of wastes at workplace and site collection places, in case of the spreading and draining of the waste during handling and transportation or in case of an accident. The indirect impacts may occur at elimination (burning, disposal) of the waste and during its transportation to the disposal place, also in the form of soil pollution and of discharge of air pollutant, respectively. Since the quality of wastes generated depends on the type of unit to small extent only, the impacts may be slightly diverse in case of different units due to the quantity of wastes generated. However, on account of uncertainty of data it is not practical to make a difference between unit types. By complying with transportation rules, as well as establishing and operating the collection places in accordance with the valid requirements, the impacts can be minimized.

3.10.4. Common impacts of nuclear facilities operated at the site

Operation of the new units fundamentally does not result in types of waste differing from ones generated in the current plant, however, it is expectable that their specific quantity will be less than the current values due to the more advanced technology. Conventional (non-radioactive) operational wastes are generated during maintenance, construction works, water treatment and preparation activities. During the year of 2010, industrial non-hazardous waste of 1811 t, hazardous waste of 372 t and communal waste of 450 t were generated at the operating power plant. The waste quantity of new units is expected to be less than this value due to the more advanced technology, the less maintenance demand and the smaller labour force necessity. Operational wastes of the new units are summarized in *Table M-2.* of the *Appendix*.

By complying with transportation rules, as well as establishing and operating the collection places in accordance with the valid requirements, the impacts caused by wastes generated can be minimized.

3.11. Built environment, socio-economic impacts

3.11.1. Description of the basic state

In this subsection general characteristics of the settlement environment are introduced: the town’s position in spatial structure, main development stages and features of infrastructure. In the assessment it is taken into consideration that the operating nuclear power plant significantly influences the everyday life and the development of Town of Paks and by the construction of the new units this positive impact may be manifested on a longer run.

3.11.1.1. Main settlement environment characteristics of the town

Physical geographic setting of the town and its changing position in spatial structure

Its location by the river Danube, on high bank is a dominant element in geography of Town of Paks. The administrative area of the town is 15000 hectares, developed at the meeting point of Transdanubia and the Great Plain, rather belonging to the Great Plain than Transdanubia concerning its landscape geographic characteristics. In its spatial structure, Paks historically has clearly visible north-south dominancy and orientation, east-west relations were always secondary. In its relationship with neighbouring settlements within the micro region there is a strong interaction of cooperation and competition towards Town of Dunaföldvár, county administrative and service relationship, as well as administrative dependence towards Town of Szekszárd and relatively weak relations towards Town of Kalocsa due to the Danube.

In the 19th century, Town of Paks was a town with significant size and population. It was a multifunctional (agricultural, artisanal, commercial and utilities) small country town. By the turn of the 19th and 20th centuries, Paks was a local regional centre, a large village with considerable industry and high quality commerce (Port, post office, railway station were in the town). This development was broken by World War I and even more by World War II. After the war, development started again, based on the region's agricultural traditions, in canning industry. (Town of Paks developed tight connections with the capital, Budapest: it was a supplier of economic, agricultural goods.)

As a result of the construction of the nuclear power plant, Paks's population significantly increased in a short time but at the same time it became a dominantly one-function town. In the life of the town, the nuclear power plant has brought fundamental changes concerning work culture as well, highly trained people with specialised skills settled in the town and gave it a unique character.

The prosperous Paks with a dynamically growing population did not manage to expand medium-level settlement functions as the population growth would have required it. Paks did not expand significantly the network of connections with other settlements above its employment centre feature. But through the power plant Paks has a higher quality infrastructure than towns of similar size, the basic infrastructure can be considered fully developed. Health services have been expanded due to the special health requirements of the power plant, but no town hospital was established.

Civil engineering infrastructure

Prior to the construction of the nuclear power plant the civil engineering infrastructure was significantly underdeveloped. The development started in the early 1970s, by the turn of the millennium, it improved to the acceptable level. As a consequence of the power plant's construction, Paks's settlement structure and physiognomy changed to a great extent. A modern town centre and a housing estate were built. The most important civil infrastructural characteristics are the followings:

- The *road network* of the town is modern. Its full length is almost 100 km, it is almost entirely paved and streets can be easily approached. Sidewalks were built along the street network, but considering bicycle paths, the town is not so well equipped.
- The town's *drinking water* supply fulfils all demands. The length of the water pipeline was 112.2 km in 2010. The drinking water supplied is of good quality, there is a drinking water reservoir of 4450 m^3 available for the town. The *sewerage system* collects almost 100% of the supplied water from the households, its length is 69.4 km. Total amount of the sewage is treated before discharge. 100% of the apartments are supplied with drinking water and 93% of them are connected to the sewerage system, which can be considered as a good value.
- The town is involved in regular *waste collection* and treatment. 15701 tons of solid waste was collected in the town in 2010. The town runs an authorized communal waste disposal site supplied with technical protection. A composting facility will also be built as part of the development. Settlements of Bölcske, Gerjen, Györköny, Pusztahencse, Madocsa and Nagydorog joined the regional waste management system as well. The infrastructure of selective waste collection is appropriate in the town. The recultivation of the former town waste disposal site was completed.
- The access to *electricity system* is 100%. The construction of *gas supply network* started in 1996, by now more than 45% of the apartments are connected to it, in case of other apartments electric stove and district heating is available.

3.11.1.2. Town of Paks and the nuclear power generation

Paks is in a very special situation compared to other towns of similar size, because its operation is basically determined by a single large company. Town of Paks and the Paks Nuclear Power Plant are strategic partners of each others, and they have been tightly interwoven in regional development for many decades. In Paks many developments were realised as “connected investment” in association with or were supported greatly by the MVM Paks Nuclear Power Plant Ltd. in the past decades.

The most important source of local taxes is local business tax, which represents approximately the half of the town’s budget. The nuclear power plant related issues are of national importance in every case, the town and the county hardly have a voice in these matters.

As far as future is concerned, no hints available in spatial development planning documents. In its chapter on energy the Review of the National Spatial Development Concept does not elaborate on the future fate of the nuclear power plant. Most of the members of the Sustainable Development Committee of the Hungarian Parliament, however, supported the extension of Paks Nuclear Power Plant. This way the town’s development could be ensured based on the nuclear energy production even on a long run. Necessary measures are continually being provided by the town, all local conceptions and plans advert the development of the new nuclear plant.

The construction of the power plant had made Paks the most dynamically developing town of the country. Paks is the eighth richest town according to personal income tax revenue. It has a service sector that is not typical in a town of its size.

The next decade, the construction works of the new units will give special importance of this interdependence and cooperation. The effect of power plant development on employment, following a temporary boom, is expected to result a 1–1.5 thousand population rise, which would not compensate for the population decline caused by the negative demographic processes and migration.

3.11.2. Impacts of the construction

Impacts of the construction and operation of the new reactor units on built environment can be divided into three main groups:

- impacts on settlement and spatial structure, townscape and cultural heritage,
- impacts on public utilities and their network in the settlements,
- impacts on public road network and transportation.

According to the information available, there is no significant difference between the reactor unit types neither during construction, nor operation concerning certain impacts on built environment. (According to supplier’s data supply available, there is significant difference in the number of construction staff only – *Table 2.5.1-3.* in *Chapter 2.5.*)

The town could benefit from the construction of new units as far as spatial structure and position is concerned. The planned development confirms Paks’s current position in the long run.

Since the construction phase with high labour demand will have prospectively a significant population growth, the workers and perhaps even their family members have to be accommodated, and this could cause great changes in the town structure too (temporary workers’ accommodations, new residential buildings construction, arrangement of transportation from neighbouring settlements). The increasing number of housing demands the development of belonging infrastructure as well. Demand will appear to develop basic services (trade, cafes and restaurants, public institutions) and to open new recreational areas, possibly near to their working place, i.e. in Paks.

The planned new developments should be sited in industrial area. The place of the new units and the building yard necessary for construction are already designated in the town’s lay-out plan. The temporary land take occurring during construction has an impact among others on built environment since these areas cannot be utilized in this period. The construction of the associated, auxiliary facilities (e.g. roads, other infrastructure elements) requires the modification of land use. When designating these areas, nature conservation and environmental protection interests should have priority.

The site of the planned development is located relatively far away from elements of cultural heritage, therefore these potentially would not be affected. When sites for associated, auxiliary facilities will be selected, cultural heritage should be taken into consideration. A preliminary archaeological survey should be prepared in protection of archaeological valuables, possibly also preliminary excavations and archaeological monitoring of the earthworks are needed.

In the construction phase, public utilities should be developed as well because of the demand of a large number of workers (and their family members) arriving to the region and working there for a longer period of time and they should be provided by the services. For example, it is expected that capacity increase will be needed in waste management and public cleansing. If a new residential area is developed, public utilities networks should also be expanded. Expansion and development of networks can result in temporary disturbance in the life of the settlement (noise, vibration, air pollution).

During construction of the new reactor units, there is a great demand for freight and passenger transport, even new roads could be needed (e.g. between the construction site and the new residential areas). Increased traffic – especially the immense heavy truck traffic – will be unfavourable concerning the condition of roads, air pollution, noise and vibration loads. Therefore preference of public transport would be desirable, both intercity and local transportation, as well as parking possibilities need to be improved.

3.11.3. Impacts related to the operation of the new units

3.11.3.1. Impact on built environment

Impacts of operation greatly depend on what kind of auxiliary developments, investments will take place during construction, whether further developments will be needed during operation. The developed capacities will presumably meet demands raised during operation, since the labour demand of operation is smaller than of construction.

The operation of the new units – if developments are realised in the construction phase – will slightly affect the built environment. Impacts of passenger and freight traffic should be expected only. These impacts can be mitigated if routes bypass residential areas, vehicles of low noise and exhaust emissions are used, if roads used for transportation routes are regularly maintained and cracks and ruts are quickly repaired, and if the so-called “quiet” road surfaces are used.

As a result of the new units the town position will be stabilised in the spatial structure and it can be considered as a definite settlement environmental advantage.

3.11.3.2. Socio-economic Impacts

Demographic change

Population change appears as an impact factor primarily due to the labour demand and increased associated service demands. Changes caused by the construction phase are more dominant than those of the operation phase. It is primarily caused by the typically high demand for construction staff and the prolonged construction time. During construction phase the excess (not local) staff number on site may reach 5000–6000, the sudden rise in itself can cause many problems.

The labour demand of operation for two reactor units is nearly 1000 workers taking into consideration the associated labour demand of supply and services as well. It may result in serious changes but can fit into the development of the region, improving, for example, its currently declining age structure.

Socio-economic impacts

Local and regional employment will significantly improve – by nearly 10% – during both construction and operation phases. The vocational training structure of public education in the county is favourable to meet both the direct and indirect demands of the new units.

The favourable employment impacts of construction and operation phases may result in better job choices in significant part of the region, the increasing personal and local government incomes can stimulate the economy. It is likely that private and joint ventures working in the region will become stronger in comparison to the baseline conditions.

In Paks the planned development would increase considerably local tax incomes in both the construction and the operation phases. The investment shall also have considerable effect on contribution and tax revenues of the country.

Impacts on individuals

The construction phase will cause changes in life quality. For local residents it may manifest as nuisances, but for most of the long-term employees it will be an actual decrease in life quality.

There are no considerable reserves in the local social, educational and health services (except for kindergartens) to supply the temporary and permanent excess staff (some of them arriving with family members), therefore the development of them is inevitable.

The existence of the nuclear power plant is not considered currently as a factor worsening the sense of safety in the region. The acceptance of the operating nuclear power plant by population is good both nationally and regionally. The Fukushima nuclear disaster has not changed the acceptance essentially. The survey data referring to the realisation of the new nuclear units, however, show that both the Paks nuclear incident in 2003 and Fukushima nuclear disaster had significant impact on the ratio of support and rejection. The other lesson to be learnt from the surveys was that the acceptance of nuclear power greatly depends on how well people are informed. The more information is available, the better the acceptance.

Since the new planned nuclear power plant units are basically to replace the existing nuclear power plant, despite the parallel operation for some period of time, in the view of the survey data it would be more favourable to communicate this towards society.

Impacts on the community

Investigating Town of Paks it can be stated that already now almost everything is connected to the nuclear power plant. Therefore, local identity is likely to change insignificantly, the change's direction will also depend on the positive or negative experiences of construction and operation. The more people would be hired from the wider vicinity during construction and operation, the stronger that attachment could get. The judgement of the affected region from outside is explicitly good, the nuclear power plant is rather attractive than uninviting for the individuals and enterprises. From this aspect a big change is unlikely.

3.11.4. Common impacts of nuclear facilities operated at the site

Combined impacts on built environment occur indirectly due to excess loads from transportation in areas along certain transportation routes. Here locally, directly next to the roads considerable impacts may occur, therefore mitigation of vibration must be an important task. In this issue the local government should cooperate with the investor (e.g. designating areas where traffic needs to be decreased, shifts should start at different times, etc.).

All other impacts affecting the built environment are of socio-economic nature. I.e. not impacts of the combined operation are dominant but those occurring after the decommissioning of the currently operating power plant. This should be investigated not in the present study, but as part of the future environmental assessment(s) of the decommissioning of the power plant.

3.12. Landscape and land use

3.12.1. Description of the basic state

Concerning the landscape protection – based on the Act LIII. of 1996 on nature conservation – it is necessary to investigate the land use, the landscape structure, the characteristics of scenery and the landscape potential in the environment of the new nuclear power plant units. The evaluation of landscape, mainly from landscape scenery point of view – regarding the appearance of the units as determinant landscape element – is extended for the 20 km surrounding of the power plant.

3.12.1.1. Land use, landscape structure

Aerial and satellite images made since the construction of the nuclear power plant until today helped to study the changes in landscape structure. The following can be stated based on the evaluation of 5 pcs of aerial and satellite images made between 1997 and 2009:

- In the 1970s – prior to the construction of the power plant existing today – agricultural landscape and scenery (close to 2/3 of it large-scale arable land) was dominant in Paks region with high ratio of near-natural area (10% forest, 6% natural grasslands, over 5% water surface). The settlement fit into the landscape type, it was a quiet, stagnating large village, the food-processing was dominant even in its industrial activity.
- Construction of the power plant caused a significant change in the landscape structure: The number of artificial elements has increased, an extensive industrial area came into existence, housing estate was built up for the employees as an associated element. Increase of forest areas (protecting forest belt) was provable. The increase of industrial areas is continuous ever since, mainly in the area between the settlement and the nuclear power plant, bordered by main road No. 6 and the Danube. This change, however, is not the direct consequence of the increase of the nuclear power plant's area, but of the establishment of associated, service industrial areas and other type of industrial and service facilities.
- Around the turn of the millennium the structure of agriculture changed significantly. The ratio of large-scale arable lands decreased to 40%, the ratio of small-scale arable lands increased to 18% (compensation). From that time large-scale arable lands are not dominant in the landscape structure and scenery anymore. As a sign of urbanisation there was a significant expansion of sport, leisure and recreation areas.

Nowadays mosaic-like distribution and diversity is still typical of the landscape structure in the vicinity of Paks and the nuclear power plant (*Figure M-19.* of the *Appendix*). The extension of agricultural areas is still significant (59%). The ratio of deciduous forest cover is high (approx. 11%). Water surfaces, grasslands and suburban residential areas are around 5%, therefore these can be considered as characteristic land uses in the region.

3.12.1.2. Assessment of present landscape features

In the description of a landscape – structure and scenery – besides its biological activity its genuineness, versatility and healthiness[33] are also being assessed. These features are primarily

[33] Attila Csemez – Ákos Balogh: Landscape protection in the environmental impact assessments (prepared in 1986 on behalf of the National Authority for Environment Protection and Nature Conservation (OKTH))

determined by lack or existence, quality and quantity of plant populations, other landscape elements and fringes:

- At present biological activity of the vicinity of Paks can be considered medium. Forest cover is a bit lower than national average, grassland cover is also relatively low. The ratio of water surfaces (mainly the Danube and angling ponds) is larger than average. Agricultural areas covering more than a half of the area are partially active biologically, since during one part or the whole of the vegetation period they are covered in plants.
- Degree of anthropogenic influence is remarkable, (power plant, other industrial areas, traffic areas, high voltage overheadlines, etc.) even in semi-natural vegetation patches. (E.g. the protecting forest is rather a plantation than a real forest. The grazing in the ecopark significantly worsened the life conditions of the original sandy grasslands.) Due to human activities the region of the planned new units has almost lost its genuineness, thus the area’s genuineness is low. Almost original, semi-natural vegetation patches can be found along the Danube and to the north-west, where the hill-chain is mainly covered in vineyards and orchards. The protected Ürge-mező is a part of it.
- Concerning its geographic features, the studied region shows those of the Great Plain. From versatility point of view the region’s landscape structure was a lot more versatile, fragmented and vivid even before the construction of the power plant than an average Alföld (Great Plain) landscape. Its main reasons are the water surfaces and forests, the Danube and its riverine vegetation along it, which are the dominant fringes of the landscape scenery.
- From landscape’s point of view the healthiness of the area keeps declining. Intense human disturbance was typical even before the construction of the power plant, consequently flora and fauna had been degraded, rare species had retreated and had become extinct. Green surfaces covered in natural vegetation in most of the year had already been missing. Industrial utilization is often accompanied by sick vegetation, erosion, devastated-degraded surfaces as well as weeding and invasion of alien species (e.g. grasslands under transmission lines or intense weeding in protecting forest). In the past years this adverse process was enhanced by several actions (e.g. the expansion of the industrial area, the opening of M6 motorway and the ecopark).

In summary, it can be stated that from a landscape and scenery point of view, the region is significantly changed, traces of human influence are dominant. The appearance of the Danube and its riverine vegetation in landscape structure and scenery is a positive feature, as well as the significant fragmentation, versatility, and the natural characteristics of spatial fringes.

3.12.1.3. Scenery characteristics

Scenery is produced through visual perception, primarily by recognizing elements of forms and colours. Landscape scenery is qualified aesthetic in general, if it is various and composed from natural and semi-natural elements. The experience of space is also important, which is widened by the horizontal fringes and tightened by the vertical ones. In the most aesthetic landscape sceneries the various forms of relief, the water surface and the green vegetation are present together.

The close vicinity of the power plant has a moderately rich landscape structure. Amongst positive elements dominant from landscape and scenery point of view, water surface, riverine vegetation and, on the west, relief elements can also be found. Negative visual elements are non-existing or hidden (e.g. waste disposal site). The town and the power plant are very dominant built elements in the landscape.

The appearance of the power plant as a visual element depends on the subjective judgement of the individual. Landscape aesthetic evaluation of the whole of the society is influenced by several sociological, mental, emotional, psychological (even political) aspects. When making a visual judgement of a power plant, it is significantly influenced by that it appears as a symbol of high-level work culture, planning and exactitude. It exudes the intellectual capital invested, top-level technology even in its appearance.

In summary, it can be stated that landscape appearance of the region is not outstanding (neither in positive nor in negative direction).

3.12.1.4. The power plant activity in shaping landscape and settlement environment

The operating power plant's active environmental protection activity plays a role in the landscape structure forming. Several programmes started by the support of MVM Paks Nuclear Power Plant Ltd., of them the followings have to be mentioned from landscape's point of view:

- rehabilitation and water supply of Fadd-Dombori Duna-holtág (*oxbow on the river Danube*),
- revivification of Dunaszentgyörgyi láperdő (alder swamp) along the route of the water supply,
- establishing the fishing paradise next to the fence of the nuclear power plant,
- supporting foundations, actions dealing with regional and settlement development, ("Together against the ragweed", Duna-Mecsek Regional Development Foundation[34], "Plant a tree, arbor vitae – Save the source of oxygen[35]").

3.12.2. Impacts of the construction

The *landscape structure*, which means the type and way of large-scale land use of the whole of the landscape receiving the planned development, changed significantly when the currently operating power plant was built, and a new dimension of landscape use has appeared in the region. The earlier agricultural landscape has transformed into industrial one. In present case, however, the new units will be built in a landscape structure of power plant usage, therefore in this case there will not be any further changes concerning the landscape structure.

Small-scale modifications of mosaics of *spatial structure* are possible principally in the close vicinity of the power plant. Impacts are resulted firstly by the building up of the site, secondly by location of temporary building yard facilities and thirdly by the construction of associated e.g. infrastructural facilities (power network, roads, railways, harbour, etc.). In the immediate vicinity of the site further land use changes may occur, e.g. it is practical to expand the size of the forest shelterbelt towards north or certain land use mosaics (dairy farm, motocross course, etc.) should be partly or fully relocated to a new place. These land use changes occur in the immediate vicinity of the new site, within a few 100 m and 1–2 km at the most and they cause minor modifications in the spatial structure.

The impact of the construction phase on the *land use* is significant in the extended, 100 ha construction area and building yard during the 5–8 year-long construction period, it may even cause detectable disturbance in the landscape scale. According to expertises, transportation may have the most significant impact. In order to keep disturbance at a minimum as much construction material as possible should be transported by water. Even transportation by railway is more advantageous than transportation on public road, except at the eastern border of Town of Paks.

The road transportation would disturb the traffic of neighbouring roads (traffic slow down, traffic jam). The load on roads can result in the deteriorating conditions of roads and buildings along them, because of the significant volume of vehicles loaded with construction materials and the generated vibration.

[34] Source: http://www.atomeromu.hu/duna-mecsek-teruletfejlesztesi-alapitvany
[35] Source: http://www.paks.hu/varos/civilszervezet.php

Since the construction phase is longer than the average, it is worth dealing with *temporary changing of the landscape scenery* separately. During the construction there will be variable and invariable scenery elements. Variable element is, for example, the sight of facilities depending on their preparedness, invariable elements are, for example, the movement of construction workers, the appearance of barracks, machinery and transportation equipment. The increased human presence, as well as traffic decreases the harmony of present balanced industrial appearance.

The facilities of the nuclear power plant could not be seen in the scenery in the first phase of their construction (grading, foundation). When the construction of superstructures starts, the facilities start to determine the visual appearance of the tight and wide environment. Heights, volumes and cubage of the new units and facilities will be similar to the existing power plant's ones, therefore, although they are new elements, but overall the scenery will not be different from the previous one. Complete fitting into the landscape or blocking out is impossible neither in case of the reactor buildings nor in case of the much higher chimneys. While the former ones are extended and dominant landscape elements, the slim (narrow) chimneys are not dominant elements of the scenery.

In many cases an unfavourable scenery element does not disturb people. If a person meets the scenery of a characteristic industrial plant as a worker or an employee, his/her relationship with this scenery will be much better than of somebody else, who wants to relax in the area or (s)he is just passing through it. The nuclear power plant may have disruptive effects seeing it from the interior of settlements. In these areas, however, the negative discretion is mitigated by that the power plant is the largest employer of the region. Specifically recreational areas appear only at some points in the area, in their case the negative scenery can be eliminated by blocking out. The existing power plant is only visible discontinuously from main road No. 6 and M6 motorway. It is expected that the length of present shorter visibility sections will increase, the landscape scenery impacts will gradually increase during the construction phase.

The landscape scenery's impact area will gradually increase during the construction process. Taking into account the above, in the first period the changes will be practically only visible in close proximity, from beside the fence. Later, by the construction of the high structures (chimneys, power plant buildings) till reaching their full height the impact area will increase continuously, until it reaches the estimated vicinity of 20 km.

3.12.3. Impacts related to the operation of the new units

The changes of *land use and landscape structure* are equivalent to the changes described at the construction of units, namely considerable changes of land use and landscape structure are not expected.

In order to assess the landscape comprehensively, biological activity, genuineness, versatility and healthiness of present state were assessed as well. After commissioning the new units:

- The *biological activity* of the area will slightly decrease, since the areas planned to be built-up are species-poor grasslands now, with foundation remnants in some places. The shrinkage of green surfaces resulted by built-up and paved roads could be compensated, if the free surfaces of the industrial area and part of the recultivated building yard are parked, and a protecting forest belt is planted along the site border.
- The *degree of anthropogenic influence* is significant even without the construction of the new units. This activity intensifies it. The degree of influence is further increased by the associated infrastructure facilities. As far as *versatility* is concerned, no significant change is likely. Appearance of new fringes, and the significant expansion of existing ones are not expected.
- No significant change is expected concerning the *healthiness* of the landscape. After construction works – that are likely to worsen the landscape's healthiness temporarily – are

over, the degraded and disturbed surfaces and the building yard will be parked and presumably planted with plants, so they would not be occupied by invasive species.

The *landscape scenery changes* are caused by existence of the associated facilities. Significant impact could not be expected, because the facilities of new units have similar cubage (height, volume, texture) than the existing ones.

The area of changes in scenery is shown by *Figure M-20.* of the *Appendix*. In this figure those places are shown from where the approx. 50 m high buildings could be seen within circles with radius of 10, 20 or 30 km, without taking into consideration the coverage and blocking out effect. Units of the power plant will be visible from west side within a 10 km radius circle, while from east within the 20 km distance almost the whole area can be seen. Between 20 and 30 km the visibility decreases yet. Considering also the fringe forest at the banks of the Danube, we have determined the impact area from the point of view of scenery as the circle with radius of 20 km around the centre of new site. (Naturally the new power plant will be visible within this area as mosaic only and depending on the weather conditions, therefore the real impact area may be smaller variably in time and in space.)

Figures M-21. – M-27. of the *Appendix* show some scenery images made during the investigation of the new facilities' expected appearance.

3.12.4. Common impacts of nuclear facilities operated at the site

Landscape changes (landscape structure, scenery) should not be studied without taking baseline conditions into consideration. Thus statements in previous sections refer to the period when all facilities operate together. Impacts different from these can be caused by the new situation occurring after the decommissioning of the currently operating power plant (e.g. demolition of existing buildings).

4. Boundary of impact areas for variations considered

4.1. Impact areas of the radiological impacts

In course of qualification of the impacts the spatial extension of the impacts is an important aspect, because wider extension could increase the number of the affected population and the importance of the impact as well. Environmental impacts caused by radioactive releases, as well as by direct and dispersed radiation could be categorized on the basis of the qualification categories of *Table 4.1-1.*

Table 4.1-1. **Qualification categories of radiological impacts of the new units**

Change of condition	Exposure levels (E) [μSv/year]
Neutral	E ≤ 90
Tolerable	90 ≤ E ≤ 1000
Loading	1000 ≤ E ≤ 10000
Damaging	E > 10000

The upper limit of neutral impacts is 90 μSv/year. According to the proposal written in the document entitled "Dose constraint of the new units at the Paks site" [42], in the determination of dose constraint of the new units the currently accepted value (90 μSv/year) for the operating power plant shall be taken into account because the planned activity will be the same (operation of nuclear power plant) and the "size" of the sources (installed total capacity) is also roughly the same. The 90 μSv/year dose constraint value was defined for the Unit 1–4 of Paks Nuclear Power Plant in the permit No. OTH 40-6/1998 of National Public Health and Medical Officer Service (NPHMOS). The value of the dose constraint is much less than the dose limit of the general public. It is also smaller than the differences of the natural (background) exposure depending on time and location. If not the same (or nearly the same) constraint value was specified for the new facility as for the operating nuclear power plant, it may result that the qualification of the two power plants' same radiological environmental impact affecting the same environment would not be the same.

The 1000 μSv/year dose limit, which is applied as the upper limit of the tolerable impact, is defined in the Ministry of Health Decree 16/2000. (VI. 8.). According to this decree, the sum of the external and the internal dose from artificial sources should be below this dose limit except for exposure caused by medical diagnosis and therapy, voluntary nursing and voluntary participation in medical research.

The upper limit of the dose level considered as a loading impact is 10000 μSv/year. This dose limit is also defined in the Ministry of Health Decree 16/2000. (VI. 8.). According to this decree, this is the lowest interventional dose level where protective measures (sheltering) should be taken in case of a nuclear or radiological emergency or extraordinary event.

From radiological point of view the impact area *lies within the controlled area* in terms of gaseous and liquid releases, as well as dose consequences *in case of normal operation*. Furthermore, the exposure does not reach the value of 90 μSv/year; therefore it is considered as a neutral impact. The extension of the impact area is shown by *Figure M-28.* of the *Appendix*.

Environmental release into a more extended area can only be possible, if incident or severe accident occurs. *Design basis accidents* can be divided into two categories based upon their frequency. Discharge limits are assigned to these categories. Using the proposed discharge limits, it can be assured that releases will not reach the value that triggers the introduction of protective actions or implies economical consequences beyond 800 meters.

Based on the analyses performed, in a typical case, when releases occur throughout the stack, the estimated dose consequence will decrease at approximately 4 km from the source to one-fifth of the value given at 800 m. Accordingly, if the EUR criteria are fulfilled, exposure should not be greater than 1 mSv in category DBC3 at distances greater than 800 m and in category DBC4 at distances greater than 4 km. Therefore, the radiological impacts will not be loading beyond these distances. If the EUR criteria are fulfilled, dose exposure will be below 90 μSv/event at a distance greater than 7 km in case of category DBC3 event and at a distance greater than 40 km in case of category DBC4 event. Therefore, the radiological impact is neutral beyond these distances.

For controlling our statements, we made calculations. In case of the EPR-type reactor's LOCA[36] (category DBC4) [29], at 800 m from the source we estimate 0.29 μSv/event as short term exposure. Taking into account the general nutritional habits, the committed effective dose is 1.5 μSv/event during 50 years. These values are lower with approx. three orders of magnitude than those conservative values that can be concluded from the EUR criteria.

The *events beyond design basis* (DEC – design extension conditions) are divided into beyond design basis emergencies and serious accidents. Release limits should be prescribed for beyond design basis emergencies, while release limits are not attributed to severe accidents but their cumulative occurrence frequency should be limited. The course of severe accidents is significantly influenced by emergency response in order to mitigate consequences. Protective measures are considered successful, if the discharge is below the limits of the beyond design basis emergencies. Discharge limits for the beyond design basis emergencies are proposed in the document of EUR. Assuming the proposed discharge limits it can be assured that releases will not reach the values, which trigger evacuation at a distance greater than 800 m, temporary relocation at a distance greater than 3 km, and trigger relocation for more than one year time at a distance greater than 800 m or causing economical consequences. Assuming that – according to the EUR criteria – the measured dose is maximum 30 mSv at 3 km from the source, it will follow that the dose consequence of the event will be maximum 10 mSv at 7 km distance and 1 mSv at 100 km distance.

For controlling our statements we made calculations for the EPR-type units with available data of a DEC category accident [29]. Based on our calculations, at 800 m distance we assessed 34 μSv, and at 3 km distance we assessed 12 μSv. These values are several orders of magnitude lower than those that can be concluded from the EUR criteria.

The values concluded from the EUR criteria are summarized by *Table 4.1-2.* It has to be emphasized that these values do not refer to any specific type of unit, but are upper limits for a fictitious unit, which is the least favourable one that can still be constructed fulfilling the EUR criteria.

Table 4.1-2. Distances in the plume axis (km) from the source according to the dose limits given in the EUR criteria in case of different emergencies

Category	Target value			
	30 mSv	10 mSv	1 mSv	90 μSv
DBC3*	–	–	0,8	7
DBC4*	–	–	4	40
DEC**	3	7	100	1400

* Referring to late committed effective dose.

** Referring to early effective dose (calculated for 7 days).

[36] LOss of Coolant Accident

4.2. Impact areas of the conventional environmental impacts

The preliminary estimated impact areas of conventional environmental impacts related to the construction and operation of the new nuclear power plant units, as well as to the presumed incidents, accidents and emergency events are shown in table form. In *Table 4.2-1. – 4.2-3.* spatial extension of conventional environmental impacts is given in breakdown by impact factors of each environmental element/system. The impact area of each environmental element/system can be seen in map form in *Figure M-29. – M-38.* of the *Appendix*.

Table 4.2-1. Impact area of the conventional environmental impacts of the construction phase

Impact factor	Extension of the impact area	Interpretative notes
Impacts on air quality		
Construction work	Circle with a radius of 500 m around the construction site	Significant, several year-long air polluting activity. Most significant release is dust load (floating dust).
Passenger and freight transportation	50–100 m belt along transportation roads until traffic distribution points (Csámpa, Paks, M6 motorway junction)	
Impact on microclimate		
Built-up (new facilities, pavement)	100 m vicinity of the construction area and the building yard	Insignificant changes due to urban effect
Impacts on surface water environment		
Water intake (domestic and service water)	Water intake structure, pumping station, inflow section of the cold water channel, its vicinity of max. 100 m	Due to bed morphological changes at the water intake structure, and adverse change in condition or use caused by water deficit.
Water inflows – Water inflow resulted from foundation engineering dewatering – Inflow of rainwater – Inflow of (treated) communal and industrial sewage	 Max. 5 km vicinity of the construction site (its impact is restricted to the period of foundation works) Max. 1 km (taking into account its small quantity compared to water stream of the Danube) <100 m from the discharge place	Determination of impact area is based on that area, where as a result of water inflow the surface water qualification class may deteriorate.
Other impacts – Construction of pumping station feeding the cold water channel – Construction of new section of hot water channel and flood control dam	 500 m upstream and downstream Area of intervention and building yard and belt of 500 m	 Due to the impact on the hydrodynamic and morphologic condition of the Danube. Channel construction has an impact on the river wall.
Impacts on subsurface waters		
Factors affecting ground water circumstances	The direct impact area is largely the investment area and the building yard. The eastern boundary of the impact area is the bed of the cold water channel. (The impact areas are not continuous; their precise boundaries can only be determined by means of hydraulic modelling.)	The water level, the gradient of ground water and the flow regime are affected, beyond the natural factors, by artificial impacts as well: operation of the cold water channel (bed of the channel is not insulated, it has a direct hydraulic connection with the ground water); infiltration /drainage of rainwater; filling and coverage condition; possible failures of public utilities network; deep foundations.
Dewatering of foundation building pits	The direct and indirect impact area is the foundation building pits and a belt of max. some 10 m. Eastwards the impact area may spread up to the line of the cold water channel.	The foundation building pits can only be implemented by means of lowering of the ground water level. The average ground water level is at a depth of 8–10 m at the investment area. The intervention also affects level, flowing direction and velocity of ground water. Compaction of water-bearing formations is an indirect

Impact factor	Extension of the impact area	Interpretative notes
	(The precise impact area can only be assigned by means of hydraulic modelling.)	impact of dewatering, which may cause even non-uniform subsidence on the surface.
Impact of built-up density on ground water	The impact area is the same as the spreading of the investment area and the building yard.	The built-up density restricts surface infiltration of rainwaters, it reduces the ground water level, however, due to the limited evaporation, an increase in water level can be expected. These two impacts (may) neutralize each other.
Subsurface water intake (providing drinking water demand)	The estimated direct and indirect impact area is the region with approx. 5 km radius of Waterworks of Csámpa. (The impact area can solely be specified more precisely after wide-range data collection, with help of hydraulic modelling.)	Direct impact: decrease in stationary levels of subsurface waters, its extent is not expected to be beyond a few meters. Indirect impact: On account of the intensive water intake, the hydraulic gradient may turn into negative endangering the subsurface water-bearing layers. The chemism of subsurface waters may change on account of changed water-rock reactions. In consequence of decrease in pore water pressure a compaction may occur in the water-bearing layers, which may result in even lowering of the surface.
Impacts on soil and geological agent		
Terrain preparation, settling, relocations of public utilities	Area of approx. 400 m × 600 m of the investment area. The max. area that is allowed to be built up is 24 ha. Its building yard connects to the construction area northwards, its size is 76.2 ha.	
Soil dusting	The estimated impact area is, starting from the centre of the investment area, a zone with a length of 1.5 km and a width of 0.6 km to the south-south-eastern direction, and a zone with a length of 1 km and a width of 0.6 km to the northern direction. (Precise determination is solely possible by modelling.)	The average grain size of soils concerned by earth works changes between 0.1 and 0.3 mm, therefore these soils are prone to dusting. The phenomenon of soil dusting caused by wind covers the area of foundation building pits, slopes, access roads until the depth of ground water. The impact area represents the sedimentation area of soil particles transported by wind to different distances.
Erosion of slopes of building pits on account of rainwater (sheet erosion)	The impact area is practically the same as the total surface of slopes created. Consequently, dimensions of the impact area do not exceed boundaries of the investment area and the building yard.	The stability of slopes of foundation building pits, transportation roads is endangered by erosion processes. Such impact is generated by sheet erosion caused by intensive rainfalls. This indirect impact concerns the geological agent got onto the surface as a result of earth works.
Impact of foundations on subsurface	The direct impact area is the area of the facilities, and a narrow zone with a width of max. some meters. (The precise values can be calculated by means of detailed geotechnical modelling.)	This impact represents intensive soil-physical stress (compaction) of the geological agent. Due to the weight of facilities, an increase in layer loads can be expected everywhere. The expectable boundary depth of soil stresses causing compaction in the area of nuclear power plant can be specified as 47 m according to the archive calculations.
Impacts on wildlife and ecosystems		
Impacts on terrestrial wildlife	All construction site – both on and off the project site – are considered as direct area of impacts affecting wildlife.	In the direct impact area the destruction of wildlife, in other places its disturbance is expected. The area of disturbance is situated partly in the Tolnai Duna

Impact factor	Extension of the impact area	Interpretative notes
	The indirect impact area consists of the impact areas of any other environmental element (air, water, earth) or cause of impact (noise, vibration, waste management).	Natura 2000 area.
Impacts on aquatic wildlife	Direct construction site of the construction works of the fresh water cooling system's facilities (water intake structure, new cold and hot water channel, flood control dam) and the Danube section of a few 100 m downstream the construction site.	Implementation of the fresh water cooling system's facilities at the meeting point of the new channels and the Danube involves also the intervention into the living space of the Danube (dredging, riverside planning works), affecting the Tolnai Duna Natura 2000 area.
Noise and vibration load		
Noise load caused by construction work, passenger and freight transportation	The border of impact area is the distance from noise sources (from the border of construction area and from the centreline of the transportation route), it extends in case of constructions works up to 3100 m distance, in case of transportation up to 40 m distance from the road. Residential areas within this area (Paks, Dunaszentbenedek, Csámpa) are endangered.	The noise impact area was demarcated taking background load of neighbouring areas, their building zone classifications and the noise emission of the planned activities into consideration in compliance with the regulations. In case of the traffic impact area, from the point of view of both noise and vibration emission, the areas to be considered are those along the railway until the settlement of Előszállás, and those along roads until traffic distribution points (Csámpa, Paks, M6 motorway junction).
Vibration load caused by construction work, passenger and freight transportation	The construction area and the building yard, the 100 m wide belt around them (direct impact area), as well as the 80–100 m wide belt along roads and railway lines used for transportation (indirect impact area).	
Generation of non-radioactive wastes		
Wastes generated during construction works	The impact area does not exceed, or exceeds with some meters only, the area of putting down, consequently it remains within the construction area anyway, while in case of a waste depository it does not affect size of the impact area of the depository.	The impact receptor is (may be) partly the construction area, where the wastes are generated, but mainly the area, where they are stored until transportation and, if they are not utilized, where they are put down. The geological agent is the impact receptor.
Waste transportation	50–100 m belt along transportation roads until traffic distribution points (Csámpa, Paks, M6 motorway junction).	With respect to the construction significant waste transportation is needed, that is, specifying more precisely, transportation of excavated earth to be registered as waste according to the current regulation, is needed.
Impacts on built environment		
Spatial structure, infrastructure, socio-economic impacts	The impact area will include all areas, where town development investments will take place due to the construction of the new reactor units. In this phase their exact location is not known, but it is expected these developments would take place typically in the built-up area of Town of Paks. Therefore, Town of Paks can be considered as impact area.	Town development investment: establishment of new housing estate and temporary accommodations, construction of infrastructure elements or even construction of cultural or sport facilities.

Impact factor	Extension of the impact area	Interpretative notes
Landscape and land use, landscape impacts		
Visibility, landscape impact	Region with 20 km radius around the construction place	Beyond this distance even this scenery element with considerable dimension will not be determinative in the scenery.
Works in the construction area	The impact can be possibly detected at the southern edge of Paks and the western edge of Dunaszentbenedek.	Significant excess load is not expected in any settlements, on the one hand, due to the distance, on the other hand, in case of Dunaszentbenedek due to the load mitigation effect of the floodplain forest.
Transportation activity	50–100 m belt along transportation roads.	

Table 4.2-2. Impact area of the conventional environmental impacts of the operational phase

Impact factor	Extension of the impact area	Interpretative notes
Impacts on air quality		
Test operation of diesel generators	Circle with a radius of 500 m around the new units	It means temporary load, a few hours monthly.
Passenger and freight transportation	50–100 m belt along transportation roads	
Impact on microclimate		
Built-up (new facilities), urban effect	The site and its 100 m vicinity	
Operation of the fresh water cooling system	Hot water channels and the 4–5 km section downstream their inflow point, some 10 m vicinity of the banks.	After 4–5 km the surface mixing of the heat tail usually occurs, therefore characteristic climatic changes are not probable.
Impacts on surface water environment		
Cooling water intake	Section between the new cold and hot water channels to be constructed	The water demand is max. 132–172 m^3/s depending on the capacity of the units and the temperature difference, which is 19–25% of the lowest stream flow of the Danube (700 m^3/s).
Warmed-up cooling water discharge (by complying with the temperature limit expected to be stricter)	4.5 km in case of 2×1200 MW unit capacity, 8.5 km in case of 2×1600 MW unit capacity	Assuming 26.7 °C background water temperature and 30 °C discharge temperature. The impact area is the boundary of the 1 °C increment of temperature.
Other service water intake	The impact area is local in the vicinity of the water intake	The service water intake is insignificant (‰ order of magnitude) compared to the lowest stream flow of the Danube (700 m^3/s).
Inflow of (treated) sewage	<100 m from the discharge place	The treated sewage discharge of each unit is fraction of the lowest stream flow of the Danube. The inflow of these sewages does not cause water quality class deterioration at any water quality parameter.
Impacts on subsurface waters		
Impact of deep foundations on ground water	The direct impact area is the same as footing areas of the facilities, but the size of the impact area changes in time, it is larger in case of average and low ground water levels, while it may cease in case of a high water stage.	The foundation level of containments of reactor units and turbines will always be under the actual ground water level. The deep foundations, by means of forming an obstruction, deviate the natural flowing direction of ground waters.
Bed colmation caused by operation of series of bank-filtered wells	The plant-side bed section of the cold water channel	The intensive operation of bank-filtered wells may involve more intensive siltation of bed of the cold water channel at the infiltration area of the channel.
Subsurface water intake (providing drinking water demand)	The direct and indirect impact area is expected to be smaller than the impact area of the construction phase (region with approx. 5 km radius of Waterworks of Csámpa).	More precise impact areas can only be determined by means of hydraulic modelling.
Impacts on soil and geological agent		
Loading impact of facilities on subsurface	The extension of the impact area is similar to one in the construction phase (the area of the facilities and a narrow zone with a width of max. some meters)	Compaction of the load-bearing soil under foundations slows, but continues during the period of operation. The impact of consolidation processes is similar to ones occurring in the construction phase, but the duration of the impact is longer.

Impact factor	Extension of the impact area	Interpretative notes
Vibration impacts of turbine foundations (engine foundations) on soils	The impact area is the same as the footing area of the facility (turbine hall). This direct impact area does not exceed dimensions of the investment area.	This impact represents intensive soil-physical stress of the geological agent. Soils may continue to compact under foundations and even liquefaction may occur in a disadvantageous case. Locations of facilities causing such impact are not yet known in the present stage of design. The harmful impact can be prevented by means of soil stabilization, in that case it is not possible to talk about an impact area.
Impacts on wildlife and ecosystems		
Impacts on terrestrial wildlife	Almost only the indirect impact area should be considered. It is the sum of habitats where changes in environmental elements (air, water, earth) are expected to be traceable. As direct impact area the environment of the new transmission line network can be considered, where damage or death of flying specimen may occur.	The positive impacts have a so-called positive impact area. Provided that water from the new reactor units might be emitted to Fadd-Dombori Duna-holtág (*oxbow lake on the river Danube*), then this oxbow lake and its direct vicinity are also part of the impact area. Furthermore, since the canal system providing water supply goes through the Dunaszentgyörgyi láperdő (*alder swamp*), this area is also defined as impact area. The same is true for the angling lakes and the nicely parked environment, which are ideal habitats for aquatic and waterside wildlife.
Impacts on aquatic wildlife	It lies about 2.5 km to the south of the mouth of the existing hot water channel	The present impact area (belonging to the operating power plant and justified by a monitoring system) will be extended due to the construction of the new hot water inflow point. Its extent is the distance between the existing and the planned hot water channel (which is situated below). (Currently the change in state of aquatic wildlife can be detected in an approx. 2 km long section of the Danube.)
Noise and vibration load		
Noise load caused by the operation of power plant facilities	Circle with a radius of 500 m around noise sources.	There is no endangered facility.
Noise load caused by passenger and freight transportation	Along the main road No. 6 up to approx. 50 m distance from the road's centreline.	There are facilities to be protected in the residential areas of Paks and Csámpa, so these areas can be considered as impact area.
Vibration load caused by operation, as well as passenger and freight transportation	It is the same as the impact area of the construction phase: the construction site and the 100 m wide belt around it, as well as the 80–100 m wide belt along transportation roads and railway lines.	In case of the traffic impact area, the areas to be considered are those along the railway until the settlement of Előszállás, and those along roads until traffic distribution points (Csámpa, Paks, M6 motorway junction).
Generation of non-radioactive wastes		
Wastes generated during operation	The direct impact area is the immediate environment of the site collection place of hazardous wastes, as well as of the collection place of non-hazardous wastes (it anyway remains within the site). The impact area of wastes transported (the waste burning plant, the depository for hazardous and non-hazardous wastes) shall be determined when performing the environmental impact assessment of the given facility.	The impact receptor of impacts of operational wastes appears in the area use and it may be the geological agent. The indirect impact area of deposited wastes is part of the impact area of the depository.

Impact factor	Extension of the impact area	Interpretative notes
Waste transportation	50–100 m belt along transportation roads until traffic distribution points (Csámpa, Paks, M6 motorway junction)	
Impacts on built environment		
	Town of Paks as the town receiving the planned new facility is the impact area during operation.	The operating power plant contributes to the development of Paks as well as its wider vicinity through significant financial support (e.g. support of foundations). It is expected that the staff of the new units will carry on these traditions, thus the whole county could be demarcated as impact area of positive socio-economic impacts. In our opinion, however, it is primarily not an environmental issue, therefore, it is not indicated in the figure of the impact area.
Landscape and land use, landscape impacts		
Visibility, landscape impact	Region with 20 km radius around the site of the power plant.	Particular moments in time and space, by taking into account the land cover of the area (plants, buildings) and the meteorological conditions, the impact area may decrease to 1–2 km or some 10–100 m. There are significant regions even within the 20 km zone, from where the new facilities are not visible.
Other impacts (landscape structure, change in landscape potential)	It is expected to include only a few km vicinity of the planned facilities. Beside this, new developments in the area of Paks associated with the construction of the new reactor units may also be considered as part of the landscape impact area. (Their location is not known yet).	

Table 4.2-3. Impact area of the conventional environmental impacts of incidents, accidents and emergency events

Impact factor	Extension of the impact area	Interpretative notes
Impacts on air quality		
Fire, explosion	Estimated impact area is 1–3 km.	Presumed cases: oil fire in case of failure of the turbine’s oil system, the transformer, the auxiliary oil system and the circuit breakers; failure of the gas bottle store or gas bottle; interim transportation of hazardous substances; fire in the site hazardous waste or industrial waste storage; explosion at the tanks located in the hydrogen unit or nitrogen tanks.
Impacts on surface water environment		
Leakage of diesel oil from the diesel oil vessels of the diesel generators	The impact area is maximum 20 km by taking into account indirect pollution (because of contacting with the polluted subsurface water body).	Direct pollution can be avoided completely by proper installation.
Impacts on soil and geological agent		
Leakage of diesel oil from the diesel oil vessels of the diesel generators	The direct impact area is virtually the same as the infiltration area of diesel oil (a surface of approx. 100 m^2 in case of the leakage of the considered 30 m^3 diesel oil), it may slightly and to small extent change, if the soil stratification is not homogeneous. In case of presence of finer-grained layers with worse filtration capability, this surface of 100 m^2 may slightly increase, but the difference is irrelevant.	The most often potential pollutant at the site which is present in the largest quantity is the diesel oil. It is expected that a maximum quantity of diesel oil of 500 m^3 will be stored at the area of the nuclear power plant (probably in underground double-wall vessels equipped with leakage detector).
Generation of non-radioactive wastes		
Spillage, leakage of wastes during storage at workplace- and site collection places, during their movement and transportation or when an accident occurs during transportation	Since the pollution occurred with wastes can quickly be observed, the impact can be ceased, the impact area is limited to the environment of the given incident and does not exceed the boundary of the site. The impact area of environmental impacts occurred due to accidents during off-site transportation is the immediate environment of location of the accident.	Environment pollution may occur during storage of wastes at workplace- and site collection places, when wastes are spilled, escaped during their movement, transportation or when an accident occurred during transportation.

4.3. Summarized impact area and settlements within it

The size of the summarized impact area was determined by unifying the impact areas of each environmental element based on the preliminary investigation of environmental impacts of the construction and operation of new nuclear power plant units. As resultant, i.e. as the summarized impact area the landscape impact area of visual impacts shall be taken as basis. A circle having a 20 km radius around the new power plant's site is defined as visual impact area. It should be noted that depending on the land cover, the blocking effect of the facilities and current weather conditions, this impact area may be much smaller in space and time. So this impact area shows the maximum extent possible. Only one element of the impact area extends beyond this circle, this is the noise and vibration impact area of railway transportation (especially during construction). This extends until the first railway hub (Előszállás) within a 100 m vicinity of the railway route. It should be seen that the real impact area is that part of the belt along the railway route, where there are residential areas or built elements, since these are sensitive to noise and vibration load.

The summarized impact area is shown by *Figure M-39.* of the *Appendix*, the settlements within the summarized impact area are listed in *Table 4.3-1.*

Table 4.3-1. **Settlements within the impact area**

	Settlement	Micro region	County	Region
0–15 km vicinity				
1.	Bátya	Kalocsa	Bács-Kiskun	Southern Great Plain
2.	Bikács	Paks	Tolna	Southern Transdanubia
3.	Bogyiszló	Szekszárd	Tolna	Southern Transdanubia
4.	Bölcske	Paks	Tolna	Southern Transdanubia
5.	Drágszél	Kalocsa	Bács-Kiskun	Southern Great Plain
6.	Dunapataj	Kalocsa	Bács-Kiskun	Southern Great Plain
7.	Dunaszentbenedek	Kalocsa	Bács-Kiskun	Southern Great Plain
8.	Dunaszentgyörgy	Paks	Tolna	Southern Transdanubia
9.	Fácánkert	Szekszárd	Tolna	Southern Transdanubia
10.	Fadd	Szekszárd	Tolna	Southern Transdanubia
11.	Foktő	Kalocsa	Bács-Kiskun	Southern Great Plain
12.	Géderlak	Kalocsa	Bács-Kiskun	Southern Great Plain
13.	Gerjen	Paks	Tolna	Southern Transdanubia
14.	Györköny	Paks	Tolna	Southern Transdanubia
15.	Kajdacs	Paks	Tolna	Southern Transdanubia
16.	Kalocsa	Kalocsa	Bács-Kiskun	Southern Great Plain
17.	Madocsa	Paks	Tolna	Southern Transdanubia
18.	Nagydorog	Paks	Tolna	Southern Transdanubia
19.	Németkér	Paks	Tolna	Southern Transdanubia
20.	Ordas	Kalocsa	Bács-Kiskun	Southern Great Plain
21.	Paks	Paks	Tolna	Southern Transdanubia
22.	Pusztahencse	Paks	Tolna	Southern Transdanubia
23.	Szakmár	Kalocsa	Bács-Kiskun	Southern Great Plain
24.	Szedres	Szekszárd	Tolna	Southern Transdanubia

	Settlement	Micro region	County	Region
25.	Tengelic	Szekszárd	Tolna	Southern Transdanubia
26.	Tolna	Szekszárd	Tolna	Southern Transdanubia
27.	Újtelek	Kalocsa	Bács-Kiskun	Southern Great Plain
28.	Uszód	Kalocsa	Bács-Kiskun	Southern Great Plain
15–20 km vicinity				
29.	Cece	Sárbogárd	Fejér	Central Transdanubia
30.	Dunaföldvár	Paks	Tolna	Southern Transdanubia
31.	Dusnok	Kalocsa	Bács-Kiskun	Southern Great Plain
32.	Fajsz	Kalocsa	Bács-Kiskun	Southern Great Plain
33.	Harta	Kalocsa	Bács-Kiskun	Southern Great Plain
34.	Homokmégy	Kalocsa	Bács-Kiskun	Southern Great Plain
35.	Kölesd	Szekszárd	Tolna	Southern Transdanubia
36.	Medina	Szekszárd	Tolna	Southern Transdanubia
37.	Miske	Kalocsa	Bács-Kiskun	Southern Great Plain
38.	Öregcsertő	Kalocsa	Bács-Kiskun	Southern Great Plain
39.	Pálfa	Paks	Tolna	Southern Transdanubia
40.	Sárszentlőrinc	Paks	Tolna	Southern Transdanubia
41.	Vajta	Sárbogárd	Fejér	Central Transdanubia
Further settlements affected by train transportation route				
42.	Előszállás	Dunaújváros	Fejér	Central Transdanubia

5. Environmental impacts related to decommissioning of new unit variations considered

Designing the abandonment and decommissioning, respectively after expiration of lifetime of the nuclear power plant is already started as part of the investment-preparatory activity of the plant. The possible solutions, impacts of the decommissioning shall be studied and assessed before start of construction. These analyses are actualized regularly during lifetime of the plant, and also immediately before start of decommissioning activities. Phases of lifetime of the existing units of Paks Nuclear Power Plant and the planned new units are shown in *Figure M-41.* of the *Appendix*.

According to item 31 in Appendix No. 1 of the Government Decree No. 314/2005 (XII. 25.) on the environmental impact assessment and IPPC procedure, the decommissioning of the nuclear power plant is an activity, even by itself, for which an environmental impact assessment has to be performed.

5.1. Process and aim of abandonment, decommissioning of nuclear power plant

The decommissioning of the nuclear power plant represents aggregate of administrative and technical activities. Execution of them makes it possible to remove objects subject to regulatory supervision and to create an acceptable final condition of the site (pre-planned condition, that is, condition determined by the decommissioning strategy). The aim of decommissioning of the nuclear power plant is to reach all of these results.

The process of decommissioning of a nuclear facility, for example, of a nuclear power plant, is a long lasting and complex activity. It is already started when designing the facility by means of considering aspects of decommissioning during the design. This process is continued during licensing, construction and operation of the facility. In this long-term process works can schematically be divided into the following parts:

- Preparation of the future decommissioning. The following activities are classified into this group: elaboration of the Preliminary Decommissioning Plan, determination of the decommissioning strategy (at site and facility level), regular review of the Preliminary Decommissioning Plan (including regulatory activities, as well), creation of the decommissioning data base and its continuous maintenance (including execution of radiological surveys, continuous follow-up of detail designs and as built designs of the plant, as well as follow-up of hazardous materials) and continuous processing of operational wastes.
- Execution of the environmental impact assessment procedure for the future decommissioning, including execution of the preliminary study, as well.
- Immediate administrative and technical preparation of the concrete decommissioning activity, including elaboration of the Decommissioning Safety Report, establishment of the decommissioning management organization, elaboration of a downsizing plan, elaboration of documentation of application for Final Shut-down Licence and the regulatory procedure related to it. The specifically technical-natured activities of the (interim) period of some years before shut-down of the reactor unit are classified into the scope of technical preparation.
- Preparation of the concrete decommissioning activity, which starts with shut-down of the unit. Finalization of the Decommissioning Plan is classified into this group, including execution of the radiological survey belonging to it (confirming it) and also the relevant regulatory procedure, which ensures a base for possible assignment of the licensee's rights. Works involving both radiological and conventional environmental impacts are the next ones within the frame of the concrete decommissioning activities. Operations and

activities, such as, decontamination[37], decommissioning and removal of radioactive materials, wastes, components, demolition of building structures, as well as management of inactive and radioactive wastes generated, are needed to be performed within this scope. After completion of these works it is allowed to cease regulatory supervision of facilities or separate buildings, as well as to demolish facilities or buildings, which are already inactive due to decontamination activities, with conventional building industrial equipment. The final radiation protection control of the site, the elaboration of the Final Decommissioning Report, as well as the cessation of regulatory supervision of the site, belong to last steps of the concrete decommissioning activities.

5.2. Decommissioning strategy to be used when decommissioning the new nuclear power plant units

The actually valid scope of concrete decommissioning tasks, their planning and detailed elaboration are always site-specific and significantly depend on the strategy selected for decommissioning of the facility.

When selecting decommissioning strategy for a nuclear facility and considering also possible options, during its specification, a number of factors shall be taken into account, fundamentally as follows:

- features of national projects related to radioactive waste management (waste streams, storages, timings),
- national decommissioning policy,
- features of facility to be decommissioned,
- safety and healthy requirements,
- environmental requirements,
- requirements for further use of the site,
- taking into account of political, economical, social impacts and of requirement for acceptance by population,
- requirement for availability of technology, feasibility of decommissioning,
- costs of decommissioning process, considering available resources,
- taking into account of risks of decommissioning process.

The abovementioned factors shall be analysed and considered compared to each other, in weighted way, but striving to ensure the relative balance.

Preliminary selection of the decommissioning strategy in the present stage is necessary because we have to estimate the environmental impacts of decommissioning and the impact factors related to decommissioning, and, in the absence of a preliminarily selected strategy, it would solely be possible if impacts of all decommissioning strategies were studied. This solution is not practicable since with respect to the environmental impacts, at the present level of knowledge, only presentation of an enveloping impact group can be estimated.

The decommissioning strategy to be concretely used after shut-down of units will subsequently be specified on the basis of much wider horizon detailed analyses. At the level of the present document a preliminary decommissioning strategy is needed to be selected which, with respect to its impacts, probably envelopes environmental impacts of the other selectable strategies. Optimization of the preliminarily selected strategy is not necessary since it will be performed within the frames of elaborating the national programme according to guidelines of [85]. The optimized decommissioning strategy may override the preliminarily selected version. Here and now it shall be confirmed that possible other versions are not more unfavourable than the preliminarily selected

[37] Removal of radioactive pollution.

strategy from the point of view of environmental impacts. The sufficient conservatism is required with respect to the environmental impacts only, at the same time analyses according to other factors needed for final selection of the decommissioning strategy (for example, analysis of economic and social impacts, consideration of guidelines for further use of the site, examination of availability of the technology, etc.) are allowed to be, and shall be, put aside.

Considering the above mentioned facts the immediate decommissioning version is selected as decommissioning strategy of the new units given that the area will be handed over without any further limitation. This option is the preferred decommissioning strategy of the nuclear facilities, but particularly of the nuclear power plants, all over the world. Since the preliminarily selected decommissioning option does not ensure, and hardly ensures, respectively, opportunity and time for partial (or full) decay of radioactive materials (wastes) accumulated in the nuclear power plant, this variant, mainly with respect to factors having a role in the radiological sense, can be considered as the most disadvantageous from environmental aspect. However, the other conditions listed in *Subchapter 5.3.2.*, which are necessary for execution of the immediate decommissioning option (waste storage facilities are completed, the interim storage for spent fuels and financial resources needed for financing of the decommissioning process, are available) are evidently complied with. Completion of the waste storage facilities is allowed to be supposed by means of appropriate expansion of the National Radioactive Waste Storage (NRWR) facility to be constructed in Bátaapáti. As it is specified in the document [86]: "…design, dimensioning of the facility and time schedule of its implementation and operation have to be harmonized with requirements of the Paks Nuclear Power Plant, and expandability shall also be considered at design level". Interim storage of high activity and/or long-life radioactive wastes can be provided within technological systems of the new units until start of decommissioning works. If a facility of interim storage for spent fuels will be built also for the units to be newly constructed, then it will serve the full lifetime of new units and the decay period demand possibly occurring when the decommissioning is in progress at units. Availability of the necessary resources to finance the decommissioning process is required by law in Hungary (section (1) of § 62 in the Act No. CXVI of 1996 on nuclear energy), therefore the availability of such resources can be supposed as ensured by the law. On the basis of the facts mentioned above the immediate decommissioning option is feasible and, with respect to the factors having a role in the radiological sense, can surely be considered as the most unfavourable solution from environmental aspect.

5.3. Environmental impacts of decommissioning

5.3.1. Unit-specific considerations

Reviewing possible variations of the new units, environmental impacts related to the decommissioning are assessed for five types offered by different suppliers (AP1000, MIR.1200, ATMEA1, EPR, APR1400). The content and range of data service provided by suppliers are widely inhomogeneous with respect to expectable environmental impacts of decommissioning.

However, on the basis of available information ensured by the suppliers, it seems that there is a consensus in that in case of the new units the operation of decommissioning is more simple compared to decommissioning of the pressurized water power reactors presently operated, and simultaneously with this management and disposal of specifically less quantity of waste shall be prepared (for example, [87]). In case of the new type nuclear power plants this feature, which is advantageous from the point of view of decommissioning, is confirmed at the level of design and there is a reference to it in case of almost all types offered. At design level the following measures are taken in order to increase in safety of decommissioning, for example in case of the reactor type AP1000 [88]:

- Inherently simplified design: within the frame of it the number of structural elements is significantly decreased. For example, in case of the type AP1000, the number of planned valves is decreased by 50% compared to the similar, but older pressurized water power units, by 35% the number of pumps, hereby decreasing both the length of pipelines and the number of heating and ventilating components by 80%. As a result of the facts mentioned above the process of decommissioning becomes shorter and simplified, less activated or contaminated structural elements shall be managed, upon the whole environmental impacts of the decommissioning process become more favourable.

- Limitation of occurrence and spreading of contamination at design level: within this, for example, surfaces are covered, hereby preventing infiltration of contaminations into concrete and by this facilitating decontamination of surfaces, or in the secondary circuit the efficiency of ventilation is improved which decreases spreading of contamination.
- Introduction of group of designer's measures facilitating decommissioning: effects of the abovementioned designer's measures are also significant from the point of view of operations, but also further designer's considerations are introduced deliberately for facilitating decommissioning. Mentioning only the most important ones within this, the following measures are emphasized: optimized establishment at design level of access routes important during decommissioning of large equipment, zones established for putting down the potentially contaminated equipment, or the different movable protections and covers which are specifically designed for facilitating the decommissioning.

This thought is confirmed by the general designer's endeavour (for example, [89]) which improves operations circumstances by means of increasing quality and load-bearing capability of fuel used in reactors, and simultaneously contributes to decrease in extent and dangerousness of radioactive wastes to be managed during decommissioning.

Taking into account the facts mentioned above, as well as in the absence of information contrary to them, it is not necessary, and there is no opportunity, to make differences with respect to decommissioning and abandonment environmental impacts of the five reactor types.

5.3.2. Description of environmental impacts of decommissioning

5.3.2.1. Review of environmental elements/systems concerned by decommissioning

It is expected that the decommissioning will concern, to different extent, all environmental elements and systems. In the following elements and systems concerned, both radiological and conventional environmental impacts occur:

- The environmental elements concerned are as follows (considering interpretation of the Act No. LIII of 1995 on general rules of environmental protection): water, soil, wild life, as well as the built (artificial) environment created by man, furthermore their components.
- The environmental systems concerned: the ecosystems, the settlement environment (including also changes in infrastructure, traffic, water supply, sewage practice, energy supply, etc.) and the land (landscape and land use).
- The independent impact factors to be examined beyond the environmental elements/systems are as follows: noise and vibration load, and waste management (which is one of the dominant scopes of activities from the point of view of decommissioning).

Beyond them also social and economical impacts related to the environment have to be studied according to content requirements for the environmental impact assessments. Within this it is necessary to deal with the employment problems expectable due to the decommissioning, the change in population occurring on account of it, the other human aspects, the life quality, the cultural circumstances (for example, store of learning picked up, behaviour, collective values).

5.3.2.2. Activities having impact on environmental elements/systems

These activities will precisely be indentified in the environmental impact assessment, taking into account all site- and facility-specific variables, as well as the decommissioning strategy selected (possibly overridden), which were mentioned above. Within the scope of these activities it is essential to deal with the following ones:

- management of hazardous (radioactive and toxic) materials and wastes,
- management of liquid- and gaseous state (radioactive and inactive) emissions,
- storage or final disposal of radioactive wastes,
- transportation (including both active and inactive transportations),
- demolition of buildings,
- storage, recycling, processing of wastes, final disposal of remains, within this use of inactive building rubbish at the site or outside of it, and area filling, as well as earth works belonging to that,
- potential accidents, non-planned events, among them the different fire cases (including inflammation of radioactive or toxic materials), the discharge or leakage of contaminants and gases, the maintenance failures, the structural damages caused by external effects (for example, earthquakes, floods, sabotages), shall be studied.

5.3.2.3. Environmental impacts

Potential impacts of the decommissioning are listed per environmental element/system, together with their short description. The following list shall be considered as guidance only for execution of the environmental impact assessment. For the impacts included in the list it is always specified whether the given impact appears as radiological or conventional one for the environmental element/system concerned. It has to be noted that also favourable ones will be among impacts of the decommissioning process (for example, the thermal environmental load derived from the requirement that the thermal energy originated from operation of the facility shall be removed, will cease), but the qualification shall be implemented within the frame of the environmental impact assessment. Potential impacts of decommissioning of the plant are as follows:

- **Impacts on natural environmental elements/systems**
  - Air: the decommissioning involves demolition of buildings, chopping of rubbish generated, dismounting of technological systems and machines, etc. Movement of large size and heavy motor vehicles, machineries is supposed during activities accompanying the decommissioning. Considering also the meteorological features of the region, the quality of air is the primary factor which is affected by the decommissioning process, since all of such activities may involve discharge of radioactive and inactive gases, aerosols and dust. – Conventional and radiological impacts together.
  - Water: the process of decommissioning changes this environmental system depending on hydrological and hydrogeological features of the site. Possible pollutions of surface and underground waters, which are caused by polluting components of discharged and dissolved materials, have to be taken into account. Removal of non-natural originated surfaces (demolition of roads and buildings) modifies downflow of surface waters, water draining of the area and infiltration of effluents into the ground water. – Conventional and radiological impacts together.
  - Earth and soil: importance of impacts belonging to here is strongly varying as a function of the decommissioning strategy selected. The buildings shall be demolished in accordance with the strategy seledted. After that controlled rubbishes will be removed out of the site. Changes in earth may be caused by equalization of level,

compaction and removal of underground structures. Sedimentation of polluted particles getting into the air during demolition may affect quality of the soil, although it is expected that the polluted areas developed in such way will remain within the site. – Conventional and radiological impacts together.

- Flora and fauna: impacts concerning the flora are caused by appearance and sedimentation, on surrounding surface-soils and on leaves of plants, of dust generated during works. Impacts concerning the fauna may be caused by, on the one hand, increase in noise level (with respect to the station of certain species, as well as to the behaviour of that), on the other hand, also change in flora may have a role as a secondary cause (for example, in case of disappearance or appearance of plants serving as nutriment, or in consequence of change in hiding-places). – Conventional impact.
- Land (landscape): its modification, which can be considered during decommissioning, may probably result in a positive change if the decommissioning strategy selected by us is followed. The fact of decommissioning, demolition may affect free time and recreation natured use, tourism, development of tourist trade, availability of the area for industrial purpose, change occurred in use of the industrial area, unused area and road use rights. – Conventional impact.

- **Impacts on societal, social, economical systems**
  - Land use, utilization of land: the change occurring during decommissioning is probably advantageous, the area can be used for other purposes. – Conventional impact.
  - Culture: the impact is caused by the change in systems of habits related to the decommissioning. Since the change in the system of cultural habits consists of opposite sign components (on the one hand, decreasing emotional load due to decommissioning of the plant, on the other hand, fear of possibly worsening living conditions also due to decommissioning of the plant), therefore analysis of the expectable impact is particularly important with respect to the decommissioning. – Conventional impact.
  - Infrastructure: impacts affecting quality of environment and life are classified into this group. The decommissioning increases traffic of heavy vehicles which, with respect to usual presence of the plant, is generally considered to less extent. For the water and electricity supply and the network of health facilities, the decommissioning may result in a change. Their conservation is a prerequisite of keeping the quality of life, but it depends on that what kind of future is envisaged for the site. – Conventional impact.
  - Human aspects: indirect impacts of the decommissioning occur. When studying the impacts it is assessed that how do discomforts suffered change the quality of life, the style of life previously implemented, and whether it is possible to sustain the usual well-being and, through it, the social safety. Furthermore, activities related to the decommissioning which increase the radiation exposure of workers and the danger of several occupational diseases shall be studied within the scope of health and safety. The decommissioning project, and the documentation belonging to it, shall specify these risks and also the methods by means of which it is possible to minimize the dangers. – Conventional and radiological impacts together.
  - Population and economy: it can not be excluded that shut-down of the plant will have a significant societal, economical impact as a result of which the employment and the regional revenue tax will decrease. A societal problem may occur within the scope of suppliers of the facility due to the decreasing job opportunities. The number of employees will be less in the decommissioning phase than during the operating phase,

although impacts differing from it may occur for a shorter period. – Conventional impact.

Consequently, the environmental impacts connect to the activities of the decommissioning process and to the typical environmental elements/systems to be studied, therefore the environmental impacts can easily be presented and systematized in a matrix structure where the environmental elements/systems are shown on the one axis, while the decommissioning project activities to be considered are represented on the other axis, and elements of the matrix are composed of the environmental impacts. This matrix representation usefully contributes to overview of the impacts, however it is not allowed to be considered as finalization of the system of impacts since to analyse the secondary and connected impacts a more careful assessment is needed. The matrix representation of identification of environmental impacts is shown in *Figure M-41.* of the *Appendix*.

Numerical characterization of the impacts, as well as elaboration of the safety assessment for the decommissioning will be included in the preliminary decommissioning plan.

Note: environmental impacts of disposal of radioactive wastes generated during the decommissioning (and of course of spent fuel) shall be evaluated within the frame of the environmental impact study for the relevant waste storages.

5.4. Financing, costs of the decommissioning activity

According to section (1) of § 62 in the Act No. CXVI of 1996 (Nuclear Energy Act) on nuclear energy, costs of decommissioning of nuclear facilities are financed by the Central Nuclear Financial Fund (CNFF or Fund) as a separated state fund. During implementation of the new units, preparations shall be made in order to modify the CNFF so that it is possible, among other things, to finance decommissioning of the new units in accordance with the relevant laws. The Hungarian Atomic Energy Agency, as trustee of the Fund, is entitled at the appropriate time to initiate harmonization of the CNFF with appearance of the new units.

Costs of the decommissioning, at the present level of knowledge, can only be estimated. On the basis of prognoses provided by suppliers of the plant units and referred in *Subchapter 5.3.1*, it can be prognosticated that decommissioning of the new type reactors will probably be simpler and less waste will be generated during the decommissioning compared to the waste quantity which is predictable for decommissioning of energetic reactors currently used.

6. Assessment of possible trans-boundary impacts

The planned activity falls under the scope of the Convention on Environmental Impact Assessment in a Transboundary Context signed in Espoo, Finland in 1991, and the European Community Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment as amended by Council Directive 97/11/EC, 2003/35/EC and 2009/31/EC. The Government decree 148/1999. (X. 13.) of Hungary prescribes the application of Espoo Convention. Annex 1 of that document lists those activities in which the provisions of Espoo Convention should be applied. Regarding these activities, countries that consider themselves affected can request the implementation of international impact assessment (whether or not any effects could be expected on their territory, that is, whether or not their territory is included in the environmental impact area). It is important to investigate the possible transboundary impacts even in the preliminary consultation period. (The nearest country to the site of the planned new units is Serbia (63 km). Next in sequence are: Croatia (74.5 km), Romania (119.5 km), Slovakia (132 km), Slovenia (172 km), Austria (183 km) and Ukraine (324 km).) The definition of transboundary impact is included in Government decree 148/1999. (X. 13.). In *Chapter 4* we discussed the definition of impact area, now we connect these results with the assessment of possible transboundary impacts. Contentual requirements are not detailed in the decree. These impacts should be estimated and evaluated in the same way as the other impacts; however, their transboundary impacts should be analysed later. Taking into account the expectations, regarding the new units we describe which environmental elements and systems could potentially be involved in transboundary *radiological environmental impacts*. [42]

In order to determine transboundary impacts, the following questions should be clarified: Given our activity, can transboundary impact factors and impact processes associated with the activity occur at all? Which are those impact factors where transboundary impacts cannot occur; or there is only a very little probability of transboundary impacts? How will transboundary impacts and impact processes disperse and accumulate related to a possible load? [35] Some of the questions are general; others are more dependent on the type of activity and area characteristics. The following three factors play a significant role in the judgement of transboundary impacts: factors of impact that suppose the possibility of wider dispersion, sensitivity of the impact area and the dispersion tendency of impacts, any dispersion promoting or preventing characteristics of the impact area. Therefore information about these three factors should be assessed for impacts. [42] [90] The significance of transboundary impacts of an activity, at the level of previous investigation or of regulatory assessment can be judged through the following steps: Based on the site, on the characteristic of the activity and on the applied technology, it should be decided whether transboundary impacts can theoretically occur. Those impact factors and processes of the activity (*Chapter 4*) should be determined and selected that could have a real probability to cause unfavourable transboundary environmental-ecological processes.

The probability and the mode of dissemination of already started processes, which taken into account, occurred by facts of impact should be estimated. Based on this estimation, the transboundary impacts should be judged and the excepted affected area should be approximately defined. If the probability of transboundary impacts is stated, the affected countries should be designated. That is, the sensitiveness of the area for processes of impact should be determined. Based on this the actual transboundary impacts should be selected by the comparison of impact processes and the sensitiveness of the area. The significance of transboundary impacts should be determined. [42], [91]

In the following, by answering these questions concerning the new units, we want to assess the possibility of transboundary impact. The “significant” impact assumes that the change in state is not temporary but it causes permanent change or environmental load for long duration. The new nuclear power plant is going to be constructed in the interior of the country, at significant distance from the borders. This means that taking the construction site into account, transboundary impact is only possible in very extreme cases. Regarding the operation of the new units, the expected impact factors and processes as well as their spatial extension are defined in *Chapter 4.* (Concluded from the characteristic of the activity; factors and processes should be categorized into two groups: radiological impacts and conventional impacts. These groups should be separated in terms of transboundary impacts as well.) We do not repeat the previously described processes, but we emphasize those, that – by their characteristic, intensity – have associated transboundary radiological impacts. The sensitivity of transboundary areas is not known in detail. [92] The safety of the nuclear power plant determines basically the characteristics of the transboundary environmental effects. In the course of the operation of the nuclear power plant, gaseous and liquid releases are expected primarily.

Assessment of atmospheric releases

Referring to *normal operational releases* we studied the source document [93]. Based on this it can be stated that *during normal operation transboundary radiological impacts should not be considered*, if the new units comply with the nationally and internationally accepted regulatory discharge limits resulted from the dose constraint related to the facility. [93]

In case of transboundary impacts of *design basis accidents* the EPR reactor type was applied as the reference unit in our calculations made by PC COSYMA program. We took into account the statements included in *Chapter 3*, that if the new units fulfil the requirements of the EUR and of the new Nuclear Safety Requirements, the possible impacts will not put risk on the population of the surrounding countries. That is consistent with the criteria of limited environmental impact. In normal atmospheric conditions the expected activity concentrations will be lower at the national borders than those we considered (values are 100–1000 times lower). *According to the above mentioned analysis, radioactive atmospheric discharge beyond the national border is neutral even in design basis accidents.* These statements were taken on the basis of the EUR and Nuclear Safety Requirements detailed in *Chapter 3* and the content of *Chapter 4.*

The calculations regarding atmospheric discharge, made by the PC COSYMA programme and based on available data of EPR units, were performed for design basis accidents with very low frequency and for severe accidents. The most detailed data was available for this unit type. In the analysed discharge situations the highest committed effective dose consequence estimated for reference person was in case of the EPR unit type. Results are shown by *Table 6-1.* Calculations were also made for severe accidents, their results are included in *Table 6-2.*

Table 6-1. **Results of the calculations made on the EPR type units (TA4 = DBC4 – design basis accident with very low frequency)**

Surrounding country	**Distance [km]**	**In 7 day time**	**In long period**
		Dose [μSv]	**Dose** [μSv]
Serbia	63	$5.0\cdot10^{-3}$	$2.0\cdot10^{-2}$
Croatia	74.5	$4.2\cdot10^{-3}$	$1.7\cdot10^{-2}$
Romania	119.5	$2.5\cdot10^{-3}$	$1.1\cdot10^{-2}$
Slovakia	132	$2.3\cdot10^{-3}$	$9.8\cdot10^{-3}$
Slovenia	172	$1.6\cdot10^{-3}$	$7.5\cdot10^{-3}$
Austria	183	$1.6\cdot10^{-3}$	$7.1\cdot10^{-3}$
Ukraine	324	$7.4\cdot10^{-4}$	$3.9\cdot10^{-3}$

Table 6-2. **Results of the calculations made on the EPR type units (TAK2 = DEC2 – severe accident)**

Surrounding country	**Distance [km]**	**In 7 day time**	**In long period**
		Dose [μSv]	**Dose** [μSv]
Serbia	63	$5.8 \cdot 10^{-1}$	$1.3 \cdot 10^{1}$
Croatia	74.5	$5.0 \cdot 10^{-1}$	$1.1 \cdot 10^{1}$
Romania	119.5	$3.4 \cdot 10^{-1}$	7.4
Slovakia	132	$3.1 \cdot 10^{-1}$	6.7
Slovenia	172	$2.4 \cdot 10^{-1}$	5.3
Austria	183	$2.3 \cdot 10^{-1}$	5.0
Ukraine	324	$1.4 \cdot 10^{-1}$	3.0

Based on recommendations of the International Atomic Energy Agency and on the emergency response plan and action plans, it is very likely that immediate precautions should not be applied in the surrounding countries even in case of the environmental release of a “significant effect”, since the dose levels that justify their application are 3–4 orders of magnitude higher than the dose levels presented here.

Assessment of discharges into water

There is no transboundary radiological environmental impact on water that can be qualified as significant, because the impact of radioactive substances released into surface waters is already neutral at the national borders. The impacts of discharges into the Danube were analysed by a simple calculation methodology [94], which was presented in the Safety Reports Series No. 19 of IAEA. As it was described in the chapter analysing the combined environmental impacts of the operating and the new units, the residents of Gerjen, which is situated 10 km downstream from the power plant, may be exposed to the maximum dose load (8 μSv) from radioactive pollution discharged into the Danube during normal operational releases and anticipated operational occurrences. Beyond the national border, which is about 100 rkm downstream from here, this value will be orders of magnitude smaller.

Assessment of non-radiological impacts

With respect to the *conventional (non-radiological) impacts*, on the basis of the preliminary calculations, in case of discharge of conventional pollutants into surface waters, transboundary impacts shall be considered neither in construction phase, during normal operation, nor in case of incidents and accidents. Impacts on surface waters in the construction phase are described in *Subchapter 3.5.2.*, the operation phase is discussed in *Subchapter 3.5.3.*, decommissioning is dealt with in *Chapter 5*, while their impact areas are detailed in *Chapter 4*. The impacts of anticipated operational occurrences and design basis accidents are presented in the relevant parts of *Chapter 3*. The impact area of impacts concerning surface waters studied remains within country boundaries. Taking into account the impacts of sewage discharge and inflow of industrial waters, transboundary impacts shall not be considered even in case of incidents.

With respect to subsurface waters, soil, as well as waste management, the impacts remain local in every case, transboundary impact shall not be considered in any case.

No opportunity of transboundary impact shall be considered in case of environmental impacts concerning air quality, continental and aquatic living world, settlement environment and landscape, as well as regarding expectable noise and vibration load.

7. Summary

As a result of ageing of Hungarian power plants and the rise in consumer demand, by 2020 about 5000 MW, by 2030 further 4000 MW new power generation capacity is needed in order to maintain the safe electricity supply in Hungary. Construction of a new nuclear power plant can be a good solution to replace a part of the missing capacities, since nuclear electricity generation is economically effective, and ensures a long-term and safe electricity supply.

Implementation of a nuclear power plant has to be preceded by political decision, thorough preparation and licensing procedure. The political decision was made on March 30, 2009 when the Hungarian Parliament consented to the preparation of the construction of new rector units on the Paks site by Parliament Resolution No. 25/2009. (IV. 2.) This resolution, however, does not represent effective decision on the realisation of new nuclear power plant units since only professional work, started after the theoretical permission, may provide answers for many questions such as financial and investment structure, technical characteristics, types of units, supplier, fit to the existing system, and environmental impacts.

In order to prevent adverse environmental impacts, Act LIII. of 1995 on general rules of environmental protection requires the preparation of environmental impact assessment "*prior to the commencing of activities having a significant environmental impact or the potential of it*". The method of environmental impact assessment process and the requirements of the environmental impact study are regulated by the several times amended Government Decree 314/2005. (XII. 25.) on the environmental impact assessment and the IPPC procedures. According to the Decree, environmental license can be granted for the implementation of new nuclear power plant units only on the basis of environmental impact assessment. According to the Government Decree, the first phase of the authorisation procedure is not obligatory in case of the construction of nuclear power plants. The applicant of the environmental protection licence, however, decided to initiate the preliminary consultation. Based on this, the territorially competent, Pécs-seated South-Transdanubian Environmental, Nature Conservation and Water Management Inspectorate – by involving the competent administrative authorities – will issue an expert opinion on the content requirements of the environmental impact assessment study to be submitted in the second phase of the authorisation procedure, thus promoting the study's successful preparation.

Present document is a base document for the preliminary consultation application prepared by PÖYRY ERŐTERV Co. and its subcontractors commissioned by MVM Hungarian Electricity Ltd. according to the Annex 4 of the related Government Decree 314/2005. (XII. 25.).

The planned development

On July 8, 2009, following the Hungarian Parliament Resolution, MVM Hungarian Electricity Ltd. founded the Lévai Project. Its aim is to prepare the implementation of new nuclear power plant units on the Paks site. From September 2012 the tasks related to the preparation for the implementation of the new nuclear power plant units are executed by MVM Paks II. Nuclear Power Plant Development Ltd., the new project company established by MVM Hungarian Electricity Ltd.

The area designated for the new units is a reserve area of the existing nuclear power plant. The two new units would be sited to the north of the existing four units, in their immediate vicinity. Below are the main reasons for recommending the Paks site and not a new place for siting the new units:

- There is no need to create a new (probably a green field) site with possibly high costs since it is an existing, safely operating nuclear project site.
- Since the start of the operation, in the past 30 years the site had been checked from various safety and environmental aspects, therefore the vicinity of the nuclear power plant is one of the most thoroughly explored and studied areas in Hungary.
- In the 30 km vicinity of the nuclear power plant, except for Town of Paks, the population density is lower than the national average.

- In the vicinity of the site the infrastructure is well developed and available.
- The site could be economically connected to the already developed national electric power transmission network.
- The existence and operation of the Paks Nuclear Power Plant is accepted by the people living in the vicinity, it may provide a promising basis for developments.
- Experience and knowledge as well as vocational trainings are readily available to meet the demands of the planned development.

The new units' site of 106 ha is the property of the MVM Paks Nuclear Power Plant Ltd. Out of this area approx. 29.5 ha is the area of the existing nuclear power plant, 76.3 ha is the so-called building yard, already designated as industrial area in the spatial development plans.

The planned new units will be chosen from the so-called Generation 3 or 3+ reactor units with international references. These were developed in the 1990s from Generation 2 units where the aim of development was to decrease the likelihood of severe accidents, and to mitigate the consequences of severe accidents taking place with very small probability. Generation 3+ unit types intensively employ passive safety systems and use natural resources (these are operated by gravitation, natural circulation, or by the energy of pressurised gases). As a result they do not need emergency electricity power intake from outside.

The preliminary investigation prepared during the preparatory activities of the implementation of the new nuclear power units recommended realising pressurized water reactors, not only because over 80% of the new reactors are of this type, but also because it is justified by the existing professional background in Hungary and the many years favourable operational experience gained in managing the nuclear power plant units of the Paks Nuclear Power Plant. It is expected that the new units would be chosen from these types of pressurized water reactors:

- AP1000 type, supplier is the Japanese-American Toshiba-Westinghouse,
- MIR.1200 type, supplier is the Russian Atomstroyexport,
- ATMEA1 type, developer/producer is the French-Japanese Areva-Mitsubishi,
- EPR type, supplier is the French Areva,
- APR1400 type, supplier is the South-Korean KEPCO.

Based on the investigation of applicable cooling options, two-stage, fresh water cooling system using water intake from the Danube was chosen for the planned new power plant units.

The planned development at the Paks site includes the implementation and operation of two nuclear power units of 1000–1600 MW net electric power for generating electric power for trading.

The current state of environment of the new nuclear power plant's site

At present, the environmental conditions of the vicinity of the new site are significantly influenced by the proximity of the existing 4 reactor units and the Interim Spent Fuel Storage. Environmental (primarily radiological) discharges emitted by these facilities are being checked by a monitoring system from the beginning. Based on these measurements it can be stated that the nuclear power plant does not cause environmental impacts exceeding the threshold values under normal operating conditions. Most of the impacts are not at all or hardly detectable and do not exceed background pollution. Under normal operating conditions radiological discharges do not affect residents outside of the safety zone of the nuclear power plant.

Conventional environmental impacts of the operating nuclear power plant are not considerable, detectable in the immediate vicinity of the power plant only. Except for the heat load from warmed-up cooling water discharged into the Danube. Its impact area may expand down to the mouth of River Sió. The pollution of aquatic environment is the only dominant impact that differs from the former status without the new power plant, apart from land take and visual impact as a result of the power plant's existence. As a result of the operation of the power plant, the receiving surface water body, the river Danube gets conventional pollution and radiological discharge as well as heat load from the use of fresh water cooling system. The power plant keeps these discharges under threshold values.

The new site earlier was designated as an industrial area, suitable for siting the auxiliary activities of the existing power plant, in large part degraded grassland, built-up and paved in a smaller part. To our present knowledge it does not have significant natural, cultural heritage or any other type of value. Further investigation is needed, however, to explore this issue in detail.

Expected environmental impacts

The preliminary assessment of environmental impacts related to the planned new reactor units included the construction, operation and decommissioning phases. Both radiological and conventional environmental impacts of the planned development were studied. Impacts of the new development were estimated separately, then these were merged with the background pollution, i.e. the combined environmental impacts of the three existing facilities potentially causing radioactive emission: the planned new units, the existing 4 reactor units, and the Interim Spent Fuel Storage were assessed.

During the preliminary investigation of *radiological impacts*, the exposure of radioactive atmospheric emissions and liquid discharges of normal operational conditions and of anticipated operational occurrences (of those whose frequency exceeds the 10^{-2}/year value) was determined in case of the 5 considered unit types. The dose contribution of emissions and discharges was determined using internationally accepted models. Based on the received data, and regarding the realisation of two units, assuming and adding an anticipated operational occurrence to each individual unit, it can be stated that the impact of the new units can be assessed neutral for the residential population.

Under normal operational condition, the spatial expansion of impacts remains within the controlled zone of the nuclear power plant concerning the dose caused by both gaseous and liquid emissions and the dose of direct and dispersed radiation from radiological point of view.

During the study of incidents causing radiological impacts, according to international regulations, analyses were prepared using the data available. It was presented that radioactive emissions of various breakdowns and accidents potentially taking place during the operation of the considered types of reactor units, remain below the EUR (European Utility Requirements – developed by Western European nuclear power plant operators) and ICRP (International Commission on Radiological Protection) requirements.

When discussing *conventional environmental impacts* it was stated that most of the causes of impacts of the construction phase result in more significant impacts than the similar causes of impacts of the operation phase. In case of a nuclear power plant the construction period is long, it is likely to last for 5–6 years. Significant, but relatively local (spreading to a distance of a few hundred meters, or a couple of km at most) changes are expected both in air quality and in the state of waters and earth. In the vicinity of the site it is likely to have considerable noise and vibration loads as well. According to our present knowledge, however, these changes are not affecting significantly the residential areas except for transportation.

Conventional environmental impacts of operation phase are mainly minor in comparison with the impacts of construction phase, even when the combined impacts of the three facilities are taken into consideration. Based on our investigation it can be stated that even fresh water cooling, which is considered as the conventional environmental impact factor with the most significant consequences, can be realised in accordance with the currently existing environmental condition system.

In present phase of the study, no technical details of certain alternatives and types of units are available. Therefore our estimates were based on either concrete data, if these were available, or if data referring on certain alternatives were available only, estimates were based on critical pollution load. If none of these data were available, then preliminary estimates were made based on our professional experience.

Based on the Preliminary Consultation Documentation and on our present knowledge, it can be stated that no environmental, nature conservation and landscape protection reason was found that would exclude the realisation of any considered type of reactor units and cooling alternatives. Most of the environmental impacts caused by the planned development are not major, they are unlikely to cause significant changes, and they will occur in the immediate vicinity of the project site, out of residential areas.

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Appendix

Table M-1. Licensing procedures necessary for the implementation of the nuclear power plant

Licensing procedure	Authority licence	Competent authority	Legal background*
Environmental licensing – Preliminary consultation – Environmental impact assessment (international impact assessment procedure)	Authority's opinion Environmental protection licence	South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate	Act LIII of 1995 Government decree 314/2005. (XII. 25.) Government decree 148/1999. (X. 13.) Council directive 85/337/EEC, 97/11/EC and 2003/35/EC
Water-privilege licensing – Principled water rights permitting procedure (its execution is not an obligation) – Water rights implementation permitting proc. – Water rights operational permitting procedure	Principled water rights permit (its acquisition is not an obligation) Water rights implementation permit Water rights operational permit	South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate	Act LVII of 1995 Government decree 72/1996. (V. 22.) Decree 18/1996. (VI. 13.) of the Ministry of Transport, Communication and Water Management
Nuclear safety licensing – Site licensing – Construction licensing – Commissioning licensing – Operating licensing – System-level and system element-level licensing	Site licence Construction licence Commissioning licence Operating licence Production (type), procurement (type), installation, operating, building, utilisation, etc. licences	Nuclear Safety Directorate of the Hungarian Atomic Energy Authority (HAEA NSD)	Act CXVI of 1996 Government decree 118/2011. (VII. 11.) (amended by 37/2012. (III. 9.) Government decree) and its appendices, the Nuclear Safety Requirements (NSR), volume No. 1–4 Government decree 112/2011. (VII. 4.)
Electricity industrial licensing – Power plant licensing – Building licensing (for the construction, utilisation and operation of the power plant and the production transmission line)	Principled licence of the power plant that significantly affects the operation of the power system Construction licence of the power plant Producer's operating licence Building and utilisation licence for the power plant (Principled building), building and operating licence for the production transmission line	Hungarian Energy Office (HEO) Hungarian Atomic Energy Authority (HAEA) Territorially competent notary Metrology and Technical Safety Authority of the Hungarian Trade Licensing Office (HTLO)	Act LXXXVI of 2007 Government decree 273/2007. (X. 19.) Government decree 382/2007. (XII. 23.) Act CXVI of 1996 Act LXXVIII of 1997
Determination of dose constraint	Decision about the determination of dose constraint	Office of the Chief Medical Officer of the National Public Health and Medical Officer Service (NPHMOS)	Decree 16/2000. (VI. 8.) of the Ministry of Health Decree 15/2001. (VI. 6.) of the Ministry of Environment
Other licensing procedures			
– Selection of the site, examination of geological adequacy	Approval of the geological research plan Approval of the geological research's final report	Hungarian Office for Mining and Geology (HOMG)	Decree 62/1997. (XI. 26.) of the Ministry of Industry, Commerce and Tourism
– Designation of the safety zone	It is executed in the construction licence	Hungarian Atomic Energy Authority (HAEA) by the involvement of the Office of the Chief Medical Officer of the National Public Health and Medical Officer Service (NPHMOS)	Government decree 246/2011. (XI. 24.)
– Physical protection of the nuclear facility	Police permit Approval of specialised authority in the nuclear safety licensing procedures Licence of the physical protection system	National Police Headquarters (NPH), Passport Office Hungarian Atomic Energy Authority (HAEA)	Decree 47/1997. (VIII. 26.) of the Ministry of the Interior Government decree 190/2011. (IX. 19.)
– Fire protection of the nuclear facility	Licence for the installation and utilisation of fire protection equipment	Professional Municipal Fire Department, Hungarian Atomic Energy Authority (HAEA)	Government decree 261/2009. (XI. 26.) Government decree 118/2011. (VII. 11.)
– Monitoring radioactive emissions and the environment	Approval of the annual emission limit and the design emission levels in the nuclear safety licensing procedures Approval of Emission Monitoring Regulations and Environment Monitoring Regulations	South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate, Hungarian Atomic Energy Authority (HAEA)	Decree 15/2001. (VI. 6.) of the Ministry of Environment
– Air protection	Decision about the determination of emission limits and requirements, as well as about the method and frequency of monitoring	South Transdanubian Environmental Protection, Nature Conservation and Water Management Inspectorate	Government decree 306/2010. (XII. 23.)

* The general rules of authority procedures are included in Act CXL of 2004.

Table M-2. Non-hazardous and hazardous wastes of operation by EWC subgroups, according to Decree 16/2001. (VII. 18.) of the Ministry of Environment on list of waste

EWC code	Name of waste
06 01	Wastes from the manufacture, formulation, supply and use (MFSU) of acids
06 02	Wastes from the MFSU of bases
06 04	Metal-containing wastes other than those mentioned in 06 03
13 01	Waste hydraulic oils
13 02	Waste engine, gear and lubricating oils
13 03	Waste insulating and heat transmission oils
13 05	Oil/water separator contents
15 01	Packaging (including separately collected municipal packaging waste)
15 02	Absorbents, filter materials, wiping cloths and protective clothing
16 02	Wastes from electrical and electronic equipment
16 06	Batteries and accumulators
17 01	Concrete, bricks, tiles and ceramics
17 02	Wood, glass and plastic
17 04	Metals (including their alloys)
17 05	Soil (including excavated soil from contaminated sites), stones and dredging spoil
17 06	Insulation materials and asbestos-containing construction materials
17 09	Other construction and demolition waste
19 08	Wastes from waste water treatment plants not otherwise specified
19 09	Wastes from the preparation of water intended for human consumption or water for industrial use
20 01	Separately collected fractions (except 15 01)
20 02	Garden and park wastes (including cemetery waste)
20 03	Other municipal wastes

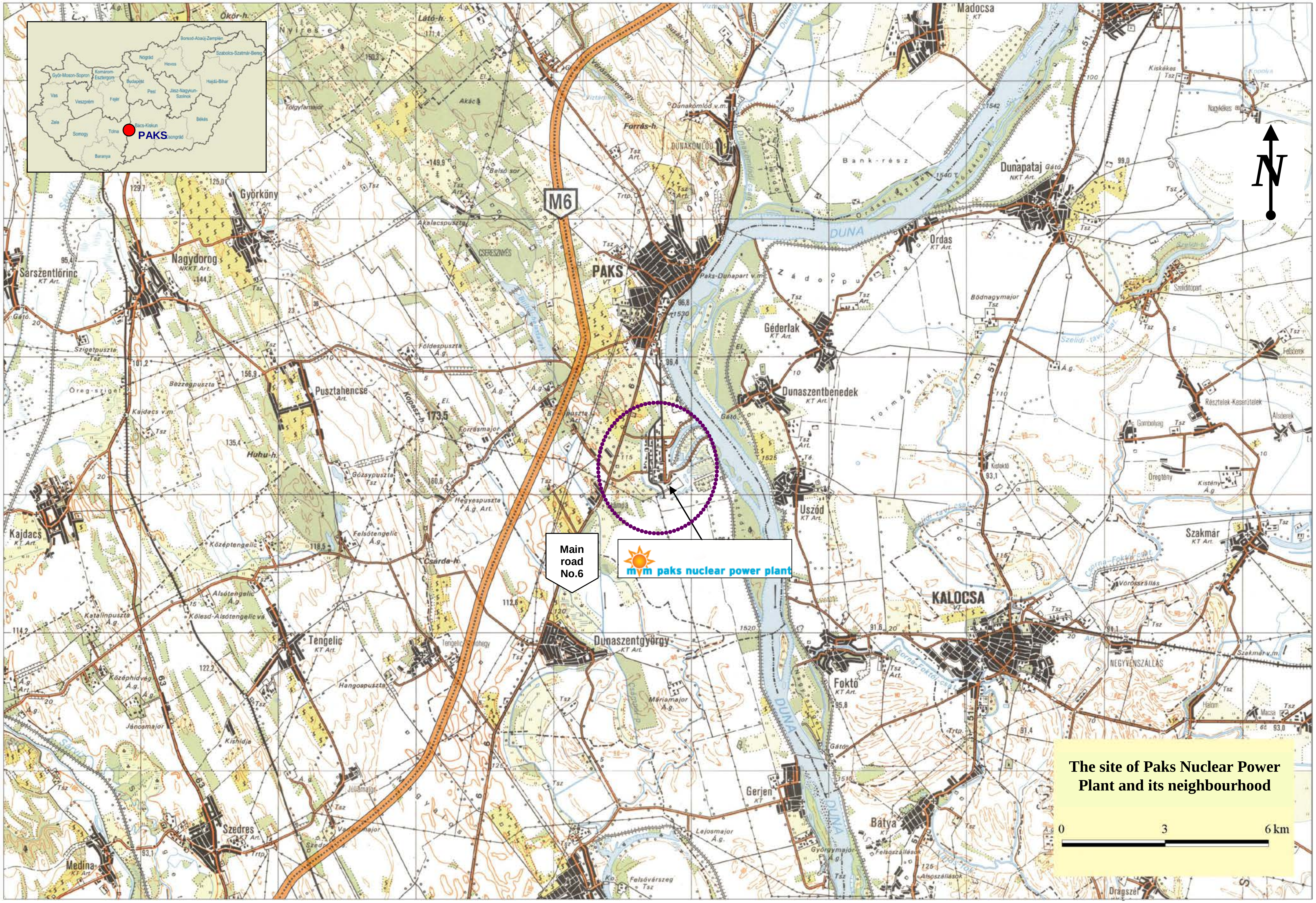


Figure M-1. The site in Paks and its neighbourhood

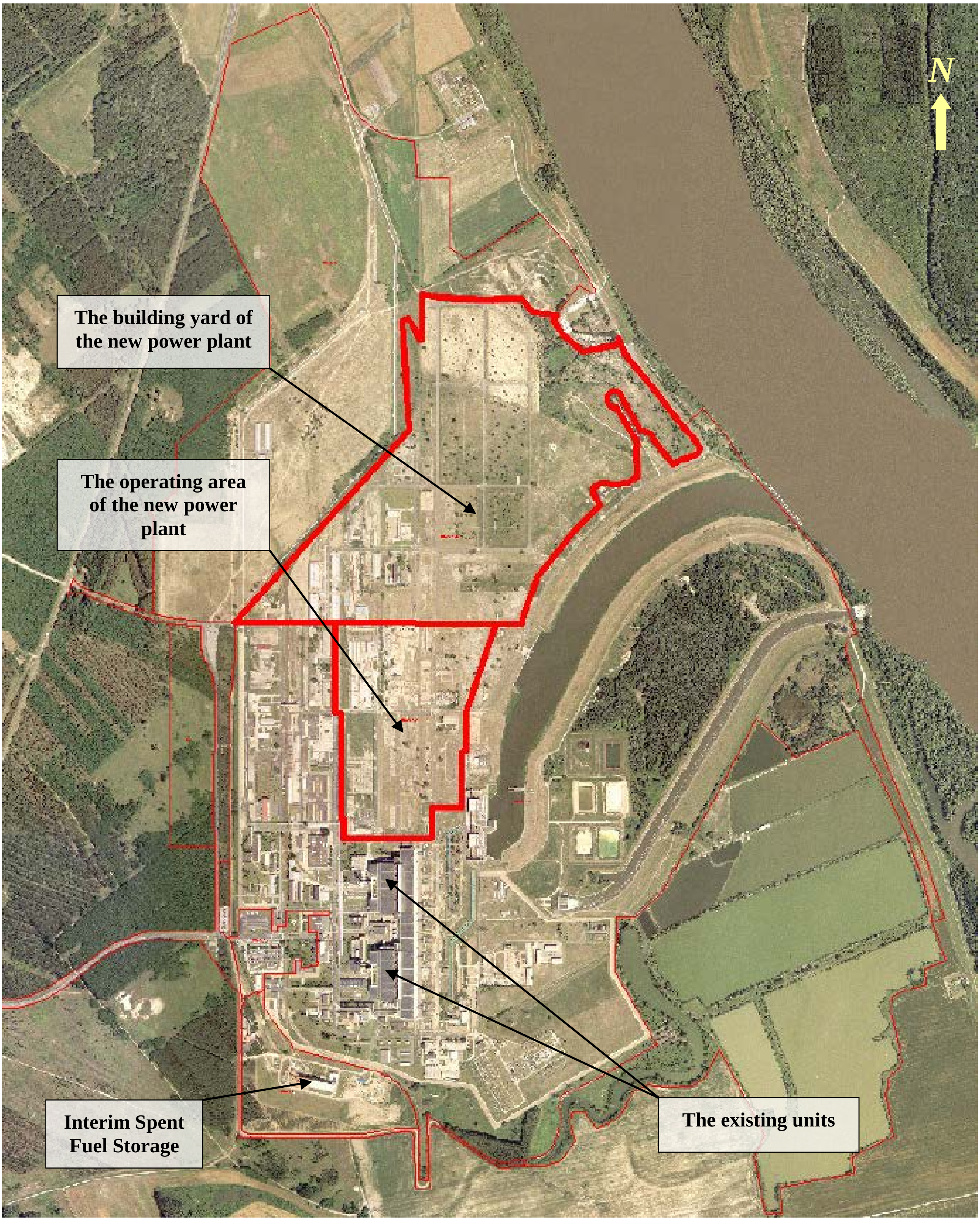
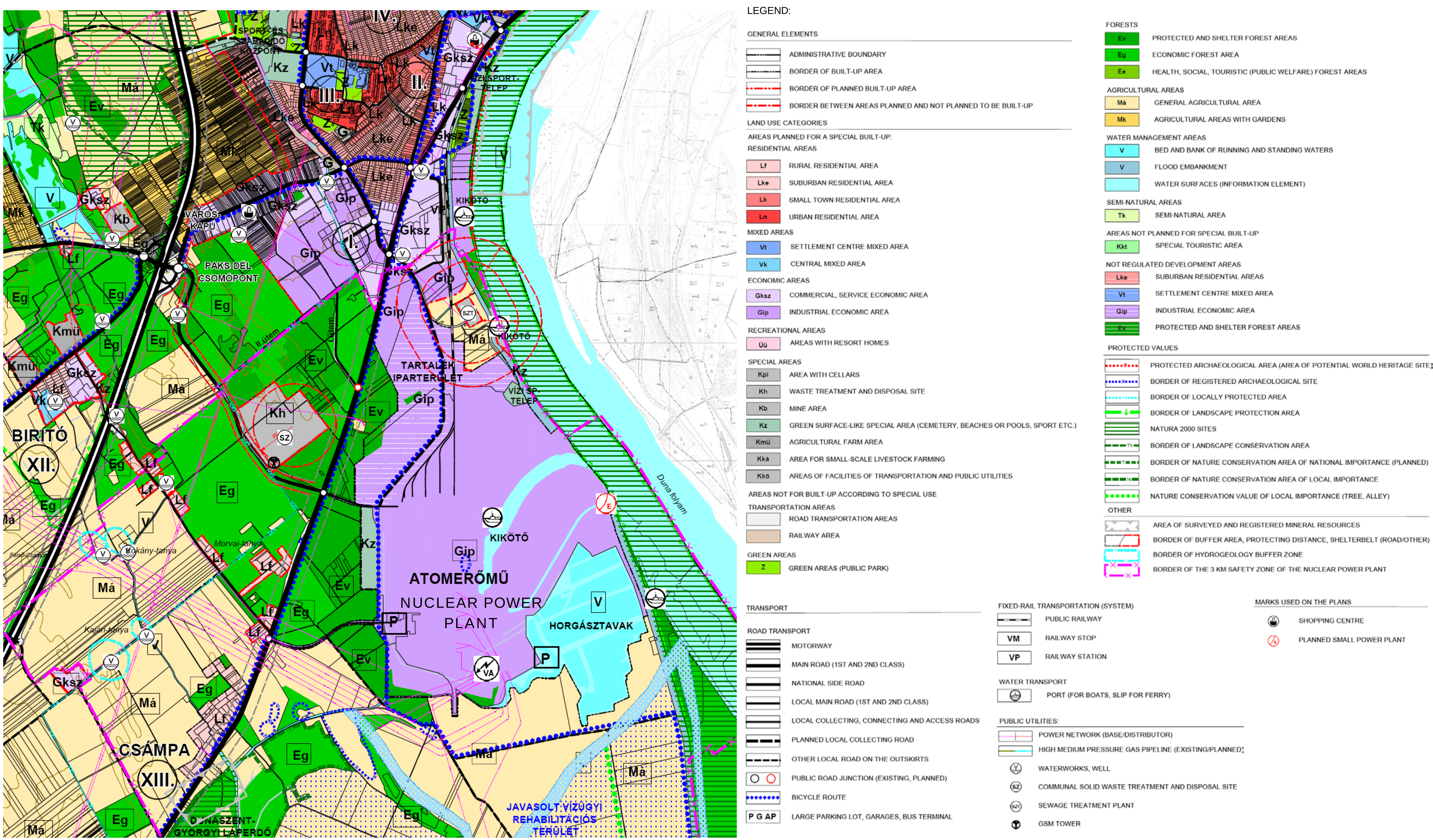


Figure M-2. The site in Paks with indicating the location of the planned new nuclear power plant



Abstract of plan approved by Decree No. 3/2003. (II. 12.) amended by Decrees No. 10/2088. (III. 13.), No. 85/2008. (IX. 16.), No. 121/2009. (XII. 16.) and 79/2011. (XI. 23.)

Figure M-3. The nuclear power plant and its vicinity in the Settlement Structural Plan of Town of Paks

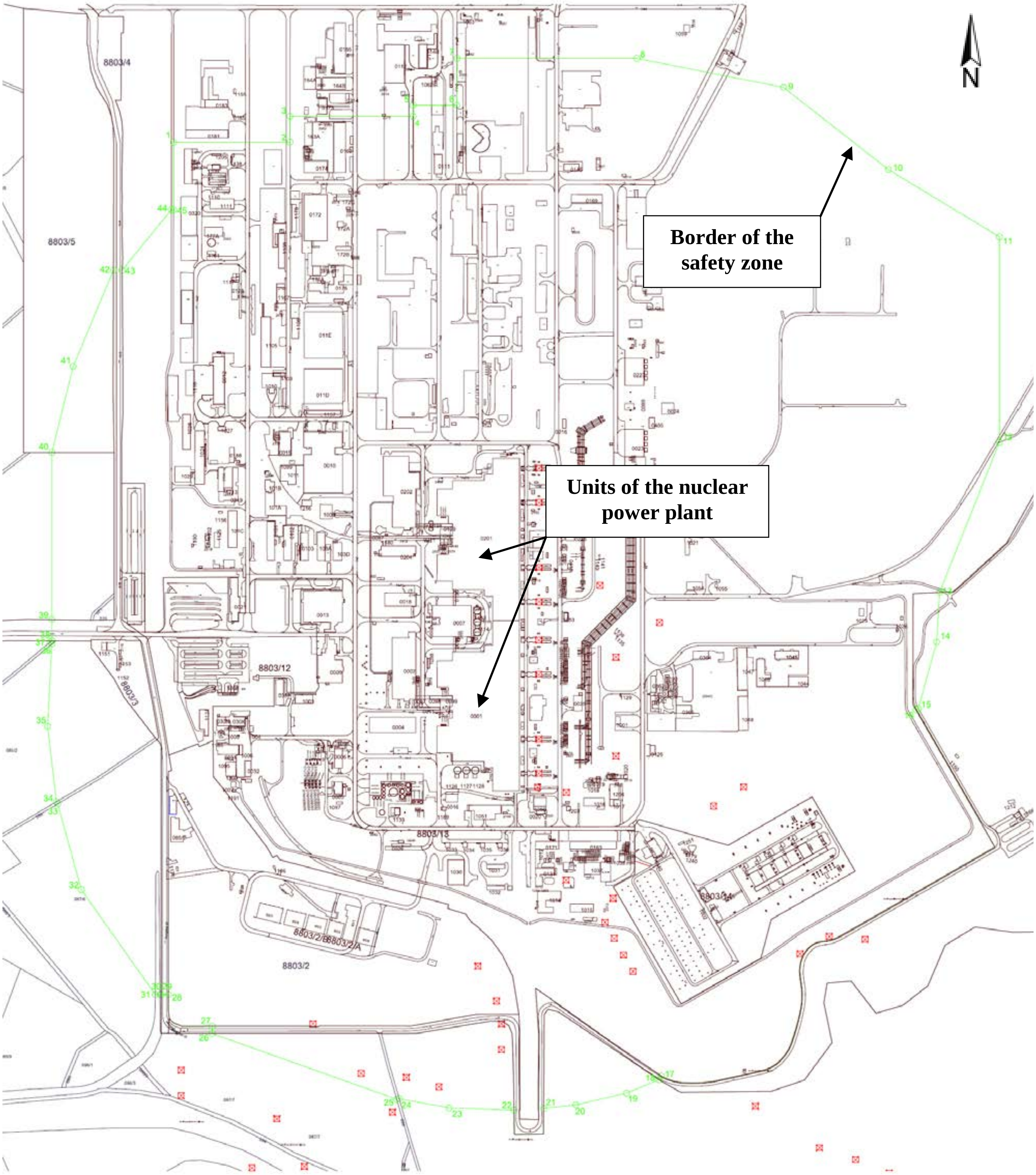


Figure M-4. The safety zone of Paks Nuclear Power Plant

Affected environmental elements/system	Impact factor	Direct impact	Indirect impacts	Man as final impact bearer
Air – climate	1. Construction works (dust, exhaust of hauler vehicles and construction machinery)	Air quality decrease in the direct environment		Health impacts
	2. Transportation of workers and construction materials to the construction site	Air quality change in the wider environment		
	3. Excess traffic due to temporary population rise			
	4. Appearance of new facilities (urban effect)	Climatic changes in the direct environment	Climatic changes in mesoclimate	Nuisance
Surface and groundwaters	5. Decrease of groundwater level	Change in groundwater levels and flow conditions	Change in quality of surface waters due to settling	
	6. Relatively large built-up area	Change in groundwater's flow, infiltration and evaporation conditions	Quality change of groundwaters	Disturbance of uses
	7. Water withdrawal (drinking water, social and technological water demand)	Decrease in quantity		Difficulties of water withdrawal
	8. Waste water production and treatment	Deterioration of water quality of receiving body		Restrictions of usage
Earth	9. Permanent and temporary (staging) land take	Decrease in quantity		Decrease in total stock
	10. Opening and exploitation of quarries	Decrease in quantity		
	11. Soil protection	Protection of humus content		
	12. Construction works (excavating work, earthworks, road and public utilities construction works)	Change of soil quality		Changes in circumstances of usage
	13. Disposal of excavated material	Increase in quantity		
	14. Waste generation during construction works	Soil contamination		Restrictions of usage
Wildlife-ecosystems	15. Land-take	Destruction	Change of life conditions	
	16. Construction works	Deterioration of life conditions	Fauna disturbance → Migration, degradation	
	17. Planting plants, landscaping	New living community, protecting function		Change in ecological processes
Built elements	18. Built elements used in transportation	Deterioration of condition	Change of condition	Rise in demand for maintenance
	19. Appearance of new buildings on the site of the power plant and in its vicinity	Change of values		Change in use and aesthetics of settlement environment
	20. Appearance of new service facilities in the town	Change of values		
Urban environment (Noise, vibration)	21. Construction works (number of construction staff present)	Consumption, production, change of enterprises	Changes in settlement structure	Changes in settlement development, socio-economic impacts
	22. Construction works	Demand for infrastructure Change in noise and vibration levels		Nuisance, disturbance
	23. Transportation of workers and construction materials to the construction site	Change in noise and vibration levels		
	24. Large number of temporary population, their supply, traffic	Change in noise and vib. levels Changes in structure and function		Tension, conflicts
Landscape	25. Long-term continuous construction works, accommodation of temporary population	Change in land use Change in landscape		Change of life conditions

Figure M-5. Potential environmental impact processes of the construction phase of the nuclear power plant

Affected environmental elements/system		Impact factor	Direct impact	Indirect impacts	Man as final impact bearer
Air – climate	1.	Radioactive discharge of operation	→ Change in background load		Growth of risk
	2.	Emission of conventional air pollutants of operation, transportation	→ Change of air quality in the immediate vicinity and along access roads		Health impacts
	3.	Heat emission of operation into the atmosphere	→		
	4.	Existence and urban effect of the power plant	→ Change of air temperature of close environment	Change in micro- and mesoclimate	Occasional disturbance of certain uses
	5.	Air pollution incident	→ Increase of radioactivity exceeding background radiation in the environment		Growth of health risks
Surface and groundwaters	6.	Water withdrawal (cooling and social water demand)	→ Decrease of quantity of surface and groundwaters		Restriction of usage
	7.	Existence of built-up and paved surfaces	→ Change of runoff and infiltration conditions		
	8.	Radioactive discharge of operation	→ Change of quality of surface waters		Growth of risk
	9.	Emissions of conventional pollutants of operation – production and treatment of sewage water	→ Change of quality of surface waters	Contamination of groundwaters	Restrictions of use
	10.	Operation – hot cooling water discharge	→ Change of water temperature of receiving water body		Temporary disturbance of certain uses
	11.	Water pollution incident	→ Pollution rise exceeding discharge limit in receiving water body and groundwaters	Settling of radioactive substances on surface waters	Temporary restriction of certain uses
Earth	12.	Existence of the power plant as a building	→ Permanent load of soil and rock layers	Potential shift of layers	Safety problems
	13.	Operation – production of conventional wastes	→ Soil contamination		Restriction of use
	14.	Operation – production of radioactive wastes	→ Soil contamination		Growth of risk
	15.	Soil contamination incident	→ Increase of pollution exceeding background load		Restriction of use
Wildlife-ecosystems	16.	Existence of high-voltage electricity network	→ Collision, electromagnetic impact	Change of life conditions → Migration, degradation	Decrease of biodiversity
Built elements		(no direct impact)		Deterioration of condition	Rise in maintenance demand
Urban environment (Noise, vibration)	17.	Existence of the facility	→ Existence and development of the settlement	Intensification of urban effects	Possibility of co-development Improvement of use opportunities
	18.	Operation of the facility	→ Noise and vibration Light effect		Nuisance
Landscape	19.	Existence of the facility	→ Restrictions of landscape use → Landscape disturbance		Change of life conditions

Figure M-6. Potential environmental impact processes of the operation phase (including test operation) of the nuclear power plant

Affected environmental elements/system		Impact factor	Direct impact	Indirect impacts	Man as final impact bearer
Air – climate	1.	Radioactive discharge of operation	→ Change in background load		Growth of risk
	2.	Emissions of conventional air pollutants of operation, transportation	→ Change of air quality in the immediate vicinity and along access roads		Health impacts
	3.	Heat emission of operation into the atmosphere	→		
	4.	Existence and urban effect of the power plant	→ Change of air temperature of close environment	Change in micro and mesoclimate	Occasional disturbance of certain uses
Surface and groundwaters	5.	Water withdrawal (cooling and social water demand)	→ Decrease of quantity of surface and groundwaters		Restriction of usage
	6.	Existence of built-up and paved surfaces	→ Change of runoff and infiltration conditions		
	7.	Radioactive discharge of operation	→ Change of quality of surface waters		Growth of risk
	8.	Emissions of conventional pollutants of operation – production and treatment of sewage water	→ Change of quality of surface waters	Contamination of groundwaters	Restriction of usage
	9.	Operation – hot cooling water discharge	→ Change of water temperature of receiving water body	Settling of radioactive substances on surface waters	Temporary disturbance of certain uses
Earth	10.	Existence of the power plant as a building	→ Permanent load of soil and rock layers	Potential shift of layers	Safety problems
	11.	Operation – production of conventional wastes	→ Soil contamination		Restriction of usage
	12.	Operation – production of radioactive wastes	→ Soil contamination		Growth of risk
Wildlife-ecosystems	13.	Existence of high-voltage electricity network	→ Collision, electromagnetic impact	Change of life conditions → Migration, degradation	Decrease of biodiversity
Built elements		(no direct impact)		Deterioration of condition	Rise in maintenance demand
Urban environment (Noise, vibration)	14.	Existence of the facility	→ Existence and development of the settlement	Intensification of urban effects	Possibility of co-development Improvement of use opportunities
	15.	Operation of the facility	→ Noise and vibration Light effect		Nuisance
Landscape	16.	Existence of the facility	→ Restrictions of landscape use → Landscape disturbance		Change of life conditions

Figure M-7. Cummulative impact processes of nuclear facilities operating on the Paks site

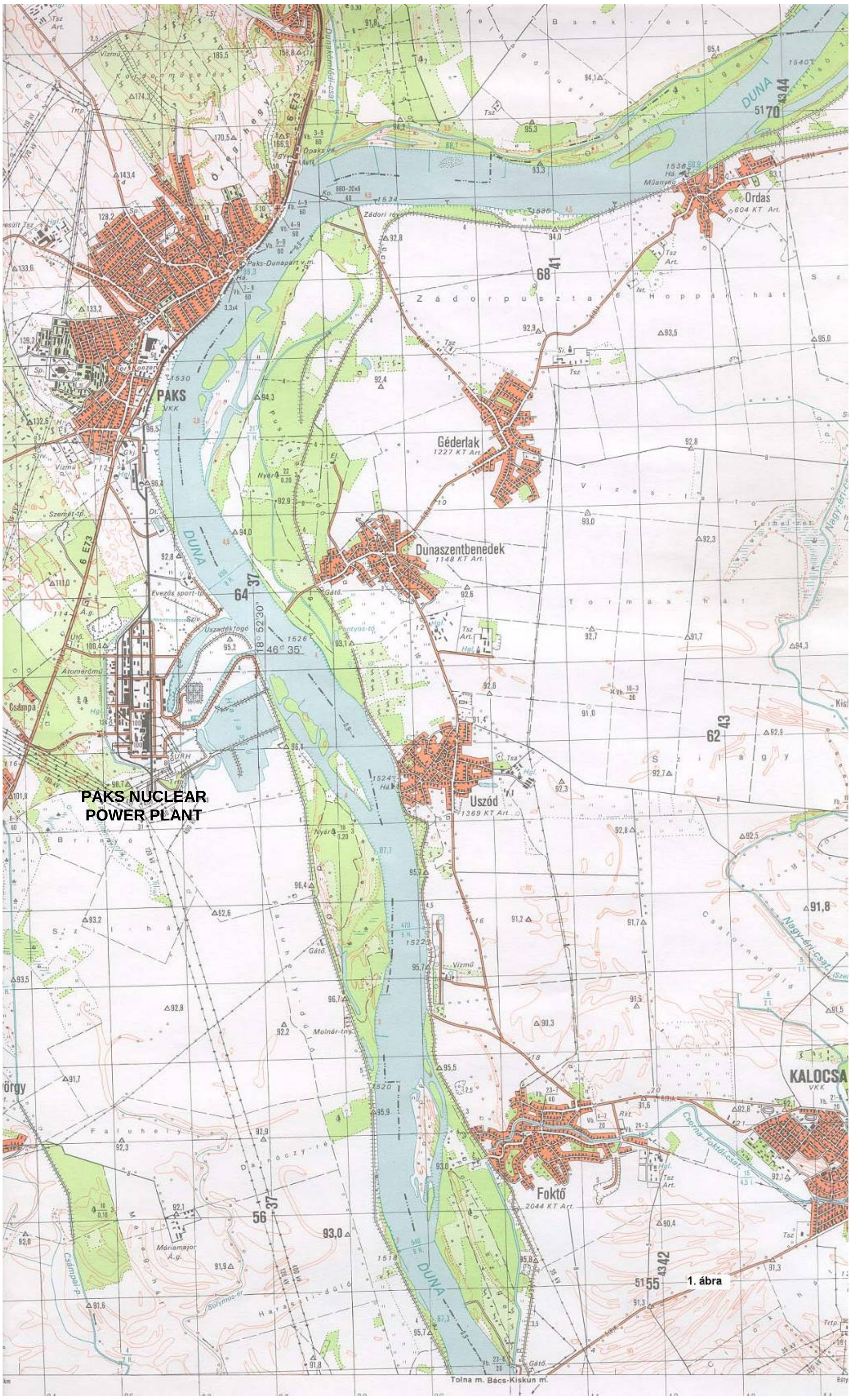


Figure M-8. General map of the Danube-section between 1517–1540 rkm

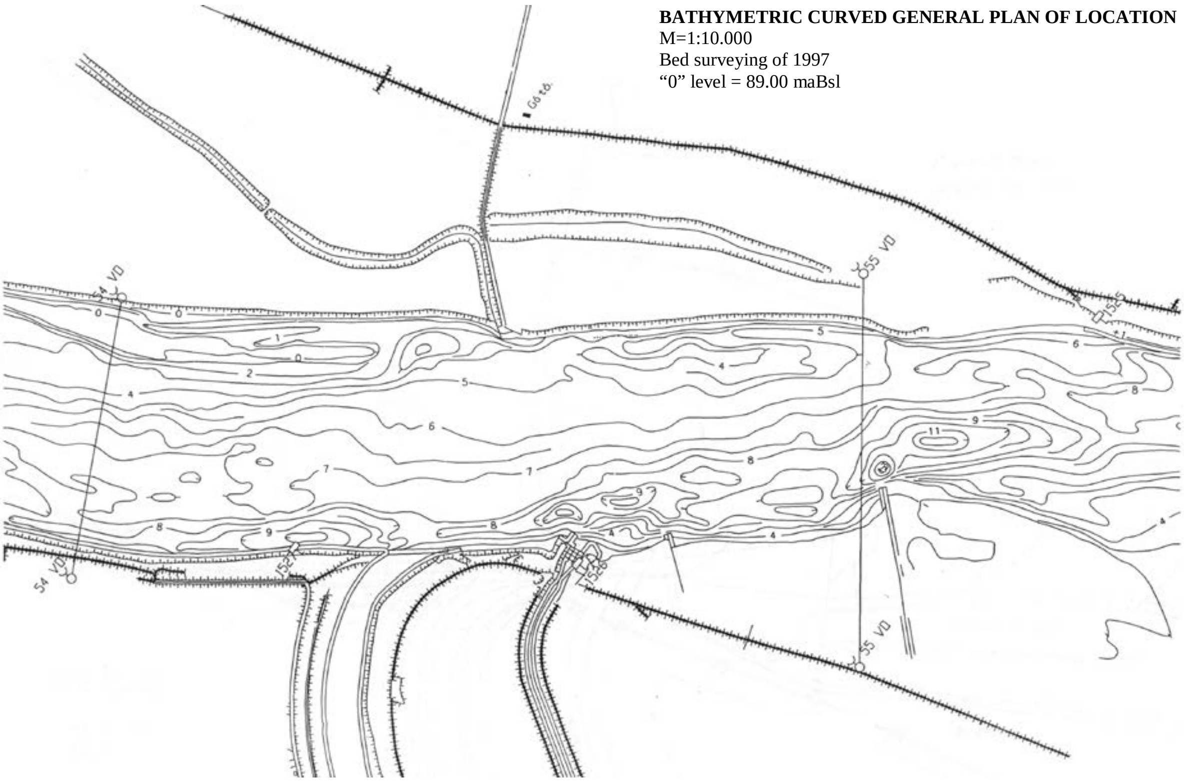
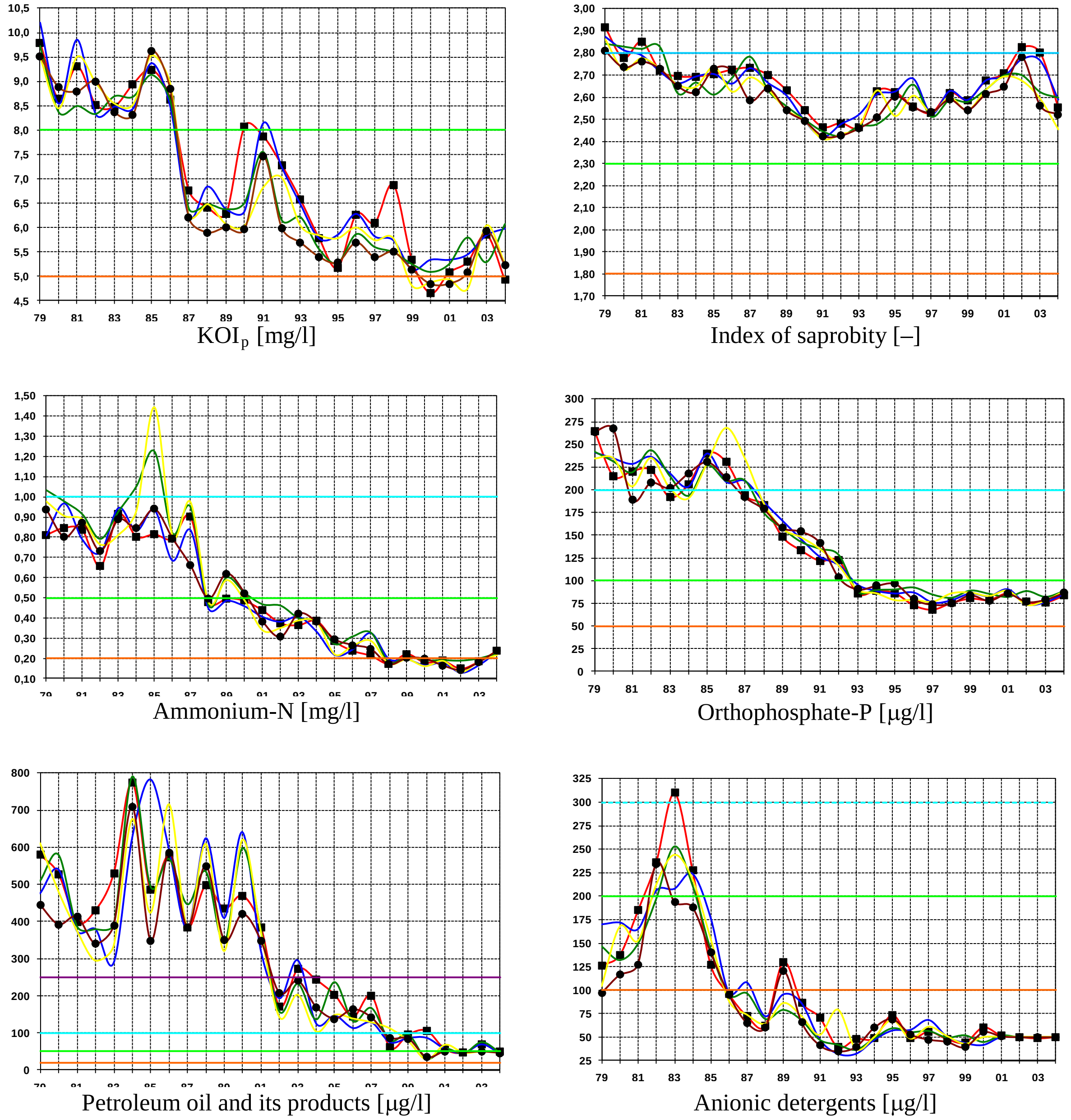


Figure M-9. Result of surveying of Danube bed in 1997



Red – Dunaföldvár (mean), blue – Fajsz, green – Baja, yellow – Mohács, purple – Hercegszántó.

Figure M-10. Annual values with 90% durability of water quality parameters at the section of Dunaföldvár–Hercegszántó (1979–2004)

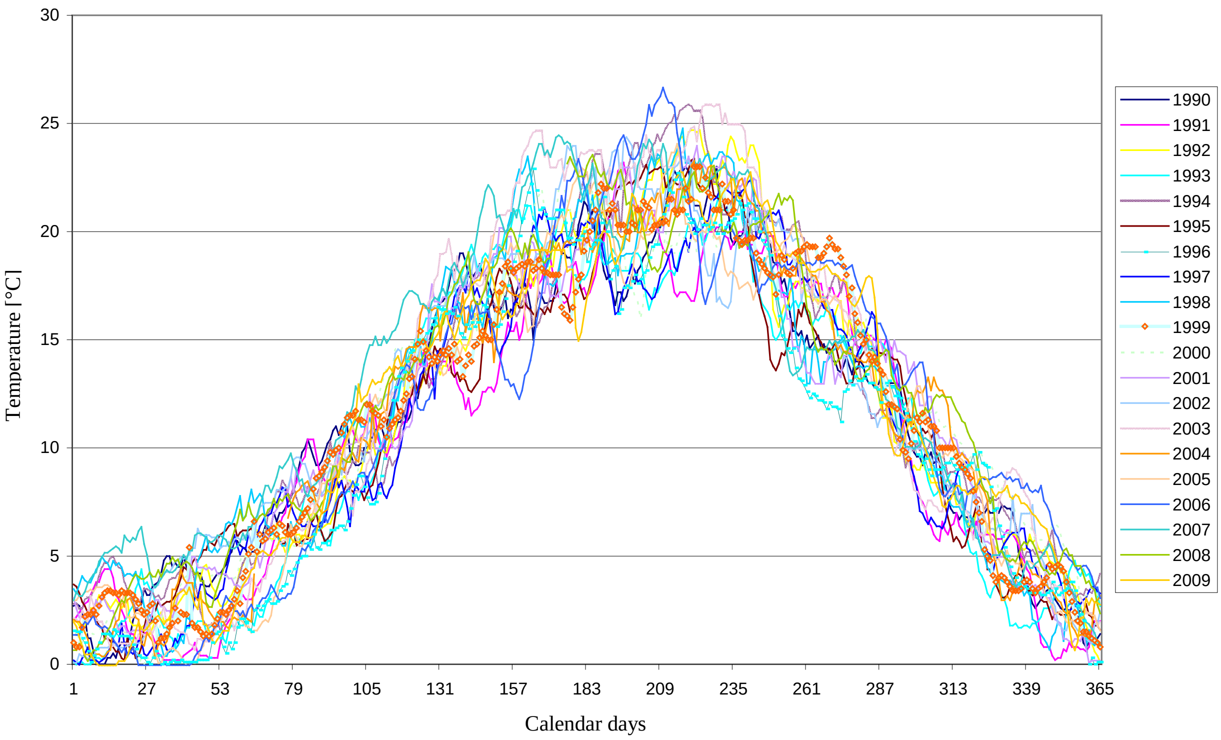


Figure M-11. Annual water temperature values of Danube at the measuring station of Paks (1990–2009)

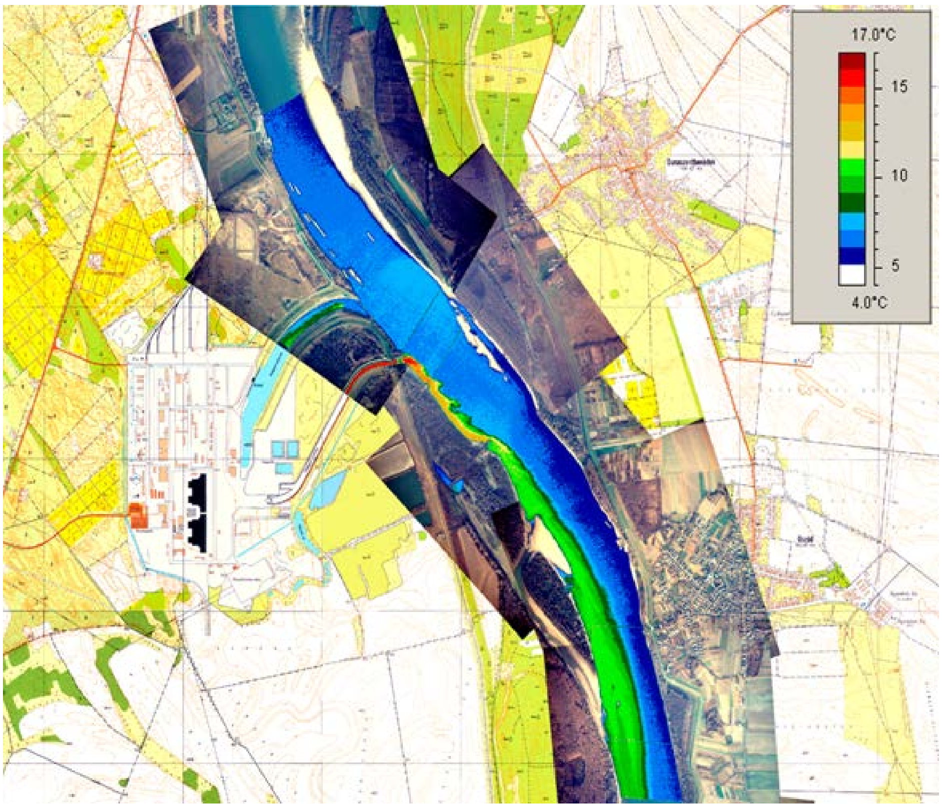
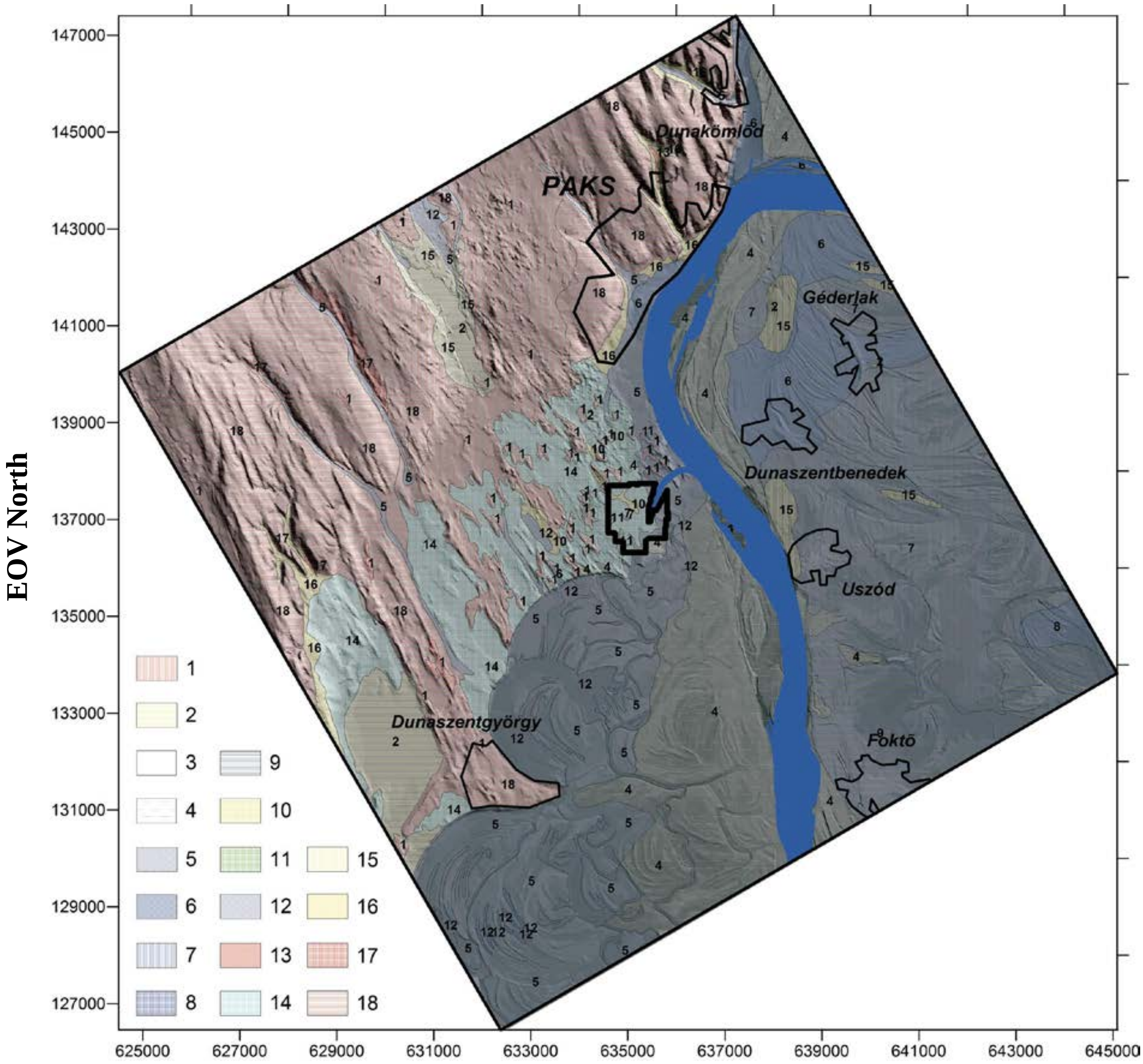


Figure M-12. Thermal map of Danube on the basis of thermal imaging (20th of November, 2005)



Holocene formations: anemoarenyte (1); lymnetic clay aleurit (2); lymnetic peat (3); fluvial sand (4); fluvial aleurit sand (5); fluvial sandy aleurit (6); fluvial aleurit (7); fluvial clayed aleurit (8); fluvial aleurit clay (9); fluvial lymnetic aluerit sand (10); fluvial lymnetic aleurit (11); fluvial lymnetic clayed aleurit (12); fluvial-slope aleurit sand (13).
Pleistocene formations: fluvial anemoarenyte (14); fluvial sand (15); slope-facies aleurit (16); anemoarenyte (17); aeolilan loess set (18).

Figure M-13. Surface geological formations of the area of nuclear power plant

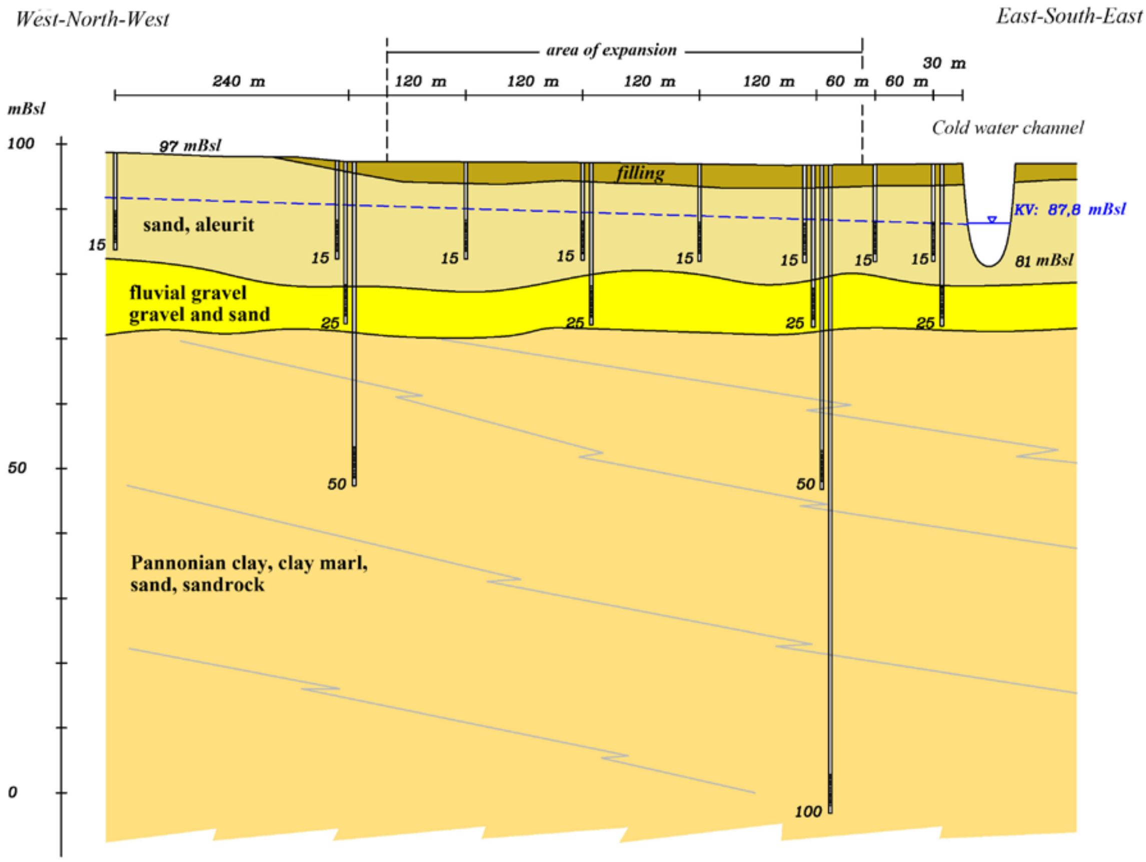


Figure M-14. Geological section through the area of planned new units

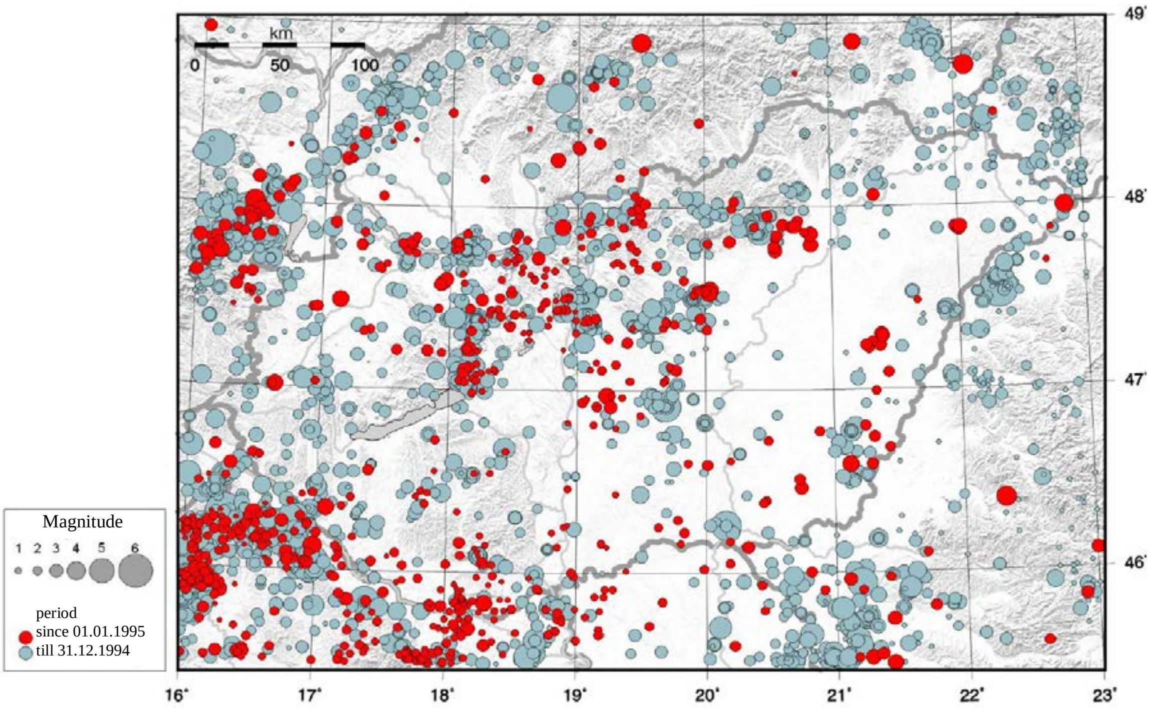


Figure M-15. Epicentres of earthquakes originated in Hungary and in its environment (up to 2005)

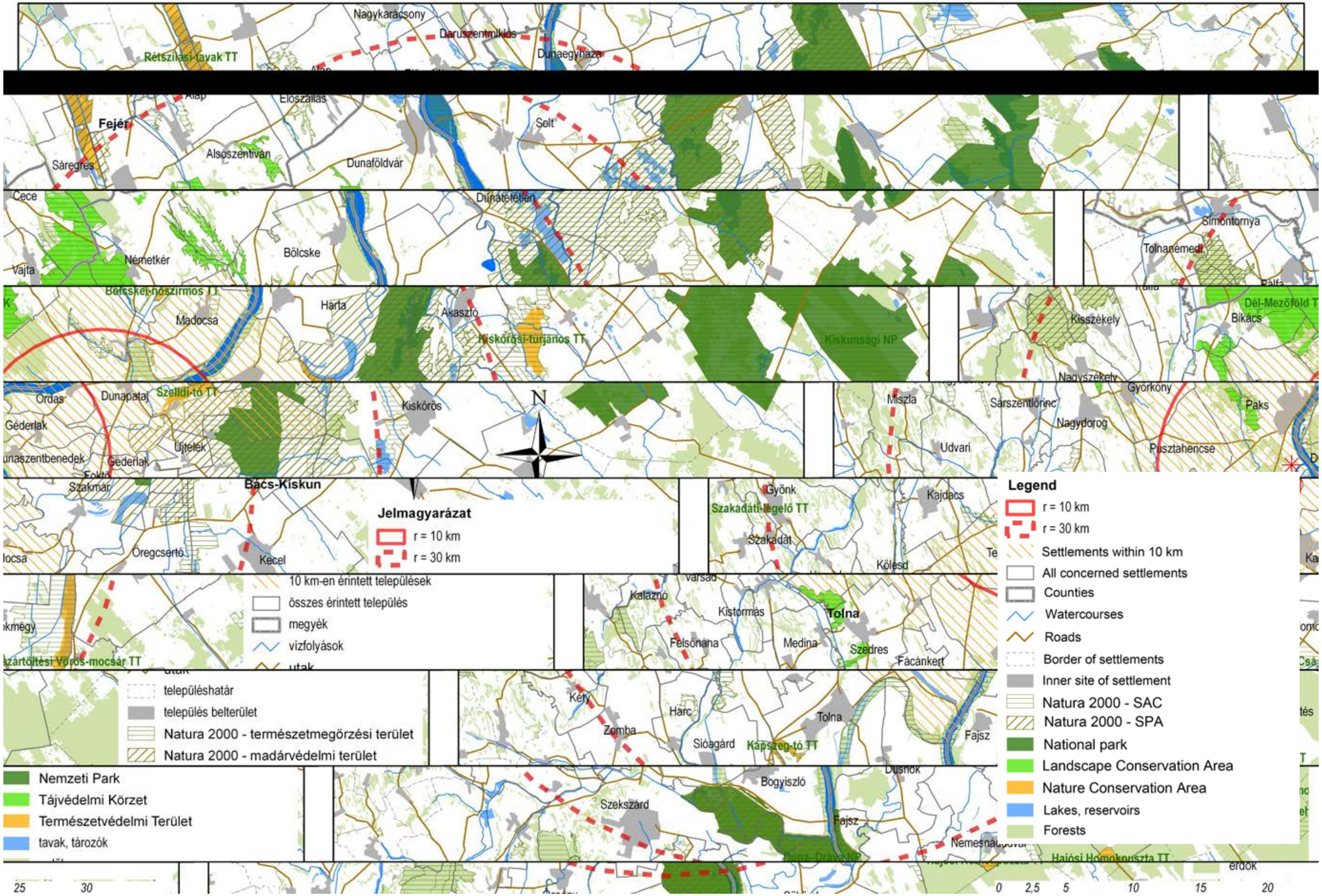


Figure M-16. Protected natural areas of the surveyed area

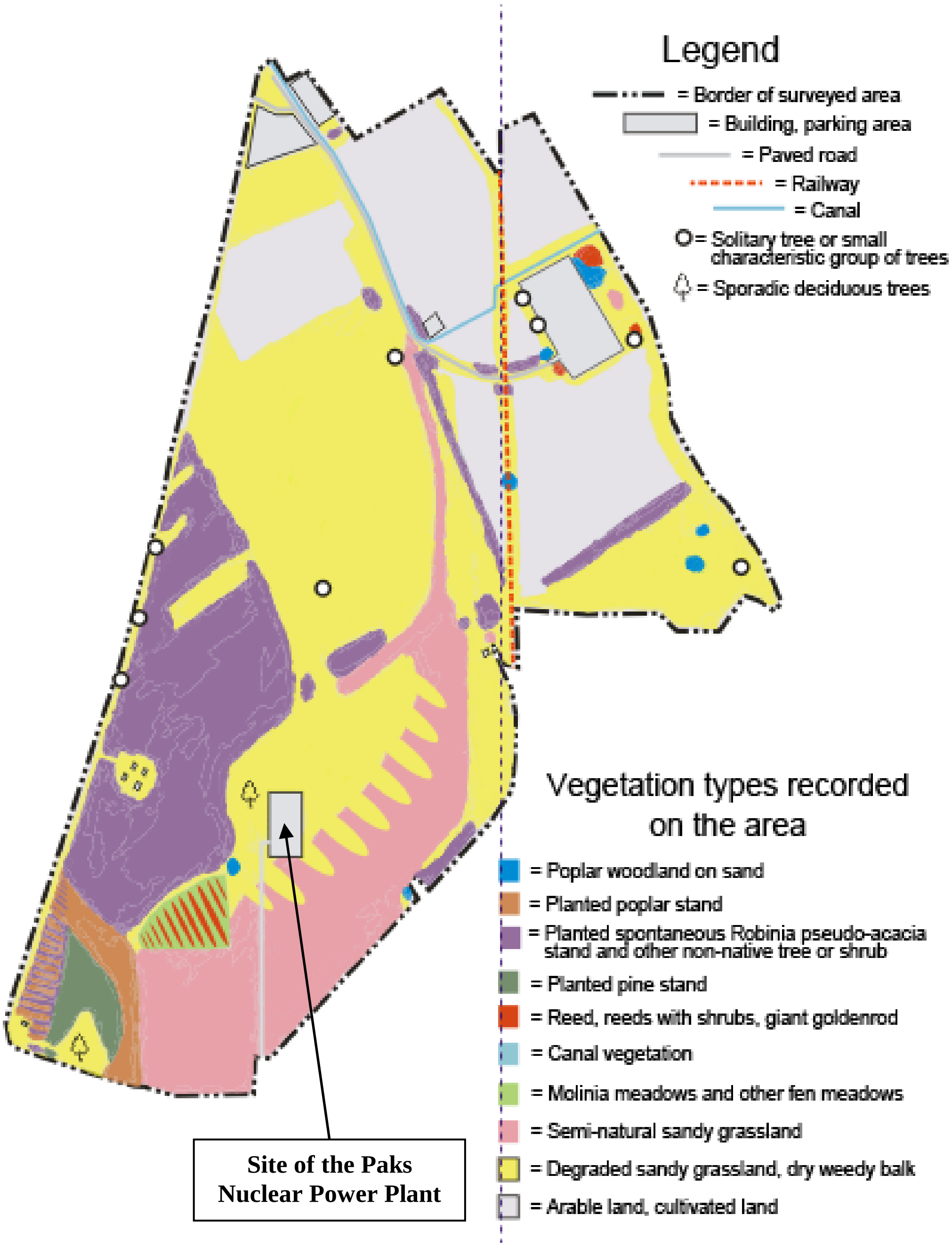


Figure M-17. Vegetation map of the detailed vegetation survey

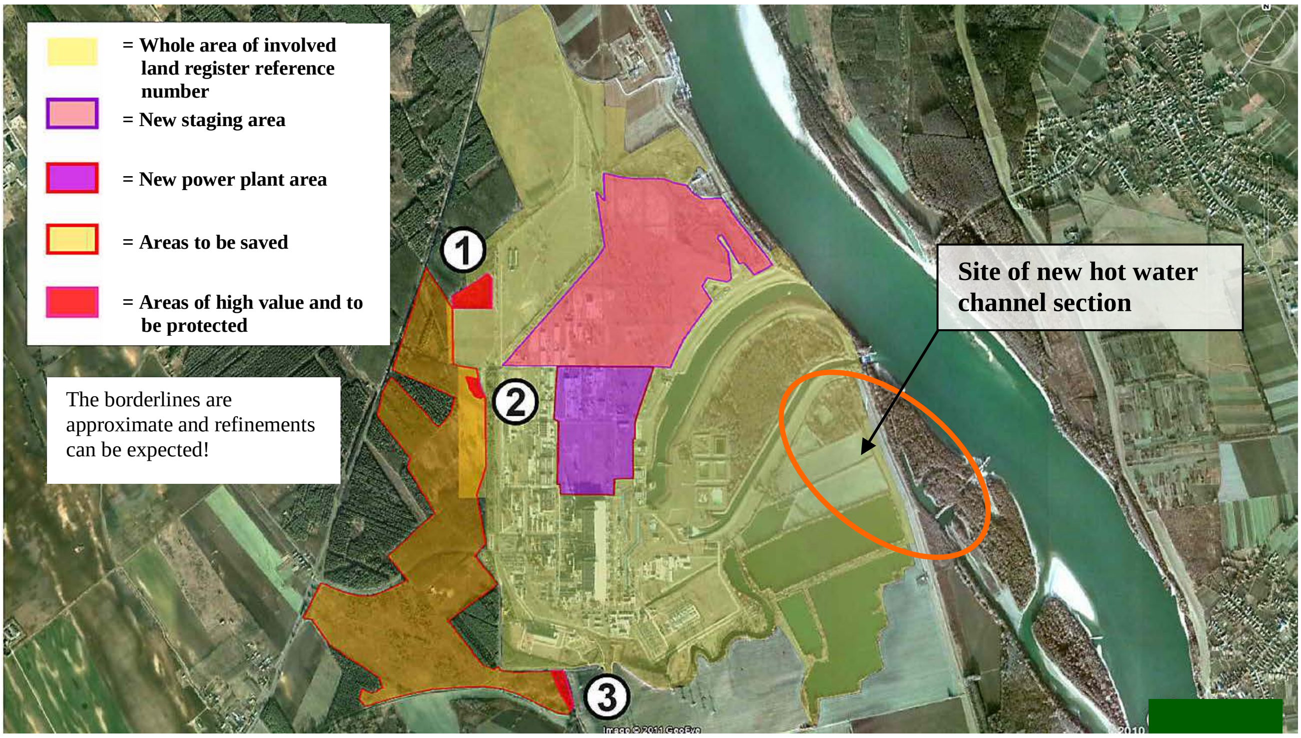
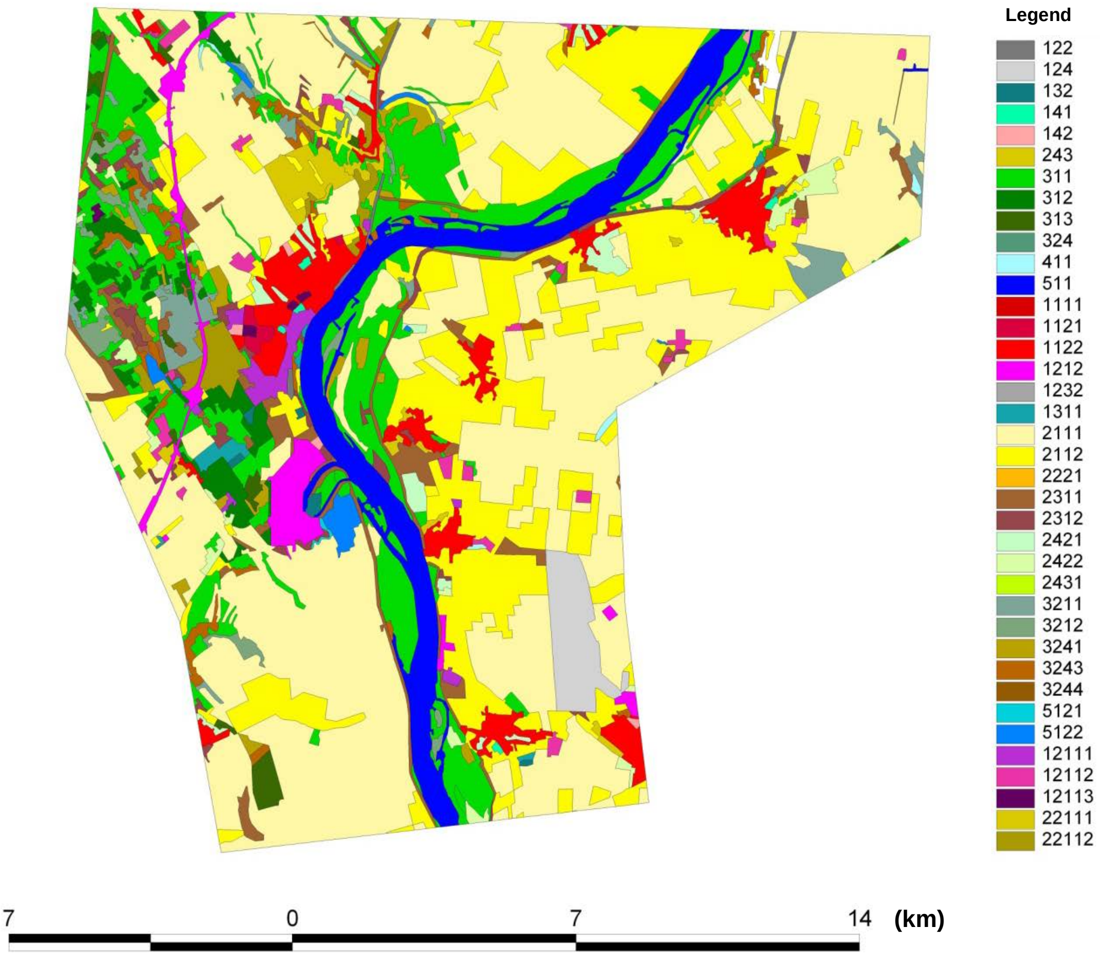


Figure M-18. Site of the development and areas to be saved because of nature conservation



M = 1:200 000

Source: FÖMI, digital aerial photography (colour and colour infra), 14 July 2009

Legend:

122	Road and rail network	1111	Town centres	3211	Natural grasslands
124	Airports	1121	Multi-storeyed residential buildings, blocks of flats	3212	Natural grasslands with trees and shrubs
132	Disposal sites (refuse, slurry pond)	1122	Suburban residential areas, suburbs	3241	Juvenile forests and cutting areas
141	Urban green surfaces	1212	Special technical facilities	3243	Spontaneously growing shrubs and woodlands
142	Sport, leisure and recreational areas	1232	River ports	3244	Nursery
243	Primarily agricultural areas with significant natural vegetation	1311	Open air mines	5121	Natural lakes
311	Deciduous forest	2111	Large-scale arable land	5122	Artificial lakes, reservoirs
312	Coniferous forest	2112	Small-scale arable land	12111	Industrial and trade facilities
313	Mixed forest	2221	Orchard plantations	12112	Large agricultural farms, farm centres, smaller farms
324	Transitional woody, shrubby areas	2311	Intensive pastures and degraded grasslands	12113	Educational and health institutions
411	Swamps	2312	Intensive pastures and degraded grasslands with trees and shrubs	22111	Large-scale vineyards
511	Watercourses, canals	2421	Gardens (outskirts of town)	22112	Small-scale vineyards
		2422	Gardens (outskirts of town) with buildings		

Figure M-19. Land cover in the vicinity of Paks Nuclear Power Plant in 2009

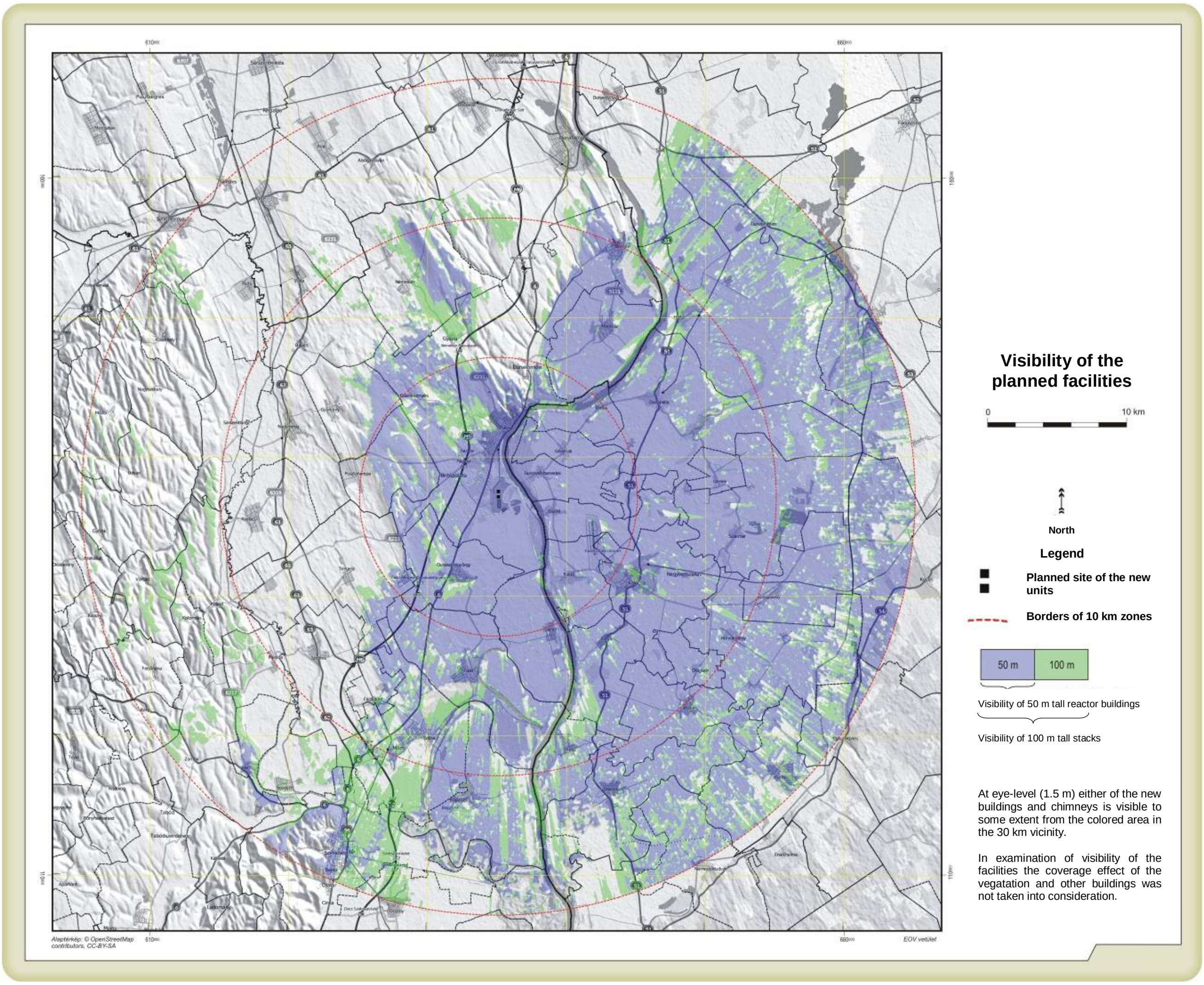


Figure M-20. Visibility of the planned facilities

Figure M-21. Bird’s eye view from Paks town with the new EPR units

Figure M-22. The new EPR units from the western end of the cold water channel

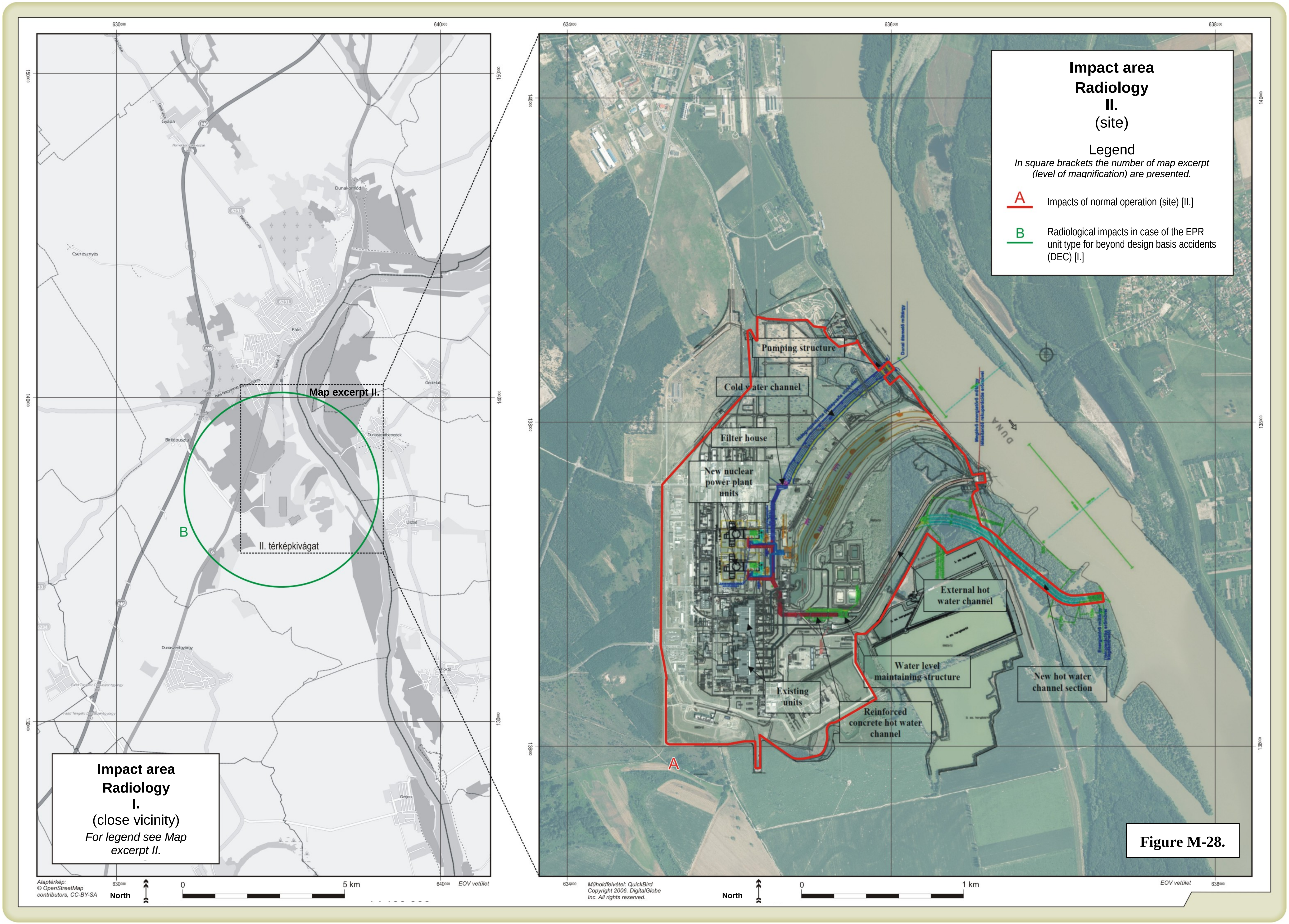
Figure M-23. The new MIR.1200 units with the existing power plant in the background

Figure M-24. The new ATMEA1 units from the western end of the cold water channel

Figure M-25. The new AP1000 units from M6 motorway

Figure M-26. The APR1400 units from the power plant residential area

Figure M-27. Layout of the fresh water cooling technlogy [95]


Map excerpt II.
B
II. térképkivágat
Impact area
Radiology
I.
(close vicinity)
For legend see Map excerpt II.
Alaptérkép:
© OpenStreetMap contributors, CC-BY-SA
North
0
5 km
EOV vetület
Impact area
Radiology
II.
(site)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A
Impacts of normal operation (site) [II.]
B
Radiological impacts in case of the EPR unit type for beyond design basis accidents (DEC) [I.]
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
DUNA
A
Figure M-28.
Műholdfelvétel: QuickBird
Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület

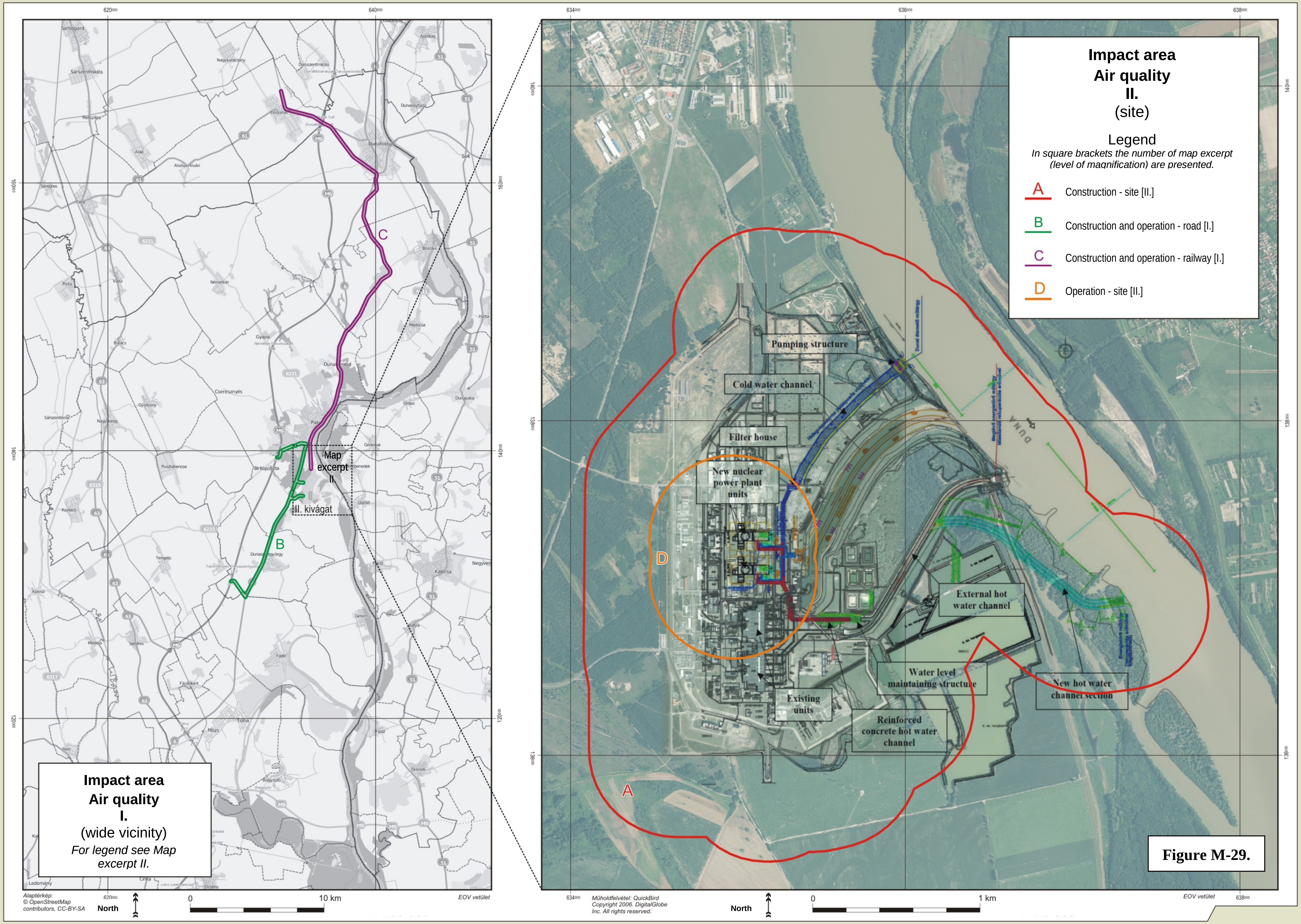

Impact area
Air quality
I.
(wide vicinity)
For legend see Map excerpt II.
Map excerpt II.
II. kivágat
A
B
C
D
10 km
North
EOV vetület
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
Impact area
Air quality
II.
(site)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
Construction - site [II.]
Construction and operation - road [I.]
Construction and operation - railway [I.]
Operation - site [II.]
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
DUNA
1 km
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.

Figure M-29.

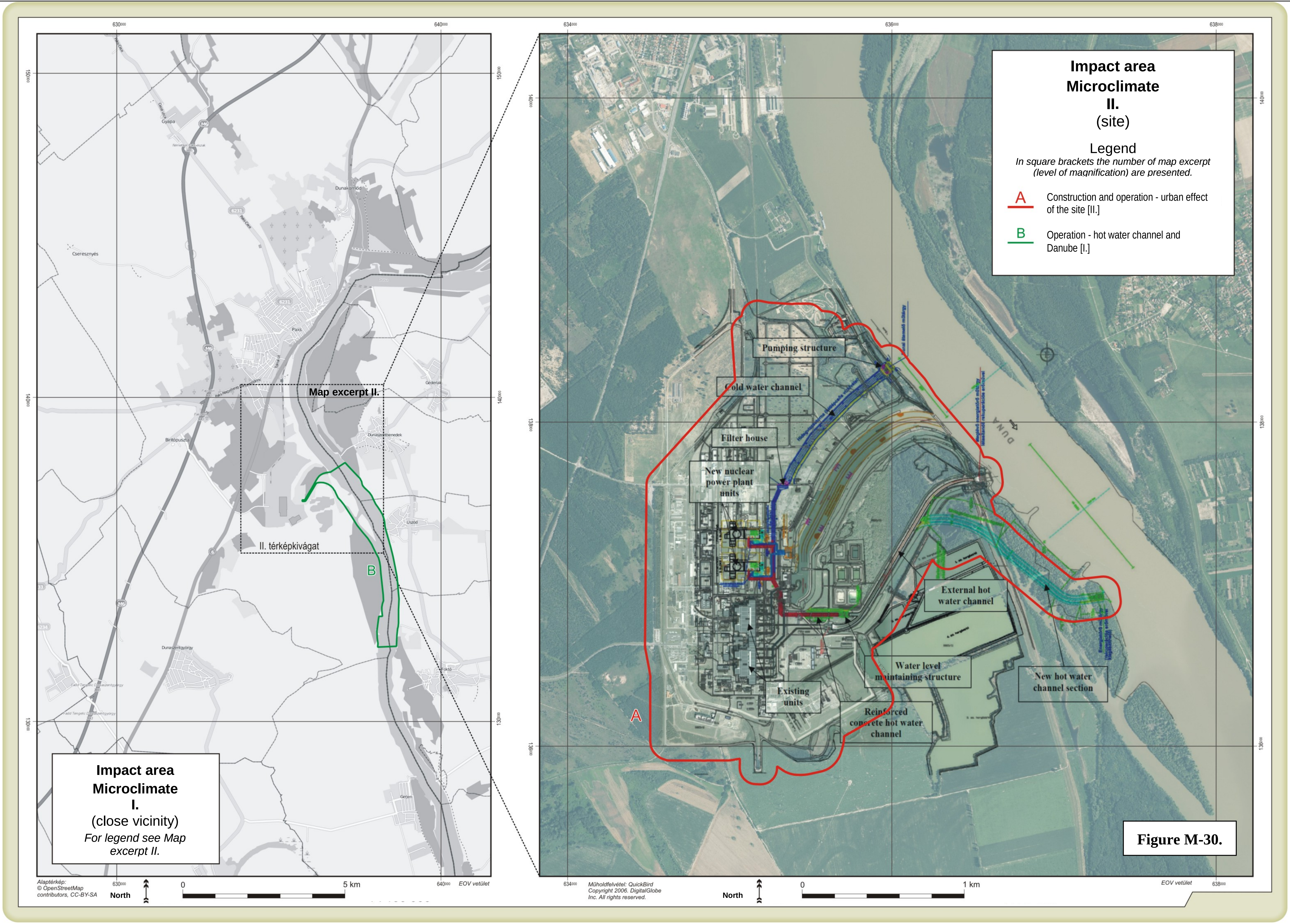

Impact area
Microclimate
I.
(close vicinity)
For legend see Map excerpt II.
Map excerpt II.
II. térképkivágat
B
Paks
Dunakömlőd
Cseresznyés
Gyapa
Dunaszentbenedek
Uszód
Dunaszentgyörgy
Gerjen
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
North
0
5 km
EOV vetület
Impact area
Microclimate
II.
(site)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A
Construction and operation - urban effect of the site [II.]
B
Operation - hot water channel and Danube [I.]
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
A
DUNA
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület

Figure M-30.

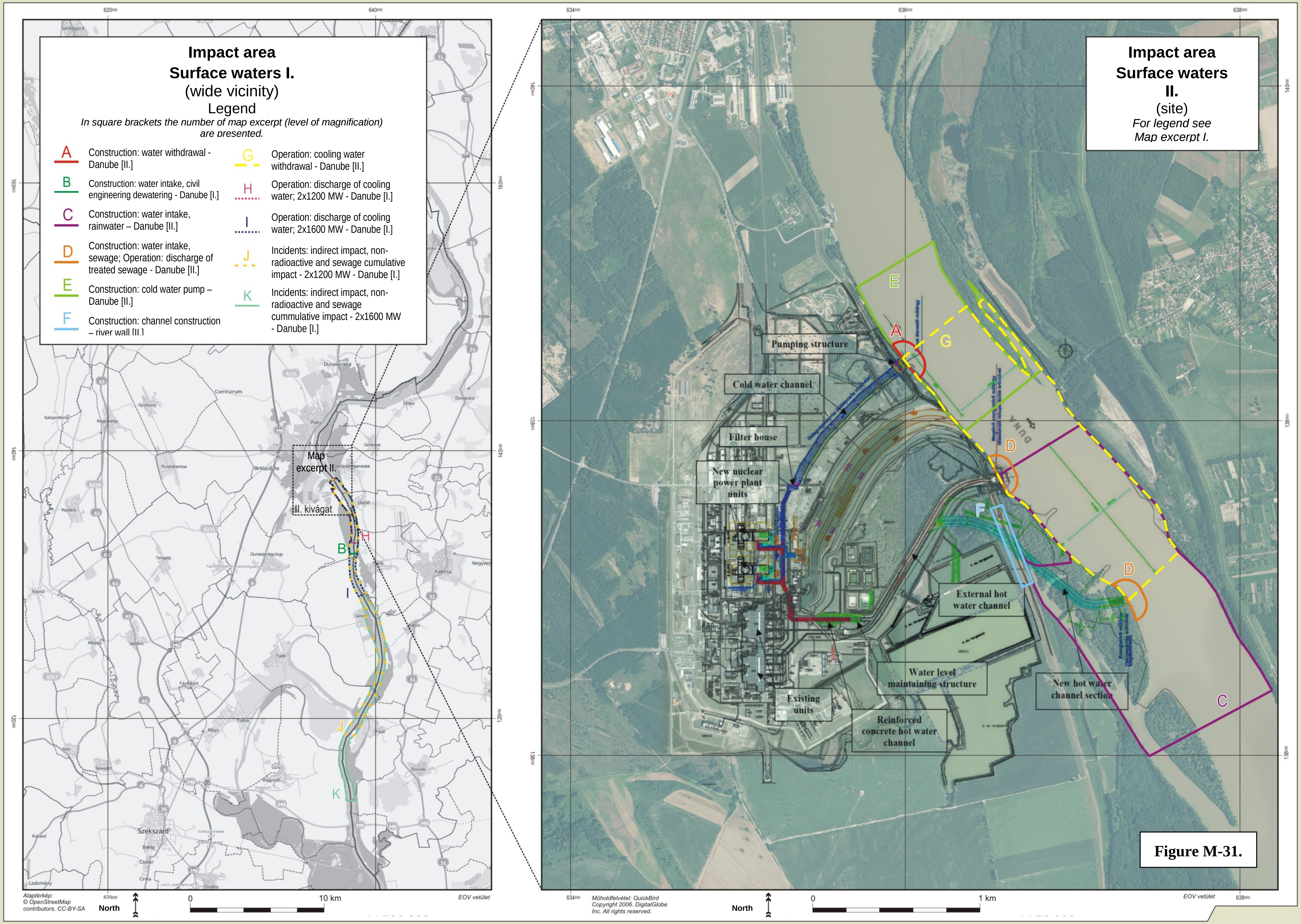
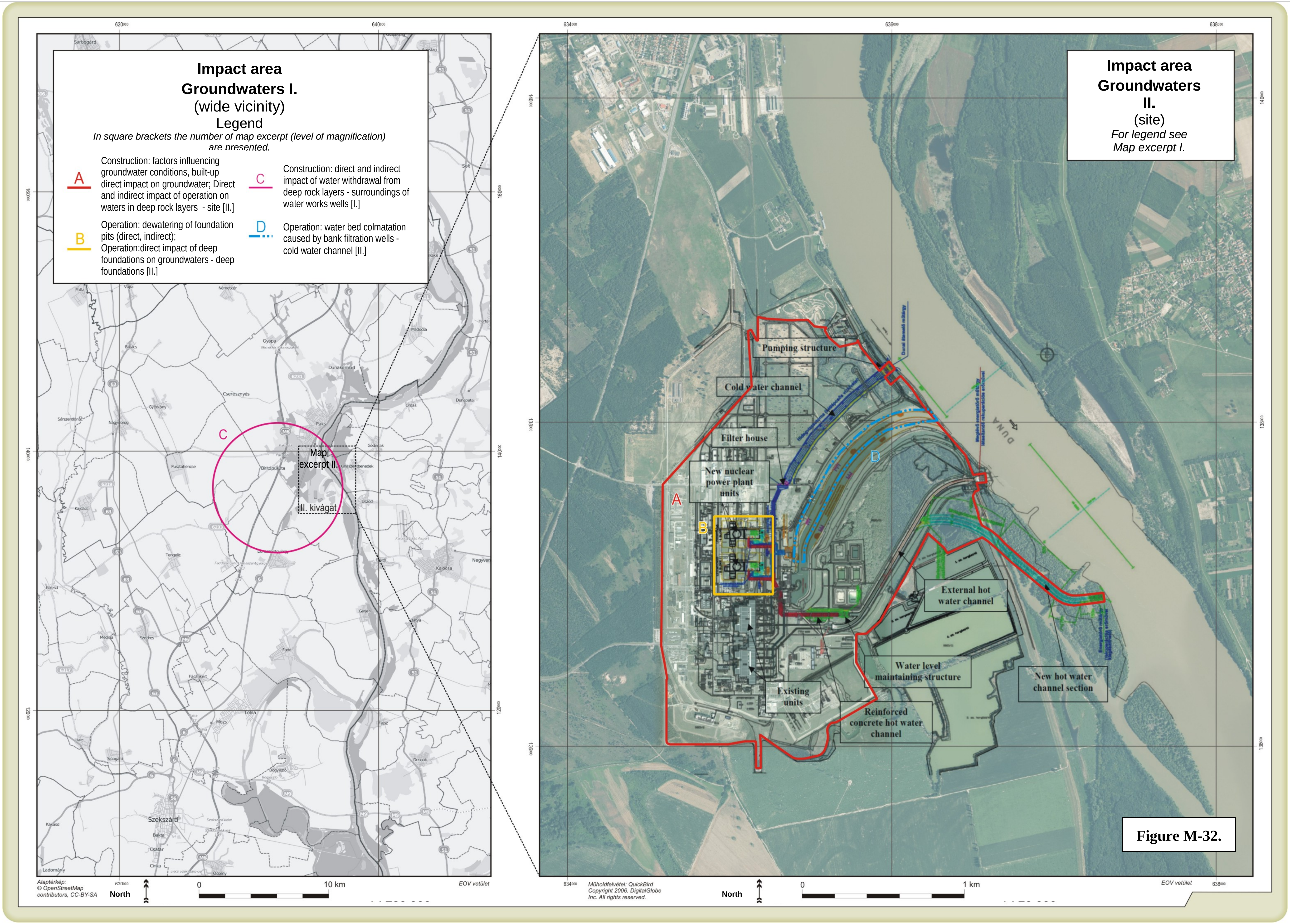

Impact area
Surface waters I.
(wide vicinity)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A Construction: water withdrawal - Danube [II.]
B Construction: water intake, civil engineering dewatering - Danube [I.]
C Construction: water intake, rainwater – Danube [II.]
D Construction: water intake, sewage; Operation: discharge of treated sewage - Danube [II.]
E Construction: cold water pump – Danube [II.]
F Construction: channel construction – river wall [II.]
G Operation: cooling water withdrawal - Danube [II.]
H Operation: discharge of cooling water; 2x1200 MW - Danube [I.]
I Operation: discharge of cooling water; 2x1600 MW - Danube [I.]
J Incidents: indirect impact, non-radioactive and sewage cumulative impact - 2x1200 MW - Danube [I.]
K Incidents: indirect impact, non-radioactive and sewage cummulative impact - 2x1600 MW - Danube [I.]
Map excerpt II.
II. kivágat
Szekszárd
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
North
0
10 km
EOV vetület
Impact area
Surface waters II.
(site)
For legend see Map excerpt I.
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület

Figure M-31.


Impact area
Groundwaters I.
(wide vicinity)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A
Construction: factors influencing groundwater conditions, built-up direct impact on groundwater; Direct and indirect impact of operation on waters in deep rock layers - site [II.]
B
Operation: dewatering of foundation pits (direct, indirect);
Operation:direct impact of deep foundations on groundwaters - deep foundations [II.]
C
Construction: direct and indirect impact of water withdrawal from deep rock layers - surroundings of water works wells [I.]
D
Operation: water bed colmatation caused by bank filtration wells - cold water channel [II.]
Map excerpt II.
II. kivágat
Paks
Szekszárd
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
North
0
10 km
EOV vetület
Impact area
Groundwaters
II.
(site)
For legend see
Map excerpt I.
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
Existing units
Reinforced concrete hot water channel
New hot water channel section
DUNA
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület
Figure M-32.

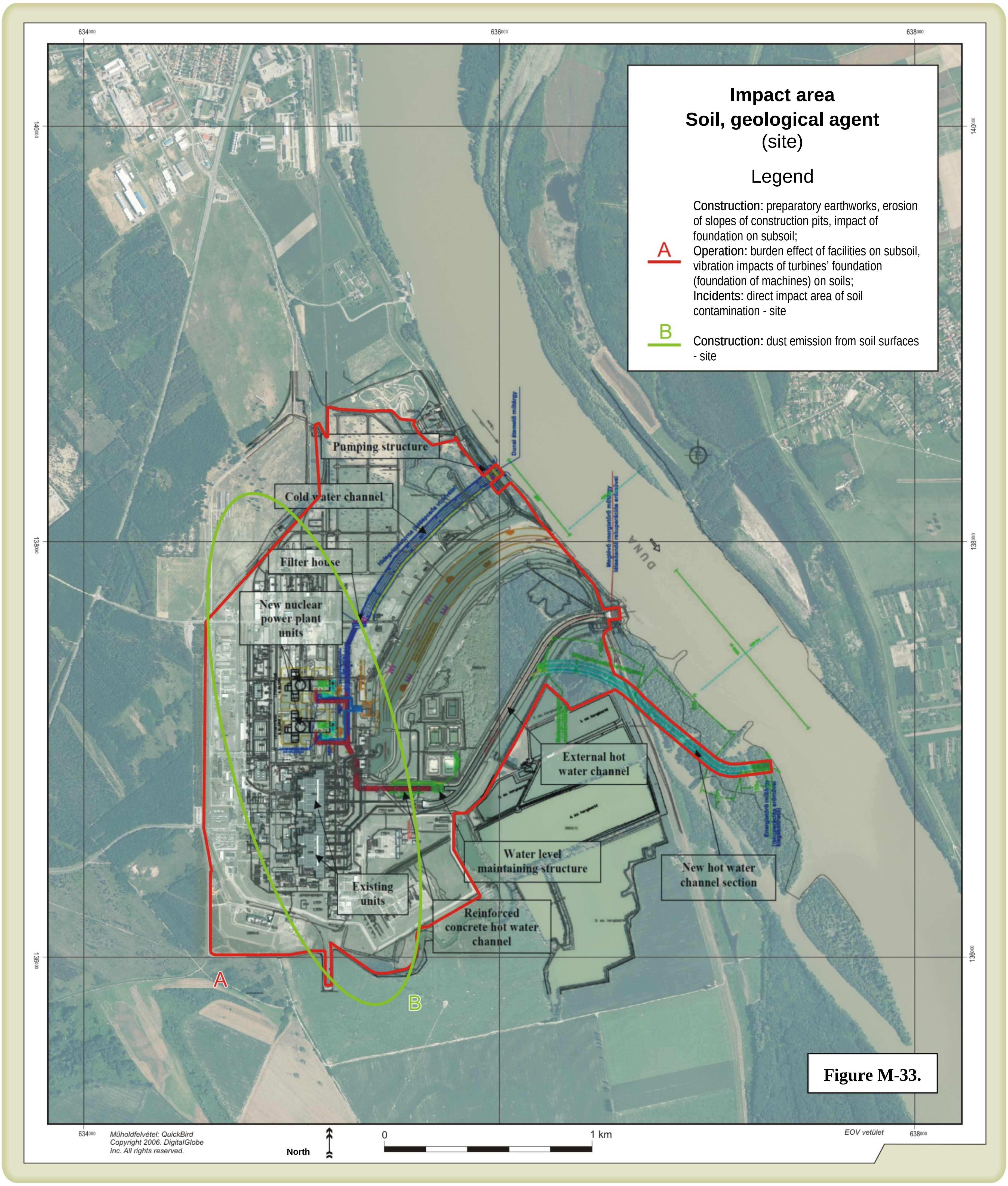
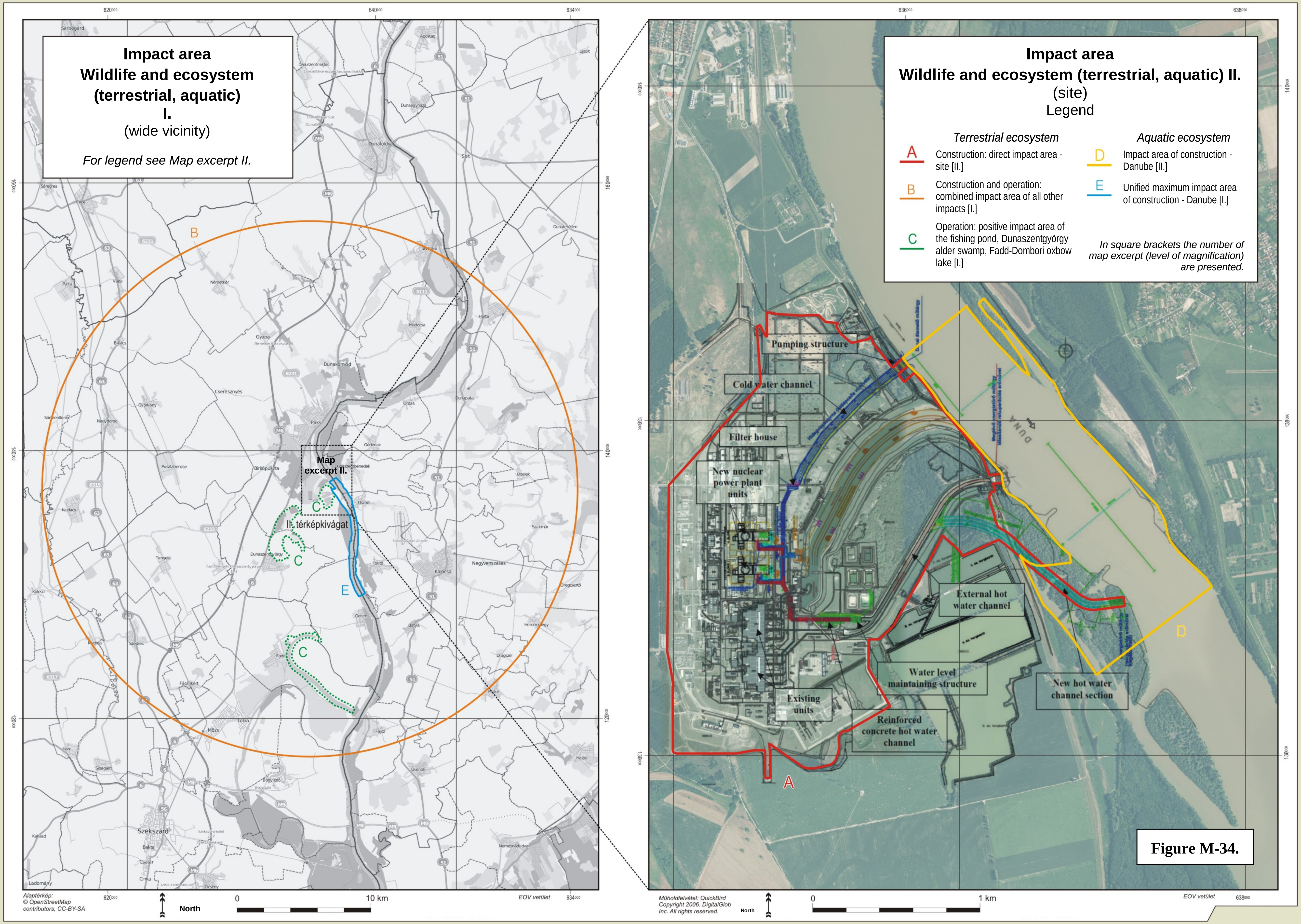
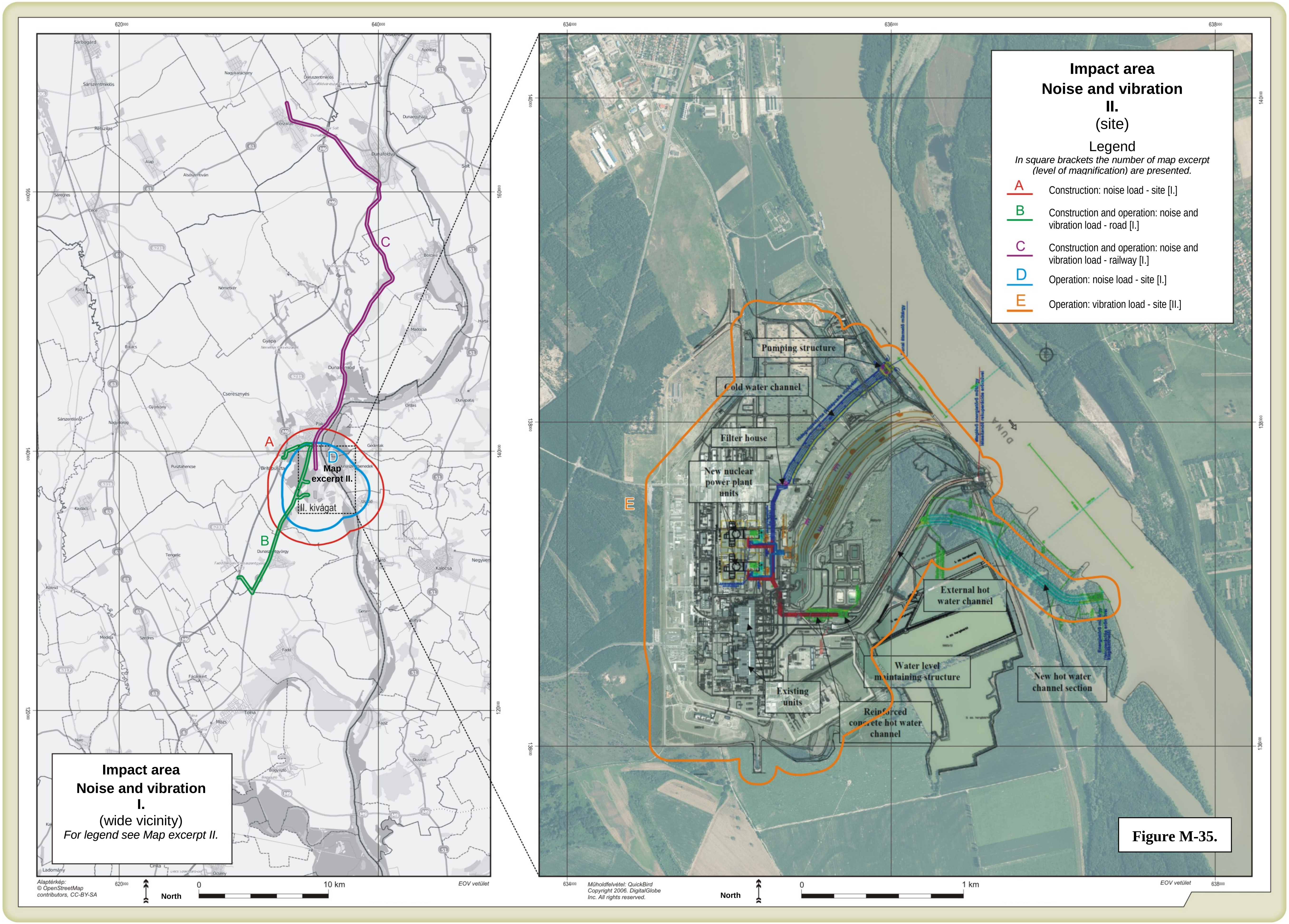
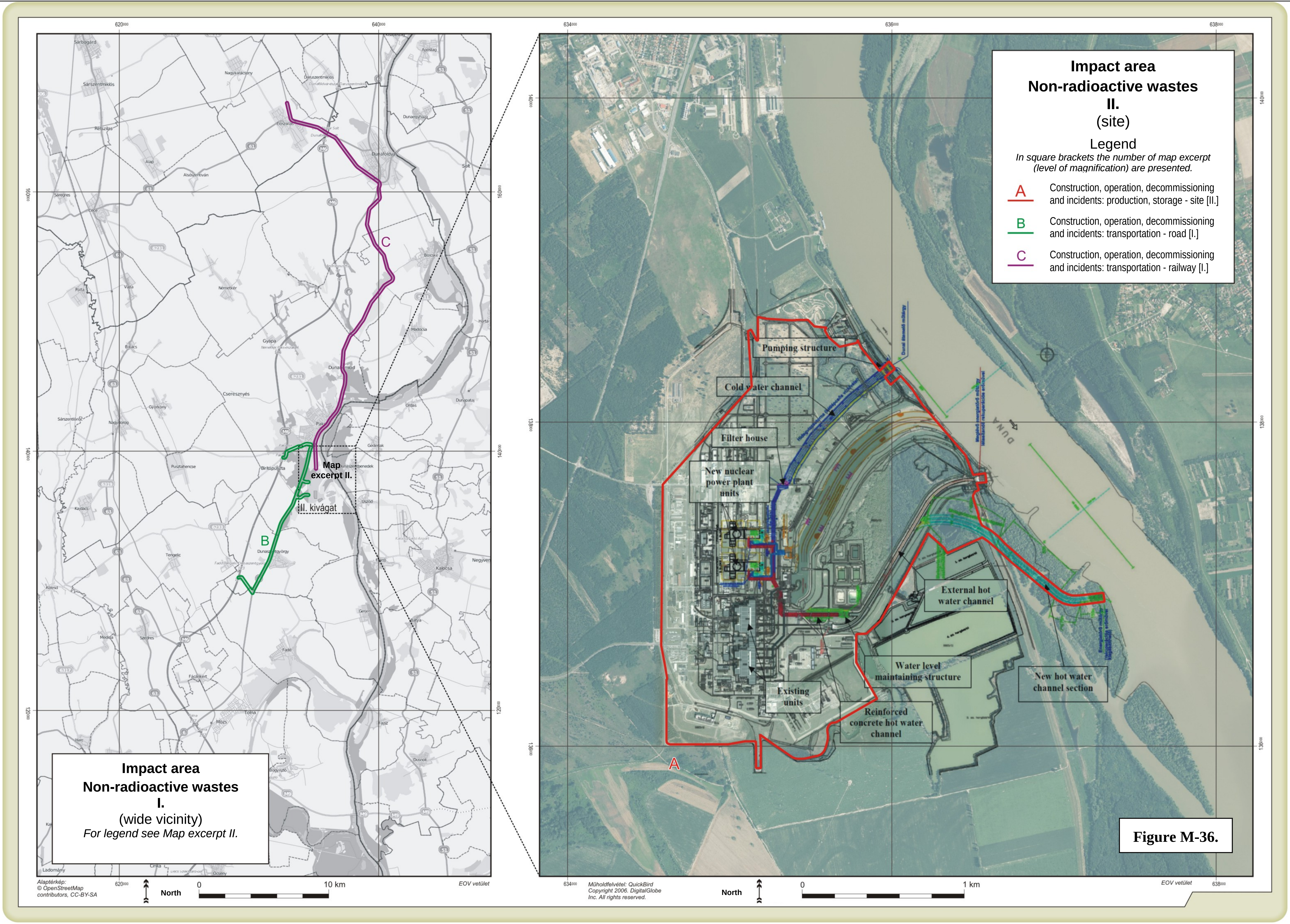

Impact area
Soil, geological agent
(site)
Legend
A
Construction: preparatory earthworks, erosion of slopes of construction pits, impact of foundation on subsoil;
Operation: burden effect of facilities on subsoil, vibration impacts of turbines' foundation (foundation of machines) on soils;
Incidents: direct impact area of soil contamination - site
B
Construction: dust emission from soil surfaces - site
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
DUNA
A
B
Műholdfelvétel: QuickBird
Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület

Figure M-33.


Impact area
Wildlife and ecosystem
(terrestrial, aquatic)
I.
(wide vicinity)
For legend see Map excerpt II.
Map excerpt II.
II. térképkivágat
B
C
E
North
0
10 km
EOV vetület
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
Impact area
Wildlife and ecosystem (terrestrial, aquatic) II.
(site)
Legend
Terrestrial ecosystem
A Construction: direct impact area - site [II.]
B Construction and operation: combined impact area of all other impacts [I.]
C Operation: positive impact area of the fishing pond, Dunaszentgyörgy alder swamp, Fadd-Dombori oxbow lake [I.]
Aquatic ecosystem
D Impact area of construction - Danube [II.]
E Unified maximum impact area of construction - Danube [I.]
In square brackets the number of map excerpt (level of magnification) are presented.
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
DUNA
A
D
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlob Inc. All rights reserved.
North
0
1 km
EOV vetület
Figure M-34.


Impact area
Noise and vibration
I.
(wide vicinity)
For legend see Map excerpt II.
Map excerpt II.
II. kivágat
A
B
C
D
North
0
10 km
EOV vetület
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
Impact area
Noise and vibration
II.
(site)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A Construction: noise load - site [I.]
B Construction and operation: noise and vibration load - road [I.]
C Construction and operation: noise and vibration load - railway [I.]
D Operation: noise load - site [I.]
E Operation: vibration load - site [II.]
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
E
DUNA
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület
Figure M-35.


Impact area
Non-radioactive wastes
I.
(wide vicinity)
For legend see Map excerpt II.
Map excerpt II.
II. kivágat
B
C
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
North
0
10 km
EOV vetület
Impact area
Non-radioactive wastes
II.
(site)
Legend
In square brackets the number of map excerpt (level of magnification) are presented.
A
Construction, operation, decommissioning and incidents: production, storage - site [II.]
B
Construction, operation, decommissioning and incidents: transportation - road [I.]
C
Construction, operation, decommissioning and incidents: transportation - railway [I.]
Pumping structure
Cold water channel
Filter house
New nuclear power plant units
External hot water channel
Water level maintaining structure
New hot water channel section
Existing units
Reinforced concrete hot water channel
A
DUNA
Műholdfelvétel: QuickBird Copyright 2006. DigitalGlobe Inc. All rights reserved.
North
0
1 km
EOV vetület
Figure M-36.

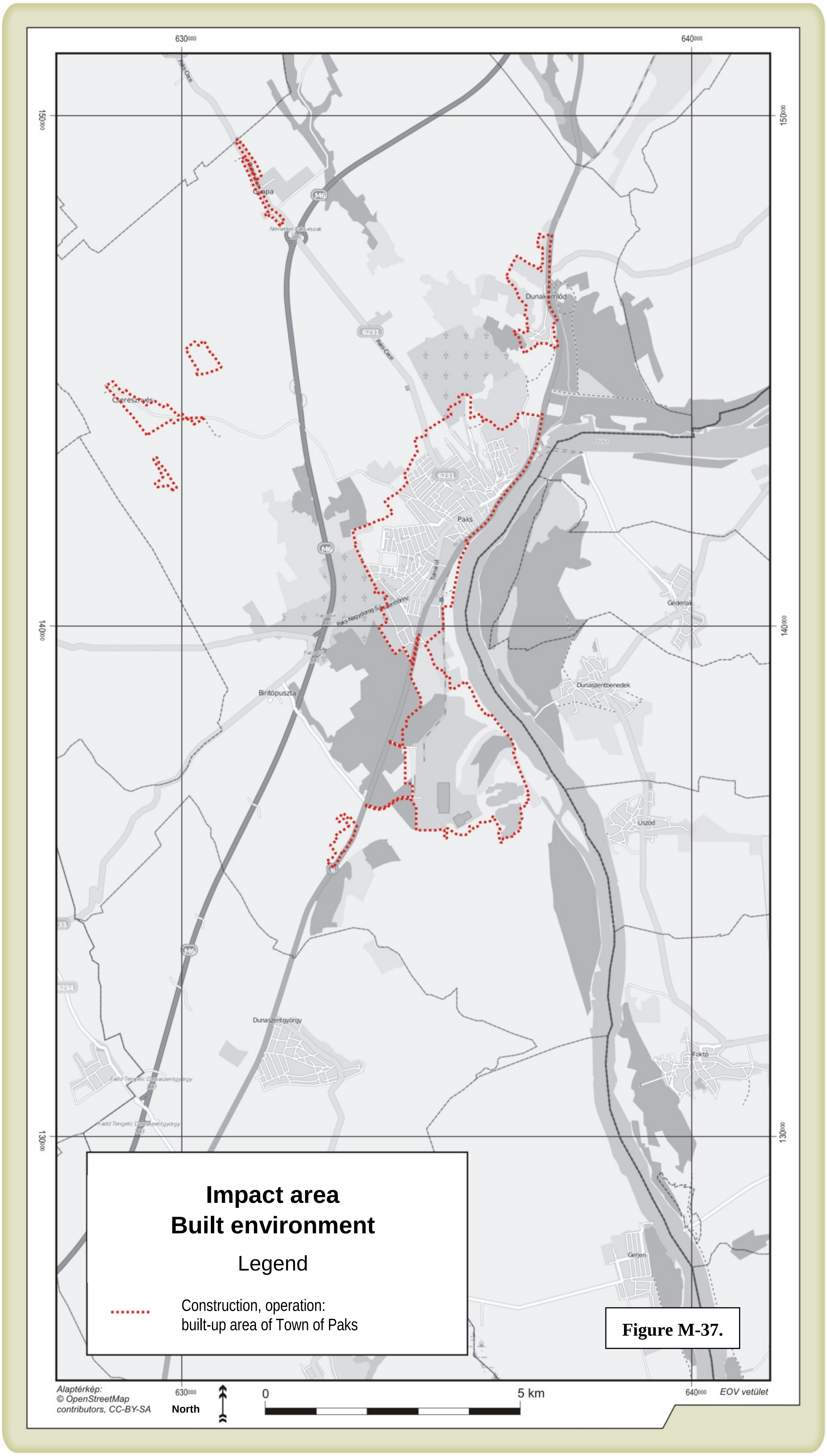

630000
640000
150000
140000
130000
Csapa
M6
6231
Dunakömlőd
Cseresznyés
Paks
Tolnai út
Paks-Nagydorog-Sárszentlőrinc
Biritópuszta
Gédarlak
Dunaszentbenedek
Uszód
Dunaszentgyörgy
Foktő
Gerjen
Impact area
Built environment
Legend
Construction, operation:
built-up area of Town of Paks
Alaptérkép:
© OpenStreetMap
contributors, CC-BY-SA
North
0
5 km
EOV vetület

Figure M-37.

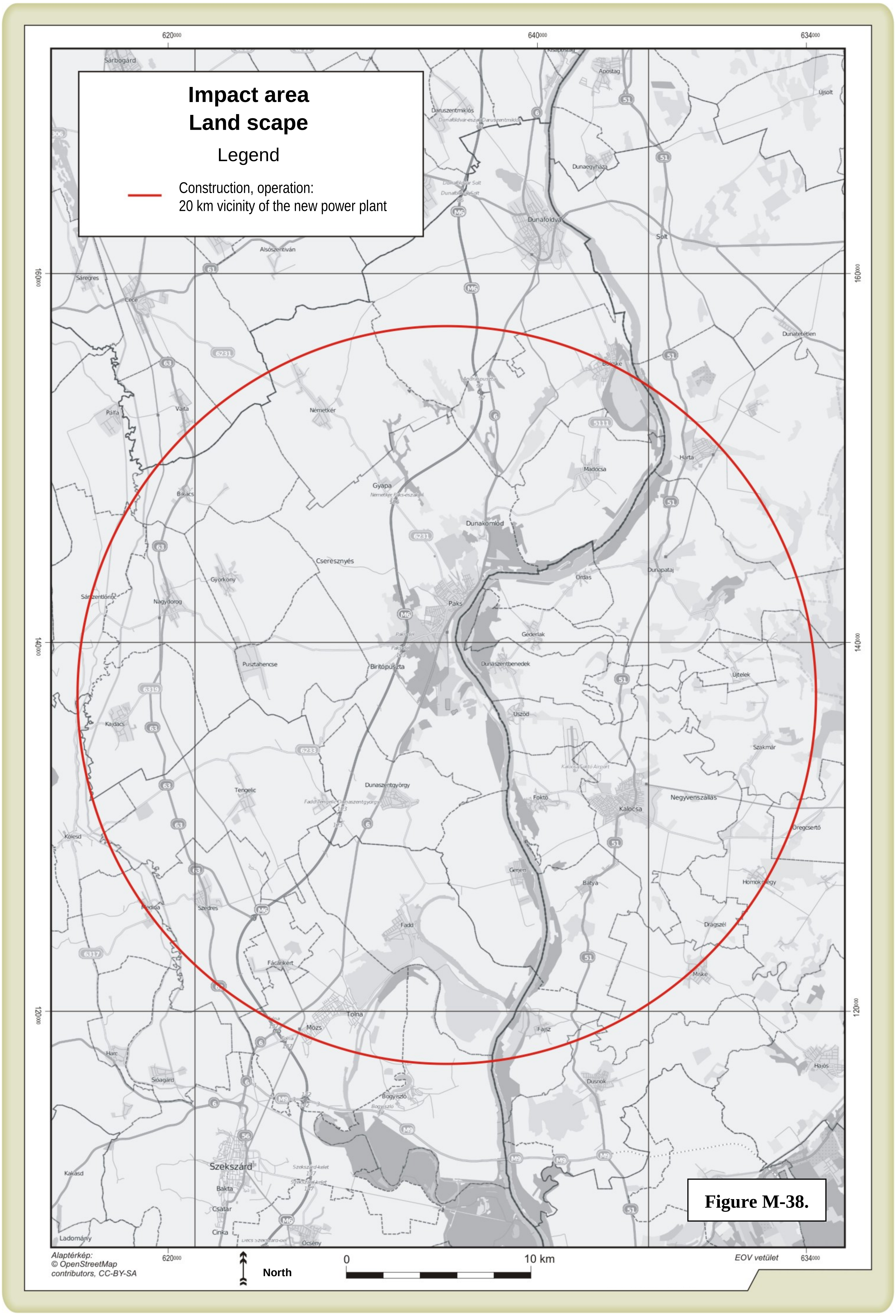

Impact area
Land scape
Legend
Construction, operation:
20 km vicinity of the new power plant
Paks
Szekszárd
Kalocsa
Dunakömlőd
Dunaföldvár
North
0
10 km
Alaptérkép:
© OpenStreetMap
contributors, CC-BY-SA
EOV vetület

Figure M-38.

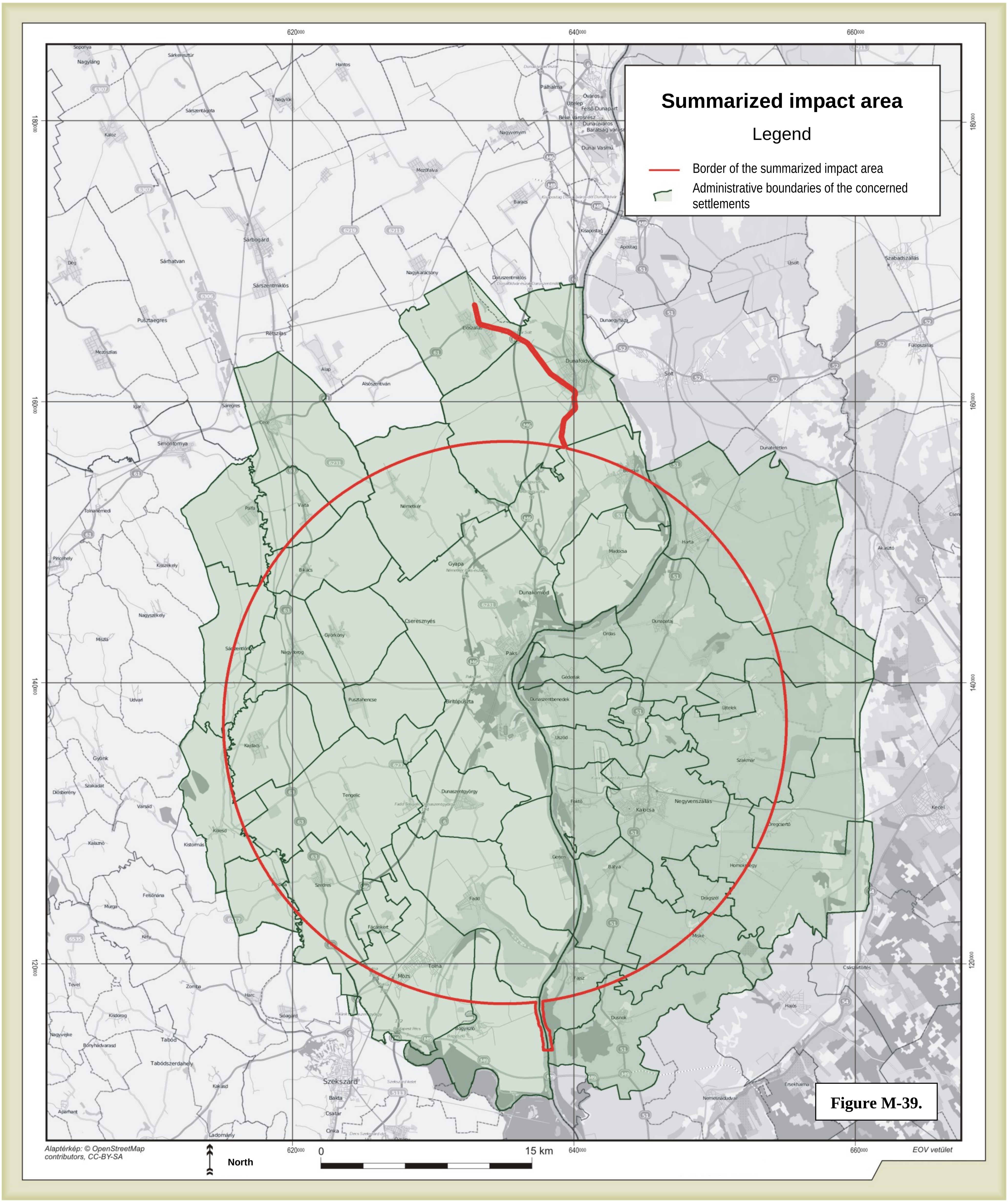

Summarized impact area
Legend
Border of the summarized impact area
Administrative boundaries of the concerned settlements
Paks
Kalocsa
Szekszárd
Dunaföldvár
Tolna
0
15 km
North
Alaptérkép: © OpenStreetMap contributors, CC-BY-SA
EOV vetület

Figure M-39.

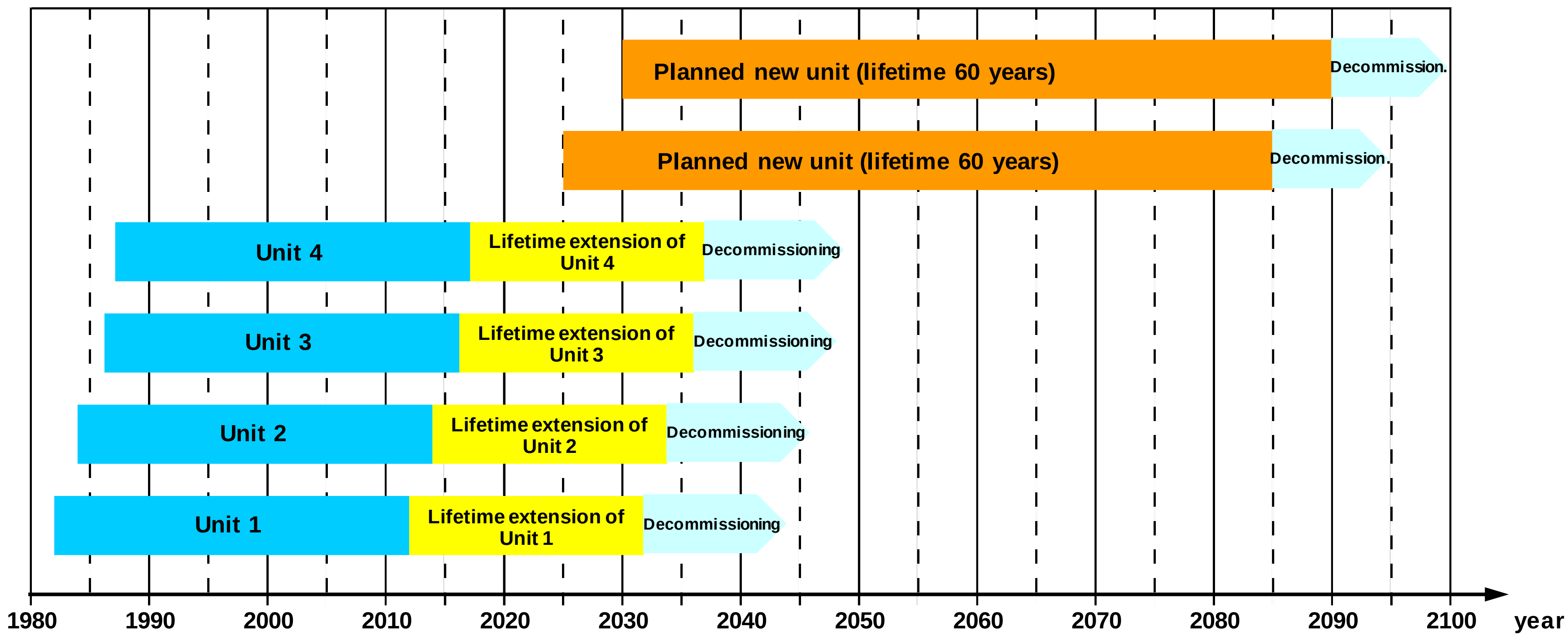


Figure M-40. Lifetime of the existing units of Paks Nuclear Power Plant and lifetime of the planned new units

			Environmental elements/systems affected by impacts									
			Natural environmental elements/systems					Societal, social, economical systems				
			Air	Water	Earth and soil	Flora and fauna	Land	Land use, utilization of land	Culture	Infrastructure	Human aspects	Population and economy
Activities of decommissioning project	Management of dangerous (radioactive and toxic) materials		C+R	C+R	C+R	C+R	C	C+R	C	C	C+R	C
	Liquid and gaseous emissions		C+R	C+R	C+R	C+R					C+R	
	Storage of radioactive wastes		R	R	R	R	C	R			R	C
	Transportation		C			C				C	C	C
	Demolition of buildings		C+R	C+R	C+R	C	C	C		C	C	C
	Storage, recycling, processing of wastes		C	C	C		C					C
	Use of inactive building rubbish, earthworks		C	C	C	C	C	C		C		C
	Risks of demolition activity (potential accidents, non-planned events)	Fire cases	C+R				C				C+R	C
		Leakages	C+R	C+R	C+R						C+R	
		Maintenance faults							C		C	
		Structural damages caused by external impacts	C+R	C+R	C+R			C		C	C+R	C

Legend: C – conventional environmental impacts
R – radiological impacts

Figure M-41. Matrix representation of identification of environmental impacts